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God as First Cause – a Review of the Kalam Argument

The Kalam argument for God states in its traditional form that everything that comes into being must have a cause; thus, the universe has come into being and so must have a cause, which is surely God. This argument apparently relies on the universe not being infinitely old. Modern reiterations of this position, especially as advocated by William Lane Craig, assert that physical infinities are not acceptable and that the universe is in any case not infinitely old. Here I review this position. Quantum physics, it seems, enables a causal 'arrow of time' to be identified better than classical physics does, making better sense of the idea of a First Cause. There are indeed serious problems with physical infinities, implying that an argument for an infinitely old universe has to be rigorously stated. The most important modern cosmological models are discussed. Considerations involving increase in entropy production, stability and the Borde-Guth-Vilenkin theorem suggest that the universe or any time-extended cosmos is very likely to have had a start in time. From this it follows that the Kalam argument holds, but it should also be seen in the context of wider theological viewpoints.

Key words: God, causation, First Cause, Universe, Kalam, William Lane Craig, Big Bang, physical infinity, paradox.

At a wedding reception in the 1970s in the North of England, I was conversing with the host, a charming and civilised academic in an arts subject who was evidently not a religious believer. On learning that I was a physicist, he asked me about the state of current opinion on the origins of the universe. He was sad that the Big-Bang theory seemed to be firmly established now. 'I very much prefer the Steady-State theory,' he said, 'and always have done. The trouble with the Big-Bang theory is: *it will have us all going back to church again!*'

This gentleman was reluctantly voicing, in a very basic way, the so-called 'Kalam cosmological argument' for the existence of God. The Kalam argument originates from ninth to eleventh century Islamic scholars, and in its simplest form states that anything that comes into existence must have a cause. Our universe has come into existence, if it had a beginning in time. Its initial cause must therefore lie outside itself, and the obvious candidate for such a cause is God.

To succeed in this way, the argument requires good confidence in believing that the universe had a beginning in time. Over later centuries, many astronomers and scholars tended to assume that the universe had always been in existence although the Earth had a finite age. The situation changed, however, with the twentieth-century discovery that the universe is expanding and apparently originated in an event some fourteen billion years ago known as the Big Bang. Arguments of the Kalam type have now become relevant again, and the philosopher William Lane Craig is especially associated with reviving modern interest in this approach to natural theology.[1] It is of course entirely possible to adhere to the strict scientific practice of astronomy and ignore any metaphysical implications of the subject. Craig quotes a Yale University astronomer, Beatrice Tinsley, who consulted a group of her colleagues about the matter on his behalf: she replied that their initial reactions 'were the same as mine – no relevance'.[2] Stephen Hawking would perhaps disagree. 'A point of creation would be a place where science broke down,' he is reported as saying at a conference in honour of his seventieth birthday.[3] 'One would have to appeal to religion and the hand of God.'

The modern presentation of the Kalam argument has tended to focus on the question of whether our universe had an absolute beginning in time, or whether it has had an infinite past history. This leads into an extensive discussion of cosmology. There are also questions about the fundamental feasibility of infinite physical quantities, with reference made to Cantor's mathematical theory of infinities. A great deal of the cosmological discussion is highly technical. In this paper my aim is to present an account that is more easily read by non-specialists, and to enlarge on some of the aspects of the argument. It is not necessary, in my view, to go into details about Cantor's work. I have made considerable use of recent accounts of the relevant cosmology by Craig and Sinclair[4], Spitzer[5] and Gordon[6], and for these I express my appreciation.

Causation in physics

To give a good basis for the main premise of the simple Kalam argument, it would be useful to identify classes of physical objects that come into existence owing to causes; otherwise the argument will be solely about one object, our universe. This is not easy, although two possibilities come into mind: elementary particles and compound physical systems. The problem with elementary particles, however, is that while they do make a sudden appearance in particle interactions, what seems to be happening is

1 Craig, W.L. *The Kalām Cosmological Argument*, London: Macmillan Press (1979).
2 Craig, W.L. *op. cit.*, (1), p. 121.
3 Reported by L. Grossman in *New Scientist*, 14 Jan 2012, p. 6.
4 William Lane Craig and James D. Sinclair, in Craig, W.L. & Moreland, J.P. (eds.) *The Blackwell Companion to Natural Theology*, Chichester: Wiley-Blackwell (2009), pp. 101-201.
5 Spitzer, R.J. *New Proofs for the Existence of God*, Grand Rapids: Eerdmans (2010), pp. 47-74.
6 Gordon, B.L. *Inflationary Cosmology and the String Universe*, in Spitzer *op. cit.*, (5), pp. 75-104.

that quantum fields in space are being raised from their 'ground' state, normally not physically noticeable, into an excited state manifested as a particle. So the question of the particle's 'coming into being' is perhaps debatable. Likewise, it might be claimed that a compound physical system is merely a new arrangement of already existing parts.

Such issues can be avoided if we re-express the Kalam argument in a more general way, by saying that a cause is required *for any physical object or system to be in the state that it is in*, where the state it is in comprises its intrinsic features, including the fact that it exists.[7] Some situation must have given rise to this as its cause – acting either from earlier in time or else from outside time. If the cause is associated with an earlier physical state of something, the latter in turn requires a cause. If causes from outside time are excluded, we will thus find ourselves tracing a chain of physical causes back to the beginning of time, if that can be identified. At this point, only a cause from outside time is available, by which the system, indeed the universe, came into being. A first cause from outside time invites identification with a divine agent as Creator.

The philosophical concept of a 'cause' is a notoriously tricky topic. It would appear that everyone knows what a cause is until they start to think about the matter, and the more they think about it the less clear it becomes. Much has been written on this subject. I take the question to be metaphysical, and one where our basic intuitions may be as good a guide as anything. Nevertheless, within the context of physics there are some things that can usefully be said.

When the state of a physical object changes, this is in general due to the action of a physical force. In classical – that is to say, pre-quantum – physics, a force is an interaction between two objects, each acting as an external agent for the change of state of the other. The cause for the object's later state is thus the force, in conjunction with its earlier state. In classical physics, forces and state changes (for example, changes of velocity) can operate continuously and are deterministic. New objects do not come into being, although waves can be radiated. However, objects can be rearranged to form new physical systems. So, a comet might be captured by a planet to become a new moon of the planet, and we might say that a 'new system' has come into being. This comes about as a result of various forces that have made the respective bodies change their state in this way.

Quantum physics introduces two particularly important new factors, of which the first is state-changing quantum events that happen discretely, not continuously, in time. Secondly, there is wide agreement that the oc-

7 One would presumably present a 'process philosophy' version of the argument, in which only *processes* are treated and cause each other, but space is too limited to do that here.

currence of a quantum event is not usually deterministic; in other words, exactly which event happens out of a set of possibilities, or where or when it happens, is affected by random chance and is to this extent uncaused. However, full determinism is not necessary for a causal chain to be traced. Quantum events always happen within a given physical framework with given dynamic conditions and their occurrence is subject to these. So, for example, the decay of one radioactive nucleus into another occurs randomly on the timescale of its half-life, but it occurs because certain nuclear forces are acting. Thus, beta-decay is due to the so-called 'weak nuclear force', in whose absence the decay would not occur. So the cause of the new nuclear state is the weak force acting on the previous nuclear state, although the precise details of the decay event are only partially caused. To take another example, an atomic particle may have a wave-function such that it could be detected in any one of several particle detectors. Which of them detects it is random, but the fact that one of the possibilities happens at all is caused by the exposure of the particle to the detection system, without which no quantum event would occur.

The central point here is that if a new physical state occurs through a quantum process, this is to be *causally* attributed to the prior circumstance that *made it finitely probable*. In this way, a chain of physical causes is still implied, and can be traced back to the beginning of the universe as before, and the latter still requires a non-temporal First Cause according to the Kalam argument.[8]

In classical physics, there has always been a certain difficulty in defining what causation really means, because Newton's second law of motion is symmetric in time. The future and the past are linked one-to-one, and we could well talk about 'mechanisms' instead of causes. Laplace's famous statement that a perfect intelligence could predict the entire future of the universe from its state in the past works in both directions: one could calculate the universe's entire past given an exact knowledge of its state in the future! The thermodynamic property that entropy (disorder) must always increase in time is often invoked to generate an 'arrow of time', but this depends on our universe having started in a state of low entropy and high order – an interesting fact in itself. A universe that *ended up* in a state of low entropy would still obey the laws of dynamics, but it must start in an initial state that is incredibly well-tuned at every level.

The concept of physical causation seems in fact somewhat clearer in the quantum context, in which an object acquires what could be called a 'dis-

8 Given the randomness found in nature, one might ask if God too could 'play dice', in Einstein's dismissive phrase, to create one universe out of many random possibilities! But, of course, there is no requirement for a 'quantum God' just because the universe is influenced by quantum principles.

position' to change its state with a certain probability.[9] The term 'cause' seems very appropriate to apply to the physical reason for this state-changing disposition, and the situation is not time-reversible: a direction of time is implied when we talk about probabilities.[10] This quantum point of view introduces an 'arrow of time' that seems intrinsic to the elementary processes of physics.

Now, it might be protested that our discussion here has become a little complicated. Why not bypass the physics and just simply assert that the universe must have had an external cause for its coming into being? The point is that for a First Cause argument to work, we do need to establish the principle of prior physical causation in time. Indeed, the role of the First Cause may differ from that of subsequent physical causes. It is responsible for something coming into being – acquiring a physical state in the process – while the later physical causes produce changes to existing physical states, generally speaking. There are some interesting issues here, but they do not really affect the argument. Do new elementary particles come into existence in 'creation' processes, or are they merely excitations of quantum fields? Do new quantum fields come into existence as the universe expands? Whatever the answers to questions such as these, the premise that a physical state requires a cause would seem to cover all the options.

Is infinity real?

At the heart of the Kalam argument is the question of whether the universe really had a beginning in time. In one sense there is a general agreement on this: the Big Bang marks the beginning of time for our universe. And here the Kalam argument also tends to be accepted up to a point: our universe must have had a cause. However there is a strong school of thought that the cause for our universe was in a pre-existing physical system of some kind, rather than in an extra-physical agent such as a Deity. One can then perhaps avoid the need for a Creator by supposing that the pre-existing physical system had an infinite past history, with no beginning in time at all. We will probe this viewpoint further later. Meanwhile the plausibility of a physically infinite system of any kind should be examined; this has proved to be a major discussion point in the context of the Kalam argument.

9 There are statistical interpretations of quantum physics that are in conflict with these statements. I do not accept them, on the grounds that quantum physics surely does apply to single quantum objects. Of course, the 'Many Worlds' interpretation introduces an arrow of time with a vengeance!

10 I am referring to physical probabilities here, rather than Bayesian probabilities, which more concern the believability of an assertion.

It is beyond our present scope to attempt a thorough examination of the concept of infinity, but fortunately this is not necessary.[11] The most basic distinction to be made is between what are known as 'potential' and 'actual' infinities. This subject has an ancient history, starting from Aristotle. A potential infinity is a quantity that can be as large as we choose, without limit, but in any given circumstance always has a finite size. An actual infinity is a quantity or a set of quantities that really is infinite. A further important distinction is between infinities as purely mathematical concepts, and the possibility that a physical object or system may be actually infinite. Much debate has taken place over whether the latter possibility makes any sense. Can an 'actual infinity' exist in nature? Aristotle denied this; others over the centuries have disagreed.

In mathematics, a breakthrough came when Cantor, in the late nineteenth century, devised a theory of infinite quantities that was eventually made rigorous. Infinities could now be dealt with mathematically, an essential step to their credibility as potential descriptors of physical quantities. It is important to note that, mathematically speaking, infinity is not a 'number' (despite common use of the term); it is better to call it a 'magnitude'. Its properties are very different from those of a normal numerical quantity. If we add any quantity, finite or an infinite, to another infinite quantity, the result is again infinity. Thus addition is possible but ineffectual. On the other hand, if we subtract one infinite quantity from another, we may obtain zero, a finite result, or an infinite result, depending on the situation. Subtraction of infinities from each other is thus not a universally well-defined mathematical operation.[12]

Although a consistent mathematical account of 'actual infinities' can be set out,[13] bizarre situations can arise in attempting to make physical entities infinite. The question is whether we should just learn to live with this, or whether the situations are unacceptably paradoxical. A physical infinity should be an actual infinite quantity that is not introduced artificially by our description of a system. Zeno produced his famous paradox of Achilles 'never' overtaking the tortoise by choosing to subdivide the time into an infinite number of intervals. This is not a true physical infinity, because a better mode of description will make it go away. We will now examine a selection of paradoxes in this area. The issue is that the physical implementation of an actual infinity can introduce new factors that are not present in the mathematics as such, or in finite physics.

11 Barrow, J.D. *The Infinite Book*, London: Jonathan Cape (2005), presents an accessible account of many of the issues.

12 The different classes of infinite power defined by Cantor need not be discussed here since they are not relevant for present purposes.

13 However there is a school of mathematical philosophy called 'intuitionism' that denies actual infinities in mathematics.

Paradoxes and difficulties with physical infinities

1. Hilbert's hotel

The best-known physical-infinity paradox[14] was devised by the mathematician David Hilbert, who was enthusiastic about mathematical infinities, but a sceptic regarding their physical realisation. He proposed a hotel with an infinite set of rooms, which are all fully occupied one evening when a new guest appears. 'No worry,' says the hotel owner, and he proceeds to move the guest from room 1 into room 2, the guest from room 2 into room 3, and so on *ad infinitum*. Now room 1 is empty for the new guest, despite the fact that the hotel had been full before, and indeed one can fit any number of new guests into the hotel in this way! This is paradoxical since the idea of a hotel being 'full' seems physically a rather well-defined notion.

2. Craig's library

Craig proposed a number of paradoxical tricks that could be played with a library that contains an infinite number of books.[15] These are numbered with odd and even numbers on the spine. For example, we could remove the odd-numbered books, one by one, and each time move the remaining books up to close the gap. Amazingly, after an infinity of odd-numbered books have been removed, the bookshelves are still completely full!

3. Benardete's book

It is proposed that we have a book with an infinite number of pages.[16] The first page is 0.5 cm thick, the second is 0.25 cm thick, the third is 0.125 cm thick and so on. The total thickness is 1 cm. We read page one and then page two and then turn the book over and open the back cover to read the final page. But it seems that there cannot be a final page! What is its page number? Can one count backwards through the pages of this book? If not, why not?

4. The infinite sphere[17]

In three-dimensional space, four non-coplanar points define a sphere. We

14 Hilbert, D. *On the Infinite* (original 1925) in Benacerraf, P. & Putnam, H. (eds.) *Philosophy of Mathematics, Selected Readings*, 2nd edn., Cambridge: Cambridge University Press (1983), p. 183.
15 Craig, W.L. *op. cit*, (1), p. 85.
16 Adapted from Benardete, J.A. *Infinity, an Essay in Metaphysics*, Oxford: Oxford University Press (1964), p. 236.
17 Adapted from Nowacki, M.R. *The Kalam Cosmological Argument for God*, New York: Prometheus Books (2007), p. 254.

place three points at finite distances from the zero of coordinates and a fourth point in a well-defined direction relative to the coordinate axes, but at an infinite radial distance. It then follows (as can be seen by first imagining the fourth point at a very large finite distance) that the sphere through the four points must include the infinite flat plane on which the first three points lie. The same conclusion holds for any fourth point at infinity, placed in any direction, either side of this plane. Therefore *all* points at infinity lie on the same infinite sphere! Alternatively, this same flat plane lies on an infinite number of *different* infinite spheres, or maybe the infinite sphere does not really exist. Geometry in infinite space, thus, breaks down from our normal point of view.

5. Tristram Shandy[18]

The literary character Tristram Shandy is writing his autobiography but takes a year to write up one day of his life! In this version he is imagined to live from minus infinity to plus infinity in time, an infinite set of days. Mathematically, it is possible to put the single days in this set into one-to-one correspondence with sequences of 365 days, to let the book be written. But physically, it is not possible to do this so that each single day *precedes* in time its corresponding set of 365 days. And if he has been writing from minus infinity, what is the date he is currently writing about? The entire task becomes unspecifiable when an infinitely negative starting-date is proposed – a paradox.

Here are some further suggestions:

6. Hilbert's hotel with change of bed linen

We now suppose that the hotel owner refuses to move a guest without first changing the bed linen in the new room. So guest 3 must move from room 3, whose bed linen can then be changed so that guest 2 can move in. The same now happens in room 2, and finally the bed linen in the vacated room 1 can be changed and the new guest can enter. This sounds like a very reasonable activity, from a physical (and hygienic) point of view. But it cannot be done for an infinite hotel! The hotel-keeper must start at room number infinity – but how? It is, in short, impossible to 'count back from infinity', and yet from a physical point of view the operation sounds very plausible.

7. Craig's library with shelf-clearance

In this operation on Craig's library, the odd-numbered books are once

18 cf. Craig, W.L. *op. cit.*, (1), p. 97, where he argues against B. Russell's erroneous account of Tristram Shandy.

again all removed. But this time, we move the remaining books along to clear the shelf space, starting from the original position of book number one. By the time a million books have been removed, there is a very long stretch of cleared space. When *all* the odd-numbered books are gone, the length of clear shelving is infinite: there is not a book anywhere in sight. Yet we know that an infinite number of even-numbered books must still be in the library somewhere! On top of this, the situation is observationally indistinguishable from the case where there really are no books in the library at all.

8. The unstable object

A problem arises if we try to consider a physical object that has existed quietly for an infinite time, but then 'decays' into something else. On the face of it, why should this not occur at a given time, t? But if it possesses a finite physical decay constant, the infinitely old object must have already decayed. So if it still remains in existence just prior to time t then its decay constant must be zero – and so it will never decay. There is no such thing as an 'infinitesimal' physical decay constant: it is finite or zero. So this kind of object lies outside ordinary physical description and presumably cannot exist.

9. The bouncing ball

A hard ball is dropped on to a hard surface. Having a coefficient of elasticity less than unity, it will in the ideal case bounce an infinite number of times, in a finite time interval, before coming to rest. But although Newtonian physics is in principle time-reversible, there is no way to make *this* process happen in reverse, even if energy is supplied! This seems paradoxical. (In practice, the motion will be damped, removing the infinity, and one may speculate that this may apply to other singular processes.)

A number of problems are illustrated here, quite apart from the anomalous algebraic properties of infinities. Some paradoxical tasks, it might be objected, just take an infinite time to complete. But this does not cover all the problems, and the possibility of infinite time is what we are debating. Indeed, Hilbert's hotelier could perhaps move all his guests in a Newtonian universe (where instantaneous messages are not disallowed) but not in an Einsteinian universe (where messages travel no faster than the speed of light). To list some general points:

1) It is impossible to initiate a count through an infinite sequence starting at the infinite end, although physically we might wish to do this.
2) Infinite magnitudes have mathematical properties of a different kind from the finite numerical quantities associated with known physical systems; yet it is physical systems, strongly characterised by their

mathematical properties, that we are seeking to make infinite.

3) An infinite physical quantity can differ qualitatively from a corresponding finite physical quantity.

4) Extrapolation from a finite to an infinite physical situation may not be possible.

5) Conversely, 'action at infinity' can involve structures or processes at infinity that relate paradoxically to the finite.

6) No experimental evidence is available, or indeed possible, to verify if a physical quantity is actually infinite, since all our measurements, techniques and experiences are finite.

For reasons such as these, it is tempting to reject physical infinities outright, as incompatible with our practical understanding of nature, as Craig is inclined to do. This seems a reasonable viewpoint. However, it could perhaps be that with sufficient care, in a given situation, the unacceptable features may be avoided and so I would suggest a more cautious approach. What is certainly not admissible is to talk about infinity in a glib way, naively asserting that some system 'could be infinite'. We must strictly insist that the onus lies on the proposer to justify the infinite proposal. That is, its properties must be demonstrably well-defined and workable. Otherwise, the default position must be not to accept it.

Cosmological models

In the present context, then, only well-specified, good-quality cosmological models are to be considered. We will now attempt a summary of the most important of these.[19] As is well known, our universe is expanding, in the sense that all its galaxies (or to be more accurate, clusters of galaxies) are moving away from each other. The further away from us a particular galaxy is, the faster it is receding from us. It is generally agreed that this is due to the fabric of space expanding, rather than to movement of the galaxies themselves. It is widely believed that the first instants of the universe were marked by a sudden period of super-fast expansion, known as 'inflation'. Before this, the 'real' Big Bang event took place. Einstein's theory of General Relativity (GR) is assumed to govern the behaviour of space and time in nearly all circumstances.

If the Big Bang represents the true start of time then the Kalam argument can be applied: a cause will be required for the universe, in its initial expanding state. This applies even if there is a singular situation such as the universe being instantaneously infinitely dense. Unhappy with this,

19 A readable and comprehensive account of these issues can be found in Barrow, J.D. *The Book of Universes*, London: Vintage (2012).

cosmologists have proposed a variety of theories in which the Big Bang was preceded by an earlier physical system which by some process gave rise to our universe. To some, a desirable feature would be that earlier system's past history should extend infinitely far back in time, so as to maintain a seamless fabric of physics and apparently avoid a First Cause. For convenience I will where appropriate refer to a Big-Bang initiated system as 'a universe' and a pre-existing system as 'the cosmos'.

Here, then, are the major types of cosmological theory that are current. They are not all mutually exclusive.

1. Basic Big Bang

Our universe started with the familiar Big Bang that we know of; time also started then.[20] The Kalam argument applies.

2. Oscillating universes

Here, our universe is held to be the latest of an infinite sequence of Big Bangs. In each case, the universe eventually collapses in on itself again, a so-called 'Big Crunch', after which another Big Bang occurs, and so on. This does not have to involve a singular state. One problem is that physical entropy gradually accumulates in the successive universes, so that after an infinite sequence, a thermodynamic equilibrium will have been reached and nothing much of interest can happen. Our universe is far from being in this state. A related issue is known as the 'radiation problem'. During a collapse and re-expansion, starlight passing through space is recycled and will appear as background radiation in the next cycle of the universe. After many cycles, this will overwhelmingly dominate the starlight that is generated in the latest new universe. Our own universe has about a hundred times as much background radiation energy as starlight energy, though this is not immediately obvious since radio telescopes are needed to measure the background radiation. An infinitely old cosmos would have accumulated very much more background radiation than this, and its gradual production eventually consumes the energy required to make stars. This has not happened.

An important point to note is that the cycles of oscillation are believed to slow down with time, and would have been increasingly faster in the past, so much so that the process must have had a beginning. Moreover, present observations on distant supernovae indicate that our own universe will not recollapse at all, but will expand indefinitely. It would be very improbable that we chance to be living in the first universe of an infinite series

20 As upheld, e.g., by Al-Khalili, J. *Black Holes, Wormholes and Time Machines*, 2nd edn., Boca Raton: CRC Press (2012), p. 55.

that happens to do this,[21] since there is no apparent reason why our human existence should be connected to this property of our universe.

The present conclusion, certainly as voiced by Vilenkin and others (see below), is that an infinitely-old oscillating universe does not work. In any infinitely old system, if there are any degenerative or instability processes, these will have operated by now – but our own universe exists in a healthy state. Perhaps there is one other way out. Even if the system is infinitely old and thermodynamically dead, in really rare instances it might bounce by chance into a low-entropy universe capable of generating galaxies and stars. The probability against this, in any given cycle, is enormous. The immediate counter-argument is that we seem to occupy a universe that is larger and has much smaller entropy than is really required for our own existence, implying a random thermodynamic fluctuation that is vastly more improbable than it would need to be.

There are attempts to evade entropy problems by making *pieces* of an oscillating cosmos have low entropy. This requires general expansion, however, which we now discuss.

3. An expanding cosmos

A stationary cosmos in GR is difficult to achieve; they tend to expand or contract, and the latter is not helpful. In devising expanding models, the intention is to avoid the problems related above by making the cosmos expand indefinitely, usually by means of the phenomenon of 'inflation'. Within an expanding cosmos, regions can form that have new and different properties and give rise to new universes through Big Bang events. The new universes generated in this way may be called 'bubble universes' or 'island universes'. They are self-contained and our universe is said to be one of them.

The expansion rate of our universe is given by the so-called 'Hubble parameter', which is believed to have been always positive, and so our universe had a beginning in time. A powerful extension of this idea has been established by Borde, Guth and Vilenkin (BGV)[22] who showed that in any universe or cosmos with normally-behaved space and time, provided that its Hubble parameter is greater than zero when averaged over time (there is no basic reason why it cannot vary), such a universe or cosmos must have had a beginning in time. This theorem is of wide application, although it neglects possible quantum effects, and it arises by insisting

21 J.D. Barrow and M. Dąbrowski (see Barrow *op. cit.*, (19), p.79 and reference) showed that oscillating universes must always eventually behave in this way in certain general circumstances.
22 Borde, A., Guth, A. & Vilenkin, A. *Inflationary spacetimes are not past-complete*, Phys. Rev. Letters 90 (2003) 151301; arXiv:gr-qc/0110012.

that relative velocities cannot exceed the velocity of light.

The BGV theorem implies that the most popular expanding cosmos models, apparently all or nearly all those in wide circulation today, must involve a beginning in time and cannot be taken as having an infinite past history. This position has been confirmed recently by Vilenkin.[23] The theorem is far-reaching, and it can also apply to oscillating universe models that try to avoid entropy problems by expanding cycle by cycle.[24]

4. Cosmos models claiming an uneventful infinite past-history

In some models the cosmos has an infinite past history that is asymptotically uneventful; that is, as we trace time back towards minus infinity, a certain state is approached with all major change becoming negligible. The BGV theorem is avoided since the average Hubble parameter may be zero in this scenario. There are two main obstacles to these 'Emergent Universe' models. One is that the quiescent asymptotic state may turn out to be unstable, either through GR or through quantum effects, and collapse without giving rise to a universe.[25] The other is that it may indeed turn into an expanding universe, but with a finite probability per unit time. In either case, the infinite uneventful time-interval has zero probability to occur (cf. infinity paradox 8). It appears that all the seriously proposed models of this type fall into one of these classes. Another perspective on this topic is discussed in the following section of this paper.

5. Universes in which time changes its nature at the Big Bang

The Hartle-Hawking universe[26] is described by GR back to the start of normal time. At that point, it did not have zero size and an infinite singularity, but had a finite radius a instead. Negative time values are now represented by a coordinate called 'imaginary time',[27] which extends only as far back as $-a$, at which point the radius of the universe is zero. The problem is how to interpret 'imaginary time', whose introduction was for mathematical convenience and to avoid a singularity. Whatever the

23 Vilenkin, A. conference talk, Cambridge 2012, available at www.ctc.cam.ac.uk/stephen70; Mithani, A & Vilenkin, A. *Did the Universe Have a Beginning?* ArXiv 1204:4658 (2012).
24 Also the so-called 'ekpyrotic universe' of Steinhardt, P. & Turok, N. Phys. Rev. D 65 (2002) 126003 and further references; see Gordon, B.L. *op. cit.*, (6), p. 80.
25 The problem with instability in a supposedly infinitely old structure is formidable. *Any* instability, however small, is likely to destroy such a structure. Once the possibility of instability has been plausibly raised, then the onus lies on the model-builder to demonstrate that it does not apply in the given case. Vilenkin and others appear indeed to have done the former, and so the default position is to assume that such models are unlikely to be past-infinite.
26 Hartle, J. & Hawking, S. *Wave function of the Universe*, Phys. Rev. D 28 (1983) 2960.
27 'Imaginary' is used in its technical mathematical sense, as Hawking explains in *A Brief History of Time*, London: Bantam Press (1988), p. 134.

answer here,[28] the time dimension of the universe eventually ceases to function in a time-like way as we trace it back, which means that at some stage it is unable to support causal processes. Causative time is thus not infinitely old and so we may still ask what caused the primal physical state that gave rise to the first physically caused event.

An alternative GR-based proposal with this general theme has the universe contracting to a minimum size and then re-expanding; but time also changes its direction at this juncture and somehow was running in reverse during the contraction process.[29] This, then, will not resolve the matter; we just have a pair of conjoined normal Big Bang universes, each with a definite start to its own timescale, and the question of initial causation remains – in duplicate.

Coordinate transformations and singularities

If what has been said is true, current claims that the cosmos is infinitely old are implausible. Even so, and despite the conceptual hazards involved with physical infinities, modern cosmological theories often still assign infinite extension to space or time in a universe, or a part of one. (Some of these structures may be potentially rather than actually infinite.) Here I discuss a further way of dealing with this situation; the non-mathematical reader may prefer to pass over these paragraphs. In many situations, the theorist can make use of what is called a coordinate transformation. Instead of working in terms of what one might call 'ordinary time', say, a mathematical transformation is employed to convert the time values into a different set of time values, and one works with these instead. In the context of Einstein's GR theory, suitably well-behaved mathematical transformations, of space and/or of time, are entirely allowed. The equations of physics appear different when expressed in different coordinate systems, of course. In any given calculation, the usual idea is to seek the set of coordinates that makes the calculation simplest technically.

In this way the principles of GR make it quite permissible to use a different cosmic timescale from the normal one, if we wish.[30] Let us then

28 Hawking himself (*op. cit.*, (27)) suggests that imaginary time is just like a space dimension, but this makes no sense literally since then the pre-time-zero universe would look like a four-dimensional spatial hemisphere and so have an outer 'edge' at its radius a, contrary to Hawking's desire for 'no boundary'. For further discussion of this somewhat obscure proposal, see, e.g. Holder, R. *God, the Multiverse and Everything*, Aldershot: Ashgate (2004), pp. 58ff.
29 Aguirre, A. & Gratton, S. Phys. Rev. D 65 (2002) 083507. The same authors have presented an analogous theory in which inflationary ideas are implemented; however from the Kalam point of view, similar comments can be made. The arrows of time diverge from a particular plane; but what then was the ultimate cause of the conditions there? (Phys. Rev. D 67 (2003) 083515). Vilenkin *op. cit.*, (23) lists more recent examples of this kind of 'no boundary' model, to which the same comment may be made.
30 See, e.g., Craig, W.L. & Sinclair, J.D. *op. cit.*,(4), p. 145.

propose the following to deal with infinite negative cosmic times. Nothing would seem to disallow us from transforming the 'normal' timescale t into an alternative scale t' such that when t reaches minus infinity, t' takes a finite negative value, $-t_0'$; in the new timeframe this represents the actual beginning of the cosmos.[31] The universe now has a finite history! The simplest case is that of a cosmos that extends uneventfully to minus infinity in t, when its (asymptotic) state was S. After the time-coordinate transformation, the chain of causes now terminates at time $-t_0'$ with the same state S and the Kalam argument posits that this first state requires a non-temporal cause. The possibility of this kind of cosmos has already been put in doubt on the grounds of physical instability, but now it seems that the Kalam argument applies anyway. In the first timeframe, where the past history was infinite, it was unclear whether or not the asymptotic state S of the universe requires a cause. In the second timeframe, it becomes unambiguous.

The alternative would be a cosmos with an infinite number of causal events in its infinite past history. If the history is transformed so as to be finite, this set of events becomes squashed into a singularity at $-t_0'$, which is potentially problematic. However it may well be valid to treat this entire physical structure 'as a whole'. Then the simple Kalam argument can be applied to the situation, provided that we have a coherent description of the singularity, so as to allow us to think of the infinite event sequence in a unified way. Given that it is sufficiently well-defined and characterised, it then requires a cause. This requires careful evaluation in any given case, but the overall implication is again that apparently infinitely old universes may often still be subjected to the Kalam argument. Certain oscillating universes start with a singular set of infinitely rapid oscillations.[32] The considerations outlined here would apply to these.

It remains conceivable that if the infinite collection of events were completely disparate and lacking mathematical coherence, then it could be a species of 'chaotic singularity', so ill-specified as to lack a good physical or mathematical description. I am not aware that anyone is seriously suggesting cosmological theories of this sort, which could imply an unsatisfying infinite set of logically disconnected states. 'Explanation' would probably then break down, and it is not clear that the situation is meaningful. One of the arguments of this paper, however, has been that an infinite physical system must be described in terms of a rigorously well-defined formulation before it can be taken seriously.

31 There are many possible ways to do such a mathematical transformation. E.g. the relation $t' = t/(1 + t/t_0')$ would achieve it simply, but is far from unique. In practice, logarithmic transformations have been frequently employed.
32 See, e.g., Barrow *op. cit.*,(19), p. 168.

'Universe from nothing' scenarios

Some cosmologists claim that the universe could have arisen 'from nothing' by starting out as a 'fluctuation' from a spatial vacuum full of quantum fields – in other words, not really from nothing. A more far-reaching proposal with this title was put forward by Vilenkin.[33] In his book he suggests that there existed a prior state, which I will here call the proto-universe, that turned into a new cosmos or universe that has developed into the one we now live in.

The proto-universe is initially thought of as a small, closed universe that in GR would expand to a maximum size and then collapse again. It has its own internal space and time dimensions. We are now asked to imagine, firstly, that a universe is a quantum object. This means that certain kinds of quantum behaviour can be attributed to it, in particular that it can make a transition into another quantum state, namely one corresponding to the earliest stage of our own universe – also imagined as a quantum object. A second step is to imagine the dimensions of the proto-universe being mathematically reduced to zero, so that it does not possess any internal structure, even time. This state is dubbed 'nothing', although it is still said to be a quantum object. Its transition into a 'real' universe remains mathematically calculable, in terms of the familiar quantum notion of a 'tunnelling' process. The real universe is thus jump-started into a finite radius (from which it then undergoes inflationary expansion) without an initial singularity.

There are a number of issues here. One is that nothing *obliges* our universe to have originated by this means. A second is that to treat a universe as a quantum object is to extrapolate quantum theory a tremendously long way from its tried and trusted use. Normal quantum physics asks about different observable properties of a particle, and their observation by external apparatus. A quantum universe is not subject to this, it is not clear how an observation could be set up, and cosmologists often take refuge in a 'many worlds' interpretation, in which observations do not really take place.[34] It may be better to acknowledge either that there is something important in this area that we do not understand, or else that a universe cannot safely be regarded as a quantum object.

33 Vilenkin, A. *Many Worlds in One*, New York: Hill and Wang (2006), pp. 180ff. He is rather critical of the Hartle and Hawking model (pp.190f).

34 When I asked Hawking at a conference in 1987 how quantum events occurred with his quantum universe, he replied, 'That is a good question. I think a Many Worlds approach is needed.' But while the latter interpretation eliminates random choices, it does not tell us about how the universe splits (or seems to split) into the many versions of itself. This, like conventional random quantum events, remains without a good explanation. A good account of this family of interpretations can be found in Barrett, J.A. & Byrne, P. (eds.) *The Everett Interpretation of Quantum Mechanics*, Princeton: Princeton University Press (2012).

Then there is the role of time. Quantum processes in the laboratory take place in real time, and if the transition of the proto-universe into the new universe occurred in an external timeframe, the use of quantum concepts would be more transparent. This is not the case here, and the absence of time deepens the obscurities, even though the mathematics can still be set out. Another problem is that quantum gravity is ignored. Taking the proto-universe mathematically to zero radius may be invalid: many cosmologists doubt that any distance smaller than the Planck radius is possible.[35] Quantum field effects have also been argued as preventing the proto-universe from having zero radius.[36]

But in any case we can still ask how come this so-called 'nothing' object could exist, even if it is outside time. As a physical object, it needs a cause, clearly also from outside time, and mathematical laws of nature are still required. In his book, Vilenkin himself is indeed quite willing to imagine God as a celestial mathematician whose creative act gives rise to all this.[37]

Similar responses can be made to the ideas sketched by L. M. Krauss in his book *A Universe from Nothing*.[38] A major problem here is a shifting definition of 'nothing', which could refer to 'empty' space-time within which a new universe is generated by quantum effects, possibly on vacuum fields, or else to 'true nothing'. In the first case, the reply is that the previously existing space and its vacuum fields, together with relevant laws of nature, cause the universe to appear – but they are obviously not 'nothing' and they too need a cause. The arguments and models presented in previous sections will still apply to this situation.

To say that a universe appears 'from' true nothing makes no literal sense, because true nothing does not exist to have a relationship with anything, such as a universe; the term is being inappropriately reified. Dropping the misleading terminology, proposals of this latter kind mean simply that there was an absolute beginning to the universe.

The cause of the universe in such scenarios is usually said to be, in effect, 'laws of nature'. The first issue here is that laws of nature, as normally used, are laws of *nature*. They act on what is there, and 'nothing' does not exist to be acted on! Laws causing a universe to appear as if from 'nothing' would surely require an external existence – they certainly cannot be associated with the non-existing 'nothing'. But then, creative power must

35 The so-called Planck radius (10^{-35} m) is the extremely small distance, calculated in terms of the speed of light, Planck's constant and Newton's gravitational constant, at which quantum effects should be present in gravity. There is a corresponding Planck time, 10^{-43} s.

36 J. Gott & L-X. Li, quoted by Craig & Moreland, *op. cit.*, (4), p. 178.

37 Vilenkin, A. *op. cit*, (33), pp. 199ff.

38 Krauss, L.M. *A Universe from Nothing*, New York: Free Press (2012). A similar lack of precision is shown in Stephen Hawking's *The Grand Design*, London: Bantam Press (2010), pp. 179ff.

also be present. All this is effectively indistinguishable from the Mind and Creative power of a Deity; one may well feel that God is being brought in incognito by the back door. Whether such a Deity is personal is another question, of course, and probably not one for cosmology.

Some final words

I have attempted here to present the Kalam argument in a way that builds on the work of Craig and others with fewer technicalities, although a certain consideration of physics is unavoidable. This is a complex topic, where experts can disagree and absolute proofs are lacking, and the best that can be done is to summarise as well as possible the latest position. There is no generally accepted quantum theory of gravity at present, and the biggest 'known unknown' is how such a theory would affect the situation. Acting at small times and distances, a quantum theory might in general be expected to remove singularities in its account of the physics of space-time. It would introduce more randomness into the theory,[39] but only partially, for complete randomness would destroy the theory.

A serious general problem in this subject is that all pre-big-bang cosmological models are speculative, but some are much more so than others. An author who is willing to alter the laws of physics *ad lib* and *ad hoc* can produce a cosmos with a wide choice of features. The judgement on any given model, whether it is too contrived to be reasonable, can be a subjective matter. Very little of this is subject to experimental test.

If the summary of the current position by Vilenkin and others is correct, cosmologies with an infinite past history are not easily viable at present, and so the universe 'probably' had a beginning. Therefore, the Kalam argument would seem to hold. In fact, even if the past history is infinite it may well hold anyway. What the Kalam argument demonstrates, if its premises are accepted, is that the attempt to ignore non-temporal causes eventually fails, and a non-temporal and non-physical First Cause for the universe (or cosmos) is required after all. In his own model, Vilenkin sought to take the causality chain one physical step further back, but that is the limit. The physics has a starting-point.[40] The nature of the external First Cause is not strictly specified by the argument, but if the First Cause is not God in the traditional sense, an alternative non-physical agent is

39 Quantum theory bases its account of physics on observables and possible observations, and observations are always finite. Likewise, probabilities are finite. A quantum theory of gravity will principally affect space-time at the Planck scales, which are beyond our foreseeable experimental capabilities. Classical singularities can depend on time being infinitely precisely determined at the point where the singularity occurs, but quantum effects may tend to smear out the determinate nature of time values.

40 A complex-structured universe might have multiple starting-points. This does not really affect the Kalam argument, however.

required that has a functional similarity to God.

However a few comments must be added regarding the theological side of the discussion. Some theologians may object that the divine Act of Creation is continuous throughout physical time, not confined to one instant.[41] With this perspective in mind, the question will be whether it is better to see 'creation' as the cause of the universe *coming* into existence, or of its *being* in existence. If the universe were in fact infinite in time, then surely we would seek a cause for its being in existence, and so we would be obliged to see God's creative activity in a more timeless way. Such a viewpoint can also of course be applied to a universe with a finite history. Is the Kalam argument, then, dispensible? The reply is that the Kalam argument does not exclude this perspective, but should be seen fundamentally as a demonstration of the limitations of naturalistic philosophy. Starting with a naturalistic, physical causal chain, which of course we do believe has taken place, we find that something more is implied. To say that the initial state of the universe is due to God's activity is in no way to deny God's activity at other times, or in a broader sense; this is not the purpose of the argument. There is no claim that God does not cause the continuous existence of the universe, or even that the first instant of the universe is necessarily different from the others.

From here one is led naturally into questions regarding the possibility of an ontologically self-subsistent universe – the viewpoint held by materialist philosophers, but doubted by many theologians – and into a much wider area of debate concerning the relationship of God to the universe. For present purposes, we have bypassed these questions by instead considering *phenomenal* self-subsistence: in other words, the universe is possessed with laws of nature and they operate. Within this framework, at present, it seems that the Kalam argument is as sound as any argument is likely to be. It does not in itself, however, imply much about the *nature* of God as First Cause. For this we must turn to other considerations than cosmology.

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41 cf. Carroll, W.E. 'Aquinas and Contemporary Theology: Creation and Beginnings', *Science and Christian Belief* (2012) 24(1).