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Modern Cosmology and the Problem of the Beginning of the Universe

In this paper we shall discuss the views of modern cosmology regarding the beginning of the Universe, together with some theological ideas arising in connection with this. We shall mainly concentrate on those theories that are based on some physical observations and axioms that may be said to be more or less established within the scientific community. One needs of these presupposed theories is Einstein's general relativity, along with the standard Friedmann model of an expanding Universe that follows from it.

There is, without doubt, a great deal of speculation today regarding both the notion of a universe without a beginning and the quantum origins of the Universe. Some of this makes use of the idea of the wave function of the Universe, where this is applied in order to achieve a quantization of gravity.[1] Unfortunately one need only recall the words of the famous American physicist M. Gell-Mann, uttered on another occasion, but nevertheless also valid with respect to the status of quantum gravity, to the effect that "this theory suffers from the disease of nonexistence!"

[1] Hawking, *A Brief History of Time*; Vilenkin, *Many Worlds in One.*

That is not to say that we would reject all speculation about quantum gravity: it is quite possible that some of this will survive in future theories. Nevertheless, it would be premature to discuss today something not proved either by physical observation or established theory like quantum physics with its Copenhagen interpretation confirmed by the sheer number of its physical applications.

The existence of the wave function of the Universe is still a very dubious idea, because the main justification for it is found in the EVERETT many-worlds interpretation of quantum physics, which itself remains highly controversial. What remains unresolved in this interpretation is not just the notion of probability and actual occurrence of a "splitting' of one universe into many, but also, due to the unitary character of evolution and its reversibility, that of a "merging" of different universes.[2]

Non-commutative geometry, which resembles the generalization of the so-called algebraic formulation of quantum physics, comes closer to the standard formulation of quantum theory.[3]

The name for the process by which the Universe is thought to have originated is the 'Big Bang'. The Universe, as observed by telescopes on Earth and on various satellites in space, is expanding in time, and this expansion is observable in the form of the red shift of the spectral lines of far off Galaxies.

The expansion of the Universe was predicted as a consequence of EINSTEIN's General Relativity by the Russian scientist Alexandre Alexandrovich FRIEDMANN in 1922,[4] and experimentally confirmed in the USA by E. HUBBLE in 1929. In fact, it is the expansion of the space of the Universe, and this is why the beginning of this expansion marks the beginning of space and time themselves. Hence it is not a beginning that itself occurs "in" time or "in" space.

According to modern observations, the Universe is 13.8 billion years old. The point (or in some models, surface) of the beginning of time is referred to as the 'cosmological singularity'. This expres-

[2] SAUNDERS et. al. *Many Worlds?*
[3] HELLER, *Creative Tension.*
[4] FRIEDMANN, Über die Krümmung.

sion was introduced by G. Lemaître in 1931.[5] Singularities resulting from the General Theory of Relativity occur not only in cosmology, but also inside black holes. The general property of singularities is that at a singular point the time line is cut. It is not that something "in time" is finished, but rather that in General Relativity — this being itself the physics of time — time itself can disappear… Today we are thus witnessing the appearance of a quite new science — the physics and mathematics of singularities.

Inside black holes one can have — depending on their rotation — different kinds of singularities: these can be space-like, time-like or light-like singular surfaces (every point of which is a singular point.)

A great deal of attention is paid in cosmology both to the singularity of the past — i.e. the Big Bang, understood as the Beginning of the Universe — and to possible future singularities, such as the Big Crunch and Big Rip, understood as the end of the Universe. Big Rip would mark the end in the event of a too-rapid expansion of the Universe, providing a phantom field can exist in Nature. The Big Crunch, on the other hand, represents the collapse of the Universe.

Right from the moment that the cosmological singularity was discovered, a lively discussion has ensued between physicists , philosophers and theologians, about what it could mean.

Alexandre Friedmann, in his book "The world as space and time",[6] has written: "On the basis of a self-evident analogy, let us call the time interval required for the curvature radius to grow from zero to some R the time from the creation of the world".

Meanwhile Pope Pius XII, who was familiar with astronomy and remained in close contact with the scientists of the Vatican observatory, wrote in his encyclical[7]: "So, with all of the evidence typical of a physical proof, modern science has confirmed that the existence of the Universe is not necessary, where this has furnished us with conclusions about the time when the world arose at the hands of the Creator."

[5] Lemaître, The Beginning of the World.
[6] Friedmann, *The World as Space and Time*.
[7] Pius XII, Le prove della esistenza.

The official Soviet philosophers — marxists, in the Soviet Union — came to very much the same conclusion as the Pope: a singularity of an expanding Universe provides an apologia for both idealism and the clergy ("popovshina"). The result was that university students in the Soviet Union were not permitted to study relativistic cosmology! At the same time, it was proclaimed that the Universe is, and must be, eternal in time and infinite in space.

One must, however, mention that another discoverer of the expanding Universe, who predicted the red shift of spectral lines as its experimental consequence, Abbot George Lemaître, wrote more tentatively that "As I understand it, a theory of this type stands completely apart from any metaphysical and religious questions. It leaves the materialist free to dismiss any transcendent Being: he can adopt the same reasoning for the depths of space-time as for non-singular points in it. For the believer, it removes any attempt at closer acquaintance with God [...] corresponding to the words of Isaiah about a 'Hidden God', perhaps? Hidden, that is, even at the point of Creation itself".[8] We shall discuss the theological differences between these two contrasting views — those of the Pope and of Lemaître — in due course.

Even so, one can hardly fail to see the connection between these words of Lemaître and his activities in the 1940s and 1950s, when he was engaged in a search for models of an "eternal" Universe without a beginning or an end. And one may also recall the remark of Einstein, who characterized Lemaître's idea of a singularity as "a tribute to his religious views."

Does this mean, then, that Einstein himself had the same view as the Pope?

And how did cosmology and the discussion of its implications develop later in the 20th century?

At first, the majority of physicists thought that the notion of a singularity implies some sort of incompleteness on the part of General Relativity — as with, for example, the Coulomb potential in electrodynamics. This potential goes up to infinity at the initial point, but

[8] Lemaître, *L'Hypothèse.*

according to quantum theory some screening effect is supposed to arise over small distances, which then precludes an infinite value for the force. Is the situation with a cosmological singularity the same?

This looked so reasonable that in an early version of the textbook on theoretical physics of Landau and Lifshitz[9] it was claimed, on the basis of the work of E.M. Lifshitz and I.M. Khalatnikov (which was later proved by the authors to be mistaken), that the most general anisotropic solution of Einstein's equations consistent with the expansion of the Universe was one that involved no singularity at all!

However, in the UK in 1965-1967, R. Penrose and S. Hawking proved a general theorem according to which there must be a singularity involved in any mathematical model of the Universe that is consistent with General Relativity that is either isotropic or anisotropic, and that features both expansion and gravity manifesting itself as attraction!

After this, Belinsky, Lifshitz and Khalatnikov found a mistake in their paper, and proved that one has a singularity even in an anisotropic solution for an expanding Universe. Hence, in more recent editions of the textbook of Landau and Lifshitz,[10] everything is correct.

In 1965 the American engineers Penzias and Wilson discovered by radar the primordial radiation or "first light" of the Universe, which is thought to have existed before the originating of the stars themselves...Today, this light is invisible, as it is in the form of radio waves. However, in the early Universe it was visible, and the sky was not dark, so that during the so-called recombination era the whole sky was shining like a sun.

Calculating on the basis of observation the density of this radiation, one can arrive at an important feature of the Universe: the local density of the entropy of the Universe itself. This turns out to be finite, and is equal to the ratio of the number of photons of primordial radiation to the number of protons. This number is equal to one billion. The finiteness of this value excludes many otherwise quite rationally in-

[9] Landau & Lifshitz, *Field Theory* (1962).
[10] Landau & Lifshitz, *Field Theory* (1967).

telligible models of a temporally infinite, “eternal” universe, because in these one is required to have an infinite “memory” of an infinite past, equal to the local entropy, which itself must also be infinite!

Hence it makes more rational sense to think of the Universe as temporally finite. One may recall here the words of G. Lemaître, that “the Universe is reasonable because it is finite! In a universe that is infinite in space and time one has the “nightmare” of infinity. It is impossible to explain anything in it, because for any cause one will have to look beyond, for a preceding one, and so on… to infinity”.[11]

As it happens, one of the first men to speak about the finiteness of the Universe was not a scientist, but the American poet Edgar A. Poe, who said that “the Universe must have had a beginning in the past, because the sky at night is dark!”

This is a popular version of the Olbers paradox,[12] which uses only such simple notions as the finiteness of the velocity of light, of the number of sources, and of the time of its propagation from source to observer.

The experiments known as COBE, WMAP recently PLANCK, conducted at the end of the 20th and beginning of the 21st centuries, have made it possible to measure the age of the Universe more precisely: it is close to 13.8 billion years old. Hence Friedmann’s expanding universe model is today simply known as the “standard model”. But what is the situation today as regards the problem of singularity?

Certain paradoxical implications of the Friedmann model for the very early phase of the Universe’s existence — such as the paradox of causality (Why do disconnected parts of the Universe have the same temperature?) and the paradox of flatness (Why is space in the early Universe so close to Euclidean flat space?) — have led many scientists to conclude that there must have been another era prior to that of Friedmann expansion itself. This is known as the ‘inflation era’, and is dominated not by matter or light but by so-called ‘dark energy’, involving a special inflation field.

[11] Lemaître, *L’Hypothèse.*

[12] Grib, *Basic Concepts.*

During this era gravitation is supposed to have manifested itself not as attraction but as repulsion. This dark energy is observable even in the modern era of the Friedmann Universe itself, over large distances, but in the inflation era it was far stronger.

So it seems that given the overturning of the attractional character of gravitation, the Penrose-Hawking theorem will not be valid for this case, and a path to the embracing of "eternal" universes with inflation is opened up.

Yet it has also transpired that this is wrong. The American physicists A. Borde, A.H. Guth and A. Vilenkin[13] have proved a more general theorem than that of Penrose and Hawking to be valid for gravitation as repulsion. According to this, for any (on average) expanding Universe with positive energy of matter (weak energy condition), there must have been a singularity in the past.

The consequences of this theory are as follows:

1. Cyclic (or oscillating) universes will have to be excluded. The example of such a universe first discussed by A. Friedmann[14] is that which is popular in Indian mythology: before the onset of our expanding universe there existed some other universe which, after its expansion, collapsed down to a small volume — this then being the beginning of our universe. One could imagine an infinite number of such universes following one after another. In order for this to be free of infinite entropy (memory) one could follow the idea of Tolman. In spite of the existence of the collapsing era, in any subsequent universe the expansion would have to be larger, so that the "average" for cycles' expansion is not zero. If one takes into account the sequence of cycles, then one must suppose that the volume of each subsequent universe increases in time in such a manner that even though overall entropy grows, the local entropy obtained by dividing the whole entropy by the volume always remains finite!

Even so, the theorem cited prohibits an infinite number of such universes: there must still be a beginning.

[13] Borde, Guth & Vilenkin, Inflationary space-times.

[14] Friedmann, *The World as Space and Time.*

2. Eternal inflation. According to this conception, when inside some inflationary expanding universe one has a bubble consisting of a false vacuum, giving birth to another inflationary universe, so that it then becomes possible to speculate about the existence of an infinite number of such universes in the past. The entropy paradox is to be solved, then, by means of Tolman-style reasoning. This scenario will also now be forbidden.[15]

This theorem certainly does not exclude temporally finite universes that are without any singularity, but which involve some version of the idea of spontaneous quantum origination of the universe in question from nothing. This would include the proposals of S. Hawking and A. Vilenkin. However, as we said earlier, if one is to take these proposals seriously one must subscribe to the idea of the wave function of the Universe, along with the Everett many-universes interpretation of quantum physics, which is still very far from being confirmed.

What this means, then, is that one must take singularities seriously! It means that instead of trying to avoid them, one must construe them as novel features of space-time itself. In conventional space-time, objects such as tables, trees, etc., are allowed to have "edges", so why should we rule out the possibility of some world-lines or regions of space-time itself "terminating" at certain points or surfaces?

Thanks to the activities of scientists such as Geroch, Tipler, Hawking, Ellis and Penrose, we can formulate certain conceptions pertaining to the science of singularities in General Relativity.

A singular point is a point where the curvature tensor (more exactly the invariant formed from it) is infinite. But such a point cannot be contained in space-time. Therefore everything in the Universe will have its beginning in the point of cosmological singularity, but it (i.e. the singularity itself) will not belong to it! Moreover, this point corresponding to the Big Bang can be defined mathematically as the set of all time-like geodesic lines that converge together as one passes

[15] Borde, Guth & Vilenkin, Inflationary space-times.

further into the past — a set that may be considered to constitute one object!

Indeed, there is one particularly salient property of this point — one that has made it a topic of discussion amongst both physicists and theologians. This is the property known as "Hausdorff non-isolatedness".[16] What this amounts to is that in spite of the fact that it counts "for us" as located very far in the past — some 13.8 billions years ago — "the distance from it to us" is in fact zero! The point describes a global property of a universe containing a beginning within itself.

In his popular book Hawking[17] compares the beginning of time with the North Pole. If somebody asks what lies north of Paris, one can answer 'London', if they ask what lies north of London one can say 'Edinburgh', etc. But what lies north of the North Pole? Everything lies to the south of it. The notion of something being north of the North Pole makes no sense… Likewise, the notion of "earlier" makes no sense when one is speaking about the beginning of time itself.

Is that a complete answer? Within such reflections one thing not taken into account is the important property of time known as 'Becoming'. In both Special and General Relativity there is no Becoming in time; instead, there is a so-called 'block universe' in which time and space are treated along the same lines. Becoming certainly figures in quantum physics, though, and, as has been proved by the breaking of the so-called Bell's inequalities, it occurs due to measurement. So the beginning of time, as the beginning of Becoming too, must be some sort of act!

Can quantum gravity provide some sort of solution to this problem?

To complete our overview of how things stand in modern physics with respect to the beginning of the Universe, let us offer some additional remarks about singularities.

It is sometimes said that if the Universe, in the past, was very small, then it could have had, for example, the size of a human finger.

[16] Tipler, *The Physics of Immortality.*

[17] Hawking, *A Brief History of Time.*

But how can one imagine all one hundred billion galaxies, with the same number of stars as now, compressed into such a small volume? Is the density of matter in a singularity also infinite — and what could the physics of all that be like? We have given an answer to this question in the papers summarized in our book.[18] There was no infinite density of particles close to the beginning, because there was no matter in the form of particles at that time. Particles and galaxies were created from a vacuum later, by the gravitation of the expanding Universe. There was an period of particles being created prior to that of the first nuclei being created, and so on. Today, gravitation is small, and particles are not created. They will also not be created if the gravitation of the expanding Universe is very strong, approaching a singularity. But there is some period during which, from its outset, time has the order of Compton time, defined by the mass that the particle has once the process is underway. An observable number of visible particles (the Eddington number) will be obtained, if superheavy particles with a mass of the order of the Grand Unification scale are created, and these then decay on visible particles. However, one may also suppose that there was an inflationary period prior to the era of particle creation, with either an inflation field or dark energy playing the role of matter. Yet, as has been shown by V. Belinsky, E. Lifshitz and I. Khalatnikov,[19] in the general case of anisotropic space-time one can safely ignore the matter component in Einstein's equations, so that a singularity can even exist in a vacuum.

Now it is time to turn to the theological and philosophical discussions surrounding all of this.

The existence of a cosmological singularity in the past means that the physical Universe is not "self sufficient": it cannot be explained using physical laws derived solely from itself. In a sense, this is analogous to Gödel's theorems in mathematics, showing that mathematics, or at least the ideal world of mathematics construed as some sort of formal system, is not self-sufficient. In a sense, this is similar to the situation with the existence of a person as "me". I am not self-

[18] Grib & Rodrigues Jr. *Nonlocality.*
[19] Landau & Lifshitz, *Field Theory* (1967).

sufficient, because in order to understand myself, I must appeal to something external to me.

This can be construed as an apophatic definition of what is meant by the idea of the Universe being created out of nothing by God. The claim that "the Universe was created by God" may thus be considered equivalent to an affirmation of the non-conformity of the Universe to the totality of its own laws.

Here one may also recall G. Lemaître, and say that a "pessimistic atheist" could agree with all this, declaring that our Universe is, unfortunately, not self-sufficient... In opposition to this, though, an "Optimistic believer" might say that crushing the idol of the self-consistent Universe leaves one free to pray to the One who is higher than the Universe itself.

There have also been attempts to arrive at a cataphatic (i.e. positive) theological interpretation of the cosmological singularity. For example, in his books F. Tipler[20] goes so far as to identify the singularity with God.

Everything in the Universe, including its own laws, is taken to have originated in the past singularity. As we said earlier, the "distance" from the singularity to any event in the Universe is zero, even though the distance from us to it remains large: it is very far away in the sky (i.e. the astronomical sky) — some 13.8 billion light years away.... There has been some theological speculation about the meaning of such notions as "far", "close", "higher", "heaven" and even "distance" (see the Scottish theologian T. Torrance,[21] and the Russian theologian Y. Druskin) when speaking about the relation of human beings to God. These speculations are close to those of Tipler. One might even recall Newton's insistence on God's use of absolute space in his relation with us and with everything in the Universe. So, in spite of Tipler's critics, there is room for fruitful discussion here.

Nevertheless, one should be careful about this sort of use of mathematics and its applications to physics. We have already considered

[20] Grib, Mamayev & Mostepanenko, *Vacuum quantum effects*; Tipler, *The Physics of Christianity*.

[21] Torrance, *Space, Time and Incarnation*.

the absence of any notion of "temporal becoming" in General Relativity. To this one might also then add that singularity is defined as a geometrical property — as a set of all lines terminating in the past. This does not mean that besides such lines, it will also contain all the creatures that happen to be located on these lines. At any rate, this is by no means clear.

Apart from a past singularity, there can also be a future singularity — constituting the End of the Universe. Even more: one can also speak about the possibility of a "present" singularity.

General Relativity opens up the possibility of there being solutions to EINSTEIN's equations that lead to an expanding Universe terminating at any moment in time, thanks to a "weak singularity": at any moment in time, then, time itself can terminate. Such solutions are described as "incomplete", in contrast to the typical FRIEDMANN solutions involving the Big Bang and Big Crunch, which are said to be "complete". This means that the Universe is non-sufficient even in the sense that it is not evident that it is guaranteed that at any immediately subsequent moment one will see the same Universe with the same laws and that it will exist.

Here one may perhaps be tempted to recall the theological idea of "continuous creation": God preserves the Universe from annihilation, "giving being to its being". And unlike in the English translation, in the Slavic translation of the Credo from Greek, God is not called "Almighty" but "Vsederjitel", i.e. the "All-keeper". The Universe exists because it is kept by God.

Summing up, it is worth remembering the words of the Polish theologian Y. ZHICHINSKIY,[22] who referred to theological speculations of the kind pursued by TIPLER as "a mysticism of the singular point", manifesting a theology of a "God of the gaps".[23]

The apophatic interpretation of the singular point surely seems preferable, though. Yet this need not mean that no general positive points can be found in modern discussions of cosmology and theology. In any case, there is here a point where both sides – physicists

[22] ZHICHINSKIY, Nothing or Logos?

[23] TIPLER, *The Physics of Christianity.*

and theologians – are presented with a fine opportunity to engage in potentially fruitful discussions and disputes.

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