CONTEMPORARY COSMOLOGY AND "*CREATIO EX NIHILO*"

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Abstract

We introduce Einstein's theory of General Relativity and Einstein's equations. We discuss a particular solution of Einstein Equations, the Friedmann-Lemaitre-Robertson and Walker (FLRW) metric which is homogeneous and isotropic. FLRW represents the beginning of Relativistic Cosmology, that is a cosmology based on Einstein Theory of General Relativity. We also briefly introduce the concepts of Dark Matter and Dark Energy which, together with FLRW, constitute the basic ingredients of ΛCDM model, or standard model in Cosmology. Fr. George Lemaitre was one of the scientists who found the FLRW solution. He is considered the father of modern Big-Bang. We describe how he introduced the theory of the primeval "atom" which is basically the Big-Bang hypothesis to which it was opposed the Steady State Universe of Fred Hoyle. This dispute became more heated when Pius XII, in 1951, alluded that the Big Bang and creation in the book of Genesis, in the Bible, seemed to be in agreement, winking at a concordist position typical of neotomist theology. It is very likely that Lemaitre was the pontiff's chief adviser on the danger that this position entailed both on the theological and scientific level. He will always be a proponent of a clear split between the theological and scientific plans considered as "parallel and never intersecting". The discovery of cosmic background radiation (CMB) in 1965 marked the triumph of the Big Bang theory which is still used nowadays. We will also deal with the problem of finding a physical theory which describes the first moments of the universe, Quantum Gravity, the Hartle-Hawking solution and its consequences for the debate between science and theology. We will illustrate how in Christian theology the concept of creation is completely different from the demiurge god invoked by certain positions of deisms. In fact, many scientists fear that in order to explain the origin of the Big-Bang we need to introduce a deistic idea of God who starts the process of the Universe.

INTRODUCTION

The Universe, as we know it nowadays, started with a very hot and dense phase, which is usually called Big-Bang, 13,83 years ago. From 0 to 10^{-43} s., which is called the Planck era, there is an agreement in the scientific community that the Universe was behaving according to the laws of Quantum Mechanics or, better, the gravitational field should have been a quantum field theory of gravity. Quantum fluctuations drove Cosmic inflation and were responsible of structure formation. Cosmic inflation was a very fast, exponential, expansion of the Universe at a rate much bigger than today. It has happened right after the Big-Bang. Around three hundred seventy-five thousand years after the Big-Bang the first light of the Universe was emitted. This light can be still detected, and it is the famous CMB (Cosmic Microwave Background) radiation. After the age of CMB there was a period

called the dark ages and the first star was formed around four thousand years after the Big-Bang. Successively Stars, Galaxies and Planets formed. The Universe continued to expand. According to the laws of gravity this expansion should happen in such a way the universe decelerate since gravity is an attractive force. Recently it has been proved that the universe is accelerating due to presence of dark energy.

The plan of this paper is to make a short introduction to our physical Universe, we will discuss the Standard Model in Cosmology (also called ΛCDM) and the recession of the galaxies (Hubble-Lemaitre law). We will expose the Big-Bang model and the related "Primeval Atom" hypothesis of George Lemaitre and we will confront and contrast this model with the Steady State Universe of Fred Hoyle. We will continue with Pius XII discourse "Un'Ora" delivered to the Pontifical academy of science in 1951 and the problem of concordism in theology. We also discuss the Hartle-Hawking proposal in Quantum Cosmology and its theological consequences. We will, finally, introduce and explain the Christian doctrine of "*Creatio ex Nihilo"*.

GENERAL RELATIVITY AND RELATIVISTIC COSMOLOGY

Albert Einstein is rightly considered one of the physicists who, more than others, made fundamental contributions to 20th century physics. He tried to formulate a theory of gravity as field theory and not as a force that is an "action at distance"as in Newton's theory. In this a massive body feels "immediately" the presence of another body, and we can say that this scheme implies a propagation with an infinite speed of gravitational perturbation. Of course Einstein was familiar with Maxwell's electromagnetism and, rightly, wondered how gravity could be described not as an action at distance but as a field whose perturbations propagate with the speed of light. To answer these questions, Einstein took ten years after Special Relativity and finally came to the formulation of General Relativity in 1915. This theory represents, in the history of physics, the beginning of a union between physical theories and complicated mathematical theories. In fact, General Relativity would not exist without Riemannian Geometry, or rather the Lorentzian Geometry. The General Theory of

Relativity is based on two fundamental postulates: the gravitational mass of each body is equal to its inertial mass. That is, the numerical value of the mass for which two bodies attract is equal to that of the inertial mass, which indicates how a body is opposed to movement. The second postulate is the principle of covariance which says that the laws of physics are the same, therefore covariant, in every reference system. In particular, "non-inertial" reference systems are included, i.e. those that have relative acceleration one respect to the other. In the theory of Special Relativity, the velocity between two reference frames is always constant. Now Space-Time becomes a physical entity, no longer an indifferent actor to physical phenomena happening in it like in ordinary physics, but it is modified by the presence either of massive bodies or, equivalently, energy. Massive bodies or energy, in fact, change Space-Time, which acquires curvature. In this way gravity is no longer a force at a distance but becomes a field[1]theory. This means that if I have a body of mass m_1 and perturb its position, another body of mass m_2 feels the displacement (perturbation) of the position of m_1 not immediately, but after a time equal to the one that takes the light to travel the distance between the bodies m_1 and m_2. One consequence of all this is that if a ray of light is emitted by a distant star and the Sun is between the star and us, then it is deviated by the curvature generated by the mass of the Sun. Therefore, the apparent position of the star with respect to an observer on the Earth does not coincide with its real position because its light rays are deviated by the Sun.

Immediately after the publication of the theory of General Relativity, many physicists and mathematicians made many efforts to derive exact solutions of Einstein's equations. Friedmann, Lemaitre, Robertson and Walker (FLRW), independently, noticed that if one assumes that the distribution of matter in the universe is homogeneous and isotropic, on a large scale, the solution of Einstein's equations predicts a universe that is, in the spatial part, the (three-dimensional) surface of a four-dimensional sphere whose radius represents time. This sphere expands and then the universe expands over time. To make a heuristic analogy, three-dimensional space behaves as if it were a two-dimensional spherical surface on which all galaxies and all other elements of the universe are located.

[1] A good reference to this first part on the General Theory of Relativity can be found in Cfr. S. Weinberg, *Gravitation and Cosmology*, New York, New York, USA, John Wiley and Son, 1972, 67-70, 91-93.

Like a balloon, if we inflate the balloon the distances of the points on the balloon increases, so, in analogy, the distance between galaxies increases over time. Einstein did not like this solution. He called it "abominable". For this reason, he modified the equations of General Relativity, his equations, by introducing a constant, called a cosmological constant, which provided, as solution, a static universe, which didn't expand. However, the measure of the recession of the Galaxies by Hubble and, before that, the red-shift of the spectral lines of the light coming from stars gave an observational evidence that the universe was actually expanding. Knowing this, Einstein said to have done the biggest mistake of his life[2].

But if the universe expands then there must have been, going back in time, a primordial epoch in which the universe was very tiny. This was the idea of the Belgian priest and cosmologist George Lemaitre, who hypothesized that at the beginning of time the universe should have been of the size of an atom (which he called the "primeval atom"), and therefore the laws that governed this "primeval atom"- universe were those of quantum mechanics[3].

This theory of the evolution of the primordial universe aroused many suspicions among many scientists who noticed a too close concordance with the biblical narrative of creation in Genesis. Fred Hoyle, an English astrophysicist, called Lemaitre's primeval-atom theory the "Big-Bang". He elaborated his own theory of evolution of the universe called the Steady State Universe. In this theory the universe expanded but maintained a constant energy-matter density, so that the universe had no beginning and no end. However, to keep the density constant it was necessary to assume a continuous production of matter-energy.[4]

The two theories of evolution of the Universe were antagonistic for several years. Things got quite complicated around early 1950s, when on November 22, 1951 Pope Pius XII, who was surely one of the most attentive pontiffs to science, gave a speech, in Italian, entitled*" Un'Ora"* to the Pontifical

[2] Cf. Ibid., 407-458.
[3] Cf. D. Lambert, *The Atom of the Universe*, Cracow, Polonia, Copernicus Center Press, 121-145.
[4] Cf. S. Weinberg, *Gravitation and Cosmology*, New York, New York, USA, John Wiley and Son, 1972, 459-464.

Academy of Sciences[5] in which he seemed to suggest that the cosmological theory of the Big-Bang confirmed the biblical account of the creation of the world in Genesis. In this talk, of clear Neo-Tomist structure, he repeated the five "ways" of the existence of God of St. Thomas Aquinas especially the I and V, based, respectively, on mutability and purpose. In the one on mutability, following the neo-tomist strand, he brought to support mutability the very fact that natural sciences registered a chain of continuous transformations in phenomena. As for finality in nature, he interpreted the second law of thermodynamics, according to which, in natural processes, the entropy of a closed physical system always increases as a sort of finality in Nature. This theological position in which scientific phenomena and theories were used to confirm theological positions was later named "Concordism". Lemaitre was always suspected his theory of the Primeval Atom wanted to support creation narratives in the Bible. He felt that Pius XII's speech was a further and very dangerous threat for his Big-Bang theory. There was also another probable problem looming on the horizon because the following year the meeting of the International Union of Astronomy (IAU) was to be held in Rome and Pius XII had been invited to deliver the inaugural speech. Lemaitre then flew from South Africa, where he was, to Rome where, with the help of P. O'Connell, S.J. director of the Vatican Observatory and quite close to the pontiff, met Pius XII. Of course, it is not known what the topic of the discussion was during their meeting. The fact is that Pius XII on 7 September 1952 gave the inaugural address to the IAU but made no mention of the Concordism.[6]

For his part, Lemaitre continued to keep and profess that the theological and the scientific planes were two independent "magisteria" as two parallel planes that did not intersect. In 1965, two scientists from Bell Laboratories, Penzias and Wilson, detected radiation on the wavelength of microwaves by a large antenna built for astrophysics purposes. The radiation was homogeneous and isotropic, with a temperature of about 3 degrees Kelvin. This radiation, now known as the Cosmic Microwave Background Radiation (CMB), represents the first light emitted from the universe 380,000

[5] Cf., Pio XII, *Un'Ora*, (http://w2.vatican.va/content/pius-xii/it/speeches/1951/documents/hf_p-xii_spe_19511122_di-serena.html).
[6] Cfr. Józef Turek, « George Lemaître and the Pontifical Academy of Sciences», in *Vatican Observatory Publications* 1989 2-n.13 167-175.

years after the Big-Bang. Before, the Universe was too dense and every photon emitted was reabsorbed. The CMB could only be explained by the theory of the Big-Bang and not the Stationary State [7].

The current model of the universe accepted by the scientific community tells us that the Universe, in which we live, was born 13.83 billion years ago from a very hot and dense phase with a cosmological singularity called Big-Bang singularity. Singularity means that in the beginning of the Universe, Einstein's Equations are no longer predictive. Soon after, the Universe underwent a great expansion, much more than the one with which it expands now, an exponential expansion known as "inflation".

DARK MATTER AND DARK ENERGY

In recent years, astronomers have noticed that, studying the distribution of the radial velocity of matter as function of the distance from the center of galaxies, the mass observed does not explain the velocity distribution. The measurements of the radial velocity distribution can be explained well if one makes the hypothesis that there exists more matter than the observed one. This extra matter has been called Dark Matter, because it is not visible in the optical range[8]. This matter does not interact with radiation and it does not loose sufficiently kinetic energy to relax into the disk of galaxies, as it does baryonic matter (matter which is composite of more elementary particles called quarks (at least three) and interact through the strong force). This implies that this sort of matter is electrically neutral and it has been found that its velocity is far from being relativistic, therefore it is called *Cold*-Dark Matter.

The study of a double galaxy cluster 1E0657-558 (the "bullet cluster") has confirmed the existence of cold Dark Matter, which has only gravitational interaction with itself and with baryonic matter[9]. The amount of Dark Matter in the universe amounts at 26,8 % of the total matter according to

[7] Cfr. S. Weinberg, *Gravitation and Cosmology*, cit. 511.
[8] Cfr. P. Peebles, *Principles of Physical Cosmology*, Princeton (NJ), USA, Princeton Series in Physics, 1993.
[9] Cfr. S. Weinberg, *Cosmology*, Oxford, UK, Oxford University Press, 2008.

the recent measurements of the Planck satellite[10] [11]. Dark Matter behaves, gravitationally, as completely ordinary matter; for example, it causes gravitational lensing[12].

In the early eighties of the last century, the mechanism of the cosmological constant was reconsidered for explaining an early period of the Universe in which it began to be thought that the Universe have expanded very fast, with an exponential rate. This hypothesis was later called Cosmological Inflation. In fact, the puzzling thing was that Cosmic Microwave Background Radiation resulted at thermal equilibrium. Without invoking the mechanism of Cosmological Inflation, FLRW metric solution of Einstein's Equations has a "particle Horizon", which means that not all the different regions of the Universe could, originally, be causally connected and then at thermal equilibrium.

Cosmological Inflation, with an exponential expansion, implies an acceleration opposite to the gravitational attraction. This phenomenon is believed to be caused by the quantum vacuum of a field called the "Inflaton". This vacuum has generated a huge contribution in the Einstein's General Relativity Equations driven by the cosmological constant, the same that Einstein introduced and withdrew when the galaxies' recession was discovered[13]. This produces in the equations of motions, in which one imposes the FLRW metric solution with matter that behaves as a fluid, a negative pressure, which gives reason to the emergence of a sort of anti-gravity force[14]. This anti-gravity force explains a primordial huge expansion.

In 1998 observations of Type Ia supernovae showed that the Universe is expanding accelerating[15]. This result implies, as in the case of Cosmic Inflation, that there exists a kind of force, which is opposite to Gravity. The mechanism known, up to now, to explain this antigravity force is "Dark Energy". Dark Energy is believed to be the vacuum point (zero point) energy of fundamental quantum fields. In fact, the zero-point energy of the harmonic oscillator, which is, basically, the system

[10] Cfr. Planck Collaboration, «Planck 2015 results XIII. Cosmological Parameters», in 2016a *Astronomy &Astrophysics*, 594 A13.
[11] Cfr. Planck Collaboration, «Planck 2015 results XIV. Dark Energy and Modified Gravity», in 2016b *Astronomy &Astrophysics*, 594 A14.
[12] Cfr. S. Weinberg, *Cosmology*, cit.
[13] Cfr. R. Wald, *General Relativity*, Chicago (IL), USA, Chicago University Press, 1984.
[14] Cfr. S. Weinberg, *Cosmology*, cit.
[15] Cfr. S. Weinberg, *Cosmology*, cit.

on which any quantum filed theory is based, is not zero but has a finite value. The sum of all these vacuum modes, for each fundamental interaction, generates an energy ("Dark Energy" because one does not see it), which is present in the Einstein's Equations via the cosmological constant term (again). The last cosmological measures, obtained through the Planck satellite, seem to point out that the best theory capable to explain the cosmological measures is ΛCDM, that is the Einstein's theory of General Relativity with Cold Dark Matter and Dark Energy. In the ΛCDM theory, the amount of Dark Energy is 68,3 % of the total Universe mass[16] and Einstein's General Relativity still remains the theory that explains better the cosmological data than other theories of gravity (called alternative theories of gravity).

QUANTUM GRAVITY AND SOME CONSIDERATIONS ON SCIENCE AND THEOLOGY DEBATE.

Now we will talk about the "quantum era" of our universe, what Lemaitre had called the primeval atom, because it gave rise to many debates on issues of science and theology. As it is generally believed, quantum gravity is a phase of our universe that goes from the initial moment of the universe (time t=0) to Planck's time which is about 10^{-43}s. It's a very small interval of time in which Einstein's equations, which we talked about above, lose predictive meaning. Majority of scientists thinks that this breakdown of the laws of the gravitational field signal the need to combine two worlds of physics that seem irreconcilable: quantum mechanics, which provides physical laws for particle behavior at the atomic and subatomic level, and Einstein's General Relativity, which describes the behavior of bodies on large scales beyond the galactic ones. This theory that should (the conditional tense is necessary since we do not have yet any definitive theory) combine general relativity and quantum mechanics is called Quantum Gravity. One of the first approaches to Quantum Gravity is the so-called canonical approach, which basically consists of define a Hamiltonian theory and to pin down an equation for the

[16] Cfr. Planck Collaboration, «Planck 2015 results XIV. Dark Energy and Modified Gravity», in 2016b *Astronomy &Astrophysics*, 594 A14.

wave function that should describe the entire early universe. This equation is called Wheeler-DeWitt [17] and lacks of the time variable, so it is said that the wave function of the early universe is timeless. This fact has caused a lot of confusion, but it should be clarified that a parameter of evolution is still necessary to describe the evolution of the universe. For example, in some cases, as the universe expands anyway, the volume of the universe is used as a parameter of evolution.

Hartle and Hawking have come up with a solution to the Wheeler-DeWitt equation that goes by the name of "Hartle-Hawking proposal". This solution is quite mathematically complicated and aims to eliminate the problem of the initial singularity. The Hartle-Hawking solution proposes a kind of phase transition at Planck's time from the Lorentzian to the Riemannian regime. In this way, below Planck's time, Space-Time is described by compact Riemannian surfaces that have no singularity and therefore no privileged points. For this reason, as Hawking has repeated in public lectures and in more than one of his writings[18], there is no beginning and there is no need for a God to act as a "first"cause that initiates the process through which the universe evolves. Another fundamental feature is that the Hartle-Hawking solution, below Planck's time, has an imaginary time and then time behaves like any other spatial coordinates. The phase transition at Planck's time is characterized by a passage from imaginary time to physical time of true evolution. The Riemannian phase (imaginary time era) of the universe from the initial moment (t=0) of the universe to Planck's time represents the vacuum state of the Hartle-Hawking solution. Hawking argues that the vacuum state is the "Nihilo" (The Nothingness) in the doctrine of "Creatio ex Nihilo" and that the imaginary time under Planck's time would explain the absence of time in "Creatio ex Nihilo" since God, according to theological doctrines, creates outside time. As William Stoeger, S.J., explained very well[19], these positions are a complete misunderstanding of the basics of theological doctrines by Hawking. The "Nihilo" above means that there is really nothing, not even the laws of physics, whereas, instead, in this quantum vacuum there is

[17] A Explanation Comprehensive of the early universe can be found in Cfr. E.W. Kolb and M. Turner, *The Early Universe*, New York, New York, USA, Addison-Wesley Publishing Company, 1994, 447-464.
[18] See for example Cfr. S. Hawking and L. Mlodinow, *The Grand Design*, New York, USA, Bantam Books, 2010.
[19] Cfr. W. R. Stoeger, S.J., «The Cosmology of the Big Bang is in conflict with the divine creation?», in G. Consolmagno, S.J. (ed.), *The Heavens Proclaim,* Vatican City, Vatican City State, Libreria Editrice Vaticana, 2009, 174-181.

both an energy and physical laws that regulate phenomena. Moreover, to say that time does not exist in the sub-Planckian region because time is imaginary is a complete misunderstanding of the concept of absence of time in theology. Hawking takes a concept that is valid only in physics, time, and tries to transfer it to theology without reflecting enough of the different meaning time has in theology.

The problem is that the Big-Bang and the singularity refer to an original event of which the cause is not known and it is feared, on the part of scientists, that this cause could be thought to be God who, as a demiurge, is the "first" or "original" cause of the universe and after disappears , a kind of deism. Probably, this is one of the reasons Hawking felt the need to develop a model of Quantum Gravity that is completely autonomous and does not need to resort to an original cause, that is, according to him, one can do without God. However, here are two points we need to clarify. The first is that the Hartle-Hawking model is not the fundamental "solution" to Quantum Gravity, but a possible solution of which it is not even known whether it is realized in nature.[20] The second is that to think that one should resort to a God-demiurge as a "first cause" that is impossible to explain otherwise is a philosophical error. Descartes made a similar mistake when he appealed to the existence of a good God to make sure that no one had deceived him (the devil of Descartes) when he built his philosophical system. This God, who is used only when one cannot explain something, is called God of the gaps. This is not a correct way of thinking in theology. In fact, if one day it were discovered that there is a phase of the universe before the Big-Bang (and there are already theories which talk of a pre-Big Bang era...) then this God-demiurge would no longer be useful. Then science would not need this concept of God and God does not exist!

However, the problem of the beginning of the universe continues to puzzle the minds of many scientists, because the Big-Bang is on original state of which it is not know the cause and it is feared that this "first cause" could be a God-Demiurge. Furthermore, the concept of beginning of the Universe is generally confused with the concept of creation in theology.

[20] Cfr. "There."

The concept of Christian creation is, however, completely different from that of a God-demiurge of scientists. God creates, first of all, from a state where before there was really nothing, "Creatio ex Nihilo", neither an initial energy nor any physical law. Rather, God creates both energy and physical laws out of nothing and keeps them in place, He sustains them, supports His own creation. This theological doctrine is called "*Creatio Continua*". Creation is a "relationship" as St. Thomas Aquinas said "*Creatio est Relatio*"[21]. Creation has a Trinitarian structure[22]: God creates the world, the universe, in a relationship of Love, which is the third person of the Trinity, the Spirit, through the Son, The *Logos,* the second person of the Trinity. This "Trinitarian" creation is called "*Creatio ex Amore"* [23]. Since the world is created through the *Logos*, it has a logical structure.

Since God creates "*ex Nihilo*" this means that there is really no distance between God and the created things[24]. God is the ultimate cause of all creatures and give the "being" to all things. He acts in the world through the secondary cause "*Causae Secundarum"* which are the chain of causes in the world, the natural laws and they all derive from a ultimate cause that is God "*Causa Prima"* [25].

CONCLUSIONS

In old times there has been a close relation between cosmology and religion. In the ancient cultures from the beauty and harmony human beings saw just looking at the skies and observing the motion of celestial bodies, they always tried to hypothesize the existence of a God, who was thought as the "architect" of this harmony. Shadows of this general idea has certainly influenced the concordist position that saw the Big-Bang theory as a scientific confirmation of God's creation. In our opinion, in order to avoid dangerous shortcut between theology and science, Lemaitre was right in stressing a neat separation between the theological and scientific methods, as two non-overlapping "magisteria", which have two different epistemologies.

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[21] See Cfr. Thomas Aquinas, s., *Sum. Theol.* I, q. 45 A3.
[22] See Cfr. P. Gamberini, S.J. *Un Dio Relazione*, Rome, Città Nuova Editrice, 2007, 148-163.
[23] Cfr. S.J. Youngs, «Creatio Ex Amore Dei: Creation out of Nothing and God's Relational Nature» in *The Asbury Journal* ,2014, 69/2 165-186.
[24] Cfr. R. Haight, S.J. *Faith and Evolution: A Grace-filled Naturalism*, New York, USA, Orbis Book, 2019, chapter 3.
[25] See Cfr. Thomas Aquinas, s., *Summa Contra Gentiles*, II Book , chapters 42 & 45.

We have also highlighted that the Big-Bang theory puzzles scientists since a primeval hot and dense state is seen as something that needs a sort a "first" cause, in order to be explained, who could be the concept of God "creator" from Deism. We have explained that Creation, in Christian Theology, is a concept completely different from the God creator that scientists have in mind. In this direction, we have analyzed also the Hartle-Hawking no-boundary boundary proposal which has been advertised by the author as a self-contained solution of Quantum Gravity which does not need any external "first cause". They have also claimed this model explains the theological concepts of "*Creatio ex Nihilo"* and "creation without time" only using physical concepts. We have shown that this way of reasoning is very misleading since confuses philosophical and theological concept with physics concepts which have a completely different meaning (like the vacuum in quantum theory that is completely different from the nothing "*nihilo*" in theology and philosophy).

Creatio ex Nihilo is an astonishing dogmatic doctrine of Christian theology that recognizes God creates all things out of nothing and therefore the ultimate being of all things is in God. In this way God annuls His distance from all created things and is present in all things. Then He is really the "*Causa Prima*" of all things.

Logical impossibility to formulate a proof of existence of God, however, does not prevent a woman and man of faith from seeing in the harmony and order of the universe a beauty that reflects the imprint of the Creator who created the universe by Love. However, this is not proof of God's existence, it is, rather, an argument who can only strength the faith of a believer.

Following the statement in the letter that S. John Paul II sent in 1990 to the director of the Vatican Observatory, Fr. George Coyne, S.J., we strongly believe that "Science helps religion to purify herself from any superstition, religion helps science to free herself from any idolatry".