Theism and Physical Cosmology[1]

Hans Halvorson[2] *Helge Kragh*[3]

I. Introduction

Christianity and other monotheistic religions (Islam and Judaism) assume a transcendent and sovereign God who created the universe and continually maintains its existence. The world only exists because of an ultimate and supernatural cause which is, as Newton said, "not blind and fortuitous, but very well skilled in Mechanicks and Geometry" (Cohen 1978, 282). Whether in a general philosophical sense or in a scientific sense, cosmology has always been part of theism, but it is only relatively recently that cosmology based on physics and astronomy has entered the discussion concerning the existence and role of God. A limited application of physics to the study of the universe can be found in the second half of the nineteenth century when the cosmological consequences of the law of entropy increase were eagerly discussed in relation to the Christian doctrines of a world with a beginning and end in time. However, physical cosmology is essentially a twentieth century science which emerged as a result of the discovery about 1930 that the universe is in a state of expansion that possibly started a finite time ago. Cosmology as a subdiscipline of physics differs in some respects from mathematical, philosophical and classical observational cosmology, but of course the different approaches are in constant interaction. In a modern sense, physical cosmology became established after the discovery of the cosmic microwave background in 1965 which quickly turned the hot big bang model into the standard model of the

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2 Department of Philosophy, Princeton University

3 Department of Science Studies, Aarhus University

universe. Jim Peebles' *Physical Cosmology* of 1971, possibly the first book with this title, may be taken as the beginning of modern physical cosmology.

Although physical cosmology based on general relativity theory and elementary particle physics is thus a modern science, many of the theologically relevant questions related to current cosmology are old. Has the universe come into existence a finite time ago? Will it come to an end? Why is the cosmic evolution and the laws of nature of just such a kind that they permit intelligent life to exist? These and other questions of obvious relevance to theism are currently being discussed in the light of the most recent cosmological theories and observations, but the questions themselves (and, indeed, many of the answers) were familiar to medieval philosophers and theologians. This is also the case with the question that is sometimes considered the ultimate one: Why is there a cosmos? There is no reason to expect that today's advanced physical cosmology, or the even more advanced of tomorrow, will provide final answers that satisfy theists and atheists alike.

II. Creation and the big bang

Einstein's general theory of relativity shows that the structure of spacetime is itself a dynamical variable, subject to causal influence by the material constituents of the universe. Indeed, Einstein immediately saw the potential to apply general relativity to large-scale cosmological questions. The first cosmological model of Einstein (1917) described a static universe, i.e. one whose spatial geometry is constant over time. Such a model was not consistent with the original field equations; thus Einstein modified the equations by the addition of a cosmological constant Λ. Although Einstein later said that the introduction of the cosmological constant was his greatest blunder, in recent years there have emerged independent reasons for introducing it into the equations.

Be that as it may, Einstein's static universe was empirically inadequate: it cannot account for the redshift data gathered by Edwin Hubble and others in the 1920s. The redshift data indicates that distant stars are moving away from us, and moving faster in direct proportion to their distance. Thus, the data indicate an expanding universe.

In the 1920s and 1930s, a number of cosmological models of general relativity were proposed that predict the expansion of the universe. The most accurate account of the data is given by the family of Friedmann-Robertson-Walker (FRW) models. The key characteristic of these models is that space is *homogeneous*, and hence isotropic (i.e. looks the same in all directions). From the homogeneity assumption, it follows that the entire 4-dimensional spacetime divides neatly into a stack of 3-dimensional "spaces" each of which has constant curvature. The three possibilities for this curvature correspond to the three classical geometries: Euclidean (flat), spherical (positive), or hyperbolic (negative). In a given FRW spacetime, the geometry of space at one time is merely a rescaling of the geometry at any other time. Thus, a coordinate t ("time") can index the stack of spaces, and if $h(t)$ is the metric of space at one time, then there is a scale factor S such that $h(t')=S(t')h(t)$ for all other times t'. The behavior of this scale factor S thus encodes the dynamics of a FRW universe.

In those FRW spacetimes that can reasonably be thought to model our cosmos (e.g. those with massive objects), the time parameter t has an absolute lower bound t_0. In particular, as t decreases towards t_0, the scale parameter $S(t)$ goes to zero. What happens when t reaches t_0? In short, these models cannot say what happens, because there are *no* points of spacetime with time coordinate t_0. That is, t_0 is an ideal point that is never reached: the universe exists at times after t_0, but not before or at time t_0.

The FRW spacetimes are extremely accurate descriptions of the large scale structure of our universe. Since these models describe a universe with a *finite lifetime*, it is reasonable to conclude that the universe is not eternally old.

But many physicists and philosophers hesitate to draw this conclusion. In fact, the standard view in the 1950s and early 1960s was that the singularities of the FRW models were consequences of false idealizing assumptions, namely assumptions of perfect isotropy and homogeneity. But this escape route from singularities was definitely closed when Robert Geroch, Stephen Hawking, and Roger Penrose proved the “singularity theorems,” according to which *almost all* spacetimes are singular, and in particular, almost all cosmological models describe a finitely old universe.

A number of theists take the past-singular nature of cosmological models as confirmation of the claim that God created the universe *ex nihilo*. The list of advocates of this “big bang theology” includes Pope Pius XII, Francis Collins (director, US National Institutes of Health), and apologists William Lane Craig and Hugh Ross. And indeed, big bang cosmology does provide *prima facie* support for theism. After all, big bang cosmology says that the universe has a finite age, and (traditional) theism says that God created the universe out of nothing. Does big bang cosmology not confirm traditional theism? We give several reasons to be cautious about such claims.

Advocates of big bang theology are most interested in the claim that the universe is finitely old. Thus, the chain of inferential support should run as follows:

Big Bang Model → *supports* → Universe Finitely Old → *supports* → Theism .

Before discussing the first supposed inferential relation, we note that not all theists are committed to the claim that the universe is finitely old. For example, Aquinas claims (in several places, including the *Summa Theologica*) that Reason cannot demonstrate the finitude of the universe. But Aquinas also thinks that Reason can demonstrate the existence of God; therefore Aquinas does not think that the very concept of God as creator implies that the universe is finitely old. (Contrary to some contemporary theologians, though, Aquinas claims that a Christian theist should *believe* that the universe is finitely old.

For Aquinas, the finite age of the universe is a revealed doctrine, like the divinity of Christ.) Contemporary theologians Arthur Peacocke and Ian Barbour also claim that the doctrine of the "creation" of the universe is best interpreted as one of the universe's timeless dependence on God, and that such dependence does not demand a temporal creation event. For the remainder of this chapter, we will not discuss further the question of whether theism requires, or strongly supports, the claim that the universe is finitely old. (Arguments for this claim are assessed in (Copan & Craig 2004).) For now we focus on versions of theism that are committed — in a perhaps naive way — to creation ex nihilo. Even on this understanding of theism, there are still reasons to exercise caution in seeing the big bang as confirming the prediction that God created the universe.

§ 1. If the current big-bang (BB) model provides confirmation for theism, then this means that theism makes the BB model likely. (This claim follows from standard probabilistic reasoning, in particular Bayes' theorem.) Let's be more precise. We are considering a version of theism according to which God created the universe out of nothing, in particular entailing a finite age for the universe. The BB model says that the universe is about 13 billion years old. Should the theist have expected that? It is difficult to answer that question. Many theists in the Judeo-Christian tradition expect a much smaller number, something on the order of several thousand years (see Byl 2001, Kelly 2000). But if a theist allows that God created the universe billions of years ago, then why expect 13 billion as opposed to 26 billion or even 99^{10} billion years? Indeed, if all finite values have equal probability (conditional on theism), then they all have probability zero. (Indeed, there are obvious problems with attempting to falsify a hypothesis that some parameter — e.g. the age of the universe — has a finite, but otherwise arbitrary, value.)

The reasoning in the previous paragraph leads, however, to a optimistic conclusion for the theist. In particular, suppose that it were shown that the universe *did* exist before the big bang. Would such a discovery undermine theism? Not in the slightest. For one, God might have created the universe ten minutes before the big bang. Or the current big bang might have been a big bounce; but the universe might have been created ex nihilo previous to the big bounce. The point is that insofar as the failure of the big-bang model would not undermine theism, so the success of the big-bang model does not support theism.

§ 2. Even more extremely, suppose that the big-bang model were disconfirmed in favor of some model that posits a universe without beginning (e.g. the steady state model, see next section). Surely the success of such a theory would yield a direct contradiction with the doctrine of creation ex nihilo! But not so fast: science employs numerous idealizations, and one of its favorite idealizations is to replace a large finite value with an infinite value. For example, in explaining phase transitions, it is routine to assume (contrary to fact) that one is dealing with a system that is infinitely extended. So, might not the best model be one with an infinitely old universe, even though the age of the actual system is just some huge finite number?

Even more strongly, creation ex nihilo is supposed to be miraculous — something for which the standard laws of nature cannot give an account. But then why should a theist expect to be able to derive creation ex nihilo from our best scientific theory? Compare with other supposed miracles, e.g. within Christianity the claim that Jesus changed water into wine. Do Christian theists claim that chemistry should predict that water can transform into wine? Of course not: God is supposed to be able to transcend the laws of nature, and the laws of nature are no guide as to what did in fact happen. But then it would not seem crazy to suppose that the best (most explanatory, most elegant) cosmological theory would posit an infinite past, whereas in reality God got things started a finite amount of time ago.

§ 3. Suppose however that the theist takes a harder line and says that theism requires (or suggests) cosmological models with a bounded time parameter. So, the time parameter should have no values lower than some number which we can set to zero.

But the interval (0,*t*) is topologically isomorphic to (-∞,*t*); i.e. there is a translation scheme that takes an bounded interval to an unbounded interval. This isomorphism has been exploited more than once: first by E.A. Milne in 1935, and then independently by Charles Misner in 1969. In particular, Misner replaces the time parameter *t* with the negative of its logarithm (i.e. -log *t*) in order to assuage worries that a bounded time parameter makes no sense. According to Misner, even in models that begin with singularities, "the Universe is meaningfully infinitely old because infinitely many things have happened since the beginning." Interestingly, Misner's move can hardly be motivated by a desire to obviate the need for a creator of the universe: Misner is catholic.

The conventionality of the temporal metric is noted by the catholic philosopher of science Ernan McMullin, who concludes that the theological doctrine of creation ex nihilo should not be interpreted metrically (McMullin 1981). Rather, claims McMullin, the ex nihilo doctrine should be interpreted order-theoretically: the time series has a first point. Unfortunately, this order-theoretic criterion does not match our intuitions. On the one hand, FRW models *fail* the order-theoretic criterion: they have no first moment of time. On the other hand, an ideal first moment of time could be adjoined to *any* spacetime, even those that have a metrically infinite past (see Earman 1995). Thus, a simple order-theoretic criterion cannot account for the theological significance of cosmological models.

A more adequate criterion of when a cosmological model is consonant with creation ex nihilo would require a detailed analysis of spacetime singularities (for extensive discussion of the latter topic, see (Earman 1995)). The best current account of when a spacetime is truly singular (as opposed to merely being described with inadequate coordinates) is given by the notion of having inextendible geodesics. Thus, the BB theologian would do best to claim that creation ex nihilo is confirmed precisely by those cosmological spacetimes that have a past-inextendible geodesic. (Indeed, this criterion does hold for FRW models.) The main problem with such a proposal is that it ties a robust, intuitive theological doctrine down to an extremely precise technical feature of Lorentzian manifolds (as described by differential geometry). The risk then is that by doing so, we add extraneous content to the doctrine: a future model might fail the technical criterion while still being consistent with the theological doctrine. Furthermore, many Christian theists claim that core theological doctrines are perspicuous – in particularly, not understood exclusively by an elite class of priests or scholars. But the notion of a Lorentzian manifold having incomplete geodesics can hardly be said to be accessible to the average layperson.

§ 5. Finally, BB theology overreaches if it says that general relativity and the singularity theorems have settled once and for all that the universe had a beginning in time. In fact, relativistic cosmology predicts its own invalidity for times close to a dynamic singularity, such as the big bang. (For a dissenting opinion, see (Misner 1969).) The reason that relativistic cosmology predicts its own own invalidity is that in the neighborhood of singularities, gravitational effects are intense, and quantum effects can be expected to play a predominant role. But general relativity does not incorporate quantum effects, and indeed it is untested in such regimes of intense gravitational force. Thus, there is little reason to believe that the singularity theorems make a valid prediction about the structure of a future successor theory of general relativity that includes quantum effects. We discuss this issue further in Section 4.

§ 6. As we have seen, many people have found big-bang cosmology congenial to a theistic world view. Typically, atheists and agnostics have merely attempted to defeat claims that big bang cosmology requires belief in a creator. But there is a vocal minority — we might call them "big-bang atheologians" — who make the much stronger claim that big-bang cosmology undermines theism. The most notable proponents of this big-bang atheology are the philosophers Adolf Grünbaum and Quentin Smith. In the case of Smith, quantum cosmologies (see Section 4) are also taken to provide evidence against theism.

In putting forward their arguments, Grünbaum and Smith make a number of points that seem to have been overlooked by those who invoke the big bang to support theism. One such point is that our best cosmological models have no first state. Thus, a theist who invokes the big bang cannot say that there is a state of the universe, say α, such that God created the universe in state α. He or she will have to invoke a more sophisticated notion of God creating initial temporal intervals, or something like that.

Big-bang atheologians also argue that it makes no sense to accept both that there were no times before the big bang (since time itself comes into existence with the universe) and that the universe was caused. Of course, many theists claim that God causes the universe timelessly, and they would attempt to defend the coherence of such a notion in the face of these criticisms.

III. Steady state theory

Conceptually founded on the "perfect cosmological principle" — the postulate that the universe in its large-scale features is not only spatially but also temporally homogeneous — the steady-state theory was introduced in 1948 by Fred Hoyle, Hermann Bondi and Thomas Gold. Although the classical steady-state theory was abandoned in the 1960s because of its inability to account for new discoveries (such as the cosmic microwave background and the redshifts of quasars), it remains an instructive case in the cosmology-theology discussion. Moreover, the theory is not quite dead yet, as some of its characteristic features survive in the quasi-steady-state cosmology (QSSC) still defended by Jayant Narlikar and a few other cosmologists. This model does not satisfy the perfect cosmological principle, but it assumes an indefinite cosmic time scale during which matter is continually created. In this respect it is an alternative to the big-bang theory and its supposed association with divine creation. In 1994, at a time when he was developing the QSSC model, Hoyle referred to big-bang cosmology as "a form of religious fundamentalism" (Hoyle 1994, 413). According to the classical steady-state theory, the universe has expanded for an infinity of time and will continue to do so for ever; yet the average density of matter remains constant because matter, or rather matter-energy, is continually being created out of nothing. (In later versions of the theory, matter creation was not ex nihilo.) Both features — the infinite time scale and the continuous creation of matter — were controversial and caused concern of a philosophical and also a theological nature.

It was widely assumed in the 1950s that the steady-state universe was contrary to theism or at least made God superfluous as a creator of the cosmos. After all, how can God have created a universe which has existed in an infinity of time? The argument may seem to pose a real problem for theism, but the theologians were well prepared — it had been discussed since the thirteenth century when Thomas Aquinas suggested that God could indeed have created an infinitely old universe. Moreover, theological responses to an infinitely old universe were far from new, for they had already been developed in relation to eternally cyclic models, either in the more speculative versions of the nineteenth century or the relativistic models that were proposed in the 1930s onwards.

According to the Thomistic doctrine of creatio continuans, God causes things to exist in the sense that their existence depends wholly on his power. If they were left to themselves they would turn into, or return into, nothingness. From this point of view creation is basically a metaphysical rather than a physical and temporal concept, and an eternal yet created universe is perfectly possible. As theologians in the 1950s were quick to point out, Hoyle's eternal universe was not particularly heretical, for it was still in need of a creator. Not only did they mobilize the old concept of continual divine creation, emphasizing that cosmic creation is primarily about the ontological dependence of the world on God, they also stressed that faith in God has little to do with physical cosmology in whatever of its versions. Erich Mascall, a priest and philosopher of religion, saw no reason why the steady-state model should cause worry among the faithful. As he said in 1956, "The whole question whether the world had a beginning or not is, in the last resort, profoundly unimportant for theology" (Mascall 1956, 155).

Views similar to Mascall's have been held by many later theologians and Christian philosophers, but not by all. There is disagreement about how solidly based in the Bible the concept of atemporal continual creation is, and also about the significance of an absolute beginning of the world. The view that cosmology is essentially irrelevant to Christian belief has not gone uncontested. As Ernan McMullin has pointed out, Christian doctrines are more than metaphysics and codes for moral conduct; they are also cosmic claims that say something about the universe and what it contains of things. For this reason theologians need to pay attention to cosmology in particular and to science in general.

Some Christian scientists and philosophers have seen the continual creation of matter, as posited by the steady-state theory, as a manifestation of perpetual divine creation. Thus, the Catholic philosopher Philip Quinn has adopted the old notion of creatio continuans to the case of steady-state cosmology. The argument is essentially that since ex nihilo creation of matter violates energy conservation, there must be an external creative cause that accounts for the violation, and this cause he identifies with perpetual divine creation. This kind of reasoning has been severely criticized by Adolf Grünbaum, who flatly dismisses the claim that underlies the idea of perpetual divine creation, namely that nothingness is the natural state of the universe. According to Grünbaum there is no room for divine creation in either big-bang or steady-state cosmology. "Steady-state cosmology," he concludes, "is indeed *logically incompatible* with [the] claim that divine creative intervention is causally necessary for the nonconservative popping into existence of new matter in the steady-state universe" (Grünbaum 1996, 529).

IV. Quantum and string cosmology

As we mentioned previously, there are reasons to suspect the invalidity of classical general relativity in regimes near a singularity — most importantly, for times very close to the big bang. In particular, when lengths are very small, and curvature and temperatures are very high, then — if the gravitational force behaves like all other known forces of nature — quantum effects will take over, and we should accordingly expect different outcomes. This observation is itself sufficient to utterly destroy the aspirations of big-bang theology — unless there are good reasons to think that the finite-age prediction of relativistic cosmology will be preserved in a quantum gravity or in string theory. In this section, we briefly review the known data about singularities in theories that attempt to unify gravity and quantum mechanics. Our review supports two conclusions: (1) We do not know yet if the best model will predict a finitely old universe, but (2) there are good reasons to think that the big bang is not necessarily an absolute beginning.

There have been a number of proposed theories of quantum cosmology. Perhaps best known of these is the proposal of Stephen Hawking, which results in a universe with no boundary — motivating the famous question, "what place, then, for a creator?" The bearing of Hawking's cosmology on theism has already been discussed extensively by Craig & Smith (1995). As noted by Drees (1990), Hawking's approach is just one among several competing attempts to incorporate quantum effects into relativistic cosmology, and we are not compelled to accept its idiosyncratic metaphysical picture. More to the point, Hawking's cosmological model is ad hoc in the sense that it does not flow from a more comprehensive unification of quantum theory and gravity. In this section we turn to two cosmological theories that do result from systematic and comprehensive unifications of general relativity and quantum theory: loop quantum cosmology and string cosmology.

Loop quantum cosmology (LQC) is an approach to cosmology within the framework of the loop quantum gravity (LQG) program (Rovelli 2004), which itself starts with the idea that unifying quantum theory and general relativity will require "quantizing" the gravitational field — and hence the structures of spacetime itself. Roughly speaking, to quantize a theory means that the quantities (e.g. position, momentum, scalar curvature, etc..) are replaced by "matrices," or more generally with "operators on a Hilbert space." This replacement can have profound physical consequences, most particularly the spectrum of a quantity (i.e. the numerical values it can possess) can become discretized where it was previously continuous, or bounded where it was previously unbounded, and quantities can be forced to obey a Heisenberg uncertainty principle,

For our purposes, the important question is what happens to those quantities (e.g. spatial curvature) that grow unboundedly large in classical FRW spacetimes as time t approaches the initial singularity t_0? To answer this question requires going through intricate technicalities involving domains of definition of operators, etc.. To summarize, however, the most prominent proposal (championed primarily by Martin Bojowald and collaborators) results in a scale parameter $S(t)$ that is bounded away from zero, entailing that curvature is *bounded from above*. More is true: the spacetime of LQC extends through the big bang, i.e. the universe existed *before* the big bang.

The jury is still out on whether LQC is our best cosmological theory. Nonetheless, LQC may very well be correct; that is, there is a non-negligible probability that LQC is true. Thus, there is a non-negligible probability that the big bang is not the beginning of the universe, and a fortiori, not the creation event (even if there was one).

Loop quantum gravity is not the most popular (in terms of sheer number of researchers) approach to unifying quantum theory and gravity. The title of most popular belongs to string theory, and so string theory's take on the big bang is of crucial interest for those wishing to assess the bearing of physical cosmology on traditional theistic doctrines.

All indications from string cosmology point to the fact that the universe existed before the big bang. In particular, string theory claims that if we apply fundamental symmetry transformations to cosmological models of the recent universe, then we get a copy of the universe (with important quantities inverted) that might be called the "pre-big-bang universe." In this scenario, the big bang disappears and is replaced by a saddle point in the dynamical evolution of spacetime curvature: before this point, curvature is increasing, and after this point, it is decreasing.

According to Gasperini (2008), string cosmology's prediction of a pre-big-bang universe results from a principled application of symmetry principles. Furthermore, string theory has a built in mechanism (namely a minimum string length) that seems to rule out singularities of infinite curvature or spatial length shrinking to zero. As was the case in LQC, the values of physical quantities in string theory are constrained by quantum mechanical laws; and so some quantities that grew beyond bounds in classical theory are well-behaved in quantized versions of that theory.

We currently lack the empirical data that would choose between competing models of quantum cosmology. But these models are empirically inequivalent — and are also inequivalent to classical relativistic cosmology. To the extent that these models can be tested, it is an empirical question whether the big bang was the beginning of the universe.

V. The multiverse and other non-standard cosmologies

There are several alternatives to the standard hot big-bang picture of the universe starting in t=0, with or without inflation. Eternally cyclic models in which the contracting phase changes into an expanding one without passing through a singular state were already proposed by some cosmologists in the second half of the nineteenth century. Such models, in which there is no definite beginning of the universe, are traditionally seen as contrary to theism. While classical cyclic models presupposing a closed universe do not agree with current observations, the twenty-first century has witnessed two new proposals: "conformal cyclic cosmology" developed by Roger Penrose, and the "new cyclic cosmology" developed by Paul Steinhardt and Neil Turok.

Penrose develops his cyclic cosmology by applying insights from general relativity to another longstanding puzzle of physics, namely the second law of thermodynamics. The second law of thermodynamics states that the entropy of a closed system never decreases. But this is puzzling, because the radiation content (cosmic microwave background) of the early universe appears to be highly disordered, whereas the current universe is somewhat ordered. Penrose's solution to this problem is to suppose that *gravitational* entropy was much lower in the early universe. As he puts it, "almost all of those [gravitational] degrees of freedom were somehow not activated" (Penrose 2006, 2759).

In conformal cyclic cosmology, Penrose claims that as the big bang is approached, massive objects play a negligible role, so that the physics is governed by degrees of freedom that are invariant under rescaling of lengths and times. Such degrees of freedom are called "conformal invariants." Thus, Penrose claims, we make a mistake to model the early universe by a Lorentzian manifold with a metric (as is done in classical general relativity). Rather, spacetime should be described by a *conformal manifold*, which is essentially a conformal equivalence class of general relativistic spacetimes.

The "cyclic" part of Penrose's cosmology comes from noticing that the future of one ever-expanding universe can be smoothly bridged to the past of another big-bang universe by means of such a conformal manifold. In this case, the big bang is not a true beginning, but only a sort of phase change from one “epoch” to another.

The new cyclic cosmology of Steinhardt and Turok develops ideas from string theory to describe a universe going through an endless sequence of cycles — in which case, the big bang is not the beginning of time. Although the Steinhardt-Turok model has attracted a fair amount of attention, it is not widely accepted. Nor is this the case with the pre-big-bang bouncing cosmology argued by Gabriele Veneziano and Maurizio Gasperini on the basis of string theory. (A classical version of the bouncing universe was proposed by George Gamow in 1954.) According to the pre-big-bang model the universe is not only eternal into the future, it is also eternal into the past, the two cosmic phases (contracting and expanding) being separated by a non-singular big bang. Since neither of the two models operate with an absolute beginning, they may seem to be problematic from a theistic point of view. However, the theist can always appeal to perpetual divine creation, just as in the case of the steady-state universe.

The modern idea of the multiverse is theologically more controversial. In its so-called landscape version, which since 2002 has been promoted and developed by Leonard Susskind and many other physicists, it is based on the apparent non-uniqueness of the equations of string theory. The solutions of the equations describe, in a sense, possible worlds with different physical parameters, interactions, types of particles, and even dimensionality; the multitude of solutions are then identified with really existing worlds which generally are causally separate from ours. As a mechanism for generating the huge number of universes, multiverse physicists make use of the eternal inflation scenario. Moreover, the multiverse is closely associated with anthropic reasoning: we find ourselves in our universe, with its particular physical laws and content of particles, not because other universes are impossible or improbable, but because our kind of life cannot exist in other universes. The theory of the multiverse has seductively great explanatory power (while it has almost no predictive power), which is a major reason why many physicists and cosmologists find it attractive. On the other hand, other physicists dismiss it as pseudoscience because it is practically untestable.

It is common among supporters of the multiverse to conceive it as an alternative to a divinely created world and ideas of natural theology. Because it represents our universe as a chance universe, special only by the fact that we live in it, the multiverse has been likened to another and more famous anti-design theory, neo-Darwinianism. Steven Weinberg puts it as follows: "Just as Darwin and Wallace explained how the wonderful adaption of living forms could arise without supernatural intervention, so the string landscape may explain how the constants of nature that we observe can take values suitable for life without being fine-tuned by a benevolent creator" (Weinberg 2007, 39). At least to some theists, the multiverse stands in sharp contrast to Christian belief. As Richard Swinburne sees it, "To postulate a trillion trillion other universes, rather than one God in order to explain the orderliness of our universe, seems the height of irrationality" (Swinburne 1996, 68). On the other hand, there is no one-to-one correspondence between the multiverse and belief in a divine creator. It is possible to answer affirmatively to the question, "does God love the multiverse?", such as the physicist Don Page did at a symposium in 2008 (see Page 2008). Even if there are 10^{500} universes (but not, perhaps, if there are an infinite number of them), they could have been providentially created by the almighty God with a purpose we cannot fathom. Why not? It has even been suggested that multiverse explanations are reminiscent of divine explanations and unintentionally reintroduce a transcendent creator.

The anthropic principle, an integral part of multiverse cosmology, has similarly been discussed in theological contexts and, again similarly, without any consensus emerging from the many discussions. In its most common version, called the weak anthropic principle, it states that what we observe is selected by our existence in a universe with just such properties that allow us to exist. Swinburne and some other theists in favor of design arguments find the anthropic principle to be, at best, unnecessary and obfuscating. To them, the values of the cosmic parameters and constants of nature appear to be fine-tuned because they are fine-tuned, the designer being God. The atheist Richard Dawkins goes further, arguing that the anthropic principle is an alternative to the design hypothesis and provides strong evidence for a world without God. However, theists do not generally see anthropically based arguments as a problem for a divinely created world. William Lane Craig and John Polkinghorne are among those who hold that the anthropic principle is compatible with divine design and can even be seen as indirect support for theism.

In relation to the design argument, as reinvigorated by the discussions of the anthropic principle, some physicists and philosophers have returned to an old objection to it, namely that it is not an argument for the Christian God; it is at best an argument for a cosmic architect in a deistic sense, or for that matter several such architects. On the other hand, theists have replied that even if this objection be true it does not constitute a proof that the God of theism does not exist. Although design arguments frequently occur in connection with the anthropic principle, it needs to be said that they were not part of the original anthropic program initiated by Brandon Carter in 1974.

VI. Infinity and the universe

Although the universe is generally believed to be temporally finite in the past, it may well be spatially and materially infinite. If space is infinite and the cosmological principle is assumed to be valid, the universe will contain an infinite number of galaxies, stars, atoms and everything else. Such actual infinities not only cause philosophical and logical problems, they may also cause problems of a theological nature. These are not specifically related to modern physical cosmology but have been discussed since the early days of Christianity. On the other hand, they may be seen as even more relevant today, when the favored cosmological model has zero curvature, meaning that space is flat.

Although a flat cosmic space does not necessarily imply an infinite universe, many cosmologists assume that the universe is indeed spatially infinite.

The theological implications of an infinite universe were discussed by the church fathers and, in greater detail, by Johannes Philoponus in the sixth century. Many of the arguments were of the same kind as those used in the attempts to prove the impossibility of a temporal infinity. At the time of the scientific revolution it was commonly assumed that physical space cannot be truly infinite, only indefinitely large. Infinity was seen as a divine attribute not to be found elsewhere; to claim that nature is infinite would be to endow it with divinity, a heretical view characteristic of pantheism. While the generally accepted view among theists was, and to some extent still is, that an infinite universe is philosophically absurd and theologically heretical, there was no consensus on the issue. In fact, several Christian scientists, from Descartes in the seventeenth century to Edward Milne in the twentieth, have argued that an infinite universe is in better agreement with God's will and omnipotence than a finite one. The correlation between finitism and theism, and infinitism and atheism, should be seen as historically contingent rather than justified by either scientific or theological reasons.

During the early period of modern cosmology, relativistic models with zero or negative curvature were sometimes associated with materialism and atheism because they implied a universe of infinite size. Conversely, Einstein's closed and finite universe was welcomed by theists. According to Ernest W. Barnes, the mathematically trained bishop of Birmingham, infinite space was "a scandal to human thought," as he said in 1931 (Barnes 1931, 598). His argument was epistemic as well as theological: only if God's universe is finite can we hope to understand the full range of his activity. His contemporary, the Catholic priest and pioneer cosmologist Georges Lemaître, thought likewise that the universe had to be finite in order to be comprehensible. In agreement with his later warning against the "nightmare of infinite space" (Godart & Heller 1978, 359), both of his two innovative cosmological models, the expanding model of 1927 and the big-bang model of 1931, were spatially closed. The steady-state model of the 1950s was not only unpopular among Christians because of its lack of a cosmic creation, but also because it implied a homogeneous universe of infinite extent. According to Stanley Jaki, a Benedictine priest and historian of science, the infinite universe is a scientific cover-up for atheism.

The present consensus model of a geometrically flat accelerating universe is usually taken to imply an infinite cosmos. The general attitude of cosmologists is to ignore the troublesome philosophical problems and speak of the infinite universe as just an indefinitely large one. They rarely reflect on the weird epistemic consequences of an actual infinity and even more rarely on the theological consequences. The South-African cosmologist George Ellis is an exception to the rule. He and his collaborators have argued forcefully against an infinite universe, suggesting that the flat space of the consensus model is probably an abstraction that does not hold physically. If the universe is really infinite and uniform it can be (and has been) argued that there will be an infinity of identical copies of all human beings and indeed of everything. Such a consequence, as discussed by Ellis, Max Tegmark, Alan Guth and others, clearly is theologically disturbing. Even more disturbing, says Ellis, is it that God may then not be able to keep track of and give attention to the infinite number of beings in the universe. Moreover, if there is a multitude of cosmic regions, each of which is inhabited with intelligent beings, one may need to contemplate a multitude of Christ-figures, incarnations and crucifixions. Ellis was not only willing to consider such a scenario, he also thought that it strengthened the case for a finite universe: “Surely an infinite number of Christ-figures must be too much, no matter how one envisages God” (Ellis 1993, 394).

VII. The end of the world

The cosmological field equations are time-symmetric and the fundamental laws of physics are assumedly valid at any time. Thus, modern cosmology is not only about the past of the universe, it also offers scenarios about its far future, including speculations about the fate of intelligent life. Given that the apocalyptic passages in the Bible speak of an end of the world and a possible new creation, the cosmic future may seem to offer another point of contact between cosmology and theistic religion. Scientifically based speculations about the state of the cosmos in the far future and the possibility of endless life were first discussed in the late nineteenth century in connection with the controversy over the heat death predicted by the second law of thermodynamics. Some of the German scientists involved in the controversy argued that life might persist even in the very high-entropic environment of the far future, and they explicitly referred to the eschatological aspects of cosmology. Characteristically, while the heat death scenario was welcomed by Christian authors, it was vehemently opposed by materialists and atheists who argued for an eternal universe with eternal life. As Eddington, an advocate of the inevitable heat death, later asked: “Since when has the teaching that ‘heaven and earth shall pass away’ become ecclesiastically un-orthodox?” (Eddington 1935, 59).

Since the 1970s “physical eschatology” has emerged as a new subfield of astrophysics and cosmology, pioneered by Freeman Dyson, Jamal Islam and others. The field deals primarily with the state of the universe in the remote future as based on extrapolations of cosmological models and the assumption that the presently known laws of physics will remain indefinitely valid. The favored scenario is the open ever-expanding universe where extrapolations typically result in an ultimate future (at about 10^{100} years from now!) in which the universe consists of nothing but an exceedingly thin electron-positron plasma immersed in a cold radiation of neutrinos and photons. Other studies presume a closed universe collapsing in a big crunch and others again investigate the nearer future of humankind, say a few million years from now. While many of these studies are not concerned with the final state of life, some are, and it is this latter group that constitutes physical eschatology proper. According to John Barrow and Frank Tipler, the research field is, “the study of the survival and the behavior of life in the far future" (Tipler & Barrow 1986, 658). Physical eschatologists usually ignore the religious associations of their studies or deny that they exist. Tipler is a controversial exception, however. Not only does he argue that some kind of life can continue forever in a closed universe, he also claims that it is the very collapse of the universe that permits eternal life. When the final eternity has been reached at what he calls the "omega point," life becomes omniscient and the temporal becomes atemporal. According to Tipler, the final singularity is God and "theology is nothing but physical cosmology based on the assumption that life as a whole is immortal" (Tipler 1995, 17). His views are undoubtedly extreme, but (and perhaps for this reason) they have caused much discussion among theologians.

The term physical eschatology indicates a connection to biblical eschatology, but it is far from clear that the two are related in any meaningful sense. The message of the Bible is not so much the end of the physical universe as it is about the imminent return of Christ, the transformation of humans from flesh to spirit, and the final kingdom of God. It is about the ultimate destiny and goal of humans, not of self-reproducing robots. The scenario of a closed universe, such as argued by Tipler, may appear to be more compatible with the biblical view than the case of the ever-expanding universe, but even in the former case it is hard to establish a meaningful connection. While the end of the world does not conflict with the Bible, the claims of immortality of intelligent life forms (not necessarily humans) do. The Bible says that God alone is immortal and that all his created beings are doomed to extinction unless God decides otherwise.

Several theologians have expressed concern about the cosmologists' scenarios of the end of the universe and stressed that there is a world of difference between these scenarios and proper eschatology. According to Wolfhart Pannenberg the Christian affirmation of an imminent end of the world is scarcely reconcilable with the cosmological extrapolations of the state of the universe zillions of years ahead. Karl Peters probably speak for the majority of theologians when he writes: "If the expanding universe is indeed open, expanding forever, then how can one speak of God recreating the universe? If the universe is closed, then it is likely to end in a 'big crunch' of mammoth black-hole proportions. Again, it is difficult to see how a new creation can take place" (Schwarz 2000, 180). Whereas Pannenberg, Peters, Arthur Peacocke and others tend to think that physical and Christian eschatology are either contradictory or incommensurable, Craig has taken a more reconcilable view. According to him, the cosmologists' versions of secular eschatology furnish grounds for taking seriously the hypothesis of a transcendent creative and omnipotent agent. This agent may not be the classical God, but more likely God in a panentheistic version.

VIII. Conclusions: Cosmology and God

Should cosmological questions be answered by religion or by science? Theistic religions have always made cosmological claims. But in the twentieth century, it became possible to discuss cosmological questions within the context of the mathematical and empirical sciences. Thus, cosmology provides a central locus for interaction between religious and scientific world views.

However, the story of the interaction between cosmology and theism is by no means clear cut. A naive reading of twentieth century cosmology might count the big bang as supporting theism, and steady-state cosmology as supporting atheism. (And of course, philosophers such as W.L. Craig have attempted to justify this view.) But such a view misses many nuances, both in the historical record, and in physical cosmology itself. From a historical point of view, there has been very little correlation between religious views of scientific cosmologists and their proposed cosmological models. From a epistemological point of view, there are numerous obstacles to claiming that the big bang confirms the hypothesis that God exists. And from a metaphysical point of view, God's hand is not manifest even in big bang models: these models have no first state for God to create, and these models have no time for God to exist in before the big bang.

However, we do not intend to support a sort of neo-positivism according to which scientific cosmology can neither support nor undermine (nor motivate reinterpretation of) theological claims, such as the doctrine of creation ex nihilo. To the contrary, cosmology's implications for metaphysics (and in particular, for theism) has provided, and will continue to provide, a strong motivation for studying this field of physical science.

Recommended readings

A good source for modern cosmology and its philosophical and religious contexts is (Hetherington 1993). The historical interaction between cosmology and religion in the twentieth century is dealt with in (Kragh 2004), and, from a different perspective, in (Worthing 1996). An interesting dialogue about the (a)theistic implications of physical cosmology can be found in (Craig & Smith 1995). A popular account of loop quantum cosmology is given in (Bojowald 2009); more technical accounts are given in (Ashtekar 2009) and (Wüthrich 2006). Popular accounts of string cosmology are given in (Gasperini 2008), (Veneziano 2004) and (Veneziano 2009). For Steinhardt and Turok's cyclic cosmology, see (Steinhardt & Turok 2007). For Penrose's conformal cyclic cosmology, see (Penrose 2010).

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