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Anthropic Coincidences and the Multiverse Idea

Are we meant to be here? Or is mankind just a fluke in a meaningless universe?

According to the *Letter to Diognetus*, a Christian work of the early second century, "God loved the race of men. It was for their sakes that He made the world." Scripture and Christian tradition concur in teaching that the human race has a central place in the divine plan. In the Book of Genesis, the six days of creation culminate in the creation of man, and man alone of all the creatures is said to be made "in the image of God." St. Paul tells the Ephesians that they were chosen by God and destined to be His sons "before the foundation of the world."

On the other hand, we have often been told by atheists that science has shown the universe to have no purpose at all, and the human race to be just an accidental by-product of blind material forces. Steven Weinberg, the eminent particle physicist, expressed this view in a famous passage in his popular book *The First Three Minutes*:

> "It is almost irresistible for humans to believe that we have some special relation to the universe, that human life is not just a farcical outcome of a chain of accidents . . . but that we were somehow built–in from the beginning. . . . It is very hard for us to realize that [the entire earth] is just a tiny part of an overwhelmingly hostile universe. . . . The more the universe seems comprehensible, the more it also seems pointless."

Indeed, many people think this is the key lesson that science has to teach us. A particularly forthright champion of this view is the zoologist Richard Dawkins, who writes that "the universe we observe has precisely the properties we should expect if there is at bottom no design, no purpose, no evil, no good, nothing but blind, pitiless indifference." The late Stephen Jay Gould argued that humanity is a freak accident of evolutionary history, merely "a tiny twig on an ancient tree of life." Bertrand Russell averred that we are "a curious accident in a backwater" of the universe.

One can understand why some people come to this conclusion. The physical universe *is* indifferent to us. It *is* often harsh. We *are* just a tiny part of a cold, dark, empty, vast universe. Even so devout a Christian as Blaise Pascal wrote in his *Pensees*, “The eternal silence of the infinite spaces frightens me”. And yet none of this answers the basic question: Is the human race an accident, or were we (in Weinberg’s phrase) “built–in from the beginning?”

As it happens, new light has been shed on this question by the discoveries of modern physics. It has been noticed, especially since the work of the astrophysicist Brandon Carter in the 1970s, and increasingly in the last 25 years, that there are many features of the laws of physics and the structure of the universe that seem arranged --- in some cases, indeed, very precisely and delicately “fine–tuned” --- to make the existence of life possible, including intelligent beings such as ourselves. These are often called “anthropic coincidences”. (One sometimes hears the expression “anthropic principle”, but that term should be avoided since it has a variety of meanings and tends to create confusion.) At least on the face of it, these “anthropic coincidences” would appear to support the idea that we *were* built–in from the beginning. Even some former atheists and agnostics have seen in them impressive evidence of a divine plan.

Others, however, have raised scientific objections to the idea of anthropic coincidences, arguing that it is based on unjustified assumptions. And still others, while admitting that there are anthropic coincidences, have argued that a hypothesis called the “multiverse” can explain them in a perfectly naturalistic way. In this lecture I will first give some examples of anthropic coincidences, then respond to the objections, and finally discuss the multiverse idea.

So what are some of the features of the universe and its laws that make life possible?

One such feature is that the world obeys the principles of quantum mechanics. Quantum mechanics tells us that at small scales the world is grainy, rather than smooth. The very fact that matter is made up of discrete particles, such as protons and electrons, out of which complex structures can be built, is a quantum effect. Moreover, those structures are only stable because of quantum mechanics. In a non-quantum world, even if there were particles similar to protons and electrons, the electrons would get pulled into atomic nuclei by their electrical attraction, instead of having stable orbits around them, and atoms would therefore simply collapse into tiny useless clumps. It is the famous Heisenberg Uncertainty Principle that prevents this. (This principle says that a particle cannot have definite position and momentum at the same time. If an electron fell to the center of an atomic nucleus and remained there, it would have a definite position --- the center of the nucleus, and a definite momentum --- zero.) Moreover, even if electrons could somehow be kept orbiting atomic nuclei in a non-quantum world, they would have an infinite number of ways of doing so, meaning that no two atoms of the same element would be alike, and no atom would behave consistently over time. Atoms would behave chaotically, without stable properties.

Quantum mechanics may also be necessary in order for there to be room for human free will to operate, since, without quantum mechanics, the laws of physics would be "deterministic", meaning that every physical event would flow in a unique and inevitable way from past physical events. "Quantum indeterminacy" rescues us from that.

One should not take for granted that the world is quantum mechanical, as though things had to be that way, or as though it is the most obvious way for a universe to be built. Quite the opposite is true. Quantum mechanics has a strangeness to it that strikes all physicists who work with it as deeply mysterious and contrary to ordinary "common sense".

There is another aspect of the quantum world that is important for life and also very strange. It is called the Pauli Exclusion Principle and it applies to such particles as electrons. It prevents all the electrons of an atom from falling into the lowest "energy level", which would result in all atoms having basically the same chemical properties. The rich palette of chemical elements that one sees in the Periodic Table, which allows the fantastic variety of chemical compounds needed for life, is due to this Pauli Principle. That principle is traceable, in turn, to the fact that the so-called "electron field" has a strength that is not expressible in terms of ordinary numbers, or even complex numbers, but only in terms of peculiar mathematical entities called Grassmann numbers, which have the curious property that any Grassmann number times itself is zero.

Next, consider the fundamental forces of nature, which are usually said to be four in number: These are gravity, electromagnetism, the strong force, and the weak force. One should really also include the force associated with the so-called Higgs field as a fifth. If any of these forces did not exist, it seems that life would not be possible. Electromagnetism holds electrons and nuclei together to form atoms, atoms together to form molecules, and molecules together to form larger structures, such as living things. Electromagnetism also gives rise to the existence of light, which is the means by which the Sun warms the Earth and provides the energy that plants and animals need to live. The strong force holds atomic nuclei together, which otherwise would fly apart due to the electrical repulsion of the protons in them. Without gravity, matter would not condense into stars and planets, which are needed as habitats for life. Moreover, the gravitational expansion of space-time and the gravitational clumping of matter into stars are what allowed the universe to have reserves of usable energy to sustain life. The weak force makes possible the nuclear reactions that power stars like the sun. The Higgs force is needed to give mass to particles such as electrons and quarks.

It is not only the existence of these forces, but their specific characteristics, their complex interplay, and the fact that their strengths are in exactly the right relation to each other that make life possible. To take just one example, neutrons and protons get their masses primarily from the strong force. But neutrons are heavier than protons by just a slight amount, about 1 part in 700. This is due to the Higgs force, which makes the quarks inside neutrons slightly heavier than those inside protons. If it weren't for this fact, protons would be heavier than neutrons, which would allow them to radioactively decay into neutrons. This would make ordinary hydrogen atoms unstable --- a disastrous effect, since almost all organic compounds contain hydrogen --- water being a particularly important example. Or if the electromagnetic force were not much feebler than the strong force, the extra electrical energy packed into a proton because it is electrically charged would make it heavier than a neutron and the same disaster would occur.

The kinds of matter particles that exist are also important. The fact that there are particles with properties like those of electrons, neutrons, protons, and so-called "pions" is vital. Without neutrons, only a few types of nuclei would be possible, and therefore only a few elements of the Periodic Table would exist. Without particles like the pion, which generates the attraction between neutrons and protons, no atomic nucleus (other than hydrogen's) would be able to hold together. And, of course, particles like electrons and protons are necessary to have atoms at all.

The characteristics of space and time are also critical. We take for granted that there are three space dimensions and one time dimension. But this did not have to be the case by any mathematical, logical, or metaphysical necessity. Particle physicists study mathematical theories whose space-times have other numbers of space dimensions. Indeed, in M theory, which many people suspect is the correct unified theory of all forces, there are ten space dimensions, seven of which are rolled up to subatomic size. It seems to be crucial for life that there are exactly three "large" space dimensions (i.e. ones which extend for macroscopic distances), as in our universe.

If there were *more* than three large space dimensions, gravity would depend on distance differently than the famous "inverse square law" discovered by Isaac Newton. Gravity would be comparatively stronger at short distances and weaker at long distances than Newton's law says. As a result, planets would either escape the pull of stars, or would plunge into them, but could not orbit them.

If there were *fewer* than three large space dimensions, on the other hand, complex neural circuitry, as is needed in a brain, would not be possible. If one tries to draw a complicated circuit diagram on a two–dimensional surface, one finds that the wires have to intersect each other many times, leading to short–circuits. In three or more dimensions, however, wires (or neurons) can go around each other without touching.

Not only is the *number of dimensions* of space-time important, but so is its geometry. If space-time were Euclidean, for example, time could not have a past-future distinction. Objects would be able to travel back into their own past, which would wreak havoc with cause and effect. Finally, if the universe had not been extremely spatially flat soon after the Big Bang, the universe would either have collapsed in on itself within a tiny fraction of a second after the Big Bang or would have expanded so ferociously fast as to rip apart even atoms.

So far I have talked about "anthropic coincidences" that are gross *qualitative* features of the universe and its laws, including the principles of quantum mechanics, the types and strengths of the basic forces, the kinds of particles that exist, and the geometry and number of dimensions of space-time.

But many of the anthropic coincidences are *quantitative* and involve some of the "constants of nature" being numerically very close --- in some cases extremely close --- to certain special values. It is often said that these constants are "fine-tuned" to make life possible. One of the best examples is a parameter called the "Higgs vacuum expectation value", which physicists call "v" for short. The mathematical structure of the Standard Model of particle physics does not in itself require v to have any particular value. *A priori*, v could have been much bigger than it's observed to be --- in fact, even as much as 10^{+17} times bigger, which is one hundred million billion times bigger. Or it could have been much smaller ---in fact, even 10^{40} times smaller, which is ten thousand billion billion billion billion times smaller. Or it could have been *anything* in between. But life would not have been possible in our universe had v not been quite close to the value it is seen to have --- in fact, within about 50% of it. Truly life is balanced on a knife edge! This was shown in 1998 by me and several other theoretical physicists in a paper that is now widely cited in the scientific literature.

What do physicists make of all the anthropic coincidences? There is a wide spectrum of opinion. Some of the leading physicists of recent decades, including Yacov Zel'dovich, Andrei Sakharov, Sir Martin Rees, Steven Weinberg, Andrei Linde, Leonard Susskind, Frank Wilczek, and Stephen Hawking to name but a few, have been interested in these coincidences and have studied them. Nevertheless, the subject provokes discomfort and even hostility in much of the physics community. Why? Partly it is due to the specter of "teleology". Many scientists have a strong aversion to teleological thinking, because, at least in the physical sciences, the Scientific Revolution of the 17^{th} century was to a large extent made possible by the rejection of teleology in favor of mechanism. But there is more to it than that. For some scientists, anthropic coincidences conjure up the frightening specter of religion.

Yet, scientific skepticism about these ideas is not based entirely on such prejudices. There are several objections to the idea of anthropic coincidences that must be taken seriously.

One objection is that we cannot really know what is necessary for life to arise. Life might take forms that are utterly alien to our experience. While all the life we know about is based on a certain kind of physics, who knows whether different physical laws might have allowed completely different kinds of life to exist?

Many of the anthropic coincidences are not vulnerable to this argument, however.

For example, if space had not been fantastically flat early in the history of the universe, the universe would have either collapsed or blown apart so fast that not even atoms or even the nuclei of atoms would have been able to form, let alone living things.

Or consider another example: if the parameter v had been significantly larger than it is, it would not just have meant that chemistry would have been different, so that perhaps different kinds of life based on somewhat different chemistry might have existed. Rather, there would have been *no chemistry at all!* The reason is the following: If v had been large, protons and neutrons would have been unstable, and the only particles available to make atomic nuclei out of would have been a kind called the "Delta + +". Moreover, those Deltas would have been unable to stick together to form multi-particle nuclei, so the only kind of atomic nucleus would have consisted of a single Delta ++. The resulting atom would have behaved chemically just like helium --- which is chemically *inert.* So, to repeat, if v had been significantly larger, the universe would have had *not* just *different* chemistry, but *no* chemistry at all, and thus almost certainly no life either.

Nevertheless, the objection we've been discussing has some merit. While there are *some* features of the laws of physics which are clearly vital --- in the literal sense that life would be impossible without them, there are others where that is not so clear. In those cases, all we can say is that it *seems extremely unlikely* that that life could have emerged, but we can't absolutely rule it out. Absolute certainty, however, is beside the point. We would still be left with very powerful, even if not absolutely conclusive, indications that the cosmos was made for life, including complex life such as ourselves. After all, scientists like Steven Weinberg, Richard Dawkins, and Steven Jay Gould reached the opposite conclusion *not* because of absolutely certain proofs, or indeed any kinds of proofs, but simply because of facts that seem to them suggestive.

A second objection is that conventional scientific explanations may exist for some, if not all, of the facts that now appear to be anthropic coincidences. In fact, among the examples I gave of anthropic coincidences I included two where we may already have at least a partial scientific explanation. The fact that the electromagnetic force is much weaker than the strong force, for instance, is probably partly explained by the idea of "grand unification." There are reasons to believe that the electromagnetic force, the weak force, and the strong force are all really aspects of one underlying "grand unified" force. If that is so, then the strengths of the different forces are not independent of each other, but are tied together. Indeed, in a typical grand unified model — and many such models have been proposed — the electromagnetic force *does* tend to come out weaker than the strong force. To take another example, the extreme "spatial flatness" of the universe shortly after the Big Bang can be explained by a process called "cosmic inflation" that probably happened in the early universe. (Though I should point out that cosmic inflation itself seems to require some "fine tuning" of parameters.)

We can see then that is quite likely that at least some of the facts about the structure of the universe and its laws that seem necessary, or at least favorable, to the emergence of life may have conventional scientific explanations. But even if that proved to be true of *all* of them, it would not explain away the coincidental nature of these facts. The critical point was well expressed by the noted astrophysicists Bernard Carr and Martin Rees. In a classic article in the journal *Reviews of Modern Physics*, they wrote

> "One day we may have a more physical explanation for some of the relationships . . . that now seem genuine coincidences. For example, [some of them] may eventually be subsumed as a consequence of some presently unformulated unified theory. However, *even if all apparently anthropic coincidences could be explained in this way, it would still be remarkable that the relationships dictated by physical theory happened also to be those propitious for life*."

In other words, suppose that there are twenty numerical relationships that have to hold in order for life to be possible, and suppose that in some physical theory every one of those twenty relationships happens to hold as a consequence of some single underlying physical principle. That would *itself* amount to an astonishing coincidence.

This brings us to a third objection, which is closely related to the second. Einstein famously asked whether God had a choice in how He made the world. A few physicists suggest that all mathematical relationships in the laws of physics will turn out to be dictated by some deep underlying principles that leave no room for things to have been otherwise, that is, that the laws of physics may somehow be “unique”. Then everything about the physical world—the kinds of particles that exist, the kinds of forces and their relative strengths, the number of dimensions of space and its degree of flatness, and so on, down to the smallest detail --- had to be just one way on account of some fundamental physical principle. If so, a Creator would not have had the freedom to arrange the laws of nature to be favorable to life. They had to be just as they are and life has nothing to do with it.

However, this is plainly wrong. No deep underlying physical principle could have tied God’s hands, for the simple reason that He could have chosen some *other* principle or principles on which to base the laws of physics. For example, while the relative feebleness of the electromagnetic force --- which we saw to be favorable to life --- may be a necessary outcome of a “grand unified” framework, it was by no means necessary that the world be based on a “grand unified” framework. In fact, we still do not know whether it is. So, in this particular matter, God clearly did have a choice — indeed, many choices, as there are many mathematically self–consistent frameworks that involve “grand unification”, and many that do not.

As a matter of fact, there are an infinite number of mathematically self–consistent sets of laws of physics that could have been chosen by a Creator as the basis for the structure of a universe. This is incontrovertible. For example, a pendulum is a perfectly self-consistent physical system. One could imagine a universe whose basic equations were simply those of a pendulum. Alternatively, the basic equations of a universe could be those of N coupled pendulums, where N is any number you choose. I have just specified an infinite number of different possible universes, and I haven’t even scratched the surface of all the mathematical possibilities.

Whenever a knowledgeable physicist suggests that the laws of physics of our universe may be “unique”, the only possible ones, what he or she really has in mind is the idea that there may be a unique set of self-consistent laws *that satisfies certain assumed preconditions.* For example, some theorists believe that there is only one possible set of laws — “M theory” or superstring theory — that can incorporate simultaneously the principles of quantum mechanics and the principles of Einsteinian gravity. However, there is no *a priori* reason why a universe has to have either quantum mechanics or Einsteinian gravity. In short, the universe could have been made differently, and if it *had* been made differently, then life might not have been able to arise. These assertions would not be disputed by any fundamental physicist.

Before one leaps to the conclusion that the anthropic coincidences inevitably point to a cosmic purpose that includes life, and therefore to a God who made the universe for life, one should be aware of the fact that some of the scientists who have most strongly argued that there are anthropic coincidences are devout atheists (Steven Weinberg being a notable example). It is their view that the laws of physics being "propitious" for life has a purely naturalistic, scientific explanation that has nothing to do with humans or other life being important in the cosmic scheme. The naturalistic explanation they point to is nowadays called the "multiverse hypothesis".

The idea of the multiverse is most easily explained by an analogy. There are many things about conditions on the planet Earth that are propitious for life. If the Earth were much smaller, then it would not be able to retain an atmosphere. If it were much bigger, it would retain a lot of hydrogen in its atmosphere, which might be bad for life, or its gravity would be so great as to crush living things. If it were much closer to the sun it would be too hot to have liquid water, if much farther away it would be too cold. Has someone "fine–tuned" conditions here to make life possible? Not necessarily. There are a vast number of planets in the universe, probably over 10^{22} of them (ten thousand billion billion) just in the part of the universe we can see with telescopes. Indeed, in the context of present–day theory, it is not unlikely that the universe is of infinite spatial extent and contains an infinite number of planets. Some planets are hot, some cold, some big, and some small. They undoubtedly span a vast range of physical and chemical conditions. It seems inevitable that some of them would happen to have the right conditions for life.

To put it another way, if one tried one key in an unknown lock, it would be an astonishing coincidence if it worked. But if one tried a million keys it would not be greatly surprising if one of them did.

The multiverse idea is that not just the temperatures and other properties of *planets* may vary from place to place, but that many of the features of physics that we have generally believed to hold universally, so-called "constants of nature", actually vary from place to place within the universe. The strength of the electromagnetic force, the mass of electrons, and even the number and types of forces and particles, may vary from one region of the universe to another. Then it might be almost inevitable that in some regions conditions were right for life to appear. And of course, to the inhabitants of such exceptional regions, it might seem that someone had arranged the laws and features of the universe with them in mind.

What I have just described is what physicists usually have in mind when they speak of a "multiverse". In this version of the idea, there is just one universe, but it has many regions, and very basic features of physics vary from region to region. Deep down, all regions of the universe are governed by the same *fundamental* laws, but these fundamental laws can manifest themselves very differently in different places.

So what "multi-" stands for in this version of the multiverse idea is a multiplicity of *regions* within a single universe. In other words, in this version, a multiverse is just a strange type of universe. There are, however, more radical versions of the multiverse idea, in which the existence of many universes is posited. For example, in some scenarios, one universe can split off from another universe, in much the same way that a small balloon might be pinched off from a larger one. What results is a number of universes that are physically disconnected from each other. But one does not need to invoke such radical ideas. In what follows, when I say "multiverse", I have in mind the version more commonly considered by physicists, where there is just one universe with many regions.

Some religious people think the multiverse idea is simply an atheist fantasy, an idea cooked up for no other reason than to explain the anthropic coincidences without God. This is wrong. In several kinds of theories that fundamental physicists have studied over the last 30 years --- for reasons having nothing to do with anthropic coincidences and their possible religious implications --- the universe *does* have a multiplicity of regions in which basic features of physics are different, such as different types of particles and forces. This can happen in theories where two conditions are satisfied. Condition #1 is that the universe is so large that it has many regions so far apart that they haven't had time to affect each other. This would likely be the case, for example, if the universe has undergone cosmic inflation, as there are reasons to believe it did. Condition #2 is that the fundamental laws of physics are such that certain parameters once thought to be constants of nature are actually variables whose values can depend on local factors. In a number of kinds of theories that physicists think have a good chance of being correct, the laws of physics are like this.

If these two conditions are satisfied, then, in regions of the universe so far apart that they have never affected each other, local factors can select different values of the variable parameters.

So the multiverse idea is not at all far-fetched from a fundamental physics point of view. Nor is it just some atheistic scientists who find it plausible --- many religious scientists do also. Moreover, it is not just some religious people who are hostile to the multiverse idea. Many atheist scientists (perhaps even a majority of them) dislike the idea intensely, because they see it as untestable and therefore "unscientific".

In my view, it is not unreasonable to suppose that we live in a multiverse and that this might explain in a naturalistic way some of the anthropic coincidences. Nevertheless, I don't believe that this would nullify the force of the anthropic coincidences as evidence for purpose in the universe. For one thing, there are certain anthropic coincidences that the multiverse idea cannot account for, and in particular many of those having to do with gross qualitative features of the universe. For example, the multiverse hypothesis would not explain why the world is quantum mechanical. It does not seem possible that *some* parts of the universe are quantum mechanical while others are not. The principles of quantum mechanics are part of the very grammar of physical law in our world, and mathematical consistency requires that they apply to all parts of the universe. Similarly, the multiverse hypothesis would not explain why there is such a thing as the gravitational force: one cannot have gravity exist in some parts of the universe and not in others.

Moreover, there are a large number of anthropic coincidences that need to be explained. For a multiverse scenario to explain *one* anthropic coincidence would require only that *one* physical feature varies among regions of the universe. For a multiverse scenario to explain *most* of them, however, it would require that *dozens* of features vary among the regions of the universe. One would have to imagine that from one region to another *all* of the following things varied: the number of space dimensions; the number of kinds of forces and their characteristics and strength; the kinds of particles; the degree of spatial flatness; the value of parameters like v; and much more. In other words, not *any* multiverse scenario will do the trick, but only those in which a sufficiently rich smorgasbord of possibilities is realized among the various regions of the universe.

But if we live in such a rich and variegated multiverse, one is entitled to ask why. A multiverse can only exist if the fundamental laws of physics are such as to produce one. So, why should it happen that the fundamental laws of our universe are just the right kind to produce a multiverse structure, and why are they such as to produce a multiverse with so rich an array of possibilities? Those facts about the laws of nature could *themselves* be seen as remarkable anthropic coincidences!

What physicists have come to realize in recent years is that the fundamental laws of physics have to be *very special* if life is to have any possibility of existing. They can be special in possessing just the right qualitative features and just the right values of various constants of nature. Alternatively, they can be special in being just the right kind of laws to produce a rich and highly variegated multiverse structure. But *in one way or the other* they must be very special indeed.

In the final analysis one cannot escape from two very basic facts. First, the laws of nature did not have to be as they are; and, second, not any old laws of nature can lead to a universe with life, but only ones that are special in some highly non-trivial way. And this suggests strongly, I would argue, that we were "built-in from the beginning" and "meant to be here".

In my view, these facts lend themselves most naturally to a religious interpretation. At the very least, they utterly destroy the claim, so often put forward by atheists, that the discoveries of science point to a universe without meaning or purpose in which man is an accidental by–product.

Having said all this, we remain with a question very troubling to many: Why is the universe so large? How can we claim to be important in a universe that dwarfs us in its scales of space and time? There is at least a paradox here. It is a paradox that was not lost upon the Psalmist, who exclaimed, "When I consider the heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; What is man, that thou art mindful of him, and the son of man, that thou visitest him?"

One answer, of course, is the traditional one. The universe was not made only for our benefit. As the Psalmist also said, "the heavens proclaim the glory of God." If it is the glory of God that they proclaim, then there is no particular reason why they should have to be made to human scale. In fact, in the fifteenth century, Cardinal Nicolas of Cusa, an important theologian, philosopher, and church official of that era, argued that a universe of infinite extent would more aptly reflect the infinite splendor of God.

The traditional answer is a good one, but there is another. It turns out that the very age and vastness of the universe themselves have “anthropic” significance. Life emerged in our universe in a way that required great stretches of time. Most of the elements needed for life were made deep inside stars, which had to explode and disperse those elements into space to make them available to be formed into planets and living things. That alone required billions of years. Biological evolution required billions of years more. Thus, the briefness of human life spans, and even of human history, compared with the age of the universe may simply be a matter of physical necessity, given the developmental way that God seems to prefer to work. It takes longer for a tree to grow to maturity than the fruit of the tree lasts. It took much longer for the universe to grow to maturity than a human life lasts.

Physics can also suggest why the universe has to be so large. The laws of gravity discovered by Einstein relate the size of the universe directly to its age. The fact that the universe is many billions of light–years across is a direct consequence of the fact that it has lasted several billion years. Perhaps we would be less daunted by a cozy little universe the size of, say, a continent. But such a universe would have lasted only a few milliseconds. Even a universe the size of the solar system would have lasted only a few hours. A universe constructed in such a way as to have time to evolve life had to extend vastly in space as well as in time. So that the frightening expanses that are so often said to be a sign of human insignificance actually, like so many other features of our strange universe, point to man, as they also proclaim the glory of God.