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The Road to the Anthropic Principle

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The Road to the Anthropic Principle

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1. Introduction

Hardly any principle of modern physical science has been more controversial than the anthropic principle (AP) that was first explicitly formulated in the 1970s. The general meaning of this view or principle is that what we observe must be compatible with our existence, if not necessarily only with *our* existence. From this innocent observation attempts are made to derive non-trivial consequences about nature in general and about the structure and development of the universe in particular. In view of the great importance of the anthropic principle in modern physics and cosmology, only relatively little has been written about its historical roots and how the principle evolved during its early phase.[1]

If a birthday is to be assigned for the anthropic principle, 12 September 1973 would be a good choice. On this date Brandon Carter gave a talk at the meeting of the International Astronomical Union in Warsaw in which he coined the term "anthropic principle" and, more importantly, spelled out its significance and some of its potentials as a tool of science. Curiously little is known of how Carter arrived at his ideas and how they were initially received. The aim of the present essay is to contribute to the historiography of the anthropic principle, if only in a limited and preliminary way. Although the idea has a rich prehistory, it

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[1] For the history of design arguments and anthropic ideas, see Bettini 2004 and Barrow and Tipler 1986. A useful bibliography for the early period is provided in Balashov 1991.

is only with a considerable amount of hindsight that one can find anticipations of it in the pre-1960 literature. For this reason I only refer briefly to these earlier views – anticipations if one likes – while I focus on the decades 1960-80 which was the period in which the modern anthropic principle was formulated and first applied as an explanatory tool in cosmology. The more recent interest in the principle is closely related to the controversies over the multiverse and the string landscape in which the anthropic principle enters as an integral part. Since I have dealt with these aspects elsewhere,[2] they play no important role in this essay, which does not go beyond the late 1980s.

The major part of the extensive literature on the anthropic principle is either technical – meaning applications of anthropic reasoning to problems of physics and cosmology – or critically and philosophically oriented. Philosophers have been no less interested in the principle than physicists have. In addition, a great many works focus on the religious implications (if any) of the anthropic principle. Although critical and evaluative aspects cannot be sharply distinguished from the descriptive aspects, this essay is largely of a historical and descriptive nature. It is not meant to be one more contribution to the already too long list of analytical and discursive works on the anthropic principle.

2. From natural theology to anthropic ideas

The general idea that the world we experience is special and somehow conditioned by the presence of humans to observe it can be traced far back in time. With some good will it can be found in ancient Greek-Roman culture and possibly in some other ancient cultures as well. In his famous poem *De rerum natura*, composed about 50 BC, the poet and natural philosopher Titus Lucretius

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[2] Kragh 2009.

Carus advocated an atomistic cosmology inspired by the ideas of Democritus and Epicurus. In sharp contrast to the widely accepted Aristotelian view, he presented the universe as infinite in space but finite in time. Based on the shortness of human history, he argued that "the whole of the world is of comparatively modern date, and recent in its origin; and had its beginning but a short time ago."[3]

To jump ahead in time, scholastic philosophers in the late middle ages eagerly discussed ideas of an anthropic nature in connection with God's free will and omnipotence. Did God design the universe with the purpose that it should accomodate his chosen creatures? The discussions among the schoolmen included elements that much later would turn up in the context of the anthropic principle.

In so far that anthropic-like arguments were common in the past, it was almost always in the popular and at the time uncontroversial form of natural theology. An early example is provided by Bernard Le Bovier de Fontenelle, permanent secretary of the Royal Academy of Sciences in Paris and the author of the immensely popular *Entretiens sur la pluralité des mondes*. In this work, a classic of pluralist literature published in 1686, Fontenelle explained the inclination of cometary orbits relative to the ecliptic by arguing that otherwise the comets would have destroyed life on Earth. Had the orbits been "normal" – similar to those of the planets – we would not be here.[4] This may be interpreted as an early example of anthropic reasoning, but it may also and perhaps with better justification be read as just an example of the kind of old-fashioned teleology of

[3] Lucretius 1997, p. 10. The case of Lucretius and other ancient thinkers is examined in Ćirković 2003b.
[4] Ćirković 2002.

which the period was so rich. Indeed, somewhat similar ideas were ventured by Edmund Halley, William Whiston and a few other natural philosophers.

Much later, the naturalist and pioneer evolutionist Alfred Russell Wallace published a controversial work, *Man's Place in the Universe*, in which he proposed an anthropocentric cosmology. Claiming that a universe without humans would be an absurdity, he argued that the purpose of the universe was man as a spiritual being. Wallace suggested that the position of the Earth, which he thought was in the centre of the Milky Way, could not be regarded a coincidence "without any significance in relation to the culminating fact that the planet so situated has developed humanity."[5] Another contemporary scientist who is sometimes mentioned as a precursor of the anthropic principle is Ludwig Boltzmann, who in the 1890s famously suggested that the present low entropy, or high degree of cosmic organization, is the result of our world being in a statistically unlikely state. According to Boltzmann, the only reason that we witness this exceedingly unlikely situation of a deviation from high entropy is that our very existence depends upon it.

Basing his argument on the probabilistic notion of entropy that he had introduced in 1877, in 1895 Boltzmann developed a remarkable scenario of anti-entropic pockets in an infinite or just exceedingly large universe:

> If we assume the universe great enough we can make the probability of one relatively small part being in any given state (however far from the state of thermal equilibrium) as great as we please. We can also make the probability great that, though the universe is in thermal equilibrium, our world is in its present state. … Assuming the universe great enough, the

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[5] Wallace 1903, p. 411.

> probability that such a small part of it as our present world be in its present state, is no longer small. If this assumption were correct, our world would return more and more to thermal equilibrium, but because the whole universe is so great, it might be probable that at some future time some other world might deviate as far from thermal equilibrium as our world does at present.[6]

A contemporary of Boltzmann, the British physicist and telegraph engineer Samuel Tolver Preston entertained ideas that had a similar anthropic flavour. In a paper of 1879 he observed that the region of the universe inhabited by man must be "amply extensive enough to allow an amount of activity and variability of energy adapted to the conditions of life." He furthermore suggested that "We may happen to be in a part [of the universe] where the mean temperature of the component matter is exceptionally high, as, of course, from the fact of our being in existence, we must be in a part which is suited to the conditions of life."[7]

Arguments somewhat resembling those of the anthropic principle were forwarded by James Jeans in the 1920s, when he gave several talks that included speculations about the role of life in the universe. For example, in a lecture delivered in 1926 he pointed out that "the physical conditions under which life is possible form only a tiny fraction of the range of physical conditions which prevail in the universe as a whole." As an example he mentioned that the liquid state (and hence ordinary water) required certain quite special conditions. Jeans elaborated:

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[6] Boltzmann 1895, p. 415. For a recent review of Boltzmann's many-worlds scenario, see Ćirković 2003a.

[7] Preston 1879, p. 462. Bettini 2004.

> Primeval matter must go on transforming itself into radiation for millions and millions of years to produce an infinitesimal amount of the inert ash on which life can exist. Even then, this residue of ash must not be too hot or too cold, or life will be impossible. It is difficult to imagine life of any high order except on planets warmed by a sun, and even after a star has lived its life of millions of millions of years, the chance, so far as we can calculate it, is still about a hundred thousand to one against it being a sun surrounded by planets. In every respect – space, time, physical conditions – life is limited to an almost inconceivably small corner of the universe.[8]

Neither Jeans nor others at the time drew consequences with regard to the constants of nature or cosmic evolution from the fact that life does exist.

In his heroic but ill-fated attempt to establish a fundamental theory of all of physics, Arthur Eddington thought that he was able to explain numerical coincidences between the constants of nature by an epistemic analysis of the nature of observation. In his method of so-called selective subjectivism he appealed to selection arguments somewhat similar to those that would later be associated with the anthropic principle. He thought that the cosmic number (the number of particles in the universe) and most other constants were determined by mental and therefore human factors, namely "the influence of the sensory equipment with which we observe, and the intellectual equipment with which we formulate the results of observation of knowledge." This influence, he said, "is so far-reaching that by itself it *decides* the number of particles into which the matter of the universe appears to be divided."[9]

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[8] Jeans 1926, p. 40, a lecture delivered at University College, London, on 9 November 1926.

[9] Eddington 1939, p. 60. Emphasis added.

Again, a mild kind of anthropic reasoning can be found in the paper of 1948 in which Hermann Bondi and Thomas Gold introduced the steady-state theory of the universe. Referring to the classical problem of the heat death in an infinitely old static universe, they wrote: ”That our universe is not of this type is clear not only from astronomical observations but from local physics and indeed from *our very existence*.”[10] However, there is probably no reason to pay much attention to the statement or to believe that Bondi and Gold intended it to be a statement about the role played by human observers with cognitive faculties. Probably without knowing it, they were merely repeating what dozens of scientists and philosophers had said more than a century ago in connection with the controversy over the heat death, in many cases with direct reference to the existence of human beings.[11]

3. Russian predecessors?

As indicated, anthropic-like arguments can be found in much of the early history. However, they only clearly appeared in the context of the evolving universe about 1960, when they were introduced in different ways by Grigory Moiseevich Idlis in the Soviet Union and Robert Dicke in the United States. Idlis forwarded his anthropic arguments in a speculative paper from the Kazakh Academy of Sciences in 1958, published in Russian only. Its title in English was ”Basic Features of the Observed Universe as Characteristic Properties of a Habitable Cosmic System.” In a later historical review, Idlis referred to his early anthropic ideas, summarizing them as follows:

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[10] Bondi and Gold 1948, p. 255. Emphasis added.

[11] On the entropic controversy ca. 1870-1910 and its possible bearing on anthropic-like arguments, see Kragh 2008.

> Our entire infinite Metagalaxy … does not represent just one of the cosmologically possible, non-stationary Friedman worlds, but constitutes a precisely typical, habitable world at the stage of existence of intelligent life therein, since all corresponding properties of the Metagalaxy, directly observed by us, are, generally speaking, just the necessary and sufficient conditions for the natural origination and evolution of life to higher intelligence forms of matter, similar to man, finally aware of itself.[12]

Although Idlis later claimed to be the true discoverer of the anthropic principle, his paper of 1958 made almost no impact at all and remained unknown to scientists in the West.[13] It seems not to have aroused much attention among Russian scientists either.

Another Russian, the physicist and cosmologist Abraham Zelmanov, has been mentioned as a possible father of the anthropic principle, many years before Carter. A specialist in relativistic cosmology, Zelmanov did important work on inhomogeneous cosmological models which he first published in a dissertation of 1944 from the Sternberg Astronomical Institute in Moscow. According to Dmitri Rabounski, by that time he had formulated a version of the anthropic principle, which he discussed with his colleagues but apparently without publishing his thoughts. He is to have said:

> Humanity exists at the present time and we observe world constants completely because the constants bear their specific numerical values at

[12] Idlis 1982, p. 357.
[13] For Idlis' claim, see http://www-philosophy.univer.kharkov.ua/Idlis1_eng.pdf and Idlis 2001. I have not seen Idlis' paper, which, as far as I know, has never been translated into English. According to Zel'dovich 1981 the source is *Proceedings of the Astrophysical Institute of the Kazakh SSR Academy of Sciences* 7 (1958), 39-54.

> this time. … The Universe has the interior we observe, because we observe the Universe in this way. It is impossible to divorce the Universe from the observer. The observable Universe depends on the observer and the observer depends on the Universe. … If no observers exist then the observable Universe as well does not exist.[14]

This gives some of the flavour of the anthropic principle, but only in a very general and speculative way. Besides, the authenticity may be questioned. As long as more convincing evidence for Zelmanov's part in anthropic history is lacking, I see no reason to take Rabounski's claim, or for that matter Idlis', seriously. Russian predecessors apart, the path to the modern formulation of the anthropic principle went over Dirac's cosmological theory of 1937-38 based on the large number hypothesis.

4. Dicke's cosmic coincidences

In 1937 Paul Dirac suggested a new conception of cosmology based on what he called the Large Number Hypothesis, which is the postulate that whenever two very large numbers turn up in nature (such as 10^{40} and 10^{80}), or can be constructed from natural constants, they must be related in a simple way. It was known at the time that the ratio of the electric to the gravitational force between a proton and an electron (of mass M and m, respectively) is such a large dimensionless number, namely about 10^{39}. Dirac pointed out that if time is measured in units of the time it takes light to pass a classical electron, $\Delta t = e^2/mc^3$,

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[14] Biographical introduction by D. Rabounski in Zelmanov 2006, p. 8, a translation of Zelmanov's dissertation of 1944. Rabounski says that the statement is Zelmanov's principle, as given "in his own words," but does not provide any source or documentation. See also Rabounski 2006. According to Idlis 2001, Zelmanov formulated a version of the anthropic principle in a paper of 1970.

then the age of the universe as roughly given by the present Hubble time T_0 will be approximately the same number:

$$\frac{e^2}{GmM} \cong \frac{T_0}{\Delta t} \cong 10^{39}$$

That is, from this apparent coincidence, and by assuming *e*, *m*, *M* and *c* to be true constants, Dirac concluded that the gravitational constant decreases slowly in time: $G \sim 1/t$. From similar arguments he made the radical proposal that the number of particles in the universe increases with the square of cosmic time.[15] From the perspective of this essay, what is important is only that according to Dirac, the value of the Hubble time *T* (approximately the age of the universe) reflected the ratio of the electric and gravitational forces, from which he inferred that the constant of gravitation decreased in time. Although Dirac's varying-*G* cosmology was considered unorthodox and had very few adherents, it was well known by physicists and cosmologists.

The first physicist to consider Dirac's hypothesis in the light of the existence of human observers seems to have been Robert Dicke, a professor at Princeton University who was equally at home in quantum theory, general relativity, cosmology and microwave instrument technology. Dismissing the possibility that "nature is somewhat capricious," in papers of 1957 Dicke referred to Dirac's explanation of the large dimensionless numbers, which he in some ways found to be attractive. However, he also criticized the hypothesis because it lacked empirical evidence and disagreed with the equivalence principle on which Einstein had built his theory of gravitation.

[15] Dirac 1937. On the history of Dirac's cosmology and the Large Number Hypothesis, see Kragh 1990, pp. 224-346.

From Dicke's point of view, the large numbers of the orders 10^{40} and 10^{80} could not have been much different from what they actually are. ”The age of the universe, 'now', is not random but conditioned by biological factors," he said.[16] Humans could not have evolved had the age been much smaller, nor would they exist if the age was much greater. These comments were made in passing, in papers dealing with other subjects, and they did not attract any attention at the time. The following year Dicke repeated and amplified his argument that Dirac's reasoning contained a logical loophole since it assumed that the epoch of humans is random. From astrophysical estimates he argued that the epoch is limited by the life-time of stars and the time it takes to produce carbon and distribute it in the surrounding space. ”The present epoch," he said, "is conditioned by the fact that the biological conditions for the existence of man must be satisfied."[17] According to Dicke, the present value of the Hubble time should be understood not as a result of the Large Number Hypothesis but as a consequence of there being at least one habitable planet with human life. At the time he did not see his anthropic consideration as a clear alternative to the variability of physical constants.

In a later paper of 1961, entitled "Dirac's Cosmology and Mach's Principle," Dicke considered the two large numbers

$$N_1 = \frac{\hbar c}{GM^2} \approx 2 \times 10^{38} \quad \text{and} \quad N_2 = \frac{T}{\hbar / Mc^2} \approx 10^{42}$$

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[16] Dicke 1957b, p. 375, and similarly in Dicke 1957a.

[17] Dicke 1959, p. 33. Reprint of paper originally published in the *Journal of the Washington Academy of Sciences* in July 1958.

where M denotes the mass of the proton and $\hbar$ (= $h/2\pi$) is Planck's constant. The first number is the inverse dimensionless gravitational coupling constant, which can also be written in terms of the Planck mass, namely

$$N_1 = \left(\frac{m_{Pl}}{M}\right)^2 \quad \text{with} \quad m_{Pl} \equiv \sqrt{\frac{c\hbar}{G}}$$

The second number is the age of the universe T expressed in a dimensionless form. The expressions, which notably include Planck's constant, are not quite the same as those Dirac had considered, but the difference is of no significance. What matters is that they are both "large" in Dirac's sense and that $N_1 \sim N_2$. Dicke now noted that "carbon is required to make physicists," or that the present age is characterized by the existence of carbon and other elements heavier than helium. Without these elements, human observers would evidently not be around. The order of magnitude of the lifespan of a main sequence star can approximately be calculated to

$$T_{star} \sim \frac{\hbar}{Mc^2}\left(\frac{GM^2}{\hbar c}\right)^{-1}$$

Because $T \sim T_{\mathrm{star}}$, this agrees with the result derived from Dirac's Large Number Hypothesis, except that now it comes out as a consequence of our existence as observers. In this sense the relation is self-selected.

More specifically, Dicke concluded that "with the assumption of an evolutionary universe, T is not permitted to take one of an enormous range of values, but is somehow limited by the biological requirements to be met during the epoch of man."[18] Notice that Dicke did not claim to have explained the age of the universe, only to have given an alternative explanation of the puzzling coincidence $N_1 \sim N_2$. Nor did his argument include any indication at all for some teleological design of the universe. Although Dicke did not explain the Hubble age, he did offer an argument that its value cannot be arbitrary. Far from being a deductive or predictive argument based on a fundamental hypothesis, in a sense he explained the past from the present, namely from the undeniable existence of humans. This mode of reasoning, so different from the deductive mode traditionally used in the theoretical sciences, is characteristic for the methods associated with the anthropic principle.

As to the smallness of the gravitational coupling contant, Dicke appealed to Mach's principle, although realizing that "this may not be a very satisfactory answer." He concluded his brief paper by noting that Dirac's numerical coincidences could be explained by "the existence of physicists now and the assumption of the validity of Mach's Principle." The existence of *physicists* was presumably not essential to his argument. During the following years Dicke returned several times to Dirac's hypothesis, but without calling attention to the role of human observers. He suggested that the size of the gravitational coupling constant might be understood on the basis of Mach's principle and that this might imply a gravitational constant varying in time, but not following Dirac's expression $G \sim 1/t$.[19]

Dicke's critical analysis of the large numbers found in nature generated a brief reply from Dirac, who in a letter to *Nature* returned to the cosmological

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[18] Dicke 1961, p. 441. Reprinted in Leslie 1990, pp. 121-124.

[19] See the papers included in Dicke 1964, especially p. 80. Together with his student Carl Brans, Dicke developed a new scalar-tensor theory of gravitation which implied a progressive weakening of gravity, but at a slower and less determinable rate than the one proposed by Dirac.

views he had espoused 1937-38 but not developed subsequently. Dirac flatly disagreed with Dicke: "On this [Dicke's] assumption habitable planets could exist only for a limited period of time. With my assumption they could exist indefinitely in the future and life need never end. There is no decisive argument for deciding between these assumptions. I prefer the one that allows the possibility of endless life."[20] This was more than just a casual remark, for Dirac had for a long time been devoted to the doctrine of eternal life in the universe. In private notes of 1933 he stated as his belief that "the human race will continue to live for ever and will develop and progress *without limit*." What he characterized as an "article of faith" was "an assumption that I must make for my peace of mind."[21]

5. Carter's anthropic principles

It was Brandon Carter, an Australian-born lecturer at Cambridge University, who coined the name "anthropic principle" and elevated it to such a status that cosmologists began to take it seriously. Born in Sydney, young Carter did undergraduate studies in physics and mathematics at the University of St. Andrews, Scotland, and Cambridge University. He continued with graduate studies at Cambridge, where he had Dennis Sciama as his supervisor. During a period as research fellow 1968-72 he stayed with Wheeler in Princeton and Chandrasekhar in Chicago.[22]

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[20] Dirac 1961.
[21] Farmelo 2009, p. 221. Dirac's emphasis.
[22] After a period as lecturer at Cambridge University 1973-75, Carter moved to Paris to work for the Centre Nationale Recherches Scientifique. He retired in 2009 from his position as Directeur de Recherches at the Laboratoire de l'Univers Théorique. Apart from his work on the anthropic priniple, Carter's main line of work has been on black hole physics, in which area his research is recognised as fundamental.

Carter had for some years been occupied with trying to understand the role of microphysical parameters in cosmology, and in 1967, while a 25-year-old Ph.D. student at Cambridge University's Department of Applied Mathematics and Theoretical Physics (DAMTP), he wrote an extensive manuscript on the subject. Only the first part of the work, entitled "The Significance of Numerical Coincidences in Nature," appeared in the form of a stencilled preprint that circulated among a small number of physicists without attracting much attention.[23] He also gave his first talks on the subject in Cambridge.

It was Carter's intention to extend the notes, which mainly dealt with fine-tuning coincidences in nuclear physics and astrophysics, with a separate part dealing with cosmology, but it took several years until this second part was completed. Carrying the title "Large Numbers in Astrophysics and Cosmogony," it only circulated as a regular DAMTP preprint after 1973.[24] The purpose of Carter's preprint of 1967 was "to clarify the significance of the famous coincidence between the Hubble age of the universe and a certain combination of microphysical parameters,"[25] that is, the relationship $N_1 \sim N_2$ considered by Dicke in 1961. However, he never got that far. The parameters he considered to be fundamental were the coupling constants of the electromagnetic, strong and gravitational interactions, and the mass ratios of the proton, neutron, electron, and pion.

From the point of view of the later anthropic principle, what is interesting about the notes is not so much their content as what they do *not* contain.

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23 Forty years later Carter placed a transcript of the notes on the arXiv website together with a postscript (Carter 2007). See also Bettini 2004, which provides a useful history of the anthropic principle.

24 In Davies 1982, p. 132, Rees, Ruffini and Wheeler 1974, p. 425, and a few other sources there are references to Carter's unpublished and provisional preprint of 1968.

25 Carter 2007, p. 1.

Surprisingly, Carter was at the time unacquainted with the works of Dicke, and consequently he did not follow up on Dicke's line of reasoning or mention Dirac's Large Number Hypothesis. Nor did he formulate an anthropic principle or some general perspective like it, and he did not suggest any connection between the numerical coincidences and human observers. In short, there is little in the notes of 1967 that points toward the later anthropic principle. Carter only came to know about Dicke's earlier works in 1968, when he spent some time as a postdoc in Princeton where Dicke was working as a professor of physics.[26]

The first time Carter had an opportunity to present his more elaborated ideas was at a meeting at Princeton in 1970 commemorating the works of the British mathematician William Kingdon Clifford. This meeting was organized by John Wheeler, with whom Carter had stayed as a postdoc in the spring of 1968. His interaction with Wheeler, both then and later, was important to the line of thought that eventually resulted in the anthropic princple. On the 21st of February 1970 Carter presented a set of lectures notes on "Large Numbers in Astrophysics and Cosmology" in which he outlined some of the ideas that came to be known as the anthropic principle. By that time he had become acquainted with Dicke's earlier work and also with Dirac's principle of the large numbers. While following an undergraduate course on stellar astrophysics in Cambridge he had learned about Dirac's hypothesis from Bondi's textbook *Cosmology*, which some years later motivated him to think of an alternative to it. Carter rejected Dirac's conclusion as "an error of blatant wishful thinking," as he later expressed it.[27]

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[26] E-mail from Carter to the author of 18 February 2010.

[27] Carter 1989, p. 190. Bondi 1952 dealt critically with Dirac's cosmology based on large numbers on pp. 159-163.

PRINCETON UNIVERSITY
JOSEPH HENRY LABORATORIES

CLIFFORD DAY CELEBRATION

21 February, 1970

Theme: Where do we stand today, and what developments can we look forward to, on Clifford's vision of particles as made of curved empty space?

All sessions will take place in the Professors' Room, 218 Jadwin Hall

9:00 am William Kingdon Clifford — Edwin Power, University College, University of London

The Vision of Clifford and Einstein — John A. Wheeler, Joseph Henry Laboratories, Princeton University

The Large Numbers — Brandon Carter, Institute for Theoretical Astrophysic Cambridge University

Discussion

12:30 pm Lunch Presidential Dining Room, Prospect

2:00 pm Position Statements of Participants

5:00 pm Cocktails Prospect

6:00 pm Dinner Room E, Prospect

7:30 pm Adjournment

Although neither of the notes of 1967 and 1970 were published, their content was known to at least some cosmologists before 1974, when Carter, motivated by his reading of Dicke and Dirac and, not least, his discussions with Wheeler, finally published his ideas. This occurred in the proceedings of a meeting of the International Astronomical Union held in Cracow 10-12 September 1973 and dedicated to the 500th anniversary of the birth of Copernicus. Wheeler, who chaired one of the sessions, suggested that Carter presented his ideas on the place of human observers in the universe, which he did. Motivating Carter's lecture, Wheeler said that "The considerations of Hawking, Dicke and Carter raise the question whether man is involved in the design of the Universe in a much more central way than one can previously imagine."[28] It was an extended version of this lecture that appeared in print the following year. Much later Carter told about his reasons for making a public announcement of the anthropic principle:

> My motivation in bothering to formulate something that was (as I thought) so obvious as the anthropic principle in the form of an explicit precept, was partly provided by my later realisation that the source of such (patent) errors as that of Dirac was not limited to chance oversight or lack of information, but that it was also rooted in more deep seated emotional bias comparable with that responsible for early resistance to

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[28] Longair 1974, p. 289. The session chaired by Wheeler was on "The Structure of Singularities," a theme in which Carter's address did not fit at all. Apparently Carter replaced a speaker who did not turn up at the meeting.

> Darwinian ideas at the time of the "apes or angels" debates in the last century.[29]

It is unclear when Carter reacted against Dirac's argument for a varying constant of gravitation, but it was presumably at some time about 1970. When Carter started his work on the numerical coincidences in nature, Dirac was still in Cambridge as the holder of the Lucasian Chair of Mathematics. Like Carter, his was a member of DAMTP, but he had no office in the building and rarely came to the department. There seems to have been no interaction between Dirac and Carter, except that Carter followed Dirac's undergraduate lectures on quantum mechanics. He recalls having tried to put questions to Dirac, but with no more luck than most other people who addressed the great physicist.[30] Dirac was notoriously taciturn.

In his seminal article on "Large Number Coincidences and the Anthropic Principle in Cosmology" Carter objected to an uncritical extension of the so-called Copernican principle, the doctrine that we do not occupy a privileged place in the universe.[31] "Unfortunately," he said, "there has been a strong (not always subconscious) tendency to extend this [Copernican principle] to a most questionable dogma to the effect that our situation cannot be privileged in any sense."[32] Although there is indeed no privileged place in the universe, there is a

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29 Carter 1989, p. 189.
30 Communication from Carter to the author, E-mail of 7 February 2010.
31 At least from a historical point of view, the term "Copernican principle" is unfortunate. Although Copernicus removed the Earth and hence humans from the centre of the universe in a geometrical sense, his world system was far from uniform or without privileged parts. It has been argued that the weak anthropic principle is not really contrary to what is generally known as the Copernican principle, but can be considered an instance of Copernicanism (Roush 2003).
32 Carter 1990, p. 125. The paper was originally published in Longair 1974, pp. 291-298. I quote from the more easily accessible version in Leslie 1990.

privileged time – contrary to the perfect cosmological principle of the steady-state theory – namely the epoch of life.

Like Dicke, Carter was convinced that the large number coincidences were not evidence in favour of ”exotic theories” such as those proposed by Dirac and Pascual Jordan. ”I am now convinced,” he said, that ”these coincidences should rather be considered as confirming ‘conventional’ (General Relativistic Big Bang) physics and cosmology which could in principle have been used to predict them all in advance of their observation.”[33] He proposed that the coincidences could be understood by using ”what may be termed the *anthropic principle* to the effect that what we can expect to observe must be restricted by the conditions necessary for our presence as observers.”[34] In other words, what we observe is a specific state of affairs rather than a typical one; for there could be nobody around to observe a typical state of affairs. Our very existence requires special conditions, which is the key message of the anthropic principle.

According to this ”weak” anthropic principle (WAP), human observers are a kind type of measuring instruments; it is necessary to take into account our special properties when interpreting data, just as it is necessary for other measuring instruments. In addition to the weak selection principle, Carter also introduced a ”strong” version (SAP) stating that ”the Universe (and hence the fundamental parameters on which it depends) must be such as to admit the creation of observers within it at some stage.” He added, ”To paraphrase Descartes, ‘Cogito ergo mundus talist est’.”[35] According to Carter, it was possible to derive some of the numerical coincidences considered by Dirac and Eddington on the basis of the strong anthropic principle, which could therefore be assigned

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[33] Carter 1990, p. 126.
[34] Ibid.
[35] Ibid., p. 129.

predictive power. As an example he derived Eddington's relation between the cosmic number and the inverse square of the gravitational coupling constant in the form $nH^{-3} \cong M^{-3}$.

The word "must" in Carter's formulation of the strong anthropic principle was obviously problematic. Did he really mean that the universe *had* to be such as to make observers inevitable? If so it could at best be understood as a metaphysical claim. Carter did not offer any help for interpretation in his paper of 1974, but he did point out that by itself the strong anthropic principle was unable to explain things. As John Barrow noted some years later, if restricted to a single universe it suggested design and was therefore "religious in nature."[36]

Carter suggested that his weak anthropic principle would only have explanatory power if associated with the idea of a world ensemble, the assumption of many universes with all possible combinations of initial conditions and fundamental constants. These universes could not be mere Leibnizian possibilities, with our world as the only one actualized, for in that case it would be hard to avoid a teleological interpretation of the anthropic principle. Carter therefore assumed the other universes to be really existing. Although such a many-worlds hypothesis might seem "philosophically undesirable," he said, it "does not really go very much further than the Everett doctrine."[37] Whereas Carter suggested that the fundamental parameters might vary from one universe to another, he did not admit the possibility that they might vary within our own universe.

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[36] Barrow 1983, p. 149.

[37] Carter 1990, p. 133. Whereas all the worlds of the many-worlds interpretation are often claimed to be real, Carter considered as real only those worlds which can accommodate observing organisms of some kind.

The reference to the "Everett doctrine" was to the interpretation of quantum mechanics proposed in 1957 by Hugh Everett, according to whom non-observed outcomes of quantum events exist in other worlds that are no less real than ours. In the somewhat different version argued by Bryce DeWitt in 1970, the strange picture of a constantly splitting world became well known to physicists and adopted by many theorists working on quantum cosmology.[38] While neither Everett nor DeWitt related the many-worlds picture to cosmology, others did. According to some physicists, not only is the interpretation a logical possibility, it is the *only* logical way to understand the act of measurement in quantum mechanics. Indeed, Carter thought that "one is virtually forced by the internal logic of quantum theory" to accept the many-worlds interpretation. Yet, when Carter referred to the Everett-DeWitt interpretation, it was a minority view (as it supposedly still is). It may have been the only way for him to justify the many worlds that the anthropic principle seemed to require. Only with the eternal inflationary scenario in the early 1980s did a physically more realistic theory of many worlds emerge.

Carter clearly believed that his new anthropic principle was a valuable scientific approach, but he also realized that it was extraordinary and potentially problematic. "I would personally be happier," he admitted, "with explanations of the values of the fundamental coupling constants etc. based on a deeper mathematical structure in which they would no longer be fundamental but would be derived."[39] In later discussions, critics of anthropic explanations would accuse them of being cheap substitutes for explanations of the traditional, deductive-nomological kind. For example, if we want an explanation of why the

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[38] The Everett-DeWitt interpretation became widely known only with the publication of DeWitt and Graham 1973, dating from the same time as Carter enunciated the anthropic principle.

[39] Carter 1990, p. 133.

Earth is covered with an ozone layer it may be argued that if such a layer, shielding the inhabitants of the Earth from lethal ultraviolet radiation, did not exist, advanced life would not have evolved. While this is an explanation of sorts, obviously it is not a satisfying one. If it is accepted as a valid explanation, why look for another explanation in terms of complex physical and chemical processes in the atmosphere? Carter was aware of the problem. An anthropic prediction, he wrote, "will not be completely satisfying from a physicist's point of view since the possibility will remain of finding a deeper underlying theory explaining the relationships that have been predicted."[40]

6. Receptions and early elaborations

Among the physicists and cosmologists who were aware of and referred to Carter's anthropic ideas before the 1974 publication were Martin Rees, Freeman Dyson, John Wheeler, Barry Collins, and Stephen Hawking. Some of them (Dyson, Wheeler and Hawking) had participated in the Clifford meeting at Princeton in 1970 at which Carter had talked about his new approach.

Dyson shared the opinion of most physicists that Dirac's hypothesis of a decreasing gravitational constant was wrong. In a 1972 review of the possible time variation of the constants of nature, he briefly referred to what he called Carter's "principle of cognizability." With this he meant "the conclusion that the presence in the universe of conscious observers places limits on the absolute magnitudes of γ and δ and not only on their ratio."[41] The two quantities mentioned by Dyson were the inverse of the combinations of constants that had

[40] Ibid., p. 130.

[41] Dyson 1972, p. 235. Dyson was receptive to anthropic arguments. As he wrote the year before: "As we look into the Universe and identify the many accidents of physics

Participants in the 1970 Clifford Memorial meeting in Princeton. In the front, from the left, John Wheeler, Robert Dicke, Eugene Wigner, Edwin Power with a picture of Clifford, Stephen Hawking, Brandon Carter and Cecile DeWitt. Standing behind Hawking and Carter are Charles Misner, Bryce DeWitt and Freeman Dyson. Courtesy B. Carter.

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previously been discussed by Dicke, namely $\gamma = 1/N_1$ (the gravitational coupling constant) and $\delta = 1/N_2$. Dyson expressed the constants as

$$\gamma = \frac{Gm^2}{\hbar c} \quad \text{and} \quad \delta = \frac{H\hbar}{mc^2}$$

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and astronomy that have worked together to our benefit, it almost seems as if the Universe must in some sense have known that we are coming." Dyson 1971, p. 59.

Participating in a meeting in Trieste dedicated to the seventieth birthday of Dirac, Wheeler mentioned the same year ”the explanation of Brandon Carter that many cycles of the universe are possible and the constants in this particular cycle are such as will permit life.”[42] Similar remarks appeared in a book of 1974, coauthored by Martin Rees and Remo Ruffini, where Wheeler expressed his ideas of a universe selected by the presence of man. Referring to Dicke, he wrote:

> … the right order of ideas may not be, here is the universe, so what must man be; but here is man, so what must the universe be. … So why on this view is the universe as big as it is? Because only so can man be here! In brief, the considerations of Carter and Dicke would seem to raise the idea of the ”biological selection of physical constants”. However, to ”select” is impossible unless there are options to select between. Exactly such options would seem for the first time to be held out by the only over-all picture of the gravitational collapse of the universe that one sees how to put forward today, the pregeometry black box model of the reprocessing of the universe.[43]

In fact, in his published article of 1974, Carter did not refer to the idea of a cyclic or oscillating universe but only to an ensemble of universes. Yet Carter was

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[42] Mehra 1973, p. 58. See also Wheeler 1973. In an address at a symposium at the Smithsonian Institution in 1973, commemorating the 500th anniversary of the birth of Copernicus, Wheeler asked: “Has the universe had to adapt itself from its earliest days to the future requirements for life and mind?” He suggested that although this was a question “stranger than science has ever met before,” it should be taken seriously and not be dismissed as meaningless. Wheeler 1975, p. 283.

[43] Rees, Ruffini, and Wheeler 1974, p. 307. Wheeler’s chapter entitled “Beyond the End of Time” was adapted from two lectures delivered in 1971. The term “anthropic principle” did not occur in the book.

aware of the cyclic possibility, which he contemplated in discussions with Wheeler in the years 1968-72.[44]

In 1973, the year of Carter's Cracow lecture, Collins and Hawking used what they called the ″Dicke-Carter idea″ to come up with a ″most attractive answer″ to the question of why the universe has such a high degree of isotropy. They reasoned in quantitative details that anisotropic universes evolve towards being highly anisotropic and that this would preclude the formation of galaxies. Since the existence of galaxies is presumably a necessary precondition for the development of intelligent life, our universe must be isotropic. To turn this observation into a kind of explanation they adopted the anthropic approach with its hypothesis that ″there is not one universe but a whole infinite ensemble of universes with all possible initial conditions.″ Collins and Hawking concluded that life would be possible only in a tiny subset of the ensemble of universes. ″The fact that we have observed the universe to be isotropic is therefore only a consequence of our existence,″ they wrote. The two physicists repeated the provoking conclusion at the end of their paper: ″The answer to the question 'why is the universe isotropic?' is 'because we are here'.″[45]

Hawking gaver a shorter presentation of the paper at the Cracow symposium of the International Astronomical Union. At this occasion he repeated the formulation, but made it clear that what he really meant was that ″the isotropy of the Universe and our existence are both results of the fact that the Universe is expanding at just about the critical rate.″[46] Clearly, there is a great deal of difference between the two formulations.

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[44] Personal communication (E-mail from Carter of 7 February 2010).
[45] Collins and Hawking 1973, p. 319 and p. 334. See also Barrow and Tipler 1986, pp. 422-430.
[46] Hawking 1974, p. 285.

The anthropic principle made its entrance into physics and cosmology in the late 1970s, at first without much fanfare and not with a great deal of controversy. In an influential review of anthropic structural aspects of the universe, published in *Nature* in 1979, Bernard Carr and Rees brought together all the anthropic arguments known at the time. The article did much to make scientists acquainted with the anthropic principle as a possible tool of science. However, although Carr and Rees found the principle to be greatly interesting, they expressed themselves cautiously. "From a physical point of view, the anthropic 'explanation' of the various coincidences in nature is unsatisfactory," they wrote, repeating Carter's evaluation from five years earlier. They added that it "may never aspire to being much more than a philosophical curiosity."[47] In his Milne Lecture of 1980, Rees expressed himself in a similar hesitant way about the scientific nature of explanations based on the anthropic principle: "At best it can offer a stop-gap satisfaction of our curiosity regarding phenomena for which we cannot yet obtain a genuine physical explanation."[48]

In one or more of its several versions, the anthropic principle soon appeared also in more extensive reviews and popular books, such as the English physicist Paul C. W. Davies' *Other Worlds* from 1980 and *The Accidental Universe* from 1982. The new way of thinking about the universe was further disseminated by articles in popular science journals, including *Scientific American* and *Sky and Telescope*.[49] The publication in 1986 of John Barrow and Frank Tipler's comprehensive *The Anthropic Cosmological Principle*, still unsurpassed in

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[47] Carr and Rees 1979, p. 612. For later and more comprehensive discussions of apparently fine-tuned physical and cosmological parameters, see Barrow and Tipler 1986 and Hogan 2000.

[48] Rees 1998, p. 66, the Milne Lecture of 1980. First published in *Quarterly Journal of the Royal Astronomical Society* 22 (1981), 109-124.

[49] Gale 1981, a thoughtful and philosophically informed account, helped to make the anthropic principle known to a broad audience.

detail and perspective, as well as speculation, marked the maturity of the anthropic principle and its widespread dissemination to parts of the scientific community. When I reviewed the book in 1987, I was impressed but also critical:

> Under cover of the authority of science and hundreds of references Barrow and Tipler, in parts of their work, contribute to a questionable, though fashionable mystification of the social and spiritual consequences of modern science. This kind of escapistic physics, also cultivated by authors like Wheeler, Sagan and Dyson, appeals to the religious instinct of man in a scientific age. Whatever its merits it should not be accepted uncritically or because of the scientific brilliancy of its proponents.[50]

Several other reviews concluded in a similar critical manner. For example, according to one reviewer, "the anthropic perspective appears to be part of the current zeitgeist."[51]

In 1988, the first international conference devoted to the study of the anthropic principle and its implications took place in Venice with participation of Carter, Sciama, Hoyle, George Ellis, Barrow and others.[52] The following year another international meeting took place in St. Petersburg (then still Leningrad), where a wide range of aspects related to the anthropic principle was discussed by Russian and invited foreign scientists.[53] Latest by that time anthropic

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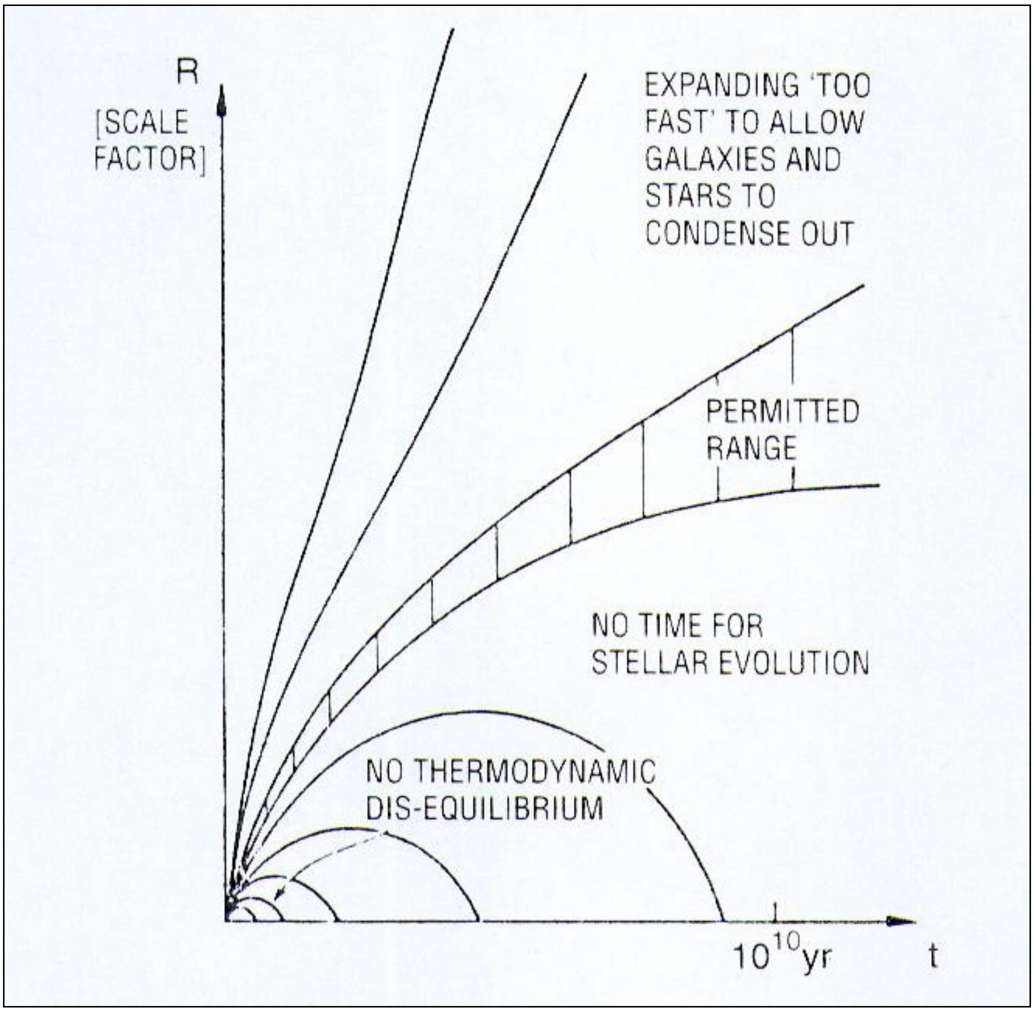
[50] Review of Barrow and Tipler 1986 by H. Kragh in *Centaurus* 39 (1987), 191-194.
[51] Review of Barrow and Tipler 1986 by J. A. Goldman in *Leonardo* 21 (1988), 333-334.
[52] Abramowicz and Ellis 1989; Bertola and Curi 1993.
[53] Balashov 1990 is a review of the St. Petersburg meeting. The great Russian cosmologist Yakov Zel'dovich adopted the "anthropogenic principle" in a paper of 1981 in which he defended the priority of his compatriot Grigory Idlis (Zel'dovich 1981).



A simple illustration of weak anthropic anthropic reasoning, as offered by Martin Rees in his Milne Lecture of 1980. If the initial expansion rate of the universe had been slow, it would start contracting before stars could be formed or perhaps even atoms could be formed. If the expansion is much faster than the critical rate, matter would have receded at such a high speed that it would not have condensed into stars and galaxies. Only for a range of initial conditions lying close to the critical value $\Omega_0 = 1$ will it be possible for complex structures to form and hence for life to evolve: in this respect (as in many others), the universe seems to be fine-tuned for life.

reasoning had become part of cosmology, if still a small and definitely a controversial part.

It is of course possible to appreciate the sensitivity of structures of matter to small changes in the numerical values of the fundamental parameters without accepting the anthropic principle. Fine-tuning is not necessarily an argument for the special position of intelligent life forms. This is what the Russian astrophysicist Iosif Rozental argued in a review of 1980 concerned with the effects that a hypothetical change of the constants would have. Covering much of the same ground as Carr and Rees, he found it unjustified to conclude in favour of the anthropic principle or otherwise to highlight complex biological structures.

As Rozental emphasized, the connection between the constants of nature and the phenomenal world of physics occurs already at the lower levels, such as in chemical compounds, atomic structure, and the stability of nuclear matter. Consequently he advocated a kind of non-anthropic anthropic principle, what he called the ″principle of effectiveness″ (and which Leibniz would surely have appreciated). The idea was that ″our basic physical laws, together with the numerical values of the fundamental constants are not only sufficient but also necessary for the existence of ground states.″[54] These ground states could range from atomic nuclei to galactic clusters, but Rozental saw no reason to single out biological or neurological structures as particularly interesting.

As Carter pointed out in 1974, anthropic explanations have force only in the context of the multiverse (a term still to be coined), the hypothesis of a whole range of hypothetical universes with varying properties. Carter explained that what he meant was "an ensemble of universes characterised by all conceivable combinations of initial conditions and fundamental contants." Moreover: "The

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[54] Rozental 1980, p. 296.

existence of any organism describable as an observer will only be possible for certain restricted combinations of the parameters, which distinguish within the world-ensemble an exceptional cognizable subset."[55] The association of the anthropic principle with the world-ensemble or multiverse is not a necessary one, however, and it was not generally accepted in the 1970s and 1980s.[56] Only later did it become common to see an intimate connection between the two concepts, with the multiverse explaining anthropic fine-tuning. Many scientists were and are uncomfortable with postulating an immense amount of universes to explain some of the properties of the one we live in. Understandably, it does not strike them as a very economic approach.

Rather than thinking in terms of many spatially (or hyper-spatially) separated universes, one could think of a single oscillating universe and conceive the anthropic principle as related to its various cycles or temporally following universes. This idea, which had been briefly mentioned by Wheeler in 1972, did not appeal to most anthropically minded physiciststs. It did however appeal to Dicke, who for long had been interested in cyclic models of the universe. When Dicke more or less rediscovered the big bang universe in the years 1963-64, his reasoning was in large measure based on the conception of a previously contracting universe. In 1982 he explained how he saw the connection between the cyclic universe and the anthropic principle:

> Suppose we have just one universe, but one that oscillates. It could be very nearly flat, just barely closed. … After many oscillations, the universe

[55] Carter 1990, p. 131, who did not discuss which organisms qualify as "observers" and for what reasons.

[56] Deakin, Troup, and Grant 1983 argued that the concept of a world ensemble was unnecessary to the anthropic principle and that it only added to the speculative nature of the principle.

> might contain many particles. It might then expand to the size of a walnut and collapse in about a millisecond. But it would bounce, and on each oscillation there would be a new and bigger universe. And somewhere down the line you would finally get to a universe big enough, with a long enough time scale, and we would exist.[57]

7. A resurgence of teleological belief?

Another problem, apart from the many universes, which turned up at an early date and helped making the anthropic principle controversial, was its implicit teleological nature and apparent connection to religious modes of thinking. Physicists were not the only ones to take the anthropic principle seriously, so did philosophers and theologians. As Paul Davies pointed out in a review article of 1983, the strong anthropic principle represents a radical departure from the conventional concept of scientific explanation. It claims that the universe is somehow constructed as were living organisms, and more specifically intelligent life forms such as humans, its very *purpose*. ”In this respect the strong anthropic principle is akin to the traditional religious explanation of the world: that God made the world for mankind to inhabit.”[58]

The same controversial association between teleology and the anthropic principle was made by Carr in a talk to a conference of 1982 on ”Cosmos and Creation” arranged by the Science and Religion Forum at the University of Surrey. Unusually for an astrophysicist, the title of his address referred to the ”purpose of the physical universe.” After a careful and sympathetic survey of the cosmic coincidences making up the evidence for the anthropic principle, Carr

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[57] Quoted in Simmons 1982, p. 22. Dicke’s rediscovery of the big bang universe in 1963-64 was based on the idea of a bouncing universe with many big bangs and big squeezes.
[58] Davies 1983, p. 33.

mentioned possible explanations in terms of either a many-worlds or a many-cycles universe, but found these to be "rather bizarre." It might very well be, he suggested, that no ordinary physical explanation could be found for the coincidences. Then what? "One would have to conclude either that the features of the universe invoked in support of the Anthropic Principle are *only* coincidences or that the universe was indeed tailor-made for life. I will leave it for the theologians to ascertain the identity of the tailor!"[59]

The anthropic principle, so different from most other principles or laws of science, was not welcomed by the majority of astronomers and physicists. William Press, an astronomer at Harvard University, saw the principle as a "resurgence of teleological belief in science" which was "threatening to the modern scientific enterprise."[60] Malcolm Longair, a mainstream astrophysicist at Cambridge University, referred briefly and critically to the principle in his Halley lecture of 1985: "I dislike this theory profoundly and regard it as an absolute last resort if all other physical arguments fail. The whole essence of the argument seems to run counter to everything one aspires to achieve as a scientist."[61] Other physicists objected to the anthropic principle because it was too ambitious, claiming to be able to answer why-questions instead of the how-questions with which scientists are traditionally occupied. The Chicago astrophysicist David Schramm did not think that anthropic reasoning was within the purview of proper science: "There is a circularity in this sort of reasoning and it would be premature to try to attach anything physical to the coincidences," he said. "Physics tries to answer the 'how' questions, and in some sense it is a

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[59] Carr 1982, p. 253. Other speakers at the conference included John Polkinghorne, Michael Shallis and Stanley Jaki.
[60] Press 1986, a critical review of Barrow and Tipler 1986.
[61] Longair 1985, p. 187.

philosophical rather than physical undertaking to have a go at these 'why' questions, since they are unanswerable by the techniques of physics."[62]

The generally sceptical attitude toward the anthropic principle in the late 1980s, at a time when inflation was accepted by a majority of cosmologists, can be further illustrated by *The Early Universe*, a monograph written by two distinguished theoretical astrophysicists at the Fermi National Accelerator Laboratory (Fermilab), Edward Kolb and Michael Turner. The authors dealt extensively with inflationary models, but characteristically they mentioned the anthropic principle only in a footnote and then without taking it seriously: "Since it is possible that the realization of physical law is different in different inflationary regions, inflation may, God forbids, provide some rational basis for the anthropic principle, as inflation provides a multitude of 'Universes' from which to choose."[63]

Alan Guth, the principal discoverer of the inflation model, would later become an advocate of the multiverse, considering it intimately linked to inflation and providing a much needed justification of the anthropic principle. But this was not yet the case in 1988, when he was interviewed about questions of cosmology. Asked about his opinion of the anthropic principle, he responded as follows:

> Emotionally, the anthropic principle kind of rubs me the wrong way. I'm even resistant to listening to it. Obviously, there are some anthropic statements you can make that are true. If we weren't here then we wouldn't be here. As far as the anthropic principle as a way of approaching things, I find it hard to believe that anybody would ever use the anthropic principle

[62] Quoted in Simmons 1982, p. 20.
[63] Kolb and Turner 1994, p. 315 (originally published 1990).

> if he had a better explanation for something. … I tend to feel that the physical constants are determined by physical laws that we can't understand now, and once we understand those laws we can make predictions that are a lot more precise.[64]

Guth further distanced himself from the view that life has any special role in the physical world or that the laws of nature were contrived to allow life to exist. "It is a rather poor way to try to determine the laws using the fact that life exists," he said. "The anthropic principle is something that people do if they can't think of anything better to do." There is little doubt that at the time most of Guth's colleagues in astrophysics and cosmology agreed with him.[65]

The controversy over the anthropic principle began heating up in the 1980s, when scientists and philosophers discussed in earnest whether or not it belonged to the realm of science. Many of the standard arguments against anthropic reasoning appeared in an article of 1985 written by the American particle physicist Heinz Pagels, executive director of the New York Academy of Sciences, according to whom Carter's principle was reactionary and pseudoscientific. He believed – wrongly it turned out – that "the anthropic principle will soon be relegated to its proper role: as a museum piece in the history of science, gathering dust."[66] Not only was the anthropic principle scientifically and methodologically questionable, it was also potentially dangerous from a wider social and political perspective. Why had anthropic

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[64] Interview in Lightman and Brawer 1990, p. 479.

[65] Roger Penrose did. According to him, the strong anthropic principle "tends to be invoked by theorists whenever they do not have a good enough theory to explain the observed facts" (Penrose 1990, p. 561). See also the interview in Lightman and Brawer 1990, where Penrose characterized the anthropic principle as "a way of stopping and not worrying any further" (p. 430).

[66] Pagels 1985, reprinted in Leslie 1990, pp. 234-237 (p. 236).

reasoning, in spite of its obvious shortcomings, become so popular? According to Pagels, the reason might be found in socio-psychological rather than scientific contexts.

> The anthropic principle's simplicity accounts for some of its appeal, particularly to the the growing number of scientists who write for a popular audience. It is easier to convey a simple redundancy – that we can only see what we can see – than to grapple with the abstract mathematical arguments following from the unified field theories. In many respects, the anthropic principle is the lazy man's approach to science.[67]

Why spend years of hard labour seeking for a fundamental explanation of the nature of things, uncertain if the search will ever succeed, if anthropic arguments might produce an easy answer? As to insult believers in the anthropic principle, Pagels suggested that they were unknowingly participating in a quasi-theistic project. After all, was there any essential difference between the anthropic principle and the teleological argument for a divine creator of the universe? The anthropic principle, so Pagels suggested, "is the closest that some atheists can get to God."

The controversy that raged in the 1980s was only the beginning of a more extended debate that has gone on until the present, in more recent time nourished by ideas of the multiverse and the landscape version of superstring theory. But this ongoing controversy is not part of this essay, which has focused on the origin and earliest development of the anthropic principle.[68]

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[67] Ibid.

[68] Aspects of the later controversy, including the links to string theory, inflation, and the multiverse, are dealt with in Kragh (forthcoming).

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