The Return of the Anthropocentric Universe

Kunitake Ito

1

Copernicus published *De Revolutionibus Orbium Celestium* in 1543 and proposed the heliocentric picture of universe. More than two hundred years later, Kant declared in *Critique of Pure Reason* that we needed Copernican revolution in metaphysics. Another period of two hundred years has passed since the publication of *Critique*, and, today, we seem to be observing that cosmology has made a full circle or "revolution" in its historical development. Anthropocentricity dramatically returned into our thoughts about the universe after such a long period of absence.

Man, not geometrically and ontologically central to our universe since the time of Copernicus, now suddenly becomes central in some sense to the structure of our physical world. The reason is that man's very existence requires specific values and relationships between the physical constants, and very specific initial conditions, and we actually find such values characteristic of our universe. Owing to the rapid development of contemporary astrophysics, it is becoming increasingly clear that within the paradigm of standard evolutionary cosmology (i. e. the so-called "big-bang cosmology") the existence of man imposes certain strict limits on the range of possible physical parameters characteristic of a universe compatible with life. And the actual parameters are indeed "fine tuned" for our existence. Therefore, man is in an important sense central to this universe. Copernican revolution in metaphysics was an understandable but in the end unnecessary detour. We can once again meaningfully talk about the aim and design of universe. These are the lessons we are told to learn from today's cosmology of the "anthropic principle".

2

The introduction of the "anthropic principle" marks a drastic departure from the time-honored scientific tradition governed by the "cosmological principle". The cosmological principle has always been implicitly presupposed as the meta-principle of modern scientific methodology since the time of Galileo or Pascal,

and it was also explicitly endorsed by Einstein in his cosmological application of Relativity Theory. It says that the structure of the universe is temporally and spatially uniform and indifferent to any specific kinds of existence in it. Pascal famously said, "In our universe, no place is the center and every place is a center". The anthropic principle denies this cosmological uniformity and indifference. There is a specific and privileged center in the universe, and it is the existence of man.

There are a variety of versions of the anthropic principle and the reasons and motivations for their introduction are various. But basically there are two levels at which the anthropic principle enters the cosmological picture. One is the level of the argument about the balance between the values of physically fundamental fine structure constants. Another level is given by the discussion of the range of possible initial boundary conditions of universe.

According to our standard physics, all physical processes are to be described in terms of four physical forces: gravity, electromagnetism, strong and weak forces. Gravity acts between any two masses and is an active force. Electromagnetism describes interactions between electric charges. Strong force holds an atomic nucleus together, and weak force governs radioactive decay.

It is known that from the parameters describing the four physical forces and from the parameters describing the quantum mechanical "exclusion principle" only four dimensionless quantities (pure numbers) can be formed. These quantities are referred to as electromagnetic, gravitational, strong, and weak "fine structure constants". Their numerical values determine the strength of the electromagnetic, gravitational, strong, and weak interactions, receptively. The largest constant is that of strong interactions; it is roughly equal to ten. Next in strength are electromagnetic interactions; their fine structure constant is of the order of one hundredth. Next is the weak force; its constant is of the order of ten to the minus tenth power. The weakest is gravity; its constant is about minus thirty eight powers of ten.

The masses of all equilibrium structures present in our universe, from the smallest to the largest scales, such as atoms, men, planets, stars, galaxies, can be expressed in terms of, for example, proton mass multiplied by some appropriate powers of the gravitational and electromagnetic fine structure constants, those powers determined from the physical theory. Similarly, all size of natural objects in the universe can be expressed in terms of, say, the size of the hydrogen atom multiplied by some other powers of these fine structure constants. In other words, their characteristics depend on the strengths of these four forces as evidenced by the values of fine structure constants.

All the mass ratio and scales of natural objects are therefore relative in the sense that they would radically change if the value of the fine structure constants were different, but those changes would be such as to preserve the relationships between them as expressed in terms of the appropriate powers of those constants.

For example, if gravity were a million times stronger than it actually is, and if other forces could remain the same, we would have a different universe than our own; it would have planets and stars a billion times less massive and the lifetime of a hydrogen burning main sequence star (like sun) would be only one hundred years.

If this is the theoretical consequence of contemporary physical theory, the following question is to be naturally posed. Why is our actual universe as it is? Why is gravity as weak as it is and not a million times stronger? Why are other interactions not stronger or weaker than they actually are?

It is to this question that the anthropic principle was proposed as a plausible answer. It was first formulated (in its "weak version") by Robert Dicke, and developed further by Brandon Carter (in its "strong version") and others[1]. The point of the answer is that the actual values of the fine structure constants are determined by the fact that man exists in the universe. The values of the constants that we actually have are necessary to have a universe in which the conditions are appropriate for the origin of life and its evolution toward man.

Carter's argument for the reason why the gravitational fine structure constant is of the order of the twentieth power of the electromagnetic fine structure constant runs as follows. Planets can only form around "convective stars" (stars in which energy is transported from the core outward primarily through large scale mass motion), and if we assume that life can exist only on planets, we need convective stars. On the other hand, we need some stars to be radiative (that is, with energy transported from the core outward through radiation) because only stars with material not thoroughly mixed by convection may become supernovae and thus explode scattering heavy elements needed for life throughout space. It can be shown that if the ratio of the two constants in question were larger than the above quoted value, there would be no convective stars and therefore no planets with life; and if smaller than above, there would be no radiative stars and therefore no heavy elements in interstellar space.

So the existence of life on planets, as we know it, requires a specific ratio between the gravitational and electromagnetic fine structure constants, that is, the actual one that we find in this universe. Moreover, if the origin of life is a low probability process, one needs many potential sites for its development and this leads to a universe with a very small value of the gravitational fine structure constant.

The observed ratio of the strong to electromagnetic fine structure constants is close to the ratio of the proton to electromagnetic masses and the strong force is only barely binding for atomic nuclei. If it were a little weaker we would have only hydrogens; a little stronger and we have atoms of enormous sizes. This and other ratios involving the strong constant and masses of elementary particles turn out to be necessary for the existence of a variety of chemical elements needed for life. The ratio of the weak to the gravitational fine structure constants is related to

the production of helium in the first few minutes after the initial explosion through cosmic nucleosynthesis. If the ratio were slightly smaller, all hydrogen would become helium, so there could be no water, and no life; if the ratio were much different from its observed value, the conditions needed for stars to become supernovae and to release the heavier elements necessary for life into space would be absent.

All these facts suggest that the universe is just barely fit for the existence of life. Our universe is full of numerical "coincidences" between basic constants and these coincidences seem "fine tuned" for the existence of life. Man is the upshot of the evolution of life and observing and understanding this fact. Therefore, man is an essential element for the complete realization of this universe--.

This is the first level of the argument for the anthropic principle. As is noted above, the second level comes from the paradigm of big-bang cosmology. One of the most difficult problems of this evolutionary cosmology is that of solving Einstein's equation within the framework of the known laws of physics and of known values of the fine structure constants for explaining away the process from the "true beginning of universe" to the period of big-bang universe. At this level the ensemble of possible theoretical universes is determined by the range of possible initial boundary conditions to the solutions of this equation, and the ensemble allows, in addition to our highly symmetric actual universe, many asymmetric universes. Carl Collins and Stephen Hawking demonstrated that the ensemble of the initial conditions that gives rise to universes capable of containing stars and planets is of measure zero[2]. This could be interpreted to mean that if the universe were to be actualized by mere chance, it would have an infinitesimally small probability to contain life and man, even at this second, more restricted level of discussion.

An alternative philosophical interpretation much more popular consists of actually attributing existence to all those possible universes. (So the universe is really not uni-verse but multi-verse!) It leads to a somewhat trivial conclusion that our own universe is characterized by the set of conditions required for life precisely because we happened to be in it and therefore observe it, meanwhile in all other universes, in which there are no conditions for life, there are no intelligent observers. A variant of this philosophical picture postulates the existence of an infinite number of expansion—collapse cycles in our universe, with a reprocessing of all the universe at every "big crunch" followed by a new "big bang" stage. The universe "transforms, or transmutes, or transits, or is reprocessed probabilistically" and this reprocessing of the universe reprocesses also the physical constants, which in this view, are not part of the law of physics but are part of initial value data. They are given anew for each cycle of the universe's expansion. So why does our cycle of the expansion of the universe have the values of the physical constants it does? Because they are biologically selected. John Wheeler, eminent physicist and one of the proponents of this

diachronically cyclical picture of multi-verse, notes, "only so man can be here!"[3]

Wheeler 's idea is called the "participatory anthropic principle". It is an extension of the idea that the observer retroactively creates phenomena in delayed choice experiments. The claim is that the universe must be habitable because observers are necessary to make it real. Wheeler admits this reasoning is exceedingly speculative and notes that the observer in question need not be anything like a human being. It is only one small step from this admission to some quasi-theological argument that our universe is created by some super-competent, divine intelligence. John Barrow and Frank Tipler have proposed a "final" anthropic principle to the effect that life must arise in the universe, and then must never die out (otherwise it is hard to see why it must arise in the first place)[4]. John Leslie, Richard Swinburne and others are more audacious and straightforward[5]. They claim that our universe was indeed "designed" to proceed perfectly in much accordance with the "plan" of the divine creator. According to them, contemporary cosmology has finally succeeded in providing solid material for the argument from design for the existence of God.

3

Appealing to an anthropic principle in order to explain fundamental physical features of the universe is certainly an attractive option for several reasons. Whereas standard, traditional scientific explanations fall short of providing satisfactory accounts of the ultimate origins and structure of the universe, the anthropic principle provides some hopes of picking up where such explanations leave off. However, needless to say, what makes the anthropic principle approach rather provocative is that it hints at the existence of deep connections between the universe and man, making striking claims about man's place in the universe, and is willing to allow the revival of classical arguments for a divine cosmic designer, as is just mentioned. The principle involves additional philosophical and religious themes as well; the significance and value of human life, the goal-orientedness of nature, and the degree to which the universe is anthropocentric. Therefore, it is too natural that, although the principle is defended by some prominent scientists, philosophers, and theologians, some versions of it are, at least, quite controversial and subject to a number of telling criticisms.

The glitter of the anthropic cosmology comes from its peculiar amalgamation of scientific insights and philosophical reflections. We need to carefully distinguish each other for the assessment of its validity and significance. The scientific questions associated with the anthropic principle include:

1) Claims about how the universe would have differed if various of its physical constants and conditions had been different.
2) Alternative standard scientific explanation for the cosmic "fine tuning".

3) Physical models involving multiple universes, along with theories concerning their relationships and consideration of the manner in which they arise, evolve, and decline.
4) The physical circumstances necessary for the survival of various forms of life.

On the other hand, philosophical considerations shall be concerned with:

1) Distinguishing the various versions of the anthropic principle with regard to their logical and scientific status.
2) Evaluating the mode of explanation being provided by each version of the principle.
3) Scrutinizing the principle's anthropocentric character.
4) Investigating its scientific status and religious or mythical significance.

Now, scientific knowledge is evolving day by day, and new discoveries by means of giant telescopes are much expected to speed up our understanding of the universe. It is all the more important, then, to be clear-headed about the philosophical questions. Particularly, the first two philosophical questions in the above list should be minutely analyzed. The picture of anthropic cosmology is complicated, and we have to do some logical thinking before we are thoroughly adapted to it.

Perhaps, at first sight, the most suspect character of the anthropic principle is that the argument seems to be fundamentally a post hoc, after the fact argument. It seems arguing that the values of physical forces in the universe should be so and so because otherwise the existence of life in the universe would impossible. However, this post hoc mode of explanation itself is unobjectional, if it is taken literally. Obviously any theory of the universe must account for its present condition and we know that the earth in its present state does support intelligent life; hence we must be ready to discard any theory from which it would follow that the conditions of temperature, pressure, gravity, chemical composition and other factors, which are supposed to be necessary for the existence of the earth and life, cannot exist anyhow in the universe.

Therefore, the really interesting and mysterious character of the principle comes not form its post-hoc-ness but from its insistence that the coincidences, which the supporters of the principle argue to be necessary for the existence of life, disclose a kind of "plan". In other words, the structure of the universe is said to have been meticulously designed in order to make possible the appearance and existence of man in some place and at some time. Here are at least two philosophical questions worth analyzing logically. One is the question concerning the validity of teleological talk of "biological selection" in any evolutionary theory, evolution of universe, evolution of life, or perhaps both. The other is more abstract question of the conceptual relationship between "coincidence" and "plan" or "design". Of which kind of coincidence is it reasonable to talk about design?

There was a fierce debate on the issues related to the latter question on *Mind* magazine when Ian Hacking first pointed out that popular discussion of the anthropic principle was full of logical confusions[6].

Hacking's criticism consisted mainly in two points. (1) There are two distinct notions of multi-verse. (Collins and Hawking type): There are many coexistent universes, although our is the only one of which we can have positive knowledge. (Wheeler and Leslie type): There are many successive universes but we are able to have positive knowledge only about the most recent, the one that we are in. The proponents of the anthropic principle such like Brandon Carter are treating these two notions as "logically identical". But from the standpoint of probability logic these notions are strongly non-identical.

(2) The inference of the principle from the former type is sound but trivial. It is in fact a deductive truth based on another particular a priori principle. On the other hand, the inference from the latter type is invalid. Its is a special fallacy generally committed in vulgar probabilistic reasoning. The fallacy should be named "the inverse gambler's fallacy". The fallacy was committed in the eighteenth century when many opponents of the argument from design criticized the argument of John Arbuthnot and other members of "Royal Society Divine" of England, and it is repeated in contemporary cosmological discussion as a sort of quasi-theological argument (a curious historical twist, indeed!).

The Hawking type model of coexistent universes postulates the existence of all logically possible universe consistent with big-bang cosmology, and by employing the a priori "principle of plenitude" it deduces the existence of a universe capable of supporting life, since this is one possible universe. This is almost similar to the argument which Hume put in the mouth of Philo in Part VIII of Dialogues concerning Natural Religion. There is no appeal here to probability. All possible universes come to pass, hence ours does. Why are we observing an orderly universe, why is it that the most recent universe is orderly? Because we can exist only in an orderly universe. No surprise, no need for a creator.

By contrast, some probabilistic reasoning is involved in the second argument based on the Wheeler sequent universes model. It is surely extremely improbable that a random concatenation of the forces, particles, energies, or basic physical laws should, in a single trial, form into anything orderly, let alone something that supports intelligent man. But instead of supposing the universe to be made by one single roll of myriad dice, think of a sequence of indefinitely or infinitely many chance trials. Then, sooner or later mere chance would give an organization like ours. We need invoke nothing other than chance to explain the order in the universe and the fine adjustment of means to ends.

This reasoning is as much fallacious as the famous "gambler's fallacy". If we throw a pair of fair dice, and if the dice have no capacity of memorizing their previous throws, the chance of getting double six in a single trial is 1/36. In thirty-six rolls, the chance of getting at least one double six is about two thirds. A

gambler observed a sequence of 35 rolls without a single double six. He thinks of the chance of double six in 36 rolls, and reasons that it is smarter to bet that double six will occur on the next toss. This is an elementary error. The inverse gambler's fallacy is just the reversal of this error. When a gambler entered the room a roll was about to made. The role was double six. He is then asked to bet on the question, "Is this the first roll of the dice, or have many rolls been done earlier tonight?" If he bets on the latter possibility, he is committing the inverse gambler's fallacy.

The point of Hacking's criticism is that there is no probabilistic reasoning which automatically favors the occurrence of the unusual. Only what we can reasonably say is "The world is very unusual, but unusual things do occur by chance". In order to go further than this banality, we need to specify the nature of the unusual, to characterize that nature as a result of special coincidence, and, if necessary, to postulate the designer of such coincidence. But it is not an easy task. If we consider the world to be something like "the work written in the signs of mathematics", as Galileo put it, then any kind of introduction of the designer is useless, because the designer is presupposed from the beginning. On the other hand, if we consider the world as something like a network of laws constructed by human conjectures, as, for example, Duhem thought, then the explanation of any unusual event should be of the form "Either there is a hidden cause, or else, fortuitously, we have something as surprising as an event that happens only once in such and such times on a chance device of a certain sort". Chancy coincidences are relative to our chance set-up. There is no coincidence per se in the universe--.

When this criticism appeared, strong objections were raised from both camps of physics and philosophy. The opponents agreed to the opinion that Hacking misrepresented the anthropic principle and that there is no inverse gambler's fallacy in the principle. The major three points of counter-criticism were;

(1) The anthropic principle is not what to be a priori deduced from the co-existent multiple universes plus the principle of plenitude. The principle of plenitude is simply false, because not all logically possible universe are logically compatible with each other. Only physically possible universes are postulated in the coexistent universes model because it is restrained by the condition of big-bang stage, and the foundation of this coexistence is not the matter of simple logical possibility but that of much more complicated mathematics. It requires, for example, some sort of generalized ergodic principle in order to stipulate that the sampling of the different sets of physical parameters by different universes is representative.

(2) The argument from the Wheeler sequent universes is not dependent on the reasoning of the inverse gambler's fallacy type. The argument lays no importance on the fact that our universe is the last one of the indefinite sequence of cyclical universes. Rather it puts stress on the fact that our universe allows the existence of man who observes and understands the structure of the universe. It is in fact not

concerned about a particular universe but any universe which can sustain the existence of intelligence, any kind of intelligence at least as much sophisticated as ours. It aims to explain the fact that, among all conceivable combinations of initial conditions and fundamental physical constants, observers exist only in an exceptional cognizable subset of the ensemble.

(3) The argument for the principle makes use of probabilistic reasoning, but it is only a part of it. The argument starts from the fact of large number coincidences among physical constants, but the real target is the correspondence between the condition for the existence of intelligence and the capacity of that intelligence. This correspondence is not characterized by the words "unusual" or "implausible". It is simply "amazing". The unusual is to be identified in the context of chance set-up, but the amazing is methodologically prior to any particular construction of theoretical model. Extremely amazing events are not to be believed in without amazingly good reasons. Divine design or plan is just a candidate for such amazingly good reason.

These counterpoints against Hacking are much important because they bring out the skeleton of the anthropic principle in clear relief. (Hence, Hacking's criticism is also significant.) When the anthropic principle says that our universe must be such as to admit the presence of observers, it is not meant that this universe's basic character makes observership inevitable. All that is being said is that its absence cannot have been inevitable. It is because of this fact that the observed conditions of the universe seems not just suitable, but, all the more, very remarkably suitable for its existence. The remarkable development of astrophysical understanding is inviting us to the search for some amazingly good reason of this amazement.

If this is the true sense of today's anthropic cosmology, then this picture can be a real vision of "Our Place in the Cosmos"[7]. All technical talks of the anthropic principle generally tend to concern the theoretical details of physical forces and logic of the evolution of intelligence. Some proponents of the principle seem to be utterly indifferent to the fate of man. They seem to be only interested in the existence of intelligence. They sometimes look like hoping the emergence of higher intelligence, or rather, hoping themselves to become hyper-intelligent. But if the element of "amazement" is an indispensable part of this story, then whole aspects of human mind, that is, sensation, understanding and emotion or feeling, are all included in this cosmological picture. Only with the inclusion of full-blown human mind, the principle could be entitled to be called "anthropic".

But, then, what is "amazement"? Why are we amazed at the beauty of cosmological fine-tuning? Is there any "theoretical" explanation of the origin of this amazement? If amazement is absolutely prior to any theoretical analysis, why do we search for its cause and reason? The puzzle remains...

4

Pascal wrote in the seventeenth century, "Man is only a reed, the weakest in nature, but he is a thinking reed." Kant wrote in the eighteenth century, "We are obliged to restrict the domain of knowledge so that we could make room for faith." These are the typical expressions of the complex mental condition of modern scientific spirit. The spirit is "complex" in the psychoanalytical sense because it is mixed with both the elements of humility and pride. Pascal concluded this famous dictum by saying, "Thus all our dignity consists in thought. It is on thought we must depend for our recovery, not on space and time, which we could never fill. Let us then strive to think well; that is the basic principle of morality."

Contemporary astrophysics seems to have made man capable, at least theoretically, to "fill space and time." If so, with the tremendous expansion of its theoretical field, post-modern science might have succeeded in dispelling the typical emotional complex of modern scientific mind and in transforming "the basic principle of morality". Is it true? In order to get a hint for this question, let us finally do a small exercise in the history of philosophy.

When he was young, Kant was very much interested in cosmology. He published *Universal Natural History and Theory of the Heavens* and proposed a famous speculation about the nature and formation of galaxy. But he also developed there a version of the argument from design which is much similar to our anthropic principle.

> In the islands of Jamaica, as soon as the sun rises so high that it throws the maximum of bearable heat on the earth, shortly after 9 o'clock in the morning, a wind begins to rise from the sea which blows from every direction over the land; its strength increases in the measure in which the elevation of the sun increases. About 1 o'clock in the afternoon when it is naturally hottest, the wind is most violent and subsides again gradually with the setting of the sun, so that toward evening the same stillness rules as at sunrise. Without this desirable arrangement the island would be inhabitable. All coastal lands which lie in that zone enjoy this same benefit. It is most necessary for them because they, being the lowest regions of dry land, suffer the greatest heat; for the higher regions of the land, where this sea wind does not reach, are less in need of it because their higher site places them into a cooler region of the air. Is not all this most beautiful, are not here in view visible goals which are implemented through wisely applied means?

Kant concluded that it would be an "astonishing accident, or rather an impossibility" if these useful arrangements "should have matched one another in their natural tendencies so closely as if a superior wise choice might have coordinated them even if no man lived in such an island" (although "they can be deduced from the most universal and simplest laws of nature")[8].

Needless to say, Kant later purged any bit of this kind of teleological

explanation from the whole domain of scientific enterprise. For the mature Kant of *Critique*, there is no room for the theoretical discussion of the divine arrangement or the harmony of the universe in itself. All these things are the matter of faith and we only have the systematic structure of nature as the byproduct of the mental construction of phenomena. We should be content only with the architectonic beauty of scientific theories themselves. You cannot have your cake and eat it too; we know some beautiful theories but we don't know if nature in itself is harmonious or not. (We can hear a distant echo of this Kantianism in the above cited Hacking's view of coincidence.)

This scientific spirit is gallant but insecure, because it is always under the threat of scepticism. Before Kant, Hume wrote about Berkeley's idealism that its "only effect is to cause that momentary amazement and irresolution and confusion, which is the result of scepticism."[9] Kant's transcendental idealism is much more elaborate than Berkeley's immaterialism, so that it commands much longer amazement. But it still is a version of idealism and causes irresolution in the end. It does not answer the question "Why have these mental apparatus, which so powerfully construct the systematic picture of phenomenal world, emerged from the world in itself?"

Among the various thinkers who took the path of Humean naturalistic cognitive picture, it was Darwin who resolved the mystery most decisively . In his youth, he was an ardent follower of William Paley's Natural Theology (1802), but, he wrote, "The old argument from design in nature, as given by Paley, which formerly seemed to be so conclusive, fails, now that the law of Natural Selection has been discovered."[10] Kant made an interesting claim in *Critique of Judgement* that "we may confidently assert that it is absurd for me even to entertain any thought of so doing [getting a sufficient knowledge of organized beings] or to hope that maybe another Newton may some day arise, to make intelligible to us even the genesis of but a grass from natural laws that no design has ordered. Such insight we must absolutely deny to mankind."[11] Both Kant and Darwin started as the advocate of divine designer, but only Darwin could see the possibility of becoming "another Newton".

The history of physics in the twentieth century can be described in various ways. But if we particularly pay attention to its cosmological side, it may be seen as the process of growing up of this new Newton. Nurtured by the development of high-energy physics, armored with the evolutionary model of origin and formation of the universe, he now declares the anthropic principle. He believes that he has in his hand a new key to unlock the "great chain of being". He is now free from the "irresolution" which has so long been characteristic of Kantian humility. Hence, he is also free from "confusion"? Perhaps not yet. He is at least confused about the meaning of "amazing coincidences". He is not clear as to when and where he is supposed to be amazed first of all. His basic morality should still remain to be "striving to think well."

Notes

[1] Robert Dicke, "Dirac's Cosmology and Mach's Principle", *Nature*, 192, 1961. Brandon Carter, "Large Number Coincidences and the Anthropic Principle in Cosmology", M. S. Lomgair, ed., *Confrontation of Cosmological Theories with Observation*, Reidel, 1974. Among many good introductory papers and books on the anthropic cosmology, George Gale, "The Anthropic Principle", *Scientific American*, 245, 1981, is most readable. The most comprehensive, definitive survey is John Barrow and Frank Tipler, *The Anthropic Cosmological Principle*, Oxford Univ. Press, 2nd ed., 1996. Paul Davies, *The Accidental Universe*, Cambridge Univ. Press, 1982, is also important.

[2] Carl Collins and Stephen Hawking, "Why is the Universe Isotropic?", *Astrophysical Journal*, 180, 1973.

[3] John Wheeler, "Beyond the End of Time", in M. J. Rees, R. Ruffini, J. Wheeler, eds., *Black Holes, Gravitational Waves and Cosmology*, Gordon and Breach, 1974.

[4] Cf., Barrow and Tipler, *op. cit.* in note [1], ch.10.

[5] John Leslie, "Anthropic Principle, World Ensemble, Design", *American Philosophical Quarterly*, 19, 1982, "Modern Cosmology and the Creation of Life", in E. McMullin, ed., *Evolution and Creation*, Univ. of Notre Dame Press, 1985, Universes, Routledge, 1989. Richard Swinburne, *Evolution of the Soul*, Clarendon Press, 1986, "Argument from the Fine-Tuning of the Universe", in J. Leslie, ed., *Physical Cosmology and Philosophy*, Macmillan, 1990.

[6] Ian Hacking, "The Inverse Gambler's Fallacy: the Argument from Design. The Anthropic principle Applied to Wheeler Universes", *Mind*, 96, 1987. Cf. also Hacking, "Coincidences: Mundane and Cosmological", in J. M. Robson, ed., *Origin and Evolution of the Universe; Evidence for Design?*, McGill-Qeen's Univ. Press, 1987. The former article is critically discussed by M. A. B. Whitaker, "On Hacking's Criticism of the Wheeler Anthropic Principle", P. J. McGrath, "The Inverse Gambler's Fallacy and Cosmology—A Reply to Hacking", and John Leslie, "No Inverse Gambler's Fallacy in Cosmology", all appeared in *Mind*, 97, 1988.

[7] "Our Place in the Cosmos" is the title of the most recent article of John Leslie (*Philosophy*, 75, 2000), in which he develops a version of pantheism on the ground of the anthropic cosmology.

[8] Immanuel Kant, *Universal Natural History and Theories of the Heavens*, S. L. Jaki, trs., Scottish Academic Press, 1981, p.83.

[9] David Hume, *An Enquiry concerning Human Understanding*, § 122.

[10] F. Darwin, *The Life and Letters of Charles Darwin*, 3vols., Appleton, 1897, vol.1, p.282.

[11] Kant, *Critique of Judgement*, J. C. Meredith, trs., Clarendon Press, 1952, § 85.