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The Father, the Son, and the Stars: Bengt StrÃűmgren and the History of Danish Twentieth Century Astronomy

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August 2004

Centre for Science Studies, University of Aarhus, Denmark
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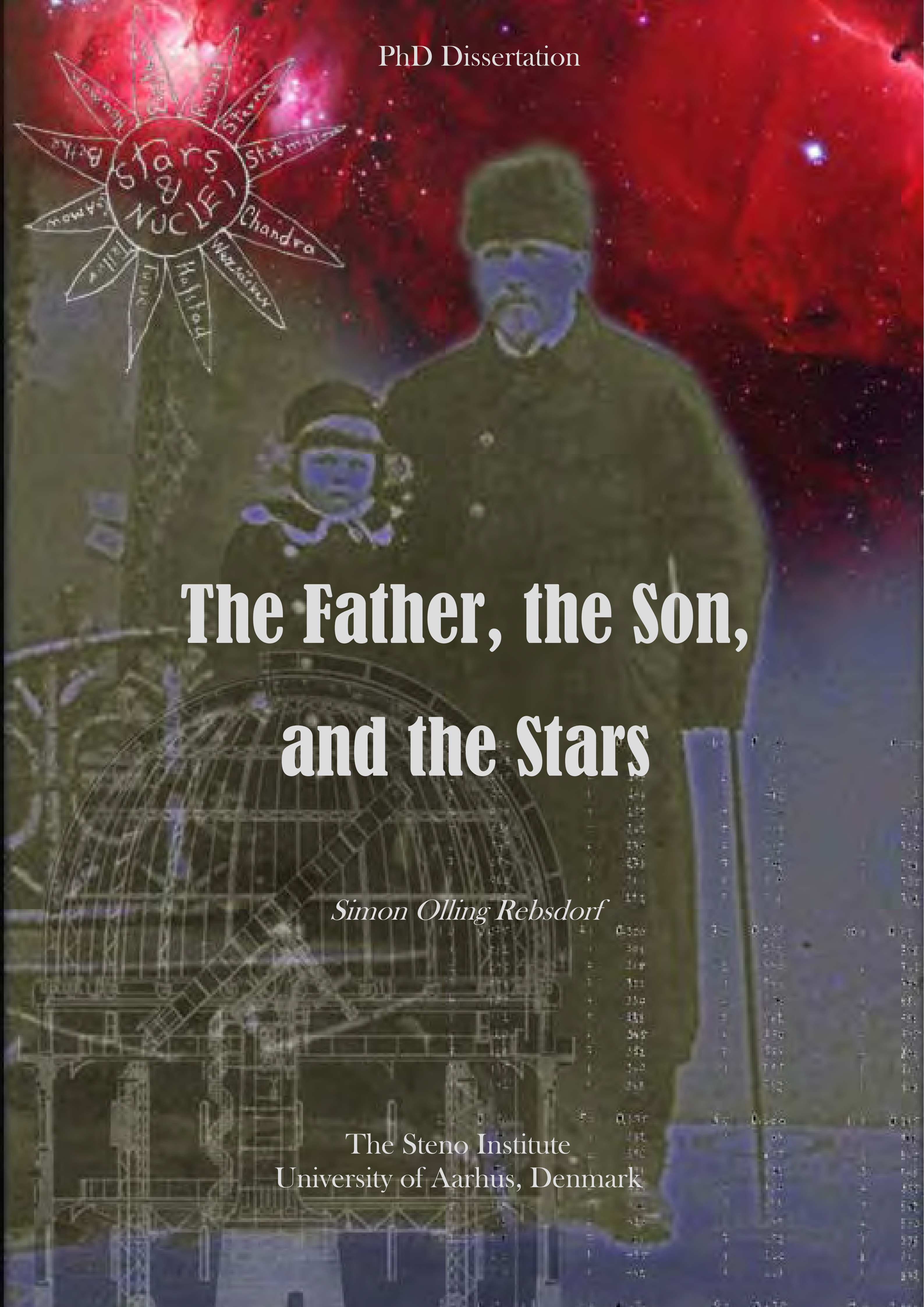
PhD Dissertation



The Father, the Son, and the Stars

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The Steno Institute
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The Father, the Son, and the Stars

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Front page collage: Elis and Bengt Strömgren, ca. 1910 (courtesy of Nina Strömgren Allen); Orion nebula photograph (credit: Robert Gendler's CCD gallery); drawing of the Yerkes Observatory refractor; an observation table in Bengt Strömgren's handwriting; and an excerpt from a letter to Bengt Strömgren written by G. Gamow (top left corner, see chapter five, figure 18). The names in the star are (clockwise from the top): Russell, Sterne, Strömgren, Chandra, Weizsäcker, Hafstad, Tuve, Teller, Gamow, Bethe, Neumann, and Einstein (see chapter five).

CONTENTS

ACKNOWLEDGMENTS

Several institutions and people have helped me in writing this dissertation. I have listed some of the most important of these below.

I have received financial support from two institutional bodies. I am grateful to the Carlsberg Foundation for granting the first half of my PhD stipend as an exception from the rule that grants for salaries will not normally be given to PhD students. The Faculty of Science at the University of Aarhus funded the second half of my stipend via the History of Science Department, thus making it possible to complete a three year period of research training. I wish to thank head of the History of Science Department, Henry Nielsen, and head of the faculty, Erik Meineche Schmidt, for all their efforts to make this possible. My supervisor, Helge Kragh, has played a major role in shaping my research by his direct supervision, encouragement, and concrete feed-back, which I have enjoyed ever since the beginning of my Master Thesis writing.

I would also like to thank the staff at the Astronomy and Astrophysics Department (AAD) at the University of Chicago for welcoming me as a research visitor for 4.5 months in the spring of 2003, especially Noel Swerdlow (also for patiently waiting for me for hours at my first arrival in O'Hare Airport), Melissa Minkow and Jennifer Smith has been very helpful in making my stay an excellent experience. Also, I wish to thank the staff at the Morris Fishbein Center for the History of Science and Medicine at the University of Chicago, especially the director, Robert Richards, for encouragement and fruitful discussions and for inviting me to give a paper at the bi-weekly seminar. I wish to thank Stephen Shapin for useful suggestions and profitable discussion at the seminar. Furthermore, I wish to thank the staff at the Yerkes Observatory for all their help and warmth, especially the librarian Judy A. Bausch and Richard Dreiser for all her effort and helpfulness in many ways.

As my PhD project has unfolded in parallel with the large Danish History of Science (DVH) project, which is also sponsored by the Carlsberg Foundation, I wish to thank Henry Nielsen, Kristian Hvidfelt Nielsen, Henrik Knudsen, Henrik Kragh Sørensen, and the other participants in the DVH-workshop for useful comments and discussions. I am most grateful to Nina Strömgren Allen, to Karin Strömgren Campbell and to Ole Strömgren for profitable correspondence, interviews, and hospitality; to Lalitha Chandrasekhar for inspiring discussions and for granting me access to the private Subrahmanyan Chandrasekhar Papers at the Joseph Regenstein Library in Chicago; to Donald E. Osterbrock for multifarious help and good ideas; to Karl Hufbauer for help and for generously sharing his detailed biographical time-line (1908-1940) with me; to Gustav Holmberg for his aid and thoughts; to Erik Heyn Olsen for sharing with me his careful work on an almost complete bibliography of Bengt Strömgren; to the Niels Bohr Library at the Center for History of Physics; to the American Institute of Physics, for contributing with copies of interviews; to the Joseph Regenstein Research Library, Chicago; to Peter Vandervoort at the AAD for sharing knowledge and photos with me; to the Lund University Library; to the Royal Danish Academy of Sciences and Letters; to the Niels Bohr Archive (NBA) in Copenhagen for photos and manuscripts; to Finn Aaserud at the NBA, for munificently handing me copies of hard-to-get documentation, and for valuable historical discussions; to Helle Kiilerich at NORDITA for finding sources; to Ole Fastrup for providing photographs and other sources; to Henry Nielsen also for access to archival material from the Norwegian Nobel Committee; to Torkild Andersen for assisting with his access to documentation in the Carlsberg's director's protocol; and once again to Helge Kragh for assistance and intellectual support in many ways.

Finally, I wish to thank Charlotte for everything.

PREFACE

(TO THE SECOND EDITION)

The present monograph is a refurbished version of my two-volume PhD dissertation, which was submitted to the Faculty of Science at the University of Aarhus on August 31, 2004. A very thorough and competent reading of the my text was undertaken by an evaluation committee consisting of professor Dominique Lambert, Facultes Universitaires Notre-Dame de la Paix, curator David DeVorkin, National Air and Space Museum, and director Kurt Møller Pedersen (chairman), the Steno Museum, all of whom I wish to thank sincerely.

My PhD defense took place on December 1, 2004, nearly 75 years after the doctoral defense of Bengt Strömgren, the biographical subject of this dissertation. I was indeed very gratified to receive the PhD degree in science on the basis of my dissertation and my oral discussion with the evaluation committee, which turned out to be very constructive. In fact it was so helpful, that it became apparent for me to produce a second edition, in particular because the committee – and I – wished for the introduction of an *index nominorom* as well as a subject index, as the text lists numerous persons, institutions, and societies As a result, I have produced one collective index. This had been my plan all along, but following our discussions, various other small details and important facts needed some correction, change, or addition.

Now, this demand has been facilitated thanks to the advantageous policy of the management of the new Steno Institute, which allows me to spend several weeks on renovating the former two-volume work into one, complete monograph. In this connection, apart from the help of the evaluation committee, I wish to thank also the print shop of the Faculty of Science.

Viborg, February, 2005 S.O.R.

PREFACE

(TO THE FIRST EDITION)

Throughout my studies of astronomy, cosmology, and physics at the Niels Bohr Institute in Copenhagen, I became very interested in the theory of science and thereby in the history of natural sciences, which is often used as a source of case studies for use in making theories of science and technology. Entering into the history of modern astrophysics and cosmology in connection with my master thesis at the History of Science Department at the University of Aarhus, I became aware of the immense role played by a relatively small number of scientists in the early 1930'es. It struck me that Danish scientists played a crucial role in the forming and furthering of many prevalent astrophysical theories. The main character in this enterprise was Bengt Strömgren. More than that, the role played by him with regard to Danish research policy in the cold-war period as well as to the flow of scientific knowledge across Danish borders called for a more thorough investigation. In particular because I learned that his complete private archive was just being catalogued and was located in the basement just underneath my student's office. Eventually, it became possible to get the required funding and there I was, ready to immerse myself into the life of a scientists who grew up in his father's observatory and ended up being honorary professor and director of the same observatory before he retired in his home, the Carlsberg Mansion of Honor.

Almost three years later, nearing the expiration of my PhD stipend, I was in the arranging committee of an international conference on Science and Technology in the European Periphery (STEP). The History of Science Department hosted the summer event in the picturesque surroundings of the Sandbjerg Estate in Southern Jutland, Denmark. On the last day of the conference, or rather, during the night following the conference banquet, I had a lengthy conversation with my supervisor. He told me something that really boosted my self-confidence and excited me to a higher energy level – exactly what I needed before a long, warm summer in the name of the completion of this dissertation. A couple of months earlier, he read the first ca. 200 pages of my dissertation in detail and coherence. Apparently, now was the time for him to unveil his reaction after some weeks of reflection:

'Not long ago, I began to fully realize the idea of your using the relation between father and son,' he said. Not that we had forgotten to discuss the dissertation in his office earlier, but this occasion was seemingly the best in a long time for us to speak more bluntly about the project.

'I realized,' he continued, 'how the history of science can learn from this unique – and sometimes private – narrative of two scientists and human beings who happened to be in the same family.' I saluted him with a toast and told him that this really meant a lot to me.

This dissertation is the main outcome of my three-year PhD stipend. It has made its way to reality with the History of Science Department as a natural base. The topic of the dissertation is the field of astronomy and astrophysics in Denmark but also internationally, essentially in the period from the turn of the century to the fifties. As such, the dissertation is related to my master thesis, which was a research biography on the British astrophysicist and cosmologist Edward Arthur Milne (1896-1950). The main focus of the dissertation is the Swedish born Dane, Bengt G.D. Strömgren (1908-1987), but I am also squinting at his father, Elis Strömgren (1870-1947). The relationship between father and son runs through the historical narrative, which, to the best of my knowledge, is the first scientific biography of Bengt Strömgren.[1] For archival reasons, and due to the temporal limitation of three years of study, the biography stops the detailed investigations around the death of the father, in 1947. Subsequently, a more thematic approach has been taken.

The aim of this dissertation is to answer a set of questions concerning the history of astronomy in Denmark in the twentieth century:

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[1] A list of obituary notices and short biographies is given on page 496 in the bibliography.

- How did the field of astronomy develop in Denmark in the period?
- How can the rise of Danish astrophysics be explained and what was its basis?
- What was the impact of Bengt Strömgren on the development of the field of modern astrophysics, on the scientific community, and the public image of the field, nationally as well as internationally?
- If the father-son relationship between Elis and Bengt Strömgren did affect the developments, to what extent what this the case?

First of all, the discipline of astronomy and astrophysics must be defined. While astronomy concerns empirical and theoretical studies of the sky, one subgroup of astronomy is that of cosmology, addressing questions as to the large-scale structure and dynamics of the entire collection of galaxies, the universe as a whole. Astrophysics is treated here as another subgroup of astronomy, investigating the physics of stars and the space inhabited by them. The practitioners of astronomy can be divided into at least professionals and amateurs, although the borders have been transgressed by both groups in many sub-disciplines. There has been a rather active group of amateur astronomers all over Denmark, and the question of whether to focus on the elite or the amateurs or their mutual interaction is answered in this dissertation by the genre of this enterprise: Being a kind of scientific biography of Bengt Strömgren, who was brought up in the academic environment, the spotlight is largely directed at the academic world.

The Use of Archival Sources (Reading Guide)

This dissertation consists of eight main chapters, of which chapter one is a historiographical introduction to what I have chosen to call a scientific biography, which follows in chapters two to eight. The dissertation consists of two parts. The first element comprises the main part of the dissertation text, the historical narrative of the life and science of Bengt Strömgren. The second ingredient is the list of archival sources, the bibliography, eight appendices, the content of which will be described below, an index. The scientific biography is treated as a history of science genre and a mixture of problems, pitfalls, and virtues of the genre are treated, including the role, not only of biography, but also by the biographer writing the historical narrative. Historiographical problems, methods, and historiographical approaches are discussed and the choice and character of the archival sources on which this dissertation is based are discussed in rather general terms. More specific information about the archives can be found below. This reading guide constitutes a commented listing of my use of archival material in parallel.

The primary archival sources for this study of astrophysics in the first half of the century are found mainly in Denmark and in the USA.[2] The main source is the Bengt Strömgren Archive (BSA) located in Århus. The BSA contains professional and private correspondence; saved documents of scientific institutions, academies, organizations, and associations; observatories; companies; publication material; and documents concerning Bengt Strömgren’s public appearances. The complete collection of the *Nordisk Astronomisk Tidsskrift* (*NAT*) at the History of Science Library in Århus; the Nordjysk Amatør Astronomisk Forening (NAFA); Rigsarkivet (R, the State Archives); and the Archive of the Norwegian Nobel Institute in Oslo (ANNI) have all contributed crucially to the first historical chapter on Bengt Strömgren’s heritage (chapter two).

The BSA and the Elis Strömgren Collection in Lund (ESC) have been essential for a full picture of the relationship between father and son. In the History of Science Department’s archives, the Ejnar Hertzsprung archive is also situated, contributing with a number of relevant correspondences (EHA). Along with an invaluable diary of Elis Strömgren, kindly lent to me by Ole Strömgren (OS), it has been possible to complete chapter three on Bengt Strömgren’s upbringing and early career from 1908 to 1929.

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[2] Right before the bibliography at the end of the dissertation, the various archive and interview abbreviations are listed.

In addition to the above mentioned archives, the Royal Danish Academy of Sciences and Letters Archive in Copenhagen (RA) has provided me with a number of crucial documents, both in the making of chapter four and of chapter seven. The Niels Bohr Archive in Copenhagen (NBA) has contributed considerably with source material in the unravelling of the developments leading to Bengt Strömgren's first landmark article in 1932, treated in chapter four.

My search for answers to the question of Bengt Strömgren's relationship with the Nobel laureate Subrahmanyan Chandrasekhar led me to the University of Chicago Archives at the Joseph Regenstein Library, Special Collections Research Center (UCA). Here, on a 4.5 months research visit, Chandrasekhar's widow, Lalitha Chandrasekhar, kindly granted me access to the Chandrasekhar Papers (UCA, SCP), which turned out to be consequential for my study, as they include extensive correspondences between the two scientists and friends. The Yerkes Observatory Archive (YOA), the UCA (including other important findings than the SCP), and the Elis Strömgren Collection (ESC) constitute the backbone of chapter five, which is a comparative study of two local contexts, the Copenhagen and Yerkes observatories.

Chapter six can be considered to be a chimera with regard to the archival sources. As the amount of material is rather limited, the role played by the material found may seem over-representative. The YOA and the UCA plays important parts in the narrative, as do the ESC and the Bundesarchiv (BA) in Koblenz, concerning Werner Heisenberg's Copenhagen visit in 1941. Interviews, made by me and others, run through the chapter as a necessary device of bringing factual archival findings together with biased recollections in a flowing narrative.

Chapter seven is the last chapter with the same degree of detail as the preceding chapters. The reason for this is my choice of periodization. I have chosen to stop around the death of Bengt Strömgren's father, since the main focus throughout the previous text has been the father-son relationship, as I have intended to catch up in the title of my dissertation, *The Father, the Son, and the Stars*. What happens after Elis Strömgren passes away in 1947 is not of lesser relevance, of course. On the contrary, the manifold events following Bengt

Strömgren's maturing career, not least after going abroad for sixteen years, deserves as detailed investigation as given in chapters two to seven, if not even more. Unfortunately, if this was required, I would need at least another two years of research for the result to become at least acceptable.

In chapter seven, the most important archival material consists of the RA, which has proved useful in the history of the reunification of astronomers, right after the war. This was the first international post-war event, and was therefore covered in the media. Other important sources are concerned with the narrative of the build-up of the research institution, the Brorfelde Observatory, which was led by Bengt Strömgren. The BSA, NBA, EHA, and the UCA (SCP) are key sources. In the treatment of Bengt Strömgren's motivations for leaving Danish research in 1951, the Carlsberg Board of Directors Protocol for 1950 has been quite valuable.

The archival sources for the less detailed chapter eight are essentially newspaper clippings, oral interviews (MI, CI), some causeries by the colleague of Bengt Strömgren, Bengt Gustafsson (BG), and the BSA. One main focus is the 'clash' between Bengt Strömgren's and his near friend, Chandrasekhar, later Nobel laureate. Another main theme is the continuation of the Brorfelde observatory project. Besides, the advent of the European Southern Observatory is treated as well, as the Danish government endorsed its convention in 1967, the year when Bengt Strömgren returned to Denmark after sixteen years in the States. Chapter eight functions also as a brief follow-up in the name of completeness, either for those who intend to continue the research, or for those readers, who like to know about the basic developments in Bengt's life and in Danish astronomy in the period of 1951-1987. The last part of the chapter in particular is based on rather meager archival material, mainly the BSA. Besides, there is more available secondary material to support this chapter, which has been used to a reasonable extent.

One archive that I did not manage to visit during the course of my PhD study is the International Astronomical Union's Secretariat in Paris, where the documents from the General Secretariat 1948-1952 (Bengt Strömgren) are located. Biographical data in this chapter comes partly from the meager biographical sources on Bengt Strömgren and as such, these data are at risk of being if not ambiguous, then at least debatable. The reason is that often biographical texts such as obituary notices, autobiographical memoirs, and other biographical material tend to be somewhat hagiographic, panegyric, presentist, whig, romanticized, glorified, anachronistic, or biased in other ways. In addition, many biographers collect biographical data from other biographers and thus factual errors may be inherited by newer biographies, if they omit using primary archival material. In addition, Bengt Strömgren's many public appearances in newspaper interviews contribute to a nuanced picture.

The final chapter is my attempt to summarize and conclude the preceding ca. 400 pages. It serves mention that I have not had the opportunity of visiting relevant archives located in Princeton (IAS), New York (NASA), Stockholm (Nobel), Garching in Germany (ESO), or Paris (IAU). This would be required in a future study. Following this concluding section, a series of appendices follow.

To the best of my knowledge, the content of appendices A – H cannot be found elsewhere in the published literature. Appendix A contains a list of the Copenhagen Observatory staff in the period 1905-1970. The seven pages appendix includes predominantly the permanent staff, and for the sake of completeness, the presidents of the University of Copenhagen and faculty of science deans are included in the list. It is included because it gives an overview of the progress of growth of the staff as well as it points at special periods of stagnation.

Appendix B resembles appendix A in latent usefulness for chapter eight, but not in the size of contained data, since it only covers the period of 1956-70 in two pages. The staff of the University of Aarhus was very limited in size, as the natural sciences faculty was created only in 1954.

Appendix C is a four page list of officers of instruction at the Astronomy and Astrophysics Department at the University of Chicago in the period 1930-1952. Compared with appendix A, it displays the difference between two universities, in Copenhagen and in Chicago, as will be treated extensively in chapter five.

In the same chapter, I refer to the curriculum at the department, which was divided in Chicago campus and the Yerkes Observatory. The list covers the period 1936-1952 in 5 pages and is included because it actually displays in quite some detail what was taught in the classes. Furthermore, appendix D reflects the research activities to some extent. In chapter eight, reference to changes in the curriculum are given as a weighty reason why the close friendship between Bengt Strömgren and S. Chandrasekhar was torn apart.

The citation index of twenty-two selected twentieth century astrophysicists in appendix E contains an investigation of the citation patterns of a selected list of the most important of astrophysicists in the period covered by this dissertation. Background and method is described in the appendix. The results are used in the introduction as well as in the last chapters, as it puts Bengt Strömgren in a general comparative framework as a scientist and places him in the top part of the select elite of prominent astronomers, at least when the measure of citation index is deployed as a marker of success, or scientific impact.

Appendix F is included also for the sake of completeness. The mere concept of “honors and distinctions” imports implicitly a whole range of problems of hagiography and panegyrics. Nevertheless, I have chosen to include the data, which anyway is a natural outcome of my research, lest the reader would find it interesting.

The next appendix, in contrast, is of a much more entertaining character. The reason for including Bengt Strömgren’s satirical, if not sarcastic, essay from the mid-fifties entitled “Astronomy Made Easy” is the fact that here and there I have stumbled into mention of the short paper. The ten pages have apparently turned into a somewhat cultic text among astronomers in the west. Transcriptions exist here and there, and I found the original print in the BSA. After learning that the text was wanted also at the AAD in Chicago, I decided to transcribe it and include it in the dissertation. For one thing, it has not been published hitherto, but another reason for making it publicly known is the fact that it might be one of the best sources of insight into the sense of humor of Bengt Strömgren. Therefore, appendix G contributes to the completeness of the picture of the main character of this dissertation, for those, like me, who have never had the privilege of meeting Bengt Strömgren in person, 'in all his grandeur.'

The last appendix is a virtually complete bibliography of Bengt Strömgren. Erik Heyn Olsen, former colleague of Bengt Strömgren, kindly gave me the list of publications, which he once collected while working on a survey article on 'Strömgren photometry' and stellar classification.[3] As bibliographies in a way comprise the heritage and evidence of a scientific life, I found it compelling to include it in this dissertation. I have only corrected the bibliography and added a number of publications not found by Olsen.

The dissertation concludes with a name index and a subject index, as I list many persons, institutes, societies and organizations throughout the text.

I have made a series of oral interviews and have also had considerable E-mail correspondence with the family of Bengt Strömgren, more specifically, his three children. Apart from interviewing them (KNSI, KSCI, OSI), I have consulted some former colleagues of Bengt Strömgren: Poul Erik Nissen (PENI), Mogens Rudkjøbing (MRI), and Bengt Strömgren's secretary in 1953-1957, Barbara Perkins (PI). More than that, I have met with Peter Vandervoort, who gave me valuable information about the AAD in the fifties. In addition, I have used interviews made by historians at the American Institute of Physics, Center for History of Physics, MD, USA, in the 1970'es and 1980'es. Finally, the dissertation is permeated with secondary sources like obituaries, biographies, history of science papers and books, newspaper articles and scientific publications of the numerous scientists involved in the narrative.

Thanks to the great help of Nina, Karin, and Ole Strömgren, I have collected a relatively large number of family photographs. The wealth of family pictures can be traced throughout the text in my attempt to illustrate the events and people surrounding Bengt Strömgren. It is my hope that the illustrations

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[3] Olsen 1994.

Figure 1: Photo of some basic texts of great importance to my history of astronomy study (photo by S.O. Rebsdorf, the summer of 2004).

complement the texts with an additional level of historical documentation, since it is my belief that graphics improve the reading experience by injecting more verve and life into the historical narrative (additional photos from YODA, NBA, Peter Vandervoort at AAD, and other sources). Moreover, in the dissertation, I have chosen to use lengthy citations extensively. These are also included with the aim of authenticity displaying how the actors really wrote, and to make the reading a livelier and hopefully more historical experience.

Before we commence, here are some final details which would be helpful to the reader of the dissertation, however trivial they might appear. When I have considered the meaning of a citation unclear, a comment in square brackets is added to the citation within the apostrophes in the attempt of clarifying the connotation. I have made my own translations of excerpts of historical documents from Swedish and Danish to English, and therefore, I am solely responsible for any mistranslation or other possible errors in this respect. After all, *English is not my primary language* and that is the reason for my somewhat stiff written English. In some instances, certain specific Danish proper names do not exist in the English language. Hence, I have put a translation of the relevant proper name in brackets as a guiding English wording, being well aware that the translation might not be completely conventional. Throughout the dissertation, “Bengt” refers to Bengt Strömgren only and any mention of Elis Strömgren will use his first name in order to prevent confusion of the two Strömgrens. Generally, “Strömgren” will be qualified with a first name, Bengt or Elis (or Erik or Hedvig).

In the footnotes, a letter from ‘correspondent A’ to ‘correspondent B’, sent in the month “Month” on the date “dd” in the year of “19yy”, located in “Archive X” is noted as: “correspondent A → correspondent B, Month dd, 19yy, Archive X”. Last names are supplemented with first name initials. When referring to publications of authors sharing their last names with other authors in the bibliography, the name is qualified with first name initials. In particular in the case of Bengt and Elis Strömgren, the last name is qualified with the first name initial, thus e.g. “B. Strömgren 1925a, 4” refers to the first publication by Bengt Strömgren in 1925 on page 4, while “E. Strömgren 1945” refers to Elis Strömgren’s newspaper article from 1945. Finally, unless otherwise explicitly stated, references to figures in the text refer to figures within the chapter that includes the reference.

Studying this dissertation requires some knowledge of astronomy, particularly certain parts of chapter four, which make up a study of the cognitive development and conceptual changes of certain astrophysical theories of stellar chemical composition. The historical narrative is primarily aimed at professional historians of astronomy and astrophysics rather than professional astronomers.

The summaries in Danish and in English given below serve to help the busy reader to get an overview of the content and general idea of my dissertation.

DANSK RESUMÉ

(SUMMARY IN DANISH)

Denne ph.d.-afhandling omhandler udviklingen af astronomi og astrofysik i hovedsagelig første halvdel af det tyvende århundrede, som var en vækstperiode for dansk videnskab. Afhandlingen omfatter også efterkrigstidens udviklinger frem til 1980'erne, og er til dels en forskerbiografi om den danske astronomiprofessor, Bengt Strömgren (1908-1987). Desuden anlægges et far-søn perspektiv i den historiske fortælling, da Bengt Strömgrens far, Elis Strömgren, var professor før ham ved Københavns Universitets Observatorium. Ph.d.-studiet er baseret på arkivforskning i Danmark, Sverige og USA, på mundtlige interviews samt anden primær og sekundær litteratur.

Bengt Strömgren modtog talrige videnskabelige udmærkelser og æresmedaljer og tjente som præsident for den Internationale Astronomiske Union og ESO-Rådet. Endvidere virkede han som direktør for Københavns, Yerkes og McDonald observatorierne og for American Astronomical Society samt det Kongelige Danske Videnskabernes Selskab.

Hovedformålet med nærværende afhandling er at give en omfattende, kritisk-historisk analyse af en af de vigtigste figurer i astro-videnskaberne i moderne tid ved hjælp af forskellige sociologiske og historiografiske teknikker. Desuden har afhandlingen til formål at kortlæg
ge Strömgren's rolle i vekselvirkningen mellem dansk og amerikansk videnskab såvel som hans betydning for videnskabens popularisering i danske tidsskrifter og bøger. Afhandlingen inkluderer videnskabelige, teknologiske og institutionelle udviklinger og undersøger bl.a. Strömgrens teknologiske innovation ved hjælp af metoder der trækker på moderne teorier for kreativitet. Den studerer nationale og internationale vekselvirkninger mellem videnskabsfolk, hovedsagelig akademikere, men også amatørastronomer og

andre implicerede aktører. Et sideformål med afhandlingen er at præsentere den danske astronomihistorie for et internationalt publikum.

Det indledende kapitel behandler historiografiske spørgsmål vedrørende den biografiske genre, litterær biografi såvel som forskerbiografi. De anvendte historiografiske problemer bliver diskuteret, herunder bl.a. repræsentation versus præsentation, hagiografiske egenskaber ved biografien, biografiens normative strukturer, tematik versus kronologi, komparative studier af lokale kontekster, videnskabelige netværk, vurdering af historiske erindringer samt videnskabens generationsaspekter.

Diskussionen efterfølges af en introduktion til Strömgrens kulturelle og videnskabelige baggrund og arv, da han voksede op med astronomi i sin fars observatorium i København. De vigtigste astronomer og deres observatorier introduceres, ligesom observatoriernes daglige opgaver og aktiviteter behandles. Dernæst undersøges Strömgrens barndom og ungdom, hans private og offentlige undervisning samt hans tidlige karriere. Forældrenes indflydelse på Bengt Strömgren behandles, i særdeleshed faderens opmuntring, pacing og 'career management' fremhæves, da det resulterede i spørgsmål om nepotisme, men også betød en kick-start af den unge astronoms stjernekarriere.

Det yderst inspirerende videnskabelige miljø i København analyseres, med vægt på Niels Bohrs Institut for Teoretisk Fysik, som spillede en følgerig rolle for Strömgrens valg af astrofysik, og videre for dansk astronomi. Anvendelsen af kvantemekanik i den nye teoretiske astrofysik blev forestået af Strömgren og hans medarbejdere, som videreførte en klassisk beregningsastronomisk tradition – legemliggjort ved Elis Strömgren – men overførte den til det nye felt, kvantefysik i stjernerne.

Bengt Strömgren virkede som drivkraft i arbejdet for at genoprette den danske astrofysik i Danmark vha. sine innovative stjernemodel-studier og derved var han med til at placere Danmark centralt på det astrofysiske verdenskort. Hans tidlige arbejder udgjorde de første skridt i en ny og frugtbar retning mod originale teorier for stjernestruktur og senere for det interstellare rum, og således udfordrede han hævdvundne teorier i det internationale videnskabelige samfund.

Gennem hele livet vekselvirkede Strömgren intenst med adskillige fremtrædende astronomer og fysikere på den internationale scene, bl.a. Chandrasekhar, Struve, Gamow, Landau, Bohr, Bethe, Weizsäcker, Eddington, Milne, Hertzsprung og Russell. Strömgrens indflydelse for det internationale videnskabelige samfund var stor – også i hans senere år. Elis Strömgren insisterede på at behandle astronomi som et internationalt foretagende, og hans søn videreførte denne anskuelse. Under anden verdenskrig forstærkedes offentlighedens billede af Bengt Strömgren som en talentfuld internationalist og beskeden videnskabsmand, der levede og åndede for sin videnskab.

Strömgren skabte et vigtige samarbejde mellem dansk og udenlandsk astronomisk forskning, i særdeleshed med Yerkes observatoriet og University of Chicago. To lokale kontekster og samtidige institutioner, afdelingerne for astronomi i Chicaog og i København underlægges i afhandlingen en tværkulturel sammenligning. Det resulterende samarbejde mellem institutionerne affødte vigtig udveksling af både viden og videnskabsfolk.

Da Strömgren forlod Danmark sidst i 1950 blev begivenheden fulgt på nært hold af pressen. Det var en tid hvor dårlige forhold for videnskaben var på den offentlige dagsorden. Hans rejse til Staterne i seksten år var et hårdt slag mod dansk astronomi og videnskab bredt. Han vendte tilbage til sit fødeland i 1967 og flyttede ind i Carlsbergs Æresbolig hvor han blev resten af sit liv.

En vigtig årsag til hans afsked med dansk videnskab var det langvarige byggeri af det nationale filialobservatorium, Brorfelde Observatoriet, som behandles i kapitlerne seks til otte. Groft sagt kan Brorfelde siges i det mindste at have tjent som et vigtigt forberedende projekt til dansk indlemmelse i det internationale big science projekt Europæisk Syd Observatorium i 1967, hvilket behandles kursorisk i sidste kapitel af afhandlingen.

SUMMARY

This dissertation deals with the development of astronomy and astrophysics in Denmark, predominantly in the first half of the twentieth century, being a period of growth for Danish science. Moreover, it touches upon later developments in post war years until the 1980'es. The dissertation is partly a scientific biography, focusing on the Danish professor of astronomy, Bengt Strömgren (1908-1987). Furthermore, the historical narrative sets a father-son perspective, as Bengt Strömgren's father, Elis Strömgren, was professor before him at the Copenhagen University Observatory. The PhD study is based on archival research in Denmark, Sweden, and the USA; oral interviews; and other primary material and secondary and literature. Bengt Strömgren received numerous scientific distinctions and honorary awards and served as president of the International Astronomical Union and the ESO Council. Furthermore, he served as director of the Copenhagen, Yerkes, and McDonald Observatories, of NORDITA, of the American Astronomical Society, and of the Royal Danish Academy of Sciences and Letters.

The main purpose of the dissertation is to give a comprehensive, critical-historical analysis of one of the most noted figures of astronomy in modern times by use of various sociological and historiographical techniques. Furthermore, the dissertation attempts to map Strömgren's role in the scientific interaction between Denmark and the USA as well as his importance for popularization of science in Danish magazines and books. The dissertation includes institutional and technological developments and it investigates e.g. technological innovation by use of modern theories of creativity. It studies the national and international interaction between scientists, mostly academics but also amateur astronomers and other implicated actors. An additional purpose of the dissertation is to

present for an international audience the history of Danish astronomy through the eyes of Bengt Strömgren.

The introductory chapter deals with historiographical questions concerning the genre of biography, literary as well as scientific. The employed historical problems are discussed, counting topics such as representation versus presentation, hagiographical traits normative structures of biography, thematic versus chronological approaches, comparative studies of local contexts, scientific networks, judging the historical value of recollections, and generational aspects of science.

The discussion is followed by an introduction to the cultural and scientific background and heritage of Strömgren, growing up with astronomy in his father's observatory in Copenhagen. The most important Danish astronomers are introduced, their observatories are presented as are their daily tasks and activities. Then, the childhood, adolescence, the private and public education, and early career of Strömgren is inspected. The influence of his parents is also investigated, in particular the paternal encouragement, advancement, promotion, and 'career management' of his father, resulting in questions of nepotism, but also resulting in an early kick-start of a stellar career.

The highly inspirational scientific environment in Copenhagen is analyzed with emphasis on Niels Bohr's Institute of Theoretical Physics, playing a consequential role for Strömgren's choice of astrophysics and ultimately for Danish astronomy. The application of quantum mechanics in the new field of theoretical astrophysics was undertaken by Strömgren and his co-workers. He continued the classical tradition of computational astronomy – embodied by his father – but transferred it to the fresh field of quantum theory in stars.

Strömgren was functional as a driving force in restoring the field of modern astrophysics in Denmark by his innovative stellar model studies; and in consequence, Denmark was placed in a central spot on the astrophysical world map. His early work constituted the first steps in a new and fruitful direction towards novel theories of stellar structure and later of interstellar space, challenging prevalent theories in the international scientific community.

Throughout his life, Strömgren interacted intensely with prominent astronomers and numerous noted physicists on the international scene, including Chandrasekhar, Struve, Gamow, Landau, Bohr, Bethe, Weizsäcker, Eddington, Milne, Hertzsprung, and Russell. Strömgren's influence on the international scientific community was immense, also in his later years. His father's insistence on treating astronomy as an international enterprise was inherited by his son. During the Second World War, the public image of Strömgren was that of a talented internationalist and modest scientist, who lived for his science.

Strömgren was influential in creating an important base for co-operation between Danish and foreign astronomical research, in particular the Yerkes Observatory and the University of Chicago. Two local contexts and contemporary institutions, the departments of astronomy in Copenhagen and Chicago, are subjected to a cross-cultural comparison. The resulting co-operation between the institutions entailed an important transfer of knowledge and of scientists.

When Strömgren left Denmark in late 1950, the event was covered closely in the media, as the general conditions of science were on the public agenda. His going to the States for sixteen years was a serious blow to Danish astronomy and to Danish science in general – and it was regretted publicly. He finally returned to the Danish Carlsberg Mansion of Honor in 1967, where he stayed for the rest of his life.

An important reason for his leaving Danish science was the delayed build-up of the national branch Brorfelde Observatory, which is treated in chapters six to eight. By and large, Brorfelde at least served as a significant preparatory project for Danish involvement in 1967 in the international big science project, the European Southern Observatory, which is treated in briefly in the last chapter of the dissertation.

One

Introduction

Creating scientific biography

The Carlsberg Mansion of Honor was crowded that summer day in early July, 1987. Family, old friends, colleagues, and other relatives were all invited for a last goodbye to the father and husband, scientist and mentor, and the last resident of the Carlsberg Mansion for more than twenty years, Bengt Strömgren. The chairs in the hall were divided into two groups by a central walkway, leading to the decorated, white coffin. To honor his Swedish origin, the bright Pompeji Hall was gracefully decorated with yellow and blue flowers, accompanied by red and white flowers for his love of Denmark, where he grew up, was educated, wedded his beloved companion in life, Sigrid, and brought their three children into the world.

Three important facets played all-important roles in the life of Bengt Strömgren, his family, his science and his underlying philosophical program. No one can portray these facets better than his relatives and friends who themselves experienced living with him.

✦

At the funeral feast, selected relatives and guests gave brief orations about a many-facetted and industrious personality, who survived two wars and published his last scientific paper at age 79. His daughter, Nina, spoke on behalf of her mother – and her brother and sister – when she expressed her peace of heart, in spite of the eternal void left inside; and she praised the memory of her father, which would always be kept deep within their souls. Erik Strömgren illustrated the enrichment of living a life with his brother Bengt by revealing short anecdotes from a distant past.[1]

> He was the big, strong brother that you could always count on. I knew that in dangerous situations, he would always risk life and limb to help his little brother. Only in one respect I would sometimes feel slightly deserted by him – he was from early on very absent-minded. This could entail that at the very moment we played in the sandbox under the acacia in the Observatory's garden, when he needed to relieve himself in the house, he stayed away; apparently he had thought of something interesting and had thus forgotten all about the sandbox situation. Later, similar regrettable absences were caused by our father, however, who would capture him with a view to discussing some advanced astronomical problems.

Erik characterized the individual traits that in particular stamped his brother:

> I think about his exceptionally accurate memory, his vigilance to everything happening around him, his attention to other people's needs, his empathy […] his quiet cheerfulness, his cunning humor, his uprightness […], and his modesty. He never asked for anything and was born without elbows. So much the more, it pleased his closest friends that he was given so much, and that he gained so many warm friendships.

✦

[1] The following quotes all originate from MS 1987.

Bengt's successor, Professor Anders Reiz, was invited also to talk about Bengt's life, as it was marked by one major aspect: science. He spoke on behalf of the many, many people who had experienced collaborating with him in different fields. Reiz was educated by Bengt and eventually got the professorship that Bengt had left in the fifties, to the benefit of American science.

> Bengt was *one* of my universities; the smallest, but the one that was most important to me. This applies to my professional education, but he also left his mark on my human development […]. Already by the mid-thirties, Bengt had marked himself as one of the leading figures through a series of original investigations of astrophysics. Very early on, he became aware of the central position of astrophysics, and he had the best external conditions through nature and nurture […].
>
> His learning was colossal, his interests ranging over all exact natural sciences: Pure and applied mathematics, statistics, experimental and theoretical physics, optics, and he had a thorough knowledge of atomic physics, only mastered by few astronomers. He bore his learning lightly as a flower, never for decoration – it was to be used.

✦

The Danish national poet, and Bengt's contemporary, Piet Hein, also mounted the rostrum to express his indebtedness to Bengt "for a friendship, which was kept in spite of all differences in attitude and aptitude, and held for 60-70 years, despite periods where, for external reasons, we met very seldom." Piet Hein thanked Bengt for one conversation in the early twenties:

> As 15-16 year-olds, we went together on long, taciturn bi-cycle rides. From one of those rides, I remember one long, important two-line discourse. I said: “Bengt, don’t you think that it is the strangest thing that you can think?” Then, a few kilometres passed, and Bengt said: “No. I think it is the strangest thing of all that anything exists on the whole.”

Accordingly, those two epistemologically diverse questions became naturally connected from early on, and to Piet Hein, that particular conversation represented “a human contact of the kind that you can live and die on.” The dialogue reveals Bengt’s object of philosophizing, *viz.* his early choice of attempting to comprehend ontologically the existence of things, rather than reflecting epistemologically on human knowing and cognition. Bengt’s major project in professional life became a search for understanding the history and development of our Galaxy, The Milky Way.

1.1 The Scientific Biography

"How can one make a life of six cardboard boxes
full of tailors' bills, love letters and old postcards?"

Virginia Woolf about the art
critic and artist Roger Fry[2]

Documenting ways of living is what biography is about. The *scientific* biography is of the same genre as the *literary* biography, but the degree to which the lived life has been included has varied tremendously through the years. Because science has assumed an ever larger role in culture, scientists have become public figures, role models, and even heroes. Accordingly, scientific biography has grown steadily in popularity. The scientific biography has for long been a central medium in the transmission of images of scientists and ideas about science and technology. Whether in the form of triumphant accounts of the heroines and heroes of science or more rounded, critical studies, the lives of such famous figures as Tycho Brahe, Charles Darwin, Madame Curie, Albert Einstein, Isaac Newton and Niels Bohr have always been assured a ready market and an animated audience. Today, the general public is thirsty for news about science and devours scientific biography with delight. Until the publication of Michael Shortland and Richard Yeo's Cambridge anthology *Telling Lives in Science* published in 1996, very little criticism or comment has accompanied the recent rebirth of interest in scientific biography.[3] When it comes to the literary biography, more meta-literature has been published than is the case with scientific biography, primarily in the form of anthologies of articles written by biographers from the humanities.[4] For scientific biography, still more conferences and other scholarly activities on the subject appear, though.

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[2] Edel 1986, 19-20.
[3] Shortland & Yeo 1996.
[4] From the mid-1980s (with few exceptions), several anthologies has been published on literary biography, e.g. Clifford 1962; Bruce Nadel 1984; Edel 1984; Novarr 1986; Oates 1986; Epstein 1987; Homberger & Charmley 1988, Young 1988; and Richard & Jensen 1999.

Nobel laureate of physiology or medicine Joshua Lederberg gives at least five perspectives that scientific biography can offer:[5]

1. On the substantive content of science
2. On the philosophy of science as a process of discovery and verification
3. On science as a social institution
4. On the relationship between science and the forces that shape human individuals
5. On the history of science

The fifth perspective includes a lot, to say the least, and it includes 1-4, if one takes a broad pluralistic historiographical perspective on the history of science and the scientific biography, since such an approach attempts, like this dissertation, to combine several sorts of elements of scientific life into one de-fragmented account of a life lived in history.

The first choice the biographer must make is that of picking a subject. As the literary biographer André Maurois asserts, a landscape painter does not set himself down anywhere: "He stops before a natural landscape and says, "That is well placed, or well grouped"."[6] The biographer can have assorted motivations for his choice but the most common argument for his choice is obviously that of choosing people who have played an important part in history.

Time and again, biography involves touches of panegyric writing, i.e. singing the hero's praises, in particular when it comes to the personal virtues of the studied subject. Moreover, many obituaries in particular comprise hagiographic writing, which in itself calls for critical reading if they are intended to serve as useful historical sources and not mere idealizations or idolizations. Also the scientific biography often – still today – presents reactionary caricatures of science that may seem grounded on meager research and sentimental hero-worship. This is exemplified by Dava Sobel's presentation of John Harrison:

[5] Lederberg 1990.
[6] Marois 1986, 7.

Longitude: The True Story of a Lone Genius Who Solved the Greatest Scientific Problem of His Time.[7] The English inventor John Harrison is presented in the 'true story' as a misunderstood, oppressed and virtuous lone genius fighting against an obstruent and irrational Establishment. The book has been labeled "New York Times Bestseller", which clearly demonstrates that the whiggish hagiographical narrative of hero overcoming adversity has proved very popular!

In the case of Bengt Strömgren, there are plenty of examples documenting such uncontroversial general allegations of widespread mythologizing. And those affirmations fit nicely with some of the criteria for choosing a certain subject for a biography. The rhetoric of previous biographers and writers of obituary notices on Strömgren contains such usual elements, and it is evident that when it comes to the life of Bengt Strömgren, these romantic declarations all agree in their descriptions of his career, his publications, his personal character, his significance, and in the delineations of the many honorary appreciations he has enjoyed. One reason for the agreement can be due to references to one or few sources, though.

His career has been characterized as "meteoric" for an "outstanding astronomer" who "left his mark on almost every field".[8] A momentous astrophysical paper of his from 1932 was "continually referred to as the Cognoscenti of this field"[9], he "was famous for his masterly reviews"[10], he showed "an astonishing skill of estimating whether physical assumptions were permissible" and "his knowledge was encyclopedic".[11] His personal character has been exceedingly pictured as to being a "remarkable man", humble and modest, "although as brilliant as any of his contemporaries he tended to hide his brilliance behind a quiet but confident manner."[12] He was harmonious and a man of compromise, thus "by his quiet but decisive manner he established the harmony between delegations necessary to its effective functioning" and he served as a

[7] Sobel 1996.
[8] Kulsrud 1987, 217-218.
[9] Ibid.
[10] Osterbrock 2001a , 2.
[11] Rudkjøbing & Reiz 1988, 161-162.
[12] Kulsrud 1987, 217.

"superb diplomat."[13] His mental condition has clearly made a big impression on his colleagues and "Bengt had an outstanding memory".[14] A French co-worker has even called him an "*enfant prodige*" who even "has never offended anybody."[15] The rhetoric of praises is perfectly fulfilled by Wolfgang Priester who have stated that Bengt Strömgren's "warmhearted nature secures him a place of honor in the history of astronomy."[16] Regarding his weighty scientific contributions "the importance of this work for the future of astronomy will only slowly emerge" and he has been viewed as having "the widest possible view of science."[17]

As to the citation index of Strömgren's scientific production, of 48 selected astrophysics papers from 1931 to 1987, Strömgren has been cited 1,522 times in other astrophysics papers[18], which is a relatively large number. In appendix E, the ten most cited of Bengt Strömgren's papers are listed, revealing also the absolute number of citations to each publication. In order to assess the amount of citations and in order to place Bengt Strömgren in a more general picture, we need to investigate also the citation indices of other prominent astronomers of the twentieth century. Not many studies like this have been made in the field of modern astronomy and astrophysics, but one interesting examination had been carried out by Stephen Brush in 1990.[19] In the present study, the citation indices of 22 selected influential astrophysicists have been listed in order to get a hint as to the impact of Bengt Strömgren's scientific production. Although one should proceed with caution in conclusions of such external studies, the listing in Appendix E (table 3) shows that Bengt Strömgren was located among the top of the selection of the most-cited astrophysicists, thus indicating that he had a vast influence on his field of research.

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[13] Kulsrud 1987, 221; Osterbrock 2001a, 2 (last quote in the sentence).
[14] Kulsrud 1987, 222.
[15] Cayrel 1989, 609-610.
[16] Priester 1987.
[17] Kulsrud 1987, 221; Osterbrock 2001a, 2.
[18] The bibliographic database of NASA Astrophysics Data System (ADS) on the Internet, http://adswww-harvard.edu. See also appendix E for details about Bengt Strömgren's citation index and the comparisons with 22 other prominent twentieth century astrophysicists.
[19] Brush 1990. For further details about this study, see Appendix E.

If the purpose of biography is to present isolated narratives in the sense of human life and work portrays, that is, scientific vitae about the researcher's projects in life, the 'undying fame' of Bengt Strömgren may seem as a good argument for depicting his life and career biographically. If the function of biography furthermore is to constitute a peephole into (scientific) culture, to work as internalist case studies for cognitive processes or as contextual case studies of local scientific contexts or networks, then evidently additional legitimizations may be needed than blind admiration or devotion. Hence the citation index indicates more substantially the influence and impact of Bengt Strömgren on the scientific community.

The Genre of Scientific Biography

Scientific biography has no particular method; and it is no rigid genre. There is a polygonal nature of the discipline, which includes elements of history writing, sociology, psychology, scientific analysis, and history of ideas and culture. Biography is history in both meanings of the word: narratives about a human life as well as historical accounts of a lived life, being a part of history. Scientific biography specifically mediates the history of science by focusing on the persons who actually did the research, empirical or theoretical, and who wrote the papers or other work – or persons who in other ways played parts in scientific life or organization. At the same time, biography draws some attention to the biographer, who acknowledges his own interest both in the field of science – the work of science – and the scientist himself.

The word biography is a derivation from the Greek nouns *bios* (ways of living) and *grafé* (documentation, representation) and thus it literally means a documentation of the way a human being has lived his or her life, be it written, played or sung by the biographer. Certain aspects of a lived life are usually emphasized in biography, and these aspects are reflected in the traditions of literary biography, scientific biography or political biography.[20] While 'scientist'

[20] Söderqvist 1999, 53.

Suetonius	Plutarch
System	Linearity
Theme	Chronology

is a term from the 19th century – and since 'science' as a limited societal institution largely is a product of 17th, 18th and 19th centuries – scientific biography in this connotation is a relatively young genre. However, the genre of biography can in fact be traced all the way back to the archaic Greek tradition of writing praises to powerful men and heroes.

A highpoint in the biographical tradition of ancient times is the Roman biographer and historian of culture, Suetonius, who portrayed Roman emperors in detailed descriptions of moral characteristics of the figures. Another important biographer to whom many biographers pays homage is the Greek biographer and essayist Plutarch, who shored up for the audience what remained of the great legends and myths of the noble Greek and Roman statesmen and politicians through parallel biographies giving emphasis to the moral aspects of biography. The biographer and historian of science Thomas Söderqvist makes a useful distinction between the 'Suetonian' and the 'Plutarchian' type of biography. Whereas Suetonius systematically went over his subject's work, Plutarch employed a more strict chronological structure in his parallel biographies.[21] The two approaches reflect two distinct ways of conceiving of biography: The Suetonian line of attack signifying histories about scientific ideas and cognitive processes and the Plutarchian manner of representing stories about a lived life.

The biographical tradition of the Victorian age in the late nineteenth century was that of heroic portrays of modernity and progress, the 'Life and Letters' tradition. Across the twentieth century, scientific biography still provided history of science with narratives of the people undertaking science, the lives behind – and in – science. Until the mid-twentieth century, the researcher's quest for knowledge was depicted in narratives with power of thought, individual

[21] Söderqvist 1999, 56.

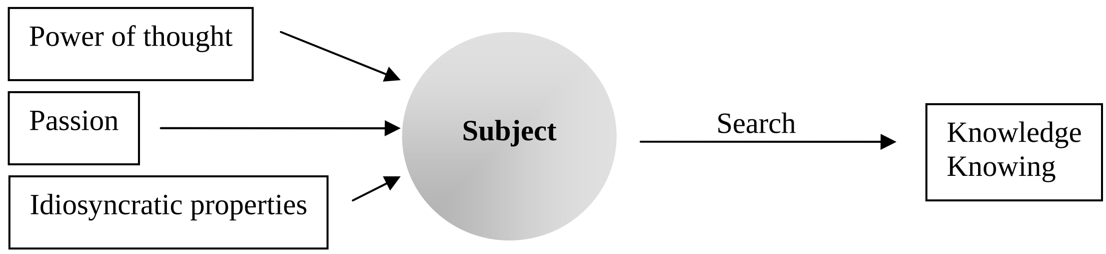

Figure 1: Early conceptions of the individual scientist's search for knowledge.

passion, and idiosyncratic properties as the primary ingredients for the biographed subject to investigate nature.

After ca. 1940, numerous theoretical systems expelled biography to the sideline. Positivistic philosophers of science were not as interested in the discovery any more. The psychological and historiographical pitfalls were considered too likely and too deep; and instead, the focus of historians of science became the accumulation of knowledge, for instance represented by the internalistic approach to the history of science of Alexandre Koyré.[22] With the Marxist turn in the 1930'es, history of science and culture was already riding high with iconoclastic readings of Newton's Principia followed by forty years of debates on internalism versus externalism. This was also ushered in by the moderate sociologist of science Robert K. Merton's 1957 model of *Puritanism, Pietism and Science in seventh century England*.[23] Arguably, this was of significance to biographers, as personal matters were regarded peripheral by Merton, if not irrelevant, to the understanding of scientific enterprise as institutionally based cognitive disciplines. The demeaning of the subjective individual was to the benefit of classes and economical factors and thus the focus on social, political and cultural contexts clearly meant hard times for biography.[24] Compared with Victorian biographies, the search for knowing was hence viewed as the work of a cognitive collective. Scientific development was considered to

[22] Koyré 1998.
[23] Merton 1957.
[24] Söderqvist 1992, 9.

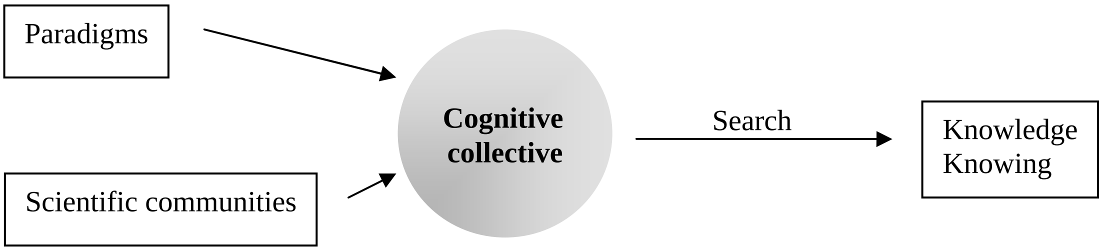

Figure 2: Turning away from individualistic history of science.

be controlled by more abstract and complex entities like paradigms and scientific communities rather than merely human scientists.[25]

As recounted in Söderqvist 1992, the sociology of science's neglect of individual aspects of science caused a counter-reaction from the biographer Thomas L. Hankins, who wrote *In Defense of Biography* in 1979. This was an attempt to restore biography and bring it into the heat again. Other historians like L.F. Holmes advocated that biography could be viewed as the entrance portal to studies of "the fine structure of scientific creativity."[26] Since the concept of creativity naturally includes the individual aspect, biography naturally came in by combining creativity with scientific undertaking and reasoning.

Since the early 1950'es, the creative person became a hot topic within several fields of psychological and sociological studies, and creative personalities became the heroes of culture. Now, the 'heroes' of today may not only be lone creative Einsteins anymore. Even though creativity is once again in focus and individuality is regarded a progressively important factor in the understanding of creativity and creative behavior, the inclusion of social and collective factors are also necessary for a modern portrayal of creativity.[27] Finally, in the 1990'es, biography came marching in with full strength, as mentioned above. The possible reasons for this have been articulated by many experts and non-experts. A recent global trend of individualization of many sorts of human activity is one rationalization, as it initiates the audience's interest in getting to know those individuals and their stories. I certainly find that there is an urge of "turning even

[25] Kuhn 1962.
[26] Hankins 1979; Holmes 1981.
[27] Rebsdorf & Jakobsen 2003, 30.

the most prominent heroes into normal human beings", as well as there is a parallel trend of wanting to do the opposite, turning normal private individuals into heroes of their own little world. Unknown private people have apparently acquired a taste for writing their autobiography and the audience in fact exists, which is indeed a firm confirmation of the trend.

Another explanation is that there is a tendency among the audience to regard all participants of a (scientific) community as having almost equal importance, or at least such equality is experienced in the actor's self-image. As actor-network theories and collective biographies are also riding relatively high in the history of science, knowing the individual histories of the actors in a scientific community contributes to the whole picture. With histories of big science research projects like CERN or ESO[28], the collectiveness even becomes a necessary prerequisite for the historian. At the same time, the scientific enterprise as a search for knowledge and knowing has been extended with other goals of science, such as personal fame, national prestige, military race, politically stimulated research by all sorts of reasons etc. Finally, the view of the work and use of a scientist has changed dramatically across the twentieth century and perhaps there might even be a drop of nostalgia in the heart of the reader of biography. Notwithstanding, such nostalgia clearly involves the risk of producing single-minded hagiography instead of nuanced biography.

The concept of hagiography originates back to the Greek word *hagios*, meaning saint, and denotes literature which describes life and awe of Christian saints. Hagiography initially treated the doings of martyrs and accounted for miracles in connection with holy graves, icons, relics or statues. Today, the term hagiography is applied for characterizing biographical accounts of admiring nature that praise the subject as some kind of saint or hero. A brother to hagiography is the panegyrical historical report. *Panegyricos* means speech at a public assembly, and is used today to denote an exorbitant tribute, or eulogy. According to Söderqvist, most – if not all – biographies share hagiographical or

[28] CERN is the abbreviation of Centre Européen de la Rescherche Nucléaire, ESO abbreviates European Southern Observatory, two twentieth century big science projects. See e.g. Price 1963. The history of ESO mainly from a Danish perspective is treated in chapter 8.6.

panegyrical traits, by which the biographer touches upon our central assumptions regarding the nature of science qua human phenomenon.[29] After having completed what could be considered at least partly a scientific biography (chapter two to eight), I will agree with Söderqvist that it is virtually impossible to prevent these traits.

The genre has for long been an important medium for picturing scientists and scientific ideas. The intension of the scientific biography is to present narratives about the lived life in science. This issue has been central for the creation of detached spectators of scientific communities and to the self-image of these communities. By means of anecdotes, memoirs, and portrays of prominent natural philosophers and scientists, biography has provided the audience with knowledge narratives ever since the seventeenth century. As already discussed, in spite of the blooming of history of science throughout the previous thirty-five years, scientific biography has been regarded as old-fashioned and stale, and as a historical resource of little interest in itself. Today, biography is one of the most popular forms of contemporary writings about politicians, musicians, authors, businessmen, sports elitists, and what have we. But perhaps there are too many biographies. The English poet and critic Samuel Johnson has been portrayed in 270 different biographies. James Joyce in 75 life stories, Charles Dickens in 60. Turning to the scientific biography, Isaac Newton has been depicted in at least 30 monographs and furthermore in innumerable articles; the life of Charles Darwin has been exposed in countless biographies as well.

Moreover, the field of astronomy has a long tradition of scientific biography ranging from al-Biruni to Aristotle, from Brahe to Baade; from Copernicus to Chandrasekhar. Recent examples of astronomy biographies make up the following selected list:[30]

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[29] Söderqvist 1992.
[30] Osterbrock 2001b, Wali 1991, Brück 2002, and DeVorkin 2000.

- *Chandra: A Biography of S. Chandrasekhar* by Kameshwar C. Wali
- *Henry Norris Russell: Dean of American Astronomers* by David DeVorkin
- *Agnes Mary Clerke and the Rise of Astrophysics* by Mary T. Brück
- *Walter Baade: A Life in Astrophysics* by Donald E. Osterbrock

Time and again, scientific biographies are written by people of the same trade as their subject and this also hold good in many astronomy biographies. In the above examples, Osterbrock is Professor Emeritus of astronomy and astrophysics, Wali is professor of physics, Mary Brück is former lecturer of astronomy and then there is DeVorkin, curator at the National Air and Space Museum in Washington, coming from a tradition of both science and history as former Chair of the History Division of the American Astronomical Society.

Thus, with four great biographies at hand, some standards of the field can be briefly sketched. The four selected biographies constitute excellent contributions to the genre in their own individual ways. Osterbrock and DeVorkin tend to focus on the internal development of astrophysics with two figures from observational astronomy and theoretical astrophysics respectively. While both authors give readable and moderately technical accounts of the professional life of their subjects, DeVorkin is more scholarly and detailed in style than Osterbrock, who seems to look for a broader audience and also addresses institutional aspects of the history of astronomy. At the same time, DeVorkin includes important religious aspects of Russell's life, thereby giving the biography an additional human perspective. Wali is more dramatic in style and by including the immanent racial issues he brings forth an exuberant portrayal of the modest Indian physicist, the astronomer and Nobel Laureate, Subramahnyan Chandrasekhar, who became a close friend of Bengt Strömgren, as we shall see. With a firm feministic touch, Brück brings up the story of the woman astronomer of pre-Einstein science, Agnes Clerke. Brück chronicles both the life and work of this extraordinary lady in an accessible and non-technical language. She uses her subject to introduce many of the great figures of the age, counting Lockyer, Pickering, and Huggins. This is a great example of a way to use the subject as a prism of its age, science and culture. At the same time, one should bear in mind, that the mere notion of such abstract 'prisms' involves pitfalls of specificity.

Though, since only one of the listed biographies of astronomers were written by authors trained in history of science, perhaps they reflect the standards of the scientific community more than of the historical community. Notwithstanding, the four chosen biographies count as weighty monographs to the genre in the field of astronomy.

Using a figure as a 'mirror' or a 'prism' of her age, the age will obviously be viewed from the eyes of the subject, but in the end, this perspective will always be introduced by the biographer anyway. It could be objected that any age has always been viewed from the eyes of individuals, *qua* human beings living history, and therefore the depth of the pitfall is somewhat defined by the degree to which the audience regards the representational aspect of the biographical account in question. If 'prism' is implicitly synonymous with 'representation' then biography as works of prisms of an age can be a dangerous enterprise. The portrayal of an 'age', and era, a context, or a development in time must consist of numerous specific events and actors. Clearly, the historian's use of an individual in a historical biography or other narrative can contribute to a new picture, to new aspects of a certain period, but I would consider it rather perilous to claim that the individual represents the period as a mirror or prism, through which we, the readers, can look into the past. Finally, if the concept of the prism is not regarded to be representation but instead presentation – one view of many – then I see no reason for not bringing it into play. Naturally, it should then be explicitly stated in what sense the concept should be understood.

Another important source of inspiration is the many scientific *auto*biographies of scientists that have also found their way to the audience. One popular example is *The Autobiography of Charles Darwin: 1809-1882*, in which the scientific icon recollects the influences of e.g. people close to him, his love of hunting, and the thorny relationship he had with his authoritarian father.[31] Astronomy also has such autobiographies, for example Cecelia Payne-Gaposhkin's life story.[32] Even Bengt Strömgren's recollections exist in the form of an account of the many "Scientists I have known and some astronomical problems I have met," which is narrated with a strict chronological, Plutarchian structure, written in Strömgren's office at NORDITA in the autumn of his career.[33] But, as always, with recollections, the biographer should tread cautiously before using the recollected 'facts' from his past. Not only factual dates and places are open to doubt and risk of anachronism. The remembrance of whole sequences of events will always be biased to some extent, and the biographer's duty is to choose cautiously and expertly among the many statements of recollections as well as explicitly state whenever there is doubt as to the reliability of a certain citation or quote – as with any historian.

Despite that fact that countless biographies have been read over the years, the genre has attracted little attention from historians. One reason could be that scholars writing *about* biographies are often the ones writing the biographies themselves. Scientific biography promises the audience a glimpse into the minds of the few individuals – often the aristocracy of science – who made discoveries of the physical world, who took part in important decision making, who made technological innovations etc. Furthermore, the genre embarks on religious and philosophical traditions of personal character, moral integrity and the relation between the subject and social and political pressure. A burning issue for the biographer in this respect is the question of the ways of structuring the narrative.

Life Simulation: Suetonius Meets Plutarch

With the chosen terminology, two aspects to choose from are the Suetonian and the Plutarchian lines of attack. Following Suetonius' approach, scientific ideas and cognitive processes should be prearranged systematically as to the various

[31] Darwin 1993.
[32] Haramundanis 1996. Haramundanis has edited Payne-Gaposhkin's autobiography and other recollections.
[33] B. Strömgren 1983. NORDITA abbreviates Nordic Institute for Theoretical Atomic physics and is located next to the Niels Bohr Institute in Copenhagen.

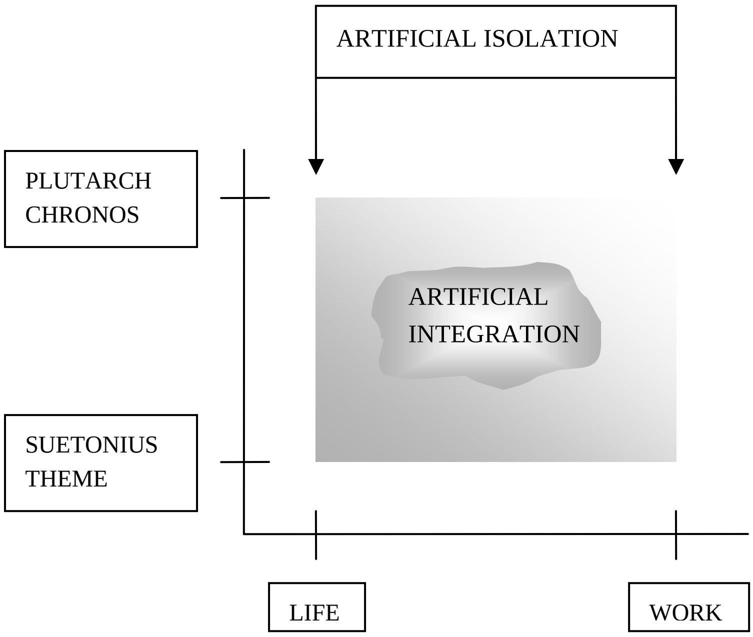

Figure 3: Structural challenges of biography. Life-work versus theme-chronology.

doings and work of the subject, hence entailing a thematic construction, where the continuity and fluidity of a developing life would most likely disappear. In contrast, the Plutarchian approach seems more palpable, especially when a weighty archive of personal correspondence is accessible, as in the case of Bengt Strömgren. Though Plutarch employed the exact chronology in many parallel biographies, the present biographical narrative of Strömgren is no meticulously linear chronology. But still the overall arrangement of Bengt Strömgren's lifespan is naturally structured following this recipe.

How are we to join the two concepts of life and work? How do we make Plutarch and Suetonius meet? Many biographies, and indeed numerous obituaries, are divided into these two parts, perhaps because they are so difficult to merge. In other words, the dilemma appears in the choice between 'artificial isolation' and 'artificial integration'. Artificial isolation occurs when life and work are completely isolated in the biographical narrative. Artificial integration may take place, when the biographer retrospectively attempts to integrate the private sphere and professional life of the subject. But perhaps the scientists should be viewed as both 100% human being and 100% scientist, instead of trying to divide her life into fractions and degrees of *how* much a scientists and how much a private human being she was. Both artificial integration and isolation will take place throughout this biography, though, and this is evident in the constant struggle between chronology and a thematic approach. The upbringing of Bengt Strömgren was marked considerably by his father's science, which gradually became part of Bengt's life. Following his childhood in an almost necessary chronological order obviously involves other themes than science also.

On a substantial level, biography plays with at least three elements: the subject, his work, and time (i.e. context). First of all the subject is a social being. By combining the individual and his work, this can be claimed to point outward at the context. But an opposite arrow is likewise necessary, since external investigations of historical developments bring understanding to the ways individuals act. Modern scientific biography has developed into what is somewhat redundantly denoted as existential biography.[34] Redundantly for the reason that the term 'biography' itself should indicate that it concerns writing about human existence. Nevertheless, the additional term 'existential' emphasizes that the writings are concerned not only with the work of the subject, but moreover it treats the private life of the subject. The existential biography is nicely exemplified by Thomas Söderqvist's large monograph *Hvilken kamp for at undslippe* ("What a struggle to escape") about the Danish immunologist and Nobel laureate Niels Kaj Jerne.[35]

Any artificial isolation of individual and context should be avoided, thus biography that fancies only life or work seems sterile and is hardly ever seen, due to an act of artificial isolation. Though, many obituaries tend to be structured in ways that divide family relations and adolescence, scientific career and post mortem scientific impact, and hence do not combine the various complex elements that make a life (in science). The typical structure of most biographies

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[34] Söderqvist, 1998.
[35] Söderqvist 1998, Söderqvist 2003. Söderqvist has treated the historiographical topic of biography as an edifying genre extensively. See e.g. Shortland & Yeo 1996, 45-84.

is of the following order (particularly in obituaries, commemorative words and the like):

1. Family background
2. Birth and childhood
3. Scientific contributions
4. Possible controversies
5. Marks of honor
6. Personal characteristics of the subject
7. Family Tree

My choice in this respect has been an attempt to let the historical events speak for themselves before choosing the super- and substructure of the relevant parts of Bengt Strömgren's biography, which I very much consider to be merely some simulation of a life rather than a true story of what really happened. Following the above numbering, in this dissertation, the narrative briefly introduces with 6, and after this historiographical introduction (chapter one), chapters two and three represents more or less point 1, 2, 3, and 6 and then more of the above points follow in mixed order and simultaneously (3, 4 and 6). Point 5 can be found in Appendix F. In addition, of course, contextual themes are intertwined with the above mentioned, and thus the overall structure is in fact controlled by both Suetonean and Plutarchean variations. Finally, I have chosen to follow Bengt Strömgren's life in large detail only until his father dies in 1947. Following this event, the narrative does not stop, but the degree of detail is decreased and a more thematic approach is taken thenceforth.

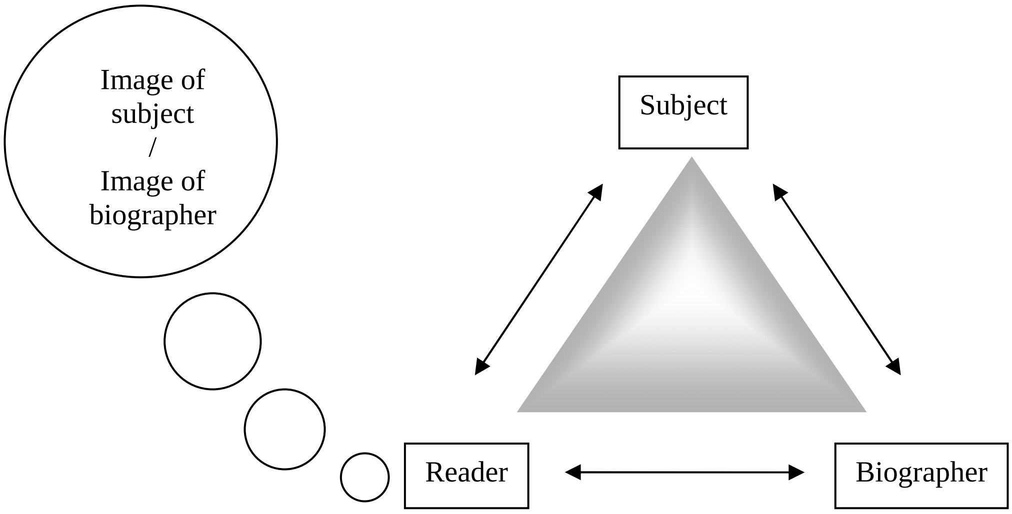

Figure 4: In biography, three egos meet: The subject, the biographer and the reader.

The Biographical Troika: Biographer, Subject, and Audience

> I'm writing a chronicle here. This story will either be interesting or it won't, though that's neither here nor there. My intension was to be true and in this I have succeeded […] It just seems obvious to me that with a little of imagination and style, there's nothing easier than churning out a novel. We'll stick with the truth.
>
> Denis Diderot in *Jacques the Fatalist*[36]

In the picaresque novel *Jacques the Fatalist*, Diderot writes ironically about the mediation of truth. Or ironically it seems, as the concept of truth appears somewhat uncertain, or undefined, in a fictitious (e.g. untrue) novel. At the same time, the quote says something about the flimsiness of writing chronicles, or history. Another aspect of Diderot's writing with resemblance to the field of history is Diderot's strikingly modern way, in which he makes explicit conversation with the reader, which is exemplified by the following quote: "But look here, Reader, if you keep on interrupting me and I interrupt myself like this,

[36] Diderot 1999, 199.

what will become of the story of Jacques's loves?"[37] Diderot engages the active participation of the reader in the unfolding of the episodes, through authorial harangues, questions, puzzles, alternative versions, and ascribed reactions. Diderot acknowledges that the reader is the active player in the experience of a history, fictitious or not. And a trichotomy is apparent: The author, Diderot, the subject, Jacques, and the audience, us. He even expresses annoyance by the reader's suspected impatience when he (Diderot) meticulously describes a landscape or other. The reader, being the intended receiver of the written chronicle, obviously deserves attention. It is not only the author that is at risk of identifying with the subjects he is writing about, but the reader is too and is perhaps even intended to do so.

Obviously, it also takes three to bring a biography to life: The biographed, the person being the *subject* of the biography; the *biographer* investigating the past and writing about the subject; and the audience of biography, the *reader*.[38] Though, the subject in Diderot's chronicle never really lived and is indeed fictitious. The genre ranks in all positions within and between research, popular science and literary or fictive accounts and it can be viewed as a counter-current against more postmodern presumptions of contingent relations between life and work. There is often a touch of intermediation in biography. The identification of the reader with the subject – and indeed the influence of the subject on the biographer – is a likely result of writing biography.[39] A somewhat widespread opinion is that biography reveals more about the biographer than of the subject; that the biography reflects the personality of the historian rather than the treated subject. This may be correct to some extent, but I see no reason why such a view should loose validity in other fields of history writing as well, although the content of other genres, e.g. institutional or internalist history of science, might appear less 'personal', or psychological, at first sight than a scientific biography does by its very nature.

[37] Diderot 1999, 32.
[38] Richard & Jensen 1999.
[39] Kragh 1987, chapter 15.

Throughout this biographical study of Bengt Strömgren, I have become gradually more aware of the triangle in figure 4, not least during the conduction of oral interviews and by reactions of some of my popular papers on Bengt Strömgren cause calls from the audience about their view of the scientist. The image of the subject being created by biography is probably not shared by the reader and the biographer, even though the biographer's intentions are to create a picture, which is the result of many premises and choices. The biographer's choices also come from considerations of the purpose of portraying the chosen subject, and ultimately from thoughts about the biography's objectives.

The Role of Biography

Scientific biography plays many roles. One function is the story being a morally edifying text. Another role is that of breaking down myths and legend about the subject. Scientific biography can also be used as an end of recruitment of prospective students of science; it can work as case studies of cognitive processes; as a role model; and as the notorious 'prisms' of scientific culture.

The biography as an edifying genre has been treated historiographically in Söderqvist 1992. One relevant example of a moral and edifying biography is that of the Danish industrialist, Haldor Topsøe, who wrote Bengt's obituary in the newspaper *Berlingske Tidende*, in which he overtly presented the virtues of Bengt Strömgren as a research politician, as an ambassador of Danish science, and as an advocate of free research. Topsøe entitled the obituary, "Bengt Strömgren's lesson", meaning that we, the readers, the politicians, should learn from Bengt Strömgren's moral issues as to how research policy should be made.[40]

Somewhere H.G. Wells should have said of the difficult genre of biography that "a man's biography should be written by a conscientious enemy", i.e. the biographer should attempt to break down existing myths.[41] Whether Wells in fact stated this aphorism or not, I find it quite indicative all the same. At least

[40] Topsøe 1987. See chapter eight for a detailed account.
[41] Undocumented statement.

if being a ‘conscientious enemy’ of the subject implies an eagerness to depict virtues as well as defects and otherwise demystify the once mighty, but scrupulous actor. This does not entail for the biographer to work as an iconoclast only, but rather to balance pros and cons. A relevant neologism in this respect is the notion of *pathographies*, coined by novelist Joyce Carol Oates, who denotes a kind of biography that, of late, has been too much with us. Such biographies portray their subject “not just warts and all, but as mostly warts – the sum of their pathologies.” As was noted in a review: “It speaks well of [the biographer] that he abandoned writing a biography of Picasso because he could not stand to be so long in the company of such an unpleasant man.”[42] Clearly, this is rather radical, and in the case of Bengt Strömgren, I have had no trouble in this respect. From all I have learned, Strömgren was a pleasant, polite and calm man in all possible respects, which obviously makes it rather complicated to play the role as the conscientious enemy. Nevertheless, interesting events await us, as Bengt Strömgren’s father was not as pleasant or polite or calm as his son turned out to be.

One might object that if the biographer believes it is indeed possible to break down myths, he would be mistaken, for would this not necessary entail the creation of yet another, if different, myth and turn the whole enterprise only into a replacement of myths instead of breaking down old ones? I am convinced that this is true, for the reason that the mere concept of breaking down myths involves a realist view of history and that the non-mythical exists in historical writing. Most likely, myth breaking entails myth making.

Scientific biography may also be used as an eye-opener for readers who are not familiar with science, and thereby as an active tool for recruitment of future students of science. In this connection, biographies as case studies of cognitive processes can serve didactical purposes. By watching and learning about the discoveries of the innovative scientists of history, we can discover with them, and learn about science, it may be claimed. A common purpose of biography is that of systematically functioning as case studies of cognitive

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[42] Will 2001.

processes. This way of using the genre often involves constructivists-didactical purposes of natural science teaching: Read about Galilei's life and work and understand physical phenomena! By following creative scientists, the student becomes familiar not only with the scientist's personality, behavior or context, but also with the science itself. Often, national icons of science are brought to light in e.g. university teaching and by thinking of national role models as building blocks of feelings of national identity, the biography serves as a potential generator of interest in the student who perhaps seems to be ignorant of science. Harry Collins and Trevor Pinch utilize the related general term "official history of science" as one of six types of historical enterprises. Official history is then understood as a means of "distributing credits and providing a field with its self image" and points at the palpable suggestion that the genre of biography is only one of many history genres contributing to both national as well as scientific self images.[43]

But what does biography say about scientific communities, when it involves only unique stories of selected parts of history? For instance, as "the Victorian age was one of hero-worship", Victorian biographies were regarded as exemplary in particular.[44] In Denmark we have our own heroes, and it is not exactly easy to find iconoclastic biographies, although it may just be a matter of time. Niels Bohr biographies seldom, if ever, denigrates any aspects of the many-facetted icon and national role model of creative thought, of fundraising, and particularly as anchorman for the quantum revolution. But can biography really serve as a prism of culture? Can scientific biography work as a mirror of scientific communities? It can be argued that the mere specificity of biography in itself indicates that this is immanently impossible, and that 'the particular' can say nothing about 'the general'. On the other hand, as already discussed, the non typical and the unique contributes in its own way to history, and just as knowledge of scientific communities can tell us something about scientists,

[43] Collins & Pinch 1998, 165.
[44] Skidelsky 1988, 5.

scientific biography invites the reader into certain parts of scientific communities as well. The arrow not only points in one direction.

This scientific biography has many purposes and it clearly serves to be emphasized that it is in fact not really a biography, although I use the term frequently. First and foremost, it is a PhD dissertation in the history of science. The structure and genre is that of the scientific biography and the degree to which my subject exemplifies, or represents, the historical context of the astronomical community – as already discussed – is for the audience to judge. Regarding the historian's role as iconoclast, I have rather attempted to be as sophisticated as possible, whatever conclusion might result from that. No historian would deny that a certain bias is manifest in the process, if not at least subconsciously – as I will discuss later. For one thing, it has not turned out to be a pathography. On the other hand, building up Bengt Strömgren as some kind of national icon in the name of national identification is hopefully not the result experienced by the reader. A balance of both extremes seems to be the best solution.

National identity and cultural pride is a difficult subject for me to write about, particularly because I have been brought up in the relatively minute Danish culture myself. For the foreign reader to grasp Danish values and traditions there is a complicated task at hand. A rough and very general guide to a history of Danish culture is given in the end of this chapter.

Case studies of cognitive processes can be found in chapter four in particular, the purpose of which is not of didactical sort though. Rather, I found it necessary to actually understand the content of Bengt Strömgren's scientific research, and hopefully I succeeded. The conceptual development goes hand in hand with the scientific communities, which I consider to be very important also for the understanding of scientific enterprise. The communities of astronomers are treated throughout the dissertation on various levels. Social facets of colleagues, of friendships, of (scientific) debates, and of enmities all find their place in the historical narrative. Aspects of appropriation of science, institution building, and astronomical practice are necessary elements for contributing with a fuller understanding of the scientific enterprise, and they are included in the dissertation where it comes naturally. Finally, the psychological tension between Bengt Strömgren and his father runs through the narrative.

The Biographer's Intimacy Dilemma

As Thomas Söderqvist mentions in his Jerne-biography, it sometimes happens, "whether you want it or not, that the biographer's work with a contemporary person creates a close personal relationship between the two."[45] Such closeness can be an important source of insight but it also entails the risk of intellectual seduction and thus intimacy can endanger the final result. As a historian, you use yourself as human being during an interview. An interview, as a social event, is a sensitive one. The physical introduction of a tape recording machine can change the setup and the intimacy, which may have been built up between the interviewer and the interviewee. In one case, the interviewee, Bengt Strömgren's daughter Nina Strömgren Allen, remembered quite a lot from her past as a little girl who admired her father. In other cases the interviewee did not remember much from the past, or maybe much may be remembered, but it lacks detail and it may be viewed as being a mere reproduction of common conceptions of the past, e.g. general statements like "the Great Depression was tough", "Niels Bohr had a great impact on the future of theoretical physics", etc.

Since Bengt Strömgren died in 1987, intimacy with the subject is not the case in writing his biography, but intimacy did arise all the same during archival research. I had the opportunity of interviewing all three children of Bengt Strömgren, his two daughters Nina Strömgren Allen and Karin Strömgren Campbell, and his son Ole Strömgren. This has had consequences for my choices, since intimacy, or closeness, did show up along the study – but in a positive way. During my research visit in Chicago, I had the opportunity of visiting Karin Campbell and her husband Joe Campbell several times in Stoughton, Wisconsin. At one of my visits, her sister Nina was present, and I had

[45] Söderqvist 1998, 25.

the chance to interview both at once.[46] Karin, Joe, and Nina became my friends and I got to know Karin and Joe especially well since I socialized with them on several occasions, and especially thanks to their great hospitality.

On my first visit on April 9, 2003, Karin invited me to her heated outside hot tub, which is not as commonly used in Denmark as in the USA. It was freezing cold outside and during parts of this interview – at 10pm – I was wearing bathing shorts; Karin was wearing a bathing suit. For an hour and a half our bodies were immersed in the outdoor hot tub by the Stoughton river running close by; the hot tub was filled with heated water, and the air was just below the freezing point. The night sky was covered with stars, and the Moon enlightened the conversation. In a rather informal and cozy situation like this, I found a tape recorder completely inappropriate and awkward. Listening to Karin's recollections of her father, the astronomer, while relaxing under the black velvet firmament of sparkling stars in a hot tub lit by the nearly half Moon, I decided instead to attempt to remember the important parts of the interview rather than jumping out to get my recording machine; and then I would swiftly attempt to remember and write down the parts afterwards.[47]

How could any historian ever be able to stay distant and objective from the interviewee after such an experience? Should the historian necessarily attempt to reach such an 'objective distance' and is this in fact impossible? The practice of writing biography will always include some human aspect of intimacy, since biography is about writing a life by definition, even when it is ancestors and not the biographed himself in question. As Maurois puts it, "it is not easy to understand how it is possible to construct a historical character without spoiling him. He was what he was. We cannot change him." So what, then, is the biographer to do? "To make of a man a system consistent with itself, clear, yet false, or to give up all attempts at making an intelligible system of him – such is the dilemma of the biographer."[48] Though, in the particular case of

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[46] This interview is abbreviated KNSI. See the Archives chapter for further details.
[47] After I transcribed the interview, I discussed the interview with Karin Strömgren Campbell once again to correct any misunderstandings of mine (KSCI).
[48] Marois (1986), 6-7.

Bengt Strömgren, it is hard to tell whether the biographer has spoiled him or not, but any spoiling of Bengt Strömgren is likely to assume. The image of the subject has surfaced through the interaction between the biographer and the historical artifacts such as archival material, oral interviews, university annals etc, and more source criticism comments will follow below.

High Adventure Storytelling: Fictional and Historical Narrative

> Every man has two erotic biographies. Usually people talk only about the first: the list of affairs and of one-night stands. The other biography is sometimes more interesting: the parade of women we wanted to have, the women who got away. It is a mournful history of opportunities wasted.
>
> Milan Kundera 1980.

In Sigmund Freud's psychoanalytical study of Leonardo da Vinci, sexual activities and gender issues played a considerable role in the explanatory background of the biography of the inventive Renaissance man.[49] The scientific biography, however, does not usually profess in accounts of sexual activities, but nevertheless, Kundera indirectly presents a pertinent relativist view on truth representation in biography writing: Even the autobiographical narrative meets certain difficulties if the audience asks for a "true story", since Kundera claims that it is unclear what the term "true" refers to, even when it comes to the plain memory of the autobiographer. Or at least Kundera suggests the existence of more than one, true, life story. Certain events from the past are remembered; other incidents might be forgotten subconsciously or intentionally when a life story is to be told. Thus, according to Kundera, the individual may have several competing stories that represent different 'truths', that is, different recollections of what is believed to be real experienced past events.

If this is already the case for autobiography, how, then, does the biographer regard the 'amount of truths' in his writings about a distant, in many cases even dead, subject? Luckily, the biographer has probably no awareness of

[49] Freud 1910.

such challenging self-images or individual and personal life stories that once lived in the mind of the biographed subject. Yet it is still an existing snag and an important question taken up by many literates, whether the biographer is at all able to give a fair account of a lived life or not.

It is clear that when a historical account is given, other stories will emerge in time for various reasons, e.g. new archival material, new historiographical methods of treating the past etc.; this is the essential activity of historical research. This interpretive aspect of historical practice is naturally included in scientific biography. Whether various historical, and hence biographical, narratives are denoted as just different interpretations or, more ambitiously, as different 'truths about the past', it is beyond doubt that the biographer must be aware that whatever story is told, it will be temporary.

An oft-spoken question vis-à-vis biography is that of the provisory character of the genre, or, one might add, of historical accounts in general. In the introduction to the anthology, *The Troubled Face of Biography*, the editors take a faintly relativist stance when it comes to biography as a genre:[50]

> There can never be a definitive biography, merely a version, an attempt, an essay which in time reveals how completely all such attempts bear the impress of the age in which it was written. Few biographies last. Not only do certain subjects seem, over time, to be more or less interesting, but the frame of interpretation, the cultural luggage, can change so comprehensively that the important biographies of one age are the library discards of the next.

This resembles Collingwood's historical relativism, which gave currency to the belief that historical truth is unattainable and that all history writing is molded by the individuality of the writer.[51] Although Homberger and Charmley are primarily concerned with the literary biography, their comment is also applicable to scientific biography. One is just to wish that this biography will last.

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[50] Homberger & Charmley 1988, xi.
[51] Collingwood 1966, 282.

A customary normative aspect of biography is the characteristic lyrical style of writing. In many biographies, one finds that they are well-written, poetic narratives. This constraint of the literary genre may instigate high expectations to the biographer among the audience, thus standing between science and art, or storytelling. When literary “life-writers speak of their art” – quoting the subtitle of the 1986 anthology *Biography as High Adventure* – biography is indeed viewed upon as a work of art:[52]

> Like the novelist, the biographer must have an eye for detail and must learn the technique of controlled dramatic narration; he must keep his own voice out of the story so that the subject and his times can live again; and he must have insight into character, capture the inexplicable, and rely on the power of suggestion – especially through the telling quotation.

The first part of the quote goes for ordinary history writing as well whilst regarding the second part of “capturing the inexplicable” and “relying on powers of suggestion”, such norms may be found within literary biography, but not always in scientific biography. Perhaps this is a bit of a stretch due to Oates’ fascination of the literary genre, to which he has contributed through more than a generation as one of few professors of biography at the University of Massachusetts, Amhurst. According to Oates, the prose of biography must “radiate a sense of intimacy and familiarity”, quite as though the author himself has lived the life and walked the ground. This “can only be acquired by visiting the landmarks where one’s subject lived and died.[53] Clearly, Oates’ literary demands of the biographer resembles some of the difficulties met during the investigations of Strömgren’s life and work, although it is indeed questionable whether the biographer’s experience of visits to actual historical sites necessarily would be well-reflected in the biography, as Oates’ *re-enactment* notion concerns, using Collingwood’s terminology (“…so that the subject and his times can live again”). It appears to me as an idealistic, or rather aesthetic, if

[52] Oates 1986 125.
[53] Oates 1986, 127.

unnecessary, requirement of a genre that is represented by a variety of styles of written text. It is indeed one of the laudable goals of biography to make the subject and his times live again, but through the lens of the biographer! The novel is a thing we can understand, and following André Maurois:[54]

> In real life, living human beings are dangerous enigmas; it is impossible to foresee their actions; ideas seem to come to them, and then fly away with confusing rapidity […]. On the other hand, a character in a novel is built up of what the author has put into it; it is a creation of a human intellect and, as such, is accessible to a human intellect.

Maurios continues by comparing novels with biography in stating that biography perhaps even has an advantage over the novel, since when we read about a very well-known subject, we know in advance what changes fortune and what to expect, and a slow march of the drama toward historical events of the subject for which we are waiting, "endows our emotion with that poetic grandeur which the ever-present idea of Destiny gives to Greek tragedy."[55] But what about the less well-known historical characters waiting for their biography to be written? And who knows what to wait for? Bengt Strömgren was an acclaimed and recognized scientist of his time, but today his is only, or predominantly, known to astronomers and astrophysicists. Thus, in this instance, no ideal of portraying marching Greek-style dramas is even possible. It should not be forgotten, though, that the historical narrative depends on the empirical material, the archive.

According to the biographer Leon Edel, "it is not pleasant to have great parts of archives flung in the reader's face; and the subject ends up fenced in by walls of quotation and abysses of anecdote. Biography still has to learn the art of the portrait."[56] Being more a statement about the storytelling virtues of the biographer, Edel is concerned about what lies between the lines of the obvious and more factual contents of an archive:

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[54] Marois 1986, 4.
[55] Maurois 1986, 5.
[56] Edel 1986, 22-23.

> What is important in Hemingway's archive, which is large, are the answers to the questions that will relate his doubts, his failures, his struggles, and not the answers to his successes that are written in the public prints.

Biography can suffer the risk of being a mere recital of facts, more than an explanation of an individual's exact doings, more than a study of feat, when the biographer allows himself and the reader to "glimpse the myths within and behind the individual, the inner myth we all create in order to live, the myth that tells us we have some being, some selfhood, some goal, something to strive for beyond the fulfillment of food or sex or creature comforts."[57] As Edel remarks in comparing modern biography with ancient writings:[58]

> The great problem that we must face at the start is the oppressive weight of modern archives. Gone are the days when biographies could be written out of half a dozen shoe boxes, or pieced together out of little facts like the royal grant of wine to Chaucer, or Shakespeare's second-best bed.

Modern archives preserve virtually everything, although gaps do indeed still appear. The Bengt Strömgren Archive covers the period from 1915 to 1977, but not even one single letter is left from the Second World War.

The trail of papers from birth certificate to funeral speeches is never continuous or complete. And each paper trail is unlike any other paper trail, and since each biographer is unlike any other biographer, the right way to fill gaps remains unknown and can not be given in a tool-kit, whereas the wrong ways are legion. Being confronted with gaps calls for special powers of reconstruction. The problem of filling gaps involves more than material; it is likewise a question of rhythm. According to Edel, gaps in archives tempt the fledgling biographer to speculate, and the artistic biographer to invent, and the scholarly biographer to give a lecture on history. During the Second World War there is a complete gap in the Bengt Strömgren Archive. My own speculation enters to a certain extent,

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[57] Edel 1986, 28.
[58] Edel 1986, 22-23.

which I state explicitly in the relevant paragraphs. On the other hand, I do not intend to invent or lecture on history.

1.2 Using Voices of the Past

> The unknown future for the subject is the well-known past for the biographer. The biographer must use the advantage of this difference but not take advantage of it.
>
> Leon Edel[59]

The historical practice and its underlying historiographical considerations are mutually complementary to such a degree that it is quite complicated to separate them. The historian's choice of inclusion or exclusion of a particular archival collection in the story is mirrored in the underlying historiographical considerations, but these considerations are also affected by increasing experience with archival work, and hence by the historical practice undertaken by the historian. Thus, it is practically a circular process, and it will be treated as such in the following.

As with Diderot and Kundera, it is uncertain what the truth is. Obviously the uncertainty is manifest as fictitious novels are concerned, but not much more security can be found when it comes to history writing. A common (lay) misconception of historical practice is that of unveiling or uncovering an objective past by means of artifacts of the past, be it old correspondence, notebooks, diaries, recorded messages, publications, logbooks, preserved movies, individual reminiscences – written or in the memory of living individuals – or other kinds of artifacts from the past. It is uncontroversial that such historical realism suffers serious problems. Without entering deeply into philosophical questions of the existence of a past, wherever we would find it, it is fair to give it serious consideration, since it undermines the whole of historical practice, whichever conclusions may come out of an archival working process.

[59] Edel 1986, 48.

I do not in any way dispute the brute fact that the past has happened in one way, and one way only. The process of writing these very words happen in this one way and not in any another way, unless speculative theories of parallel universes is taken into account – and they are not. I do not subscribe to any view that there should be competing or alternative preceding series of events. The ontology of the past in this respect, that is, the objective existence of the past as one single series of events, is fairly unproblematic from this pragmatic point of view. It is evidently true that the events in history have happened in one way only. But when it comes to *writing* histories of the past, a long chain of problems immediately appears.

Now, the challenge appears as soon as the historian begins to interfere with the leftovers of the past, the historical artifacts. A reduction of the data preserved from the past has already taken place before the artifacts ended up in an archive – or were found by digging in an excavation. Coincidence is one reason for an artifact to presently exist. The natural transitoriness of paper, or of a clay amphora in the dirt, may be the reason that some relic never made it to the present. Conscious choices may exist as other causes for a correspondence to still be preserved or to be burned in the fireplace due to e.g. sad war memories – as has perhaps been the case of the Strömgren correspondence of 1940-1945. One can think of all sorts of untraceable reasons for the destruction or preservation of artifact from the past. Today, for e.g. the Danish State Archives, this question is very real, as not all documents can be preserved, so one needs to make decisions and criteria as to which parts of existing material should be discarded. Though, the chain of barriers between the raw artifacts, if such a notion exists, and a history of the past is still a long one.

One success is to find some specifically wanted relics; another challenge is for the historian to ask herself if the found archives constitute the total, or if there should be more relevant items hidden somewhere. There probably should, and then the sensible question arises, whether is would be worth investing a lot of resources looking for what might be waiting to be found in an attic somewhere – or maybe just around the corner. This is one link in the chain of data reduction.

The historian’s interest in choosing one relic or one particular correspondence instead of another is an additional link in the chain. This interest can be dictated by imperatives from the aim of the investigation, be it the historian’s own individual interests or the particular interests of the history work group in which the historian is working. Another ‘interest’ could be that the knowledge of the historian is limited to an extent that it makes him leave certain parts out of the story, since they are regarded unimportant due to the historian’s lack of information. The historian can only know so much and therefore this is a common, often unconscious reason for data exclusion. The reasons for choice are legion, and lots of links exist in the chain that makes it a complex task to attempt reconstructing the line of reasoning behind the choices; choices that led from finding a number of relics and ending up with some representational or unique collection of historical artifacts and then telling a story that they allegedly represent.

This is yet another link in the chain. Does the chosen archival collection tell its own story? Other choices as to which sentences to quote, which topics to be concerned about and so forth, constitutes a direction in the mindset of the historian and hence in the story to be told. Thus, the data do not speak for themselves. If they did, the historian’s sole obligation would be to find the collection – maybe transcribe it into modern standards – and then publish it in raw form. In most cases this is evidently not the typical approach. The historian chooses what to include and what to leave out of the mediated story. This also holds in this dissertation. Furthermore, the ways to place some previous events in local – and even global – contexts are diverse and presents lots of possible alternative stories based on the same amount of sources.

It is a complex task to continue my reconstruction of historical practice, but it is obvious and uncontroversial that the concept of a “true story” of “what really happened”, as is seen in the title of Sobel’s monograph, is not only problematic. It is absurd. And therefore, the historian should be very careful, not only when explicitly stating that a subjective historical interpretation is under way, but also when presenting quotes or other documentation, because they are the result of a chain of reduction links.

This is all well known to most historians, but I find it imperative to underline the importance of explicitly stating that all possible flaws coming from realist historical practice are also at risk to be found in this dissertation. It is important to acknowledge and maintain the statement that the story I am about to tell is one story, which is a result of a lot of choices, conscious as well as unconscious, however implicit they might seem in the text. Other historians would write other stories based on the same amount of relics, at least owing to the fact that they by nature are given other individual mindsets, no matter what tradition might constitute their historiographical basis. Thus, the utopian historiographical ideal of an unbiased history of the past is inherently unachievable. Naturally, this is by no means justification to avoid the responsibility of the historian to present the reader with options and to suggest which is most likely.

The Historical Value of Recollections and Memoirs

> Remembering is only a vanishing condition. Through memory, the experience presents itself to receive the consecration of recollection […]. Recollection is ideality, but as such it is strenuous and conscientious in a way completely different from indiscriminate memory […] This is why it is an art to recollect.
>
> Søren Kierkegaard in the opening to *Stages on Life's Way*[60]

Bengt Strömgren was known for his photographic memory.[61] As his Danish co-worker Poul Erik Nissen recollected: "You can see it in his scientific papers. Seldom will you find a graph; always tables of numbers. Once he even corrected some erroneous digits in one of my tables, which was copied out of an older table

[60] Kierkegaard 1991, 8-10.
[61] Following e.g. the citations on page 2 and 8.

of his. He simply remembered all those rows of numbers."[62] Another former co-worker, Mogens Rudkjøbing, did not remember many details from his collaboration with Bengt Strömgren, during an interview I made in 2002. But among other things, one thing that Rudkjøbing remembered vividly was "Bengt Strömgren's incredible memory".[63]

Throughout this dissertation, I use recollections of numerous people. I have made various interviews of living persons, among which there are scientist colleagues, other former colleagues, and relatives of Bengt Strömgren.[64] Besides, a number of interviews were made in the 1970'es by a group of historians of science at Center for History of Physics, American Institute of Physics, MD.[65] Finally, I have corresponded extensively by E-mail with the children of Bengt Strömgren.[66] Apart from these interviews, Bengt Strömgren wrote his own autobiographical memoirs in 1983, as already noted on page 17.

Recollections play a double role. Firstly, the recollections of the subject, e.g. as they manifest themselves in the 1970'es interviews of Bengt Strömgren, tend to be given personal value, in that they constitute the subject's own expressions of that he believed really happened. Secondly, recollections play the devil's role, as they, each time they are used, have to be judged concerning retrospective bias and anachronism. Even though Bengt Strömgren arguably had a splendid memory, this does not considerably improve the value of his interviews as historical sources. The simple reason being, of course, that the past events are indeed recalled in retrospect. Therefore, there is the obvious risk of historical bias. The psychoanalyst Ernest Schachtel phrased it like this, in relation to his investigations of childhood memories:[67]

> Memory as a function of the living personality can be understood only as a capacity for the organization and reconstruction of past experiences and impressions in the service of present needs, fears and interests…Just as there is

[62] PENI.
[63] MRI.
[64] MRI, PENI, PI, KSCI, KNSI, and OSI (see the archives chapter).
[65] CI, HBI, HI, and MI.
[66] COR.
[67] Sachs 1995, 166.

> no such thing as impersonal perception and impersonal experience, there is no impersonal memory.

Historical bias can consist of interests of all sorts; knowing-all in retrospect, personal judgments of other people and their behavior, perhaps of people not living any longer and not being able to defend themselves, etc. Clearly, it is important for the historian to explicitly state, or indicate by use of appropriate phrases, whenever he or she interprets or speculates, and when a recollection may be problematic. It is important that the historical narrative is sufficiently transparent for the reader to see *that* the historian is interpreting and in particular *when* he does. Generally, I have used the above mentioned recollections in concert with other archival material, in order for the historical product to be as credible as possibly doable. By the nature of recollections, they are potentially problematic compared with sources written when the historical events unfolded. Finally, contemporary archival material such as contemporary correspondences, diaries, and newspaper clippings are often given a higher status as valuable sources, because they were written at the time of the events, without any risk of creating the retrospective know-all. Thus, the contextual, or 'anti-whig', line of attack is obviously more constructive, inasmuch there are accessible archives to support this approach.

1.3 Eventualization, Comparison, and Networks

This project does not subscribe to any one particular historiographical approach but attempts to employ a de-fragmented, or pluralistic, historiographical line of action. Over the last thirty years, history of science can be claimed to have been fragmenting itself into many specialist subgroups that do not always communicate constructively with each other: biographers, internalists, localists, institutionalists, constructivists, feminists, sociologists, post-modernists etc. However, without boldly stating that this PhD project will profess all such methodologies, different historiographical perspectives are taken where appropriate in a historiographically pluralistic manner. Or, in the words of Peter

Galison, professor of the history of science and of physics, science is a mosaic of cultures.[68] I will attempt to paint a picture of astronomy, where no particular aspect of the field takes particularly central stage and where as many aspects as possible are combined, such as observational practice, publishing, teaching, meeting at congresses, theoretical as well as observational astronomical enterprise, etc, as well as the aspects of scientific dependence on the support of society.

Not surprisingly, the conceptual development of astrophysics has been treated with an 'internalist' approach in order to follow the cognitive scientific contributions of the biographical subject, Bengt Strömgren.[69] Furthermore, to appreciate the environment in which the subject takes action, he must be presented in a social context. Institutionalist approaches are taken into account in addition to sole biographical writing, and the investigation in chapter five draws on comparisons of two local contexts, an American and a European. Moreover, this dissertation treats two scientific traditions, classical astronomy and 'modern' astrophysics, embodied by father and son.

The history of Danish twentieth century astronomy has been treated by various authors. One general feature of this group of writers is that nearly all of them are themselves scholars of the trade; they are astronomers writing about the field of astronomy.[70] This dissertation differentiates itself from earlier approaches in that it follows the life of the most influential astronomer in Denmark in the twentieth century. The history of his science naturally follows his trail, as did his many apprentices.

Comparative studies in history are widely honored but still relatively little practiced, although they can contribute with a broad understanding of historical developments and foster the possibility of making cross-cultural comparisons.

[68] Galison 1997, 46.
[69] Steve Fuller (2000) and Steven Shapin (1992) use 'externalism' and 'internalism' as mutually opposed terms. History of science has developed from this dichotomy towards utilizing instead the concept of 'contextualism', or 'zeitgeist', in the meaning of e.g. Paul Forman's essay on "Weimar Culture, Causality, and Quantum theory, 1918-1927" (Forman 1971). See also Kragh 1996.
[70] On the history of Danish astronomy, see e.g. Andersen 2002 & 2003; Thykier 1990; Gyldenkerne 1962 & 1986; Nielsen 1961 & H. Nielsen 1962; Pihl 1983 and Rebsdorf 2002, 2003 & 2004. For a comparison with Swedish astronomy, 1860-1940, see e.g. Holmberg 1999.

The thematic approach is central to the process of comparative studies. In chapter 5.3, I survey the activities of Bengt and Elis Strömgren at their respective institutions in Denmark and in the USA, during Bengt Strömgren's eighteen months stay at the University of Chicago and at the Yerkes Observatory. Few are the similarities, and a comparison of the two institutions tells us about both parallels and differences between the two local contexts, the Copenhagen Observatory and the Yerkes Observatory, two scientific institutions located in two different national contexts. Many aspects of locality play roles in the comparison, such as scales of research, research topics, scientific styles, method and practice, curricula, student class sizes, life conditions, personalities, rates of scientific and technological development, politics, and more generally notions of e.g. mental locality, cultural locality, social locality, and national locality. For instance, the notion of national locality has been treated by historians in more or less comparative studies of British physics versus Continental physics regarding methodology and scientific style. Such two local contexts are not two isolated contexts. Rather, in the case of Bengt Strömgren's astronomical institutions, the two contexts in question were connected by one particular thread of many, the Strömgren correspondence. Father Elis corresponded closely with his son, Bengt, throughout the whole period, and the correspondence has been transcribed into a database in order to investigate it thoroughly from various angles.[71]

To study all the listed aspects comparatively, one needs to explore the ways in which the two contexts differ and thus the ways in which each locality is unique. In theoretical jargon, the practice of 'eventualization' stems from the later period of Michel Foucault. It is connected to the reassurance of an active subject, focusing on the possibilities to make a difference in the various local contexts. Foucault proposes that human beings ought to take up the challenge of making an effect. And one special strategy for this is to shape events out of things and matters that most often are unnoticed and taken for granted. The specificity, or rather, in the words of Foucault, the eventualization of past occurrences concentrates on things and matters that are made to be seen as e.g.

[71] ESC. The "Strömgren Correspondence" takes place between 1936 and 1938.

neutral, natural, or objective.[72] The historian's shaping of unique past events comes about by approaching them from different angles, and as Michel Foucault, I find this way of reasoning to be a fertile way of understanding the past fuller and firmer. Historical eventualization, or focus on specificity, seems to be an appropriate counterpart to more general history of science accounts. In other words: chapter five contains quite a number of details, all contributing with their specificity to a collective picture of the events in both contexts. The comparisons are made explicitly where appropriate throughout the narrative.

The separation of father and son played many roles in the history and from the Strömgren correspondence several aspects of historical knowledge can be extracted. Firstly, close and distant colleagues appear in both contexts. This is useful to get a feeling about the number of scientists in the field at the time. Not surprisingly, there were huge differences between Denmark and the States in this respect. Many of these important differences are highlighted in chapter 5.2. Secondly, neighboring and remote communities of both contexts show up. In Chicago, Bengt Strömgren thrived in a vibrant environment surrounded by a large number of astronomers, while his father in Copenhagen kept his connections to the usual academic organs of the university, as well as his close connections to German scientific communities in particular. Thirdly, one gets an idea of what was public knowledge and what was intended to remain secluded knowledge, concerning e.g. career issues but also in cases of certain fresh theoretical discoveries intended to be published instead of shared with contending colleagues.

Chapter five is concluded with an attempt to map the scientific (and social) network of Bengt Strömgren. In practice, the map is done by use of two approaches. Firstly, I discuss whether it is reasonable to extrude the network from his scientific correspondence with the community of astronomers and other scientists. This network is also mirrored to some extent by the quotes and collected correspondence presented throughout this dissertation. The predictable result is that it is rather thorny to conclude much from scientific correspondence,

[72] Foucault 1997, 49.

unless the historian has virtually complete access to all correspondences and thus is able to map all pertinent correspondents mutually and in relation to the investigated subject. This has not been the case in my investigation, although numerous archives have been in use. Secondly, another way of observing and mapping the scientific circles of the subject can be obtained by noting the lists of people who received offprints of the Bengt Strömgren's papers. This seems to be a far better line of attack. Clearly, it was out of luck that the Strömgren correspondence contained not only one such distribution lists, but in fact two lists, the second being a limited list of the closest circle of colleagues who were intended to receive the limited number of offprints, as decreed by the publisher.

1.4 Generational Aspects of Science

Historical literature about families of astronomers is rather limited, although a promising PhD dissertation is under way from the British historian of science, Emily Winterburn, at Imperial College, London. It is entitled *The Herschel Family and Nineteenth-Century Astronomy* and forms a somewhat feminist historical narrative of the Herschel family, with special focus on Caroline Lucretia Herschel (1750-1848), the sister of William Herschel (1738-1822) and the aunt of John Frederich W. Herschel (1792-1870).[73]

Bengt Strömgren's father, Elis Strömgren, was professor of the Copenhagen Observatory until 1940 when his son succeeded his chair and the observatory directorship. Questions of nepotism were highly relevant when Elis Strömgren applied for his son as scientific assistant – when he was only seventeen years old – but this was not unprecedented in the history of astronomy. During Bengt's stay in the USA, the director of the Yerkes Observatory was Otto Struve, whom we will get to know in chapter five. Struve was himself the last of four generations of eminent astronomers. With his great grandfather being the director of several Russian observatories in the early nineteenth century, there

[73] I discussed the theme with Winterburn at the British Society for the History of Science Postgraduate Conference, Centre for the History of Science, Technology and Medicine, University of Manchester, January 6-8, 2004. On this occasion, I also gave a paper entitled "Creating Biography: The Father, the Son and the Stars" on the historiography of scientific biography.

was a strong tradition in his lineage of practicing astronomy. Another example is that of father Karl and his son Martin Schwarzschild, both noted German-American theoretical astronomers in the twentieth century; and other cases exist.

The first astronomer in the Struve-dynasty of four eminent astronomers was Friedrich Georg Wilhelm Struve (1793-1864).[74] He was born in Altona, Germany, and was appointed professor at the Dorpat Observatory from 1813; director in 1817. In 1838, he became director of the Pulkova Observatory near St. Petersburg, which was constructed to his specifications through the patronage of Tsar Nicholas I. Struve placed the study of double stars on a fully modern basis, published a catalogue of over 3,000 binary stars, and carried out early determinations of stellar distances. In 1819, his son Otto Wilhelm Struve (1819-1905) was born and later he succeeded his father as director of Pulkova and discovered 500 binary stars. The elder son of Otto Wilhelm Struve was Karl Hermann Struve (1854-1920) who was director of the Berlin observatory from 1904. His younger son was Gustav Wilhelm Ludwig Struve (1858-1920) who also made an astronomical career as director of the Kharkov observatory in 1894.

Finally, his son was Otto Struve (1897-1963), educated at the University of Kharkov, but his studies were interrupted by The Great War and the Russian Civil War, which left him a refugee in Turkey. He was later brought to the Yerkes Observatory, where he completed his doctorate at the University of Chicago and promptly joined the faculty. He directed four observatories: Yerkes, McDonald, Leuschner, and the National Radio Astronomy Observatory – where he was the first director and encouraged the first search for extraterrestrial intelligence. Otto Struve edited the *Astrophysical Journal* for more than 15 years.

The Schwarzschilds make up another example, perhaps more comparable with the Strömgrens. The German astrophysicist Karl Schwarzschild (1873-1916) published his first paper on the theory of orbits at the age of 16. He studied at Strasbourg and went to Munich where he obtained his doctorate with a

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[74] The following two paragraphs on the Struve family are based on a letter found in the Yerkes Observatory Archives, from Otto Struve to a journalist who was interested in writing a biographical article on the ancestral tree of the four astronomers; O. Struve → P.G. Egnatoff (Canada), February 24, 1938, YOA.

dissertation on an application of Poincaré's theory of stable configurations of rotating bodies to tidal deformation of moons. At a meeting of the *German Astronomical Society* in Heidelberg in 1900, he discussed the possibility that space was non-Euclidean. In the same year, he published a paper giving a lower limit for the radius of curvature of space as 2,500 light years. In 1901-1909 he was professor at Göttingen University where he collaborated with figures such as Felix Klein, David Hilbert and Hermann Minkowski. In 1914, he volunteered for military service, serving in Belgium, France and Russia. While he was in Russia, he wrote two papers on Einstein's relativity theory and one on Planck's quantum theory. Schwarzschild's relativity papers gave the first exact solution of Einstein's general gravitational equations, conveying an understanding of the geometry of space near a point mass. He also made the first study of black holes showing that bodies of sufficiently large mass would have an escape velocity exceeding the speed of light and so could not be seen. However he contracted an illness while in Russia and died soon after returning to his home.

His son, Martin Schwarzschild (1912-1997), earned his PhD in Göttingen. He left Germany in 1936 for research and teaching in Oslo, Harvard, and Columbia, and, in 1947, after serving in the U.S. Army in the Second World War, he joined the faculty of Princeton University. His work on stellar structure and evolution led to an improved understanding of e.g. pulsating stars, differential solar rotation, and the ages of star clusters. Schwarzschild's 1958 book, *Structure and Evolution of the Stars,* taught a generation of astrophysicists how to apply electronic computers to the computation of stellar models. He eventually became colleague with the subject of this thesis, when Bengt Strömgren went to a professorship at Princeton in 1957.

Thus, the Strömgren correspondence is by no means a unique case regarding a father-son relationship. But perhaps the existence of the Elis Strömgren Collection, in which the Strömgren correspondence is found, is unique as to completeness and extent. Both the Struve and the Schwarzshild families inherited the astronomical discipline. The family as a kind of institution is represented by these academic families and it could be argued that the

Strömgrens themselves constituted a kind of scientific institution, although I do not find the concept of institution to be appropriately used in that relational sense.

It is claimed in Lewis S. Feuer's monograph, *Einstein and the Generations of* Science, that "generational movements" in modern times have given rise to the highest forms of creativity.[75] In the monograph, Feuer undertakes case studies of various great physicists such as Ernst Mach, Niels Bohr, Louis de Broglie, Max Planck, Albert Einstein, etc. Though the term 'generational' in Feuer's case is used in a broader sense than just ancestral generations, Feuer is interested in the impress on scientists of e.g. revolutionary philosophy, bohemian friends, social circles of free thought, and other non-scientific inspirational contexts. Though not exactly pertinent to the themes of this dissertation, Feuer is interesting reading which conveys new angles and vantage points in my search for retrospective psychological explanation.

Another monograph concerned with creativity and generations is the M.I.T. researcher Frank J. Sulloway's controversial book, *Born to Rebel: Birth Order, Family Dynamics, and Creative Lives*.[76] This study is focused on the influence of birth order in personalities, however, but concludes rather surprisingly that, because of the evolutionary hierarchy in families, first-born children are more likely to be conformists, while the later-borns tend to be more creative and are more likely to be rebellious. This result is interesting in this connection at least from the point of view of Bengt Strömgren and his brother, Erik Strömgren. In fact, Erik chose to study psychology and became a very influential psychiatrist.

Erik's choice of scientific field fell rather late, though, at least compared to his older brother who chose astronomy when he was still in lower secondary school. An aspect not considered by Sulloway in this respect is the important role of the parents. Evidently, Elis Strömgren favored his oldest son, as it will become obvious to the reader in the following chapters.

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[75] Feuer 1974, v.
[76] Sulloway 1996.

Retrospective psychological explanation would indeed be welcome in this study – but then I would request professional advice from experts in order to undertake such a study. As for the reference to Sulloway, it is undeniably interesting in its own right. However, Sulloway's monograph does not seem to be directly applicable in the case of this kind of biography. After all, its main concern is the influence of birth order in personalities and their creativity rather than focusing on the role of parents, which is the chosen subtopic in my dissertation. On the other hand, the relationship between Bengt and his *brother* disserves more attention in a future study, which could indeed be met by using Sulloway, concerning questions of kin selection, parental discrimination, investment, and favor among siblings. The relationship was somewhat impenetrable – and therefore interesting – but I also had to prioritize and weigh it against the other aims of my project and the history of the field of astrophysics.

A Brief History of Danish Culture

Turning now to a short introduction to the history of Danish society and culture, it is my hope that – however rough and unsophisticated – it gives the foreign reader an idea of the concept of 'Danishness' before she begins the next chapter.[77]

The current shape and coverage of Denmark is the result of successive cedings of territory due to its exposed location by the access routes to the Baltic. Until recently, the Danes were an exceptionally homogenous people, which generally can be attributed to the gradual loss of marginal parts of the realm in the course of time. Rather than merely weakness and prosperity, historical experiences of this kind have determined the development of the modern Danish national character. The resultant consensus attitude is still a key element in Danish political culture, which was also embodied by Bengt Strömgren in international comparisons with other internationalist scientists in the postwar years (see e.g. page 7).

[77] This paragraph constitutes my paraphrase of Danish Foreign Ministry 2004.

The traditionally high degree of homogeneity and consensus in Danish society is also closely connected with some historical features – e.g. a strong doctrinal influence of the Lutheran State Church, the uniformity of the broad Danish population brought about by absolutism, the late industrialisation which did not create a large urban lower class until the 20th century, and the inability of the political parties to gather an absolute majority on their own, which has made compromise a condition of political life.

In 1905, The Social Liberal Party (Det Radikale Venstre) broke away from the Liberal Party as an independent party appealing especially to urban intellectuals and smallholders. This established the party pattern which was to dominate Danish politics until 1973 – when electoral support for the four traditional parties declined dramatically at the so-called ‘landslide election’ and a number of new protest parties entered the parliamentary arena.

In keeping with a careful policy of neutrality, with a German bias, which resulted from the defeat by Germany in 1864, Denmark remained neutral during the Great War and Danish trade and industry profited from the war-time conditions. In the hope of weathering the storm, the same line was taken when Hitler seized power in Germany in 1933. However, this time it did not work and on 9 April 1940, German troops ‘peacefully’ occupied Denmark.

The Social Democrat government decided to give in and reluctantly began collaboration with the occupying power. Gradually, British-backed popular resistance to the occupying power increased to such a level that the policy of collaboration fell to pieces in August 1943. The government resigned and parliamentary life ceased to function. The fabrication of a ‘peaceful’ occupation came apart and the last eighteen months of the war were dominated by growing armed resistance to the Germans and their increasingly brutal retaliation.

By the end of the war, despite its unclear position, Denmark had achieved recognition as an allied power, due to the activities of the resistance movement and it was therefore invited to become a founding member of the United Nations in 1945. It joined NATO in 1949 – in concert with Norway – and thus definitively relinquished the policy of neutrality, which had been a key element in Danish security policy since 1864. The Marshall Plan assistance from 1948 instigated a massive modernisation of Danish farming and from the mid-1950s industrialisation really launched. In 1963, the value of industrial exports for the first time surpassed that of agriculture.

At the same time a comprehensive welfare programme was introduced, based on the principle of the right of all citizens to receive social benefits within the framework of the legislation – the Danish tax-funded welfare model. Thus, an increasing affluence and the growth of the welfare state constitute two characteristic features of the Danish society in the first half of the 20th century.

The traditional party structure collapsed as a result of an incipient youth revolution of 1968 and growing resistance to heavy taxation. Danish academic culture also underwent important changes in the late 1960’es as it developed from a long period of professorial power to a more flattened hierarchical university structure, which was ushered in with the aforementioned youth revolution.

Of relevance to the issue of generational aspects of science is the concept of national icons of science, typically exemplified in Denmark by Niels Bohr. Such emblematic figures constitute another important factor in Danish intellectual society, which was particularly manifest in the media. Niels Bohr lived a somewhat public life in the Carlsberg Mansion of Honor from 1931-1962.

The Carlsberg Mansion of Honor was originally intended to be a stamping ground for large groups of learned scientists, artists, and politicians. A public life was an almost inevitable part of being a high ranking professor in Denmark; this also applied to both Elis at the Copenhagen Observatory but even more to Bengt Strömgren who moved in with the iconic memories of a series of important Danish academics, in particular Bohr. Living in the Carlsberg Mansion committed the inhabitant to live a relatively public life and to function as a hospitable host of prominent foreign visitors. From time to time, the national professor was on the front page of the newspapers, in particular in 1950, when Bengt Strömgren aired his plans of leaving Danish astronomy to the benefit of American stellar research, as we will see in chapter seven.

Let me briefly familiarize the reader also with the Carlsberg Foundation, as it runs through the narrative. This foundation has a quite unique place in the history of philanthropic foundations. Without detailing it here, at least it serves mention that the Danish philanthropic foundation was very early in its creation.[78] Founded in 1876 by the brewer J.C. Jacobsen, it was established almost a quarter of a century before the emergence of great foundations such as the German Carl Zeiss Foundation from 1889, the Swedish Nobel Foundation from 1900, or the American Rockefeller Foundation, founded in 1913. Six years after the creation of the Carlsberg Foundation, Jacobsen transferred his brewery, The Old Carlsberg, to the Carlsberg Foundation. By this act, he wished to secure the future of the brewery. Jacobsen's wish was to create a fund having permanent scientific obligations and direct responsibility to a private business. The main purpose of the Carlsberg Foundation was – and still is – to manage and allocate funds for the Carlsberg Laboratory, and in particular to support and further basic scientific research within the humanities, social sciences, and natural sciences.

A final remark should be made regarding father-son relationships in Denmark. Apart from having a reputation of being informal in dealing with people, Danes typically put a lot of focus on their personal freedom. Therefore, nowadays, for a typical Danish reader, it may appear somewhat strange, incomprehensible, or perhaps even inappropriate that Bengt simply followed in his father's footsteps by his engagement in astronomy and eventually took over the professorship at the event of Elis' retirement in 1940; issues of nepotism are most frequently regarded to be of a negative value. On the other hand, at the time of Bengt Strömgren's early career, at least in the first half of the twentieth century, the idea of taking on the profession of a parent was generally more common. It was unexceptional to stay within any professional pattern of one's family, in contrast to present standards – or demands – of individual freedom within Danish families.

Now, the following chapter does not generally meet the standards of sophistication and promise of this historiographical introduction for reasons of

[78] This paragraph is based on Glamann 1976.

limitation. Being based on mainly secondary sources, chapter two is more rough than its successors, as it has another aim, namely that of introducing the heritage of Bengt Strömgren, of his astronomy, and of the Danish astronomical community in the early twentieth century astronomy.

Two

Ouverture-de-Siècle Astronomy

Bengt Strömgren's Heritage

Across the nineteenth century many astronomical societies were founded in Europe and America. The Astronomical Society of London was conceived by fourteen gentlemen in 1820 and shortly after the Royal Astronomical Society was founded with the simple objective of promoting astronomy. In Germany, the dedication to the 'advancement of science by supporting projects, which require systematic cooperation of many people' was brought to fruition in 1863 with the Astronomische Gesellschaft (AG). Already before the Great War, more than 400 members from all over the mainly Western world joined on the initiative of the international society. In America, on the occasion of a solar eclipse, a group of amateurs and professional astronomers in North California united to form the Astronomical Society of the Pacific in 1889, which is today the largest general astronomy society in the world. This was a time when astronomy was a well-established discipline, if not a profession. In the 1890s only a few astronomical research institutions existed and in America only about four immature journals had appeared.[1] In 1899 the American Astronomical Society was brought to life and it would take only a couple of decades before the international cooperation between various societies meant the establishment of the International Astronomical Union after the Great War. In Denmark an astronomical yearbook

[1] Sponberg & DeVorkin (2001). The four journals were: Popular Astronomy, Publications of the Astronomical Society of the Pacific, Astrophysical Journal, and Astronomical Journal.

Figure 1: Copenhagen Observatory by the turn of the century. The Botanical Garden is still located behind the observatory hill (UCO).

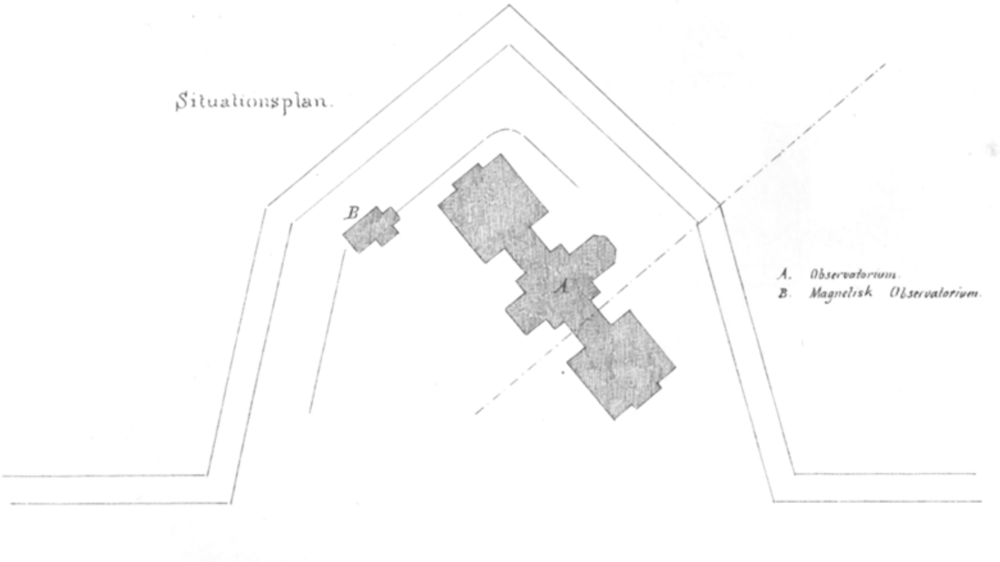
entitled *Urania* had been in circulation a few years from 1844 to 1846, the editor of which was the Danish writer and literary critic Johan Ludvig Heiberg. The professional discipline was strengthened only few years later with the institutionalising act of building the Copenhagen Observatory in the late 1850s. Although the old Rundetaarn observatory had been in function for several centuries, the new observatory meant a fresh beginning for the discipline.

Figure 2a-2c on opposite page:

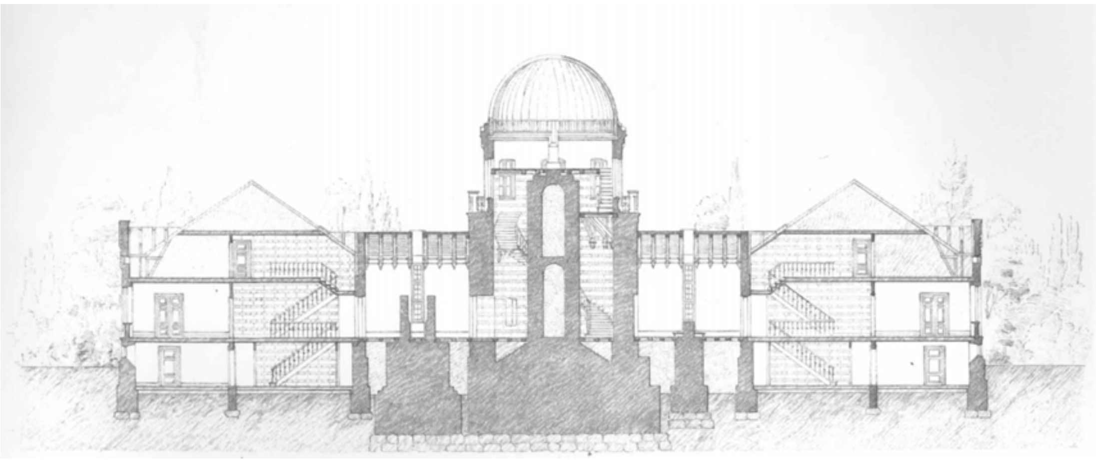
2a: Situational plan of the placement of the Copenhagen Observatory (A). The small building (B) is the magnetic observatory (Thykier 1990, 224-229).

2b & 2c: Architectural sketches of the Copenhagen Observatory (Thykier 1990, 224-229). Middle drawing is the cross section which shows the professor's mansion to the left, the observer's apartment to the right and the telescope dome in the middle. Lower drawing is the ground floor of the building.

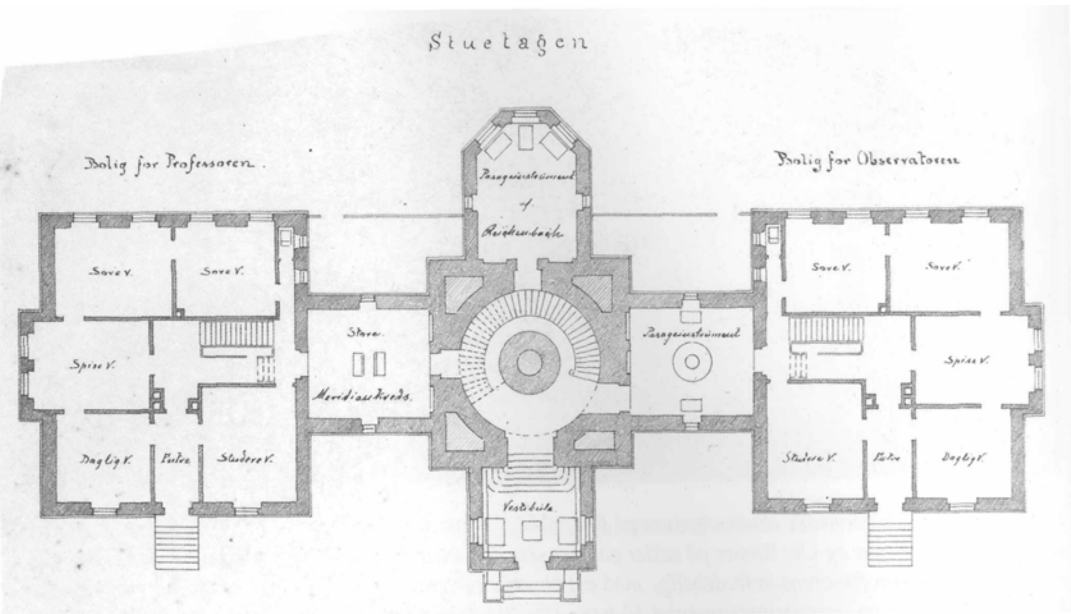
2a


Situationsplan.
B
A
A. Observatorium.
B. Magnetisk Observatorium.

2b



2c


Stuetagen
Bolig for Professoren.
Bolig for Observatoren

2.1 The Copenhagen Observatory

Being created in 1859 in the Danish capital, the Copenhagen Observatory (CO) on the street Østervoldgade 3 was founded on the Quitzow's bastion between the botanical garden and the Rosenborg Castle. It replaced the obsolete observatory at Rundetaarn which was too small for research purposes. Rundetaarn had served as university observatory for 220 years. From 1861, the three-winged building came in use. It was of a type, which became a model for observatories of the time. It was sketched by the architect Christian Hansen from the Copenhagen Art Academy, who drew the observatory of Athens before that.[2] CO's front faced due south with the main entrance in the middle and above this the main instrument was situated beneath a large revolving cobber dome to protect instruments from fall of rain and snow and hence corrosion. This instrument was a 0.28 m refractor with a 4.9 meters focal length for visual observations. In the connecting corridors towards east and west were set up a transit instrument and a meridian circle, respectively. The west wing housed the professor with family and the east wing was the home of the observer. Later, this wing also housed a scientific assistant and the observatory's keeper. In the early twentieth century, the payment for state-employed leaders, like the observatory director, was around 6,000 Kroner a year, while the salary for an assistant was in the neighbourhood of 2,000 Kroner.

In the basement, several pendulum clocks were located as in many other observatories, there was no need for heating the midsection of the building and thereby disturb observations with unnecessary air turbulence. In addition to the observatory building there was a small garden house with earth-magnetic instruments (see figure 2a). Later, a Zöllner photometer was purchased for the garden house. In 1895, the observatory director until 1907, Thorvald Thiele, replaced the old refractor with a Repsold double refractor with larger objective for both photographic and visual observations. It consisted of two lens telescopes; the visual telescope was 0.36 meters in diameter, while the photographic telescope was 0.2 m (with focal lengths of 4.9 m and 4.8 m respectively).

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[2] Thykier 1990, 220.

Period	**Position**	**Astronomer**
1857-1875	Professor, director	Heinrich Louis d'Arrest
1875-1907	Professor, director	Thorvald N. Thiele
1888-1914	Observer	Carl Frederick Pechüle
1907-1940	Professor, director	Svante Elis Strömgren
1914-1921	Observer	Johannes Braae
1922-1960	Observer	Julie M. Vinter Hansen
1940-1957	Professor, director	Bengt G. D. Strömgren
1958-	Professor, director	Anders Reiz
1961-1964	Observer	G. van Herk
1961-1963, 1965-	Observer	Kjeld Gyldenkerne
1965-	Observer	Svend M. Laustsen
1967-1978	Professor	Bengt G. D. Strömgren

Table 1: Professors, directors and observers at CO from 1875-1970 (excerpts from Andersen 2002 and from Appendix A).

The work at the observatory has been divided into four elements by Andersen (2002), since the foundation of the institution until the late 1950s: observation, calculation, theorizing and historical writing.[3] Observations of nebulae and stellar spectra through the visual refractor in the great dome were carried through by the professor and director Heinrich Louis d'Arrest. The observers Carl F. Pechüle, Julie M. Vinter Hansen, and Jens P. Møller constitute a trail of visual and photographic observations of asteroids and comets.[4] Another trail of work can be found in the determination of stellar positions with the observatory's meridian circle and the transit instrument (Hans Carl Fr. Chr. Schjellerup, Niels E. Nørlund, and Johannes Braae).

Computational work was carried out by numerous people of the CO staff. Elis Strömgren worked for three decades with the periodical trajectories and the classical mechanical three-body problem as well as comet orbits, asteroids from the Trojans and the periodic comet Comas Solá, proper motions and much more. The theoretical work done in Copenhagen can be summarized to Thiele's

[3] Andersen, 2002. The following passage goes by this reference.
[4] Later, Peter Naur, Svend M. Laustsen and Jørgen Otzen Petersen followed the trail, as we will wee in chapter eight.

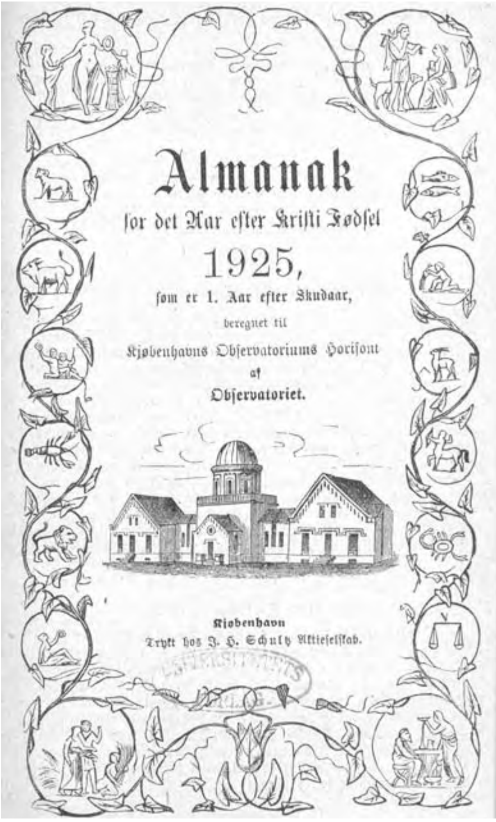

Figure 3: Face of the Danish Almanac of 1925, showing the front of the Copenhagen Observatory surrounded by the constellations of the zodiac.

methods for determination of the trajectories of double stars and his theories of error.

The intellectual history of scientific work done in Denmark constituted – among other writings – the French edition of Al-Sûfi's catalogue by Schjellerup, Elis Strömgren’s Danish version of the Latin descriptions of Ole Rømer’s instruments, originally written by Rømer’s assistant, Peder Horrebow. Another work was an English version of Tycho Brahe’s description of his own instruments on Hven. In addition, Elis Strömgren also published a large amount of short texts about Nordic amateur observatories.

The Copenhagen Observatory was organized under the University of Copenhagen. It undertook education of students at the faculty of natural sciences. It handled astronomical tasks such as scientific research by observation and calculation of empirical data, development of theoretical models, computation of the Almanac, and communication of international news. Furthermore, the institution was obliged to take care of the Time Service, which administered accurate timekeeping for Danish society.[5] Apart from being an academic organ for the students of astronomy, the well-stocked observatory library played an important role as a literary source for mathematicians as well, at least in the first couple of decades of the twentieth century.

The qualified calculators at the observatory also assisted other Copenhagen institutions with advanced calculations. Physicists from the UITF were assisted by workers at the CO in complicated integrations and even the Danish Forest Research Institute got help. For many years, the observatory basement even served as a station of reference for measurements of pendulums in order to determine the local value of the constant of gravitation. The Geodetic Institute undertook these measurements under the direction of Niels Erik Nørlund.[6]

During the Great War, Danish astronomy found itself in a quite unusual situation. International cooperation was strong before the war, but was only weakened as it was in many fields of science. Nevertheless, Denmark played a major part in international collaboration owing to the central bureau for astronomical telegrams, which was located in Copenhagen. The meeting place for Danish astronomy was the CO. Apart from the professor and director of the observatory, Svante Elis Strömgren, there was an observer and a scientific assistant and some casual labourers undertaking calculations, observation work and odd jobs. All the permanently employed lived in the observatory building, as did the observatory's keeper. Another capital observatory was the Urania Observatory at Frederiksberg, in the western part of Copenhagen, which functioned more as a mediator of popular astronomy for the people. In contrast, the CO represented scientific research and academic education. Outside the capital, a series of amateur astronomers operated around the country and in Århus there was installed a well-visited telescope to the benefit of those Jutlanders fascinated by the starry sky.

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[5] Detailed in chapter 3.2.
[6] National Survey and Cadastre, until 1928 ”den danske Gradmaaling”.

The relationship between astronomy and closely associated exact sciences changed throughout the first quarter of the century. In the 1920'es – and the 1930'es in particular – the relations between physics and astronomy were strengthened and since then the two disciplines gradually melted more together. The number of staff members at the CO was quite small across the first half of the century. As can be seen from Appendix A, right from Elis Strömgren's appointment and all the way to 1952, the permanent staff number changed only between three and four persons: The director, his observer, and one or two assistants. In addition, various people went in and out the observatory, working as calculators, secretaries and helpers. Customarily, the helpers and calculators were students, of which some later became assistants and observers.

Urania and the Astronomical Society

The mouthpiece for the popularizing of astronomy in Denmark and soon in all Scandinavian countries was published for the first time in 1916. This was the same year as the Astronomical Society was instituted, the librarian and amateur astronomer Carl Emil Luplau Janssen, announced the mission of the society and its periodical in the introduction to the first December volume[7]

> With the existing volume, Astronomical Journal [Astronomisk Tidsskrift] is brought to life […]. The principal purpose coincides with the Astronomical Society's, that is, to advance knowledge of astronomy in all its branches and to contribute to foster the scientific position of this science in the North. Our journal will be the organ for all Danish worshippers [dyrkere] of Urania and the link between members of our new society.

Luplau Janssen took care of editing the journal, which was scheduled for publication ten times a year. The magazine soon found readers in the neighbouring Nordic countries and already in the third volume of the journal, the editor and the executive committee chose to change the title to Nordic

[7] Janssen 1916.

Figure 4: The Urania Observatory on Frederiksberg was inaugurated by the telegraphist and amateur astronomer Victor Nielsen in 1897-98. It was a private observatory with scientific aims and was equipped with a 25 cm refractor and two photographic instruments. Here, Carl Emil Luplau Janssen and his wife Aase Worsøe L. Janssen, née Mollerup, look over the garden, probably in the late 1940ies. (Fastrup 1997, 21; Courtesy of NAFA).

Astronomical Journal (Nordisk Astronomisk Tidsskrift, henceforth *NAT*). As a natural result, the editorial office was extended with Nordic representatives. The professor of astronomy in Christiania Jens Fridrik W. Schroeter acted for Norway while Walter Gyllenberg of the University of Lund represented Swedish astronomy.[8] The Journal kept its title until 1967, when it was renamed "Astronomisk Tidsskrift". The Astronomical Society soon became a mouthpiece for amateur astronomers as well as professionals, especially in Denmark with a dozen of local observatories in addition to Copenhagen Observatory and the Ole Rømer Observatory in the Jutlandic town Århus.

The Ole Rømer Observatory was inaugurated in 1911 on the recommendation of Elis Strömgren that the German private astronomer Friedrich Krüger could build an observatory near Århus for his own funding. Krüger directed the observatory until his death in 1916, when Elis Strömgren's assistant for four years, Ruben Andersen, succeeded Krüger as the single astronomer on the site until 1927. Interestingly, in the event, Elis Strömgren ignored the

[8] From 1920, the editorial list was expanded with the Finnish professor Ragnar Furuhjelm (*NAT*, 1920).

applications of both Luplau Janssen and Ejnar Hertzsprung. In 1927, the assistant at the CO, Axel V. Nielsen, was appointed assistant in Århus. After Andersen's eleven difficult years alone, Nielsen's company meant the rearmament of education and research, variable stars in particular.

Luplau Janssen succeeded the observer Victor Nielsen, who died in 1918, at the Urania-observatory at Frederiksberg in Copenhagen, which was equipped with a reflector; and it was quite popular for lay people to stop by Urania to glance at the starry sky through the telescope. In 1919, Luplau Janssen bought the observatory, supported by a financial loan from the Carlsberg Foundation of 50,000 Kroner[9]. He was an active popularizer of astronomy through books and newspaper writings and his home was divided into a bedroom, a library, the observatory dome and the usual necessities. Allegedly, due to the large size of his sky atlas, it was located under his bed, where observers were allowed to go and get it anytime – even in the dead of night when Janssen and his wife were sleeping. Luplau Janssen's relationship with CO was rather strained and he was a complex character who felt haunted by professor Elis Strömgren. In 1917, Janssen submitted a doctoral dissertation, which turned out to be so flawed that he had to retract it. The professor was in the evaluation committee and after the incident; he was blacklisted by Luplau Janssen. Conversely, Elis Strömgren, who was indeed also a complex character, may have seemed silent on the face of it, but in later correspondence with Bengt Strömgren he overtly expressed his low esteem of the staff at the Urania Observatory (see chapter five).

The Urania observatory is probably best known for Ejnar Hertzsprung's relatively brief working period there. Hertzsprung was a Copenhagener, working as a chemical engineer in St. Petersburg and his interest in scientific photography brought him into the field of astronomy. He worked at Urania as a private astronomer in 1902-1909 and in 1905 he noted that certain stars tended to have relatively small proper motions. Therefore, he concluded, they were probably distant and luminous. In 1909 he went to Potsdam Observatory and stayed there until 1919 when he was appointed associate professor at the Leiden Observatory,

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[9] Fastrup 1997.

being a part of Leiden University, the oldest university in the Netherlands. There he stayed until 1944, being the observatory director for the last nine years. During the Leiden stay, he received yearly financial help from the Danish Carlsberg Foundation since 1930 and the funding paid for his salary.[10] Finally, after retirement he moved to the Danish small town Tølløse, continuing his measurements of doublestar plates at the Brorfelde Observatory, apart from keeping contact with the Urania Observatory until he passed away in 1967.[11]

2.2 The Swedish Professor

Svante Elis Strömgren was born in May 1870 in Helsingborg. Hs mother was Adelaide Sofie Petterson (1834-1927) and he got his first name from his father, the grocer, Svante Strömgren (1826-1869), about whom we only know that he died before his son was born during Adelaide's pregnancy. Elis was brought up with a single mother and in 1887, Elis became a student in the Swedish town Helsingborg and studied mathematics and natural sciences at the University of Lund. His studies led to a doctoral degree and a lectureship in astronomy in 1898. Allegedly, Elis proposed to two other sisters of the prominent Lidforss family in Lund before he finally got a "yes" from the youngest sister, a dentist named Hedvig Lidforss. Whether this story is true or not, they married on June 5 of 1902 in Copenhagen. Three years later he was appointed assistant under the editor of *Astronomische Nachrichten* in Kiel and in 1904, he became associate professor at the University of Kiel. Concurrently, he made calculations for the associated Central Bureau for Astronomical Telegrams. This work proved very important for his further career, as we shall see.

Two years later in Copenhagen, Thorvald Thiele handed in his resignation of his professorship and directorship of the CO. He explained his motivation with an eye disease, which encumbered his observations severely. Instead, his responsibility of the university's actuarial mathematics was so massive that he found it imperative to take this challenge that did not require

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[10] Oversigt. Det Kongelige Danske Videnskabernes Selskab, 1930-1950.

[11] More biographical details about Hertzsprung can be found in Thykier 1990, 276-281. His portrait is displayed in chapter 7.1.

Figure 5: Elis Strömgren (1870-1947). This portrait is probably shot around 1905 (Blaauw 1994, 95).

good eyes. In addition, a new professorship was under way in this particular discipline of applied mathematics. He agreed to remain acting observatory director until a successor was found.

Five Danish astronomers submitted their applications for the professorship and among them Thiele's son, assistant Holger Thiele, the observer Pechüle and Dr. phil Carl Burrau. Since neither one of these contestants were regarded sufficiently proficient, the faculty decided to have a contest, including non-Danish citizens. As neither Holger Thiele nor Pechüle were any longer under consideration, a contest committee was created by the faculty consisting of Thorvald Thiele and Pechüle and the dean of natural sciences. However, Thiele chose not to partake in the committee and finally the faculty recommended a committee, among others the director of the old institution Den danske Gradmaaling, G.K.C. Zachariæ. Three professors from the faculty were also included in the committee. Of the four contenders, two Danish and two Swedish, it was decided that the Swedish applicant Elis Strömgren, at the time residing in

Kiel, would be appointed professor of astronomy from October 1907.[12] At first his position was temporary, but in April 1908 he was appointed full professor. He became member of the Royal Astronomical Society of London in 1916 and of the executive committee of Astronomische Gesellschaft in 1917. From 1921 to 1930 he served as President of the AG.

The Idea of a Remote Observatory

As in many other fields, there has been increasing internationalization and globalization of science in the twentieth century. This general tendency has also been valid for Danish astronomy and astrophysical research. The trend has meant a downgrade of small national observatories and thus international cooperation among astronomers has been given a still higher priority. The birth, short life and decline of the Brorfelde Observatory constitute a central and striking story of Danish institutionalizing in the astrophysical field of research. The story of the idea of an external observatory outside the light, pollution and noise of Copenhagen can be traced all the way back to the end of the nineteenth century. One conclusion of the story is the decision made by Bengt Strömgren in 1950 to leave Danish astronomy due to lack of funding for the building project.[13]

In the late nineteenth century, two different commissions had been appointed by the Ministry of Education[14], induced by Thiele, for the investigation of a location for an external observatory. By September 1907, the Ministry of Education appointed yet a third commission to specify the plans for the erection, economy and operation of a new observatory. The most important members of the commission were Thiele (chairman), Elis Strömgren, and Holger Thiele. The financial limits for the project made it difficult and time demanding to reach a satisfactory solution for the observatory staff, the university Konsistorium (the

[12] The other applicants were Dr.phil. Carl Burrau, Copenhagen (again); M.Sc. Hans Emil Lau, newly graduated *Magister* in astronomy (1906) and later co-worker with Hertzsprung at the Urania Observatory; and Dr. phil. Hugo von Zeipel, Uppsala. Yearbook 1909-1910, 117-121.

[13] This narrative will appear continually throughout the dissertation in chapters two and five to eight.

[14] Kirke- og Undervisningsministeriet.

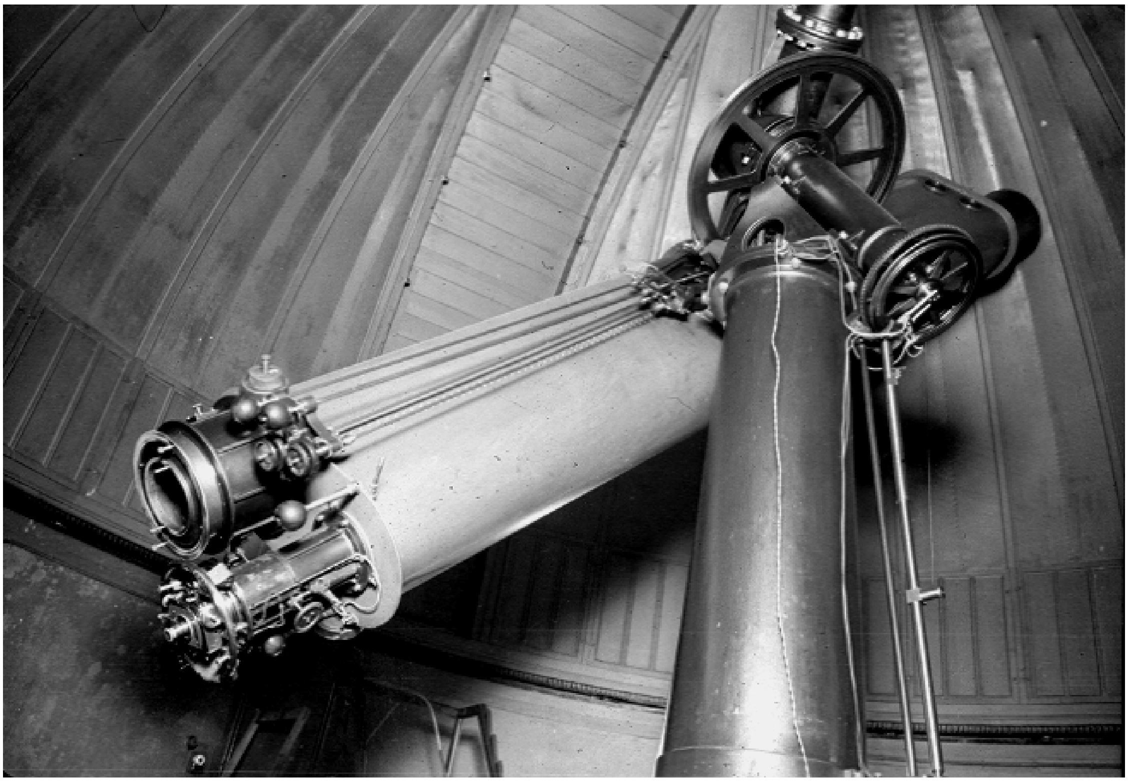

Figure 6: The Repsold double refractor erected in 1895 by T.N. Thiele for photographic and visual observations. It was made of two lens telescopes: A visual telescope (0.36m, focal length 4,9m), and a photographic telescope (0.2 m, focal length 4.8m) (undated, UCO).

Senate)[15] and the ministry. The issue of a remote observatory was new to Strömgren, who had just arrived from Kiel and yet his opinion about the matter was crucial, considering he was the only professor of astronomy. This proved decisive for the development of the plans, for as it turned out, the whole affair took a new turn a few years later, on April 10, 1909, when Strömgren requested the ministry for their approval of his leave from the commission. Since the professor's participation was a precondition of the continued work in the commission, the ministry was forced to disregard the whole idea, after years of work and meetings.

It may have induced feelings of annoyance among the majority of the commission as Strömgren in reality vetoed the whole idea of an external observatory at Sofienholm not too far from the small town Tølløse, which was

[15] The Konsistorium consisted of 18 or 19 members. 5 being deans and 13 being elected for 4 years by the Academic teachers' assembly (lærerforsamling) of the members therefrom who were also members of the Faculty (Royal Resolution of September 1902, Yearbook 1903).

the location being chosen at the time. And he had his reasons. In his letters to the ministry, Strömgren wrote, "an observatory at Sofienholm is too far from everything and isolation has too often turned out as a disadvantage for scientific research as well as from a human perspective."[16] At the time, the infrastructure of Copenhagen and its outskirts would entail lots of travel hours by Strömgren's employees if an observatory was to be established at Sofienholm, far from Tølløse and Holbæk train stations. Several foreign astronomers agreed with Strömgren on the impracticalities involved with a remote site. In a letter to Strömgren, the prominent German astronomer Max Wolf listed six points against en external observatory. Apart from practical and educational difficulties, he reasoned against the idea using arguments as to social importance: "The influences of an isolated location on the mental balance and zeal are very damaging; even though years can pass, these influences can ultimately affect [the workers] in the worst way, in particular concerning collegial relations etc."[17]

By the end of September 1910, Thiele died. A few weeks later the ministry finally broke up the third commission. Besides, Strömgren was not of the opinion that the observation reports made in 1906 and 1907 managed to convince him to believe that the Tølløse area was superior with regard to "the goodness of the air."[18] Nevertheless, inspired by letters from the professors Antonio Abetti (1908) and Jacobus C. Kapteyn (1909), Elis Strömgren suggested a small external observatory just outside the capital, if close to a railway.[19] Here, modern instruments were to be installed, accompanied by a small residence for two astronomers and a couple of guest rooms. Yet he maintained that there would still be only one institution, namely the Østervold Observatory. Elis actively fostered his plans of building such a small observatory, not far from the capital; and the nearby small town Holte was considered a possible site candidate. This idea of Elis never succeeded to convince his colleagues, though;

[16] Nielsen 1962, 37.
[17] Nielsen 1962, 46. In the Yearbook of the University of Copenhagen for 1911-12, an extensive and detailed report by the Commission is given on pages 707-782.
[18] Nielsen 1962, 37.
[19] It follows from the Yearbook (note 17) that the endorsements of Abetti and Kapteyn were highly appreciated by Elis Strömgren. They both agreed with his negative attitude towards a central observatory.

and soon the Great War raged, if not in neutral Denmark. Yet the Danish state economy was obviously badly affected.

After the war, Elis proposed the build-up of a Danish astrophysical institute in Denmark and he suggested Ejnar Hertzsprung as its director. On the face of it, Hertzsprung seemed interested in Elis' plans and requested an update on the whole scheme, a report "which you [Elis] talked about in the spring and which […] you would complete before new year."[20] Apparently, there was a communicational misunderstanding, since Elis was of the opinion that Hertzsprung was supposed to write Elis and tell him whether he was interested or not:[21]

> Concerning my report […]: Either you will come to Denmark and we will try to establish the astrophysical laboratory for you that we negotiated, or you will not get here and in that case my plans will be altered. We agreed that you should contact me, as soon as you reached a decision.

Hertzsprung asked Elis to repeat his plans in detail before he would be able to decide his involvement and he waited for long. In May 1921, Elis finally wrote him a somewhat different scheme:[22]

> If you approve of the idea, then I am willing to submit a memo to the authorities, in which […] I will recommend to ask you to come to Denmark and establish an astronomical institute for your main interests and on which terms you would be willing to do so.

However, Hertzsprung declined Elis' prospective offer due to the fact that he estimated his general conditions at the Leiden Observatory to be better than they appeared to be in Denmark, especially regarding instrumentation but also his profitable social position in Leiden. Moreover, other concerns of a more personal character were suppressed underneath the surface. In a rough draft of a letter,

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[20] Ejnar Hertzsprung (Leiden) → Elis Strömgren, March 20, 1920, EHA.
[21] Elis Strömgren → Ejnar Hertzsprung, August 15, 1920, EHA.
[22] Elis Strömgren → Ejnar Hertzsprung, May 21, 1921, EHA.

Figure 7: Across a generation, Elis Strömgren did research on the three-body problem, which describes the mutual dynamical movement of three massive bodies in space. He investigated the complex movement of a mass, e.g. a comet, moving in the gravitational field of two other large masses. In a *Festschrift* of 1923, he gave the names of 49 co-workers who had all participated in his program with numerical calculations since 1913. Among the helpers were Jens Johannsen, Ruben Andersen, Johannes Braae, J. Fischer Petersen, Julie M. Vinter Hansen, Erna Mackeprang, Estrid Nielsen, and Jens P. Møller (E. Strömgren 1923 and E. Strömgren 1925).

which was probably never sent, Hertzsprung referred to another affair, namely his earlier candidacy for the position as director of the Ole Rømer Observatory in Århus, which was eventually occupied by Ruben Andersen in 1916:[23]

> When [the position in] Århus was available (from where I could have come to Copenhagen later), my candidacy was even discouraged on your part. Therefore, I have the feeling that there is no sincere wish to have me back in Denmark.

In addition, Hertzsprung's salary had been increased recently and he lived in an "excellent official residence." However, these matters were never included in the

[23] Ejnar Hertzsprung → Elis Strömgren (rough draft, never send), June 6, 1921, EHA.

final letter to the Copenhagen Professor. Instead, Elis could read Hertzsprung's politely, if insinuating, argument:[24]

> Considering the described conditions here and the stagnation of the observatory plans in Copenhagen (it has now been more than ten years since the observatory commission was broken up without any replacement initiative), I consider it presumptuous of me to make a proposal, which would not entail any progress [for me] compared with what I have already.

Hertzsprung clearly felt unwelcome in Denmark, but at the same time, he was not assured that Elis would really work genuinely for the new institution, since he had obviously been the negative force against the whole idea of the remote institution ten years earlier. The somewhat strained relationship between Hertzsprung and Elis Strömgren never ceased. It is worth remembering that the available position in Århus in 1916 had also been applied for by Luplau Janssen. Perhaps the animosities between the people at the Urania Observatory and the CO came from these appointment matters also. Elis Strömgren was a powerful director concerning the evaluation of dissertations as well as appointing scholars for even remote positions like the directorship in Århus. Thus early on, Elis Strömgren did indeed show his strong character and lacking tendency of compromise in cases of disagreement. By putting away any idea of a remote observatory project the new Swedish professor was certainly noticed within the walls of the university.

For 27 years, Elis Strömgren remained chairman and editor of the *NAT*, the journal for the four Nordic countries Denmark, Sweden, Norway and Finland. He worked for the organization of international astronomical cooperation and in his position as director of the Copenhagen Observatory, he conducted empirical and theoretical research on cometary orbits and the three-body problem and was a driving force behind numerous observations of variable stars and lunar occultations. He was an astronomer in the tradition of classical astronomy and

[24] Ejnar Hertzsprung → Elis Strömgren, June 20, 1921, EHA.

astrometry; he lectured on astronomy for the students in the rooms of the Observatory, of which one wing was also the official residence of the Strömgren family from 1908.

The year before the outbreak of war, Elis Strömgren served as the Danish representative in an international time conference in Paris. At the October 1913 Time Conference it was decided, "to establish an international union for the completion of a uniform time-keeping all over the world."[25] The motivation for such an amalgamation was that by use of radio telegraphic time signals, everyone would be able to record time signals emitted from the central in Paris. Though, due to practical and technical difficulties it would take some time before it was realizable but for countries relatively close to the central, European countries in particular, "the problem is solved completely, since it is possible to record the Eiffel Tower time signals two times a day."[26] After the war, Elis applied the ministry of education for the purchase of a radiotelegraphic receiver of 2,700 Kroner for the record of the time signals from the Eiffel Tower and the money was granted.

With the war followed serious financial problems for the director and his observatory and staff. The university teaching of astronomy did not take place in the rooms of the University Campus but in the observatory building. From the professor's mansion, there was access to stellar globes, instruments, and astronomical literature. More importantly, the students could watch the stellar hemisphere by use of the Repsold double refractor in the observatory dome, which consisted of two lens telescopes for photographic and visual observations. The war years were very difficult for the observatory director. In spite of practicing economy, he was not able to avoid exceeding the budgets. Especially the paper bills were severely exceeded due to CO's dedicated work for the international proliferation of scientific papers between warring nations and his arguments were heard in the ministry.

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[25] Yearbook (1915-20), 261.
[26] Ibid., and Yearbook 1913-14, 20.

In 1914, Pechüle had passed away, only to be replaced by Johannes Braae. Pechüle's professional duties had mainly been calculation and editorial work with the Almanac as well as taking care of the time signal. After the War, Johannes Braae worked as observer, J. Fischer Petersen as assistant, and the helper Julie Marie Vinter Hansen was appointed assistant in spring 1919. This was the first time since the turn of the century that the permanent staff was increased from only three to four employees and this time by a woman. Not many women had the opportunity of taking the high school exam, which was the entrance ticket to an academic career and astronomy was markedly a man's discipline until the 1920'es. Vinter Hansen was a remarkable exception, though, as she was the first female *mag.scient.* (master of science) in 1917. In 1922 she got the observer position and was in fact the first woman in Europe to get a final university examination in astronomy at a University after the passing of a resolution in the Danish Parliament in 1921, which established equal access of the sexes to public posts.[27] Vinter Hansen was editor of *NAT* and a busy writer. In 1931 she was elected Fellow of the Royal Astronomical Society and in 1940 she received female astronomer's highest distinction of the American Astronomical Society, the so-called A.J. Cannon Gold Medal. Other female employees had been casual labourers: Estrid E. Nielsen had calculated the Almanac in 1910-1920 and she was succeeded by Erna Mackeprang, who came from a Danish insurance company. She worked diligently until 1946, but her real function was being the director's secretary; and he was very satisfied with her work.

The management style of Elis Strömgren was rather strict. Perhaps this was necessary in order to maintain a good observatory reputation internationally due to the limited staff number. Undoubtedly, his temper played a role too. Learning by heart marked his education and his state of mind was known to be rather peppery. He would even receive his employees in audience in his bedroom at mornings, when the jobs of the day were to be delegated. In his later years he

[27] Julie M. Vinter Hansen received her *embedseksamen* (final university examination) at the University of Copenhagen; Larsen 2001.

Figure 8: Julie Marie Vinter Hansen (1890-1960), photograph taken on the occasion of her appointment as scientific assistant in 1919. In 1939, she made research travels to Japan and USA. She needed to stay at the American Lick Observatory until the conclusion of the Second World War (BSA.08).

became known in family circles as being especially fond of good food and was often having his second meal in a nice Copenhagen restaurant after eating dinner at home. Elis Strömgren was probably not a dipsomaniac, but his grandchildren agree on the whole that he indulged most in drinking alcohol.[28]

The Intellectual Dentist

Elis' wife, Hedvig Strömgren, née Lidforss, was delivered on July 12 by Anna Marie Swartling (1839-1917) and she was born into academia and university life in Lund.[29] Her father, Volter Edvard Lidforss (1833-1910) was professor of European linguistics at the University of Lund with specialization in French and German language. One of her six siblings, Bengt Lidforss (1868-1913), became professor of botany (1910-1913) in Lund and after the turn of the century he emerged as a charismatic leader within the Swedish working-class movement. He

[28] KNSI.
[29] The following data about Hedvig Strömgren are found in DBL 1983.

Figure 9: Hedvig Strömgren, dentist, historian of dentistry, feminist, and author of imaginative literature (1877-1967) (courtesy of Karin Strömgren Campbell).

wrote in the social democratic newspaper *Arbetet i Malmö* about natural sciences but also about political, philosophical and literary concerns. Thus growing up surrounded by academics, Hedvig also ended up marrying a professor herself. She grew up in Lund and after seven years in the girl's school she became student from Lund's Cathedral School when she was 18.

Her mother was intellectually skilled and she questioned her own daughter privately for the high school exam. At the time, it was not at all common for a girl to become a student, but Hedvig did.[30] Being raised in a family of polyglots, Hedvig was also linguistically very proficient. Nevertheless, after studying mathematics and zoology for three semesters, she chose to become a dentist and in 1902, she passed her final exams at the Dentist Institute in Stockholm. After marrying Elis, she moved with him to Kiel, where she practiced dentistry and pedaled the dentist's chair to power the dental drill. In 1908, when she got her *jus practicandi,* which was the dentist work authorization from the Danish Health

[30] Gribsø 1957.

Service, Elis became professor of astronomy in Copenhagen.[31] Thenceforth, she also practiced her dental treatment of patients in a room of the Observatory. In 1917, she became school dentist at the Royal Vajsenhus, which was a school for children without means founded by King Frederik IV in 1727.

Hedvig was active in founding the history of odontology research in Denmark and made numerous trips to abroad libraries and dentist schools. She built up a huge library of dentistry in the basement of the observatory and wrote several works on the history of odontology in Scandinavia and in ancient Rome.[32] Not only did she write non-fiction, she also had several fiction novels published.[33] Being a woman in a man's world, the worked for feminism, as it was conceived of in the first quarters of the century. Among numerous committee posts, she was member of the executive committee for the Kvindernes Læseforening (Women's Reading Union) in 1911-17, the Medicinsk-Historisk Selskab (Medical Historical Society) in 1921-27, and the Danish Women's International League for Peace and Freedom in 1921-28. A high point of her women advocacy work surfaced in 1939 when she received the Tagea Brandt's Travel Grant created by the women's liberationist Tagea Brandt. Six women received the grant that year; among others the world famed author Karen Blixen-Finecke but also the observer at the Copenhagen Observatory, Julie Marie Vinter Hansen.[34] So, Hedvig was a hard working, intellectual mother and while her work went on in the dentist room, astronomy was the main activity in the rest of the building.

2.3 An Enthralling Nobel Prize

In astronomy, a comprehensive international cooperation has developed through time and it has been a widespread view among astronomers that astronomy has an even more international status than any other science. A common argument among scientists for this statement has been the rotation of the earth in relation to

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[31] Elis was appointed professor in October 1907, but they only completely moved to Denmark in 1908.
[32] She published books in 1919, 1927, 1930, 1935, 1941, 1945 and 1955. The latter being a ground-breaking work *Index of dental and adjecant topics in medical and surgical works* (DBL 1983).
[33] *Det förgångna*, 1925, *Förr dog man av det…*, 1938 (DBL 1983).
[34] *Politiken*, 1939, March 17, 13, "Seks Kvinder faar hver 10,000 Kroner".

the night sky. The somewhat positivistic line of reasoning has been that the earth is a flattened sphere that rotates with regard to the starry sky, therefore putting astronomy in a special place concerning the necessity of international group effort. An additional argument has been the continuing discovery of new sky objects, which must be observed without delay, in order for their data not to be gone forever. Elis Strömgren was a warm-hearted advocate for this view of his field. Clearly, other extra-scientific aspects such as political factors also play important roles – sometimes even more important than science itself – for views of the international character of scientific enterprise, not only outside astronomy, but indeed inside this field as well.

Before the Great War, the intercontinental exchange of astronomical discoveries was centered in Kiel. Astronomische Gesellschaft created the Central Bureau for Astronomical Telegrams in 1884, 21 years after the foundation of the society. Shortly after the outbreak of war, it became impossible for the Kiel Bureau to maintain telegraphic and postal communication between allied astronomers. Therefore, Elis Strömgren suggested that the Copenhagen Observatory should attempt to uphold a provisory mid-station. His suggestion was approved. He led the bureau until 1920, when it was decided to move it to Brussels.

Elis' effort of maintaining the bureau despite enormous difficulties during the war was broadly appreciated in scientific circles. As an appreciation for his work as middleman between the fighting nations – though Denmark remained neutral during the Great War – he was nominated for the Nobel Peace Prize by several European scientists. The Christiania professor of astronomy and Norwegian editor of *NAT*, Jens Fridrik W. Schroeter, wrote a proposal to the Nobel committee in March 1920. Schroeter found it important that the Danish professor's work for keeping the international cooperation in spite of war was acknowledged. Furthermore, he proposed "that the peace prize this time should be given to professor Strömgren for his far-reaching cultural work within astronomical research" – including his efforts for taking in German astronomy in the international community.[35] The international character of astronomy in particular, as compared with other scientific disciplines, was emphasized in the motivation for suggesting a nomination of Elis, with positivist arguments like the ones given above. Östen Bergstrand, professor of astronomy and director of Uppsala Astronomical Observatory, stressed the immediate importance of rapid communication of new astronomical findings or phenomena on the starry sky and that the international telegrams played a vital role in this respect:[36]

Hvem faar Aarets Nobelpris?

Akademiet træder sammen paa Torsdag.

Skal Professor Strömgren have Fredsprisen?

Stockholm, Mandag.

Privat for Politiken.

Videnskabsakademiet sammentræder paa Torsdag for at udpege Aarets Nobelpristagere. Som sædvanlig er her en hel Del Rygter i Omløb angaaende de forskellige

Figure 10: "Who receives the Nobel Prize of the year?" (*Politiken*, November 8, 1921, 6).

> It is easy to see the unprecedented hard blow that was directed towards the astronomical research with the outbreak of the world war. Not only through its inhibitory effect […] on scientific work [but also] its impact on the – for astronomers – so tremendously important international relations. If in the latter case astronomy could stand up against this blow, standing alone among the sciences, then it is essentially due to professor Strömgren […].
>
> Strömgren has performed a monumental work of enormous importance in the name of peaceful culture. Normally it would obviously be to the benefit of astronomical science; but the fact that it has been possible to go through such work in *one* cultural area increases the great importance even for science and culture *as a whole*, since it substantiates the possibility of continuing international relations in this area […].

The Finnish professors Karl F. Sundman and Ragnar Furuhjelm – national editor of *NAT* – wrote another proposal to the member of the Swedish parliament and nominator for the prize, Alfred Petrén, with similar

[35] Schroeter (University Observatory, Christiania) → Norwegian Nobel Committee (Christiania), March 1, 1920, ANNI.
[36] Bergstrand (Uppsala) → Norwegian Nobel Committee (Christiania), March 8, 1920, ANNI. Author's translation from Swedish handwriting.

wording and motivation, underlining Elis' substantial service for peace work.[37] On the basis of these letters from leading Scandinavian representatives of astronomy, of letters from most managers of astronomical institutions in Germany and Austria-Hungary, and from the results of a significant report made by associate professor in Lund, Knut Lundmark, the nominators Alfred Petrén and Wilhelm Björck handed in their nomination of Elis Strömgren for the 1920 Peace Prize.

In the summer of 1919, Lundmark visited the Copenhagen Observatory and he investigated the peace work enterprise that Strömgren had undertaken during the war, "in the name of the progress of international science and international fraternization."[38] This investigation led to his weighty report. The statues of the Norwegian Nobel Committee clearly expressed that a part of the Nobel Prizes be given to the person who "shall have done the most or the best work for fraternity between nations, for the abolition or reduction of standing armies and for the holding and promotion of peace congresses."[39] In the nomination by Petrén and Björck, right words and opportunistic rhetoric was in play, such as "activities of cultural-historical interest" and "peace endeavors", and a number of Elis' specific activities were listed. These doings comprised "taking over telegraphic news mediation for the whole world" and "arranging […] the outcome of the most important astronomical journals between warring parties." Furthermore, the nominee's struggle for "mediating scientific papers from a series of astronomers from the allied countries" in the leading continental journal *Astronomische Nachrichten* was applauded because by this effort, he managed to "achieve the exceptional result of publicizing articles during the whole war written by scientists from allied countries (Italy, Russia, English dependencies)." Finally, the nominators laid emphasis on the fact that not only were the "international astronomical relations preserved during the whole war in

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[37]Furuhjelm & Sundman (Helsinki) → Petrén (Oslo), March 2, 1920, ANNI.
[38] Petrén & Björck (Stockholm) → Norwegian Nobel Committee (Christiania), 1920, ANNI. The following citations in this paragraph are from this nomination letter.
[39] Nobel Committee Statutes. Can e.g. be found at www.nobel.se.

the most efficient manner", but "as it is, it seems probable that they will remain preserved in all future."

Notwithstanding extensive documentation, diligent nominators and three nominations in the years 1920, 1922 and 1923, Elis was never awarded the Peace Prize. Apparently, his work was not sufficiently beneficial to human mankind but rather to the benefit of astronomers and their field. His work for maintaining communication of scientific progress despite war difficulties may have been regarded too scientifically internal. Such arguments might have been satisfactory in earlier nominations but as it has been described in Nielsen & Nielsen 2001, the awarding of the peace prize in 1920 to the League of Nations "heralded a new era in the history of the Peace Prize, which coincides with the inter-war years and is primarily characterized by the considerable number of prizes to statesmen."[40]

In 1921, Elis Strömgren was elected chairman of the executive committee of the AG, succeeding the director of the Munich Observatory, Hugo Seeliger.[41] Elis had been member of the executive committee already from 1917 and he kept his position as member and chairman until 1930. The bureau played an important part in the naming and cataloguing of numerous variable stars and it was vital in the support of *Astronomische Nachrichten*, which was one of the major astronomical journals of the early twentieth century. The Central Bureau became one of several sub-departments of the new International Astronomical Union created in 1919.[42] During the first general assembly in 1922, which was held in Rome, it was settled that the headquarters of this bureau should be in Copenhagen. On October 1, it was transferred according to the wish of Elis Strömgren, being its director.[43]

The Bureau published circulars and telegrams and receivers of telegrams and subscribers of circulars were distributed on five continents. Allegedly, during the period from the Great War until April 9, 1940, the postal connection was not

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[40] Nielsen & Nielsen, 2001, 66. The formal nominators for Elis Strömgren were: 1920: W. Björck, A. Petrén; 1922: E. Björnsson, A. Petrén; 1923: 3 members of parliament, A. Petrén (same reference, 596).
[41] Schmeidler 1988, 20.
[42] The advent of the IAU is treated in chapter 3.2.
[43] Blaauw 1994, 6.

interrupted one single time.[44] Some months after the German occupation, the news service was functioning again, even though communication was limited to countries not being at war with Germany. Before the USA entered the war scene, the Bureau succeeded to establish a neutral sub central in Lund. In consequence, the communication stayed continuous even during the war in spite of strict constraints in the allowed content of encoded telegram messages. Therefore, the Central Bureau was indeed vital for Denmark's role in the dissemination of astronomical news (the Bureau existed until 1965).

2.4 The Scientific Heritage

The astronomical tradition in the Nordic countries in the first third of the century was characterized by the use of methods borrowed from advances in modern astrophysical practice and theory. In Sweden, a group formed around the astronomer Bertil Lindblad, which specialized in observational astrophysical studies of stars and the Milky Way system.[45] In Denmark, methods were also borrowed from international progress in astrophysical fields of practice. Comets were observed and the Copenhagen Observatory participated in e.g. German observational star catalogue programs. On the theoretical level, classical astronomy was tightly connected to numerical calculation, for instance by Elis Strömgren's detailed studies of the three-body problem.

Across the decade 1919-1929, three assistants were appointed, but only to succeed each other (see Appendix A). The student J. A. Kristensen was selected in 1921 but stayed only for two years; Jens Johannsen was appointed student assistant in late 1922 after two years as a calculator but he left his position already in the fall of 1924. Finally, Jens P. Møller succeeded Kristensen in the autumn of 1923 and kept his assistantship until 1944. Since late 1921, Bengt Strömgren served also as calculator and helper, until he was appointed assistant in September 1926. The competition was tough for other upcoming astronomers-

[44] E. Strömgren 1945.
[45] Holmberg 1999.

Country	**# articles**	**# writers**
Denmark	284	51
Sweden	60	21
Abroad	52	34
Norway	32	7
Finland	9	6

Table 2: Number of texts and authors of astronomical subjects in the period 1916-1935 distributed on nationality (*NAT*, 1916-1935).

to-be, considering the Professor's favourite, his own son, as will become apparent in the following chapters.

During the period 1916-1935 the activity in the respective Nordic countries has been illustrated in table 2.[46] It is not surprising to note the over-representation of Danish writers in the journal. One reason is that the journal was edited by the chairman of the Danish Astronomical Society, Elis Strömgren. He was very productive himself and had an extensive network of national colleagues whom he naturally may have promoted to a larger extent than colleagues from neighboring or other countries.[47] The topics chosen by the various writers in *NAT* (1916-1935) have been collected in table 3, with the ten most productive writers in the period (apart from Bengt Strömgren). Apparently, Finnish and Norwegian astronomy was not at all well represented in the journal. In Norway though, the prominent astrophysicist Svein Rosseland established the first theoretical institute of astrophysics in the world in 1934 with a famous mechanical differential analyzer, but this fact was only touched briefly upon in the journal.

Remarkably, there was no contribution from the Finnish editor Ragnar Furuhjelm in the journal whatsoever in the period. The only contributor was senior lecturer Hilding Slätis – from Finland's Swedish Academy in Åbo – with texts on museology and astronomical instrumentation. Luplau Janssen edited the *NAT* from 1916-1919. Then, in 1920, Vinter Hansen took over the Danish editing

[46] The table represents the local context only and thus tells nothing about the bigger picture of international astronomy or its Scandinavian representatives.
[47] This is discussed in chapter four.

Writer	*Profession*	*# Texts*	*Subjects of texts / articles*
Svante Elis Strömgren DK (Cph)	Professor, director of C.O., **chairman** of the Nordic Astronomical Society	65	Stellar development, cometary origins, fundamental concepts of modern stellar astronomy, amateur observatories, international cooperation during the great war, IAU, the RAS centennial (1922), observational astronomy, amateur astronomers, exercises, new observatories, history of astronomy, three- body problem, meetings, conferences, literature reviews (not counted), biographical notes
Julie M. V. Hansen DK (Cph*)*	Observer, Danish **editor** of NAT. (MSc 1927)	48	On stellar temperatures, planetary nebulae and helium stars, stellar colors, international congresses, color equivalents, solar eclipse, September 21, 1922, observational astronomy, clocks, solar eclipses, biographical notes, literature reviews (not counted), congresses, amateur meetings
Axel V. Nielsen DK (Cph, Århus)	Stud. mag. 1923, cand.mag. 1927, assistant at Ole Rømers Observatory from 1927	31	Observational astronomy, variable stars (including observations of these),history of astronomy (Ole Rømer), meteorites, literature reviews (not counted)
Bengt G.D. Strömgren DK (Cph)	High school student 1923, assistant at C.O. 1926, MSc 1927, PhD 1929.	25	Comets, observational astronomy, photoelectric registration of meridian passages, the size of the universe, geographical timetables, astrophysics, stellar interiors, cosmology, astronomical instrumentation, literature reviews (not counted)
Jens P. Møller DK (Cph)	Assistant at C.O. from 1923, cand.mag.	20	Nomograms, sky maps, planetary photography, new techniques with photographic plates and statistics
C.E. Luplau Janssen DK (Cph)	Mag.scient	16	The Milky Way, distance methods, fixed-star temperatures, stellar magnitudes, various observatories, novae, investigations of Mars, obituaries, the meteor section
Kristian Lous No (Oslo)	Observer, Norwegian **editor** of *NAT* from 1928[48]	14	Movements of nebulae, globular and open clusters, binary spectra, work at Harvard Observatory, planetary oppositions
Knut Lundmark S (Uppsala, Lund)	Associate professor, professor 1932	13	Absolute magnitudes, spiral nebulae, stellar distances, Tycho Brahe and astrophysics
Torvald Köhl DK (Odder)	School teacher, amateur astronomer	9	Fire balls, pronunciation of stellar names sunspots, observatories, green flashes of the sun
Östen Bergstrand S (Uppsala)	Professor, Swedish **editor** of NAT	7	The extent of the universe, stellar movements, calendar reform, the life of Tycho Brahe, solar corona, literary reviews (not counted)
Ruben Andersen DK (Århus)	MSc, director of the Rømer Observatory, Århus	7	Magnitude and color, parallaxes, articles on astronomical instrumentation (1923-1927)

Table 3: Productivity and subjects of writers in *NAT* in the period 1916-1935 (*NAT*, 1916-1935). Abbreviations: Cph. = Copenhagen, DK = Denmark, S = Sweden, No = Norway.

[48] There was no Norwegian editor of *NAT* in the 1927 issue. The Norwegian editor until 1926 was Jens Fridrik W. Schroeter (Oslo, Kristiania until 1925).

office and the following year, Elis Strömgren became the chairman of the Astronomical Society. Interestingly, Janssen's articles in the *NAT* appeared only during the time of his editorship. From 1920, his name never appeared in the journal again and the sixteen texts of his in the table were all published before 1920.

From foreign countries, there were several notable contributors of articles in the popular Nordic journal such as H.N. Russell from Princeton, Erwin F. Freundlich (from Potsdam), P. Guthnick (Berlin), A.S. Eddington and S. Chandrasekhar from Cambridge and E.A. Milne (Oxford). Productivity investigations like this give clues about the extent of the scientific network of the editorial staff in a time of growing numbers of educated astronomers. Usually, a foreign paper in *NAT* was the result of the translation of an oral talk given by the astronomer on the occasion of a Danish research visit. And usually – until 1960 – Julie M. V. Hansen took care of these translations.

The study reveals a relatively intense activity within a Danish center and shows what was done in order to propagate and popularize subjects and results of international research in the field to Scandinavian readers with dedicated, if unprofessional, astronomical interest. Also amateurs had the opportunity to write and did so. One very active amateur astronomer and popularizer was the teacher Torvald Köhl mentioned in table 3. As will be demonstrated later, Bengt Strömgren also worked comprehensively with popularizing complicated topics for a broader audience already from his student years.

Turning briefly to a sketch of parts of the cognitive development of astrophysics, we will draw the most important lines of the scientific basis which Bengt Strömgren and other astrophysicists of his time would develop further. Obviously, numerous additional scientists should be included here if the purpose was to outline a history of astrophysics before Bengt Strömgren's times. This is not the aim, though. Instead, I will introduce some of the scientists of relevance to Elis and Bengt Strömgren after a short introduction.[49]

[49] Clearly, figures such as Gustav Kirchhoff, Robert Bunsen etc. contributed to the development as well.

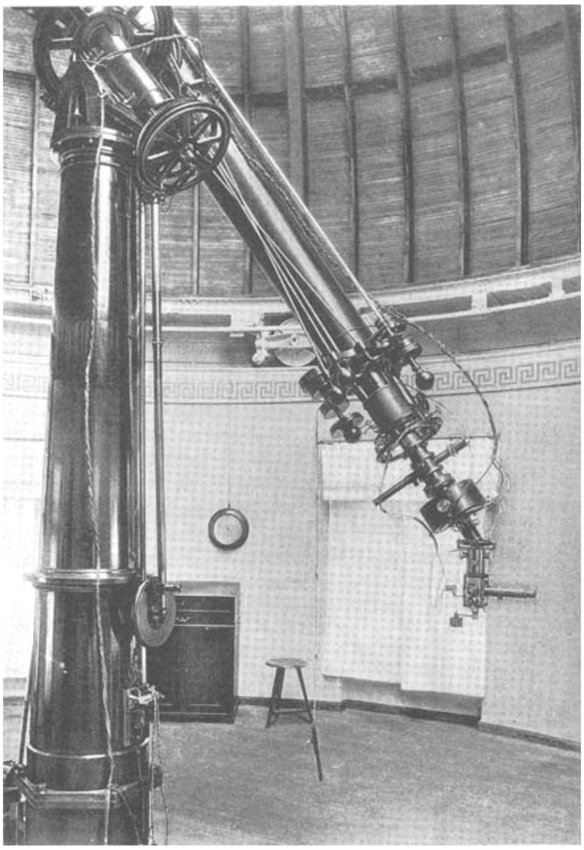

Figure 11: Paul Guthnick and Richard Prager’s photoelectric photometer installed on the 12 inch refractor at Berlin-Babelsberg. Bengt Strömgren worked there on several visits in the early twenties (Hearnshaw 1996, 198).

Astrophysics was generally based on Joseph Fraunhofer’s discovery in 1814 of spectral lines by mounting a prism on his telescope and directing it towards the sun. In 1821, he measured the wavelengths of the lines and two years later he reported line spectra of both planets and stars. The Italian astronomer Angelo Secchi also arranged a spectroscope on his telescope in the 1860s and found stellar spectra containing absorption lines, a discovery which constituted the basis of his classification of stellar spectral types with respect to their appearance.[50] Stellar spectroscopy was born and it soon initiated new problems, not to be solved by nineteenth century scientists, since it was not possible to account for the way spectral lines were influenced for certain compositions by temperature and density of the gas in which the lines were created. However, in the early twentieth century, astronomical spectroscopy went through vital changes and the hitherto qualitative spectroscopy became quantitative.[51]

[50] This classification has later developed into the so-called Harvard-classification: (W)OBAFGKM. O-star types are the hottest with surface temperatures of 40.000EKelvin while M-type stars are the coldest, T ~ 3.000 EK. A thorough account of the history of spectroscopy is given in Hearnshaw 1986.
[51] DeVorkin & Kenat 1983a, 102. See also DeVorkin & Kenat 1983b and 1990.

The photoelectric effect was first observed by the German physicist Heinrich R. Hertz in 1887, when he showed that ultraviolet light was able to intensify the strength of a spark from a discharging inductor. The pioneering researches of Julius Elster and Hans Geitel in Wolfenbüttel near Brunshwick entailed a breakthrough in 1889, when they found that alkali metals showed the effect the most strongly of the various elements they examined. From then on, the effect could be used for practical photometry. A theoretical understanding of the phenomenon was still awaiting the scientists though. The same year as Albert Einstein's special theory of relativity was published, he attempted to explain the photoelectric effect by suggesting that it could be considered to behave like particles in some instances and that the energy of each particle, or photon, depends only on the wavelength. Einstein's theory was verified later through further experimentation, of course; and his explanation of the photoelectric effect contributed significantly to the development of quantum theory.

On the hands-on astronomical level, various astronomers and physicists found ways to apply the physical phenomenon for practical purposes, e.g. Paul Guthnick at the Berlin Observatory, who made his first experiments in 1912. One year later, the observatory moved to a new site on Babelsberg in the outskirts of Berlin and during the Great War, numerous experiments were made there.[52] This location turned out to be crucial for Bengt Strömgren in his formative years as a scientific novice.

Another German astronomer with great interest in the new technology was Hans Rosenberg, who worked together with Edgar Meyer at Tübingen Observatory. Beginning also his first experiments in 1912, Rosenberg became yet another German figure who was part of Elis Strömgren's network and who turned out be important to Bengt. He was one of the many Jewish scientists who had to flee Germany under National Socialism and he got help from his Danish colleagues Elis Strömgren and Ejnar Hertzsprung.

Going back to the theoretical investigation of stars, the German astronomer, physicist and mathematician Karl Schwarzschild suggested in 1906

[52] Hearnshaw 1996, 185-199.

that radiation played an important role carrying energy through the sun's atmosphere and his work lead to the new radiation equilibrium theory for stars, making use of Stephan-Bolzmann's law for temperature determination.[53] Another important equation of stellar dynamics was unearthed by Robert Emden, who in 1907 made detailed and systematic work on so-called polytropes. This work proved useful many years later for Arthur Stanley Eddington's enormous work on the internal constitution of the stars from 1926, which will be treated in detail in chapter 4.2. The understanding of the evolution of stars changed crucially in 1913 with Russell's ground-breaking graphical form of the diagram already found by Hertzsprung and with Eddington's theory of radiative equilibrium, the dynamics of stellar interiors underwent novel treatment. The importance of ionized states of stellar matter was pointed out in 1917 by the British astronomer James H. Jeans, and same year, Eddington improved theoretical models based on ionization.

Detection of stellar line spectra and the analysis of the structure of the elements were the decisive building blocks, which brought understanding of the chemical composition and physical conditions in stellar interiors. From the beginning of the Great War, numerous analyses were made of the role played by atmospheric temperature and pressure conditions on stars and in October 1920 the Indian physicist Megh Nad Saha set up an equation in the *Philosophical Magazine*.[54] With certain temperature- and pressure conditions it was now possible to calculate pressure and temperature in stellar atmospheres by use of relative intensities between selected line intensities. Saha's method was a combination of physical chemistry, quantum theory and the theories of atomic structure, but his ionization theory was put on a more secure basis by the two Cambridge theoreticians, Professor Ralph Howard Fowler and Edward Arthur Milne. They questioned the precision of Saha's calculations and they estimated that the solar temperature according to Saha's theory was too high and that this could be explained by the relatively limited knowledge of pressure in stellar

[53] Arny 1990, 214.
[54] Saha 1920, Rebsdorf 2000, 14.

atmospheres. By use of new calculations, Milne and Fowler were astonished to find atmospheric pressures to be much lower than that of the earth. It was a common presumption that they were more or less alike.

From 1924, Milne entered discussions of stellar structure, which elapsed well into the thirties. These discussions turned out to be inspirational for Bengt Strömgren and made him enter the field of theoretical astrophysics, as I will develop further in chapter 4.5. Yet the road to his choice of theoretical astrophysics as his main field of expertise was long but exciting, as we will see in the following chapters. Apart from his mild mother Hedvig, Bengt's early life was marked by one man in particular, namely the strict director of the Copenhagen Observatory, Bengt's father, Elis Strömgren.

Three

Growing Up with Astronomy

Upbringing and Early Career

1908-1929

Mister and Mrs. Strömgren made a well-bred and cultured couple, both with fine breeding and manners. Especially Hedvig came from a home with a broad general education, speaking French, Greek, Latin, German, Swedish, Danish, and later she learned some Russian. Elis spoke German, English, Swedish, and he gradually learned Danish too, although he kept a Swedish accent though his life.

Before Elis and Hedvig moved to Denmark, Hedvig gave birth to their first son, Bengt Georg Daniel Strömgren on the 21st of January 1908 in Göteborg.[1] He was born at 10:15am weighing 3.9 kg, having brown hair, blue eyes and "seemingly well-proportionate hands and feet with long nails that needed to be cut immediately."[2] While Elis was already working in Copenhagen, Hedvig stayed in Göteborg to get the help and companionship of her sister Gerda of Geierstam and her brother in law, the psychiatrist Emmanuel of Geierstam. In mid-February the family went to Copenhagen together, Hedvig with her *jus practicandi* and Elis with his new promising professorship. As any other new parents would do, Elis and Hedvig wrote down little notes in a diary about the progressive development of their first son. For instance, on Bengt's 1.5 years

[1] Bengt was named after his maternal uncle, the botanist Bengt Lidforss, "Georg" after a paternal ancestor, and "Daniel" on account of this name's beauty; OSI.
[2] OS.

Figure 1: Elis and Bengt Strömgren, 1910. First picture of Bengt Strömgren (Courtesy of Nina Strömgren Allen)

'birthday' Elis wrote "The longest [sentence] he can say is: Once upon a time there was a prince and a princess. For the most part he speaks German but he understands Danish as well."[3]

3.1 Born under a Lucky Star

Only 22 months after Bengt's birth, his sibling Erik Robert Volter Strömgren was born on November 28, 1909. In Elis' diary the only sign of Erik's delivery is his birth date accompanied by the word "Welcome."[4] Clearly, their interest was less with their second child, as it was no longer a new experience. Many years later, Erik Strömgren became professor of psychiatry in 1945 at the University of Aarhus in Denmark and has been known for demonstrating the nature of mental illness and for making psychiatry a respectable part of medicine.[5] The next note in the pamphlet came on August 20, 1911, when Bente, as Bengt was nick named by his father, wondered about the use of our body fluids. He asked his father

[3] OS.
[4] The next note specifically about Erik, who was given the nick name Eke, appeared only in February 1912, where Elis wrote that "Eke's upbringing now seems […] to be rather complete", OS,
[5] For a scientific and technical short biography of Erik Strömgren (1909-1993), see Schioldann, 2002.

"what is blood for?"[6], and got the answer that it was to secure the head, arms, and legs and "he was very interested". At the age of around 3.5 years, Bengt made his first experience of stargazing through the Observatory's refractor: "Bente was truly happy. He really saw the stars and behaved nicely."[7] Another quote, which was accentuated in the diary the same year, was the following brief-and-to-the-point statement, which Bengt said one day to his father: "Für Bente ist der inwendige Mensch wichtiger als der auswendige."[8] Without making anachronistic extrapolations it nevertheless serves mention that this view on vanity was apparently kept in Bengt's mind for the rest of his life according to interviews with his children.[9]

According to Bengt Strömgren, living the childhood in the Observatory was comparable with the British TV-series *Upstairs/Downstairs* from the 1980'es, "although it was also different".[10] The professor's mansion was extensive and Bengt and Brother Erik had their "own little world" on first floor and in the big Botanic Garden, "which was then a quite peaceful place." The top of the west wing harbored the children's private chambers and a large playroom, which constituted their private existence and which was also "the most humorous" part of the large childhood home.[11] Another part of their life was the one shared with their parents on the floor below. Downstairs was inhabited by[12]

> lots of amiable people and always our housekeeper. She stayed with us for several years until she died. In addition to her we had a house assistant, a morning lady; and there was a laundress, a sowing lady, an ironer, and two extra helpers during springtime cleaning. The three worlds were kind of separated, but my brother and I often went down to the basement.

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[6] OS.
[7] OS, September 25, 1911.
[8] OS, August 1, 1912.
[9] KNSI.
[10] "Disposition for samtale 20. og 21. maj 1969" (May 20. and 21., Bengt Strömgren's own handwriting in Danish), BSA.07, A. The next two citations are also from this source.
[11] Havelund 1978, 12.
[12] Havelund 1978. See map of the CO, chapter 2, figure 2b.

Figure 2: The Strömgren family in the Observatory garden, ca. 1911. Bengt Strömgren to the left with long hair – as it was commonplace at the time – and Erik to the right (Courtesy of Ole Strömgren).

The fact that their parents were Swedish affected daily life and made it an unusual home compared with other Danish homes and Bengt himself "had a feeling that it was somewhat different, a bit more stiff, more formal. I never told my parents. My brother did." The two sons always addressed their parents in the third person – as is evident from letters between Bengt and Elis, even in later years – and it proceeded like in many other Swedish homes of that time. The house language was Swedish, but the brothers addressed each other in Danish.[13] According to Bengt, they lived a spoiled childhood and they never got beatings, "not after the age of two. This was a principle of our father. The upbringing of small kids comprised a smack in the bottom", but then it was all about dialogue to make the young boys understand.

In the autumn of 1913, Bengt began his schooling in Krebs' school very close to the Observatory. Yet the teaching of social manners was taught at home. When Hedvig and Elis threw a party, the young boys entered the dining room "in

[13] The ESC includes countless examples.

fine garments and said how do you do". During summers at the observatory, there were numerous garden parties, usually crowded with astronomers discussing scientific matters. The observatory garden was extensive, but nothing compared with the Botanical Garden, to which the boys were allowed to enter with the professor's key after closing time. "The keys never really meant anything, though, as we climbed the fence instead".[14]

After five years in Krebs' school, Bengt left it as number one in the class to be transferred to the elite school Metropolitanskolen, which "was a tough transition"; the young novices beginning in the middle school were labelled "sutter" and "were treated extremely condescendingly by older pupils in the second of middle school, the "ex sutter".[15] "Whenever pupils of first and second middle school had gym lessons together, the oldest pupils introduced the class by cornering the sutter and giving them a good spanking called "sutteklø"; but we hit back to the best of our abilities." Metropolitanskolen was situated very close to the University of Copenhagen buildings. Elis and Hedvig expected that both their sons managed to get the best grades – and so they did; as Bengt archly pondered in a Danish newspaper interview: "we did more or less what was expected from us". Indisputably, the parents paced their talented sons to a large extent, an assertion promoted further below. As can be seen from numerous notes in Elis' diary, Bengt did excellent in school. In the summer of 1916, during the Great War, the proud father noted that Bengt read "for his own pleasure Sjögren's Historical Reading Book, 700 pages, and [he] explained that it was the best book he had ever read".[16] One might suspect that this son-to-father statement was made to make 'Pappi' happy rather than being an honest expression.

The brothers enjoyed a close relationship with their parents and it was "again another world when we were down in the living rooms of the adults." Their home was "marked by both of my parents, but I think that it was my mother who influenced me the most on my attitude on life." These sentiments of

[14] Havelund 1978, 12.
[15] Havelund 1978 (The next two citations are also from this source). Erik left Kreb's school in 1920, also as number one in his class. OS, 1920.
[16] OS, 1916. The book was probably *Historisk läsebok för Skolan och Hemmet*, 1875-76 by the Swedish historian Karl August Otto Sjögren.

life are only to be found in later interviews of Bengt Strömgren, since no such explicit viewpoints have been extended in his own writings, which is almost of a strictly scientific kind. However, from my interviews with Bengt's three children it is beyond doubt that Bengt had inherited Hedvig's tenderness and warmth rather than the strict and firm personality of the patriarch professor.

3.2 Public and Private Education

As Bengt grew up in the professor's mansion, where he lived until he got married in 1931, his father began to talk to him early on about natural science, especially astronomy and mathematics, and the conversations gradually went into education, "which my father was quite convicted to. In many ways my father was an excellent teacher"[17], as Bengt recalled. Already at the age of 11, astronomy and mathematics had become a large part of Bengt's life. He reached far in mathematics in the periods when Copenhagen schools were closed several times due to an influenza epidemic in November 1918[18] and for one month in January 1919 (The so-called Spanish disease). In November, Bengt wrote a postcard from Copenhagen to his father, who was on a trip to Halmstad in Sweden, "Dear Pappi! Thank you so much for your letter. […]. The algebra is so easy to understand. Today, we went for a football match and it was so much fun."[19]

Games and mathematics walked together hand in hand quite naturally. An eloquent example of Elis' education lessons is the document displayed in figure 3 showing what went on in the observatory during the influenza epidemic in January 1919. The young apprentice – still ten years old - was taught calculus on a high level by his father: numerical differentiation and integration, complex numbers, partial differentiation, "the art of numerical computation using the standard logarithmic-trigonometric tables" and other subjects.[20] Further documentation can be found in Elis' diary, in which he wrote: "During the Spanish vacation, Bente turned seriously to chemistry and mathematics. He read

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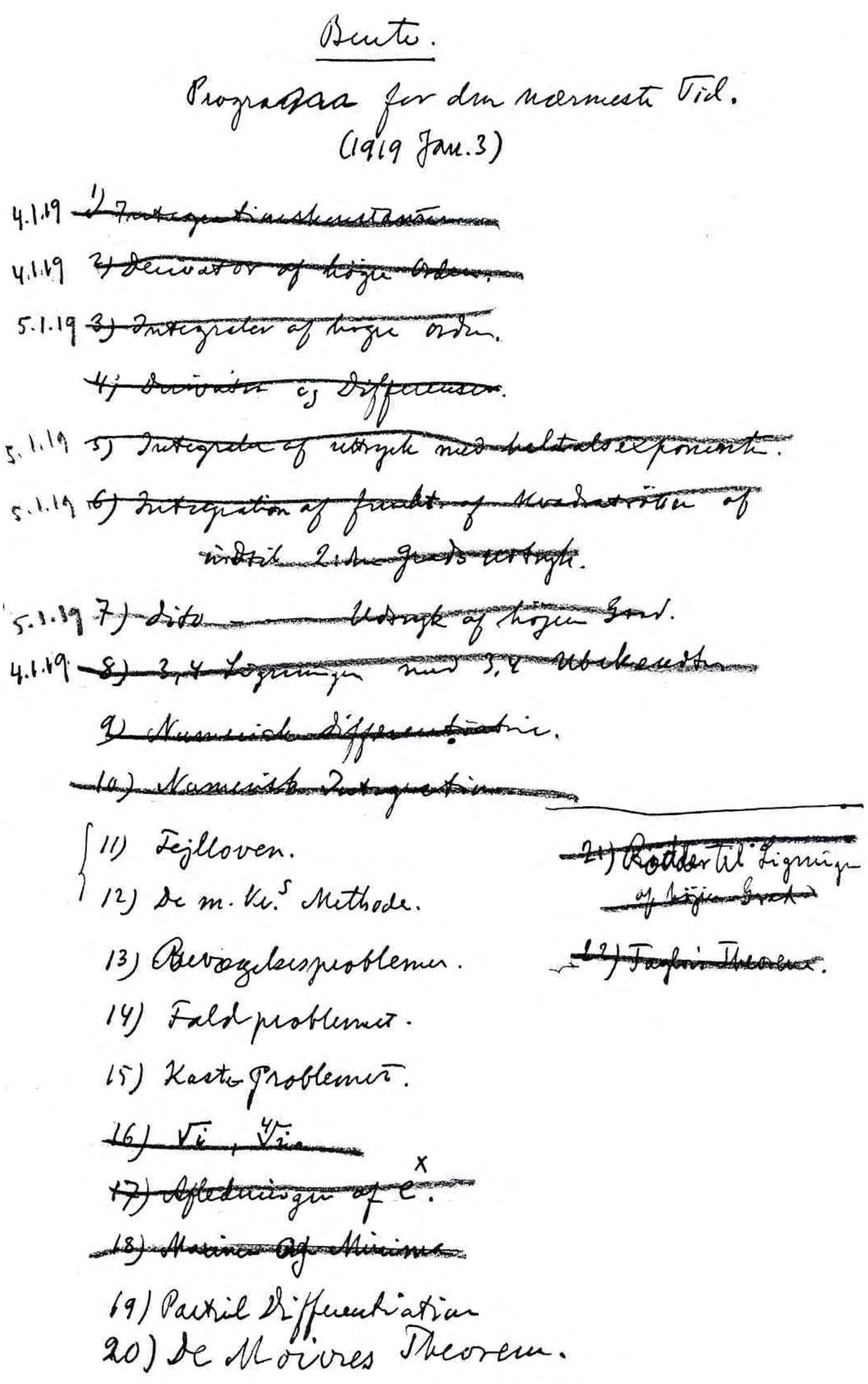
[17] Havelund 1978.
[18] "Dear Pappi [pet name for his father]! Now we will begin in school on Monday, if the epidemic doesn't get worse" (ECS, November 15, 1918, from Björboholm, Sweden, to the Observatory).
[19] B. Strömgren → E. Strömgren, November 17, 1918, ESC.
[20] Strömgren 1983, 1.



Bente.

Programma for den nærmeste Tid.

(1919 Jan. 3)

4.1.19 1) Integrationskonstanten

4.1.19 2) Derivatør af højere Orden.

5.1.19 3) Integraler af højere Orden.

4) Derivater og Differenser.

5.1.19 5) Integration af Udtryk med heltalsexponent.

5.1.19 6) Integration af Funktioner af Kvadratrödder af indtil 2det Grads Udtryk.

5.1.19 7) Ditto Udtryk af højere Grad.

4.1.19 8) 3,4 Ligninger med 3,4 Ubekendte

9) Numerisk Differentiation.

10) Numerisk Integration

11) Fejlloven.

12) De m. Kv.s Methode.

13) Bevægelsesproblemer.

14) Faldproblemet.

15) Kasteproblemet.

16) $\sqrt{i}$, $\sqrt[4]{i}$

17) Afledningen af e^x.

18) Maxima og Minima

19) Partiel Differentiation

20) De Moivres Theorem.

21) Rødder til Ligninger af højere Grad

22) Taylors Theorem.

Figure 3: Elis Strömgren’s “Plan for January 1919”. Elis’ handwritten text is translated below: 1) The integration constant, 2) Derivatives of higher order, 3) Integration of higher order, 4) Derivative and different, 5) Integration of expressions with integer exponent, 6) Integration of functions of square roots of up to 2nd degree expressions, 7) Ditto, expressions of higher degree, 8) 3,4 equations with 3,4 unknowns, 9) Numerical differentiation, 10) Numerical integration, 11) The error law, 12) The method of least squares, 13) The problem of movement, 14) The fall problem, 15) The toss problem, 16) $\sqrt{i}$, $\sqrt[4]{i}$, 17) Derivatives of e^x, 18) Maxima and minima, 19) Partial differentiation, 20) De Moivre’s Theorem, 21) Roots of equations of higher degree, 22) Taylor’s theorem.” (January 3, 1919, ECS).

Einar Biilmann's book,"[21] and during the whole year, he continued his mathematical studies, differential calculus in particular. Instead of spending Sunday mornings in church, Elis taught linear equations to Bengt: "One Sunday morning of 1919, I began introducing the z-coordinate. "If I imagine an equation in x, y, z…" Bengt immediately responded: "Then there will be no solution; Then Pappi needs two equations.""[22]

At that time, parts of the topics were situated in the high school mathematics curriculum, while today such themes are more likely to be found in the university's first year mathematics classes. From the list of mathematics tasks to be undertaken by Bengt, the crossed-out topics in figure 3 probably represents the lessons already gone over by Elis. Even throughout the summer holiday, mathematics was on the agenda. Elis' boy wrote a card from the family's usual Swedish holiday location, Björboholm, to England:[23]

> Dear Pappi! How are you in England? […] I am fine and Mammi and Eke will arrive tomorrow. Thank you so much for the letter, which I received a couple of days ago. I have read everything about integration. Today, we went to the woods to pick blueberries. We got 13 litres altogether.

The initial mathematics lessons of Bengt pictures a young man, exceedingly early settled in a stimulating scientific environment. An indisputable objection to this optimistic statement would be that the talented boy – the oldest brother – had no choice and was prematurely paced by the ambitions of his father. Owing to the adolescence at Østervold, Bengt reminisced, still, "it was only natural that I found the activities at the Observatory interesting."[24] The historical value of such retrospective remarks is somewhat dubious, some would probably even denote them anachronistic, but on the other hand this actually constitutes the childhood recollections of Strömgren. Bengt had always been engrossed by the fancies of his little brother, who gradually became more and

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[21] OS, 1918-19. Einar Biilmann was professor of chemistry. He wrote numerous school books.
[22] OS, 1919. Pappi was the nick name of Elis made up by Bengt and Erik.
[23] B. Strömgren (Björboholm) → E. Strömgren (England), June 17, 1919, ESC.
[24] Havelund 1978.

Figure 4: Bengt Strömgren, his cousin Vibeke, nicknamed Vibi, and brother Erik in Björboholm, Sweden, on a summer vacation. Vibeke was the daughter of Hedvig Strömgren's sister Gerda of Geirstam. Undated (Courtesy of Nina Strömgren Allen).

more absorbed in psychology and psychiatry. During their summer vacations they spent their time with their aunt 'Adreg', the physician Gerda Geirstam, née Lidforss, and her husband Emmanuel. Aunt Adreg was named accordingly owing to her eccentric personality – she was known to view things all backwards. Hence she was nicked with the reverse of her real name, and Gerda was transformed to Adreg. Bengt and Erik became absolutely fascinated by the earnestness and intensity by means of which their uncle, the psychotherapist Emmanuel of Geirstam was occupied with his work. When Bengt began to make his own money, a considerable part of his earnings was spent on psychological and other literature, which they were both very preoccupied with.[25]

[25] MS 1987, Erik Strömgren's recollections.

Figure 5: Erik and Bengt in a rowing boat near Björboholm, Bengt directs his little brother while controlling the tiller. Undated, perhaps 1921 (courtesy of Nina Strömgren Allen).

The Time Service

Early on, Bengt had been allowed to carry out accurate time estimates with the Repsold broken-axis transit instrument in the Observatory and in the fall of 1920 he began systematic observations.[26] His father was aware of the obvious risk that he would be in the way of the observation work of the permanent staff. Thus he wrote to observer Johannes Braae: ”If you devote him some of your time, I would of course be glad, as well as I am pleased when you help other beginners, but it would be against my wish, if such helpfulness should entail the loss of a night of observation, if only that one time.”[27] Bengt also took part in calculations of cometary trajectories and “it was all extremely exciting and quite natural to work with.”[28] It was an old tradition that the Copenhagen observatory had the

[26] OS, 1920.
[27] E. Strömgren → Braae, October 11, 1920, ESC.
[28] Havelund 1978.

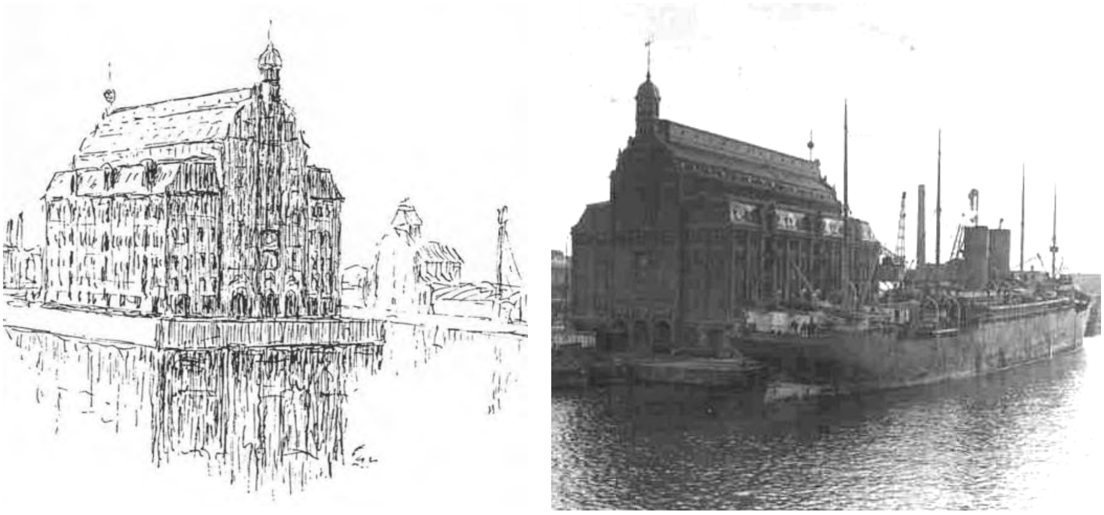

Figure 6: Left: The silo storehouse in Copenhagen. The “time ball” is seen on top of the left hand side of the roof (Kampmann 1955, 29). Right: Photo of the storehouse from the other side (RL).

obligation to take care of public time through the so-called Tidstjenesten (Time-Service).

The rotation of the earth is an appropriate and relatively stable time measure. The fairly smoothly flowing astronomical time unit called the sidereal day is the time between two successive upper culminations of the vernal equinox. After one sidereal day, the celestial sphere has returned to its original position with respect to the observer, but in order for the observer to find the sun on the same spot on the sphere, the earth has to move a bit more than that due to the earth’s own orbit around the sun – the number of sidereal days is one higher than the number of solar days, due to the earths own orbital motion around the sun. Therefore, the solar day, or synodic day, is 3 minutes and 56.56 seconds (sidereal time) longer than the sidereal day.

In the observatory, the sidereal day is naturally employed, but in daily practice it is clearly the synodic day, which makes practical sense in society. By use of a pressure and temperature regulated so-called Riefler clock, which was purchased by the Observatory in 1903, time was mechanically measured and registered. Already in 1771, King Christian VII’s personal physician and ‘prime minister’ Johan Struense demanded that the Danish professor of astronomy and successor of Ole Rømer's professorship, Christian Horrebow, should find a solution of the big differences of timekeeping between various public Copenhagen clocks. As a result, a time signal was placed on top of Rundetaarn, the national observatory of that time. Some hundred years later the time signal was moved to Nikolai Church, where an electrical control signal was sent through a telegraphic wire from the Copenhagen Observatory at Østervold. During the years 1868-1909, a big five feet diameter ball was raised and dropped every day at one o'clock pm in order for the caretakers around the city to adjust their respective clocks.[29]

The navy was dissatisfied with the position of the ball far from the harbour, since accurate time keeping was vital for longitudinal determinations on the sea. In 1909 the marine's voices were heard. The time signal was on the Budget[30] and the ball was moved to the roof of the so-called Silopakhus (silo-storehouse) in the Copenhagen harbor (on Midtermolen). Until 1923, a worker from the firm Hassel & Teudt took care of the ball, when time signals were sent telegraphically from the observatory. Then, the smith H. Kretzschmer overtook the duty until 1932 when another smith, Johannes Ørnbak, had his apprentices see to the somewhat outdated task, until the signal ceased functioning in March 1941.[31]

Thus, for long, an accurate time signal was needed from the observatory. Through comparisons between sidereal time – by use of accurate determinations of stellar transits – and the mechanical Riefler clock, it was possible to establish a very accurate time by contemporary standards. Thus, in the first years of the twenties, the social task of the observatory was undertaken by the young Strömgren amongst others. The method by which time was measured was soon highly improved by the innovative teamwork between a Danish engineer and Bengt, as we will see in chapter 3.3.

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[29] *Berlingske Aftenavis,* March 28, 1941, "Frk. Klokken har slaaet Kuglen ud!"
[30] *Rigsdagstidende,* 1909-10, Tillæg A, Sp. 1257-58.
[31] *Berlingske Aftenavis,* March 28, 1941, "Frk. Klokken har slaaet Kuglen ud!" See also Kampmann 1955.

Interwar Years

In the early 1920'es, the Great War had weakened several European countries, including Denmark, with a considerable unemployment as one of many sad results.[32] Being the nation's most profitable exchange trade, agriculture had its net proceeds reduced considerably and also the net income of urban industry went down, leading to frequent mass firings. The foundation of the Social Democratic government in office, led by Prime Minister Thorvald Stauning, began to crumble as liberals appealed to Danish farmers with a new cut down policy. In December 1926, the conservative Venstre-government won the general election and cut backs in e.g. education were effectuated leading to tightened belts for teachers and other public servants whilst private schools awaited better times. Shortly after the population felt the cut backs, a tendency towards the left on the political continuum emerged.

The liberal government was challenged by a fresh coalition between the Social Democratic Party and the Social Liberal Party (det Radikale Venstre). Burning issues of defense policy proved fatal for the Venstre party at the end of their parliamentary term. During the electioneering, the Social Democrats and the Radicals used new opportunities. Chances of war seemed minimal, but fear of war was still present in the people's minds. The horror of the Great War was not forgotten and during the campaign this was an appealing issue; military use of poisonous gas was in particular a feared subject, which could perhaps be compared with the ubiquitous fear of nuclear bombs during the cold-war period. The liberal cooperation was lost and in spring 1929, a new ministry was created in a time, where the nation's general conditions seemed better. Unemployment was reduced to 16% and worker's salaries were increasing.

Technology moved fast. The national Kastrup Airport was inaugurated in 1925 and aviation played a still larger role. The telephone gradually became more common and the radio had great cultural influence. Until 1925, the air was one chaos due to numerous private and often primitive radio clubs. By this year, the Danish State took over responsibility for the distribution of all national radio.

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[32] Excerpts from the Danish general history of Kaarsted, 1991.

A big national main antenna came in effect in 1927 with programs send by the Statsradiofonien. Later, in 1930, listener's associations showed up in the radio council. Politicians soon opened their eyes for the opportunities of making radio programs with political messages and the radio played a major role in the internationalization of cultural life, with a hitherto unseen geographical coverage.

Danish scientific research in the mid-war years was predominantly located in Copenhagen at the University, other higher schools, colleges, and e.g. the Carlsberg Laboratory. In Århus, the second national university was dedicated in 1928, but the natural sciences faculty was only inaugurated in 1954.[33] Denmark enjoyed a considerable international position within the natural sciences until the Second World War. Several scientists were well known internationally. At the Copenhagen University it was, amongst others, the physicist Martin Knudsen, working with hydrography and properties of the gases; the mathematician Harald Bohr and also Elis Strömgren at the Copenhagen Observatory. At the Carlsberg Lab it was Søren P.L. Sørensen and Kai Linderstrøm-Lang, who investigated enzymes. Poul Brandt Rehberg and the Nobel laureate August Krogh (1920) examined blood circulation, respiration and insulin production. The most well-known by far was the Nobel laureate Niels Bohr, receiving the prize in 1922 for his work with atomic physics. Later he enjoyed an iconic reputation for his international institute at Blegdamsvej as the institutional cradle of quantum mechanics.

In Denmark, the period of Bengt Strömgren's upbringing and early career until the early 1930'es, was characterized by quite small scientific institutions not very expensive to society. However, the prestige of Danish science was growing, in particular owing to the aforementioned main international figure of Danish science, Niels Bohr. During the Great War, the hatred between earlier congenial spirits had risen with the losses of lives in the trenches. Thus, after the war, in November 1918, several scientific societies sought to banish German and Austrian scientists from future international congresses. The attitude was somewhat dissimilar in Scandinavia, as these countries were not directly

[33] Nielsen 2004.

Figure 7: The first IAU General Assembly was held in Rome from May 2 to 10, 1922. In the President's chair, B. Baillaud. On his right hand: General Secretary Arthur Fowler. On his left hand, Vice-President F.W. Dyson, President of the IAU from 1928-1932. Behind-in between Baillaud and Dyson: Elis Strömgren and on his right side, behind Fowler: Henry Norris Russell. (YODA).

involved in the war. It was characteristic of many Danish scientists to search for ways to bridge the deep cleavage between the opposing parties. Niels Bohr was a classical example, but also Elis Strömgren was active in such attempts.

After the war ended, there was established a series of "inter-allied" congresses in Paris, London and Brussels, where it was decided to create some new institutions and among others a new astronomical central in Brussels. Before the work was initiated in this central, it was agreed that the CO should be the connecting link between Brussels and Kiel.[34] In 1919, the International Research Council was created in Brussels. The purpose of this council was to coordinate international activities in a variety of scientific branches and to prompt the

[34] E. Strömgren 1945.

creation of international unions to secure scientific progress.[35] As a direct consequence of the statutes of the International Research Council, the International Astronomical Union (IAU) was set up in the summer of 1919. A sub-department was also instituted, namely the International Central Bureau for Astronomical Telegrams, which proved to play an important part in the history of the Copenhagen Observatory, as already touched upon in chapter two.

In Elis Strömgren's opinion, Danish involvement in the fresh IAU cooperation was not self-evident. Initially he was against the principle of the neutral states' entry into the inter-allied associations. Elis found it "undignified to mould scientific unions, in which scientists of whole nations a priori are excluded by reasons irrelevant to science and without any regard to the positions of the individual scientists."[36] Notwithstanding, after further consideration, he realized the opportunity of asserting himself in what he regarded as the decisive question of introducing German scientists. There was no doubt in his mind: "The days of intransigent standpoints within astronomy are numbered." Yet, by participating in the IAU it would be possible for Denmark to actively work against the International Research Council's principle of cordoning, which was written into the statutes of the council in 1919.

Even though Elis neither voted for nor against a Danish representation, Denmark became a member state the same year and the Danish Union Committee was put together of Elis Strömgren and Niels E. Nørlund, who had been assistant under Strömgren in 1908-1912 (see appendix A). During the first IAU general assembly in 1922, held in Rome, it was decided, among other things, that the head office of the central bureau should be located in Copenhagen.[37] This bureau issued numerous circulars and telegrams and the many subscribers were soon distributed on five world continents, obviously giving rise to great bustle at Østervold.

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[35] Blaauw 1994, 1.
[36] E. Strömgren → Royal Academy of Sciences and Letters, regarding international scientific cooperation, January 20, 1922. RA, Protocol No. 1181-1922.
[37] Blaauw 1994, s. 6.

An important scientific institution, which was created in Denmark in 1920, was obviously Niels Bohr's Institute of Theoretical Physics. When Niels Bohr was appointed professor of theoretical physics in 1916, he soon realized the need for a new institute due to the very limited space at the Polytechnical College in Copenhagen.[38] He did not only want to house the studies of theoretical physics, but he also needed a location for experiments – spectroscopic investigation in particular – and he succeeded in retrieving the required funds. The building of Bohr's institute was completed in late 1920 and shortly after the inauguration in March 1921, the new University Institute of Theoretical Physics (the UITF in Danish abbreviation) became a hotbed for theoretical physics at the highest international level.[39] But it attracted students from other fields of natural science as well – the young Strömgren was indeed one of them.

3.3 Bengt's Early Career

Following upon Bengt Strömgren's immersion in advanced mathematics during his school years, he had the opportunity, facilitated by his father, to begin making astronomical observations. One of the employees at the Observatory - perhaps it was the assistant-to-be Jens Johannsen - taught him to operate the observatory's time-determination instrument. The Copenhagen Observatory had the obligation of taking care of public time through the so-called Time Service, since there were neither telephone signals nor radio signals to indicate local time until the breakthrough of mass communication via radio signals in the early 1920'es.[40] Until then, Danish time was determined in the Observatory and sent telegraphically to the silo storehouse, as already described in chapter two. In addition to Bengt's observational work, he began to read scientific articles in the German periodical *Astronomische Nachrichten*. As Elis wrote in his diary in

[38] Polyteknisk Læreanstalt. This chosen translation is used throughout the text.
[39] On the history of the UITF, see Robertson 1979 and Aaserud 1990.
[40] The first regular radio transmissions of news and music in Denmark were transmitted in 1924 (Nielsen, Nielsen & Siggaard Jensen, 1996, 143).

1921, “Bengt studies a lot – old papers in A.N. [He] reads a lot - journals.”[41] Elis’ pacing of his son is furthermore exemplified by the arrangement of several

[41] OS.

Figure 8: Frank Küstner (1856-1936) took good care of Bengt on trips to Germany (Blaauw 1994, 95).

travels to Elis' German colleagues during Bengt's weekly Easter school 'holidays'. In 1921, Elis made his son visit the German professor of astronomy Gustav Eberhard at the Astrophysical Institute in Potsdam. Eberhard had done important work on stellar calcium emission lines in 1904 – a hint on stellar surface activity – together with the lieutenant general and astronomer Hans Ludendorff, who was director of the Potsdam observatory and had done important work in the field of spectrography and variable stars.[42]

In a June letter of 1921 to Elis' German colleague and friend, the astronomer and specialist in photographic astrometry Frank Küstner at the Bonn Observatory, Elis asked for Küstner's advice regarding a useful working plan for "an observer who would very much like to undertake a right ascension program" by use of the Observatory's transit instrument. Furthermore, Elis gave the detailed constraints of observable stellar magnitudes visible under the Danish weather conditions.[43] Küstner replied that owing to the latitude of the Danish Observatory, it was advisable to undertake "position determinations of the bright

[42] E. Strömgren 1941; Hearnshaw 1986, 335-337. Variable stars were later identified as e.g. pulsating stars.
[43] E. Strömgren (Copenhagen) → F. Küstner (Bonn), June 27, 1921, BSA.01, A.

circumpolar stars from +65E", since the current settlement of these quantities were attached with uncertainties and hence desired a precise reestablishment.[44] Elis kindly replied to Küstner that "the assistant would like an advice regarding the selection of the fundamental stars" and that the same assistant posed a few question to be redirected to Küstner.[45] Though, the mentioned assistant was not one of the employees at the observatory, but a rather young helper.

In yet another memo to Küstner, Elis wrote, regarding some received technical notes from Bonn, "I forward the letter [...], until the young man, who is to observe, is back from a holiday trip."[46] This young man sent a letter to his father in mid-July from Björboholm, in which he claimed "I have no further questions to Küstner."[47] Hence, initially it was not revealed to Küstner, who this young assistant really was. The reason for this clandestine conduct remains unknown, but it is ostensible that in the intension of being taken seriously, the young age of Bengt should not be uncovered. After the summer holiday, Bengt undertook more than 2,000 observations of 113 polar stars in the period 1921-1923 in collaboration with his fellow student, Jens Johannsen[48] and he "used every clear night but it was in a peculiar fashion, from a half hour after sundown, when it was dark enough, until 10 o'clock, because I was a school boy and I had to go to bed early."[49] Frank Küstner was a highly respected astronomer, the author of the first meridian catalogue including faint stars. His preface to a very important series of Bonn publications had impressed Bengt, who met Küstner in Copenhagen and in Bonn and who "remembered his kind general encouragement" of the upcoming young scientist.[50]

Another prominent figure who visited the observatory in Bengt's youth was the 1921 Nobel laureate of physics, Albert Einstein. It happened on his travel

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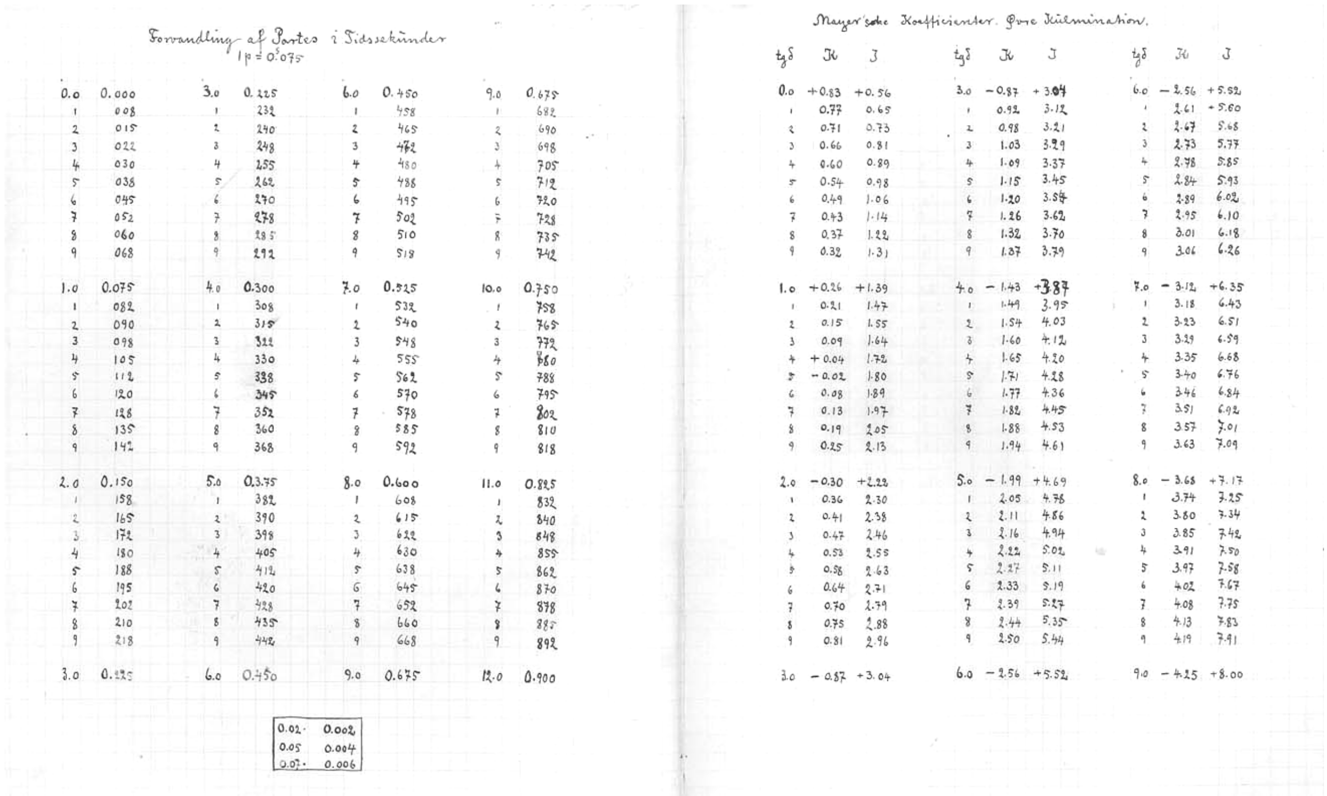
[44] F. Küstner → E. Strömgren, July 4, 1921, BSA.01, A.
[45] E. Strömgren → F. Küstner, July 19, 1921, BSA.01, A.
[46] E. Strömgren → F. Küstner, August 4, 1921, BSA.01, A.
[47] B. Strömgren (Björboholm) → E.S. (Copenhagen), June 14, 1921, ESC.
[48] HBI, 2 and Schroeter 1925, p. 74. Also in OS a note is found (1921): "[Bengt] embarks on Küstner's program after summer holiday together with stud. Mag. Jens Johannsen." (author's translation).
[49] HBI, 2.
[50] B. Strömgren 1983, 2.



Forvandling af Partes i Tidssekunder
1p = 0s075

0.0	0.000	3.0	0.225	6.0	0.450	9.0	0.675
1	008	1	232	1	458	1	682
2	015	2	240	2	465	2	690
3	022	3	248	3	472	3	698
4	030	4	255	4	480	4	705
5	038	5	262	5	488	5	712
6	045	6	270	6	495	6	720
7	052	7	278	7	502	7	728
8	060	8	285	8	510	8	735
9	068	9	292	9	518	9	742
1.0	0.075	4.0	0.300	7.0	0.525	10.0	0.750
1	082	1	308	1	532	1	758
2	090	2	315	2	540	2	765
3	098	3	322	3	548	3	772
4	105	4	330	4	555	4	780
5	112	5	338	5	562	5	788
6	120	6	345	6	570	6	795
7	128	7	352	7	578	7	802
8	135	8	360	8	585	8	810
9	142	9	368	9	592	9	818
2.0	0.150	5.0	0.3.75	8.0	0.600	11.0	0.825
1	158	1	382	1	608	1	832
2	165	2	390	2	615	2	840
3	172	3	398	3	622	3	848
4	180	4	405	4	630	4	855
5	188	5	412	5	638	5	862
6	195	6	420	6	645	6	870
7	202	7	428	7	652	7	878
8	210	8	435	8	660	8	885
9	218	9	442	9	668	9	892
3.0	0.225	6.0	0.450	9.0	0.675	12.0	0.900

0.02	0.002
0.05	0.004
0.07	0.006

Mayer'ske Koefficienter. Øvre Kulmination.

tgδ	K	J	tgδ	K	J	tgδ	K	J
0.0	+0.83	+0.56	3.0	−0.87	+3.04	6.0	−2.56	+5.52
1	0.77	0.65	1	0.92	3.12	1	2.61	+5.60
2	0.71	0.73	2	0.98	3.21	2	2.67	5.68
3	0.66	0.81	3	1.03	3.29	3	2.73	5.77
4	0.60	0.89	4	1.09	3.37	4	2.78	5.85
5	0.54	0.98	5	1.15	3.45	5	2.84	5.93
6	0.49	1.06	6	1.20	3.54	6	2.89	6.02
7	0.43	1.14	7	1.26	3.62	7	2.95	6.10
8	0.37	1.22	8	1.32	3.70	8	3.01	6.18
9	0.32	1.31	9	1.37	3.79	9	3.06	6.26
1.0	+0.26	+1.39	4.0	−1.43	+3.87	7.0	−3.12	+6.35
1	0.21	1.47	1	1.49	3.95	1	3.18	6.43
2	0.15	1.55	2	1.54	4.03	2	3.23	6.51
3	0.09	1.64	3	1.60	4.12	3	3.29	6.59
4	+0.04	1.72	4	1.65	4.20	4	3.35	6.68
5	−0.02	1.80	5	1.71	4.28	5	3.40	6.76
6	0.08	1.89	6	1.77	4.36	6	3.46	6.84
7	0.13	1.97	7	1.82	4.45	7	3.51	6.92
8	0.19	2.05	8	1.88	4.53	8	3.57	7.01
9	0.25	2.13	9	1.94	4.61	9	3.63	7.09
2.0	−0.30	+2.22	5.0	−1.99	+4.69	8.0	−3.68	+7.17
1	0.36	2.30	1	2.05	4.78	1	3.74	7.25
2	0.41	2.38	2	2.11	4.86	2	3.80	7.34
3	0.47	2.46	3	2.16	4.94	3	3.85	7.42
4	0.53	2.55	4	2.22	5.02	4	3.91	7.50
5	0.58	2.63	5	2.27	5.11	5	3.97	7.58
6	0.64	2.71	6	2.33	5.19	6	4.02	7.67
7	0.70	2.79	7	2.39	5.27	7	4.08	7.75
8	0.75	2.88	8	2.44	5.35	8	4.13	7.83
9	0.81	2.96	9	2.50	5.44	9	4.19	7.91
3.0	−0.87	+3.04	6.0	−2.56	+5.52	9.0	−4.25	+8.00

Figure 9: Bengt's meticulous tables of numbers, 1921-23 (booklet 1: Bengt Strömgren's individual correspondence, 1921-23, UCO).

back home from Sweden after having just received the Nobel Prize in Stockholm on December 10. Einstein lived in the observatory "for a few days" that winter. Although Bengt and his brother met the great physicist of the time, they "didn't quite appreciate Einstein's greatness. We were too young."[51]

The following year, in 1922, Bengt was sent on another scientific expedition by the help, or pressure, of his father. This time it was to visit Paul Guthnick at Neubabelsberg Observatory in Berlin-Babelsberg. As Guthnick was one of the first astronomers to use the photoelectric cell for astronomical purposes, on this winter visit, Bengt became interested in photoelectric photometry. A few years later, Guthnick sent a letter to the natural sciences faculty with the best recommendations of Bengt as a potential assistant at the Danish Observatory – an issue we will return to later.

[51] HBI, 3.

An alternative development of Bengt's future career was about to unfold, namely that of becoming a German citizen. In 1923, Elis was invited to be appointed professor of theoretical astronomy at the Berlin University under the best conditions and with top salary ("höchstes Spitzengehalt"). He was intended to be appointed director of the Astronomical Calculation Institute in Berlin-Dahlem, but the timing was not entirely the best. As it turned out, the family never moved to Germany. Elis received the invitation in a time when the situation seemed most hopeless for Germany. In a classified letter to the director of the Ole Rømer Observatory, Ruben Andersen, Elis wrote about the position, "Considering my family, I did not dare to take it."[52] Had it not been for Hedvig's dentistry, Elis might have taken the offer and moved with his family to Berlin. Instead of taking it, he capitalized on the offer to ensure budget increases locally, which, sadly, turned out to be less than he had hoped for. The Observatory's annual budget for 1924 was augmented from 7,000 to 8,000 Kroner. As director of the observatory, he fought against exceeding economic difficulties in the mid-twenties. "I have to start canceling journal subscriptions; binding is practically terminated; the work on problème restraint, which is close to its conclusion, has rested for half a year due to lack of funding and I can buy no instruments…"[53] Ultimately, the Strömgrens stayed in Denmark.

Just after passing the middle-school exam in the summer of 1922 with an "outstanding" average score of 7.89 and a prize of 20 Danish Kroner, Bengt joined a group of observers[54]. While in his first year of high school – at Metropolitanskolen – he began assisting in observations of the orbits of the comet Baade, by use of the transit instrument already familiar to him. In September, he gave a talk on photography in school, which was highly complimented by his teacher, but on October 6, Bengt was given a detention at school, after he had been throwing his sandwich wrappings in a class. The school

[52] E. Strömgren → R. Andersen, June 8, 1925, ESC (Elis wrote about "the invitation two years ago").
[53] Ibid.
[54] OS, 1922, June 30. The group consisted of E. Strömgren, Julie M. Vinter Hansen – from 1930 editor of *NAT*, Aage Nielsen and Jens P. Møller, see B. Strömgren 1922, 345-348.

Figure 10: Elis, Erik and Bengt in the office of the professor. This photo is unique in that it shows the observatory inside the walls. Perhaps the photograph is intended to displays the proud father looking in a strict way on his oldest son who is given a desk, while the younger brother from an upright position glances at his father in a most respectful manner. Bengt on the other hand looks a bit unsatisfied with the situation (undated, probably from 1925. Courtesy of Ole Strömgren).

watchman laughed about the whole incident and released the young rebel after half an hour instead of one, which was the original agreement. When Bengt went home, he made his first comet observation with the large refractor and he also did some planet observations together with Julie Vinter Hansen.[55] This work eventually resulted in his first joint publication, a two-page table of positions entitled "Komet 1922c (Baade)" which was published in *Astronomische Nachrichten*. He was then fourteen years old.[56]

[55] OS, 1922, September 18 and October 6.

[56] B. Strömgren 1922. According to Nissen and Gustafsson 1990, 7, Bengt's first publication appeared when he was seventeen years old. This is not entirely true. Even though the joint paper on Comet Baade from 1922 was a mere table of data rather than an actual full article, it was a publication after all.

It appears as though Elis' diary was predominantly attributed to his oldest son, while Erik was only given short comments here and there. Each time Bengt was given good grades in school, the very fine grades of his little brother were written beneath without further comment and each time Bengt's results were just slightly better. Though, Erik's grades were not to be ashamed of and if comparisons were made between the brothers, the difference of age should have been taken into account. As an example, Elis took the following note in the summer of 1923 ("Ug" designates the best possible grade and in the note book it was accompanied by the grade mean average number):[57]

> Bente pure ug (7.83).
> For the 5th time Ug and Metropolitanskolen's highest mark.
> (N.B. Two [high school] *students* got better grades in 1919, but no one in the school).
> Eke 7.69.

Apparently, it was important for Elis to proudly underline the fact that in spite of those high school students who did best, his oldest son was still number one in school – and Eke's fine grade was noted afterwards without further comment.

A couple of months before Bengt's sixteenth birthday, the time was ripe for the study of analytical mechanics. In January, Elis noted in his little diary that his son read about elliptical functions, a subject of which he was "very busy and flushing."[58] On Bengt's birthday, his proud father wrote another note that disserves mention: "On this remarkable day Pappi needs to write down how much of a joy it is to follow these studies. It seems as though there are no difficulties whatsoever; everything is self-evident [to Bengt]."[59]

In the summer of 1923, the next astronomical expedition was ready and this time Bengt was accompanied by his father. For two weeks they traveled through Lübeck, Hamburg, Bremen, Cologne, and in Bonn, Bengt accounted for

[57] OS, June 30, 1923. Metropolitanskolen housed both the secondary school and the Gymnasium, the latter being the institution for students, while the word student is not used in Danish for school pupils.
[58] OS, 1924, January 14.
[59] OS, January 21, 1924.

his observational program to Küstner. According to Elis' diary, "the Bonn gentlemen were rather astonished".[60] On June 10, they visited Guthnick in Berlin-Babelsberg and every morning for three days Bente spent his time with him.[61]

Already in his second year at high school, Bengt Strömgren had been in touch with Bohr's institute.[62] In 1923, Bengt was invited to participate in "work on the reduction of the laboratory spectra of hafnium", the element with atomic number 72, which had been discovered recently at the UITF by Georg von Hevesy and Dirk Coster.[63] The physicists Hans M. Hansen and Sven Werner measured the optical spectrum of hafnium using a quartz-prism spectrograph in the UITF laboratory and in their following publication "The optical Spectrum of Hafnium" the authors displayed their gratitude to "several of their colleagues in this institute, especially Mr. V. Th. Jantzen and […] Mr. B. Strömgren" for assistance in the calculations of the spectral lines of the element.[64] Until that time, at the age of fifteen, Bengt's practical laboratory experience had been limited to astronomical observations and related practical work.

Bengt made also use of his computational skills for other institutions in order to earn small fees for his work here and there. In addition to his computations for the UITF, he made calculations for the Danish Forest Research Institute.[65] For his payment in March, he invited his father to a Harold Lloyd movie in the Copenhagen movie theatre World Cinema.[66] Around that time, his father gave an unusually detailed portrayal of his personality, which is otherwise unparalleled in Elis' words in the diary:[67]

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[60] OS, 1923, July 3-16.
[61] OS, 1923, July 3-16.
[62] In a letter from UITF to B. Strömgren, he was thanked for his excellent calculation work, and 125 Danish Crowns were sent to him (Bengt Strömgren, November 23, 1923, NBA).
[63] B. Strömgren 1983, 2. Actually, Bengt wrote in his recollections that "already in 1924, as a high-school student" he had been invited to participate in the calculations, but as is apparent in the preceding note, he was thanked for his work already in 1923.
[64] Robertson 1979, 70-71; OS, 1923; Hansen & Werner 1923, 18. Valdemar Thal Jantzen worked at the UITF as a student before graduating as engineer.
[65] OS, February 1924.
[66] OS, March 5, 1924.
[67] Ibid.

> Bengt works just about always. Hardly ever goes out. Sometimes movies. As always, [he] is good, happy, and friendly. Appreciates his appearance; willingly wears new costumes with long pants. His physical strength is unheard of. [He] has a number of general interests, is looking at Marx' "Das Kapital". Philosophically interested (Determinismus).

Later the same year, Elis noted that Bengt read Oswald Spengler's famous post-war monograph *Decline of the West*, in which the author in a rather pessimistic way attempted to predict the course of Western European-American culture and where some deterministic logic of history was considered.[68] These were the formative years of a teenager who discovered a large world growing around him not only as a quite traveled young man, but also as a still more enlightened citizen.

On the face of it, Elis viewed his teenage son as a hardworking, culturally engrossed young man with a good stamina; sociable and jovial, reading masterpieces of literature and having inclinations for philosophical reflections about human knowing and science. As can easily happen when parents project their own – sometimes failed – ambitions to their children, embodied in pacing and promotion, an opposite projection might also come about. Perhaps the intellectual aspirations of the talented son had a comforting and even self-promoting effect on Elis. Being the specialist scientist, who was not exactly known to have as broad and deep intellectual capacity as did his wife,[69] the patriarch's private self-image conceivably enjoyed influential encouragement from his son's diverse activity and mental faculty. Such projection, or perhaps just common parental pride, is a likely result of the parents publicly displaying their offspring for the sake of their own vanity.[70]

It is more difficult to make a picture of Hedvig's view of her oldest son, due to meager historical documentation. She was herself as passionately engaged into dentistry as was her husband into astronomy and it seems very probable that

[68] OS, December 6, 1924. Spengler's two volume work was originally published in 1918 and 1922 (Spengler 1918).
[69] From KNSI and OSI.
[70] As treated by Sulloway 1996 on e.g. page 54.

she did also, if not directly, encourage her sons to academic life, if using less strict upbringing manners than her better half. In an interview of 1957, Hedvig reminisced that when she grew up in Lund, her siblings used to say about their parents Volter and Anne Marie: "Our father is professor, *but it is mother, who has got the wits*."[71] Perhaps the same was true for Bengt's father and mother.

Through Elis' daily dealings with academic colleagues and perhaps from Elis' early relationship with Niels Erik Nørlund, who had worked as scientific assistant at the observatory from 1908 until 1912, the teenager from the observatory knew about future plans within the walls of the university. Nørlund became professor of mathematics at the University of Lund in 1912 and he took over the professor's chair of mathematics in Copenhagen in 1922 under the condition that the position was combined with the directorship of the old institution Den danske Gradmaaling. This institution, which was established in 1816 by the astronomer Schumacher, performed the superior triangulation survey of Denmark. Nørlund spent much of his time on geodesy and he offered guidance for students. After only a few years, the university had its first graduates with the title of master of geodesy.[72] A new topic he took up was seismology and he applied the Carlsberg Foundation for financial support to launch seismographic stations in Copenhagen and in Ivigtut and Scoresbysund in Greenland.[73]

Bengt got wind of Nørlund's plans and wished to participate in such an expedition to Greenland. In March and April 1924, Elis negotiated Bengt's prospective involvement with Nørlund. His contribution should be longitudinal determinations using radio – to get accurate time information – and a transit instrument, which he was of course familiar with already. Another assignment would be pendulum observations, possibly for making preliminary determinations of gravitational anomalies. The strategy was to pass the high school exam before the expedition. Through negotiations with Metropolitanskolen, Elis made it possible for Bengt to take the written exams in

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[71] Gribsø 1957.
[72] Bang 1983, 486. Nørlund was dean of the Natural Sciences Faculty in 1924-1925, see Appendix A.
[73] Bolt 1997.

Figure 11: Elis Strömgren (From Hansen, J.M.V. (1947), *The Observatory*, 67, 142-143).

September 1924 and then after the completion of the expedition he was intended to take the oral exams in December or February 1925.[74] In a letter to Nørlund, in the summer of 1924, Elis asked for information as to the status of the expedition. Nørlund answered shortly after that "The Greenland plans can not be furthered now, but I have the best hopes for next year and would in that case be delighted if Bengt would participate."[75] But as it turned out, Bengt never made it to Greenland. The reason for this is unknown, but the expedition was indeed carried through, in 1925 however. Probably, the prolongation of the date of the expedition made it impossible for it to fit into Bengt's tight schedule of exams.

As regards Bengt's brother Erik, he returned from school in spring 1924 with a report card of the "usual quality", which was in the high end of the scale. The next day, Elis had a serious conversation with his youngest son, where Erik supposedly claimed that he "intended to begin his life with more determination." Elis pondered that Erik "might have been thinking about Bente's great progress

[74] OS, March and April 1924. Extensive notes about the expedition plans can be found in Elis' little diary.
[75] E. Strömgren → N.E. Nørlund, June 26, 1924 and N.E. Nørlund → E. Strömgren, July 24, 1924, ESC.

(of latest the Greenland question). He [Erik] regards it as certain that he will follow the polytechnic road, possibly electrotechnics. Bente and Pappi immediately introduced mathematical studies".[76]

After the summer commencement, Elis was, once again, able to write down with pride the best marks of both his sons. Bengt was number one (7.85) and Erik shared the second place with another pupil named Stig Juul (7.75). For that, Erik received 75 Kroner from the Andræ's Grant.[77] Now Erik also began to make calculations for money, as he made the so-called calendar notes for the year 1925 for the Danish newspaper *Berlingske Tidende*.[78] The oldest son studied advanced mathematics and theoretical physics in the fall of 1924, then being 16 years old. He read the periodical *Ergebnisse der exakten Naturwissenschaften*, which later turned out to be the mouthpiece for a crucial paper of his in the late 1930'es. He studied Planck and atomic theory, he investigated Salmon-Fiedler's algebra on linear transformations, and he read the Copenhagen mathematician Christian Juel's so-called rational mechanics. Furthermore, Heinrich W. Olber's work on calculating the orbits of comets was studied by Bengt, as were other scientific textbooks and theses. He even participated in a relativity theory reading group on bi-weekly evenings. Elis wrote one night in his diary that he had a wonderful evening with Bengt and he continued, "I am sure that he will grow up to be someone very notable."[79]

The observational work undertaken by Bengt in previous years with Jens Johannsen was prepared for publication after the summer vacation, during which father and sons had been in Scotland and England.[80] Bengt calculated some second and third approximations for the forthcoming paper and Küstner, who had been involved in the project right from the start, received the calculations for his opinion, while Bengt wrote the article text. At the same time as he finished the scientific work, his father took care of the negotiations with the intended

[76] OS, April 16, 1924. Later, Erik thought about becoming a teacher, as he spoke with Hedvig about in November 1924 (OS, November 11).
[77] OS, June 28, 1924.
[78] OS, August 16-17, 1924.
[79] OS, October 7, 1924.
[80] OS, July 1924.

publisher, the Royal Swedish Academy. These negotiations began in the spring. Elis helped his son (and Johannsen) intensively in having their results published right away and even before the first stellar transits were registered, the proofs of the *KVA* paper had already been written, with empty spaces ready to be completed with empirical data such as star name and observation time. The paper was therefore in press only days after the stellar registrations.[81]

In reply to Elis' request to publish the paper written by his son and Jens Johannsen, the Uppsala professor Hugo von Zeipel asked Elis to inform him about Bengt's nationality, since "for foreigners it is very hard to publish in the KVA"[82]. On von Zeipel's request for a compressed version of the paper, Elis inquired if this was necessary in order to meet the demands. The secretary of the Royal Swedish Academy of Sciences, the chemist Henrik G. Söderbaum, had proclaimed to von Zeipel that the nationality problem could be handled, but that it would be less complicated if the name of "a Jens Johannsen, obviously of Danish nationality" who "even had his name mentioned before Strömgren's" was removed from the title page and instead was "gently positioned in the text as an assistant."[83] One should notice that now Johannsen was observatory assistant and Bengt Strömgren only a young calculator who was not even permanently employed. To this suggestion, Elis was reluctant and found it "unfair to his [Bengt's] co-worker if his name completely disappeared", but regardless it nearly did, as can be seen from the title page where Johannsen is mentioned only in the subtitle[84], as suggested by Söderbaum. In spite of regulations of the Swedish Academy, an exception was made owing to the national origin of Bengt – after all he was at least born in Gothenburg – but also because of his father's membership of the scientific society and the paper was finally permitted. The

[81] Andersen 1988, 52.
[82] KVA abbreviates Kungliga Svenska Vetenskapsakademiens Handlingar (Publications of the Royal Swedish Academy of Sciences), v. Zeipel (Uppsala) → E. Strömgren (Copenhagen), May 18, 1924, BSA.01, A.
[83] v. Zeipel → E. Strömgren, October 10, 1924, BSA.01, A. Söderbaum's suggestions were attached to this letter.
[84] The subtitle reads: "After observations of Bengt Strömgren and J. Johannsen in the years 1921-1923 employed at the Repsold transit instrument of the Copenhagen Observatory" (B. Strömgren 1925a).

observatory family received the permit for publication on October 22, 1924 and only a few weeks later, the first of many so-called “press campaigns” began.[85]

The public eye rapidly found out about the fresh young scientist. In the Danish newspaper *Politiken*, “a scientific portrait” was given in the fall of 1924, which announced Bengt’s publication on his improved method of precision determinations of the cataloguing of stellar positions in astronomical yearbooks. The newspaper article applauded the advent of “a new star” whom “at the age of 16 has published an astronomical paper in the Publications of the Royal Swedish Academy. Luckily, for the young scientist, his age excuses him of the appellation prodigy *child.*”[86]

Undoubtedly, it was extremely difficult for other candidates than the professor’s son to get inside the walls of the CO. In the autumn of 1925, once again, Elis Strömgren worked actively for the promotion of his son. One fine example is the student of geology, Einar Anton Andersen, who regarded it “almost impossible for others to choose that discipline [astronomy].”[87]

He explained his hopes to the German astronomer Paul Guthnick in Neubabelsberg that Bengt would get a soon-to-be-vacated assistantship at the Observatory, a suggestion supported by Bohr, H.M. Hansen and the dean of the natural sciences faculty, N.E. Nørlund.[88] Nørlund vouched for Elis’ recommendation that Bengt should be appointed assistant at the CO; likewise, the faculty endorsed the proposal. Nevertheless, the highest instance, the members of the University Senate (Konsistorium) were worried about probable allegations of nepotism.[89] Elis requested his Swedish professor colleagues von Zeipel and Bergstrand to give their recommendations of his son’s qualifications, which were later received by the faculty. Both professors expressed their high opinions of Bengt Strömgren and also Paul Guthnick from Neubabelsberg spoke

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[85] This was Elis’ word for his son being interviewed by and displayed in the newspapers; OS, October 22, 1924.

[86] Politiken, 1924, November 8, “Et videnskabeligt portræt”, 7. Author’s italics.

[87] Andersen 1988, 52.

[88] Niels Erik Nørlund held the professor’s chair in the period 1922-1956 was the dean of the faculty in 1924-1925, and was the president of the University of Copenhagen in 1933-34 (Slottved 1978, 230). See also appendix A.

[89] E. Strömgren (Copenhagen) → P. Guthnick (Neubabelsberg), October 19, 1925, ESC.

Herr Professor Dr. Niels Bohr
ærbödigst fra
Bengt Strömgren

KUNGL. SVENSKA VETENSKAPSAKADEMIENS HANDLINGAR
TREDJE SERIEN. BAND 2. N:O 2.

BESTIMMUNG DER REKTASZENSIONEN VON 131 POLNAHEN STERNEN

NACH BEOBACHTUNGEN VON *BENGT STRÖMGREN* UND *J. JOHANNSEN* IN DEN JAHREN 1921—1923 ANGESTELLT AM REPSOLD'SCHEN DURCHGANGSINSTRUMENT DER KOPENHAGENER STERNWARTE

VON

BENGT STRÖMGREN

MITGETEILT AM 22. OKTOBER 1924 DURCH H. VON ZEIPEL UND Ö. BERGSTRAND

STOCKHOLM
ALMQVIST & WIKSELLS BOKTRYCKERI-A.-B.

BERLIN
R. FRIEDLÄNDER & SOHN
11 CARLSTRASSE

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Figure 12: Front page of the *KVA* paper. Handwritten text in the top of the offprint: “Mister Professor Dr. Niels Bohr, yours truly, Bengt Strömgren”. Copy from NBA (B. Strömgren 1925a).

highly of Bengt by supporting his assistantship on the basis of the 1921-1923 study “which could be considered everywhere as an ample doctoral work.”[90] Annoyed at the “protracted and fruitless discussions” of Bengt’s appointment, Elis reported to Guthnick that “some were concerned about setting a precedent” due to the fact that no one challenged Bengt’s abilities.[91]

Nevertheless, in this first attempt Bengt did not get the appointment on account of age. In an irate letter to Guthnick, Elis directed his *ad hominem* blames at Nørlund for the result, thus “Dear Nørlund [...] first gave enthusiastic help, but then ruined everything [...], but now I count nearly on the fact that his future will not be based in Denmark.”[92] Now, it is unknown in what ways Nørlund in fact went against Bengt’s appointment, as we know that he vouched for Elis’ recommendation, but the providence of Elis did not prove true, however, until the mid-1930’es when Bengt Strömgren was invited to the University of Chicago. Although Bengt did not get the appointment in this first attempt on account of his young age – and due to the obvious questions of nepotism brought up by the natural sciences faculty – the Konsistorium finally appointed him assistant at the Observatory in 1926.[93]

Technological Innovation

It was not only existing technology and ideas that was employed by the young innovative high school student. Stellar photometry was not the only branch of astronomical research in which photocells were employed in the interwar years. Bengt was one of the first ever to introduce the photocell for astrometry, by which he managed to record accurate times of meridian passages by allowing the image of a star being monitored to cross a grid of parallel wires in the focal plane of the telescope.

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[90] P. Guthnick (Neubabelsberg) → E. Strömgren (Copenhagen), October 21, 1925, BSA.01, A.
[91] E. Strömgren → P. Guthnick, November 1, 1925, ESC.
[92] E. Strömgren → P. Guthnick, November 25, 1925, ECS.
[93] Bengt was appointed on a one-year basis from November 1, 1926. His assistantship was extended with one year at a time until 1932 when he was appointed lecturer of astronomy, see Yearbook 1926-1927, 13.

In early 1924, Bengt proposed to his father the insertion of a direct "radio writing on the chronograph" and this idea was further developed.[94] While he read the proofs of his *KVA* paper in January 1925, he began planning new ways of having the observatory's meridian circle photocell correspond with a telegraphic tape. One late afternoon he entered the parent's bedroom while Elis took a nap. There, he told his father about his latest ideas: "And then we put a lattice in front of the objective and determine effective distances". Elis was "very fascinated and kissed him intensely in the cheek."[95] After some experiments one Sunday in January, the innovative Danish engineer and inventor Knud Rahbek was promptly contacted and he agreed to do the practical set-up of the apparatus for Bengt's novel experiment. The idea of Bengt's new experimental system was to facilitate automatic registrations of stellar transits without help of the human eye. Stellar transits were used for accurate timekeeping for stars with well-known right ascensions, but also for determinations of stars with unknown right ascension. The method employed hitherto was the so-called chronograph method, by which the observer gave a signal on a chronograph using a telegraphic key at the instant of a star passage across vertical metal thread in wire gauze on the meridian circle.[96]

The Repsold micrometer method, which was also familiar to Bengt, involved a sort of drum, which was revolved while a star passed across a thin movable wire. His novel method, by contrast, involved no risks of human error. It had an even greater accuracy, since a photoelectric cell now would do the observation job. The problem consisted of amplifying a small current, which was generated from the cell when it collected the starlight. Therefore, the engineer Rahbek was invited into the project. The current of the actual photocell was ten billion times too small for registering stars of the fourth magnitude in the observatory's 120 mm meridian circle. Knud Rahbek and Bengt worked for some time together and found a solution with very small delay in the impulses stemming from the amplifying setup. According to an interview with Rahbek in

[94] OS, spring 1924.
[95] OS, January 14, 1925.
[96] B. Strömgren 1926, 10.

Politiken, the collaboration had been delightful, but the notes from Elis' diary do not agree on the whole with this statement.[97]

The first meeting between Elis, Bengt and Rahbek, and with Julie Vinter Hansen as witness, went peacefully.[98] Bengt explained his plans of using the new setup for meridian observations as well as determination of effective distances. The observatory ordered a photocell for Bengt's project, which they received from the firm Braunzweig in early February. Two days later Bengt came up with an idea for amplification of the weak currents. After one week, Bengt had a small intellectual fight with Rahbek in the company of both Elis and the assistant Jens P. Møller. When Møller and Rahbek proposed their objections concerning the difficulties with such an enormous amplification, Bengt offered his electrical setup and "their doubt disappeared", as Elis proudly noted.[99] Later that same day, Rahbek came to Elis and told him how impressed he was. "He asked if it was presumptuous of him to wish for his name to be included in the prospective publication of the invention. Rahbek worked so intensely with the matter during the weekend that his family was displeased with it."

One Sunday in late February, Rahbek and Bengt made their final experiments. Yet, after still more tests in other laboratories in Copenhagen, they succeeded to make the amplification in the special setup. On Monday, March 9, Rahbek didn't show up as promised for an afternoon meeting. Elis called him and asked if he had forgotten about their agreement. According to Elis notes, Rahbek answered, "Yes, really" and thus Elis "was rather biting."[100] When Rahbek finally arrived he wanted to have a word with Bengt. This time he appeared less subservient than when he had most graciously requested for his participation in a possible joint publication: "He explained that the amplification setup was *his* and not Bente's and if we didn't want to acknowledge that, he would break the co-operation because otherwise he would feel completely

[97] *Politiken*, January 9, 1926, 6.
[98] The following account is paraphrased and translated from OS, January 29, 1925 to March 11, 1925.
[99] OS, February 11, 1925. The next citation is from the same source.
[100] OS, March 9, 1925.

unnecessary."[101] The quarrel was not mentioned further in Elis little journal, but apparently Rahbek continued his cooperative desires and he was certainly mentioned in interviews and newspaper commentaries about the joint innovation.

During Bengt's experimenting, he also studied Eddington's theory for stellar interiors, which we will return to in chapter four. He also made more calculations for the Bohr institute and went to hear a talk in the Fysisk Forening (Physical Society) by Ralph Howard Fowler about the Saha-Milne equation. After the talk, he took part in discussions with Fowler.[102] Between his written and oral high school exams, Bengt went to Berlin-Potsdam for a small congress in the Astronomische Gesellschaft (AG) and on June 25 he got the so-called "white kiss" for having the best marks.[103] He graduated from the Copenhagen high school Metropolitanskolen, scoring 7.87 ("outstanding") as the mean result of all his examinations.[104] His brother was following him closely as number three that year with a mean result of 7.75. The grades were neatly noted in Elis' little journal.

As it turned out, the experimental setup became more expensive than anticipated. Elis was given advice by the President of the Polytechnical College[105], Peder Oluf Pedersen that they should apply for funding at the H.C. Ørsted Foundation for the final experiments: "I cannot promise anything but there is a possibility. Your son should get in touch with inspector Harding about formalities." Marius Christian Harding was a chemist, historian, and director of the Polytechnical College. Elis responded – according to his own diary notes – "Yes, Professor Pedersen, but won't you give inspector Harding some informing words, so that he will not be too astonished?" "I already did that."[106] Two days later, Bengt delivered his application to the foundation and in late January the

[101] OS, March 9, 1925.
[102] OS, March 30, 1925.
[103] OS, June 26, 1925. His marks on the Danish scale were as follows: Written Danish mg+, neatness ("orden" in Danish) mg+, and he got Ug in all other disciplines: Mathematics, Danish, History, Classical Civilization, French, German, English, Physics, Chemistry and Natural Science (naturfag).
[104] He graduated on June 4, 1925, and won the Andræ'ske travel Grant, see *Indbydelsesskrift* 1926, 33.
[105] Today denoted the Technical University of Denmark.
[106] OS, December 9, 1925.

executive committee decided to give a grant of 3,900 Kroner for the final arrangements.[107]

In the words of the Hungarian-British author Arthur Koestler, who defined the creative process as “bisociative processes which intentionally connects two hitherto unrelated thoughts”, Bengt’s idea is an example of individual creative behavior, at least in Koestler’s terminology.[108] Telegraphic tape, the meridian circle, and the photocell were mentally and then practically connected by Bengt. Another researcher of creativity, Margaret A. Boden, would phrase the emergence of his novel idea using the notion of conceptual spaces:[109] The conceptual space of “photocells” – and the principles of organization, which collect and structure this particular area of thought – was juxtaposed by the conceptual spaces of “telegraphic tape” and of ”meridian circle”. Thus, by breaking down the usual thought patterns of these three spaces, they were transformed into a generating system, spanning a new conceptual space, in this case of automated photocell-astrometry. Whichever description chosen, the striking fact was that Bengt was actually one of the first figures to attempt photoelectric registration of stars in this way at age eighteen.

One acquaintance of Bengt who was tremendously important in the early years was Piet Hein (1905-1996), who went to the Metropolitanskolen two years above Bengt. After studying physics at the UITF (see figure 3 in chapter four), Piet Hein turned out to become some sort of Danish national poet with his famous “Grooks”, using the pen name Kumbel, and his innovative thoughts were exemplified by his drawings, sculptures, buildings, and design in general. Hein’s creative potential undoubtedly inspired Bengt from very early on. As already outlined in the introduction, Bengt went on bicycle rides with his friend and Hein formed close friendships with both Bengt and Erik.[110] According to an interview with Erik Strömgren, Hein gave the young Strömgrens a general education by use of his “indefinitely deep knowledge” as he was “colossally well-read“.

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[107] B. Strömgren → Emil Herborg’s Legat, June 1, 1929, RA.
[108] Rebsdorf & Jakobsen 2003, 39; Koestler 1964.
[109] Rebsdorf & Jakobsen 2003, 97-99; Boden 1996, chapter 4.
[110] Schioldann 2002, 53. The next quotation is from this source also.

Figure 13: The Second IAU General Assembly held in Cambridge, July 14-22, 1925. Excerpt from group photo. In the back row, second person from the right is Bengt Strömgren wearing his student's cap. Number four from the right is E.A. Milne (BSA.03, C).

The IAU General Assembly in Cambridge

Following the high school graduation in the summer of 1925, Elis brought his young, widely traveled son on another vacation to foreign countries. This time they went on a trip through Hamburg, Rotterdam, London, Cambridge, Dover, Paris, Brussels and home again. At the same time, Erik went on a trip to Brussels and Amsterdam. Owing to their father's presidency of the Central Bureau of Telegrams and his membership of the International Astronomical Union, Elis planned to participate in the second General Assembly of the IAU in July 14-22, which was to take place in Cambridge. Bengt was seventeen years old and he followed his father to the meeting. At the university observatory, they were both invited to a garden party arranged by the professor of astrophysics Hugh Frank Newall and IAU vice-president and astronomer, Arthur Stanley Eddington.[111] This was Bengt's first meeting with Eddington and he remembered him to be

[111] The General Assembly in Cambridge, July 14-22, 1925, was the second international meeting of this kind (the first having been in Rome on May 2-10, 1922). 189 astronomers attended this assembly, and at its conclusion the union counted 22 member states, see Blauuw, 1994.

"one of the astronomers who impressed me the most. He was a very kind man and it was not difficult to talk with him."[112]

Also the English astronomer Edward Arthur Milne, Beyer professor of applied mathematics in Manchester, attended this meeting, at which an important question was brought up by Elis Strömgren regarding the international nature of the IAU. With his usual taste for internationalism, Elis convinced 59 members of twelve countries to sign a statement asking the president, at that time the Dutch astronomer Willem de Sitter, and the executive committee, "to make all possible efforts to render the Union international in the complete sense of the word, so that at the next meeting all nations can be represented which desire it".[113] The burning issue was the war boycott on Germany; the French and the Belgians did not want to admit German astronomers to the IAU, while the astronomers of the other countries were willing to let them in. Furthermore, astronomers from the United States wished to participate in the union, but would only do so on the condition that astronomers from all countries were allowed. An Italian statement even read, "no further meeting of the IAU should be held until it can be completely international".[114] Nonetheless, the proposal was rejected due to formalities in the decision-making of the statutes of the International Research Council. Elis Strömgren played an effective intermediary role as president of the AG with his close contact to German scientists. Being a scientist from a neutral country, he did not agree with the narrow proceedings of the International Research Council. He was confident that a complete ceasefire with German astronomers was necessary. Germany was still no member state, but following Elis' internationalist determination towards bringing scientists together, he did everything in his power to have also non-Germans join the AG congress in 1926, which was to be held in Copenhagen. He succeeded, as we shall see in the following. It was probably owing to his father's convictions that young Bengt was drawn into international affairs on this occasion and thereby he may have had some initial second hand experience with such questions.

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[112] HBI, 8.
[113] Cf. note 111, on page 76.
[114] Cf. note 111, on page 77.

During the Cambridge assembly, the Strömgrens stayed at the Craven Hotel in London where also von Zeipel and Lundmark spent their nights. In a letter to Mother Hedvig, Bengt proudly reported his experience from the extraordinary international event:[115]

> Zeipel and I have become brothers. Lundmark has told me that he exerted himself for eight years to accomplish that. We usually eat together with Zeipel, Asklöf (in England he is called Mr. Ascoff), and Lundmark and we have a wonderful time. At the farewell party at Trinity College we witnessed a lot. The grace was especially festive with two orators and a choir of schoolboys […]. Then a cup of beer was passed around the table and everyone had to drink from it […]. Pappi is now dressing up for a dinner with the government. Yesterday we went to Greenwich for its 250eth anniversary and I was allowed to watch both the king and queen. Yesterday night there was "conversazione" at the Royal Society and we saw a lot of things, e.g. Newton relics and models of all the oldest locomotives.

Sten Asklöf was a young experienced Swedish astronomer with expertise in photographic astrometry by whose experience Bengt could draw lots of knowledge. Besides networking with Swedish colleagues, he arguably got a feel of how distinguished scientists interacted at festive events and he arguably enjoyed the classy style and old traditions of the scientific aristocracy, as did undoubtedly his father.

The Public Eye

In January 1925, Bengt received a letter from a Swedish, female admirer, Anna Stina Kjellin, who had cut out a portrait of the young astronomer from the Danish popular magazine *Husmoderen* (Housewife) at the time of his publication in *KVA*. She wrote:[116]

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[115] B. Strömgren (London) → Hedvig Strömgren (Copenhagen), July 1925, ESC; Holmberg 1999, 153.
[116] A.S. Kjellin → B. Strömgren, January 8, 1925, BSA.01, B.

> Dear mister Strömgren,
>
> Please forgive me for writing to you even though I don't know [you] except from your appearance. You may find it odd that I know about your looks but I have a clipping of your portrait from "Husmoderen" and I keep it in my diary as my most precious thing. Forgive me, sweetie, but I would so much like to have a "real" photo of you. You see, you are my ideal and you will always be […]. Be kind and say yes. No, my darling (forgive me), now I must send off my […] letter in the hope that you will at least mail me a card with you on it.
>
> Yours ever,
> Anna Stina Kjellin, Sparbanken,
> Hudiksvall (Sweden).

No other letters of this kind can be found in the Bengt Strömgren Archive, but evidently Bengt kept this particular letter from a Swedish bank clerk. The letter brings forth the idea that young, handsome, personable, always well-dressed representatives of science – like Bengt Strömgren – played a role for the lay man in a time where belief in progress perhaps was difficult to find in society. However irrelevant this might seem in the big picture, the incident still indicates Bengt's effect on lay people, and hence on parts of society. It remains unknown whether Bengt replied with an attached photo.

Being a serious upcoming and promising scientist, Bengt's public image in the inter-war period remained the same in various newspaper portraits. He seemed perfect; being the best hardworking pupil in school and high school; giving public talks on scientific topics from an early point in life; creatively inventing new technology and having the luck of living the good life in the middle of academia – even sleeping in a bedroom that shared the roof with the number one national telescope! The public image of scientists in the late 1920'es and 1930'es can be said to be that of the absent-minded inhabitant of the remote academic ivory tower. Perhaps the young Bengt did not completely embody the stereotype picture of such archetypal scientists, as it was occasionally promulgated in the press. From his portraits, though, it is clear that

Et videnskabeligt Portræt.

Det lille Geni paa Observatoriet.

Professor Ellis Strömgrens 16-aarige Søn, Astronomen Bengt Strömgren, har gjort en ny og betydningsfuld Opdagelse.
Sammen med Ingeniør Rahbek har han konstrueret et elektrisk Apparat, der automatisk registrerer Stjernernes Bevægelser.

Den 16-aarige Videnskabsmand.

MAGISTER-KONFERENS PAA TO AAR

Den 19-aarige Astronom Bengt Strömgren blev igaar Magister efter kun 2 Aars Universitets-studium.

Magister Bengt Strömgren, fotograferet ved Apparaterne, han har opfundet, og hvormed han ad foto-elektrisk Vej registrerer Stjerne-Passager.

Figure 14: Mosaic of Bengt Strömgren’s depiction in Danish newspapers, 1924-1927. Upper left: *Politiken*, November 8, 1924, 7; ”A scientific portrait.”

Lower left: *Nationaltidende*, January 8, 1926, 3; “The young genius at the Observatory: Professor Ellis [*sic.*] Strömgren’s 16-year-old son, the astronomer Bengt Strömgren has made a new and important discovery. Together with engineer Rahbek, he has constructed an electronic device, which automatically registers stellar movements.”

Right: *Berlingske Tidende*, November 24, 1927, 1; “*Magisterkonferens* in two years: The 19-year-old astronomer Bengt Strömgren became *magister* yesterday after only two years of study. Magister Bengt Strömgren photographed next to the apparatus of his invention, by which he registers stellar transits photo-electrically.”

he was taking his business very seriously; in interviews he was extremely accurate and down to the point in describing his work and he always seemed modest, as he usually emphasized his co-workers instead of himself. No wonder he made an impression on Scandinavian laymen.

An AG Congress in Copenhagen

On the international scene, the matter of embracing Germany as a member-state in the IAU was still not settled. Further discussions took place before and probably during a 1926 AG meeting held in Copenhagen, which was hosted by the AG President Elis Strömgren. As described in Blaauw 1994, Elis received a letter from the IAU's President and General Secretary acknowledging the possible inclusion of German astronomers in IAU who desired it.[117] And who would be more obvious to act as adhering body as the AG? Elis did not share this attitude, since the self-image of AG was that of an international astronomical society rather than a German scientific community. After informing the IAU President Willem de Sitter about the submission of the IAU letter to the AG Council, Elis indicated that perhaps it was best to stop thinking about the idea of having the AG represent German scientists. The Astronomische Gesellschaft had been founded in 1863 as an international society dedicated to the "advancement of science by supporting projects, which require systematic cooperation of many

[117] Blaauw 1994, 85.

Figure 15 (also on the preceding page): The Copenhagen AG conference, 1926 (from *Nordisk Astronomisk Tidsskrift*, 1926, s. 81).

people".[118] At the time of the Copenhagen congress, the International Astronomical Union had already existed for seven years. Within a few years, the global responsibilities of the AG were increasingly transferred to the IAU.

Out of approximately 500 members of the Astronomische Gesellschaft, 138 members met at the international Copenhagen congress in August 1926. Interestingly, attending members not only came from the Scandinavian and German speaking countries but also a few from other countries. Nineteen countries were represented, Germany being the best represented country (58 members), Sweden (23), Denmark (12), England (7) and Holland (6). 34 papers were presented and among the prominent contributors were Arthur S. Eddington (UK), Paul Guthnick (Ge) Knut Lundmark (S), Elis Strömgren (DK), Leslie J. Comrie (UK), and Otto Struve (USA). 18-year-old Bengt Strömgren also enjoyed the opportunity of giving a paper on the published results of his observations with the transit instrument. Numerous astronomers participated in the discussion of his talk, including the pioneers of photoelectric photometry Guthnick and Hans Rosenberg, who had initially introduced Bengt to the exciting field of astronomy.

This was one of the first of Bengt's entertainments "on stage" in front of an international learned audience. During the congress week, Bengt presented his experimental apparatus to the international visitors of the observatory. In a

[118] Schmeidler 1988.

Figure 16: Group meeting at the Astronomische Gesellschaft congress at Østervold, August 1926. Standing (from the left): Hedvig Strömgren, Bengt Strömgren (behind Hedvig), Poul Guthnick (Berlin-Babelsberg), Arthur S. Eddington (Cambridge), Erik Strömgren (Bengt's brother). In the middle, at the back, Elis Strömgren. Number 4 from the left is Friedrich Küstner, seated. This group is only a selection of the 138 participants. From *Nordisk Astronomisk Tidsskrift* (1962), 44-45.

speech given in the Palads Hotel in Copenhagen a few days after Bengt's paper, Küstner brought Bengt's photoelectrical apparatus to light as nothing less than "a new epoch in the history of meridian astronomy."[119] The Rask-Ørsted Foundation and the Danish Scientific Society[120] subsidized the congress financially. In his capacity as President of the AG, Elis gave a solemn speech on the history of the society, its beautiful work and activities etc. He emphasized the 'internationality' of the association and highlighted its post-war efforts of conserving its ability to bring together astronomers from many nations, in spite of a relatively bad economy.[121]

[119] OS, August 20.
[120] Danmarks Naturvidenskabelige Samfund.
[121] Hansen 1926, 86.

The anniversary of the foundation of Tycho Brahe's Uranienborg on Hven in 1576 was celebrated on the occasion of the AG meeting. The Swedish Academy of Sciences hosted an event on the little famous Island between Denmark and Sweden in Øresund where Tycho Brahe once made his momentous, accurate observations. In the sunny morning of August 18, the astronomers from nineteen countries boarded a steamer to Hven. In addition, there were numerous other specially invited guests, amongst others the professors Niels Bohr, Nørlund and Hans Vilhelm Munck-Petersen (University President in 1923-24), University President Johannes Fibiger, the mayor Peder Hedebol and from the Ministry of Education, permanent secretary Fr. Graae, who was a committed civil servant with regard to the field of astronomy.[122] On Hven, Elis Strömgren pompously emphasized his position as being both Swedish and Danish in his heart. It was a great satisfaction for him "to know that we once again have a matter to which our two nations have a common interest", namely the build-up of Uranienborg's ruins.[123] After returning from Hven, the party ended the Tycho Brahe's day in Tivoli and the atmosphere during the conference was generally joyful, now when old friends and colleagues were reunited after years of separation during the sinister years of war.

3.4 The Mecca of Quantum Physics

In the fall of 1925, Bengt Strömgren enrolled at the University of Copenhagen, where he spent merely a year and a half studying for the comprehensive examinations required in mathematics, physics, chemistry and astronomy. According to Bengt there was no choice because they were "very definite courses and you had to get over that hurdle. And it was a hurdle, because you had to take seven written and six oral examinations in one month – and know it all.[124]" It is beyond doubt that Bengt regarded the standard part of the curriculum as a cumbersome 1.5 year period of the education, but "when you were past this hell where there was no choice, there were many choices [of educational

[122] "Fra Astronomernes Besøg paa Hven i gaar", *Politiken*, 1926, August 19, 7-8.
[123] Hansen 1926, 90.
[124] HBI, 9.

literature].”[125] Due to the pace of the development of the new matrix and wave mechanics it was a time of a somewhat mixed curriculum with pre- and post quantum mechanics subjects. The classic monograph on spectral lines was Arnold Sommerfeld’s *Atombau und Spektrallinien* from 1919, which “was supplemented with the Schrödinger book on wave mechanics”.[126]

The first two years of the science curriculum in Copenhagen were held at the Polytechnical College, where future engineers, intending high school teachers and upcoming research scientists were exposed to the teaching of the exact scientific disciplines. And the classes were large: “there were [physics-] classes of a couple of hundred people and in chemistry the same. We were taught chemistry together with the pre-med students. Astronomy was [*sic*.] smaller classes, 30 or 40.“[127] While studying at the Polytechnical College, Bengt gave talks in the role of assistant at the observatory, which had finally been granted to him. On November 3, 1926, for instance, he gave a talk in the ‘Society for the dissemination of science’ on his usual topic “The photoelectric method in determination of positions of fixed stars.”[128] This example shows a conviction at a very early age towards sharing current studies with colleagues, in this instance the students and other members of the society. Along with his friend and fellow student Christian Møller, Bengt studied theoretical physics at the UITF with the professors Niels Bohr and H.M. Hansen.[129]

In his work on the reduction of spectroscopic data of hafnium in 1923, Bengt had early experiences with many of the employees at the UITF and became acquainted with the professional work at a physics laboratory. Now,

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[125] HBI, 11.
[126] HBI, 10. Sommerfeld’s classic monograph has been published in eight versions from 1919 until 1978 (Sommerfeld 1919). Erwin Schrödinger’s book was just a collection of six papers in German periodicals (Schrödinger 1927). According to Helge Kragh, the first textbook devoted specifically to quantum mechanics was *The New Quantum Mechanics* by the Cambridge physicist George Birtwistle from 1928. Other early monographs on the subject were dated from 1928 and onwards (Kragh 1999, 170-171).
[127] HBI, 9.
[128] “Selskabet for Naturlærens udbredelse” (1926), BSA.03, D.
[129] Hans Marius Hansen was professor of physics from 1923 until he became president of the University of Copenhagen the last 8 years of his life, from 1948-1956. Niels Bohr was professor of theoretical physics in the period 1916-1956 (Slottved, 1978, 198, 231).

Bengt studied theoretical physics at the same institution with the professors Bohr and Hans M. Hansen and according to Strömgren[130]

> That year [1925] Niels Bohr didn't give many lectures, but he came regularly to the student's colloquium, once a week. In the beginning it was Niels Bohr, Hansen and Kramers. Then later it was Heisenberg and when the time of my examination approached it was Oskar Klein.

The significance of these figures came to Bengt on various levels. While Bohr obviously influenced him on an inspirational level, the Swedish physicist Oskar Klein was important on the educational level. The Dutch physicist Hendrik Anton Kramers inspired him on the all-important theoretical level, as will be apparent shortly.[131]

In May 1926, a little more than a year after 24-year-old Werner Heisenberg had pioneered quantum mechanics, the German physicist took over the duties as lecturer, "which consisted of giving two one-hour lectures each week in theoretical physics".[132] The students attending these lectures – there were only ten that year – were in the second part of the course for the degree of *Magister* (equivalent to the Master of Science degree). Among them were Mogens Pihl, Christian Møller and Bengt, who soon completed their first part of the degree at the Polytechnical College. The lectures in theoretical physics dealt with classical and statistical mechanics, electrodynamics and the theory of relativity. While some theoreticians in Copenhagen continued elaborating on the foundations of the quantum theory, many physicists were looking for applications of the new theory.

As a consequence of the building extensions of the UITF in 1926, not only theoretical physics were taught. Now there was sufficiently laboratory space available to enable a course in experimental physics in the second part of the

[130] HBI, 11.
[131] Kramers went to Copenhagen from a visit in Leiden in 1916, and after the inauguration of the UITF in 1921, he served as first assistant followed by a lectureship in the period 1924-1926; Oskar Klein worked at the UITF in two rounds, the first being from 1918 to 1922, the second from 1926 to 1931 (Robertson, 1979).
[132] Robertson, 1979, 111.

study. This course was thus transferred from Polytechnical College to the UITF, where H.M. Hansen lead the demanding course, which consisted of "three six-hour practical classes each week, extending over two semesters."[133]

By November 1926, it was time for the introductory exam (Forprøven), of which the exam requirements of astronomy comprised his father's lectures and a more comprehensive study of Eddington's work among others.[134] In physics Bengt and his fellow students were concerned with classical mechanics, thermodynamics and theory of light and the syllabus included readings of e.g. Bohr and Planck. He studied Biilman's work on inorganic and organic chemistry and in mathematics, it was Bohr-Mollerup's analysis and Hjelmslev's geometry.[135] In addition, it was allowed for him to report the total number of hours (65) with practical exercises all the way back from 1921 until 1926, probably due to an exemption grant from formal rules.[136] He completed his introductory exam in late January 1927 and as usual his father wrote down the results from the tests. Not surprisingly, the end result was close to perfect. Out of fourteen exams, the only exams in which he didn't get the best grade "Ug" were written physics and written chemistry. Other professors than Elis Strömgren undertook the evaluation of his astronomy exams and Elis was not present during Bengt's oral astronomy exam.[137]

In spring, Bengt got a quite extraordinary letter from the director of the Leander McCormick Observatory at the University of Virginia, S.A. Mitchell. Mitchell asked if Bengt would consider an assistantship with an apartment and a salary of $1,500, which would be increased. Elis wrote his son about the letter, as Bengt was in Northern Jutland for Easter vacation, but Elis' assumed that Bengt would answer Mitchell that he was "too young. And you are aware that I am of the opinion that our observatory cannot do without you. Mitchell will visit us in the first week of August, after the solar eclipse, which he will observe in

[133] Robertson 1979, 112.
[134] Before this exam, Bengt had passed the compulsory *filosofikum* exam in May with the result Ug. RA, Bengt's application for Emil Herborg's Legat, 1929.
[135] In the years 1920-1923, Harald Bohr and Johannes Mollerup published a series of four textbooks on mathematical analysis written in Danish that soon turned into classics; Bohr & Mollerup 1920-23.
[136] OS, November 1926.
[137] OS, January 31, 1927.

Norway."[138] Bengt promptly replied his manipulative and authoritarian father that "I don't even reflect on Mitchell's offer, but it was nice anyway." It appears as though Bengt was oppressed by the plans and wishes of his father. Had Elis encouraged Bengt to accept the offer, it is highly probable that Bengt had done so – as any young Danish scientists would have done. On the other hand, though, Bengt had very good opportunities in Copenhagen already. So, Bengt had his first formal invitation for a position at a foreign observatory at the age of nineteen and was obviously aware of his own worth and repute from a very early stage. During the next AG meeting attended by Bengt, which was held in Heidelberg in the summer of 1928, he met notabilities such as Eddington and Russell, if merely greeting them briefly. Also Mitchell was present at the meeting, and he discussed with Bengt once again the possibility of going to the States.[139]

Less than two years after Mitchell's first letter, Bengt was invited once again, this time with a salary of $1,800 as instructor and fellow for a two-year period. Once again, Bengt declined the offer. He wrote Mitchell that he regarded the conditions in Copenhagen so favorable that he could "not decide to leave for America just now". Mitchell offered him work with variable stars using a wedge photometer and Bengt expressed his interest in visiting the Leander McCormick Observatory sometime in the future.[140]

Not even four months after the examination, Bengt requested the faculty for authorization to take his *magisterkonferens* in astronomy and astrophysics. Permission was given in July 1927.[141] The same summer, Erik graduated from high school with the best results in all oral exams and in written mathematics. His family had also been good teachers after all. After the summer holiday, Erik enrolled the faculty of medicine. From this time on, Elis included more frequently little notes in his diary about his youngest son, as he gradually grew

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[138] E. Strömgren (Copenhagen) → B. Strömgren (Lønstrup), April 14, 1927, ESC. Bengt's answer (next quote) was undated, and is also located in ESC.
[139] The Heidelberg meeting was held in July 18-21, 1928. Is was reported in *Vierteljahrsschrift der Astronomischen Gesellschaft*, **63**, 3, 1928, 247.
[140] S. A. Mitchell (Virginia, USA) → B. Strömgren, July 3, 1929; B. Strömgren → S.A. Mitchell, June 25, 1929, BSA.01, A.
[141] OS, July 7, 1927.

more studious – a property which was obviously regarded tremendously important by Elis.

For the duration of his student years, Bengt became a member of the executive committee of a club named “Parentesen,”[142] an academic student’s club under the natural sciences faculty for students of physics, chemistry and mathematics. Bengt served as secretary of the club for a year from the fall of 1925. Numerous Parentesen meetings were held Friday evenings at ‘the Borch’ and among the various subjects were “complex and hypercomplex numbers”[143]. Years later, on February 1928, the 20 years old *magister*, Bengt Strömgren, gave a talk on “anagalactical nebulae” at the Borch.[144]

Throughout Oskar Klein’s second period at the UITF (1926-1931), Klein gave lectures on physics and assisted in supervising the graduate students and “with his help, particularly through reading his papers,” Bengt “became familiar with quantum mechanics.”[145] Klein’s paper on the correspondence principle in wave mechanics was of particular importance to Bengt, “I learned more from that than from most of the other papers [on quantum mechanics].”[146]

As to the astronomical traditions for the observation of proper motion and positional measurements, Bengt later recalled, “there was a strong tradition in Danish astronomy, which was also vivid in those years. Something which proved important to me was that the tradition, particularly in my father’s time as a professor, comprised calculations of numbers, numerical mathematics”.[147] These calculations constituted a necessary part of Bengt’s early private education and the meticulous computations of large sets of numbers turned out to be crucial in his later theoretical work. Not surprisingly, his early scientific experiences with

[142] “Parentesen” is Danish for ‘the Bracket’. In 1926 there were fifteen members of the club.
[143] “Parentesen holds a meeting on Borch’s College on Friday November 20, 1925 at 8 pm. Dr. Phil J.F. Pál will talk about: “Complex and hypercomplex numbers” (Bengt Strömgren, secretary)”; “Parentesen” (little leaflets)1925-1928, BSA.03, D.
[144] Anagalactic is synonym for extra-galactic, beyond our galaxy. Ibid, Friday, February 17, 1928 at 8 pm.
[145] B. Strömgren, 1983, 2.
[146] HBI, 10. It should be noted that this obviously is a retrospective recollection of Strömgren, which therefore may be coloured by hindsight. Nevertheless, the reminiscence is Strömgren’s own. Klein published his most important papers in the German physics journal *Zeitschrift für Physik*, and his only paper published there in 1927 was Klein 1927. Hence this appears to be the paper referred to by Strömgren.
[147] May 20 and 21, Bengt Strömgren’s own handwriting in Danish, BSA.07, A.

classical astronomy were significant for Bengt's development as a scientist not only with regard to the scientific results, but also regarding his scientific style.

The new quantum theories were of great importance to astrophysics.[148] In particular, they were crucial for Bengt, who had hitherto been preoccupied with classical astrometry and the observation and calculation of cometary orbits. Quantum mechanics was an eyeopener:[149]

> In 1927, when I prepared for the final examination in connection with my graduation from Copenhagen University, I regularly attended institute lectures and colloquia [...], it must suffice to say that it was an overwhelming experience. During that year and indeed until I left Copenhagen in 1936, I could listen regularly to talks by physicists who shaped the development of atomic theory and quantum mechanics. And there was Niels Bohr who meant more than anyone else.

From the time when Bengt entered university in 1925, physics and astrophysics had become parts of the picture of his scientific world,[150]

> [...] particularly after I had taken the first examinations in mathematics, physics, chemistry and astronomy in January 1927. The following year was a wonderful year of study, I must say completely marked by one man, Niels Bohr. It was not the lectures in particular, it was the colloquia; it was conversations to which Niels Bohr in a most amiable way gave his time, which meant so much to me; and there was advice about what to learn.

At the same time there were other colloquia for the students to attend. There was for instance the colloquium where Heisenberg first presented the uncertainty principle and "then we heard many lectures by Niels Bohr".[151] On the social level, Bengt shared the company of Møller and Mogens Lublin in a "very cozy

[148] See e.g. DeVorkin & Kenat 1983a, 1983b, and 1990 and Hufbauer 1990.
[149] B. Strömgren 1983, 2.
[150] May 20 and 21, Bengt Strömgren's own handwriting in Danish, BSA.07, A.
[151] HBI, 11. Heisenberg 1927.

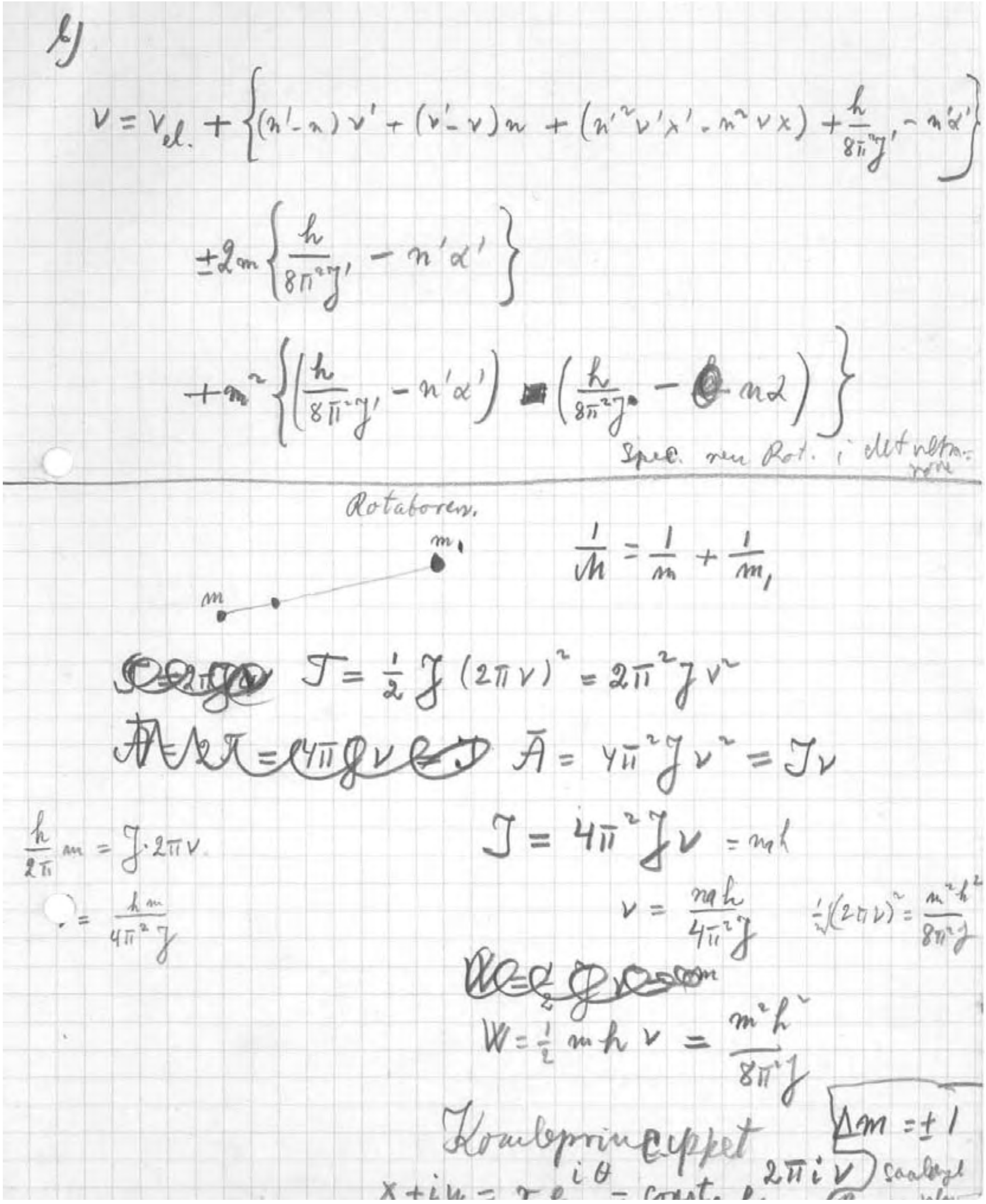

Figure 17: Bengt Strömgren's calculation draft for the atomic physics final examination, 1927. During written exams, students were gathered in an examination hall. They could make draft calculations before writing fair copies for evaluation (UCO).

mathematics club.[152] We met in the old observatory on Østervold and studied differential equations following Schlesinger and Horn."[153]

Soon the time was ripe for the final examinations for the Master of Science degree, which was, in Bengt's case, transformed into the higher-ranking

[152] Mogens Lublin studied mathematics and handed in his master thesis in 1930 on methods of the solution of non-linear differential equations.
[153] Strömgren 1981, 100.

degree of *magisterkonferens*. On the annual summer vacation to Björboholm, Bengt received a permission from the dean of the natural sciences faculty Carl E.H. Ostenfeld[154] to go for the exam. Bengt's scientific production was permitted to replace the usual main test and he was informed that the content of the examination would be given by Bohr and H.M. Hansen, who would be evaluating as well. Oskar Klein surveyed the exam.[155] He received his assignment from H.M. Hansen to give a talk on the "main features of the relationship between stellar spectra and their constitution", which was to be given in the rooms of the UITF on November 22 in the afternoon but was rescheduled to November 15.[156] When the talk was done, Niels Bohr got up and said: "Yes, now this examination has ended just as brilliantly as it began."[157] In addition to this talk Bengt went through two written four-hour tests of atomic physics and optics in the old buildings of the Copenhagen University on October 20 and 22 respectively. The atomic physics final was on "The application of quantum theory to the interpretation of spectral band structure" and the optics examination was on "Frauenhofer deflection images for two identical parallel slits and its applications to the measurement of fixed star diameters."[158] He graduated as the youngest *magister* that year along with three other physics students and his fellow student Christian Møller earned his Master's degree in physics two years later (see figure 18).

During the following years at the UITF, quantum mechanics was applied to atomic physics and soon proved useful also within astrophysics.[159] These years were highly intense and active at the institute; in 1927 alone there were twenty-five foreign visitors. As already mentioned, in the late 1920'es, most physicists were looking for applications of the new quantum mechanics; so clearly, Bengt was at the right place at the right time. A frequent visitor to the UITF in those

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[154] Carl Emil Hansen Ostenfeld was dean of the natural sciences faculty (1926-27) and professor of botany in the period 1923-1931 (Slottved, 1978, 191; Appendix A). C.E.H. Ostenfeld → B. Strömgren, July 7, 1927, ESC.
[155] OS, November 15, 1927.
[156] University official Erik Bech, "Magisterkonferens", November 1927, BSA.02, A.
[157] OS, November 22, 1927.
[158] "Kladde til skriftlige opgaver i atomfysik" and "Kladde til skriftlige opgaver i optik", October 20 and 22, 1927, BSA.01, C. Furthermore, this is documented in OS, October 20 & 22, 1927.
[159] See e.g. Robertson 1979.

years was the English physicist Ralph Howard Fowler, who had done pioneering work with Milne on the theory of stellar radiation. On another occasion, Bengt once again met Fowler in Copenhagen and they discussed the idea of a model atmosphere, already considered by Bengt at the age of nineteen. Years later he remembered Fowler's "kind smile when he told me that it might not be so easy."[160]

3.5 Choosing Astrophysics

Armed with the latest theoretical knowledge in the field of quantum mechanics and atomic physics, Bengt felt ready to engage fully in astrophysics. His disciplinary interests were strongly influenced by his years at the UITF. He viewed the new quantum mechanics as being "far the most exciting, more exciting than regular astronomy. No question."[161] Though, with his thorough knowledge in classical astronomy, embodied by his father, he was very much aware that this did not make up a prospective future activity. The future called for applied quantum mechanics. During his studies for the Master's degree, he was "very much impressed with what was going on there [at the UITF]"; he "had the idea that the time was ripe for applications of the new quantum mechanics to astrophysical situations."[162] Bengt considered the state of astrophysics as follows:[163]

> When you look at the theory of stellar interiors and the theory of stellar atmospheres in those days - it was very much pre-quantum mechanics. It was quite clear that there would be very important applications of the new physics to astrophysics. Although I didn't immediately go in that direction, already when I prepared for the final exam I was sure that this was what I wanted to take up ultimately – simply, the application of the new physics in astrophysics.

[160] B. Strömgren 1983, 3.
[161] HBI, 11.
[162] HI, 4.
[163] HBI, 12.

At this point – at the peak of quantum mechanics and the Copenhagen interpretation – the environment at the UITF was highly international, not least owing to Bohr's efforts. With his background, being up-to-date on classical astronomy, Bengt was receptive of the new trends in quantum mechanics at that time. His research plan was apparently clear to him at that early point, although no contemporary documentation indicating his initial determination has been found.

So, the plan was clear to Strömgren. However, he waited two more years to begin purposefully fulfilling it. His forthcoming doctoral work would pave the way towards an academic career as a research scientist. This work, which turned out to be a study of parabolic orbits in the tradition of classical astronomy, was initiated only two years after his graduation. It may seem amazing that Bengt chose a classical topic for his thesis. In comparison with quantum astrophysics, his chosen topic might seem like somewhat pedestrian topic.

The general economical climate in mid-war Denmark was not favorable to science. As state funds were low, the scientists were kept in a tight rein, with the entrepreneur Niels Bohr as the exception. As I have stressed in this chapter, the development within Danish astronomy went rather slow, and the astronomers were still predominantly focused on classical astronomy. In hindsight, astronomy was in a rather weak position. Perhaps this is a feasible contextual explanation why Bengt wrote his doctoral dissertation on the classical subject of *Formulas and Tables for Determination of Parabolic Orbits* instead of his fresh favorite field of astrophysics. Understandably, conceiving of the big thoughts was not the typical characteristic of Danish astronomy in the mid-war years.

His Master's examination was awarded the best of the faculty in 1927 and for spring 1928, Bengt received The natural sciences faculty's Master's Stipend for the best exam of the year – "of 1,800 kroner, which was enormous" – and during the years of his doctoral work, he was busy with all sorts of practical and theoretical work at the Observatory.[164]

[164] Bengt's Application for Emil Herborg's Legat, RA, 2; HBI, 22.

Figure 18: Copenhagen Conference at the UITF, Auditorium A, 1929.
First row from left: **Niels Bohr**, Ralph de Laer Kronig, Ivar Waller, Johan Peter Holtsmark, **Hendrik Anton Kramers**, Svein Rosseland, Wolfgang Pauli, Ernst Pascual Jordan, Paul Ehrenfest, **George Gamow**. Second row: Léon Rosenfeld, **Oskar Benjamin Klein**, Charles Galton Darwin, Samuel Abraham Gouldsmit, **Christian Møller**, W. Sejersen, Mogens Pihl, Walter Heitler, Lothar Wolfgang Nordheim. Third row: Bjørn Trumpy, **Sven Werner**, **Bengt Strömgren**, Hendrik Brugt Gerhard Casimir, Chou, Gelius Lund, Erwin Fues, Eric Hückel (Courtesy of the Niels Bohr Archive, NBA).

He gave calculation tutorials for university students in astronomy, undertook astronomical observations with the instruments of the Observatory and popularized astrophysical research in *NAT*. Among his publications were an introduction of Harlow Shapley's results on extragalactic nebulae and the size of the universe (see chapter 4.5). In a feature article in the Danish newspaper *Nationaltidende*, Bengt took up the question of the boundaries of astronomical endeavor and whether astronomy should only walk on safe grounds regarding the optical instrumentation limits. He illustrated the question with the irony of Thomas Henry Huxley:[165]

> It is not clear what compensation the *Eohippus* gets for his sorrows in the fact that, some millions of years afterwards, one of his descendants wins the Derby.

Eohippus is Greek for Dawn Horse embodying the primeval horse and with the Huxley parable, Bengt explained that if one agrees with Huxley, one should never blame astronomers for taking their inferences to the most extreme limits. Suppose the winner of the Derby quite well able to remember having been the Eohippus? Suppose the astronomer able to look back through all veils of death and birth, through all evolutions of evolution, even to the moment of the first faint growth of the universe? By the allegory, Bengt prompted a belief, which was to hold for the rest of his life, that astronomical research should be managed not only by principles of immediate usefulness and that they should not only speak about the direct ontologically provable. Rather, the function of scientific research should be directed by principles of curiosity and broad perspective and the inferences, even if only rendered probable in a weak empirical sense, should be taken for the sake of the big perspective.

During the summer of 1929, Bengt went on a long bicycle ride across the Danish country from the Observatory to the north Jutlandic town Blokhus. He caught the Kalundborg-Århus ferry at 5:30pm and was in Hobro at 9:30, where he went into a temperance hotel for dinner. From Hobro half an hour before midnight he went north to Aalborg, where he arrived in the middle of the night at 2:30am without trouble, since,[166]

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[165] Strömgren 1928. Strömgren doubtlessly referred to Huxley's *The Struggle for Existence in Human Society* from 1888, in which Huxley writes about evolution and the allegedly erroneous evolutionist assumption that evolution signifies a constant tendency to increased perfection; Huxley 1888, 199.
[166] B. Strömgren (Lønstrup) → Hedvig Strömgren (Copenhagen), July 4, 1929, ESC.

> it was light all night […] The morning ride was rather tough due to headwind […] Both the bike and I have been completely fresh the whole trip and it was even 250 kilometers without stopping. I have bathed every day and by the way I have read Dostojewsky or played badminton or just sun bathed.

As the archives indicate, this appears to be one of the only relaxing and unscientific events for the young physically strong doctoral candidate in two years. After his return to Copenhagen, he would begin thinking about his doctoral defense.

He also issued articles on the question of nebulium, the hypothetical chemical element that Ira S. Bowen reduced to doubly ionized oxygen; on the rotation of the Milky Way, and on several other topics. Furthermore, he gave lectures on stellar evolution[167], he joined the German Physical Society, published two treatises on formulae of orbits[168], went on several visits to Berlin, Dresden, Stockholm, and Prague. From the Habsburger Central Station in Berlin, Bengt wittily wrote his Mother Hedvig, about his linguistic experience in the Czech Republic: “Czech wasn’t that difficult. The bus stop is called stainee and if you want to say: stick a finger in your throat, it is simply: Strc prst skrz krk!”[169]

In his observational work at Østervold, Bengt also got naturally involved with technical business regarding the observatory’s instrumentation and he corresponded with numerous companies in his search for the best electric, magnetic and optic components such as magnets, electric resistances, reversion prism, double lattice tubes and photo cells.[170] Finally, Bengt requested the faculty for allowance to defend his second treatise for his doctoral degree, which was accepted. His dissertation on “Formula and tables for determination of parabolic orbits” was the result of extensive calculations using a mechanical Archimedes

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[167] “Om Solens och Stjärnornas Utveckling” (foreløbigt program), a talk given at the 18th Scandinavian Natural Science Researcher’s meeting, August 27, 1929, BSA.01, C.

[168] Deutsche Physikalische Gesellschaft. Strömgren 1929a and Strömgren 1929b.

[169] Bengt Strömgren (Habsburger Hof, Berlin) → Hedvig Strömgren (CO), Sept. 22, 1929, ESC.

[170] Among others he corresponded with Reinhold Toepfer (May and June of 1926, drawings of a “reversionsprisma,”), Osram, Berlin (1926-1928, double-lattice tube), with Siemens und Halske and Siemens Schuckert (March 1926, resistance), with The Varley Magnet Company (March 8, 1927, Varley Tapped Resistances particulars) and Carl Zeiss, Jena (November 29, 1928, photocells), ”Instruments and electric components”, 1926-1928, BSA.05.

Figure 19: Drawing of the candidate and his father. The official opponents were actuary Carl Burrau and Professor N. E. Nørlund, as Professor Strömgren was not able to take on the duty for obvious reasons (*Politiken,* December 13, 1929).

calculator.[171] The formulae, which were to serve for numerical calculations, were thus given in a form suited for this calculation machine. On the basis of a recent publication by the astronomer Gerald Merton on modified Gaussian methods for determinations of orbits, Bengt devised a new method for calculating trajectories.[172] The dissertation was chiefly mathematical, including an appendix of tables and nomograms. The nomogram was a method frequently used at the time for solving complicated calculations, by which mathematical functions could be read off directly on a drawn diagram – a nomogram.

Bengt shed new light on Merton's classical problem by use of a clever application of methods of vector calculus and the dissertation turned out to be Bengt's last paper on classical astronomy for many years. Following the reception of his doctoral degree, he turned almost completely toward

[171] B. Strömgren 1929b.

[172] Gerald Merton, who was a member of the Royal Astronomical Society and also served as head of the British Astronomical Association's Comet Section, received his PhD at Cambridge in 1927 for a dissertation entitled "Determination of cometary orbits and perturbations."

astrophysics and to his plans of bringing quantum mechanics and astrophysics closer together.

A Sociable Doctor

In the press, the doctoral defense of the twenty-one year old candidate was followed with awe and the ceremony, which lasted for two hours in the university's Annex Auditorium[173], was depicted e.g. in *Politiken* as follows:[174]

> In the fine semicircle around the doctor's desk, the following larger or smaller heavenly bodies attended, among others: The Swedish Minister Ewerlöf, Professors Dines Andersen, Harald Bohr, Niels Bohr (the Nobel laureate became doctor at age 26), […] H.M. Hansen, Johannes Hjelmslev (pro-vice chancellor [prorektor]), Martin Knudsen, the happy and rightly proud Professor Elis Strömgren, […] and a nebula of doctors. On the first row of the over-crowded lecture hall were, among others, the candidate's mother, dentist, Hedvig Strömgren and various other representatives of the Strömgrenean lineage.

After the academic ceremony, the Strömgren family went from astronomical enjoyment to gastronomical pleasures. Another specially invited person had been attending the doctoral defense who was not mentioned in the newspaper column, a pretty girl in her mid-twenties.

In the autumn of 1929, Brother Erik had suggested Bengt to become more socially active as a complement to his deep immersion into the impersonal astronomical enterprise. Before defending his doctoral dissertation, a dancing teacher, Sigrid Kaja Hartz, was found and she gave private dancing lessons to Bengt in her parents' home with her wealthy mother as chaperone. Bengt had never held a girl in his arms, "and he fell for her on the spot and she for him".[175] After six lessons, each time allegedly ruining a pair of Sigrid's shoes by stepping on her feet, he took her to the Botanical Garden outside the Observatory and

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[173] "The defence will take place Thursday, December 12 1929 at 2pm in the Anneks Auditorium A, Studiestræde 6, o. G." NBA, December 1929.
[174] "Under Stjernerne", *Politiken*, December 13, 1929.
[175] COR.

Figure 20: Left: Bengt Strömgren 1929, the photo is shot on occasion of his doctoral degree (courtesy of Ole Strömgren). Right: “The youngest doctor [of philosophy],” drawing by his friend, the poet and architect, Piet Hein (*Politiken*, December 12, 1929, 9).

proposed. Sigrid was in the audience at Bengt’s doctoral defense and she was very fascinated by the elegance of his hands while he was talking and gesticulating. Thus, it was all done “in the good old way”: His doctoral ring was dated December 12 and the engagement ring December 14.[176]

The wedding was held on March 3, 1931 in Tårbæk. Sigrid (1903-1991) was the daughter of grocer Axel Marius Hartz (1869-1925) and Marian Sophie Schou (1870-1934), who lived in a high-class mansion called Liselund in the north of Copenhagen. The Schou’s was a very rich family owning the Schou soap production, and her brother Carl Peter Hartz worked in his old family firm “Standard” in a row of shopping streets in central Copenhagen (Strøget), which later became the soap manufacturer Schou-Epa (Tatol), having branches all over

[176] HBI, 29 and KNSI.

the country and in Sweden and Norway. Sigrid had inherited social grace and elegance from her mother and according to one of Bengt's daughters, "Sigrid was very socialized, athletic and elegant" and to some extent, "she was a snob."[177]

Sigrid became Bengt's beloved companion in life and being the socialized counterpart to Bengt's slightly monomaniacal character concerning science she made cooking arrangements and did a good job being the astronomer's wife, which "wasn't easy," as his daughter Karin reminisced.[178] Many years later, Sigrid was described in the following way by one of Bengt's colleagues: "Sigrid's vibrant energetic personality was a perfect match for Bengt. Throughout their lives Sigrid's strong Danish personality and her total devotion to Bengt created the warm inviting atmosphere so rarely found around great men."[179] Thus, praising in style, this biographical memoir written for the American Philosophical Society nevertheless says a lot about the astronomer Russell M. Kulsrud's experiences when visiting the Strömgren family as a colleague.

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177 KSCI.
178 KNSI.
179 Kulsrud 1987.

Figure 21: Sigrid Caja Hartz and Bengt Strömgren, photo taken in March 1931 at Liselund, Denmark, where their wedding dinner was held (courtesy of Nina Strömgren Allen).

Four

Continuity and Innovation

Stellar Composition

1929-1936

In October 1929 the price at the New York Stock Exchange went down to the bottom.[1] Investments were severely reduced and businesses and companies went bankrupt. Every day, tens of thousands went into lives of unemployment. By limiting American import, the economical crisis began to spread from USA, having more than one third of the World's total industrial production and still playing a larger role on the World Market. Other countries reduced their import as a result; Germany in particular was suffering due to large war indemnity to the allied forces. The crisis found its way to Denmark in the summer and fall of 1930. Butter prices dropped by 35% and bacon by 50%. Since more that 60% of all Danish export comprised pork and butter, the drop down of prices hurt the farmers dramatically and their spending power was weakened extensively. The result was a propagation of the crisis to the whole Danish population and its industry. In the winter of 1930, unemployment was 15%, the year after 24% and in 1932 it climbed to 38%.

Many contemporary novelists portrayed tough daily life before and during the Great Depression through their fictional persons – and many with a communist sympathy. Some Danish authors claimed to represent the urban proletariat and attacked liberalism from a communist stance. They described

[1] The following paragraph predominantly consists of excerpts from Kaarsted 1991.

young well-educated people weary of life. Desultoriness and disintegration characterized many contemporary novels and the “stumbling generation” was a collective term relating these young inter-war individuals. Bengt Strömgren did not exactly represent this group in society, as his plan for life had long been clear. He was well integrated into academia. Rather, hiding behind safe university walls, he had already read many of the classics, including Marx, Freud, Dostojewsky, and Spengler, but any particular interest in Danish authors is undocumented. Numerous writers were influenced by Marx and Freud and their perceptions of the great importance of sexual life affected many intellectuals in the early 1930’es, giving them an alibi for sexual display and development. Erik Strömgren followed the development of psychological writings closely and with huge interest.

The same dividing lines that characterized Danish parties’ policy could essentially be found in literature as well. During the mid-war period, many authors wrote socialist realist novels centering on the human being in daily life – novels with various backgrounds in more or less outspoken communistic or social democratic ideology. One group was the intellectual socialists; the left winged so-called Cultural Radicals. Many authors sympathized, to various extents, with communism rather that with the Social Democratic party and such deliberations were to be found in magazines like *Kritisk Revy* (1926-28), which was edited by the locally famous architect and author, Poul Henningsen. Poets like Otto Gelsted and authors like Hans Kirk were diligent contributors representing the influence of art and culture-policy from the Soviet Union. As will become apparent in chapter five, Elis Strömgren was not particularly keen on their ideas, although he met with several of the figures privately. Also the journal *Kulturkampen* turned against the social democratic bourgeois cultural policy, but first and foremost, it fought Nazism, which was found sneaking its way into Danish society in the early 1930’es. Extreme left-wing people admired Stalin’s Soviet Union whereas some right-wing people approved of Nazism with its German order and plan.

4.1 Bad Observatory Conditions

Needless to say, job opportunities were very limited at the turn of the decade. Students who finished their studies in mathematics, physics, chemistry or astronomy usually prepared themselves for positions in the gymnasium (high school, upper secondary school) and the university curriculum was tailored so that they be competent for this purpose. The standard of the Danish high schools was high and it was a fine education. In astronomy there was also the possibility of making a career at e.g. the Geodetic Institute, but the customary appointment would still be in a high school and the assistant's wages were just below the salaries of teachers. Even though assistant positions were not looked down upon, they were not exactly at a premium since by such state salaries, students were not encouraged to follow the scientific university career. For example, it became a protracted affair to have the Ministry of Education sanction Bengt Strömgren's lectureship in 1932. After he finished his doctoral degree at age 21, he turned away from classical astronomy to the benefit of numerical calculations of abstract astrophysics problems. At this point on the career track, it was expected of the doctor to begin teaching students. His father appropriately made a considerable effort of convincing the minister of education that there should be a lectureship in astronomy, with particular emphasis on astrophysics. In a letter to the natural sciences faculty he emphasized that he had wanted such a lectureship for several years, which he regarded a necessity. Owing to the rapidly developing field of astronomy, Elis regarded teaching lessons in astrophysics very important,[2] and they should be

> given by a teacher, who, apart from being a professional astronomer, also was educated in the fields of atomic theory – and not the least since our university is connected to an institute, which is the gathering place of atomic theory. Therefore, there will be even better opportunities for the lecturer to stay in contact with the development of science within this area, which constitutes the underpinning for applied physics in astronomy to-day.

[2] E. Strömgren → Natural sciences faculty, June 8, 1929, ESC.

Now, who would be more well-suited for this appointment than his own son? Elis also reasoned by use of arguments relating to the rising number of students of late, as well as his interest in relief of his twenty years of teaching alone. His proposal was put on the faculty's agenda as number one on June 20, 1929.[3] Nevertheless, the recommendations from the university's natural sciences faculty were ignored by the ministry the first time. Only one and a half year later, Elis reiterated to the science faculty his request for a lectureship. He reported that Bengt had made up a course on theoretical astrophysics.[4] This time his call was fruitful. The Konsistorium recommended to the Ministry of Education an inclusion of Bengt Strömgren's appointment in the 1932-1933 budgets. Thus, he was appointed "lecturer of astronomy, particularly astrophysics", from April 30, 1932, for two years with an annual salary of 2,400 Kroner. It was a question of strict economy and the budgets were low these years.[5] But when his appointment was finally secured, his salary turned out to be quite profitable nonetheless.

Already in 1927, Niels Bohr and N.E. Nørlund had nominated Elis Strömgren as a member of the Royal Danish Academy of Sciences and Letters. They called attention to two important aspects of his work, *viz*. cometary orbits and the three-body problem. "By the study of the cosmogony of comets it is of importance to know, whether they are hyperbolic, parabolic or elliptic," and concerning his work for determining the properties of three-body orbits they wrote,[6]

> even though it does not give the same insight into the nature of the problem as does Poincaré's, Levi-Civita's, and Birkhoff's mathematical work, it gives a survey of important classes of solutions and the calculations in question has been undertaken with high ability and not poor acuity.

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[3] Ibid.
[4] R, January 20, 1931.
[5] R, June 16, 1931.
[6] Niels Bohr and Niels Erik Nørlund → Royal Academy of Sciences and Letters, February 1927, RA, Prot. No. 764/1927, 1-4.

Although their praises were not expressed in superlatives, they still concluded that the chairman of the Astronomische Gesellschaft for a decade and member of numerous astronomical societies, was recommendable as a domestic member, also owing to his significant work with the central bureau.

Two years later, he became member of the society's Emil Herborg's Grant committee, which proved to be quite helpful for his son, as Bengt applied for the scholarship the very same year with an impressive curriculum vitae. His history of getting the best grades through his student years, his practical experience at both the UITF and the observatory, his reception of various stipends, his list of eight scientific publications (and two forthcoming), his experience with teaching students with exercises, and his position as scientific assistant at the CO made him an appropriate candidate. In the application he even mentioned that since 1925, he had assisted professor Strömgren with calculation exercises. As he had probably learned from his father, it was a good strategy to show his scientific importance by mentioning his invitations to jobs in both Germany and the USA, but at the same time note that he still intended to stay in Denmark – "at least for some time to come."[7]

One week passed, Professor Martin Knudsen wrote Elis with the good news that "two vacant portions of Emil Herborg's Grant has been granted to Mag.sc. Bengt Strömgren and cand.mag. R.E.H. Rasmussen."[8] It seems likely that Elis of formal reasons was not directly involved in the decision concerning the matter of his son, but in reality, his word has undoubtedly counted all the same. From the budgets, it follows that Bengt received the scholarship of 450 Kroner a month retrospectively for April – June and 150 Kroner for July – December. He kept receiving the funding in 1930 and 1931, with an annual salary of 1,800 Kroner. Until his appointment as lecturer in spring 1932, he was given the same monthly wages for January – March.[9]

The number of positions for astronomers was remarkably low during the Great Depression and the state of experimental equipment was nothing worth

[7] B. Strömgren → Emil Herborg's Legat, June 1, 1929, RA. Special Archive (Orig. 1274-1929).
[8] M. Knudsen → E. Strömgren, June 7, 1929, RA. Special Archive (Orig. 1274-1929).
[9] Emil Herborg's Legat, Budgets, RA.

mentioning. Even though the observatory instruments were fine, most of them were already dated. The consequence of the absent investments in new equipment was obviously that graduate astronomers, who wished to make a scientific career in astronomy needed to enter the field of theoretical astronomy, as this was less expensive than observational astronomy. Another alternative was to travel abroad.

The 1930'es was a hectic time for international astronomy. In the United States, large observatories had bloomed since the turn of the century. By use of still better data accuracy they were able to support or reject fresh theories. Moreover, modern observational cosmology was a new-born child in progress, as a discipline and as a profession. Edwin Hubble and Milton Humason's discovery in 1929 of a possible expansion of the universe played a leading role in this development since their observations constituted the first empirical data material to support a large scale dynamical expansion theory. These latest developments and novel cosmological theories were closely followed and popularized by Bengt Strömgren in *NAT*.[10]

Internationally, it was a time of building new astronomical institutions, also in some Scandinavian countries. In Sweden, the new Saltsjöbaden observatory was dedicated in 1931 near Stockholm, with the president of the Royal Swedish Academy of Sciences, Bertil Lindblad, as the observatory director. Three years later, the prominent Norwegian astrophysicist Svein Rosseland established the first theoretical astrophysical institute in the world, which was funded by the Rockefeller Foundation. The institute was later famed for its mechanical differential analyzer for large numerical computations, which was frequently used until the 1950'es. Rosseland was among the first foreign students under Niels Bohr in the early 1920'es and in Oslo he was appointed professor of astronomy in 1928. The handling of numerical calculations became a necessity of the 1930'es, when the CO bought electromechanical calculators for this purpose. Already in the 1920'es, the observatory's Brunsvica calculators had been replaced by more modern Archimedes calculators. Yet, Danish astronomers

[10] B. Strömgren 1933b.

with hopes for institutional expansions had their patience severely tried for yet a series of years. The plans for modernizing Swedish astronomy were fulfilled by the inauguration of Salsjöbaden, making the neighboring country of Denmark a respected representative of astronomical research as well as the prestigious host of the 1938 IAU general assembly. Naturally, the development in Sweden was followed closely by Bengt Strömgren. Perhaps this was part of the inspiration that finally made him revive the idea of a remote observatory in Denmark. Geographically, Copenhagen would not work as such a location, but as was known from Sweden, remote observatories were a good and necessary idea, if one wanted to keep track of the best observational research results. Though Danish plans for another institution, e.g. a remote observatory, or even more funding for existing research, was unmanageable for the director, who was put in a difficult situation by the low state economy leading to scarce funding, as we will see in the following chapters.

In the fall of 1931, Elis wrote a letter to the management of the Carlsberg Foundation, in which he gave the history of his private economy. He had build up a large Swedish debt as a student and even when he was appointed professor in 1907, with a wage of 3,600 Kroner, the debt was growing. “The inter-war period was especially difficult, when Danish currency was low compared to the Swedish one. Only a couple of years ago, my situation became brighter”, but at that moment, Elis spent more than 4,000 Kroner a year on payment of interests and insurance. By this rate, his payments would be completed only at retirement age.[11] What had lightened his situation were some grants from Carlsberg and the income from the international Central Bureau. Thus, he hoped for further grants from the foundation, in order to stay as scientifically independent as possible at the time. The Carlsberg grants are given in figure 1, in which the micro-economy of the observatory is illustrated. This private funding was comparable to the amounts of money flowing from state funding as salaries and other expenditures such as travel expenses, new equipment, literature for the library etc. From the figure it follows indirectly that the university wages were not particularly high.

[11] E. Strömgren → Management of the Carlsberg Foundation, September 28, 1931, ESC.

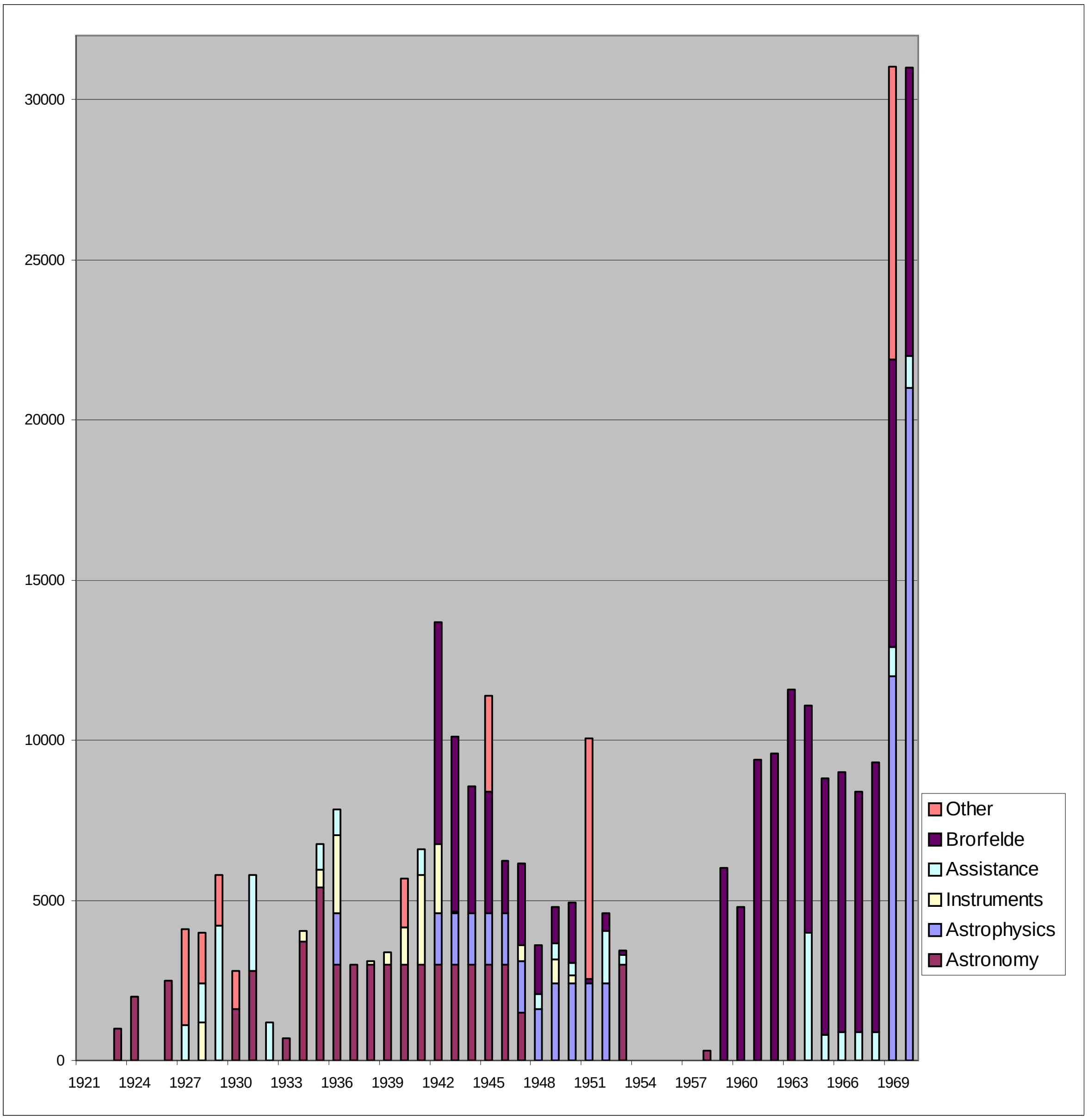

Figure 1: Carlsberg Foundation grants to CO research (year, Danish kroner), 1921-1970 (Source: *The Royal Danish Academy of Sciences and Letters*, 1921-1970).
Astronomy: Classical astronomy. Three-body problem, asteroids (1953); *Astrophysics*: Scientific work; *Instruments*: Calculator (1928), scientific instruments; *Assistance*: Calculations/observations of e.g. variable stars; *Brorfelde*: astrophysical and optical measurements, *Other*: Publications, purchase, expeditions, excavation of Stjerneborg on Hven (1951). The last two years in the period signifies large grants related to astrophysical research at the Brorfelde Observatory.

The missing grants of 1954-1957 was a result of Bengt Strömgren's leave to the USA. No other professor was acting and thus no formal decision authority existed. Only with Anders Reiz' professorship from 1958, the flux of applications for grants increased (chapter eight). The largest grants for the Brorfelde project are not included in this histogram, but will be treated in chapters six to eight.

The Carlsberg Foundation supported professorships (3,000 kroner) and lectureships with grants for ‘scientific work’, which could be regarded an appanage contributing to some degree of scientific freedom.

Concerning state funding, the university quaestor approved or rejected the professor’s applications for university supplies for e.g. new equipment. In the inter-war years no support for purchasing instruments were granted by the neither Carlsberg Foundation nor the state, except smaller grants for e.g. purchasing calculation machines for the CO in the 1920’es. Notwithstanding, as strange as it may seem, Elis apparently did not apply the Carlsberg Foundation for any large scale funding of new technology, at least in the 1930’es. In fact, the foundation granted all applications from the university’s natural science institutes in the period from 1931 until the mid-fifties.[12]

Danish Academic Life

With his lectureship in 1932, Bengt continued his academic career at the University of Copenhagen by giving weekly lectures on astrophysics for a growing number of students. Besides his unrelenting astrophysical research, which will be treated in detail in chapter 4.2, throughout the 1930’es, he did continue some work on classical astronomy – but only on a still more popular basis. He reviewed texts of classical astronomical topics, he wrote popular articles for *NAT*, and he participated in conferences and other academic meetings.[13] His work for popularizing was not just left to amateurs and workers at private observatories, like the important private astronomer Thorvald Køhl in the province town Odder or Luplau Janssen at the Copenhagen Urania Observatory. Thus, before his appointment as lecturer, Bengt had been actively involved in arranging a meeting predominantly for Danish amateurs at CO.

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[12] According to Torkild Andersen, member of the Carlsberg Foundation grants committee until 2005.

[13] At the Natural Science Researcher’s Meeting in late August 1929, he gave a paper on his continued work on photoelectric record of stellar transits (*NAT*, 10, 1929, 115-117), and one year later he attended Astronomische Gesellschaft’s annual congress (OS, August 1930; *NAT*, **11**, 113-121). In November 1931 he gave yet another lecture on the “The applications of the photocell,” with illustrations and demonstrations sponsored by Selskabet for Naturlærens Udbredelse, the Polytechnical College November 11, 1931 (BSA.01,C); see also *NAT*, **12,** December 1931, 159).

The amateur astronomer Thorvald Køhl (1852-1931) disseminated astronomical knowledge widely. After working some years as newly educated school teacher, his astronomical work began in connection with numerous visits to the CO. The combination of school work and strenuous work at night with astronomical observations resulted in bad nerves and he applied for an appointment on the countryside. In 1883, Køhl was appointed headmaster of a Jutlandic municipal school in Odder but from 1903 he was able to give up his school work completely with some economical support from the state and from the Århus County. The last thirty years of his life were dedicated to amateur astronomy. From his private observatory in Odder he took part in collective projects of observations of variables and meteorite astronomy, some of these being under the direction of Elis Strömgren. For instance, Køhl collected more than 7,000 meteorite-observations in the period 1875-1930. Yet Køhl regarded the popularization of science as his primary and most important duty. Throughout his life he gave nearly 2,000 talks on popular astronomy and in an admiring letter to the natural sciences faculty, Elis declared,[14]

> I dare to express that when the state of Danish amateur astronomy is so great – better than in most countries – then this may to a considerable extent be attributed to the enlightening enterprise, which has been undertaken by Mr. Køhl in a number of years through lectures, popular astronomical writings and by individual influence.

The meeting of amateur astronomers was a successful one-time event, during which the observatory personnel demonstrated the various instruments for the attendees. On this occasion, Bengt gave a talk on lunar occultations and pointed out how it was possible for observers with only small means to make important scientific efforts. He explained the significance of a large amount of observers of the lunar edge during a lunar occultation, because accurate determination of the Moon’s location on the firmament was limited by the

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[14] E. Strömgren → The natural sciences faculty, July 8, 1927, ESC. See also *NAT*, **12**, 1931, 80.

Figure 2: Amateur meeting at the CO, September 12-14, 1931, held by Astronomisk Selskab's sections for observation of variable stars and lunar occultations.
Selected persons from the photo: 2. Erna Mackeprang, calculator; 7. Frida Palmér, Lund; 13. Elis Strömgren; 15. Hedvig Strömgren; 16. Axel V. Nielsen; 17. Electrician Møller Nicolaisen, Vejle; 18. Professor Knut Lundmark, Lund; 20. Observer Julie M. Vinter Hansen; 27. Sigrid Strömgren; 28. Bengt Strömgren (*NAT*, 1931, **12**, 80).

unevenness of the lunar edge. Thus he made it clear how a distance between two observers of only some kilometers on the Earth's surface was enough in order to reduce the error of the location determination.

The 1931 amateur issue comprised the obituary of Thorvald Køhl, who died in March the same year and although it was not stated explicitly in the *NAT*, the event was probably arranged on the occasion of celebrating his work, which included more than 2,000 public lectures and numerous popular textbooks on astronomy. Elis Strömgren praised Køhl in the obituary notice filled with gratitude and hence signalled the importance of cooperation between university science and private self-taught astronomers. Not surprisingly, the director of the

Urania Observatory, Luplau Janssen, did not appear owing to tensions between him and the professor.

Besides undertaking his theoretical work on the three-body problem, Elis engaged his son in a textbook project, which set off a small additional income for the two astronomers. It was initiated due to a persistent wish by the undergraduate students of astronomy and physics, who were all required to follow an astronomy course. Hitherto, the textbook on the curriculum was a classic by the Norwegian author Hans Geelmuyden. His astronomy textbook, *Lærebog i Astronomi* from 1908, was a classic masterpiece of dry theoretical astronomy. The new Strömgren textbook was based on Geelmuyden and included classical mechanics and spherical astronomy. Furthermore, Elis chose to incorporate fifty pages of his favourite topic, the three-body problem. As an appendage to these classical topics, following two chapters of the solar system, the young doctor worked out forty pages on stellar astronomy, counting regular astrophysics. And this was new. The book won popularity among astronomy students and in the mid-thirties the authors translated the book into German, and later they had it translated into Russian.

In the German 1933 version, Bengt's contributions to the chapters of modern astrophysics now counted 170 pages, as he was the lead author on stellar astronomy and all sections dealing with modern atomic physics. The overall purpose of the book was twofold; On the one hand, it was intended to constitute preparatory reading for astronomers to-be, but at the same time it was thought of as a connecting link between amateur- and scientific astronomy. Among others, it was reviewed by Friedrich Becker at the Bonn University Observatory, who warmly recommended the comprehensive textbook for both the readers of the German periodical *Die Himmelwelt*, in which the review was to be found, but also for undergraduate students, "who will find the book to be a splendid guide."[15]

But not all of Bengt's work was located at the Observatory. Close by, he still had the best collection of physicists at the UITF and he frequently attended

[15] Becker 1933. Strömgren & Strömgren 1931 was based on Geelmuyden 1908.

Figure 3: Copenhagen Conference, the UITF, Auditorium A, 1932.
Persons, from left: **Werner K. Heisenberg**, **Piet Hein**, **Niels Bohr**, Leon N. Brillouin, **Leon Rosenfeld**, **Max Delbrück**, Walter Heitler, Lise Meitner, Paul Ehrenfest, Felix Bloch, Ivar Waller, Jacques Solomon, Erwin Fues, **Bengt Strömgren**, Ralph de Laer Kronig, Steensholt, **Hendrik A. Kramers**, **Carl Fr. von Weizsäcker**, J.P. Ambrosen, Guido Beck, Harald Herborg Nielsen, Erik Buch Andersen; Fritz Kalckar, Jens Rud Nielsen, **Ralph H. Fowler**, Egil A. Hylleràs, Miss Lamm, Eva Rindal, **Paul A. M. Dirac**, Charles Galton Darwin, Charles Manneback, Gelius Lund (Courtesy of NBA).

meetings and conferences, visited his colleagues for technical discussions, and met new visiting scholars from around the world. And at Bohr's institute, Bengt soon met a researcher who became a close friend for many years – and a Nobel laureate two generations later.

In May 1932, R.H. Fowler, the astrophysicist who worked closely together with E.A. Milne, wrote Niels Bohr a letter, recommending his young student, Subramahnyan Chandrasekhar, for a year of research with Bohr starting in September the same year. As Fowler noted, Chandrasekhar had "already done first class work in astrophysics, but he wants to study the wider general aspects of quantum mechanics […] Probably young Strömgren knows his work too, if you want to hear more of him."[16] Two months later, Chandrasekhar asked Bengt for help to find lodging for an impending long stay in Copenhagen beginning in late August.[17] Bengt responded to Chandrasekhar that he was "very glad to hear that you are going to spend some months at Professor Bohr's Institute. I shall be very glad to assist you in finding a pension here in Copenhagen […] You will probably soon be able to go on with the language in Copenhagen, many understand English."[18] Following a brief pension survey, he wrote "there is a pension three minutes from Bohr's Institute: Have's Pensionat, Trianglen 2, where many physicist have stayed." This was where Chandrasekhar lived for the almost a year. Have's Pensionat was managed by Margaret Have and was the more prestigious of the two pensions used by visitors to the UITF.[19]

Chandrasekhar had not been entirely satisfied with his two year's stay at Trinity College in Cambridge with Fowler, where he developed the feeling that he "hadn't made any impression, to the extent that I could judge myself, on the environment" even after doing quite a large amount of theoretical work.[20] He depicted his stay like this:

> Fowler was there and I saw him once in six months. I was just by myself and I did not know whether I was making any headway or not. I used to know [Paul] Dirac moderately well, so I asked Dirac what I should do as I was getting rather discouraged. He suggested: "Why don't you go to Copenhagen?" Because that was the time everybody went to Copenhagen, you know.

This initial correspondence between Bengt and Chandrasekhar constituted the launch of a close and warm friendship. Chandrasekhar made many other "very good friendships" in Copenhagen, among others with Victor F. Weisskopf, Leon Rosenfeld, George Placzek, and Max Delbrück. Many of these physicists also stayed in the pension, which made the atmosphere dynamic compared to his stay

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[16] Ralph Howard Fowler (Cambridge) → Niels Bohr, May 13, 1932, NBA.
[17] Chandrasekhar (Cambridge) → BS, July 25, 1932, BSA.01, A.
[18] BS → Chandra, August 2, 1932, UCA, SCP.
[19] BS → Chandra, August 10, 1932, UCA, SCP. Wali 1991, 100.
[20] CI 19; the following quote is from same interview.

in Cambridge, "where you stay in a room of your own and […] I didn't mix with people very well." So, Chandrasekhar "had, personally, a very happy life in Copenhagen."[21]

Chandrasekhar was born in 1910 in Lahore[22] in India to a high-caste Brahmian family and had been brought up in an Indian academic family with a Nobel laureate in the lineage.[23] Bengt's impression of the theoretician was sympathetic. He promptly wrote his father, being on a professional trip to Boston, that "Chandrasekhar is a very pleasant and fine man. He was well installed and has been here to see the observatory."[24] In his reply, Elis wrote something that soon became a habit of his in correspondences with his son. He encouraged Bengt by proudly quoting his colleagues' praises of him: "Leuschner said to [Knut] Lundmark yesterday that "B.S. is a very clever man.""; greetings to Sigrid."[25] Undeniably, Elis felt partly creditable for Bengt's early successes. Had he only known about the future impact of a forthcoming paper of 1932, which entailed new insight into the interior of stars, it would probably not have been necessary for him to underline such figures' opinions of Bengt, except of vanity. By DeVorkin's words, with the novel paper, Bengt "saw his work gain quiet favor among those most influential in the field, though his conclusions about the evolutionary state of giants remained unappreciated".[26] We will now turn to the development of stellar models from the mid-twenties.

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[21] Ibid.
[22] The city is now in Pakistan. Wali 1991.
[23] Chandrasekhar's uncle, Sir Chandrasekhara Venkata Raman (1888-1970), received the 1930 Nobel Prize for Physics for his discovery of the so-called Raman Effect.
[24] B. Strömgren (CO) → E. Strömgren (Boston), August 31, 1932, ESC.
[25] The German-American Armin Otto Leuschner co-worked among others with Holger Thiele on surveys of minor planets in the early 1920'es. Elis reported to Bengt from a meeting with Leuschner at the University of California in 1932. E. Strömgren → B. Strömgren, September 1, 1932, ESC.
[26] DeVorkin 2000, 250.

Figure 4: Subramahnyan Chandrasekhar (1910-1995) as Fellow of Trinity College, Cambridge, 1934 (Wali 1991, photo no. 12).

4.2 Looking Inside the Stars: Eddington's Legacy

In 1932, Bengt published the important paper in which he concluded that the main constituent of a star was hydrogen and not the heavier elements as was generally assumed in the late 1920'es. The hypothesis was not quite novel, but Bengt made it reappear as another Phoenix from the ashes.[27] The proposal was advanced by Eddington at about the same time, although at a different level, based on mathematical-analytical methods. The assertion had far-reaching consequences as it meant a radical change of the prevailing views on the physical conditions inside stars. It paved the way for Hans Bethe's and Carl Friedrich von Weizsäcker's theories of stellar energy loss through the conversion of hydrogen into helium in nuclear reactions and was thus a central step in a fruitful line of reasoning towards nuclear physicists' understanding of stellar energy sources at the end of the 1930'es (treated in chapter 5.4). The hypothesis of hydrogen

[27] Main parts of this chapter (4.2) are included in Rebsdorf 2003a. Chapter 4.2 will focus thematically on the intellectual development of the hydrogen hypothesis, and will thus consist of an internalist, thematic, or suetonian turn away from the biographical chronology.

preponderance provided the missing link in the understanding of the values of stellar luminosities and radii. In addition, it also furthered the knowledge of the effective temperature and internal structure of stars.

Eddington's "instant classic" from 1926, entitled *The Internal Constitution of the Stars* (or just *ICS*)[28], was a great masterpiece within astronomical literature. Stellar interior theories had undergone great progress during the preceding years. Eddington's renowned monograph was appreciated because of its clear and comprehensive exposition of all relevant subjects, from thermodynamics and radiation, the mass-luminosity-relation, and the theory of variable stars to problems concerning the source of stellar energy, and the coefficient of opacity. Even more, it was admired for its clear exposition of the theory of radiative equilibrium but also because it emphasized two serious difficulties within the framework of Eddington's 'standard model'. The first of these was a persistence of an order-of-magnitude discrepancy between observed and deduced opacities of stellar matter. The other was the so-called stellar-energy problem of finding the source of energy-generation processes, which remained unsolved until specialists in nuclear physics entered the field in the late 1930'es (see chapter 5.4). In her autobiography, Cecilia Payne-Gaposchkin wrote that Bengt Strömgren's theory of hydrogen abundance played "a central role in the theory of the origin of solar energy that emerged in the late 1930'es."[29]

By the end of the 1920'es, the discrepancies between observed and theoretically derived stellar opacities became apparent. Bengt Strömgren accepted and used new numerical calculations of the stellar opacity coefficient found by theoretical physicists, which allowed him to explain larger hydrogen abundances in stars than previously assumed. This new way of solving the problem of the discrepancies proved decisive not only in paving the way for new results of stellar compositions of the work of Bengt and others, but ultimately for explaining the hydrogen abundance of the entire universe.

[28] Eddington, 1926. Regarding the "instant classic" designation, see Hufbauer, 1990, on page 8.
[29] Haramundanis, 1996, 25.

In *ICS*, Eddington was aware of the fact that the order-of-magnitude opacity discrepancy could be removed by assuming high hydrogen abundance in the stars, but he did not regard this as a proper way out of the problem. Consequently, he would wait for either the discovery of new absorption mechanisms, or some further development of Heisenberg's quantum mechanics.

Let us now turn to the basic assumptions that constituted the mathematical framework and models by the theoretical astrophysicists at the time. It is imperative to stress that the so-called "stars" in question were but simplified and idealized models consisting of uniformly and spherically distributed matter without any rotation, pulsation or magnetic fields. In Eddington's theoretical treatment there were three basic differential equations in play, which had to be solved on the basis of sensible stellar boundary conditions concerning both the physical centre and the surface characteristics. The equations were those of hydrostatic equilibrium (1), the mass-gradient (known as the equation of continuity, 2) and of radiative equilibrium (3).[30]

$$\frac{dP}{dr} = -g\rho = -\frac{GM(r)\rho}{r^2} \qquad (1),$$

$$\frac{dM(r)}{dr} = 4\pi\rho r^2 \qquad (2),$$

$$\frac{dp_r}{dr} = -\frac{\kappa\varepsilon M(r)\rho}{4\pi c r^2} \qquad (3).$$

Other assumptions were required in the attempt to explain stellar structure. One fundamental supposition was made as early as 1907 by the Swiss physicist and astrophysicist Robert Emden in his classic work *Gaskugeln*[31], in which he built up a polytropic stellar model by assuming that the material is a perfect gas of uniform composition, with the gas pressure per unit volume given by $p_g = NKT = (\rho/\mu)KT$, where μ is the mean molecular weight and K the gas constant.

[30] Here P is the total stellar pressure at radius r, g is the gravitational acceleration, ρ the mass density, G the gravitational constant, M the mass (as function of r), the radiation pressure is p_r, κ the opacity, ε the energy generation per unit mass, and c the constant speed of light. Owing to assumed spherical symmetry both P, g and ρ will only depend on the distance r from the centre.
[31] Emden, 1907. A polytrope is a solution to Emden's equation.

The so-called polytropic assumption was that the (P,T)- and (ρ,T)- relations were characterized by the equations $\rho / \rho_c = (T / T_c)^n$ and $P / P_c = (T / T_c)^{n+1}$, where n is the polytropic index. In addition, Eddington presupposed from 1917 and onwards that the radiative heat transfer was governed by the expression for blackbody radiation, stating that the energy density E was proportional to T^4. At high gas temperatures, T, the radiation pressure, i.e. the pressure of the photons, was[32] $p_r = aT^4/3$ and accordingly, the total pressure was the sum $P = p_r + p_g$ (p_g being the gas pressure). A novel feature of Eddington's additional assumptions related to Emden's was the appearance of the radiation pressure p_r. The equation of radiative equilibrium (3) determines the radiation pressure required to push the energy $\varepsilon M(r)$ generated inside the sphere of radius r out across the sphere. Finally, it was assumed that the stellar material was completely ionized plasma with separated electrons and protons.

The three basic differential equations were thus to be integrated into the boundary conditions, which was done by Eddington in the *ICS*-chapter "Solutions of the equations". The boundary conditions necessary for obtaining a solution comprised the assumption that the mass in the centre ($M(0) = 0$) vanished and that the gas pressure and the radiation pressure became negligible at the stellar surface (p_g, $p_r \to 0$, $r \to 0$). This left one constant of integration undetermined and hence there was an infinite set of solutions for given κ and ε.

From the surface boundary conditions – and under the assumption that the opacity and energy generation are constant – Eddington found that the total pressure P was proportional to p_r ($P \propto p_r / \kappa\varepsilon$) and therefore that $P \propto T^4$. Therefore it followed that the condition for a polytrope $n = 3$ ($n + 1 = 4$) was recovered. In any polytrope $\rho_c \propto M / R^3$ and $P_c \propto GM^2 / R^4$ in the stellar centre and elimination of the stellar radius R gives

$$\frac{P_c^3}{\rho_c^4} = const \times M^2 .$$

[32] The constant a is the so-called radiation constant: $a = 4\sigma/c$, (σ is the Stefan-Boltzmann constant, c the constant speed of light).

In brief, Eddington introduced the convenient ratio $\beta = p_g/P$ of the gas pressure to the whole pressure and he found[33]

$$1-\beta = const.\times(\mu\beta)^4 M^2 \qquad (4).$$

According to Eddington, since the constant did not depend on ε and , but only on the polytropic index n, it was possible to calculate the β value in the quadratic equation with given M and μ. The purpose of determining 1-β (= p_r/P) from assumed chemical composition and stellar mass was obviously to determine the product $\kappa\varepsilon$, namely by using the proportionality between P and p_r ($P \propto p_r/\kappa\varepsilon$). From an assumed opacity value it was now possible to determine the energy generation ε, or equivalently L/M.[34] The mass-luminosity relation could be expressed as[35]

$$\frac{L}{M} = \varepsilon = \left(\frac{p_r}{P}\right)\frac{4\pi cG}{\kappa} = 4\pi cG\frac{(1-\beta)}{\kappa}.$$

Thus, Eddington's model assumed that luminosity depended on mass, opacity and chemical composition, i.e. $L = L(M, \kappa, \mu)$. The M/L-relation was a consequence of Eddington's radiative equilibrium models.

Eddington's analysis of 1926 indicated that the vast gas spheres were in radiative equilibrium[36] with electrons and ions associated with the efflux of heat from inside the star. As we have just seen, this also indicated that the stellar luminosity was uniquely determined by the mass of the gas spheres apart from κ and μ. It was widely accepted within the community of astronomers that the motor, which gives power to the stars, was not the result of a gravitational collapse, but that the power source was caused by subatomic particle processes.

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[33] Here, M is the mass (as function of r), the radiation pressure is p_r, κ the opacity, ε the energy generation per unit mass, and μ is the mean molecular weight.

[34] The stellar luminosity L is defined as the total radiation flux emitted in space from the star in all directions, per unit time, and is given by $L = 4\rho r^2 F$ for an ideal spherical star with radius r, which emits its radiation isotropically with the total flux F.

[35] Eddington 1926, 146. G is the constant of gravitation.

[36] An amount of matter is said to be in radiative equilibrium when there is a constant net-flux of radiation through the matter, e.g. through an atmospheric layer, and when all energy is transported by means of radiation only. Furthermore, inward gravitational pressure is counterbalanced by the outward pressure of radiation.

The theoretical framework summarized here constitutes the essence of the stellar compositional elements of Eddington's standard model. When compared to results based on observation, however, Eddington's theoretical predictions of stellar masses and luminosities fell into serious difficulties.

The Hydrogen Hypothesis Wiped Out

The determination of the luminosity values, which were based on observation, was carried out through the standard procedure of converting differences of absolute magnitudes *m* into a ratio of total radiation by a formula based on a definition of change in magnitudes. About this definition Eddington stated: "A change of five magnitudes signifies a hundredfold increase or decrease of light. One magnitude corresponds to a light ratio of $(100)^5$ ".[37] In principle, the relation between the already known distance modulus and the effective temperature T_e and stellar radius *R*,

$$m - m_O = -5\log\left(\frac{R}{R_O}\right) - 10\log\left(\frac{T_e}{T_O}\right),$$

facilitated the possibility to determine the luminosity of e.g. a binary star if some technical corrections were added.[38]

When Eddington compared his results with observed values, he found that the stars almost gave the dependence of luminosity on mass, which had been predicted theoretically. However, to reach agreement between the values, he had to raise the theoretical opacity by a factor to nearly ten times his value. Eddington mentioned two possible explanations to this problem in the *ICS*. Perhaps the theoretically calculated opacities were too low. Accordingly the correct luminosities could then be predicted if the values were revised. Another way of circumventing the difficulty was connected with the chemical composition of stellar interiors.

[37] Eddington 1926, 14.
[38] With given values of visual magnitude, spectral type (yielding knowledge about effective temperatures) and mass, the latter calculated mechanically by use of Kepler's third law based on observed orbital motion giving empirical values of semiaxes, orbital period and mass-ratios.

It was generally assumed that interior stellar matter consisted largely of heavy elements such as iron, with a total mean molecular weight of μ = 2.1. Ionized matter, or plasma, consisting largely of hydrogen would, on the other hand, have a mean molecular weight of 0.5. Eddington pointed out that if the ionized matter was taken to be a mixture of hydrogen and heavy elements with a mean molecular weight of 1, then an agreement between the theoretical luminosities and the observational data could be obtained. In order for this to be the case, the fraction of hydrogen needed to be far more than ½. On the other hand, by adopting μ = 1, the radiation pressure would be smaller than the gas pressure in all but the most massive stars. Eddington had attached great importance to his finding that the two pressures were of the same order of magnitude. Bengt later recollected that at the time the *ICS* was published, Eddington was consequently reluctant to give up the assumption that stellar interiors consisted largely of heavy elements. "Instead he hoped that improved calculations might lead to higher opacity values."[39] This abandonment of the hypothesis of large hydrogen abundance was re-evaluated half a decade later by Bengt when it turned out that no other solutions were left.

Until the early 1930'es, the assumption among theoretical astrophysicists was that stellar composition was more or less comparable with that of the earth. As early as 1923, however, Milne and Fowler had deduced very low atmospheric pressures of about 10^{-4} atmospheres[40] of G2-stars like the sun from their reinterpretation of the Saha equation. This fresh value of the atmospheric pressure caught them by surprise and thus represented a consequential finding, since Megh Nad Saha's earlier value for the pressure was about 1 atmosphere. A decade later, the American astronomer Henry Norris Russell recalled that it was "startling and revolutionary" because "every one had become subconsciously accustomed to thinking of the sun's atmosphere as similar to the Earth's."[41] The Milne-Fowler value was only concerned with the stellar atmosphere though.

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[39] B. Strömgren 1972, on page 246.
[40] They found effective pressures in the sun's and other stellar photospheres around $P_e = 10^{-4}$ atm. for most of the elements, see DeVorkin & Kenat 1983, 102-132.
[41] DeVorkin & Kenat 1983a, 122.

With regard to the stellar *interior*, the composition was still perceived as being comparable with that of the earth.

Hence, the assumption of similarities between stellar and terrestrial composition was soon to be abandoned in favour of a theory that emphasized the light elements as main constituents. Beforehand, in 1925, Cecilia H. Payne (later Payne-Gaposchkin) completed her thesis on stellar atmospheres in which startling results appeared. Hydrogen and helium, she calculated, were more abundant in stellar atmospheres than the rest of the elements she examined. However, Russell could not accept this assertion and in a letter to Payne, which was written in January 1925, he stated: "It is clearly impossible that hydrogen should be a million times more abundant than the metals."[42] In 1928, the German astronomer Albrecht Unsöld also found evidence for a high abundance of hydrogen in the solar atmosphere - despite the fact that it had earlier been argued that the light weight of hydrogen would cause it to rise to the outer parts of a star and become concentrated, leaving the issue of the interior composition unresolved.

Four years after having written the above-mentioned letter to Payne and four years after having achieved convincing observations, Russell also took the stand that hydrogen was superabundant in stellar atmospheres. This was the main objective in a landmark article of his, which was published in 1929.[43] Russell developed the case for hydrogen's preponderance in the solar atmosphere through a series of arguments, including some new quantum mechanical derivations of abundances from line profiles and calculations of element abundances in the solar atmosphere. He found that hydrogen was orders of magnitudes more abundant than any other elements. However, he still did not discuss the possibility of corresponding hydrogen abundance *inside* the stars and thereby giving the model star a more homogeneous composition.

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[42] DeVorkin 2000.
[43] Russell 1929, 11-82.

Figure 5: Arthur Stanley Eddington (1882-1944). He was chief assistant at the Royal Observatory at Greenwich from 1906 to 1913, at which point he became professor of astronomy in Cambridge. Eddington was knighted in 1930. He helped clarify the theory of relativity and made mathematical contributions to the subject. Yet his most important work was *ICS* which was published in 1926.[44] Later he was best known as a popularizer of science, whereas his later works concentrated on epistemological and philosophical topics. Eddington is treated in a traditional scientific biography in Douglas 1956 (www.google.com).

Between the Devil and the Deep Sea

Although the *ICS* remained the standard work on stellar structure from its publication and until the early 1930'es, not all English astrophysicists were happy about Eddington's strong position. Around the turn of the decade there was little consensus among the leading astronomers and astrophysicists with regard to how knowledge about the source of stellar radiation could be positively obtained. Eddington and Milne represented two conflicting attitudes with respect to the methodological approach. Neither did James Hopwood Jeans regard Eddington's stellar theory to be appropriate. Jeans adduced that stars behaved like liquids instead of like gases. In the period from 1929 to 1932, Milne advocated that stellar interiors could be described through theoretical stellar models with centrally compressed cores having temperatures of trillions of degrees, which formed a contrast to Eddington's postulated central temperatures of only billions of degrees. Bengt followed this so-called Eddington-Milne

[44] Eddington 1926.

debate in *The Observatory* with increasing interest. The methodological dispute was a source of inspiration to Bengt and helped him articulate and pursue his research plans to enter the field of astrophysics.

Eddington had for some time elaborated on his theoretical stellar gas model and claimed that he, through this model, was able to calculate the luminosity L of a star with a given mass M, without knowing the source of the emitted light. From his astrophysical gas model, he computed a series of luminosity values that were in reasonable agreement with most of the observed values of L, although his theory did not manage to account for the low L-values of white dwarfs. This question was later scrutinized by Subrahmanyan Chandrasekhar, who became the leading figure in connection with the development of the theory of white dwarfs.

Milne disagreed with Eddington's convictions and was instead convinced that one needed to treat M and L like independent variables when the source of radiation was unknown. He viewed the problem as a problem where one needed to calculate the existing stellar equilibrium conditions with the given values of M and L, which to him seemed to be the central enterprise. Besides, he was confident that he had found a flaw in some of Eddington's work. Milne drew some remarkable conclusions from his own calculations. Among his conclusions were new values for certain stellar temperatures and radii. Computations for specific star types resulted in central temperatures around 10 trillion degrees and the largest corresponding r-values, according to Milne's calculations, amounted to several light years. Milne elaborated eagerly on his theory until 1932 when he turned to his heterodox cosmological program[45] and in this period he published about 20 papers on the results of extensive mathematical calculations. Milne criticized Eddington for not having noticed – or at least considered – the infinity of other mathematical solutions. He felt that Jeans and Eddington misunderstood the true inference which should have been drawn from Eddington's pioneer work.

45 See e.g. Kragh & Rebsdorf 2002 and Rebsdorf & Kragh 2002.

The whole debate was summarized in *The Observatory*'s February issue of 1931, where a meeting of the Royal Astronomical Society had resulted in a 12-page synopsis. Milne did not agree with Eddington's supposition that one gas law could apply throughout the entire star, from the centre to the outermost atmospheric layers. Instead, he constructed stellar models with the gas laws only applying to the stellar surface and where different equations of state governed the matter near the central parts of the star. Eddington was surprised at both Milne's confidence and at his failure to accept that Eddington's solution was the correct one. Concerning "the well known discordance between astronomical and physical calculations of opacity" Eddington stated that according to his theory it amounted[46]

> to a factor of about 10. Milne's theory increases this discordance. I cannot understand why he should have claimed that his theory cures it; on his own showing his solutions give a luminosity of the sun greater than L_0 (which corresponds to my solution), and therefore still more discrepant with observation. Professor Milne is between the devil and the deep sea - or rather between me and the deep sea.

Milne's campaign against Eddington's standpoints eventually turned to Eddington's advantage and it was clear at the end of 1931 that Eddington's theory triumphed, but the reason might have been methodological, owing to the ideas of both Jeans and Milne. Jeans was trying to hark back to something like liquid stars and Milne "tried to inject a principle of indeterminacy into the theory, because what goes on inside a star can never be directly observed."[47] Accordingly, Eddington was generally regarded as having the best of the exchanges that followed, though a weighty profit from the debate reflected the induced will among other astrophysicists to try fresh approaches to the opacity problem. Bengt, in particular, was searching for other solutions.

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[46] Greaves 1931, 36. For detailed readings of the so-called Eddington-Milne controversy, see Rebsdorf 2000, 27-31.
[47] Cowling 1966, 126.

4.3 Strömgren Gets Involved

One month after the Eddington-Milne polemic, Bengt sent a paper to *Zeitschrift für Astrophysik*, which contained his latest attempt to explain theoretically the stellar structure. In his paper, he investigated Milne's views on stellar structure in a positive spirit and faced some of the main arguments against Milne's centrally condensed model where the largest parts of the matter were situated centrally. The most important of these arguments concerned Milne's difficulties with substantiating the existence of such a type of model. Another of the crucial contentions was that there was an unsatisfactory dependence between the assumed model and the results that followed therefrom. Finally, it turned out from such a model that "the discordance between 'theoretical and astronomical' coefficients of opacity [was] made worse, perhaps much worse."[48] By means of a method, which was somewhat more hypothetical-deductive than what was usually seen in Bengt's work, but still far from Milne's rather rationalistic views,[49] he deduced some physical properties from a postulated compressed stellar nucleus. He even indicated that "in discussing the consequences of the postulate one should not restrict oneself to the standard model."[50] Bengt showed that the postulate of a point source model, according to the ideas of Milne, granted results analogous to those obtained in the standard model. Milne's ideas of a non-constant coefficient of opacity $\kappa = \kappa\ (\rho,\ T)$ evidently opposed the conventional assumption of the standard model of constant κ and ε values. Nevertheless, Bengt held the view that "a discrepancy factor of 15 as against EDDINGTON'S 10 is quite plausible". Furthermore,[51]

> [i]f the nucleus had to contain say 90% of the mass, then the discrepancy factor would be much greater [...] but there is no particular reason to assume this. Accepting MILNE'S views we are thus led, I think, to a physically plausible stable model according to which the process of energy-liberation can be understood.

[48] B. Strömgren 1931b, 369.
[49] Greaves 1931, 39. See also Rebsdorf & Kragh, 2002, 52.
[50] B. Strömgren 1931b, 369.
[51] Ibid.

In their correspondence of 1931, Bengt and Milne discussed technical details and agreed on including mutual references in their papers in *Monthly Notices of the Royal Astronomical Society*, and Bengt expressed his consensus with Milne:[52]

> Regarding the interpretation of the result I quite agree with you, that there are possibilities for "centrally condensed" configurations on other κL-distributions than that of the Standard Model; I was very interested to hear of the result obtained for the model with two constant values of κL. [...] I shall of course regard the results as confidential.

Bengt's approach was quite orthodox and his 1931-paper, although being important, should not be considered a landmark-article. Rather, it was a somewhat sympathetic investigation of Milne's model which had not been generally accepted within the rather small community of researchers in the field. According to Cowling, Milne's suggestion that models might become different from Eddington's through making the gas become degenerate near a star's center "appeared unlikely because of the reduced compressibility of a degenerate gas."[53] Milne's introduction of gas degeneracy – together with Fowler – formed a new variable in the equations, *viz.* the state of matter at great densities where Pauli's exclusion principle could be violated. Later, Chandrasekhar showed the unimportance of degeneracy until white-dwarf radii were being approached. In Bengt's contributions "to the discussion of Milne's ideas of the possible existence of stellar models of main-sequence stars with high-temperature, high-density cores", his conclusion, however, "was negative and it agreed with conclusions reached almost simultaneously by T.G. Cowling and H.N. Russell."[54]

Nonetheless, the problem of the opacity remained unresolved. Comparison of theoretical predictions, based on the mass-luminosity relation

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[52] February 16, 1931, B. Strömgren → E.A. Milne, BSA,01, A.
[53] Cowling 1985.
[54] B. Strömgren 1983, 3.

with observed results on *M* and *L*, resulted in theoretical luminosity values being too high. With Eddington's evaluation of the coefficient of opacity in the *ICS*, which was based on Kramers's theory of radiation emitted by an electron in a Coulomb field, there seemed to be no way out of this discrepancy. Kramers's classical electromagnetic theory of continuous X-ray emission from 1923, written at the UITF, gave values of the opacity coefficients that were at variance with the astronomical value.[55] With his emission values of free electrons, Kramers had calculated the absorption coefficient for all frequencies and the "mean values" according to the so-called "Rosseland mean", which was named after the Norwegian astrophysicist Rosseland, who went from Bergen to the UITF in 1920.

Novel Quantum Attempts

Attempts to solve the opacity riddle were undertaken not only by astronomers, but also by physicists. The Cambridge physicist John A. Gaunt presented an estimate of the so-called partial absorption coefficient in the *Philosophical Transactions* in 1930. This coefficient was analyzed according to quantum mechanics for the different states of ionization for bound K, L, M and N electrons and for free electrons. Where Kramers got over the difficulty of quantization calculations in his classical theory from 1923 by means of correspondence arguments, Gaunt's explicit aim was to do the same work by means of quantum mechanics, with the foundations laid by Oppenheimer in 1927 "upon the bed-rock of SCHRÖDINGER'S equation."[56] To Gaunt the motivation was the hope of finding larger absorption values and thereby turn the existing astrophysical theory into a more adequate theory of absorption. After vast matrix calculations, Gaunt found approximate formulae from which he concluded that Kramers's expression for the opacity coefficient was a "good approximation for

[55] Kramers 1923.
[56] Gaunt 1930a. Gaunt refers to Oppenheimer 1927.

small energies."[57] Gaunt did not directly attempt to solve the discrepancy, but his contribution, nevertheless, proved useful for Strömgren.

Besides being a source of inspiration to Bengt's attempt to revive Eddington's hydrogen hypothesis, it is beyond doubt that Gaunt's paper had a considerable impact on Bengt's choice of career direction. In 1930, after Bengt had gotten his doctoral degree on parabolic orbits, a difference of interests emerged between him and his father.[58] As Bengt recollected, these growing differences of interest, which also concerned the approach to astronomy came "after I had my PhD in 1929. This was the time to choose a direction in which to go. It didn't take so long till I got quite absorbed in problems of stellar interiors. You may remember that this was a time when Gaunt published – this is Transactions of the Royal Society – a paper on the calculation of the opacities."[59] In this paper, Bengt stated that it "interested me enormously, and here [...] my familiarity with numerical problems helped me a great deal."[60] Moreover, Bengt recalled that "it was quite clear then – now we are in 1930-31 – that the opacity question was one of the major questions in the theory of stellar interiors."[61] Even though there may have been differences of opinion with regard to Bengt's disciplinary direction of career, Elis may soon have seen the advantages for his son of immersing himself into the new and exciting research area of theoretical astrophysics. Elis attempted to contribute with his classical astronomical knowledge, as illustrated by a letter which he wrote to Bengt concerning a meeting in London where several prominent astronomers had attended: "A detail: Now they calculate tables of Emden's equations. You know that I have a lot in stock. It is probably mainly worthless now, but perhaps my tables on certain points go further than Comrie's. I believe that we have applied some

[57] Gaunt 1930a, 204.
[58] Elis Strömgren held the position as professor of astronomy at the Copenhagen Observatory from 1907 until he was succeeded by his son after retirement in 1940.
[59] HBI, 18.
[60] Ibid.
[61] Ibid.

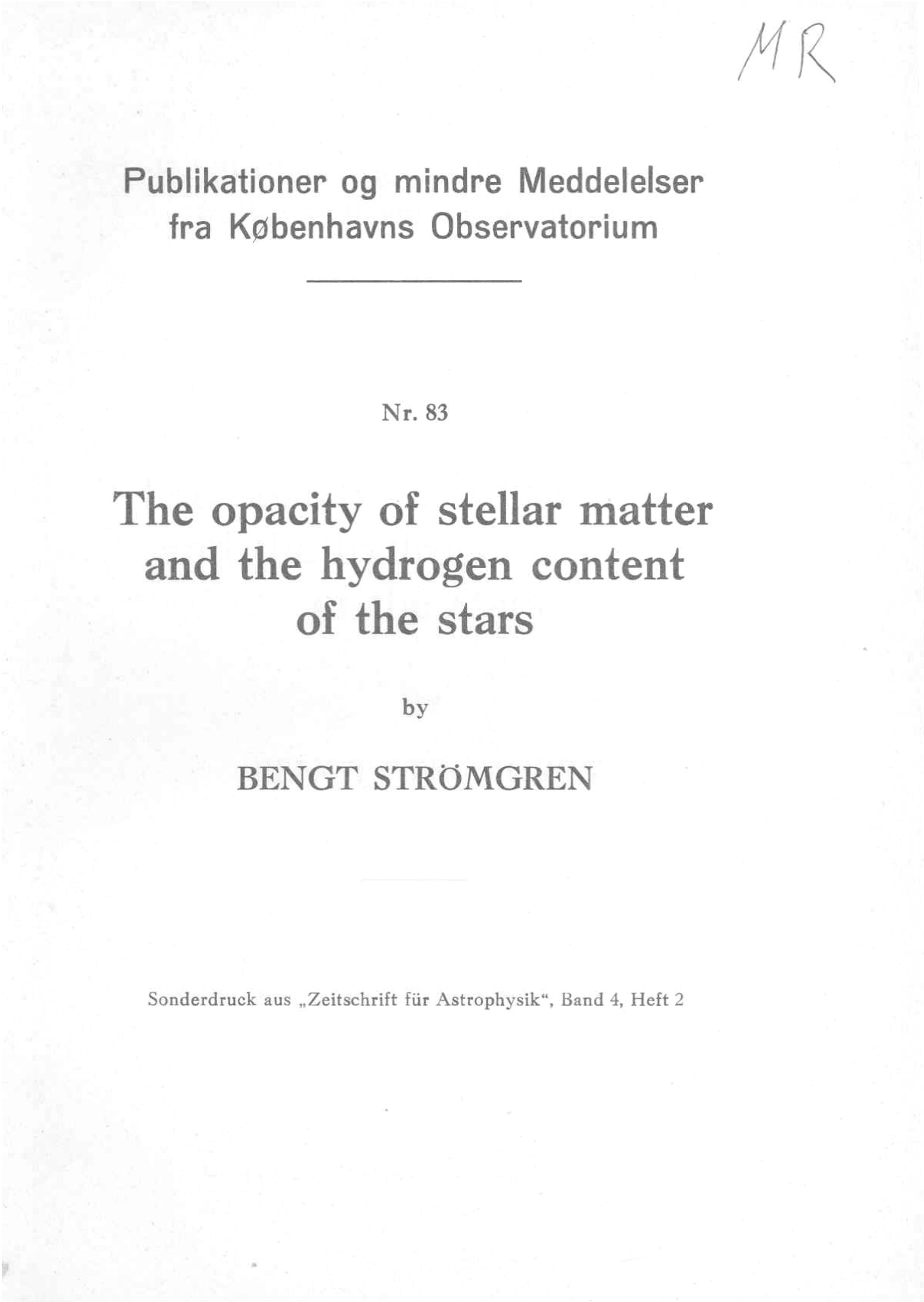
mathematical subtleties within the most complicated fields."[62] By "we", he meant father and son.

Gaunt's calculations were challenged by the Japanese physicist Yoshikatse Sugiura who had earlier been a guest researcher at the UITF. In November 1931, he published a paper entitled "Some notes on the stellar opacity coefficient", in which he entered the problem. Since "no satisfactory explanation of the discordance could be given", Sugiura gave a rather technical account of a new estimate of a corrected opacity coefficient which was "fairly close to the astronomical value."[63] His calculations were in a different order of density and temperature than Gaunt's and his correction was represented by the mean value of a correction factor to Kramers's result from 1923.

Sugiura had calculated the absorption coefficient of free electrons, which he estimated to be 8-9 times Kramers's value, and his result thus promised a solution to the discrepancy. As it was well known at the time, however, the contributions to the total absorption coefficient of free electrons would not increase the coefficient of opacity. Consequently, in mid-1931 the improved quantum approach actually indicated, even more clearly than before, that there were fundamental complications in the basic theoretical assumptions, which were required to be resolved. This indication was based on a great faith in the validity of the fresh quantum mechanics, though.

[62] Leslie John Comrie (1893-1950) from New Zealand was astronomer and pioneer in mechanical computation, working in England for many years. E. Strömgren (London) → B. Strömgren (Copenhagen), August 8, 1931, ESC,

[63] Sugiura, 1931. Y. Sugiura visited the UITF in the period 1925-1927 (Robertson, 1979, 158).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Publikationer og mindre Meddelelser
fra Københavns Observatorium

Nr. 83

The opacity of stellar matter
and the hydrogen content
of the stars

by

BENGT STRÖMGREN

Sonderdruck aus „Zeitschrift für Astrophysik“, Band 4, Heft 2

Figure 6: Front page of Bengt Strömgren’s 1932-paper. Copy from the offprint that Bengt gave to Mogens Rudkjøbing, hence the initials MR (courtesy of Mogens Rudkjøbing).

4.4 Reviving the Hydrogen Hypothesis

Introducing his landmark article in *Zeitschrift für Astrophysik* entitled "The opacity of stellar matter and the hydrogen content of the stars", Bengt questioned the proposals of both Gaunt and Sugiura, even though their work had evidently inspired him. In an introductory comment on their values of calculated multiplication factors of free electrons, Bengt wrote that "both GAUNT'S maximum value 5-6 and SUGIURA'S 9" were "so far only estimates."[64] These estimates did not affect the total coefficient of opacity. Therefore Bengt acknowledged their contribution to the resolution of the problem in an indirect sense.

Also the German astrophysicist Ludvig F. B. Biermann took part in theoretical stellar research. He held the view that the two conflicting coefficients actually agreed and presented a method of removing the missing factor of 10.[65] The argument was, firstly, that the larger astronomical value, denoted as k^a, could reach its minimum value if the centrally condensed model was acknowledged. Then the factor was decreased to 6. Secondly, he doubted the theoretical value, k^t, which was based upon a formula of Jeans' and derived from Eddington's value with a multiplication factor of 2. Thirdly, Biermann proposed the use of not only the 'first class stars' figuring in one of Eddington's lists, but also the second class stars were considered, thereby diminishing the discordance and just reconciling the data.

Strömgren rejected Biermann's approach in his opacity paper: "I think BIERMANN is almost certainly wrong". He therefore faced the problem that "[t]here remains thus the fact that k^a / k^t is from 6 to 20 for first class stars and somewhat less when second class stars are also used."[66] Inevitably, the only way left to reduce the astronomical coefficient of opacity was the one "already pointed out by Eddington, that stellar material contains a large admixture of hydrogen. It is known that a mixture containing about 1/3 of hydrogen by

[64] B. Strömgren 1932, 120.
[65] Biermann received his doctoral degree in Göttingen with a dissertation on convection in stellar interiors.
[66] B. Strömgren 1932, 121.

Figure 7: Bengt Strömgren working by an electromechanical calculator, ca. 1934 (Osterbrock 1997, 175).

weight reconciles EDDINGTON'S k^a and k^t in the case of Capella."[67] Bengt succeeded in reproducing all luminosities with $\mu = ½$ and $k^t = 1$ and in conclusion he stated that "the material of stars with known (M, R, L) seems to harmonize well with the hydrogen hypothesis." Although he admitted that "the mere fact that the luminosities are well produced does not mean so very much", he still argued that "the hydrogen hypothesis is the only hypothesis in harmony with present theoretical physics. But still further evidence is urgently wanted."[68] Hoping that a closer study of the stars would ultimately lead to further information on the stellar composition, he envisioned that it would "eventually be possible to predict the composition of the stars from the physics of atomic nuclei."[69] His insight was later proved to be right.

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[67] B. Strömgren 1932, 119.
[68] B. Strömgren 1932, 150-151.
[69] B. Strömgren 1932, 151.

Bengt's fresh results were obtained by detailed calculations using classical numerical methods. This is where Bengt diverged in particular from Eddington, Jeans and Milne, who all attacked such theoretical astrophysical problems in a methodologically much more speculative and hypothetical-deductive way. Bengt's 'numerical style' turned out to be essential for modern astrophysics. In contrast to today's high-speed computations of advanced mathematical models and algorithms, such calculations implied a vast effort by the human computer in the early 1930'es. With great practical experiences from his work on classical astronomy, Bengt cherished such computations with a small desk calculator:[70]

> I never found that difficult and even liked that sort of work. You work for days and weeks just step by step integration. But I was quite familiar with the numerical techniques [...] from my previous work in classical astronomy.

In the paper he investigated the effect of stellar models of varying hydrogen and helium content. In order to start with real stars, he inverted the process, that is, he took the masses and the luminosities of real stars and determined their composition. With variable composition, luminosity was no longer only a function of mass, but also of hydrogen content.

Due to the apparent impossibility of reaching a higher theoretical value of the coefficient, Bengt found it imperative to accept the hydrogen hypothesis in contrast to the common assumption of the late 1920'es. In a paper from 1983, Bengt described his train of thoughts in the beginning of 1932:[71]

> [I] convinced myself that there was now no escape from the conclusion that the hydrogen content of solar and stellar interior matter was much higher than assumed in Eddington's work. Eddington had pointed out that the assumption of higher hydrogen content could remove the opacity discrepancy, but as stated in *Internal Constitution of the Stars* he was reluctant to accept this solution because

[70] HBI, 45.
[71] B. Strömgren 1983, 3.

> it would upset his ideas of the role of radiation pressure, and instead he hoped that improved opacity calculations would save the day.

Eddington's main argument against this hypothesis was "that this hypothesis would be in disagreement with earlier conclusions as to the intensity of radiation pressure" although it was already an established assumption that the hydrogen in stellar atmospheres occurred in the proportion of about 1/2 by weight.[72]

With the improved opacity values, although not directly yielding desirable values – and with improved composite modeling – Russell also declared his positive convictions to the hydrogen preponderance from his chair in Princeton. His approximate models seemed to work better if high hydrogen abundance was used, but he was still focusing on stellar atmospheres and not on the entire stellar composition. As described by DeVorkin, Russell invited Eddington to America in February 1932 where Eddington was to give a lecture on the expanding universe – and he used the occasion to comment on stellar composition. "As for hydrogen, I am becoming more and more convinced that it is really altogether the main constituent of stellar atmospheres", he wrote. He maintained that hydrogen amounted to as much as "99 percent or more of the atmosphere by weight." According to DeVorkin, Eddington wanted to know whether Russell's "99 percent was a calculation or a conjecture" and Russell soon admitted that it was a guess. Eddington's worry was directed towards the question of energy generation, since "the transmutation of one percent of the hydrogen won't keep the sun going for very long."[73] It should be mentioned that in 1926 Bengt had at first sight regarded the hydrogen hypothesis as being weak. At that time he accepted Eddington's argument in the *ICS* that the assumption was *ad hoc*, introduced to reconcile k^a and k^t in the specific case of Capella.[74] But by 1932, the weakness was gone and the *ad hoc* label likewise.

Another contribution to the hydrogen hypothesis was included in a two-page note submitted by the Indian astronomer Shailendra Nath Mitra from

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[72] Eddington 1926, 249.
[73] DeVorkin 2000, 247.
[74] B. Strömgren 1932, 122.

London. Using the methods of the standard model, he calculated the density values of the white dwarf star Sirius-B accompanying Sirius. Inserting $\mu = 2.5$ in the equation, he obtained a density value 30 times the accepted empirical value. The purpose of his preliminary note was thus "to suggest that the discrepancy can be removed by assuming in accordance with the recent ideas of Russell and Unsöld that there is an abundance of hydrogen" and he confirmed that the "accepted value for the mean density of Sirius-B corresponds to $\mu = 1.13$ i.e. to about 70% hydrogen."[75] In Mitra's words his note suggested "one more reason for the hypothesis of the abundance of hydrogen in the stellar interiors" since it "seems to remove, as was pointed out by EDDINGTON and recently by STRÖMGREN [...] the discrepancy between the 'theoretical' and the 'astronomical' opacity."[76] Eddington's reformulation of the hydrogen hypothesis concurrently with Bengt's, although through a different approach, represents an interesting example of parallel discoveries.

Eddington's Similar Findings: An Historical Doublet

During the winter of 1932 Eddington examined the consequences of assuming a high hydrogen abundance inside the stars. He found that the discrepancy disappeared under the assumption that stellar gases consisted of about 1/3 hydrogen by weight, in accordance with Bengt's result. In a paper written in April that same year, Eddington wrote that "I received a letter by B. Strömgren dealing with the same problem. Our results are in remarkably close agreement, and many of the points brought out in this paper appear also in his."[77] Replying in a letter to Bengt on March 17**,** Eddington put emphasis on the congruity of their results:[78]

[75] Mitra 1932, 330.
[76] Mitra 1932, 330. Within the sociology of science, such synchronous scientific enterprises are denoted as multiplets, meaning discoveries made simultaneous and independently by different scientists or science teams. See e.g. Kragh, 1987.
[77] Eddington, 1932a, on page 473.
[78] A. S. Eddington → B. Strömgren, March 17, 1932, BSA.01. A. Krueger 60 is a double star system, which was frequently used in various examples of astrophysical calculations (see e.g. Eddington, 1926, 150).

> My results agree with yours almost exactly [...]. Except for Krueger 60 I think you have done all that I have done and more. I shall not be deterred from publishing my results, however; nowadays for two investigators to agree is much a rare phenomenon that it deserves to be recorded! More seriously, there is sufficient difference in our procedure to make the agreement a very interesting check. I wonder what the constancy of hydrogen content portends.

The last question was answered shortly after when stellar positions in the so-called Hertzsprung-Russell diagram provided a two-dimensional distribution of stars, yielding an expression for stellar distributions of objects with the same mixture of elements with regard to mass and age. Being a loyal Dane, Bengt Strömgren suggested to rename the hitherto called Russell diagram, owing to Ejnar Hertzsprung's discovery in 1908, of which, independently, Russell in 1913 found a similar diagram.[79]

The methodological or stylistic differences between the works of Eddington and Bengt were also manifest in this connection: Bengt adopted the mixture of elements found by Russell in the solar atmosphere and calculated its opacity, whereas Eddington employed a general theory of the so-called guillotine factor which "should apply to any likely mixture."[80] This factor was just a phrase coined by Eddington in his calculations and it was based on Kramers's theory of absorption.[81] Because Eddington was convinced about the "trustworthiness of Kramers's theory", he sought to improve the values of the guillotine factor, which was included in Kramers's theory, in order to calculate improved opacity factors; "the accordance of the results supplies a valuable check."[82] In a reply to Eddington's letter, Bengt responded: "I thank you very much for your kind letter. It was very interesting to me to hear of your work, and I was very glad to learn that our results agree so well."[83]

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[79] Bengt's was not alone to suggest this naming. There was a strong push from the Dutch in America as well as Continental astronomers.
[80] Eddington 1932a.
[81] Eddington 1932b.
[82] Eddington 1932b, 364.
[83] B. Strömgren → A.S. Eddington, April 2, 1932, BSA.01, A.

Reflecting on the causes to these new developments in astrophysics, Bengt later asserted that “the development in the theory of stellar interiors [...] took place as a consequence of a breakthrough in theoretical physics.”[84] There is no doubt that the rapid developments in physics triggered the idea of large hydrogen abundances inside stars. Yet, as to the first steps of determining the hydrogen content, the papers of Gaunt and Sugiura played an important qualitative role because they set the development on the fresh astrophysical theories in motion.

Looking back in 1972, Bengt Strömgren stated that his numerical recalculations of stellar luminosities, which were based on Gaunt’s and Sugiura’s results, “showed even larger discrepancies between theory and observation than before, when it had been assumed that μ was about 2. The conclusion that the mean molecular weight must be revised seemed unavoidable.”[85] Thus, the hope of Eddington that “improved calculations would save the day” could not be redeemed. The quantum mechanical calculations of Gaunt and Sugiura, based on bound-free transitions in a Coulomb field, resulted in values, which were in close agreement with Kramers’s opacity. This knowledge consequently provoked the acceptance of the hydrogen hypothesis.[86]

The following year, Bengt published a follow-up to his 1932-paper on the interpretation of the Hertzsprung-Russell diagram which comprised the results of an investigation of the relations between mass, luminosity and radius for 40 components of double-star systems. He showed that the calculated hydrogen content index, which determined the mean molecular weight, depended systematically on the position of the stars in the Hertzsprung-Russell diagram.[87] This new relationship indicated that stellar radii grow with age, i.e. with decreasing hydrogen content.

[84] B. Strömgren 1972, 246.
[85] B. Strömgren 1972, 246.
[86] B. Strömgren 1983, 3.
[87] B. Strömgren 1933a.

Right after Chandrasekhar had returned to Cambridge's Trinity College, after his one-year stay in Copenhagen, he wrote to Bengt about the proposed larger hydrogen content:[88]

> I met Eddington but only for a very short time. I told him that according to your taking into account scattering will quite presumably rule out the 99% Hydrogen solution. He did not appear very convinced, but I have an appointment with him next week when I will show him your curve and discuss the matter more closely.

Sixteen days later, after having discussed Bengt's work on hydrogen content with Russell and Eddington, Chandrasekhar wrote to his colleague in Copenhagen. Eddington, he reported, seemed "rather satisfied with the 'possibility of the possible non-possibility of the 99% hydrogen solution' (!!) - especially as in one of the cases he has worked out there seems to be a rather large positive residual which could be removed by using scattering."[89] However, when Chandrasekhar told Eddington that Bengt had studied the systematic variation of hydrogen in the Hertzsprung-Russell diagram, Eddington said that he would "more like the hydrogen to be constant for all the stars, rather than have another disposable constant in the theory."[90] When Chandrasekhar made the remark that 100% hydrogen for the massive stars could make it very difficult even to contemplate centrally condensed solutions, Eddington,[91]

> seemed only half satisfied. In any case I am sure he is really (secretly!) pleased, as the perfect gas theory combined with your hydrogen-content curves in the *R-M* diagram really contain all the information summarized in the Russell diagram.

In a historical survey of the development of "theories of stellar development", Bengt gave a popular lecture at an Astronomisk Selskab meeting in 1934, in which he concluded by looking in the crystal ball of theoretical

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[88] S. Chandrasekhar → B. Strömgren, May 26, 1933,BSA.01, A.
[89] S. Chandrasekhar → B. Strömgren, June 11, 1933,, BSA.01, A.
[90] Ibid.
[91] Ibid, *R-M* refers to radius-mass.

Figure 8: Edward Arthur Milne (1896-1950). Milne's scientific life is treated in Rebsdorf 2000. His early career is depicted in Smith 1990 and Smith 1998 (hitherto unpublished photograph of Milne, found in UCA, SCP).

astrophysics. He construed that the next step towards comprehending stellar development was "a deeper understanding of the atomic processes of stellar interiors."[92] With Chadwick's discovery of the neutron, atomic physics was indeed highly popular and following only five years of research, the world's astronomers were about to reach the proposed goal.

4.5 The New Cosmology

With roots in the general theory of relativity – and in the American astronomers Edwin P. Hubble and Milton Humason's discovery of a linear relationship between galactic distance and spectral redshift – cosmology was a fresh empirical discipline by the end of the 1920'es. In addition, the universe had grown larger after the finishing of the "Great Debate" between Harlow Shapley and Heber D. Curtis on the scale of the universe. The insight to the structure of the meta-galactic universe, or island universe, was increased, whereas the question of conditions of Galactic movement was still unsettled. With new

[92] B. Strömgren 1934a, 14.

observational data supporting galactic recession, cosmology as an empirical discipline was new.

One important theoretician of the 1920'es, who turned away from astrophysics to the benefit of cosmology, was Milne. Milne's work covered a wide field. His career was split into an orthodox and scientific fruitful astrophysical phase and a more heterodox cosmological phase. After a revelation-like theoretical discovery of his in 1932, Milne coined – as a mathematician – a hypothetical-deductive, almost geometric, simplification of earlier cosmological large-scale models, by use of a very straightforward principle. He simply assumed an initial state of the universe with a large number of point galaxies, moving with random velocities and with no mutual gravitational attraction. Along with severely simplifying assumptions, these initial conditions made the consistent cosmological framework for a rival theory to Einstein's and other scientist's mathematically "monstrous" theories using the general theory of relativity.[93]

In 1932, Milne visited Copenhagen after a visit at the Einstein Institute in Potsdam. There, he had some important astronomy discussions with Einstein and Erwin Finley Freundlich, which introduced the seeds to Milne's new theories of kinematical relativity. Both Elis and Bengt Strömgren had read his original two-page *Nature* paper "World Structure and the expansion of the universe,"[94] in which his new controversial ideas were introduced. He was thus invited to the Danish capital to give a talk at both Bohr's colloquium and Astronomisk Selskab. He consented to go and they arranged that he should arrive early December for a dinner party together with the Bohr family at the Observatory. The dinner went well and next day Vinter Hansen took him on a sight seeing in Copenhagen in the late morning. Then he gave a talk at the UITF on his expansion theory and world-structure in the light of the special theory of relativity followed by an evening lecture to Astronomisk Selskab and the Physical Society (Fysisk

[93] Milne is treated biographically in Rebsdorf 2000 (page 30 in particular), in Kragh & Rebsdorf 2002, in Rebsdorf & Kragh 2002, and in Rebsdorf 2003b. Milne attempted to reform physics with his new cosmology – or rather cosmo-physical theory – his so-called 'kinematic relativity'.

[94] E. Strömgren → B. Strömgren, October 4, 1932, ESC. Elis discusses Milne's "World Structure" with his son; Milne 1932a.

Forening) on “the Sun’s Outer Layers as a Typical Stellar Atmosphere.”[95] In his talk, he emphasized the work of a theoretical astrophysicist as being[96]

> as strict and as disciplined as a geometers, who’s work it is to propose theorems that follow logically from a well-defined set of axioms. The work of the theoretical physicist is to deduce conclusions […] He is not primarily interested in the question of correspondence with “reality”.

This rationalist view of the astrophysicist at work was not exactly consistent with Bengt Strömgren’s line of attack. Yet Bengt may have expressed his disagreement with Milne’s methodological considerations, if in a friendly manner. Milne’s view of the relations between model and reality was not mirrored in Bengt’s work at all. Bengt rather employed empirical data in his comprehensive numerical integrations and was thus more inclined to an inductive approach to science.

Following the visit of the British theoretician, Milne wrote a bread-and-butter letter to Bengt, in which he expressed his appreciation of the young astronomer:[97]

> I must say to you how much I admire the completeness and extent of your knowledge of astronomy, indeed all physical science, at so young an age. The future before you is brilliant, and I wish you all success.

These were the words of a prominent astrophysicist and soon-to-be winner of the Royal Astronomical Society’s Gold Medal (1935), but also from an ambitious theoretician, inclined to reform physics by means of a new theoretical foundation, his so-called kinematical relativity. Even though Milne’s kinematical relativity more or less died with him in 1950, his ‘potential paradigm’ aroused

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[95] E. Strömgren → E.A. Milne (Oxford), November 15, E.A. Milne → E. Strömgren, November 24, E. Strömgren → E.A. Milne, November 28, ESC. Bengt and Sigrid Strömgren hosted Milne, the Bohrs and Bengt’s parents on December 3, 1932.
[96] Milne’s talk on solar physics was translated by Vinter Hansen: Milne 1932b, 5. For further details, see Rebsdorf 2000, chapter 5.2.1, pages 29-31.
[97] E.A. Milne (Einstein Institute, Potsdam) → B. Strömgren, December 8, 1932, BSA.01, A.

philosophical controversy between hypothetical-deductive ‘cosmo-physicists’ and more empirically-minded scientists and thus affected the models and methods of the new scientific cosmology as a young discipline. Bengt Strömgren did not actively partake in the controversy, but was obviously an interested reader of the debates in e.g. *Nature*.[98] The Copenhagen visit was indeed inspiring for Bengt and the following year, he published a popular survey of recent cosmological theories, including Milne’s. In this overview of contending theories, Bengt diplomatically observed that in the initial state of the ‘Milne-universe’, “the gravitational forces in this state must have been of importance.” This was Bengt’s own conclusion, though. In Milne’s theory, vanishing gravity was an inherent part of the model of the very early universe, since the gravitational constant *G* was proportional to time. However, Bengt’s problem with this was the mere thought of vanishing gravitation of a whole galaxy. Bengt did not explicitly debate Milne’s lack of gravitational inclusion but obviously he did not agree with such hypothetical thinking.

4.6 Observatory Life and Family Life

It is impossible to set a date, from which Bengt’s life predominantly consisted of science in one way or another. It happened early, if gradually, and science, as a life form, was just what he had heard his father’s voice advocate for him throughout his childhood, adolescence and early mature life. From the time when Bengt and his beloved wife Sigrid took a house together on Hellerupvej on the Northern side of Copenhagen, his everyday life was not entirely about science anymore. Something new and vivacious had found its way into his life. When he met Sigrid for the dancing lessons, he experienced a new world. He held a girl for the first time and soon they were engaged and married. The next very important thing to happen in their private life became the birth of their first daughter, Karin Elisabeth, who was born on May 5, 1933. Bengt was a scientist with a capital S, not a religious person, as was neither his father. Still, he followed the Christian cultural tradition with his wife, as the majority of Danes

[98] See also Kragh & Rebsdorf 2002.

did at the time and Karin was baptized accordingly.[99] Sigrid taught dancing and gymnastics until she got pregnant and after delivering Karin, she became the supportive housewife who took care of home and social events, while her husband took care of science.

During Chandrasekhar's Copenhagen stay, he and Bengt worked together on scientific matters such as the theoretical problem of non-uniform chromospheres and Bengt's continued photoelectric experiments. Bengt tried to do pulse counting by use of his photocell arrangement but did not succeed, since the amplification "of each photoelectron" was still only about "100, instead of what we have today, 10^6."[100] They naturally attended each other's lectures, e.g. Chandrasekhar's "The Problems of the Stellar Atmosphere" and Bengt's "Theories for the Developmental History of Stars and Stellar Systems" in Fysisk Forening;[101] they followed the activities at the UITF together and Chandrasekhar was invited to Hellerupvej several times. Yet in the summer of 1933, Chandrasekhar reported to Bengt that he had decided to spend the winter with Milne in Oxford.[102] During this stay, Chandrasekhar met Eddington, who was quite impressed with what he had learned about Bengt's work.[103] Shortly after, Bengt wrote Chandrasekhar about "very fine congress at Bohr's institute," where more than forty foreigners had arrived, "and many highly interesting discussions were held, on Dirac-holes, nuclear constitution, measuring, etc. You have missed something."[104] Seemingly, Bengt would have liked his congenial colleague to stay longer in his hometown than only for one year.

Following Chandrasekhar's leave from Copenhagen, he corresponded frequently with Bengt. In these letters, we find weighty documentation of his scientific as well as private doings and they portray the nature of the friendship between the two young astronomers.[105]

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[99] Bengt's religious believes will are touched upon in chapter eight.
[100] HBI, 16.
[101] February 13 and March 13, 1933, respectively (BSA and NBA).
[102] S. Chandrasekhar → B. Strömgren, July 30, 1933, BSA.
[103] S. Chandrasekhar → B. Strömgren, September 8, 1933, BSA.
[104] B. Strömgren → S. Chandrasekhar, October 6, 1933, UCA, SCP.
[105] B. Strömgren → S. Chandrasekhar, October 6, 1933, UCA, SCP.

> I am quite worried because I have not found time to write to you before. But first there was a congress in Göttingen, where I had to lecture twice, then proofs for the Zeitschrift and abstracts of the lectures and again proofs. Also my lectures here have begun. Now I could of course have found the time but unhappily I always put up writing. […] My wife and the baby are going on very well indeed. The baby has doubled her size since you saw her. She was christened a few weeks ago, which did not impress her very much; she is called Karin Elisabeth. Her parents think she is a very intelligent beauty and very sweet and kind. I will soon send some photos of her. Please remember me to Milne. I hope his daughters are well too.

Perhaps Bengt was not very much impressed himself either in the church. The year after Karin's birth, Sigrid's mother, Marian Hartz, passed away. The old generation was replaced by a new generation, so to speak.

Through the private and professional friendship of Elis Strömgren and his Swedish colleagues in Lund, Bengt had often visited the city's university and knew it well. Years later, he was invited to give a seminar presentation on another problem that he occupied himself with "a little now and then" in 1933, this time of a purely mathematical sort. He concerned himself with dissecting a curve into two normal Gaussian curves, which included a complicated numerical solution of "a complicated equation of 9. degree."[106] As Elis Strömgren applied the Ministry of Education for a three year reappointment of his favorite astronomy lecturer with a continued wage of 2,400 Kroner a year, Bengt gave himself more work in Sweden.[107] Perhaps as a consequence of his lecture in Lund the year before, Bengt was approved as lecturer for a forty hour course on atomic physics' applications in astronomy, which added 1,200 Kroner to his salary that year. In October same year, Bengt gave eight lectures in Lund as a part of his two

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[106] B. Strömgren → S. Chandrasekhar, October 6, 1933, UCA, SCP. His mathematical work turned into a paper: Strömgren 1934b.
[107] E. Strömgren → The Ministry of Education, January 31, 1934; University of Copenhagen to The Ministry of Education, June 20, 1934, R.

Figure 9: Photograph of the Strömgrens in their house on Hellerupvej, on the occasion of Nina's christening (Courtesy of Nina Strömgren Allen).

semester course in theoretical astrophysics, that he held in Copenhagen.[108] Through his frequent visits in Lund and also by joining social events such as the Scanian Nations' Party in Lund, Bengt became friends with the Astronomer Walter Gyllenberg among others. On this occasion, Bengt spend the night in Gyllenberg's observatory office.[109] As Bengt was fluent in Swedish, he might have felt once again the close relations with his father's homeland and his own nation of birth.

During 1934, Bengt put up his theoretical work. He had promised the German astronomer Hans Rosenberg in August 1933 to write two chapters in the *Handbuch für Experinemtalphysik* and even that he would have them done in only six to eight months. His articles should be about problems and objectives of

[108] K. Lundmark → B. Strömgren, June 20, 1934, reporting the approval of the preceding course, BSA.01, A. October 16 – December 5, 1934: Bengt Strömgren gave eight lectures at Lund's university, LU (Fil. Fak. MN Sek, Dagbok, December 7, 1934), and *Lunds Universitets Årsberättelse 1933/33-1934/35* (Lund: Ohlsson, 1936), 60. Bengt gave 12 more lectures in his Lund course on theoretical astrophysics, February 10 – May 15, 1935, LU (Fil. Fak. MN Sek, Dagbok, May 28, 1935).
[109] W. Gyllenberg → B. Strömgren, February 26, 1935, BSA.01, A; On March 2, 1935, Bengt attended "De Skånska Nationernas Skånsk Fest" at the University of Lund.

astrophotometry and they were finally published in 1937.[110] He wrote popular texts on reflecting telescopes and astrophotography in *NAT* and he lectured his astrophysics classes.[111]

In 1935, Bengt and his Indian friend were reunited in Copenhagen for some months, as Chandrasekhar visited the UITF for a shorter period from April to June. During his Copenhagen stay, he wrote a paper to the Nordic magazine on stellar structure, a paper that reflected his major concern of astrophysics and which ushered an important future monograph of his on the same theme.[112] Later that year, when Chandrasekhar was back in Cambridge, Bengt wrote him concerning[113]

> a very important event, namely that we have just got another little daughter. Karin is very happy about her little sister. It seems now to be a law (far more well-established than that about the odd numbers) that astronomers always have little daughters!

Bengt probably referred to Milne, who also had two daughters and with whom he had corresponded rather closely since his visit in Copenhagen in 1932. Sigrid and Bengt named her Nina, born September 17, and being "a little darker than Karin and not as fragile as Karin was, when she was quite small."[114] Now Bengt's private life with Sigrid had secured him the status of a father of two daughters, whereas he had – long since his 1932 landmark article on hydrogen content of stars – secured himself in the community of astrophysicists. And he was naturally contacted as the specialist of hydrogen content. For instance, the astronomer H. Slouka in Prague wrote Bengt for advice on calculating stellar hydrogen content from data on eclipsing variables.[115]

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[110] B. Strömgren → H. Rosenberg (Kiel), August 21, 1933, BSA.01, A. See B. Strömgren 1937a and B. Strömgren 1937b.
[111] B Strömgren 1934c, B. Strömgren 1934d.
[112] S. Chandrasekhar (Cambridge) → Bengt Strömgren, March 1, 1935, Chandrasekhar is looking forward to seeing Bengt in less than three weeks, BSA.01, A.
[113] B. Strömgren → S. Chandrasekhar, September 17, 1935, UCA SCP. Bengt wrote the letter the very same say as Nina was born.
[114] B. Strömgren → S. Chandrasekhar, November 27, 1935, UCA, SCP.
[115] H. Slouka (Prague) → B. Strömgren, March 1935, BSA.01, A.

4.7 Following up a Landmark

With Bengt's 1933 paper "On the Interpretation of the Hertzsprung-Russell-Diagram", which in Denmark was thenceforth eponymous for the two astronomers, the thinking of stellar evolution was changed. Under certain simplifying assumptions, which are satisfied by most stars, the properties of a star are determined by only its mass. This statement is so powerful that it has been codified as the Russell-Vogt (or just Vogt's) theorem, although it is not really a theorem in the mathematical sense. In this important paper, he made use of Vogt's theorem to show that the stellar position on the diagram was only determined by the star's hydrogen abundance and mass.[116] As described by David DeVorkin, Bengt constructed theoretical distributions of stars, varying hydrogen content and then varying mass, by use of vast calculations.[117]

The result was based on reduction of hydrogen content through processes of element synthesis, as suggested by Robert d'Escourt Atkinson and Fritz Houtermans in 1929.[118] Their work presupposed that hydrogen existed abundantly in the stars, which helped gain the acceptance of predominance of the lightest element and gradually Atkinson expanded the theory, devising a cyclic model by which helium was created by the disintegration of unstable nuclei. Their starting point had been the Russian physicist George Gamow's novel idea that an alpha particle could, even with its relatively low energy, escape from or penetrate into a nucleus by tunneling through the nuclear barrier field in agreement with the equations of the fresh quantum mechanics.[119] By 1932, with the fresh hydrogen hypothesis and with the unearthing of the neutron, Bengt was able to suggest a line of stellar development of main-sequence stars and dwarfs, in which they moved up and to the right in the H-R diagram, converging toward the region of giant stars. With his 1933 paper, it was probable that evolution lines actually were resembled by lines of constant mass and he was the first person to

[116] B. Strömgren 1933a.
[117] DeVorkin 2000, 250.
[118] Atkinson & Houtermans 1929.
[119] Hufbauer 1990, 14.

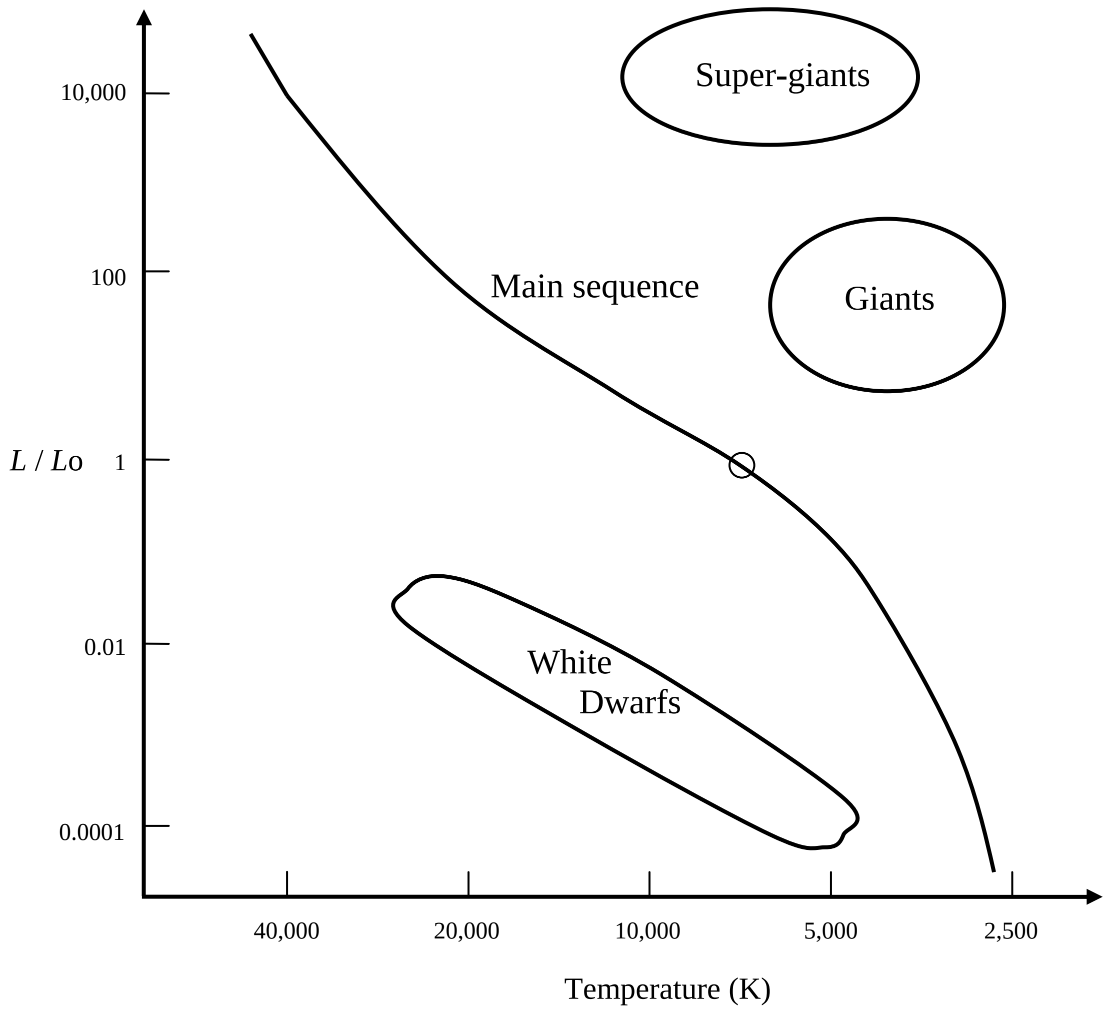

Figure 10: A schematic Hertzsprung-Russell diagram (temperature versus luminosity plot). Russell used the spectral class, which is related to the temperature, in their plots. The luminosity classes are white dwarfs, main sequence stars, giants and super-giants.

evoke that when hydrogen was consumed, by some nuclear synthesis, “the stars expand.”[120]

Not surprisingly, this was an important finding in the ideas of stellar evolution, but with his lectureship and following administrative obligations, his theoretical work was put up for some time. The next astrophysical paper on the production line came in 1935 and it followed a quite different track.[121] It was well known at the time that the observed central intensities of the solar absorption lines presented a difficulty in the way of theoretical explanation, which had remained unsolved for half a dozen years. The main concern of Bengt

[120] B. Strömgren 1933a, 247, DeVorkin 2000, 250.
[121] B. Strömgren 1935a.

was stellar modeling and he applauded that Chandrasekhar had begun studying the so-called non-uniform chromospheric problem, in which he attempted to describe turbulence and streaming phenomena in stellar atmospheres. Bengt, however, had got the idea of considering stellar models with varying molecular weight. In a letter to Chandrasekhar, he explained his idea of examining Eddington-models with an increasing molecular weight near the centre. "According to Eddington, decreasing μ has no very interesting consequences, but increasing might. On the other hand, increasing μ is not quite improbable in stars with appreciable hydrogen content." Bengt did not regard such μ-effects to be very large, but "they might influence central temperatures sufficiently to be of interest in connection with questions of energy generation."[122] Ever since Atkinson and Houtermans' work on element synthesis and the discovery of the neutron, still more astrophysicists were able to contemplate the problem of energy generation and propose more coherent theories. Already in 1931, Bengt Strömgren expressed his enthusiasm about the new ideas of energy generation. He wrote Milne that "we are again as far as ever from the understanding of the sources of stellar energy;"[123] but so much awaited the astrophysicists at this point. And it was not only the discovery of the neutron, which paved the way toward new theories of energy generation. In 1932, physicists had also greatly increased the credibility of Atkinson's hypothesis. By use of particle accelerators, they revealed a wide family of proton-induced nuclear reactions. In addition, following Hufbauer 1990, the "discovery of the positron challenged existing theories by revealing that this particle was the electron's opposite rather than the proton".[124]

Bengt published a short paper on observational instrumentation, namely on the Schmidt Telescope, which was a technological matter to which he returned when there was not much else to work with during the isolated time of the occupation.[125] Apart from this paper, the most important of his publications

[122] B. Strömgren → S. Chandrasekhar, November 27, 1935, UCA, SCP.
[123] B. Strömgren → E.A. Milne, February 10, 1931, BSA.01, A.
[124] Hufbauer 1990, 14.
[125] B. Strömgren 1935b.

of 1935 was an article in *Zeitschrift für Astrophysik* on the influence of electron captures on the contours of Fraunhofer lines". As he had worked in some years with the problem of stellar atmospheres, the publication, accompanied by a 1936 paper on stellar pulsation, led to appreciable discrepancies after continued work based on solar model atmospheres. The latter paper treated the damping effect, which he convinced himself to be caused by neutral hydrogen atoms, but only with Rupert Wildt's discovery of the role played in the solar atmosphere by the negative H-ion, the discrepant theories and observations fell into place.[126]

[126] B. Strömgren, 1936a, B. Strömgren, 1983, 5.

Five

There and Back Again

Two Local Contexts

1936-1940

New Years Eve of 1935-36 proceeded on Hellerupvej in Copenhagen with no particular events out of the ordinary. Bengt had his usual preparatory academic concerns of teaching, writing papers, and undertaking theoretical research. On January 1, 1936, Niels Bohr, Louis Hjelmslev and N.E. Nørlund wrote a proposal to the Royal Danish Academy of Science and Letters for the recommendation of Bengt Strömgren as a new member of the scientific society. Bengt's nominators, all obviously his close colleagues, substantiated their proposal on the basis of his work in celestial mechanics, his innovative photoelectric registration methods, and, most importantly, his recent work in astrophysics. With special reference to his publications in 1931 and 1932, they characterized him as "a many-sided researcher, who has enriched astronomy with a series of extraordinarily valuable works. He has also, at a very young age, gained wide recognition abroad and therefore we find that his membership would be beneficial to our society." Nørlund also reported Ejnar Hertzsprung's support for Bengt's membership.[1] However, the proposal apparently needed some recurrence and even with reiterated recommendation by Hjelmslev and Nørlund one year later, it took three years before Bengt was finally appointed member of the Danish society, in 1939.

[1] Bohr, Hjelmslev, and Nørlund → Royal Danish Academy of Sciences and Letters, January 1, 1936, RA. The proposal was not submitted until January 29, 1936 (Nørlund's letter was of same date).

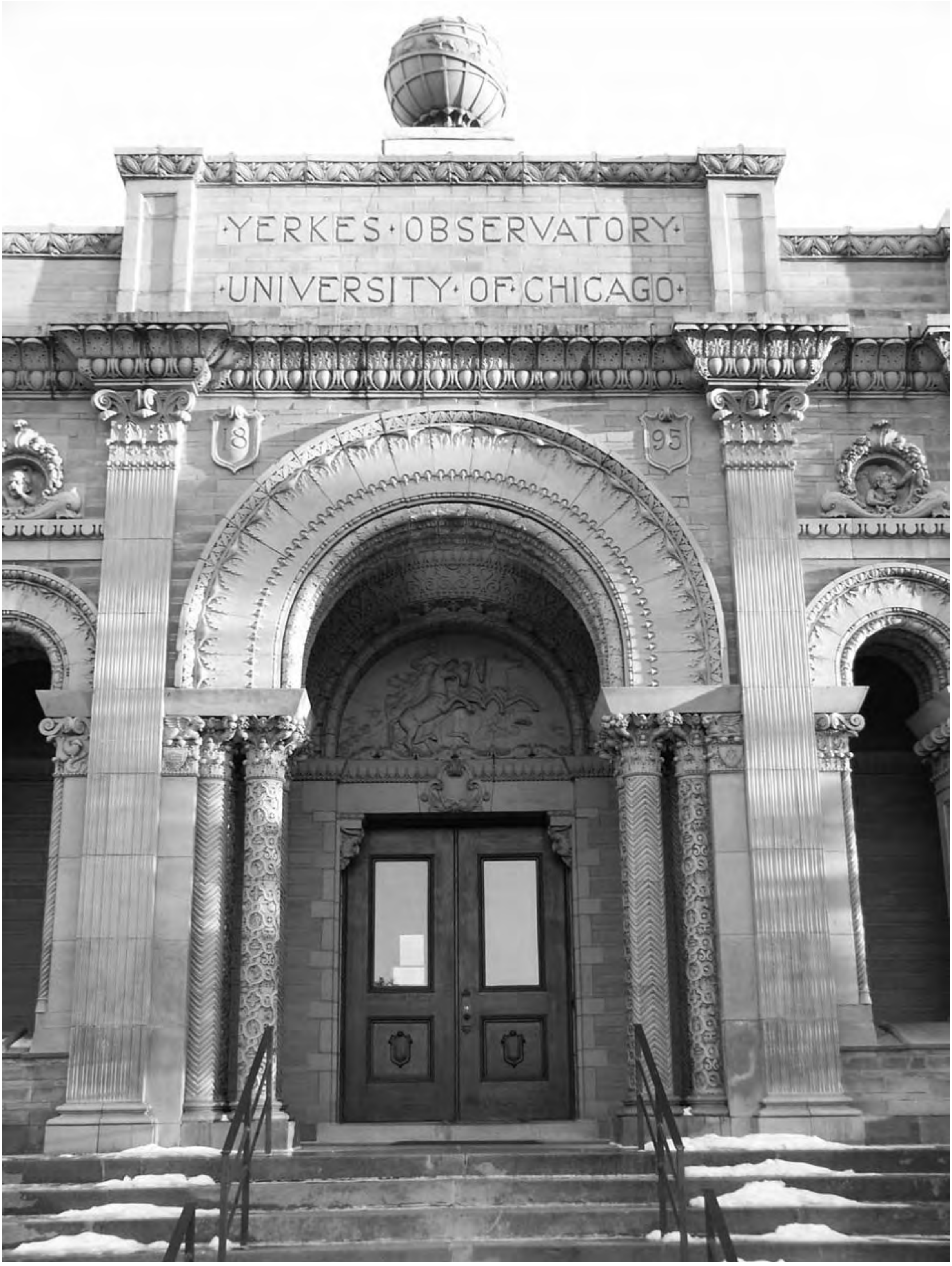

Figure 1: The door was opened for Bengt Strömgren to do astronomical research at the American Yerkes Observatory; main entrance to the observatory (photograph by S.O. Rebsdorf, April 2003).

5.1 An Invitation Out of the Blue

Initially, Bengt was not aware of these preliminary recommendations for his inclusion into the society. Even if he had been so, his future decisions would probably not have been much affected, because only four days after New Years Eve, an incoming telegram became enormously influential for Bengt and his family – and ultimately for Danish science. Bengt was invited to one of the largest observatories in the USA and not only for a visit, but for a research position. A night letter cabled message entered on the observatory telegraph with the following request:[2]

> WOULD YOU CONSIDER ASSISTANT PROFESSORSHIP THEORETICAL
> ASTROPHYSICS UNIVERSITY CHICAGO THREE YEARS SALARY
> FOUR THOUSAND DOLLARS YEAR. RESIDENCE CHICAGO COOPERATION
> WITH YERKES AND MCDONALD OBSERVATORIES. LETTER FOLLOWS.
>
> STRUVE

The invitation was very welcome indeed – and it came out of the blue. Clearly, Bengt knew all about the Observatory in Williams Bay, Wisconsin, having the world's largest forty-inch refracting telescope in the colossal dome, which was built in 1897. And he "had always hoped to go to America. That was *the* thing to do." Niels Bohr had also talked to Bengt about getting a Rockefeller Fellowship, "and I'm sure he could have gotten it for me, but I wasn't quite ready. One thing and another had to be finished."[3] But now Bengt suddenly had the opportunity of doing both observational and theoretical research there and even work with spectroscopy at the larger eighty-two-inch reflector at the new McDonald observatory located on a mountaintop in Texas, which was nearing completion and was directed by the Chicago astronomers.

Bengt waited for two days and the promised letter arrived from the director of the Yerkes Observatory, Otto Struve. Bengt was officially offered a position as assistant professor at the faculty of the Department of Astronomy and

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[2] O. Struve (Yerkes Observatory) → B. Strömgren (CO), (telegram) January 4, 1936, YOA.
[3] HBI, 29.

Astrophysics at the University of Chicago. Struve explained that on the occasion of the impending retirement of professor William Duncan MacMillan,[4]

> we would like to take this opportunity to bring to the University a distinguished astrophysicist, who would be able not only to develop the work in theoretical astrophysics on the campus […] but would also cooperate with the Yerkes and McDonald observatories in their research programs.

He continued,

> I know that this offer will come to you somewhat as a surprise, and it is possible that you have other plans for the future. On the other hand, the possibilities of important work in astronomy are so good here that I hope you will give this matter serious consideration. Your father, who has visited Williams Bay at least once, during the war, can tell you more about the type of country.

The position was made for three years, with the possibility of prolongation and the assistant professor was obliged to give an advanced course in theoretical astrophysics, in fact the first one on campus. The structure of an American academic year was somewhat different from the Danish semester arrangement, as it was nine months, consisting of three quarters, instead of the traditional Danish two-semester system at the University of Copenhagen. The fourth quarter was usually spent with research and vacation. Furthermore, the Department of Astronomy consisted of two parts, one of which was located at the Yerkes Observatory in Wisconsin, while the other and smaller one was on the campus of the University of Chicago. For the Strömgren family, this meant living on campus three quarters of the year and then residing in a small cottage close to the Yerkes Observatory in the summer quarter.

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[4] O. Struve (Yerkes Observatory) → B. Strömgren (CO), January 6, 1936, YOA. See also Appendix C: Officers of instruction at the Astronomy and Astrophysics Department, 1930-1952. Being an opponent to the idea of an expanding universe, MacMillan developed his own Newtonian alternative, as detailed in Kragh 1995.

Not only technology allured Bengt to dream about the United States. Struve had done his research well and knew how to appeal to Bengt's affection for theoretical physics and mathematics. The director managed to advertise for the University by calling Bengt's attention to the many prominent professors on campus. Among the astronomers, the mathematical astronomer Walter Bartky was pointed out. Among the physicists, Struve included the Nobel laureate Arthur Compton, and Carl Eckhart, who had made theoretical proofs of the equivalence between quantum and matrix mechanics in 1926. Moreover, there was the Dean of the faculty, Henry Gordon Gale, who had taken the place of the late professor and Nobel laureate Albert A. Michelson as head of the Physics Department. Of the mathematicians, Struve pointed out the prominent professor Gilbert Ames Bliss; finally he gave the names of some prominent physical chemists.

One can imagine the eagerness deep in the Danish scientist's heart of finally leaving Danish small-scale instruments and go for American large-scale observation technology. There were relatively few modern observatories in Europe of importance. As to physics, Europe was the strong center, but with empirical astronomy, one had to go to the States. As Elis had once visited the Yerkes Observatory, the institution did not seem completely remote to Bengt. Clearly, the young astronomer wanted to go, but what about the responsibilities as husband and father? What about his role as the professor's son, when the professor was to be retired only in a few years?

We can easily imagine Bengt's worries of leaving his well-established life in Copenhagen, not only owing to his fathers' approaching retirement. Probably some persuasion of Sigrid also awaited him. Having two small kids, it was not altogether straightforward to leave Denmark and he had to consider financial matters. This was the dilemma of many a scientist, a commonplace choice between professional career and family life. Until then, Bengt's career had highest ranking and everybody probably still encouraged his family to go for the challenge, disregarding individual wants of the supporting housewife. At the same time, prospective openings awaited the Strömgrens in the land of opportunities. Mother Sigrid "of course was not altogether pleased to begin with, considering how happy we are here [in Copenhagen]." Notwithstanding, Bengt managed to convince her to go and in a May letter to Chandrasekhar he wrote "[b]ut now she is looking forward very much too. When we asked Karin, whether she would like to go to Chicago, she said at once she thought it [was] a good idea."[5] Still, being "one of the most important opportunities I had in my whole career", seen in retrospect, Bengt was convinced that the marriage "wouldn't have prevented it."[6]

Moreover, one may imagine that Bengt immediately asked the patriarch for advice. After all, when it came to shaping his son's career, he often had the last word. Obviously, Elis thought it was a splendid and opportune idea to go to the States, but not for too long, as we will see later. Bengt had so many obligations in Denmark and the university demanded high-quality teaching. After all, Bengt had already introduced the first courses of theoretical astrophysics – and who would be able to succeed him? The only relevant prospective successor was the assistant Jens P. Møller. Julie Vinter Hansen was too busy with the Central Bureau and neither her, nor Elis, had the background, knowledge, or experience with modern astrophysics for class teaching. Moreover, in only four years' time, the university needed a professor to replace Elis and no other assistant professors of astronomy were available than Bengt.

Bengt cabled Struve the following message to the McDonald Observatory:[7]

> HEARTLY THANKS FOR OFFER HOPE TO BE ABLE TO ACCEPT AT ANY RATE FOR FIFTEEN MONTHS LETTER FOLLOWS.
>
> BENGT STRÖMGREN

Thus, Bengt was not able to stay in the States for more than fifteen months, or eighteen months as a maximum. In a follow-up letter, he explained his reasons

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[5] B. Strömgren → S. Chandrasekhar, May 7, 1936, UC, SCP.
[6] HBI, 29.
[7] Postal Telegraph, B. Strömgren → O. Struve, January 18, 1936, YOA.

Figure 2: Main entrance to Eckhart Hall – named after Carl Eckhart – on the University of Chicago campus, in which Bengt Strömgren was given an office during his first half year on campus (University of Chicago website).

for a necessary limitation of the Chicago stay. “Had I only to consider the scientific point of view I would not hesitate at all in accepting the offer,” which was “extremely tempting.” Naturally there was more to it, as he found it “very difficult to make the decision *now*, to stay in the United States for all future.” His concern was the graduate students, for whom the permanent loss of their only astrophysics teacher “would be rather serious.” In addition, being “married and the father of two small children,” he inquired whether he would get travel money. As it turned out, the university would pay $500 for travel expenses.[8] At the same time, Bengt’s modesty was lucidly exemplified by a question to Struve: “I would like to know whether there is a room available in the University buildings, where I could work.”

[8] The citations in this paragraph are all from this letter: B. Strömgren (CO) → O. Struve (Williams Bay), February 5, 1936, YOA.

Struve, thus treating Bengt's letter as an acceptance, promptly replied with the formalities, salaries, tax information, and the state of the department's library, which interested Bengt. Struve reassured him that "you will, of course, be given a separate office for your exclusive use" in Eckhart Hall on the campus.[9] With the future appointment thus settled, Bengt reported his American offer to the natural sciences faculty in Copenhagen. He expressed his desire to remain tied to Copenhagen and requested a leave from the lectureship and assistantship until January 1, 1938.[10] Then he wrote both the president of the Chicago University, Robert M. Hutchins, and Struve with his final acceptance of the position for eighteen months and his views of a bright future: "I am looking forward with the greatest pleasure to working at the Chicago University and especially to cooperating with Yerkes and McDonald. And I beg to thank you very sincerely for what you have done for me in arranging everything in such a satisfactory way."[11]

Now, how did Elis feel about loosing his son for more than a year? Struve wrote him a letter of gratitude, in which he greased his palm by praising Elis' talented son: "It will be a great privilege for all of us to be associated with so distinguished a scientist." With this letter at hand, Elis answered in a high-flown, maudlin manner (hence the somewhat lengthy quote):[12]

> And now to the topic if the day: my son's moving (with his family) to Chicago. I can assure you that I am extraordinarily pleased by this, in spite of the sad separation. Naturally it will be hard for me to be separated for long from *my friend and collaborator*. I believe that many realize what it has meant to me, to guide the development of this young man at first and then to follow his footsteps. No one would be able to feel completely right about it. And everyone will understand that the farewell will be hard. Nevertheless, I am deeply happy

[9] O. Struve → B. Strömgren, February 18, 1936, YOA (a transcription can be found at NBA).
[10] January 22, 1936, B. Strömgren → Natural sciences faculty, R.
[11] B. Strömgren → R..M. Hutchins (Chicago), and B. Strömgren → O. Struve, March 6, 1936, UCA, PP1 and YOA. Bengt reported to the faculty the absence for 18, not 15 months, on March 4, 1936, R.
[12] My own italics. O. Struve → Elis Strömgren, March 4, 1936, and E. Strömgren → O. Struve. March 18, 1936, YOA. The second letter was in German, and the translation from German into English has been made by Donald Osterbrock.

> about his new appointment. […] I am myself absolutely certain that you will enjoy working together with my son. That you rate my son highly scientifically is evident from the whole thing. I may say – and all who knows him will agree with me – that his personal qualities are at the same high standard as his scientific ones. […]
>
> Yours most respectfully,
>
> Elis Strömgren

So understandably – and pleasantly for Bengt – the patriarch was happy about the whole issue, though quietly sad about 'losing' his son for the first time. The obvious question is why Bengt had been chosen at all and which considerations had possibly motivated Struve to pick Bengt from a series of qualified candidates? And why Chicago of all places? After all, the largest observatories were located in California, not in the Mid West, even though the Yerkes Observatory was – and still is – the home of the world's largest refracting telescope.

The Entrepreneur's Dream

As thoroughly recounted in Osterbrock 1997, President Robert Hutchins and Otto Struve launched a plan of creating the best observatory and the best astronomy department in the World. The meeting of minds between the two entrepreneurs was evident from willingness in the President's Office to grant salaries and from Struve's diligent search for the best candidates on the globe.

The large American observatories in the early twentieth century were, most importantly, the central Californian Lick Observatory, which was in operation from 1888, the Mount Wilson Observatory in south California, which was established in 1904 – and then there was the Yerkes Observatory. With a grant of $500.000 from the industrialist patron Charles T. Yerkes to build an observatory in 1892, five years passed until the first star was observed through

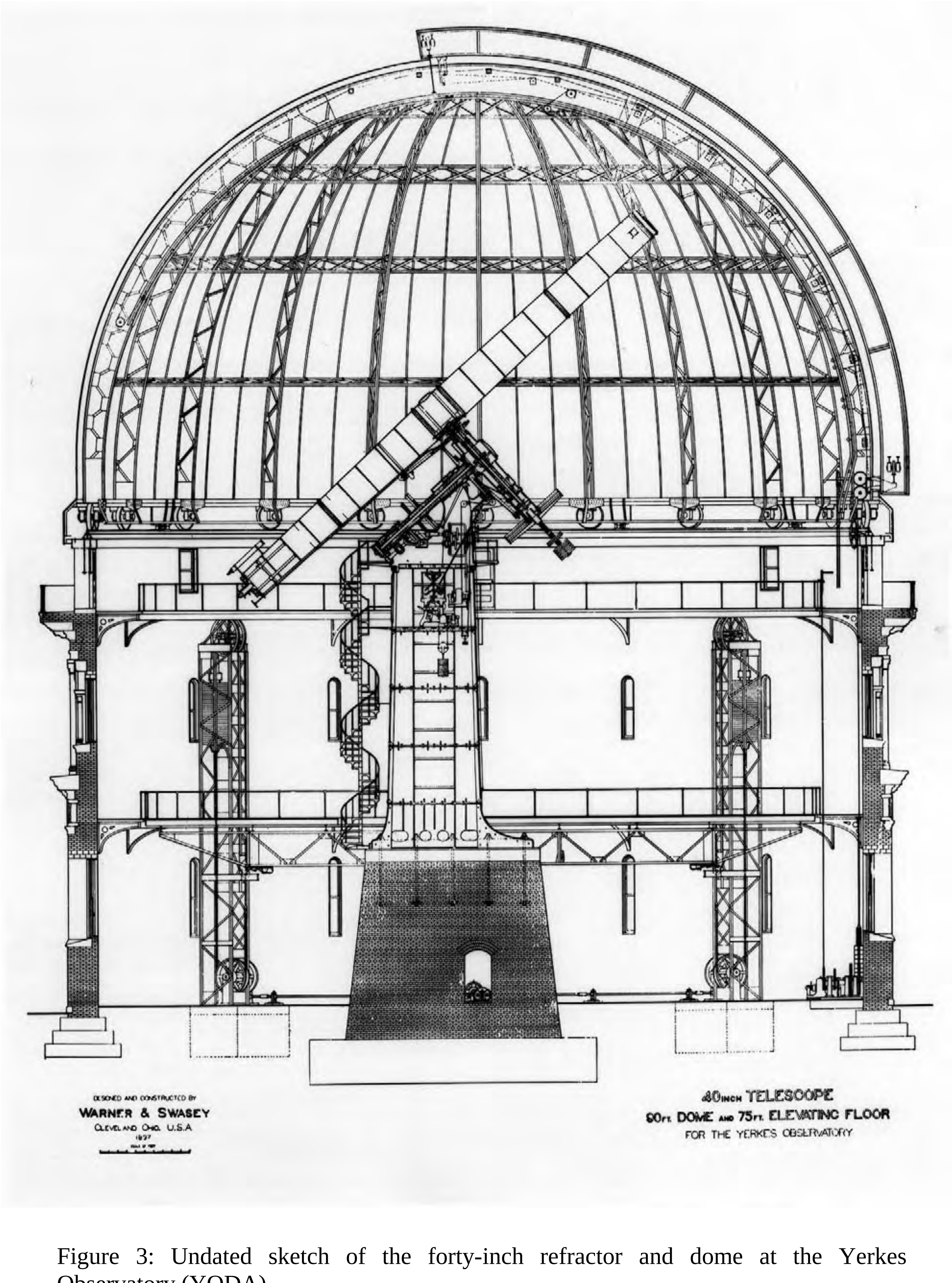

Figure 3: Undated sketch of the forty-inch refractor and dome at the Yerkes Observatory (YODA).

the forty-inch refracting telescope in May 1897 (figure 3). George Ellery Hale was the first director – and he turned out to become a very important scientific entrepreneur in the USA – but when the Carnegie Institution granted large funds for the Mount Wilson Observatory, Hale went south with his family, leaving the director's chair vacant for Edwin B. Frost. He remained director of Yerkes until 1932, when he retired as a virtually blind astronomer. Hale had managed to withdraw Carnegie's financial support from Yerkes to the project in Mount Wilson. The University of Chicago president, William R. Harper, was angry of losing Hale and threatened to cut off the Yerkes budget. Thus Frost was caught in the middle and lead Yerkes through a long depression with no weighty scientific or instrumental improvements. Nevertheless, in spite of relatively bad conditions compared with the more successful Lick Observatory, Yerkes fostered a number of PhDs with considerable impact on astronomical research; most importantly Edwin Hubble (1917), Otto Struve (1923), Nicholas T. Bobrovnikoff (1925), William W. Morgan (1931) and Philip C. Keenan (1932).[13]

With Frost's retirement, the Yerkes Observatory went into a new and progressive era. Struve had undertaken research on radial velocities of B stars until the mid-twenties. Yet, after having reviewed Cecilia Payne-Gaposhkin's doctoral thesis, which used fresh developments of Megh Nad Saha's theory, he was converted. Payne showed how measured spectral lines could be used to derive the physical conditions in the stellar atmospheres and Struve soon realized that the newest branch of astrophysics would take over more and more from the older "astronomical spectroscopy [which] consisted almost exclusively of the study of the positions and displacements of lines."[14] As assistant professor at Yerkes, Struve was of the opinion that the Yerkes refractor was antiquated and its spectrograph even more so. He applied for a position at the Mount Wilson Observatory but Struve was Russian with a remarkable family history. His lineage comprised four generations of astronomers (see chapter 1.4). According to Osterbrock, the director of Mount Wilson, Walter S. Adams, did not explicitly

[13] Osterbrock 1997, 73-74.
[14] Osterbrock 1997, 86.

recommend foreigners at American observatories. Notwithstanding, Adams appointed the German theoretician Walter Baade only two years later.

Nevertheless, Struve never made it to Mount Wilson. At the same time, the University of Chicago had appointed a new president, the young Robert Hutchins who was only thirty years old when elected. Hutchins' presence meant a new and fruitful epoch for the astronomy department – and for the university as a whole. Together with the dean, Henry Gale, he voted for Struve as Frost's successor and by 1932 Struve was promised a new reflecting telescope. This should probably not be located near Williams Bay, as this had been a rather bad site for decades with poor observing conditions. Thus motivated, Struve gradually led the Yerkes Observatory back on track as he decided it was time to build up the Yerkes staff. Unlike Frost, Struve became a demanding director, who craved productivity, good work ethics, creativity and "survivors" among his staff.[15] So far, he had hired his staff from within Chicago, but now he decided to go outside, find the best astrophysicists in the world and bring them to the Yerkes Observatory. Therefore Struve was of the impression that America hosted only few, if any, able young astrophysicists. Hutchins was indeed keen on Struve's dream of creating the best observatory. Struve was given the mandate by Hutchins and Gale, as there was no search committee or department-vote at that time. So, with the secured approval from the president and his dean, Struve was ready to go ahead with his search. He had already appointed the three PhDs William W. Morgan, Christian T. Elvey, and Philip C. Keenan, but the real change came with three additional appointments following the official approval from Gale and Hutchins.

In 1935, Struve went to a summer school at Harvard where he met with Shapley and did some opportunistic networking. Struve got advice from the prominent astronomers Shapley and Russell amongst others. From these meetings and on recommendations from other sources, he formed a list of future aspirants with the required qualities.

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[15] Osterbrock 1997, 173.

5.2 Struve's Candidates

Struve indeed made a long list of excellent young researchers, foreigners as well as domestic people.[16] But it all boiled down to three particular scientists: The observational astrophysicist Olin C. Wilson at Mount Wilson, and two theoreticians, Svein Rosseland from Norway, and the Dutchman Marcel Minneart. As Wilson declined Struve's offer, the observational astrophysicist Gerard P. Kuiper was asked instead. He was interested and gladly accepted. Kuiper, who was born in Harenkarspel in the Netherlands had studied at Leyden and moved to the USA in 1933. He was appointed at the Lick Observatory and then taught at Harvard (1935-36). Kuiper's fellow student from Holland, Bart J. Bok, was assistant professor at Harvard and recommended Kuiper to Struve and with Hutchins' acceptance, Kuiper was appointed in 1935. Following the appointment at Yerkes, he moved to the McDonald Observatory in Texas in 1939.

The successor of the soon-to-be retired professor of astronomy on campus, William MacMillan, should be the outstanding theoretical astrophysicist Svein Rosseland, who was 41 years old in 1935. Rosseland had worked at Mount Wilson in 1924-1926 on a fellowship from the Rockefeller Foundation. His appointment as professor at the University of Oslo in 1928 was followed by the directorship of the Astronomical Institute. Even though Rosseland had declined an offer from Shapley at a salary of $6,000 in 1930, Struve was told that Rosseland was now "morally free to accept a position in which he could be able to devote a larger part of his time to research", because the Norwegian institute was then "completely organized".[17] So, Struve offered him a permanent position, which he found difficult to decline. Having considered the offer for days, Rosseland still found it "difficult to come to a clear decision".[18] Instead, he suggested a temporary one-year appointment, which he would indeed be interested in. Struve acknowledged Rosseland's suggestion with Hutchins' accept

[16] This paragraph follows Osterbrock 1997, chapter 7.
[17] Struve's notes about Svein Rosseland, undated, probably 1935, YOA.
[18] S. Rosseland (Oslo) → O. Struve, September 11, 1935, YOA.

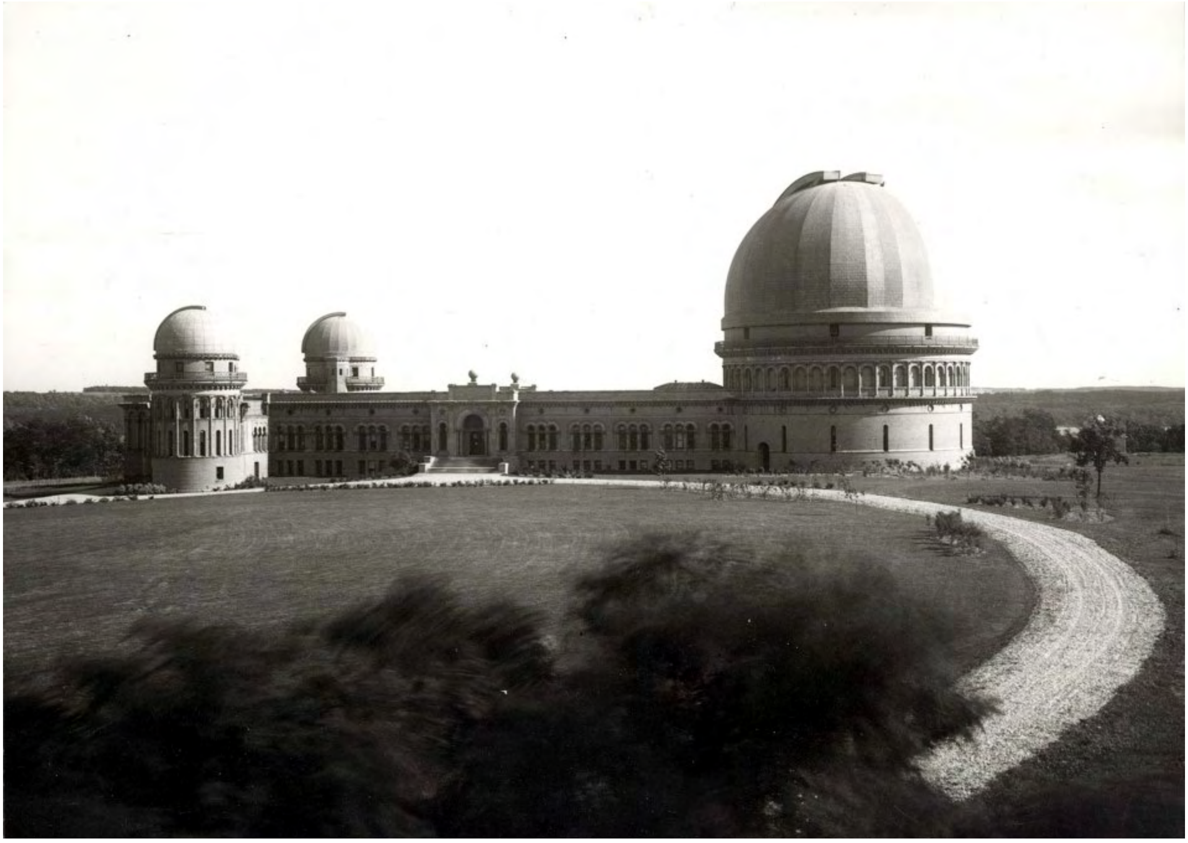

Figure 4: The Yerkes Observatory with its big dome and two smaller domes. Behind the trees in the right part of the picture, Lake Geneva peeps out. The photograph is probably taken in the early 1930'es (YODA).

and offered a salary of $5,500, $500 less than Shapley's earlier offer. Still, Struve hoped that Rosseland would chose to stay after the expiration of one year. Nevertheless, as it turned out, a month later, Rosseland finally declined Struve's offer on the basis of two local matters.

Firstly, Rosseland believed that he would "find much stimulance [*sic*] during my coming work on stellar hydrodynamics from the close contact with advanced theoretical workers in the field of applied hydrodynamics." Rosseland meant "the professors Bjerknes and Solberg, who a year ago published the imposing volume: Hydrodynamique Physique."[19] Secondly, he had plans of developing "a system of machinery for the solution of mathematical problems encountered in astrophysics and geophysics." After a visit to the Cambridge Exposition, Rosseland had seen the Bush differential analyzer and upon his

[19] Bjerknes, & Solberg 1934. Halvor S. Solberg (1895-1974) was professor of theoretical meteorology from 1930 after being a student under Vilhelm F.K. Bjerknes (1862-1951); Universitetet 1961.

return to Oslo, he started to construct a machine of higher capacity.[20] Thus, as he explicitly wrote Struve, "my secret desires when going to America would be to find a place where I could continue the work on the perfecting of mathematical machines for astronomical purposes on a grander scale than is possible here." In addition, he was not very impressed with the salary and concluded that Struve should rather look for somebody else.[21]

Struve had indeed other prospects on his mind. Neither Shapley nor Russell took the Yerkes Observatory seriously yet, or even thought that Struve was able to rebuild it into a first class research institution. So, with the still benevolent help from these two prominent astronomers, Struve's eyes fell upon two young European theoreticians, since Shapley was unwilling to spare the most obvious American candidate, the theoretical astrophysicist Donald Menzel. One of them was the German theoretician Rupert Wildt, who was engaged with a German Jew and for this reason found himself compelled to flee Germany. Russell recommended Wildt, but still he doubted his abilities to do broad astrophysical work at the Yerkes Observatory.

The other candidate was Bengt Strömgren. Already in August 1935, "Bart Bok suggested Bengt Strömgren, who," Struve believed, had done "outstanding work in certain theoretical aspects of astrophysics," but [Struve] was uncertain because of his young age – he was only 27 years old. As soon as Struve was certain that Rosseland would never come to the state of Illinois for the position, he requested Rosseland's advice instead, since he knew about matters first hand. In particular, Struve would like to know confidentially what Rosseland thought of Strömgren – if he thought that he would be a suitable candidate. Struve himself thought that "[t]he young Strömgren is probably not far enough advanced to merit a full professorship, but if he should like to come to America he would

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[20] The calculation machine was constructed by Vannevar Bush but it became obsolete by 1950 with the invention of the digital computer. For a detailed account of the mechanical machines of the 1940'es, see Thernøe 1944.
[21] S. Rosseland → O. Struve, December 5, 1935, YOA.

doubtless [*sic*] rapidly acquire the necessary prestige."[22] To Kuiper, Struve wrote of Strömgren,[23]

> He is, of course, too young to be given a full professorship but we could invite him for one year as assistant professor and hope that he would prove sufficiently valuable to be appointed permanently […]. Unfortunately I have never met him and his youth is such that he may not be entirely independent to conduct his own research.

Not knowing that Bengt was actually Struve's second choice, Kuiper was immediately sympathetic of the idea. He was "glad that you [Struve] considered B. S. as the first candidate, and I sincerely hope that he will accept the offer."[24] After ascertaining that Kuiper was enthusiastic about Strömgren, Struve went to see Hutchins to get his approval. The president was very fond of young researchers – the younger the better – and the approval was only a formal matter.

Furthermore, Struve wrote Russell that he had an impression of Strömgren's work as being "too abstract in character to be of value to the Yerkes Observatory, and this is one of the prerequisites for the position in Chicago."[25] Russell agreed that "Strömgren is good" but also that his work was "rather abstract."[26] Still, some months later he wrote that "Bengt Strömgren is extremely good to judge by his published work. I have never met him personally, but there is no question of his ability or his versatility." However, Russell apparently had forgotten that he in fact met Strömgren once, at the AG Meeting in Heidelberg in 1928.[27] Shapley, on the other hand, did not help Struve much. He was able to find imperfections in all the candidates that Struve proposed. In one of his letters to Rosseland, Struve's view of the whole state of American astrophysics was blatantly expressed:[28]

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[22] O. Struve → S. Rosseland, December 19, 1935, YOA.
[23] O. Struve → G.P. Kuiper (Harvard), December 19, 1935. YOA.
[24] G.P. Kuiper (Harvard) → O. Struve, January 7, 1936, YOA.
[25] O. Struve → Henry N. Russell (Princeton), August 28, 1935, YOA.
[26] H.N. Russell → O. Struve, September 5, 1935, YOA.
[27] H.N. Russell → O. Struve, January 3, 1936, YOA; HI, 9.
[28] O. Struve → S. Rosseland, December 19, 1935, YOA.

> It is a great pity that there are no theoretical astrophysicists in America besides Professor Russell and Dr. Menzel. It is imperative that we start a new school of thought at one of our universities and gradually develop a group of competent astrophysicists.

Probably, when Struve managed to secure all his fresh candidates to Shapley's surprise, some sort of rivalry emerged between Chicago and Harvard. Shapley tried, firstly, to get Rosseland to Harvard. Secondly, he attempted to go for Struve, but failed. Allegedly, when asked whether researchers should go to Harvard, Hutchins "time and again would say, "Why second best?""[29] Hutchins did all in his power to make Chicago look the best, seemingly even if it came to denigrating Harvard.

Now, the Danish candidate was perhaps too young and perhaps his work was too abstract but nevertheless, with Hutchins' support, Struve acted promptly and cabled Bengt Strömgren as recounted above. With Bengt secured as one of the theoretical astrophysicists, who would be stationed on campus, Struve still needed yet another researcher, since "Hutchins was quite insistent that I should try to get a second man to join the department of astronomy on campus."[30] He asked several astronomers for advice and his list came down to five persons, whom Kuiper rated in the following order: Marcel Minnaert, Subrahmanyan Chandrasekhar, C. Donald Shane, Fred L. Whipple and Robert Atkinson.[31] Russell agreed that the Dutch theoretician Minnaert was "definitely the best" choice. Unfortunately for Minnaert, though, as it turned out, Hutchins objected that Minnaert was too old after having met him at a Chicago conference in early January. According to Osterbrock, Struve asked his colleague George Van Biesbroeck about Minnaert's age and swiftly "relayed his guess, fifty, to the president."[32] Also the Dutch astronomer Kuiper wrote Struve that "I had not realized that his age is close to fifty, as professor Van Biesbroeck says, but quite

[29] HBI, 35.
[30] O. Struve → H.N. Russell, January 2, 1936, YOA.
[31] G.P. Kuiper → O. Struve, February 8, 1936, YOA.
[32] Osterbrock 1997, 177.

possibly that is correct. Minnaert gives the impression to be not over 40, on account of his vitality."[33] In reality, Minnaert was only 42, but by the time Kuiper got the correct answer from a Dutch friend, it was already too late. Minnaert was never invited to Chicago and the next on Kuiper's list was in line to be given the offer.

As soon as Struve received Bengt Strömgren's affirmative answer, he was ready to go for Chandrasekhar as the theoretician to complement Strömgren. Hutchins was very favorable to that choice and suggested Struve to write Chandrasekhar as soon as possible. Serious consideration indeed paved the way to his decision and not only scientific matters were taken into account. Russell valued Chandrasekhar highly in a letter to Struve:[34]

> He is the most brilliant of the group and bids fair to be one of the best men of the coming generation in theoretical astrophysics. He has an admirable training and a pleasing personality. He is very young – I believe only 25. As you may know, he is at Harvard now. […] His political views are pretty radical but I don't imagine that you [*sic.*] will prejudice him with President Hutchins.

Shapley, on the other hand, was not as praising and wrote Struve that Chandrasekhar was "more a mathematical physicist than as astronomer". He seriously questioned the advisability of getting him for the department. In a letter to Hutchins, Struve cited Shapley for writing about the 'radical' Chandrasekhar, "He is a communist, as is pretty well known and he does not hesitate to talk politics very vigorously. He admits that he is much interested in politics, especially in England." At the same time, Shapley did not consider "the radicals" to be a "disadvantage in the faculty".[35]

> I grant that they might be dangerous in a state university but how troublesome in a place like Chicago University only Mr. Hutchins can judge. You probably

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[33] G.P. Kuiper (Harvard) → O. Struve, January 7, 1936, YOA.
[34] H.N. Russell → O. Struve, January 3, 1936, YOA.
[35] O. Struve → R.M. Hutchins, January 13, 1936, PP1.

> know that Chandrasekhar is extremely dark, but he has the bearing of an aristocrat.

The young president replied Struve rather emphatically,[36]

> the only consideration which should be permitted to affect Chandrasekhar's appointment is his distinction and promise as a scholar. I am not interested in his political views […] Nor am I depressed [*sic.*] by your suggestion that Chandrasekhar's work is abstract or that he is a mathematical physicist or that Shapley questions the advisability of your getting him. The only instance that I know of when Professor Shapley showed good judgment was the occasion when he invited you to Harvard.

Not exactly impressed by Shapley's judgment, Hutchins seemed rather tired of such unscientific arguments; but there was more to it that that.

Even Kuiper had informed Struve that Chandrasekhar was what most of them called "of the Oriental race". As Osterbrock describes so well, Chandrasekhar was "aristochratic and handsome", having rather dark skin and in many parts of the United States he would be considered black.[37] Dean Gale was an outspoken bigot, which both Hutchins and Struve knew all about.[38] Gale was not interested in having a dark Indian lecturer on campus and obviously Gale's small prejudice instigated annoyance in Hutchins' mind. In a rather opportunistic letter to the dean, Struve expressed his own "grave doubts" regarding the appointment of Chandrasekhar, "not because of his scientific work […] but because of his nationality […]. His complexion is of course quite dark, but his features are quite different from those of the American Negro". He went on about the rumors of Chandrasekhar's radical political views that "I do not know how serious this would be but an astronomer-politician has always seemed to me to be an absurdity and I cannot very well imagine that there is anything dangerous in

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[36] R.M. Hutchins → O. Struve, January 15, 1935, PP1.
[37] Osterbrock 1997, 179.
[38] Osterbrock 1997, 180-181.

his behavior."[39] Russell also saw some difficulties in hiring Chandrasekhar: "It seems to me to be very hard for westerners and Asiatics to become really acquainted."[40] Regardless, only one week after receiving Bengt's acceptance of the offer (February 18), Struve made up his mind and wrote Chandrasekhar to offer him the position (February 25) with the back-up of Hutchins and during a visit of Chandrasekhar to Yerkes in March, Struve was only more convinced of the Indian theoretician's extraordinary ability.

Clearly, it was not altogether easy for dark foreigners in Chicago in the 1930'es, but in Williams Bay, Struve was confident that life would be gentler to foreigners than on campus. In a formal letter to Dean Gale, Struve praised Strömgren and Chandrasekhar to the skies. He wisely wrote that after Chandrasekhar's visit to Yerkes, he was told that "a definitive effort has been made at Harvard to retain him there, and I strongly suspect that this is, at least in part, caused by rumors that we are interested in him."[41] Therefore, by underlining the urgency to choose whether or not the University of Chicago should go for Chandrasekhar, Struve would like to know Gale's opinion immediately after the candidate was presented to the dean on the same occasion. During Chandrasekhar's visit at Yerkes, Struve got his definitive acceptance of the offer, but this was before they went to campus to meet the bigot dean. Struve wrote Hutchins about what had happened at this event:[42]

> I was afraid that he [Chandrasekhar] would be unusually sensitive with respect to the reception he received in Chicago, and I feared that he may have had the impression that he would not be welcomed on the campus […] I had no opportunity to discuss this matter with him before he took the train for the East, and I am not certain that my interpretation of the situation is correct. Whatever the reason, he has informed one of his friends at Harvard that "Although I had told Dr. Struve that I would like very much to go to Yerkes, I still feel personally undecided."

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[39] O. Struve → H.G. Gale, February 3, 1936, UCA, PP1.
[40] H.N. Russell (Princeton) → O. Struve, February 5, 1936, YOA.
[41] O. Struve → H.G. Gale, March 4, 1936, UCA, PP1.
[42] O. Struve → R.M. Hutchins, March 23, 1936, UCA, PP1.

The friend was Gerard Kuiper. Curiously, the very same day, Struve sent an affirmative letter to await Chandrasekhar when he came back to Trinity College, in which he expressed his joy in Chandrasekhar's decision to come to Yerkes. He continued:[43]

> I am confident that the addition to our faculty of Strömgren, Kuiper, and yourself will mean a new chapter in the history of the Yerkes Observatory. I cannot recall a single instance in the history of astronomy when three men of so closely related scientific interests were at one time added to the staff of the same institution; and it is certainly no exaggeration to say that we shall now have the best group of astronomers in the world.

The first and most important hurdle of getting the right promising staff to Yerkes made it seem as though Struve and Hutchins' dream would come true. Kuiper's meeting with Chandrasekhar at Harvard changed his impression of the brilliant astrophysicist to the even more positive after having scientific discussions with him. Even before the meeting, he assessed that "Chandrasekhar classes out Minnaert as the first solar physicist now living, considerably above Unsöld, who made several mistakes in theory, and is not a very good observer." Furthermore, he compared a certain pair of prominent British astrophysics to Strömgren and Chandrasekhar as follows: "The present state of our knowledge of stellar structure is largely due to him and B. Strömgren, not to Milne and Eddington.[44]

But Chandrasekhar was still undecided, as he let Kuiper know in a letter. From the fact that Struve had already mentioned an appointment date of January 1, 1937, Kuiper thought that everything was arranged. Now knowing that Chandrasekhar was still undecided, he wrote him a letter to his boat, which might help bringing a quick decision and in the same instance he wrote Struve, "There is just one possibility which I can see, which may make him hesitate to accept: the question of the race problem. That would then apply to the U.S.A. in

[43] O. Struve → S. Chandrasekhar (Cambridge), March 23, UCA, PP1.
[44] G.P. Kuiper (Harvard) → O. Struve, January 7, 1936, YOA.

general."[45] Struve, on the other hand, foresaw no difficulties unless Chandrasekhar himself would not get "cold feet". As the racial question was regarded "quite serious", Struve was not certain that "even with the best intentions on our part we shall be able to avoid all humiliations for him". However, Struve found the effort distinctly worthwhile and if they all worked together towards the same end they should "doubtless be able to retain him on our staff".[46] Six days later, Struve reassured Kuiper that Chandrasekhar had officially accepted the appointment in a cablegram.[47]

Struve had been quick at pulling the trigger, as he informed Bengt about Chandrasekhar's appointment already by March 12. Clearly, this letter was sent to Copenhagen immediately after Chandrasekhar's initial, if only oral, acceptance of the offer, but before his doubts came to light. Struve wrote Bengt that he was "amazed to find how closely related his [Chandrasekhar's] work is to yours". He continued: "For many reasons it seems best to have him [Chandrasekhar] spend a considerable fraction of his time at the Yerkes Observatory".[48] The important reason was obviously the racial issue, which turned out to be solved naturally by the arrangement that Bengt should spend his first time in Chicago, so the Yerkes staff was well represented on campus. In April, Bengt wrote Struve that he was "very glad indeed" to learn about Chandrasekhar's coming to the department, not least because "I consider him to be a very good friend of mine". One month later, Bengt asked for Chandrasekhar's forgiveness "for not having written at once to tell you how happy we should be if you came to the Yerkes Observatory, while we are in Chicago. I really hope you will accept the offer."[49] Undoubtedly, Bengt was thrilled to be reunified with his colleague and friend, whom he had first met in Copenhagen, where Chandrasekhar quickly learned Danish language. At the end of it, Otto Struve had found three of the most able young astrophysicists – and all

[45] G.P. Kuiper (Harvard) → O. Struve, March 20, 1936, YOA.
[46] O. Struve → G.P. Kuiper, March 21, 1936, YOA.
[47] O. Struve → G.P. Kuiper, March 27, 1936, YOA.
[48] O. Struve → B. Strömgren, March 12, 1936, YOA.
[49] B. Strömgren (Copenhagen) → O. Struve, April 6, 1936, YOA; B. Strömgren → S. Chandrasekhar, May 7, 1936, UCA, SCP.

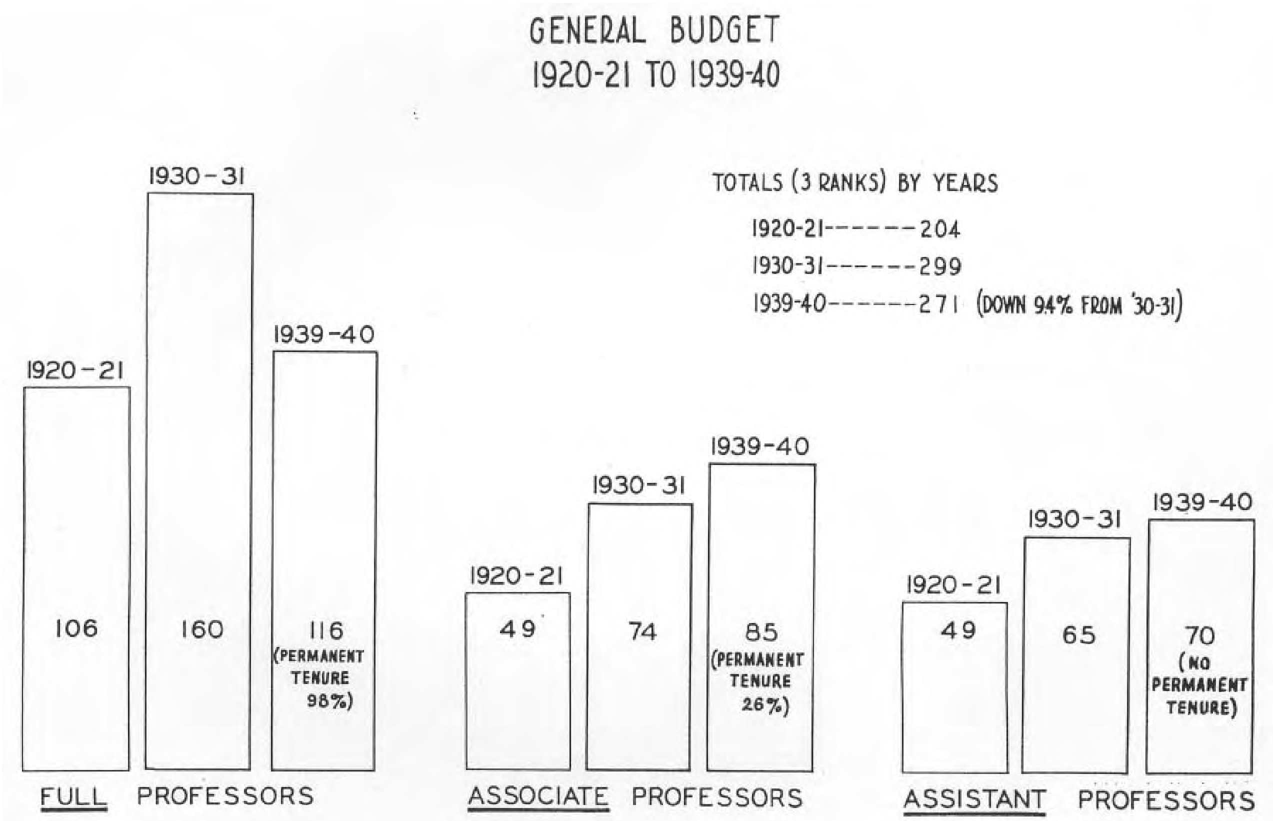

Figure 5: Size of professorial staff for instruction and research, general budget of the University of Chicago, 1920-1940 (UCA, PP1).

by second choice. Wilson had declined to the benefit of Kuiper; Minnaert's mistaken age resulted in getting Chandrasekhar instead; and Rosseland's business in Norway brought Bengt Strömgren into the picture.

Leaving Danish Academia

As Bengt formally accepted the Yerkes offer in late February, he had roughly half a year left for preparations and completing obligations that he was not interested in bringing with him to the United States. Mrs. Struve and Sigrid were in contact by mail and fixed a large list of practicalities. Bengt applied for visas at the American vice-consul and even applied for a visa to their young nursemaid, Annie, who helped Sigrid with household and nursing their two infant children, Karin and Nina. The young Strömgren family even subscribed to the *Chicago Tribune* in order to get acquainted with the conditions in the big city.

Bengt's eighteen months in Chicago and Yerkes were scheduled to begin on October 1, at a salary of $4,000 per year. In addition, the University Board of Trustees agreed to pay $500 for the travelling expenses of his whole family.[50] At the time, 1 dollar equalled ca. 4.44 Danish Kroner. Compared with Danish salaries, $4,000 was thus nearly 18,000 Danish Kroner, which was an enormous wage for an assistant professor. American expenses turned out to equal that high standard, though, as the rent for their first apartment was $765, that is, 3,400 DKK. The income of the other astronomers was in the same neighbourhood; Bartky had the same wage in spite of his professorship; Kuiper's salary was increased in late 1937 from $3,700 to $4,000, while Morgan's salary as assistant professor was only $3,000 at the time of Bengt's arrival. At this time, Struve's income was increased by $1,000 to $7,500. The average salary of assistant professors at the University of Chicago were less than Bengt's initial salary, namely ca. $3,500 a year. While associate professors earned a little more than $4,500, full professors' wages were around $7,000 in 1936-1937. Even though the salary scale was lower than at Harvard and Princeton, we conclude that from a local point of view, Bengt was relatively well paid from his first day in Chicago.

Bengt's appointment would be met by the salary of professor MacMillan who retired the coming fall. In recommendation of Bengt's appointment, which was sent to Hutchins' secretary, Emery T. Filbey, Dean Gale noted that concerning an eventual prolongation of the appointment period, Bengt "would prefer to reconsider the matter at the end of the period".[51] If one asked Bengt himself, or his father for that matter, this was evidently not the case. The idea was ultimately to stay only for eighteen months, regardless of Struve's hopes. In fact, only six days after Bengt and his family arrived in Chicago, Elis wrote Bengt that his future position was as good as secured, as we shall see in chapter 5.3.

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[50] Appointment documents, February 24, 1936, UCA, PP1.

[51] H.G. Gale → E.T. Filbey, February 20, 1936, UCA, PP1.

The travel plan was to leave Copenhagen in mid-September, arrive in New York and reach Chicago by train one of the following days. The handling of academic responsibilities in Denmark during Bengt's leave were described in a letter to the natural sciences faculty, including the examining of six students with astronomy and/or astrophysics as their chief subject.[52] Struve had already secured two astrophysics courses for Bengt, Theoretical Astrophysics and Problems in Astrophysics, which were to be given in autumn and winter terms respectively.[53] But Struve warned Bengt not to make the courses too advanced, "since we have never had any competent instruction in astrophysics." More than that, Struve asked Bengt not to spend too much time in the preparation of his lectures and instead use the notes and lectures from his Danish teaching. The reason for this was obvious: "The President and the administration of the university values particularly your research ability and they hope that your time will permit you to devote your energy primarily to research and not so much to teaching."[54] So Bengt knew how to prepare himself for the trip and between teaching and preparing, he met one person in particular, who helped him set off a very significant project.

In springtime 1936, a garden party was held at the Copenhagen Observatory. One of the visitors was the German physicist Friedrich Hund, famous for his work on the structure of atoms and molecules. During "a long discussion" with Bengt "of the question of stellar structure", he suggested that Bengt wrote an article for the *Ergebnisse der exakten Naturwissenschaften* on problems of the internal constitution of stars.[55] The article was to follow one that Hund himself intended to write concerning the equation of state of stellar interior matter. Bengt agreed with Hund to write the article before he left for the States. He did all the preparations and gathered the material, but as it turned out, it would not be until he was well installed in Chicago that the text finally fell into

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[52] B. Strömgren → University of Copenhagen natural sciences faculty, March 11, 1936, R.
[53] UCA, OPUC, 1936-37, 229; Otto Struve → B. Strömgren (Copenhagen), March 18, 1936. See appendix D.
[54] O. Struve → B. Strömgren, April 9, 1936, YOA.
[55] B. Strömgren 1983, 3.

place.[56] This exemplifies co-work of physicists and astrophysicists in the late 1930'es and the article turned out to become a well-cited classic in its field, because Bengt managed to collect existing knowledge and put it together into one comprehensive and coherent text. This was of use to many researchers, although it was written before the theoretical physicist Hans Albrecht Bethe's work on the carbon cycle. Moreover, it was the article that introduced the physicists to stellar interiors rather than Eddington's *ICS*, even though it was written in German.[57]

During the summer vacation, Bengt went to the family's new summer house in Asserbo in the Northern parts of Zealand, which they kept during their stay in the States; they were certain to come back. "I have been obliged to bring some of my work with me, but in the afternoon and in the evening I join the others", wrote Bengt to Chandrasekhar in July. "I think you would enjoy it, though in some respects it is a primitive life we are leading. The bathroom is in a sort of tent hidden by trees near the house!"[58] Soon after the vacation, he was ready to pack his papers in suitcases and the family was altogether prepared for the exciting journey to the States.

Bengt had great and ambitious plans for his future research in the States. In August, Bengt wrote Struve about his prospective future activities. And there was enough to get going.[59] First of all, Bengt intended to continue the purely theoretical work on stellar interior and stellar atmospheres, which he was carrying out in Copenhagen. Of special interest were problems concerning stellar models with convective cores and in stability problems. Furthermore, his objective was to investigate the problem of hydrogen content of stellar atmospheres and that of the quantum-mechanical calculation of their continuous absorption coefficients. In a more distant future, he wished to examine the theory of subordinate stellar absorption lines and to work in the field of the theory of novae. However, he was "particularly looking forward to work, which require

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[56] HBI, 38.
[57] HI, 15.
[58] B. Strömgren → S. Chandrasekhar, July 22, 1936, UCA, SCP.
[59] B. Strömgren (Copenhagen) → O. Struve, August 15, 1936, YOA. Quotations in the remaining part of this paragraph are from this source.

close cooperation between theoretical and practical astronomy." In this respect, he thought of problems, which had arisen in connection with his work on the interpretation of the Hertzsprung-Russell diagram. He looked forward to discussions with Kuiper on many of these issues and finally he was able to do work that was not possible in Denmark.

Then, he was interested in special problems of spectral photometry, both of the continuous spectrum and of spectral lines that were connected with the theoretical work on stellar atmospheres. He figured that detailed comparisons between theory and experiment would turn out to be fruitful. Especially if the result of investigations of hydrogen content of stellar atmospheres should confirm the view that the continuous absorption in A-star atmospheres was practically due to hydrogen alone. An important effort in this connection would be to refine both theory and experiment.

More than that, as most of Bengt's protracted work in Copenhagen on photoelectric registration of meridian transits had taken place at the UITF, he asked Struve if he could perhaps utilize his experiences in this field for astrophotometric work in the Ryerson Physical Laboratory, which was conveniently located just next to Eckhart Hall. Bengt had studied Christian T. Elvey's photoelectric work "with the greatest interest". He thought it would be "a great satisfaction to me if, as a final result, a highly sensitive and yet convenient photoelectric photometer could be constructed and utilized in the solution of some astrophysical problems."[60] Elvey was transferred to Texas in 1935, as the first University of Chicago faculty member stationed there. He was assistant director in charge of the McDonald Observatory, but without the title.[61] Elvey and his associate Franklin E. Roach, who was Struve's first PhD student after he had become director of Yerkes, had been put to work measuring the spectra and surface brightness of galactic nebulae, which was the only possible program with small telescopes, until the large eighty-two inch reflector was completed in 1939.

[60] Ibid.
[61] Osterbrock 1997, 192.

In addition to instrumentation work with photometry, Bengt proposed to continue his work with geometrical optics, which had interested him for some years.

In conclusion, Bengt's optimistic and ambitious plans comprised involvement in most existing fields of modern astronomy at the time: Investigation of theoretical astrophysics of stellar interior and atmospheres, undertaking quantum mechanical calculations, refining methods in practical astronomy and its cooperation with theoretical astrophysics, working with geometrical optics and developing and building new instrumentation. Bengt clearly showed his depth as well as his broadness in the fields of astronomy, but perhaps they comprised all too many and too ambitious initiatives in the optimistic mind of the young researcher. Moreover, perhaps his many goals expressed his gratitude to having been chosen for the position rather than constituting a realistic plan for future work. After all, he was already a skilled researcher and arguably, he may have regarded his future time of only eighteen months in Chicago and Yerkes to become vastly more productive than had it been in Denmark.

5.3 The Strömgren Correspondence

Science is not national, but scientists are
Louis Pasteur, 1884.

The 1930'es were times of change concerning international contact patterns. Earlier, France, England, Russia and Germany mainly constituted the central parts of the astronomical world map, also as considered from Denmark. There was an orientation towards Eastern or Southern institutions like the Russian Pulkova Observatory outside St. Petersburg or German observatories. Yet, from the decade before the Second World War, student tours to the USA became still more frequent and the number of applications to American observatories and other research institutions increased. The orientation of Danish astronomy

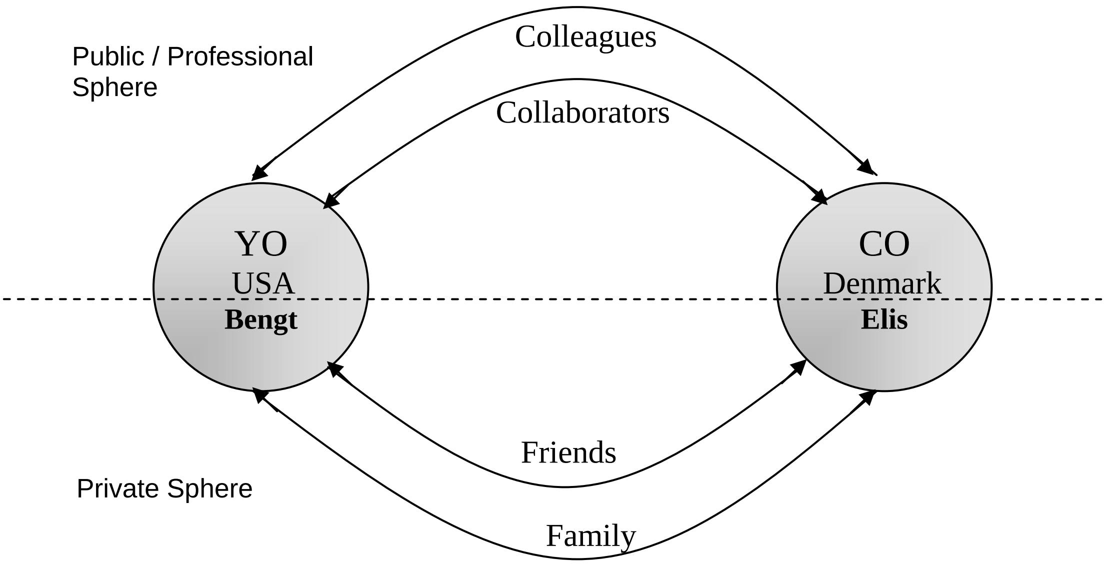

Figure 6: Diagram of four important aspects of the Strömgren Correspondence, 1935-1939, between Elis and Bengt Strömgren at the Copenhagen (CO) and Yerkes (YO) observatories. It is divided in a public – or professional – sphere and a more private sphere; they wrote professionally as both colleagues and collaborators; and they corresponded privately in the capacities of both friends and family.

towards the West became apparent in the 1930'es, as it also happened in e.g. Sweden in the 1920'es and 1930'es.[62] As already recounted, there were political-economical motives as well as techno-scientific reasons for the Western orientation of Danish astronomy – and of Scandinavian astronomy in general. One important reason was the boycott of German astronomy, which hampered international contact between astronomers inside and outside Germany in particular. Lack of resources, dismissals of scientists, and the shut-down of projects testified the negative development. Scientifically, the growing progress of American astronomy was initiated already from the turn of the century. Instead of going to Paris, Pulkova or Berlin, astronomers gradually went more to American research institutions like George Hale's Mount Wilson Observatory. With Struve's revival of the Yerkes Observatory, this also gradually became a more popular catalyst for improving the career of foreign astronomers; this also holds for Bengt Strömgren.

[62] Holmberg 2003, 198; see also Holmberg 1999 for an account of Swedish astronomy until 1940.

After Bengt moved to Chicago with his family – and later to Williams Bay in March 1937 – obviously father and son needed to communicate by mail instead of the daily oral dialogues in the rooms of the Copenhagen Observatory, which has clearly not been saved for future historians. They did so in Swedish and they did it quite frequently. Of 131 letters between Elis and Bengt in the period 1935-1939, only nineteen letters were written before or after the two astronomer's separation, yielding an average correspondence frequency of almost seven letters each month in the period while Bengt was in the States.[63] In addition, various letters were naturally sent both ways between other members of the family, with Hedvig and Sigrid Strömgren as particularly active writers. The correspondence between Bengt and Erik was rather limited, as they were probably both too busy with their respective work to write each other more than short greetings, even though Elis also attempted to persuade Bengt to write his younger brother more than he did.

Quoting Elis' letter to Struve on page 212, the designation "my friend and collaborator" indicates his perception of the relationship between himself and Bengt, although other aspects and more nuanced levels may undoubtedly have existed between father and son. On the other hand, since Elis Strömgren was regarded by his granddaughter as "a strict dictator who favored his oldest son," and since Erik Strömgren allegedly even "hated his father" until he passed away in 1947, arguably the view of the father-son relationship was very dependent on the point of view.[64]

Meticulous descriptions of theoretical and practical activities at the Copenhagen and Yerkes observatories can be found in the correspondence, as could probably be found in any correspondence between two *friendly colleagues*. Then, discussions went on about the community of scientists at the new host institution in Chicago, interchange of knowledge and practical advice regarding instruments, observation methods, exchange of scientific results and transfer of knowledge to European and Scandinavian readers (mainly through *NAT*).

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[63] ESC, "The Strömgren Correspondence", 1935-1939.
[64] KNSI.

Another important aspect of the correspondence is the *collaboration* between the director and the assistant professor. This was manifested by joint publications, such as the translation of their substantial monograph *Lehrbuch der Astronomie*, scheduling of education and examinations, and production of exercises for students. Elis played the role as Bengt Strömgren's director, when he decreed the young Strömgren to undertake various obligations for the CO. The fact that these friends and collaborators where also family complements the history with an interesting additional factor.

Elis played the natural role as Bengt's father. Being both director and father made it perhaps even easier for him to dictate what Bengt should – and should not – do and when things should be done. Messing with their private sphere brings forth knowledge of their political interests and attitudes, fatherly advice on grave or important choices in life, insider information, gossip about other colleagues, feelings about sad cases of Jewish scientists having job-difficulties, and much more. His strict way of conducting Bengt's professional life is apparent throughout the Strömgren correspondence, as will also become obvious henceforth.

Going Abroad and Securing Home Position

Bengt arranged the trip with a Danish captain, who booked two cabins on a steamship from Ireland to New York City. Sigrid, Bengt, Annie, and the girls caught the train from Copenhagen through Hamburg to Bremen in Germany. From Bremen, they took a boat to Cobham – now Cork (Cobh) – in Ireland.[65] From Ireland, they travelled by the high-class steamer "S.S. Columbus" on a very windy trip to New York City. The party of five filled a whole cabin with their luggage and they stayed at Hotel Taft in New York. They just had time for a sightseeing in the morning and after admiring the Empire State Building, they shared two compartments in the train to Chicago where Otto Struve met them by car. First thing was the University. After a tour on the University of Chicago campus, Struve drove them to Williams Bay. Then, they were lodged in "a whole

[65] B. Strömgren (Ireland) → E. Strömgren (Copenhagen), September 13, 1936, ESC.

Figure 7: S.S. Columbus, the very steamship that brought the Strömgren's from Ireland to the USA (courtesy of Nina Strömgren Allen).

guest apartment" in the outsized director's mansion next to the observatory building.[66] Little did they know that this would become their own home for six years in the future.

On their second day in Williams Bay, Bengt and his family went to an "astronomer's lunch", where they met the whole staff at the Yerkes Observatory. Present were the physics research associate George W. Moffit; professors of practical astronomy, Frank E. Ross and George van Biesbroeck; the astrophysics instructors Philip Keenan and William Morgan; the German visiting astronomer Hans Rosenberg; the assistants Mary R. Calvert, Louis Henyey and E.L. McCarthy; and the assistant professor of practical astronomy Gerard G. Kuiper. They were all there and Bengt found them "all nice and kind."[67]

Next morning Struve brought Bengt and his family back to Chicago to meet the dean and Bengt would finally look over his office at Eckhart Hall as well as the lecture hall. The campus astronomer, associate professor Walter

[66] B. Strömgren (Chicago) → E. Strömgren (Copenhagen), September 26, 1936, ESC.
[67] Ibid; see also Appendix C.

Bartky, was also present at the meeting and Bartky and his wife followed the party to help the Strömgrens find a place to live. They visited apartments and houses on campus from a list made by the university's apartment office and a rental firm. One house and one apartment were the results of the hunt and the Strömgrens finally chose an apartment on 5229 Dorchester Avenue, "ca. 15 minutes walk from the university, 5-10 minutes from Lake Michigan and ca. 5 minutes from an Illinois Central Station to the Loop […]. The apartment is nicely furnished with oriental carpets and a Steinway grand piano."[68] Bengt continued: "the rent is $90 a month including heat; probably no more than the rent for the apartment without the furniture. The owners were eager to have very fine people, preferably from the university. They told [us] with much aversion that a brewer would have rented the apartment." This was a time of coal heating and as Struve wrote to Bengt, he would better decide whether to buy one ton of briquettes for $11 or if he rather would like to go for half a ton for the furnace.[69]

Two days later, the day before Bengt's first lecture, he was invited for lunch with President Hutchins. He told his father that Struve was very proud about that, "since Hutchins never before used to greet new professors. Struve says that Hutchins is very interested in astronomy at the university and at the observatory."[70] Struve, Gale and Kuiper were also invited for the lunch. The same day as Bengt gave his first lecture, he received a hush-hush letter from his father about future plans.[71]

> I was invited to a very successful dinner party […] by Edvard Saltoft together with [Danish Prime Minister] Stauning, the permanent under-secretary of state Graae, Police Director Thune Jacobsen […] and several other prominent figures […]. On this occasion I had an interesting conversation, which must be considered strictly confidential (this must under no circumstances be brought to Denmark). […] Graae approached me immediately and informed me that the

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[68] Ibid. "The Loop" is the local Chicago place name which simply signifies downtown Chicago.
[69] O. Struve → B. Strömgren (Chicago), October 7, 1936, YOA.
[70] Ibid.
[71] E. Strömgren → B. Strömgren, September 29, 1936, ESC. Edvard A. Chr. Saltoft (1883-1939) was a famous (portrait) painter, and among many prominent Danish statesmen, he painted Prime Minister Stauning, King Christian X, and the geologist Lauge Koch (Engelstoft 1952).

> Ministry of Education the very same day had received a document from the Ministry of Finances, in which they endorsed […] that an extraordinary professorship will be given to B.S. from April 1, 1938 [under certain formal conditions].

According to Elis, this clearly paved the way for B.S.'s, i.e. Bengt Strömgren's, return to Denmark: "Hence, I assume that you will return in 1938 (a prolongation can possibly be obtained, if necessary)." By mingling with the top of Copenhagen high ranking figures – and perhaps even by pulling strings on the right occasions – Elis knew about things before others did. In effect, his son was naturally one of the first persons to know about the ministry decision. On the same occasion, the Police Director asked Elis in a teasing way as to the origin of the intellectual standard of both his sons, "whether it derives from the father or both their parents. To this I answered […] chivalrously". Apparently, Elis had been considerate enough also to give Hedvig part of the hereditary credit, but arguably with a fairly ironic touch.

Only one week later, in fact, the Education Ministry wrote their proposal of Bengt's future appointment as extraordinary professor to the natural sciences faculty, which was to be cancelled by January 1940. In a late October faculty meeting, the proposal was discussed and it was agreed that the ministry had not acted according to the wishes of the faculty. Apparently this was because the faculty did not want the extraordinary professorship to be annulled when the ordinary professorship would be vacant after Elis Strömgren's retirement in 1940. As it turned out, the ministry had its way, regardless of the voices of the faculty headed by the dean, the professor of comparative anatomy, Carl M. Steenberg.[72]

Obviously, this confidential letter from Elis was of tremendous importance to Bengt. He knew with great probability that he was secured a distinguished position back home whatever happened in the United States. Bengt replied to his father that he would tell no one about the professorship. Only when

[72] Faculty meeting, Tuesday October 27, 1936, ESC.

the matter was definitely settled, Struve would be informed and Bengt assured his father, "as you know, I hope that cooperation between Yerkes and McDonald can be established. Struve has told me, that the future of theoretical astrophysics in America is the most serious issue in American astronomy at present." This was evidently another of his many plans with the research visit: To establish a connection between Danish and American astrophysics.[73] In the years to come, he succeeded in fulfilling this wish to some extent although the Second World War turned out to delay the efforts considerably. In a somewhat warmer reply, Elis attached a letter from the ministry, accompanied by the words of a more respecting, less dictating, but still melancholic father:[74]

> But regard it as confidential for the present. First and foremost nothing to Struve or the American authorities. Not until it is necessary. Also because I think that it would be wrong of you not to stay in America, where you also have greater opportunities of using your abilities in the best ways. It is […] a great victory for you and your friends. But otherwise there are many circumstances here in the close surroundings that you should take into account when it comes to making the right decision. If you will listen to me, then please do: Not for one moment have I been wistful since you left. I still live in the thought that you and your family will do as good as you could ever wish for. The small problems in daily life are over with, and I concentrate on the memory of all the best that once was.

One can hardly help thinking that the rhetoric of Elis' kept a hidden agenda of having Bengt think more about the need in Copenhagen for his coming back to succeed his tired father. Not least because in the end of the letter, Elis could not help expressing his sincere wishes once again: "Yes, Bente, now I have no more to tell you. It would indeed be lovely to have you here and as member of the faculty, my last years, but… Well, this is a question for later times." On the other hand, Elis explicitly uttered that it was up to Bengt for himself to decide.

[73] B. Strömgren → E. Strömgren, October 12, 1936, ESC.
[74] E. Strömgren → B. Strömgren, October 26, 1936, ESC.

A New Environment

Entering the University of Chicago was quite an overwhelming experience. Everything was bigger than in Denmark, the "Quadrangles" on campus hosted so many internationally distinguished scientists, more students followed natural science classes and then naturally there was the close connection between campus and the remote observatory in Williams Bay, while the McDonald Observatory was nearing its completion in Texas. Arguably, the need for a Danish remote observatory under the University of Copenhagen became still more apparent in Bengt's mind during his stay in the USA. It all seemed big to Bengt, "coming from the small European places. It was [large]."[75] And even on an American scale, Chicago was large for an American astronomy department. There was no such teaching of theoretical astrophysics on the West Coast, as Bengt pondered, "The Mount Wilson people weren't in the least interested in that. That would disturb their activities of observing, utilizing Mount Wilson and the coming Palomar." On the East Coast there was Harvard, but the astronomy staff had not yet reached the point where they would give a broad-based education in physics.

The Yerkes Observatory's expense budgets constituted 0.2-0.3% of the University of Chicago general budgets (in 1937 the Yerkes Observatory budget was of $12,579, while the total university budget was of ca. $5,000,000). This percentage constituted maintenance of the buildings and related expenses. In addition to the general budgets, professorial salaries were obviously the all-important factor of university economy. A major difference between Scandinavian and American universities was the types of income flow to the institutions. In the period 1929-1939, student fees contributed 31% of the total income, various endowments added with 36.6%, sales, services, and sundry with 18.3%, and the remaining income of 13.8% came from gifts and grants.[76] The Danish universities were essentially funded by the state and thus supported by

[75] HBI, 34. Next quote comes from the same source.
[76] UCA, PP1, October 26, 1938 (general budgets); UCA, PP1, January 24, 1939 (general budgets).

the Danish population through taxes. I addition, of course, grants played a major role in the general budgets of Danish research institutions.

Bengt basically taught elementary and advanced astrophysics on campus the first six months, i.e. the fall and winter quarter. At the same time, Struve put the graduate student, Gordon W. Wares, to work making tracings of stellar spectra for Bengt to use in his theoretical research (Wares was assistant from 1939, see Appendix C). Bengt worked on problems of stellar atmospheres, which he also "discussed a good deal with the students".[77] Bengt analyzed Wares' spectra to measure the relative abundance of sodium with respect to hydrogen in stellar atmospheres. Therefore, Struve soon found a cottage for the Strömgrens in Williams Bay, so that they could come for the weekends and research with Struve, Kuiper, Morgan, and Wares could be facilitated.[78] As a result, Bengt was quickly acquainted with the Yerkes staff and Struve was more and more certain that Bengt should perhaps live in Williams Bay instead of Chicago.

Another activity during Bengt's time on campus was the *Handbuch der Astrophysik* articles that he was asked to write already in 1935.[79] They were to be on thermodynamics of stars and pulsation theory as well as on ionization theory in stellar atmospheres. Milne had written the first review articles in the *Handbuch* but since this new task was requested after the Eddington-Milne controversy, he declined to write it. Furthermore, "he had included his own ideas on the pulsation theory, which had been proven to be wrong."[80] More than that, he was just on the verge of his new cosmological models of kinematical relativity. All in all, he was not inclined to bring it up to date. Since Elis Strömgren was on close friendly terms with the editors of the *Handbuch*, Eberhard and Guthnick, he was told about the problem and he asked Bengt if he would write the texts. Bengt consented and they were both published in 1937.

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[77] HBI, 34.
[78] Osterbrock 1997, 212.
[79] Gossl (Berlin) → B. Strömgren (CO), September 23, 1935, reporting receipt of the first installment of a chapter in *Handbuch der Astrophysik*, expressing the hope that the second installment will soon arrive. BSA,01,A.
[80] HI, 12. B. Strömgren 1936a; B. Strömgren 1936b.

An extra set of review articles written by Bengt were in the *Handbuch der Experimentalphysik*. Originally, the editor, Hans Rosenberg, was supposed to write the articles. Rosenberg was “independently wealthy”, “he had no positions, but just did this for fun”.[81] Being one of the Jewish scientists in National Socialist Germany, he left his mother country fairly early for the Yerkes Observatory. Rosenberg proposed Elis Strömgren to be the editor, but the Danish astronomer “said he couldn’t do this”.[82] It was mostly astrophysics and his field was purely classical astronomy. In the end, Bengt became the editor and he wrote two articles that Rosenberg himself had planned to write. Bengt spend the whole winter term of 1935 reading everything that was written about astrophotometry, which was in fact possible at the time. Bengt acquired close to complete knowledge about the topic, which had always interested him considerably. Photometry was an important part of his life; he had been introduced to the technology early on by Guthnick and Ludendorff in Germany and now he wrote review articles about the subject as a whole. Mastering the subject at this point also made him fit for bringing it further by novel research. This he did, in particular after the Second World War. He wrote the review papers before going to the States and completed the proofs there.

In a letter to mother Hedvig, Bengt reported the way of a typical day in Chicago.[83] The family arose at 7.30am, when their daughters would normally wake up as well. After breakfast, Bengt would walk to his office, where he worked until 11.30am. In his office, there was a calculating machine but no typewriter. Instead, the university had a “bureau of typewriting, where you could have everything typewritten for 5-8 cents a page.”[84] Sometimes, Karin would go to the kindergarten, sometimes Sigrid took care of both children in a park on campus. Normally, Bengt would go home for lunch, except twice a week, when he enjoyed his lunch at the Quadrangle Club with his colleagues just next to Eckhart Hall, which was a restaurant and hotel for the academic staff. From

[81] HBI, 16.
[82] HI, 13. B. Strömgren 1937a; B. Strömgren 1937b.
[83] The following paragraph is a paraphrase of letter, B. Strömgren (Chicago) → Hedvig Strömgren (CO), November 27, 1936, ESC.
[84] B. Strömgren → E. Strömgren, November 27, 1936, ESC.

1.30pm to 3.20pm, he gave two lectures from Tuesday until Friday. Then, he worked in his office until 5pm or 6pm and finally he went home for dinner. The family was mostly at home in the evenings, although sometimes they went to the cinema just around the corner of Dorchester Ave. On Saturdays, when the family was not on weekend in Williams Bay, Bengt went back from work at noon. Then, they would visit the Shedd Aquarium, the famous Museum of Natural History or other local sights.

Nevertheless, the preferred destination for the children was Marshall Fields in the Loop, which housed a large toy department. When Bengt got an account in Marshall Fields, he wrote about it to his mother, as he also wrote that they had bought a cat for the apartment. This did not turn out to please the patriarch in Denmark. Elis wrote Bengt:[85]

> Two things I am discontent with: That you have got yourself a cat – as opposed to dogs you cannot trust cats and it makes it a bit unsafe with your two little kids. The other thing is that you have got an account at Marshall Fields (Mammi and Nanni agree concurrently). I suggest that you think about these problems.

Clearly, Elis did not stop dictating how his son should live his life, even when it came to such relatively inconsequential matters. Bengt had numerous obligations in Denmark. Among other commitments, he wrote six Danish articles for the *NAT*, mainly thanks to Elis' diligent pacing from Copenhagen Observatory of his remote colleague and friend in the States.[86] More importantly, when it came to the collegial, professional relationship between Elis and Bengt, one might suspect that any uneasiness with Elis' ways of interfering would be transferred from the private to the professional sphere. Thus, when Elis wrote long lists of jobs for Bengt to take care of and Bengt declined to answer, it might have had its reasons. He probably had enough in his American tasks already – and finally, he was able to turn the deaf ear to his father!

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[85] E. Strömgren → B. Strömgren, December 19, 1936, ESC.

[86] B. Strömgren 1937e, f, and g; B. Strömgren 1938b, c, and d. Additionally, Bengt wrote four reviews for *NAT*, *viz.* B. Strömgren 1938e, f, g, and h.

Figure 8: A family trip to the park on the University of Chicago campus. Left: Sigrid holding hands with Nina and Karin. Right: Bengt holding Nina while Karin glances at Sigrid behind the camera. Undated, but the photo is probably shot in the fall of 1936 (courtesy of Nina Strömgren Allen).

In the same letter, we find an example of Elis Strömgren's dispositions of vanity and professional pride, as he gossiped to his son about his Swedish colleague, Knut Lundmark, with whom he was not entirely on friendly terms:

> A characteristic Lundmark story: You may remember that [Östen] Bergstrand in the last edition of the Nordic Family Book had a long and fine biography of me (one and a half column). Now, Lundmark, who has taken over Bergstrand's role, has reduced it to ONE THIRD! He assumes that I cannot do him any good any longer.

Bengt Strömgren bliver Professor

Bengt Strömgren.

I Gaar Eftermiddags bevilgede Folketingets Finansudvalg Universitetet Midlerne til Oprettelsen af et ekstraordinært personligt Professorat i Astronomi, der skal besættes med den unge Videnskabsmand *Bengt Strömgren.*

Den vordende Professor bliver en af de yngste, vort Universitet har haft, og for Bengt Strömgren er det endnu et Skridt fremad paa den straalende Karrière, han allerede har gjort.

Han er født 1908 — og altsaa 28 Aar gammel — som Søn af Professor i Astronomi ved Københavns Universitet *Elis Strömgren.* 1925 blev han Student fra Metropolitanskolen, og to Aar efter, 1927, blev han mag. scient. Allerede før han var fyldt tyve, havde han skrevet adskillige Afhandlinger i Fagskrifter, og 1929 blev han Dr. phil. paa en Afhandling om „Formeln und Tafeln zur Bestimmung parabolischer Bahnen". Han var derefter i nogle Aar ansat som Lektor ved Københavns Universitet, men blev for et Aars Tid siden knyttet til *University of Chicago*, hvor man tilbød ham Professoratet i Astrofysik. Fristet af de glimrende Arbejdsvilkaar, der blev tilbudt ham, tog han imod det, men nu har Rigsdagen stillet Midler til Raadighed, saa denne unge Videnskabsmand atter kan bringes tilbage til dansk Videnskab.

Foreløbig er det ekstraordinære Professorat fastlagt for Perioden 1936—1940, og da den vordende Professors Far, Prof. Elis Strömgren netop i 1940 bliver 70 og maa trække sig tilbage fra Universiteets ordinære Professorat i Astronomi, er der vist Grund til at antage, at den unge Professor Bengt Strömgren til den Tid flytter over i det ordinære Professorat, og det ekstraordinære atter nedlægges.

phil.

Figure 9: Danish news media coverage: "Bengt Strömgren appointed Professor". Excerpt from the Danish text: "[…] Tempted by excellent working conditions [in Chicago], he accepted the offer, but now the Parliament has granted money so that the young man can be brought back to Danish science once again." (newspaper clipping from *Politiken*, November 18, 1936). Bengt's salary was 6,519 Kroner, which was motivated "by the wish to keep him at the Copenhagen University" (*Berlingske Tidende*, November 19, 1936).

Bengt never answered his father's vain complaints but mostly stuck to professional matters. At the same time, Bengt himself took after his father in the inclinations towards acting as fine gentleman coming from a fine background. For instance, he wrote his mother about their experiences in the Danish Society, Dania:[87]

> Most members are kind, although they are somewhat common people, but last Sunday, it was fine with the consul general and other notabilities. […] Now, it is in the middle of the night and Sigrid is already asleep, since I have been working on this letter for so long. Karin shakes her head when she talks about the pace by which her father writes his letters.

[87] B. Strömgren (Chicago) → Hedvig Strömgren (CO), November 27, 1936, ESC.

Bengt enjoyed his time in Chicago. In November 1936, Elis wrote him some good news from Denmark:[88]

> My dear boy! Last night and today, the official announcement about the professorship has been published in the newspaper. I send you clippings. So now it is in order. Congratulations! […] Wollen wir hoffen, dass Europa nicht inzwischen zu unsüss wird.

Concerns about the general political development had finally found their way into their letters – and once again even in German as in their old letters – most likely to allude to the danger of the rise of the Nazis in Germany. Elis also informed his son about salaries and allowances for the extraordinary professorship, all adding up to 8,919 Kroner a year. When the news about the professorship was finally publicized in the Danish press, Bengt would no longer hide the plan for Struve. Since no written documentation has been found of Bengt telling about the news to Struve, Bengt probably preferred to tell Struve personally. By December, Struve definitely knew about Bengt's considerations, although Bengt was still undecided. In Danish newspapers, the theme of Bengt Strömgren was all about getting him back to Denmark once again and not loosing him to foreign countries with more advanced technology. Bengt replied to this father: "I must say that I thrive very well here but if all goes well with the professorship in Copenhagen, which everything indicates then I do not think that I will have any misgivings of going home."[89] In late January 1937, Elis pondered about the whole issue:[90]

> The Denmark-USA question: I am more and more convinced that you should contemplate moving to Denmark. You know what it would mean to me (and to us) if you not seriously return to Denmark, and yet, Mammi and I still wish that you stay. What speaks in favour of staying in America is obvious: scientifically (and economically) it would be of enormous importance. Speaking for coming

[88] E. Strömgren → B. Strömgren, November 19, 1936, ESC.
[89] B. Strömgren → E. Strömgren, November 27, 1936, ESC.
[90] E. Strömgren → B. Strömgren, January 18, 1937, ESC.

> to Denmark: personal relations in the faculty. […] There is yet a third possibility: to come to Denmark and go back [to the USA] again. To me, this would be the ideal solution: You return in April 1938 and go back to the USA in 1940. I will give you the advice not to tell anything definitely to Struve or the Chicago-people yet.

In yet another communication, Elis resumed his considerations after pondering more on the matter:[91]

> It would be right of you to return in April next year. Your friends here, many in number, probably expect it from you and they are in their right to do so. Then you stay here for some time. After some years – ca. until I retire – you may have a feeling about how it will be like and which conditions you will have: The State, The Carlsberg Foundation, and the Rockefeller. If you find it too small then you have the opportunity – with kettledrums and trumpets – to go back to America again. Actually, I think this is a magnificent program.

As it turned out, Bengt never needed to play the kettledrum. The rise of National Socialism and the growing instabilities in Denmark did their job to keep him close to his family in Copenhagen for many years, as we will see.

In addition to these burning issues, Elis made a long list of duties that Bengt needed to attend to. The list included financial matters, reviews of Danish textbooks, a statement about Karl A.O. Thernøe's gold medal paper, and decisions regarding a Russian translation of their *Lehrbuch der Astronomie* (Thernøe was appointed assistant in 1937). Bengt had a serious flu, then a cold, and on top of it he had a cyst removed operationally in December 1936, resulting in the postponement of many duties. On the other hand, in mid-February, even Elis realized that his distant son had too many obligations in Denmark, and wrote him that "I hope that you will not take anything new in Europe. Now, you should have some rest for your American duties."[92]

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[91] E. Strömgren → B.Strömgren, February 2, 1937, ESC.
[92] E. Strömgren → B. Strömgren, February 17, 1937, ESC.

Helium in Stars

With regard to his academic work, Bengt had much more freedom than he was accustomed to in Denmark. At the time, there was a principle “that you were not in any way asked to participate in particular work. You chose your own work, and that was so for every member of the department in principle […] This was so throughout the university.”[93] According to his great research plan already recounted, which he presented to Struve, Bengt continued his theoretical work on stellar atmospheres. He wished to understand the damping phenomenon, particularly in solar types. Since 1935, it had already been partially clear that the solar damping was due to neutral hydrogen. The whole problem was still not understood, until the role of the negative hydrogen, the H^- ion was discovered by Rupert Wildt in 1938-1939. The presence of the hydrogen ions explained why the hydrogen gas pressure was sufficiently large to explain the damping.

In addition to the mentioned review articles, Bengt wrote a seventy pages article for *Ergebnisse der Exakten Naturwissenschaften*, which Hund had encouraged him to write at the garden party in Copenhagen, as recounted on page 229. Bengt finished it in spring 1937 “in three weeks, during temperatures of 100 [^{o}F]”[94], but it had been under way since months before he went to the States. Bengt sent the manuscript to Copenhagen, where Thernøe read the proofs “very thoroughly as usual”.[95]

This paper turned out to be enormously influential not only to other astronomers, but also to physicists, who immersed themselves into the cross-disciplinary field of astrophysics. The result of Bengt’s landmark article from 1932 on new calculations of opacity and mean molecular weights was that the stellar composition was roughly one-third of hydrogen and two-thirds of “metals”. His new investigation, which was carried through in connection with his writing for the *Ergebnisse*-paper, was an attempt to answer the next obvious

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[93] HBI, 34.
[94] HI, 15; Strömgren 1937c.
[95] E. Strömgren → B. Strömgren, August 24, 1937, ESC.

question: How would the addition of helium change the model? Concerning the helium abundance idea, Bengt reminisced:[96]

> The reason that I took it seriously was that, particularly, von Weizsäcker had discussed what he called the building-up hypothesis, the alpha-particle hypothesis, and concluded that the abundance would give a certain ratio of helium to heavy elements, which I assumed.

The only observational basis to support a helium hypothesis was estimates of relative amounts of hydrogen and helium, but determinations were rather weak. The final result was a model comparatively close to the present relative composition by weight, which Bengt found to be (60-70%, 26-36%, 4%). The reasoning behind this finding is described below.

Now that Struve was aware of the possibility of loosing Bengt for Denmark, he wrote a letter to his assistant professor on campus, in which he presented some problems that Bengt should discuss with Mrs. Strömgren: "I believe that you have made a very fine start in your teaching activities at Chicago, and due to your efforts, a definitive program of instruction in theoretical astrophysics has, for the first time, been incorporated at our university."[97] In effect, Struve proposed the idea of having Bengt and his family move to Williams Bay permanently. "Since I gather from your remarks that we cannot now count definitely upon your remaining here after April 1938, I am particularly anxious to derive as much from your research activities as is possible." If Bengt and Sigrid were willing to make the change, it should be effectuated after the end of the winter quarter lectures, and Struve would in that case look for a house nearby the Yerkes Observatory.

At the same time, President Hutchins desired to indicate to Bengt "the very high esteem in which you are held by the administration. Accordingly, he [Hutchins] has instructed me to recommend that you be promoted to the rank of

[96] HBI, 38.
[97] O. Struve → B. Strömgren, December 30, 1936, YOA.

Associate Professor with a salary of $5,000."[98] Struve realized that the promotion perhaps would cause some embarrassment, since only a few days earlier Bengt told Struve about the possible plans of going back to Denmark. Nevertheless, Struve emphasized very clearly that the university very much wanted him to stay after the end of the present appointment. There were no restraints involved by the promotion, and Struve asked Bengt to wait make any final decisions before he had been in Denmark and was able to "carefully analyze the advantages offered by the two positions". Furthermore, Struve would like to discuss the matter with Niels Bohr, who had planned to visit the States in the spring. Obviously Struve was of the opinion that Bohr "has a very good case for trying to get you back to Copenhagen, I also believe that, considered internationally, and from the point of view of the best advantages to astronomy, our own claims are no less reasonable."[99] Evidently, Struve was sincerely hoping that Bengt would eventually decide to return to the big observatories in the States after all.

For Bengt, this meant a completely new situation. Now being free to decide and with the return to Denmark being "very probable", he agreed that spending as much time as possible on research at the Yerkes Observatory was indeed preferable.[100] As to Sigrid's attitude towards moving, luckily, "Mrs. Strömgren is very happy about the prospect of living in Williams Bay permanently."[101] On the other hand, Bengt warned against "scientific isolation" of the Chicago staff and suggested to work for preserving the close connection between the observatory and the University. Moreover, he found the contact between researchers and students vital for the motivation of new future astronomy researchers – and not least for the future of astronomy. Therefore, he suggested fortnightly seminars for the students on campus with participation of Yerkes researchers. Finally, he was glad about the promotion to the higher rank,

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[98] Ibid.
[99] Ibid.
[100] B. Strömgren (Chicago) → O. Struve (Yerkes Observatory), January 1, 1937.
[101] B. Strömgren → O. Struve, January 1, 1937 (Bengt Strömgren posted two letter the same day to Struve), ESC.

and his proud father wrote him that also Nørlund was “very impressed and – after what he has done for you – also very glad”.[102]

Before moving to Williams Bay in April 1937, Bengt worked intensely with finishing the proofs for a supplement for the *Lehrbuch der Astronomie*. Concurrently, the plans of having it translated into Russian were under way. He also wrote three papers for the *Astrophysical Journal*. The first article was on the content of hydrogen and helium in the interior of stars and the problem of “element building”. The second paper was about the calculation of line intensities in stellar spectra – a mathematical problem, which he struggled with for a long period. The third article was on the hydrogen content of stellar atmospheres for A-type stars including a method which was described in his *Handbuch der Astrophysik* review paper. Yet, not only theoretical work was awaiting him. The future should entail observational work as soon as they moved to Williams Bay. His plan was to investigate selective absorption in space depending on distance. His absorption paper was published in 1937 as planned, whereas the next very important paper on the content of light elements was published only in 1938.[103] This paper contributed considerably to a change of the general view of the chemical content of stellar interiors, and consequently, if indirectly, also the development of fresh nuclear theories.

In the summer of 1936, the German physicists Carl Fr. von Weizsäcker met with the Hungarian-born American physicist Edward Teller at one of the illustrious Bohr colloquia in Copenhagen. He talked with Teller about his plans of investigating nuclear reactions in stellar interiors.[104] The colloquium took place just a few months before Bengt went to the States. Then, in the fall of 1936, Bengt reviewed a manuscript of Weizsäcker’s at the Yerkes Observatory. The following winter, Bengt received an article, also by Weizsäcker, which discussed “the problem of the building up of the heavier elements from hydrogen in the stellar interiors”. This paper corresponded closely to the preliminary manuscript

[102] E. Strömgren → B. Strömgren, February 1, 1937, ESC.
[103] Strömgren 1937d, Strömgren 1938a.
[104] HI, 15.

which he reviewed in the fall.[105] Weizsäcker's paper, which Bengt judged "important though partly speculative", brought the problem of the helium content in the stars to the forefront.[106] Earlier, in 1931, Albrecht Unsöld treated the helium problem theoretically in *Zeitschrift für Astrophysik*, basing his calculations on Elvey's measures of helium lines.[107] The theoretical part of Unsöld's investigation could now be considerably improved. Bengt wrote Struve that he planned[108]

> to trace completely the consequences of Weizsäcker's deduction that the helium content is say five to ten times the content of heavier atoms (by weight), for the stellar interior. For the sun, Weizsäcker's result is not impossible a priori, as far as I can see. […] I guess that the result for the sun will be something like 70% hydrogen, 27% helium and 3% Russell-mixture.

Bengt was convinced that it was even easy to determine hydrogen content, helium content, and the "Russell-mixture", i.e. the portion of heavier elements by weight. His guess was based on Weizsäcker's uncertain conclusion that the helium content was high. However, Bengt found it imperative to work out the upshot of the helium hypothesis completely and then attempt to judge it in that way. This could be done by help of Kuiper's galactic cluster material and his work on the location of their main sequence in the H-R diagram. Thus, being well prepared for shifting house, Bengt was also geared up for shifting his research area to intensive investigations of helium content.

In order to reach a relation between the hydrogen and helium content, *X* and *Y*, Bengt drew on his earlier work and used the mass-luminosity relation, as had also Eddington done in 1932.[109] In Bengt's 1932 paper, it was assumed that the helium content could be neglected. Now he considered a similar application of the mass-luminosity relation, but with an additional unknown parameter in the

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[105] B. Strömgren (Chicago) → O. Struve (Yerkes Observatory), February 21, 1937, YOA.
[106] Weizsäcker 1937.
[107] Unsöld 1931; Elvey 1929.
[108] B. Strömgren → O. Struve, February 21, 1937, YOA.
[109] Eddington 1932a.

equations. The chemical composition could thus be determined as a function of a parameter only and Bengt chose the mean molecular weight, μ. Moreover, assuming a high ratio of helium content to heavy element content, *Z*, the problem became definite once more. With a relatively small amount of *Z*, Bengt found *Z* to be,[110]

$$Z = [9.27 - 10]\tau \frac{\mu^{7,4}}{1+X} \beta^{7,5} \left(\frac{M}{M_O}\right)^{5,5} \left(\frac{R}{R_O}\right)^{-0,5} \left(\frac{L}{L_O}\right)^{-1} .$$

Considering the mean molecular weight as a parameter, for a star with observationally known values of the mass, *M*, the radius, *R*, and the luminosity, *L*, an assumed value of μ led to definite values of β from equation (4) in chapter four. Bengt also found an expression for the guillotine factor, τ, and thus he was able to calculate *Z* from the above equation. Now, summing the element contributions to one, i.e. $X + Y + Z = 1$, and by introducing μ under the assumption that hydrogen and helium are completely ionized and that the number of free particles of the Russell-mixture is ½, Bengt separated *X* and *Y*:

$$X = -0.6 + 0.8\frac{1}{\mu} + 0.2Z,$$

$$Y = 1.6 - 0.8\frac{1}{\mu} - 1.2Z .$$

Like this, except for a small error due to the assumption that *Z* was relatively small, it was possible to compute the relative content of hydrogen and helium. Bengt calculated the values of *X* and *Y* for the sun, for Sirius A, and for four other stars and his examinations ultimately lead to the conclusion that “the ratio of the content of helium to the content of heavier elements is high, 6 being a lower limit of the ratio”.[111] More than that, assuming a plausible value of the helium to heavy elements ratio, he obtained chemical compositions, “which are

[110] B. Strömgren 1938a, 524.
[111] B. Strömgren 1938a, 520.

very closely correlated with the chemical compositions previously found on the assumption of negligible helium content.

Finding relative values for e.g. the sun (60%, 36%, 4%) and Sirius A (79%, 19%, 2%), he still emphasized that the mass-luminosity discussion alone could not decide for or against the hypothesis of high helium content. Yet, Bengt did not find himself able to make any definite decision for or against the helium hypothesis. What was needed to reach a more unambiguous conclusion was better determinations of atmospheric compositions and theoretical discussions of energy generation and transmutation. The paper was only published a year after the Strömgrens moved to Williams Bay.

Moving to Williams Bay

The Strömgren family moved in late March and was installed in a house just a few minute's walk from the Yerkes Observatory, and, finally, Bengt got a driver's license in order to be able to drive by himself back and forth between the state borders between Wisconsin and Illinois, between Wiliams Bay and Chicago. Thenceforth, Bengt went to Chicago only once a month. Williams Bay was their home for a full year and it was a rather busy year for Bengt. Although they were taken good care of by Bengt's colleagues and had numerous social gatherings and parties around the observatory, for Sigrid, the move meant fewer parties with fine Chicago people, less dancing, less frequent visits to museums, and less shopping at the Loop. In effect, Sigrid's enthusiasm for living in a small town like Williams Bay gradually began to drop.

The Yerkes Observatory staff consisted of many people. As can be seen on the map (figure 11), eleven astronomers lived close to the premises of the observatory. Struve lived in the large director's manor close to the observatory, while Chandrasekhar, Kuiper, Morgan, van Biesbroeck, Louis Henyey, and additional assistants and instructors were all stationed close by. In this way, the private life of the astronomers was mainly concerned with astronomy, as their homes were all geographically neighboring their workplace. This fitted well into Struve's working philosophy of spending as much time with astronomical

Figure 10: A new home in Williams Bay, two minutes walk from the Yerkes Observatory. The girls are playing with the son of a colleague while the hard-working astronomer takes a nap in the sun on his deck chair close by (courtesy of Nina Strömgren Allen).

research as altogether possible. During Bengt's one-year stay in Williams Bay, he lived with his family not far from the astronomers' enclave.

The astrophysics courses given by Bengt on campus were succeeded by the Yerkes instructor of astrophysics, Philip C. Keenan, who was to move to Chicago. Struve had reported his plans to the dean already in January about the succession of Bengt's teaching position, in order to prevent any interruption of the theoretical astrophysics classes. Keenan associated closely with Strömgren and was intended to "obtain from him all the advice that will be required in order to make the teaching continuous". In a letter, he stated: "I am certain that Strömgren will be of more use here [at Yerkes]"[112] Strömgren had involved Struve in his investigations of the hydrogen content of the stars, for which Struve

[112] O. Struve (Yerkes Observatory) → H.G. Gale, January 7, 1937, UCA, PP1.

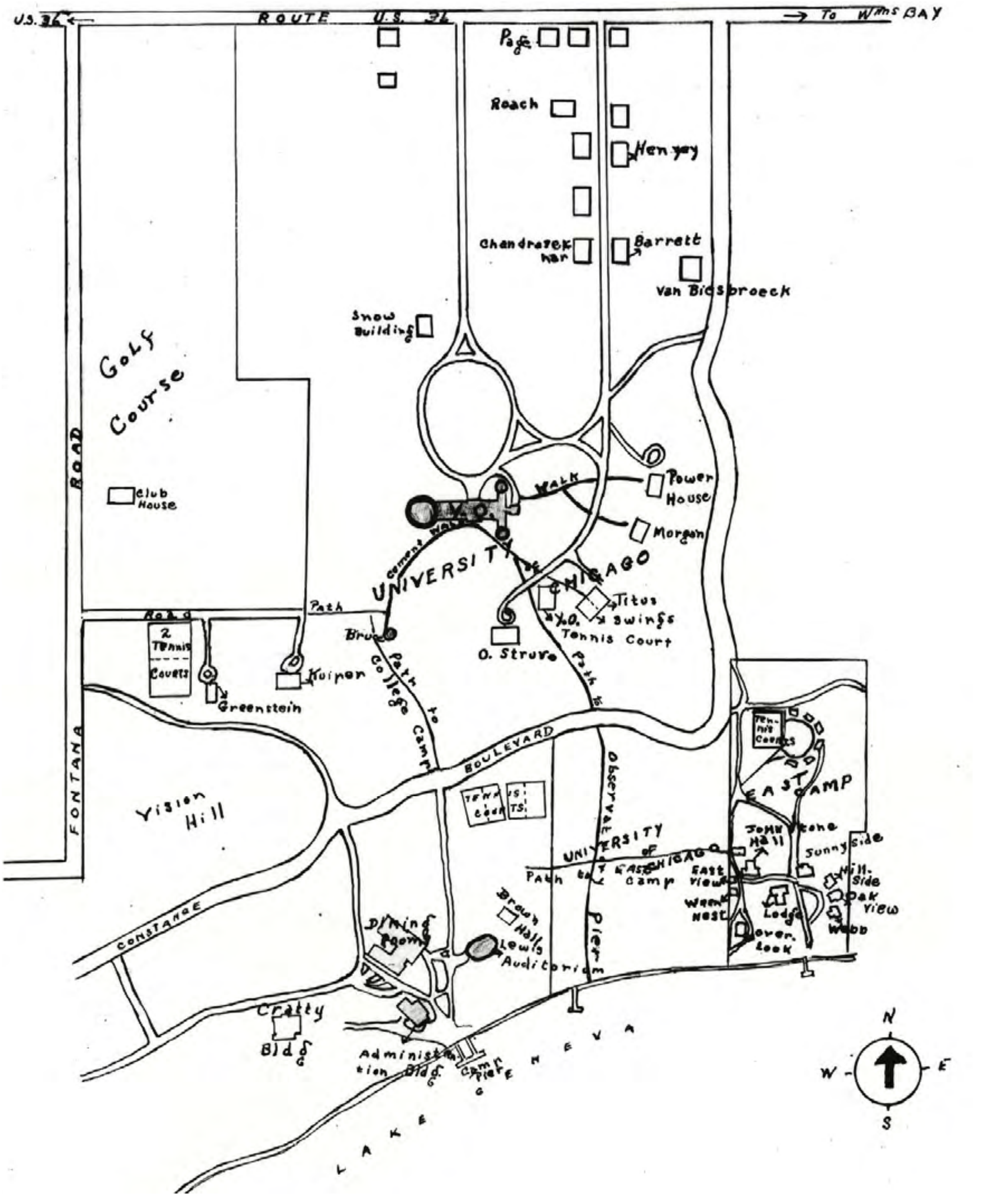

Figure 11: Undated map of the Yerkes Observatory premises close to Lake Geneva including the houses of most of the staff. We find the houses of Struve, visiting assistant professor Polydore Swings (Bengt Strömgren's successor), Kuiper (formerly Edward E. Barnard house), Morgan, Chandrasekhar, van Biesbroeck, associate emeritus Storrs B. Barrett, the assistants John Titus, Louis G. Henyey, and Franklin E. Roach[113], and the instructors Thornton L. Page and Jesse Greenstein (close to golf course). Before leaving Williams Bay, the Strömgren family lived in a house close to the top right corner of the map, which is probably from 1939. The houses still exist today (YODA, see also Appendix C).

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[113] In fact, Franklin E. Roach lived in Texas at the McDonald Observatory until 1936 when he left for a teaching position in Arizona. The reason for his name being on the map remains unknown (Osterbrock 1997, 196).

was supplying the observational data while Strömgren was responsible for the theoretical discussion. Thus, Struve had been permitted by the dean "to arrange the personnel of the department of astronomy and astrophysics to the best advantage of the University. Accordingly, I have proposed to Dr. Strömgren that he come here after the expiration of the winter quarter and remain here indefinitely."[114]

Interestingly, Struve also wrote to the father of his Danish soon-to-be-promoted employee about his plans of moving him to Williams Bay. He told Elis about the "unfortunate disregard for modern developments" of astronomy, which allegedly was a result of "the character of your son's predecessors", Forest Ray Moulton and MacMillan. Their teaching had a "tendency to emphasize the more abstract problems of theoretical astronomy".[115] Struve explained that he had found Chicago "a weak subdivision of the department of mathematics", partly due to the geographical separation between the Yerkes Observatory and Chicago but also due to "personal differences". The retirement of MacMillan was an obvious "opportunity to remedy this situation, and your son seemed admirably fitted to carry this change into effect".[116] Seemingly, Struve found it important to extol Bengt's "unusually broad knowledge not only of astrophysics but also the more classical aspects of astronomy" and concluded that he had been able "without friction to introduce into the plan of instruction" the series of courses.

Struve reported to Elis that now this difficult part of Bengt's assignment had been completed, it was "no longer necessary to keep so outstanding an investigator in a position" which required so much teaching. Furthermore, Struve ensured Elis that not only would the change exclusively permit Bengt to devote himself to research, "but it will also improve the living conditions for his family".[117] Perhaps Sigrid would not agree. Elis responded that the plans for Bengt's return to Denmark were almost certain, and Struve acknowledged that he would not put Bengt under more pressure to have him stay in Chicago. At the

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[114] Ibid.
[115] O. Struve → E. Strömgren, January 15, 1937, YOA.
[116] Ibid.
[117] Ibid.

Figure 12: A birthday party in the dining room at the Strömgrens in the summer of 1937 in Williams Bay. From left: Sigrid and Karin Strömgren, Annie (maid), unknown child, Helen Morgan, her son Billie on her on her leg, Nina Strömgren, Bengt Strömgren in profile, unknown (Courtesy of Nina Strömgren Allen).

same time, Struve asked Elis if he intended to attend the AG meeting in Breslau, as he considered going there himself. They both met later in Breslau, and as we will see below, this German meeting turned out rather dramatically (see page 267).[118]

In spite of Struve's hopes of keeping Bengt, or at least getting him back to the Yerkes Observatory after a few years in Denmark, he already wrote some other astronomers in order to secure a successor of Bengt, if only temporarily. Another of Struve's candidates was Theodore Dunham, Jr. at the Mount Wilson Observatory in Pasadena, California. As he informed Dunham, Bengt was "strongly tempted" to go back to Denmark.

Apparently Struve was more than satisfied with Bengt's results and zeal. During a conversation in the summer of 1937, Struve told Bengt confidentially that "we want you ahead of all astronomers in the world, quite absolutely."[119] If,

[118] E. Strömgren → O. Struve, March 11, 1937; O. Struve → E. Strömgren, March 24, 1937, YOA.
[119] B. Strömgren → E. Strömgren, June 21, 1937, ESC.

Figure 13: Left: Bengt playing with Nina and Morgan's son, Billie. Right: Storrs B. Barrett, Karin, Nina, Bengt and Helen Morgan, Willams Bay, summer 1937 (courtesy of Nina Strömgren Allen).

contrary to Struve's expectations, Bengt would not return, then the Yerkes staff needed another "equally eminent astrophysicist in his place". As Struve wrote Dunham,[120]

> Strömgren, Chandrasekhar and Kuiper form a very fine team. […] What we really need is a professor of theoretical astrophysics who will organize the teaching of astronomy and build up a school somewhat similar to that of Milne at Oxford and of Eddington at Cambridge. I am quite certain that the University will make it possible for you, should you so desire, to obtain material at the McDonald Observatory or at Williams Bay.

However, Dunham politely declined the offer, as his conditions at Mount Wilson were satisfactory. Instead, Polydore Swings turned out to become Bengt's successor. President Hutchins also promised Struve money for yet another astronomer, who should be stationed in Chicago. Struve wanted Marcel

[120] O. Struve → Theodore Dunham, Jr. (Mount Wilson Observatory), June 25, 1937, UCA, PP1.

Minnaert, but he definitely declined the offer as he had just retrieved more resources for his research in Holland.[121]

Bengt presented a plan to Struve in which white dwarf stars should be investigated systematically. For this, Bengt needed a modification of the photographic Schmidt camera. It was "not easy to get new instrumental equipment [to Yerkes] but Struve has done what he can". Bengt praised Struve's style of management in this respect, as only "the day after we agreed about the right procedure, he writes to seven or eight places to investigate the possibilities of borrowing a mirror."[122] Mount Wilson lent the sixteen-inch mirror to Yerkes and Morgan got involved in close collaboration with Bengt and Struve on the measurement of the white dwarfs. Bengt's aim was to collect as much observational material as possible for his ensuing theoretical research in Denmark.

Morgan was Bengt's co-worker in observational work, whereas Chandrasekhar complemented Bengt's work by developing new theories of stellar structure. Little documentation exists of their mutual interaction while in Williams Bay since their offices were located in the same main aisle of the observatory and they frequently discussed their matters locally. There is no doubt, however, that Bengt regarded his friend from the Copenhagen days highly. For several years, Chandrasekhar read Bengt's proofs and exploited "every appropriate chance to talk about my papers" and in a letter to his father, Bengt continued: "Chandrasekhar is the most wonderful colleague you could ever imagine […] In Oxford, Chandrasekhar is called 'Strömgren's ambassador'."[123] On the social level, the Strömgrens spent much of their time together with Chandrasekhar, Kuiper, Morgan, and Struve in particular – as he reminisced, "we became close friends".[124] Chandrasekhar did not visit the Chicago campus often but on few occasions, Struve asked Hutchins, and not

[121] B. Strömgren → E. Strömgren, June 21, 1937, ESC.
[122] Ibid.
[123] B. Strömgren → E. Strömgren, July 1, 1937, ESC.
[124] HBI 47.

Gale, if Chandrasekhar could visit Chicago.[125] So, Hutchins did everything he could to make Chandrasekhar feel as pleasant as possible, in spite of the fact that Gale was against his presence on campus.

Coming from a different culture, and then living in the British imperial center, followed by a life as American citizen for the rest of his life, Chandrasekhar still felt connected to his homeland. His uncle, the Indian physicist and Nobel laureate of 1930, Chandrasekhara Venkata Raman, asked for assistance with plans for an Indian observatory. Raman hoped to convince an Indian millionaire to pay the needed $800.000 for the enterprise. Chandrasekhar soon involved Bengt in the idea and he produced a detailed proposal, which was sent to Raman. The idea was to make an observatory which could be operated by Indian astronomers with limited education. The main instruments were a 60cm Schmidt telescope and a 60cm astrograph for photographic-photometric and calorimetric saturations for spectral classification of faint stars.[126] Elis was very enthusiastic about the idea of creating the Indian observatory but the ensuing development of the plans remains unknown to the author.

The Vainu Bappu Observatory, which traces back to 1786 – when the noted English astronomer William Petrie set up his private observatory at his garden house at Egmore, Madras – eventually came to be known as the Madras Observatory. Later it was moved and functioned as the Kodaikanal Observatory since 1899. M.K. Vainu Bappu took over as the Director of the Kodaikanal Observatory in 1960. The Kodaikanal observatory was not equipped with instruments of modern standards. Though it is highly unlikely that Chandrasekhar himself would ever return to his homeland, he was indeed willing to work actively for the creation of a modern observatory in India, which could replace the existing, obsolete observatories, such as the Kodeikanal.

Bengt commenced regular observations with the large refractor in the spring of 1937. As an introductory study of interstellar absorption, which could

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[125] For instance, in early 1938, Hutchins reassured Struve: "By all means, have Mr. Chandrasekhar lecture [on campus]", R.M. Hutchins → O. Struve, January 26, 1938, UCA, PP1 (Astronomy Department, 1924-39, Box 100).
[126] B. Strömgren → E. Strömgren, August 12, 1937, ESC.

Figure 14: Staff at the Yerkes Observatory, 1937. From left, seated: Alice Johnson, **Subrahmanyan Chandrasekhar**, Mary R. Calvert, **Bengt Strömgren**, Marguerite van Biesbroeck, **Gerard P. Kuiper**, **Lalitha Chandrasekhar**, **Jesse Greenstein**. Second row, from left: **George van Biesbroeck**, three unknown persons, **Louis G. Henyey**, Edith Kellman, **William W. Morgan**, unknown. Third row, from left: Two unknown persons, **Otto Struve**, Frank R. Sullivan, E. Lloyd McCarthy (tall), and three unknown persons (YODA).

only be set in motion when his spectrometer was made in July, he began with Cepheid spectra. He collaborated with Morgan with these spectra, and he found Morgan to be "an excellent and interested co-worker". At the time, Morgan was immersed in his important work on creating a two-dimensional classification system for stellar spectra in close relation to the Hertzsprung-Russell diagram. Together they observed in the early hours and as they were allowed to use the forty-inch refractor four times in a fortnight, Bengt went "to bed at ca. 9pm and get up at 1am. Then I sleep again from 4am until 8,30am. In this way, I don't feel that I have observed at all."[127] After completing his *Ergebnisse* paper during two weeks of intense work, he was able to follow his observations with the mirror

[127] B. Strömgren → E. Strömgren, May 17, 1937, ESC.

borrowed from Mount Wilson. He found it "lovely to enter such work in all its detail" but he had to be patient as the delivery date of the prism for the spectrophotometer for continuous spectra had been postponed – and he should wait until October.[128] In August he, Struve, and van Biesbroeck went to Cleveland to test the mirror, which had finally been completed. On the side, Bengt lectured only two hours a week, and he was busy since the observational preparations for his return to Denmark should be completed before spring 1938.

During Bengt's stay in the USA, Struve considered the most important work at Yerkes to be the collaboration of Struve with Bengt and Kuiper in the study of the eclipsing binary ε Aurigae, which was printed in 1937 in the *Astrophysical Journal* – edited by Struve himself.[129] Kuiper had found the first clue to the solution of an old riddle concerned with the combination of the photometric and the spectroscopic data of the binary star, which seemed to lead to contradictions unparalleled in the study of other eclipsing binaries. There was no doubt about the binary nature of ε Aurigae but there was "a widespread discrepancy between the ratio of the surface brightness of the components derived from the light-curve and that derived from the spectral types."[130] With the usual uncertainties, the troika of Yerkes astronomers concluded that they had indeed established an important characteristic of the mechanism of light obstruction in the case of ε Aurigae, which removed the discrepancy.

According to Struve, Kuiper had more than once been ready to give the matter up because of the insurmountable difficulties in the interpretation of spectroscopic and atmospheric problems. In a letter to Elis Strömgren, the director proudly reported:[131]

> The work has received an almost embarrassing amount of publicity but I have always felt that it really constituted one of the most important contributions to astronomy that have come from the Yerkes Observatory. The work could not

[128] B. Strömgren → E. Strömgren, August 12, 1937, ESC.
[129] Kuiper, Struve & Strömgren 1937.
[130] Ibid, 571.
[131] O. Struve → E. Strömgren, March 22, 1938, YOA.

> have been done if it had not been for the close collaboration of your son, Kuiper, and the Yerkes group of spectroscopists.

He continued,

> I am quite certain that neither Kuiper nor I would have dared to propose the hypothesis of ionization […] by the radiation of the F star, if it had not been for the brilliant theoretical investigation by Bengt. The essential factors of this theory were completed by him in a few days.

This work was done mainly in Williams Bay. Even though Struve somewhat immoderately judged this joint paper so important, another paper turned out to constitute Bengt's next landmark article, namely his work on interstellar hydrogen, which will be treated soon.

One thing was the journal publications which contributed largely to the esteem of the revived observatory in Williams Bay, another was the publication of monographs. Chandrasekhar worked for several years on his first monograph on the study of stellar structure and he discussed it widely with Bengt, among others. By 1938, it was ready for print at the University of Chicago Press, and it was published in 1939 with the editors being Frederick H. Seares at Mount Wilson, the dean Henry Gale, and Struve.[132] Already in 1937, Bengt was aware of the prospective contents of the book and sent Chandrasekhar a small, red, humorous, home-made mini-pamphlet measuring two times three inches and counting only five pages entitled "Chandra Monograph".

In the "Table of contempts [*sic.*]", Bengt recounted the content of Chandrasekhar's future publication with thirteen chapters, which in fact turned out to be only two more than the real publication. Of the five proposed appendices, Bengt suggested the following items:[133]

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[132] Chandrasekhar 1939.

[133] Interestingly, this document was preserved in Chandrasekhar's archives. Perhaps he was touched or amused enough to save it. B. Strömgren → S. Chandrasekhar, undated, 1937, UCA, SCP (box 29).

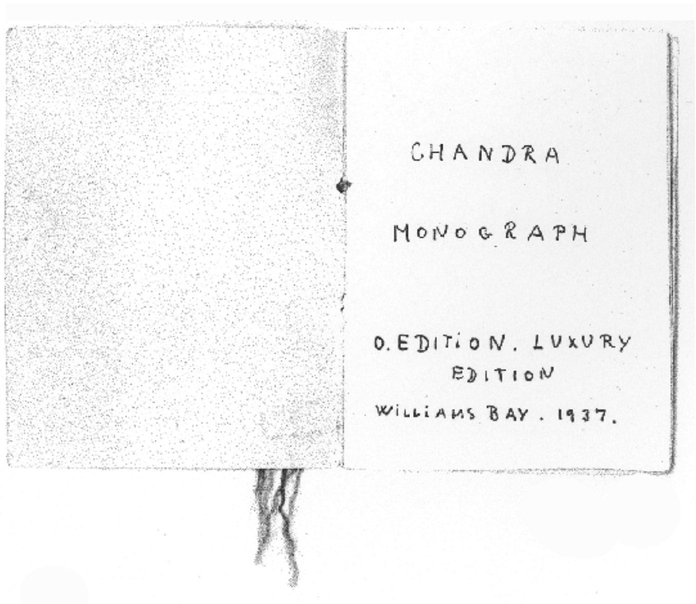

Figure 15: Page 1 of the "Chandra Monograph", in Bengt Strömgren's handwriting (USA, SCP).

Appendix 1. Proof of $\Delta = k \log w$

Appendix 2. On the proper use of postulates in astrophysics

Appendix 3. On the proper use of the bones in astrophysics

Appendix 4. Irrelevant references

Appendix 5. Guide through the wilderness of the notation

Bengt often used the concept of "the bones" concerning theoretical astrophysical questions. For instance, in a 1937 letter to Chandrasekhar, he wrote: "The convection theorem business has made no progress worth mentioning this week. Do you feel it in your bones or in your brains that the convection theorem is wrong? My opinion is as yet based on a feeling in my bones."[134] On the last page, Bengt issued the following imaginative notes of sarcasm "From the reviews":

"…A readable introduction to Eddington's *I.C.S.*…"

"…Join the author in his fight against the tyranny of mathematics and physics for the cause of free thought. Hang rigor…" […]

"…A gift for popular exposition only to be compared to Jeans. A valuable addition to popular astronomical literature…"

"…A wealth of footnotes breaks the monotony of the text…"

[134] B. Strömgren → S. Chandrasekhar, January 15, 1937, UCA, SCP (box 29).

Bengt was very much aware that Chandrasekhar had gone through quite some trouble in his attempt to resolve the so-called Eddington-Milne controversy concerned with the question of which boundary conditions one should use in determining the equilibrium configurations of stars (the debate is briefly recounted in chapter 4.3). Chandrasekhar had already discovered that not every star could become a white dwarf but that there was a limiting mass. Not every star could reach that kind of peaceful retirement stage as Eddington was convinced.[135] The ensuing controversy also involved the question of the degenerate cores of stars – whether they, as Chandrasekhar stressed, could be relatively degenerated or not. As thoroughly recounted in Wali 1991, the debate went on for several years, starting in 1933, and Eddington frequently directed his growing criticism of Chandrasekhar by implying that he had made fundamental errors of principle. Chandrasekhar ended up with a feeling of dismay after years of theoretical work – "instead of gaining recognition for having raised a challenging question", as Wali puts it.[136] The young scientists fought against the establishment which was represented by the icon of international prestige, Eddington. The somewhat sarcastic notes "from the reviews" referred to this controversy by making fun of his monograph, *I.R.C.*, which had hitherto been praised as the primary bible for astrophysicists. Furthermore, Bengt expressed his sympathy with Chandrasekhar by encouraging the intended reader to join forces against the rigor of Eddington, which he indirectly indicated to be an impediment to free thought! As to the future of the monograph, Bengt was right. Chandrasekhar's *An Introduction to the Study of Stellar Structure* became an indispensable handbook for future researchers in the field of astrophysics, and it was republished in 1958.

[135] Wali 1991, 123.
[136] Wali 1991, 126.

German Astronomy

In early July 1937, the 32nd AG meeting was held in Breslau in Germany and Elis was naturally invited. On the occasion, he went through Paris for the fiftieth anniversary of the Société Astronomique de France followed by the two hundredth anniversary in Göttingen. He wrote his son about the anniversary of the prominent German institution:[137]

> Göttingen was of course interesting in many ways, but from other perspectives it was completely unsuccessful. The whole party (six days!) was only concerned with domestic influences with no regard to foreigners. I myself can of course tolerate quite a bit, but without doubt, for almost all of the foreign representatives, the result was the exact opposite to what was intended. One quote: The representative of Chile was more pro-Hitler than even the most violent Nazis. He declared: "Der Gott, der Eisen waschen liess, er hat auch den Führer geschaffen." Oxford and Cambridge declined to attend, like the big Northern American universities (only Idaho was represented). French scientists, on the other hand, sent a fine representative, Gaston Julia, damaged from the war (his nose was shot off). Spoke nobly and made a strong impression. Yes, those Frenchmen!

Struve also attended the Göttingen bicentennial, and in the company of Elis he went to Breslau.[138] Hans Ludendorff had been the president of the AG since 1932, and in Berlin there were important issues to discuss – and not only regarding scientific matters. While several Eastern American states had not attended the Göttingen party, they considered also to resign from their membership of the AG. Numerous Jewish scientists had been expelled from their academic positions in their home-country as since 1933, among others Hans Rosenberg who made it to the USA by help of both Elis Strömgren and Ejnar

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[137] Perhaps the reference to Idaho was a mistake. Elis probably meant Illinois instead, the state in which Chicago is located. E. Strömgren → B. Strömgren, May 23, 1937, ESC; E. Strömgren → B. Strömgren, July 19, 1937, ESC.
[138] O. Struve → E. Strömgren, April 7, 1937, YOA.

Hertzsprung.[139] Hertzsprung and Elis served as the communication channel between Rosenberg and the States, where Struve and President Hutchins did all in their power to help get financial funding to the somewhat older German astronomer, who should work as a research visitor. Rosenberg only managed to get funding as an exiled astronomer at the Yerkes Observatory for a three-year period, from 1934 to 1936. The funding was divided in a main part from the Rockefeller Foundation and the Emergency Committee in Aid of Displaced German Scholars.[140]

Later, also the Jewish astronomer Richard Prager was in trouble due to the wish of the intransigent National Socialist party to prevent him from continuing his variable stars research at the Berlin-Babelsberg Observatory. The matter caused much correspondence and concern on the part of the executive committee of the IAU, and also in the AG. As recounted in Blaauw 1994, even though Prager had earned respect of the international astronomical community for his extensive work on variables, his dismissal was a consequence of anti-Semitic measures of the German Nazi-government. According to a letter from Hertzsprung to Shapley of October 1936, Prager had discussed the situation with Hertzsprung in Leiden. Hertzsprung proposed that the executive committee of the IAU "as soon as feasible friendly but firmly tells the A.G. that the IAU intends to take over the naming" and cataloging of variable stars, which had hitherto been taken care of by Prager in Berlin.[141] British and Dutch astronomers even dealt with plans of providing financial support for their German colleague for the duration of the period of his observations of variable stars.

Already at the preceding AG meeting in Bern two years earlier, "the intransigent Nazis made an attempt to displace Prager from the executive committee", as Elis put it in a letter to Struve.[142] Even though Prager was elected

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[139] See e.g. Kragh 1999, chapter 16.
[140] "The Rockefeller Foundation: $3,000 salary for Dr. H. Rosenberg, Dept. of Astronomy, from April 1, 1934 to June 30, 1935. $3,000 second half of salary from the Emergency Committee on Aid of Displaced German Scholars." The Rockefeller salary period was extended to September 30, 1935, which was extended again to May 1, 1936. Undated document, UCA, PP1 (box 6). The case of Hans Rosenberg is treated in Theis et. al. 1999.
[141] Blaauw 1994, 125-126.
[142] E. Strömgren → O. Struve, May 24, 1937, YOA. The next two quotes are from the same letter.

secretary at the Bern meeting with a considerable majority, he was forced to leave his position afterwards by the National Socialists. Yet, Elis was slightly afraid of any "one-sided support on the part of the foreign country" but if it was possible to have Prager continue his work at Berlin-Babelsberg, with support from the AG, then the problem would be solved for some time. The pension salary of Prager was very low, and he received no remuneration from the German state for his observations and he even had expenditures for his work. As Elis pondered, "it is all about justice and decency," and that was the reason for him to take such thorough care of the matter. Thus, Elis had produced a formal request, which he presented at the Breslau meeting. He had already secured Struve's support in advance for the reason that he regarded American support to be crucial. Elis, F.J.M. Stratton and K.J. Donner jointly requested for 1,500 Reich Marks to the support of Prager and the request was endorsed, to the satisfaction of not only Prager, but indeed also Elis, Ludendorff and numerous other members of the society.[143] The matter of the IAU action remained unsettled during the Stockholm General Assembly in August 1938, taking place in Stockholm. Eventually, Prager managed to flee Germany and make it to Harvard, where he took up his work.

At the Breslau meeting, Elis and his colleagues learned about yet another serious issue. Some younger German astronomers intended to establish a purely German astronomical society. He reported the alleged potential danger to his son:[144]

> [I]t is a precondition that it must not harm the AG but it may happen anyway, if a whole group of young German astronomers – from financial reasons – then leaves the AG. This plan was vehemently opposed by Ludendorff, Guthnick, and others, but still a new society will probably be realized. We will see. I don't think that it will be so dangerous. If even fifty astronomers leave the AG, it does not really matter: After all, we have 500 members.

[143] E. Strömgren → O. Struve, April 3, 1937, YOA; Struve → E. Strömgren, May 24, 1937, YOA.
[144] E. Strömgren → B. Strömgren, July 14, 1937, ESC.

Although Elis was not as worried as some of his colleagues, he was still concerned about the future of the old international society. "If the Nazis triumph, it is probably over for the internationality of the AG, as far as I can grasp the situation […]. To me, personally, this would be tragic," he wrote Struve.[145] Bengt followed the Breslau congress closely by reading his father's accounts and by listening to Struve's experiences from the meeting. To Struve, the most important issue was to prevent complete isolation of the German scientist. He was apparently "impressed with Pappi's great influence" on the older members of the society.[146]

Local Contexts

Elis went home from the Breslau meeting with mixed feelings. Having worked so hard for the internationalization of astronomy both during and after the Great War, it must have been an insurmountable task for him, once again, to struggle against the centrifugal forces of devoted national socialist astronomers caring more about nation and race than about science as an international undertaking. Of course, already in 1936, the German physicist Philipp Lenard published a textbook in the preface of which he justified the title: "*German* physics?" or "Aryan physics", by maintaining that the belief that "science is international and will always remain so!" was "inevitably based upon a fallacy. In reality, as with everything that man creates, science is determined by race and by blood". Furthermore, "nations of different racial mixes practice science differently".[147] Clearly, such radical views were in complete contrast to the conceptions of Elis.

Elis read with enthusiasm the bestseller *Inside Europe* by the British critic and journalist John Gunther (1901-1970). Beginning his life in Chicago, and at the city's university, Gunther worked for the Chicago London Bureau before publishing his highly socio-political book describing and interpreting the state of Europe in the 1930'es. He spent the 1930'es in Europe, watching the build-up to the Second World War. Living in London, Paris, Vienna, and St. Moritz, he

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[145] E. Strömgren → O. Struve, May 24, 1937, YOA.
[146] B. Strömgren → E. Strömgren, August 12, 1937, ESC.
[147] Kragh 1999, 236.

covered stories from Moscow and Vienna to Syria and Turkey, and not only met the right people (Leon Trotsky, Maxim Gorky, H.G. Wells, etc.) but had their respect, sometimes their friendship. In the book read by Elis, the leaders and despotic dictators of the world were described in quite personal accounts. Not only their political agenda but also their personal quality and character were subject to his scrutiny. Later, Hitler put Gunther on a Gestapo death-list, but without any luck. Elis immediately recommended the book to Bengt, ascertaining him that "If you haven't read "Inside Europe" then do it! It is wonderful."[148] Whether his son took the recommendatory advice remains unknown. Nevertheless, anxieties of the possible international consequences of the rise of National Socialism were clear also within the Danish circles of science.

From a Scandinavian perspective, Elis reported to his son about his disagreements between himself and both a Swedish astronomer and a Dane, living in Leiden. The Swede was Knut Lundmark, who, many years earlier, wrote the Nobel report on Elis Strömgren's merits as caretaker of international cooperation at the Central Bureau during the Great War. The relationship between Lundmark and Elis developed to something rather cold over the years, as has already been illustrated on page 244. At the Breslau meeting, Elis wrote his son about the election of Bertil Lindblad in the AG's executive committee and he noted in brackets, that "naturally, another Swede was frightfully distressed".[149] It is beyond doubt that he referred to Lundmark. In the same period, he complained to Bengt about his Swedish colleague with gossip and rumors. In 1937, Lundmark established a society for the popularization of astronomy to amateurs as well as professionals. It was named "The Astronomical Society Tycho Brahe" and Elis was not fond of its existence from the beginning. He wrote his son:[150]

> I don't think I even mentioned to you that Lundmark has founded a Southern Swedish astronomical society with the name "Tycho Brahe". […] Lundmark

[148] E. Strömgren → B. Strömgren, February 2, 1937, ESC.
[149] E. Strömgren → B. Strömgren, July 14, 1937, ESC.
[150] E. Strömgren → B. Strömgren, July 21, 1937, ESC.

> seems to have all astronomers outside of Lund as enemies and doubtlessly among his slaves in Lund anybody would use any opportunity to break out. I was not invited to the constituting meeting (but L.J. was present). The member's fee is 6 Kroner. The objective is clear: to hamper both the Swedish and the Danish society.

"L.J." obviously denoted Carl Emil Luplau Janssen, with whom Elis was also not entirely on friendly terms. As recounted earlier, Luplau Janssen favoured the popularization of astronomy. Something that was not to the same extend regarded as a necessary public task by Elis, except for his work with the *NAT*. Nevertheless, he managed to extol the Danish popularizer Torvald Köhl in the early 1930'es. Yet another unfavourable mention of Lundmark was given in a letter to Bengt concerning an incident in Breslau: "You cannot possibly imagine how terribly Lundmark is developing and how hated he is in Sweden."[151] Perhaps the hate was more evident in Denmark, more specifically at the CO. The reason for Elis to bring odium on Lundmark is difficult to disentangle but one possibility is the difference of approach to science and to the public between the two colleagues – and the consequences of this variance.

Lundmark spent his student years together with his fellow student Bertil Lindblad under professor Östen Bergstrand. His scientific career consisted not only of purely astronomical research such as determining distances to spiral nebulae, classifying and cataloguing various nebulae at Lund University, where he was appointed professor in 1927. He also found the popularization of astronomy to be as important as plain research, as he regarded the natural sciences as being parts of culture just as much as fields from the humanities. As the British novelist and scientist Charles Pearcy Snow was concerned with the problem of "the two cultures" in 1959, so was Lundmark long before that time. Snow argued that practitioners of either of the two cultures know little, if anything, about the other and that communication is difficult, if at all possible, between them. In the 1930'es, Lundmark complained about the neglect of

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[151] E. Strömgren → B. Strömgren, July 31, 1937, ESC.

humanistic education among his research colleagues.[152] At the same time, he stressed that fields like astronomy could contribute with important insight to people from the humanities.

Perhaps Elis did not agree with Lundmark that the merging of the two cultures was necessary, if at all desirable. His wife, Hedvig, wrote novels as well as history of dentistry, but arguably, Elis himself was not especially literarily inclined to concern himself with other matters than science and science-politics. After all, he was not as broadly educated as was his spouse. Elis was more, perhaps solely, prone to theoretical astronomy while Lundmark also found it imperative to reach out to a broader audience. As to Bengt's opinions, he never got himself involved into such *ad hominem* discussions with his father about the Swedish professor but remained silent in his responses to Elis' complaints and gossip.

Not surprisingly, the other Danish astronomer with whom Elis had many disagreements was Ejnar Hertzsprung residing in Leiden. Once again, Elis reported his experiences at the Breslau meeting to Bengt and he was quite direct in his evaluation of the character of Hertzsprung. He attached a request to the letter which was formulated by Hertzsprung:[153]

> Ahead of the conference there had been a protracted written debate lead by Hertzsprung with his usual psychological defect and want of tact […]. Remarkably, Hertzsprung had Shapley on his side. I knew nothing about his request before I came to Breslau […]. He had the idea that Prager should no longer work with variables. Hence, our request fitted well with his [Hertzsprung's]. H's request was stopped by the executive committee and never made it to the meeting.

More than that, Elis gave an ironic comment to the German language used by Hertzsprung: "Notice the language, composed by a man who has lived eight years in Germany!" Occasionally, Hertzsprung visited Denmark, and on one of

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[152] Snow 1959; Holmberg 2003.
[153] E. Strömgren → B. Strömgren, July 14, 1937, ESC. The next two quotes are from this source.

those visits, he met with the CO assistant from the fall of 1936, Karl Thernøe (see Appendix A). Elis was very content with Thernøe's zeal and ability. Thernøe's assistantship was mainly concerned with calculation assignments and numerical integration of Elis' problème restraint trajectories and in the summer of 1937, Thernøe won the Copenhagen University's gold medal. Elis wrote about him that "every day, Th[ernøe] wins more appreciation and esteem from me".[154] Elis and Hertzsprung travelled to Denmark by train after the Breslau meeting, and promptly Hertzsprung visited Thernøe with a definite agenda to attract Thernøe to Leiden:[155]

> They had a conversation in which Hertzsprung encouraged Thernøe to travel abroad!! He is sweet. Thernøe was decided already (he knew about the man from V.H. [Julie Vinter Hansen]) and his answer was dismissive. I can tell you that he can not be pushed.

Bengt laconically replied that "the story of Hertzsprung and Thernøe is magnificent".[156] Hertzsprung won the Bruce Medal in 1937 and probably on this occasion, he went on a tour to the USA and visited the Yerkes Observatory. Bengt reported to his father that "everything went on painlessly and without any mention of embarrassing topics. I think that everyone here were relieved when he left. It is a pity that H. is so impossible on certain points. After all, he is quite nice and kind."[157] Moreover, Bengt gossiped back to Elis with an incident, which is given *in extenso* below.[158]

> I will now write about Hertzsprung's arrival here, but don't pass the story on to others. Struve picked him up in his car in Chicago at nine o'clock in the morning. H. [Hertzsprung] declared that they had to drop by a hotel to deposit

[154] E. Strömgren → B. Strömgren, June 9, 1937, ESC.
[155] E. Strömgren → B. Strömgren, July 14, 1937, ESC.
[156] B. Strömgren → E. Strömgren, August 12, 1937, ESC.
[157] B. Strömgren → E. Strömgren, December 11, 1937, ESC.
[158] B. Strömgren → E. Strömgren, January 16, 1938, ESC. See also appendix G – in the appendix of that text, Bengt referred to the following Hertzsprung incident).

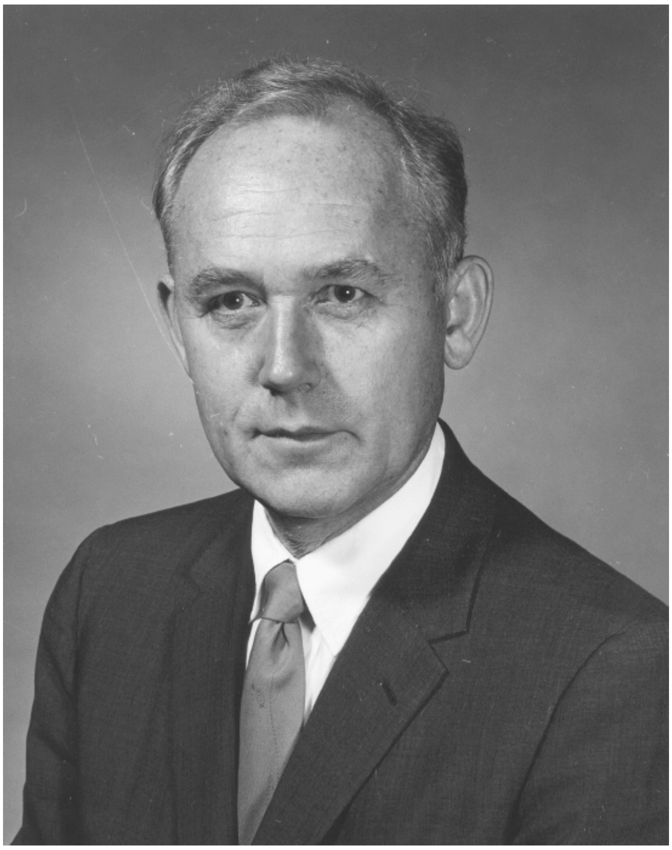

Figure 16: Kaj Aage Gunnar Strand (1907-2000). During the War he entered the U.S. Army, and then the U.S. Army Air Force where he flew as a Captain and chief navigator on B 29 tests. As head of the Navigation Department he was involved in operational training of special air crews, including the first atomic bomb crew. Strand is known for his advances in the photographic astrometry of double stars (Dick 2001).

some [photographic] plates. Struve then waited for H. outside the hotel. Time was running short when Stebbins[159] and other people were expected for lunch at Struves followed by a colloquium. However, three quarters passed by and Struve went inside to search. H. was in the bathroom to take a shower but promised to hurry up. Nevertheless, it took another hour because some craftsmen were summoned to fix the lock in the safe, which was supposed to contain the plates. Why they should be safer in the hotel never cleared up. At last they got off but after fifteen minutes of driving, H. asked if they could make a turn around and drive back to the hotel as he had forgotten his money. It is rather difficult to turn on the outer drives where they were – but they succeeded. However, soon after, H. discovered that he had his money anyway and Struve could turn the car around. In the meantime, I entertained the still more starved guests in Williams Bay. In the end, we all had a nice lunch after all the efforts.

[159] The Bruce medalist Joel Stebbins (1887-1966) directed the University of Illinois Observatory 1903-1922 and the University of Wisconsin's Washburn Observatory 1922-1948. Stebbins developed photoelectric photometry to a point where it succeeded photography as the photometric standard. He used the new technique to investigate eclipsing binaries, the reddening of starlight by interstellar dust, variable stars, and the sun (see also chapter 8.2).

In this way, father and son managed to mutually strengthen their image of the personal character of the Leiden astronomer.

Another Danish astronomer who went abroad was Kaj A.G. Strand. Strand began his research career working with Hertzsprung using photography to measure precisely the relative motions of nearby stars. Elis did not regard Strand particularly highly during his education at the CO. Strand was one year older than Bengt Strömgren and in 1933 he became Ejnar Hertzsprung's personal assistant at the University Observatory in Leiden. In 1937, Strand submitted a doctoral thesis on photographic measurements of binaries, based on his research in Leiden.[160] The thesis was accepted by the faculty in Copenhagen the same year – but Elis regretted this. His concern was the view that Strand did not contribute with anything original to astronomy. In contrast to Strand, Elis was sure that "a man like Thernøe will probably write an original doctoral dissertation with his own original performance".[161] Elis attempted to go against the faculty's decision to accept the dissertation by Strand. Clearly, in Elis' view, Strand was not to blame alone. Hertzsprung was in Elis' fore sight. Elis wrote to Bengt that he was certain that he had had made his opinion about Hertzsprung clear "in a way, which may be useful in the future".[162]

Hertzsprung was one of the official examination opponents for Strand's doctoral thesis on practical astronomy, Nørlund was the other official opponent. Since Elis was not among the opponents, he was upset and made it clear to the faculty that this was not in accord with the statues of the Copenhagen University. The regulations clearly stated that no external opponents were necessary unless the faculty did not manage to contribute with experts itself. Elis stressed that there were no less than three such experts. However, Elis never made it as opponent in this case and Strand received his doctorate. In 1938, Strand brought knowledge of the relative motion-technique to the Sproul Observatory in

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[160] "Dansk Astronom afgiver Rapport om Planet 5000 Gange større end Jorden", "*Berlingske Tidende*, November 28, 1942, 9.
[161] E. Strömgren → B. Strömgren, April 20, 1937, ESC.
[162] E. Strömgren → B. Strömgren, July 14, 1937, ESC.

Philadelphia where it was used in the search for extrasolar planets. From 1938-1942 Strand worked under Peter Van de Kamp as a Research Associate at Swarthmore College, and began a photographic double star program with the 24-inch telescope. Strand himself concentrated on 61 Cygni and in 1942 he announced that he had detected wobbles in the movement of this binary star, which indicated the presence of a planetary companion. From 1946, Strand worked as visiting professor of astronomy and the following year as research associate at the Yerkes Observatory and besides his positional astronomy research he taught in research problems in this field (see appendix D, p. 42). In 1958, he was appointed head of the Astrometry and Astrophysics Division at the U.S. Naval Observatory, rising to the position of Scientific Director in 1963.[163]

While Bengt spent his time in the US, Elis undertook the usual education and supervision of his students. His favorite assistant working under him at the time was Thernøe, whom he described as "probably the best man until now". In September 1937, Elis described the activities at the CO:[164]

> Møller and Thernøe are working with their exercises. Møller has got eight [students] in his class (five male, three female). For the time being, we have seven machines working (five now, and two on lease from Dalton). We plan to purchase some more. Thernøe has three in total.

In the fall of 1937, Jens P. Møller gave a course in "calculation of parabolic trajectories based on three observations". Møller asked Elis to do this, and Elis found him competent for the job. After Bengt's leave from Copenhagen, Thernøe continued his theoretical astrophysics classes and made use of Bengt's written calculation exercises.

In Chicago, Bengt, and later Keenan, gave courses in theoretical astrophysics on campus. This was a prerequisite for students wishing to work at the Yerkes Observatory – and of interest to students specializing in physics.[165]

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[163] Dick 2001.
[164] E. Strömgren → B. Strömgren, March 12, 1937, ESC.
[165] UCA, OPUC 1936-1937, 227.

The courses in classical astronomy were given by Bartky with emphasis on the development of the mathematical principles and methods forming the basis of the physical sciences. He taught celestial mechanics, descriptive astronomy, analytic mechanics, and e.g. periodic orbits. Fortnightly, the advanced students were expected to participate in the so-called Departmental Club meetings for the review of memoirs and books and for the presentation of research results. The advanced students could go to the Yerkes Observatory to practice modern methods of research. In the years 1936-1938, this included[166]

> researches in solar physics with the spectroscope; micrometric observations of double stars, planets, satellites, nebulae, and comets; studies of photographic stellar spectra and determinations in motions in the line of sight; photography of stars, planets, satellites, nebulae, etc.; photographic investigations of stellar parallax; research in visual and photographic photometry; special astrophysical researches.

To enable the advanced students to follow the research, the Yerkes staff laid out required courses of collateral reading. Later, in 1938-39, the McDonald Observatory was included as a possible aim for advanced students. Only few students went there for obvious geographical reasons as Mount Locke is located in Texas. They could still use observational material obtained with the 82-inch reflector though. In Williams Bay, van Biesbroeck taught astrometry, Struve instructed in stellar spectroscopy, Chandrasekhar gave courses in theories of the stellar interior, Kuiper in statistics and dynamics of stellar systems, and Bengt instructed advanced students in “the theory of absorption and emission power of matter” and in the theory of stellar atmospheres.[167]

In this way, the Yerkes staff taught in the fields of research. Not surprisingly, the difference in scale between the astronomy departments of the universities of Chicago and Copenhagen University was evident. What turned out to be an important outcome of Bengt’s stay in Chicago was obviously his

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[166] Ibid.
[167] UCA, OPUC, 1937-1938, 233.

manifold experience with American traditions of teaching, research, practice and administration. Compared with Danish astronomy teaching, the teaching in Chicago progressed on a considerably larger scale.

Besides Elis' academic work, he spent some of his time with local networking in the Copenhagen high society. He was fascinated by Otto Gelsted's poetry. Gelsted, introduced in chapter four as a representative of the influence of culture-policy from the Soviet Union, occasionally visited Elis at the CO, if only when he was in a good mood. He was of a somewhat moody psyche. During the Christmas days of 1937, Gelsted was invited to a party in the observatory together with the artist Edward Saltoft. After inviting them, Elis wondered why they did not respond. Indirectly, Elis heard that Saltoft was stationed at the municipal hospital for psychological reasons. Regarding Gelsted, Elis asked him in a letter if he had not received the invitation. No answer. Elis reacted in a rather creative way as he told his son:[168]

> Then I thought: I guess I better speak his own language and wrote the following letter, which is inspired by his sweet poem from the collection of poems […] "Where is Jytte's knock-knees?...":
>
> Where is Otto's blotting paper?
> where did Otto's pens go?
> where is Otto's writing paper?
> where did all the ink go?
> Where did the whole of Otto go?
>
> And behold: He immediately turned up in person! He was quite fatigued but decent as always. He excused himself excessively that he could not show up for the party because he is writing a book about Johannes V. Jensen just now. The

[168] My own translation from "Hvor er Ottos Klatpapir? / hvor er Ottos Penne? / hvor er Ottos Brevpapir? / hvor er blækket henne? / Hvor er hele Otto?". In 1938, Otto Gelsted, née Einar Otto Jeppesen, published the book "Kurven i hans Udvikling" about the Danish national author Johannes V. Jensen.
E. Strömgren → B. Strömgren, December 31, 1937, ESC.

> most important cause is two-fold: He is in a period now and he has got no smoking.

Elis found Gelsted to be “a particularly inviting man; and his poems are enchanting”. At a party held by Gelsted earlier the same year, Elis met the politician K.K. Steincke. He found the meeting “very interesting” and noted Steincke’s “worries about Danish Nazism, which according to him is rising much stronger than generally believed, partly with foreign financial support”.[169] Anxiety for the future and the immanent fear of Nazism became still more evident, even in the heart of the German friendly astronomer, who once had lived in Germany and who once considered to move there for a permanent position. Thus, the anxiety was transferred to Williams Bay as well through the massive Strömgren correspondence.

By constantly updating his son, Elis obviously made it easier for Bengt to return to Denmark. He found Bengt’s life in Wisconsin fantastically exciting but he also knew that his son was more than busy finishing his research. In an attempt to prepare Bengt for the future, the old professor gave his view of the situation, with the eyes of a father:[170]

> Now you have your life position, including pension scheme and everything. Now, the time is ripe to keep calm about your life. By this I don’t mean less work, but work in more easy forms, with less rush and with more peace for human nature (i.e. answering letters!). All the rush was only natural as long as your object was to [work] for a safe future. Now, this is no longer necessary and you don’t need to take new work when you are preoccupied with – and have promised to take care of – other work.

At the same time, Elis referred to a long list of obligations, i.e. Danish matters, that Bengt had taken on his shoulders but which he [Bengt] had treated shabbily, according to his father. Elis and Hedvig helped Bengt and his family find a house

[169] E. Strömgren → B. Strömgren, December 5, 1937, ESC.
[170] E. Strömgren → B. Strömgren, October 5, 1937, ESC.

in Hellerup[171], very close to their first apartment on Hellerupvej. In the last many letters containing chiefly practical information, nearing their leave from Williams Bay, Elis wrote a nota bene to Sigrid: “Sigrid! S.O.S.! S.O.S.! S.O.S.!!! When you return, I would like to have Bengt for a whole day for myself, if possible – S.O.S. – with a subsequent whole night”.[172] The old father missed his son and soon they would be reunited. Bengt answered only few of Elis’ copious letters in the last period of his stay. He had only one final research tour left before going back to his homeland. He wanted to visit the McDonald Observatory. It is interesting – yet difficult – to guess what Bengt thought about the controlling nature of Elis, though it was not exactly typical for a Danish father to interfere in his adult child’s matters like Elis did.

Going to Texas

On January 24, he and Struve arrived in Austin, Texas. They had a comfortable and enjoyable journey down south. Unfortunately Sigrid was not able to join him. The parents both regarded the trip to be too draining for their girls to travel under the warm and cumbersome conditions in the south. While Bengt was away, Sigrid prepared the approaching trip to Denmark. Bengt and Struve visited the University of Texas, which had made an agreement with the University of Chicago in 1932 to the build up of the McDonald Observatory by use of funding from the W.J. McDonald Observatory Fund under the will of the late W.J. McDonald – a Texan philanthropist.[173] Four astronomers already worked permanently at the Observatory by 1938, the associate professor of astrophysics Christian T. Elvey, the research associate Carl Keenan Seyfert, the assistant Jesse Rudnick, and the astronomer Paul Rudnick who completed his PhD at Yerkes in 1936. Seyfert finished his PhD at Harvard and Shapley and Struve helped him get the position at the McDonald Observatory.

Struve and Bengt went to El Paso at the Mexican border on a weekend trip and Bengt had the first Mexican meal in his life. He was much impressed by the

[171] The house was located on Svejgaardsvej 25; E. Strömgren → B. Strömgren, January 21, 1938, ESC.
[172] Ibid. Elis Strömgren kept reminded Sigrid several times his letters to her husband.
[173] UCA, BTM, September 8, 1932, on page 239.

observatory dome on the mountain top and he was very enthusiastic about the prospective 82-inch instrument. “The starry sky is more beautiful than I have ever experienced it before. There are ca. 300 – at least partly – clear nights a year.”[174] Bengt gave a intense course for the staff by lecturing one or two times a day on interstellar problems. He instructed Paul Rudnick to be in charge of some photoelectric observations of Cepheid stars for Bengt, the results of which should then be sent to Copenhagen later.[175]

After a few weeks in Texas, Bengt and Struve went home to Williams Bay, and Bengt collected all his paper work to pack it and bring it home. Clearly, he was many an experience richer compared to his autumn arrival less than eighteen months earlier. Much had changed. He was now fluent in English with an American accent; he had given courses to American students in Chicago and at the Yerkes Observatory; he had learned more about large scale equipment and the build-up of large telescopes; he had undertaken the planning of a Schmidt reflector system for photometric investigations; he had observed systematically with the largest refractor in the world; and his theoretical work with stellar interiors had secured himself as wearing the strongest suit of this field of astrophysics.[176] His work of spectroscopic observations, together with Morgan, and his collaboration with Kuiper and Struve had given him the challenges and knowledge which definitely made him the best candidate as the successor of his father’s professorship only few years ahead. Furthermore, his frequent discussions with Chandrasekhar had been crucial for the development of his scientific reasoning.

Bengt had changed and he had matured dramatically. Struve, on the other hand, was not happy of losing his close friend and colleague for the small Danish Observatory. He still hoped that Bengt would change his mind after one or two years in Denmark and then return for a permanent position. Therefore, Struve fixed the staff list in the curriculum catalogue for 1938-1939 in such a way that

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[174] B. Strömgren → E. Strömgren, February 18, 1938, ESC.
[175] Osterbrock 1997, 196-197.
[176] Annual Report, 1936-1937, uncatalogued, YOA.

Bengt was on the list but only as being on leave of absence.[177] Except of being a merely practical convenience, since it would be easier for the University to reappoint Bengt after one year, the "leave of absence" tag could also be taken as another symbol of expression of Struve's hope of getting the Dane back to Williams Bay. Yet, Struve should find a replacement for Strömgren – although it was a difficult task. As he wrote President Hutchins a year after Bengt's return, he regarded Bengt's zeal, ability, and acumen decisive for the Observatory:[178]

> It was my opinion while Strömgren was a member of the faculty here that our astronomy department was the best of any institution in the world. Strömgren's decision to return to Denmark has weakened us considerable, and an effort must be made to replace him with a man of equal ability.

Struve realized that in order to retain the best astronomers, it was necessary to increase their salaries. He also stressed that careful judgment had to be used in granting the increases since otherwise the observatory would "undoubtedly lose some of the best men we now have." His concern was indeed of a serious kind and after thorough research and weighing recommendations from Russell and Shapley among others he decided to try Dr. Karl Wurm, an astronomer at the Potsdam Astrophysical Observatory, as the successor of Strömgren. As it turned out, Wurm worked as assistant professor for one year but then he left Wisconsin again (see Appendix C).

Bengt looked forward to going back. Not least because of Sigrid's impact on his feelings. Sigrid was a generally educated big city woman who had soon become tired of the small town life at Lake Geneva.[179] More than that, the political development in Europe was influential for the Strömgren's to go back – and ultimately to stay in Denmark.

The director of the CO had managed to prepare everything in the best order for Bengt's return. The family was scheduled to return from New York on

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177 "B.S. leave of absence, no salary 1 year from April 1, 1938", 1937, UCA, PP1.
178 O. Struve → R.M. Hutchins, July 13, 1939, UCA, PP1 (1938-1940).
179 KNSI.

Figure 17: Farewell at Walworth Station, 10 miles from the Yerkes Observatory. From left: Karin, Nina, Sigrid, Bengt, Chandrasekhar, George Van Biesbroeck, and unknown young man, March 1938 (courtesy of Nina Strömgren Allen).

March 26 and via Bremen they planned to be back in Copenhagen on April 4, 1938.[180] Elis wrote Bengt in advance that his work for getting more calculating machines to the observatory bore fruit. The curator of the University of Copenhagen intended to donate a machine to the Almanac Office, "I mentioned the 5 or 6 million Kroner that the Almanacs have profited for the university in my years of calculating them and thought that under such circumstances, the observatory needed better calculating conditions." The curator agreed and during their conversation, "the curator said that your son can easily have as many instruments he wants from the Carlsberg Foundation!"[181] Thus, Bengt and his family left for Denmark but Chandrasekhar joined them on the first part of their trip. He and Bengt had been invited by George Gamow to participate in a

[180] E. Strömgren → B. Strömgren, January 23, 1938, ESC.
[181] E. Strömgren → B. Strömgren, March 8, 1938, ESC. In 1939, 3,060 Kroner came on the Budget "for the purchase of en electronic calculation machine for the observatory", *Kongelig Dansk Hof- og Statskalender*,1938-39, 230.

conference in Washington, which was just fitted into Bengt's travel plans. And this was no coincidence.

5.4 Solar Life Supply: The Washington Watershed

With Bengt's publication in *Ergebnisse der Exakten Naturwissenschaften*, the problem of stellar interiors and energy production was open for investigation by theoretical physicists and not only astrophysicists. Bengt was used to collaboration between astronomers and physicists already from the early 1930ies and naturally he welcomed their views on the riddle of the time: What sources of energy created the massive radiation in stars?

In the late nineteenth century, Hermann von Helmholtz suggested a mechanical theory of the sun's life supply. The heat from the sun came from the conversion of gravitational energy to heat energy in the process of condensation of material. Forerunning theories proposed chemical reactions as the source of energy generation, but William Thomson, Lord Kelvin, pointed out that the most energetic chemical reactions known at the time would not keep the sun radiating for more than about 3,000 years. Nineteenth century physicists calculated classically the potential energy of the sun, E_{pot}:

$$E_{pot} = -\frac{GM}{R}\ .$$

A similar amount of energy was set free when the sun was assembled from interstellar gas or dust in the dim past; in fact, somewhat more, due to the increasing density of the sun's material towards its center. One half of the liberated energy is transformed into kinetic energy in concurrence with the so-called mechanical virial theorem and the other half of the energy is radiated away. With the values of solar radiation, there would be sufficient energy for the sun to live for ca. 10^{15} seconds, or about 30 million years. At the time, this was long enough for physicists, but not for biologists, as Charles Darwin's theory of evolution became gradually accepted. Helmholtz argued with the biologists that 30 million years was not enough.[182]

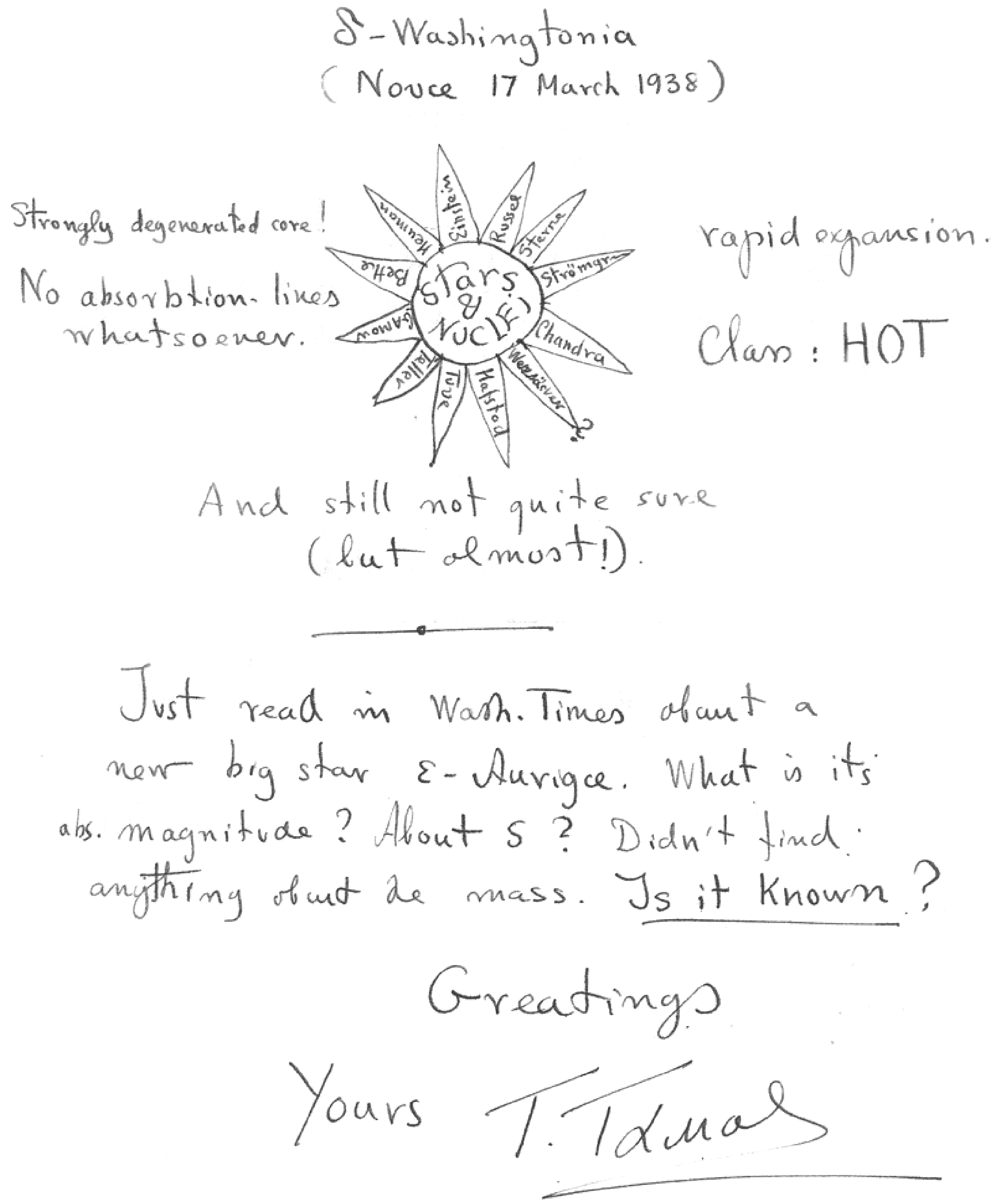
[182] A classic on this topic is Burchfield 1990.

With Becquerel and the two Curie's discovery of radioactivity, the age of the earth could be determined. Later, by use of meteorites, the sun was estimated to be ca. five billion years old. The theory of gravitation was not sufficient. Curiously, already by the end of the nineteenth century, the American geologist Thomas C. Chamberlain in fact suggested some sort of atomic power supply in the Sun. Eddington was very concerned about the sources of stellar energy. According to his preferred theory of the 1920'es, solar matter underwent complete annihilation, turning nuclei and electrons into radiation (we remember that the neutron was only discovered in 1932).[183] By use of Albert Einstein's mass-energy relation, Eddington found that the proposed processes would contribute with energy creation for about 1,500 billion years. Though, he was well aware that complete annihilation had never been observed. As recounted in chapter 4.7, in 1929, Atkinson and Houtermans construed that nuclear reactions could occur in a stellar core of high temperatures and by the early 1930'es, there was a general consensus that stellar energy was produced by nuclear reactions.[184]

As already discussed above, one consequence of Strömgren's discovery of the preponderances of hydrogen and helium in stellar interiors reduced the possible scenarios ready for investigation by the theoretical physicists. By knowing about the element content, the number of probable atomic processes was reduced considerably to nuclear processes involving basically hydrogen and helium. Another reason that physicists turned their attention to these questions was that Eddington, Russell, Strömgren, Rosseland, and other theoretical astrophysicists were constantly trumpeting the problem's importance. As detailed in Hufbauer 1990, between 1935 and 1937, several theoretical physicists issued wide-ranging investigations of relevant nuclear-reaction physics; Gamow, Weizsäcker, and Bethe in particular.

Already by January 1937, Gamow, who held the Chair of Physics at the George Washington University from 1934, had plans of gathering the best physicists and astronomers to discuss the burning issue of nuclear energy

[183] An excellent treatment of the development in the period 1917-1920 is given in Hufbauer 1981.
[184] North 1994, chapters 15 and 16; Bethe 1967. The history of the energy generation in the sun is also treated in Hufbauer 1981, 1990, and 1991.


δ-Washingtonia
(Novae 17 March 1938)

Strongly degenerated core!
No absorbtion-lines whatsoever.

rapid expansion.
Class: HOT

STARS & NUCLEI

Einstein, Russel, Sterne, Strömgr., Chandra, Weizsäcker, Hafstad, Tuve, Teller, Gamow, Bethe, Neuman

And still not quite sure
(but almost!).

Just read in Wash. Times about a new big star ε-Aurigae. What is its abs. magnitude? About 5? Didn't find anything about the mass. Is it Known?

Greatings

Yours T. Tdma

Figure 18: Gamow used the common Greek symbolic terminology of astronomy in his naming of the "new star" *δ* Washingtonia, "discovered" on March 17, 1938. This was the trademark form of Gamow's humorous letters, always rich in symbols, decorated with drawings, handwritten graphs, Hindi-looking letters in his correspondence with Chandrasekhar, and sometimes, as in this case, giving his signature in Greek letters. In fact, the Washington Conference was held during three days from March 21 to 23, 1938. (Gamow → Chandrasekhar, January 13,1938, UCA, SCP).

production in stars. Gamow, Edward Teller, and Merle Tuve, also with this university, were not in very close contact with the Chicago group of astronomers, but Gamow knew Bengt from his research visit to the UITF in 1929-1930.

In the fall of 1937, Gamow informed Chandrasekhar about the history of the conferences annually held by the George Washington University – and sponsored by the Department of Terrestrial Magnetism of the Carnegie Institution – on the subject of theoretical physics. In recent years, the themes of the meetings had been on nuclei, molecules, and particle physics respectively. The theme of the 1938 Washington Conference was intended to be on the sources of stellar energy. The scale of the conference was intended to be low with "no crowd, no formal papers, limiting the number of invited members to about a dozen". Gamow told Chandrasekhar about his plans for the conference, since he found it imperative that both Chandrasekhar and Strömgren would attend: "It is too bad about Strömgren. Of course he must be the ace of the conference and we are doing our best to fix the conference before he goes (may be beginning of March [1938]. Then we will have a big fight there." Gamow would also like Chandrasekhar to recommend "one or two really good *theoretical* astrophysicists in this country to be invited".[185] Gamow admitted in the letter that he was "becoming gradually more and more interested in stellar problems and hope to learn a lot from the chat with you and other members". Entertainingly, he told Chandrasekhar that "I have almost discovered a new star" (see figure 18).

Chandrasekhar replied to Gamow that "It is my opinion that no astrophysicist is more competent to 'help' the physicists than Strömgren is" and he recommended two American astrophysicists.[186] One of them was the new professor of astrophysics at Harvard and authority on the sun's chromosphere, Donald Menzel, who discovered the oxygen content of the solar corona in 1933 with Joseph C. Boyce. The other recommendation was of the astrophysicist Theodore Sterne with the Harvard College Observatory, Cambridge, Massachusetts.

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[185] G. Gamow → S. Chandrasekhar, January 7, 1938 (wrongly dated 1937), UCA, SCP.
[186] S. Chandrasekhar → G. Gamow, December 29, 1937, YOA. See also DeVorkin 2000, 425, note 76.

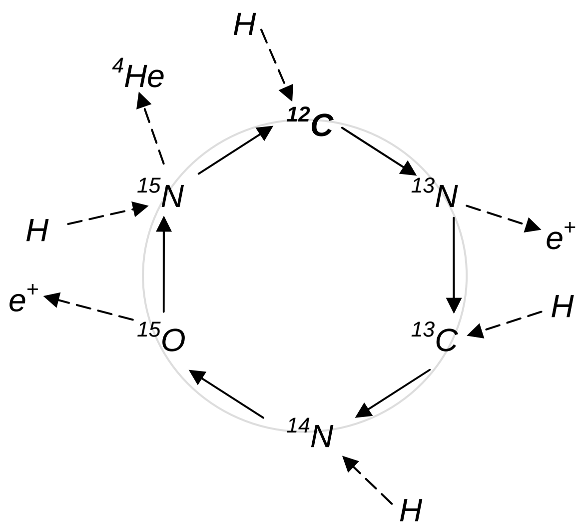

Figure 19: Graphic representation of Carl Friedrich von Weizsäcker's somewhat symmetric carbon cycle, which indicated that the most important source of energy in ordinary stars was the reactions of carbon and nitrogen with protons, and combining four protons and two electrons into an *alpha*-particle (Weizsäcker 1938, 639). The emission of neutrinos and gamma-particles was not included explicitly in Weizsäcker's tentative model (the existence of the positron, e^+, was predicted by Paul Dirac in 1931 and it was discovered the following year by C. Anderson (Kragh 1999, 197)).

One of the most important physicists to enter the realm of astrophysics in the late 1930'es was Weizsäcker. During postdoctoral visits in Copenhagen he had met Bengt on several occasions. He worked on a monograph on atomic nuclei that he completed in 1936, during which he investigated the astrophysical applications of nuclear physics.[187] He found it probable that more knowledge of nuclear reactions would suffice to resolve the problem of energy generation in stellar interiors.[188] The ensuing year he followed his observations up with a detailed paper, the manuscript of which he sent to Bengt in Williams Bay before publication, as already described above. Weizsäcker drew upon fresh knowledge of the neutron, of deuterium, of tritium and of many various nuclear reactions in his discussion of promising energy producing processes.[189]

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[187] Weizsäcker 1937.
[188] Hufbauer 1990, 21.
[189] Weizsäcker 1938.

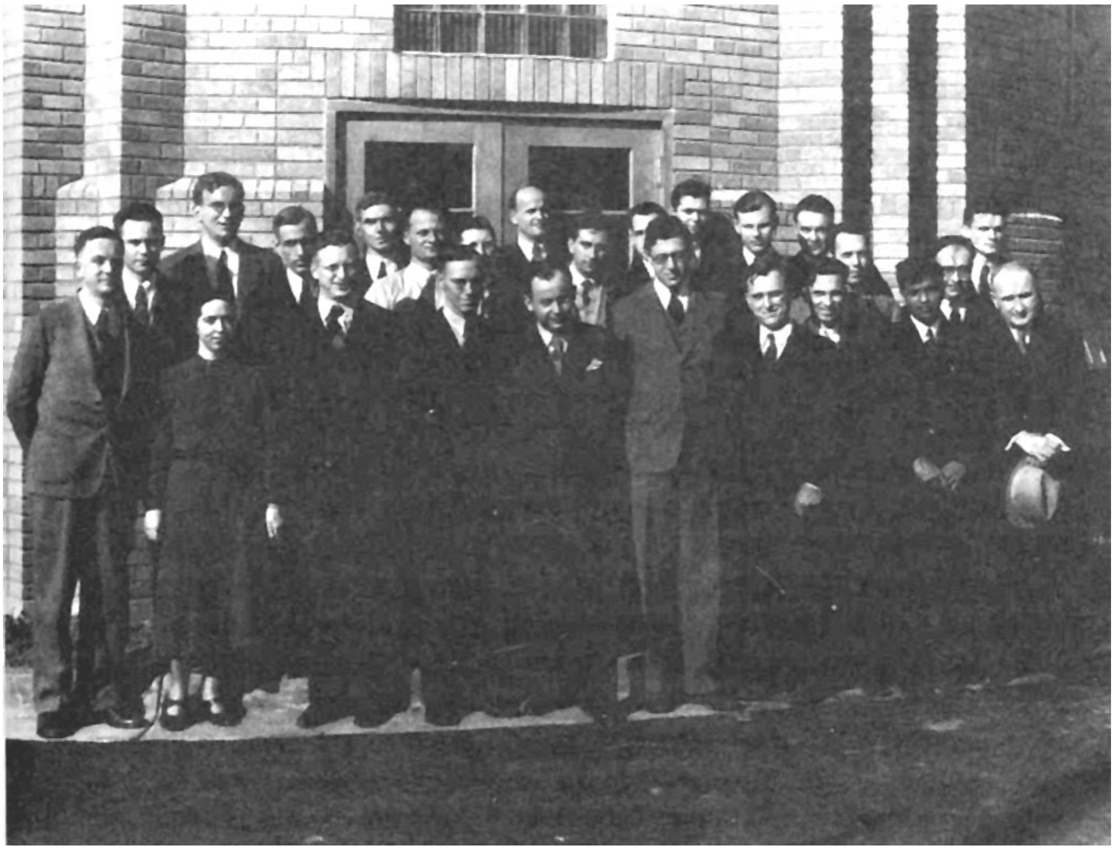

Figure 20: The conference in Washington to bring theoretical astrophysicists and physicists together, March 21-23, 1938. Of the 34 participants, 25 appeared on the group photograph. From left: **M.A. Tuve**, M.A. Wulf, Mrs. Tuve, **G. Gamow**, F.L. Mohler, **D.H. Menzel**, K.F. Herzfeld, **H.A. Bethe**, L.R. Hafstad, R.J. Sieger, R. Gunn, **E. Teller**, J. v. Neuman, W.A. Wildhack, **T.E. Sterne**, F.L. Talbot, **B. Strömgren**, R.C. Meyer, C. Beck, N.P. Heydenberg, R.B. Roberts, **S. Chandrasekhar**, G. Breit, C.L. Critchfield, Fleming (WC, 11).

Weizsäcker, working at the Kaiser Wilhelm Institute of Physics in Berlin, was confronted with three insurmountable problems. Following Hufbauer 1990, Weizsäcker was at variance with current stellar theory in necessitating very small reactive cores so that neutron densities would suffice for the synthesis of heavy elements. Moreover, he was at odds with the latest observational work in implying that helium was abundant in stellar interiors. Biermann, also working in Berlin, may have convinced Weizsäcker that Strömgren's theoretical findings seemed less credible than Unsöld's empirical elemental abundances found already in 1931 (page 252). Finally, Weizsäcker was unable to provide an adequate explanation of the observed abundances for heavier elements.[190]

As laboratory research had not yet established the existence of nuclei with mass number 5, which was thought to be essential for the element building to progress beyond helium, Weizsäcker indicated that isotopes with mass numbers 5 and 8 were incapable of existence. He decided on suggesting a cyclic process in which the carbon nucleus served as a catalyst in the energy generating synthesis of helium. Weizsäcker's analysis of the stellar-energy problem, which was of a rather qualitative character, was unique but his ideas were soon eclipsed by Hans Bethe's research. On the other hand, Bethe did not even try to explain the element formation. He was solely interested in the energy question.

Elis also received the manuscript from Weizsäcker, which, he admitted to Bengt, "I spelled my way through".[191] The reason was that Weizsäcker and Hund planned to visit Copenhagen for a September congress at the UITF. On this occasion they both visited Elis at the CO. "It was very pleasant. I find Weizsäcker particularly friendly and well-behaved. Obviously, he respects you very much and he unassumingly discussed his own results"[192] Weizsäcker's manuscript also prepared the Yerkes staff and as recounted in DeVorkin 2000, Gamow tried to convince Russell to attend the conference although he was very busy planning a European tour to end at the IAU General Assembly in Stockholm in August 1938. Gamow sent him Weizsäcker's manuscript on nuclear resonance effects and their applications to his theory for an evolved star. The manuscript excited Russell but he could not find the time, and thus he "missed out what turned out to be a watershed event in the history of the stellar energy problem".[193] Also the theoretician John Wheeler was invited but he was also unable to attend.

Gamow fixed the date so that Strömgren would be able to attend on his family's way to Denmark through Washington and New York. Strömgren had

[190] Hufbauer 1990, 22.
[191] E. Strömgren → B. Strömgren, September 3, 1937, ESC.
[192] E. Strömgren → B. Strömgren, September 25, 1937, ESC.
[193] DeVorkin 2000, 253.

not been in any close contact with stellar nuclear reactions until this meeting. After waving goodbye to the Yerkes staff, Sigrid, Nina, Karin, Bengt, Lalitha and Subrahmanyan Chandrasekhar went to the East by train on March 19 from the station in Walworth close to the Yerkes Observatory (figure 17). They arrived in Washington, and the fourth Washington Conference on Theoretical Physics was launched on March 21. The meeting counted thirty-four participants, mainly physicists and half a dozen astrophysicists – all from American institutions.

The first meeting entitled “Nuclear transformations in stars” was opened by ‘the ace of the conference’ [Bengt Strömgren], who outlined the present status of the problem of temperature and density distribution in the interior of stars. For the theory of internal structure of stars, two physical properties of stellar matter were treated as having “extreme importance: The opacity and the rate of energy-production.”[194] In the second meeting, Bengt reported on calculations of opacity in its dependence of temperature and chemical constitution of stellar matter. Menzel reported other calculations of opacities and the questions regarding the validity of present derivations of opacity-formulae “led to an animated discussion between all participants”.[195]

Chandrasekhar, Gamow, and Tuve issued the results of the Washington Conference in *Nature*, in which Weizsäcker’s so-called “aufbauhypothese” was commented. The hypothesis mainly stated that stellar interiors were continually build up of heavier elements from hydrogen and that such processes liberate sufficient amounts of energy to account for the radiation of the stars. However, Weizsäcker’s model schemes of transmutations of helium into lithium and back to another helium isotope, while emitting radiation and positrons, were contradicted by experimental evidence. It was evidently uncertain, which processes should account for the stellar energy production.[196] Bengt’s experience of the first part of the conference was “that no solution was in sight. But that certainly there was a hope that the input from nuclear physics was around the

[194] WC, 4.
[195] Ibid.
[196] Chandrasekhar et al. 1938.

corner".[197] And around the corner was Bethe, who became interested in the nuclear aspects on occasion of the Washington conference. Before that, he had been presented with Weizsäcker's and Gamow's efforts to identify the reactions powering the stars. One morning during the conference he "said that he had thought about Weizsäcker's cycles and that he had alternative ideas, and he gave a talk right at the meeting on his carbon cycles," and then "he gave the carbon cycle, exactly as he formulated it".[198] Bethe made use of the updated view of stellar interiors given by Bengt and by Chandrasekhar's newly completed manuscript of his monograph on stellar structure. He also learned more about Weizsäcker, Gamow, and the Russian physicist Lev Landau's proposed solutions during the most recent years. As testified in the conference report, "Dr. Bethe now proposes to take up a more detailed study of this question."[199]

Thus, on the train journey back to the Cornell University in Ithaca, Bethe said to himself, referring to Gamow's telling a few years later,[200]

> It should not be so difficult after all to find the reaction which would just fit our old Sun […]; I must surely be able to figure it out before dinner!" And taking out a piece of paper, he began to cover it with rows of formulas and numerals, no doubt to the surprise of his fellow-passengers. One nuclear reaction after another he discarded from the list of possible candidates for the solar life supply; and as the Sun, all unaware of the trouble it was causing, began to sink slowly under the horizon, the problem was still unsolved. But Hans Bethe is not the man to miss a good meal simply because of some difficulties with the Sun and, redoubling his efforts, he had the correct answer at the very moment when the passing dining-car steward announced the first call for dinner.

As noticed by Hufbauer, Gamow exaggerated Bethe's pace of discovery as he kept giving colloquia on and corresponding about his solution to the solar life supply within two months after the conference in Washington. Bethe concluded

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[197] HI, 18.
[198] CI, 76.
[199] WC, 4.
[200] As recounted by Hufbauer 1990, 24-25; following Gamow's popular book *The Birth and Death of the Sun*, Gamow 1940, 112-113.

that the most likely reaction processes to convert hydrogen into helium were the CNO reaction cycle given in figure 19 and the proton-proton chain, which simultaneously fuses two protons and beta decay to produce a positron, e^+, a neutrino, ν, and the mass-two isotope of hydrogen called deuterium (1). Then the deuterium reacts with another proton to produce a helium-3 isotope and a gamma-ray (2). Finally, two helium-3 isotopes – produced in separate implementations of the first two steps – fuse to form a helium-4 nucleus and two protons (3):[201]

$$(1)\quad {}^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu$$
$$(2)\quad {}^{2}H + {}^{1}H \rightarrow {}^{3}He + \gamma$$
$$(3)\quad {}^{3}He + {}^{3}He \rightarrow {}^{4}He + {}^{1}H + {}^{1}H$$

More than Weizsäcker, Bethe managed to complement the nuclear reaction schemes with the quantification of both the nuclear reaction physics and the integration into stellar-structure theory by use of his knowledge from Strömgren and Chandrasekhar in particular. Bethe found an impressive agreement between the predicted temperatures of the proposed thermonuclear reactions and the estimated central temperatures given by the astrophysicists. In *Physical Review*, he reported,[202]

> The agreement of the carbon-nitrogen reactions with observational data is excellent. In order to give the correct energy evolution in the sun, the central temperature of the sun would have to be 18.5 million degrees while integration of the Eddington equations gives 19. For the brilliant star Y Cygni the corresponding figures are 30 and 32. This good agreement holds for all bright stars of the main sequence, but, of course, not for giants […] For fainter stars, with lower central temperatures, the reaction *H+H=D + epsilon*$^+$ and the reactions following it, are believed to be mainly responsible for the energy production.

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[201] The neutrino, ν , was predicted by Wolfgang Pauli in 1929 and discovered only in 1956 by F. Reines and C. Cowan (Kragh 1999, 197).
[202] Bethe 1939, §7, §9, and §10.

Here, *D* denoted the deuterium isotope (^2H in our notation), and *epsilon*$^+$ was his notation of the positron (e^+).

Only four months after the IAU General Assembly in Stockholm, where Bethe's ideas were widely, if only tentatively discussed, he was honoured with the New York Academy of Science's Morrison Prize. Interestingly, Bethe's full account of his scheme of reactions was published in his landmark article in March 1939, only after the prompt expressions of appreciation and recognition among most astrophysicists. Russell heralded the paper. As recounted by DeVorkin, Russell co-organized a symposium on the progress in astrophysics at the American Philosophical Society in early 1939. At the seminar, Russell allegedly "apologized to his audience for not being Hans Bethe, "the man whose recent and brilliant work has inaugurated a new and very promising stage of astrophysical study"".[203] With the Morrison Prize of $500, Russell declared Bethe's solution of the stellar energy problem as "the most notable achievement of theoretical astrophysics of the last fifteen years".[204]

5.5 Back again

After the completion of the conference, Chandrasekhar joined Bengt, Sigrid, and the girls for a short visit at Harvard, and afterwards, he accompanied the Strömgrens to the pier to wave goodbye to the Danes on the boat. Via Bremen, Hamburg, and taking the Gedser Ferry, they were in Copenhagen in the evening where all their relatives and many others welcomed them in the harbor. Bengt found things very little changed from when they left one and a half year earlier. He thanked Chandrasekhar by mail for taking care of them on their departure and assured him that everything was in the best order:[205]

[203] DeVorkin 2000, 255.
[204] Hufbauer 1990.
[205] B. Strömgren → S. Chandrasekhar, April 16, 1938, UCA, SCP.

Figure 21: The Strömgren family and their maid Annie on the deck of S.S. Columbus, travelling second class. Enlarged cutting in lower left corner showing Sigrid, Karin, Bengt, Nina and Annie, all looking at the harbor (courtesy of Nina Strömgren Allen).

My parents are well, and so is my brother. My brother is just finishing his thesis. Of the people at the observatory Mrs. Vinter Hansen is gradually regaining strength after her long illness. Thernøe is full of energy. He had improved the methods to calculate Emden function and wanted to show them to me, therefore the delay. It seems to be very nice indeed.

The day after Bengt's arrival, there was a big celebration at the UITF, when the cyclotrone and the high voltage instruments were shown to authorities and donors.[206]

> It was fine to see Bohr again. He is quite interested in all the recent work on nuclear processes in the stellar interior. Rosenfeld, Peacock, and Frisch are here, and Møller of course. I had a letter from Gamow in which he wrote that he was very happy about the recent Washington conference.

At the same time, Bengt expressed how he missed Chandrasekhar:[207]

> Sigrid has finished arranging our new home, and everything is very nice. We have visited the summer house a few times and are looking forward to moving out there by the end of June. I am lecturing now, but only two hours a week. I wish I could hear your lectures, and also to watch the little incidents with the students that you describe.

Bengt's return to his extraordinary professorship was a continuation of his work before leaving for the USA, only his salary had been increased by the natural sciences faculty in the successful attempt to lure him back to Denmark.

Bengt's visit to the McDonald Observatory in January was only a beginning in the improvement of observational techniques required for measuring faint spectral lines. The proceeding development of experimental techniques and the dedication of the McDonald Observatory constituted important steps towards the beginning of a new spectroscopic period for stellar atmospheres. Rupert Wildt played an important part in the development of atmospheric theories in relation to the H^- ion. Wildt calculated the abundance of the H^- ion and estimated the continuous absorption due to H^-. He pointed out that this absorption was stronger than the one originally considered by Menzel, of absorption by free electrons in the field of neutral hydrogen. Bengt wrote to

[206] B. Strömgren → S. Chandrasekhar, May 25, 1938, UCA, SCP.
[207] Ibid.

Figure 22: The 6th IAU General Assembly in Stockholm from August 3-10, 1938 (YODA).

Chandrasekhar about his scheme that "You will notice that I am rather enthusiastic about the H^- idea right now. That may change, however, so please don't tell about it, so it gets outside Yerkes."[208] Bengt's secrecy indicated that he scented a serious outcome of his theoretical investigations.

After returning to Denmark, Bengt went on a visit to Berlin-Babelsberg where he stayed with Weizsäcker and had discussions with Biermann about the presence of H^- ions in stellar atmospheres. Like many other astronomers, Bengt was "a bit frustrated. There was something wrong."[209] Bengt gave a paper on the solar atmosphere, where he took into account the H^- ion and following further discussions on the basis of his talk, everything fell into place. The result of his work was published in the *Festschrift* for his father, which was published in 1940

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[208] B. Strömgren → S. Chandrasekhar, August 23, 1938, UCA, SCP.
[209] HI 19.

on occasion of his 70th birthday and retirement from active service.[210] This article contained “a realistic model” of the chemical composition of the solar atmosphere, that is, tables of corresponding values of pressure, temperature, and H^- absorption. The model agreed “remarkably well with the composition of meteorites”.[211] The crystallographer at the Physics Department in Chicago, Willy Zachariasen, guided Bengt to some papers of the Austrian-born geo-chemist Victor Moritz Goldschmidt. Goldschmidt derived abundances of the metals in meteorites. Using Goldschmidt’s numbers, Bengt showed their agreement with his calculations of the content of the elements Na, K, Ca, and Mg in relation to the total content of metals. Moreover, he calculated the ratio of this Russell mixture and the hydrogen content. This ratio determines the number of negative hydrogen ions per hydrogen atom. In the classic article, he concluded that the solar atmosphere consists essentially of hydrogen, only with tiny fractions of “metal atoms”. He found e.g. that the amount of sodium atoms is only one per million hydrogen atoms.

Still concerned with energy production, Bengt went to the sixth IAU General Assembly held in Stockholm to meet his friends and colleagues from Williams Bay, among others. The event was hosted by the chairman of the Swedish National Committee, von Zeipel, and the director of the Saltsjöbaden Observatory, Lindblad. With Germany still not a member of the IAU, the eleven German astronomers could only be welcomed as guests. The assembly was attended by 285 members plus guests and the members represented twenty-six member states (see figure 22).

Bengt went with Sigrid to the Stockholm conference, which was only his second IAU meeting, as he did not attend the Paris General Assembly in 1935. At the assembly he met William McCrea for the first time, among others. He was elected to be secretary of commission number 35 on stellar composition but as he reported to Chandrasekhar, he found the commission meeting “very dull” and the

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[210] B. Strömgren 1940a. The *Festschrift*, which was edited by Knut Lundmark, included articles by the following list of astronomers: S. Chandrasekhar, A.S. Eddington, R. Grammel, W. Gyllenberg, Y. Hagihara, C. Heuman, E. Holmberg, B. Lindblad, H. Ludendorff, J.P. Møller, A. Reiz, E. Schoenberg, and O. Struve.
[211] Rudkjøbing & Reiz 1988, 149; Nissen & Gustafsson 1990.

international constitution commission meeting "was not very exciting".[212] Formal organizational matters were less appealing to Bengt than scientific discussions. On the other hand, he found a larger lecture meeting on stellar statistics very interesting. Bart J. Bok, Shapley, Lindblad, and Unsöld gave lectures, and the Dutchman Jan Oort, the German astronomer Walter Baade, and others took part in the discussions. Rosseland was also present, and Bengt told Chandrasekhar about the progress of Rosseland's plans of yet another monograph on stellar internal constitution:[213]

> His book on the interior had hardly advanced, and what he wanted most of all was to write a book about what we know about internal constitution, containing only 300-400 empty pages. So I do not think that you need fear the competition!

The assembly was a witches' cauldron for frequent and lively discussion of the ideas of Weizsäcker, Bethe and Gamow and the theories of nuclear energy production in stars. Bethe had not yet published his important paper, so the theories were still rather tentative. In the end, Bengt was more positive about Bethe's paper which appeared in April 1939 than he was about Weizsäcker's paper from 1938, since Bethe managed to calculate the energy production in the interior of the sun, as already described. Moreover, Bengt believed that Bethe "had better physical input" than Weizsäcker;[214]

> We knew, after all, from the model work, what the temperature was about, what the density was and what the chemical composition was. Then we just had to look at, sort of all the possibilities of reactions under those conditions. And he [Bethe] had done that systematically – and it was just the right thing to do.

It was thought, all the way through 1950 that the carbon cycle was the main process of stellar energy production. In 1950, however, it became clear that the

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[212] B. Strömgren → S. Chandrasekhar, August 23, 1938, UCA, SCP (concerning Bengt's election as secretary, see HI 21).
[213] B. Strömgren → S. Chandrasekhar, August 23, 1938, UCA, SCP.
[214] HI 22. See also Bengt's popular account of the new theories in B. Strömgren 1940b.

proton-proton process described on page 294 was the primary process for the sun.

It is somewhat striking, but not atypical, that it was the theoretical physicists, and not the astrophysicists, who eventually solved the problem of nuclear reactions in stellar interiors. Even though Bengt and some of his astronomer colleagues were very much familiar with nuclear reactions, "it was so difficult to sort out what was going on in nuclear physics at the time that it took nuclear physicists who had devoted all their time to the field to sort it out. That is my impression – that we felt like amateurs".[215] The nuclear physicists felt the same way about astrophysics, and clearly this is one reason why the Washington joint-venture came out so successfully. The astronomers gave convincing reasons for stellar interior conditions and the physicists worked out the possible reactions. From an epistemological point of view, the situation was interesting. There was a mutual symmetry of confidence in results of the other group of experts. Once the physical conditions in the stars were accepted, "the communication was easier".[216] In cosmology, for instance, the aspect of mutual confidence was somewhat different. Here, cosmological theoreticians such as Paul Dirac, Eddington, and Milne, were not necessarily impressed by the empirical results from observational research, such as the Hubble expansion, prompted by Hubble and Humanson from 1929 and thenceforth.

One theoretical physicist who went against the conditions and methods of the astrophysicists was Lev Landau. Just after coming back to his professorial chair in Moscow from a visit in Leningrad in January 1938, Bohr sent him a reprint of Strömgren's *Ergebnisse*-paper. Bohr wanted to be sure that Landau examined Bengt's paper before publishing himself a related paper in *Nature*, for which the deadline for proofs was very close. Landau answered Bohr like this: "I did not manage to find anything which has any essential connection with my work. Only astrophysical pathology and some known nuclear transformation

[215] HI 24.
[216] Hufbauer 1990, HI 24.

physics!"[217] In Landau's paper entitled "Origin of Stellar Energy" in *Nature*, he issued the ease of calculating the critical mass of a star, for which the "'neutronic' state begins to be more stable than the 'electronic' state".[218] By 'neutronic' state, Landau referred to the unstable state of matter, to which matter of the usual 'electronic' state transforms in bodies of very large masses. In such compressible states of matter, "all the nuclei and electrons have combined to form neutrons". Assuming that neutrons behaved like a Fermi gas, Landau calculated the critical mass to be larger than one thousandth of the solar mass. For bodies with masses exceeding the critical mass, "an enormous amount of energy is liberated" in the 'neutronic' phase. In conclusion, Landau stressed that the conception of the neutronic state of matter gave "an immediate answer to the question of the sources of stellar energy".[219]

Landau did not present any tangible nuclear processes but kept his argument in purely energetic terms. In his conclusion, a star could be regarded as a body with a neutronic core in steady growth liberating the energy and thereby maintaining the star at its high temperature. Finally, Landau believed that the investigation of such a model should make the construction of a consistent theory of stars possible.

In the capacity of the IAU president, Eddington contrasted the bright future for astronomy with the ever more threatening political state of affairs in Europe in his message at the closing of the Stockholm meeting: "on the international side no one dares to prophesy. But, if in international politics the sky seems heavy with clouds, such a meeting as this at Stockholm is as when the sun comes forth from behind the clouds.[220] His concern came true – only fifteen months later, the Second World War broke out and it took ten years before the next assembly would be held. Sigrid and Bengt met the Kuipers in Stockholm and they came to stay with the Strömgren's in Copenhagen after the congress. Kuiper gave a lecture at the CO and he had long discussions with Bengt and his

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[217] L. Landau → N. Bohr, January 14, 1938, NBA.
[218] Landau 1938, 333.
[219] Ibid.
[220] Blaauw 1994, 116-117.

Figure 23: Left: Bengt and Elis, both caricaturized as rather strict looking academics during Erik Strömgren's doctoral defence, ten years after his big brother defended his doctoral thesis (Politiken, January 6, 1939, 8). Right: The proud father surrounded by his two learned sons (*Berlingske Tidende*, same date, 6).

colleagues. Kuiper left for Germany and Holland, and Bengt went back to his obligations as professor.

His brother Erik was close to finishing his doctorate, which he defended on January 5, 1939, in the rooms of the Copenhagen University. The doctoral thesis was on mental illness and heredity. The conclusion of his thesis, which was based on more than one thousand visits on the Danish island Bornholm, was that information, education, and treatment was favorable in preference to surgical operations such as sterilization of e.g. schizophrenics. Erik belonged to the so-called Munich school of statistical psychology (figure 23).[221] Now, Elis and Hedvig's descendants had both made it into academia, and Elis was ready to lean back, retire, and follow his son's careers, keeping himself to the sidelines. As to Bengt's career, distant calls from the USA tempted him to go back to Williams Bay, although this time, the situation was generally different than when he was invited for the first time.

[221] *Berlingske Tidende*, January 6, 1939, 5-6; *Politiken*, January 6, 1939, 7-8.

An Arduous Career Decision

Already in June 1937, when Bengt still lived in Williams Bay, he had informed Struve that it was not altogether impossible that he would return to the Yerkes Observatory after some years.[222] Clearly, Struve hoped that Bengt would return to follow the completion of – or later to use – the McDonald Observatory in Texas. For this reason, as we have already seen, Struve had only changed the status of Bengt in the curriculum, stating that Bengt was still affiliated to the University of Chicago, but on a year's leave of absence. In November 1938, Struve invited Bengt to come to Williams Bay and "share the responsibilities": Bengt would be the director of Yerkes and Struve would be director of McDonald and chairman of the astronomy department in Chicago.[223] Bengt cabled Struve with his final decision, which was the result of protracted and difficult considerations:[224]

> THOUGH DEEPLY IMPRESSED BY EXCELLENCE OF PLAN WOULD NOT AT PRESENT BE INCLINED ACCEPT APPOINTMENT IF OFFERED. LETTER FOLLOWS.

Struve forwarded the unexpected message to President Hutchins and expressed his immediate feelings:[225]

> I am deeply disappointed and feel a perfectly good plan which would have been advantageous to the University, to Mr. Strömgren, and to myself is going to pieces because of lack of enthusiasm on Strömgren's part. I am sure the time will come when he will regret this step but, of course, that does not improve the situation here. I am at a loss to know what to suggest but I shall keep the matter in mind and will make further recommendations if I can think of some other solution.

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[222] B. Strömgren (Williams Bay) → E. Strömgren (Copenhagen), June 22, 1937, ESC.
[223] HBI, 47.
[224] O. Struve → R.M. Hutchins, November 28, 1938, UCA, PP1.
[225] Ibid.

Hutchins regretted Bengt's inclination. To Struve, for whom scientific research was the only value, Strömgren's decision was beyond grasp. His disappointment was lucidly expressed in a letter to Pol Swings, in which he labelled Bengt as a "great fool". Struve raged that not only had Bengt rejected "an exceptional opportunity for himself and for the advancement of science," but his choice had obliterated "several advantages, financial, and otherwise, which I could have secured for the Observatory if he had accepted".[226] Finally, Struve was positive that that no one could take over the Yerkes directorship but Bengt.

In the promised follow-up letter from Bengt, the reasons for declining were explained to the unsympathetic director. Bengt considered the matter for several weeks after receiving Struve's letter but in late November he made up his mind. He found Struve's plan of reorganization to be excellent, he found the research opportunities in Wiliams Bay and in Texas "wonderful" and the prospective "friendly cooperation" with Struve all seemed wonderful.[227] In spite of all these assets, Bengt intended to stay in Denmark. He found his opportunities for theoretical research great, having the UITF close by; he hoped to build a new remote observatory outside Copenhagen; and he wanted to live in peace and harmony.

Bengt was "very tempted" but due to the dark future in Europe and especially after Hitler pushed the Munich settlement through in September 1938 and gave autonomy to the Sudeten-Germans in Czechoslovakia, Bengt and Sigrid "felt that if there was a catastrophe in Europe, we would rather be here [in Denmark] than away."[228] So Bengt declined the offer. Interestingly, he held one door open though: If the plans for the new observatory would fall to pieces then he might reconsider the matter of going to the USA. For the time being, however, his decision was final, after balancing all the pros and cons. Bengt also wrote Chandrasekhar very personally about his difficult career decision:[229]

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[226] O. Struve → P. Swings, December 12, 1938, YOA. See also Osterbrock 1997, 229.
[227] B. Strömgren → O. Struve, November 29, 1938, YOA. See also Osterbrock 1997, 228,
[228] HBI, 47.
[229] B. Strömgren → S. Chandrasekhar, January 16, 1939, UCA, SCP.

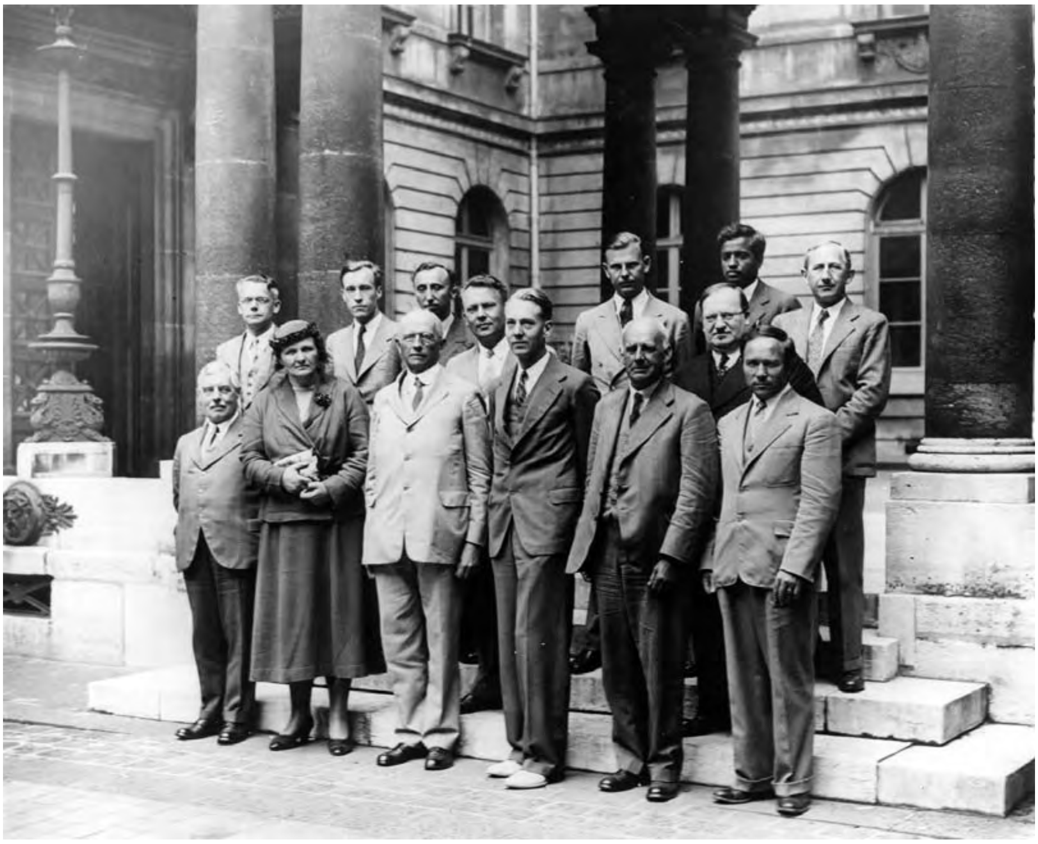

Figure 24: Paris Conference on Novae, Supernovae, and White Dwarfs, July 1939. Front row from left: F.J.M. Stratton, Cecilia Payne-Gaposhkin, H.N. Russell, Sergei Gaposhkin, A.S. Eddington, unknown; second row: Carlyle S. Beals, unknown, P.F. Swings, G.P. Kuiper, Bengt Strömgren, S. Chandrasekhar, and W. Baade. Knut Lundmark is standing in front of Chandrasekhar (YODA).

> I wish I knew your immediate reaction, when you heard that I did not want to accept. You may have looked very glum and said that you had expected that. I had a terrible time before I made the decision. […] Yes, I was in doubt like I have never been before. When I chose my career, married, and went to Chicago the first time, I was never in doubt at all. The first days I did not tell anybody except Sigrid, in order not to be influenced while my ideas were yet quite hazy. After a while I also talked to Niels Bohr. He was extremely helpful and understanding, seeing both sides of the problem. After I had gradually come to the conclusion that I would not accept, I also talked to a few other men at the university to make sure that I was right in assuming that the plans for a new observatory here were almost certain to go through within a few years.

After that, Bengt cabled the telegram to Struve. Already when Bengt was in the USA, he had an informal consent from the Copenhagen University that it would work actively for building a remote observatory outside Copenhagen.[230] This was an additional motivation for getting Bengt back to Denmark after his eighteen months in the States. Bengt was clearly inspired by the Chicago model, and he was confident that he would work to try and implement the model in Denmark. Thus, the planning of what turned out to be called the Brorfelde Observatory already commenced in 1938, after Bengt's return. Five years later, in an interview in *Berlingske Tidende*, during the German occupation of Denmark, Bengt complained about the Danish instrumental conditions and he referred to the early plans of a remote observatory: "In fact, five years ago detailed plans for such a university observatory were worked out".[231] As to Sigrid's opinion in the Denmark-USA issue, she left the decision entirely to Bengt:[232]

> Now she is telling me once in a while that I should have written that I would be willing to accept, but then she is too much impressed by the difference between Yerkes and the present Copenhagen Observatory, while I have the advantage of a complete mental picture of the new observatory. The future may show that it would have been to our advantage had we chosen Yerkes.

The providence of his last sentence turned out to be all too right. Bengt reported the progress of the plans of the prospective remote observatory to Chandrasekhar in spring 1939:[233]

> My work for a new observatory here is making very satisfactory progress. I expect that the matter will be taken up formally about a year from now, at present all negotiations are informal and confidential. In this, as in most matters the all-important question is, will Europe be left in peace. Of course we are living under a feeling of constant pressure. Daily life in Denmark is very little affected, but we are well aware of the danger of the whole situation.

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[230] Gyldenkerne 1986, 97.
[231] Vendt 1943.
[232] B. Strömgren → S. Chandrasekhar, January 16, 1939, UCA, SCP.
[233] B. Strömgren → S. Chandrasekhar, May 2, 1939, UCA, SCP.

Before Bengt's leave from Williams Bay, he had made an agreement with Struve that they would work for a closer collaboration between the two observatories. The collaboration should manifest itself by transfer of knowledge and by the exchange of astronomy researchers. In a letter to Elis right after Bengt's departure from Williams Bay, Struve reported that at the suggestion of Bengt, they had recently decided to build a twenty-inch Schmidt reflector for the McDonald Observatory. Struve hoped that this instrument would be in operation in late fall 1938. "I shall depend upon Bengt's advice for the observing program, and this will, I hope, insure an active collaboration between Copenhagen and Yerkes".[234]

Indeed the political situation hampered everything. All the plans were interrupted in 1939 and not until after the war the plans could be realized. One example is Louis Henyey. Being under Strömgren's tutelage in Williams Bay, he thrived in astrophysics. In 1939, encouraged by Struve, he applied for a Guggenheim Fellowship to spend a year at the CO. Here, he should work on research with his previous tutor. He got the fellowship but with the beginning of the Second World War, he was advised not to go abroad as were other Guggenheim fellows. What seemed to be a prospective deal and fruitful outcome of Bengt's visit was now reduced to the hope that the war would not drag on for too long.[235]

The last international event for astrophysicists on the eve of war was the rather small international Conference on Novae, Supernovae and White Dwarfs (figure 24). It was held in Paris in July and it was the second in a series of annual astrophysics conferences organized in France. It was subsidized by a wealthy publisher and it was intended to rival the prestigious Solvay conferences in physics.[236] Fifteen prominent astrophysicists were invited and the event was headed by Russell and Eddington. Bengt had done much to persuade Chandrasekhar to join him at the Paris congress and in a letter from Asserbo to

[234] O. Struve → E. Strömgren, March 22, 1938, YOA.
[235] Henyey's fellowship was supposed to commence in October 1939. O. Struve → R.M. Hutchins, September 4, 1939, UCA, PP1.
[236] Osterbrock 1997, 229-230.

Chandrasekhar's Hôtel du Pont-Royal in Paris, he expressed his joy that Chandrasekhar had chosen to attend and that he was "now in Europe. The day after tomorrow I am leaving Copenhagen […] It will be awfully nice to see you again, and just talk about the things we will have to discuss and gossip about".[237]

The Paris conference turned out to be Chandrasekhar's last meeting with Eddington, who had developed from an acknowledged astrophysicist into a somewhat mystic of 'cosmic numerology' with his 'fundamental theories' of nature.[238] Already in the early 1930'es, he ventured into the attempt of combining the constants of nature into dimensionless numbers, as they contain no social conventions or references to time and space. In his posthumously published book *Fundamental Theory* from 1946, Eddington had arrived at four such "pure numbers or ratios contained in the natural structure of the universe; these are in the truest sense constants of nature".[239] He also continued to defend his own version of the equation of state of a degenerate gas at very high densities – the theory that for long had been politely debated by Chandrasekhar, who used the correct Fermi-Dirac equation of state. All the physicists and younger astronomers knew that Chandrasekhar was right but the great prestige of Eddington kept the argument of applying the relativistic equation of state in its own way alive. Because no one was willing to press the point on Eddington, Chandrasekhar was deeply hurt.[240]

As recounted in Wali 1991, after the end of the meeting, Chandrasekhar was "really extremely upset and annoyed, because of the way in which the whole discussion had gone". Standing entirely by himself after lunch, waiting to leave in the next hour, "Eddington suddenly appeared next to me. He said: "I am sorry if I hurt you this morning. I hope you are not angry with what I said"". Chandrasekhar said: "You haven't changed your mind, have you?". "No," he said. "What are you sorry about then?" replied Chandrasekhar and turned

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[237] B. Strömgren (Asserbo) → S. Chandrasekhar (Paris), July 13, 1939, UCA, SCP.
[238] See Kragh 1999, 218-223.
[239] Eddington 1946. See also Eddington 1935.
[240] Osterbrock 1997, 231.

away.[241] Bengt had no row with Eddington, and he was only glad to meet Chandrasekhar, who already knew about Bengt's decision of declining Struve's offer. After their farewell, Chandrasekhar went back to the States for the last time in several years and Bengt returned to his research in Copenhagen.

He continued assisting with his and Struve's plans of a twenty-inch Schmidt telescope in Texas and made technical drawings of the reflector.[242] Struve had involved van Biesbroeck in the plans besides worrying about finding a replacement for Bengt. He continued his work on interstellar hydrogen, as detailed below and the Royal Danish Academy of Sciences and Letters finally elected him as a member of the exclusive scientific society. Ahead of him was five years of collegial isolation, which will be recounted in the next chapter, but before unearthing the war years, we will return the discovery of the glowing spatial regions surrounding certain hot stars, later to be named Strömgren Spheres.

5.6 Glow Between the Stars

With Bengt's extraordinary professorship he had no administrative duties until his father would retire, and Bengt would succeed Elis' ordinary professorship and directorship of the CO. Therefore, Bengt resumed his work even more productively than in the USA. The results obtained by Bethe in the late 1930'es had important consequences for the astronomer's estimates of stellar age. The life-time of solar type stars was anticipated to be about 10^{10} years, but at the same time it was evident that massive main-sequence stars had much shorter lifetimes, of about 10^{7} years in extreme cases. This led them to conclude that star formation must occur under conditions such as those observed in our neighborhood of the galaxy at the present epoch. A compelling question naturally arose from this conclusion: Is there a sufficient amount of matter in interstellar space to allow for such processes?[243]

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[241] Wali 1991, 138.
[242] B. Strömgren → G. v. Biesbroeck, January 24, 1939, YOA.
[243] B. Strömgren 1972, 249.


M. Rudkjøbing.

Publikationer og mindre Meddelelser
fra Københavns Observatorium.

Nr. 118.

The Physical State of Interstellar Hydrogen

by

Bengt Strömgren.

Særtryk af The Astrophysical Journal,
Vol. *89*, No. 4, Maj 1939.

Figure 26: Bengt's classic paper from 1939. Preprint courtesy of Mogens Rudkjøbing (B. Strömgren 1939).

It was well known that particles existed in interstellar space and that they caused the absorption and reddening of starlight traveling through space, but the amounts observed were rather moderate. Bengt investigated theoretically the photo-ionization of interstellar gas and discovered the great importance of the radiation from the relatively rare, hot O stars in fixing the physical conditions in space. As a result, in 1939, he published "The Physical State of Interstellar Hydrogen" in *The Astrophysical Journal*.[244] This became a classic and at the same time it ushered in a new area of his research, which would last until ca. 1953, when his photoelectric photometry research on spectra took over.

In the paper, he showed that homogeneously distributed interstellar atomic hydrogen was ionized by ultraviolet light from O- and B- stars in particular, until certain sharply determined radial distances.[245] These shells of ionized hydrogen, like the diffuse Orion Nebula, later became known as Strömgren Spheres, and the paper was based on relatively simple methods, considerations, and calculations. His theoretical calculations turned out to match the intensities of hydrogen emission lines observed by Struve at the McDonald Observatory in extended areas of the Milky Way. The match was evident when the hydrogen density in interstellar space was of the order of magnitude of one atom per cubic centimeter. The crucial conclusion reached by Bengt was that our galaxy contains very large amounts of hydrogen, also outside the limits of observable ionized areas.[246]

Bengt's interest in the problem of the formation of these so-called HII-regions around stars was initiated in connection with Struve's development of a new technique for observing very faint stars. In fact, already in 1936, during a drive from Yerkes to Chicago, they had one of many "interesting conversations".[247] Struve made an important discovery of Balmer line glow in extensive regions of the galaxy and Bengt's interest was triggered on the questions of the interstellar medium when he heard about Struve's ideas in his

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[244] The paper is reprinted in Lang & Gingerich 1979, 588-592.
[245] B. Strömgren 1939.
[246] See also Rudkjøbing & Reiz 1988, 148-149.
[247] HBI 46.

car on their way to campus. Until that time, it was known that a number of diffuse nebulae emitted an emission spectrum of strong Balmer lines, arising from $n = 2$ transitions of the hydrogen atom. What Struve found, in addition to these well-known areas, was that even large regions of hundreds of square degrees on the sky had a faint glow. At the McDonald Observatory, Struve developed what was called the Centipede – a device pointed toward the Pole, which could record faint spectra of extended areas, having a focal length of one hundred meters.[248] By use of this, Struve and Elvey were able to measure this glow and it immediately challenged Bengt to develop a theoretical model that matched observation.

Bengt constructed a stellar model of a luminous star with high temperature embedded in a uniform medium of hydrogen. The salient result of his investigation was a sharp transition. Eddington had published a paper on diffuse matter in space but it did not consider the present problems of ionization.[249] The general assumption was that the density of interstellar gas was very low even though numerous efforts were made at Mount Wilson to identify more absorption lines. Nevertheless, it was not possible to conclude that the amount of mass was distinctly high or that there was a large amount of hydrogen. In Bengt's paper, which was published after he returned to Copenhagen, he attributed the discovery of extended areas in the Milky Way in which the Balmer lines were observed, to Struve and Elvey. "The recent discovery, by Struve and Elvey, of extended regions […] has opened up new and highly important possibilities for the study of the properties of interstellar matter." His colleagues had found emission lines in eight out of fifteen fields by spectroscopic observations on Mount Locke in Texas.

In a paper from 1937, Eddington considered the problem of the ionization of interstellar hydrogen and expressed the opinion that, in a normal region of interstellar space, hydrogen was entirely un-ionized, the reason being that the ionizing ultraviolet radiation is strongly absorbed by interstellar hydrogen.

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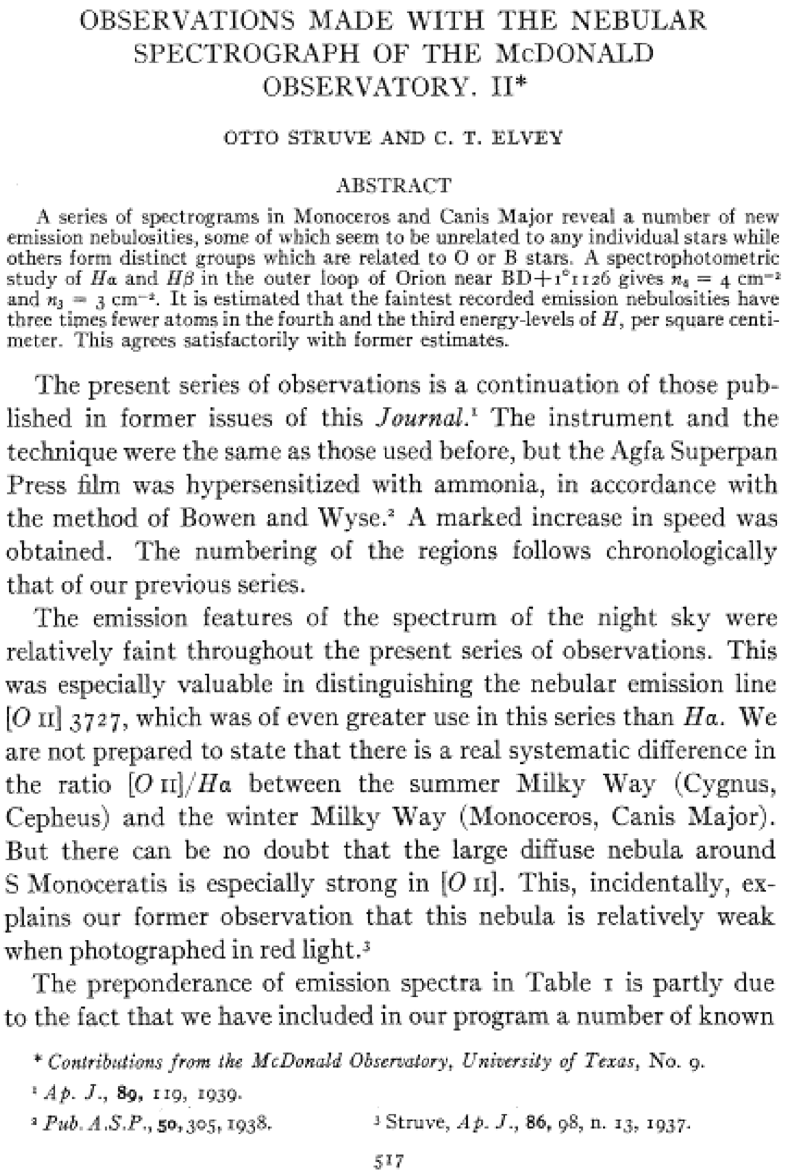
[248] HBI, 26.
[249] Eddington 1937.



OBSERVATIONS MADE WITH THE NEBULAR SPECTROGRAPH OF THE McDONALD OBSERVATORY. II*

OTTO STRUVE AND C. T. ELVEY

ABSTRACT

A series of spectrograms in Monoceros and Canis Major reveal a number of new emission nebulosities, some of which seem to be unrelated to any individual stars while others form distinct groups which are related to O or B stars. A spectrophotometric study of $H\alpha$ and $H\beta$ in the outer loop of Orion near BD+1°1126 gives $n_4 = 4$ cm^{-2} and $n_3 = 3$ cm^{-2}. It is estimated that the faintest recorded emission nebulosities have three times fewer atoms in the fourth and the third energy-levels of H, per square centimeter. This agrees satisfactorily with former estimates.

The present series of observations is a continuation of those published in former issues of this *Journal*.[1] The instrument and the technique were the same as those used before, but the Agfa Superpan Press film was hypersensitized with ammonia, in accordance with the method of Bowen and Wyse.[2] A marked increase in speed was obtained. The numbering of the regions follows chronologically that of our previous series.

The emission features of the spectrum of the night sky were relatively faint throughout the present series of observations. This was especially valuable in distinguishing the nebular emission line [*O* II] 3727, which was of even greater use in this series than $H\alpha$. We are not prepared to state that there is a real systematic difference in the ratio [*O* II]/$H\alpha$ between the summer Milky Way (Cygnus, Cepheus) and the winter Milky Way (Monoceros, Canis Major). But there can be no doubt that the large diffuse nebula around S Monoceratis is especially strong in [*O* II]. This, incidentally, explains our former observation that this nebula is relatively weak when photographed in red light.[3]

The preponderance of emission spectra in Table I is partly due to the fact that we have included in our program a number of known

* *Contributions from the McDonald Observatory, University of Texas*, No. 9.

[1] *Ap. J.*, **89**, 119, 1939.

[2] *Pub. A.S.P.*, **50**, 305, 1938.

[3] Struve, *Ap. J.*, **86**, 98, n. 13, 1937.

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Figure 25: Struve & Elvey's paper from 1939. As Struve was the editor of *Astrophysical Journal*, he had placed at Bengt's disposal the results of their investigations before their publication (Struve & Elvey 1939, provided by American Astronomical Society via the NASA Astrophysics Data System).

Bengt's investigation generally confirmed Eddington's view but with one important modification. High-temperature stars and clusters of such stars in particular were found to be "capable of ionizing interstellar hydrogen in regions large enough to be of importance in problems of interstellar space".[250] His own attempt was "to arrive at a picture of the actual physical state of interstellar hydrogen" and he "found that the Balmer-line emission should be limited to

[250] B. Strömgren 1939, 527.

certain rather sharply bounded regions in space surrounding O-type stars or clusters".[251] Moreover, he found relations between the gas density, the luminosity of the star, and the size of the sphere of ionized hydrogen around it. He found that such regions should have diameters of about 200 parsecs, or ca. 650 light years, which was found to be in general agreement with Struve and Elvey's observations. He calculated the density of hydrogen in these areas, later to be denoted HII regions, or "Strömgren Spheres", namely $N = 3\ \text{cm}^{-3}$.

The starting point was building on his 1937 joint paper with Kuiper and Struve, in which they found an expression of the relation between hydrogen atoms, free electrons, and neutral hydrogen atoms.[252] This expression involved, among other variables, the temperature of the exciting star, the ionization potential, statistical weights of the ions and a hydrogen atom in its ground state. Furthermore, the radius of the star and the distance of a point in interstellar space from the exciting star figured in the expression. After eight pages of calculations and making various simplifying assumptions, Bengt gave the resulting values of the size of the ionized spheres for different stars showing an increase of the ionized volume as one passes from low-temperature stars to high-temperature stars.[253]

The analysis "immediately gave the number" as his results "set up an upper limit to how much interstellar matter there could be. And the interval between what was established in the ionized regions, and what was the maximum, was not so large."[254] Thus, right away, it was clear how much hydrogen there was, and since Struve's results referred to bulky volumes, Bengt was able to conclude the existence of substantial amounts of interstellar hydrogen. Furthermore, in a larger perspective, Bengt concluded that the amount of interstellar matter in the entire universe was considerably larger than previously assumed, though in an invisible and neutral form.

[251] B. Strömgren 1939, 526.
[252] Strömgren, Kuiper & Struve 1937.
[253] B. Strömgren 1939, 533.
[254] HBI 27.

Elis' list	**"Rest of Europe"**	**USA**
Nørlund	***Bergstrand***	Rosenberg
Hjelmslev	*Von Zeipel*	Struve
N. Bohr	*H.H. Plaskett*	Ross
M. Knudsen	*Schönberg*	Van Biesbroeck
H.M. Hansen	*Heckmann*	Kuiper
Elis Strömgren	*Seidentopf*	Morgan
J.P. Møller	*Hopmann*	Chandrasekhar
J.M. Vinter Hansen	*Grotrian*	Shapley
Thernøe	Hertzsprung	Schlesinger
Svanhof	*Kienle*	Russell
Eddington		*Shane*
Milne		*Trumpler*
Guthnick		*Gaposchkin*
Prager		*Wright*
Ludendorff		
Lindblad		
Lundmark		
Gyllenberg		
18 (*14*)	10 (*1*)	14 (*10*)

Table 1: Scientific network determined by use of offprint distribution consisting of a selected list of scientists to receive offprints of the paper B. Strömgren 1937d in 1939, Italics indicate people chosen not to receive the offprints anyway, after it turned out that the number of prints was 25 instead of 50. Boldfaced names indicate scientists who should also be given the offprints of Bengt's two papers in *Handbuch der Astrophysik* (B. Strömgren 1936a and 1936b). First column contains a list of scientists close to Elis, second column other astronomers in Europe, and third column is a list made by Elis of astronomers in the USA (E. Strömgren → B. Strömgren, July 1 and 14, 1937, ESC).

5.7 The Strömgren Network

Concluding chapter five, we will investigate the scientific network of Bengt and Elis from documentation found in the Strömgren correspondence as well as from their other correspondence. It is discussed whether it is reasonable to extrude their network from their scientific correspondence with the community of

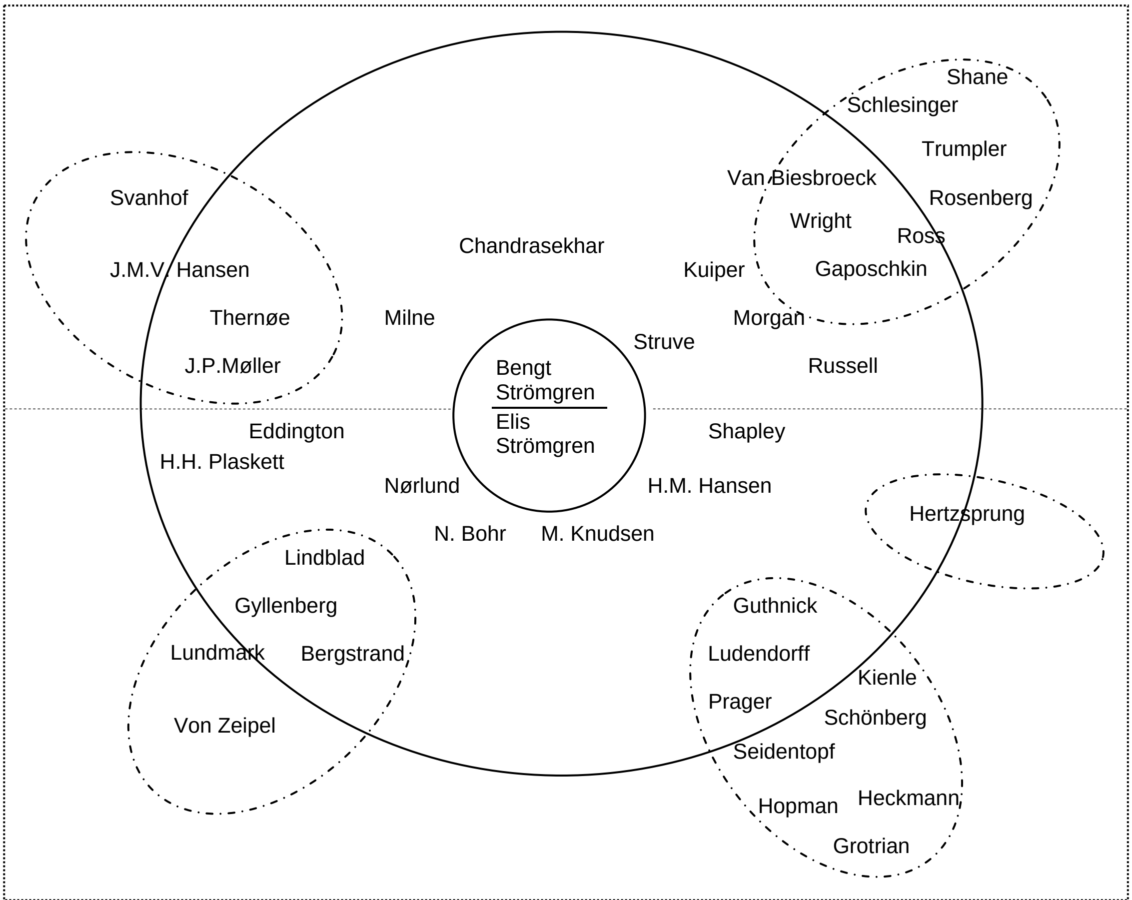

Figure 27: Collective network chart of Bengt (and Elis) Strömgren in the late 1930'es based on offprint distribution. Dotted ellipses contain actors that are estimated more peripheral in the network than actors closer to the centre of the full circle. Børge Svanhof was calculator at the AO; H.H. Plaskett founded with Milne a major school of astrophysics at Oxford University; Walter R.W. Grotrian created a diagram of graphical representation of atomic spectra later named after him; Erich Schönberg worked at the German Greiswald Observatory; Hans Kienle became the director of Heidelberg Observatory, Otto Heckmann at the University of Göttingen; William H. Wright was the director of the Lick Observatory from 1935, where also the Swiss astronomer Robert J. Trumpler worked from 1918; Frank Schlesinger held a position at Yale University Observatory; C. Donald Shane was a Berkely University astronomer (Seidentopf remains unknown to the author).

astronomers and other scientists. This network is also reflected to a large extent by the quotes and collected correspondence throughout this dissertation.

Another way of observing the scientific circles of the Strömgren's can be obtained by noting the lists of people who received offprints of their papers. In the summer of 1937, Bengt and Elis made a list of scientists to be given an offprint of Bengt's papers in *The Astrophysical Journal*, which is given in table 1. Naturally, owing to Bengt's upbringing surrounded by his father's colleagues, visiting his father's friends, and his first unleashed participation at conferences with his father standing on the side, the predominant part of Elis' scientific network quickly became part of Bengt's network as well. Thus, by making a list of receivers of Bengt's offprints, a natural reduction of scientists took place, *viz*. the seclusion by discipline. After all, Bengt's field of expertise was astrophysics and the relevant recipients of his offprints were connected to his research in one way or another. It is tempting to try and divide the list of scientists in table 1 into a network map showing more clearly the inclusion – and exclusion – of astronomers and other scientists made by Elis and himself. Even though Elis proposed the list, Bengt endorsed it, knowing that Elis knew well about his set of connections.

Thus, from figure 27, an attempt to reach such a division of the scientific community of colleague astronomers and physicists is given. Obviously, the permanent staff at the CO would also be included if they were not able to borrow Elis' editions of the offprints from his observatory office. The CO staff constituted an obvious part of Elis' network, as did the Yerkes staff for Bengt. If instead we employ the correspondences located in the most important archives visited by me as a measure of the network of Bengt, the picture is very much modified. In the period of e.g. 1915-1947, that is, Bengt's active years as correspondent from his boyhood to the death of his father, 606 letters exist in the Bengt Strömgren Archive (BSA). Of these, many correspondences concern institutional matters and the majority of letters have only one or two items per correspondent. The counting and ordering of the most frequent correspondents to and from Bengt Strömgren contribute to the 'top ten list' of correspondents given in table 2. Other archives taken into account in the list are the Niels Bohr Archive (NBA), the Otto Struve letters located in the Yerkes Observatory Archive (YOA), and the Chandrasekhar Papers (UCA, SCP). The resulting list consists of Struve in the USA; Chandrasekhar in England and the USA, Lundmark in Lund; the German astronomer at the Astronomical Calculation Institute in Berlin-

Scientist	Correspondent → Bengt	Bengt → correspondent	Total number of letters	Period of correspondence
O. Struve	8 / 46	3 / 38	95	1936-1947
S. Chandrasekhar	15 / 6	2 / 45	68	1932-1936 / 1934-1954
K. Lundmark	42	8	50	1929-1940
G. Stracke	18	8	26	1931-1933
F. Küstner	10	11	21	1921-1929
Å. Wallenquist	15	-	15	1925-1935
N. Bohr	0 / 9	0 / 5	14	1923-1961
H. von Zeipel	5	7	12	1924 only
E.A. Milne	7	3	10	1931-1937
J.M.V. Hansen	8	-	8	1925-1940

Table 2: Bengt Strömgren's ten most weighty private correspondences. The ten most corresponding individuals are listed. The first number refers to the Bengt Strömgren Archive (BSA). Where a stroke is present, the number following it refers to another archive. In the case of Otto Struve, the numbers refer to YOA; in the case of Subramahnyan Chandrasekhar, it refers to UCA, SCP; and in the case of Niels Bohr, it refers to NBA (in this case, the investigated period goes beyond 1947, namely to 1961).

Dahlem G. Stracke; Frank Küstner at the Bonn Observatory; Åke Wallenquist from Sweden who worked at the Dutch Bosscha Observatory in Java in Indonesia 1928-1935; Niels Bohr at the UITF; the Swede Hugo von Zeipel from Uppsala; E.A. Milne in Oxford; and finally Julie M.V. Hansen, writing mainly postcards from various vacations in Europe.

Not surprisingly, the table tells only little about Bengt Strömgren's closest colleagues, if at all about his scientific network in any good way. It does point at the fact that Bengt spent many hours on calculations in the late 1920'es and early 1930'es – something we knew already. As to the extensive correspondences with Lundmark, we find that they were mostly about the planning of Bengt's lectures in Lund in the mid-thirties. Stracke's correspondence is even less representative of making an important actor in the suggested network as it only runs over two years. Finally, among the top five on the list, the correspondence with Küstner has been frequently employed in chapter three. Furthermore, the overlap between figure 27 and table 2 is only partial and rather coincidental, except perhaps concerning the top figures in the test, Struve, Chandrasekhar, and Lundmark.

A conclusion of the attempt to unravel the scientific network of Bengt Strömgren by using his private correspondence is that the test probably displays more about itself than about the objects of investigation. Correspondences, in this case, does to some extent reflect important actors of the scientific or private network, but it displays nothing as to the hierarchical structure of such a network, if it should exist. The offprint distribution displayed in figure 27 seems more convincing as some sort of measure of the system of scientists surrounding, in this case, Bengt Strömgren. A certain group of astronomers fit into the core of figure 27. Besides, the central actors in the figure constitute the scientists that are already encountered in this biographical narrative. Clearly, this is no coincidence. Apart from the mere correspondences, other aspects contribute on various levels to a more nuanced network picture and perhaps the narrative itself is the best representation at hand to describe who interacted, how frequently they did so, and most importantly, what they interacted about. Such additional aspects comprise all the other sources of historical documents listed in the archives and bibliography section in the second volume of this dissertation, including publication references, co-authorships, the contents of the correspondences, interviews, etc. A future study would require more than only surviving correspondence. The use of citation and co-citation patterns to identify networks and schools would seem valuable.

Six

Five Isolated Years

Institution Building

1940-1945

Not many documents have been kept from the five years of war. In the Bengt Strömgren archive, there is a complete gap in the period 1940-1945. No correspondence whatsoever has been kept and the reasons for this could be legion. It was not uncommon to discard the memories from the war after the liberation and lacunas can be found in many private archives. Looking for historical documentation in other archives is naturally required. Only very few letters sent by Bengt during the war has been found. One of them, from 1942, reports the Strömgrens' conditions and life in Denmark and is located in the Joseph Regenstein Library Research Archives in Chicago (UCA, SCP). Correspondence by mail was often hampered by the censorship of the German authorities. Therefore, e.g. the letter from Bengt to Chandrasekhar was sent from Lund in the neutral country of Sweden. In the Yerkes Observatory Archive, two letters to Struve are positioned and in the Elis Strömgren Collection in Lund, a few additional documents of relevance have been found. Furthermore, one letter from Bengt to Niels Bohr has been found. The history of Danish war-time astronomy is also found in newspaper clippings; and furthermore, memoirs and recollections from the time are useful, however biased they may be.

One particular document is remarkable from a general historical perspective. David J. Campbell, the grandson of Bengt Strömgren, wrote the paper while he went to high-school in 1984. It is the result of an interview with his mother about what life was like for a little girl during the German occupation.[1] What makes it worthy of note is the fact that Bengt Strömgren read the proofs of the paper and thus endorsed its contents of war-time descriptions. According to the three children of Bengt and Sigrid Strömgren, Bengt never spoke to them about the years of war.[2] This document, supplemented with the above mentioned historical documentation, comprises my archival findings concerning the Copenhagen Observatory after the outbreak of war until the liberation in 1945.

6.1 The New Professor and His Duties

Following the success of the Blitzkrieg, new opportunities emerged for National Socialist policy outside the German Reich. After having defeated and occupied the largest part of Europe, beginning with the invasion of Poland in September 1939, the succeeding European countries were Denmark, Norway, Holland, Belgium, Luxembourg and eventually France by late June 1940. The German occupation of Denmark on April 9, 1940 ushered hard times for the Danish population and made many Danes turn their eyes towards the distant and tranquil stars. Following the blackouts in Copenhagen, the disturbing city lights disappeared and, if not for anything else, at any rate the darkening made astronomical observations easier. Looking at the infinity of the universe, the horrible events on the world scene perhaps seemed less important for a while.

At the same time, during the war, Danish astronomical research was put on the back burner. However, this is not inconsistent with the Danes' turning their eyes towards the sky, which simply reflects a growing popular interest in the night sky and its stars – mirrored in the newspapers. Astronomical research on the back burner, on the other hand, came from the decline or isolation of professional research in most sciences during the war period. To Bengt, the war became five years "in relative isolation and with quite limited resources" and he

[1] Campbell 1984. David is the son of Joe and Karin Strömgren Campbell.
[2] KNSI, OSI, KSCI, COR.

felt constrained to postpone his work on interstellar matter, since he was "cut off from any possibilities of learning about observational results".[3] As described in chapter three, the Central Bureau succeeded to establish a neutral sub-central in Lund before USA entered the war scene. Only a few months after the day of the German occupation, the news service was effective again, in spite of the fact that communication was limited to the non-belligerent countries. Thus the communication remained continuous during the war, but this was only communication of short news about celestial events and not the least comparable to private letters with free discussions of technical issues between colleagues. Already before the occupation, in the fall of 1939, Bengt wrote Struve,[4]

> Here all is well so far. There are great difficulties in getting sufficient amounts of coal, gasoline, and many other things, but the situation is not desperate. In Denmark, military activities do not interfere greatly with daily life. In Sweden it is already worse. When I visited Lund the other day, I found that most of the younger people at the observatory were with the army. We are living under an enormous mental strain, however.

He continued that "it might have occurred" to Struve that Bengt might have entirely changed his view "with regard to the relative merits of Yerkes and Copenhagen. However, the situation is rather that I do not see my way yet." Struve sent him various literature about the inauguration of the McDonald Observatory, which took place in September 1939. Bengt numbered his letters to Struve thenceforth, to let Struve know if any correspondence would get lost.

Struve thanked Bengt for the letter and assured him that no new developments of any great importance had taken place at Yerkes or in Texas. He also expressed that he "was somewhat disappointed in Wurm", the one-year appointed German successor of Bengt. Yet, Struve maintained,[5]

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[3] B. Strömgren 1983, 6; HBI 51. Bengt mediated his already completed research in German journals as well as in the *NAT*: See B. Strömgren 1940b & d, 1941a, b, c, & d; 1942, 1943a & b.
[4] B. Strömgren → O. Struve, September 28, 1939, YOA.
[5] O. Struve → B. Strömgren, October 16, 1939, YOA.

> I would not want this remark to hurt him in Germany. He was quite useful to us in many respects but I had the impression that he was only moderately interested in scientific matters, an effect which is doubtless related to the general situation in Germany.

Struve found Unsöld far more active, "and I was very favourably impressed with his knowledge and general attitude toward scientific problems." Unsöld got along well with Chandrasekhar and "was in no way aggressive or unpleasant" – an impression Struve had from earlier meetings with the young astronomer. In 1939, Unsöld was on a research visit at the Yerkes and McDonald Observatories, during which he made the first detailed analysis of a star other than the sun.[6] Struve updated Bengt with the plans of modernizing the Yerkes Observatory with a forty-inch Schmidt telescope. Bengt answered Struve in his number-two-letter and underlined that his last consideration for some time had been made concerning the possibility of going to the States. He found that it would not be wise to make any changes of plans for the future while times were still troubled.[7] In Struve's reply, there was no mention whatsoever of Bengt's final decision. After the German occupation of Denmark in April 1940, he opened up:[8]

> During the past few weeks we have been thinking a great deal about you and your family. […] You see that we in this country are still working as usual, and living a relatively peaceful existence. It is almost incomprehensible to us that nearly all of Europe is involved in a war.

Struve was also concerned if the *Astrophysical Journal* was reaching the subscribers in Europe. After holding back several issues, the Yerkes staff decided to send all accumulated numbers to Europe but Struve had not yet found out whether any subscribers did in fact receive any material at all.

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[6] It was a B0 type star named τ Scorpii. Unsöld's visit was only for a few months and is not included in appendix C.
[7] B. Strömgren → O. Struve, December 23, 1939, YOA.
[8] O. Struve → B. Strömgren, April 25, 1940, YOA.

In Denmark, the observatory staff went through relatively drastic changes. Following a trip to Japan, Julie Vinter Hansen left to the Mount Wilson Observatory in California after receiving the so-called Tagea Brandt Prize grant together with Hedvig Strömgren in 1939.[9] Accidentally, she was compelled to stay in the States during the length of the war and only returned after the liberation of Denmark. Thernøe and Jens P. Møller served as the observatory's scientific assistants, and with Elis' retirement, the staff number was effectively reduced from five to only four permanent positions (see appendix A). In addition, the observatory had three regular calculators, *viz.* Mogens Rudkjøbing, who began calculating for the CO in 1934; Erna Mackeprang, already from 1921; Hans Quade Rasmussen, who began as a calculator in 1941, and Kjeld Gyldenkerne, in 1943 (see appendix A).

The ordinary professorship at the University of Copenhagen was passed on from father to son and the directorship of the Copenhagen Observatory naturally came with it. Bengt finally inherited his father's position as the top authority of Danish astronomy at the research institution, only 32 years old. The ceremony took place in late August, 1940 and on the occasion of both Elis' retirement, and of his seventieth birthday, the honorary *Festschrift* anthology was presented to him by its editor, Knut Lundmark. Elis wrote an expression of his gratitude to Struve, in which he also reported the conditions in Denmark.[10]

> Everything goes so well with us, as it is possible at these times, probably better than one outside of Denmark generally believes. Bengt takes over the observatory on September 1. Luckily, he is happy about his activities and everything goes well to him and his little family. My wife and I have moved. We found a very nice apartment very close to the observatory.[11] I am not working with anything that does not interest me. I have the astronomical central bureau,

[9] This was a women rights travel grant, which the same year was recieved by five women, the Danish author Karen Blixen being one of them.
[10] E. Strömgren → O. Struve, November 1940, 1940, YOA. Concerning Bengt's new position, see Yearbook 1940.
[11] Hedvig and Elis Strömgren moved to the street Stockholmsgade 43.

Figure 1: The Rosenborg Castle, photographed from the Copenhagen Observatory in 1932 (RL).

> which – after only a short break – is functioning again and naturally there is a lot of correspondence.

Already during their summer holiday, Bengt and his family moved from their house in Hellerup into the observatory. Bengt was now the grown-up in his childhood home and his little daughters could play in the same attic that he had shared with brother Erik. Sigrid wrote Lalitha Chandrasekhar a moving letter about life in Denmark:[12]

> Bengt is very busy planning his new observatory, but times are not very encouraging. It is the most peculiar feeling that every time we make plans for the future we always have the thought, "if we are still alive", "What are the coming months going to bring". As it is now, we feel so happy just being together, we live for each day and are grateful for every day that goes right.

[12] Sigrid Strömgren → Lalitha Chandrasekhar, January 30, 1940, UCA, SCP.

Sigrid got pregnant in early 1941, and in September that year, On September 18, in the evening, Sigrid gave birth to their first son, Ole, and the girls found it very exciting. There was a curfew and no one was allowed outside after 7pm. This was good for the children as their parents were always home, but arguably it was hard on the adults. When Sigrid went into labor, she and Bengt “had to take a white flag with them and wave it as they went down to the waiting taxi” from the small observatory hill, “hoping they would not get shot at.”[13]

The reason for their caution was the fact that the Copenhagen Observatory was located right across the street from the Rosenborg Castle, which housed the Palace Guard. The castle was taken immediately by the Germans and during the war the Guards were replaced by German soldiers including the Hitler Youth. The oldest daughter, Karin, remembered walking to school past the long castle walls:[14]

> The German soldiers, bored in peaceful Denmark, had fun pointing their guns at me and following me in their sights all the way down the street. They did that for five years, almost every day, which proves that you can get used to almost everything.

For people in the suburbs, it was not as bad, but for people living in the center of Copenhagen daily life was more trying. The first years were relatively peaceful in Denmark. The Danish resistance was not organized and Germany had their hands full fighting in Russia and Africa. Like most Danes, the Strömgrens had very little money to buy food due to inflation. Germans confiscated much of the good food, “while we were left with potatoes, dark bread, salted herring and other fish, blue milk, and very fatty pork once a week.”[15] They did not have coffee, tea, and liquor and heat and electricity was rationed. The observatory was big with many unheated rooms, except for two central rooms which were heated

[13] Campbell 1984, 2.
[14] Campbell 1984, 1.
[15] Ibid., 1.

with stoves. The family sat around on winter days "with our hats and mittens on because it was so cold in the house".[16]

6.2 The German Cultural Institute: Heisenberg in Copenhagen

Founded in Europe during the first part of the Second World War, the German cultural institutes constituted a new coinage in the culture policy of the Third Reich. The purpose of these institutes was to oppose hostile propaganda in countries either occupied by or obedient to Germany, but primarily it was to demonstrate Germany as the dominating cultural power in Europe. After all, subsequent to the defeat of France, German dominion over most of continental Europe was indisputable. The term "scientific institutes" was also used to designate these institutes, and the name was deliberately chosen in order to highlight their scientific focus.[17]

The Danish-German Association (Den Dansk-Tyske Forening) was born in July 1940 as a continuance of the Danish-German Cultural Society founded in 1916 (Det Dansk-Tyske Kultur Selskab). It was inaugurated in September 1940 with the first chairman being director general of the Danish Railways (DSB), Peter Knutzen. The number of members of the association never reached more than ca. 1,400 persons in October 1942 and the card index of members allegedly shows that the predominant part of the members lived in Copenhagen. Moreover, it showed that they were well-to-do citizens, many of whom constituted the intellectual part of the population. Practically none of the members came from the working class or lower middle class.[18] One of the members was Elis Strömgren. However, Elis had been member of the Danish-German Cultural Society since the 1920s, but his membership was probably regarded in a somewhat different light after the occupation by other not-so-German-friendly Danes.

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[16] Ibid., 2.
[17] Nordlien 1998, 68.
[18] La Cour 1947, 407. Although La Cour's three volume monograph was heavily biased in the description of actors in the political world throughout the occupation, being written just after the war, factual information as the content of the card index are taken at face value here.

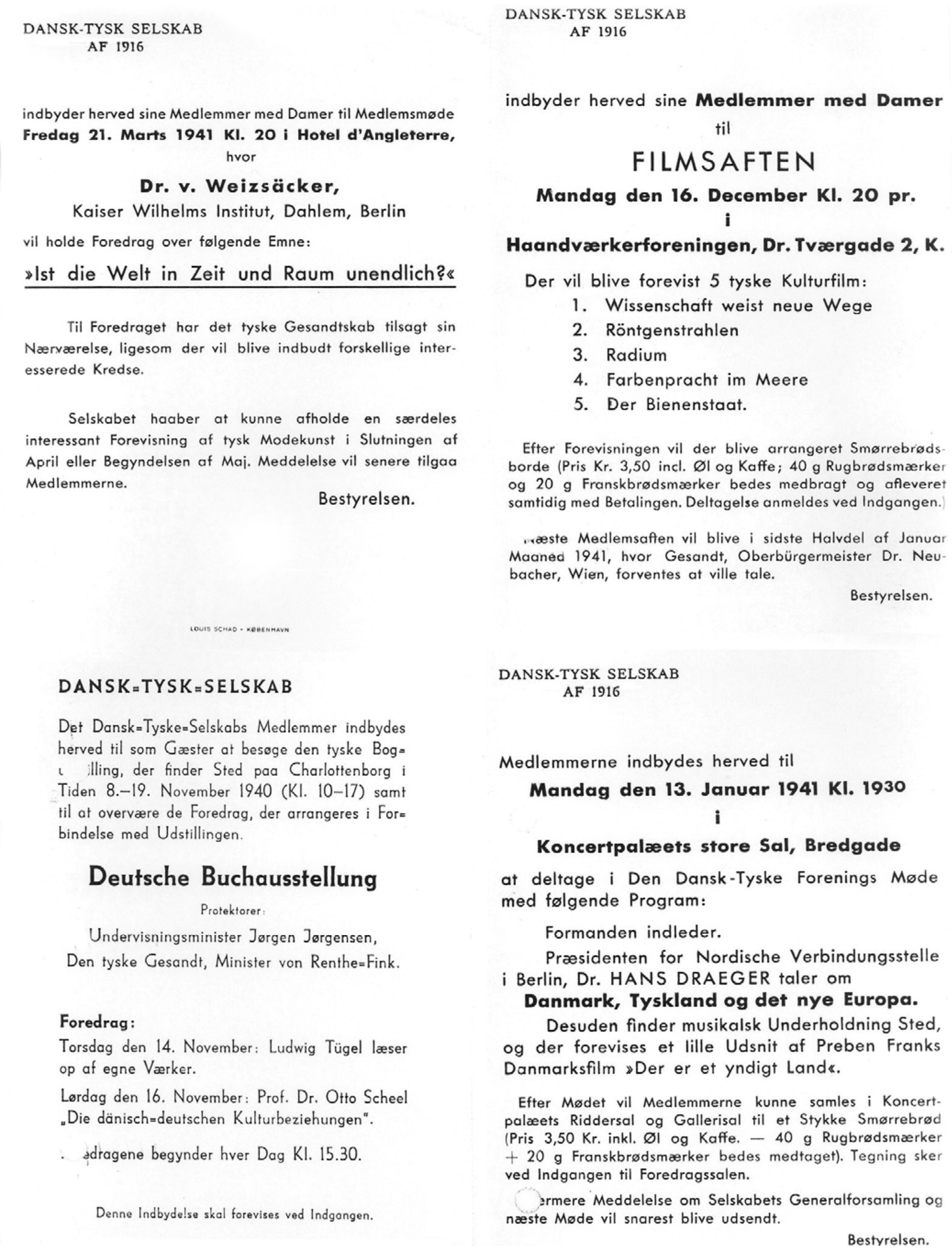
One example is the music teacher, amateur astronomer, and biographer of Tycho Brahe, Arthur Nielsen from the provincial town Frederica in Jutland. Nielsen was an active member of the Danish resistance movement, which will be described in more detail in chapter 6.3. He was the chairman of the local section of a national resistance group called the Ring. The Ring was created by the school teacher Frode Jakobsen, who disagreed with the cooperative policy of the Danish government in 1941. Later, Jacobsen created the Danish Liberation Council (Danmarks Friheds Råd) and became minister in the liberation government. After the end of the war, Arthur Nielsen wrote Julie Vinter Hansen to welcome her home after her six years in American exile:[19]

> It was with regret that I learned about the otherwise excellent Elis Strömgren's attitude towards the German criminals. Since the occupation, I have perhaps annoyed His Holiness by stamping all my observations: NOT FOR FELONS. An armed neutrality arose between us. […] Now he is not willing to correspond with me anymore, so my variable stars go directly to Axel V. [Nielsen].

In a letter from the assistant at the Ole Rømer Observatory in Århus, Axel V. Nielsen, to Luplau Janssen one year later, he explained the "terminology" of Arthur Nielsen in an attempt to let it reflect the narrow-mindedness and rabid tongue of the anti-German Arthur Nielsen: "To him [A. Nielsen] the following identities hold good: Nazi = felon and German (in most cases) = felon."[20] Thus, regretting that Elis had been involved with Germans during the war, the opinions of Arthur Nielsen were perhaps representative of the feelings in the hearts of Dane's directed against so-called "German-friendly" Danes.

In figure 2, some of the activities of the Danish-German Cultural Society are displayed. The lecture given by Weizsäcker in March 1941 in the top left corner will be treated below. In the top right corner of the figure, members *with ladies* were invited to a show of five German "cultural movies" about the new pathways of science, about X-rays and radium, and more. In the lower left corner

[19] A. Nielsen → J.M.V. Hansen, August 18, 1946, R (J.M.V. Hansen's private archives).
[20] A.V. Nielsen → C.E. Luplau Janssen, August 14, 1947, R (J.M.V. Hansen's private archives).



DANSK-TYSK SELSKAB
AF 1916

indbyder herved sine Medlemmer med Damer til Medlemsmøde
Fredag 21. Marts 1941 Kl. 20 i Hotel d'Angleterre,
hvor

Dr. v. Weizsäcker,
Kaiser Wilhelms Institut, Dahlem, Berlin

vil holde Foredrag over følgende Emne:

»Ist die Welt in Zeit und Raum unendlich?«

Til Foredraget har det tyske Gesandtskab tilsagt sin Nærværelse, ligesom der vil blive indbudt forskellige interesserede Kredse.

Selskabet haaber at kunne afholde en særdeles interessant Forevisning af tysk Modekunst i Slutningen af April eller Begyndelsen af Maj. Meddelelse vil senere tilgaa Medlemmerne.

Bestyrelsen.

LOUIS SCHAD - KØBENHAVN

DANSK-TYSK SELSKAB
AF 1916

indbyder herved sine **Medlemmer med Damer**
til

FILMSAFTEN

Mandag den 16. December Kl. 20 pr.
i
Haandværkerforeningen, Dr. Tværgade 2, K.

Der vil blive forevist 5 tyske Kulturfilm:

1. Wissenschaft weist neue Wege
2. Röntgenstrahlen
3. Radium
4. Farbenpracht im Meere
5. Der Bienenstaat.

Efter Forevisningen vil der blive arrangeret Smørrebrødsborde (Pris Kr. 3,50 incl. Øl og Kaffe; 40 g Rugbrødsmærker og 20 g Franskbrødsmærker bedes medbragt og afleveret samtidig med Betalingen. Deltagelse anmeldes ved Indgangen.)

Næste Medlemsaften vil blive i sidste Halvdel af Januar Maaned 1941, hvor Gesandt, Oberbürgermeister Dr. Neubacher, Wien, forventes at ville tale.

Bestyrelsen.

DANSK=TYSK=SELSKAB

Det Dansk=Tyske=Selskabs Medlemmer indbydes herved til som Gæster at besøge den tyske Bog=Udstilling, der finder Sted paa Charlottenborg i Tiden 8.–19. November 1940 (Kl. 10–17) samt til at overvære de Foredrag, der arrangeres i Forbindelse med Udstillingen.

Deutsche Buchausstellung

Protektorer:
Undervisningsminister Jørgen Jørgensen,
Den tyske Gesandt, Minister von Renthe=Fink.

Foredrag:

Torsdag den 14. November: Ludwig Tügel læser op af egne Værker.

Lørdag den 16. November: Prof. Dr. Otto Scheel „Die dänisch=deutschen Kulturbeziehungen".

Foredragene begynder hver Dag Kl. 15.30.

Denne Indbydelse skal forevises ved Indgangen.

DANSK-TYSK SELSKAB
AF 1916

Medlemmerne indbydes herved til
Mandag den 13. Januar 1941 Kl. 1930
i
Koncertpalæets store Sal, Bredgade

at deltage i Den Dansk-Tyske Forenings Møde med følgende Program:

Formanden indleder.

Præsidenten for Nordische Verbindungsstelle i Berlin, Dr. HANS DRAEGER taler om
Danmark, Tyskland og det nye Europa.

Desuden finder musikalsk Underholdning Sted, og der forevises et lille Udsnit af Preben Franks Danmarksfilm »Der er et yndigt Land«.

Efter Mødet vil Medlemmerne kunne samles i Koncertpalæets Riddersal og Gallerisal til et Stykke Smørrebrød (Pris 3,50 Kr. inkl. Øl og Kaffe. — 40 g Rugbrødsmærker + 20 g Franskbrødsmærker bedes medtaget). Tegning sker ved Indgangen til Foredragssalen.

Nærmere Meddelelse om Selskabets Generalforsamling og næste Møde vil snarest blive udsendt.

Bestyrelsen.

Figure 2: Some selected activities of the Danish-German Cultural Society (ESC).

of figure 2, a book display protected by the minister of education, Jørgen Jørgensen, and the German envoy, Cecil von Renthe-Fink was arranged. The German poet, Ludwig Tügel (1889-1972), recited his own works, followed by a talk by the German professor of linguistics and proponent of National Socialism, Dr. Otto Scheel, entitled: “The Danish-German cultural relations”. The final selection of the society’s programs was a talk by some Dr. Hans Draeger on “Denmark, Germany, and the new Europe”, appropriately followed by a Danish movie with the title of the Danish national hymn, “Der er et yndigt Land”.

The German Cultural Institute in Denmark was inaugurated on May 4, 1941, with the official objective of “improving the cultural, scientific and artistic connections between Denmark and Germany”.[21] This institute was the sixth in a series of similar institutions in other European countries, and the leaders of these institutes were intended to be prominent German cultural figures. As described in Nordlien 1998, the daily work was distributed between a scientific department, an academic department and a linguistic department. The first leader of the Danish institute was professor Otto Scheel. At the dedication in the Copenhagen National Museum’s ceremonial hall, the Danish Prime Minister, Thorvald Stauning, was present, accompanied by von Renthe-Fink, the German foreign minister’s representative von Twardowski, the Danish minister of education Jørgen Jørgensen, the president of the University of Copenhagen professor, Carl E. Bloch, and a group of academics from the Danish universities. Also the two professors Elis and Bengt were attending the opening ceremony.[22] “The University of Copenhagen had denied hosting the event” and it became difficult for the Germans to create contacts to Danish academic and scientific milieus.[23]

In Germany, Werner Heisenberg’s travels outside his homeland to give lectures and attend meetings became increasingly difficult with the advent of the war. Each trip required extensive approvals and notifications, and the hardest instance to convince was the Reich Ministry of Education (Reichserziehungs-

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[21] *Berlingske Tidende*, May 4, 1941, 11.
[22] *Politiken*, May 5, 1941, 3.
[23] Nordlien 1998, 71.

ministerium).[24] Heisenberg had been intensively followed by the German authorities since the late 1930s. Numerous SS reports of various kinds had caused conflicts over his fate. The conflicts were instigated due to polycratic institutional enmity under National Socialism. He had been given the label of "white Jew" practicing non-Aryan physics, that is, theoretical physics like quantum mechanics or the theory of relativity, instead of the undertaking of more 'useful' experimental physics.[25] This categorization had caused a rather hostile attitude towards his science. Hence his complaining messages to the public when giving lectures or other talks on foreign territory and the Ministry of Education held German scientists in a strait-jacket.[26] Notwithstanding, the Ministry of Education, especially the influential Party member since early 1933, Abraham Esau, was convinced that Heisenberg was ultimately important to the prestige of German science even though the physicist was neither an anti-semite nor member of the NDSAP.[27] Heisenberg was a controversial figure, and due to his relations to Jewish physicists in foreign countries, several of his requested trips were cancelled by the education ministry. Moreover, the opinions of the German father of quantum mechanics among Danish scientists were not only sympathetic.

In February 1941, Elis Strömgren received a letter from the director of the Danish-German Society, Captain Ernst Ipsen, who, with von Renthe Fink's declared interest, would like the German physicists Carl Fr. von Weizsäcker from the Kaiser Wilhelm Institute in Berlin to give a popular talk in the rooms of the society in Copenhagen.[28] The idea became a reality and occasioned by the success of this arrangement, Weiszäcker proposed yet another arrangement in the autumn of the same year at the German Cultural Institute. It was during this arrangement that the Bohr-Heisenberg meeting took place during the late evenings in Copenhagen. Weizsäcker's earlier talks had set into motion a series

[24] For details, cf. Walker 1995, chapter 6 in particular.
[25] See Kragh, 1999 for more about the "White Jews".
[26] A detailed 25 page paper in German astronomy during and after the Second World war can be found in the Yerkes Observatory Archives (YOA, IAU binder, box 226, F1).
[27] The Danish National Socialist Labour Party; Walker 1995, 138.
[28] Ernst Ipsen (chairman of the Danish-German Cultural Society (Dansk-Tysk Kulturselskab)) → E. Strömgren, February 20, 1941, ESC.

of policy decisions that led to “Heisenberg’s most controversial foreign lecture.”[29]

According to the historian Mark Walker (1995), the official report of Weizsäcker’s lectures in Copenhagen ascertained that he had a good influence on lay audiences as well as scientific colleagues. Therefore, he invited Heisenberg to join him for an astronomical working week, which was scheduled to take place at the German Scientific Institute in Copenhagen, from September 18-24, 1941. However, the main reason for Heisenberg to go to Copenhagen was to visit Niels Bohr.[30] Bohr’s mother was Jewish, and hence he was dubbed a “non-Aryan.” On the other hand, Bohr and his colleagues at the UITF had been authorized to carry on with their scientific work the first two years of the occupation. This was explained by the somewhat fictitious political claim that the Danish government had initially invited the German forces and was cooperating with them. Therefore Danish Jews were treated relatively well the first couple of years.

As it turned out, the German Education Ministry was not at all on cloud nine with authorizing Heisenberg to visit Denmark. Weizsäcker, on the other hand, was free to leave for the conference in concert with three German astronomers, namely the empirically oriented Hans Kienle together with the theoreticians Albrecht Unsöld and Ludwig Biermann. The focal theme of the conference was planned to be the composition of stellar atmospheres as this was also one of the main research topics of the director of the Copenhagen Observatory, Bengt Strömgren. In this connection, Heisenberg should give a talk on his work on cosmic radiation.

Weizsäcker invited Niels Bohr to join the event and he hoped that Bohr would “understand the situation” that from the German side they should be glad if Danish physicists would be present at the German institute, but on the other hand, Bohr should not feel forced to come.[31] Weizsäcker asked Bohr to invite as many Danish scientists as possible to join the meeting, and he also warm-heartedly invited Bengt to take part in the event. Weizsäcker requested Bengt to

[29] Walker 1995, 144.
[30] Walker 1995, 145.
[31] NBA, Carl F. von Weizsäcker → Niels Bohr, August 15, 1941.

give a talk on his acclaimed *Ergebnisse* paper and Elis was also invited to the meeting.[32] On the word of Weizsäcker, the success of the meeting would be determined by the amount of participation by the Danish astronomers, and therefore, Bengt Strömgren would do Weizsäcker a great favor if he did indeed decide to take part in the grand event.

Even so, the German Ministry of Education still did not allow Heisenberg to go. They argued that another astronomy conference had already been arranged in Würzburg for October same year, and that numerous scientists from foreign countries would attend, including Danes in particular.[33] The ministry wanted to use the German conference to terminate the Copenhagen conference. But since the director of the Copenhagen Cultural Institute, Otto Scheel, pointed out that the conference had already been announced, it was argued that a cancellation would be damaging to the fresh institute. The Würzburg congress would not be harmed, as the two Strömgrens would also attend on that occasion.[34] Perhaps it was also helpful for Weizsäcker that his father, Ernst von Weizsäcker, was the German State Secretary, and thus for tactical reasons, the proposal was irrevocably approved after much discussion as late as early September (in fact, as a boy, Bengt met the young son of the Ambassador, who visited the observatory on Østervold as he was interested in natural sciences).[35] The scientific trump card, Heisenberg, could go to Denmark allright, but only for a couple of days, and on the condition that he "kept a low profile."[36]

Concerning the September meeting, Bengt wrote in a letter to Niels Bohr about the coordination of the meeting that Heisenberg was scheduled to arrive in Copenhagen already in the evening of September 15 and that he was to stay at the Tourist Hotel. The conference would begin on September 19, but Heisenberg could obviously not stay for long. Everything seems to show that it was the Danish astronomers who were involved in the coordination of the astronomy week, not least Bengt Strömgren. Three days later, Kienle and Biermann arrived,

[32] NBA, Carl Friedrich von Weizsäcker → Bengt Strömgren, August 15, 1941.
[33] Walker 1995, 146.
[34] Walker 1995, 147.
[35] HI, 11-12.
[36] Walker 1995, 148.

and Weizsäcker turned up later.[37] Bengt and Elis Strömgren did indeed participate as well. Elis Strömgren had a close relationship with German colleagues, and he had brought his son up inside this network. Whereas Elis could perhaps be designated "German-friendly" due to his involvement with people from the occupying power, Bengt was less active in this respect and went sturdily against everything that went on at the political stage.[38] This did not entail, though, that Elis had any deliberation towards National Socialism, but rather that he had a large set of scientific connections in Germany that he preferred to keep on nurturing. The important thing for Elis was to keep his science international, disregarding the external political situation. Clearly, it was difficult, if not impossible, for him to stick to this kind of separation.

Heisenberg arrived on Monday, September 15, and he was welcomed by an official from the German Cultural Institute. The next day he met with his old student from the late 1920s who had made a professor and observatory director of himself, Bengt Strömgren. Later he visited his former colleagues at the UITF. Tuesday evening, he "walked under a clear and starry sky through the city, darkened, to Bohr." Heisenberg told his wife Elisabeth Heisenberg about his visit in Denmark. He continued:[39]

> Bohr and his family are doing fine; he himself has aged a little, his sons are all fully grown now. The conversation quickly turned to the human concerns and unhappy events of these times; about the human affairs the consensus is given; in questions of politics I find it difficult that even a great man like Bohr can not separate out thinking, feeling, and hating entirely. But probably one ought not to separate these ever.

Later that evening, Heisenberg sat "for a long time with Bohr alone; it was after midnight when he accompanied me to the streetcar". The following evening was

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[37] B. Strömgren → N. Bohr, September 13, 1941, NBA.
[38] KSCI.
[39] On his way back to Germany on Saturday 21, 1941, he wrote a letter to his wife, in which he thoroughly described his actions during the short visit. The letter can be found on the Internet: http://werner-heisenberg.unh.edu/Copenhagen.htm and comments are located on the website of the Niels Bohr Archive, www.nbi.dk/nba. The two following quotes are from this source.

Institut für theoretische Physik
der Universität Leipzig
Prof.Dr.W. Heisenberg.

LEIPZIG C 1, den 23.Sept.1941.
Linnéstr. 5

547

Bericht über die Teilnahme an einer astrophysikalischen Arbeitstagung im Deutschen wissenschaftlichen Institut in Kopenhagen.

Die astrophysikalische Arbeitstagung im Deutschen wissenschaftlichen Institut in Kopenhagen war auf die Zeit vom 18.-23.9.41 festgesetzt. Da ich aus privaten Gründen am 21.9. ~~bereits~~ wieder nach Deutschland reisen musste~~n~~, habe ich meine Reise im Einverständnis mit dem Auswärtigen Amt bereits am 15.9. angetreten. In Kopenhagen wurde ich von einem Herrn des Deutschen wissenschaftlichen Instituts empfangen. Am 16. besuchte ich Prof. Dr. Bengt Strömgren an der Sternwarte Kopenhagen und vereinbarte mit ihm die Einzelheiten des Programms der Arbeitstagung. Ausserdem nahm ich Fühlung auf mit den Physikern am Institut für theoret. Physik der Universität Kopenhagen. Die übrigen Tagungsteilnehmer kamen am Abend des 17.Sept. nach Kopenhagen und am 18. fanden allgemeine Vorbesprechungen über den Verlauf der Tagung statt. Die Tagung begann am 19. mit einem Vortrag von Dr. Biermann, Babelsberg über die Theorie der Novae. Von dänischer Seite nahmen an der Arbeitstagung nur die beiden Professoren Strömgren (Ellis Strömgren und Bengt Strömgren) und die Mitglieder der Kopenhagener Sternwarte teil. Am Abend des 19.hielt ich meinen Vortrag über den jetzigen Stand~~punkt~~ unserer Kenntnisse von der kosmischen Strahlung. Zu diesem Vortrag waren ausser den Kopenhagener Astronomen auc noch verschiedene Mitglieder der deutschen Kolonie in Kopenhagen erschienen. Am 20. fanden sowohl vormittags wie nachmittags Sitzungen im Rahmen der Arbeitstagung statt. Am Mittag des 20. waren wir Gäste des deutschen Gesandten in Kopenhagen. Schon am Abend vorher hatte ic Gelegenheit, den Landesgruppenleiter kennenzulernen und mich mit ihm über die vorliegenden Fragen zu unterhalten. Am 21. morgens reiste i von Kopenhagen ab.

Von dem Zusammensein mit dänischen Kollegen habe ich den Eindruck gewonnen, dass unsere Beziehungen zu den wissenschaftlichen Kreisen in Skandinavien jetzt recht schwierig sind. Man stösst überall auf eine sehr reservierte,oft auch ablehnende Haltung. Nur wenige dänische Kollegen sind bei der augenblicklichen Lage zu einer wissenschaf lichen Zusammenarbeit in einem mehr oder weniger offiziellen Rahmen, wie ihn das Deutsche wissenschaftliche Institut darstellt, bereit. Die Dänen nehmen diese Haltung ein, obwohl mir gegenüber fast alle Kollegen betont haben, dass sie über das Verhalten der deutschen Wehrmacht nicht die geringste Klage vorzubringen hätten.

Heisenberg

Figure 3: Werner Heisenberg forwarded this document to the Ministry of Education in Germany, reporting the result of the meeting in Copenhagen (Werner Heisenberg (German Institute of Theoretical Physics, Leipzig) → Reichserziehungsministerium, September 23, 1941, BA, 2943, 547).

also spent with the Bohr's and Thursday morning, Heisenberg went to the Langelinie pier along the harbor with Weizsäcker:

> Now there are German war ships anchored there, torpedo boats, auxiliary cruisers and the like. It was the first warm day, the harbor and the sky above it tinted in a very bright, light blue. At the first light buoy near the end of the pier we stayed for a long time looking at life in the harbor. […] At the pavilion on the Langelinie we ate a meal, all around us there were essentially only happy, cheerful people, at least it appeared that way to us. In general, people do look so happy here. At night in the streets one sees all these radiantly happy young couples, apparently going out for a night of dancing, not thinking of anything else. It is difficult to imagine anything more different than the street life over here and in Leipzig.

On the face of it, Copenhagen could apparently be compared with Heisenberg's home town. Perhaps life was not that bad in Copenhagen after all. While Heisenberg gave a lecture at the UITF, Biermann and Kienle were busy at the CO, discussing astrophysical questions with Bengt.

The working week was launched on September 19 and the only Danes attending the workshop were the Strömgrens and the observatory staff being the two assistants Karl Thernøe and Jens Møller, since Julie Vinter Hansen stayed in the USA during the length of the war. Boycott was a possibility, and so no physicists participated in the meeting as they had in fact boycotted the event from political reasons, nor did anyone else from Danish academia, except the university president Carl E. Bloch. During and after the founding of the German Cultural Institute, "a number of brisk militarist speeches on the New Order in Europe were given", and on principle, virtually no one wanted to go to the institute. Heisenberg wondered about the Danish attitude against the merging of the two cultures:[40]

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[40] Ibid.

> It is amazing, given that the Danes are living totally unrestricted, and are living exceptionally well, how much hatred or fear has been galvanized here, so that even a rapprochement in the cultural arena – where it used to be automatic in earlier times – has become almost impossible.

In addition, some members of the NDSAP were present.[41] Heisenberg gave his key note paper Friday evening on cosmic radiation and after he had completed his business doings, he left to visit the Bohr family once again.

As it was required of all German scientists visiting foreign countries, Heisenberg needed to write a brief report reflecting his experience of the workshop, even though he did not partake in the full program. He wrote it on his way back from Denmark, and the report was soon sent to the German Ministry of Education.[42] As the report clearly demonstrates, Heisenberg valued the prospects of cultural relations between Denmark and Germany poorly (figure 3). Hardly any Danish scientists were interested in occupying themselves with an official institution like the German Cultural Institute, and Heisenberg did not regard the specific workshop to be a success:[43]

> After being together with the Danish colleagues I have got the impression that our relations to the scientific circles in Scandinavia are quite difficult now. Concerning the scientific institute, only a few Danish colleagues are ready to cooperate for the time being in more or less official settings.

When it came to Weizsäcker's report to the ministry, his general opinion was much more optimistic and on a more positive standing. Another report from representatives of the German authorities attending the conference demonstrated even further optimism, claiming that the workshop was a great success because it drew Danish research into the German Cultural Institute – in spite of the fact that not even a single physicist from the UITF showed up. Three years later,

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[41] Walker 1995, 149.

[42] Werner Heisenberg (German Institute of Theoretical Physics, Leipzig) → Reichserziehungsministerium, September 23, 1941, Ba, 2943, 547).

[43] Ibid.

Heisenberg gave yet another talk in the Copenhagen Cultural Institute. The Danish government had already resigned in 1943 and his colleagues at the UITF wanted to have less than ever before to do with the Institute. His talk was given almost only to a German audience, even though the Strömgrens and the observatory staff attended once again.[44]

6.3 Danish Resistance

During the last two years of the war, the conditions got gradually worse. The university continued its activities, but many times there were rumors of mass deportations of students and teachers, such as were started by the Germans in Norway. During the last year of the war, Bengt lectured to small groups of students dispersed all over the city of Copenhagen, "as it was considered too dangerous to have larger audiences of students".[45] From dusk till dawn it was extremely dangerous to walk in the street. From the observatory, the Strömgren family could hear "sabotage explosions, rifle shots and machine gunning more or less continuously almost every night, but we got quite used to it, and so did the children".[46]

Even though, of all the warring and occupied countries, Denmark was a country with relatively high standards of living, politically, Denmark had accepted the occupation power and in no ways worked against it. Yet, out of the gradually more discontent Danish population grew the resistance movement, which was organized and became effective from about the middle of the war-period. The British Special Operations Executive (SOE) was the secret military organization created for breaking down the enemy. Its purpose was to collect and organize any illegal activity against the German occupying power. SOE had departments covering all occupied European countries and the Danish division was established in 1940.[47]

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[44] Walker 1995, 175.
[45] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP. The next quote is also from this source.
[46] Ibid.
[47] For detailed reading about the Danish resistance movement, see e.g. Trommer 1980 or Hæstrup 1979.

In June 1941, when the German troops attacked the Soviet Union, all the occupied countries were dictated to arrest all communists, to make a law against any communist activity, and to dissolve the Communist Party. As this demand was followed, numerous Danish communists were aspired to engage in the resistance movement. In 1942, SOE succeeded to introduce a new leader into Denmark together with some telegraphers, but there was still lack of explosives. The occupation power decided to expand the Entlösung to Denmark, which meant that the time had come for the Danish Jews to be put in concentration camps. This decision instigated the Jewish action on October 2 and 3, in which more than 95%, or ca. 7,500, of the Danish Jews were brought safely to Sweden, as the Jewish majority lived in Copenhagen. When the prosecution of Jews began in Denmark, the Strömgrens "felt paralyzed, but only for a few days and weeks; it was always possible to get accustomed to the new situation".[48]

Some of these escaping Jews were the physicist, professor Georg von Hevesy and his wife. Hevesy had worked at the UITF since 1920 and took part in the discovery of the element hafnium – the work that involved Bengt in reduction calculations (see chapter 3.3). When Hevesy and his wife fled Denmark, Bengt and Sigrid agreed to hide their two eight and ten year-old daughters until passage could be found for them also. They were hid in a small attic room in the observatory. Obviously, this was kept top secret, since anyone caught hiding Jews would be sent to a concentration camp also.[49] Bengt told his daughters not to even tell their best friends about the hidden girls. For ten days, they played in the attic room, "and one day they were gone, when we came back from school".[50] The family reunited in Sweden, Georg von Hevesy received the Nobel Prize of chemistry in 1943 and was appointed professor of chemistry at the University of Stockholm.

Opposite to the CO, neighboring the Rosenborg castle, were the barracks, in which prisoners were kept by the occupation power. Sometime in late 1944, a number of Hungarian captives escaped the barracks. Early one Sunday morning,

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[48] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP.
[49] Campbell 1984, 3.
[50] COR.

a group of soldiers came banging on the observatory front door. Fortunately it was "only soldiers" and not the Gestapo. The whole family "were all herded downstairs and stood barefooted on the icy floor, as a sixteen-year-old pointed his gun at my father, playing with the trigger all the time and obviously enjoying his power". While the family was guided with riffles and grenades, the other soldiers searched the house. Bengt was "as white as a sheet because he was hiding secret documents about the Danish resistance in the basement".[51] As Bengt wrote Chandrasekhar, "nothing was found, although we, like several other university institutions, did keep things, which the Germans ought not to get hold of". While this was going on, there was shooting in the streets, "and a bullet went trough the children's room".[52]

Many people from academia worked actively in the resistance movement. When it was reorganized in November 1943, the SOE and the Liberation Council (Frihedsrådet) divided Denmark in six regions, and later the island Bornholm was included with a seventh region.[53] In the remaining months of 1944 and in early 1945, there was a gradual increase in the amount of tons of British sabotage material dropped by the Royal Air Force (RAF). For obvious reasons, no list exists at present of people, including scientists, who were actively involved in the Danish resistance movement during the war. Under the occupation it was regarded very risky to make such a list and the scientists knew only about members from their own group in the resistance organization.

Every faculty at the university housed activists who were members of underground movements.[54] Just as resistance activities took place at e.g. the Rockefeller Institute, the Geodetic Institute, the Agricultural College (Landbohøjskolen), the Copenhagen Observatory also played a part in helping the resistance movement. Bengt obviously kept this secret to his children. For retribution of the Danish resistance's growing number of successes, the Gestapo would shoot several people – often famous and noted people, such as pastors,

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[51] Campbell 1984, 3.
[52] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP.
[53] Region 1: Northern Jutland, (ca. 8,000 members), 2: Mid-Jutland (8,000), 3: Southern Jutland (6,000), 4: Funen (4,500), 5: Zealand (10,000), 6: Copenhagen (17,000), 7: Bornholm (600). Johannesen 1995, 51.
[54] Borgen 1945.

professors, and poets. Bengt Strömgren, perfectly aware of the high risk, was involved in getting messages to the RAF through the university and other scientific institutions. For what we know, the material hidden by Bengt in the basement was secret documents about the Danish resistance movement. Thankfully for the Strömgrens, the Germans were not looking for written documents but instead for some Hungarians that never went inside the house, and the fate of whom remains unknown.

Bengt and Sigrid also harbored "some members of the Danish resistance in the observatory for some time during the war," a period of considerable nervousness for him and his family. "After the war ended, they would keep all the lights in their house on as a reaction to the dark and dreary experience of the occupation."[55] After the unpleasant Nazi visit, Bengt and Sigrid sent their children away. "It was clear at the time that the war would not last very much longer, and so we sent them to Taarbæk outside Copenhagen to live with Sigrid's uncle and aunts", Holger, Ellen, and Nicolette Schou.[56]

6.4 Necessitated Research

Many of Bengt's former colleagues in Williams Bay soon were on leave for government service. Elvey, Keenan, Kuiper, Page, and more left the Yerkes Observatory for military duty. Struve continued his direction of the observatory, and Chandrasekhar did some theoretical war work in addition to his research. On a visit to Lund in the spring of 1942, Bengt managed to forward a very emotional letter to Chandrasekhar, which is given nearly in its entirety here:[57]

> May this letter, sent from Sweden, reach you to tell you that almost every day my thoughts go to you and Lalitha. In spite of all that has happened in the world, I sometimes feel as if it were only a few days since we took leave of each other […].

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[55] Kulsrud 1987, 222.
[56] COR, B. Strömgren → S. Chandrasekhar, December 18, 1945, UCA, SCP.
[57] B. Strömgren → S. Chandrasekhar, May 1, 1942, UCA, SCP.

> Ever since the war began, we have been living under a tremendous mental pressure. I need not tell you what April 9, 1940, meant. It is not that we suffer very much as yet, physically. Most of my work I have been able to carry out almost undisturbed, up till now. But we never know what might happen next day, or next month. It takes a terrific mental effort not to feel powerless, at times, against the evil forces. If I were only concerned [with] myself, I might feel quite safe behind a mental defense line, but with Sigrid and the children I sometimes feel terribly vulnerable.
>
> Still I am optimistic, in a way. I feel almost 100% certain, now, that the evil powers will be crushed, and why should it not be possible that we come out of it all sufficiently unscathed, physically and mentally, to be able to work for a happy future […] Now let me close this letter telling you that no war and no separation, however long, can change my friendship and love for you […].
>
> Yours ever, Bengt

Being cut off the international proliferation of scientific research papers, Bengt was still allowed to go to Stockholm and spend two weeks with Lindblad. He gave a series of lectures and after his return he corresponded with the Swedish professor. Even though the CO staff only learned about the major war-time developments in astrophysics after the war ended, there was, via Sweden, some exchange of literature.[58] Without supporting observational data, Bengt and his staff ventured extensively into theoretical astrophysics. Together with Kjeld Gyldenkerne, Mogens Rudkjøbing, and Karl Thernøe, he worked on vast calculations of tables of stellar model atmospheres. The starting point was a paradox formulated by Eddington in his *ICS* in 1926. When comparing the yellow giant star Capella with the sun, using the standard model, he found a higher luminosity with an unexpectedly low density, and a much lower temperature. This did not agree with observations, indicating that the two stars have approximately the same color and temperature, in spite of Capella being a giant.

[58] HBI, 53.

Gamow suggested in 1939 that in giant stars, outside the inert core there is a shell in which the temperature might be high enough to fulfil both conditions.[59] Then there would be both hydrogen fuel and a sufficient temperature. The Swedish PhD of astronomy from Lund University, Anders Reiz, could travel freely by boat between Sweden and Copenhagen, and he worked in 1941 with Bengt on the problems concerning stellar evolution.[60] "This is what Reiz and I tried to do, just again integrate from the outside, and go through a shell that has sufficiently high temperature and then finish it off with this inert helium core, and that worked."[61] The model had the right temperature for the shell. Whereas Gamow's idea was only qualitative, they found that this was probably one viable model for a giant star. But they still felt very far from understanding stellar evolution, "because we didn't go step by step. And really, this only became possible when you could do it with the electronical computer."[62] The calculation group continued working on structure calculations of the pressure and opacity for forty model stellar atmospheres. Though the sequel to their paper was never published, it was intended to report the results of calculations of the continuous spectrum for the same model stellar atmospheres.[63] The main result of the theoretical work of Bengt's research team was that hydrogen was abundant not only in stellar interiors but also in stellar atmospheres. During wartime, Bengt published twenty papers, of which only one was the above mentioned joint paper with his young colleagues at the CO. In Bengt's career, there were only few joint publications, except in his later years, when observational research at the European Southern Observatory was made public in scientific journals.[64]

Throughout the ten years from his appointment as professor, he was responsible for the teaching. He taught the elementary, the intermediate, and the advanced courses, with classes of thirty to forty apprentices – though from ca.

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[59] Gamow & Critchfield 1939.
[60] Reiz earned his doctorate in 1941 in Lund. For further details, see chapter eight; HBI 51, Yearbook 1953-58, 239.
[61] HBI 51.
[62] HBI 51.
[63] B. Strömgren, Gyldenkerne, Rudkjøbing, and Thernøe 1944; BS → Chandrasekhar, 1945, September 30, UCA, SCP.
[64] HBI 26.

1943, teaching was reduced to virtually nothing, as will be described in chapter 6.5. The advanced courses were "never more than three or four" students. His instruction was arguably motivated by the fact that he enjoyed teaching, "Even this elementary teaching, where I used a textbook, it was all right. We combined the teaching with exercises. They had to do problems which were of a very standard nature".[65] Of his students through the decade, Bengt emphasized in particular three, namely Rudkjøbing, who became professor of astronomy at the University of Aarhus in 1957; Reiz, who succeeded Bengt in his chair in 1958, and then there was Bengt's entrusted young co-worker Gyldenkerne.

It was difficult not to be able to compare theoretical research to fresh observational results. In order to endure daily life during the bleak years, Bengt made some recreational digressions of his work. In *NAT*, he published a series of three papers concerning the historical development of astronomical telescopes, a history of technology ranging from Galilei's use – but not invention – of the telescope, to modern telescope technology such as the Schmidt telescope construction issued in 1932.[66]

Another diversion was a far-reaching series of calculations of sine tables for the use of calculating beams in optical systems. He was inspired by earlier work by Henri Chrétien and his work became a "best seller for some years".[67] Apparently, he found numerical computation to be a way of keeping up his spirits up during the period of the German occupation. The optical sine papers, with ten figures, and rounding off, were purely routine and thus the work served its function as, if not for keeping in shape as a calculator then at least for productive pastime. They were widely circulated and used, "selling quite good for some years" immediately after the war, before the advent of the electronic calculator.[68]

A third example of his recreational work using his computational ability was an interesting way of transferring knowledge from exact astronomy to

[65] HBI 25.
[66] B. Strömgren 1944d, 1945a, 1945b.
[67] B. Strömgren 1983, 7, Kulsrud 1987, Rudkjøbing & Reiz 1988, 150.
[68] B. Strömgren 1945d, HBI 53.

statistical psychiatry, from big brother to little brother. From the very first of his scientific work, Erik Strömgren was able to profit from his brother's special knowledge of calculation methods, and Erik explained it like this:[69]

> It may make you wonder, if the exact methods of astronomy could find use in a field as apparently inexact as psychiatry. […] In the 1920'es and 1930'es, psychiatric research was centered on the question of a connection between certain body types and certain mental disorders. The description of the types was a very subjective matter, and it was important to replace the intuitive estimate with exact measurements. The difficulty was that within each of the types there were great variations on e.g. height and breadth, leaving the absolute numbers worthless. Confronted with this problem, Bengt pointed out to me that in astronomy there was an analogy, *viz.* star clusters. Here, there were methods by which to distinguish between the collective movement of the cluster and the eigen movements of it's stars. These methods could also be used for describing the body types, which he did.

Bengt published his results in the journal, *Acta Psychiatria et Neorologia*, and Strömgren posed the problem very much in the form of the mathematician's:[70]

> In a series of investigations […] Erik Strömgren has considered the problem of the determination of an anthropometrical index intended for the separation of the pycnic and leptosome constitutional type. […] For a number of persons a division into two constitutional types, pycnic (*p*) and leptosome (*l*), is assumed to have been carried out by an experienced investigator. For the same persons a number (*n*) of anthropometrical measures (height, width of thorax, etc.) X_1, X_2, X_3, … X_n, have been determined. It is now desired to combine the measures into an anthropometrical index which reproduces, as closely as possible, the given division into groups *p* and *l*.

[69] MS 1987.
[70] Strömgren 1946a, 747.

By use of linear combinations of deviations of measures, matrix algebra, and eigen values, Bengt assumed types of diagnostical criteria for e.g. psychic trauma, hallucinations, etc., by giving each patient a set of values, c_1, c_2, c_3, …, c_n, corresponding to the *n* diagnostical criteria. The diagnostical index was then defined as a linear combination of the c's, and with a group of *N* patients, *N* equations were thus to be solved by the method of the least squares, yielding a division of the patients into groups according to values of the diagnostical index. Then, finally, the agreement of the division with the diagnosis could be investigated, and accordingly, like in the exact sciences, model could be tested on reality, as the logical positivist would probably maintain. Curiously, Bengt's paper depicts a scientific researcher of an exact scientific field of astronomy entering the not-as-exact field of psychiatry, and the cogency was to the point, as it usually was in his publications.

As the opportunities to pursue astronomical research were limited, he turned to the study of geometrical optics. He developed a lens system to reduce third order aberrations to zero and constructed a small 6-inch astrograph that accomplished this. Already in 1935, Bengt corresponded with Bernhard Schmidt, who worked at the Hamburg Observatory.[71] Bengt received "most interesting comments" from Schmidt, showing that "he was not only a master of technical optics, but he had a deep understanding of the theoretical side."[72] The same year, Bengt published a paper on the theory of the new Schmidt telescope, which was a nice preparation for his work in the forties.[73] During the war, Bengt asked himself if the standard Fraunhofer lens system could be modified and perfected "through the use of the same devices that so improved the performance of the spherical mirror? The result was quite satisfactory, a system consisting of a crown and flint lens in near-contact and a Schmidt plate located halfway between these lenses and the focal plane." In 1945, his work resulted in the publishing of a paper on general wave tracing.[74] The advantage of this kind of work was also

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[71] Strömgren 1983, 6; BSA.01,A, B. Strömgren → B. Schmidt, November 12, 1934 and January 24, 1935.
[72] B. Strömgren 1983, 6.
[73] B. Strömgren 1935b.
[74] Ibid, B. Strömgren 1945e.

considered by Bengt to be of a somewhat recreational sort and "on days when everything looked dark, it was routine work".[75] His work on the Schmidt telescope was far from coincidental, however. Rather, it constituted important preparations for the remote observatory, the plans of which had been inside his head since the late 1930'es and which slowly progressed, although appreciably delayed by the war.

6.5 Two Auspicious Birthdays

The jubilees on the occasion of Ole Rømer and Tycho Brahe's birthdays appropriately fell in 1944 and 1946 respectively (300 and 400 years). They resulted in the release of substantial funding from the Carlsberg Foundation and therefore constituted further steps in the right direction, but still, state funding was uncertain to rely on. Here, the early events of the branch observatory are accounted for. The subsequent occurrences are recounted in the following chapters seven and eight.[76]

With Bengt's wish of reviving the old project plans of a remote observatory under the University of Copenhagen, he was in company with the old Thiele. As described in chapter 2.2, Thiele worked actively for the establishment of a small observatory outside Copenhagen. In 1910, however, Elis prevented further realizations of the idea by stepping out of the observatory commission. Later the Great War contributed to the impossibility of realizing the idea. Although in the twenties Elis had cursory plans of establishing a small observatory not too far from the capital, they were never brought to life. Now, for the fourth time, a Danish astronomer worked for reviving the idea, and he succeeded, although the plans dragged on so long that he eventually found himself compelled to leave Danish astronomy.

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[75] HBI 53.

[76] The history of the Brorfelde Observatory is treated in Høg 1953; Nielsen 1953; Gottlob 1955; Gyldenkerne 1962, 1986, and 1990; Laustsen 1961; and H.S. Nielsen 1962. This narrative follows these sources but it is complemented with new primary sources.

Figure 4: Left: Transportation of the 25 cm reflecting telescope from Østervold, Easter, 1945. Right: The telescope building on Hyldebjerg, build at the CO and originally erected close to the magnetic observatory (see figure 2a, chapter two). A synchronic motor was mounted on the telescope for its automatic motion and was connected by electric wires via pylons to the Sofienholm Manor (Gyldenkerne 1986, 99).

In August 1943, Bengt went into the Dean’s office for a two-year period as the office revolved between the senior faculty members.[77] It was an administrative burden to him during the difficult years, but it was “also very useful with regard to the cooperation with the administration of the University” since he was mainly involved in the matters of getting sufficient funding for the branch observatory.[78] Bengt’s administrative work in his position as the new observatory professor was all concerned with preparations for its build-up. Having no observation facilities for research, Bengt felt that “even if we could have access to big instruments, being invited as visitors, you must have a firm basis and you must create a tradition, and for that it was necessary to have even a small observatory. And that was the aim.”[79]

Bengt spent much time preparing the plans for the projected new branch station observatory outside Copenhagen. Already in 1942 and 1943, the Carlsberg Foundation subsidized the initiation of atmospheric investigations ofdifferent sites on Zealand (see figure 1, chapter 4.1). Bengt and his colleagues

[77] Yearbook of the University of Copenhagen, 1943/1944, 1-2 and 1944/1945, 1-2.
[78] B. Strömgren → S. Chandrasekhar, December 18, 1945, UCA, SCP.
[79] HBI, 52.

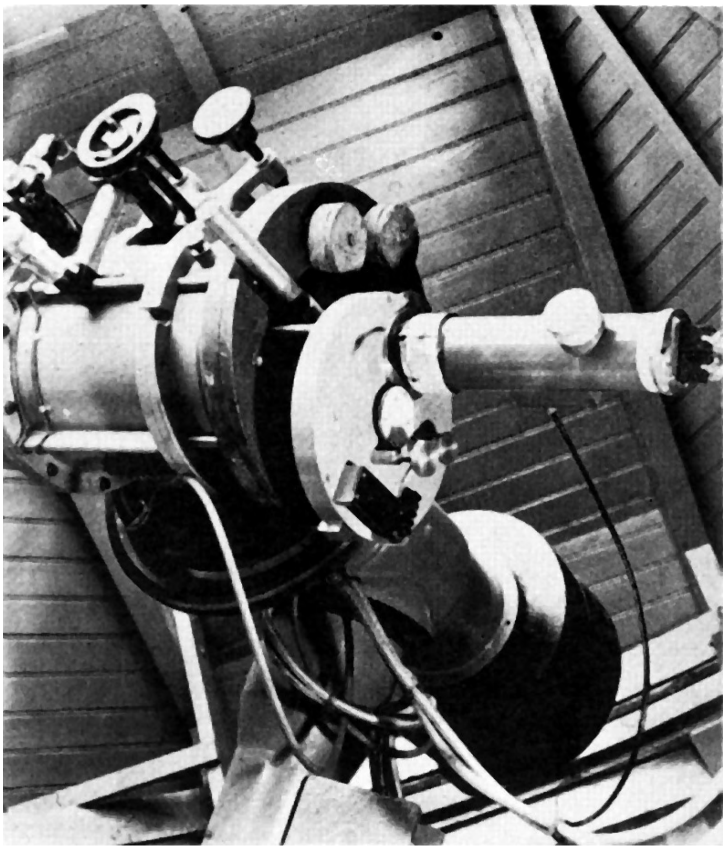

Figure 5: The 25 cm telescope on Hyldebjerg, mounted with a photometer (Gyldenkerne 1986, 104).

made a list of potential localities for the observatory and he undertook the management of the construction of a special camera for the registration of the atmospheric tremor and it was mounted on a 25 cm reflector. In 1944, for the Ole Rømer-jubilee, the university got a fund from the Carlsberg foundation for the erection of a meridian circle at the new observatory, and as Bengt wrote Chandrasekhar right after the liberation: “We also have certain hopes in connection with the Tycho Brahe jubilee”, which would take place in 1946.[80] The memorial celebration of Rømer took place in the assembly hall of the University of Copenhagen and was arranged by the university and the Polytechnical College.[81] The support from Carlsberg of 350,000 Kroner was earmarked for the construction of a meridian circle by a specialist firm.[82] This was a suitable instrument to use under the climatic conditions of Denmark and after all, this was

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[80] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP. Bengt wrote several feature articles on Ole Rømer’s life and work: B. Strömgren 1944b, c, and f.
[81] Yearbook 1944/1945, 207). Speeches from the event are given in *Nordisk Astronomisk Tidsskrift*, 1944, 73-95.
[82] B. Strömgen → University of Copenhagen trustee, June 9, 1949, NBA.

the type of instrument that was developed by Ole Rømer around 1704 for the determination of stellar positions.

The list of locations was reduced to comprising only two sites, since "if you know conditions you can eliminate lots of areas".[83] During the Easter of 1945, the 25 cm reflecting telescope was moved from Østervold to Hyldebjerg hill at the Sofienholm Manor, 7 kilometers from the city of Tølløse in mid-Zealand – and a few kilometers from the village Brorfelde. This site had already been in Thiele's fore sight in 1907. It was erected on the hill, as was also another 25 cm telescope, which was raised at Krogshøj hill in a state forest close to Elsinore. The atmospheric seeing was recorded photographically according to Bengt's new method, which was tried for the first time on a large scale. The aperture of the telescope was covered with two openings sufficiently far apart for the turbulence not to be correlated. With a prism, the two images were formed and since small apertures give sharp images, the opening moved around, making it possible to measure the relative displacements. The images of very bright stars were recorded with very short closing times. As Bengt evoked, he once told the administration at the university that "in the process we had measured 16,000 star images. This was the number. But he must have misunderstood, because he was overheard to tell other people that we had investigated 16,000 *sites*."[84]

After the comprehensive investigations, Krogshøj was rejected. Bengt feared that the light from Copenhagen would be too much, and the seeing was better on Hyldebjerg. He finished a large report including the plans for the observatory and sent it to the ministry of education. In his 1945 letter to Chandrasekhar, he expressed his concern as to the economical situation of his nation: "The university has decided to put the observatory at the top of a long list of things they want. Now developments depend on the general situation in Denmark."[85]

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[83] HBI 52.
[84] HBI 53.
[85] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP.

Public Astronomy

Besides the various duties of technological management, observatory planning, and routine academic assignments, Bengt was an active popularizer of his science. Looking at the stars and forgetting the horrific world events was done publicly by Bengt at the CO and Ruben Andersen in Århus, as was richly illustrated in newspaper interviews with the two astronomers. In an interview-article in a Danish paper entitled "The stars illuminate the blacked-out country", Bengt was introduced as "Denmark's youngest professor". He told the readers about the obvious duties of the observatory, i.e. the time service and the Central Bureau, but also about the ungraspable conditions in stellar cores and the importance of electrical calculators for the making of new theories of the stars surrounding us. As to the Moon, he considered it "of almost no interest scientifically", although, "perhaps in a few hundred years it will become tremendously interesting, if we are able to reach it with rocket ships".[86]

In August 1943, Bengt spoke at length about the questions of the structure of the Milky Way and the big issue of the developmental history of the whole universe. He talked about the prospects of the Earth and the Sun, but also about the prospects of improvements for the practical working conditions for astronomers in the country through the build-up of a branch observatory. "The working conditions are in many ways satisfactory, especially concerning theoretical research", but astronomy is not only a desk job and the still new professor clearly complained about the instrumental conditions:[87]

> The last purchase of a large instrument happened in 1895. Since those times, an immense development has taken place in the astronomical arts of observation. The acquisition of new and modern instruments is badly needed. It would be natural to erect such instruments in an observatory outside the city […]. For my part, I strongly hope that it will not be too long before those plans can be realized.

[86] Demer 1940.
[87] Vendt 1943, 6.

Although being located in the end of the interview, it is obvious that the comment was a matter of serious concern for Bengt. His wording could even be read as a threat to the politicians. After all, he was still the professor of the nation personifying Danish astronomy, and indirectly perhaps in a way even personifying Danish pride, as discussed at the end of chapter one. Five years had already passed since the university promised to work for the establishment of the observatory. If nothing happened soon, perhaps Bengt would be forced to look for a job somewhere else?

A few months later, he appeared in another interview with the sub-title: "Danish science works, while the war rages".[88] The main results from the latest two years of basic research were highlighted as the finding of interstellar matter.[89] The collective efforts of numerous astronomers working on theoretical problems were naturally transferred to another more attentive aspect of life: "Perhaps more than in any other issues, it holds good in this matter that it is the international cooperation, which has led to the final victory."[90] Clearly, this was not just a conclusion of a popular science feature article. Even more, it was a somewhat frustrated comment on the general development of the war in the newspaper *Social-Demokraten*.

The popularization of astronomy was considered by Bengt to be an important part of being a professor, and already the same year of his new position, in 1940, he published the popular book *Universets Udforskning* (The exploration of the Universe).[91] In 1944, a reporter read the book and visited the observatory for an interview of the professor to learn about the necessary prerequisites for the layman, in case he wanted to study the heavens. After denigrating the scientific value of Bengt's own recent monograph, he listed a series of important authors for the very interested reader:[92]

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[88] Olaf-Hansen 1943.
[89] The early model atmospheres is described in e.g. Hearnshaw 1986, 408-411.
[90] Ibid.
[91] B. Strömgren 1940c.
[92] "Min Studieplan IV: Astronomien", *Ekstra Bladet*, April 22, 1944.

> Bergsøe, Eddington, Flammarion, Jeans, Luplau Janssen, Torvald Køhl, Nissen, E. Strömgren, B. Strömgren, and Störmer. As one will learn, numerous writers have treated subjects from astronomy, but many of them are obsolete or in other ways insufficient.

In the paper, Bengt issued "a way, in which people without any prerequisites can become acquainted with astronomy".[93] He complained about the lack of good popular literature and recommended instead a subscription of the local journal *NAT*.

On the proposal by the newspaper *B.T.* to establish an astronomical folk high school, Bengt directed his enthusiasm of the idea to the readers, although he found the issue to be outside the scope of his job description. He was very much aware of the prevalent interest of astronomy in the country and referred to "popular books and journals, societies, public lectures, and astronomical demonstrations". "Even within the Astronomical Society", he continued, "there are organisations which arrange for private astronomers to participate in astronomical observation work of scientific value – by observing variable stars and lunar occultations".[94] As to the question of institutionalizing, he referred to prospective extensions of existing institutions such as folk-observatories, high schools and perhaps increased efforts at the Danish Folk University.[95] But only if it became evident that there was a prevalent public urge for closer contact with astronomy. This never happened, even though the activity among Danish amateur astronomers was intense for many years.

On the night of May 4, 1945, it was announced that Denmark would be liberated the following day. During the celebration, Sigrid biked out to see their children in Taarbæk, also because it was Karin's birthday. Sigrid's sister Ellen opened her home to the freedom fighters around the neighborhood for lunch. There was not much to eat, but Ellen had kept some food in reserve in case things

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[93] "… en Maade, hvorpaa Folk uden Forudsætninger kan lære Astronomien at kende". *Ekstra Bladet*, "Min studieplan IV: Astronomien", lørdag 22. april, 1944.
[94] "70,000 Observationer er udført af Privat-Astronomer", *B.T.*, March 24, 1945, 8.
[95] The Danish Folk University still exists and was founded in 1898 by its pioneering figure, Claudius Wilkens, with the aim of disseminating knowledge of scientific results and methods for the public.

got really bad. As Karin remembers, “after lunch, we ran around, waving flags and singing Danish, English, and American songs. My mother and aunt had saved a bottle of wine for this long-awaited occasion.”[96]

[96] Campbell 1984, 4.

Seven

Post War Astronomy

Institution Building

1945-1951

The time following the liberation was marked by a combination of high expectations of state reforms and an urge to go back to a normal way of life after the occupation. The Ministry of Finance was confronted with the task of bringing order into the administration of the loans that had been taken on the American market during wartime. It was considered especially important to quickly settle the due government loans. At the same time, the launched Marshall plan became consequential for the economical development of Denmark in the post-war years.

The number of permanent employees at the CO was increased by one, as Julie Vinter Hansen returned from her American exile. But as there was a gain, there were also losses. During preparatory observational work with the CO's large refractor for the use of the new branch observatory, the assistant Jens P. Møller suffered from a heart attack in the dome. He died only forty-five years old. Elis described him as an excellent photographer, an able theoretical scientist, and an invaluable help for the Central Bureau. Besides, "he was an expert on comets, an outstanding teacher, and a great popularizer."[1] So, the number of scientific employees remained three, consisting of professor Bengt Strömgren, observer Vinter Hansen, and assistant Thernøe, until 1947, when two additional assistants were appointed, Mogens Rudkjøbing and Hans Q. Rasmussen. In 1946,

[1] E. Strömgren 1944.

Mackeprang ceased as the observatory's permanent calculator and acting secretary, but Gyldenkerne kept on assisting the Copenhagen Observatory with his computational skills.

The professor's first astronomical event outside Denmark after the liberation took place in Sweden. On July 9, 1945, there was a total solar eclipse in the northern parts of Sweden and in Finland, which turned out to be a success for the practical co-operation in the Scandinavian community of astronomers. From Uppsala and Lund, and from Copenhagen, were sent three parties of astronomers to observe the eclipse. The Danish expedition was subsidized by the Carlsberg Foundation and it was a complete success. The Danes were lucky in deciding to observe at the northern Swedish coastline. Finnish astronomers, who settled to observe inlands, sadly had cloudy weather. The main purpose of the expedition was to observe the time dependency of the solar intensity just before and after the totality by observing the solar edge. The observatory mechanic, Poul Bechman, had constructed a parallel set-up for the Copenhagen expedition, carrying two telescopes provided with photocells, each connected to galvanometers for the registration of intensities for two different frequencies.[2]

Bengt and a constructor named T.W. Carstensen arrived at the rendezvous point in the hamlet of Brattås where they were welcomed by the Swedish head expedition, led by Lindblad. Two days before the eclipse, the two astronomers from the Ole Rømer Observatory arrived. "It was planned in advance that Ruben Andersen and Axel V. Nielsen were to participate in the observations", as Bengt wrote in *NAT*.[3] A party of three astronomers from Copenhagen also managed to make it just in time at the rendezvous point only two hours before the rare event. With the advent of Thernøe, and the students K. Steenberg Olsen and Peter Naur, the clouds disappeared and the sky stayed clear for the duration of the event.[4] During their socializing, Bengt discussed Chandrasekhar's recent paper on stellar dynamics with Lindblad, who was "very impressed".[5]

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[2] B. Strömgren 1945c.
[3] Ibid.
[4] B. Strömgren 1946c.
[5] B. Strömgren → S. Chandrasekhar, September 30, 1945, UCA, SCP.

Back in Denmark, Bengt waited anxiously to learn how things were going in Williams Bay. In October, Chandrasekhar answered his letter, in which he had told his close friend about all the horrible events of the past five years in Copenhagen. Chandrasekhar replied:[6]

> I cannot tell you how very happy Lalitha and I were to have at last received your letter of September 30 [1945]. It was a relief to know that you, Sigrid and the children, are all well. That steadfastness of purpose and courage of conviction can overcome all the misery and misfortunes of the past years and gives one the hope that all may still be well in this sorry world. And, for one part, we have thought of you all constantly all the time and with how much gladness will we not look forward to meeting you all?

Chandrasekhar continued the letter with sad news about Milne. The Briton had had a most difficult time during the war in London, "he was V-bombed out of his home last year [1944] and his second wife died in August this year. As he writes, "growing anxieties and lack of any kind of help makes the mere task of living a most difficult one". I am deeply grieved with all this."[7]

Bengt had to make up for all the loss of his class teaching during the war. He gave eleven lectures a week on account of the abnormal war-conditions. The following semester was normalized and he was now unchained from his office of Dean at the faculty of natural sciences. His father had retired and Bengt was in charge. Like numerous other scientists, soon after the Allied triumph in Europe, Bengt complained about salaries and the general working conditions for Danish researchers. Ever since the liberation, the Danish academic world criticized conditions publicly. Already in December 1945, there was a protest meeting, where the academics demanded to have their salaries doubled. The point was made that research not serving any particular purpose, i.e. 'free research', should be given first priority. In the newspaper *Politiken,* it was argued that in America, the professor's salaries did not supersede the salaries of filling-station attendants!

[6] S. Chandrasekhar → B. Strömgren, October 29, 1945, UCA, SCP.
[7] Ibid., see Rebsdorf 2000, 96-97.

Moreover, if nothing was done soon, it was claimed by some rabid academic activists, choosing a rather morbid wording, “Denmark will be a cultural negro-state in ten years”.[8] Sadly for the scientists, not much came out of the efforts.

7.1 International Reunification in Copenhagen

As with many other international organizations, the war also amputated the international astronomical community. One event that turned out as being of tremendous importance was the 1946 IAU Conference held in Copenhagen. It was no General Assembly but rather a re-launch of the international enterprise after five years of unapproachableness. Therefore, perhaps this post-war event was not as important for scientific reasons as for social, collegial, and solidarity reasons. As a result, the arrangement was given special status and much publicity.

In January that year, Elis recounted the development of the IAU in the years after the Great War to the Royal Danish Academy:[9]

> This union, which has gradually been expanded to encompass the astronomy of most of the countries, has undertaken a tremendous amount of organizational work and has held 6 large congresses: In Rome 1922, Cambridge E. 1925, Leyden 1928, Cambridge Mass. 1932, Paris 1935, and Stockholm 1938. The work of the Union has almost completely rested during the recent world war, and the wish for getting it going again is very strong. For the present, it has been decided to arrange a restricted reunion of a smaller number of delegates from the different countries.

From the acting chairman of the Union, Astronomer Royal Sir Harold Spencer Jones at the Royal Observatory in Greenwich, Elis had received a message that this meeting should be held in Copenhagen if possible. The number of delegates

[8] ”Negro-state” probably referred to a state of underdevelopment; ”Dansk videnskab ønsker Lønningerne fordoblede”, *Politiken*, December 7, 1945, 1 and 10. See also “Videnskabsmændene proletariserede”, *Berlingske Tidende* (same date), on page 2.
[9] E. Strömgren (Stockholmsgade, Copenhagen) → Royal Danish Academy of Sciences and Letters, January 1946, RA, Protocol No. 1175.

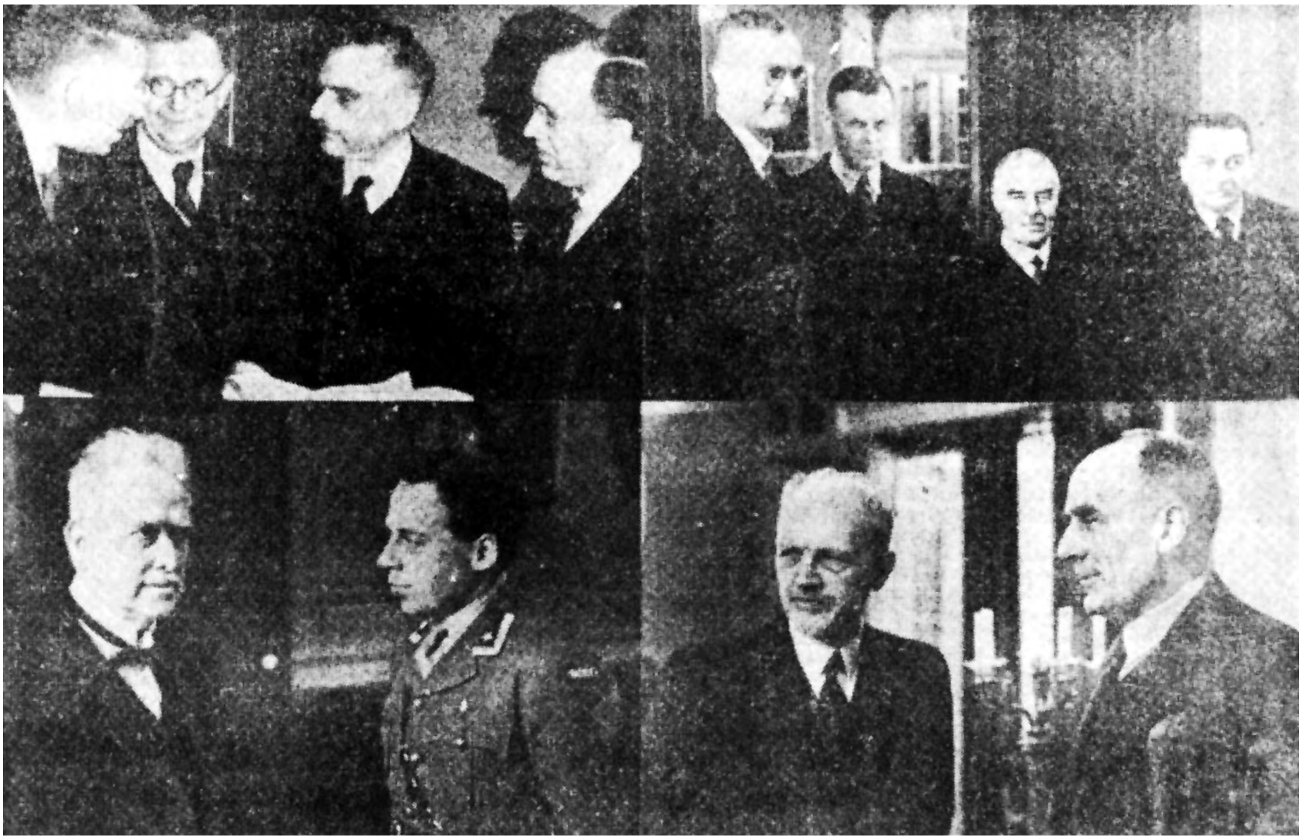

Figure 1: The 1946 IAU Conference in Copenhagen. The mosaic is from Blaauw 1994, 144, which is from Danish newspaper clippings found in the IAU Archives in Paris. From left to right, top to bottom: 1: **M. Minnaert**, W.H.M. Greaves, A. Danjon, and **B. Lindblad**. 2: G. Fayet, **B. Strömgren**, F.J.M. Stratton, and T. Banachiewicz. 3: **E. Strömgren** and G. Randers. 4: **N.E. Nørlund** and **H. Spencer Jones**. Spencer Jones was the new IAU president from 1944 to follow Eddington.

would be about twenty of thirty astronomers. Elis promptly answered Spencer Jones that in his opinion, the delegation meeting of the union would be most welcome in Copenhagen. His only concern was the practical realization as to where the meeting should be held. In the copy of Elis' letter to the Academy, there was a handwritten note stating, "The rooms of the society can be used for the arrangement."[10]

Already in November 1945, Elis informed his colleague Nørlund about Spencer Jones' idea and that the third IAU president (1935-1948), Jan Oort, would prefer the meeting to be scheduled to take place in January or February. He informed also the Foreign Ministry about the plan.[11] Eventually, the

[10] Ibid.
[11] E. Strömgren → N.E. Nørlund, November 4, 1945, RA (IAU box).

Figure 2: Ejnar Hertzsprung (1873-1967) is briefly biographed in the end of chapter 2.1.

conference was scheduled to be held on March 6-13 in the Academy of Sciences building. In February, Elis sent a list of the official participating delegates and he asked Nørlund to reserve two nights on March 8 and 10 as he had agreed with Bengt that they would host two dinner parties each, held ”with the Strömgrens and with us” (see the IAU program on page 364). The idea was that by this arrangement all the delegates got the opportunity of visiting the observatory and to visit Elis in the street Stockholmsgade; “unfortunately, the parties are without ladies”.[12] The national arranging committee turned out to consist of Nørlund, the two Strömgrens, and Hertzsprung. Right after the war, in July 1946, Hertzsprung moved from Leiden to the provincial city of Tølløse in the center of Zealand to live close to the site of Bengt’s projected observatory – he lived there until his death in 1967. It was his idea to work there as a catalyst for educating young promising astronomers, such as he had “generated” e.g. Kuiper and Strand in

[12] E. Strömgren → N.E. Nørlund, February 13, 1946 & February 18, 1946, RA.

Leiden.[13] From August 1946 to August 1949, Kjeld Gyldenkerne worked as Hertzsprung's personal assistant, as agreed between Hertzsprung, Bengt, and the Direction Board of the Carlsberg Foundation.[14]

The American Astronomical Society and the IAU asked Struve whether he would be willing to attend in Copenhagen along with Harlow Shapley. Struve wrote President Hutchins at the University of Chicago for permission to go on this post-war trip to Europe:[15]

> I consider this meeting of very great importance, and my going to Europe at this time could bring results of value to our Department. However, I do not regard this trip as at all a pleasant diversion, and I should certainly not go at my own expense.

Hutchins was glad to have Struve go to the conference and added "I hope that, contrary to your expectations, you will enjoy it."[16] Bengt invited the Struves to stay with him and his family in the director's residence, an offer gladly accepted by Struve; "it will be a very great pleasure to see you and your family and I hope that we can have some good talks about astronomical and non-astronomical matters."[17] Finally, Bengt and Struve would be able to meet again and for a second time, Struve did a good job in luring one of his favorite astrophysicists to the USA.

The American astronomer Joel Stebbins from the Washburn Observatory in Wisconsin, Harlow Shapley, and Struve traveled together to Europe and their trip was subsidized by the Rockefeller Foundation.[18] They arrived in Copenhagen via London – all the way by plane – on the day of the official opening reception in the Academy of Science's building in central Copenhagen. In the meeting

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13 E. Hertzsprung → B. Strömgren, November 6, 1949, EHA. In this letter, Hertzsprung asked Bengt for help to find another assistant, as the Carlsberg Foundation terminated its funding of Gyldenkerne's assistantship from August 1949. In this connection, Hertzsprung wrote about his original motivation for moving from Leiden to Tølløse.

14 E. Hertzsprung (Leiden) → B. Strömgren, July 13, 1946 & E. Hertzsprung (Tølløse) → B. Strömgren, November 6, 1949, EHA.

15 O. Struve → R.M. Hutchins, January 22, 1946, UCA, PP2.

16 R.M. Hutchins → O. Struve, February 6, 1946, UCA, PP2.

17 O. Struve → B. Strömgren, February 7, 1946, YOA.

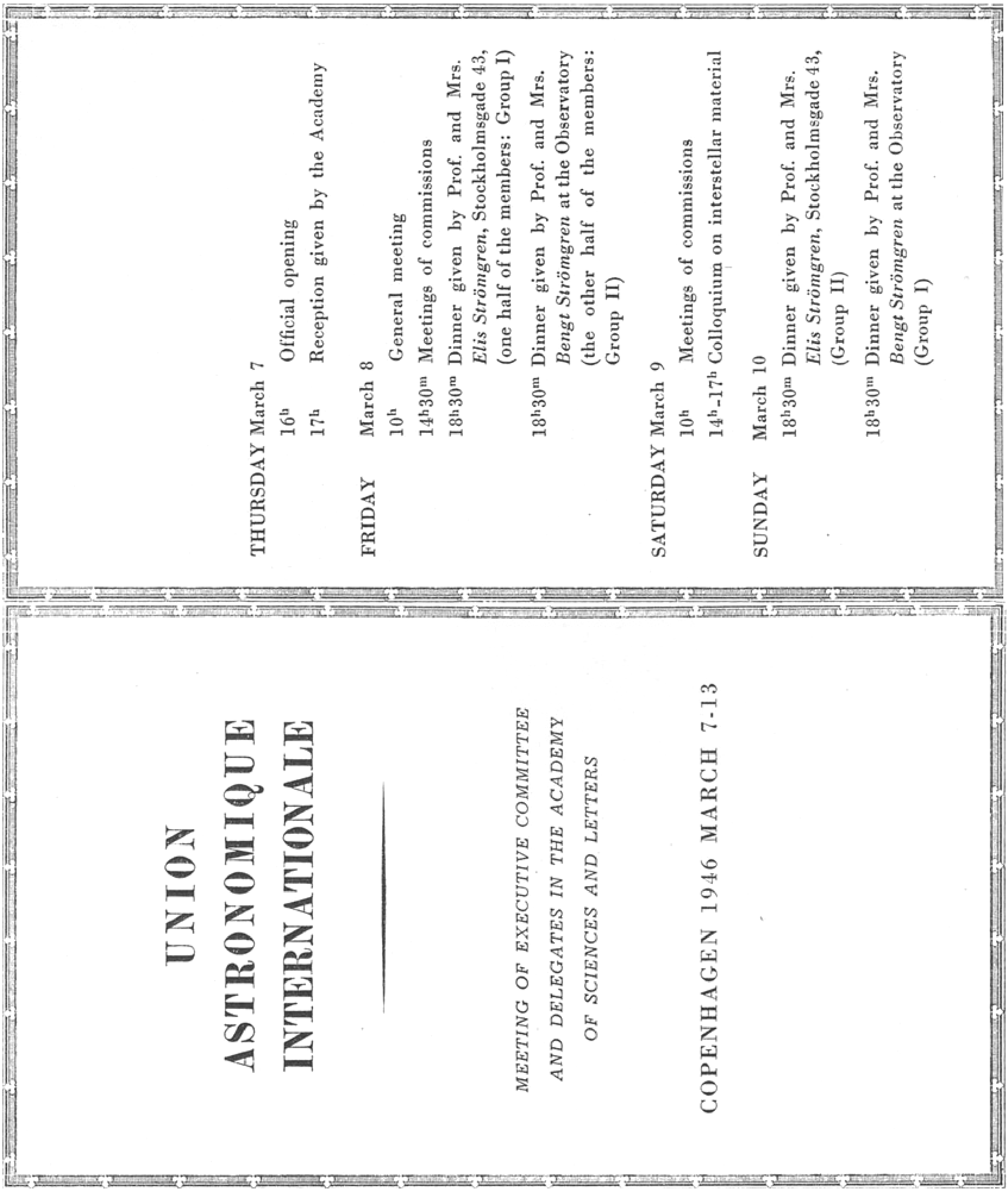
18 O. Struve → H.M. Miller (Rockefeller Foundation, New York), March 22, 1946, YOA.

program in figure 3, the twenty-four attending delegates from fourteen countries are listed. The day before the beginning of the official schedule, the executive committee held a meeting to confirm the reconstitution of the committee. As the USA and the USSR came out of the war as the two dominating world powers, the executive committee was considered better off having these ‘superpowers’ represented in the committee, which was broadened officially at a meeting on March 8.[19]

The meeting was finally commenced and two public lectures were given during the week in the name of international astronomy. Harlow Shapley spoke about “Galaxies” and Spencer Jones’s lecture was on “Halley and his Time”.[20] According to the astronomer and historian of science, Adriaan Blaauw, the meeting reports suggest that these were days of hard work. Besides astronomical topics, the conference led to the creation of new standing commissions with the aim of promoting international contacts between astronomers for the improvement of research and teaching, and not only for observing facilities. In particular, the commissions were founded to the benefit of making astronomical centers in countries with few financials means.[21] Ever since its creation, Germany had never managed to enter the IAU and according to Blaauw 1994, no names of German and Japanese astronomers were included in the revision of the commission memberships, pending the results of the investigation of individuals’ attitudes during the war.[22]

Pictures from the conference were released in the Danish press and it was highlighted that the American delegates traveled by airplane (figure 1).[23] At one of the dinner parties in the Observatory, Karin Strömgren remembered that her mother Sigrid wanted to serve “a real ham. This had been saved for a long time to better times, and it smelled awful. She cooked it for two days and nights, but

[19] Blaauw 1994, 143.
[20] E. Strömgren 1946a; Blaauw 1994, 142.
[21] Blaauw 1994, 147.
[22] Blaauw 1994, 149.
[23] ”Berømte Astronomer”, *Politiken*, March 8, 1946, 8; “Astronomerne mødes i København“, *Berlingske Tidende*, same date, page 3.



UNION
ASTRONOMIQUE
INTERNATIONALE

MEETING OF EXECUTIVE COMMITTEE AND DELEGATES IN THE ACADEMY OF SCIENCES AND LETTERS

COPENHAGEN 1946 MARCH 7-13

THURSDAY March 7
16^h Official opening
17^h Reception given by the Academy

FRIDAY March 8
10^h General meeting
14^h30^m Meetings of commissions
18^h30^m Dinner given by Prof. and Mrs. *Elis Strömgren*, Stockholmsgade 43, (one half of the members: Group I)
18^h30^m Dinner given by Prof. and Mrs. *Bengt Strömgren* at the Observatory (the other half of the members: Group II)

SATURDAY March 9
10^h Meetings of commissions
14^h-17^h Colloquium on interstellar material

SUNDAY March 10
18^h30^m Dinner given by Prof. and Mrs. *Elis Strömgren*, Stockholmsgade 43, (Group II)
18^h30^m Dinner given by Prof. and Mrs. *Bengt Strömgren* at the Observatory (Group I)

Figure 3: The Copenhagen IAU conference program (RA).

MONDAY	March 11	
	10^h	Meetings of commissions
	14^h30^m	General meeting
	20^h15^m	Public lecture by Prof. *Shapley* in the Aula of the University. Subject: Galaxies
TUESDAY	March 12	
	10^h	Final Session
WEDNESDAY	March 13	
	20^h15^m	Public lecture by Sir *Harold Spencer Jones* in the Aula of the University. Subject: Halley and his time.

The office of the General Secretary at the Academy will be open from 9^h30^m to 12^h and from 14^h to 17^h on all weekdays from March 6 to March 13 (assistant secretaries Mme P. O. Pedersen and Miss Mackeprang). Mail will be delivered at the office by Miss Mackeprang.

At lunch-time March 8, 9, 11 and 12 tables will be reserved for members of the meeting in the Palace Hotel („Paladshotellet").

On account of the business character of the meeting and the delegates not bringing much luggage no evening dress is required.

Members of the ***Executive Committee*** attending the meeting:

Spencer Jones, Danjon, (Stebbins), Oort

Delegates:

Belgium	*Delporte*, Hotel Cecil
Czechoslovakia	*Link*, Hotel Terminus
Denmark	*E. Strömgren*, Stockholmsgade 43
France	*d'Azambuja*, Hotel Astoria
	(*Danjon*, Hotel Astoria)
	Fayet, Hotel Terminus
Great Britain	*Greaves*, Hotel d'Angleterre
	(*Spencer Jones*, Hotel d'Angleterre)
	Stratton, Hotel d'Angleterre
Netherlands	*Minnaert*, Hotel Cecil
	(*Oort*, Stockholmsgade 43)
Norway	*Randers*, Hotel Cecil
Poland	*Banachiewicz*,
	Witkowski,
Spain	*Gullón y Senespleda*, Hotel d'Angleterre
Sweden	*Lindblad*, Hotel d'Angleterre
Switzerland	*Guyot*, Hotel Cecil
U. S. A.	*Shapley*, Hotel d'Angleterre
	(*Stebbins*, Hotel Terminus)
	Struve, Observatory Östervoldgade 3
USSR	*Mikhailov*, Hotel Astoria
	G. Shajn, Hotel Terminus
	Mrs. *G. Shajn*, Hotel Terminus
Vatican City State	*Junkes*, Stenosgade 4

Danish National Committee:

Hertzsprung, Nørlund, B. Strömgren, E. Strömgren but everybody was apparently happy to have real meat, so it was finally a success."[24] The conference was concluded with Spencer Jones' lecture on Edmund Halley and an agreement to hold the seventh General Assembly in Zürich. An old invitation from Switzerland during the war could now be realized. Interestingly, an invitation was also received on behalf of the USSR, the delegates of which had just been included in the IAU. As we will see in chapter 8.1, however, the proposed 1951 Leningrad Assembly was never brought to fruition.

As Struve had been in touch with Bengt soon after the war, he had learned of the Danish astrophysicist's brilliant work on stellar model atmospheres. As described in chapter six, Bengt's work using quantum mechanics and vast calculations had shown hydrogen to be abundant also in stellar atmospheres – and Struve had been impressed.[25] As a result, Struve's stay in Copenhagen occasioned him to invite Bengt to come to the USA as a visiting professor for a ten months period in 1947-1948. Bengt recalled his reunion with Struve: "So at that time we just took up the connection again. But a lot of time had been lost."[26] Following Struve's stay in Denmark, Bengt proposed the inclusion of four IAU astronomers in the Danish Academy of Science. Spencer Jones, Lindblad, Oort, and Struve were proposed as future members. After the IAU meeting, Struve was happy to learn that he had been elected as foreign member of the academy. Clearly, Bengt had shares in the decision.[27]

At that time, in Williams Bay, Chandrasekhar had been offered a research professor position with a salary of $10,000 at the Princeton University, over fifty percent more than he earned in Williams Bay. He was intended to succeed the soon retiring professor Russell. Struve was afraid of loosing his eminent theoretician and he and Hutchins were determined to keep him. Hutchins called Chandrasekhar in for a personal conference and the acting dean, Warren C. Johnson, recommended a raise to $8,500. As detailed by Osterbrock,

[24] KSCI.
[25] Osterbrock 1997, 275.
[26] HBI, 48.
[27] B. Strömgren → E. Hertzsprung, Feb. 6, 1946, EHA.

Chandrasekhar accepted Russell's offer in Princeton, as he found it honorable to succeed the great astrophysicist Russell. Struve asked if a distinguished service professorship would change his mind, which it would not. Hutchins then decided to match the Princeton salary. So, Struve had to go to the IAU conference in Denmark, while Chandrasekhar was still undecided. By October 1946, Chandrasekhar finally chose to stay after all and the post-war years became a rather turbulent time in Williams Bay.[28] As can be seen from appendix C, apart from a dozen of permanent employees, almost fifty new faces passed through the Astronomy and Astrophysics Department in the five 'golden years' years following the war.[29] One of these, of course, was Bengt Strömgren.

7.2 A Hamlet Observatory in Brorfelde

Before leaving to the USA, Bengt had his grand plans of the future observatory to nurse. He was anxious to learn more about the general economical developments in Denmark, as they would influence the choices of the Ministry of Finance. And of course, the Tycho Brahe jubilee awaited him with the prospect of gaining more funding for the projected observatory. As indicated in chapter six, his plan had been sent to the ministry and he awaited answers. Though, he was aware of the fact that it was a difficult time to expect definite answers. The over-all plan was that the observatory would considerably improve the working conditions for Danish astronomical research. This would be achieved by the erection of three observational instruments, each under its own dome: A meridian circle, the building of which was already supported with 350,000 Kroner by the Carlsberg Foundation; a 50 cm Schmidt telescope; and a lens-astrograph for photographic field recordings. In parallel with the building-up of a meridian circle building and the two domes, the instruments would be constructed, including some auxiliary instruments such as a clock construction, collimators, electronic equipment, and control consoles. Then, the required additional personnel would be one observer, two assistants, and an observatory keeper. The

[28] Osterbrock 1997, 275-279.
[29] Osterbrock 1997, 280.

Figure 4: Tycho Brahe standing on Hven, looking upwards. The statue made by the Swedish sculptor Ivar Johnsson was presented on August 25, 1946. The making of the statue was subsidized by the Swedish Wicanders' artfund (E. Strömgren 1946b, 106).

total costs of the observatory was estimated to be 1,948,000 Kroner including concrete foundations, instrument constructions, two official residences, and a water supply building.[30]

The New Empiricist's Birthday

The celebration of the quadricentennial of the birth of Tycho Brahe took place on his exact birth date, December 14. Born in 1546 in Scania, being part of Denmark at the time, Brahe eventually became the embodiment of the 'new empiricism' of astronomy, and as such, his celebration was a timely event for underlining the importance of the new Danish branch observatory.[31] Due to the cold Danish climate in December, an outdoor event on Hven was scheduled to take place already in August. A statue had been prepared already during the war, but its erection was delayed and thus it was presented on the grounds of

[30] B. Strömgren → University of Copenhagen trustee, June 9, 1949, NBA. The letter, kept by Niels Bohr, resumed the content of the 1945 plans.

[31] North 1994, 299 ff. 'Tycho Brahe Danus', the Dane Tycho Brahe, was also biographed in B. Strömgren 1947b.

Uraniborg, occasioned by the Swedish authorities. The crown prince and princess of Sweden attended in concert with an audience consisting of representatives from the Danish and Swedish cultural circles. Elis and his colleague Lundmark evaluated the significance of Brahe's twenty consequential years on Hven. On occasion of the festive event, Elis wrote a feature article to the newspaper *Nationaltidende*, in which he recounted the influential science of "the Son of Denmark" at Uraniborg and Stjerneborg on the Island of Hven.[32]

Not only Danes noticed the event. The Copenhagen natural sciences faculty made a list of distinguished astronomers to receive a degree of honorary doctor of philosophy. Among the elected scientists were Hutchins, Struve, Shapley, and Hertzsprung. The University of Copenhagen chose the event as an appropriate occasion for demonstrating the feeling of connection with science in a number of countries.[33] Struve wrote Hutchins about their invitations to go to Copenhagen for the official reception of the diplomas and for the celebration of Brahe. Hutchins was too busy to leave Chicago but Struve went by plane. Struve attended the event as did Hertzsprung, pleased to receive the honor.[34] In a confidential note to Chandrasekhar, Bengt asked him his opinion of having Hutchins on the list:[35]

> In my mind there is no doubt that he has contributed greatly to the advancement of Astronomy. Just compare the rise of Yerkes and McDonald with the decline of the Californian Observatories and Harvard (for heavens sake these uncautious [*sic*] remarks are only meant for you). If it had not been for Hutchins I am not sure that this would have been the situation.

The reason for not including Chandrasekhar's name in the list was explained by the university's wish to keep some political and regional equilibrium. Thus,

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[32] E. Strömgren 1946c.
[33] The complete list of honorary doctors counted Struve, Shapley, Hutchins, Spencer Jones, Stratton, Danjon, Oort, A.A. Mikhailov, G. Shajn, Lindblad, and Hertzsprung (B. Strömgren → S. Chandrasekhar, June 29, 1946, UCA, SCP).
[34] B. Strömgren → O. Struve, June 17, 1946, YOA; Struve → Hutchins, July 3, 1946, UCA, PP2; B. Strömgren → E. Hertzsprung, June 17, 1946, EHA.
[35] S. Chandrasekhar → B. Strömgren, June 29, 1946, UCA, SCP.

Bengt continued, "had it been a list of those that have contributed most to Astronomy, your name would have been on!" For instance, the director of the Simeis Observatory on the Crimea, Dr. G. Shajn was included perhaps more in the name of reunion with Russian science. Also the director of the Pulkova Observatory, A.A. Mikhailov was included on the list (see note 33).

Besides all the attention on Danish astronomy that was generated at the jubilee, what was ultimately important to Bengt was the fact that the Tycho Brahe jubilee released another Carlsberg grant. 200,000 Kroner were given to the observatory venture for complementing expenses to topical costs and for securing architectural sketches and the foundation of the main building on the premises of the site.[36] The following year, the University of Copenhagen purchased a plot close to the hamlet Brorfelde and after meticulous investigations of instrument producers; Bengt ordered the construction of a meridian circle at the Newcastle firm Grubb Parsons. The plan of 1947 was for the observatory to be operational and complete in 1956. Had the general economical situation in Denmark – as well as the right prioritizing in the Ministry of Finance – been to the favor of astronomy, this was perhaps a realistic plan. Nevertheless, this was not the case.

Additionally, as the costs of foreign equipment were tripled, the only opportune solution appeared to be the establishment of a local repair shop. The mechanic at the CO at Østervold, Poul Bechmann, was eventually appointed director of the Brorfelde repair shop in 1949. Before its build-up, a temporary shop had been arranged in the garden house behind the Copenhagen Observatory. Bechmann was educated at the UITF's shop in the 1920'es and turned out to be of considerable practical importance for the construction and set-up of many of Brorfelde's instruments. Taking care of all the arrangements was a great challenge to Bengt. But a serious event in the family entailed even more work for Bengt.

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[36] Gyldenkerne 1986, 97.

Emancipation

1947 was a weighty year for the young professor. Not only because he was invited formally to visit the University of Chicago as visiting professor for almost a year, but also because in April, he lost his father. He immediately informed Struve:[37]

> I have to tell you that my father died a few days ago, on April 5. My father had not been well the last few months. Two weeks ago he was taken to the hospital suffering from a gastric ulcer. There was hope that he would recover, if not completely, but a thrombus suddenly ended his life. There were few people my father liked more than you. He often spoke of you and was happy to see you while you were here in Copenhagen.

Struve promptly replied Bengt,[38]

> I know that it must have been a great shock to you that your father has died and we all send our condolences to you and to the members of your family. Your father had a long and distinguished career in astronomy. I believe he felt tired of life when I saw him last fall. Mrs. Struve and I will long remember our pleasant associations with him and with your mother. We enjoyed especially the sightseeing tour through the city on which he went with us.

Chandrasekhar was also informed immediately and he returned his words of sympathy for Bengt upon the death of his father. Bengt was preparing the trip and was thus in time for taking his leave of his father with a proper funeral before going to the States the following summer of 1947. Apart from Bengt, one of the colleagues closest to Elis was perhaps the observer Julie Vinter Hansen, who wrote his obituary in *NAT*. She chose not to praise his scientific work, his obvious earnings with the central bureau, or his exceptional and sometimes stubborn work for international astronomical cooperation. Instead, she

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[37] B. Strömgren → O. Struve, April 9, 1947, YOA.
[38] O. Struve → B. Strömgren, April 14, 1947, YOA.

accentuated his importance for the Danish Astronomical Society, for which he was chairman since 1920;[39]

> From that moment, he dedicated a great part of his working capacity and a lot of time to work for the interests of the society. […] He opened the doors of the university observatory for our members so that on specifically scheduled dates they had the opportunity of observing the sky through the observatory's refractor. But first and foremost, it was the "Nordisk Astronomisk Tidsskrift", which had the professor's interest […]. When we are still in receipt of government grants, it is solely owing to his dogged initiative.

In the same issue of the *NAT*, Lindblad saved some laudatory words for his colleague and countryman. Contrary to Vinter Hansen, Lindblad focused on the international aspect, in particular on Elis' scientific network:[40]

> His international attitude was even very personal and few may have had a resembling knowledge about his contemporary scientists within astronomy based on personal acquaintances. […] It is with great satisfaction that we can now think about the fact that he just made it to invite representatives of the International Astronomical Union for the meeting in Copenhagen.

Speculation about how Bengt felt about his somewhat sudden loss of his father should be made with caution. One likely result of the loss was perhaps the fact that it was also the loss of yet another Danish bond. On the other hand, his influential mother was thriving, and according to the children of Bengt, even more thriving after than before the death of her husband![41] It is tempting, yet undocumented, to suggest that Bengt's loss instigated feelings of emancipation. One immediate consequence of Elis' death was the lot of work left to be taken care of. Clearly, he had had many irons in the fire and Bengt was the one to

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[39] Hansen 1947a. Vinter Hansen also wrote an obituary on the scientific work of Elis in *The Observatory*, Hansen 1947b.
[40] Lindblad 1947.
[41] KSCI, OSI, & KNSI.

organize the spreading of the various duties and tasks. As for teaching, Bengt had some very busy preparatory months, "giving both this and the next term's courses, so that I have had up to twelve lectures a week, and much had to be attended to after the death of my father".[42]

Now, as explained in the preface and introduction, not only did Bengt say goodbye to Elis Strömgren, but we will also bid farewell to the father and thus to the degree of biographical detail that has been running through the narrative so far. I have chosen the event as an appropriate narrative milestone, from which the dissertation will play down the previous chronological, or Plutarchian, structure and biographical detail. This is done to the benefit of a more thematic, if Suetonian, approach to the most important occurrences in the history of Bengt Strömgren and post-war astronomy. Clearly, the immediate objective of this choice is a limitation of this scientific biography. Having said this, let us digress to Bengt Strömgren's plans of going on leave from Copenhagen to visit his old American Observatory.

The Golden Years

Bengt was looking forward to working at the Yerkes Observatory again, "not least to the prospect of the long talks with [Chandrasekhar]"[43] After Struve's formal invitation, Bengt discussed the problem with the President, J.S. Nørregaard, "and a few others at the university. They all promised their cooperation, and could see no difficulties."[44] Bengt's plan was to travel by boat from Gothenburg on June 20, arrive in New York ten days later and immediately take the train to Chicago. Then he would get a room with the Van Biesbroecks and start research in Williams Bay on the first of August. Sigrid and Ole would not join him until October, while Karin and Nina stayed in Copenhagen for school and they would be taken care of by their grand mother Hedvig.

The early post-war period comprised the 'golden years' of research activities, as named by Osterbrock, with numerous exchanges of scientists to and

[42] B. Strömgren → S. Chandrasekhar, May 27, 1947, UCA, SCP.
[43] Ibid.
[44] B. Strömgren → O. Struve, February 26, 1947, YOA.

from the Astronomy and Astrophysics Department in Chicago, in Williams Bay, an in Texas. In the period 1947-1949, Kuiper was appointed director of the Yerkes Observatory, while Struve became the chairman of the whole department. In September 1947, a few months after Bengt's arrival, the Yerkes Observatory commemorated its fiftieth anniversary. In recognition of this event, the meeting of the annual American Astronomical Society was held at the observatory. During the ten months of Bengt's stay, a number of important changes were effectuated at the observatory. Kaj A. Strand resigned from his position as research associate to the benefit of a directorship of the Dearborn Observatory. He kept supervising and taking part in the astrometric program during weekly visits. Mogens Rudkjøbing was appointed as post doc fellow for eight months on the Chicago campus. Bengt helped him getting financial funding, as he was "very anxious to go."[45] Morgan continued managing group work on stellar classification with the purpose of making the Atlas of Stellar Spectra. The McDonald observatory had been operational for ten years now and Struve worked intensively on observational astrophysics together with William A. Hiltner who had been appointed during the war.[46]

Bengt was willing to give a summer course before the beginning of the autumn quarter, which would be on "the design of modern astronomical advances in astrophysics". Chandrasekhar had been put in charge of the graduate teaching program and suggested that Bengt would lecture on the theory of stellar atmospheres in the autumn quarter, which he did. During the same quarter, Strand would give classes in astrometry.[47]

Bengt's plans for his stay were to observe with the new 20-inch Schmidt camera in Texas, as well as the 82-inch reflector. Despite Bengt's hope that the Schmidt telescope would be ready when he arrived, the mirror of the Schmidt camera was accidentally damaged in 1946 when it was tested in the telescope.[48]

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[45] B. Strömgren → O. Struve, February 26, 1947, YOA.
[46] Non-catalogued annual report, 1947-1948, of the Yerkes and McDonald observatories written by the Yerkes director, Gerard P. Kuiper (14 pages), YOA.
[47] Appendix D, 42.
[48] O. Struve → B. Strömgren, February 26, 1947 & B. Strömgren → O. Struve, same date, YOA.

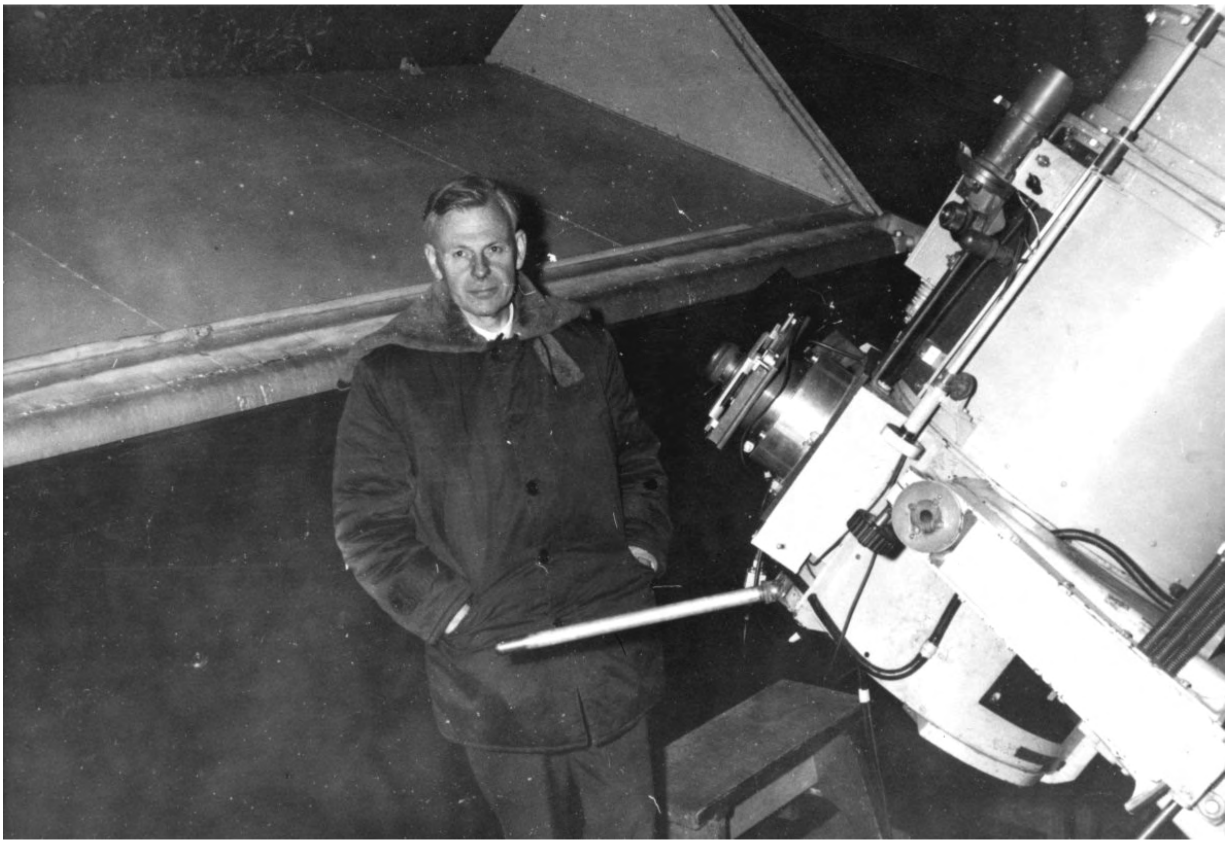

Figure 5: Bengt at the McDonald Observatory's twenty-inch telescope, probably in 1948 (Courtesy of Nina Strömgren Allen).

He would use the American telescopes in his continued investigations of interstellar concentrations of ionized matter. He also got himself involved in the development of new photoelectric equipment at the two observatories. Together with the McDonald Observatory director, Hiltner, he surveyed the galactic distribution of interstellar hydrogen. In collaboration with professor of spectroscopy, Gerhard Herzberg and assistant professor Thornton L. Page, they used a refrigerated photoelectric photometer on the 32-inch telescope. Bengt made an investigation of the density distribution and chemical composition of the interstellar gas.

He had "a marvellous and profitable time" at McDonald and was "quite happy with the measures together with Hiltner of hydrogen emission regions. We have measured the emission (with the aid of the interference filters and photomultiplier) at about 200 points".[49] Bengt sent the manuscript of a

[49] B. Strömgren → S. Chandrasekhar, January 21, 1948, UCA, SCP.

forthcoming paper for Chandrasekhar to read, who congratulated Bengt on his "beautiful work" on the mapping of hydrogen emission regions, "It is marvellous to see you doing for interstellar physics what you have already done for stellar atmospheres".[50]

Bengt calculated curves of the growth of interstellar absorption lines. This was used to determine the density of various elements and in a 1948 paper he published his findings. The paper turned out to become one of Bengt's most cited papers.[51] In the paper, Bengt considered small, relatively dense clouds of neutral hydrogen, in which the ionized radiation from the stars only penetrate the outer layers. On the basis of observational data obtained in Texas, he found e.g. the hydrogen density to be around ten atoms per cubic centimeter. He showed that the strong deviation from thermodynamic equilibrium, which takes place in interstellar space, led to the result that the fraction of the number of neutral and ionized atoms of the same element could differ by factors up to at magnitude of 1,000.[52] This factor would be 1 if one did not take the ionization of the stellar radiation into account. By this weighty finding, Bengt once again added a contribution to the solution of one the problems that interested him the most, namely that of the relative abundance of the elements in the universe.

A consequential bi-product of a particular investigation using photoelectric photometry contributed to the high citation index of the paper. Bengt found that an optical narrow-band filter at the Balmer Hβ-line gave a sensitive index by comparing the intensity of the radiation through the filter with the radiation from a neighboring element. However complicated, this became the jumpstart of photoelectric narrowband photometry, which, instead of broad bands, deployed narrow spectral regions (100-200 Ångstrøm).[53]

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[50] S. Chandrasekhar → B. Strömgren, February 5, 1948, UCA, SCP.
[51] B. Strömgren 1948a; on the citation index, see appendix E.
[52] B. Strömgren 1948a, 242; Rudkjøbing & Reiz 1988, 150-151.
[53] Thykier 1990, 283. See also B. Strömgren 1983, 8. The development is treated further in chapter 8.2.

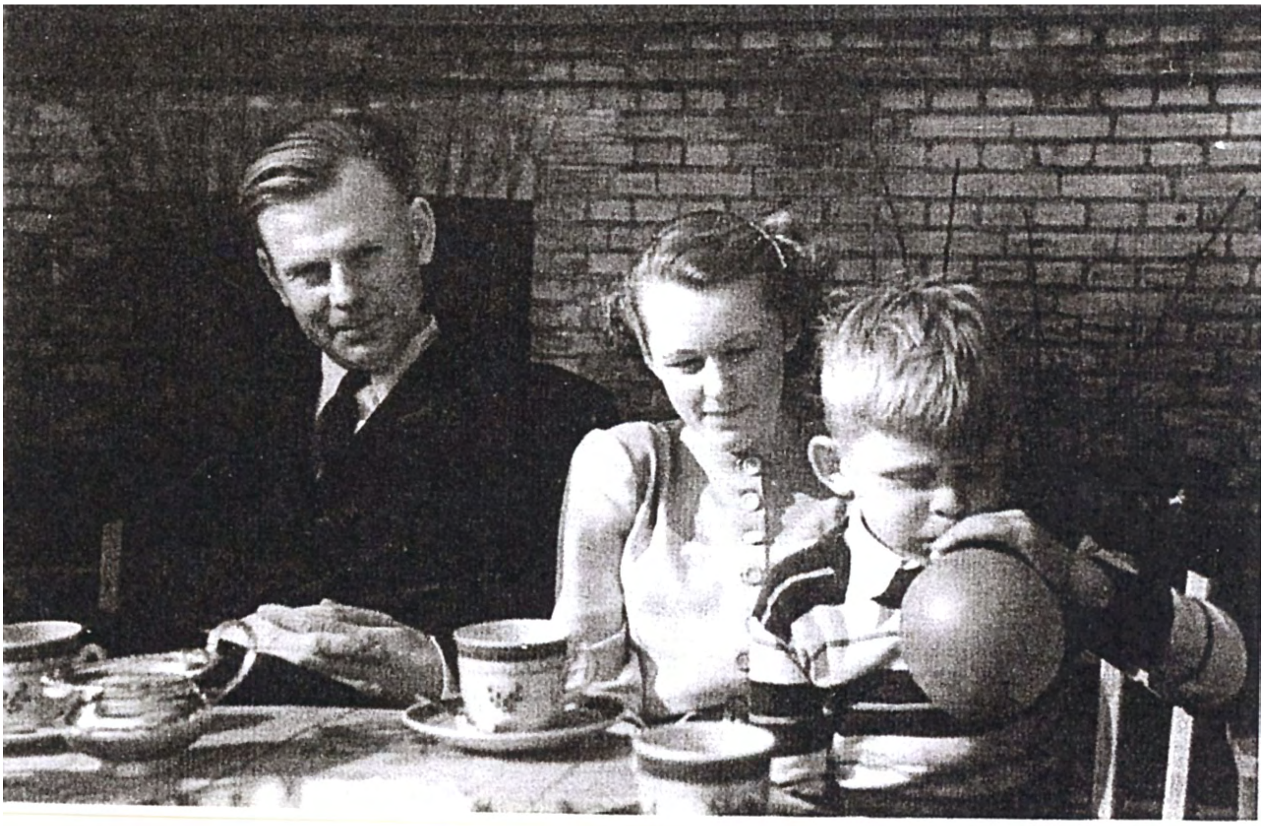

Figure 6: Bengt, Karin, and Ole Strömgren in front of the Copenhagen Observatory, probably 1949 (Courtesy of Nina Strömgren Allen).

Years of Frustration

The year 1948 turned out to be a year of many honorary distinctions, a lot of administrative work, and frustration regarding the slow marching of the plans of the new observatory. After Bengt's return from his profitable research visit at his favorite observatories, he had some scientifically fruitless months. He cordially thanked Chandrasekhar and his wife for all the many things that occurred during his stay:[54]

> I am now reliving much of it, and the happy hours and days I spent with you and Lalitha come back to me, clearly as if it were only yesterday. I treasure the memory of them as belonging to the best of my life. […]

[54] B. Strömgren → S .Chandrasekhar, August 2, 1948, UCA, SCP.

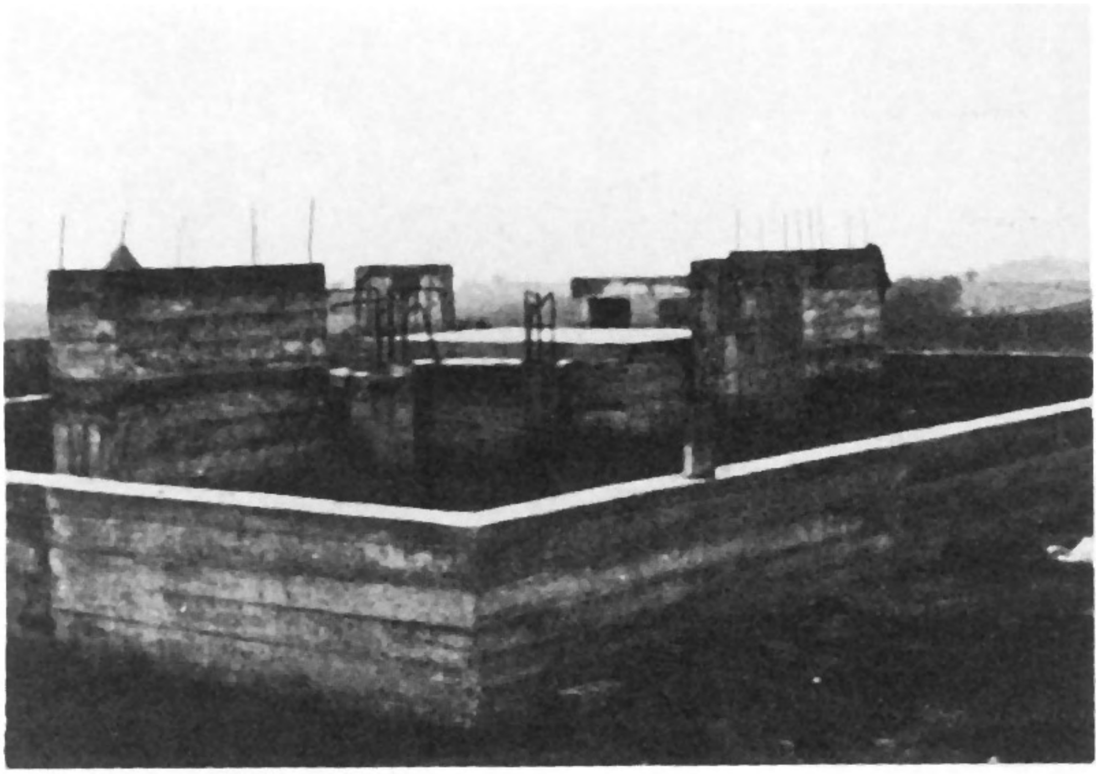

Figure 7: Foundations of the meridian circle at the Brorfelde Observatory (Gyldenkerne 1986, 100).

> I have had to pay for the time I could spend in U.S.A. by taking care of innumerably details and routine matters connected with the new observatory, the instruction, and getting things going again, generally. Fortunately, this period seems to be over now. I expect the meeting in Zürich will be interesting.

The last comment referred to the seventh IAU general assembly to be held in Zürich on August 11-18, in 1948.

Being prepared in Copenhagen, the Zürich meeting constituted the restoration of international undertakings interrupted by the war. A dominating theme naturally was the reference to this lengthy interruption of assemblies since 1938 in Stockholm. 279 members and guests from 28 countries attended the meeting.[55] Earlier intentions of making the IAU more scientifically inclined led to the birth of the IAU Symposia and the appointment of a general secretary to succeed the third one, Jan Oort. Bengt was elected as Oort's successor as general

[55] Blaauw 1994, 154.

secretary of the IAU for a six-year period. The same year, he was elected member of the Executive Committee, International Council of Scientific Unions, member of the Royal Astronomical Society, and member of the Danish Academy for the Technical Sciences (ATV).[56] Bengt's election as General Secretary of the IAU happened in an "unusually difficult time resulting from the Second War disorganization,"[57] as will become apparent in chapter eight. The organization of the local national project, on the contrary, was led firmly by Bengt, although it was delayed time and again.

The foundations of the meridian circle building were scheduled to be completed as soon as possible in 1949 or 1950, as they supposedly needed a year to cure properly. By 1950, the concrete foundations were poured of the main building and the meridian circle building. But there was still lack of funding. Bengt was getting tired of absent political decisions and of all the waiting for Danish observational astronomy to blossom.

In 1948, the ministry of education requested the trustee of the University of Copenhagen for detailed economical plans for the new observatory. The plans were slightly changed compared with the 1945 plans. In the 1945 plan, a telescope of the Cassegrain type had been included in the list of projected instruments. In 1949, Bengt sent the new plan to the trustee, which instead of the Cassegrain weighted the importance of the repair shop more heavily.[58] The reason was the aforementioned triple costs of foreign instruments. Instruments were estimated by Bengt to be ca. 615,000 Kroner, contributing to a total expense estimate of the observatory of 1,948,000 Kroner.[59] Bengt displayed his timeline of the project to be such that the Schmidt telescope could be erected in its dome in 1951. Then, the same year, the building of the astrograph should be commenced and its dome built up in 1952. In parallel with the build-up of the Schmidt telescope, a new assistantship (amanuensis) should be set up in concert with the next official residence. With the third instrument completed, the

[56] Rudkjøbing & Reiz 1988, 150. ATV abbreviates Akademiet for de Tekniske Videnskaber.
[57] Mayall, 1959, 82.; Mayall's words also appear in the somewhat epigone obituary of Kulsrud 1987.
[58] B. Strömgren → The trustee of the Copenhagen University, June 9, 1949, NBA (first letter).
[59] B. Strömgren → The trustee of the Copenhagen University, June 9, 1949, NBA (second letter).

astrograph was scheduled to be operational in 1953, as was the final completion of the whole observatory. As it turned out, these plans were impossible to reach, not because they were unrealistic but due to disagreements and lack of funding. Time and again, Bengt made new applications for funding to the Ministry of Education strongly supported by the Copenhagen University. Only in 1949, three almost identical applications were sent within two months due to slight changes in the plans.[60]

A Prospective Directorship

In mid-December 1949, Struve sent his formal resignation from his position as Chairman of the department to the benefit of a professorship of astrophysics on the Berkeley campus, University of California, which was meant to be effective by July 1, 1950.[61] Hutchins, the university chancellor from 1945-1951, received the resignation from Struve, which was motivated on grounds of administration, colleague-disagreements and general financial conditions. Due to administration changes within the university, Struve found his own administrative position as chairman weakened and owing to "the presence of the enduring financial difficulties, the outlook for the future at Yerkes is bleak".[62]

In the late 1940'es, Struve was awarded numerous prestigious medals and honors. The previous year, e.g., Struve was awarded the Catherine Bruce Wolfe Medal, the highest honor of the Astronomical Society of the Pacific and in October 1949, he went to London to give his George Darwin lecture on the occasion of his reception of the Herschel Medal of the Royal Astronomical Society. He was now discontent with the situation and felt forced to take the drastic step of leaving the Yerkes Observatory "in order to create the conditions necessary for my research and also to free myself of the responsibility for a trend within our department which I cannot accept but with which I am unable to cope under the present arrangement."[63] As analyzed in Osterbrock 1997, the matter

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[60] Copies of the application are located in the NBA.
[61] Struve would then replace Sturla Einarsson, who retired in June 30, 1950.
[62] O. Struve → R.M. Hutchins, December 15, 1949, UCA, PP2.
[63] Ibid.

boiled down to the fact that he disagreed with some of his close colleagues as to what to do with the telescopes, scientific visitors at the two observatories, and research funds. In a draft eight-page memorandum, Struve "reminded himself of all the details behind the bland generalities of his letter to Hutchins". Allegedly, it consisted of mostly of a list of complaints against what he called "the completely obstructionist attitude of Kuiper and, to a considerable extent, Chandrasekhar, Hiltner, and even Morgan".[64] Moreover, Struve wrote down terms under which he would stay at Yerkes, which he probably knew were not reachable, but which he would get at Berkeley. They comprised freedom from teaching and administrative duties but also the acquisition in Yerkes of a director satisfactory to himself, namely Bengt Strömgren.[65] Soon, Bengt was offered once again a tempting position in the USA.

He continued his letter by stating that four or five principal members of his department were then at their peak of their scientific careers with a very impressive output and he bitingly – and somewhat edifyingly – continued:[66]

> Yet, I can see clearly that we are close to the brink of a dangerous precipice which my associations fail to see because of fog created by inflated egos and inflamed ambitions. Somehow, on the road to glory, our organization has lost those homely but important virtues which we associate with the names of the most respected scientists of former times: service to humanity, modesty, and generosity. Perhaps this very letter is sufficient proof that I am not exaggerating the peril. I do not have the means to deal with the situation, and yet I cannot go along the road to ruin; hence I must take this step.

It could be argued that perhaps Struve himself fell for these accusations of lack of virtues. In ending the uncompromising letter, Struve expressed his strong admiration and gratitude for Hutchins as president and chancellor. Struve did not

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[64] Osterbrock 1997, 299.
[65] Ibid.
[66] O. Struve → R.M. Hutchins, December 15, 1949, UCA, PP2.

notify any of his faculty members, his colleagues elsewhere or anyone in California of his resignation.

In late 1949, Bengt was in the USA on a short visit. He should lecture as a visiting professor at Caltech for one quarter and when passing through Chicago, Hutchins called Struve to the city to meet Bengt. Already by that time, Struve had aired the idea of leaving the Yerkes Observatory as its chairman. If indeed Struve chose to leave Yerkes, Bengt promised to at least consider accepting the directorship of the observatories, although he still had his own large project under way. Perhaps Struve’s ego had also been inflated, as he stated the need of $2,000 per year in traveling expenses and a house permanently reserved for his own use at the McDonald Observatory, if he was to retain some connection with the University of Chicago. This wish could not be met by the chancellor. With Struve’s leave, Chandrasekhar would be acting chairman until a new directorship was in place.[67]

When Struve finally went to Berkeley in the summer of 1950, he experienced an “oppressive atmosphere […] resulting from the loyalty oaths required there of the faculty members” and Chandrasekhar heard about this concern during a meeting at the Quadrangle Club. He feared the Struve might want to go back to his old position, and he expressed his latest antagonism against Struve:[68]

> I hope that Mr. Struve is not regretting his leaving this University to the extent that he wants to come back; for, the Department would most certainly not wish to be associated in any way with such an invitation. Indeed, his return to this University in any capacity will be considered by the Department as nothing short of a calamity. Mr. Struve, by his lack of his manner during the last two years (and particularly during the last months), succeeded in loosing the regard of all his colleagues and it was positively a relief to see him go. […]
>
> I hope you will forgive me for this frank statement: but it is one in which all the members of the Department will unanimously agree.

[67] This paragraph mainly uses Osterbrock 1997, 299-301 as source of information.
[68] S. Chandrasekhar → R.H. Hutchins, October 1950, UCA, PP2.

Figure 8: Sigrid, with bleached hair, and Bengt, undated, probably from the late 1940'es (courtesy of Nina Strömgren Allen).

Hutchins briefly reassured the anxious acting chairman: "Thank you for your kind letter. Have no fear."[69]

On Bengt's research visit to Caltech, as well as Princeton University, he also visited Struve in Texas in early 1950. During the visit, he spent two days with the department chairman, and according to Struve, Bengt said that he "goes on the assumption that he will accept the Chicago offer", but that there were a number of points which he would want to discuss with Hutchins and Dean Bartky concerning a refurbishing of the old director's residence in Williams Bay,

[69] R.M. Hutchins → S. Chandrasekhar, October 9, 1950, UCA, PP2.

the finishing of a director's residence at McDonald, and concerning some questions of retirement allowances.[70]

Research versus Financial Compensation

Back in Denmark, Bengt had waited since late 1945 for a final decision as to the establishment of the long awaited branch observatory in Brorfelde, but in vain. The architect and the building control department, represented by the inspector, professor Kaj Gottlob, disagreed about some details of the buildings and their differences of opinion had delayed the whole project. While Bengt was in the States in early 1950, during a conversation with the chemist Niels Bjerrum, Sigrid indicated that Bengt had written her about the offer of a tempting position in the USA. Bjerrum even learned through Sigrid that Bengt was inclined to accept the offer. Just before Easter, Bjerrum immediately informed the chairman of the Carlsberg Foundation, Johannes Pedersen, about the offer from the States due to his long wait for the observatory to materialize.[71] Pedersen wrote Bengt for an answer as to his choice in the burning issue.

Bengt answered the letters from the chairman that he was very tempted to accept the position and as a result it was decided to offer Bengt financial compensation of 10-12,000 Kroner per year on the condition that he stayed in his position in Denmark.[72] Bengt discussed the issue with Niels Bohr in May and thanked him for the conversation, "it meant extremely much to me".[73] The university president, H.M. Hansen, gave Bengt a few months to consider the burning issue seriously, before making any decision. Then, Bengt went to Princeton on a monthly research visit. Only six days after his meeting with Bohr, during a lecture tour to Washington, he received a telegram from Denmark that put the forty-year-old professor on the front page of the Danish newspapers. "You will receive a cheque of 50,000 Kroner". Bengt Strömgren had been awarded the fine Danish Augustinus Prize and he was the first recipient of the

[70] O. Struve → R.M.H. Hutchins, February 18, 1950, UCA, PP2.
[71] April 19, 1950, CBDP.
[72] May 17, 1950, CBDP.
[73] B. Strömgren → N. Bohr, May 5, 1950, NBA.

POLITIKEN

66. aargang nr. 220 København, torsdag den 11. maj 1950

OBSERVATORIUM

Her skal observatoriet ligge: Inden solen gik ned i aftes, bad vi professor Bengt Strömgrens medarbejdere, observator frk. Julie M. Vinter Hansen og dr. Mogens Rudkøbing køre med „Politiken"s fotograf til Tølløse og udpege stedet, hvor det nye observatorium skal opføres. Her staar de og ser frem mod bakkedraget, hvor vi paa billedet har indtegnet observatoriet og funktionærbygningerne.

Augustinus-prisen til Bengt Strömgren

Den store danske astronom, der for tiden gæster amerikanske universiteter, fik telefon-meddelelse fra „Politiken" om æres-prisen paa de 50,000 kr.

Professor Strömgren fortæller om stjerners opstaaen og om store planer med et nyt observatorium i Danmark

„Vort maal fred og ikke krig"

Acheson fremhæver, at Vesteuropas problemer ogsaa er USAs uden snævre nationale formaal

Fælles indsats og ansvar maa bringe Tyskland tilbage til nationernes fællesskab

Figure 9:"The Augustinus Prize goes to Bengt Strömgren". To the left, Mogens Rudkjøbing and Julie M. Vinter Hansen gaze at the fields of the prospected observatory. (*Politiken*, May 11, 1950, front page).

national distinction of honor. The prize was instituted with a principal of half a million Kroner by the Chr. Augustinus' Tobacco Factories on occasion of its 200 years anniversary. Bengt was "completely overwhelmed" when he received the telegram.[74] As to the use of the anniversary grant money, he stated that "naturally, I want to spend them to the benefit of my science" and he already had a few ideas. Bengt intended to make the money help his theoretical investigations of the chemical constitution of stellar atmospheres as well as the construction of the special prismatic telescope, the lens astrograph scheduled to be erected in

[74] "De faar en Check paa 50,000 Kr.", *Berlingske Tidende*, May 11, 1950, front page.

Brorfelde. Such an astrograph of 200,000 Kroner would be able to record large areas of the sky in very high resolution.[75]

Finally, he wanted to spend the money for the work of extending the cooperation between Danish and American astronomy. Bengt's theoretical investigations were explained in popular terms in *Politiken*. In the telephone interview article, the self-effacing personal character of the observatory director was displayed.[76] On the front of *Berlingske Tidende*, another column was reserved for the fear of loosing the internationally renowned astronomer. President H.M. Hansen austerely stated his concern.[77]

> When it gives me the greatest joy to learn that professor Bengt Strömgren has been elected as the first recipient of the Augustinus Prize, it is not only because he is one of the best names of Danish science; it is also owing to my hope that the attention aroused by the event will help furthering a final grant of the first stage of the build-up of the Tølløse Observatory.

Hansen continued in strong phrases:

> If we will wait any longer, I seriously fear that the USA will conquer professor Strömgren – right now great efforts are made and it would be an irreparable loss to Danish science and to the University of Copenhagen.

It all depended on the further development of the projected observatory.

In June, the chairman met with Bengt and reassured him that the Carlsberg Foundation would take all possible means to make him stay. Not surprisingly, though, to Bengt, financial matters were not given first priority. What mattered to him were his research conditions. The Chairman spoke to the permanent secretary Paludan-Müller, who informed him that the money for the foundation of the meridian circle and the main building were secured.[78] Only half a year

[75] For a technical description of the astrograph, see Gyldenkerne 1986, 110-111.
[76] "Augustinus-prisen til Bengt Strömgren", *Berlingske Tidende*, May 11, 1950, front page.
[77] "Universitetet frygter at miste Strömgren", *Berlingske Tidende*, May 11, 1950, front page.
[78] June 28, 1950, CBDP.

earlier, Bengt had been prepared to stay in Denmark, but now, in the summer of 1950, he was more convinced that the necessary research tasks he had to manage could only be done in the USA. He had not made up his mind yet, though. The university president Hansen, called for a meeting with Bengt, Paludan-Müller, and Pedersen, the chairman, but no meeting had been held yet. Bengt suggested the possibility that each year, for some years, he could go to Denmark for three months to take care of the Brorfelde Observatory. The Carlsberg Foundation was not interested in this arrangement. If any additional salary was to be paid to Bengt, he should stay in Denmark completely.

Science Goes On

Finally, on June 26, the faculty learned about the outcome of Bengt's considerations. He had decided to apply for a nine months leave in the year 1951. The university had lost him to the States. Even though Bengt only publicly stated his decision of leaving by June, already in April he was settled, or at least this is what he wrote to his Indian friend:[79]

> I feel happy and relieved that I have made the final decision regarding the Yerkes appointment. There remains of course the task of discussing the situation with my friends and colleagues at the Copenhagen University. Although I have kept silent, news has spread through Berkeley and Miss Vinter Hansen about the developments. Already I have a letter from Nørlund, telling me that my leaving Copenhagen University would mean "the greatest possible disaster to the University".

So, when Bengt received the letter from the Carlsberg chairman, he had already made up his mind. In the four page resignation letter to the faculty, Bengt qualified his motivations, in which he explained how much he still felt for the Brorfelde Observatory and, if possible, that he would like to be able to continue his work in this respect. Nevertheless, his own research conditions were far better

[79] B. Strömgren → S. Chandrasekhar, April 14, 1950, UCA, SCP.

in Williams Bay. Research in the nature of distant stars were given first priority, then, in second place came the practice of institution building. He sketched a plan, in which he would be freed from his administrative director's obligations of the management of the time service, the almanac, and teaching. If he could keep his office on Østervold for three months every year, he still considered it possible for him to undertake not only the direction of the Brorfelde project, but also the management of scientific work on the observatory.[80] The proposed plan would demand a new acting director of the Copenhagen Observatory and perhaps another assistant to take care of the practical completeness of the branch observatory. This assistant turned out to be Kjeld Gyldenkerne who was appointed only in late 1951.

Bengt concluded that the costs of such an arrangement would not exceed the professor's salary, as he would only require travel costs and two households per year. He found it likely that within three years, the Brorfelde Observatory would be complete and then Danish astronomy would become independent of his management.

In an October farewell interview, Bengt explained the motivations for his leave. H.M. Hansen's work for breaking the silence about the Brorfelde-situation half a year ago was saluted in the article. Time and again, Hansen had protested about the fatal consequences for Danish science if the project was further delayed, but now it was too late. In the interview, Bengt granted that it had been extremely difficult for him to reach the decision.[81]

> I would much rather stay home. But I have received the offer from the University of Chicago for the sake of my scientific work. One ought to remember that science goes on elsewhere and particularly astronomy is developing rapidly. Had we only been able to implement the work prepared long ago? Then, we could undertake special and important fields of observational astronomy as our own, but instead, as it has turned out, this work has been taken up elsewhere.

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[80] B. Strömgren → Natural sciences faculty, June 26, 1950, NBA.
[81] "Bengt Strömgren direktør for to af USA's største observatorier", *Politiken*, October 15, 1950, 1, 24.

Figure 10: Bengt in his home, October 1950, before leaving to the States ("Bengt Strömgren direktør for to af USAs største observatorier", *Politiken*, October 15, 1950, 1).

Understandably, Bengt was disappointed. It had been twelve years since his initial plans were unearthed and ten years since his first formal correspondence with the authorities. Four years after the plans were endorsed in principle, no actual build-up had been initiated. The foundations were ready but with the meridian circle near its completion, a roof would seem appropriate and no such building had been erected yet.[82]

> I do not wish to hide the fact that the slow progress of the observatory affair has been a great disappointment to me. My words should not be interpreted as a critique of the grant-awarding authorities. Caution and reluctance is understandable regarding demands from the university these days. On the other hand, I am convinced that the saved amounts do not reasonably relate to the occasioned damage on scientific research in Denmark.

[82] Ibid., 24.

Besides disappointments, Bengt looked into the future and explained the positive prospects for his leave: “Now, I will be able to elaborate the cooperation between Danish and American astronomy”.[83] Bengt’s policy in the question of this cooperation is seen clearly in his April letter to Chandrasekhar, in which he detailed his understanding of the collaborative practice:[84]

> What I hope is to avoid any bitterness in Copenhagen, and to turn their willingness to help if I stay into willingness to help co-operation between the Yerkes and Copenhagen Observatories. Co-operation on “Yerkes terms”, however, to further well-defined research projects.

More specifically, he believed that the Yerkes and McDonald research projects might profit from “Copenhagen routine assistance, and undoubtedly Copenhagen wound gradually be strengthened by the participation in such work”.[85]

Bengt signed his contract with the Chicago Department in August 1950 and in January 1951, he would go back to Williams Bay to live in the old, refurbished director’s residence formerly occupied by Struve. He anticipated returning to a prospective cooperation with his close friend Chandrasekhar, then the acting chairman, and with the staff of close to forty scientists.

Chandrasekhar was not exclusively fond of his temporary administrative duties. As he wrote Bengt:[86]

> I have had your letter of April 14 for over a month now hoping to be able to find the leisure to reply adequately. But there always seems to be an inexhaustible source of trivialities which emerge and are insistent whenever one thinks one is free! I am sure you are entirely familiar with how insistent some of these most unimportant things can be.

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83 Ibid., 1.
84 B. Strömgren → S. Chandrasekhar, April 14, 1950, UCA, SCP.
85 Ibid., the CO had two first-class measuring machines, an astrophotometer and a “Mann Coordinate-Comparator”
86 S. Chandrasekhar → B. Strömgren, May 24, 1950, UCA, SCP.

Chandrasekhar expressed his happiness at Bengt's decision to direct the Department. Furthermore, he was "most whole-heartedly enthusiastic" about Bengt's proposed cross-national co-operation arrangement.

Finally, Bengt looked forward to observational work under the colossal McDonald dome, being the third large reflecting telescope in the world, only surpassed by Mount Palomar and Mount Wilson. The budget of the Yerkes and McDonald observatories was one million Kroner and the scale of research accordingly incomparable with Danish standards. Bengt had to go, as a scientist and as a director. The prospect of carrying through his main research objective was closer than it had been before: Mapping of the developmental history of our Milky Way system.

Eight

Managing Astronomy

The Distant Dane

1951-1987

As already indicated, this concluding chapter has a more thematic approach and ranges over a far longer period than any of the preceding chapters. As a result, the amount of historical detail is decreasing. Firstly, we will follow Bengt's leave to the USA, where he took over the direction of the two observatories. His style of management aroused a heated clash between him and his close friend, Chandrasekhar, which is recounted to a hitherto unseen detail. The fate of the Brorfelde Observatory is investigated in chapter 8.3, followed by Bengt's leave to Princeton in 1957, where he stayed for ten years. Following a brief account of his return to Denmark in 1967, the historical narrative ends by introducing the history of Danish involvement in the big science project of the 1960'es and 1970'es, the European Southern Observatory.

8.1 The Old Struve Home

When Bengt went into office as head of the Astronomy and Astrophysics Department at the University of Chicago, things had changed dramatically. The staff had increased considerably and the years after the Second World War had been busy. Numerous astronomers had been hatched out and the Department

Figure 1: Bengt Strömgren with the 40-inch refractor at Yerkes, 1955 (*Rockford Morning Star*, July 24, 1955; article found in Bengt's own press cuts saved in the BSA.08, A).

budget was about $50,000 – much higher than back in the 1930'es.[1] Struve was gone and Hutchins, the chancellor, retired in July 1951. He left his imprint by orchestrating the University of Chicago into four academic divisions and an undergraduate College. The College had its own faculty, and was thus independent of the other faculties. This stand-alone unit was quite unique. The College undertook fields such as the excellence of teaching. Chandrasekhar had been the acting chairman until the new director was in place and had some experience with administration of research and teaching. The student classes were relatively small, one reason being that not many children were born during the Great depression. In e.g. 1954, the year was of approximately three hundred graduate students, out of ca. 1,400 students in total at the college. The University Department of Physics had developed into an important hotbed for nuclear physics as being the principal site of the Manhattan Project. Figures such as Enrico Fermi, Edward Teller, and Leo Szilard worked there in the group identified with the leap of nuclear physics.

Bengt, Sigrid, and their three children moved into the refurbished old director's residence next to the Yerkes Observatory. Chandrasekhar helped with the remodeling of the 'old Struve home'. Sigrid wanted to move the piano from Denmark to the USA, but it was too expensive. As Bengt was awarded the Augustinus Prize, she hoped that the piano was secured. But as Bengt felt the reception of the Prize made it more difficult to accept the Chicago position he set the whole amount aside for scientific purposes and she was rather disappointed. As Bengt wrote Chandrasekhar, "So my prize will not bring us a piano either!"[2] Even though the air was somewhat cold between Otto Struve and the old "inflated egos" at Yerkes, Bengt had no shares in earlier enmities and was still on good footing with the old director. Struve heard about the Augustinus Prize and suggested Bengt to have the news published in *Science* and in the *University of Chicago Faculty Bulletin*. Bengt wrote Chandrasekhar that "as you know, I don't like publicity, but I feel that this might help in the efforts I am now making

[1] In the early 1950'es, $1 equalled 10 Danish Kroner.
[2] KNSI, B. Strömgren → S. Chandrasekhar, May 24, 1950, UCA, SCP.

regarding Yerkes and Copenhagen co-operation".[3] Apparently, the central administration of the University of Chicago had been "a little jittery" about the award but Bengt's decision was final.[4]

In connection with his move to the States, Bengt thought about leaving his position as general secretary of the IAU, which was intended to hold until 1954. The many new activities, e.g. transactions and symposia of the IAU, the tasks for the general secretary had become too heavy for Bengt. The president, Lindblad, pressed Bengt to keep the position until after the next general assembly had been realized in 1951 and Bengt had agreed that this was the best idea.[5] Chandrasekhar wrote Bengt that he found it wise "to have offered to relinquish your Secretaryship [*sic*] of the I.A.U." although "it will be regretted by all astronomers".[6] Some of Bengt's important last work for the IAU was his involvement in the adherence of Germany as a member state, also taking it after his father, and the authorization came by April 1951. Finally, the German astronomers could participate as full members of the meetings and assemblies, and not only as guests – as they had done ever since the creation of the union in 1919. The 1951 meeting was originally intended to be held in Leningrad and Bengt made it clear that right after the meeting, he would resign. This led to the appointment of Pieter Th. Osterhoff with the Leiden Observatory, who became assistant general secretary in September 1951 for the remainder of Bengt's term. Nevertheless, the 1951 Leningrad meeting never happened and the assembly was postponed to 1952, when it would be held in Rome.

As accounted for in Blaauw 1994, the president and the general secretary both came from traditionally "neutral" countries. The provisional invitation to meet in the USSR was accepted by the IAU executive committee in September 1949 and was reconfirmed a year later. Unfortunately, the friction had been build up across the ideological borders dividing West and East, the new 'iron curtain'. As Jan Oort wrote Bengt already in 1948, "The trend in the relations between

[3] B. Strömgren → S. Chandrasekhar, May 25, 1950, UCA, SCP.
[4] S. Chandrasekhar → B. Strömgren, June 19, 1950, UCA, SCP.
[5] B. Strömgren → S. Chandrasekhar, November 8, 1950, UCA, SCP; Blaauw 1994, 160.
[6] S. Chandrasekhar → B. Strömgren, November 16, 1950, UCA, SCP.

Party and science [in the Soviet Union] appears to begin to resemble desperately closely to those we have, rightly, criticized so strongly in Nazi Germany".[7] Also F.J.M. Stratton expressed his concern by comparing with the Lysenko affair in genetics.

Trofim D. Lysenko became the Soviet senior specialist in the Department of Physiology at the Institute for Selection and Genetics in Odessa in 1929. From 1935, he was the scientific director of the institute, and from 1940 he was appointed director of the Genetic Institute at the Academy of Sciences of the USSR. As a Lamarckian, or rather Michurian, Lysenko denounced geneticists working on the basis of Mendelian thought as being enemies of the Soviet Union.[8] Lamarckism was considered to be the true Marxist biology, and its adversaries were oppressed. In 1948, Lysenko rose to dominance and declared a prohibition of education and research in standard genetics and served as a totalitarian autocrat of Soviet biology until 1953, the year of Josef Stalin's death.[9]

Some Russian astronomers claimed that only followers of "the Lenin-Stalin line of dialectic materialism" were able to draw correct conclusions from observations, while "Western scientists were insultingly described as idealists who spread confusion in astronomy and distorted and falsified facts in order to find support for their bourgeois or capitalistic world picture."[10] At a conference on cosmogony in 1953, the Russian V.E. Lvov accused astronomers such as the Russian born Gamow, Struve, Weizsäcker, and Bart Bok of having "attached some religious or pseudo-scientific significance" to what was thought to be a coincidence in spectral age determinations of stars and galaxies. Stratton expressed his concern accordingly, "I fear that cosmogony will follow genetics in the USSR and must be believed as laid down by the strongest party members and

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[7] J. Oort → B. Strömgren, November 8, 1948, Blaauw 1994, 165. 77 letters between Bengt and Oort in the period 1952-1970 are located in the Western Manuscripts of Leiden University Library, containing more material concerning e.g. ESO and IAU; Katgert-Merkelijn 1992.
[8] I. V. Michurin was a Soviet proponent of Lamarckism.
[9] See e.g. Roll-Hansen 1985.
[10] Struve & Zebergs 1962, 32-34.

not by the best astronomer."[11] Also the former president Spencer Jones wrote Bengt:[12]

> One of the Russian delegates gave an address to the Academy on the work of Lysenko and emphasized that genetic thought must develop along Marxist lines. I am aware that cosmogony is being subjected to party pressure […] I feel with Oort that the door of understanding between the east and the west is so nearly closed that we should be very cautious about taking any action which would close it still further. I am gravely disturbed about what is happening.

After Bengt's move to Williams Bay, the executive commission finally concluded that is was the opinion among many astronomers that the original schedule should still be followed for the furthering of astronomy in countries behind the 'iron curtain'. Nevertheless, the committee recommended postponing the meeting, despite widespread disappointment.[13] Lindblad and Bengt were deeply implicated in the formulation of the letter and Bengt wrote Lindblad,[14]

> I don't think there is any reason to delay further action. If you put forward to the Executive Committee the proposal to cancel the Leningrad meeting […] this will meet with full approval of the U.S. National Committee of the IAU and our American colleagues in general. […] With regard to the steps that must now be taken, I think you are able to judge the situation better than I, and I am sure that I shall agree with whatever steps you take.

Years later, Struve paid tribute to them for the "statesmanship" displayed by them when confronted with the political difficulties; "if it had not been for their

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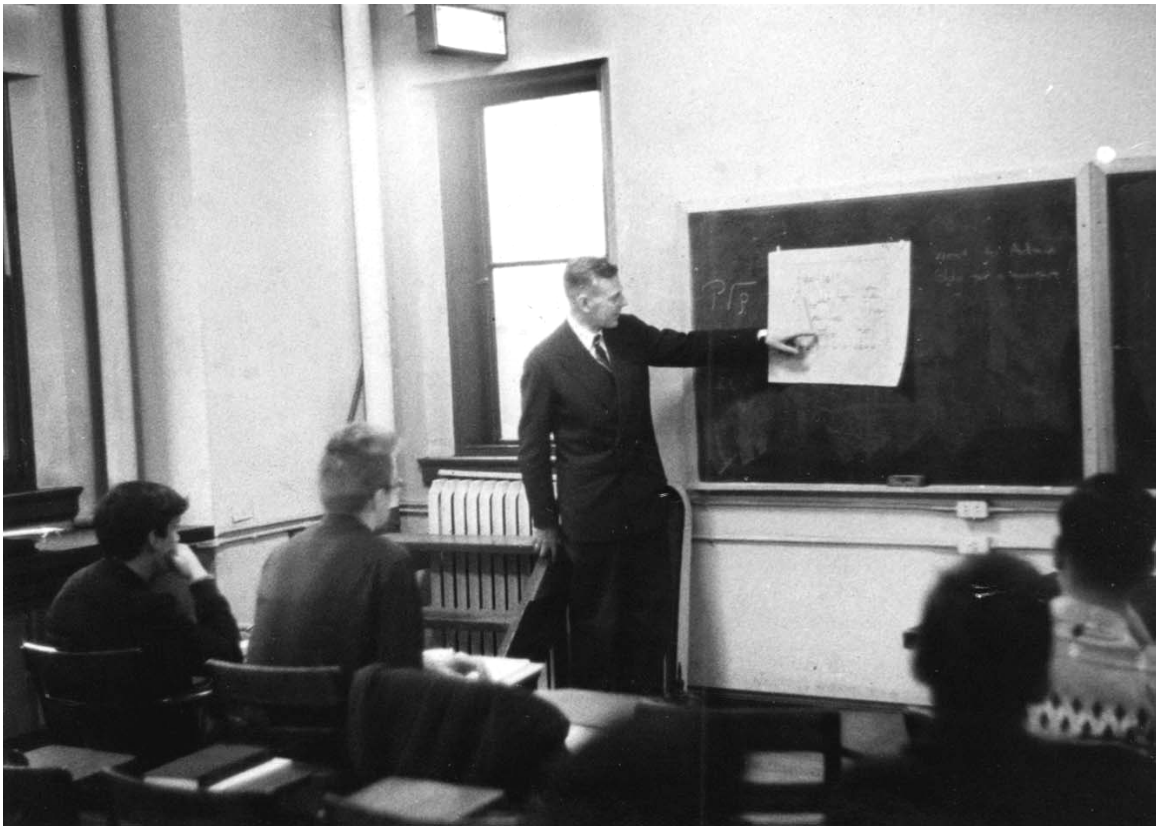
[11] Blaauw 1994, 165.
[12] H. Spencer Jones → B. Strömgren, November 9, 1948, Blaauw 1994, 165-166.
[13] Blaauw 1994, 166-168. The letter was sent by the executive committee to the USSR Academy of Science on March 6, 1951.
[14] B. Strömgren → B. Lindblad, January 16, 1951, UCA, AR.



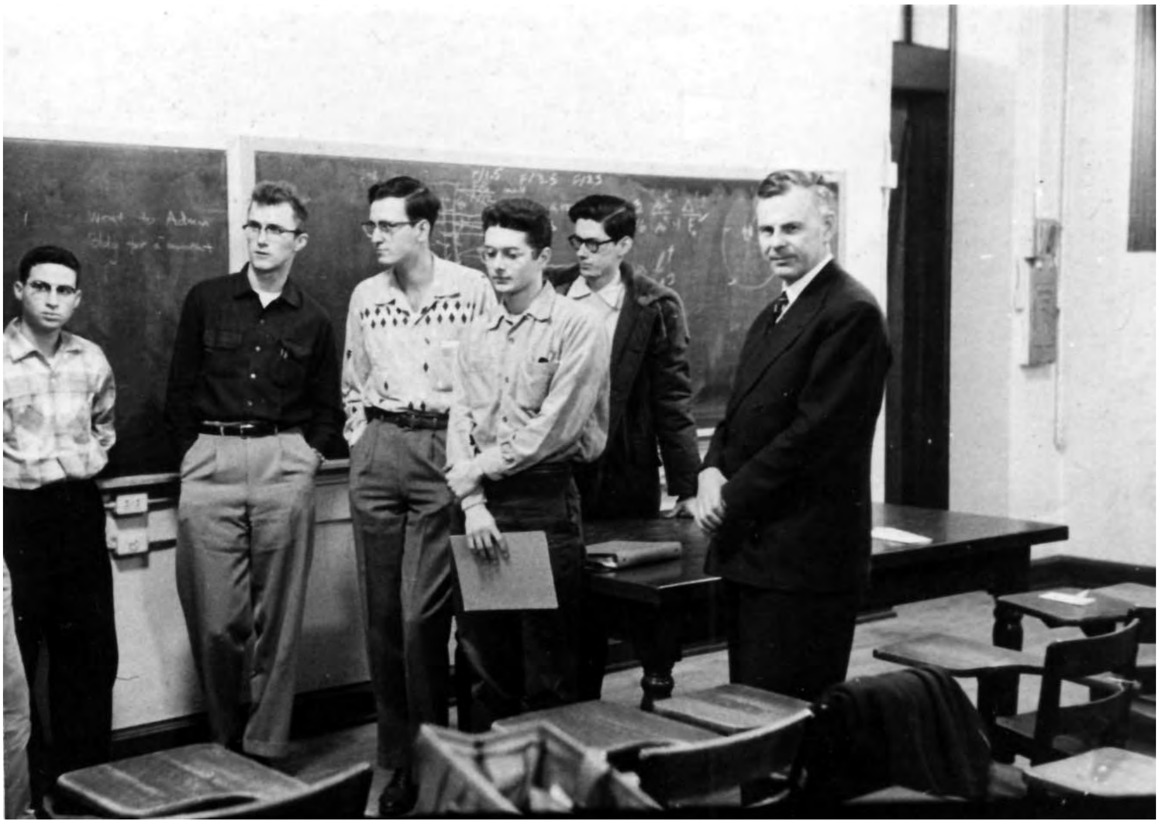


Figure 2: Upper photo: Bengt Strömgren during an advanced astrophysics lecture in the Ryerson Lecture Hall on the Chicago campus. Lower photo: Bengt's astrophysics class. Second from left is Peter Vandervoort on both pictures. The other persons except Bengt to the right remain unidentified. The photos are dated in the mid-1950'es (courtesy of Peter Vandervoort).

wisdom and forbearance, the Union might well have disappeared”.[15] Perhaps Struve overstated the risk. Luckily, USSR did not resign from the IAU, which had been a widely feared result. Bengt remained consultant member of the IAU executive committee along with Lindblad at the Rome assembly in 1952 but his active involvement slowly and steadily phased out. During a letter at his first stay in Copenhagen in the summer and fall of 1951, Bengt wrote Chandrasekhar:[16]

> Confidentially, Lindblad told me that he would resign as President if I resigned as General Secretary. I have learned enough from you to know that the appropriate answer would have been: “So, I shall resign for good reasons, and you for bad”. On the other hand, you know me well enough to realize that I did not say so.

What kept Bengt occupied until his first three months stay in Copenhagen was the direction of research and teaching at the Chicago Department. Chandrasekhar introduced him to the many tasks of managing locally the Yerkes Observatory and the remote McDonald Observatory. Already in the spring quarter, Bengt began lecturing in two astrophysics classes in stellar model atmospheres and interiors. In the summer, Bengt taught his students numerical methods and in the autumn, he lectured on optics and astronomical instruments (see appendix D, 44). In figure 2 we see an exemplary picture of his teaching on the University of Chicago campus, in the Ryerson Lecture Hall in the Quadrangles. In the upper photograph, he apparently lectured on Cepheid variables as we see him pointing at the vaguely visible instability strip in the H-R diagram. Bengt was a great mentor to Peter Vandervoort, figuring in the pictures, who is now professor emeritus of astrophysics in Chicago. According to Vandervoort, Bengt did much to promote the campus astronomy club at the Ryerson Observatory, which was instituted in 1952 on the roof of the

[15] Struve gave a talk on the history of the IAU at the ninth general assembly in Dublin, 1955, Blaauw 1994, 179.
[16] B. Strömgren → S. Chandrasekhar, September 1, 1951, UCA, SCP.

Quadrangles for use by undergraduate and graduate students. Allegedly, Bengt was the most active promoter of the observatory.[17]

8.2 Old Friends at Variance

When Chandrasekhar had finally learned that Bengt indeed wanted to go to Williams Bay, he had clearly been thrilled. In a letter he perhaps even made too much of the situation:[18]

> May I say again how delighted all of us are at this happy turn in our fortunes. It assures for us a future, which we look forward to as the brightest in our history.

Ever since Chandrasekhar's first meeting in 1932 with Bengt, when he was picked up at the Central Station in Copenhagen, they had been on good friendly terms. Clearly, the strength of their friendship is evident from the plentiful quotations from their correspondence throughout this dissertation. Though, during Chandrasekhar's Copenhagen work on polytropes in 1933, doing all his calculations long hand, he remembered Bengt to "boast of his hand computer, but never once volunteered to share it". Nevertheless, Chandrasekhar still considered Bengt to be "one of the nicest, most wonderful people".[19] Sadly, the joy and high expectations of their reunion turned into bad feelings and we will investigate the reasons for this in the following.

Only one month after Bengt's arrival to Williams Bay, Chandrasekhar and Lalitha were compelled to travel to India for several months during the winter. Part of the reason was that Lalitha's mother was getting blind rapidly. Although Subrahmanyan Chandrasekhar preferred to stay, he believed "that a month of overlapping should suffice".[20] His long awaited reunion with Chandrasekhar was indeed a warm one. Chandrasekhar had a long list of practicalities to turn over to

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[17] During my research visit at the University of Chicago, I went to a historical lecture by Vandervoort in the exact same lecture hall as depicted in figure 1. At the talk in May 2003, Vandervoort recollected his experience of Bengt as a lecturer and "a great mentor" during his studies in the 1950'es.
[18] S. Chandrasekhar → B. Strömgren, July 12, 1950, UCA, SCP.
[19] Wali 1991, 204.
[20] S. Chandrasekhar → B. Strömgren, October 19, 1950, UCA, SCP.

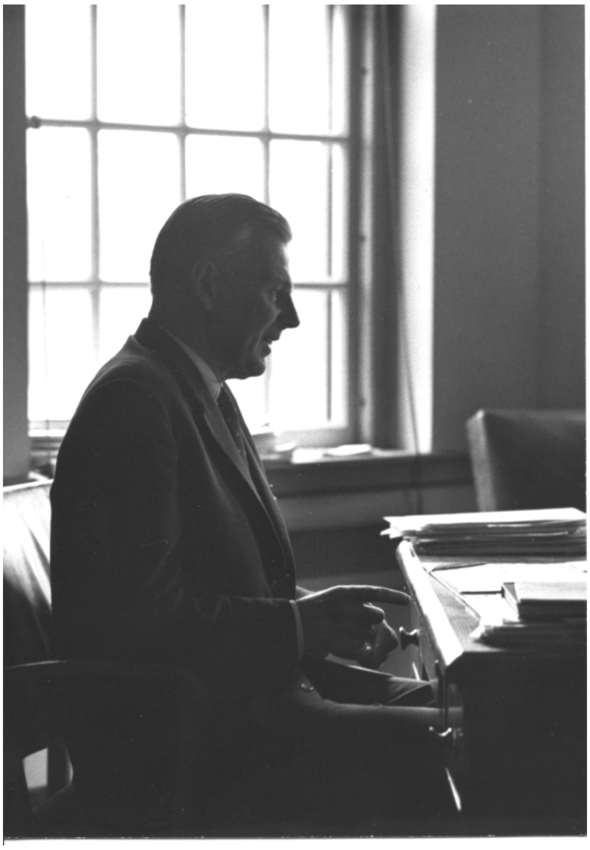

Figure 3: Bengt Strömgren in profile in the Director's office, Yerkes Observatory in the 1950'es (courtesy of Nina Strömgren Allen).

the fresh director. According to Osterbrock, Bengt was "far more considerate than Struve, especially in seeking advice from his senior colleagues and trying to heed it."[21] As a result, after the heated collegial debates and enmities from the late Struve times, apparently the Yerkes Observatory became a more relaxed research center; but perhaps too relaxed if Chandrasekhar could be asked.

As has been stated by Osterbrock, milder tensions soon arose between the new director, Chandrasekhar, and Kuiper. "Some of them were related to teaching, others to the division of resources and to Strömgren's directorial style".[22] Osterbrock's analysis seems fair. The correspondence frequency between Bengt and Chandrasekhar decreased around 1953. Naturally, they did not correspond by mail as often as they did before their geographical reunion, since their offices were under the same roof, but even after Chandrasekhar moved to the Chicago campus in 1964, they virtually ceased to communicate by letter and probably a lot of correspondence was by phone. In 1950, nineteen

[21] Osterbrock 1997, 310.
[22] Osterbrock 1997, 312-313.

letters are saved in the Chandrasekhar Papers, three letters are saved in each of the following two years, while only one letter can be found in 1953 and 1954. Then their correspondence nearly stops with a few exceptions. This tendency can be read as an indicator of the development of their friendship, but clearly it is very difficult to draw any substantial conclusions. We need much more substantiation.

Regarding the ways of Bengt's appointment, Chandrasekhar found the method at least unconventional. Chandrasekhar chaired the council of Yerkes astronomers that picked Bengt to come as director. Allegedly,[23]

> the council hardly did very much on it, because Struve had recommended Strömgren to Hutchins; I'm afraid the appointment, the decision to make Strömgren the director, was made by Hutchins and the dean. The astronomy department simply approved what in fact was an administrative fait accompli.

When Bengt "was made the director by Hutchins", Chandrasekhar "thought it was a very good thing. I admired Strömgren sufficiently to think it would be a very good appointment."[24] Looking back, Chandrasekhar found "the choice of Strömgren as director at that period to be a mistake".[25] Chandrasekhar was apparently not told about the Copenhagen three-months-arrangement. The fact that Bengt retained his directorship in Copenhagen was unknown to the acting chairman: "I was completely and totally astonished that he had made these arrangements with the administration without any information, to me or to others."[26]

Strömgren's directorial style also contributed to the reasons for the growing tension. Bengt was informed by dean Bartky that the budgets had to be reduced by five percent with effect already in the academic year 1952-1953, but not in salaries. In late 1951, Bengt wrote Bartky in the Physical Sciences Division on campus. He declared that it appeared impossible to reduce the

[23] CI, 117.
[24] Ibid.
[25] Ibid.
[26] CI, 118.

budgets and that such a reduction would have serious consequences for his department, even though he acknowledged that the general financial situation was difficult. Thus, Bengt's first years were imbued with directorial difficulties as to financial matters. But Bengt was much more experienced from his directorship of the Copenhagen Observatory than e.g. Chandrasekhar was from his one year as acting chairman, which turned out to be his only administrative responsibility in his career.[27]

From the historian Spencer Weart's interview with Chandrasekhar (CI), the issue clears up. Chandrasekhar found Bengt to be "absolutely an excellent astronomer, perhaps of a rather conventional kind, but still".[28] Notwithstanding, Chandrasekhar gave a few examples of Bengt's lack of administrative skills. "For example, during the summer he was gone I was the acting chairman again, and there were letters in his files, six months of letters, completely unanswered."[29] According to Barbara Perkins, who was appointed departmental secretary in 1955, "there was no filing job for me when I worked for Bengt Strömgren. He did the filing himself, but not frequently (laughing)."[30] Allegedly, Chandrasekhar, considering himself to be on close friendly terms with Bengt, thought he could frankly advice Bengt to resign from his directorship, since "things are so disorganized".[31] As recounted in Wali's biography of 'Chandra', Bengt did not take the criticism well. Moreover, Chandrasekhar recalled that "people made statements, Sigrid Strömgren [Mrs. Strömgren] for instance, that I had been jealous of Bengt's superior position."[32] Clearly, Chandrasekhar did not agree.

An even more nuanced picture emerges when holding the memories of Chandrasekhar's up against the recollections of William W. Morgan, from an

[27] "the only administrative thing I ever did was during the year when Struve left Chicago […] apart from that I had no administrative responsibility of any kind", CI, 68. In fact, Chandrasekhar was also acting director during Bengt's recurrent trips to Denmark.
[28] CI, 117.
[29] CI, 118. See also Cropper 2001, 447-448.
[30] Perkins worked as departmental secretary until October 1980; PI.
[31] Wali 1991, 202.
[32] Ibid.

interview made by David DeVorkin (MI). Clearly, Morgan was aware of Chandrasekhar's reaction when Strömgren was chosen as director:[33]

> Well, particularly a very influential senior member of the staff who felt he hadn't been consulted, and was very put out about it, although he had earlier been a very close friend of Strömgren's.

In 1953, Chandrasekhar and Kuiper formally recommended the reappointment of Bengt "as the chairman of the department, for one year on the termination of his present period of appointment". Also Morgan was "in favor of the reappointment".[34] According to Morgan,[35]

> there was much opposition to Strömgren by several of the senior members of the department (I was not involved). Their influence was so great that the administration re-appointed Strömgren, not for another three year appointment but for a one year appointment, which is about as much of a slap in the face for a person who was brought over as could be. You understand?

Thus, being "brought over" from outside the USA, a one-year appointment was not regarded favorable. According to Morgan, though, this was a minority of the group, if a couple of very influential people. The younger people on the staff managed to reverse the tendency and have Bengt reappointed in 1954 for another three-year-period.

If we look into the changes of the curriculum, we get another hint as to the growing discrepancies. It follows clearly from appendix D that the curriculum changed from a very theoretical set of courses in the late 1940'es to a more practically oriented program from 1951 and 1952 and onwards. In e.g. the year 1947-1948, more than half of the courses were of a theoretical nature and in the summer and autumn quarters of 1950, while Chandrasekhar was the acting

[33] MI, 69. It is more than likely that Morgan is referring to Chandrasekhar in his indicative wording.
[34] G.P. Kuiper and S. Chandrasekhar → W. Bartky, February 27, 1953, UCA, PP3; W.W. Morgan → W. Bartky, February, 10, 1953, UCA, PP3.
[35] MI, 69.

chairman, sixty percent of the courses were highly theoretical. In contrast, in the year 1951 (winter, spring, summer and fall), only one third of the courses were basically theoretical while Bengt had introduced practical courses like in e.g. optics and instruments, the practice of numerical methods, and the techniques of radio astronomy. The number of courses given by Chandrasekhar was also decreasing and there was one particular reason for this.

In 1952, Bengt named a committee entrusted with the task of revising the curriculum that Chandrasekhar designed and taught for more than fifteen years. The committee consisted of the assistant professors Aden B. Meinel, Harold L. Johnson, Adriaan Blaauw, and Daniel L. Harris, among others.[36] In 1953, the group effectively revised the curriculum of the graduate studies at the Yerkes Observatory to fit all other courses than seminar courses into a two-year program.[37] These modifications were made to further a more balanced set of courses, both satisfying theoretical and practical needs. As Chandrasekhar had been active in planning the curriculum for so long before them, undoubtedly he felt disappointed that he was not involved in the preparations of the new program.

While Chandrasekhar went away along with his wife for three months just after the Danish director’s arrival, Bengt may have made some minor changes; but clearly, the difference of opinion as to how the department should develop in the future was what really amounted to the main reason why curriculum modifications could change their relationship in such a bad direction. The revitalization of the set of courses was probably the main reason for their clash, which happened during a department meeting. Chandrasekhar, apparently, “was not aware that it was going to be brought up”. Moreover, Chandrasekhar recollected that it was all done without his knowledge:[38]

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[36] CI, 118, see also appendix C.

[37] ”Revised curriculum”, B. Strömgren’s manuscript, September 1953, found in the Chandrasekhar Papers, UCA, AR.

[38] CI, 118. the clash between Bengt and Chandrasekhar is also described in Wali 1991, 201-203.

> It was being brought up at the last minute, the meeting was going on and on and they weren't coming to this point. I had to leave and Strömgren asked me for comments. I made the remark that if they changed the program as they wanted to that was all right with me, if that was that the department wanted, but is was clear to me that the program had been so arranged that it would not be possible for me to have any more students in the astronomy department, because they would not be prepared to work with me. And that to some extent, they would have to carry on the program themselves, and I shall find my avenue of teaching in other sections of the university.

He felt left out in the cold. In addition, Chandrasekhar's field of interest changed already in 1950-1951 from stellar structure into hydrodynamics and hydro-magnetism.[39] At the same time, Chandrasekhar felt that Bengt was "probably right, from his point of view", having the director's responsibilities, "to see that I had no influence in the department. And I was, I think, right from my point of view, to give up my active relations with the astronomy department at that time."[40]

In 1952, Morgan, who had taken over the editorship of the *Astrophysical Journal* after Struve, suffered a nervous breakdown and was hospitalized for almost a year. The only astrophysicist able to take over this huge responsibility was Chandrasekhar, who had been associate manager of the periodical centered at the University to Chicago. As a result, Chandrasekhar went frequently to campus and gradually he got more involved with the Physics Department, now the Enrico Fermi Institute. He became a member of the department and began teaching applied mathematics and later he taught standard physics courses. In 1959, he rented a small apartment on campus and in 1964 Lalitha Chandrasekhar suggested they moved from Williams Bay to the city, which they did.[41]

On the social level, Bengt knew that the fifty people at the Yerkes Observatory needed a place for socializing. Therefore, he suggested the

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[39] See e.g. his courses in appendix D, page 44.
[40] CI, 119.
[41] Osterbrock 1997, 311.

construction of a pier into Lake Geneva, only five minutes walk from the observatory. He felt that it would contribute “immeasurably to relaxation and harmonious relations.”[42]

A humorous outcome of Bengt’s difficulties as director turned out to be a pamphlet entitled “Astronomy Made Easy”, written by himself.[43] According to his daughter, Nina Strömgren Allen, she typed the first copies with carbon paper and together with her father, they “had a great deal of fun with that”.[44] Bengt wrote it during long taciturn train rides in the States as a way of recreation from his management responsibilities. As he “had a lot of trouble with ‘primadonnas’ at Yerkes”, this was “a way of letting off steam about that”, his daughter remembered; “He would chuckle as he wrote.”[45]

The successor of Bengt’s directorship, in 1957, became Kuiper. Kuiper wrote the chancellor of the University of Chicago, Lawrence A. Kimpton, that he regarded the new appointment a challenge and that he should do his best to succeed. Upon some “friendly comments” by Kimpton on the Astronomy and Astrophysics Department, Kuiper could not fail to remark that,[46]

> while our position is still potentially strong, it is definitely not as good as it was ten years ago. On an absolute scale we have somewhat slipped, while three other departments of astronomy (Cal Tech, Michigan, California) have greatly advanced, and may be regarded to have surpassed us.

Perhaps, this comment was also a concealed denunciation of Bengt’s directorial capacities. Now, according to Osterbrock, all the resources got canalized into what Kuiper found to be the most important field of astronomy, *viz.* planetary astrophysics; and he “found it very difficult to distinguish between his own interests and those of his department and of astronomy”.[47] On the other hand,

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[42] W.L. Krogman → W.B. Harell, UCA, PP3, July 15, 1955.
[43] “Astronomy Made Easy” can be found in transcribed form in appendix G.
[44] KNSI, COR.
[45] Ibid.
[46] G.K. Kuiper → L.A. Kimpton, August 26, 1957, UCA, PP3.
[47] Osterbrock 1997, 312.

Figure 4: Bengt, unknown boy, Erik, and Sigrid Strömgren outside an astronomer's residence at the McDonald Observatory, Fort Davis, Texas, 1957 (courtesy of Nina Strömgren Allen).

Kuiper attempted to revive the field of solar-system research and make it again a growing area of science in times of the new 'space age'.[48]

Research in a 'Stellar Atmosphere'

During Bengt's directorship, he also found time to do research, even though he became increasingly occupied with administrative and organizational work. In the period 1951-1957, he produced twenty-five scientific publications, of which a smaller number serves to be mentioned. His scientific contributions have been divided into three broad themes by several astronomers:[49]

- 1930-1940 Problems of chemical composition in stellar structure and in stellar atmospheres
- 1938-1951 The physics of interstellar gas
- 1948 onwards Photoelectric photometry of spectral features

[48] See e.g. Doel 1996 on Kuiper and solar system research for a balanced view.
[49] See e.g. McCrea 1962.

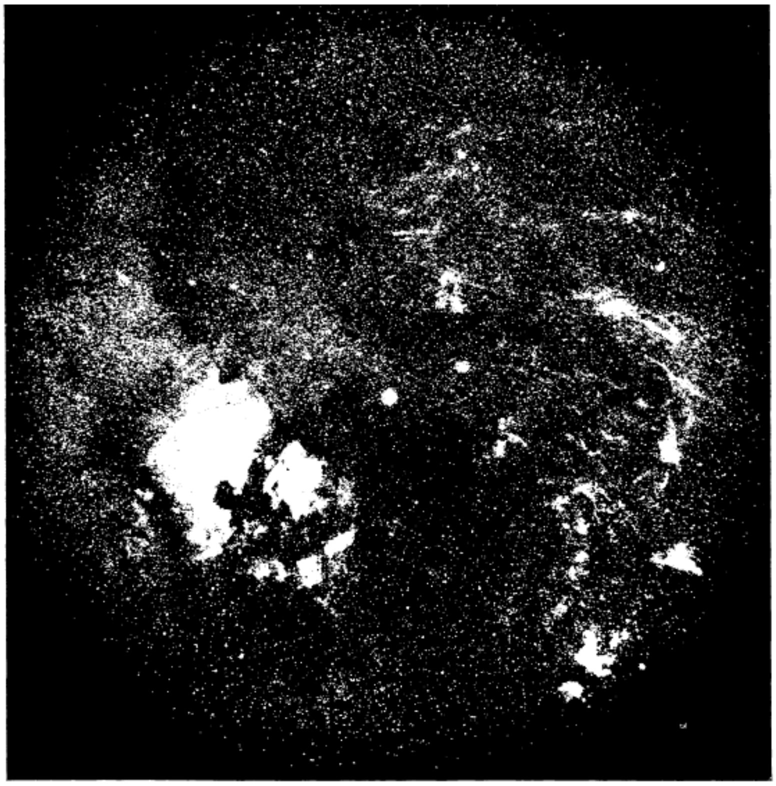

FIG. 5.—The region of α Cyg. The North America Nebula is at left center; γ Cyg is at extreme lower right. Eastman 103a-E plate with red filter. Exposure time, 35 min.

Figure 5: A picture excerpt from a 1955 joint paper by Bengt Strömgren, William W: Morgan, and Hugh L. Johnson, in which they described certain nebulous features in the Northern Milky Way (B. Strömgren, Morgan & Johnson, 1955; Provided by the NASA Astrophysics Data System).

His last important paper supplemented to his studies of interstellar emission was published in 1951, in which he managed to derive suitable theoretical curves of growth and thus to use interstellar absorption line-intensities to derive new values of interstellar chemical composition.[50]

Bengt frequently went to Texas to give lectures and to observe at the McDonald Observatory. In early 1953, he suffered from a serious car accident. Driving on a road some distance from the Observatory, he was hit by a truck. According to Karin Strömgren Campbell,[51]

> It was probably his own fault, since he was so absent-minded and clumsy […]. Luckily a nurse was driving right behind him and she took care of him, holding his skull together while waiting for an ambulance. Since that day he had a scar on his forehead.

[50] B. Strömgren 1951d.
[51] KSCI.

Figure 6: Bengt Strömgren in his office at the Copenhagen Observatory during a summer visit in the early 1950’es (courtesy of Nina Strömgren Allen).

In one of his last correspondences with Chandrasekhar, Bengt thanked for his kind letter of sympathy and added, “Fortunately Sigrid saw me at the hospital before she saw our car”.[52]

Astronomical photometry using a photocell was initiated rather early in the twentieth century by pioneers such as Joel Stebbins and Albert Whitford at the Washburn Observatory in the state of Wisconsin, and Paul Guthnick at Berlin-Babelsberg. The Stebbins and Whitford *UVBGRI* system was invented in 1943, which it was a six-color system. The system was developed at the same place by Stebbins’ group with the use of diode photocells. Then, in 1952, Bengt pioneered a new photometric narrow-band system using a photomultiplier, the so-called *abcdef* system, which was also a six-color system. The *abcdef* system was not very practical for photometric work, in part because the interference filter ‘passbands’ were too narrow to reach very faint stars (less than 10nm wide).[53]

[52] B. Strömgren → S. Chandrasekhar, February 24, 1953, UCA, SCP.
[53] Hearnshaw 1996, 435-437.

Then, Bengt investigated the possibilities of spectral classification though photoelectric photometry with interference filters. The first observations were made in 1950 at the McDonald Observatory and already in 1951 he published a paper on his ideas of the system.[54] In his collaboration with Kjeld Gyldenkerne in Denmark, he made photoelectric measures with the 32-inch reflector of the Observatoire Haute Provence in France, using a set of twenty-six filters covering the wave-length region 3350-5500Å. Morgan helped determine spectral and luminosity classes of a series of standard stars and from the analysis of this material, Bengt concluded that accurate two-dimensional classification was indeed possible for certain late-type stars.[55] Only after Bengt left his directorship at Yerkes in 1957, he began developing the widely used intermediate-band *uvby* system, which was based on the early *abcdef* system. However, it was improved by employing wider passbands (then 20 nm).

This system has become closely connected to the *β* system of H*β* line photoelectric photometry, which was invented by David Crawford during the time of his PhD dissertation under the tutelage of Bengt Strömgren in the late 1950'es.[56] A complete discussion of the properties of *uvbyβ* photometry and its use for stellar classification was given by Bengt Strömgren in a famous review article in 1966.[57] In Erik Heyn Olsen's 1994 paper "On the Complementarity between MK Classification and Strömgren Photometry", a very comprehensive bibliography of Bengt Strömgren's publications in this field is given.[58] The *uvbyβ* system has become the most widely used intermediate-band system in astronomy.[59] Photoelectric photometry was the method to be widely utilized at the Brorfelde Observatory, the history of which will be the object of investigation below.

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[54] B. Strömgren 1951a.
[55] F8-K6 stars in particular. Uncatalogued Annual Report of the Yerkes and McDonald Obsrvatory, 1952-1953, YOA (see also B. Strömgren 1953b).
[56] Crawford 1958, B. Strömgren & Crawford 1966.
[57] B. Strömgren 1966.
[58] Olsen 1994, 133-134.
[59] Hearnshaw 1996, 137.

8.3 The Remote Observatory and Its Distant Director

Going back to the early 1950'es, we will follow the main milestones in the development of Brorfelde to the extent that BS was involved. By 1949, Mogens Rudkjøbing was appointed assistant at the Copenhagen Observatory, thereby increasing the number of permanent academic employees to four. Kjeld Gyldenkerne and Peter Naur worked as temporary calculators but were appointed assistants in 1952 and 1954 respectively. In addition, Poul Bechmann had been appointed the same year as the manager of the repair shop in Brorfelde. In fact, Kjeld Gyldenkerne moved to Tølløse already in 1945 in a house rented by the observatory. He did this hoping that the new observatory would soon be built and became Hertzsprung's personal assistant. Gyldenkerne recollected that contrary to the work of measuring photographic plates in the country, "which was not exactly inspiring, the scientific personality and strong enthusiasm as well as [Hertzsprung's] comprehensive library was [inspiring]".[60] Throughout the years of planning, Bengt had underlined the decisive importance of a good library on the remote site. Hertzsprung was very interested in the new observatory and attended numerous meetings and colloquia in this connection.

Just before Bengt left to the States, in December 1950, the Carlsberg Foundation granted 2,400 Kroner per year in two years for astrophysical investigations concerning the cosmic distribution of the elements; and furthermore, 2,000 Kroner were granted additionally for excavations of Stjerneborg on Hven.[61] Nørlund had been elected as the acting director of the Brorfelde Observatory, while Bengt conserved the formal leadership for another three years. Vinter Hansen was in charge of the daily management. In 1954, Bengt asked for leaving the Copenhagen University for good, but he was convinced only to get a leave of absence without pay and thus he was still bounded to Denmark formally.

With the concrete foundations for the main building and the meridian circle poured in 1950 – but still not further developed – the protraction of the

[60] Gyldenkerne 1986, 115 (note 3).
[61] CBDB, December 8, 1950. See also figure 1 in chapter four.

Figure 7: The Copenhagen Observatory demonstration group on February 2, 1951 with a banner text saying, ”New Observatory”. From left: M. Rudkjøbing, A.A. Hermansen, J.M. Vinter Hansen, and K.A. Thernøe (photographed by Poul Bechmann, Gyldenkerne 1986, 100).

project became gradually more evident, and with Bengt’s leave, the fear of a close-down of the project may have been very real in the minds of his Danish colleagues. Danish state funding of research reached a low-point in the early 1950’es. This aroused a wide-ranging demonstration march of ten thousand students and academics, led by six rectors, to the Copenhagen City Hall and to Christiansborg – the Danish parliamentary house.[62] Compared with Sweden and Norway, it was clear that the government funding for research in Denmark was much lower. On February 2, 1951, the Danish government received the demonstration in a positive way by publicly stating that the problems of science and of the students in Copenhagen and Århus could no longer be cut off.[63] The demonstration was received by the population with sympathy and the students made humorous get-ups; students from the conservatory played their instruments; the chemists and medical students wore white coats; an archaeologist brought a

[62] The police estimated the amount of scientists, professors, academics, and students to be 10,000. Cf. note 64.
[63] The University of Aarhus was inaugurated in 1928, the natural sciences faculty in 1954; see Nielsen 2004.

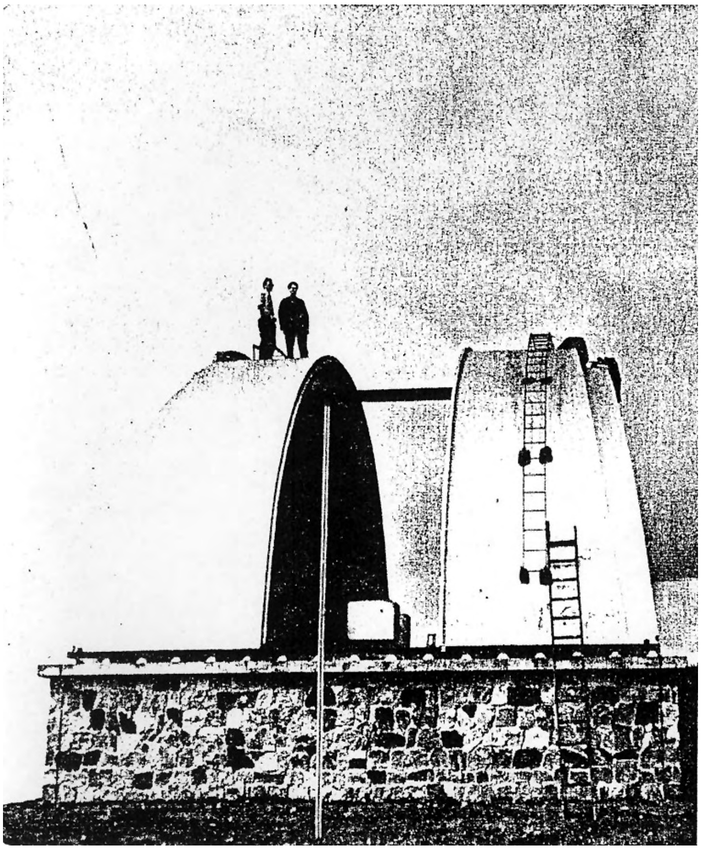

Figure 8: The meridian circle building at the Brorfelde Observatory (undated copies from a Danish newspaper, August 1953, courtesy of Karin Strömgren Campbell).

lute and another was fully armoured; the architects brought their rulers; and students from the agricultural college rode horses or tractors.[64]

The astronomers were also represented by the group in figure 7, expressing their strong wish for a new observatory. From Chicago, Bengt conscientiously followed the events and by telegram he sent his "regards to Danish science", for which Niels Bohr had proposed an effective relief supply model to the government, which was endorsed to some extent. Bengt declared:[65]

> May the demonstration march of the students and scientists from Vor Frue Square to Christiansborg cause a decisive contribution to the conditions of Danish science and students. Had I been home, I would naturally have participated in the march and I herewith send my most cordial greetings.

[64] "Positiv rigsdag modtog de 10.000 akademikere", *Politiken*, February 3, 1951, 1, 6, 7.
[65] "Var jeg hjemme, gik jeg med i toget", *Politiken*, February 2, 1951.

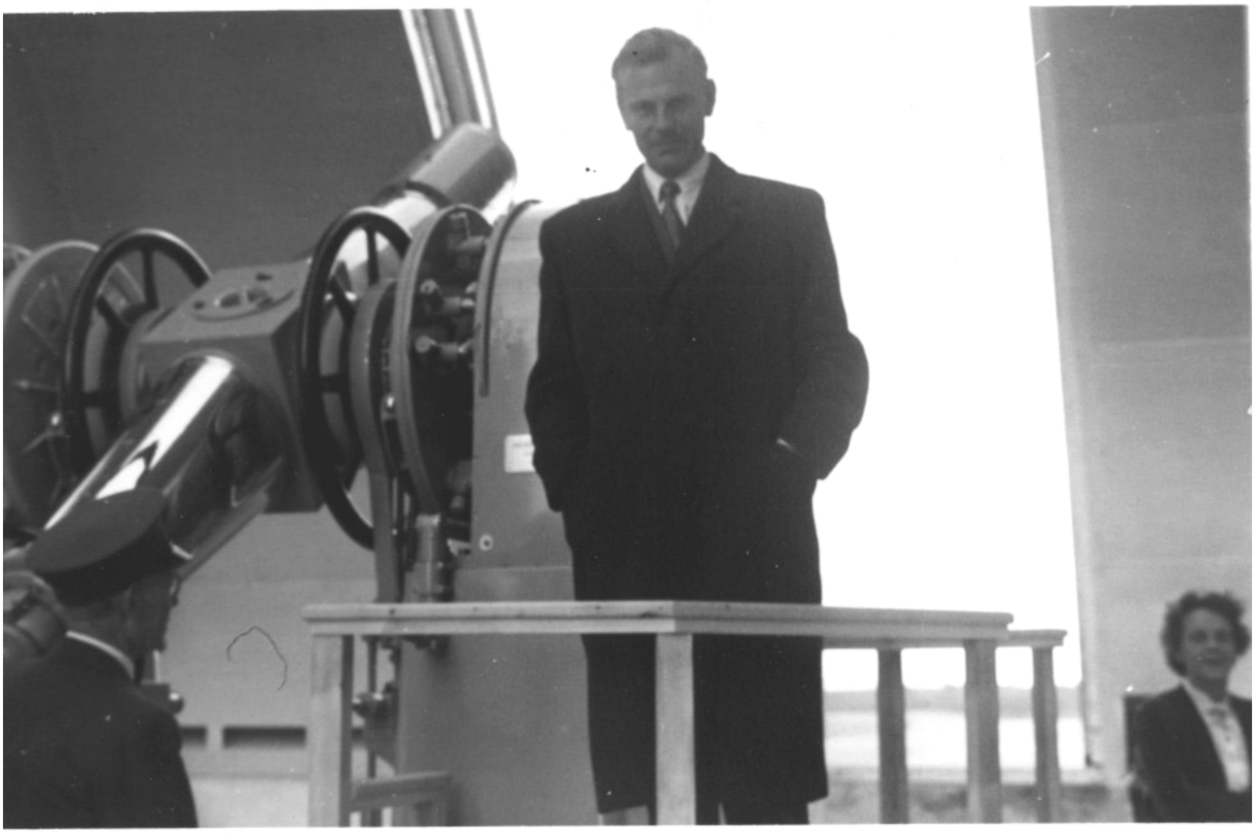

Figure 9: Bengt Strömgren at the meridian circle, Brorfelde, on the occasion of the inauguration of the new observatory in August, 1953. In the lower right corner we recognize Sigrid Strömgren (Courtesy of Nina Strömgren Allen).

The crucial step for the start of the remote observatory was taken in the summer of 1952 – the same year of Gyldenkerne's assistantship appointment when the finance committee visited the concrete foundations in Brorfelde. The committee consisted of E.A. Kock from the Ministry of Education and the two members of the Folketing, Karl Skytte and the committee chairman, Jens C. Jensen-Broby. The point of the meeting was for the committee simply to survey the two year old foundation. Attending were also Nørlund and Bengt, who had arrived in Denmark only the day before the meeting. Apparently, the committee was convinced by the astronomers that something had to be done and two million Danish Kroner were finally granted by the committee, of which ca. 200,000 were allotted to the meridian circle. At last, the project was revived and seemed more real than ever. The meridian circle was only completed in 1953, transported to Brorfelde, and erected throughout two months of hard work.

In August that year, the official festive inauguration of the observatory was held, although plenty of work still needed to be done. Interestingly, the inauguration took place around the same time as the first establishing meeting was held in Leiden between a small group of European astronomers for the creation of an observatory on the southern hemisphere. Ultimately, as we will see in chapter 8.6, the southern observatory project ended up being the major observatory project in Denmark.

Bengt went to Denmark once again to participate in the dedication of his long awaited Danish branch observatory. From that late summer day, the meridian circle was in fact operational for observation. He went back to American astronomy after the joyful summer event, but followed the development of the project closely through his correspondence with Nørlund and Gyldenkerne in particular. By 1955, the repair shop and the first three residences were built and the first employees could move to the new observation site. Two years later, the main building was completed along with the library and the fourth residence.[66]

Two New Professors

As we will learn in chapter 8.4, Bengt left the Yerkes Observatory in 1957 to the benefit of a distinguished professorship at the Institute of Advanced Study (IAS) in Princeton. At the same time, he broke the connection with the University of Copenhagen by ceasing his absence-without-pay arrangement. The need for a new Danish professor of astronomy was imperative. In fact, ever since Bengt left Denmark, his mind was not able to follow the developments in Brorfelde as closely as could be done by an attentive director nearby. The general decline of grants from the Carlsberg Foundation, and the missing Carlsberg grants in the period 1954-1957 in particular, was one manifestation of the immanent problem in the arrangement with Bengt. It seems as though having only a distant director was no good for the new remote observatory. As can be read off in appendix A, there was no occupant of the professorship of astronomy in the academic year

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[66] Gyldenkerne 1986, 99.

1957-1958 and thus no formal decision-maker. Only with Sven Anders Torsten Reiz' professorship from 1958, the flux of applications for grants increased. Before that, from the autumn of 1953, Anders Reiz worked only in a provisional position as the acting director of the Copenhagen Observatory.

Three astronomers forwarded their applications for the professorship to the University of Copenhagen in early 1958: The amanuensis, Dr. phil. Peter Naur, the associate professor Reiz, and Dr. phil. Niels Wieth-Knudsen. In April, an evaluation committee consisting of the professors Einar Andersen, Nørlund, and Bengt, reached a final decision as to the successor of Bengt.

Anders Reiz, already introduced in chapter 6.3, was born in 1915 and earned his PhD in 1939 from Lund University. He did research at the Heidelberg Observatory in 1938; at the CO in 1941 and 1946; at the Yerkes Observatory in 1948; at the Saltsjöbaden Observatory in 1951; and again at the Yerkes and McDonald Observatories in 1953-1954. Both Naur and Reiz serve as examples of the co-operation initiated by Bengt between the Copenhagen Observatory and the Astronomy and Astrophysics Department in Chicago. The scientific production of Reiz falls into three main areas: astrometry, stellar astronomy – with work on galaxy distribution and luminosity – and astrophysics. Finally, he also immersed himself into the new field of electronic calculation, using machines of the types BESK in Stockholm and SMIL in Lund. The fact that Reiz had served as acting director of the CO was not mentioned in one single word in his career biography used for evaluating the professor candidate.

SMIL and BESK constituted two Swedish first-generation computers inspired by American machines and the development of which was followed closely by Danish scientists. Already in 1946, the Danish Academy for Technical Sciences (ATV) set up a committee to follow the development of modern electronic computers in foreign countries. In 1952, the Academy founded a working committee for the planning and development of the first Danish electronic computer. The committee consisted of members of the Ministry of Defense, the Ministry of Education, and the Industry Council (Industrirådet). In October 1955, the Danish Institute of Computing Machinery, also known as Regnecentralen ('the Computing Central'), was created as a private institution. The first Danish computer, DASK, was completed in February 1958, and in 1961, the first version of its successor, GIER, was constructed.[67]

The second prospect was Peter Naur; he was born in 1928 and graduated in astronomy in 1949. In 1950-1951, he worked in nine months as research student with King's College in Cambridge. The following year he did research in the USA. Naur visited the Yerkes Observatory by the help of Bengt; then he worked at the IBM Watson Computing Laboratory; and finally at the McDonald Observatory. In September 1953, he was appointed assistant at the Copenhagen Observatory and from December 1955, he served as amanuensis. Naur's main interest was numerical computation using electronic calculators.

One of the technological implications of calculational astronomy was the development of the programming language ALGOL and its originator was Naur. In Cambridge, he worked the so-called EDSAC machine and provided a solution of asteroid trajectories in combined gravitational fields – and by his new methods the calculation speed was considerably increased. He received his PhD in astronomy in June 1957. His doctoral defense turned out to be Bengt's last official academic action in Denmark before formally leaving to the States only days after the event. At the event, Naur reminisced when he visited the Copenhagen Observatory in 1942, only fourteen years old, and was "kindly toured from the basement to the observatory dome by Bengt".[68] With IBM, he implemented stellar models based on proton-proton reactions by using punched card machines. At the Brorfelde Observatory, he helped planning and building auxiliary apparatus for the meridian circle.[69] In fact, as Naur did not get the professorship, he also served as consultant in the areas of assembly language and debugging aids to the computer laboratory, Regnecentralen, and he joined the staff of Regnecentralen in 1959. Since 1969, Naur served as professor of the Copenhagen University Institute of Datalogy (computer science).

The final candidate was Niels Wieth-Knudsen, born in 1909 and receiving his PhD in 1954. In the years 1935-1946, he served as a physics and chemistry teacher at

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[67] Gram 2002.
[68] "Da Naur blev doktor paa den lille planet 51", *Politiken*, June 5, 1957.
[69] Yearbook 1953-1958, 237-239. Naur is biographed in detail on his own website, http://www.naur.com. This is a very rich and deep website in English about the manifold scientific and otherwise academic activities of Peter Naur.

the Officer School of the Danish Army (Hærens Officerskole) and worked as scientific employee at the Geodetic Institute. From 1950, he was under the tutelage of Hertzsprung and furthermore he made observations at the Copenhagen Urania Observatory.[70]

The evaluation committee listed the three applicants in the above mentioned order and recommended Reiz as Bengt's successor to the natural sciences faculty. Reiz served as acting professor and director the first year, and from September 1959, he directed the observatory as the new ordinary professor of astronomy in Copenhagen. Danish astronomy had needed a full professor badly and it was only with Reiz' appointment that a new and fruitful development was finally initiated. Of course, Bengt had paved the way by his enormous efforts.

Observational astronomy demanded still more support from computers. In 1962, Reiz arranged to have a GIER machine at the Copenhagen Observatory, as there was not room for it at the scheduled destination, the H.C. Ørsted Institute of physics in the University Park close by. The newly appointed assistant Jørgen Otzen Petersen was told to program 'the method of the least squares' on machine language level. He collaborated with Reiz and later with assistant Henning E. Jørgensen on stellar models and pulsating stars.[71]

Another interesting development in the institutional history of modern Danish astronomy was the establishment of the natural sciences faculty at the University of Aarhus.[72] The plans of creating a second academic education and research center for the natural sciences had been underway for a long time, but the financial situation in Denmark had contributed to hamper the realization of these plans as well. The demonstration in 1952 and the following debate initiated the creation of a state fund, Statens Almindelige Videnskabsfond, which occasioned a multiplication of research grants to complement the grants from the Carlsberg Foundation. With new social-democratic government from 1953, very large grants were allotted to Danish research, atomic research in particular and in the mid-1950'es, teaching of natural sciences was

[70] Yearbook 1953-1958, 241-242.
[71] Andersen 2003, 123; see also appendix A.
[72] The last letter of the Danish alphabet, 'å' ('Å') is used today, but at the dedication of the Jutlandic university in 1928, the spelling of the city name was using the older 'aa'. The name of the university has kept its original spelling, hence it is spelled 'the University of *Aa*rhus'.

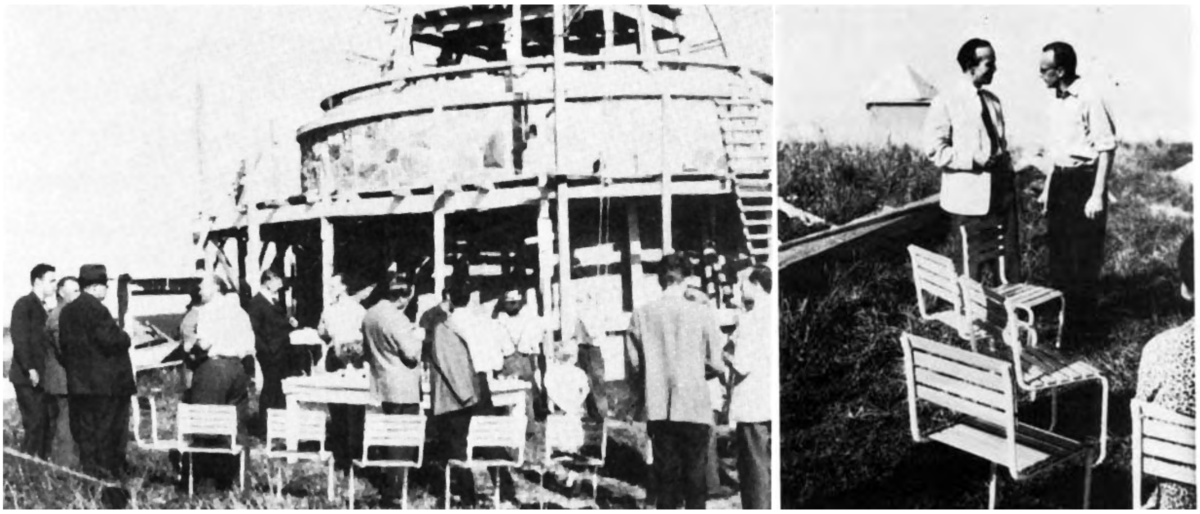

Figure 10: Left, the topping-out ceremony in Brorfelde for the Schmidt telescope dome on September 5, 1958. Right, Anders Reiz and Poul Bechmann having a talk at the ceremony (Gyldenkerne 1986, 102-103).

set off in Århus and the influx of students gradually increased from 33 undergraduates in 1956 to 90 in 1960.[73] Astronomy was naturally intended to be a part of the new faculty, which was inaugurated in 1954, and from April 1957, Mogens Rudkjøbing was appointed as the first professor of astronomy in Århus. Axel V. Nielsen was his assistant, who was appointed observer in late 1959. In 1960, Rudkjøbing succeeded Ruben Andersen as the director of the Ole Rømer Observatory and two years later the permanent staff was increased to three academics with the appointment of H. Kristensen. In 1964, 1966, and 1969, three additional assistants joined the staff.[74]

Reiz' first pressing task was the construction of photographic registration equipment for the meridian circle, which had originally been supplied with traditional measuring techniques on its arrival in 1953.[75] During the 1960'es, the meridian circle underwent various technical improvements under the direction of Reiz and only by 1978 the meridian circle was updated to a fully automatic instrument. In 1983, it was moved to the Observatory on La Palma on the Canary Islands (see chapter 8.6).

[73] Nielsen 2004, 28. The history of the natural sciences faculty at the University of Aarhus is detailed in Nielsen's institutional history.
[74] 1964: Jørn Bærentsen, 1966: Ole Møller, and 1969: Poul Erik Nissen (appendix B).
[75] Thykier 1990, 288.

Figure 11: Modern aerial photograph of the Brorfelde Observatory. In the foreground the white domes and behind the residences and main building (www.udstillinger.dnlb.dk).

The next important instrument for Reiz to complete at Brorfelde was the second main instrument, the Schmidt reflector, the dome of which was dedicated in 1958. The plan from 1947 of completing the observatory in 1956 clearly did not hold. In figure 10, the topping-out ceremony of the dome is depicted, which Bengt also attended.[76] The construction of the telescope was set off in 1961 and included Danish, Dutch, German, and Finnish manufacturers while detailed constructions took place in the Brorfelde repair shop. In 1966, it was erected but various practical difficulties delayed the project considerably and only in 1975, the telescope was operational.

Finally, the third main instrument was re-evaluated and re-dimensioned in 1967 and it was realized that the project required more funding. When grants were given by the Carlsberg Foundation as well as by the government, the Danish astronomers decided to set Bengt's astrograph aside to the benefit of another telescope to be erected at the ESO in Chile. The astrograph, to which Bengt had thought up the optics following a new principle, was hence substituted by the construction of a 1,5m reflecting telescope – roughly according to the Cassegrain principle.[77]

[76] Gyldenkerne 1986, 102.
[77] Thykier 1990, 297.

It might seem as an ill-fated coincidence that the Danish national observatory was inaugurated at the same time as the instituting ideas of the European Southern Observatory. As we will see, though, besides the scientific research done on Brorfelde, the branch observatory turned out to constitute a useful preparatory project before Danish incorporation in the European big science project by 1967.

8.4 Getting Einstein's office

1957 was a year of change. Not merely because Bengt formally left Danish astronomy and moved with his family from Williams Bay to Princeton, New Jersey, of course, but also as this was the year of the first craft going into orbit around the earth. The 20-inch diameter satellite Sputnik ushered in the space age and occasioned an explosive post-Sputnik growth of space science, astronomy, and national space programs in the 1960'es. Going to the Institute of Advanced Study as professor of astrophysics just at that time meant a tremendously interesting time of space and astronomy research on an unprecedented scale. The independent and private institution of the IAS was founded in 1930 and from the beginning it was dedicated entirely to the encouragement, support and patronage of learning through fundamental research. Obviously, with the dedicated aim of carrying out intellectual inquiry in the most favorable circumstances, this was an apposite place to be for Bengt. He took over the office formerly occupied by Albert Einstein, who died in April 1955, and he stayed with Sigrid in Princeton for ten years until their return to Denmark in 1967.

Bengt had earned much international recognition. In 1954, he was elected a member of the Advisory Panel of the National Astronomical Observatory, US National Science Foundation. The Advisory Panel endorsed plans of "an inter-university Astronomical Observatory" in early 1954 and Bengt was included in the list of prospective members.[78] In April, it was settled that the Advisory Panel should consist of the chairman, Robert R. McMath, Ira S. Bowen, Whitford from

[78] Edmondson 1997, 24.

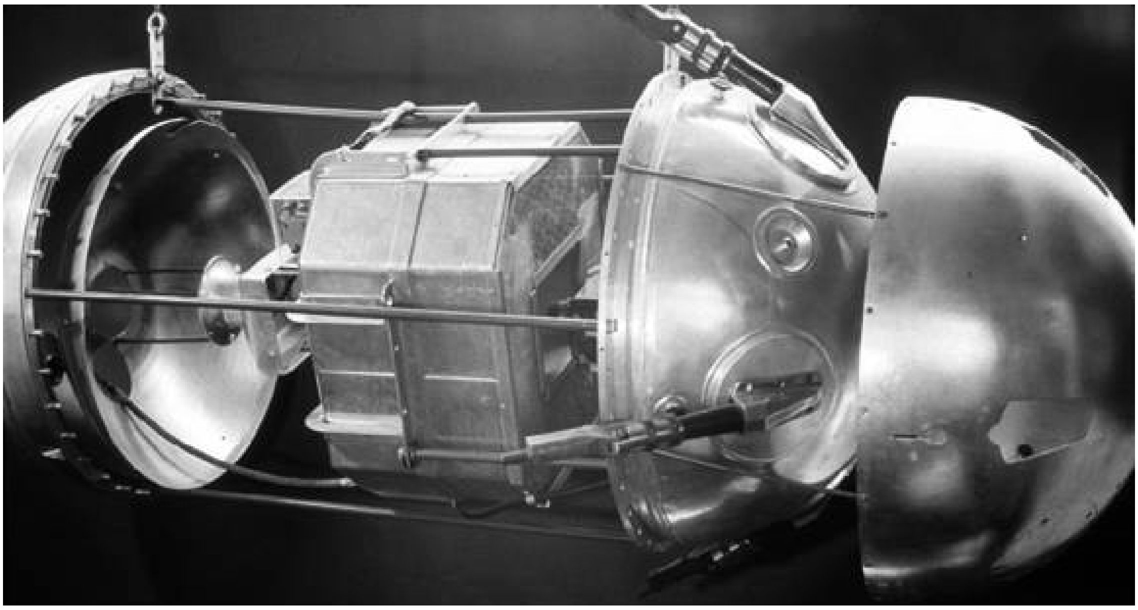

Figure 12: The Sputnik satellite heralding the space age and practical aeronautics at its launch by the USSR on October 4, 1957 (Encarta Encyclopedia).

the Washburn Observatory, Struve, and Bengt. The following year, Bengt was elected a member of the Academy of Arts and Sciences.

Although there were no observational possibilities in Princeton, Bengt soon got himself involved in the large scale project of the establishment of the Kitt Peak National Observatory. Numerous astronomers petitioned the federal government for funds to build a research center available to the entire American community of astronomers, a national facility. By 1957, the Advisory Panel decided to organize an Association of Universities for Research in Astronomy (AURA) and in May 1958, the National Science Foundation secured a mountain top, Kitt Peak in Arizona, as the site for a national observatory. Bengt was in the planning committee of the observatory, having useful and relevant experience from setting up the new observatory in Denmark, and construction began on a series of telescopes. The Kitt Peak National Observatory, or KPNO, turned out to become the most frequently used observatory for Bengt's observations for ten years, where his close co-workers were David Crawford and Charles Perry.[79]

With the establishment of the National Aeronautics Space and Administration (NASA) in October 1958, Bengt was rapidly elected member of a

[79] Edmondson 1997 treats the politics and science of the founding of the two national observatories, the KPNO and the Cerro Tololo Inter-American Observatory by the AURA.

theoretical committee for the planning of a new astronomy program in Washington. In 1960, he was chosen as a consultant research associate at the Goddard Space Flight Center's theoretical division for the launch of rockets and satellites into space. The following year, he was appointed as consultant for the Institute of Space Studies in New York. In general, in the following years, Bengt became still more occupied with political and organizational matters of international astrophysics and big science and large observatory projects. Relinquishing the big burdens of the double directorship he had before in Copenhagen and in Chicago, Bengt had now gotten rid of his heavy administrative duties. Nevertheless, he kept a somewhat bad reputation for being slow in correspondence matters, just as Chandrasekhar had complained about years earlier. For instance, in an otherwise less-important issue in connection with the AURA, "Strömgren's reply […], characteristically, was the last to be received".[80] Regardless, the ten years in Princeton were marked by many recognitions, awards and scientific medals in honor of his earnings through his life in science. Appendix F presents a virtually complete list of honorary awards given to Bengt. Besides the Danish Augustinus Prize, Bengt harvested all his honorary awards after he went to New Jersey.

One of the most important awards was the Catherine Wolfe Bruce Gold Medal, which he received in 1959 for being "one of the leading astrophysicists of our generation".[81] The highest honor awarded by the Royal Astronomical Society was given to Bengt in 1962. He received the Gold Medal for his contributions to stellar and interstellar astrophysics. According to the admiring presidential address by William McCrea, Bengt's work was "characterized by penetrating scientific insight, a comprehensive knowledge of the subject in hand and by skill and patience in the use of the required techniques whether of mathematics, of computation or of observation."[82] The same year, in Denmark, his work was acknowledged with the presentation of the Ole Rømer Medal and ten thousand

[80] Edmondson 1997, 40.
[81] Mayall 1959, 79.
[82] McCrea 1962, 83.

Kroner. He was presented in the newspaper as "the representative of astrophysics among the twenty-one professors" at the IAS.[83]

In Princeton, Bengt worked with the organization of astronomy, lectured on various research topics as visiting professor at Caltech, chaired conferences and continued his research on photoelectric photometry.[84] Once again, part of his scientific research was focused on the sources of energy production in stars. Bengt had already worked on the issue of solar life supply on a visit to Caltech and Princeton in the early 1950'es. In a letter to Hertzsprung during this visit he described his ideas:[85]

> It seems quite certain that the energy production in the sun is mostly due to the proton-proton process, not the carbon-cycle. This would imply that the convective core is smaller or perhaps negligible. Martin Schwarzschild and I have scheduled some work, which we will execute together, to investigate the new solar model more closely.

Seven years later, while permanently at Princeton, Bengt's graduate student, I. Epstein did the necessary modelling of the solar energy generation which made it clear that for the sun, the proton-proton process was in fact the primary source of solar life supply (see chapter 5.4). This was a result of the finding that the temperature in the solar core was lower than previously assumed.[86]

Before looking briefly at the years of Bengt's life back in Denmark, it serves mention that in 1966, he published a tremendously important paper in the *Annual Review of Astronomy and Astrophysics*. It was a survey of spectral classification through photoelectric narrow-band photometry which became the most cited paper in his career counting 359 citations in other papers since then – according to the ADS (see appendix E). As maintained by Anders Reiz, this paper turned into a classic bible among practitioners of the specific field of

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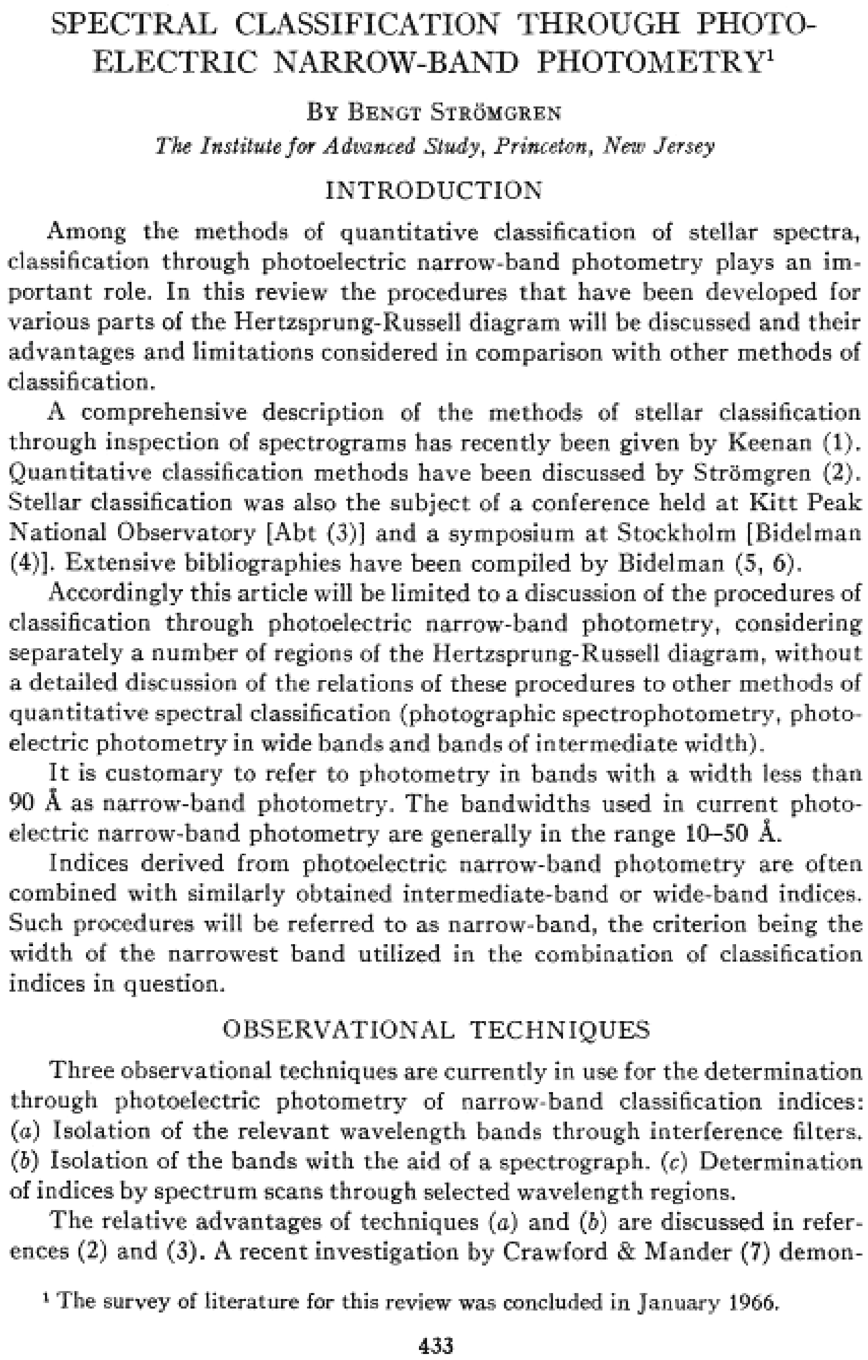
[83] "Guld til astronom", *Berlingske Tidende*, September 17, 1962, 17.
[84] For instance, in 1964, he chaired a conference at Caltech on "The Earth's Environment", *THE TECH*, October 7, 1964, 2-3.
[85] B. Strömgren → E. Hertzsprung, June 30, 1950, EHA.
[86] HI, 23.



SPECTRAL CLASSIFICATION THROUGH PHOTO-ELECTRIC NARROW-BAND PHOTOMETRY[1]

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INTRODUCTION

Among the methods of quantitative classification of stellar spectra, classification through photoelectric narrow-band photometry plays an important role. In this review the procedures that have been developed for various parts of the Hertzsprung-Russell diagram will be discussed and their advantages and limitations considered in comparison with other methods of classification.

A comprehensive description of the methods of stellar classification through inspection of spectrograms has recently been given by Keenan (1). Quantitative classification methods have been discussed by Strömgren (2). Stellar classification was also the subject of a conference held at Kitt Peak National Observatory [Abt (3)] and a symposium at Stockholm [Bidelman (4)]. Extensive bibliographies have been compiled by Bidelman (5, 6).

Accordingly this article will be limited to a discussion of the procedures of classification through photoelectric narrow-band photometry, considering separately a number of regions of the Hertzsprung-Russell diagram, without a detailed discussion of the relations of these procedures to other methods of quantitative spectral classification (photographic spectrophotometry, photoelectric photometry in wide bands and bands of intermediate width).

It is customary to refer to photometry in bands with a width less than 90 Å as narrow-band photometry. The bandwidths used in current photoelectric narrow-band photometry are generally in the range 10–50 Å.

Indices derived from photoelectric narrow-band photometry are often combined with similarly obtained intermediate-band or wide-band indices. Such procedures will be referred to as narrow-band, the criterion being the width of the narrowest band utilized in the combination of classification indices in question.

OBSERVATIONAL TECHNIQUES

Three observational techniques are currently in use for the determination through photoelectric photometry of narrow-band classification indices: (*a*) Isolation of the relevant wavelength bands through interference filters. (*b*) Isolation of the bands with the aid of a spectrograph. (*c*) Determination of indices by spectrum scans through selected wavelength regions.

The relative advantages of techniques (*a*) and (*b*) are discussed in references (2) and (3). A recent investigation by Crawford & Mander (7) demon-

[1] The survey of literature for this review was concluded in January 1966.

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Figure 13: The first page of Bengt Strömgren's most-cited paper from 1966 (NASA Astrophysics Data System (B. Strömgren 1966).

astrophysics.[87] In the paper, Bengt summed up earlier investigations since 1951 and was predominantly concerned with the observational part of photoelectric photometry (see figure 13).

[87] Rudkjøbing & Reiz 1988, 158.

A Very Fine Invitation and a Beer Crate

Around the Christmas of 1965, during a research visit at the KPNO in Arizona, Bengt's old fellow student and friend, Christian Møller, sent a letter off to Princeton, which turned out to move Bengt very much. When returning to Princeton, Bengt and Sigrid found a Carlsberg beer crate in Christmas wrapping along with a letter. In the letter, Møller aired his ideas of proposing to the chairman of the Carlsberg Directory Board that Bengt should be offered to move into the Carlsberg Mansion of Honor, and thereby Møller intended to lure Bengt out of American research and back to his homeland. It had been the declared wish of the Danish brewer J.C. Jacobsen that his house should accommodate an elect band of scientists. The series of Danish scholars living in the attractive residence included the philosopher Harald Høffding (1914-1931), Niels Bohr (1931-1962), and the archeologist Johannes Brøndsted (1963-1965). Now the mansion had been empty since the death of Brøndsted, and Møller found Bengt to be the obvious choice. Moreover, Møller suggested the forming of an extraordinary professorship. Here is what he wrote his old friend:[88]

> I was very moved by learning about your ideas in connection with the mansion of honor. As Brøndsted only lived there shortly, I regard it as Niels Bohr's residence, as we probably both do, and so I don't have to explain to you that it is a bit overwhelming to me.

When Bengt formally said goodbye to Danish science in 1957 it was due to his improved research conditions abroad, but also to stay close to his children, who all resided in the States. Now, he felt, the conditions had changed, in particular regarding the ESO project, which will be treated in chapter 8.6. On the other hand, Bengt was slightly worried about his pension salary. More importantly, Bengt and Sigrid found it "crucial to be as close to their children as possible".[89] He did not find the problem easy to solve but allowed Møller to communicate the content of the letter further to Carlsberg.

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[88] B. Strömgren → Chr. Møller, January 14, 1966, BSA.01, A.
[89] Ibid.

Møller spoke to the chairman of the Carlsberg Directory Board, Stig Juul, who reacted happily by declaring that Bengt had indeed been included on the list of prospective residents, but that the chances of getting Bengt to Denmark had been regarded as being close to zero. Juul was slightly concerned about professor Reiz' reaction, as perhaps he would prefer to remain the only Copenhagen professor of astronomy. Møller was allowed by Bengt to ask Reiz, who only encouraged the realization of the plan, in particular with reference to the approaching Danish membership of ESO. The question of pension was settled at a Carlsberg meeting and Møller waited impatiently for Bengt's response.[90]

Both Karin and Nina thought that Bengt could not decline such a glorious invitation and Bengt replied Møller that he was inclined to say yes to the attractive offer on two conditions. Firstly, Bengt needed assurance that problems of furnishing the immense residence could be solved without too many expenses on his own part, as the building is indeed very large. Secondly, Sigrid was concerned about the caretaking and expressed the need of household help, in particular owing to the representational aspect of living in the mansion of honor, which was required by the occupant.[91] In addition, Sigrid was concerned about the frequency by which they would see their children, who had all settled in the States. Bengt simply raised a private travels fund and convinced his wife that the geographical distance would not be a problem.[92] By March 1, 1966, The Directory Board sent the formal invitation to Bengt and he gladly accepted, but at the same time he referred to the fact that he felt "very insufficient" compared to the mighty Niels Bohr, and he suggested moving by April 1967.[93]

Bengt communicated his decision to the IAS and a farewell lunch was held on April 11, 1967, during which Bengt's colleague, the theoretical physicist Freeman Dyson, gave a brief speech to the "Great Dane", an epithet used by some Americans. Dyson expressed his sorrow of loosing his close colleague:[94]

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[90] Chr. Møller → B. Strömgren, January 22, 1966, BSA.01, A.
[91] B. Strömgren → Chr. Møller, February 6, 1966, BSA.01, A.
[92] Blædel 1967.
[93] Stig Juul → B. Strömgren, March 1, 1966, BSA.01, A; B. Strömgren → Stig Juul, March 6, 1966, BSA.01, A. See also "Professor Bengt Strömgren indstillet til æresboligen", *Politiken*, April 1, 1966.
[94] A copy of the two pages speech is courtesy of Karin Strömgren Campbell.

> Now that Bengt is leaving, we have learned the hard way how irreplaceable he is. Looking at replacements for him, we find that almost all astronomers other than Bengt can be divided into three classes. Class one are specialists, expert in some narrow field but lacking Bengt's breadth. Class two are wonderfully broad, always ready with a television interview or a new theory of creation. Class three are professors at Princeton University. After much deliberation in which Bengt himself participated, we have not been able to find an adequate replacement for him. This means that the astronomy group here will temporarily collapse and the Institute will be much poorer.

8.5 The Carlsberg Years

Just four days after Dyson's farewell speech, Hedvig Strömgren passed away in Gentofte, but only in the summer of 1967, Bengt and Sigrid finally returned to Denmark. Bengt was appointed extraordinary professor from May 1, 1967, a position he kept until he retired in January 1978 at the age of seventy.[95] With Sigrid he moved into the handsome town house in the large park full of exotic plants. His return meant a strengthening of Danish astronomy. As a consequence of generally improved conditions for Danish science, the staff number was increased at the Copenhagen Observatory. The growth at the university entailed large numbers of new students and from 1960-1972, the number of permanent astronomy positions in Copenhagen was increased from one professor and five astronomers to two professors and fourteen permanent astronomy positions.

The 1960'es and 1970'es were times of innovation and reorganization of astronomically related institutions in Denmark. In 1966, the Danish Ionosphere Laboratory at the Danish Polytechnical College, now the Danish Technical University, was split into the Geophysical Department at the Danish Meteorological Institute and the Danish Space Research Institute, which became independent in 1968. At this institute, research was particularly focused on cosmic radiation and magnetospheric physics.

Another important coinage was NORDITA. The seed of growth of astrophysics at NORDITA goes back to Bengt's return to Danish research. Since

[95] Yearbook 1966/1967, 152.

the 1930'es, Denmark had marked itself on the world map of modern astrophysics, also in the cooperation with prominent Nordic astronomers such as Lindblad, Rosseland, and Lundmark. The idea of a united Nordic institute of astrophysics was cert. Nevertheless, the idea was never realized. Instead, plans of an amalgamated Nordic institute for theoretical atomic physics (NORDITA) had been initiated shortly after the Second World War. In 1957, the institute was established in connection with Niels Bohr's Institute building in Copenhagen.[96] NORDITA commenced its activities with Christian Møller as director and Ben Mottelson and Leon Rosenfeld as some of the professors. Luckily for the astronomers, and on account of Bengt, the fields of work soon included theoretical astrophysics and NORDITA played a significant part in this field in the Nordic countries. A series of seminars were held at Niels Bohr's Institute and at NORDITA, where numerous foreign physicists and astrophysicists worked as visiting professors for a number of years.

Bengt directed NORDITA in the years 1971-1975 and like this, he was again back on Blegdamsvej where he had been so positively inspired to change from classical astronomy to astrophysics in his early years. In a Swedish radio transmission of the 1990'es, his colleague Bengt Gustafsson recalled a humorous event during Bengt's directorship:[97]

> One day, we saw Strömgren crawling out of his window from the institute when he was the director [of NORDITA]. Elegantly, he threw out his jacket and then jumped out across the verge, grabbed his jacket, and walked quickly along Blegdamsvej. When I reached the institute, Bengt's secretary was looking for him in his office. An official from the Nordic Council of Ministers had just arrived to meet with Strömgren, but obviously he was gone. He had a meeting with Sigrid and accidentally he had made a double booking.

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[96] Mottelson og Pethnick, 1996. The history of NORDITA is also treated in some short articles; Gustafson 1982; Jauho 1987, and the pamphlet "NORDITA 1957-82" published on occasion of the twenty-fifth anniversary jubilee in October 1982 (no author is indicated. A copy of the text is located at the History of Science Department, University of Aarhus).

[97] BG.

If Gustafsson's memory serves him well then this incident could indicate an additional feature of Bengt's personality in his later years, namely that of prioritizing private life to political matters. This is only speculation, of course. Christian Møller, the professor of physics who initially suggested Bengt to live in the Carlsberg residence, had been the close friend and fellow student of Bengt since the early 1920'es. At NORDITA, Møller was active in the first enterprising agency along with Bohr and Rosseland among others. Møller directed NORDITA for fourteen years, from its establishment in 1957 until Bengt succeeded him.[98] When Bengt was appointed director of the institution, he and Møller ended up sharing a large office desk. Upon the death of Møller in 1980, Bengt wrote his obituary and sent a very emotional letter to Møller's widow, Kirsten Møller, in which he expressed his condolences:[99]

> I write these words in the room that Christian and I shared and by the desk by which we both worked. It is so difficult to comprehend that I will no more be met with Christian's welcoming smile and that I shall no more have the feeling, which I always had, of peace of mind and happiness by being together with him. Time and again it goes through my head; my best friend is dead.

The last part of Bengt's professional life comprised turbulent years of involvement in organizational activities and research policy, besides continued scientific research. Going back to Denmark the same year as Denmark ratified the ESO Convention, Bengt immediately initiated work in concert with professor Reiz on future planning of new telescopes and general tasks in connection with the new Danish engagement in the European enterprise (treated in chapter 8.6). A long list of directorships and presidencies marked Bengt's last nearly twenty years in research. As listed in appendix H, after serving as president of the

[98] B. Strömgren 1981.
[99] B. Strömgren → Kirsten Møller, undated, 1980, BSA.01, B.

Figure 14: Bengt and Sigrid in front of the large garden of the Carlsberg Mansion. Undated, the 1970'es (courtesy of Karin Strömgren Campbell).

American Astronomical Society in 1966-1967, Bengt was president of the IAU (1970-1973), the ESO Scientific Policy Committee (1971-1974), and the ESO Council (1975-1977), and following Niels Bohr's footsteps, first as the resident of the Carlsberg mansion, in 1969, Bengt was elected as the President of the

Royal Danish Academy of Sciences and Letters after Johannes Pedersen's resignation. In a Danish newspaper column, it was stressed that[100]

> some people might say that professor Strömgren left Denmark in a time when he was badly needed. But the truth is that he fought in years to secure reasonable conditions for Danish astronomy and only accepted the American offer when it was obvious that his struggle had been in vain.

Bengt's years in the president's chair constituted difficult times of transition from a traditionally learned society to an academy, which had to be adapted to the needs of modern society.

On the domestic level, the president of the science academy put a lot of effort in improving the conditions for all fields of natural sciences in Denmark. Bengt often publicly stressed his concern that the effort to advanced basic research had to be doubled, that it needed to be internationally oriented, and that research should be as free as possible from the interference and control of public authorities.[101] Bengt warmheartedly welcomed the furthering of a broad participation of the Royal Danish Academy of Sciences and Letters in many sorts of activities in the fields of both the humanities and natural sciences. For example, he was involved in the creation of the so-called Niels Bohr Grants based on the cooperation between the academy and the trades and industries. On occasion of Niels Bohr's one-hundredth anniversary on October 7, 1985, a group of scientists and industrialists collected ten million Kroner to talented researchers. Among the industrialists was Haldor Topsøe, director of the Central Bank, Erik Hoffmeyer, and Bengt.[102] The reason for the initiative was the stagnation of fundamental research in Denmark. By such collaborative effort it became possible to get funds for fundamental research made by young promising researchers.

[100] Clipping from an unidentified newspaper found in the RA, protocol No. 605-1969 (dated: May 9, 1969).
[101] Topsøe 1987.
[102] "10 mill. Fra erhvervsliv til forskertalenter", *Berlingske Tidende*, April 17, 1982.

Figure 15: IAU President Bengt Stömgren at the fifteenth IAU general assembly in Sydney, August 21-30, 1973 (BSA.08).

Bengt's influential presidency of ESO was no sinecure as it was a time of serious negotiations. As his colleague Lo Woltjer wrote subsequent to Bengt's death,[103]

> Thanks to his wisdom and the self-confident and decisive way in which he dealt with ESO matters, many perils were avoided and a high degree of harmony was established between the delegations of the member countries which has endured up to the present.

In newspapers and magazines, Bengt was often emphasized as the next astronomer in the line of a series of great astronomers, ranging from Tycho Brahe, Ole Rømer and his assistant Peder Horrebow, or he was otherwise mentioned in connection with the national icons. An example of such rhetoric is

[103] Woltjer 1987.

found in the *Danish Foreign Office Journal*, in which Bengt was biographed on occasion of his recent return to the Carlsberg Mansion:[104]

> Denmark has rich traditions in astronomy. Tycho Brahe (1541-1601) was the first to make exact observations of the stars and Ole Rømer (1644-1710) discovered the velocity of light. Continuing his work carried out over many years at leading American observatories, Professor Bengt Strömgren is making valuable new contributions to stellar research from the Carlsberg honorary residence.

The Danish engineer and industrialist, Haldor Topsøe, wrote an interesting obituary notice in *Berlingske Tidende*, in which he chose to focus on Bengt's earnings in connection with domestic perspectives and research debate.[105] This was done also on the basis of the joint effort of getting money for the Niels Bohr Grants treated above. In the word of Topsøe, Bengt was an exemplary scientist for young promising science students of the 1980'es and Topsøe expressed his desideratum that the youth would be inspired by Bengt's scientific approach. Topsøe also counted Bengt in the line of world famous Danish scientists like H.C. Ørsted, the zoologist H.V. Brøndsted, the medical doctor Niels Finsen, the physiologist August Krogh, and Niels Bohr. By the example of the Danish astrophysicist, Topsøe accentuated that after all it was still possible for Danish science to produce an internationally renowned scientist. At the same time, he stressed that it had only been possible and still presupposed, "as Bengt so often pointed out, that we keep our doors open and participate in fundamental research to the largest possible extent."[106] The political agenda of Topsøe was not veiled as he openly used Bengt as the lever for his arguments in his latent fear that recent research policy of the late 1980'es would fall behind compared to foreign Western countries. As an industrialist and private owner of the independent research corporation named after him, Topsøe naturally wanted to invoke a

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[104] Henius 1967.
[105] Topsøe 1987. Bengt Strömgren's work for 'free research' is treated in the popular article Rebsdorf 2002.
[106] Ibid.

closer cooperation between fundamental research and its practical use, especially in the Danish industry. Finally, Topsøe appealed in a somewhat moralizing way to the readers, i.e. politicians, "to commemorate Bengt not only for his life's work but also for the general lesson and inspiration for all Danish research, and thus for the future of our country".[107]

The media coverage of the distinguished professor of astronomy was considerable and for long he had been displayed and considered the national astronomer. His wife even got a status of being "the Danish second lady" in popular magazines, displaying the life of the noble family in their Carlsberg 'castle'.[108] During the last twenty years of Bengt's life, he was interviewed occasionally when he passed a milestone or on occasion of his participation in public events and he was frequently subjected to interviews in his new attractive surroundings. These newspaper interviews often attempted to create a peephole into the scientific culture by investigating the real life of an astrophysicist and just as often, the portrayals worked somewhat as means of building up the national identity of the audience as being the citizens in a country hosting one of the biggest international scientists in the field of astronomy. It was important for several journalists to know how Bengt felt about his nationality; if he felt fully or only partly Danish. The answer was always to the joy of the patriotic reader, as "Bengt never, wherever he travelled, cut away the painter to Denmark."[109]

By 1967, Bengt was optimistic about the future of Danish astronomy. In one of the interviews, he compared the conditions with the state of national astronomy only ten years earlier. He emphasized Reiz' great work for the conditions at the Brorfelde Observatory; he underlined the basis laid for theoretical work and for the treatment of observations by means of an effective system of calculations using electronic computers; and finally, he laid emphasis on[110]

[107] Ibid.
[108] BG.
[109] Blædel 1967. See also Henius 1967, Mielche 1968, Rosenkjær 1968, Henius 1976, Nørthen 1978, and Havelund 1978.
[110] Blædel 1967.

> a group, particularly consisting of younger astronomers, participating actively in the research work and the number of students has risen as well. The Danish affiliation with ESO […] in Chile will undoubtedly create new opportunities also. Then, Danish astronomers will get access to work with the very large instruments under the best possible climatic conditions. I am also thinking about the riches of meeting astronomers from other European countries.

Another aspect of Bengt's life, completely untouched so far in this dissertation, is his religious beliefs. In a very informative, if intimate, newspaper interview, we come a little closer to his reflections on the issue. Bengt found it[111]

> difficult to be convinced by the ways of reasoning of the revealed religions, but it is something that has nothing to do with my science. To many people it probably holds that these kinds of thoughts are conceived in the childhood and early years and from then on it doesn't change.

Bengt's home was not religious, but antecedent generations were. On the other hand, Bengt preferred not to see Denmark without a national church. He was a member himself, but from his own special reasons. Firstly, he considered the protestant church to be a "vaccination against the sectarian, which, I am sure, have done much harm". Secondly, the church was important to his wife. "My children are baptized and so am I, but I am not confirmed. I didn't want to."[112] Bengt did not believe in eternal life in any form. He was a scientist of reason, not of belief.[113]

Bengt found the mere idea that human beings simply cease being a beautiful one. To Bengt, the question of 'the meaning of life' was something to which he referred to his mother Hedvig. Interestingly, he felt "very marked by my home and especially by my mother"![114] This was the reason why he was of the opinion that "a significant indication of the chances that things are fine must

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[111] Havelund 1978, 13.
[112] Ibid.
[113] For comparisons with some general historical literature on the subject of science and religion, Barbour 2000 and Ferngren 2002 make up excellent text books.
[114] Ibid.

be that you work as good as you possible can and ought to. But that is only one part of life." The other part was family life and friendships.[115]

> Passing something on to your children together and trying to create comfortable circumstances of opportunities for their own development is just as important as work and the use of your own abilities. Work, love, and family must constitute the foundation.

However, Bengt did not find the stars and his family to be connected by any astrological means of explanation. Not surprisingly, he found astrological thought and fatalism to be "nothing but empty words". Thus, Bengt would not agree with the fictitious Jacques the fatalist that "it is all written up high", in the sarcastic words of Diderot.[116] Nor would Bengt consent with the author of horoscopes, although he did in fact read them occasionally, as "I find them entertaining. But I feel sorry for those who take the horoscopes seriously."[117]

As his colleague Bengt Gustafsson recalled, Bengt took his time for his own research, "but also for us young astronomers, in spite of his business in all kinds of matters."[118] We will end this concluding characterization of Bengt by a story told by Gustafsson, his colleague in Uppsala:[119]

> One day, I was flying with him [Bengt Strömgren] to Geneva for a conference. To my surprise, this friendly, cultivated man, director of the Royal Danish Academy of Sciences and Letters and the National Committee against Cancer, took a *Playboy* magazine out of his jacket in the plane. This led to a discussion with Strömgren about […] women's role in the history of astronomy, which is so significant, and about how it would be made possible for more female astronomers to make a career. As customary, Strömgren was full of insight and came up with many good suggestions, but then he nodded in the direction of the magazine and added: But it *can* be good sometimes to look at longing women.

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115 Ibid.
116 Diderot 1999.
117 Havelund 1978, 13.
118 BG.
119 Ibid.

8.6 Little Denmark and Big Science

Returning for the last time to the Brorfelde Observatory, the Carlsberg Foundation granted two large portions in the late 1960'es. In 1966, the project received half a million Kroner to cover expenses to the purchase of a large reflecting telescope, but on the condition that Denmark would join the unified European observatory on the Southern hemisphere. As earlier indicated, it might seem as a fateful coincidence that the Danish national observatory was inaugurated – though not completed – around the same time as the first creative ideas of the ESO institution surfaced. Even more, the year that Denmark finally ratified the ESO convention was the same year that Bengt returned to his homeland after sixteen years abroad and the strongest capacities were thus gathered around the new international project; but what about the fate of Brorfelde then?

While there are different opinions as to the impact of the Brorfelde Observatory on Danish research, there seems to be consensus among living Danish astronomers that the main field of scientific importance of the branch observatory has been photoelectric photometry. In the Danish climate it was not optimal for astronomical observations and some photoelectric observations were undertaken in collaboration with e.g. the Lowell Observatory in Flagstaff, Arizona. Perhaps it could be objected that despite the fact that Brorfelde was not fully operational for so many years as a research observatory – roughly until 1975 – then the project could be viewed as a successful preparation to the ESO engagement, at least from at retrospective perspective.

The history of the early ESO years is described in detail in Blauuw 1991. As the Danish engagement in ESO was made official in 1967, the series of events will only be given a somewhat brief treatment in this chronological paraphrase of Blauuw's institutional history, supplied with further aspects from the Danish perspective.[120] As stated by Blaauw, in the spring of 1953, the Dutch astronomer Walter Baade expressed an idea that followed a compelling empirical problem for international astronomy. In fact, as proposed by Osterbrock in his relatively

[120] Blauuw 1991.

Figure 16: On occasion of the Groningen meeting, the participants went on a boat trip where they may have discussed Baade's idea leading to ESO. Mrs. Mieke Oort, Bengt Strömgren, and Bertil Lindblad (Blaauw 1991, 11).

recent biography of Walter Baade, already in 1952, on a visit to Pasadena, Jan Oort taught a graduate course at Caltech during which he discussed the matter with Baade.[121]

The problem was the fact that that virtually all observatories were located on the Northern hemisphere, in particular the large Mount Palomar, and the sky of the Southern hemisphere was therefore relatively unexplored. More than that, a majority of the interesting research objects is also located south of Equator. The solution to the problem entailed considerable planning, financial appropriation, preparatory scientific investigations and discussions in the governments of several European countries. The original idea rapidly developed into another big science project program.

[121] Osterbrock 2001b, 193-195 and 254, notes 26 and 27.

Denmark Short of a Professor

As a means to solve the palpable observational problem, Baade suggested to his colleague Jan Oort, that European astronomers ought to work for the establishment of a shared observatory on the Southern hemisphere. The idea was promptly echoed among European astronomers and a conference was held in Groningen in June 1953. In January 1954, representatives from six countries met to sign the historic declaration. The countries counted Germany, Belgium, France, the Netherlands, England, and Sweden, and they jointly expressed the wish that the scientific organizations of the respective countries would recommend the participation in the project to their authorities. Originally, a mountain top in South Africa was considered to be the most fruitful site of observation and the project was scheduled to be realized in ten years time. At the same time, it was determined that the financial contributions of the respective countries should be proportional to their gross national product, up to an upper limit. As with many large projects the time schedule turned out not to be quite realistic.

Denmark was not involved in the prefatory activities lasting for more than ten years until the big scientific project caught the wind. But the desire was real among Danish astronomers. Swedish delegates such as Bertil Lindblad and Knut Lundmark discussed the issue frequently with their Nordic neighbors. Danish astronomers hoped that their country would soon become a member state. Early on, considerations of future instruments and ideas were initiated. However, one problem in Denmark was the fact that the ‘national astronomer’, Bengt Strömgren, more or less had left Danish astronomy and his efforts in Danish scientific matters could not be extended to more than the build-up of the Brorfelde Observatory. As already discussed, until 1958, Denmark had no real decision maker, as Bengt’s professorship was only succeeded by Reiz in 1958. Formally, Bengt was the backstop of serious decisions, but in reality, he remained rather distant from Danish matters, and even more after 1957 when he went to Princeton. In addition, Denmark seriously lacked a scientific advisor to work for the project with a real mandate. And geographically, of course, Bengt’s participation in European meetings was very limited. It was only with Anders Reiz' appointment in 1958 that Denmark entered the scene, even though, despite his good intentions, Denmark was only included in ESO nine years later.

Inspiration from CERN

In 1957, Baade was elected chairman of ESO and Oort became its president. A list was soon produced of possible localities of the new observatory in South Africa. Two years later the costs were tentatively estimated to be of five million dollars. The Ford Foundation consented granting the first million under the condition that at least four nations would sign the convention, which was being written at the same time. The following years elapsed with various politically difficult tasks and the formal structure was lively discussed. In the period 1954-1960, the implicated astronomers worked out the formulation of a useful convention, of which a large part was starting from the already existing convention of the big nuclear science project, CERN. Constitutionally, the ESO convention, the financial basis, and the personal regulations resembled CERN's counterpart. Though, one important difference from the CERN convention was the vital precondition that the main establishment was required to be geographically located outside Europe.

In addition, it turned out to be rather difficult for the astronomers to convince the relevant politicians of the respective countries that the project was scientifically important. This was not a burning issue in the case of the CERN project. Contrary to the more palpable necessities of nuclear research, as regarded by the participating governments in CERN, the study of celestial phenomena were not considered as compelling, or useful, as a field of research on which millions should be spent – despite the introduction of the space age by Sputnik by 1957. The astronomers were faced with the important task of formulating and mediating the means and ends of the project so that the granting authorities would be convinced.

In 1962, another European scientific enterprise surfaced. The European Space Research Organization (ESRO) was founded, which later formed the basis of the European Space Agency (ESA). Two years earlier, a preparatory ESRO committee had been signed by eleven European countries and in 1964 and the ESRO convention entered into force in March with ten founding states, including Denmark.[122] ESRO worked for the technical development of a rocket program and of satellite activity in the ultraviolet frequency range of light. An important subpart of ESRO was the ELDO and the LPAC. ELDO, the European Launcher Development Organization was also founded in the 1960'es for the development of a satellite vehicle, but Denmark withdrew from it in 1965.[123] On the contrary, the Launching Programme Advisory Committee (LPAC) was met by Bengt Strömgren's commitment.

His activity in international research policy can be exemplified by the following line of events. He was elected member of the LPAC committee the year of Neil Armstrong's 'giant leap for mankind' on the Moon and he stayed in the committee until 1971. Bengt took active part in debates concerning the satellite program. He shared the opinion with some of the other members that ESRO's satellite program could perhaps be linked to a type of orbital observatory, a space station. In the late 1960'es, NASA offered to have ESRO's collaboration in the development of such a space telescope in the UV range, scheduled for launching in the mid-seventies. Bengt strongly recommended the idea to the ESRO Council and he sketched a plan in which ESRO would pay 2-4 million dollars and be reciprocated with one third of the total observing time. According to Krige & Russo 2000, writing in detail about the history of ESRO and ESA, the idea "generated enthusiasm […] among scientists who are worried about the future of UV astronomy in Europe".[124] Ultimately, LPAC accepted the plan.[125] By 1971, the Danish delegates considered seriously leaving the space cooperation due to a phase of transition in the ESRO as the considerations and

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[122] Krige & Russo 2000, 38, 64-65. The ten countries counted Belgium, Denmark, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland, and England. Norway, having been in the preparatory committee of 1960 chose to withdraw to observing status.
[123] Ibid., 294.
[124] Ibid., 229, 333.
[125] In 1977, the American Congress voted to fund the project of a space telescope and construction of the Hubble Space Telescope (HST) began and was completed in 1985 but the HST was only launched in 1990 due to the Space Shuttle Challenger disaster.

activities in Denmark in relation to ESRO and ESA roughly in the period 1964-1990 has been recounted recently by the Danish professor Preben Gudmandsen with the Danish Technical University. Here, we will not get into these details but rather leave the digression of ESRO involvement by merely mentioning the source for further reading.[126]

Returning to the development of the southern observatory, in 1961, England withdrew from ESO to the benefit of an Australian Commonwealth Observatory. The same year, representatives from the five remaining countries signed the ESO convention. The mission of the enterprise was to "establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organizing collaboration in astronomy".[127] The convention needed to be ratified though, before the Ford grants would be released. The three countries of the Netherlands, Germany, and Sweden ratified the ESO convention in 1963 and the next year, France followed suit. Finally, the Ford Foundation grant was released. Only Belgium still needed to ratify the pact. Hence, with a seemingly viable project at hand, Reiz found it easier to convince Danish authorities of a Danish incorporation in the promising big science project.

After extensive investigations it was concluded that the observation conditions were far better in South America than in South Africa. In the La Silla desert in the Chilean Andes Mountains, the strict climatic demands of the astronomers could be met by more than 300 clear nights per year. La Silla was chosen formally in 1964, originally scheduled to be the year of completion of the whole project. Then, in 1967, the year of the beginning of construction work in Chile, Reiz succeeded to have the ESO convention ratified on August 23, 1967, followed by Belgium two months later. Denmark came in out of the cold.

Two members of each member country were required as members of the ESO Council. The Danish members became professor Reiz and Otto Obling from the Ministry of Education. Reiz was also elected as member of committee of

[126] Gudmandsen 2003.
[127] www.eso.org.

Figure 17: The Strömgren Automatic Telescope, La Silla, earlier the 50cm telescope at the Brorfelde Observatory. Moved in 1968, set up in 1971, and put out of action in 1997 (www.eso.org).

buildings while Obling held a post in the ESO financial committee. Bengt was soon elected member of both the Scientific Committee and the Committee for Instruments. When it was decided that the observation time of the individual countries should correspond to the amount of economical shares in the community of member states, it proved important for small Denmark to work for the erection of national observatories on La Silla. In this way, the limited observation time at the shared large telescopes could be combined with observations at exclusively Danish telescopes on the same latitude.

Even though Denmark was not among the first member countries of ESO, the Danish astronomers and technicians managed to rapidly set up telescopes and begin research, especially owing to the intensive and longstanding preparatory work with the Brorfelde project. This national project had thus entailed the establishment of a solid basis of experience and as already discussed, perhaps

Figure 18: The Danish 1.5m telescope, set up in 1979 as the third in the series of new telescopes in Chile (www.eso.org).

this constitutes one of the most important impacts of the branch observatory as a preparatory means.

In 1968, another ESO committee was created for the scientific programs, proposing the erection of a central institution in Europe. This was meant to serve as a meeting place for European astronomers and as a center for the development of new equipment. Concurrently, the first 61cm common telescope was ready for the first test and one year later the official opening ceremony took place in Chile. In Denmark, the plans of moving Brorfelde’s 50cm telescope to Chile was nearing consensus and already by 1971, the telescope was functional under the new name, the Strömgren Automatic Telescope (figure 17).

Already in the beginning of the 1960’es, the build-up of a 1.5m reflecting telescope had surfaced (figure 18). From the start it had been obvious that the observation conditions in Denmark were too limited to justify the set up of such a large and expensive telescope in Denmark. Under the condition that Denmark would eventually become members of ESO, the Chile territory came naturally as the right site for set up. Following the accession to the membership, Reiz formulated an application to the ESO Council, the plans of which were endorsed in June 1969. The Council allocated a maximum amount of $210,000 for the construction of the telescope on the premise that ESO was at liberty to use half of its observations time in the first five years.

The project profited from Bengt's experience from the build-up of the KPNO and using technical drawings from a sixty-inch reflecting telescope at the Cerro Tololo Inter-American Observatory – elsewhere in Chile – this instrument served as a prototype for the future telescope.[128] The Carlsberg Foundation and the Royal Academy of Sciences and Letters subsidized the project financially and the telescope was functional in 1979.

In 1971, a successor of the original Scientific Programmes Committee from 1967 was set up, namely the Scientific Policy Committee. Bengt Strömgren was the chairman in both committees until he was elected president of the ESO Council in 1975, which was a highly prestigious position.[129] Although no Nordic astrophysical institute was ever created, in his late years, Bengt suggested the initiation of a Nordic optical telescope cooperation. By the use of funding granted by the Carlsberg Foundation once again, Bengt Strömgren and Anders Reiz directed a study which – after protracted discussions and several formulations of applications – led to a grant of eight million Swedish Kroner in 1983. Immediately, the four Nordic countries managed to collect an additional amount of twenty-one million Swedish Kroner and the Canarian Island La Palma was picked as the site for the so-called 2.5m Nordic Optical Telescope (NOT). La Palma also became the domicile for the still functional meridian circle from the Brorfelde Observatory. It was finally decided to move the meridian circle the same year. The action of moving such an important instrument must be regarded as a clear and final indication of the fact that the research status of the Brorfelde Observatory was then given a lower priority than ESO in times of increased internationalisation.

[128] Reiz 1970.
[129] Blaauw 1975.

The membership of ESO perfected the working possibilities and job opportunities of Danish astronomers. It was possible to get involved with empirical investigations of objects like the galactic plane and the Small Magellanic Cloud, both located on the Southern hemisphere. The eminent seeing meant furthered possibilities of Danish researchers to observe celestial objects with a hitherto unseen sharpness. In collaboration with astronomers from other countries, they had the opportunity of collecting research data of previously unknown accuracy. In addition, it was now possible to treat large amounts of data at home, after collecting them during the granted, if often limited, observation time abroad. They could now participate in measuring the universe by the use of the best geographically located eyes in the world directed towards the back of beyond of the universe. Once again, Denmark was taking part in the forefront of international observational basic research in astronomy.

Epilogue

Having treated the technological development of Danish astronomy we will briefly investigate the empirical and theoretical research done at the Copenhagen and Brorfelde Observatories, to which Bengt remained active to the end. In the list of citation indices of Bengt given in appendix E, three scientific papers appears in the period 1967-1987, the first two of them being joint articles published in 1976 and 1982. In 1976, Bengt and his Danish colleagues B. Grønbech and Erik Heyn Olsen wrote a paper on *uvby* photoelectric photometry of 134 standard stars made using a spectrograph photometer in Brorfelde as well as the Danish 50cm reflector on La Silla. According to the ADS, this paper turned out to become Bengt's third most cited paper in other astrophysics articles with 211 citations.[130]

The second paper selected here was published jointly by Bengt Strömgren, Bengt Gustafsson, and Erik H. Olsen once again. Gustafsson worked at the Uppsala Astronomical Observatory inaugurated in 1853, while Olsen was associate professor at the CO and worked intensively on photoelectric

[130] Strömgren, Grønbech & Olsen 1976. see appendix E.

photometry at Brorfelde for many years. The paper was a follow-up on a 1966 paper by Bengt and David Crawford mentioned on page 411, in which the location in the H-R diagram of certain un-evolved stars was discussed. With improved theoretical calculations, the paper advocated that helium abundance differences between stars in the Hyades constellation and field stars indicated low pre-stellar helium abundance for the Hyades.[131]

Latterly, Bengt published a paper in 1987, in which Erik H. Olsen was thanked sincerely in the acknowledgments paragraph for making a large data file containing a table of values of crucial parameters in the study. It was an investigation of the relations between age, chemical composition and kinematics, which was based on *uvbyβ* photometry of F stars within distances of 100 parsec. This turned out to be the final paper written by Strömgren. It was published only a few months before he died on July 4, 1987, following a short period of illness.

A life engaged in three major fields of astrophysics had ended, with the problems of chemical composition of stars, of interstellar gas, and of photoelectric photometry as the means in the search for understanding the history and development of our Galaxy. The life of Bengt Strömgren, the son of Elis, was a life with the stars. Bengt did not only inherit talent and industry from his promoting father and his intellectual mother, he also became the heir of his father's international perspective on science; Elis worked so hard for making his contemporaries understand and outlive his view, avowed by Pasteur already in 1884, that science is not national, but scientists are.

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[131] Strömgren, Olsen & Gustafsson 1982. This paper became the sixth most cited of Bengt's papers, cited 60 times elsewhere (see appendix E).

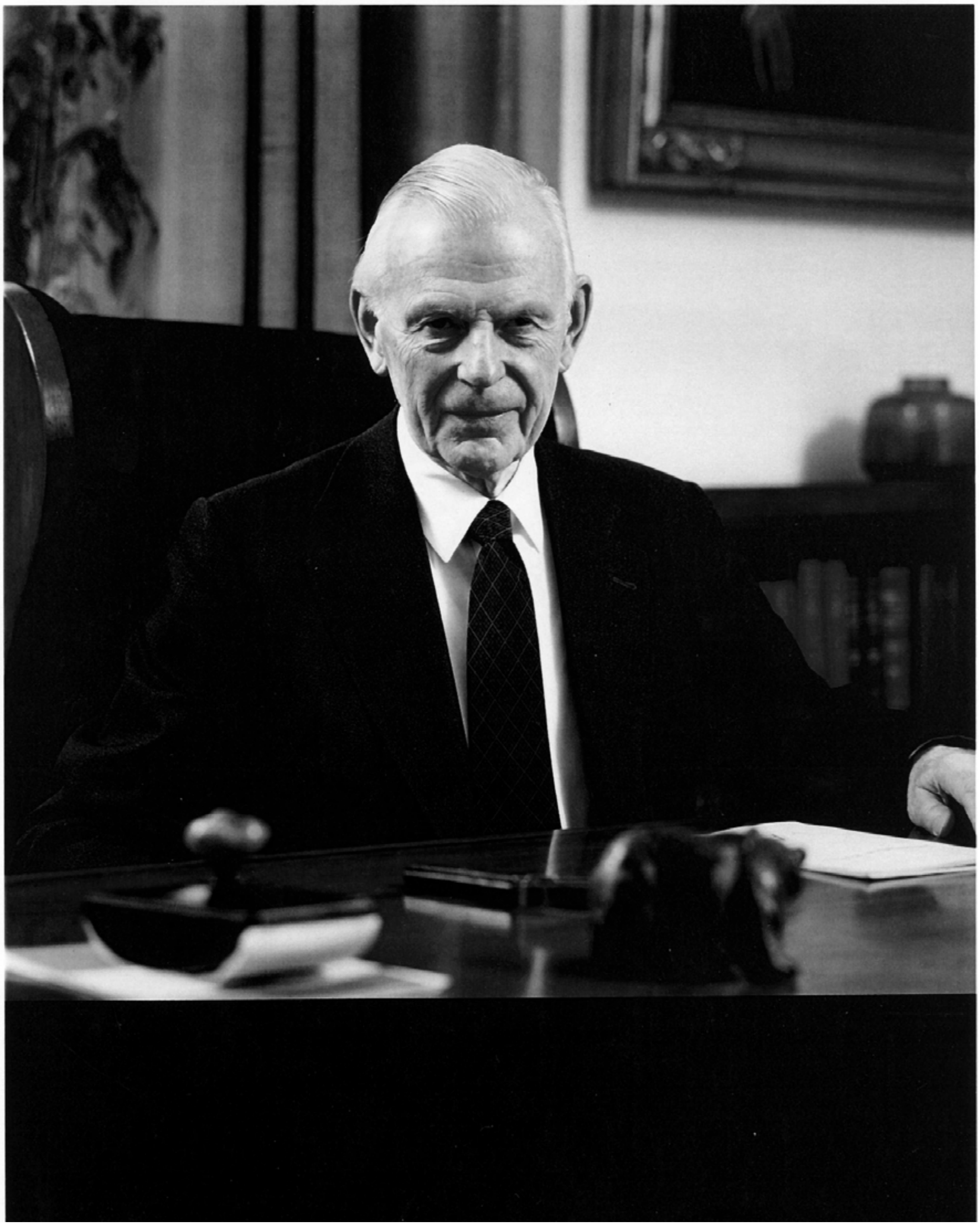

Figure 19: Bengt Strömgren at his desk in the Carlsberg Mansion of Honor, the 1980'es (courtesy of Karin Strömgren Campbell).

Nine

Coda
Summary and Concluding Remarks

In this chapter, I will summarize the preceding chapters and draw attention to some important features and characteristics of this historical study in the history of astronomy and astrophysics in the twentieth century, especially its first half. The investigation covers a rather extensive span of time and numerous questions as to the development of astronomy have been addressed and treated throughout the text. Viewing the chapters as one coherent narrative, the mere reading hopefully answers many of the questions and the bulk of the text constitutes in itself an important result of my three years of study. Firstly, I will summarize the main results from each chapter, including conclusions from the respective studies. Secondly, the dissertation will draw some main threads from the various chapters and point at the most important conclusions resulting from my study.

9.1 Summary

Summarizing the respective chapters hopefully serves a double function. Firstly, their content will be recapitulated and contribute with an overview of the general idea of each chapter. Secondly, the main conclusions will be outlined. We begin with the historiographical introduction.

One: Presenting and Representing Science

In a currently disputed literary biography of Søren Kierkegaard (1813-1855) by Joakim Garff, the narrative sets off in 1855 with the interment of Kierkegaard at Our Lady's Church in downtown Copenhagen.[1] While reading it, I was at once confronted with the subject of the biography, the Danish philosopher, with his network, his relatives, friends, and colleagues. At the same time, the feeling of the passing of time and the span of a whole life was set in a nice perspective by use of this much-used literary trick and accordingly I did that in the opening of chapter one.

Having treated the genre and role of biography, literary as well as scientific, I have tried to head out with the historiographical background and general concerns of writing the scientific, or existential, biography of Bengt Strömgren. One main concern is that of abstaining from writing a biography of a scientific *hagios*. I agree with Thomas Söderqvist that it is virtually impossible to completely prevent the traits of hagiography and panegyrical history. One reason for this is the mere fact that the historian focuses on one person only most of the time and therefore is at risk of loosing track and becoming biased, one-eyed, or even blind concerning other relevant issues than those connected with the investigated subject. Hopefully, the degree to which this has been the result of my dissertation is vanishing, despite my claim that the utopian ideal of an unbiased history of the past is inherently unachievable. In chapter one, I claim the possibility that 'myth breaking entails myth making'. With a bit of luck, however, this story appears for the reader be a nuanced work of, perhaps not a conscientious enemy, but at least of a critical historian of science (not a 'pathographer', for sure).

I find the representational aspect of biography to be a potentially dangerous enterprise. In particular if the biographer sets off with representation as being the initial mental framework and historiographical aim of biography. In that case, scientific biography appears to be a shady genre. If history of science is intended to display scientific communities also as institutionally based cognitive disciplines in a Merton sense, we need more than the idea of representation, we

[1] Garff 2003.

need a variety of aspects of science. In the attempt of displaying these communities in a scientific biography, we need to underline the effect of specificity and ‘eventualization’. I do not regard “the Father, the Son, and the Stars” to be a representation of the scientific community as such. Rather, it is a narrative of a unique series of events, taking into account relevant characteristics of the scientific community with which the subject interacts. If the outcome of this enterprise is an additional lesson about more general aspects of the community, the general practice of astronomy, the dynamics and networks, etc., then I regard it as a positive supplement. I believe that this is indeed the case. All the time, though, the reader ought to bear in mind that such upshots have appeared from the biographical perspective. On the other hand, naturally, the aim of this scientific biography is not only for the reader to learn about Bengt Strömgren. Squinting at his father, his family, his colleagues, his friends, the surrounding scientific community and culture, I try to place him in a general social and scientific framework. My historical reasoning has been not to regard Bengt Strömgren as a means of *representation* of astronomy (a mirror or prism) but rather as a means for a *presentation* of his scientific field.

The so-called postmodern “revival of narrative” has worked as a counter current to the somewhat teleological, or Marxist, history writing. However, modern tendencies towards a documentary style, a down-to-earth, or more neutral style of history writing has perhaps a seamy side, as it has been accused of losing its audience. I do not share this opinion. This postmodern challenge has had it out with Marxist history writing by returning to primary sources and a general interest in the peculiarity of the archival sources, in the so-called “telling quotation” – and even in a “telling photograph”. If my narrative has elements of anti-structuralism, then perhaps it is not all wrong. Although structure and theme obviously have important mediation features, I believe that a surplus of structure may be at risk of distorting the story of the diversity of life – in particular in the case of biography. A strong structure may entail the making of chimeras, creations of the historian’s imagination, metaphysical theories of causality, or causal chains of premises and consequences.

Postmodernism is perhaps better described as a mood, phase or period of thought than a particular school of historical theory governed by specific interpretative tools. Throughout my study, I have been somewhat hesitant about the very strong interpretive approach and I always accept wishes for more reflection. However, I am seldom convinced by the big, solemn, epic biography: The grand interpretive synthesis, themes leading to grand conclusions, hero- or villain figures – it seems to me rather implausible as such. Too strong theme may entail rigidity or inflexibility regarding the diversity of the series of past events that make a life.

My historical reasoning has been not to regard my subject as a means of *re*presentation of science but rather as a means of a presentation of science. A *re*flection of the surrounding scientific world – and hence a *re*presentation of science – through the subject, is not what I have in mind, as I consider it to be perilous. The portrayal of an age, an era, a context, or a development in time must consist of numerous specific events and actors. A potential downside of this approach, however, may be that the reader experiences the story to have impressionistic traits.

The structure of Bengt Strömgren's scientific biography is largely chronological and I acknowledge the snares of loosing the line of development of certain themes such as the development of the theories of stellar structure. This topic could have been treated thematically instead, and perhaps it would have given a better result without numerous interfering biographical details. However, my approach has instead placed Bengt Strömgren in a central position in the series of events, and hopefully the narrative does not suffer from artificial isolation, let alone artificial integration.

Finally, it is my intention that the various historical methods entertained by me convey to the scientific biography a somewhat more general view of science than only that of the individual-focused Victorian 'Life and Letters' narrative: the 'retrospective psychological' approach sketched in the end of chapter one concerning the generational aspects of science; the 'existential biographical approach' in chapter three; the somewhat internalist approach to the cognitive development of the hydrogen hypothesis in chapter four; the comparative and contextual approach and the social network investigation of chapter five; the somewhat general history of the observatory during the occupation in chapter six; the institutional narrative of the build up of the Brorfelde Observatory in chapters five to eight; the intimate unveiling of the break-up of a warm friendship between Bengt and Chandrasekhar in chapter eight; the brief report of the series of events in Bengt Strömgren's later years leading to his reputation of being an internationalist researcher working for Danish research policy and perhaps even working as an 'ambassador' of Danish science; and finally, the institutional history of scientific organization of Danish involvement in the big science project ESO. The title of this dissertation includes the three chief aspects of my dissertation, the father, Elis, the son, Bengt, and the stars, astronomy. I believe that the chosen fragments of the mosaic of modern astronomy make up apposite choices in my quest of answering the four posed questions in the preface to understand the historical development of the field.

Two: Scientific Style and Heritage

The historical background for Bengt Strömgren constituted a scene in which the tradition of classical astronomy and numerical methods prevailed. Thiele and Pechüle's work on photoelectric and visual observations and astrometry in general constituted the basis on which Elis would proceed as the new professor of the Copenhagen Observatory in 1907. With Elis, more focus was directed towards theoretical astronomy, especially the three-body problem and related astronomical calculations using numerical methods.

In the chapter, I briefly introduce the scientific background and heritage of Bengt Strömgren. The most important Danish astronomers are introduced (Thiele, E. Strömgren, Hertzsprung, R. Andersen, and Luplau Janssen), their observatories and their daily activities and tasks of Danish astronomy are treated in the chapter. Furthermore, the idea of a branch observatory outside the Danish capital is launched as a precursor of the institutional narrative of the Danish

Brorfelde Observatory, which was coined by Bengt Strömgren in 1938 but only made real more than a decade later, after Bengt had left Danish astronomy.

Elis and Hedvig Strömgren are introduced biographically and a the previously, historically non-treated nomination of Elis Strömgren for the Peace Prize has been incorporated as it also tells the story of Elis' work for internationalism and conveys an understanding of how he was conceived of among his European colleagues. The Danish and Scandinavian community of astronomers is presented and hopefully the chapter gives the reader some familiarity with the scientific community and national activities and its international influences, which, apart from Sweden, were centred around Germany and England, France and Russia, and of course, gradually more, the United States.

Three: Upbringing and Inspiration, 1908-1929

The childhood, adolescence, and the private and public education of Bengt have been recounted in chapter three and I have scrutinized the influences of his parents. Bengt's numerous activities following his father's footsteps in the AG and the IAU introduced him to international research at a very early age. I have tried also to underline the creative reasoning of Bengt in the case of the advent of his technological innovation of automated photocell-astrometry and the public image of the young astronomer has been inspected.

Through paternal encouragement and pacing, as well as through personal aspirations, Bengt Strömgren's scientific career began at a very early age. After several years of various scientific work with observations and numerical calculations, Bengt's career choice was evidently inspired by Bohr, Klein, Kramers, and other lecturers and researchers at the UITF. Clearly, Bengt was at the right place at the right time. The spirit and the stimulating environment during Bengt Strömgren's student years at the UITF were of great importance to his program of applying new physics in astrophysics. While Elis Strömgren represented the tradition of classical astronomy and trained his son in those fields, Bengt Strömgren turned away from this tradition at the time around the

Great Depression. Instead, he focused on how to apply quantum mechanics to theoretical astrophysics while using his great experience with numerical integration, transferred from classical fields such as cometary orbit calculations. This inspiration had a considerable impact on his early astrophysics research, as well as on his later investigations, as it built on his strength in meticulous numerical computations, which brought astrophysics into the footsteps of quantum mechanics, as recounted in chapter four.

I have also emphasized Bengt's Eohippus allegory to show that early on, he prompted a belief to hold for his entire life. The function of scientific research should be directed by principles of curiosity and broad perspective and the scientific inferences – however weak – should be taken for the sake of the big perspective. Finally, Bengt's doctorate and marriage are described in concert to get hold of not only his scientific life but also his wish to make a private family of his own.

Four: Restoring a Scientific Field in Denmark, 1929-1936

The consequences of the Great Depression for the Danish field of astronomy have been investigated. The account of the Carlsberg Foundation grants in the period 1921-1970 constitutes an unprecedented study of the flow of philanthropy funding to Danish astronomy. Furthermore, the graph (figure 1, chapter four) displays the effect of Bengt's leave from Danish astronomy, as investigated in later chapters. Chapter four depicts Bengt's activities as a popularizer, his collaboration with amateur astronomers, his academic life of teaching and scientific production (publication of papers and textbooks) as well as his private life, marrying and making a family. Moreover, Bengt's meeting with prominent astrophysicists of his time has been recounted, in particular Chandrasekhar and Milne, the cosmology of whom was followed by Bengt.

Most importantly, the chapter focuses on Bengt as the driving force of restoring the field of astrophysics in Denmark as a central area of theoretical research by his stellar model studies. An effective impact of quantum mechanics on astrophysics in the 1930'es was the revised theory of the internal structure of stars. Of particular importance were two physical properties of stellar matter, *viz*. the calculation of opacities and the rate of energy production, the latter being followed up by Bethe in the years to come. The development of quantum physics in Copenhagen had considerable impact on other fields of science, including the reform of astrophysics at the Copenhagen Observatory. The significance of Bengt's and Eddington's parallel discovery of how the light element preponderance could solve the opacity discrepancy is most clearly seen from the results of later comparisons, performed by Bengt in 1937, between model stars and observed stars positioned in the H-R diagram. Hydrogen was not only abundant in main sequence stars, it was superabundant.

Bengt was instrumental in transferring his inspiration from the UIFT to his father's astronomical institution. His insistence on bringing the novel quantum physics (in)to the stars resulted in new theories of stellar chemical structure – and later of interstellar space – and ultimately the hydrogen preponderance in the entire universe. According to the astronomer Bancroft W. Sitterly, Bengt's stellar model was too simple, though. Milne, Cowling and others had proposed more refined ones and "the assumption that all stars originated and developed similarly was probably too simple also".[2] Nevertheless, a plausible and coherent course of evolution was sketched out by Bengt, which generally agreed with the observed data.

Bengt's early work constituted the first step taken in a new and fruitful direction towards the hydrogen hypothesis that went back to quantum mechanical calculations undertaken by Sugiura and Gaunt in particular. The abundance of the light elements in stars and hence in the entire universe was on its way to be uncovered. Eventually, it became clear to Bengt that it was necessary to consider the helium content of stellar interiors as well, along with their content of hydrogen and heavier elements, the story of which is covered in the following chapters. Bengt's numerical style turned out to be essential for the new astrophysics and, contrary to hypothetical-deductive methods undertaken by

[2] Sitterly, 1970, 363.

Eddington, Jeans and Milne, it has remained so ever since. Finally, Bengt's efforts helped securing Denmark a significant position on the international scene of theoretical astrophysics.

Five: Local Contexts and Scientific Networks, 1936-1939

The Strömgren correspondence is used as a means of understanding the relationship between father and son and the transfer of knowledge, but also as an instrument of comparison of two different, contemporary institutions. As accounted for in chapter one, the comparative method in history often has the thematic approach as central to the process. The historical development of Danish astrophysics resulted from the transfer of knowledge between Denmark and foreign countries, in particular the USA. The preceding three chapters can be read as a cross-cultural comparison regarding many aspects.

Chapter five makes up a detailed comparative study of two local contexts, the astronomy departments in Copenhagen and in Chicago. Clearly, moving to one of the largest American observatories proved influential to Bengt and in due course for Danish science. The differences between Danish and American science were manifold and few were the similarities. Of the list of important features that make a science and that also make the local context, the factors are legion: The individual scientists, the objects of science, the manipulated instruments, laboratories and observatories, the buildings and institutions of science and their staff, the local community of scientists of a particular field of science, the dissemination of science and its public image and understanding, the appropriation of science, and the scale of research, financially and instrumentally.

Notions of mental locality, cultural locality, social locality, and national locality are rather difficult to identify. It is not obvious how we can operationalize the concepts of nation and of science. I am tacitly using the concept of nation as a way of separating scientific traditions, styles, practices, etc. Yet, perhaps culture (or mentality) makes up better means of differentiating. Nevertheless, it is more challenging to draw these borders, obviously, than with nations. The national grading has been used in the case of Denmark vs. America. In chapter four, however, I have tacitly employed a culture grading in the case of continental vs. British science. Finally, some mental grouping is often made between Scandinavia and the rest of Europe. Science can be claimed not to be national while scientists are; many a scientists have claimed that science, as a set of theories of nature, is universal and not local in any way. The border between notions like culture, mentality and nationality may appear blurred. Though, it is clear that e.g. national appropriation of science has been an all-important factor of scientific endeavour and therefore science can be – from the economical point of view – very national indeed. The many in-between aspects of science contribute to a nuanced picture of science in society, and this makes a good reason for studying them in all their specificity – in all the ways in which each locality is unique. The shaping of unique events – the eventualization of past occurrences – comes about by approaching them from different angles, and it is my hope that I have succeeded in my historical investigation of Bengt and Elis Strömgren's actions.

The relationship between Bengt and Elis, being collaborators, colleagues, friends, and family, had an important impact on the choices and research actions of Bengt. More importantly, though, their relationship serves as the key to our glimpse into the diverse activities, thoughts and events in the two local contexts of Willliams Bay and Copenhagen. In the case of the Yerkes Observatory, the collective feeling of solidarity among the group of researchers living around the observatory was important for the social thriving of the individual scientists and thus for science itself. Drawing from the American astronomical tradition and style suited Bengt well, including a familiar numerical approach, salaries, attending students, scientific knowledge and practice, and instrumentation based on a different economical scale than Bengt was used to in Denmark.

Regarding the appropriation of science, the university system and flow of funding, public expenses dominated the support of Danish research, besides philanthropists like the Carlsberg Foundation. In contrast, the expenses of American research were controlled by user's fees. The publication of research done at the Yerkes Observatory was published through the important paper, the *Astrophysical Journal,* which was edited by the observatory director and this mediation channel became accessible also to Bengt. In Denmark, the publication of important research in the 1920'es and 1930'es was customarily publicized through German journals like *Zeitschrift für Astrophysik*, or British periodicals like the *Monthly Notices of the Royal Astronomical Society.* Therefore, they did not have the same proximity for the individual Danish scientist, as was the case in Williams Bay. This was also the case for Bengt, as his numerous publications before 1936 were naturally issued in Scandinavian, German, or British Journals.

Bengt's research plans for his stay in the USA reflect the difference between the two contexts of Danish and American science. Work not possible to carry out in Denmark was multifarious: close cooperation between theoretical and practical astronomy; Spectral photometry, requiring comparisons between theory and experiment; looking for scientific confirmations and refining both theory and experiment; and practical work on geometrical optics. Of the tasks that would actually have been possible for Bengt to undertake under the roof of the CO, had he stayed in Denmark, purely theoretical astronomy of all sorts would have been the most obvious activity apart from continuing his work on photoelectric registration. In addition, theoretical work on geometrical optics was a topic that was reachable without large telescopes – a subject he in fact investigated thoroughly during the Second World War in "relative isolation".

As Chandrasekhar pondered, "the impact on astronomy of foreigners going to the USA was considerable".[3] Numerous ideas from foreign countries had made their way to further the development of astronomy and to lay the foundations of many theories of nature. Bengt and Chandrasekhar's stellar models turned out to contribute considerably to the establishment of our understanding of stellar interiors as well as e.g. Bethe's carbon cycle and proton-proton process from 1939 is now a central part of astronomy.

One promising idea of Bengt's was the plan of future collaboration between Danish and American astronomy after his return to Denmark in 1938.

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[3] UCA, SCI, 71.

Attempts were made, although the Second World War ruined the practical realization of the plan. After the war, the situation was new, in spite of the best intentions. Bengt himself went to the States again in 1947 and in 1951 for a long period, and this became ultimately fruitful for Danish astronomy. At the same time, his stay in the States resulted in delaying the branch observatory project, as I argue in the subsequent chapters. In general, Bengt's visit to the States was very influential for Danish science. He was the first to introduce theoretical astrophysics lessons, firstly in Denmark, secondly in the USA. After his visit, Struve absolutely wanted Bengt ahead of all astronomers and as already discussed above, one consequence of Bengt's discovery of the preponderances of hydrogen and helium in stellar interiors reduced the possible scenarios ready for investigation by the theoretical physicists.

Bengt's scientific contributions, as the "ace" of the Washington joint venture between astrophysicists and theoretical physicists, proved to be essential in the further development of theories of the sources of stellar energy generation. The historical narrative of Bengt's interaction with Hertzsprung, Struve, Gamow, Chandrasekhar, Bethe, Landau, and Weizsäcker covers the series of events in hitherto unseen detail. The state of science in Germany is also traced for the purpose of understanding the conditions to which German astronomers were subjected.

The advent of Bengt's ideas of the interstellar HII – or Strömgren – spheres has also been inspected. His 1939 paper on the physical state of interstellar hydrogen marked a watershed in how astronomers viewed the interstellar medium. The paper, judged by the astrophysicist C.R. O'Dell in 1999 as "an example of clarity", rapidly became accepted by the scientific community. Besides many other scientific contributions, Bengt Strömgren's work on the eponymous objects "is what seems to be mostly remembered today".[4] Looking at the significance of his research in hindsight, O'Dell even indicates that the paper made up a paradigm shift in astrophysics, although this seems to be an

[4] O'Dell 1999.

overstatement.[5] In the terminology of Kuhn, there were no anomalies leading to a crisis of normal science, and there was no scientific revolution as such.[6] Furthermore, there was no case of incommensurability between pre-1939 theories of interstellar matter and theories subsequent to Bengt Strömgren's paper. It was not revolutionary. Notwithstanding, it is today judged as the ultimately important eponymous "paper that gave us the Strömgren spheres".[7]

Finally, the scientific network of Bengt in the late 1930'es is investigated by two methods, giving hints as to who were close to Bengt and who were regarded to be more distant colleagues of Bengt (and Elis) Strömgren. It is concluded that this case exemplifies the fact that historical investigations of networks using correspondence studies constitutes a very weak, if at all useful, external study. Luckily, the list of recipients of proofs to be distributed made a better alternative. The resulting network could therefore be mapped out of luck: Not all historians of science will have the same luck of finding such informative distribution lists!

Six: Politics and Isolated Science, 1940-1945

Being based on relatively meager archival material, this chapter is also rather limited in new findings and conclusions. One thing emerges as an interesting finding, though, namely the fact that the two Strömgren professors were actively involved in arranging and participating in the 1941 astronomical working week. This week has been highlighted since Michael Frayn's play *Copenhagen* was produced in 1998, the discussion of which provoked the release of new documents by the Bohr family for the unraveling of the series of events taking place when Werner Heisenberg met with Niels Bohr in 1941. Working in relative isolation, it is understandable, from a scientific point of view, why Bengt agreed to participate in the event, while the staff of the UITF declined to take part in the German arrangement from political reasons.

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[5] "How the paradigm has shifted", O'Dell 1999, 322.
[6] Kuhn 1962.
[7] O'Dell 1999, 322.

The strength of the relationship between Bengt Strömgren and Chandrasekhar can be read from their infrequent, if intense, correspondence, especially after the liberation, as becomes apparent in chapter seven. Bengt took care of domestic duties and tasks as the new professor of the Copenhagen Observatory, he helped his brother with calculations, and he worked for the popularization and mediation of his scientific field. Most importantly, he worked for the prospected branch observatory in a time where the acquisition of funding was a more difficult enterprise than ever. Luckily, the birthdays of Ole Rømer and Tycho Brahe helped furthering the development of the project. Finally, it is rendered probable that Bengt was actively working for the resistance movement by mediating confidential information and perhaps even hiding secret documents in the basement of the observatory.

Seven: Science Goes On, 1945-1951

Following the liberation, hopes for the future arose also among scientists. It was times of Scandinavian and international unification of astronomers and the 1946 Copenhagen meeting became important, if not scientifically, then politically and of solidarity and social reasons. At the same time, the meeting became the last international event attended by Bengt's father, who died the following year. Already during Bengt's research visit in 1947, Bengt kick-started his future field of research: narrow-band photoelectric photometry. At least three non-scientific factors contributed to the motivation for Bengt Strömgren to accept Struve's offer to a position in Williams Bay as the succeeding director and professor: The loss of Elis was also the loss of a strong bond to Denmark; the bad general conditions for Danish scientists played an important part also; and finally there was the protraction of the Brorfelde enterprise.

The growing antagonism among the permanent staff in Williams Bay against Struve entailed the substitution of Bengt to be warmly welcomed and the efforts by the Carlsberg Foundation of keeping Bengt in Denmark were in vain. The prize was too high to pay for his science in his long wait for the national institution building to get going. On the other hand, going to the States had positive prospects for Danish astronomy as well, as Bengt intended to work actively for the cooperation between the Chicago and Copenhagen departments of astronomy.

Eight: Managing Astronomy, 1951-1987

The concluding chapter has a thematic approach and ranges over a longer period of time than any of the preceding chapters. Bengt's going to the USA and his activities as general secretary of the IAU is treated. Academic life in the 1950'es at the Chicago campus and in Williams Bay is depicted and the clash between Bengt and Chandrasekhar is analyzed by means of a collection of sources, which have not hitherto been combined, to the best of my knowledge. The growing discrepancies arose from Bengt's curriculum changes, his directorial style – according to Chandrasekhar – and to some extent already from the appointing procedure of making deals unknown to the acting chairman, Chandrasekhar.

Moreover, I touch upon the emergence of narrow-band photoelectric photometry, realizing that a thorough investigation requires further archival research which is outside the scope of this dissertation. The narrow-band photometry worked also as a means for the planned co-operation between Williams Bay and Copenhagen, which had been projected by Bengt already in the late 1940'es.

The fate of the Brorfelde Observatory is investigated in chapter 8.3, which turns also into a study of modern Danish astrophysics in the post-war period. Fresh individual forces like Reiz, Gyldenkerne, Rudkjøbing, and Naur are portrayed, along with the advent of electronic computing and its growth as a gradually more important means of complicated astrophysical calculations. The Computing Central and Naur's work for Danish computer power is also briefly sketched.

Perhaps Bengt Strömgren did not make his own school of astrophysics, but as accounted for throughout this dissertation, he was of significance not only as judged by his contemporaries but also as considered by later generations of astronomers. Following Bengt's leave to Princeton in 1957, where he stayed for ten years, an account of some of the most important honorary awards and medals is given, as is his involvement in the Kitt Peak National Observatory. After sixteen years in the States, a brief account of his return to Denmark in 1967 is narrated, in particular his correspondence with his friend Christian Møller. Furthermore, I present Bengt's most important organizational commitments as director, president, or general secretary of numerous institutions, e.g. NORDITA, IAU, the Royal Danish Academy of Sciences and Letters, and ESO. Danish involvement in the big science adventure of ESO concludes the chapter by paraphrasing existing historical literature, supplied with further domestic aspects from a Danish perspective.

9.2 Concluding remarks

The aim of this dissertation has been to answer a series of questions as to the history of astronomy in Denmark (and abroad) in the twentieth century. Let me rephrase the four main questions below:

- How did the field of astronomy develop in Denmark in the period?
- How can the rise of Danish astrophysics be explained and what was its basis?
- What was the impact of Bengt Strömgren on the development of the field of modern astrophysics, on the scientific community, and the public image of the field, nationally as well as internationally?
- If the father-son relationship between Elis and Bengt Strömgren did affect the developments, to what extent what this the case?

I believe that I have succeeded in the task. In the beginning, I set out the cultural and scientific context as a background for understanding the heritage of Bengt Strömgren. The substantive bulk of the historical study takes place in chapters two to seven, covering the time from the interwar years to early post-war years. Chapter eight follows up with the further development in the post war period from 1951 onwards and investigates the international significance of the Danish astronomer.

The development of the field of astronomy in Denmark has been traced and investigated with the Strömgrens as a natural turning point. At the same time, throughout the dissertation, a number of other noted scientists have been biographed to various extents. In this way, this scientific biography has turned into a sort of collective biography of the field of astronomy in the twentieth century, in particular in Denmark. I have studied the relationship between father and son and perhaps the investigation has contributed to displaying the making of science to be more human of lively, also using a variety of contemporary photographs. It has been my intent for the history of the father-son relationship to demonstrate some of the human forces in play in scientific communities as well.

I have attempted to treat the international importance of Danish astronomy and the influences from the international scene in a nuanced and detailed biography of the most important Danish astronomer of the twentieth century, which has not previously been written. The idea of history is not only to tell untold stories. Hopefully, history also brings forth new views and fresh perspectives of the events of the past, which made up what we are today. It is my hope that this historical narrative sheds new light on our view of the past. It is my intention that it brings new perspectives on scientific theory, reasoning, and practice as well as on the diverse external aspects of science and I trust that this scientific biography functions as more than a mere building mechanism of national identity or pride.

My argument is that Denmark was of considerable importance to international astronomy, especially through the work of Elis and Bengt Strömgren. But also that his stay in the USA strengthened American interests in Danish science, as manifested by active co-operation by means of the transfer of knowledge and scientists. I have contributed to existing knowledge in the history of modern astronomy and I have used existing literature as the platform for new investigations. At the same time, I have used fresh archival material to a large extent, to further the dawn of new stories and perspectives on the history of the field. Much of the existing literature on the history of Danish astronomy is written by astronomers and however informative it may be, it may also lack discussion, synthesis, contextual treatment and comparison. It has been my intention to contribute with these attributes to the existing history of science by means of the scientific life of Bengt Strömgren, thereby making it more than just a descriptive historical account, in spite of the many historical details.

Sources, Appendices, and Index

Archives

Archival Sources

ANNI: Archive of the Norwegian Nobel Institute, Oslo, Norway.

BA: Bundesarchiv, Koblenz, Germany.

BG: Bengt Gustafsson's "Causeries", Swedish radio transmission broadcasted in the 1990'es. Tape recording borrowed from Jette Strömgren, Ole Strömgren's wife, and transcribed by Simon Olling Rebsdorf in 2004. A copy of transcription is located at the History of Science Department, University of Aarhus.

BSA: Bengt Strömgren Archive, History of Science Department, University of Aarhus, Denmark. The archive consisting of Bengt Strömgren's ca. 1,700 correspondences and numerous manuscripts is catalogued in boxes numbered BS.01 to BS.08 with extension specifying archival subgroups. In this dissertation, reference to the BSA will be as to BSA.01 – BSA.08, and the extensions will be e.g. BSA.02, B (signifying the box including the University of Copenhagen Observatory).

BSA.01 Correspondence

A. Professional (all correspondents are listed alphabetically in the archive boxes)
B. Private
C. Miscellaneous

BSA.02 Scientific Institutions

A. University of Copenhagen
B. University of Copenhagen Observatory
C. Other

BSA.03 Academies, Associations, Organizations

A. Royal Danish Academy of Sciences and Letters

B. Nobel Institution

C. International Astronomical union

D. Other Academic Organizations

E. Foundations and Research Councils

F. Other

BSA.04 Observatories

A. European Southern Observatory

B. Specific Observatories

C. Instrument Projects

BSA.05 Companies

BSA.06 Material concerning publications

A. Publishers

B. Manuscripts by Bengt Strömgren

C. Manuscripts by others

BSA.07 Public appearance

A. Interviews

B. Astronomical Speeches and Lectures

C. Historical and Celebratory Speeches and Lectures

D. Speeches and Lectures by others

BSA.08 Miscellaneous

CBDP: Carlsberg Board of Directors Protocol for 1950 (courtesy of Torkild Andersen, June 26, 2004).

EHA: Ejnar Hertzsprung Archive, of Science Department, University of Aarhus, Denmark.

ESC: Elis Strömgren Collection, University Library, Lund University, Sweden. Elis and Bengt Strömgren correspondence (copies are located at History of Science Department, University of Aarhus, Denmark. Translation (Swedish to Danish) and transcription of all their correspondences in the period 1935-1939 has been made by Simon Olling Rebsdorf in 2003, and is ordered in a database located at the History of Science Department, University of Aarhus). This transcription is denoted “The Strömgren Correspondence” throughout this dissertation.

LU: University of Lund Archives, Lund, Sweden.

MS Memorial Service, talks given on occasion of Bengt Strömgren’s funeral, courtesy of Karin Strömgren Campbell (Talks given by Anders Reiz, Jens Knude, Piet Hein, Erik Strömgren and Nina Strömgren Allen (Copy located at History of Science Department, University of Aarhus, Denmark).

NAFA: Nordjysk Amatør Astronomisk Forening, Aalborg. Ole Fastrup from NAFA has provided me with hitherto unpublished photographs from the Urania Observatory (now deposited at the History of Science Department, University of Aarhus, Denmark).

NBA: Niels Bohr Archive, Niels Bohr Institute, Copenhagen, Denmark. A few letters and photographs from the University Institute of Theoretical Physics, Auditorium A, Blegdamsvej, Copenhagen.

OS: Elis Strömgren’s diary, 1908-1932, borrowed from Ole Strömgren (copies located at History of Science Department, University of Aarhus, Denmark). I have translated the chosen quotes to English from Elis’ handwriting in Swedish.

R: Rigsarkivet, Danish State Archives.

RA: Royal Danish Academy of Sciences and Letters Archive, Copenhagen.

RL: Royal Danish Library, correspondence, Prints and Photographs [Billedbasen].

UCA: University of Chicago Archive, University of Chicago Library, Joseph Regenstein Library, Special Collections Research Center, Illinois (selected copies (ca. 400) are located at History of Science Department, University of Aarhus, Denmark).

UCA Collections:

SCP: Subrahmanyan Chandrasekhar Papers, 1928-1983, courtesy of Lalitha Chandrasekhar.

PP1: President's Papers, Appointments and Budgets, 1925-1940

PP2: President's Papers, Appointments and Budgets, 1945-1950

PP3: President's Papers, 1952-1960

OPUC: Official Publications of the University of Chicago. Chicago: University of Chicago Press.

AR: Annual Reports and related

APF: Archival Photographic Files

BF: Biographical Files, 1925-40

BTM: The Board of Trustees Minutes

UCO: University of Copenhagen Observatory Archive, History of Science Department, University of Aarhus, Denmark. Tables, observation protocols, correspondence protocols, logs of time signal.

WC Report on the Fouth Washington Conference on Theoretical Physics, 1938. Copy courtesy of Donald Osterbrock, received in fall 2002, located at the History of Science Department.

YOA: Yerkes Observatory Archive, Yerkes Observatory, University of Chicago, Williams Bay, Wisconsin (selected copies are located at History of Science Department, University of Aarhus, Denmark, ca. 300 pages).

YODA: The Yerkes Observatory Digital Archive, Yerkes Observatory, University of Chicago, Williams Bay, Wisconsin.

Oral Interviews and Correspondence

In my oral history interviews I have found great help the American Institute of Physics Center for History of Physics web site concerned with the subject (www.aip.org/history/web-ohi.htm).

CI: Chandrasekhar Interview (1977): Spencer Weart interviewed Subrahmanyan Chandrasekhar in his Office at University of Chicago on May 17, 1977. American Institute of Physics, Center for History of Physics, MD, USA, has provided a full copy of the transcripts of the interview for the UCA-archive.

COR: E-mail correspondence between Simon Olling Rebsdorf and Bengt Strömgren's three children in the period 2002-2004 (Copies are located at the History of Science Department).

HBI: Hoddeson-Baym Interview (1976): Lillian Hoddeson and Gordon Baym interviewed Bengt Strömgren in his office at the Copenhagen Observatory on May 6 and May 13 1976. American Institute of Physics, Center for History of Physics, MD, USA, has provided some copies of a transcript of the interview (55 pages). The first edition of the interview transcription is also located in original in BSA.08, A.

HI: Hufbauer Interview (1978): Karl Hufbauer interviewed Bengt Strömgren in his office at the Copenhagen Observatory on April 24 1978. American Institute of Physics, Center for History of Physics, MD, USA, has provided some copies of a transcript of the interview (24 pages). Like HBI, this interview is also located in original in BSA.08, A.

KSCI: Karin Strömgren Campbell Interview (2003): Simon O. Rebsdorf interviewed Bengt Strömgren's daughter Karin Strömgren Campbell in Stoughton, Wisconsin, April 9, 2003 (unpublished, located at History of Science Department, in the Bengt Strömgren Archive).

KNSI: Karin and Nina Strömgren Interview (2003): Simon O. Rebsdorf interviewed Bengt Strömgren's daughters Karin Strömgren Campbell and Nina Strömgren Allen in Stoughton, Wisconsin, April 9, 2003 (unpublished, located at History of Science Department, in the Bengt Strömgren Archive).

MI: Morgan Interview, David DeVorkin interviewed William Wilson Morgan in his office at the Yerkes Observatory on August 8, 1978. American Institute of Physics, Center for History of Physics, MD, USA, has provided me with some copies of a transcript of the interview (16 pages).

MRI S. O. Rebsdorf interviewed the astronomer Mogens Hegelund Rudkjøbing in his office at the Department of Physics and Astronomy, University of Aarhus on January 23, 2002 (transcribed by Rebsdorf, (unpublished, located at History of Science Department, in the Bengt Strömgren Archive). Rudkjøbing worked for Strömgren in the late 1930ies as calculator, and was the first professor of astronomy at the University of Aarhus.

OSI: Ole Strömgren Interview (2003): Simon O. Rebsdorf interviewed Bengt Strömgren's son Ole Strömgren and his wife Jette Strömgren on Frederiksberg in Copenhagen, October 2, 2003 (unpublished, located at History of Science Department, in BSA.08, A).

PENI: Poul Erik Nissen Interview (2001): S. O. Rebsdorf interviewed the astrophysicist Poul Erik Nissen in his office at the Department of Physics and Astronomy, University of Aarhus on May 6 2001. The interview has been transcribed by Rebsdorf, but not published. Nissen worked together with Strömgren after his return from Princeton to Denmark in 1967.

PI: Perkins Interview (2003): Simon O. Rebsdorf interviewed Barbara Perkins in her office at University of Chicago in June 2003. She worked as the director's secretary for Bengt Strömgren atYerkes Observatory in the years 1953-1957 (unpublished, situated at History of Science Department, in the Bengt Strömgren Archive).

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Appendix A: Copenhagen Observatory Staff, 1905-1970

Documentation source: *Kongelig dansk hof- og statskalender: Statshåndbog for Kongeriget*, volumes 1905-1970, Copenhagen: Schultz' Universitetstrykkeri. (19xy designates the period 19x(y-1) – 19xy, e.g.: 1917 designates the academic period August 1916- July 17)

Year	University President	Dean of Natural Sciences Faculty	Professor of Astronomy	Director of Copenhagen Observatory	Observer	Assistant
1905	Prof.dr.jur Julius Severin Vilh. Lassen	Dr.phil. C.U.E. Petersen	Dr.phil. Thorvald Nicolai Thiele, (1838-1910)	T.N. Thiele	Mag.sc. Carl Frederick Pechüle, 1843-1914	Cand.phil. Søren Kristensen, 1871-??
1906	Prof.dr.sc. Christian H.L. P.E. Bohr	W.L. Johannsen	T.N. Thiele	T.N. Thiele	C.F. Pechüle	Holger Thiele, 1878-1946
1907	Prof. Martin Clarentius Gertz / prof.dr.sc. H.G. Zeuthen [*]	**T.N. Thiele**	T.N. Thiele	T.N. Thiele	C.F. Pechüle	H. Thiele
1908	Prof.dr.sc. Johs. E.B. Warming / M.C. Gertz [*]	N.V. Ussing	Dr.phil. **Svante Elis Strömgren**, acting, (April 1)	**S.E. Strömgren**	C.F. Pechüle	H. Thiele
1909	Dr.jur. Carl Torp	Dr.med. C. Christiansen	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	Cand.phil. Niels Erik Nørlund, 1886
1910	Dr.med. Carl Julius Salomonsen	Dr.med. E.C.S. Biilmann	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	N.E. Nørlund
1911	Dr.phil. Kris-tian S.A. Erslev	**S.E. Strömgren**	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	N.E. Nørlund
1912	Prof.dr.phil. Frants P.W. Buhl	Dr.phil. Julius Chr. Petersen	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	N.E. Nørlund
1913	Prof.dr.phil. Hector F.E. Jungersen	Dr.phil. J.N. Brønsted	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	Stud.mag. Ruben Laurits Winther Andersen, 1892-1955
1914	Prof. Johs Chr. Jacobsen	Dr.phil. H.P. Steensby	S.E. Strömgren	S.E. Strömgren	C.F. Pechüle	R. Andersen
1915	Prof.dr.jur. Harald L. Westergaard	Dr.phil. Christian Raunkiær	S.E. Strömgren	S.E. Strömgren	Mag.sc. Johs. Braae, 1887-1940	R.L.W. Andersen
1916	Prof.dr.phil. Johan Ludvig Heiberg	O.B. Bøggild	S.E. Strömgren	S.E. Strömgren	J. Braae	R.L.W. Andersen, director of Århus Observatory
1917	Dr.med. Knud Helge Faber	Martin Knudsen	S.E. Strömgren	S.E. Strömgren	J. Braae	Mag.sc. J. Fischer Petersen, 1889-??
1918	Dr.phil. Wilhelm L. Johannsen	Dr.phil. J.L.A. Kolderup Rosenvinge	S.E. Strömgren	S.E. Strömgren	J. Braae	J.F. Petersen

1919	Prof.dr.jur. Viggo Bentzon	J.L.A. K Rosenvinge	S.E. Strömgren	S.E. Strömgren	J. Braae	J.F. Petersen
1920	Prof.dr.med. Niels Thorkild Rovsing	Dr.phil. N. Nielsen	S.E. Strömgren	S.E. Strömgren	J. Braae	J.F. Petersen & mag.sc. Julie Marie Vinter Hansen, 1890-1960, April 30 1919
1921	Prof.dr.phil. Jens Otto Harry Jespersen	N. Nielsen	S.E. Strömgren	S.E. Strömgren	J. Braae (headmaster at Ordrup Gym-nasium)	J.F. Petersen & J. Hansen
1922	Prof.dr.phil. Einar Chr. S. Biilmann	Dr.phil.J.T. Hjelmslev	S.E. Strömgren	S.E. Strömgren	**S.E. Strömgren**, acting	J. Hansen & stud.mag. J.A. Kristiansen, 1898-??
1923	Prof.dr.med. Johs. Carl Bock	J.T. Hjelmslev	S.E. Strömgren	S.E. Strömgren	J. Hansen, July 31, 1922	Cand.mag. J.A. Kristensen, Sept. 9, 1922 & Stud.mag. Jens Johannsen, 1897-??
1924	Prof.dr.jur. Hans Vilh. Munch-Petersen	Dr.phil.N.E. **Nørlund**	S.E. Strömgren	S.E. Strömgren	J. Hansen	Mag.scient J. Johannsen & cand.mag. Jens P. Møller, 1899-??
1925	Prof.dr.theol. Frederik Emanuel Torm	N.E. Nørlund	S.E. Strömgren	S.E. Strömgren	J. Hansen	J. Johannsen & J. P. Møller
1926	Prof.dr.med. Johs. A. G. Fibiger	Dr.phil. A.S. Jensen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J. P. Møller & stud.mag. Axel V. Nielsen, April 1, 1926 -October 31, 1926
1927	Prof.dr.phil. Holger Pedersen	Dr.phil. C.E. Hansen-Ostenfeld	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & **stud.mag. Bengt Georg Daniel Strömgren**
1928	Prof.dr.phil. Martin Hans Chr. Knudsen	Dr.phil. C.M. Vahl	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & **mag.sc. B. Strömgren**
1929	Prof.dr.phil. Johs. Trolle Hjelmslev	Dr.phil. H.M. Hansen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B.Strömgren
1930	Dr.theol. Johs O. Andersen	Dr.phil. J.E. Steffensen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & **dr. phil. B. Strömgren**
1931	Prof. Lauritz Vilh. Birck	Dr.phil. P. Boysen-Jensen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B. Strömgren
1932	Prof.dr.med. Carl E. Bloch	Dr.phil. K. Jessen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B. Strömgren
1933	Prof.dr.phil. Aage Friis	Dr.phil. A.G. Hatt	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & **as-sociate professor B. Strömgren**
1934	Prof.dr.phil. Niels Erik Nørlund	A.G. Hatt	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B. Strömgren
1935	Prof.dr.phil. Johs. .E. Østrup	Dr.phil. J.A. Christiansen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B. Strömgren
1936	Dr.polit. Axel E.H. Nielsen	Dr.phil. C.M. Steenberg	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & B. Strömgren
1937	Prof.dr.med. C.E. Bloch	Dr.phil. Harald A. Bohr	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller & mag.sc. Karl August Oscar Thernøe

1938	C.E. Bloch	Dr.phil. T. Emanuel Hansen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller [*am*, Dec. 1, 1937] & K. Thernøe
1939	C.E. Bloch	E. Hansen	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller [*am*] & K. Thernøe
1940	C.E. Bloch	Dr.phil. H.R.G. Spärck	S.E. Strömgren	S.E. Strömgren	J. Hansen	J.P. Møller [*am*] & K. Thernøe
1941	C.E. Bloch	H.R.G. Spärck	Dr.phil. **Bengt Strömgren**	**B. Strömgren**	J. Hansen (l)	J.P. Møller [*am*] & K. Thernøe
1942	C.E. Bloch	Dr.phil. A.W. Langseth	B. Strömgren	B. Strömgren	J. Hansen (l)	J.P. Møller [*am*] & K. Thernøe
1943	Prof.dr.theol. Jens Skovbye Nørregaard	A.W. Langseth	B. Strömgren	B. Strömgren	J. Hansen (l)	J.P. Møller [*am*] & K. Thernøe
1944	J.S. Nørregaard	Dr.phil. **Bengt Strömgren**	B. Strömgren	B. Strömgren	J.Hansen (l)	J.P. Møller [*am*] & K. Thernøe
1945	J.S. Nørregaard	**B. Strömgren**	B. Strömgren	B. Strömgren	J.Hansen (l)	K. Thernøe
1946	J.S. Nørregaard	Dr.phil. N. Nielsen	B. Strömgren	B. Strömgren	J.Hansen	K. Thernøe
1947	J.S. Nørregaard	N. Nielsen	B. Strömgren	B. Strömgren	J.Hansen	K. Thernøe [*am*] & cand.mag. Mogens Hegelund Rudkjøbing, 1915- & Hans Quade Rasmussen
1948	Prof.dr.phil. Hans Marinus Hansen	Dr.phil. J.C. G. Jacobsen	B. Strömgren	B. Strömgren	J.Hansen	K. Thernøe [*am*] & M. Rudkjøbing & H.Q. Rasmussen
1949	H.M. Hansen	J.C. Jacobsen	B. Strömgren	B. Strömgren	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing
1950	H.M. Hansen	Dr.phil. A. Noe-Nygaard	B. Strömgren	B. Strömgren	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing
1951	H.M. Hansen	Dr.phil. B.C. Jessen	B. Strömgren	B. Strömgren	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing [*am*]
1952	H.M. Hansen	Dr.phil. J.H.V. Simonsen	B. Strömgren (l)	B. Strömgren (l)	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing [*am*] & mag.scient. Kjeld Gyldenkerne
1953	H.M. Hansen	Dr.phil. Poul Brandt Rehberg	B. Strömgren (l)	B. Strömgren (l)	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing [*am*] & K. Gyldenkerne
1954	H.M. Hansen	Dr.phil. H.V. Brønsted	Fil. dr. Sven Anders Torsten Reiz, acting & B. Strömgren (l)	B. Strömgren (l)	J. Hansen	K. Thernøe [*am*] & dr.phil. M. Rudkjøbing [*am*] & K. Gyldenkerne & mag.scient Peter Naur, 1928
1955	H.M. Hansen	Dr.phil. J. Bjerrum	A. Reiz, acting & B. Strömgren (l)	B. Strömgren (l)	J. Hansen	K. Thernøe [*am*] & M. Rudkjøbing [*am*] & K. Gyldenkerne & P. Naur
1956	H.M. Hansen	Dr.phil. G.D.C. Müler	A. Reiz, acting and B. Strömgren (l)	B. Strömgren (l)	J. Hansen	K. Thernøe, M. Rudkjøbing, K. Gyldenkerne & P. Naur [all *am*]
1957	Prof. dr.med. E.J. Warburg	Dr.phil. M.C.W. Westergaard	A. Reiz, acting and B. Strömgren (l)	B. Strömgren (l)	J Hansen	[all 4 amanuenses]
1958	E.J. Warburg	Dr.phil. C.G. Feilberg	[none given]	[none given]	J. Hansen	[all 4 amanuenses]

1959	Prof.dr.polit. C.L. Iversen	Dr.phil. K.A. Jensen	A. Reiz, Sept.1, 1958	A. Reiz	J. Hansen (h)	K. Thernøe [*am*], K. Gyldenkerne [*am*] & P. Naur [*am*] [Rudkjøbing prof. of astronomy in Århus]
1960	C.L. Iversen	Dr.phil.H.H. Ussing	A. Reiz	A. Reiz	J. Hansen (h)	K. Thernøe [*am*], K. Gyldenkerne [*am*], P. Naur [*am*] & cand.mag. Svend Mølgaard Laustsen [*am*], June 1, 1959.
1961	C.L. Iversen	Dr.phil. A. Schou	A. Reiz	A. Reiz	Dr.phil. G. van Herk (p) & K. Gyldenkerne, Dec. 1, 1960	K. Thernøe [*am*], P. Naur [*am*] & S. Laustsen [*am*]
1962	C.L. Iversen	Dr.phil. T.W. Bøcher	A. Reiz	A. Reiz	G. Herk (p) & K. Gyldenkerne	K. Thernøe [*am*], P. Naur [*am*] & S. Laustsen [*am*] & mag.scient. Jørgen Otzen Petersen
1963	C.L. Iversen	Dr.phil. Thøger Bang	A. Reiz	A. Reiz	G. Herk (p) & K. Gyldenkerne	K. Thernøe [*am*], P. Naur [*am*], S. Laustsen & J.O. Petersen
1964	C.L. Iversen	T. Bang	A. Reiz	A. Reiz	G. Herk	K. Thernøe [*am*], J.O. Petersen [*am*] & S. Laustsen
1965	C.L. Iversen	Dr.phil. W. Fenckel	A. Reiz	A. Reiz	S. Laustsen & K. Gyldenkerne	K. Thernøe [*am*] & J.O. Petersen [*am*]
1966	C.L. Iversen	Dr.phil. J.K. Bøggild	A. Reiz	A. Reiz	J.O. Petersen (h), K. Gylden-kerne & S. Laustsen	K. Thernøe [*am*], Cand.mag. Karen T. Johansen & mag.scient. Henning E. Jørgensen
1967	Prof. dr.med. M.L. Fog	J.K. Bøggild	A. Reiz	A. Reiz	J.O. Petersen (h), K. Gylden-kerne & S. Laustsen	K.T. Johansen [*am*], H.E. Jørgensen [*am*] & mag.scient. Richard M. West [*am*]
1968	M.L. Fog	Dr.phil. Mogens Pihl	A. Reiz, B. Strömgren	A. Reiz	J.O. Petersen (h), K. Gylden-kerne & S. Laustsen	K.T. Johansen [*am*], H.E. Jørgensen [*am*] R.M. West [*am*] & mag.scient Bodil E. Helt [*am*]
1969	M.L. Fog	Dr.phil. M.F., Morten Lange	A. Reiz, B. Strömgren	A. Reiz	J.O. Petersen (h), K. Gylden-kerne & S. Laustsen	K.T. Johansen [*am*], H.E. Jørgensen [*am*] R.M. West [*am*] & Bodil E. Helt [*am*]
1970	M.L. Fog	??	A. Reiz, B. Strömgren	A. Reiz	J.O. Petersen (h), K. Gylden-kerne & S. Laustsen	K.T. Johansen [*am*], H.E. Jørgensen [*am*] R.M. West [*am*] & Bodil E. Helt [*am*]
	[Rektor]	[Dekan for Matematisk-Naturviden-skabeligt Fakultet]	[Professor i astronomi]	[Observatorie-bestyrer]	[Observator]	[Videnskabelig assistent, fra 1935 både assistent og amanuensis]

h = head of department, a new position from 1958-59.

l = leave from C.O. p = provisional position; from 1935, the so-called amanuensis-position was introduced (designated by *am* in square brackets).

?? = Cases where the title, name, or year of death is unknown to the author.

[*] According to *Kongelig dansk hof- og statskalender*, the name before the stroke was president. According to Slottved, 1978, the name after the stroke was the university president.

In addition to Bengt Strömgren's positions in this table, he was appointed *associate professor* [lektor] in the period September1932 – August 1938, in spite of his leave of absence September 1936 – April 1938 owing to his stay at the University of Chicago and Yerkes Observatory.

After his associate professorship, Bengt Strömgren was appointed extraordinary professor [professor astronomiae extraordinarius].

From 1938, the assistantship [assistent] was, in some cases, replaced by a new appointment, the *amanuensis* [*am*], which is another term for scientific assistant. J.P. Møller was thus amanuensis from December 1937, while K.A.O. Thernøe remained assistant until September 1946 when he also was appointed amanuensis. During the Second World War, J.M.V. Hansen was working at the Lick Observatory, USA.

In addition to the academic staff at the observatory, there were assisting calculators undertaking also observations, almanac calculations and other odd jobs. Typically, it was astronomically interested students, but also other persons. Furthermore, there was a keeper and messenger of the observatory. No systematic records of the assisting calculators have been found. Some records are available in the University Yearbooks, but mainly until the 1920s.

Staff	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
Thiele, Thorv. N.	d	d	d	-																		
Pechüle, Carl Fr.																						
Kristensen, Søren		-																				
Thiele,, Holger					-																	
Strömgren, S. Elis			-	d	d	d	d/de	d	d	d	d	d	d	d	d	d	d	d/ao	d	d	d	d
Nørlund, Niels E.				-					-										-	de	-	
Andersen, Ruben								-	s				-									
Nielsen, Estrid						c	c	c	c	c	c	c	c	c	c	c						
Braae, Johannes										-								-				
Petersen, J. Fischer												-						-				
Hansen, J. M. V.										-	c	c	c	c	c							
Mackeprang, E.																-	c	c	c	c	c	c
Kristiansen, J.A.																	-	s		-		
Johannsen, J.																-	c	c		s		-
Møller, Jens P.																			-			
Nielsen, Axel V.																						-
Strömgren, Bengt																	-	c	c	c	c	c
Staff number	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	3	4	4	4	3 4

Staff	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48
Strömgren, S. Elis	d	d	d	d	d	d	d	d	d	d	d	d	d	d	-						†	
Hansen, J. M. V.														l	l	l	l	l	l			
Mackeprang, E.	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c	c		
Møller, Jens P.												m	m	m	m	m	m	m	-			
Strömgren, Bengt	s						a	a	a	a	l	l x	x	x	d	d	d	d/de	d	d	d	d
Themøe, Karl A.										-											m	m
Rudkjøbing, M.							-	c	c	c	c	c	c	c	c	c	c	c	c	c		
Rasmussen, H.Q.														-	c	c	c	c	c	c		
Gyldenkerne, K.																-	c	c	c	c	c	c
Staff number	4	4	4	4	4	4	4	4	4	4	4	4 5	5	5	3	3	3	3	3	3	4	4

Staff	49	50	51		52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Hansen, J. M. V.												h	h	-									
Strömgren, Bengt				d/l	d/l	d/l	d/l	d/l	d/l	d/l	*	-								-			
Themøe, Karl A.	m	m	m		m	m	m	m	m	m	m	m	m	m	m	m	m	m	m	-			
Rudkjøbing, M.			m		m	m	m	m	m	m	m	-											
Gyldenkerne, K.	c	c	c						m	m	m	m	m										
Naur, Peter	c	c	c		c	c			m	m	m	m	m	m	m	m	-						
Reiz, S. A. T.						-	ap	ap	ap	ap	*	d	d	d	d	d	d	d	d	d	d	d	d
Laustsen, Svend M.												-	m	m	m	m		a	a	a	a	a	a
van Herk, G.													-	p	p	p	p						
Petersen, Jørgen Otzen														-			m	m	h	h	h	h	h
Johansen, Karen T.																		-		m	m	m	m
Jørgensen, Henning E.																		-		ap	ap	ap	ap
West, Richard M.																			-	m	m	m	m
Helt, Bodil E.																				-	m	m	m
Staff number	4	4	4	3	4	4	6	6	6	6	5	5	6	6	7	7	6	5	7	7	9	9	9

Professor of astronomy — Observer [observator] — Assistant [assistent]

	Staff function
d	Director of Copenhagen Observatory
a	Associate professor
m	Amanuensis (new university assistant position from summer 1937)
x	Extraordinary professor
ap	Acting Professor
ao	Acting observer
s	Student (stud.mag.)
†	Dies the corresponding year
l	Absent on leave
de	Dean of the Natural Sciences Faculty
c	Assisting calculator and any other odd jobs
h	Head of department
*	Directorship and professorship is not given in the University Yearbook
p	Provisional position

Appendix B: University of Aarhus Staff, 1956-1970

Academic astronomy staff at the Natural Sciences Faculty at University of Aarhus in the period 1956-1970. Source: *Kongelig dansk hof- og statskalender: Statshåndbog for Kongeriget*, volumes 1956-1970, Copenhagen: Schultz' Universitetstrykkeri.

Year	**Dean of Natural Sciences Faculty**	**Professor of Astronomy**	**Director of Ole Rømer Observatory**	**Observer**	**Associate professor (and amanuensis)**
1957	Dr.phil. J. Humlum	Dr.phil. M.H. Rudkjøbing	Ruben Andersen		
1958	Dr.phil. Svend Bundgaard	M.H. Rudkjøbing	R. Andersen		
1959	Prof.dr.phil. Jens Lindhard	M.H. Rudkjøbing	R. Andersen		
1960	Dr.phil. P.V. Kristensen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	
1961	Prof.dr.phil. **M.H. Rudkjøbing**	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	
1962	Dr.phil. E. Sparre Andersen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	Fil.dr. H. Kristensen
1963	Dr.phil. H.M. Thamdrup	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	H. Kristensen
1964	Dr.phil. S.E. Rasmussen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	H. Kristensen
1965	Dr.phil. Karl Ove Nielsen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	H. Kristensen & mag.scient. Jørn Bærentsen
1966	Dr.phil.Svend Brodersen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	H. Kristensen & J. Bærentsen
1967	Dr.phil. Kai Larsen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	H. Kristensen, J. Bærentsen & Ole Møller (h)
1968	Dr.phil. Carl F. Wandel	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	J. Bærentsen & O. Møller (h)
1969	Dr.phil. Svand Saxlov	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	J. Bærentsen & O. Møller
1970	Dr.phil. E.T. Poulsen	M.H. Rudkjøbing	M.H. Rudkjøbing	Axel V. Nielsen	J. Bærentsen, O. Møller & Poul Erik Nissen
	[Dekan for Matematisk-Naturviden-skabeligt Fakultet]	[Professor i astronomi]	[Observatorie-bestyrer]	[Observator]	[Videnskabelig assistent (ama-nuensis)]

Staff	57	58	59	60	61	62	63	64	65	66	67	68	69	70
Andersen, Ruben	d	d	d											
Rudkjøbing, M. H.				d	d/de	D	d	d	d	d	d	d	d	d
Nielsen, Axel V.														
Kristensen, H.						a/m	a/m	a/m	a/m	a/m	a/m	-		
Møller, Ole											h	a/h	a/h	a/h
Bærentsen, Jørn									a/m	a/m	a/m	a/m	a/m	a/m
Nissen, Poul Erik														a/m
Staff number	1	1	1	2	2	3	3	3	4	4	5	4	4	5

Professor of astronomy — Observer [observator] — Assistant [assistent]

	Staff function
d	Director of the Ole Rømer Observatory
a	Associate professor
de	Dean of the Natural Sciences Faculty
h	Head of department
m	Amanuensis

Not included in the table in the period 1927-1957 is Axel V. Nielsen, who was appointed assistant at the Ole Rømer Observatory in Århus in 1927.

Appendix C: Officers of Instruction, U of C Astronomy Department, 1930-1952

Staff	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Seth Zug, Richard	s		-																				
Fairlay, Arthur S.	iP			-																			
Frost, Edwin B.	PA		Ea				†	-															
Roach, Franklin E.	s*		-			-	s	-															
Moffit, George W.	RP								-														
Barrett, Storrs B.	A*	-	e*						†	-													
Elvey, Christian T.	i*			a*			A*									-							
Laves, Kurt	AA		eA												-								
MacMillan, W. D.	PA							EA												-			
Bartky, Walter	aA		AA										d	-									
Calvert, Mary R.	s																	-					
Ross, Frank E.	PP										EP												
V. Biesbroeck, G.	PP															EA							
Struve, Otto	a*	A*	P*																		RA	-	
Crump, Clifford	-	AA			-																		
Ogrodnikoff, K.		-	r	-																			
Westgate, Christine		-	s			-																	
Swings, Polydore		-	rA	-					-	vA	WA			-					-	V*	RA	R	R
Keenan, Philip C.		-	s				I*	i*				r	i	i*			-						
Morgan, W. W.		-	iA	i*				a*						A*				P*					
Rosenberg, Hans				-	VA			-															
Rudnick, Paul				-	f	-	-	as		-													
Henyey, Louis G.					-	s				ab	i		a	a*				-					
McCarthy, E.L.					-	s					-												
Bok, Bart J.						-	w	-															
Rudnick, Jesse						-	f	s			-												
Chandrasekhar, S.						-	R*	a*	at	a			A*	Pt							Pt		
Strömgren, Bengt						-	at	At	ab	-								V*			-	P*	
Kuiper, Gerard P.						-	aP	AP						PP							PP		
Seyfert, Carl K.						-	R	R	R	R	R	-											
P.-Gaposchkin, C.							-	w*	-														
Hetzler, Ch. W.							-	s				-											
Sherman, Frances							-	s					-										
Greenstein, Jesse							-	nf	sf	i			a	a*					-				
Wurm, Karl									v	-													
Page, Thornton L.								-	i*									aA					
Wares, Gordon									-	s	-												
Linke, Walter R.									-	s		-											
Popper, Daniel M.									-	as	iA							-					
Rogers, Fred T.									-	s	s	-											
Titus, John									-	s	iA					-							
Babcock, Horace										-	i					-							
O'Keefe, John A.											-	s	-										
Randers, Gunnar											-	i	i*		ab	-							
Brown, Joseph												-	s	-									
Rubenstein, Pearl												-	s	-									
Henrich, Louis R.												-	s	it	-								
Williamson, R. E.												-	s		-								
Bidelman, Will.												-	s		-	-	i*		a*				
Broyles, Arthur													-	s	-								
Bauer, Carl A.													-	s		-							
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

Staff	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Münch P., Guide													-	s	-	gf		i*		a*			
Tuberg, T. Merle													-	s				-					
Dershem, Elmer													-	R				-					
Hiltner, W. Albert													-	ip	i*		a*		A*				
Sahade, Jorge														-	s		-						
Steel, Helen R.														-	nf	r	-						
Cesso, Carlos U.														-	s		gf	-					
Deutsch, Armin J.														-	s			-					
Harrison, Marjorie														-	s	-		-	r	-			
Sharpless, Stewart															-	s	-						
Janssen, Edith M.															-	s		-					
Terrazos, Luis R.															-	s	-				-	R	
Herzberg, Gerh.															-	A*	AS	PS	-				
Slettebak, Arne															-	s					-		
Krogdal, Wasley S.																-	it	-					
Phillips, John G.																-	s		iS		-		
Bernstein, Harold J.																	-	vr	-				
Chang, Y.C.																	-	vr	-				
van de Hulst, H. C.																	-	pf	-				
Rudkjøbing, M. H.																	-	pf		-			
Underhill, Anne																	-	s	CS	-			
Wrubel, Marshall																	-	s		-			
Code, Arthur D.																	-	s			-		
Hall, R. Glenn																	-	s		iA		iP	
Roman, Nancy G.																	-	s		r	R		
Strand, Kaj A.																	-	WA	RA			R	
Herbig, George H.																		-	pf	-			
Recillas, Paris P.																		-	gf	-			
Brown, Archibald																		-	pf		-		
Duke, Douglas																		-	s		-		
Hardie, Robert																		-	s		-		
Shatzel, Albert V.																		-	rA	r	-		
Huang, Su-Shu																		-	f	-	it		
Jose, Paul D.																		-	RA			-	
Edmonds, Frank																			-	s		-	
Horak, Henry																			-	s		-	
Osterbrock, Donald																			-	pf	f		
Rosino, Leonida																				-	r	-	
Ramsey, Jane																				-	s	-	
Milford, S. Nevil																				-	pf	-	
Limber, Nelson																				-	f		
Provin, Sanford																				-	f		
Ahmad, Imam I.																				-	f		
Meinel, Aden B.																				-	i*	A*	
Stephenson, Bruce																				-	s	r	-
Johnson, Harold L.																					-	aA	
Kiepenhauer, K.O.																					-	R	
Wayman, Patrick																					-	r	
Münch, Luis																					-	r	
Fujita, Yoshio																					-	r	
Fitch, Walter																					-	r	
	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52

Staff	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52
Beardsley, Wallace																					-	r	
Johnson, Hugh L.																					-	r	
Helfer, H.L.																					-	r	
Harris, Daniel L.																						-	aA
Fan, Chang-Yun																						-	R
Garstang, Roy H.																						-	R

- Director of Yerkes Observatory
- Director of McDonald Observatory
- At McDonald Observatory
- At Yerkes Observatory
- Acting chairman until director is in place at Yerkes
- At University of Chicago Campus
- Director of Yerkes and McDonald observatories (or assistant director of do.)
- On leave for government service (during WWII)
- Secretary of the Department
- Chairman of the Department

Abbreviations:

	Staff function
Ex	Professor emeritus of x
ex	Associate professor emeritus of x
Px	Professor of x
Ax	Associate professor of x
Rx	Research associate (in x)
rx	Research assistant (in x)
ax	Assistant professor of x
ix	Instructor in x
sx	Assistant (in x)
Vx	Visiting professor (of x)
Wx	Visiting associate professor (of x)
vx	Visiting assistant professor (of x)
wx	Visiting research associate (of x)

x	**Disciplinary field**
*	Astrophysics
A	Astronomy
P	Practical astronomy
p	Physics
S	Spectroscopy
t	Theoretical astrophysics

	Exceptional abbreviations
†	Dies the corresponding year
ab	"Absent on leave"
as	Astronomer
d	Dean of students at the Div. Phys. Sci., UC
f	Fellow
gf	Guggenheim Fellow
nf	National research Fellow
pf	Post-Ph.D. Fellow
sf	Special Fellow
vf	Visiting Fellow
vr	Volunteer Research assistant
CS	Canadian Federation of Women Scholar

Comments to the list of officers of instruction

Fellow students have not been included systematically except in cases where a scientist has been appointed at the University of Chicago some time after the fellowship. From 1945, all fellows have been included in this list. Guests not included in the *Official Publications of the University of Chicago*'s annual lists are not included here either. In the 1930'es, the discipline corresponding to an instructorship was not given in the *Official Publications*. After 1942, the designation for certain employees was given specifically in the lists.

From 1951, the geographical placement of employees of the department was not given, hence gray color is used in the years 1951 and 1952. Furthermore, from 1951 the designation 'research assistant' replaced the term 'assistant', which was not used anymore in the list.

The tables have been produced by the author in April 2003 during a research visit at the University of Chicago.

Appendix D: Chicago and Yerkes Curriculum, 1936-1952.

Selected astronomy courses at the University of Chicago and the Yerkes Observatory, 1936-1952. Sources: UCA, OPUC vol. 36, 1936-37; UCA, OPUC vol. 47, 1947-1948; UCA, OPUC vol. 50, 1950-1951; and UCA, OPUC vol. 51, 1951-52.

Courses of instruction, 1936-1938:

Quarter	**Y=Yerkes Obs. Q=Quadrangles** (Chicago)	**Course**	**Hour** [Day]	**Instructor**	**Course number**
Summer 1936 (p. 25) 06/22 - 08/28	Q	Dynamics of a particle*	8	Bartky	306
	Q	Celestial mechanics*	9	Bartky	322
	Y	Research courses at Y.*	Arr.	Staff	370-495
Autumn 1936 (p. 33) 10/01 – 12/18	Q	Introduction to Astrophysics	1:30	**Strömgren**	202
	Q	Theory of potential	10	Bartky	326
	Q	Application of systems of diff. equations	9	Bartky	351
	Arr.	Theoretical Astrophysics	Arr.	**Strömgren**	366
	Y	Research courses at Y.	Arr.	Staff	370-495
Spring 1937 (p. 31) 03/29 – 06/11	Q	Spherical Astronomy	1:30	Keenan	207
	Q	Dynamics of rigid bodies	9	Bartky	325
	Q	Problems of the sun and the interiors of the stars	2:30	Keenan	335
	Q	Systems of linear diff. eq.	10	Bartky	352
	Y	Research courses at Y.	Arr.	Staff	370-495
Summer 1937 (p. 27) 06/14 – 08/27	Y	Research courses at Y.	Arr.	Staff	370-495
Autumn 1937 (p. 32) 10/01 – 12/12	Q	Descriptive astronomy	1:30	Keenan	201
	Q	Dynamics of a particle	9	Bartky	300
	Q	Variable stars	Arr.	Keenan	330
	Y	Research courses at Y.	Arr.	Staff	370-495
Winter 1938 (p. 35) 01/03 – 03/18	Q	Elementary astrophysics	1:30	Keenan	202
	Q	Interstellar matter	11	Keenan	331
	Q	Periodic orbits	9	Bartky	353
	Y	Research courses at Y.	Arr.	Staff	370-495
Spring 1938 03/28 – 06/10	Q	Practical astronomy	1:30	Keenan	208
	Q	Planetary perturbations	10	Bartky	324
	Y	Research courses at Y.	Arr.	Staff	370-495
	Q	Descriptive astronomy	7 Tu, F	Staff	201

Courses with an asterix (*) is described in detail below (M, Tu, W, Th, F = days of the week)

Course numbering (Divided into 4 groups):

101-199: Courses primarily for students in the College

201-299: Courses primarily for students who have been admitted to a division

301-399: Informational and advanced technical courses that assume a previous general survey of the field or method or problem treated. Open to students with one year or more of work in a division or professional school including departmental prerequisites or with consent of Dean.

401-499: Pre-research, problem, and research courses.

Specific numbering:

306: Straight-line motion of a particle, curvilinear motion, central forces; constrained motion of a particle.

322: Gravitational theory of Sun’s heat, central forces, potential and attraction of finite bodies, properties of conic section motion.

370-495: Informal research courses are offered at the Yerkes Observatory each quarter as they are needed to meet the requirements of advanced students with the achelor’s degree. Such students should first correspond with the director of Yerkes Observatory, Williams Bay, Wisconsin, and obtain his approval.

Courses of instruction 1947-1948

Quarter	**Y=Yerkes Obs. Q=Quadrangles**	Course	Hour [Day]	Instructor	Course number
Summer 1947 (p. 19) 06/21 - 08/30	Y	The design of modern astronomical advances in astrophysics	Arr.	**Strömgren**	-
Autumn 1947 (p. 26) 09/30 – 12/20	Y	Atomic spectra	1:30 Th	Herzberg	371
	Y	The theory of stellar atmospheres	1:30 F	**Strömgren**	376
	Y	Astrometry	2 Tu	Strand	384
Winter 1948 (p. 28) 01/05 – 03/20	Y	Elementary stellar spectroscopy	1:45 Th	Struve	370
	Y	Photographic photometry	1:45 F	Morgan	385
	Y	The theory of stellar atmospheres II	1:45 W	Chandrasekhar	477
Spring 1948 (p. 29) 03/29 – 06/19	Q	Modern astronomy	-	-	202
	Q	Practical astronomy	-	-	203
	Q	Observational astron. II	-	-	252
	Y	Statistics and dynamics	2 Tu	Kuiper	383
	Y	Advanced stellar spectroscopy	2 F	Struve	472
	Y	The theory of stellar atmospheres III	2 W	Chandrasekhar	478

Courses of instruction, 1950-1951:

Quarter	**Y=Yerkes Obs. Q=Quadrangles**	Course	Hour [Day]	Instructor	Course number
Summer 1950 (p. 23) 06/21 - 09/03	Y	Special problems in astrophysics	Arr.	Meinel, Kiepenhauer, Münch	397
Autumn 1950 (p. 30) 09/30 – 12/22	Q	Statistical theory of turbulence	1:30 Th	Chandrasekhar	303
	Y	Theory of stellar interiors I	1:30 F	Chandrasekhar	374
	Y	Galactic structure	1:30 Tu	Bidelman	391
	Y	Introduction to quantum mechanics	1:30 W	Chandrasekhar	396
Winter 1951 (p. 28) 01/02 - 03/17	Y	The solar system	3 W	Kuiper	381
	Y	Photographic astrometry	2 Tu	Hall	382
	Y	Kinematics and dynamics of stellar motions	1:30 Th	Bidelman	395
Spring 1951 (p. 26) 03/26 – 06/16	Q	The theory of stellar atmospheres	1-2:30 Th	**Strömgren**	302
	Y	The theory of stellar interiors II	2-3:30 W	**Strömgen**	375
	Y	Stellar variability	2-3:30 Tu	Hiltner	383
	Y	Problems in stellar astronomy	1-4:30 Th	Morgan	385

Courses of instruction, 1951-1952:

Quarter	**Y=Yerkes Obs. Q=Quadrangles**	Course	Hour [Day]	Instructor	Course number
Summer 1951 (p. 25) 06/25 - 09/01	Y	Numerical methods: Linear eq.s of higher orders, algebraic eigen-value problems, power series, asymptotic series, interpolation	2-3:30 W	**Strömgren**	387
	Y	Radio astronomy: Techniques and results of obs. of celestial radiation	2-3:30 Tu	Johnson	395
Autumn 1951 (p. 30) 09/30 – 12/22	Q	Theories of terrestrial and stellar magnetism	1-2:30	Chandrasekhar	301
	Y	Atomic spectra	2-3:30	Bidelman	370
	Y	The theory of stellar atmospheres I	3-4:30	Chandrasekhar	376
	Y	Optics and astronomical instruments		**Strömgren**, Meinel	372
Winter 1952 (p. 30) 01/03 – 03/15	Y	Stellar spectroscopy	2-3:30	Bidelman	371
	Y	Photometry	2-3:30	Hiltner	373
	Y	The theory of stellar atmospheres I	2-3:30	**Strömgren**	377
	Y	Research problems in astrophysics	Arr.	Chandrasekhar, Hiltner,Münch, **Strömgren**	494
	Y	Research problems in stellar astronomy	Arr.	Kuiper, Morgan	495
	Y	Research problems in positional astronomy	Arr.	Strand	497
	Y	Research problems in spectroscopy	Arr.	Bidelman	498
	Y	Postdoctoral research in astronomy and astrophysics	Arr.	Yerkes staff	499
Spring 1952 (p. 30) 03/24 - 06/14	Q	Structure, composition, and evolution of stars	1:30-3 Th	**Strömgren**	302
	Y	Celestial mechanics	3-4:30 Th	Kuiper	385
	Y	Interstellar problems	2-3:30	**Strömgren**	386
	Y	Cosmic electrodynamics	3-4:30 W	Chandrasekhar	388

Appendix E: Citation Index of Selected Twentieth Century Astrophysics Papers

A search in the citation indices of a number of selected prominent astrophysicists have been undertaken by the author in June 2004. Of all the astrophysics papers included in the virtually complete NASA Astrophysics Data System (ADS)[1], Bengt Strömgren contributed with 105 registered scientific articles in the period 1922-1987 written by him or in collaboration with other astronomers. In this investigation I do not distinguish between joint papers and papers by the astrophysicist himself.

Investigating Bengt Strömgren's publication patterns and the citations to his papers, we get table 1 displaying the distribution of citations to his papers registered in the ADS, divided in decennials:

Period	# cited papers	# citations
1980-1987	5	108
1970-1979	3	223
1960-1969	13	606
1950-1959	15	137
1940-1949	3	222
1930-1939	9	226
1920-1929	0	-
	Total: 48	Total: 1,522

Table 1: Citations to the papers by Bengt Strömgren (including joint papers) which are registered in the ADS.

The 48 cited papers in the ADS fall in the limited period 1931-1987 and other scientific papers cite to these 48 papers 1,522 times. Sorting the ten most cited papers of Bengt Strömgren out of all 48 cited papers we end up with table 2. These citations take 1,271 of the total amount of 1,522 citations, thus leaving only 251 citations back distributed on the remaining 38 papers with an average number of 6.6 citations per paper.

[1] The ADS can be found on the Internet at adswww.harvard.edu. The database includes more than one million records of astrophysics papers.

# citations	Bibliographical reference
359	Strömgren 1966
215	Strömgren 1948a
211	Strömgren, Grønbech & Olsen 1976
159	Strömgren 1939
107	Strömgren 1963
60	Strömgren, Gustafsson & Olsen 1982
47	Strömgren, Morgan & Johnson 1955
45	Strömgren & Kelsall 1966
38	Strömgren 1987
30	Strömgren 1964
Total: 1,271	

Table 2: Top ten of the most cited papers of Bengt Strömgren according to the ADS, which is not complete.

Finally, in order to evaluate the amount of citations and in order to place Bengt Strömgren in a more general picture, we need to investigate the citation indices of other prominent astrophysicist of the twentieth century. In table 3, the citation indices of 22 selected astrophysicists with an important impact on astrophysics have been listed, and as can be seen from the listing, Bengt Strömgren is located as number eight in the selection. It is important to note that the ADS is not 100 % complete. Data from 1995 and beyond "should be 100% complete", whereas data from 1975 are "estimated to be 98% complete".[2] Before 1975, the completeness of the ADS records varies. For any journal scanned and placed online, the ADS is complete back to Volume 1. A complete listing of scanned journals is available from the ADS Article Service (http://cdsads.u-strasbg.fr/journals_service.html).

In table 3, the weight factor represents the credibility of the citation numbers. It is worth to notice that apparently the weight factor generally decreases downwards as does the total number of citations in column 5. One plausible reason for this is a lower number of registrations of older papers. We should also note that the registered period of publication in the table falls on still earlier years through the list, thus under-representing older astrophysicists. Therefore any conclusions should be made with caution. This said, the list at least show that comparing the number of citations to

[2] http://cdsads.u-strasbg.fr/abs_doc/faq.html (answers to Frequently Asked Questions to the ADS).

Bengt Strömgren with the citation index of his colleagues, he is located within the top eight of his contemporaries

Not many investigations have been made of the citation indices in the field of astronomy and astrophysics. One interesting study has been made, though, by the historian of science Stephen Brush in 1990.[3] In this study, Bengt Strömgren appears in a list of astronomers having contributed to the 22 most-cited papers from astronomy and astrophysics journals covered in the 1945-1954 Science Citation Index (SCI) cumulation. The papers are B. Strömgren 1939, on "The physical state of interstellar hydrogen" and B. Strömgren 1948a, "On the density distribution and chemical composition of the interstellar gas" both in the *Astrophysical Journal*. The current investigation of the citation index of the 22 astronomers is broader in period but deploys only one source of information, the ADS, having the before-mentioned weaknesses.

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[3] Brush 1990, 392.

Astrophysicist	Registered publication period	# cited papers (# papers registered)	Weight factor	Total # citations in other papers to cited publications	# citations to most cited paper (year)
Chandrasekhar, S. (1910-1995)	1931-1998	228 (365)	62 %	10,067	1,184 (1961)
Fowler, W.A. (1911-1985)	1954-1990	97 (133)	73 %	5,965	620 (1957)
Morgan, W.W. (1906-1994)	1927-1978	121 (165)	73 %	5,400	1,121 (1953)
Oort, J.H. (1900-1992)	1922-1992	106 (177)	60 %	3,148	265 (1997)
Struve, O. (1897-1963)	1923-1965	345 (694)	50 %	2,952	137 (1931)
Bethe, H. (1906-)	1940-2003	47 (63)	75 %	2,951	1,404 (1957)
Baade, Walter (1893-1960)	1921-1960	57 (97)	59 %	2,091	208 (1954)
Strömgren, B. (1908-1987)	1922-1987	48 (105)	46 %	1,522	359 (1966)
Menzel, D.H. (1901-1976)	1922-1988	90 (238)	38 %	1,218	189 (1938)
Payne-Gaposchkin, C. (1900-1979)	1923-1995	70 (238)	29 %	1,137	317 (1957)
Minnaert, M.G.J. (1893-1970)	1924-1988	30 (71)	42 %	1,035	717 (1966)
Kuiper, G.P. (1905-1973)	1926-1980	101 (167)	61 %	989	117 (1941)
Russell, H.N. (1877-1957)	1898-1956	86 (202)	43 %	975	353 (1952)
Eddington, A.S. (1882-1944)	1906-1987	64 (161)	40 %	922	222 (1926)
Biermann, L.F.B. (1907-1986)	1931-1984	48 (95)	51 %	641	79 (1948)
Jeans, J.H. (1877-1946)	1913-1933	28 (84)	33 %	484	134 (1928)
Milne, E.A. (1896-1950)	1923-1952	43 (93)	46 %	271	37 (1926)
Hertzsprung, E. (1873-1967)	1907-1969	68 (209)	33 %	253	50 (1928)
Lindblad, B. (1895-1965)	1917-1964	34 (93)	37 %	170	34 (1959)
Lundmark, K. (1889-1958)	1916-1956	15 (65)	23 %	63	15 (1921)
Guthnick, P. (1879-1947)	1901-1943	23 (88)	26 %	52	9 (1930)
Ludendorff, H. (1873-1941)	1915-1940	4 (37)	11 %	14	9 (1928)

Table 3: Citation indices of 22 selected astrophysicists from the USA (Russell, Struve, Fowler, Menzel, Kuiper (originally Dutch), Morgan), Denmark (Hertzsprung, Strömgren), the UK (Eddington, Milne, Jeans, Payne-Gaposchkin), Germany (Bethe, Ludendorff, Guthnick, Baade, Biermann), Holland (Oort, Minnaert), and Sweden (Lindblad, Lundmark), and Chandrasekhar, who became an American citizen. The weight factor reflects the fraction of the number of cited papers divided by the number of registered published papers by the NASA Astrophysics Data System. The weight factor indicates the credibility of the citation indices in the table.

Appendix F: Bengt Strömgren's honors and distinctions

Medals, Prizes and Honorary Lectures

1950	The Augustinus Prize
1958	Halley Lecture
1959	Catherine Wolfe Bruce Gold Medal
	Rittenhouse Medal ("for an outstanding achievement in astronomy", by Rittenhouse Astronomical Society)
1962	Gold medal of the Royal Astronomical Society
	Ole Rømer Medal
	George Darwin Lecture
1963	The Rosenkjær Prize
1965	H.C. Ørsted Medal
	Silver Medal of Landsforeningen til Kræftens Bekæmpelse (National Association for combatting cancer)
	Association pour le Développement International de l'Observatoire de Nice, ADION Medal
	H.N. Russell Lectureship (award for lifetime acievement, AAS).
1967	The Juel Janssen Gold Medal ("the highest astronomical award of the Paris Academy of Sciences")
	Member of Det Norske Videnskaps-Akademi in Oslo
1969	Karl Schwarzschild Medal (Astronomische Gesellschaft)

Memberships

1926	Member of Astronomische Gesellschaft
1939	Member of the Royal Danish Academy of Sciences and Letters, 1939-46, (1957-67 foreign member)
1944	Member of the executive committee of the Ole Rømer Fondet.
1947	Member of ATV (Akademiet for de Tekniske Videnskaber), (1959-67 foreign member)
1949	Corresp. member of the Akademy o Coimbra

	Member of Kungliga Svenska Vetenskapsakademien (Royal Swedish Academy of Science)
1950	Member of the Fysiografiska Selskapet in Lund
1951	Corresp. member of the Koninklijke Nederlanse Akademie Wetenschappen
1952	Medlem af Societé Royale des Sciences de Liège
1954	Member of Advisory Panel, National Astronomical Observatory, US National Science Foundation
1955	Member of American Academy of Arts and Sciences
1957	Member of Kungliga Vetenskapssocieteten, Uppsala
1967	Member of the Norwegian Academy of Sciences in Oslo.

Honorary doctorates

Harvard University
Lund's University
University of Cordoba
University of Argentina
University of Uppsala

Presidencies and other

1940-1954	Director of the Copenhagen Observatory
1948-1952	General Secretary of IAU
1951-1957	Director of the Yerkes and McDonald Observatories
Unknown period	President of Landsforeningen til Kræftens Bekæmpelse (National Association for Combatting Cancer – the Cancer Comittee) for more than ten years
1966-1967	President of the American Astronomical Society
1969-1975	President of the Royal Danish Academy of Sciences and Letters
1970-1973	President of IAU
1971-1974	President of ESOs Scientific Policy Committee
1971-1975	Director of NORDITA
1975-1977	President of the ESO Council

Appendix G

Astronomy Made Easy

Bengt G.D. Strömgren

1955

Based on lecture notes,[i]

Astronomy 000,

by Nelson Limber[ii]

Transcribed by Simon Olling Rebsdorf, February 2002

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[i] Arabic numbered notes are Strömgren's own notes in his text (6, 7, and 9). Roman numbered notes (like this) are my additional notes.
[ii] D. Nelson Limber from Princeton University received his PhD degree in June 1953.

Preface

The author of this book is an immensely rich man who could easily give a dollar to every one of the readers. However, money is not everything, in fact the author has found that what many people want more than anything else is to learn Astronomy.

The trouble is that Astronomy is a difficult subject. People are known to have studied the subject for over 15 years at a famous Midwestern Observatory without getting a degree.

This book has been written to make Astronomy easy. Many years ago, a famous Harvard Astronomer showed the way. He wrote a fine monograph dealing with the Structure of the Milky Way, and on the last page of the book he indicated how the center of the system could be located with a minimum of effort. Even today his presentation of the subject cannot be improved upon, and we have in fact included it without change in this book, Chapter I.

The author has applied the same method to other problems. Not content with this, however, he has developed entirely new methods and procedures. In fact, this is the greatest advance in education since television.

Chapter I The structure of our galaxy

In order to determine the direction to the center of the galaxy, all one has to do is view the Milky Way from the tropics.

The best view may be that of sidereal time 15-16 hours, when the Carina region is setting, Sagittarius is well up in the sky, and the cross of Cygnus is rising above the horizon. No one who had the privilege of thus seeing the Milky Way in all its grandeur would ever deny that the Sagittarius could mark the central region of our galactic system.

Chapter II Positional Astronomy, Proper Motions

Determination of positions with a meridian circle requires costly equipment, long hours at a telescope almost in the open and enormous amounts of calculation. The results are star catalogues, and when this has gone on for a century, or more, yet other enormous calculations yield proper motions. These are then discussed, partly to see how much they are in error, partly to determine the structure of our galaxy, and what it is doing.

However, the results can be derived practically without effort according to the method presented in chapter I. The alert reader will therefore find it easy to agree with the conclusions of many: SKIP IT.

Chapter III Determination of the Equinox

For the serious student, who nevertheless wants to work in positional astronomy, there is this advice: Determine the equinox.

This requires much effort, but it is a perfectly safe and harmless sport. All the results is ever used for is to find how much is in error relative to other determinations.

The serious student will find further advice in the Appendix.

Chapter IV Double star astronomy

The odds are 20 to 1 you will like double star astronomy. You set the telescope, turn the dome, check your field, etc., and for the same effort you get two stars instead of one, sometimes more.

You can then carry out the kinds of laborious measurements, but the alert astronomer will get the results by the methods of chapter I.

Take the case of Sirius. No one who had the privilege of seeing Sirius A in all its grandeur, accompanied by Sirius B, faint, faint, yet so alike its luminous brother, would ever deny that this configuration resulted from a catastrophe.

Sirius B, the mum but eloquent witness, was once a very luminous star that overspent, lost most of its mass in the resulting catastrophe and then contracted to its present inconspicuous state.

Chapter V Spectral classification

Spectral classification is very simple, really. First you accumulate standard spectra, lots of them. Then, when you have taken the spectrum of a star, you compare it with the standards. If you can match it exactly, you have classified a star. If you can’t, you write a paper.

Chapter VI The sun’s magnetic field

It has been suggested that the sun’s magnetic field is primeval. A little thought shows, however, that this cannot be so.

The sun is a conductor of perfectly enormous size, and therefore the time of decay of its magnetic field is over 3×10^9 years. Granted! But what about the earth. The earth is not so perfectly enormous, and the decay time is in fact so short that the field cannot be primeval. And now we come to the crucial point. With respect to magnetic fields, the sun and the earth must be alike.

To prove this, consider the difference between the sun and the earth. By far the greatest difference in this: The earth is inhabited, the sun is not!

Now, what does this mean with regard to magnetic fields? To determine this, all we have to do is write down Maxwell's equations, insert all the inhabitants of the earth, and we shall find that not the slightest magnetic field is produced.

Since the greatest difference between the sun and the earth thus does not give rise to any difference in the magnetic qualities, we can safely conclude that other, minor differences will not cause any differences either. We therefore have the result that the sun's magnetic field cannot be primeval.

This important result may easily be remembered with the help of the following JOKE:

Q: What is the difference between professors and the magnetic fields of celestial bodies?

R: The latter are never fossile.

Chapter VII Magnetic stars

No one who had the privilege of seeing a Thor Washing Machine[iii] in operation in all its grandeur - rocking forth and back under the influence of an electromagnetic field, the water splashing merrily, a Europium-shirt diving and then reappearing here, a Chromium-diaper popping up and going under yonder - would ever deny that magnetic stars are undergoing nonradial oscillations. Radial oscillations? You said it, what a mess!

Chapter VIII The chemical compositions of the sun

This is a difficult subject. Not only is it difficult in itself, but it is quite difficult to keep track of the changes of opinion of the greatest authorities in the field.

Put it this way: The heavy element content of the sun has been varying with time.

Now, the superficial student might say, what is it now, that is all I care to know. Not so the serious student, nor the alert student. In fact, the study of a field requires study of its development. Also, some professors are historically-minded.

This being so, a table has been prepared which makes it easy to remember the relevant facts. The table is given on the following page.

[iii] Bengt Strömgren had a Thor Washing machine in Williams Bay.

Year	Heavy elements content	Analogy
1939	65 %	Kickapoo Joy Juice
1946	12 %	California Red Wine
1948	4.5 %	Carsberg Beer, as brewed by the Royal Danish Academy
1951	1 %	Williams Bay Joy Juice, oh my gosh[iv]

It should be noticed that this does not mean that less energy is being produced in the interior of the sun. It simply means that the stuff is becoming more and more efficient, and less and less of it is needed.

The mean molecular weight similarly has been reduced from 56 to 0.56 over a period of 35 years. According to all the best authorities the luminosity is proportional to this quantity raised to the power of 7.5. A simple calculation shows that the decrease is by a factor of 10^{15}.

However, according to the principle of compensating factors, the luminosity of the sun has not changed at all.

Chapter IX Determination of the cosmical abundances of the elements

In analyzing for cosmical abundances one of the most important points is to choose a suitable sample.

Would you choose the contents of a coal bin? No, that would be foolish. Your wallet? No, it is empty. Lake Geneva? Well, not so good either. A boy’s pockets? Now, that is much better. In fact, what you have to look for is the greatest possible mess.

So, you apply the principle of maximum confusion, and you can do even better that a boy’s pockets: The Chrondrites.

In the Chrondrites we have the perfect sample for studying cosmical abundances. Although the problem of cosmical abundances has thus been solved, there remains the problem to explain how so much confusion could arise in less than an hour.

Chapter X The determination of cometary orbits

Have you ever glanced through the pages of Oppolzer’s “Bahnbestimmung”. Rather discouraging, is it not? Well, it is really much simpler that all that.

[iv] The joy juice refers to the fact that all events at Yerkes were “dry”. According to Nina Strömgren Allen, Bengt and Sigrid smuggled cheap red wine into their house and had that with their dinner. Empties were kept in a spare pantry, as they could not appear in the garbage (COR).

First of all, you want to concentrate on new comets. Then you know that the elements *ω*, *Ω*, and *i* are distributed at random. Now, don't be forced by this learned expression! It simply means that any old value is as good as the other. So, why bother to determine *ω, Ω*, and *i*.

Experience shows that it is very likely that *e* = 1 and *a* = 50.000 A.U. are values compatible with the observations. So that problem is solved also.

There remains the problem of time of perihelion passage. Well, this is after all a thing of the past, so why bother.

Now, how do you know that the comet is new? You get a spectrum, and show it to an experimental spectroscopist. If he looks startled, the comet is new.

What should you do if the comet turns out to be of the type that is not new. Well, in that case we are confident that the comet will return, and the problem of determining the orbit can be left to future generations of astronomers.

Chapter XI The spiral structure of galaxies

No one who had the privilege of seeing cream, poured into a cup of coffee and stirred, would ever deny that spiral arms are trailing.[v]

Chapter XII High velocity stars

Get out a spectrum of a high velocity star and take a good look at the region of the cyanogen band. It looks gray does it not, worn, old, nay, primeval! There can be no doubt: This is POPulation II.

Chapter XIII Accretion

No one who had the privilege of seeing the results derived from the accretion theory in all their grandeur, would ever deny that the average density of interstellar matter is 10^{-21} g cm^{-3}.

Chapter XIV Astronomical Observatories

No one who had the privilege of seeing Harvard College Observatory in all its grandeur would ever deny that [Unfortunately Mt. Limber's notes stop at this point. The serious student who wishes to learn still more is referred to the Appendix].

Appendix

The alert student realizes that knowledge is not all, he must also prepare for the occasion of the oral examination.

How can he do this? Ask those who have been through the ordeal? No, that does not work. Candidates emerging after the oral examination differ in many respects, but they have one thing in common: They do not say much.

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[v] Once in a while, Bengt Strömgren demonstrated spiral arms by stirring his coffee for his children (COR).

To help the student solve this problem, we here describe an oral examination. Naturally, the alert student is not so much interested in the past, he wants to know what lies ahead of him. Therefore, the scene of the following oral examination is a famous Midwestern Observatory, *a few years from now*.

It is the morning of the oral examination. The candidate enters a luxuriously furnished office. All the instructors are present. The candidate cannot help wishing that it were more like the passed quarter when one of the instructors was in the East, two in California, two in Texas, and one in Europe. However, he pulls himself together. The atmosphere is a little tense, but one of the professors asks the candidate how he feels. The candidate says that he feels fine. The questions begin immediately.

Q[6]: What is the effective temperature of the sun?
A[7]: 3000°
Q: How would you reconcile that with the fact that the temperature of G stars is about 6000°? What is the spectral type of the sun?
R: G
S: That is correct. And the effective temperature?
T: 6000°
U: Quite right. Now, many years ago, astrophysicists believed that the pressure in the photosphere was much higher than in the terrestrial atmosphere and then for a while they thought it was much lower. What is the correct answer?
V: It is about the same
W: Well, that is about right, in fact a little lower
X: Yes, a little lower
Y: That is correct. Now under such pressures we would expect collision damping to play a role. What is collision damping?
A: ?
Q: What broadens the solar absorption lines
A: The solar absorption lines are broadened by collision damping corresponding to a pressure in the photosphere somewhat less than an atmosphere and an effective temperature of about 6000°. This gives the spectrum the appearance of a star of spectral type G.
Q: That is absolutely correct. Now, is collision damping always a determining factor, or does Stark broadening play a role?
A: Stark broadening plays the dominant role for some lines
Q: That is right. For which lines?
A: ?
Q: How about the Balmer lines?
A: The Balmer lines are broadened by Stark effect.
Q: Right. Which stationary state absorbs the Balmer lines?

[6]Q means what the instructor says. It is not always a question.

[7]A means what the candidate says. It is not always an answer.

A: The positive hydrogen ion.
Q: Excuse me?
A: I mean the negative hydrogen ion.
Q: Of course, H^- is quite important in providing the continuous absorption that is so to speak the background of the Balmer lines, but the Balmer lines are absorbed by?...
A: Neutral hydrogen
Q: Yes, the second excited state
A: Yes, the second excited state
Q: Right. Now, can you tell me what is meant by a curve of growth in the theory of absorption lines.
A: It is a curve that indicates the growth of stellar absorption lines.
Q: Right. Now, for faint lines the strength of course grows rapidly with the number of absorbing atoms. And then?
A: Then it grows less rapidly
Q: That is correct. And after that?
A: After that it again grows more rapidly
Q: Quite right. Does it ever attain the rate of growth characteristic of faint lines?
A: No the curve goes up again, but not as steeply as for faint lines.
Q: That is absolutely correct, and you have given a good description of curves of growth. Which atomic particle is largely responsible for continuous absorption in the solar atmosphere?
A: The negative hydrogen ion
Q: That is right. Now let us turn to another subject. What is the H-R-diagram?
A: You plot H against R
Q: What?
A: You plot H against R. H is the dependent variable.
Q: Well, I can assure you that here H is neither dependent, nor variable, I would rather say independent and stereotype, ha, ha, ha, ha, ha, ha.

The instructors, who by now are a little bit tired, laugh and giggle for about two minutes. Amidst the laughter you hear such phrases as “Do you remember the time when he took a bath while Struve was waiting for him, and then thought he had forgotten his slides”, and so forth.[viii] Meanwhile the candidate is frantically consulting a copy of “Russel Dugan Stewart” which is lying on the table, just in case a very difficult question comes up that the student cannot answer. However, the candidate finds no reference whatsoever to the H-R-diagram in the book.

Q: I am sorry, Mr. X, where were we? Well, yes, what is the H-R-diagram?
A: (In a rather low voice):You plot H against R.
Q: Well of course, in a way you are right, that is if you would call the absolute magnitude H, and the spectral type R.
A: Well, what I mean is that the H-R-diagram is a diagram in which each star is represented by a point according to its absolute magnitude and its spectral type.

[viii] This is clearly a reference to the incident described in chapter 5.3 when Hertzsprung visited the Yerkes Observatory in 1937.

Q: That is quite right. Now where do you find the supergiants?
A: To the left in the diagram
Q: Well, some of them
A: And some of them to the right in the diagram
Q: Yes, but the important thing is that (makes a gesture)...
A: They are at the top of the diagram
Q: That is correct. Where are the white dwarfs?
A: Being dwarfs they are at the bottom of the diagram and being white they are to the right
Q: You mean to the left?
A: Yes, the white dwarfs are in the lower left corner of the H-R-diagram.
Q: Quite right. Now let us change the subject again. Why is photoelectric photometry better than photographic photometry?
A: It is more accurate
Q: That is correct. What is a Cesium-Antimony photocathode made of?
A: Cesium oxide
Q: Excuse me?
A: No, Cesium-Antimony
Q: Right, What is the function of a photomultiplier?
A: It multiplies
Q: What does it multiply?
A: Photos
Q. You mean photoelectrons?
A: Yes, photoelectrons
Q: Why is a photomultiplier more convenient to use than a photocell?
A: Because it multiplies the photoelectrons so there are many more of them
Q: That is correct. Now, what is a Field Lens?
A: A lens that has a field
Q: Well, yes, but you could be more specific, that is, consider the case that you have a photocathode, do you think that the sensitivity is absolutely constant over the surface?
A: No, it varies somewhat
Q: Then, would it be important that the image of the star falls on the same part of the photocathode, always?
A: Yes, that would be quite important
Q: How do you achieve this?
A: You have a Field Lens
Q: That is absolutely right. Can you tell me, what limits the accuracy of photoelectric observations of faint stars?
A: Well, sometimes you make mistakes in your reading
Q: I was not thinking of that. We.., the situation is this, you have your faint star in your diaphragm, and the light falls on the photomultiplier. Now, would you observe in daytime?
A: No, then I go to classes
Q: Well, suppose you did not go to classes...
A: I would not pass the exam at the end of the quarter.

Q: Ahem, let us put it this way now, during the day, in your diaphragm, you have the light of the star plus the day sky background. And during the night?
A: You have the light of the star plus the night sky background
Q: That is correct. Now which is the larger?
A: The light of the star
Q: Well, if it is a very faint star?
A: Then it is the night sky background
Q: That is correct. Now, is the photocurrent corresponding to the night sky absolutely constant?
A: No, it varies, and that limits the accuracy of the photoelectric observations in the case of very faint stars.
Q: You are absolutely right. Well, we have only a few more questions. How can magnetic stars be explained?
A[9]: In terms of non-radical oscillations, much like in a Thor Washing Machine
Q: Well, that is an interesting idea, I never thought of that. Now, just a few general questions that you should try to answer very briefly. What principle would you follow when determining cosmical abundances?
A: The principle of maximum confusion.
Q: Right. And in galactic research?
A: The principle of minimum effort
Q: Right. And in answering questions at an oral examination?
A: The principle of maximum likelyhood.
Q: Right. Your motto when publishing, say, the value of a constant?
A: Be anything, but be mine.
Q: Right. If you were to start your studies all over again, where would you study?
A: Here.
Q: Good. And according to which principle would you organize your course work?
A: The principle of maximum unhappiness.
Q: Well, now we have the last question. Can you mention any important research done during the last three years outside Yerkes and Mc Donald Observatories?
A: No.
Q: That is absolutely correct. Thank you, Mr. X, we will excuse you.

[9]The candidate has studied this book.

Appendix H: Bibliography of Bengt G.D. Strömgren

(courtesy of Erik Heyn Olsen)

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