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Quantum Fluctuation and Critical Analysis of the Physical Approach to the Creatio ex Nihilo of the Universe

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ABSTRACT

SUBJECT AND OBJECTIVES: The Big Bang theory and the standard cosmological models based on it imply the world's temporal finitude. The temporally finite universe, most physicists believe, must have been created out of nothing. In order to avoid the theological and metaphysical implications of such an idea, the most important scenarios that have been proposed are: (1) The universe is not temporally finite, but rather is pre-eternal; (2) The creation of the universe out of nothing can be explained purely physically; (3) There is no correlation between the temporal finitude of the universe and having a temporal beginning, so the universe always existed; (4) The creation of the universe as a brute fact is a spontaneous uncaused origination ex nihilo.

METHOD AND FINDING: In this essay, I aim to discuss and criticize scenario (2). To reach this aim, two important physical models, i.e: The Tryon-Vilenkin and Hawking-Hartle models, which have been formulated based on quantum fluctuation, will be explained. It will be shown that they are indeed explaining the creation of the universe, not out of nothing, but from something.

CONCLUSION: No physical theory can ever explain the creation of the universe out of nothing by appealing to the physical phenomena or the laws of nature. The outcome of the paper is that creatio ex nihilo of the universe out of nothing can only be explained metaphysically by appealing to some external causes.

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Introduction

The Big Bang theory and the standard cosmological models based on it imply the world's temporal finitude. The temporally finite universe, most physicists believe, must have been created out of nothing. For some physicists and philosophers, this implies some unfortunate metaphysical and theological results. To avoid such implications, scientists and philosophers have thought of some scenarios.

The most important scenarios, developed and discussed in the last few decades, have been:

1. The universe is not temporally finite, but rather is pre-eternal. So, either the universe has always been and will be at the same state: Referring to the steady-state model; *(Ref: Bondi and Gold, 1948; Hoyle 1948; Ibid, 1975; Ibid, 1992; Ibid, 1994; Bondi 1960; Ibid, 1961; Hoyle and Narlikar, 1980; Stanley, 1974; Brush, 1992; Ellis, 1993)* or if it started with the Big Bang, the beginning of the present world would not be out of nothingness, but rather from within the inaccessible pre-big-bang universe(s); e.g: Cyclic cosmologies, *(Penrose 2010; Steinhardt and Turok 2007)* loop quantum cosmology *(Rovelli 2004; Bojowald 2009)* and string theory. *(Gasperini, 2008)*

2. The universe is temporally finite, and such a universe must have been created out of

nothing. The *creatio ex nihilo* of the world, however, is a causal physical phenomenon, and hence, can be explained scientifically by appealing to the laws of nature. *(e.g: The Tryon-Vilenkin and Hawking-Hartle models)*

3. The universe is temporally finite, and yet does not have a temporal beginning. That is to say, the temporal finite universe always existed. *(e.g: Grünbaum 1991; Ibid, 1994)*

4. The universe is temporally finite, and it is not the case that it always existed. However, the creation of the universe is a spontaneous uncaused origination *ex nihilo*. *(e.g: Smith, 1988; Ibid; 1994a; Ibid, 1994b)*

Nowadays most scientists agree that neither of the scientific models being presented to show the pre-eternality of the world has proved satisfactory. There is either no experimental evidence supporting them (cyclic cosmologies, loop quantum cosmology and string theory) or there is indeed strong experimental evidence against them (the steady-state theory). Scenario (1) therefore is not popular today. Scenarios (3) and (4) are indeed philosophical interpretations of scenario (2). They are neither the only nor the most important philosophical theories in this case.

This is indeed where philosophers' opinions diverge sharply from each other: some believe in God as the creator and the sustainer of the universe, and some consider the existence of the universe as a brute fact needing no explanation. The importance of scenarios (3) and (4), however, is that they have been theorized in reaction to the implications of modern cosmology.

In this paper, I do not intend to examine scenarios (1), (3), and (4). Rather I aim to discuss and criticize scenario (2).

Contrary to philosophers, for whom the problem of the origin of the world has always been a matter of discussion, most scientists, as *Hoyle (1975: 166)* says, consider this problem "outside the range of scientific discussion". Some cosmologists, however, who believe that all phenomena can be explained scientifically, have found scenario (2) the most desirable option for scientists.

Gribbin (1986: 392), for instance, claims that the suggested models of creation in modern physics leave no place for the traditional metaphysical attitude to creation since such models well explain how the universe can create itself from nothingness at time zero (t=0).

He concludes that philosophers theorize beyond their domain. Gribbin's claim reflects the idea of some cosmologists who believe that internal elements of the universe are sufficient to explain, both epistemologically and ontologically, the creation of the world out of nothing. According to some physicists, quantum fluctuation is the phenomenon that can play this role.

In this paper, it will be shown that the models based on this phenomenon are indeed explaining the creation of the universe, not out of nothing, but from something.[1]

To reach this aim the main assumptions and implications of modern cosmology will be explained briefly.

Discussing the two important physical models, based on quantum phenomena for explaining the creation of the universe out of nothing-the Tryon-Vilenkin and Hawking-Hartle models- is the matter of the second section.

In the final section, it will be shown that no physical theory can ever explain the creation of the universe out of nothing by appealing to the laws of nature. This means that *creatio ex nihilo* of the universe out of nothing can only be explained metaphysically by appealing to some external causes.

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1. Contrary to the Big Bang model which proposes the creation of the whole universe at $t=0$, its unsuccessful rival theory, i.e: The Steady-State model, assumes the continuous creation of new matter. Although this is a dead theory now, *Grünbaum (1989, 1991, 1993&1998)* has interpreted it in such a way to show that the continuous creation of matter in this theory is not a case of *creatio ex nihilo*; rather is a physical phenomenon which can be explained scientifically by appealing to the laws of nature. *(Ref: Mousavi Karimi, 2011)*

The Main Assumptions and Implications of Modern Cosmology

Concerning the issue at hand, the main assumptions and implications of modern cosmology can be categorized as follows:

- The universe-as-a-whole, to use Smith's categorizing (1995), is true organic unity. Accordingly, it is not the case that if the parts of the world are explained, the whole of the world is explained too.

- Modern cosmology implies the temporal finitude of the universe as a whole.

- The temporal finitude of the universe implies the temporal beginning of the universe. That is, our universe has been created (or emerged) out of nothing some billions of years ago.

Although some philosophers find these assumptions controversial, most cosmologists consider them as plausible assumptions and implications of modern cosmology:

> 1. Cosmology is the study of the structure and the evolution of the world-as-a-whole. *(Rees 1998: 53)*

By the world, I mean simply everything whose existential source is the initial singularity, including singularity itself. "Everything" then includes all entities, their properties and relations with each other, laws of nature, etc. which have appeared since the Big Bang some billions of years ago.

By this definition, therefore, I preclude non-physical eternal entities, platonic worlds of abstract entities, pre-Big Bang worlds, etc. if there are such entities and existents.

The identity of the world-as-a-whole is similar to the identity of what *Smith (1995: 301)* calls "an organic unity", and is the result of a special relation between a whole and its parts. In general, Smith distinguishes four kinds of relations. *(Ref: Ibid)*

An organic unity is such that its parts have some specific type of ordering relation with each other so that the unity finds some properties in addition to the individual properties of the parts. Whether philosophers accept this assumption or not, this is the fact that the whole knowledge branch of modern cosmology is indeed based on.[1]

2. It is now a widely accepted view that modern cosmology started in 1917 when Einstein considered the world-as-a-whole and tried to apply the theory of general relativity to it.

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1. In Hume's Dialogues Concerning Natural Religion *(2007: 65-6)* Cleanthes says: But the WHOLE, you say, wants a cause… Did I show you the particular causes of each individual in a collection of twenty particles of matter, I should think it very unreasonable, should you afterwards ask me, what was the cause of the whole twenty. This is sufficiently explained in explaining the cause of the parts. However, as *Gale's (1991: 254)* example rightly shows, the existence of each part of an automobile has a causal explanation, but this does not explain the existence of the automobile.

He also assumed that the world-as-a-whole has properties such as uniform distribution of matter all over space, static behavior, constant density, and the like. *(Ref: Lightman and Brawer, 1990: 2)*

Also, Friedmann's solution of Einsteins's equations, as the solution which makes the infrastructure of all the modern cosmological models, is based on the following important simplifying hypotheses as the properties of the world-as-a-whole:

(1) The universe is homogeneous; within the homogeneous universe the matter is uniformly distributed, resulting in a constant density for the universe.

(2) The universe is isotropic; this means uniform distribution of matter in all directions.

(3) The universe is uniform; that is, all parts of the universe have similar characteristics.

(4) The laws of nature are and have always been similar throughout the universe.

All of these presuppositions, which are in one way or another approved by the cosmic data, might add up to produce the Cosmological Principle or the Copernican Principle: The world is both homogeneous and isotropic. In such a universe all points and directions are more or less equivalent, and thus there is no center of the universe”. *(Hawley and Holcomb 2000: 148-151)*

Having taken these presuppositions, Friedmann could finally reduce the original ten equations of general relativity to only two following equations, *(Ref: Coles and Lucchin 1997: 22)* which have become the normal solutions to Einstein’s field equations:

$1/R^2 (\partial^2 R/\partial t^2)^2 + kc^2/R^2 = 8\pi G\rho/3$

$2/R (\partial^2 R/\partial t^2) + 1/R^2 (\partial R/\partial t)^2 + kc^2/R^2 = -8\pi GP/c^2$

In these equations most parameters indicate the properties of the world-as-a-whole:

“R” represents the radius of the universe at a given time.

“∂R/∂t” is the rate at which the universe expands or contracts.

“∂2R/∂t2” is the rate of change of (∂R/∂t); that is, the acceleration of the expansion or the deceleration of the contraction.

“G” is the universal gravitational constant.

“ρ” is the average density of the world.

“P” is the average pressure of all matter of the world.

“k” is the constant of space curvature.

3. Friedmann’s equations show that if ρ is positive, then $(\partial^2 R/\partial t^2)$ cannot be zero.

In a word, if there is matter present in the universe then the universe must be either expanding or contracting with a varying acceleration.

In 1929 Edwin Hubble discovered that the galactic redshift increases in proportion to distance; i.e: The galaxies get away from us and the more distant a galaxy is the faster it will recede from us. *(Heidmann, 1977: 39)* This discovery, entitled "Hubble's law", is the strong evidence that the world expands.

Should the course of the world expansion be reversed, we could come to a point at which the time would stop at nothing (zero), while the density and the space-time curvature plus the temperature would increase infinitely. We would have reached a space-time singularity.

In 1965, Stephen Hawking *(Ref: Hawking and Ellis, 1965)* and Roger Penrose *(Ref: Penrose, 1965)* argued that, with the assumption of general relativity and the expanding universe which includes the existing matter, the existence of the singularity seems inexorable.

4. Singularity demonstrates the temporal finitude of the world: the world has a starting point of time.

Four of the world's most prominent astronomers describe singularity and the event of the Big Bang in these words:

> *The universe began from a state of infinite density. Space and time were created in that event and so was all the matter in the universe. It is not meaningful to ask what happened before the Big Bang; it is somewhat like*

asking what is north of the north pole. Similarly, it is not sensible to ask where the Big Bang took place. The point-universe was not an object isolated in space; it was the entire universe, and so the only answer can be that the big bang happened everywhere. (Gott et al 1976: 65)

Therefore, it is nonsensical to question the place and time of the Big Bang. In *Davies's (1978: 78-79)* words, the big bang represents the creation event; the creation not only of all the matter and energy in the universe but also of spacetime itself.

5. Since 1965, in which Hawking and Penrose showed that the universe must have a singularity, some physical models have been proposed to avoid the singularity. Of course, there is no singularity in the deceased steady-state model as well.

The first is the model of the inflationary universe which was popular in the 1980s.

According to the modified version of this model, called the "chaotic inflationary model", *(Linde 1984)* the universe is presupposed to have begun from an unexpected chaotic state. The matter and the temperature are evenly distributed but numerous bubbles, originated by the quantum fluctuations, existed in space-time. The field energy in the respective regions possessed a repulsive effect and thus developed the universe in the inflationary form.

In such a chaotic universe each bubble could have its own constituents and characteristics. This will result in the creation of small and big bubbles, which shall overtake the whole cosmos. One of the bubbles has ended up as our own world. The inflation is eternally sequential and never ends. One could assume the universe as a continuous branching process in which, countless tiny worlds inflate in order to recreate other regions within the major chaotic world.

Therefore, the singularities are possibly local and temporary phenomena, and accordingly, there may not be only one absolute origination for the whole world. However, *Borde and Vilenkin (1994: 3305)* showed that “A physically reasonable spacetime that is eternally inflating to the future must possess an initial singularity”. *(Ref: Borde et al, 2003)* In response, *Linde (1994)* accepted their conclusion.

The next two important models are loop quantum cosmology *(Rovelli 2004)* and string theory *(Gasperini 2008)* which are the result of unifying general relativity and quantum theory.[1]

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1. Also, two other non-standard cosmological models that avoid absolute singularity are the cyclic cosmologies *(Penrose 2010; Steinhardt and Turok 2007)* and the multiverse model. *(Susskind 2002)* The former model proposes a sequence of cycling pre-big bang universes, and the latter assumes really existing numerous worlds which generally are causally

According to the first model, the big bang was not the beginning of the universe; rather, our universe originated from a pre-existent universe. *(Bojowald 2009)*

Similarly, the outcome of the string cosmology is that the universe existed before the big bang, and in fact, there was a "pre-big-bang universe". *(Gasperini 2008)*

So, it seems that in both scenarios the absolute singularity and the absolute big bang disappears. *(Halvorson and Kragh 2021)*

The problem, however, is that there is no experimental evidence supporting these models. So, none of the models which assume the pre-eternality of the world are scientifically satisfactory. Moreover, it is not the case that string theory necessarily effaces singularities. *(Roiban, 2006)*

At any rate, according to these theories, our universe has been emerged, not out of nothing, but from something. So, they are out of the scope of our topic.

There are, however, two famous models which have tried to avoid the singularity, and at the same time explain the problem of how and why the temporally finite universe was created out of nothing some billions of years ago: the Tryon-Vilenkin and Hawking-Hartle models.

These models have tried to find the solution to this

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separate from ours. None of these models are widely accepted. Moreover, in both models, the creation of the world is from something, not out of nothing. So, they are out of the scope of our topic.

problem in the phenomenon of quantum fluctuation.

Quantum Fluctuation and *Creatio Ex Nihilo*

Singularity shows the temporal finitude of the world, and the temporal finitude of the universe implies that "we would truly have a *creation ex nihilo*". (Barrow and Tipler, 1996: 442) This is because as one goes back in time, one reaches a point at which the universe was "shrunk down to nothing at all". (Hoyle, 1975: 658)

It seems, therefore, what the Big Bang model requires is that the universe had a beginning and was created out of nothing.

Years before the publication of the Hawking-Penrose article (1965), having solved the equations of general relativity, Friedmann was impressed by the odd singularity conditions at the time t=0, naming it "the state of the world's creation out of nothing".

The *creatio ex nihilo*, however, seems to be a problematic notion for cosmologists. As Andrei Linde (1984: 976) says, "The most difficult aspect of this problem is not the existence of the singularity itself, but the question of what was before the singularity... This problem lies somewhere at the boundary between physics and metaphysics".

Gribbin (1976: 15) asks the same question: The biggest problem with the Big Bang theory of the origin of the universe is philosophical- perhaps even theological- what was there before the big bang?

Clearly by asking "what was before the Big Bang" neither Linde nor Gribbin mean "what existed in a time which was before the Big Bang". For the easy response is that there was no before. Rather they are seeking to find the cause of this event; that is, why the universe came into existence, if there was not nothing as the cause of the event.

Some physical models have been proposed to answer this question. The best of these models are probably those which are based on a quantum fluctuation.

Quantum fluctuation is an uncertain change in one of a system's parameters such as momentum or energy, which occurs in the world of subatomic particles according to the laws of probability. One of the bizarre aspects of quantum theory is that it allows a system to violate the law of mass-energy conservation in a very short time.

In other words, a system is allowed to "borrow" some tiny amount of energy, providing that the very same amount shall be returned into the medium in so short a time that it could not be detected within the limits of the Uncertainty Principle. This short while, better known as "Compton Time" (t_c), is the time during which mass (m) could violate the conservation law and it is computable through $t_c=h/(2\pi mc^2)$. *(Clark 1999: 87)*

To apply quantum fluctuations to the initial conditions of the world, physicists would have to describe the conditions of the universe preceding the Plank's Time (i.e: 10^{-43} second after the Big Bang). Before this time, i.e: During the Plank period, the four fundamental forces of nature (i.e: Gravitational force, electromagnetic force, weak nuclear force, and strong nuclear force) had wholly unified. The structures of space and time were so disintegrated that one could not find much similarity between what we know of as space and time and whatever space and time looked like right then.

In order to describe such conditions a comprehensive theory that combines the two basic theories of physics, i.e: General relativity and quantum mechanics, had to be presented. Such a comprehensive theory is "the quantum theory of gravity" and the cosmology, based on that, is "the quantum cosmology".

Quantum cosmology supposes that from the Big Bang to 10^{-43} seconds afterward, while the universe's dimension was about 10^{-33} centimeters, quantum fluctuations could occur. Besides, since the sum of the negative energy of the universe's gravity and its positive kinetic energy equals zero, the emergence of the universe from quantum fluctuation is presumed to be a creation out of nothing.

We have not yet encountered a satisfactory and self-consistent formulation of the quantum theory of gravity and quantum cosmology. *(Isham 1989: 90-1)*

Several theories have been proposed to construct a quantum theory of spacetime geometry but there is still no proposal that the scientific community accepts unanimously as fully satisfactory.

Nevertheless, several models of *creatio ex nihilo* have been set forth based on the quantum phenomena of "vacuum fluctuation" and "wave function".

1. Vacuum Fluctuation Models

Models developed by *(Tryon, 1973; Brout et al, 1978; Grishchak and Zeldovich, 1982; Atkatz and Pagels, 1982; Gott, 1982; Vilenkin, 1982; Ibid, 1983; Ibid, 1986)* have used the quantum vacuum fluctuations. Most of these models picture the universe as emerging spontaneously from an empty background space, and the model of *Vilenkin (1982)* depicts it as emerging from nothing.

These models envisage the whole universe to be a giant quantum mechanical virtual fluctuation of the vacuum. They assume that the microstructure of the vacuum, i.e: The state of lowest possible energy density, in quantum electrodynamics (QED) is a sea of continual reactions in which virtual particles *(Ref: Weingard (1982)* are created, and almost instantly are annihilated by their antiparticles.

It is important to point out that if the energy of pair creation that is “borrowed” from the vacuum is E=mc2, then, according to the energy-time form of the Uncertainly Principle these, “virtual” particle pairs will be unobservable as individual events so long as $\Delta E.\Delta t<h$. In other words, “such vacuum fluctuations cannot be observed directly, as they typically last for only about 10-21 seconds, and the separation between the electron and positron is typically no longer than 10-10 centimetres”. *(Guth, 1997: 272)*

Since the allowable “borrowed” energy is inversely proportional to the period of time when it should be repaid, the required energy could only be borrowed for an extremely small period of time, but this short while is already enough for the particles to appear.

The most important model of vacuum fluctuation models is one proposed by Tryon and developed by Vilenkin to explain *creatio ex nihilo*.

A. The Tryon-Vilenkin Model

Tryon was the first to use the quantum fluctuation phenomenon to explain the emergence of the universe out of nothing. He wrote:

> *In my model, I assume that our Universe did indeed appear from nowhere about 10^{10} years ago. Contrary to popular belief, such an event need not have violated any of the*

conventional laws of physics. (Tryon, 1973: 396)

Tryon’s model, however, could not explain why, given that the scale of vacuum fluctuation is typically subatomic, the universe has become so large.

Vilenkin (1982,1983&1988) proposed an improved extension of Tryon’s model. He took the notion of quantum tunneling from quantum mechanics and applied it to space-time itself.

Quantum tunnelling is a process by which a quantum system can suddenly and discontinuously make a transition from an initial configuration to a final one- as long as no conservation law makes the transformation impossible- even if the system does not have enough energy to classically attain the configurations between the two. This is possible because the uncertainty principle allows the electron to spontaneously acquire the additional energy for the short period of time required for it to tunnel through the barrier.

In this case, there is not state of the system before the tunneling, for the state of tunneling is the first state that exists and there is no time before this state. Then, by a combination of this idea with the idea of the plasticity of space from general relativity, *Ibid: 2848)* claimed that his version of the inflationary scenario can explain the spontaneous creation of the world from nothing.

Based on his model, in the absence of matter and classical time and space, our universe started in a totally empty geometry, and then, made a quantum tunneling transition with finite size in an explosive form to a closed, expanding de Sitter Universe. *(Vilenkin, 1982: 26)*

This universe is a cosmological model in which the universe is flat, i.e: The Curvature Parameter is zero, and empty, i.e: Its pressure and density is zero.

A combination of Vilenkin's model with the inflationary model can explain the enlargement of the Universe to its current size. Contrary to Tryon's theory, Vilenkin's model does not postulate a background space from which the universe fluctuates.

Moreover, prior to Hawking and Hartle, *Vilenkin (1982: 27f)* claimed that his theory presents a cosmological model, which avoids the problem of singularity at the beginning. Thus, there would be no need for boundary conditions.

Vacuum Fluctuation Models are not physically satisfactory models. Even, as *Isham (1988: 385-387)* shows, they face a deep internal incoherence. The crucial point, however, is that these models do not explain the *creatio ex nihilo* of the world.

B. The Tryon-Vilenkin Model and *Creatio ex Nihilo*

Vilenkin (1983: 2848) claims that: "The purpose of this paper is to suggest a new version of the inflationary scenario in which the Universe is spontaneously created from nothing". The problem, however, is that these models assume some situations "nothingness" which are indeed full of entities, though may lack some other entities.

For example, *Vilenkin (1983: 2851)* asserts that in his model by nothing, which is the origin of the tunneling to de Sitter space, he means "a state with no classical space-time".

The irony, however, is that Vilenkin supposes that there was, before the instant of the creation, the Higgs field with an effective potential $V(\phi)$. Higgs fields indeed are part of "grand unified theories" which have nonzero values in the vacuum, and they serve to create a distinction between particles that would otherwise be identical.

In grand unified theories Higgs fields are responsible for all the differences between electrons, neutrinos, and quarks, and as *Vilenkin (1983: 2850)* himself states, they "have several components".

Furthermore, Vilenkin's model is such that "the Universe starts in a vacuum state with $\phi = \phi_0$" in which the "vacuum energy density… will, in general, be nonzero (and positive)". *(Ibid)*

Furthermore, as we explained already, the microstructure of the quantum vacuum is a sea of continually forming and dissolving particles that borrow energy from the vacuum for their brief existence. A quantum vacuum is thus far from nothing.

As *Barrow and Tipler (1996: 441)* point out: "It is, of course, somewhat inappropriate to call the origin of a bubble universe in a fluctuation of the vacuum "creation *ex nihilo*," for the quantum mechanical vacuum is not truly "nothing"; rather, the vacuum state has a rich structure which resides in a previously existing substratum of space-time, either Minkowski or de Sitter space-time".

Accordingly, Alan Guth, in response to the Tryon-Vilenkin Model, wrote: "a proposal that the universe was created from empty space is no more fundamental than a proposal that the universe was spawned by a piece of rubber. It might be true, but one would still want to ask where the piece of rubber came from". *(Guth, 1997: 273)*

Vilenkin (2006: 185) finally accepts that "the "vacuum" is very different from "nothing". vacuum, or empty space, has energy and tension, it can bend and warp, so it is unquestionably *something*".

So, contrary to what *Smith (1988: 54)* claims that in vacuum fluctuation models "[t]he universe appears in a quantum tunneling from nothing at all to de Sitter space", even *Vilenkin (1982: 26)* himself admits that "The concept of the universe being created from nothing is a crazy one".

Those models indeed explain the transformation of something into something, and not creation out of nothing.

2. Wave-Function Models

The second version of quantum cosmology is furnished by the so-called wave-function models. The most important model of this group is the Hawking-Hartle model.

A. The Hawking-Hartle Model

This model has been formulated to achieve two main goals: Firstly, the model seeks to omit the singularity, and as a consequence, the starting point of the universe; secondly, to illustrate how the universe was created out of nothing.

In a joint article, *Hartle and Hawking (1983)* tried to explain the situation of the universe before the Plank time. They proposed a timeless universe that has only three-dimensional space. To remove the boundary conditions, time combines with the topological structure of three-dimensional space and transmogrifies to something like a dimension of space. Space-time is "rounded off" prior to the Planck time so that although the past is finite, there is no edge or beginning point.

By transforming Lorentzian space-time into Euclidian space-time it becomes possible to exclude singularities from the resulting Euclidian region. Such a change will not be feasible unless by means of a complex transformation of the time coordinate in which the real time (t) in Einstein's gravitational equations is replaced by an imaginary time ($-i\tau$).

According to *Hawking (1997: 154)*: "Only if we could picture the universe in terms of imaginary time would there be no singularities... This in turn led to the idea that the universe could be finite in imaginary time but without boundaries or singularities. When one goes back to the real time in which we live, however, there will still appear to be singularities".

This of course does not imply that the universe did not begin to exist. For, firstly, by backing to the real time there will still be singularities; secondly, "Having a beginning does not entail having a [i.e. exactly one] beginning point... Time begins to exist just in case for any finite temporal interval, there are only a finite number of equal temporal intervals earlier than it"; *(Craig, 1999: 732)* so that it is not the case the universe always existed.

At any rate, the Hawking-Hartle model supposes a ground-state wave function as a boundary condition, with no reference to anything that might have come before it, and estimates its probability according to the laws of quantum mechanics.

Since the universe has no boundaries in space or time, "one can interpret the functional integral over all compact four-geometries... to arise from a zero three-geometry, i.e: A single point. In other words, the ground state is the amplitude for the Universe to appear from nothing". *(Hartle and Hawking, 1983: 2961)*

But what properties does the ground state of the Hawking-Hartle model have?

The given answer is: "In the quantum mechanics of closed universes we do not expect to find a notion of ground state as a state of lowest energy... In a certain sense the total energy for a closed universe is always zero; The gravitational energy canceling the matter energy". *(Hartle and Hawking, 1983: 2961)*

In other words, since at the initial singularity, the total sum of the positive energy of the motion or the matter and the negative gravitational energy matched zero, the particle-antiparticle couples were created during the quantum fluctuations from the very zero energy. *(Hawking, 1997: 143-4)*

So, if the sum of the total energies of the universe is zero, then the creation of matter from pure energy (i.e: The emergence of the universe), is a type of *creatio ex nihilo*.

The Hawking-Hartle model, like the others that have attempted to describe the materialization of the universe from nothing, is highly speculative and without experimental evidence. In effect, this model "is *ad hoc* in the sense that it does not flow from a more comprehensive unification of general relativity quantum theory". *(Halvorson and Kragh, 2021)*

However, *Isham (1988: 398)* believes that this model “is what we need to describe creation ‘from nothing”.

Hawking (2011: 85) himself has claimed that according to the model, the universe “would quite literally be created out of nothing: not just out of the vacuum, but out of absolutely nothing at all; because there is nothing outside the universe”.

B. The Hawking-Hartle Model and *Creatio ex Nihilo*

The Hawking-Hartle model suffers from some problems that make it unpalatable. First of all, it utilizes imaginary time - a concept that could, like 10-dimensional or 100-dimensional space, be mathematically defined. However, the mathematical definition or existence can never guarantee the external existence and physical reality of something corresponding to such a concept.

Hawking (1997: 152) indeed considers the idea ‘that time and space should be finite without boundary’ as a proposal which ‘cannot be deduced from some other principle. Like any other scientific theory, it may initially be put forward for aesthetic or metaphysical reasons’.

Hawking (1997b: 169), perhaps in response to objections like this, emphasizes that: “I… am a positivist who believes that physical theories are just mathematical models we construct and that it is meaningless to ask if they correspond to reality”.

Therefore, he claims that "a scientific theory is just a mathematical model we make to describe our observations: it exists only in our minds. So, it is meaningless to ask: which is real, "real" or "imaginary" time?" *(Hawking, 1997: 139)*

These comments show that however good a physicist Hawking may be, how rough and inaccurate his philosophical views are. To begin with, his views are more likely to be instrumentalistic, not positivistic.

In any case, nobody- whether she is a positivist, an instrumentalist, or anything else- has claimed that the question of the reality of physical entities is meaningless, though some philosophers have claimed that it is useless. Whether scientific theories are only mathematical models or not, has no connection with the problem of the reality of physical entities, unless one reduces scientific theories to a set of scientific terms, and also assumes that scientific terms and the entities that they denote are ontologically the same.

Therefore, it is totally justified that we expect Hawking and Hartle to present a physical interpretation of the notion of "imaginary time", an expectation that is very unlikely to be met.

If Hawking's positivism or instrumentalism (whichever the case may be) is the right approach to cosmology, and so it is meaningless to ask whether "imaginary" time is real or not, then why should we accept that Hawking's model describes the reality of the world in those speculative situations of its creation (or emergence)? That is, why should we still not believe in the standard models according to which there was a singularity and the start point of time?

If it is the case that "Any real, observable quantity has to be expressed by a real number", *(Cavalleri, 1988)* then Hawking-Hartle's imaginary time would be a matter of fiction.

Moreover, quantum vacuum fluctuation involves the change of a physical variable at two different real times. The omission of the time dimension jettisons the concept of chronological juxtaposition. Consequently, the physical variables would be invariable in time, leading to a solid and static system within which the quantum vacuum fluctuations would be basically impossible.

In fact, in all fundamental theories of physics, i.e: The theories of special and general relativity, quantum mechanics, and even in the superstring theory, the distinction between the temporal and the spatial dimensions survives. So, it is not clear what exactly the physical meaning of the transformation of time into space is.

For the sake of argument, however, let us assume that whether something is real or unreal is determined by physical theories, and consequently, the imaginary time of the

Hawking-Hartle model is indeed a physical character of the initial universe.

Let us further assume that in spite of obvious differences between the natures of time and space,[1] the time has a special character at the initial state of the universe, so that there are two worlds: the initial world with imaginary time (U_i), and the later world with real time (U_r).

Assuming such universes results in the following consequences which are both plausible and yet incompatible:

(1) Both U_i and U_r are physical entities

(2) U_i is the cause (efficient or material) of U_r

(3) U_i cannot be temporally before, or simultaneously with, U_r, since there is no time before U_r, and U_i is a timeless entity

(4) All physical causes should be temporally prior to, or at least simultaneous with their, effects. *(Grünbaum, 1998; Smith, 1996)*

It should be noted that both Grünbaum and Smith believe that temporal priority or simultaneity is the requirement of all causal relationships. In this case, there would be no causal connection between Ui and Ur even if Ui is considered as an abstract non-physical entity. Some

1. Time is ordered by a relation of earlier/later than, whereas spatial points are not ordered by any such relation. If that relation is essential to the nature of time, then the notion of imaginary time, a sort of spatialized time, is metaphysically impossible.

objected, however, that the generalization of the condition of temporal priority to all cases of causations is accidental and problematic. *(Ref: Craig, 1999; Ibid, 2002)*

Another formulation of the above problem is what *Smith (1997b: 163)* calls “The central problem of quantum gravity ontology”: How is the imaginary time of the Euclidean spacetime connected to the real time of our Lorentzian spacetime?

By analyzing possible answers to the question, Smith shows that there is a contradiction in such models which use the notion of imaginary time.

To those who object that the criticism is based on the applying classical notions of space and time to the Plank era, *Smith (1997b: 165-6)* replies:

> *But a response of this sort misses the point of the criticism. The point is not that the description of the Planck era is inconsistent with classical (general relativistic) concepts. The point is that the temporal description of the relation of the Plank era to the classical era is inconsistent with itself. It is an implicit self-contradiction to assert that a four-dimensional space existed earlier than the earliest time.*

Smith (1997b) himself has proposed a solution to his formulation of the problem, which is highly controversial. He probably recognizing the above inconsistency in the model, has chosen the most implausible option: He sacrifices what is so obvious- that, "the universe in which we exist lapses in real rather than imaginary time"- *(Craig and Smith, 1995: 319)* in favor of his hypothetical model.

He claims that our universe's existing in real time is just an illusion, and "what we call real time is just a figment of our imaginations". *(Hawking, 1997: 144)*

In addition to the above physical and philosophical problems, it is not hard to show that Hawking's analysis of the creation of the world out of nothing is untenable.

Saying that if the addition of two energies equals zero, then they represent nothingness, is similar to saying that since the subtraction of one number from an equal number equals zero, then the numbers are the demonstration of nothingness. Those are the existent energies, whether or not positive and negative, which provide the actual source to create the particles, not non-existent or zero outcome of energies.

Also, branding the particles or energies as either negative or positive is merely a human convention that demonstrates different kinds of existent matter or energy.

Moreover, as we explained already, the quantum mechanical vacuum not only is not truly "nothing", but has a rich structure that resides in a previously existing substratum of space-time, either Minkowski or de Sitter space-time. In other words, virtual particles which appear within a vacuum, are indeed appearing in a space that already exists.

Some *(e.g: Krauss, 2012: 161-170)* have claimed that *quantum gravity* could allow space itself to pop into existence.

However, as we mentioned already, one obvious problem with this claim is that a satisfactory formulation of quantum gravity does not yet exist.

Smith (1997: 298) claims that “zero-three geometry [i.e: A single point] in Hawking-Hartles models is indeed a metaphorical talking of nothingness” and that “[p]roperly speaking, the universe appears from literally nothing, which is only metaphorically a zero three-geometry”.

However, as *Isham (1988: 399-400)* explains, the Hawking-Hartle model presupposes “a single configuration point” upon which the wave function that gives the probability amplitude for the beginning of the universe depends.

Smith, however, believes that there is still no problem with the creation of the world out of nothing in this model. For, “configuration space and state space of quantum gravity cosmology are timeless abstract objects (“mathematical spaces”) rather than physical existents”. *(Smith, 1998: 77)*

That is to say, from *Smith’s (1998: 77)* point of view, “literally nothing” is only incompatible with “the existence of… a concrete object… or concrete event… or… quantum vacuum, empty space or time”, whereas it is entirely compatible with the existence of “the mathematical properties of possible universes”. *(Smith, 1998: 77)*

indeed accepts that the model presupposes the existence of “certain abstract objects, numbers, operations, functions, matrices, and other mathematical entities, that comprise the wave-function equation”.

As it shall be explained later, it is obvious that Smith’s interpretation of nothingness is not what philosophers basically mean by it.

Moreover, Smith does not explain how his abstract world stands in relation to the physical world. It is not clear whether the abstract world is the efficient or material, creative or transformative cause of the physical world. At any rate, the fact of the matter is that the Hawking-Hartle model never elucidates the energy or the vacuum sources, and only represents the law of conservation of matter and energy. This model surely does not explain the *creatio ex nihilo*, but rather merely shows something comes out of something. *(Ref: Deltete and Guy, 1997; Craig, 1997)*

As Grünbaum *(1991: 233)* rightly points out, “such physicists as *Hartle and Hawking (1983)* and *Vilenkin (1983)* speak misleadingly of certain primordial physical states as nothing”.

Physics and *Creatio Ex Nihilo*

So far, we have shown that some physical models, by appealing to the phenomenon of quantum fluctuation, have been formulated to explain the creation of the universe out of nothing. Concerning quantum fluctuations, however, the question that is immediately raised is: what is it precisely that fluctuates?

Any response would imply that there was a specific something, not at all nothing, before the Big Bang. In other words, a quantum fluctuation is described by a wavefunction; there is no quantum mechanics without a wavefunction).

Ney and Albert (2013: 9) begin their book *"The Wave Function"* with the remark that, Wave functions, or some mathematical equivalent of wavefunctions, come up in every quantum theory and in every proposal for making explicit conceptual sense of the quantum theories that we presently have.

Accordingly, wavefunctions describe 'something' which exists, not 'nothing' (quantum vacuum actually refers to entities with real properties, e.g: Zero-point energy that has measurable effects on experiments.).

So, quantum fluctuation is a fluctuation of 'something' not 'nothing'. In effect, many physicists have asserted this obvious point.

These are just a few examples: According to modern physics, a vacuum isn't a pocket of nothingness. *(Yam, 1997: 82)*

Quantum mechanics tells us that the vacuum of space is not empty. *(Gefter, 2010: 29)*

In modern physics, there is no such thing as nothing. *(Morris, 1990: 25)*

A region of seemingly empty space is not really empty. *(Kolb, 1998: 43)*

Quanta, virtual or actual, false or true, are not Nothing, they are definitely Something. *(Estling, 1995: 69-70)*

Quantum mechanics never produces something out of nothing... quantum vacuum is a lot of matter-antimatter potential- not nothing. *(Sarfati, 1998: 21)*

Even *Hawking (2011)* declares that to create a Universe, "you need just three ingredients": matter, energy, and space.

So, the problem still remains: What is the origin of these ingredients?

In sum, the issue with all physical theories is that they have to presuppose some properties and entities to explain the universe's creation.

As *Polkinghorne (1988: 60)* states: Suppose for a moment that such a fluctuation was the actual origin of our universe. It would certainly not have come from something which without great abuse of language could be called "nothing". There has to be a quantum field (or actually; because of the complexity of our world, many quantum fields) given as the source of the fluctuation. The price of the "free lunch" is the provision of those quantum fields".

The common problem of all physical models is that they use the notion of "physical nothingness" which is not a real nothing at all. By this notion, physicists mean empty space in which quantum fields, a non-zero amount of field energy, or a powerful electromagnetic field *(Berdyugin, et al, 2022)* remain.

In effect, "absolute non-existence" sharply differs from "physical nothingness". Thus, no physical model can ever explain *creatio ex nihilo*.

It seems, therefore, that the basic principle of metaphysics, "*ex nihilo, nihil fit*" is correct.

Atkins (2011) however, in response to Willian Craig's insistence that 'something' cannot come from 'nothing', says: "Therd is nnthing here; I will concede that; But it's an extremely interesting form of nothing. There was nothing originally. There is nothing here now; But [through] whatever event happened at the inception of the universe, it became an interesting form of nothing, which seems to be something".

That is, he, as a chemist, claims that the entire universe is actually 'nothing'! Ironically, this position does confirm that "out of nothing, nothing comes". So, the causal origin of the existent universe cannot be "nothing".

There remains another problem for physicists who claims that the laws of physics could have created the universe from nothing.[1] *(Krauss, 2012)* For, if the universe owes its origin to the quantum theory combined with the cosmological model of inflation, "then quantum theory must have existed before the universe.

So, the next question is surely: Where did the laws of quantum theory come from?" *(Chown, 2012: 35)*

Let us briefly mention that any response to this question raises further problems. If the physical laws are the product of singularity, they cannot create the singularity and our universe. If, however, it is assumed that the laws of nature existed pre-Big Bang as some abstract eternal and self-necessary entities, then the emergence of the universe would be from something, not out of nothing.

This assumption also violates some atheists' axiom who believe that "The Cosmos is all that is or ever was or ever will be". *(Sagan, 1985: 1)*

Also, this is a metaphysical speculation and conjecture, not a scientific achievement, and no scientific evidence

1. Interestingly, when Krauss laments that "some philosophers and many theologians define and redefine 'nothing' as not being any of the versions of nothing that scientists currently describe," and that, [he is] told by religious critics that [he] cannot refer to empty space as 'nothing,' but rather as a 'quantum vacuum,' to distinguish it from the philosopher's or theologian's idealized 'nothing'. *Albert (2012)* in his review of the book responds that "all there is to say about this, as far as I can see, is that Krauss is dead wrong and his religious and philosophical critics are absolutely right".

supports such a proposition. On the other hand, if the laws are assumed as contingent temporal entities, then the question of the origins of the laws raises again.

Moreover, the alleged eternal laws are either the customary laws of our universe or some hypothetical hyper laws radically different from known physical laws and entirely outside our experience.

In the latter case, it would be totally implausible and even incorrect to apply rules like the Heisenberg uncertainty principle and quantum fluctuation to explain the universe's creation.

Furthermore, in both cases, even if it is accepted that such laws can play the role of effective cause, it is not imaginable how they could be the material cause of the universe.

To find the universe's origin, *Hawking (2011)* asked: "Did God create the quantum laws that allowed the Big Bang to occur? In a nutshell, did we need a god to set it all up so that the Big Bang could bang?" He, however, offers no answer to the question.

In his critique of Hawking, *Davies (2011)* says: "You need to know where those laws come from. That's where the mystery lies- the laws".

So, as *Gardner (2000: 303)* asserts, "There is no escape from the superultimate questions: Why is there something rather than nothing, and why is the something structured the way it is?

In response, some physicists claim that whoever said, “You can’t get something from nothing,” must never have learned quantum physics; But the fact of the matter is that whoever said, “You can get something from nothing,” must never have learned the meaning of nothing.

Conclusion

In this paper, we tried to evaluate critically the claim that the creation of the universe out of nothing can be explained purely physically by appealing to the phenomenon of quantum fluctuation.

So, firstly, the main assumptions and implications of modern cosmology were explained. Then, the assumptions and implications of the most important physical models based on the phenomenon of quantum fluctuation- i.e: The Tryon-Vilenkin and Hawking-Hartle models- were critically evaluated.

It was shown that these models are indeed explaining the creation of the universe, not out of nothing, but from something.

In the final section, it was demonstrated that no physical theory can ever explain the creation of the universe out of nothing by appealing to the laws of nature.

The outcome of the paper is that the *creatio ex nihilo* of the universe out of nothing can only be explained metaphysically by appealing to some external causes.

In this final part, it is worth mentioning that from the Muslim philosopher's point of view, any physical cosmology completely accords with the theistic idea that God has created and always sustains the universe continuously. For, the universe in its totality is indeed a contingent entity, and hence needs an agent cause as the creator of the world.

Moreover, God is the continuous sustainer of the world such that without the grace of God, the world with everything within it will be destroyed immediately. *(Ref: Ibn-Sina, 1979, Vol 3: 2-28; Mulla-Sadra, 1981, Vol. 2: 212-219; Ibid, Vol. 3: 244-278; Ibid, Vol. 5: 194-246)*

According to this, Pure Fitrah leads human beings to recognize that there is a creator for our universe, while one whose fitrah is polluted (Atheists) deny the existence of God. *(Fahs and al-Askari, (2021: 27)*

So, even if a physical model can explain the creation of the universe out of nothing, it does not imply that the world can come into existence and survive without Divine grace.

Interestingly the same view is held by some Christian theologians who believe that all physical cosmologies, and in particular quantum cosmology, completely accord with the traditional theistic idea that God always sustains the universe continuously. *(Craig, 1993; Drees, 1988; Ibid, 1990; Ibid, 1991)*

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