The Quantum Gravitational Cosmological Model without Singularity

In this paper I propose a quantum gravitational cosmological model which introduces a mass density function that reproduces the WMAP and the PLANCK missions' data quite accurately. This function implies that the Universe started with a mass equal to one half of the Planck mass, avoiding the need for a singularity (point with infinite mass density) at the beginning of (normal) time. One of the predictions of the model is that the mass of the Universe grew very rapidly according to an exponential function so that most of the mass of the Universe was "created" very early in its history (99 % of the mass of the Universe was created in the first 442 million years since the Big Bang). Because the average mass density function changes over time, this model is radically different to the Steady State Model. The model presented here assumes the existence of a Pre-universe, meaning that our Universe is not the result of a "creation process" but the result of a mysterious transformation. Finally, this formulation, which does not use General Relativity's field equations, encompasses part of the original Friedmann work. Therefore, we draw the conclusion that we don't need GR to develop an acceptable cosmological model.

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1. Introduction

Cosmological Models[1] tell us how the Universe changes with the passage of time. To be able to determine which model reflects the observations more accurately we must, amongst other things, study both near and faraway galaxies and compare them with the predictions of the theories. The model should also be able to explain the so called cosmological problems: the horizon problem, the flatness problem, the structure problem, the monopole problem, the antimatter problem, etc. In other words, cosmology should answer questions like these ones: What is the cause of the cosmological redshift? What is the cause of the Cosmic Microwave Background Radiation? Was the temperature of the Universe at the beginning extraordinarily high, and if so why? Is the existence of a singularity the only way of explaining the "creation" of the Universe? How can the Universe expand if there is nothing to expand into? What is the shape of the Universe? Has the Universe got a centre? If so, is the centre in our Universe or in the Pre-Universe? How many spatial dimensions must the Pre-Universe have to be able to have a centre which we cannot access? Has the Universe got an edge? If not, why? Was entropy so low in the beginning? If so, why? The Big Bang Theory makes a number of hypothesis to answer some of these questions (but not all) with no scientific basis whatsoever (without having a solid proof to back them up). In other cases the theory uses absurd hypothesis such as singularities which is the Achilles' heel of most cosmological models based on General Relativity. Indeed, the Hot Big Bang Model intents to explain a number of observations according to some interpretations which may not be correct.

Despite the fact that in the Quantum Gravitational Cosmological Model (*QGCM)* the mass of the Universe was created in a relatively short period of time, the model must be classified as an "evolutionary" model and not as a stationary model. The reason is due to the mass density function. Indeed, the *QGCM* and the Steady State Model have totally different mass density functions and therefore they are radically different. While in the Steady State model the average mass density of the Universe is constant, the mass density in the *QGCM* decreases with time. This means that under the new approach (a) distant galaxies should appear closer from each other than nearby galaxies, and (b) distant galaxies should appear younger than nearby galaxies. These predictions have been confirmed by astronomical observations. In the next section I shall show that the formula for the radius of the observable Universe the *QGCM* predicts, agrees with the Friedmann model under certain conditions. Then one may ask: what is the difference between the two theories then? The main difference (there are other differences as well) is that the *QGCM* explains the Universe origin from a quantum mechanical perspective, meaning, amongst other things, that there is no need of having a point with infinite mass density (singularity).

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1. See Glossary (Appendix 2) for most of the astronomical and physical terms used throughout this paper.

In other words, this model eradicates singularities once and for all. And this is a huge difference.

2. Nomenclature

SYMBOLS

$c =$ Speed of light in vacuum (m/S)
$h =$ Planck's constant $(J\,S)$
$\hbar =$ Reduced Planck's constant $(\hbar = h/2\pi)$ $(J\,S)$
$G =$ Newton's gravitational constant $(m^3/Kg\,S^2)$
$L_P =$ Planck length (m)
$T_P =$ Planck time (S)
$T =$ Time, Universal time, or Cosmological time in seconds (S). This Time is measured from the first "instant" of existence of the Universe (13,823 million years ago)
$T_\infty =$ Maximum lifetime of the Universe
$T_{now} =$ Age of the Universe in seconds (S)
$T_{now\_My} =$ Age of the Universe, now, in million years (My)
$T_{now\_By} =$ Age of the Universe, now, in billion years (By)
$\tau =$ Time constant of the Universe in seconds (S)
$\tau_{My} =$ Time constant of the Universe in million years (My)
$H_0 =$ Hubble constant $(Km/S\,Mpc)$
$M = M(T) =$ Mass of the Universe as a function of the Universal time (Kg)
$M_0 =$ Initial mass of the Universe at time $T = T_P$ (Kg)
$M_P =$ Planck mass (Kg)
$M_{now} =$ Mass of the Universe now (Kg)
$M_{tot} =$ Total mass of the Universe (Kg)
$M_\tau =$ Mass of the Universe for a time equal to the time constant of the Universe (Kg)
$V_{Planck} =$ Volume of a Planck sphere (of radius equal to the Planck length) (m^3)
$V = V(T) =$ Volume of the Universe as a function of the Universal time, T. (m^3)
$V_{now} =$ Volume of the Universe, now (13,823 million years from the beginning) (m^3)
$R = R(T)$ Radius of the Universe as a function of the Universal time (m)
$R_{now} =$ Radius of the Universe, now (13,823 million years from the beginning), in meters (m)
$R_{now\_Bly} =$ Radius of the Universe, now (13,823 million years from the beginning), in Billion light years (Bly)
$K_{radius}(T) =$ Function ("proportionality constant") used to write the formula for the radius of the Universe in a compact form. Not to be confused with spatial curvature
$K_{space} =$ Space curvature (or spatial curvature)
$\Omega_0 =$ Ratio of the observed average mass density of the Universe to its critical mass density (the mass density in a flat Universe).
$\Lambda =$ Cosmological constant
$\rho_{P\_bar} =$ Reduced Planck density (Kg/m^3)
$\rho = \rho(T) =$ Average mass density of the Universe as a function of time, T (Kg/m^3)
$\rho_{now} =$ Average mass density of the Universe now (Kg/m^3)

$\rho_C =$ Critical mass density (or critical density, or critical average density) (Kg/m^3)
$N_{p\_now} =$ Total number of protons in the Universe
$n_p =$ Average number of protons per cubic meter $(protons/m^3)$
$n_{p\_now} =$ Average number of protons per cubic meter, now $(protons/m^3)$
S_{BH} = Berkenstein-Hawking entropy of a black hole (or black hole entropy) $(J/°K)$
S_0 = Initial entropy of the Universe at time $T = T_P$ (or Universal entropy) $(J/°K)$
$S_{Planck} =$ Planck entropy $(J/°K)$
$A =$ Area (m^2)
$A_{Planck} =$ Area of a sphere of radius equal to the Planck length, L_{Planck} (or area of a Planck sphere)
$E =$ Relativistic energy (J)
$m =$ Relativistic mass (Kg)

ACRONYMS

BB = Big Bang
HBB = Hot Big Bang
HBBM = Hot Big Bang Model (another name for the *HBB*)
HBBC = Hot Big Bang Cosmology (another name for the *HBB*)
HBBT = Hot Big Bang Theory (another name for the *HBB*)
QGC = Quantum Gravitational Cosmology
QGCM = Quantum Gravitational Cosmological Model (also known as Exponential Cosmological Model)
QGCT = Quantum Gravitational Cosmological Theory (another name for Quantum Gravitational Cosmological Model)
CMBR = Cosmic Microwave Background Radiation
CMB = Cosmic Microwave Background (another name for Cosmic Microwave Background Radiation)
COBE = Cosmic Background Explorer Satellite
WMAP = Wilkinson Microwave Anisotropy Probe (Refers to the *WMAP* satellite or mission)
PLANCK = Refers to the Planck satellite or mission
SR = Einstein's Special Theory of Relativity also known as Special Relativity
GR = Einstein's General Theory of Relativity also known as General Relativity

3. The Cosmological Model

The cornerstones of this theory comprise the following postulates:

Postulate 1: Time quantization postulate.
Postulate 2: Space quantization postulate.
Postulate 3: The formula for the average mass density of the Universe as a function of the universal (or cosmological) time.
Postulate 4: The formula for the mass of the Universe as a function of the universal (or cosmological) time.
Postulate 5: The shape of the Universe

3.1 Postulates

Postulate 1: Time quantization postulate [1]

Time is discrete. This means that there is a time, T_{MIN} , which is the minimum time with physical meaning. In other words there is no time or time interval smaller than T_{MIN} . It is likely that T_{MIN} to be equal to the Planck time, T_P . The Planck time is defined as follows

$$T_P = \sqrt{\frac{h\,G}{2\,\pi\,c^5}} \tag{3.1.1}$$

Postulate 2: Space quantization postulate [1]

Space is discrete. This means that there is a length, L_{MIN} , which is the minimum length with physical meaning. In other words there is no length or distance smaller than L_{MIN} . It is likely that L_{MIN} to be equal to the Planck length, L_P . The Planck length is defined as follows

$$L_P = \sqrt{\frac{h\,G}{2\,\pi\,c^3}} \tag{3.1.2}$$

Postulate 3: The formula for the average mass density of the Universe as a function of the universal (or cosmological) time

The fundamental equation of this model is

$$\rho_{P\_bar}\,T_P^2 = \rho\,T^2 \tag{3.1.3}$$

where: ρ_{P_bar} is the reduced Planck mass density, T_P is the Planck time, ρ is the average mass density of the Universe and T is the Universal time. This postulate assumes that Newton's gravitational constant, *G*, did not change significantly since the beginning of time [2].

The reduced Planck mass density is given by

$$\rho_{P\_bar} = \frac{3\,c^5}{4\,h\,G^2} \tag{3.1.4}$$

Equation (3.1.3) implies that at the very beginning the initial mass of the Universe, M_0 , was half the Planck mass (see Appendix 1). This is

$$M_0 = \frac{M_P}{2} \tag{3.1.5}$$

Where the Planck mass is defined by

$$M_P = \sqrt{\frac{hc}{2\,\pi\,G}} \tag{3.1.6}$$

Which in turn implies that there is no singularity at the beginning of normal time.

Justification

i) As we shall see the introduction of this postulate is fully justified by the fact that it yields almost the same value for the mass density of the Universe as that measured by the WMAP mission (See Table 1, Section 5).

ii) This formula eliminates the necessity of having a singularity, or point with infinite mass density and infinite curvature at the beginning of time. The singularity is a consequence of Einstein's General Relativity. The problem is that GR cannot make valid predictions at very early times such as the Planck time. GR simply breaks down at that time because is not a quantum mechanical theory but a classical theory where none of the first two postulates presented here are taken into account. This makes the theory of General Relativity unsuitable to explain the Universe at very early times.

The Hot Big Bang Cosmology assumes that the entire mass of the Universe was created in the first instant of the Big Bang. The *HBB* model assumes the existence of a point of infinite mass density and infinite curvature known as singularity. However this hypothesis runs into difficulties simply because the model cannot explain it. Can Nature produce a point (which has no dimensions) of infinite mass density? How can even a point exist if it has no dimensions? How can we justify the existence of a singularity when the best theory of gravitation we have: Einstein's GR, breaks down at very small scales? We cannot. GR breaks down at the Planck scale because it does not take into consideration the first two postulates (**Postulates 1** and **Postulate 2**) of this formulation. In other words, because GR does not apply at the time of "creation", it is a completely useless theory when trying to find out what happens at times as early as the Planck time. Another point that seems to favour the existence of a singularity (which is a physical mystery) is that if we "run time backwards", like playing a motion picture in reverse, then galaxies would appear to meet at one point at the beginning of time. This "Motion Picture in reverse" is taken, by the advocates of the existence of an initial singularity, as an indication that the entire mass of the Universe was concentrated at that point during the BB. However, as I shall show, this is not the only possible explanation. The theory I outlined in this paper also indicates that the mass of the Universe seems to originate from a single "point". However there are two big differences between the HBBM and the model presented in this paper. The first difference is that the present theory does not requires a point with infinite density but a finite spherical volume of radius equal to the Planck length. Thus, the need for a (dimensionless) point in the beginning of time vanishes.

The second difference is that, in the present formulation, the mass of the Universe grows gradually from a finite initial value (Planck mass over 2). Because of the exponential nature of the mass function, $M = M(T)$ - see **Postulate 4**, this theory predicts that 99% of the mass of the Universe was "created" only after 442.5 million years measured from the beginning of normal time. This is, indeed, very early in the history of the Universe (13,823 million years). Because of the expansion of the Universe (I assume that the observed redshifts are caused by the expansionist hypothesis), the newly created mass, will appear to have originated from the same "point". This "point" is in fact the Planck spherical volume. See figure 1.

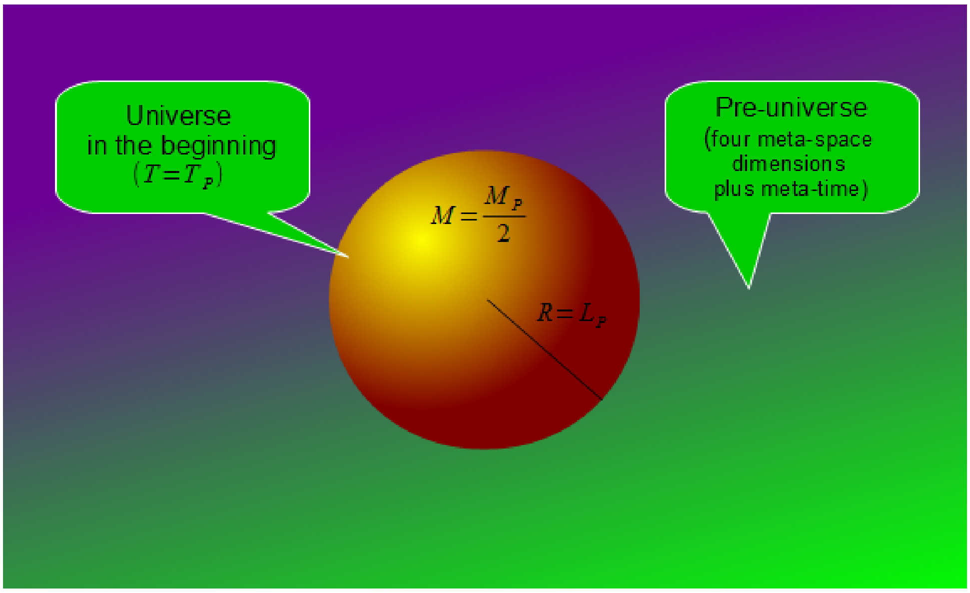

FIGURE 1: *The size of the Universe in the very beginning when the universal time was equal to the Planck time. Then, the mass of the Universe was equal to the Planck mass divided by 2 (see Appendix 1). This tiny sphere may be considered as a real or physical "point" in contrast to a mathematical point which has no dimensions.*

Thus, there is no need for the existence of a singularity (See Misconception 4: The Universe Started with a Singularity) and therefore, this concept should be abandoned.

iii) This postulate also answers the question: why didn't the Universe start in a state of maximum disorder? In other words: why did the Universe start with a low entropy state? As mentioned before, at the beginning of time, the size of the Universe was a sphere of radius equal to the Planck length. In such small volume (the smallest possible volume) the initial mass (Planck mass over 2) did not have enough room to spread. As a consequence of this "confinement", the initial matter/energy had to be relatively highly ordered and consequently the entropy of the Universe had to take the lowest possible value. Because the minimum size of a black hole coincides with the size of the Universe at the very first instant (both are spheres of radius equal to the Planck length), we can consider the Universe was like a black hole at that time (and for that time only, which is an "instant" of duration equal to the Planck time, approximately). Therefore we can calculate the entropy of the Universe at the beginning of time by applying the Berkenstein-Hawking formula for the entropy of a black hole. This is done in subsection 3.6.

Postulate 4: The formula for the mass of the Universe as a function of the universal (or cosmological) time

This postulate asserts that the mass of the Universe is an exponential function of time and is given by

$$M(T) = \left(M_{tot} - \frac{M_P}{2}\right)\left(1 - e^{-\frac{T - T_P}{\tau}}\right) + \frac{M_P}{2} \qquad (3.1.7)$$

this formula is valid for

$$T \geq T_P \qquad (3.1.8)$$

M_{tot} is the total mass of the Universe, T is the Universal time, T_P is the Planck time, τ is the time constant of the Universe or universal time constant (explained below) and M_P is the Planck mass. It is worthwhile to remark that

a) for $T=0$ the mass of the Universe must be zero because the Big Bang started at $T=T_P$
Thus for $T = 0$ there was no Universe, only the Pre-universe [3] existed (Time existed before the Big Bang!).

b) for $T=T_P$ the mass of the Universe was half the Planck mass. The Planck time may be considered the first "instant" of our Universe.

Justification

i) When the Universal time, T, is equal to the Planck time, T_P then the mass of the Universe will be $M_0 = M_P/2$ as required by **Postulate 3**. Consequently, the mass formula given above is in full agreement with **Postulate 3**.

ii) An exponential function, such as the one presented here, will ensure that most of the mass of the Universe would have been created very early in the history of the Universe as required by cosmological considerations. It is worthwhile to remark that despite the ongoing mass "creation" process, this model predicts an average mass density function that obeys an inverse square law ($\rho = K/T^2$) which predicts the correct mass density for the Universe now (13,823 million years after the Big Bang). Thus, this model is radically different to the Steady State Model (which, by the way, was abandoned) in which the mass density is constant or, in other words, independent of time.

iii) Exponential functions like the one presented here grow very rapidly at the beginning of time and then the growth rate decreases as time increases (mathematically this means that the slope of the curve decreases with time). Consequently, this postulate solves, at least, partially, both the horizon and the flatness problem. However, we have to bear in mind, that the growth rate of this function might not be enough to fully solve these problems. If this were the case, the function should be modified to make it grow even more rapidly at the beginning of time (that correction would be similar to the inflation correction introduced into the original Hot Big Bang Model to solve the same problems). Inflation is not addressed in this paper.

iv) Do exponential functions, such as the formula for the mass of the Universe, exist in nature? Yes, they do. The function for the mass of the Universe is similar to the function for the electrical charge in a serial *RC* electrical circuit. The simplest serial *RC* circuit consists of a battery (*V*) (or power supply), a switch (*S*), a capacitor (*C*) and a resistor (*R*) connected in series as shown in figure 2.

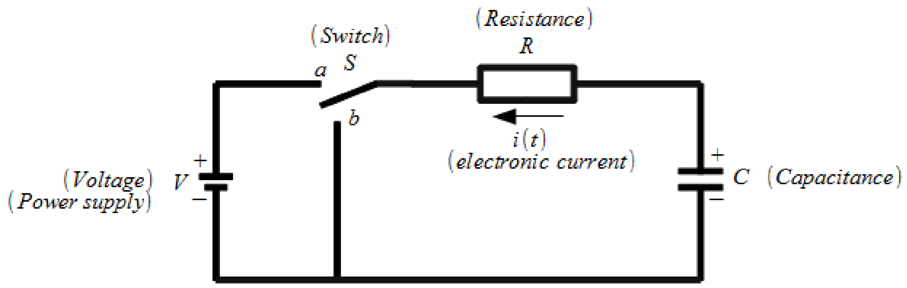

FIGURE 2: *RC* Circuit. *When the switch S is open (position b) there is no current through the circuit. When the switch is closed (position a) a current, i, flows through the circuit and the capacitor C will get charged according to an exponential function. The time constant of the circuit is RC (Resistance times Capacitance). Note that the direction of the current is the actual direction of the electrons in the circuit.*

When the switch is closed, at time $t = 0$ (position a), the electrical charge in the capacitor will grow from zero to a maximum value according to the following exponential function[2]

$$q(t) = CV\left(1 - e^{-\frac{t}{RC}}\right) = q_{tot}\left(1 - e^{-\frac{t}{\tau_{RC}}}\right) \qquad (3.1.9)$$

where $q(t)$ is the capacitor electrical charge at time t, $q_{tot} = CV$ is the final charge, t is the time lapsed since we close the switch, $\tau_{RC} = RC$ is the circuit's time constant (in this context R is the resistance of the resistor and not the radius of the observable Universe), C is the capacitance of the capacitor and $e = 2.718281828...$ is the base of natural logarithms. The time constant is the time taken by the circuit to increase the electrical charge in the capacitor in a factor of $(1 - e^{-1})$ (or 0.632) of its final value (or equilibrium value). Thus, because the equation for the mass of the Universe is an exponential function similar to equation (3.1.9), it is natural to adopt the concept of time constant of the Universe (or universal time constant) which I shall define as the time taken by the Universe to increase its mass in a factor of $(1 - e^{-1})$ (or 0.632) of its final value (or, equivalently, $63.2\% = 100 \times (1 - e^{-1})$ of its final value). It is customary to denote time constants with the Greek letter tau (τ).

Postulate 5: The shape of the Universe

In order to simplify the equations I shall assume the shape of the Universe is spherical. However, this assumption could be changed in the future as new data about the Universe is gathered by new astronomical observations.

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2. The derivative of this exponential function decreases as the independent variable (in this case time, t) increases.

3.2 The Mass Density of the Universe

The reduced Planck mass density is

$$\rho_{P\_bar} = \frac{3c^5}{4hG^2} \qquad (3.2.1)$$

$$\rho_{P\_bar} = 6.153\,996 \times 10^{95} \frac{Kg}{m^3}$$

I shall use the following conversion factor:

(a) meters to light years (*ly*)

$$K_{\mathrm{m/ly}} = 9.460\,730\,472\,580\,8 \times 10^{15} \frac{m}{ly}$$

or, equivalently

(b) meters to billion light years (*Bly*)

$$K_{\mathrm{m/Bly}} = 9.460\,730\,472\,580\,8 \times 10^{24} \frac{m}{Bly}$$

It is accepted that the radius of then observable Universe is between 45.7 and 47 billion light years [4, 5]. Thus, we adopt the value

$$R_{now} = 4.355 \times 10^{26}\, m$$

so that the radius of the observable Universe now, R_{now} , turns out to be 46 billion light years. The age of the Universe [6, 7] , now, in seconds is[3]

$$T_{now} = \frac{h^2}{2\pi^2 c G m_e m_p^2} \qquad (3.2.2)$$

Expressed in Julian years the age of the Universe is

$$T = \frac{4.362\,157\,043 \times 10^{17}\, S}{365.25 \times 24 \times 60 \times 60\, S / year} = 1.382\,284\,154 \times 10^{10}\, years \qquad (3.2.3\text{ a})$$

or

3. You don't need to use this formula if you don't want to do so. Alternatively you can use the data from the latest space missions.

$T \approx 13{,}822.84 \quad million\ years$ (3.2.3 b)
$T \approx 13.823 \quad billion\ years$ (3.2.3 c)

The fundamental equation, which is equation (3.1.3), may be applied to the present time to give

$$\rho_{P\_bar} T_P^2 = \rho_{now} T_{now}^2 \tag{3.2.4}$$

Now we solve this equation for the average mass density of the Universe, now, $\rho(T_{now}) = \rho_{now}$. This yields

$$\rho_{now} = \rho_{P\_bar} \frac{T_P^2}{T_{now}^2} \tag{3.2.5}$$

but the definition of Planck time is

$$T_P = \sqrt{\frac{h\,G}{2\,\pi\,c^5}} \tag{3.2.6}$$

Eliminating T_P from equation (3.2.5) we get

$$\rho_{now} = \frac{3\,c^5}{4\,h\,G^2} \frac{h\,G}{2\,\pi\,c^5} \frac{1}{T_{now}^2} \tag{3.2.7}$$

Simplifying we get

$$\rho_{now} = \frac{3}{8\,\pi\,G} \frac{1}{T_{now}^2} \tag{3.2.8}$$

in virtue of equation (3.2.2), the last equation may be written as

$$\rho_{now} = \frac{3\,\pi^3 c^2 G\, m_e^2 m_p^4}{2\,h^4} \tag{3.2.9}$$

The value this equation yields is

$$\rho_{now} = 9.399\,462\,317 \times 10^{-27} \frac{Kg}{m^3} \qquad \text{(theoretical value)} \tag{R1}$$

The number of protons, n_p , per cubic meter is

$$n_p = \frac{\rho_{now}}{m_p} = 5.62 \frac{protons}{m^3} \qquad \text{(theoretical value)} \tag{R2}$$

According to the WMAP data (See Table 1: Section 5), the observed value of the number of protons per cubic meter is

$$n_p(WMAP) = 5.9 \frac{protons}{m^3}$$ (observed value)

Thus, we draw the conclusion that the theoretical result (R1, R2) is an excellent agreement with the observations. The volume of the Universe, now, is

$$V_{now} = \frac{4}{3} \pi R_{now}^3 \tag{3.2.10}$$

The mass of the Universe, now, is

$$M_{now} = \rho_{now} V_{now} \tag{3.2.11}$$

The number of protons of the Universe, now, is

$$N_{p\_now} = \frac{M_{now}}{m_{p0}} \tag{3.2.12}$$

The mass density of the Universe, now, is

$$\rho_{now} = \frac{N_{p\_now}}{V_{now}} \tag{3.2.13}$$

The average mass density of the Universe, $\rho(T)$, as a function of the Universal time, *T*, is

$$\rho(T) = \frac{3}{8 \pi G} \frac{1}{T^2} \tag{3.2.14}$$

This equation can be put into words as follows:

The average mass density of the Universe is inversely proportional to the square of the Universal time.

It is worthwhile to remark that, according to equation (3.2.14), the mass density of the Universe does not depend on the radius of the Universe. Thus, we assume that this equation is valid not only for the observable Universe but also for the entire Universe (perhaps this is going too far).

The graph of this function is given in figure 3. In this figure the *y* axis represents the mass density of the observable Universe while the *x* axis represents the Universal time.

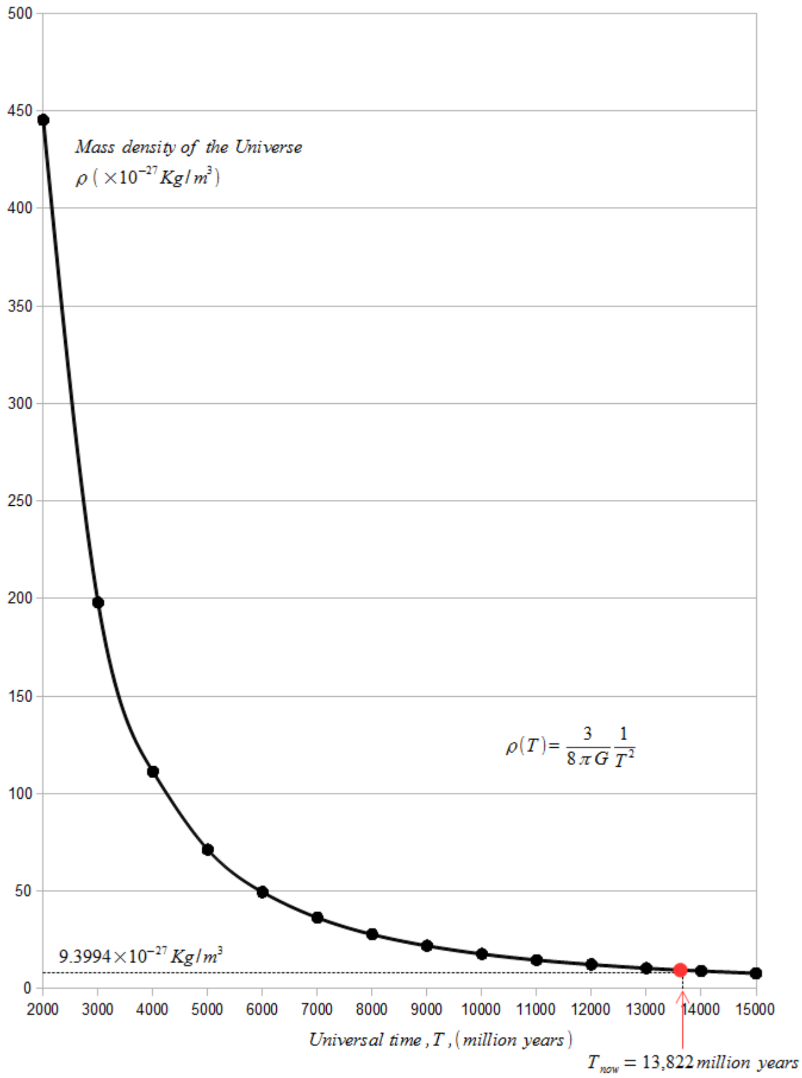

FIGURE 3: The average mass density of the Universe as a function of time. Note that the mass density obeys an inverse square law. Due to practical reasons, the time axis of the graph starts after 2,000 million years from the beginning of normal time. According to this model the average mass density, now, is $9.399\times 10^{-27}\ Kg$.

3.3 The Mass of the Observable Universe and the Time Constant of the Universe

According to this model, the mass of the observable Universe is a function of time and is given by

$$M(T) = \left(M_{tot} - \frac{M_P}{2}\right)\left(1 - e^{-\frac{T - T_P}{\tau}}\right) + \frac{M_P}{2} \quad (3.3.1)$$

To get the value of the mass of the Universe now (2015) we simply replace T by T_{now}. This gives

$$M(T_{now}) = M_{now} = \left(M_{tot} - \frac{M_P}{2}\right)\left(1 - e^{-\frac{T_{now} - T_P}{\tau}}\right) + \frac{M_P}{2} \quad (3.3.2)$$

Solving for the time constant, τ, we get

$$\tau = -\frac{T_{now} - T_P}{\ln\left(\frac{2M_{tot} - 2M_{now}}{2M_{tot} - M_P}\right)} \quad (3.3.3)$$

The problem that arises when we want to calculate the value of the time constant of the Universe, τ, is that we don't know the mass difference: $M_{tot} - M_{now}$. We can solve this problem by using the equivalent equation

$$M(T) = M_{now}\left(1 - e^{-\frac{T - T_P}{\tau}}\right) + \frac{M_P}{2} \quad (3.3.4)$$

Where we have assumed that difference between the mass of the Universe for an infinite time $(T = \infty)$ and the mass of the Universe now (13,823 million years) has to be, at least, $M_P/2$ (this is so because the mass of the Universe for an infinite time has to be greater that the mass for any other given time, and the Universe is now old enough for this assumption to be valid). If we take the limit of *M(T)* in equation (3.3.4) when *T* approaches infinity, we get

$$M(\infty) = M_{tot} = M_{now}(1 - 0) + \frac{M_P}{2} = M_{now} + \frac{M_P}{2} \quad (3.3.5)$$

In other words, because our Universe is old enough

$$M_{tot} \approx M_{now} + \frac{M_P}{2} \quad (3.3.6)$$

This assumption is fully justified since a capacitor, as the one showed in the above circuit, will get fully charged just after a few time constants. Following this analogy, the Universe should get its total mass also after a few universal times constants. This means that the time constant of the Universe should be much smaller that the age of the Universe. Mathematically, this means that $\tau \ll T_{now}$. Thus, from equations (3.3.3) and (3.1.7) we write

$$\tau = -\frac{T_{now} - T_P}{\ln\left(\frac{2M_{now} + M_P - 2M_{now}}{2M_{tot} - M_P}\right)} = -\frac{T_{now} - T_P}{\ln\left(\frac{M_P}{2M_{tot} - M_P}\right)} \tag{3.3.7}$$

Because $T_{now} \gg T_P$ we may neglect the Planck time in the numerator. Furthermore, because $M_{tot} \gg M_P$ we may neglect the Planck mass in the argument to the natural logarithm in the denominator. With these two approximations we get the following expression for the time constant of the Universe

$$\tau \approx -\frac{T_{now}}{\ln\left(\frac{M_P}{2M_{tot}}\right)} \tag{3.3.8}$$

I shall now calculate the time constant of the Universe from this equation. In order to do that, I shall assume the observable Universe is a sphere whose volume, now, V_{now} , is

$$V_{now} = \frac{3}{4}\pi R_{now}^3 \tag{3.3.9}$$

But the mass of the Universe is the density of the Universe times its volume. Mathematically

$$M_{tot} \approx M_{now} = \rho_{now} V_{now} \tag{3.3.10}$$

From the last two equations we obtain the mass of the Universe as a function of its density and its radius

$$M_{now} = \frac{4}{3}\pi \rho_{now} R_{now}^3 \tag{3.3.11}$$

Equation (3.2.14) (The blue colour indicates that the referenced equation comes from a previous subsection) was

$$\rho_{now} = \frac{3}{8\pi G}\frac{1}{T_{now}^2} \qquad \text{(Equation 3.2.14)}$$

Now from equations (3.3.11) and (3.2.14) we eliminate the density at the present time, ρ_{now} . This yields

$$M_{tot} \approx M_{now} = \frac{1}{2G}\frac{R_{now}^3}{T_{now}^2} \tag{3.3.12}$$

We may eliminate the total mass, M_{tot} , from equation (3.3.8) through equation (3.2.12). This yields

$$\tau \approx -\frac{T_{now}}{\ln\left(\frac{G M_P T_{now}^2}{R_{now}^3}\right)} \qquad (3.3.13)$$

We may evaluate this expression because we know the values for the two variables involved in the formula:

a) The age of the Universe[4] is known from the WMAP mission (See Table 1, Section 5) or from equation (3.2.2). Thus, the age of the Universe is
$T_{now} \approx 4.362157 \times 10^{17} S$

b) The value of the radius is known from astronomical observations [4, 5]. This value is
$R_{now} \approx 46 \text{ } billion \text{ } light \text{ } years = 4.355 \times 10^{26} \text{ } m$

Therefore inserting these two values into equation (3.3.13) we get the value of the time constant of the Universe

$\tau \approx 3.032\ 329\ 457 \times 10^{15} S$ (theoretical value) (R3)

To get the time constant of the Universe in million years we simply divide the time constant in seconds by a conversion factor

$$\tau_{My} = \frac{\tau}{S_{div\ My}} \qquad (3.3.14)$$

where the conversion factor is

$S_{\text{div\_My}} = 365.25 \times 24 \times 60 \times 60 \times 10^6$

Then the value of time constant of the Universe in million years is

$\tau_{My} = \frac{3.032329 \times 10^{15}}{365.25 \times 24 \times 60 \times 60 \times 10^6} \approx 96.0887 \text{ } million \text{ } years$ (theoretical value) (R4)

Thus, just after about 96 million years the mass of the Universe was, approximately, 63.9 % of the mass at the present time (which is almost the final mass of the observable Universe). Figure 4 shows the mass of the Universe as a function of time (equation (3.3.1)). In this figure the *y* axis represents the mass of the Universe and the *x* axis the Universal time.

4. When calculating the age of the Universe we have the option of using the experimental data gathered by the WMAP spacecraft or the theoretical value given by equation (3.2.2).

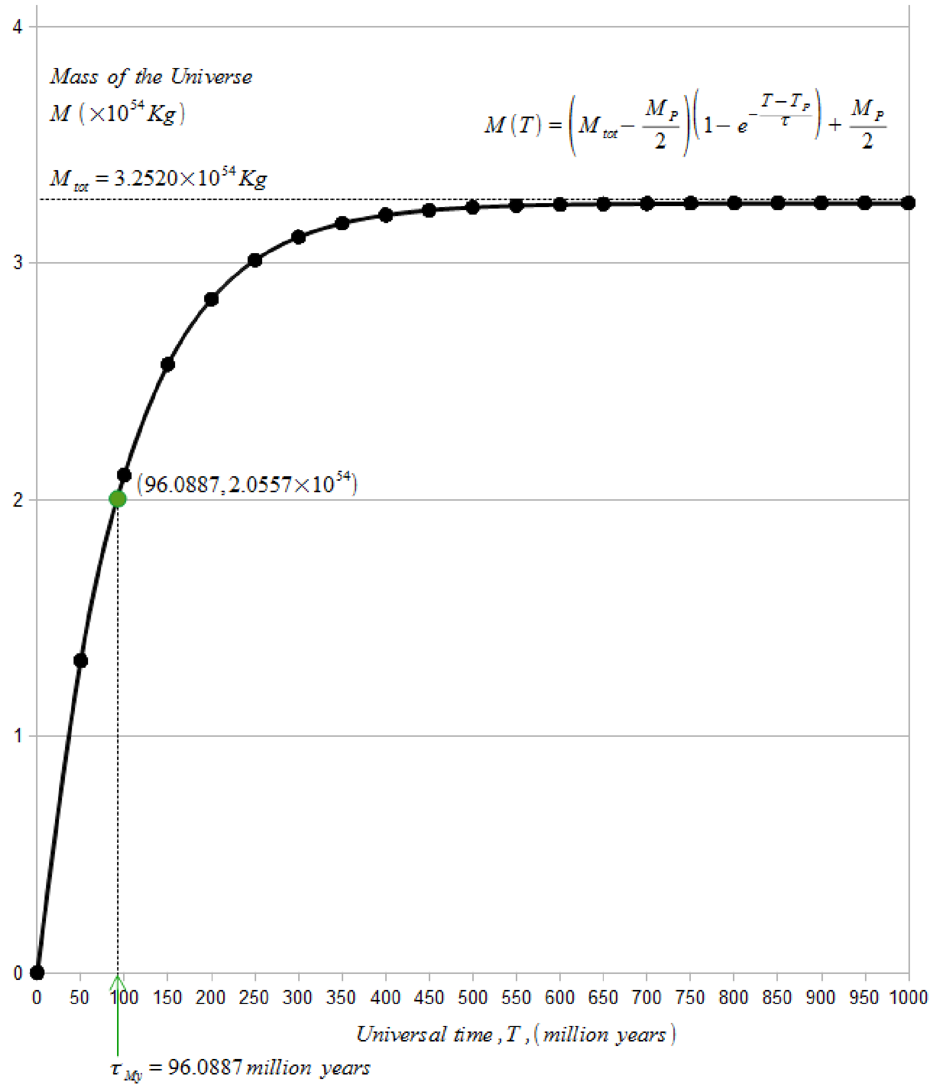

FIGURE 4: The observable mass of the Universe as a function of time. According to this model the mass of the observable Universe for a time equal to the time constant, τ , is, approximately, $2\times10^{54}\,Kg$. If necessary, the time constant of the Universe could be adjusted to match future cosmological observations. Note that for practical reasons the time scale goes up to 1000 million years only.

3.4 The Volume of the Observable Universe

The volume of the observable Universe may be easily derived from the equation for mass and the equation for the mass density. The equation for the mass density is

$$\rho(T)=\frac{M(T)}{V(T)} \tag{3.4.1}$$

Solving this equation for the volume *V(T)* we get

$$V(T) = \frac{M(T)}{\rho(T)} \tag{3.4.2}$$

The mass of the Universe is given by equation (3.3.1) from subsection 3.3

$$M(T) = \left(M_{tot} - \frac{M_P}{2}\right)\left(1 - e^{-\frac{T-T_P}{\tau}}\right) + \frac{M_P}{2} \qquad \text{(Equation 3.3.1)}$$

The mass density of the Universe is given by equation (3.2.14) from subsection 3.2

$$\rho(T) = \frac{3}{8\pi G}\frac{1}{T^2} \qquad \text{(Equation 3.2.14)}$$

Combining the last two equations ((3.3.1) and (3.2.14)) into equation (3.4.2) yields

$$V(T) = \frac{8\pi G T^2}{3}\left[\left(M_{tot} - \frac{M_P}{2}\right)\left(1 - e^{-\frac{T-T_P}{\tau}}\right) + \frac{M_P}{2}\right] \tag{3.4.3}$$

This is the equation for the volume of the observable Universe as a function of time. Figure 5 shows the graph for this function. The *y* axis represents the volume of the Universe and the *x* axis represents the Universal time.

(See figure 5 on the next page)

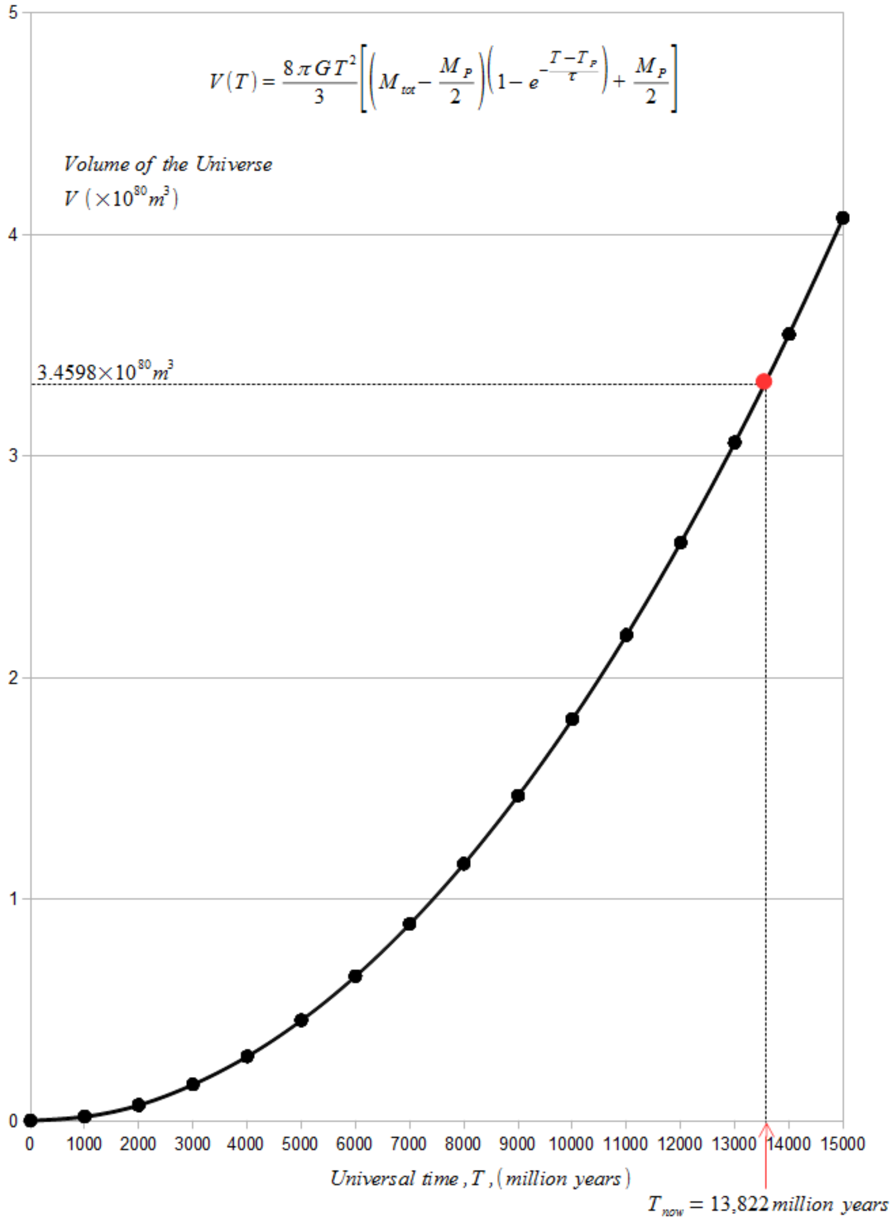

FIGURE 5: The volume of the Universe as a function of time. According to this model the volume of the Universe now (13,823 *My*) is, approximately, $V(13{,}822\,My) \approx 3.5\times 10^{80}\,m^3$

This graph shows that the Universe will expand forever but the mass of the Universe has an upper bound (See also figure 4).

3.5 The Radius of the Observable Universe

Assuming that the shape of the Universe is spherical, the radius of the observable Universe, *R*, may be calculated from the formula for the volume, *V*, of a sphere

$$V = \frac{4}{3}\pi R^3 \tag{3.5.1}$$

Solving the above equation for *R* yields

$$R = \left(\frac{3}{4\pi} V\right)^{1/3} \tag{3.5.2}$$

Combining equation (3.4.4), from the previous subsection, with equation (3.5.2) yields

$$R(T) = \left[2\,G\,T^2 \left(\left(M_{tot} - \frac{M_P}{2} \right) \left(1 - e^{-\frac{T - T_P}{\tau}} \right) + \frac{M_P}{2} \right) \right]^{1/3} \tag{3.5.3}$$

This is the equation for the radius of the Universe as a function of time. Figure 5 shows the graph for this function. In this figure the *y* axis represents the radius of the Universe and the *x* axis represents the Universal time.

If we accept that the expansionist theory of the Universe is correct, then almost all of the galaxies we observe today must have been in a much smaller volume in a distant past. We do not know how small this volume might have been, but if we place a large number of galaxies in a relatively small space then the Universe must have been a much hotter place in the past than it is today. So, let us calculate the radius of the observable Universe when the Universe was 96 million years old. This time coincides with the time constant of the Universe. The results of these calculations are as follows

$$M(96.0887\,My) = 2.06 \times 10^{54}\,Kg$$

$$R(96.0887\,My) = 1.36 \times 10^{25}\,m \approx 1.44 \times 10^{9}\,ly \approx 1.44\,Bly$$

where I have used the following conversion factor between meters and light years:

$$K_{m/ly} = 9.460\,730\,473 \times 10^{15}\,\frac{m}{ly}$$

The ratio between the mass of the Universe when the Universe was $96.0887\,My$ old and the mass of the Universe now is

$$\frac{M(96.0887\,My)}{M(13822\,My)} = \frac{2.06 \times 10^{54}\,Kg}{3.2520 \times 10^{54}\,Kg} \approx 0.6335$$

The ratio between the radius of the Universe when the Universe was $96.0887\,My$ old and the radius of the Universe now is

$$\frac{R(96.0887\,My)}{R(13822\,My)} = \frac{1.36 \times 10^{25}\,m}{4.355 \times 10^{26}\,m} \approx 0.03$$

Thus when the Universe was 96.0887 *My* old the mass of the Universe was about 63% percent of the total mass of the observable Universe; and the radius of the Universe was just 3 percent of the radius at the present time. This explains the fact that all of the galaxies in the observable Universe appear to originate from a single point and also that at that time (when the age was 96 *My*) the Universe must have been very hot. All of this suggests that the Universe started out as a very small but finite spherical region as this theory postulates. The CMB radiation could have been originated some time (which is unknown) after the Universe started out and not necessarily at the very beginning of time (the Planck time) as the Standard BB theory claims. Consequently, there is no need to introduce the concept of singularity. Figure 6 shows the radius of the Universe as a function of time.

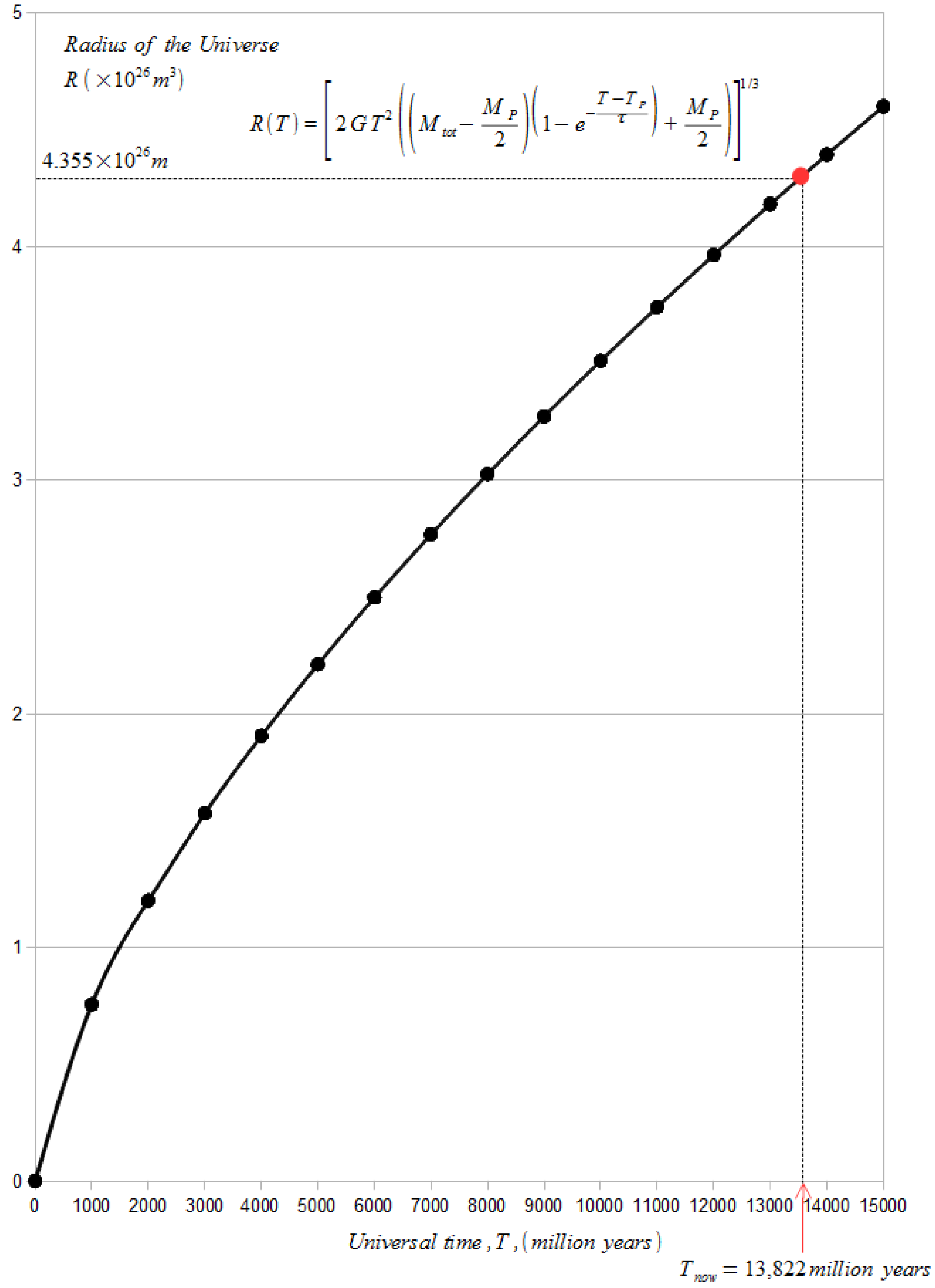

FIGURE 6: The radius of the Universe as a function of time. According to this model the

radius of the Universe, now (13,823 *My*), is, approximately, $R(13{,}823\, My) \approx 4.355 \times 10^{26}\, m$

Equation (3.5.3) can be written as follows

$$R(T) = \left[2G \left(\left(M_{tot} - \frac{M_P}{2} \right) \left(1 - e^{-\frac{T - T_P}{\tau}} \right) + \frac{M_P}{2} \right) \right]^{1/3} T^{\frac{2}{3}} \qquad (3.5.4)$$

and also in a more compact form as

Radius of the Observable Universe ("Compact" formula)

$$R(T) = K_{radius}(T)\, T^{\frac{2}{3}} \qquad (3.5.5)$$

where the "proportionality constant", $K_{radius}(T)$, is in fact, a function of time. This "constant" is defined by

$$K_{radius}(T) = \left[2G \left(\left(M_{tot} - \frac{M_P}{2} \right) \left(1 - e^{-\frac{T - T_P}{\tau}} \right) + \frac{M_P}{2} \right) \right]^{1/3} \qquad (3.5.6)$$

It is worthwhile to remark that the graph for the radius of the Universe derived in this paper (shown in figure 6) is very similar to the graphs corresponding to the Friedmann model with a space curvature: $K_{space} = 0$ (Universe with flat geometry) and cosmological constant: $\Lambda = 0$ found in the literature. See, for example, the following two references:

(Ref. 1 [8]) Fig 27.15(b) of the book: "*The Road to Reality"*.
(Ref. 2 [9]) the middle graph of Fig. 1 (corresponding to $K_{space} = 0$) of the Web article entitled: "*Friedmann Equation"*.

The close matches between the graphs shown in the above references and the graph for the radius of the Universe presented here (fig. 6), indicate the correctness of the theory presented in this paper. Despite there are marked similarities between the *QGCM* and the Friedmann model, there are essential differences too. Firstly, the *QGCM* explains the origin of the Universe from a quantum gravitational perspective (or "a la quantum gravity"), something the Friedmann model is unable to do. This mean that, in the *QGCM*, there is no need to introduce the concept of singularity. Secondly, while equation (3.5.5) has a "proportionality constant" which is a function of time, the corresponding constant of the Friedmann model is in fact a constant (does not depend on time). This means that the Friedmann model is, from this point of view (meaning partially), a special case of the *QGCM*. On the other hand, the Friedmann model predicts three possible fates for our Universe, something this formulation does not covers at the present time. However, from the physical implications' point of view, it is far more important to understand the beginning of the Universe than its end.

3.6 The Entropy of the Observable Universe

Because I have postulated that the Universe started with a size equal to the Planck sphere (of radius equal to the Planck length and a mass equal to the Planck mass over 2) and because the minimum size of a black hole is also the Planck sphere, we may, assume that the entropy of the Universe a the beginning of time may be calculated from the Berkenstein-Hawking entropy formula for black holes [10, 11, 12]. This formula is

$$S_{BH} = \frac{k_B c^3 A}{4\hbar G} \tag{3.6.1}$$

However, it is worthwhile to emphasize that the Universe is not a black hole. It was only at the very beginning of time that the Universe had exactly the size of the minimum black hole (see Appendix 1). Immediately, after that time, the Universe started to grow in size and it has never stopped growing (and it will probably never stop). On the other hand, a minimum black hole has two possible fates: (a) it can evaporate, due to a mechanism known as Hawking radiation, or (b) it can grow in size by absorbing material from nearby objects, such as stars (if there is matter of any kind sufficiently close). In contrast, the Universe cannot absorb any matter because the Universe contains all the matter there is at any given time (the Pre-universe contains only energy [3] (or Pre-energy)). As the matter of the Universe increases, the newly "created" matter appears into the Universe, so the Universe will always contain all the matter (meaning all types of matter) nature "manage to create".

According to this assumption, the entropy, S_0, of the Universe, at the first instant of time, will be

$$S_0 = \frac{k_B c^3 A_{Planck}}{4\hbar G} \tag{3.6.2}$$

and also

$$S_0 = S_{Planck} \tag{3.6.3}$$

where

S_0 = Initial entropy of the Universe
S_{Planck} = Planck entropy
A_{Planck} = Area of the sphere of radius L_{Planck}

If we extrapolate the formula for the Area of the sphere representing the Universe for any value of the radius R of the Universe we get

$$A = 4\pi R^2 \tag{3.6.4}$$

It is worthwhile to remark that this extrapolation might not be valid because the Universe is not a black hole. However, to illustrate the consequences of this assumption I shall consider that the Universe is similar to a black hole whose radius increases with time. From equations (3.6.2) and (3.6.3) we get the formula for the entropy as a function of the radius of the Universe

$$S = \frac{k_B c^3 \pi}{\hbar G} R^2 \qquad (3.6.5)$$

We may use equation (3.5.3) to eliminate R from the previous equation. This gives

$$S(T) = \frac{k_B c^3 \pi}{\hbar G} \left[2GT^2 \left(\left(M_{tot} - \frac{M_P}{2} \right) \left(1 - e^{-\frac{T - T_P}{\tau}} \right) + \frac{M_P}{2} \right) \right]^{2/3} \qquad (3.6.6)$$

This is the formula of the "entropy" of the Universe as a function of time. Figure 7 shows the graph for this function. The *y* axis, in the figure, represents the estimate of the entropy of the Universe while the *x* axis represents the Universal time. It is worthwhile to observe that the "entropy" increases exponentially with time.

The equation for the Planck entropy is

$$S_{Planck} = \frac{\pi k_B c^3}{\hbar G} L_{Planck}^2 \qquad (3.6.7)$$

This is the minimum entropy a black hole can have. If we replace L_{Planck} by the second side of equation (3.1.2) we get

$$S_{Planck} = \pi k_B \qquad (3.6.8)$$

The value of the Planck entropy is

$$S_{Planck} \approx 4.337 \times 10^{-23} \; J / {}^\circ K$$

(See figure 7 on the next page)

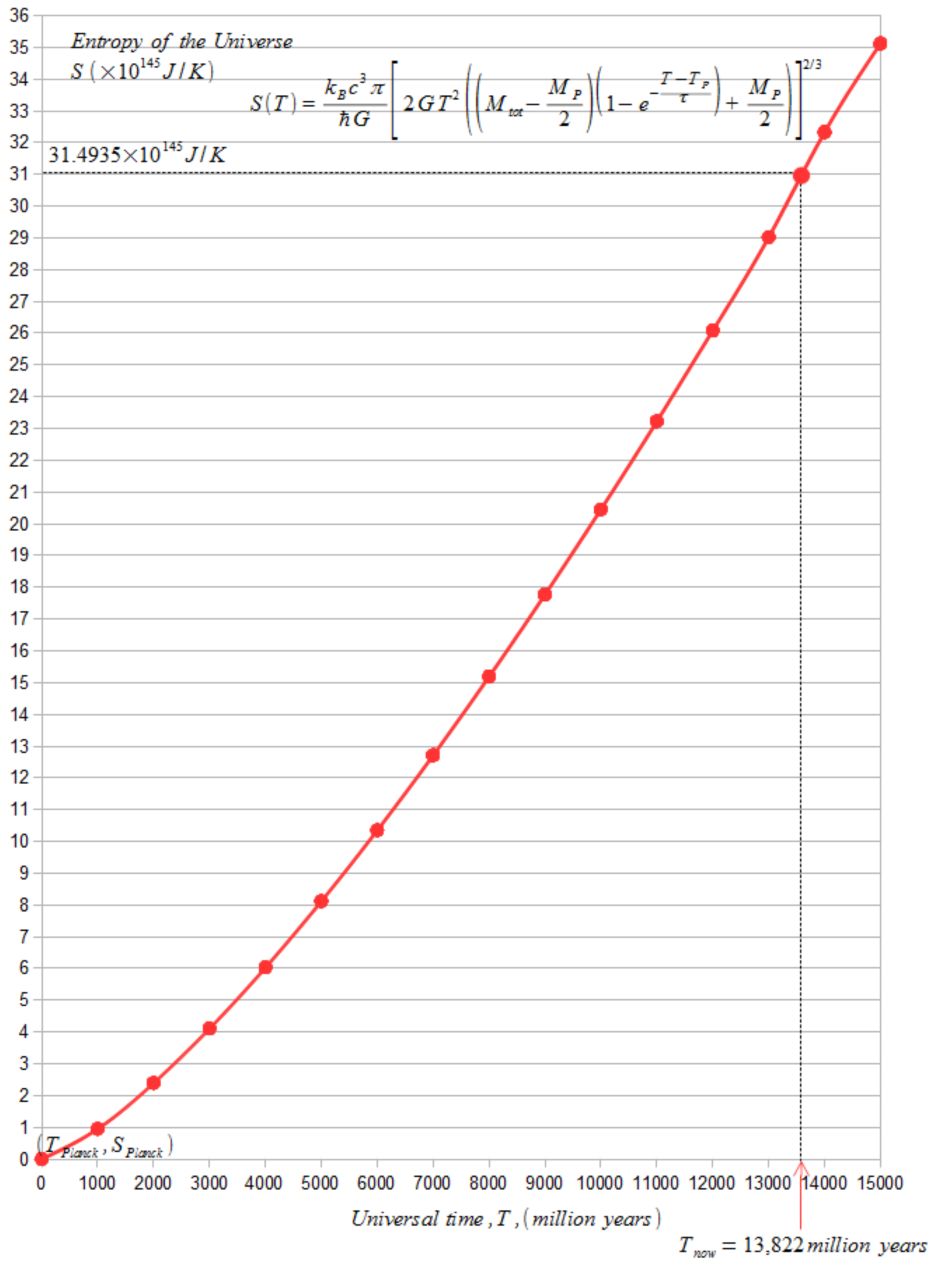

FIGURE 7: An estimate of the entropy of the Universe as a function of time. This function was derived assuming the Universe is like a black hole at any given time. Because this hypothesis is true for the Planck time only, this graph must be taken as an estimate only. The initial entropy of the Universe is $S_{Planck} \approx 4.337 \times 10^{23} J/°K$

4. Cosmological Misconceptions

In this section I shall briefly address some misconceptions I found in Cosmology.

Misconception 1:
The Universe Does not Expand into Anything

The general scientific view about the Universe is that it does not expand into anything. The following paragraph reflects this view:

"...When (the author refers to the Universe) *it expands, it does not claim previously unoccupied space from its surroundings. Some newer theories such as string theory do postulate extra dimensions, but as our three-dimensional universe expands, it does not need these extra dimensions to spread into."*

Meta-space is the infinite space of the Pre-Universe (or Meta-universe) [3]. Unlike our three-dimensional space, meta-space has, at least, four spatial dimensions. The extra dimension is needed to enclose our Universe. Therefore, if the expansionist hypothesis is correct, then our Universe expands into the Meta-space of the Pre-Universe. Just because GR does not need an extra dimension in which the Universe can expands into, doesn't mean that the extra dimension does not exist. GR's equations breaks down at the very beginning of "creation", meaning that this formulation cannot make any predictions about what happened before or immediately after the BB.

Misconception 2:
The Universe Has No Centre

The generally "accepted" scientific opinion about the Universe is that it has no centre. The following paragraph reflects this view:

"In this sense, the universe is self-contained. It needs neither a center to expand away from nor empty space on the outside (wherever that is) to expand into."

The existence of meta-space implies that the Universe must have a centre. This is so because our Universe is embedded in the spatial meta-dimensions of the Meta-universe, meaning that our three-dimensional space are dimensions created within a meta-dimension. However, this centre is not located into our Universe. This conclusion is drawn form the following analogy. Let us consider the surface of a sphere that we shall call: *Flatopia*. Let us assume that on this surface there are two-dimensional intelligent beings called *flatopians*. These beings will not be able to observe the extra dimension of the sphere simply because their world (the surface of the sphere) has only two dimensions (plus time if you like). Consequently, they will assume that Flatopia has no centre. However, for external tree-dimensional beings, such as us, the centre of the surface of the sphere (the centre of Flatopia) will be the centre of the sphere. Thus from the higher dimensional world's point of view, the Universe will have a centre, but this centre will not be located on Flatopia. Similarly, we can consider the three-dimensional sphere as the "surface" of a four-dimensional space (e.g. a hypersphere or whatever it is). Therefore, the centre of our Universe will be placed somewhere in the hypersphere, this is in the fouth-dimension (spatial). But because we live in a three-dimensional world (meaning, we cannot see the forth dimension of space), we shall not be able to access (or observe) this centre even if we were able to observe the whole three-dimensional Universe we live in. From this perspective we could say that "the Universe has no centre". But this is erroneous. There is always a centre even if the centre is not in our Universe.

Another question relating to this one is: has the Universe got an edge? To answer this question we may came back to Flatopia. In that flat world the flat inhabitants can travel in all directions (perhaps in a flat spaceship) and they will never find an edge. The reason is, as we know, because the surface of sphere has no edge. Analogously, we could travel, in principle, in an extremely advance spaceship in any direction of space for an eternity and we would never find an edge for the same reason: our “three-dimensional” Universe has no edge. This is because our Universe is, in fact, not a three-dimensional world but a fourth-dimensional one (four spatial dimensions plus time: x, y, z, w, t). If our Universe were a three-dimensional world (such as a sphere) we should, in principle, be able to get to its edge (with the appropriate technology and perhaps with a little help from a wormhole). But this is impossible because the Universe we live in has, at least, four spatial dimensions (x, y, z, w). The fourth dimension, denoted by w, is “responsible” for the non-existence of a three-dimensional edge of the Universe (for three- dimensional beings like us). If we “remove” the fourth spatial dimension of our Universe then we would run into trouble trying to explain where would we go if, in principle, we were able to cross the “edge” of the Universe. Because our Universe has four spatial dimensions we don't have to worry about the “edge” of the Universe, simply because there isn't one.

Misconception 3:
The Universe Was Created from Nothingness

Some people state that nothingness is unstable. Then they say that as a consequence of this instability, the Universe popped up into existence. I shall show that this is incorrect. First of all nothingness means non-existence. Non-existence cannot have properties because only existing things have properties. But instability is a property. Therefore instability cannot be a property of nothingness. In other words to say that nothingness is unstable does not make any sense. Thus we must rule out instability as the cause of creation.

The problem about creation can be solved by accepting that the Meta-universe was not created but it always existed. Accepting that Meta-time, unlike time, did not have a beginning is a simple and beautiful concept. Even if there is only one type of time (normal time) it could have not had an origin. Time did not have a beginning; it always existed. It couldn't have been any other way. This is because in order to create something (whatever it is) Nature needs the existence of time. Therefore time cannot be created[5]. Time (or Meta-time) along with energy (or Meta-energy) are the most primordial and basic entities there are. Nothing, in the Universe (or Meta-universe), is more fundamental that them. This is the reason why the temporal Heisenberg uncertainty principle relates energy and time in the form of uncertainties:

$$\Delta E \, \Delta t \geq \frac{\hbar}{2}$$

However, let us postulate that there is a cause for everything there is. Thus, the Meta-universe (that we shall call Meta-universe 0) had a beginning. The cause that created the Meta-universe 0 was Meta-universe 1.

5. Unless there is a more primordial type of time: Meta-time. But then, for the same reason, Meta-time could have not been created.

But because everything has got a cause, Meta-universe 1 must have been created by Meta-universe 2. For the same reason, Meta-universe 2 must have been created by Meta-universe 3, and so on.

This reasoning leads to an infinite number of Meta-universes which were the cause of the existence of a Meta-descendant. Now we may ask: What is the difference between the following two models: ***Model 1****:* this model has an infinite number of Meta-universes, and ***Model 2****:* this model has only one Meta-universe with no beginning in neither space nor time? Both models have something in common: both involve the concept of infinity. The former has an infinite number of Meta-universes with a starting point in Meta-time for each of them, while the latter has a finite number of Meta-universes (only one) with no starting point in Meta-time (an infinite Meta-time). So that whichever model we choose we cannot get rid of the concept of infinity.

Now one may ask: why would everything had to have a beginning? Is this so because we have never seen anything without a beginning? After all plants are born, animals are born, babies are born, planets are born, stars are born, galaxies are born, and the Universe itself was born. Creation is a concept that reflects our daily experience and our observations of objects such as stars and galaxies. But we don't have any experience that can be extended before the Big Bang. Extrapolating the concept of creation beyond the Big-Bang cannot be scientifically justified because we cannot get rid of infinities. Isn't it simpler to accept that Nature had a different way of doing things before the Big Bang?

Some people have asked: why is there something rather than nothing? This is an ill-founded question as I shall explain. When we have an option we chose one or more existing thing among a number of existing things. However we can say: I don't want to choose anything. This means that we did not choose any of the existing things. But this does not mean that we chose "something" called "nothing". The reason as to why "nothing" cannot be chosen is because you cannot chose something that is non-existent.

Nature did not come with nothingness and it does not come with nothingness. Nature is something and it has always been something (Nature has always been that way!). The confusion arises because we treat nothingness as an existing thing, as an option, as something Nature could have chosen from a pool of possibilities. But this reasoning is ill-founded. In other words it does not make sense. Nothingness is not a possibility or option Nature can "choose from". This is because Nature can only "chose" from existing things. All Meta-properties of the Meta-universe exit (and always existed) even if we are unable to see them or to experiment with them directly. Perhaps the confusion comes from thinking of empty space as nothingness. This is incorrect. According to Einstein spacetime is curved and matter is the source of this curvature. Bodies move in a gravitational field by following the curvature in the fibres of spacetime in the neighbourhood of massive objects. Therefore space must be something, otherwise a massive object would not be able to curve it. On the other hand, the Big Bang tells the same story: spacetime (I assume there is Meta-time which is more primordial than normal time) was created during the Meta-transformation known as the Big Bang, therefore, if spacetime was created it must be something. A web article from NASA Science [13] supports my point of view on the difference between empty space and nothingness

"Albert Einstein was the first person to realize that empty space is not nothing. Space has amazing properties, many of which are just beginning to be understood. The first property that Einstein discovered is that it is possible for more space to come into existence. Then one version of Einstein's gravity theory, the version that contains a cosmological constant, makes a second

prediction: "empty space" can possess its own energy."

In summary, we may say that Nature (the Meta-universe) was always something, Nature always existed, Nature did not have a beginning as Meta-time did not have a beginning either.

Misconception 4:
The Universe Started with a Singularity

This issue has been addressed in **Postulate 3**, Justification *ii.* However I shall expand this point a bit more here. The Big Bang Theory claims that, in the beginning, the Universe was a point with infinite mass density and infinite curvature. In his book "*A Brief History of Time*" [14], Stephen Hawking defines the term *singularity* as follows:

"A point in space-time in which the space-time curvature becomes infinite"

Also in a web article entitled *"The Beginning of Time"* [15], he explains:

"At this time, the Big Bang, all the matter in the universe, would have been on top of itself. The density would have been infinite. It would have been what is called, a singularity. At a singularity, all the laws of physics would have broken down."

Other scientists, such as Larry Smarr from the University of Illinois, quotes [16]:

"Schwarzschild was describing a singularity, a region of infinite spacetime curvature that is postulated to lie within what has more recently been termed a black hole."

It is also interesting the following paragraph from a web page [17] which adds another property of a singularity: an infinitely strong gravitational field (which is a consequence of the alleged infinite mass density of the singularity):

"Eventually, you'll reach the singularity, where the gravitational field is infinitely strong. At that point, you'll be crushed to an infinite density. Unfortunately, general relativity provides no basis for working out what happens next. "When you reach the singularity in general relativity, physics just stops, the equations break down," says Abhay Ashtekar of Pennsylvania State University."

First of all, a point is dimensionless, meaning that, strictly speaking, a point has no extension and consequently does not exist. Having said that I should say that a geometric point is a useful idea in both mathematics and physics. It allows us to understand functions, graphics, etc. But a point is just that: a useful concept with no physical reality. How could a point have an infinite gravitational field, an infinite mass density and an infinite curvature then? How could something that doesn't even exist have properties such as gravitational field, density and curvature? There must be something magical about points that some scientists and mathematicians forgot to tell us about! The big problem with the Hot Big Bang Theory is that is based on Einstein's General Theory of Relativity (GR) which is useless when dealing with scales as small as the Planck length. Despite the fact that in recent years GR has passed a series of rigorous tests, GR cannot explain the beginning of our Universe.

The reason is simple: GR does not feature any uncertainty relations[6]. In other words, GR is a classical theory and therefore does not include any quantum mechanical descriptions. On the other hand, the approach presented in this paper is a quantum mechanical "recipe" which includes quantum mechanical "ingredients" such as the Planck length, the Planck time, the Planck mass and the Planck entropy.

Misconception 5: Time Did not Exist "Before" the Big Bang

The Big Bang Theory states that time (spacetime) was created, approximately, 13,000 million years ago along with space and therefore the expression: "Before the Big Bang", doesn't make any sense. This is incorrect. There was either time (normal time) or Meta-Time (a time-like dimension or pre-time) before the Big Bang [3]. Time, like energy were never created. They always existed.

Our Universe is a "toy creation". Creation never happened and it will never happen. Our Universe is a result of a transformation (Meta-transformation): something unimaginable that happened in the Pre-Universe. One of the problems, the existence of Meta-time solves, is the philosophical problem of the evolution of the Universe. This is discussed in the next subsection (Misconception 6). Another problem, it solves, is the mystery of the observed imbalance between matter and antimatter of the Universe (one of the cosmological problems) [18].

Misconception 6: The Evolution of the Universe

Mariano Villamate [19] explains:

"Another serious problem in Cosmology is the idea of the global evolution of the Universe. This idea raises the question: with respect to what does the Universe evolve? The answer, rarely explicit, consists in admitting that the Universe evolves with respect to itself, this is, with respect to a previous state. Extending this reasoning we reach the conclusion that the evolution is with respect to the initial instant, this is with respect to a situation that is unmanageable by physics."

This means that the idea of the "evolution" of the Universe is a poorly defined concept. However, this concept is widely used in Cosmology where people talk about *evolutionary models*. Perhaps we should refer to these models as *"evolutionary" models* or even as: *non-stationary models*. In contrast, the Theory of the Pre-universe [3] that I developed implies that the Universe "evolves" with respect to the Pre-Universe. But the problem, somehow, still persists because we cannot prove the existence of the Pre-universe. However, the theory of the Pre-universe seems to explain several physical and philosophical matters in a natural manner, something that the Hot Big Bang Theory is unable do. Another possibility is that the Universe evolves towards a state of extraordinarily high entropy or, even, towards a state of infinite entropy. If this were the case, then the Universe would "evolve" towards a state in the future. To avoid any confusion it is better to replace the verb "to evolve" by "to change" with the appropriate tenses.

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6. Also known as uncertainty principles

5. Cosmological Data

The following table shows some results from the WMAP and PLANCK spacecrafts and from other sources.

Parameter	WMAP Satellite (NASA)	PLANCK Satellite (ESA)	Other Sources
Hubble constant (H_0) $\frac{Km}{S\ Kpc}$	71 ± 5 % [20]	67.8 ± 0.9 [21]	–
H_0 yields the following age of the Universe (*billion years*)	13.73 ± 0.12 [22]	13.82 [22]	13.7 ± 0.2 [23]
Mass density of the Universe	$9.9 \pm 10^{-30}\ g/cm^3$ [24] or, equivalently $9.9 \pm 10^{-27}\ Kg/m^3$	–	– $9.47 \pm 10^{-27}\ Kg/m^3$ [25]
Or equivalently n_p ($number\ of\ protons/m^3$)	5.92	–	5.66

TABLE 1: WMAP and PLANCK missions' data and other data (See also [26])

6. Conclusions

One important point about the Quantum Gravitational Cosmological theory is that while a normal explosion expands through air or through empty space (in case of an explosion in empty space), the Big Bang expanded through Meta-space: the space that existed before the Big Bang. In contrast, the Hot Big Bang theory postulates that the Big Bang did not expand through anything. Another salient point of the *QGCM* is that it does not require any singularity at the beginning of time or at any other time. As I have shown the Universe started with a finite volume and mass. In contrast, the Hot Big Bang Model makes the hypothesis of a starting point of infinite mass density and infinite curvature. A hypothesis that cannot be explained by any known laws.

GR predicts that, if the average mass density is equal to the critical density, the Universe will halt its expansion in an infinite time. The following table illustrates this point.

Standard Hot BB Theory	Quantum Gravitational Cosmological Model
$\lim_{T\to\infty} V = V_{max}$ valid for only if: $\rho = \rho_C$ (see Glossary: The Geometry of the Universe)	$\lim_{T\to\infty} V = \infty$ The model assumes that the volume of the Universe will be infinite in an infinite time.
$\lim_{T\to\infty} V = \infty$ valid for only if: $\rho < \rho_C$ (see Glossary: The Geometry of the Universe)	$\lim_{T\to\infty} V = \infty$ The model assumes that the volume of the Universe will be infinite in an infinite time. [27]
$\lim_{T\to\infty} M = \infty$	$\lim_{T\to\infty} M = M_{tot}$ The "practical" time needed to reach the total mass depends on the time constant of the Universe. So for practical purposes this time is about 700 *My* or so (see fig. 4).

This research suggests that the Quantum Gravitational Cosmological model is more suited for predicting the beginning of our Universe, while the Standard Hot Big Bang model is more suited for predicting the fate of the Universe. This conclusion is logical, after all, because GR is unable to deal with the quantum gravitational nature of the transformation (meta-transformation) that gave rise to our Universe. You must pick the tool best suited for the need. By the way, the Friedmann-type cosmological models predict three possible fates for our Universe which depends on the value of the mass density of the Universe. If the mass density is greater than the critical mass density, ρ_C , gravity will hold the expansion the Universe will collapse in a big crunch. If the mass density is smaller than the critical mass density, gravity will not be able to hold the expansion and the Universe will expand forever. If the mass density is equal to the critical mass density, gravity will be able to hold the expansion in an infinite time. One can ask: which is the value of the mass density of our Universe? Astronomical observations seems to indicate that the mass density of our Universe is exactly the critical mass density. But if this is so, what are the chances that the mass density of our Universe to be exactly the critical mass density and not a different value? Is that just a coincidence? I believe the answer is that this is not a coincidence. Something, perhaps the initial conditions before BB, or perhaps something else, set up the Universe so that its mass density is exactly the critical mass density we observe today. In contrast, the quantum gravitational cosmological model predicts one and only one fate: the Universe will keep expanding forever. You may ask: is this a limitation of the model presented in this paper? Not necessarily. If the pre-universe has no choice but to "build" a Universe with a mass density equal to the critical mass density, then there is no need to have two of the cases predicted by the Friedmann model simply because these two cases would not be "allowed" by Nature.

In summary, the most important conclusions we can draw from the *QGCM* are:

(1) The initial size of the Universe was a sphere of radius equal to the Planck length (see fig.1).

(2) The initial mass of the Universe was equal to the Planck mass divided by 2 (see fig.1).

(3) In the beginning the Universe did not contain singularities of any kind. It is likely that, at the present time, the Universe does not contain any singularities of any kind either (not even inside black holes). In other words, it seems that singularities do not exist. Therefore, singularities are the product of a theory (GR) that fails to predict the correct results at the Planck scale.

(4) It is likely that the Universe "evolves" to a state, in the future, of extremely high entropy or infinite entropy (for infinite time).

(5) The Universe will, probably, expand forever but the total mass of the Universe has a maximum value or upper bound, that for practical purposes, has already been reached when the Universe was relatively very young (It is worthwhile to compare the mass of the Universe with the charge of a capacitor in a *RC* serial circuit. The capacitor gets fully charged after a few time constants only).

(6) If the hypothesis that the Universe was similar (but not identical) to a black hole of minimum size for $T = T_P$ (and only for this time) is correct, then we are able to calculate the initial temperature and entropy of the Universe. To do this all we need to do is to borrow the formulas for the black hole temperature and entropy and apply them to the Universe for that particular time. This will give us a starting point from where we can derive the correct functions (not based on black hole thermodynamics) for the temperature and entropy of the Universe as functions of time.

Because the present model contains exponential formulas, it is already endowed to address some of the cosmological problems I mentioned earlier. However, the exponential increment given by this formulation might not be enough. If this were the case then a modification to the model should be implemented so that the formulation may explain these problems in full. One way of doing so is to adopt a smaller value for the time constant of the Universe. But this might not be enough either. A more effective way is to change the function for the mass of the observable Universe (since the function for the mass density of the Universe should remain unchanged, changing the function for the mass of the Universe means that we have to change the function for the volume of the Universe) so that, for certain period of time, the function will increase at an exponential rate faster than the function used in this formulation. Then, as time increases further, the function gradually turns into an exponential function as the one presented here. In other words, the mass function should start with an increasing slope, which marks the beginning of the inflationary period, and then, after some relatively short period of time, the slope of the function should start to decrease. This would be the end of the inflationary period. Thus, this modification should explain, at least, both the horizon problem and the flatness problem mentioned earlier.

Finally, I would like to say that the formulation presented here is incomplete and is still under development. The model should be refined by incorporating, amongst other things, a function for the temperature of the Universe and a function for the entropy of the Universe as functions of time. In other words, the refined model should explain, at least, the observed *CMB* radiation and all the other cosmological observations mentioned earlier.

Appendix 1
Derivation of the Initial Mass of the Universe

I shall derive the initial mass of the Universe from two different perspectives. For the first derivation I shall use the temporal Heisenberg uncertainty relation, while for the second one, I shall use the concept of minimum black hole.

a) Derivation of the Initial Mass of the Universe from the Temporal Heisenberg Uncertainty Relation

I shall assume that, in the beginning, the following equation, based on the Heisenberg uncertainty principle, is valid

$$\Delta E \, \Delta T = \frac{\hbar}{2} \quad \text{(A1a.1)}$$

It is worthwhile to observe that I have used the energy-time Heisenberg uncertainty relation (or temporal Heisenberg uncertainty relation) under the form of an equation. This is the primordial form of the Uncertainty principle. In this equation the energy uncertainty, ΔE , and the time uncertainty, ΔT , are given by

$$\Delta E = \frac{E_P}{2} = \frac{1}{2}\sqrt{\frac{h c^5}{2\pi G}} = \frac{1}{2} c^2 \sqrt{\frac{h c}{2\pi G}} = \frac{M_P}{2} c^2 \quad \text{(A1a.2)}$$

and

$$\Delta T = T_P \quad \text{(A1a.3)}$$

Where E_P is the Planck energy, M_P is the Planck mass and T_P is the Planck time. Substituting ΔE and ΔT in equation (A1a.1) with equations (A1a.2) and (A1a.3) we get

$$\frac{M_P}{2} c^2 T_P = \frac{\hbar}{2} \quad \text{(A1a.4)}$$

It is worthwhile to remark that at the beginning of normal time, the temporal Heisenberg uncertainty relation was an equation and not an inequation. Equation (A1a.4) suggests that in the very beginning, the initial mass of the Universe, M_0 , was the Planck mass divided by 2. In other words:

$$M_0 = \frac{M_P}{2} \quad \text{(A1a.5)}$$

b) Derivation of the Initial Mass of the Universe from a Black Hole of Minimum Size

According with Einstein's General Relativity, the Schwarzchild radius, or the radius of a black hole is given by

$$R_S = \frac{2\,G\,M}{c^2} \tag{A1b.1}$$

Now we solve this equation for M

$$M = \frac{R_S\,c^2}{2\,G} \tag{A1b.2}$$

The mass of the black hole will be minimum when the value of its radius to be minimum. But, according to **Postulate 2** (space quantization postulate), the minimum distance in the Universe is the Planck length, L_P . Thus, the minimum radius of any sphere in the Universe must be the Planck length (this is because the centre of the sphere must be accessible). Consequently, when R_S is equal to L_P , the mass of the black hole will be minimum, M_{min} . This fact can be written mathematically as follows

$$M_{min} = \frac{L_P\,c^2}{2\,G} \tag{A1b.3}$$

Considering the expression for the Planck length given by equation (3.1.2)

$$L_P = \sqrt{\frac{h\,G}{2\,\pi\,c^3}} \qquad \text{(Equation 3.1.2)}$$

we may write equation (A1b.3) as follows

$$M_{min} = \sqrt{\frac{h\,G}{2\,\pi\,c^3}}\,\frac{c^2}{2\,G} = \sqrt{\frac{h\,G\,c^4}{2\,\pi\,c^3\,4\,G^2}} = \sqrt{\frac{h\,c}{2\,\pi\,4\,G}} = \frac{1}{2}\sqrt{\frac{h\,c}{2\,\pi\,G}} = \frac{M_P}{2} \tag{A1b.4}$$

Writing the first and the last side of equation (A1b.4) (for clarity reasons) we have

$$M_{min} = \frac{M_P}{2} \tag{A1b.5}$$

But the initial mass of the Universe mass be equal to the minimum mass of a black hole. Then

$$M_0 = M_{min} \tag{A1b.6}$$

And finally

$$M_0 = \frac{M_P}{2} \qquad \text{(A1b.7)}$$

Although the Universe is not a black hole, equation (A1b.5) applies to the Universe in the very beginning (It is worthwhile to think that an “instantaneous photo” of the Universe taken at $T = T_P$ looks like the “picture” of the smallest possible black hole). This means that, at time $T = T_P$, a relatively small amount of mass (equal to $M_P/2$), was “created” by a mysterious '“meta-energy”-mass' transformation. Since then, the mass of the Universe grew exponentially as shown earlier in this paper.

Appendix 2
Glossary

Annihilation
Process by which, when matter and antimatter collide, they disintegrate. The mass of the particles is converted into pure energy.

Antimatter
Matter, made of negative energy, which, according to the American physicist Richard Feynman, travels backward in time. Charged antiparticles have the opposite sign of electric charge to their material counterparts. It is believed that for every kind of material particle there exist a corresponding antiparticle. Matter and antimatter are believed to have been created in equal amounts at the Big Bang.

Antimatter Problem
Some cosmologists think the Universe was created with equal amounts of matter and antimatter. However today's observations indicate that there is not enough antimatter to match the amount of matter observed. Thus, it seems that matter has, for some unknown reason, taken over. (I have proposed a solution to this mystery [18]).

Big Bang
Definition 1
Meta-transformation from a high entropy Meta-state to low entropy state. During this Meta-transformation all types of matter were created from only three “ingredients”: Meta-time, Meta-energy and Meta-space. Immediately after the creation of spacetime matter was created.
Definition 2
Cosmological model in which the Universe is thought to have emerged from an extremely hot, and infinitely dense point (singularity).
Definition 3
“Fireball” or “explosion” that originated the Universe.

Black Hole
Region of spacetime enclosed by a surface known as event horizon. Because nothing (not even light) can escape a black hole, these objects are termed “black”. Any objects that crosses the event

horizon disappears from the observable universe. When the pressure produced by the fusion of the matter within the star cannot withstand the force of gravity, then the star may collapse to form one of three possible cosmic objects: a white dwarf, a neutron star, or a black hole. The result will depend on the mass of the star. A black hole has a higher mass density than a neutron star and a neutron star has a higher mass density than a white dwarf.

Black Hole Entropy

The Berkenstein-Hawking entropy formula for black holes tell us that the entropy of a black hole depends on the area of its event horizon and not on its volume. The formula is

$$S_{BH} = \frac{k_B c^3 A}{4 \hbar G}$$

The Berkenstein-Hawking entropy formula for a black hole is a direct consequence of the universal uncertainty principle (UUP), which is a generalization of the Heisenberg uncertainty principle.

Black Hole Temperature

The Special Quantum Gravitational Theory of Black Holes [12] predicts that the temperature of a Black hole is given by the following formula

$$\Theta = \frac{\Theta_H}{8\sqrt{\pi}} \left(\sqrt{\frac{L_P^2}{\pi R^2} + 64\pi} - \frac{L_P}{\sqrt{\pi}\ R} \right)$$

or, equivalently

$$\Theta = \frac{\Theta_H}{8\sqrt{\pi}} \sqrt{\frac{k_B}{S_{BH}}} \left(\sqrt{1 + \frac{64\pi S_{BH}}{k_B}} - 1 \right)$$

This formula shows that the black hole temperature depends on both the mass M and the radius R of the black hole. The mass of the black hole appears in the Hawking temperature formula [12] for a black hole which is a special case of the above formula

$$\Theta_H = \frac{h c^3}{16\pi^2 k_B G M}$$

where

Θ = Black hole temperature (We used the Greek letter Theta to denote temperature because T is used to denote time)

Θ_H = Hawking temperature

R = Black hole radius

L_P = Planck length

k_B = Boltzmann's constant

S_{BH} = Berkenstein-Hawking black hole entropy

h = Planck's constant

G = Newton's gravitational constant

M = Mass of the black hole

Cosmology
The study of the Universe as a whole.

Cosmological Model
Mathematical model (theory or formulation) that describe (quantitatively and qualitatively) how the Universe (either the observable or the entire Universe) changes (or "evolves") over time. Time here refers to the Universal time, which in the Quantum Gravitational Cosmological Model is denoted by T.

Cosmological Problems
The classical problems of the Hot Big Bang cosmology or simply the cosmological problems are the following: (1) the horizon problem, (2) the flatness problem, (3) the structure problem, (4) the monopole problem and (5) the antimatter problem.

Cosmological Redshift
Redshift that includes the expansion of the Universe. This type of redshift is predicted by General Relativity.

Cosmological Time
See Universal Time.

Creation or "Creation"
Another name for the Big Bang or Meta-transformation.

Critical Density (Critical Mass Density)
Mass density for which the geometry of the Universe turns out to be flat (flat Universe). The critical density is also defined as the average mass density the Universe should have to just stop, after an infinite time, its expansion. The critical mass density is denoted by ρ_C and the formula and the corresponding value are

$$\rho_C = \frac{3 H_0^2}{8 \pi G}$$

$$\rho_C \approx 9.7 \times 10^{-27} \frac{Kg}{m^3}$$

Note that the value of ρ_C depends on the value of H_0 which may be determined either experimentally (See Table 1, Section 5) or theoretically. A Universe whose average density is equal to the critical density is said to be flat (See Geometry of the Universe).

Curvature of Space (Spatial Curvature of Space or Spatial Curvature)
Mathematical description of space that determines whether the Pythagoras theorem is correct (or valid) or incorrect (invalid) for the Universe we live in. The spatial curvature is, generally, denoted with K_{space} (k or K). The spatial curvature relates to the relative average mass density, Ω_0, as follows

(a) if the curvature is positive: $K_{space} > 0$, then $\Omega_0 > 1$ and the Pythagoras theorem is invalid.

(b) if the curvature is negative: $K_{space} < 0$, then $\Omega_0 < 1$ and the Pythagoras theorem is invalid.
(c) if he curvature is zero: $K_{space} = 0$, then $\Omega_0 = 1$ and the Pythagoras theorem is valid.

Using two dimensions instead of three it is easy to visualize the curvature of the Universe. A Universe with positive curvature is like the surface of a sphere, a Universe with negative curvature is like a hyperboloid (saddle) and a Universe with zero curvature is like a plane (See Geometry of the Universe). Astronomical measurements indicate that the spatial curvature of the Universe is very close to zero.

Dark energy
Unknown type of energy associated with the vacuum in space. Dark energy makes up approximately 70% of the Universe.

Dark matter
Unknown type of matter that does not interact with the electromagnetic force, meaning that it does not absorb, reflect or emit light, making it extremely hard to detect. Dark energy makes up approximately 26% of the matter of the Universe.

Electro-gravitational principle, The
The product of the gravitational coupling constant times the age of the Universe is equal to the product of the electromagnetic coupling constant times the hydrogen unit of time.
Mathematically:

$$\alpha_G T = \alpha t_H$$

where
α_G = Gravitational coupling constant for the proton
T = Age of the Universe or Universal age
α = Electromagnetic coupling constant (fine-structure constant or atomic structure constant)
t_H = Hydrogen unit of time

Energy-Mass Conversion
Process by which certain amount of mass, *m*, appears and an equivalent amount of energy, *E*, disappears. The formula that governs this conversion was discovered by Einstein and is

$$E = m c^2$$

The proportionality constant is c^2 , where *c* is the speed of light.

Equivalent Principle
One of the postulates of Einstein's Theory of General Relativity which states that a uniform acceleration is equivalent to a uniform gravitational field and vice versa.

Event
Each point in spacetime, in Special Relativity, is known as an event.

Event Horizon

The boundary (close surface) of a black hole beyond which no particle, not even light, can escape. An external observer can never see beyond this boundary.

Expansion of the Universe

Refers to the fact that most of the observed galaxies seem to recede from the Milky Way (See Hubble's law).

Flatness Problem, The

The flatness problem is the problem of finding the answer to the following question: Why is the observed mass density of the Universe so close to the critical density? In other words: Why is the geometry of the universe so flat?

Forbidden Survival

Possible solution to the mystery of the observed imbalance between matter and antimatter based on the fact that all (or most of) the antimatter created at the beginning of normal time (13.823 billion years ago) would have travelled backward in time to a time before the beginning of normal time. This means that antimatter would have travelled from the Universe to the Pre-universe [3] in a time equal to the Planck time or so. But because the Pre-universe cannot contain any matter or antimatter, all time travelling antimatter (created during the beginning of normal time) would have been converted into pure energy before or while crossing the temporal "frontier" [18] between our Universe and the Pre-universe.

General Relativity

A Geometric theory of gravitation developed by Albert Einstein which is accepted as the best theory we have in its domain. According to this theory the gravitational force between any two objects or particles is due to a geometric distortion of spacetime. This theory is based on (a) equivalence principle and (b) on the hypothesis that the laws of physics must be the same for all observers regardless of their motion. GR predicts that spacetime can be curved. The American physicist J. Wheeler wrote: *"space-time tells matter how to move; matter tells space-time how to curve."* The predictions of this theory includes, amongst other things, the following phenomena: the advance of Mercury's perihelion, the bending of light grazing massive celestial bodies, the gravitational redshift, the cosmological redshift, the existence of black holes and the existence of wormholes. Most cosmological models, such as the Standard Hot Big Bang Theory, are based on GR. GR is described by a system of ten, coupled non-linear partial differential equations known as Einstein's field equations. These equations are normally written as follows

$$R_{ij} - \frac{1}{2} g_{ij} R + \Lambda g_{ij} = \frac{8 \pi G}{c^4} T_{ij}$$

Geometry of the Universe

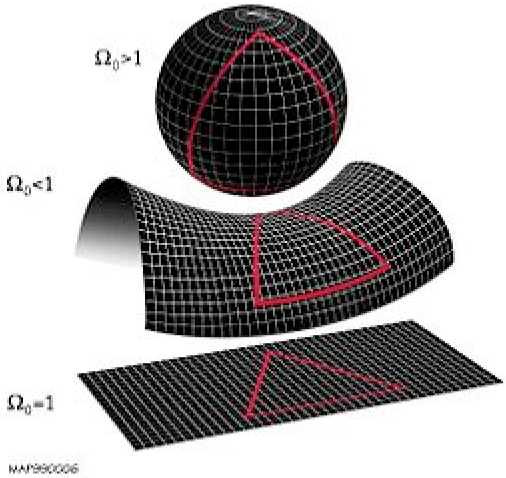
According to Einstein's General Relativity the geometry of the Universe depends on its average mass density, ρ , or equivalently, on the relative density Ω_0 (Ratio of the mean density observed to that of the density in a flat Universe). There are three possibles geometries:

a) **Spherical geometry or spherical space** $\left(K_{space} > 0 \; , \; \Omega_0 > 1 \right)$

If the density is higher than the critical density, $\rho > \rho_C$, gravity will halt the expansion in a finite time and after that the Universe will collapse in a finite time. In this case the "shape" of the Universe will be spherical and the Universe will be spatially closed. This means that parallel light rays will converge at some distant point.

b) **Hyperbolic geometry or hyperbolic space** $\left(K_{space} < 0\ ,\ \Omega_0 < 1\right)$
If the density is lower than the critical density, $\rho < \rho_C$, gravity will be insufficient to halt the expansion of the Universe. Consequently the "shape" of the Universe will be hyperbolic and the Universe will be spatially open. This means that parallel light rays will diverge at arbitrarily large distances.

c) **Flat geometry, Euclidean geometry or Euclidean space** $\left(K_{space} = 0\ ,\ \Omega_0 = 1\right)$
If the density is equal to the critical density, $\rho = \rho_C$, gravity will be just sufficient to halt the expansion when time is infinite, meaning the expansion will never stop. Consequently the Universe will not collapse. In this case the "shape" of the Universe will be spatially flat. This means that parallel light rays will remain parallel at arbitrarily large distances. This is, as we know, a feature of the Euclidean geometry.



(Graphics credit: Nasa &Wikipedia, http://map.gsfc.nasa.gov/universe/bb_concepts.html)

Gravitational Redshift
Lengthening of the wavelength of electromagnetic waves due to the presence of a gravitational field.

Horizon Problem, The
Why is the observed temperature of the Cosmic Microwave Background Radiation (CMB) isotropic? This question posed a problem to cosmological theories. A good cosmological model needs to explain the uniformity of Cosmic Microwave Background. The absolute temperature of the Universe is exactly the same in all directions you look at, varying by no more than one part in 10,000. Any information that is transmitted at the speed of light from one side (let's say the east) would not reach the other side (let's say the west) in 13,823 million years (which is the age of the Universe) because they are separated by 26 billion light years (size of the observable Universe) and information (light signals) could have not travelled that far in that time. Thus we say that opposite

sides of the Universe are not causally connected. Another way of saying this is as follows: two corners of space separated by a distance greater than the velocity of light multiplied by the age of the Universe could not possibly be causally connected because no signal cannot travel faster than the speed of light. How could two causally disconnected corners of the Universe have had almost the same temperature? The theory of inflation seems to answer this question: during inflation, the Universe expanded exponentially and regions that at the beginning of time (or close to the beginning) were mutually connected by light expanded faster than light. Space can expand faster than light without violating special relativity. Therefore we draw the conclusion that the speed of inflation is faster than the speed of light. Thus the regions of space that were very close at the beginning of time travelled at the speed of inflation.

Hubble Distance

Distance for which galaxies recede faster than the speed of light. This does not violates Einstein's Special Relativity (which states that matter and information cannot exceed the speed of light) because SR refers to motion through space while the recession velocity in Hubble's law refers to the velocity at which space itself is expanding (which is not motion through space). The Hubble distance is about 14 billion light-years.

Hubble's Law

This law is an empirical law discovered by the American astronomer Edwin Hubble. The law states that the recession velocity, v_{rec}, of a galaxy that moves away from the Milky Way is directly proportional to its distance, *D,* from the Milky Way. Thus, the further the galaxy from the Milky Way, the faster it was receding. The proportionality constant is known as the Hubble constant (H_0). The Hubble's law explains the average behaviour of galaxies so that some galaxies do not obey this law (e.g. Andromeda). The mathematical form of this law is

$$v_{rec} = H_0 D$$

The Hubble constant tell us how fast the Universe (space) is expanding around any observer. Because the speed of expansion of the Universe, v_{rec}, is a function of the distance to the observer (Milky Way), this speed (or, equivalently, the recession velocity of galaxies) is not unique. Thus, the speed of expansion of the Universe takes different values such as 2000 Km/S, 3000 Km/S, 4000 Km/S, 5000 Km/S, etc, depending on the distance, *D,* from the observer .

Hydrogen Unit of Time

Time taken by a photon to travel a distance equal to the diameter, $2a_0$, of the hydrogen atom. Where a_0 is the Bohr radius: $a_0 = 0.529\,177\,210\,92(17) \times 10^{-10} m$

Imbalance between matter and antimatter

Extra amount of matter over antimatter observed in our Universe.

Light Year

Distance light can travel in a year. Our galaxy, the Milky Way, is about 100,000 light years across. It is worthwhile to remark that this unit is a unit of distance and not a unit of time. One light year is equivalent to $9.460\,730\,473 \times 10^{15} m$.

Local Geometry
Geometry that describes the observable Universe.

Matter
The stuff most of the Universe is made of including us. Matter is made of positive energy or normal energy. Particles made of normal energy travel forward in time like us.

Meta-energy
A kind of energy that existed before the Big Bang [3].

Meta-space
Space of some kind that always existed before the Big Bang and which has, at least, one extra dimension in comparison to the three-dimensional space we are familiar with.

Meta-time
A kind of time that existed before the Big Bang [3].

Minimum Black Hole
A minimum black hole (meaning the minimum size a black hole can have) is a black hole whose size is equal to the Planck Sphere (See Planck Sphere) and whose mass is equal to the Planck mass over 2. This is the minimum volume and the minimum mass a black hole can have. According to the quantum gravitational cosmological theory, the Universe started with a sphere equal in size and mass to a minimum size black hole.

Negative energy
Type of energy antiparticles are made of or state they acquire due to backward time travel. Normal mater or particles, on the other hand are made of the normal energy (positive energy) we are all familiar with.

Normal Time
The time that started at the beginning of the Universe (13.823 billion years ago). In other words the time that started when the Universe was "created". Normal time is the same as Universal time. However, we have to keep in mind that time existed before the Big Bang. This "earlier" time is known as Meta-time or pre-time [3].

Neutron Star
Star that has consumed its nuclear fuel so that it can no longer generate the pressure and heat necessary to prevent its collapse due to gravity. If the initial mass of the star exceeds certain critical value, the star may collapse into a denser cosmic object. Depending on the mass of the star the final object may be a white dwarf, a neutron star or a black hole. When a star becomes a neutron star its protons and electrons are transformed into neutrons. Consequently, neutron stars can be denser than a normal atomic nucleus. Neutron stars are denser than white dwarfs but not as dense as black holes.

Observable Universe

Part of the Universe that is possible to observe from Earth at the present time because electromagnetic waves (light, X-rays, gamma rays, etc.) from cosmic objects (planets, galaxies, galaxy clusters, etc.) has had time to reach our planet since the beginning of the Universe. Assuming our Universe is isotropic, as it appears to be on large scales, then the shape of the observable Universe is a sphere centred on Earth. This definition does not depend on the technological capacity to detect cosmic radiation but on the possibility of electromagnetic signals reaching the Earth. Cosmological observations suggest that the entire Universe is bigger than the observable Universe. How much bigger is unclear.

Particle Horizon

Surface of a sphere which encloses a volume from which we can receive information. The radius of this sphere is the distance light could have travelled since the beginning of time (Big Bang) until now. The particle horizon is also defined as the distant to the farthest observable objects (galaxies, etc.) in the Universe at a given time T. For objects beyond the particle horizon, light hasn't had enough time to reach the Earth, even if it was emitted at the beginning of time.

Positive energy (also normal energy)

The type of energy the solar system and most known galaxies are made of. Antiparticles, on the other hand, are made of a different type of energy (negative energy).

Planck Sphere

Sphere of radius equal to the Planck length.

Pre-universe/Meta-universe

The "mother" Universe from where our Universe came from.

The Theory of the Pre-Universe

Theory proposed by the author which affirms the existence of a hypothetical immaterial Pre-universe which had no origin. The Pre-universe or Meta-universe would be made of Meta-energy, Meta-time and Mate-space.

Redshift (or Red-Shift)

Redshift is the lengthening of the wavelength of electromagnetic radiation (or the shortening of its frequency). Equivalently: the amount by which the wavelength of the spectral lines in the source are shifted to the red. There are, at least, three types of redshifts:
(1) Relativistic Doppler redshift (or Doppler effect)
(2) Gravitational redshift
(3) Cosmological redshift

Relativistic Doppler Redshift (Relativistic Doppler Effect or Doppler Effect)

Redshift governed by Einstein's Special Relativity. This Doppler effect gives the wavelength variation of the wave due to relative uniform motion. This variation does not take into consideration the expansion of space (See Cosmological Redshift). The formula for the relativistic Doppler effect is

$$\frac{\lambda_{obs}}{\lambda_0} = \frac{1+\frac{v_r}{c}}{\sqrt{1-\frac{v^2}{c^2}}}$$

λ_{obs} = Observed wavelength. Wavelength with respect to an observer from system S who is in relative uniform motion with respect to the source

λ_0 = Wavelength of the electromagnetic wave with respect to an observer from System S' who is at rest with respect to the source

v = Relative velocity between the source of an electromagnetic wave (normally light) and an observer from System S

v_r = Radial velocity of the source at emission time

For nearby galaxies the Relativistic Doppler redshift and the gravitational redshift yield approximately the same results (See Cosmological redshift).

Shape of the Universe

The shape of the entire Universe is unknown. It could be spherical, ellipsoidal, toroidal (like a torus or doughnut), etc. Most cosmological models do not model the entire Universe but the observable Universe. Thus, most models, including the *QGCM*, assume that the shape of the observable Universe is spherical.

Singularity

A point in space-time in which the mass density, the space-time curvature and the gravitational field becomes infinite. Singularities represent a great difficulty for cosmologists because they cannot justify the above mentioned properties. (See Misconception 4)

Spacetime (or Space-time)

Association of tree spatial dimensions (x, y, z) and one temporal dimension (t) which is used to describe, mathematically, a four dimensional Universe. A point in spacetime is called an event. Thus, an event can be described, in Cartesian coordinates, by a set of four numbers: (x, y, z, t).

Steady State Theory, The

Cosmological theory that states that matter is continuously being created. It also claims that the average mass density of the Universe is constant (does not change with time). This theory wrongly predicts that galaxies of all different ages should coexist in, approximately, the same region of space. This prediction contradicts the observations which show that far away galaxies (as seen from Earth) are older that the nearby ones. The Steady State Theory also claims that the Universe should remain the same over time. This also contradicts the observations. This theory has been abandoned because it can not explain these and other cosmological observations.

Time Constant of the Universe (Universal Time Constant)

Time taken by the Universe to increase its mass from 0% to 63.2% (this is $100\times(1-e^{-1})$) of its final value. It is customary to denote time constants with the Greek letter tau (τ).

Toy Creation

Refers to the "creation" of the Universe which is in fact a transformation of Meta-space and Meta-time into spacetime; and Meta-energy into energy and mass.

Universal Time

See normal time.

Universal Uncertainty Principles (or Relations)

a) The general momentum-position universal uncertainty relations

$$\Delta p_x \Delta x \geq \sqrt{\frac{\hbar^2}{4} - \frac{\hbar}{4} P_Z (\Delta x + L_Z) - \frac{\hbar}{4} (\Delta p_x + P_Z) L_Z}$$

$$\Delta p_y \Delta y \geq \sqrt{\frac{\hbar^2}{4} - \frac{\hbar}{4} P_Z (\Delta y + L_Z) - \frac{\hbar}{4} (\Delta p_y + P_Z) L_Z}$$

$$\Delta p_z \Delta z \geq \sqrt{\frac{\hbar^2}{4} - \frac{\hbar}{4} P_Z (\Delta z + L_Z) - \frac{\hbar}{4} (\Delta p_z + P_Z) L_Z}$$

b) The general energy-time universal uncertainty relation

$$\Delta E \Delta t \geq \sqrt{\frac{\hbar^2}{4} - \frac{\hbar}{4} E_Z (\Delta t + T_Z) - \frac{\hbar}{4} (\Delta E + E_Z) T_Z}$$

Universe

All there is except the Meta-universe. The Universe contains all the stuff that was "created" during and after the Big Bang. The Meta-universe is not included into the Universe to avoid confusing the reader.

Virtual particle

A virtual particle is, by definition, a particle that's involved in an intermediate stage of an event, but that doesn't interact with the "outside world". So (and most particle physicists would be a little uncomfortable with this generalization) the photon on its way to the screen, as it takes both paths, is virtual. But, when it hits the screen we can point at it excitedly and say definitively where it is.

White Dwarf

Star that has consumed its nuclear fuel so that it can no longer generate the pressure and heat necessary to prevent its collapse due to gravity. If the initial mass of the star exceeds certain critical value, the star may collapse into a denser cosmic object. Depending on the mass of the star the final object may be a white dwarf, a neutron star or a black hole. White dwarfs are not as dense as neutron stars.

Z Parameter

Parameter used for characterizing redshifts. This parameter is given by

$$z = \frac{\lambda_{obs} - \lambda_0}{\lambda_0}$$

(See Relativistic Doppler Redshift for the meaning of variables)

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