Religion and the Challenges of Science

Edited by
WILLIAM SWEET
St Francis Xavier University, Canada
and
RICHARD FEIST
Saint Paul University, Canada

ASHGATE

Chapter 6

Cosmological Theories and the Question of the Existence of a Creator

John L. Bell

In the words of G.K. Chesterton, 'The Cosmos is about the smallest hole that a man can hide his head in.' And indeed, when engaged in cosmological speculation, one's mind seems to expand to encompass the universe. As Lev Landau observed: 'Cosmologists are often in error, but never in doubt.'

Since the dawn of civilization, the question of the origin of the universe has exercised human thinking. In one early Egyptian creation myth, for example, we are told how the sun god Ra conjured up the world from Nu, the swirling watery chaos:

> Heaven and Earth did not exist. And the things of the earth did not exist. I raised ... them out of Nu, from their passive state. I have made things out of that which I have already made, and they came from my mouth.

In a Vedic hymn, Reality or Being is proclaimed as having 'arisen from Nothing'. By contrast, in Jaina cosmology time has no beginning; the universe, uncreated, has always existed. In Plato's *Timaeus* the universe is conceived as not having existed eternally, but as having been created at some past time by a demiurge acting on pre-existing substance. We are all familiar with the arresting first line of Genesis: 'In the beginning God created the heaven and the earth.' Augustine took this to mean that nothing whatsoever existed before its creation by God, that God created the world – space, time, substance – *ex nihilo*.

In Newtonian cosmology, space, time and, perhaps, matter also have always existed; but at some point in the past God acted to introduce order into the universe. Newtonian cosmology was essentially static; the universe was not conceived, in the large, as having a history: while God may have intervened at some past time, the moment of intervention could be placed indefinitely far back. In the Newtonian scheme, moreover, space and time themselves, were, like God, sempiternal, and so not subject to the problem of origin. Thus the origin of the universe could be consigned to 'minus infinity' and the question safely ignored.

Einstein retained this changeless conception of the universe when he first applied general relativity to the problem of cosmic structure. Indeed he went so far as to introduce a force of 'cosmic repulsion' into his mathematical models, when he found that, in the absence of such a force, his equations had no solutions corresponding to a static universe with a uniform non-zero matter distribution. He later remarked that the assumption of changelessness seemed unavoidable to him because 'one would get into bottomless speculations if one departed from it'.[1] With hindsight, one can see how right he was!

In the 1920s the static view of the universe was shaken by two discoveries, one theoretical, the other empirical. In 1922 the Russian mathematician Alexander Friedmann, and, independently, the Belgian cleric Georges Lemaître in 1927 showed that Einstein's equations have non-static solutions with uniform matter distribution, corresponding to a continually expanding universe. Lemaître suggested that the universe had evolved by expansion from an initial highly compressed and extremely hot state, which he called the 'primeval atom' – the first explicit formulation of what later came to be known as the 'Big Bang'. In 1929 Edwin Hubble, in apparent ignorance of Friedmann and Lemaître's theoretical results, found the first evidence of such an expansion, observing a red shift in the spectrum of galaxies in direct proportion to their distance from us. Hubble's observations seemed at first to indicate that the expansion of the universe had begun only a billion or so years ago, contradicting the evidence from radioactivity in rocks that the earth's crust must be at least 5 billion years old. Happily, this conflict was resolved by a later revision of the distance yardstick based on stellar luminosity, which resulted in the origin of the expansion being pushed back to a point some 15 billion years in the past.

Thus did theoretical physics and observational astronomy together contrive to put the 'bottomless speculations' concerning the origin of the universe firmly back on the agenda. That science seemed to support the idea that the universe had an origin of some kind naturally appealed to cosmologists of a Christian persuasion, among whom E.T. Whittaker and E.A. Milne were prominent. Whittaker held that God created the universe from nothing:

> When the development of the system of the world is traced backwards by the light of laws of nature, we arrive finally at a moment when that development begins. This is the ultimate point of physical science, the farthest glimpse that we can obtain of the material universe by our natural faculties. There is no ground for supposing that matter ... existed before this in an inert condition, and was in some way galvanized into activity at a certain instant: for what could have determined this instant rather than all the other instants of past eternity? It is simpler to postulate a creation ex nihilo, an operation of Divine will to constitute Nature from nothingness.[2]

In 1951 Pope Pius XII cited Whittaker's assertion of the consonance between the Christian tradition and the picture of the expanding universe as providing scientific evidence for the Catholic world view.

Cosmologists of an agnostic turn of mind – a majority, I would surmise – were understandably disturbed that their discoveries could be used, plausibly or not, as a prop for traditional theology. In particular the 'Big Bang' scenario, by postulating a 'beginning' to the existence of the universe, seemed to offer new and alarming support for the venerable cosmological argument for God's existence. This argument traditionally assumes the following form: (i) whatever begins to exist is caused to exist by something else; (ii) the universe began to exist; (iii) therefore, the universe was caused to exist, and the cause of its existence is (called) God.

Anxious to avoid entanglement in such scholastic disputes, many physicists welcomed the formulation of the 'steady-state' theory of the universe in 1948 by Bondi, Gold and Hoyle. This provided an alternative to the 'Big Bang' scenario – a term introduced with derisory intent by Hoyle in 1950, which ironically caught on

– according to which the universe apparently sprang into existence from nothing and then expanded, continually cooling and attenuating, into its present quiescent state. In the steady-state theory, by contrast, it is denied that the universe is any cooler or less dense at present than it was in the past, denied in fact that any change in the large-scale structure of the universe has occurred over time, and, a fortiori – most importantly from a philosophical standpoint – denied that there was ever a time at which the universe has not existed. These assertions were based on the 'Perfect Cosmological Principle', the thesis enunciated by Bondi and Gold to the effect that the universe is not only similar from place to place but also from time to time. (The purely spatial version of this – the so-called 'Cosmological Principle' – had been used extensively by the proponents of the evolving universe.) On the face of it this thesis seems to conflict with the observed expansion of the universe. And in fact the only way of preserving a changeless universe in the presence of such expansion is to postulate, as did the 'steady statesmen', a continual steady creation of matter at precisely the rate required to offset the attenuation brought about by the expansion.

For me, a vivid illustration of the steady-state theory is provided by the 'Flying through Space' screensaver with which my computer is equipped. Here one sees, on a dark background, a continuous flow of 'stars' radiating outward from the centre of the screen. This is intended to represent, as its name implies, the viewpoint of an observer moving rapidly through interstellar space, encountering 'stars' that are already 'in existence'. But equally one may view the picture from the standpoint of an observer supposed stationary, in which case the 'stars' must be taken as continually springing into being and receding outwards. Despite the continual emergence of new 'stars', the law of conservation of mass (or energy) is observed 'locally' in the sense that the total number of such 'stars' on the screen does not change with time. This is, *mutatis mutandis*, the scenario of the steady-state theory.

In order to compensate for the universe's expansion, the steady-state theory called for the appearance of no more than one hydrogen atom per cubic centimetre of space every 10^{15} years, a phenomenon well below the limits of conceivable observation. Those cosmologists eager to skirt the theological quagmire were more than willing to accept an exiguous amount of 'continuous creation' as the price to be exacted for once again thrusting the origin of the universe back to minus infinity, where they instinctively felt it belonged. This was unquestionably an important consideration for Hoyle, who in a 1950 radio broadcast stated:

> Some people have argued that continuous creation introduces a new assumption into science – and a very startling assumption at that. I do not agree that continuous creation is an additional assumption. It is certainly a new hypothesis, but it only replaces a hypothesis that lies concealed in the older theories, which assume ... that the whole of the matter in the universe was created in one big bang at a particular time in the remote past. On scientific grounds this big bang assumption is much the less palatable of the two. For it is an irrational process that cannot be described in scientific terms. Continuous creation, on the other hand, can be represented by mathematical equations whose consequences can be worked out and compared with observation. On philosophical grounds, too, I cannot see any good reason for preferring the big bang idea. Indeed, it seems to me in the philosophical sense to be a distinctly unsatisfactory notion, since it puts the basic assumption out of sight where it can be challenged by a direct appeal to observation.[3]

Steven Weinberg, a later champion of the Big Bang theory, put the matter bluntly: 'The steady state theory is philosophically the most attractive theory because it least resembles the account given in Genesis.'[4]

While the steady-state theory did not lack philosophical appeal, the observational evidence, sadly, soon began to tell against it. To begin with, continuous creation required particles and antiparticles to be produced at equal rates, which would lead to a symmetry between matter and antimatter. But the observed universe shows no such symmetry, rather a marked preponderance of one sort of matter over the other. Moreover, the discovery of quasi-stellar objects showed that the universe did, after all, change its appearance with time. The *coup de grâce* was delivered to the steady-state picture in 1965 with the discovery of the 'echo' of the Big Bang. In 1948 the physicists Ralph Alpher, George Gamow and Robert Herman had predicted that if the Big Bang scenario of a hot and dense past were correct, then some evidence of that past must remain in the form of residual radiation cooled by the universe's expansion to a temperature only a few degrees above absolute zero. In 1965 Arno Penzias and Robert Wilson happened upon this radiation field while calibrating a sophisticated radio receiver designed for satellite tracking. The radiation had a temperature of three degrees absolute – almost exactly as predicted – and subsequent observations revealed that its spectrum carries the distinctive Planck signature of heat radiation. The steady-state theory provided no plausible means of explaining the presence of a pervasive radiation field with just these characteristics. The Big Bang theory received further confirmation over its rival from the successful prediction of the cosmic abundances of helium, deuterium and lithium, all of which would be produced by nuclear reactions during the first three minutes of the expansion after the Bang. The steady-state theory could not explain this abundance of light elements.

By the mid-1960s the steady-state theory was, in the eyes of the majority of cosmologists, moribund. Nevertheless, despite the mounting observational evidence in favour of the Big Bang theory, Hoyle himself, along with a few of his followers, steadfastly refused to embrace it, undoubtedly because of a distaste for its postulation of a temporal origin of the universe. Hoyle's stubbornness in this regard was satirized in a verse by Barbara Gamow. Here Ryle is the British radio astronomer Martin Ryle, who, as a proponent of the Big Bang theory, engaged in extended debate, much of it acrimonious, with Hoyle throughout the 1950s and 1960s.

'Your years of toil,'
Said Ryle to Hoyle,
'Are wasted years, believe me.
The steady state
Is out of date.
Unless my eyes deceive me,
My telescope
Has dashed your hope;
Your tenets are refuted.
Let me be terse:
Our universe
Grows daily more diluted!'
Said Hoyle, 'You quote

Lemaitre, I note,
And Gamow. Well, forget them!
That errant gang
And their Big Bang –
Why aid them, and abet them?
You see, my friend, it has no end
And there was no beginning,
As Bondi, Gold,
And I will hold
Until our hair is thinning!'

Of course, such frivolity only served to underscore the eventual triumph of the Big Bang theory. A prominent cosmologist, Martin Rees, writing in 1999, had this to say on the matter:

> The empirical support for a Big Bang ten to fifteen billion years ago is as compelling as the evidence that geologists offer on our Earth's history ... A few years ago, I already had ninety per cent confidence that there was indeed a Big Bang – that everything in our observable universe started as a compressed fireball, far hotter than the centre of the Sun. The case now is far stronger: dramatic advances in observations and experiments have brought the broad cosmic picture into sharp focus during the 1990s, and I would now raise my degree of certainty to ninety-nine per cent.[5]

Mathematical support for the Big Bang scenario had been independently provided by the *Hawking–Penrose singularity theorems*. These demonstrate under certain seemingly plausible hypotheses within the general theory of relativity that the entire cosmos must have emerged from a universal singularity in the past, that is, had a 'beginning' in time. (These hypotheses are: (i) gravity is attractive and universal, (ii) the universe is now expanding and contains sufficient matter, (iii) there are no closed time-like lines, that is, time travel is impossible.) Before this universal singularity sprang into being, neither space, time, matter, nor the laws governing them can be said to have existed: in fact no meaning can be attached to the phrase 'before the singularity'. As in the Augustinian conception, the universe must be regarded as having materialized *ex nihilo.* But Hawking and Penrose did not follow Augustine in furnishing a reason as to *why* this singular event came to occur. All they asserted is that, under the specified hypotheses, the universe and the laws governing it cannot always have existed: they must have materialized at some moment in the past.

But the question of the universe's origin continued to nag. Reluctant to surrender this problem to the theologians and philosophers, some cosmologists attempted to remove the sting of the cosmological argument by treating the spontaneous emergence of the universe as a problem in physics. These physicists hoped that a suitable synthesis of quantum theory and relativity might enable the derivation of the initial singularity to be blocked. In that case, the putative 'beginning' or 'creation *ex nihilo*' of the universe need no longer be identified with something as elusive as a singularity, but could be instead invested with physical content. One such proposal was put forward in the early 1970s by Edward Tryon, who suggested that the universe may be nothing more than a gigantic 'vacuum fluctuation' in the sense of quantum field theory. A typical example of a vacuum fluctuation is the occasional emergence of an electron, positron and photon from a perfect vacuum; when this happens, the three particles exist only for a brief time, and then annihilate each other, leaving no trace behind. Energy conservation is violated, but only for the brief particle lifetime Δt permitted by the uncertainty relation $\Delta E \Delta t \sim h$, where ΔE is the net energy of the particles and h is Planck's constant. The smaller ΔE is, the larger the lifetime Δt of the fluctuation can be. In particular, if ΔE is zero, then Δt can be any value whatsoever, however large. Now the laws of physics place no limit on the scale of vacuum fluctuations. So if the universe is closed and has zero net energy (for this to be possible the universe's total 'positive' mass energy must be balanced by its total 'negative' gravitational potential energy), it could be itself the result of a vast fluctuation of the vacuum of some hyperspace – the 'quantum void' – in which our own universe is embedded. By way of explanation for this remarkable occurrence, Tryon engagingly offered 'the modest proposal that our Universe is simply one of those things which happen from time to time.'[6] In Tryon's scenario, the emergence of our universe is a random occurrence, a sudden precipitation from the quantum void. This cannot be regarded as a creation *ex nihilo* since the void from which the universe sprang is assumed already to be present: like Newton's cosmos, the quantum void is sempiternal. Thus, once again, we have an 'escape into infinity'.

A far more radical proposal for avoiding the initial singularity was offered by Hartle and Hawking in the early 1980s. In this – the so-called 'no boundary' scenario – the universe's initial state is timeless, in that it possesses, not three spatial and one temporal dimension, but four spatial dimensions, the additional spatial dimension being called by Hawking 'imaginary time'. (The idea of introducing 'imaginary time' was first proposed by Minkowski in 1908 in order to allow the metric of special relativity to assume a Euclidean form.)

Thus the space–time geometry of the initial state takes a Euclidean form, which makes it possible for the universe to lack a 'beginning' but yet to be temporally closed. For just as the Earth's surface has no boundary at the North Pole, this initial region of the universe also lacks a boundary: it has no singular points. The geometry of the 'no-boundary' universe is similar to that of the surface of a sphere, except that it has four dimensions instead of two. In this analogy, unfolding in Hawking's 'imaginary time', Earth's North Pole represents the Big Bang, which, like the North Pole, is not a singularity. In that case, the universe itself cannot be said to have a 'beginning' in the usual sense of the word, at least not in respect of imaginary time. Hawking has made strong claims for the objective existence of the latter:

> Only if we could picture the universe in terms of imaginary time would there be no singularities ... When one goes back to the real time in which we live, however, there will still appear to be singularities. This might suggest that the so-called imaginary time is really the real time, and that what we call real time is just a figment of our imaginations. In real time, the universe has a beginning and an end at singularities that form a boundary to space–time and at which laws of science break down. But in imaginary time, there are no singularities or boundaries. So maybe what we call imaginary time is really more basic, and what we call real is just an idea that we invent to help us describe what we think the universe is like.[7]

And on one occasion Hawking asserted:

> I still believe the universe has a beginning in real time, at the big bang. But there's another kind of time, imaginary time, at right angles to real time, in which the universe has no beginning or end. This would mean that the way the universe began would be determined by the laws of physics. One wouldn't have to say that God chose to set the universe going in some arbitrary way that we couldn't understand. It says nothing about whether or not God exists – just that he is not arbitrary.[8]

In the 'no-boundary' scenario, the universe, viewed in imaginary time, is a kind of *ouroboros,* a (finite) snake eating its own tail. Because of this one might think that it avoids the singularity problem without making an 'escape into infinity'. But a closer look dispels this impression. For the 'no-boundary' scenario is founded on an esoteric application of quantum theory to classical geometrodynamics, involving the use of path integrals over ensembles of four-geometries to compute the wave function of the universe. And the ensemble E of four-geometries required by the 'no-boundary' theory must already be assumed to be present, in an ontological sense, at least, prior to the actual universe, like Tryon's 'quantum void', E was always 'there'. Is this not, implicitly, another 'escape into infinity'?

The 'escape into infinity' is also to be seen in the most recent, and speculative, scenario to be dreamed up by cosmologists – the so-called 'ekpyrotic' model. This term, which derives from the Greek word *ekpyrosis*, 'conflagration', is intended to evoke the ancient cosmological model associated with Heraclitus and the Stoics, according to which the universe is created (and recreated) in a sudden burst of fire. Here the hot Big Bang universe is conceived as arising from the collision of two three-dimensional worlds, or 'membranes', in a five-dimensional space. The all-embracing five–dimensional space is, again, taken to be infinite and as having in some sense always 'existed'.

Although it would seem that the majority of cosmologists wish to avoid drawing theological conclusions from the fact of the Big Bang, it should be pointed out that by no means all cosmologists are opposed to the notion that the universe was 'created'. John Polkinghorne, who resigned his professorship of physics at Cambridge to become an Anglican priest, is one example. Paul Davies's recent work gives evidence of an emerging deism. Some have argued that, given the Big Bang, the hypothesis that the universe was created has at least the merit of simplicity, and is therefore to be preferred to arcane conceptions such as Hawking's. This is the position espoused by the physicist N. Dallaporta, who has averred:

> In order to justify the various ... assumptions current in present day cosmology, it is necessary for each of them to build a frame of metaphysical postulates much more involved and artificial than the opposite straightforwardly metaphysical view of a universe built according to an a priori plan, requiring a planning Intelligence adequate to having conceived it.[9]

If the attempt to explicate what, if anything, happened 'before' the Big Bang has rekindled the cosmological argument, explaining what happened afterwards has ensnared cosmologists in a different, and perhaps better-known argument for the existence of a Creator – the so-called 'argument from design'. This argument, which received its most celebrated elaboration in William Paley's *Natural Theology* of 1802, has been encapsulated by Bertrand Russell as follows: 'Everything in the world is made just so that we can manage to live in the world, and if the world was ever so little different, we could not manage to live in it.'[10] And indeed, recent work has demonstrated the exactness of the 'fine tuning' of the fundamental constants of nature necessary for ensuring that the universe has the requisite form making possible the formation of physical structures – galaxies, stars, planets – from which organic life, in particular ourselves, can eventually emerge. In his recent book, *Just Six Numbers,* Martin Rees identifies these constants. They are N, about 10^{36}, the ratio of the electrical to the gravitational force; E, about 0.007, which measures the efficiency of thermonuclear fusion of hydrogen to helium; Ω, the ratio of the actual density of matter in the universe to the 'critical' density at which the universe will eventually recollapse; Λ, the 'cosmological constant', the ratio of the putative force of cosmic repulsion to the force of gravity; Q, of the order of 10^{-5}, the ratio of the energy required for complete dispersal of a galaxy or galactic cluster to its rest mass energy; and finally D, exactly 3, the number of spatial dimensions of the universe. Had the values of these constants differed even slightly from their actual values, the structure of the universe would be altered to such a degree as to make the emergence of any form of organic life impossible. In Rees's words:

> if N had a few less zeros, only a short-lived miniature universe could exist: no creatures could grow larger than insects, and there would be no time for biological evolution.
>
> E ... controls the power from the Sun and, more sensitively, how stars transmute hydrogen into all the atoms of the periodic table. Carbon and oxygen are common, whereas gold and uranium are rare, because of what happens in the stars. If E were 0.006 or 0.008, we would not exist.
>
> Ω tells us the relative importance of gravity and expansion energy in the universe. If this ratio were too high relative to a particular 'critical' value, the universe would have collapsed long ago; had it been too low, no galaxies or stars would have formed.
>
> Fortunately for us ... Ω is very small. Otherwise its effect would have stopped galaxies and stars from forming, and cosmic evolution would have been stifled before it could even begin.
>
> If Q were [any] smaller, the universe would be inert and structureless; if Q were much larger it would be a violent place, in which no stars or solar systems could survive, dominated by vast black holes.
>
> Life couldn't exist if D were two or four.[11]

And even if human beings could exist under the last of these conditions, they would find frustrating the fact that they couldn't tie their shoelaces – there are no knots in even-dimensional spaces!

For the universe to have the structure it has, and in particular to have a structure compatible with the existence of life, these six numbers must apparently have been 'fine-tuned' to their actual values. As Rees points out, one could follow certain scientists in responding to this with a shrug of the shoulders and the remark that since we couldn't exist if these numbers failed to have these special values, and since we manifestly *do* exist, there's nothing to be surprised about. This is a version of the so-called *weak anthropic principle*, which Barrow and Tipler define as follows:

> The observed values of all physical and cosmological quantities are not equally probable but ... take on values restricted by the requirement that there exist sites where carbon-based life can evolve and by the requirement that the Universe be old enough for it already to have done so.[12]

Such a response seems less than satisfactory in that it fails to provide an *explanation* for the apparently remarkable fact that these six constants take just the values they do: the probability of their having done would seem to be infinitesimal. This has led John Polkinghorne to suggest, in a revival of the argument from design, that the 'fine-tuning' of these numbers furnishes evidence for the intervention of a beneficent Creator, who formed the universe with the specific intention of creating organic life, and, more especially, us.

Now the force of this contemporary version of the argument from design depends not just on the fact that the six constants have providential values, but also on the assumption that the universe in which they take these values is *unique*. By way of illustration let me offer the following quasi-Aesopian fable. The frogs in a certain pond, known to them as the *Universal Pond*, lead an idyllic life. Conditions in the Universal Pond are, the frogs note, perfectly adapted for batrachian existence – the water temperature is just right, neither too hot nor too cold; on the surface float a number of lily pads ideally designed, so think the frogs, for perching on; and there is an abundance of tasty insects providing an ideal source of nourishment. 'Now surely,' one can imagine a philosophically-minded frog arguing, 'the conditions in the Universal Pond cannot have arisen by chance. For the Universal Pond is, by definition, unique, and it is simply too unlikely that in this single case the temperature of the water, the dimensions of the lily pads, and the constitution of the insects would have the ideal values they in fact possess. These conditions must have been brought about by an intelligent Designer.' But what the frogs do not know is that in fact their Universal Pond is just one out of a vast ensemble of such, in which are manifested every conceivable variation of conditions. Many contain no frogs at all because the water is polluted or has dried up altogether. Others support a population of frogs leading a wretched flipper-to-mouth existence. The true explanation for the pleasant ambience afforded by the 'Universal' pond is quite prosaic, being no more than the chance fact that its inhabitants happen to reside in a pond in which such pleasant conditions obtain. The fable might conclude with a frog of unusual acuity grasping the possibility that other ponds might exist, and enunciating the 'weak batrachian principle', namely: *The observed values of all physical and limnological quantities are not equally probable but ... take on values restricted by the requirement that there exist sites where carbon-based, and, more especially, batrachian life can evolve and by the requirement that the Universal Pond be old enough for it already to have done so.*

Desirous of avoiding the conclusion that the universe was designed by a Creator, certain cosmologists have challenged the assumption of our own universe's uniqueness, suggesting that, instead, the universe we inhabit is just one among many. If physicists responded to the cosmological argument by 'escaping into infinity', some have met the argument from design with what might be termed an 'escape into plurality'. To quote Martin Rees again:

> If one doesn't accept the 'providence' argument, there is another perspective, which – though still conjectural – I find compellingly attractive. It is that our Big Bang may not have been the only one. Separate universes may have cooled down differently, ending up governed by different laws and defined by different numbers. This may not seem an 'economical' hypothesis – indeed, nothing might seem more extravagant than invoking multiple universes – but it is a natural deduction from some (albeit speculative) theories, and opens up a new vision of our universe as just one 'atom' selected from an infinite multiverse.[13]

> If indeed there were an ensemble of universes, described by different 'cosmic numbers', then we would find ourselves in one of the small and atypical subsets where the six numbers permitted cosmic evolution. The seemingly 'designed' features of our universe shouldn't surprise us, any more than we are surprised at our particular location within our universe.[14]

The 'multiverse' conception arises from the *inflationary universe* model devised by Alan Guth and others. This was originally introduced to explain the so-called 'horizon' and 'flatness' problems. The 'horizon' problem is the puzzle that widely separated regions of the universe are observed to share the same physical properties, such as temperature, even though these regions were too far apart when they emitted their radiation to have exchanged heat and so homogenized during the time since the Big Bang. The 'flatness' problem is the question of why the universe today is so close to the boundary between being open or closed, that is, why it is almost 'flat'. The essential feature of the inflationary universe model is that, shortly after the Big Bang, the infant universe underwent a brief (perhaps as little as 10^{-32} sec.) and extremely rapid expansion, after which it resumed the more leisurely rate of expansion of the standard Big Bang model. Andre Linde has taken this idea further in formulating what he called *chaotic inflationary universe* models. In such scenarios, an inflating universe fissions into a number of different fragments or 'bubbles', each of which is completely cut off from its fellows, so that the fragments are, in effect, independent universes. This fissioning process thus turns the inflationary universe into a 'multiverse'. The process may be repeated at random in the new 'universes', each of which accordingly spawns a whole flotilla of offspring – 'baby' universes – which, in their turn, reproduce in the manner of their progenitors. Individual universes would come and go, but in Linde's vision the whole ensemble of universes – the 'multiverse' – would last forever, and indeed, under the so-called 'eternal inflation' scenario, may always have existed. This is yet another 'escape into infinity'!

Towards the end of his book Rees remarks somewhat uncomfortably:

> If the underlying laws determine all the key numbers uniquely, so that no other universe is mathematically consistent with those laws, then we would have to accept that the 'tuning' was a brute fact, or providence.[15]

This prompts the following observation, with which I bring my cosmological musings to a close. Suppose that the laws of physics *did* indeed ultimately turn out to determine all the 'cosmic numbers' uniquely, so realizing the neo-Pythagorean view of the world propounded with great vigour by the celebrated English astrophysicist A.S. Eddington. Eddington, it will be recalled, championed to the point of obsession the idea that the dimensionless constants of nature have values which can be calculated a priori, perhaps most notoriously in the case of the 'cosmical number' – the total number of protons and electrons in the universe – which Eddington determined to be exactly 204.2^{256}. (The 'cosmical number' is a close relative of Rees's Ω.) He also believed that the 'fine structure constant' had the exact value of 1/137. This important dimensionless constant – the ratio to the velocity of light of the velocity of an orbiting electron nearest the nucleus of an atom in a ground state – was originally introduced by Sommerfeld: somewhat surprisingly, it failed to make the cosmologists' list of crucial numbers.[16] Eddington's intellectual adventures illustrate to perfection, it seems to me, the mental effects of cosmological speculation mentioned at the beginning of this essay.

Now if, as I have suggested, the laws of physics did turn out to determine all the 'cosmic numbers' uniquely – then the 'tuning' of the fundamental constants would be a *logical* consequence of the laws of physics. In that case, would not the acceptance of the 'tuning' as a brute fact, or providence, be tantamount to an acknowledgment that the *laws of physics* were *themselves* brute facts, or providence? Compare this with the analogous situation in mathematics. The value of π (say) is uniquely determined by the laws of mathematics, indeed, some would claim, by the laws of logic itself, but few are inclined to regard any such fact as 'brute' or providential, because mathematics, or logic, is taken to have an a priori character, a character customarily denied to physics. Most theists in fact accept that the deity is constrained to act in accordance with the laws of logic or mathematics – that is, if God eternally geometrizes, it's because he has no choice but to do so! Such laws are acknowledged by theists to be 'brute facts', only of a necessary nature over which God himself has no control. But if, by contrast, the laws of physics should turn out also to be unique or 'brute facts', that very contingency would make it natural for the theist to claim that they had been expressly selected from the spectrum of possibilities by divine choice. In order to block this new meta-version of the design argument without at the same time turning away from the goal of explaining the apparent uniqueness of the laws of physics, the agnostic might have to consider taking refuge in a sort of 'metaphysical pluralism', which countenances the actual existence of realms of being, inaccessible from ours, and governed by entirely different physical laws. Faced with this possibility, the agnostic can only hope against hope that the exact values of the 'key numbers' of our universe ever remain undeduced from the laws of physics.

Notes

1 Albert Einstein, *Relativity: The Special and General Theory*, trans. Robert W. Lawson (London: Methuen & Co Ltd, revised edition, 1924), Appendix IV: The Structure of Space according to The General Theory of Relativity (Supplementary to Section 32).

2 Quoted in J. Barrow, *The World Within the World* (Oxford: Clarendon Press, 1988), p. 227.

3 F. Hoyle, *The Nature of the Universe* (Harmondsworth: Penguin Books, 1963), p. 110.

4 Quoted in David Wilkinson, *God, Time and Stephen Hawking: An Exploration Into Origins* (Toronto, ON: Monarch Books, 2001), p. 56.

5 M. Rees, *Just Six Numbers* (New York: Basic Books, 2000), p. 10.

6 In J. Leslie (ed.), *Modern Cosmology and Philosophy* (Amherst, NY: Prometheus Books, 1998), p. 224.

7 S.W. Hawking, *A Brief History of Time: From the Big Bang to Black Holes* (New York: Bantam Books, 1988), p. 139.

8 Quoted in Howard J. Van Till, 'No Place for a Small God', in John Marks Templeton (ed.), *How Large Is God: The Voices of Scientists and Theologians* (Philadelphia; London: Templeton Foundation Press, 1997), p. 121.

9 In F. Bertola and U. Curi, *The Anthropic Principle* (Cambridge: Cambridge University Press, 1989), p. 163.

10 Bertrand Russell, *Why I am not a Christian, and other essays on religion and related subjects*, Paul Edwards (ed.) (London: G. Allen & Unwin, 1957), p. 6.

11 Rees, pp. 2–3.

12 John D. Barrow and Frank J. Tipler, *The Anthropic Cosmological Principle* (Oxford: Clarendon Press, 1987), p. 16.

13 Rees, p. 150.

14 Rees, pp 156–7.

15 Rees, p. 157.

16 Eddington's numerological obsession was, as many will recall, the subject of Bertrand Russell's amusing satire *The Mathematician's Nightmare* in his *Nightmares of Eminent Persons.*