# PHYSICALISM AND BIG BANG COSMOLOGY

OLOF NEBRIN

Abstract. I will discuss the relationship between physicalism and classical Big Bang Cosmology, and argue that the physicalist must hold to the notion that the Universe came into being out of literal nonbeing with no cause, if this person is to hold to classical Big Bang Cosmology. If my argument is sound, then it entails that a physicalist must do this in order to be consistent with Big Bang cosmology, or either give up physicalism. Theism, on the other hand, does not require that it is possible that being can arise from nonbeing. One may then argue that theism is to be prefered over physicalism, since it is arguably simpler in its assumptions on this question. This may therefore be of interest to Natural (a)Theology.

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## Introduction: Background knowledge and definitions

The Universe is in a state of expansion. The distances seperating super-clusters of galaxies are getting bigger, as space is expanding. The equations for the dynamics of the expansion is the Friedmann equations that tells us how the radius of the Universe (the scale factor), $R$, is changing as time passes. The two Friedmann equations are,[1]

$$\left(\frac{1}{R}\frac{dR}{dt}\right)^2 = \frac{8\pi G}{3}\rho - \frac{\kappa c^2}{R^2} + \frac{\lambda c^2}{3}$$

$$\ddot{R} = \left[-\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\lambda c^2}{3}\right] R$$

They predict that at some point in the finite past, $R = 0$, since $R$ is a function of time, $R(t)$. The second Friedmann equation tells us that if the cosmological constant, $\lambda$, is zero, and if the strong energy condition holds,[2] then the deceleration

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[1]Where $\rho$ is density, $\kappa$ the curvature of the Universe (either +1, 0 or -1), $c$ the speed of light, $p$ pressure, and $\lambda$ the cosmological constant.

[2]The strong energy condition is $\rho + \frac{3p}{c^2} > 0$.

of the expansion will be zero at $R(t) = 0$, where the Universe begins to exist. At times $t > t_{R=0}$ the gravitational attraction between matter will slow the expansion down, such that $\dot{R}(t > t_{R=0}) < \dot{R}(t_{R=0})$. That the Universe will have a radius of zero given the strong energy condition and $\lambda = 0$, is what George F.R. Ellis has called the Friedmann-Lemaître Universe Singularity Theorem.[3] When the radius of the Universe is zero, we reach an initial singularity where past-directed geodesics terminates. In the limit as the radius of the Universe goes to zero, density rises to infinity, and because of that, so does the space-time curvature. Geodesics can't be traced through infinite curvature, and thus terminates there. It is the very termination of geodesics that (usually) defines a singularity, so, in this paper I will define a singularity $S$, as,

**Definition.** $S$ is a singularity $=_{\text{df.}}$there is no space-time point (event) $x^\alpha$ beyond $S$ to which geodesics can be extended too, such that geodesics terminates at $S$.

$S$ is thus a space-time boundary, beyond which the space-time manifold can't be extended. $S$ will therefore be a boundary attached to the beginning of the Universe,[4] such that the Universe begins to exist at $S$. The beginning of the Universe at $S$ will be a creation *ex nihilo*, as John D. Barrow and Frank J. Tipler emphasize,[5]

> ...a true 'creation *ex nihilo*' would be the spontaneous generation of everything - space-time, the quantum mechanical vacuum, matter - at some time in the past. Such a true creation *ex nihilo* has been discussed by cosmologists in both classical and quantum gravity. In classical general relativity, it can be shown that if the Universe is deterministic, if gravity is always attractive, and if the universe is expanding on the average (this last condition is observed to be true, at least in our past light-cone), then all timelike curves have a proper time length less than some universal constant $T$ (which is roughly 30 billion years). In simple models such as the Friedman universe, the finite length of all timelike curves is caused by an all-encompassing singularity, a finite time in the past (...) At this singularity, space and time came into existence; literally nothing existed before the singularity, so, if the Universe orginated at such a singularity we would truly have a creation *ex nihilo*. The singularity is to be regarded as being on the 'boundary' of space-time...

I will argue that a physicalist who accepts the creation of our Universe at $S$ must hold to the possibility of being arising from nonbeing. I named this paper 'Physicalism and Big Bang Cosmology' and not 'Metaphysical Naturalism and Big Bang Cosmology' since a metaphysical naturalist does not necessarily need to hold to the impossibility of nonphysical processes or states, as Charles Taliaferro explains,[6]

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[3]Ellis, G.R.R. (2006), *Issues in the Philosophy of Cosmology*, p. 5

[4]Borrowing Quentin Smith's words, "The Big Bang singularities and other singularities (e.g. black hole singularities) are attached to the spacetime (...) at its boundaries. The Big Bang singularity is defined as the boundary of the universe in the earlier direction, the beginning-point of the universe." (Smith (1995), p. 169)

[5]Barrow, J. D. & Tipler, F. J. (1986) *The Anthropic Cosmological Principle*, Oxford University Press. pp. 441 - 442

[6]Taliaferro, C. (2009) in *The Blackwell Companion to Natural Theology*, Wiley-Blackwell. p. 2

> *Naturalism* has been variously described and is sometimes characterized so broadly as to be without substance. For current purposes, naturalism may be described as a scientifically oriented philosophy that rules out the existence of God, as well as the soul. Some naturalists do not deny that there are nonphysical processes or states (e.g. consciousness is not itself a physical process or state), but most embrace some form of physicalism, according to which there is no thing or process that is nonphysical.

So, my argument will most specifically address physicalism, and not metaphysical naturalism.

## Did the Universe have a beginning?

We have seen that the Friedmann equations, which govern Big Bang Cosmology, predict an initial singularity under certain conditions. But there are good reasons to deny that the strong energy condition holds. For example, the introduction of a cosmological constant, $\lambda$, (i.e. it being greater than zero) entails the falsity of the strong energy condition. Inflation (meaning by that $\ddot{R} > 0$) requires that,

$$p < -\frac{\rho c^2}{3}$$

Since the second Friedmann equation with the cosmological constant omitted is,

$$\ddot{R} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right)R$$

Which would require that $\rho + \frac{3p}{c^2} < 0$. As Andrew Liddle notes,[7] the classic example of this is having a cosmological constant acting like a fluid with pressure $p_\lambda = -\rho_\lambda c^2$.[8] Since it is the case that $\ddot{R} > 0$ right now,[9] my argument for an initial singularity given in the introduction does not seem to be applicable to our Universe! Beyond the acceleration of the expansion observed right now, many (if not most) cosmologists also think that in the very early Universe (when the Universe was just a fraction of a second old), there was a super-fast inflationary epoch. So, at first glance, the need for a beginning of the Universe seem to have been removed. This, however, was proven wrong in 2003 when Arvind Borde, Alexander Vilenkin and the father of inflationary models; Alan Guth, proved that the earlier assumption in singularity theorems that $\rho + \frac{3p}{c^2} > 0$ was irrelevent.[10] The only requirement for a geodesically incomplete Universe according to their theorem is that the average Hubble parameter, $H_{av}$, is greater than zero.[11] Reflecting on this in a very recent paper, Alexander Vilenkin and Audrey Mithani writes,[12]

> One of the most basic questions in cosmology is whether the universe had a beginning or has simply existed forever. It was addressed in the singularity theorems of Penrose and Hawking, with the conclusion that the initial singularity is not avoidable. These

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[7] Liddle, A. (2003) *An Introduction to Modern Cosmology*, Wiley. p. 103, see also p. 53.

[8] Since $\dot{\rho}_\lambda + 3\frac{\dot{R}}{R}\left(\rho_\lambda + \frac{p_\lambda}{c^2}\right) = 0$.

[9] See Riess, A.G. *et al.* (1998) *Observational Evidence from Supernovae for an Accelerating Universe and a Cosmological Constant*

[10] Borde, A., Guth, A. & Vilenkin, A. (2003) *Inflationary spacetimes are not past-complete*

[11] Where the Hubble parameter, $H$, is $H = \frac{\dot{R}}{R} = \left(\frac{1}{R}\frac{dR}{dt}\right)$.

[12] Mithani, A. & Vilenkin, A. (2012) *Did the universe have a beginning?*, p. 1

> theorems rely on the strong energy condition and on certain assumptions about the global structure of spacetime. (...) Inflation violates the strong energy condition, so the singularity theorems of Penrose and Hawking do not apply. Indeed, quantum fluctuations during inflation violate even the weak energy condition, so that singularity theorems assuming only the weak energy condition do not apply either. A more general incompleteness theorem was proved recently that does not rely on energy conditions or Einstein's equations. Instead, it states simply that past geodesics are incomplete provided that the expansion rate averaged along the geodesic is positive: $H_{av} > 0$. This is a much weaker condition, and should certainly apply to the past of any inflating region of spacetime. Therefore, although inflation may be eternal in the future, it cannot be extended indenitely to the past.

They conclude their paper by writing that none of the three major current attempts of constructing a past-eternal Universe succeeds,[13]

> Did the universe have a beginning? At this point, it seems that the answer to this question is probably yes. Here we have addressed three scenarios which seemed to offer a way to avoid a beginning, and have found that none of them can actually be eternal in the past. Both eternal inflation and cyclic universe scenarios have $H_{av} > 0$, which means that they must be past-geodesically incomplete. We have also examined a simple emergent universe model, and concluded that it cannot escape quantum collapse. Even considering more general emergent universe models, there do not seem to be any matter sources that admit solutions that are immune to collapse.

Thus, it seems to be the case that there was a beginning to the Universe even though the strong energy condition is violated.

## Is there a physical cause of the initial singularity?

The question is now, can there be a physical cause for the initial singularity? The answer is that there can't. As we've seen, the initial singularity is defined as a space-time boundary, which is the beginning point of geodesics. There is no point space-time point $x^\alpha$ beyond the initial singularity $S$, such that a physical object at $x^\alpha$ can cause $S$. Space, time, matter and energy, indeed, physical reality itself (!) comes into being at $S$, and hence a true creation *ex nihilo*. As George F.R. Ellis so nicely put it,[14]

> This is not merely a start to matter – it is a start to space, to time, *to physics itself*. It is the most dramatic event in the history of the universe: it is the start of existence of everything.

He also goes on to say that "This is a key issue in terms of the nature of the universe: a space-time singularity is a dramatic affair, where the universe (space, time, matter) has a beginning and all of physics breaks down and so the ability

[13]Ibid, p. 5

[14]Ellis, G.R.R. (2006), *Issues in the Philosophy of Cosmology*, p. 5; my emphasize.

to understand what happens on a scientific basis comes to an end."[15] Quentin Smith, even as a metaphysical naturalist arguably most famous for arguing that theism is incompatible with Cosmology, recognizes that that an initial singularity *by definition* do not have a physical cause,[16]

> Furthermore, it belongs analytically to the concept of the cosmological singularity that it is not the effect of prior physical events. The defenition of a singularity that is employed in the singularity theorems entails that it is *impossible* to extend the spacetime manifold beyond the singularity. The definition in question is based on the concept of inextendible curves, a concept that has been most completely explicated by B.G Schmidt. In a spacetime manifold there are timelike geodesics (paths of freely falling particles), spacelike geodesics (paths of tachyons), null geodesics (paths of photons), and timelike curves with bounded acceleration (paths along which it is possible for observers to move). If one of these curves terminates after a finite proper length (or finite time parameters in the case of null geodesics), and it is impossible to extend the spacetime manifold beyond that point (for example, because of infinite curvature), then that point, along with all adjacent terminating points, is a singularity. Accordingly, if there is some point $p$ beyond which it is possible to extend the spacetime manifold, beyond which geodesics or timelike curves can be extended, then $p$ by definition is not a singularity. This effectively rules out the idea that the singularity is an effect of some prior natural process.

This is why Smith argues that the Universe is *uncaused*. He summarised his view on this by writing that "The fact of the matter is that the most reasonable belief is that we came from nothing, by nothing, and for nothing."[17] This is one of my points; if the physicalist is to hold to classical Big Bang Cosmology, he or she needs to hold to the Universe having come into existence from literal nonbeing with no cause.

## Is a nonphysical cause of the Universe possible?

Alex Pruss has argued that if $E$ is a state of affairs that *can* have a cause, then $E$ is a state of affairs that *does* have a cause.[18] Where being a cause of $E$, means that "$E$ would not have occurred were no cause of $E$ to exist".[19] If Pruss' argument for this is sound, then the theist would only have to argue that it is possible that the initial Big Bang singularity have a cause, since then it would follow that the singularity had a cause. The physicalist on the other hand would then need to argue that it is impossible for there to be a cause of the singularity.

[15] Ibid, p. 29

[16] Smith, Q. (1995) in *Theism, Atheism and Big Bang Cosmology*, Oxford University Press. p. 120

[17] Ibid, p. 135

[18] See Pruss, A. (2009) in *The Blackwell Companion to Natural Theology*, Wiley-Blackwell. p. 65

[19] Ibid.

**Pruss' argument for causation.** If Pruss' argument is correct, it will be of major importance, so let's review it. Pruss starts out by defining what will be meant by a state of affairs $E$ to be caused,

$$(C \text{ causes } E) \Rightarrow ((\sim \exists D\,(D \text{ causes } E)) \,\Box\!\!\rightarrow E \text{ did not occur})\,. \tag{0.1}$$

Where,

$$p \,\Box\!\!\rightarrow\, q$$

means "were $p$ to hold, $q$ would hold", and "⇒" means entailment. Pruss also defines a 'might' operator,

$$p \,\Diamond\!\!\rightarrow\, q$$

,stands for "were $p$ to hold, $q$ might hold". Another important relation is,

$$(p \,\Box\!\!\rightarrow\, q) \Leftrightarrow \sim (p \,\Diamond\!\!\rightarrow \sim q) \tag{0.2}$$

Pruss goes on to write,[20]

> David Lewis proposed the following analysis of counterfactuals for a possible proposition p: $p \,\Box\!\!\rightarrow\, q$ holds providing there is a ($p$&$q$)-satisfying world that is more similar to the actual world than any ($p$&~$q$)-satisfying world is (Lewis 1986, sec. 1.3). While this analysis is, doubtless, not correct in all its details, the intuitive idea of a connection between counterfactuals and possible worlds should remain. When we try to see whether $p \,\Box\!\!\rightarrow\, q$ is true, we move to worlds relevantly similar to our world, but in which $p$ holds, and see whether $q$ holds in all such worlds. What features we must carry over from the actual world to the counterfactual world for it to count as "relevantly similar" is a difficult question. One might well say that, to the extent that $p$ allows, one needs to carry over laws of nature and the past of $p$, while Lewis insists that "relevant similarity" has to do with being as similar as possible to the actual world. If, on the other hand, we think that there is some world relevantly similar to our world in which $p$ holds but $q$ does not, then we say that were $p$ to hold, $q$ might not hold. In modal logic, the Brouwer Axiom, which is entailed by S5, says that if a proposition $p$ is actually true, then necessarily that proposition is possible. In terms of accessibility, this says that if we were to move to a world accessible from the actual world, the actual world would be accessible from that world: the accessibility relation is symmetric. But perhaps the best intuitive way to think about the Brouwer Axiom is to think of it as encapsulating the observation that in any nonactual situation we might consider, the events of the actual world remain relevant as alternative possibilities.

Pruss then writes that there "is an analogue of this observation in the case of counterfactuals",

$$(q \;\&\; p \;\&\; \mathbf{M} \sim p) \supset (\sim p \,\Box\!\!\rightarrow\, (p \,\Diamond\!\!\rightarrow\, q)) \tag{0.3}$$

Where **M** stands for metaphysical possibility. Pruss then defines two axioms,

$$(p \Rightarrow q) \Rightarrow (p \,\Box\!\!\rightarrow\, q) \tag{0.4}$$

[20]Ibid. pp. 65-66

$$((p \,\Box\!\!\rightarrow\, q) \;\&\; (p \,\Box\!\!\rightarrow \sim q)) \;\Rightarrow \sim \mathbf{M}p \tag{0.5}$$

(0.4) is quite obvious, if $p$ entails $q$, then that means that if $p$ were to hold, then $q$ would also hold. (0.5) is arguably obvious too. If both "if $p$ were to hold, then $q$ would hold" and "if $p$ were to hold, then ~$q$ would hold" are true, then there is a logical contradiction, and that entails that it is metaphysically impossible. Now Pruss argues from what we have defined that if $E$ *can* have a cause, then $E$ *does* have a cause. He writes, "Let $q$ be the true proposition that event $E$ occurs, and suppose that $E$ can have a cause. For a reductio, let $p$ be the true proposition that there is nothing that causes $E$, that is, ~$\exists D\,(D$ causes $E)$. However, since $E$ can have a cause, $\mathbf{M} \sim p$." From (0.3) we then get,

$$\sim p \,\Box\!\!\rightarrow\, (p \,\Diamond\!\!\rightarrow\, q) \tag{0.6}$$

That is, if it is the case that "$E$ is caused" holds, then it is the case that "were it the case that there is nothing that causes $E$, then it might be the case that $E$ occurs" holds. Pruss then let's us imagine a possible world $w$ where ~$p$ holds. Since ~$p$ is the negation of $E$ having no cause, it follows that $w$ is a possible world in which $E$ has a cause. Now since "nonexistent and nonoccurrent things can neither cause nor be caused, $E$ occurs at $w$, as does a cause, call it $C$."[21] From (0.1), we see that if there was no cause of $E$, then $E$ would not occur in $w$. This is then expressed as,

$$p \,\Box\!\!\rightarrow \sim q \tag{0.7}$$

In every possible world where $\sim p$ holds (i.e. $E$ is caused), it follows that,

$$\sim p \;\Rightarrow\; (p \,\Box\!\!\rightarrow \sim q) \tag{0.8}$$

From (0.2) we then get,

$$\sim p \;\Rightarrow \sim (p \,\Diamond\!\!\rightarrow\, q)$$

From (0.4) we get,

$$\sim p \,\Box\!\!\rightarrow \sim (p \,\Diamond\!\!\rightarrow\, q)$$

From (0.6) and (0.8) it "follows that ~$\mathbf{M}p$. But $p$ was assumed to be true, and true propositions are possible, and hence absurdly ~$\mathbf{M}p$ and $\mathbf{M}p$. Thus, the assumption for the reductio is false, and so $p$ is false. Hence, there is a cause of $E$."[22] Pruss concludes,[23]

> This is enough to show that Humeans are wrong to think that a brick could come into existence for no cause at all. For it is plain that there *can* be a cause of the state of affairs of a brick's coming into existence at $t$, and hence by the argument, there *is* such a cause.

## A possible argument from Big Bang Cosmology and Pruss' argument, against physicalism

If Pruss' argument is sound, just the *possibility* of there being a cause of the initial Big Bang singularity would falsify physicalism. One may argue;

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[21]Ibid. pp. 66-67
[22]Ibid. p. 67
[23]Ibid.

**P1.:** If the Universe, $U$ is geodesically incomplete into the past, there will be a singularity (space-time boundary) $S$ where there is no point $x^\alpha$ beyond $S$, such that no physical entity at $x^\alpha$ can cause $S$.
**P2.:** $U$ is geodesically incomplete into the past.
**C1.:** Therefore, there will be a singularity $S$ where there is no point $x^\alpha$ beyond $S$, such that no physical entity at $x^\alpha$ can cause $S$. (From P1 & P2)
**P3.:** If physicalism is true, nonphysical entities cannot exist.
**P4.:** It is possible that there may be a cause of $S$.
**P5.:** If it is possible that there may be a cause of $S$, there is a cause of $S$. (Pruss)
**C2.:** Therefore, there is a cause of $S$. (From P4 & P5)
**P6.:** If there is a cause of $S$, then there is a nonphysical entity.
**C3.:** Therefore, physicalism is not true. (From P3, C2 & P6)

First, notice that the first premise is compatible with much of quantum cosmology also, since a singularity is not defined to be a point of infinite density, temperature etc. As Quentin Smith notes,[24]

> The second reason is that there is a way in which the Hawking-Penrose theorems' prediction of a singularity at the beginning of the present expansion can be made consistent with a quantum theory of repulsive gravity. These theorems do not *define* a singularity as that wherin curvature, density, and temperature are infinite and the radius zero. A singularity is defined as a point or series of points beyond which the spacetime manifold cannot be extended. Consequently, if the effects of quantum gravity prevent a build-up of temperature, density, and curvature to infinite values, and a decrease of radius to zero, this need not mean there is no singularity at the beginning of the present expansion. The singularity could occur with *finite* and *non-zero* values.

So, what is meant by a singularity here is not restricted to the classical general relavistic Friedmann-Lemaître model.[25] The Borde-Guth-Vilenkin singularity theorem proved that a Universe that has $H_{av} > 0$ will be geodesically incomplete into the past. Since this is the only condition that needs to be satisfied, General Relativity becomes unimportant in the question of singularity theorems. As Vilenkin and Mithani pointed out, it "does not rely on energy conditions or Einstein's equations."[26] So, the second premise seems to be true of our Universe. The third premise is quite self-explanatory. The fourth premise simply states that there is a possible world $w$ where $U$ 's boundary attached at its beginning, $S$, has a cause. As long as it isn't *impossible* for there to be a cause of $S$, this will hold. If Pruss' argument is sound, it therefore follows that $S$ has a cause. And if $S$ has a cause, then physicalism is false, since a cause of $S$ would not be physical. The key premises

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[24]Smith, Q. (1995) in *Theism, Atheism and Big Bang Cosmology*, Oxford University Press. p. 126

[25]Having the metric

$$g_{\alpha\beta}dx^\alpha dx^\beta = -c^2dt^2 + R^2(t)\left[\frac{dr^2}{1-kr^2} + r^2\left(d\theta^2 + \sin^2\theta d\varphi^2\right)\right]$$

such that at $R(t) = 0$, all spatial distances reduce to zero, which leads to infinite temperature, density, curvature etc.

[26]Mithani, A. & Vilenkin, A. (2012) *Did the universe have a beginning?*, p. 1

in this hypothetical argument would then be Pruss' argument, and whether it is impossible for there to be a cause of $S$. If Pruss' argument is correct, and that for some reason, it is very, very, very unlikely that $S$ has a cause, it would still follow that there is. The physicalist would need to either show that this is impossible, or that Pruss' reasoning is wrong. The theist could simply hold to the more moderate view that it is possible that there is a cause of $S$, and then it would follow that physicalism is false. I will not defend this argument, as this is more of a hypothetical argument right now, that can be further developed. If the argument for the causal principle fails, an argument could still be made that the physicalist position is not as moderate as the theist position, since the theist does not need to assume that being can arise from nonbeing, while the physicalist *must* do this in order to remain consistent with Big Bang cosmology. I hope that this may spawn some interesting discussion on the topic, and that arguments and objections could be further developed to see if it is possible to come to some conclusion on the matter.