Journal of High Energy Physics, Gravitation and Cosmology, 2021, 7, 808-843
https://www.scirp.org/journal/jhepgc
ISSN Online: 2380-4335
ISSN Print: 2380-4327

An Alternative to the Dark Matter? Part 2: A Close Universe (10^{-9} s to 3 Gy), Galaxies and Structures Formation

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How to cite this paper: Perron, J. (2021) An Alternative to the Dark Matter? Part 2: A Close Universe (10^{-9} s to 3 Gy), Galaxies and Structures Formation. *Journal of High Energy Physics, Gravitation and Cosmology*, 7, 808-843.
https://doi.org/10.4236/jhepgc.2021.73047

Received: March 17, 2021
Accepted: June 5, 2021
Published: June 8, 2021

Abstract

A cosmological model was developed using the equation of state of photon gas, as well as cosmic time. The primary objective of this model is to see if determining the observed rotation speed of galactic matter is possible, without using dark matter (halo) as a parameter. To do so, a numerical application of the evolution of variables in accordance with cosmic time and a new state equation was developed to determine precise, realistic values for a number of cosmological parameters, such as the energy of the universe U, cosmological constant Λ, the curvature of space k, energy density $\rho_{\Lambda e}$ (part 1). The age of the universe in cosmic time that is in line with positive energy conservation (in terms of conventional thermodynamics) and the creation of proton, neutron, electron, and neutrino masses, is ~76 [Gy] (observed $\bar{H}_0 \sim 70\left[\mathrm{km}\cdot\mathrm{s}^{-1}\cdot\mathrm{Mpc}^{-1}\right]$). In this model, what is usually referred to as dark energy actually corresponds to the energy of the universe that has not been converted to mass, and which acts on the mass created by the energy-mass equivalence principle and the cosmological gravity field, F_Λ, associated with the cosmological constant, which is high during the primordial formation of the galaxies (<1 [Gy]). A look at the Casimir effect makes it possible to estimate a minimum Casimir pressure P_c^0 and thus determine our possible relative position in the universe at cosmic time 0.1813 ($t_0/t_\Omega = 13.8\left[\mathrm{Gy}\right]/76.1\left[\mathrm{Gy}\right]$). Therefore, from the observed age of 13.8 [Gy], we can derive a possible cosmic age of ~76.1 [Gy]. That energy of the universe, when taken into consideration during the formation of the first galaxies (<1 [Gy]), provides a relatively adequate explanation of the non-Keplerian rotation of galactic masses.

Keywords

Cosmological Parameters Numerical Values, Cosmology Early Universe,

1. Expanding 3d-Sphere of Matter

An order of magnitude for the average speed of baryonic matter can be calculated with a theoretical mean mass density of the universe, the Hubble-Lemaître expansion law, the cosmic time, and the assumption that the boundary of the universe is moving constantly at the speed of light.

Let us suppose that this sphere of the matter was at state 1 at the time of early creation of great structures like galaxies (<2 [Gy]), whose boundaries were expanding at the speed of light towards state 2, or the current age of the universe, written as t_Ω. Let us also suppose a material point in the sphere in state 1 (e.g. the original bulbe of matter at the center of the MW), which undergoes expansion until today. That point is not located at the mathematical centre of the sphere, but at a given location written as r_1 at state 1. The material point evolves towards a material position 2 in state 2, moving at a mean speed $\bar{\beta}$ (non-relativist). Moreover, considering expansion and displacement at the mean speed in the direction of expansion, the following equation yields the position of the material point at state 1 at time t_0 in the sphere of matter at the time of state 2 (universe age t_Ω):

$$t_0 = \frac{t_\Omega}{t_1}\frac{r_1}{c} + \frac{t_1}{t_\Omega}\bar{\beta}\left(t_\Omega - t_1\right) = t_\Omega \frac{r_1}{R_1} + \frac{t_1}{t_\Omega}\bar{\beta}\left(t_\Omega - t_1\right)$$

where: $R_1 = ct_1$; $R_\Omega = R_2 = ct_\Omega$.

The first term is the expansion of the material point in the expanding volume during the time period, and the second term is the effect of the speed modulated by the inverse of expansion. The equation has four mathematically independent variables that must be compatible from a physics standpoint. Indeed, for each quartet $\left(r_1, t_1, t_\Omega, \bar{\beta}\right)$, the value of t_0 must be lower than or equal to t_Ω, which limits possibilities, or still, forces a restriction on variable $\bar{\beta}$. In this paper, we only consider the mean value of $\bar{\beta}$ for a sphere of matter undergoing Hubble-Lemaître expansion, the boundary of which is moving at $\beta = 1$. The cosmological principle states, at least, that there are no preferred positions. However, expansion of the universe occurs in a precise order of events, each appearing at its own cosmic time, which leads to the idea that for a much larger universe than what we can observe today, one can imagine relative positions within that chronological universe. Moving forward with that idea, one can estimate an approximate position for the MW in the sphere universe. Indeed, we will see in the next section, dealing with a mass rotation model for a few galaxies with the combined action of gravitational force and cosmological gravity, that the initial formation of the MW could have started around 150 - 190 [My] after the beginning, and that main formation could have taken 380 - 450 [My]. Therefore, let us start with a sphere universe of state 1 at time 1 [Gy] ($t_1 = 1\left[\text{Gy}\right]$), that is a sphere of matter that is large enough to contain the MW bulbe. Initial formation of the bulbe yields $r_1/R_1 = 0.15\text{ - }0.19\,[\text{Gy}]/[\text{Gy}]$. Moreover, by selecting $\bar{\beta}$ according to an equation developed in the next section ($\bar{\beta} \sim 2\times10^{-3}$), and t_0, the age of the universe calculated by Planck (13.8 [Gy]) at our observation position, we get an approximate range of ages for the universe today:

$$t_\Omega \sim 73 \text{ to } 92\,[\text{Gy}]$$

That number must be seen as sufficient to create the required energy for the universe to generate a baryonic mass that is close to the mass estimated from observations of the cosmos, while providing a possible explanation for the formation periods and rotations of the galaxies being studied.

2. Pressure in the CMB and the Casimir Effect: A Possible Age of the Universe

The Casimir Effect is often used to explain what authors call vacuum energy or vacuum force. There is a model we can use to further analyze this effect and see if it can be partially explained and provide useful information.

Readers can refer to numerous works on the Casimir Effect and its electromagnetic origin [1]. If the Casimir force is expressed as shown in works where parallel plates are used, we get the following equation:

$$F_c = \left(\frac{\pi^2}{240}\right)\frac{hc}{2\pi l^4}S$$

where l represents the distance between the parallel conductive plates, and S is the surface of the plates. The constant is obtained from the integration of potential photon vibration modes between the plates (the space between the plates acts as a resonant cavity for the photons). This normally attractive force can be expressed as radiation pressure:

$$F_c = P_c S$$

The quantities of energy in the universe on a per-era basis are known, which can be expressed in the form of mean density of energy in the volume, as:

$$F_c = \left(\frac{U(t)}{V(t)}\right)S$$

From the photon gas energy expression, an expression of Casimir force, from a standpoint of properties at time t, is written as:

$$F_c(t) = \left(\frac{Nh\vartheta}{V}\right)S = \left(\frac{2\pi Nhc}{2\pi V\lambda}\right)S = \left(\frac{2\pi N(t)}{V(t)\lambda(t)}\right)\frac{h}{2\pi}cS$$

where N is the constant number of photons after the photon inflation period, or about 10^{-13} [s] ($N \sim 6.4\times10^{89}$). Moreover, if we postulate that Casimir pressure is generated by CMB photons at our position t_0, then:

$$F_c = P_c S = \left(\frac{2\pi N(\infty)}{V_0\lambda_{cmb}}\right)\frac{h}{2\pi}cS$$

The above Casimir Effect equation makes it possible to calculate pressure at time t_0 (at our position in the universe) when the mean wavelength of photons in the CMB is known. As with CMB temperature, Casimir pressure is an observable property of the universe. That wavelength is well known and derived from Wien's law, as:

$$\lambda_{cmb}=\frac{\sigma_w}{T_{cmb}}=\frac{2.89777\times10^{-3}}{2.728}=1.06\times10^{-3}\,[\mathrm{m}]$$

In a manner of speaking, that pressure is the same as theoretical pressure in a vacuum (CMB radiation pressure), considering the fact the energy of the universe decreased when the particles were created. To determine that pressure, we could estimate the position of the observer, t_1, in the universe. To do so, we know the expression for photon gas pressure at the same time, t_1, and we get the following expression to determine a possible position in the universe or cosmic time:

$$P_c=P_{gas\gamma}$$

$$\left(\frac{2\pi N(\infty)}{V_1\lambda_{fdc}^1}\right)\frac{h}{2\pi}c=\frac{\zeta(4)N(\infty)k_bT_1}{\zeta(3)V_1}$$

$$\left(\frac{hc}{\lambda_{cmb}^1}\right)\sim\frac{\zeta(4)}{\zeta(3)}k_bT_1$$

$$hc=\frac{\zeta(4)}{\zeta(3)}k_bT_1\lambda_{cmb}^1$$

The wavelength of the CMB, as perceived by an observer at point t_1, is not modified by the scale factor:

$$\lambda_{cmb}^1=\lambda_{cmb}\,(\text{constant})$$

Then with the temperature equation:

$$hc=\frac{\zeta(4)}{\zeta(3)}k_b\lambda_{cmb}T_1=\frac{\zeta(4)}{\zeta(3)}k_b\frac{\sigma_w}{T_\Omega}T_1=\frac{\zeta(4)}{\zeta(3)}k_b\sigma_w\frac{t_\Omega}{t_1}$$

Or with the expression σ_w using the Lambert function:

$$\frac{t_1}{t_\Omega}=\frac{\zeta(4)}{\zeta(3)}\frac{k_b\sigma_w}{hc}=\frac{\zeta(4)}{\zeta(3)}\frac{k_bh\,c}{\left(5+W_0\left(-5e^{-5}\right)\right)k_bhc}$$

$$=\frac{\zeta(4)}{\zeta(3)}\frac{1}{5+W_0\left(-5e^{-5}\right)}\sim\frac{0.9004}{4.9651}\sim0.18134$$

In the above equation, if we assume that the position of the MW is 13.8 [Gy] (t_1 = t_0 observable universe at our position), possible cosmic age of the universe would be 76.098 [Gy] (~76.1 [Gy]). This is a surprising result, as it implies that the following ratio of physics constants is relative to position in the universe, or:

$$\frac{k_b\sigma_w}{hc}=\frac{\zeta(3)}{\zeta(4)}\frac{t}{t_\Omega}$$

Of course, if that equation holds true, its cosmological implications are important. The equation can be rewritten assuming that Wien's law is universal and that the speed of light for photons is always the product of wavelength times frequency, or:

$$\frac{k_b}{h}=\left(\frac{c}{\sigma_w}\right)\frac{\zeta(3)}{\zeta(4)}\frac{t}{t_\Omega}=\left(\frac{\lambda\nu}{\lambda T}\right)\frac{\zeta(3)}{\zeta(4)}\frac{t}{t_\Omega}=\left(\frac{\nu}{T}\right)\frac{\zeta(3)}{\zeta(4)}\frac{t}{t_\Omega}$$

The ratio of ν-origin photon frequency to temperature T is strictly constant (1.034×10^{11} [$\text{s}^{-1}\cdot\text{K}^{-1}$]) from the initial Planck time t_p up to 76.1 [Gy]. Finally, we get:

$$\frac{k_b}{h}=k\,f\left(\frac{t}{t_\Omega}\right)\quad\text{(function of position in the universe or cosmic time)}$$

The implications of that equation are beyond the scope of this paper. The previous section, expanding 3d-sphere of matter, we arrived at the following expression, which we equate to the result we obtained for t_0:

$$\frac{t_0}{t_\Omega}=\frac{r_1}{R_1}+\frac{t_1}{t_\Omega^2}\overline{\beta}\left(t_\Omega-t_1\right)\sim0.18134$$

This constant ratio is surprising! It implies that mass speed increases with time as the universe ages, in order to conserve a quasi-constant quotient for a given structure (or a given position, t_1). In other words, using the MW as an example, its speed would appear to increase with the increase in the age of the universe. Therefore, for a sphere of matter beginning at 1 [Gy], we use the following to determine the speed of the MW at t_0 (13.8 [Gy] and r_1/R_1 assumed to be 0.181314 in the 1 [Gy] sphere to derive the speed of the MW today):

$$\beta(t_0)=\frac{v}{c}=\frac{\dot r}{c}=\frac{\frac{t_\Omega^2}{t_1}\left(\frac{t_0}{t_\Omega}-\frac{r_1}{R_1}\right)}{\left(t_\Omega-t_1\right)}=\frac{\frac{76.1^2}{1}\left(0.181340-0.181314\right)}{\left(76.1-1\right)}=2.004\times10^{-3}$$

Or $v_{mw}\sim600\left[\text{km}\cdot\text{s}^{-1}\right]$

The following three **Figures 1-3** show the form of that evolving speed, or $v=\beta c$, acceleration, *a*, and the intrinsic deceleration factor, *q*, of the MW relative to the age of the universe for a sphere of matter starting at 1 [Gy] and expanding. The MW is at position ~0.181314 [Gy] in that sphere (start of bulbe formation). We use 1 [Gy] sphere because the MW started to expand after its creation, or an initial sphere larger than 181 [My]. Note that the speed of the MW today is an estimated ~ 600 [$\text{km}\cdot\text{s}^{-1}$]. That value for the current speed of the MW corresponds relatively well with the estimates was made by [2] Kraan-Korteweg *et al.*

As for acceleration, we find a very reliable number, which is nevertheless not zero:

$$a_{mw}=\dot v_{mw}=\frac{\mathrm{d}v_{mw}}{\mathrm{d}t_\Omega}=\frac{\frac{ct_\Omega^2}{t_1}\left(\frac{t_0}{t_\Omega}-\frac{r_1}{R_1}\right)-2c\frac{t_\Omega t_1}{t_1}\left(\frac{t_0}{t_\Omega}-\frac{r_1}{R_1}\right)}{\left(t_\Omega-t_1\right)^2}$$

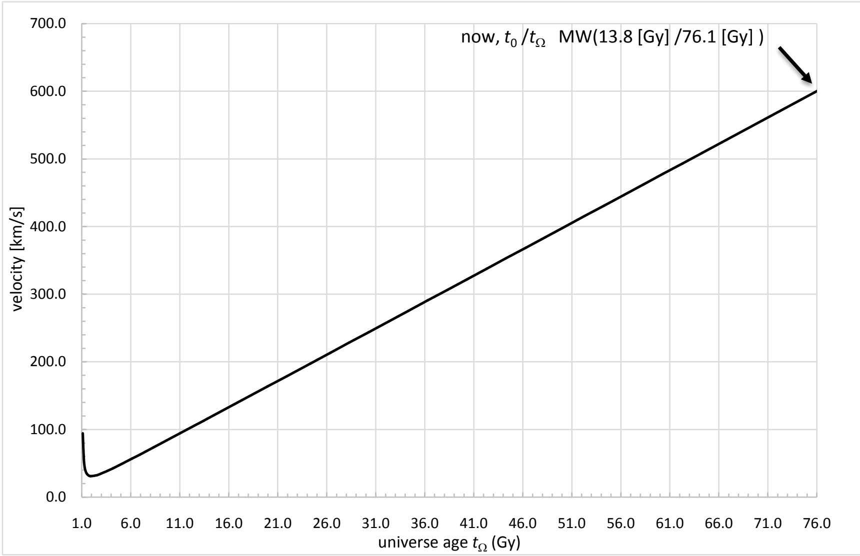


Figure 1. MW intrinsic velocity for $t_\Omega = 1$ [Gy] to 76.1 [Gy].

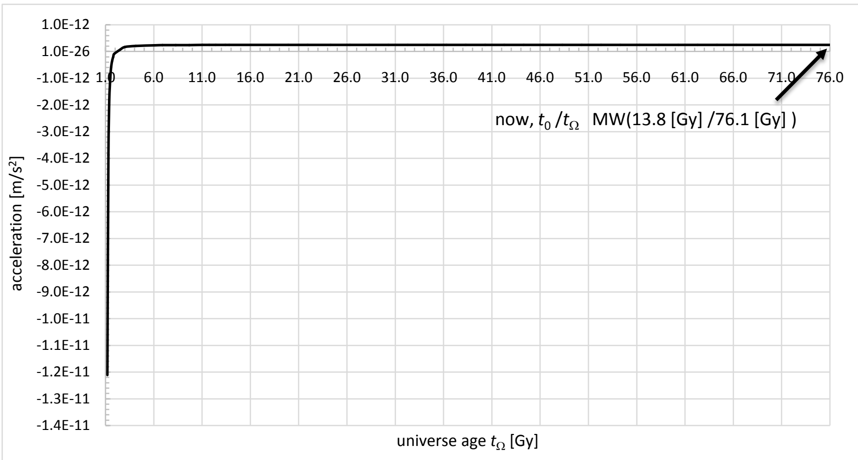


Figure 2. MW intrinsic acceleration for $t_\Omega = 1$ [Gy] to 76.1 [Gy].

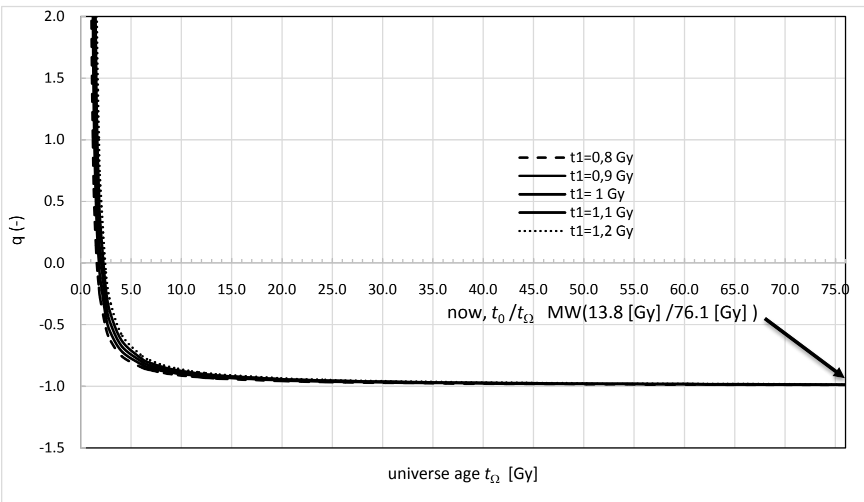


Figure 3. MW intrinsic deceleration parameter for $t_\Omega = 1$ [Gy] to 76.1 [Gy].

In brief, the MW was moving slowly in the direction of the beginning (closed universe) after principal formation up to ~2 [Gy]. Then, expansion of the mass began, and the MW started to accelerate towards the boundary (open universe). Also, the variation of acceleration, $\dot{a}$, is slightly positive (~1×10^{-33} [m·s^{-3}] at t_0), showing that the MW mass accelerates in the direction of expansion.

Finally, for an intrinsic deceleration factor, we get the following expression, which is based on the conventional definition. Moreover, it should be noted that in this version of the model, the deceleration factor, q, of the boundary of the universe is zero, as it moves at constant speed c. However, mass in the volume of the universe is moving with a negative deceleration factor (acceleration). This is an important difference because the observation of motion in supernovas does not automatically guarantee that such motion applies without distinction at the boundary of the universe. For the deceleration factor of a given mass (intrinsic) we get (based on the definition of q):

$$q_m = \frac{-\ddot{r}_m r_m}{\dot{r}_m^2} = \frac{-\ddot{r}_m}{\dot{r}_m^2}\frac{\dot{r}_m}{H} = \frac{-a_m}{\dot{r}_m H} = \frac{-a_m t}{\dot{r}_m}$$

$$q_m = -t\frac{c\dfrac{\dfrac{t_\Omega^2}{t_1}\left(\dfrac{t_0}{t_\Omega}-\dfrac{r_1}{R_1}\right)}{\left(t_\Omega - t_1\right)^2} - 2c\dfrac{\dfrac{t_\Omega t_1}{t_1}\left(\dfrac{t_0}{t_\Omega}-\dfrac{r_1}{R_1}\right)}{\left(t_\Omega - t_1\right)^2}}{c\dfrac{\dfrac{t_\Omega^2}{t_1}\left(\dfrac{t_0}{t_\Omega}-\dfrac{r_1}{R_1}\right)}{\left(t_\Omega - t_1\right)}} = \frac{2t_1 - t}{t - t_1}$$

It is apparent here that the deceleration factor tends towards −1 as the age of the universe increases. This means that expansion is constantly accelerating and the universe is open. Here, t_1 is understood to be the starting value (sphere) of the expansion factor computation, or after the initial formation of the great structures (1 - 2 [Gy]). The deceleration factor, $q_m(z)$, can be obtained either according to the relative distance to the MW, or to z, the relative cosmological redshift to the MW:

$$z = \frac{a_0}{a} - 1 = \frac{r_0}{r} - 1 = \frac{t_0}{t} - 1$$

By substituting the expression for z in q, the following equation for the deceleration factor is achieved:

$$q_m(z) = \frac{2t_1(z+1) - t_0}{t_0 - t_1(z+1)}$$

where $t_0 = 13.8\,[\mathrm{Gy}]$ and $t_1 = 1\,[\mathrm{Gy}]$, then:

$$q_m(z) = \frac{z+1}{12.8 - z} - 1$$

Figure 3 and **Figure 4** show deceleration factors $q_m(t)$ and $q_m(z)$. Based on the resulting curves, it can be seen that at the beginning of expansion, the universe, or the mass, decelerated to z_t > 5.9 (t~2 [Gy]). Then, the mass accelerated.

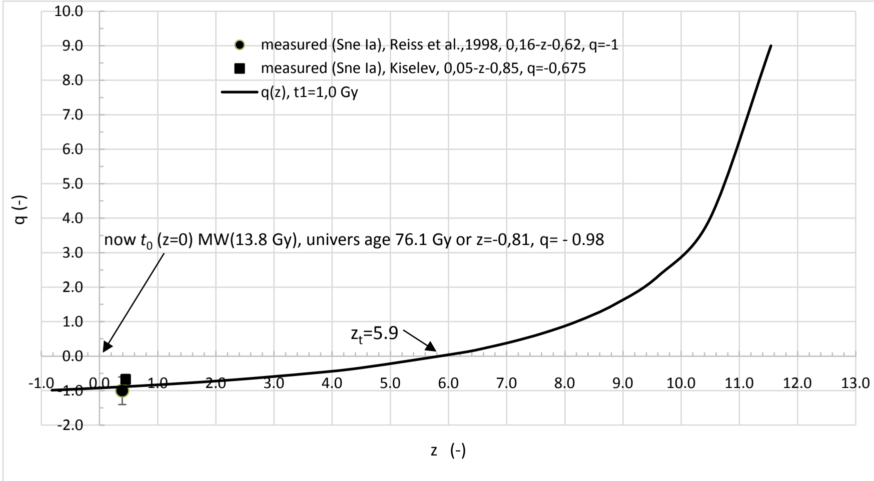


Figure 4. Masses deceleration parameter function of *z*.

Measurements by [3] Riess *et al.* and [4] Kiselev are shown on the curves. Therefore, the model seems to perform rather well in terms of deriving values of q for the low values of z. However, the model predicts a deceleration-acceleration transition earlier than most other predictive models for $q(z)$. For comparison purposes, z_t is closer to 0.7 according to [5] Giostri *et al.*, who used a calibrated parametrical model with a prescribed constant of $q(z) = 1/2$ for $t \to 0$. That prescribed value is in fact being questioned by researchers. Based on the model, the deceleration of mass in the universe is quite substantial. Then, after ~2 [Gy], expansion starts to increase, and the mass accelerates in small steps.

In the above equation, if the age of the universe is assumed to be 76.1 [Gy], then $q = -0.986$.

If we develop the above equation in terms of the Hubble-Lemaître expression, or from the beginning $r_1 = 0$ until t_Ω, noting that $t_0 = t_1 = 0$, $\dot{r} = c\beta$ and $r = ct_\Omega$ correspond to the speed of expansion and observed distance, and if $t_\Omega - t_1 = t$, then:

$$\beta = \frac{v}{c} = \frac{\dot{r}}{c} = \frac{\frac{t_\Omega^2}{t_1}\left(\frac{t_0}{t_\Omega}\right)}{\left(t_\Omega - t_1\right)} = \frac{t_\Omega}{t}$$

Or:

$$\dot{r} = \left(\frac{1}{t}\right) r = Hr$$

Which is in fact the Hubble-Lemaître expression as observed from our viewpoint, with $H = \frac{1}{t}$. However, it should be noted that validation of the Hubble-Lemaître law principally comes from the observation of galaxies, a period of the existing universe after their formation, around 0.1 to 2 [Gy], or the expansion of a sphere at time t_1 towards another sphere at time t_2, and not from a dimensionless starting point towards a sphere. This is an important detail because it puts into perspective the fact that the Hubble-Lemaître law is experimental, resulting from the observation of great structures over a period of time which logically begins when those structures have already been formed.

Let us return to Casimir pressure which, relative to *z*, is:

$$P_c \sim \left(\frac{2\pi N(\infty)}{V_1 \lambda_{fdc}^1}\right)\frac{h}{2\pi}c = 16\pi\left(5+W_0\left(-5e^{-5}\right)\right)\xi(3)\frac{k_b T_{fdc}(z+1)^3}{\lambda_{fdc}^3}$$

$$\sim 16\pi \times 4.965 \times 1.202 \frac{k_b T_{fdc}(z+1)^3}{\lambda_{fdc}^3}$$

$$\sim 1.291 \times 10^{-11}(z+1)^3$$

$$P_c = P_c^0 (z+1)^3$$

Based on this approach, such minimum or zero Casimir energy pressure, P_c^0, would be lower than what can be obtained from our position in the universe, and only corresponds to the pressure found with the original photons and no matter. This may correspond to the volumic energy state from point zero to our position. Today, pressures as low as $\sim 10^{-10}$, or extreme vacuum, have been measured at [6] Conseil Européen pour la Recherche Nucléaire. Expressing that pressure in terms of amplified pressure between two parallel reflecting plates at distance *l* from each other (cavity), the maximum distance required to arrive at that minimum pressure is in the order of 0.1 [mm], or:

$$l_{\max} = \left(\frac{\pi hc}{480 P_c^0}\right)^{\frac{1}{4}} \sim 1.001 \times 10^{-4}\,[\mathrm{m}]$$

To see if that minimum pressure corresponds closely with experimental results designed to determine whether the theoretical value obtained for that pressure is in the order of magnitude of the estimated pressure. Decca *et al.* [7] tested the Casimir effect using a torsion oscillator between two gold-coated parallel plates. The smallest pressure mentioned is in the order of 3 [mPa], or one billion times greater than the minimum pressure obtained, P_c^0. They reported the following measurements (**Table 1**):

Table 1. Measured length and Casimir pressure by [7] Decca.

$l\,[\mathrm{nm}]$	$l^4\,[\mathrm{nm}^4]$	$P_c^{exp}\,[\mathrm{Pa}]$
1.6500000000E-07	7.4120062500E-28	1.0200000000E+00
2.0000000000E-07	1.6000000000E-27	4.9000000000E-01
3.0000000000E-07	8.1000000000E-27	1.10E-01
4.0000000000E-07	2.5600000000E-26	3.35E-02
5.0000000000E-07	6.2500000000E-26	1.55E-02
6.0000000000E-07	1.2960000000E-25	0.0075
7.4000000000E-07	2.9986576000E-25	3.20E-03

An empiric correlation can be obtained from the data with the following equation:

$$P_c^{exp} \sim \frac{1\times 10^{-26}}{\left(l^4\right)^{0.957}}$$

If we estimate the minimum pressure predicted in the above correlation with the maximum l value (1.001×10^{-4} [m]), then:

$$P_c^{\min} \sim \frac{1\times 10^{-26}}{\left(l_{\max}^4\right)^{0.957}} \sim 2.038\times 10^{-11}\,[\mathrm{Pa}]$$

That number is very close to the estimated minimum Casimir pressure or the following ratio, which does not indicate the existence of a minimum pressure for a maximum value of l in the experiments by [7] Decca *et al.* However, if this minimum truly exists, the result of those experiments would yield a result in the order of magnitude of the predicted value, or:

$$\frac{P_c^{\min}}{P_c^0} \sim \frac{2.038\times 10^{-11}}{1.291\times 10^{-11}} \sim 1.58$$

By using the Casimir Effect, we get amplification of that pressure by photon resonance in the CMB in the different experimental setups and, in particular, in the cavity between the reflecting plates. That amplification can be expressed as:

$$P_c = \eta P_c^0$$

where,

$$\eta = \frac{\left(\frac{\pi^2}{240}\right)\frac{1}{l^4}}{\frac{2\pi N(\infty)}{V_0\lambda_{cmb}}} = \left(\frac{\pi^2}{240}\right)\frac{V_0\lambda_{fdc}}{2\pi N(\infty)l^4} = \frac{1.006\times 10^{-16}}{l^4}$$

and for P:

$$P_c = \eta P_c^0 = \frac{1.006\times 10^{-16}}{l^4}\times 1.291\times 10^{-11} = \frac{1.3001\times 10^{-27}}{l^4}$$

The theoretical coefficient is equal to 1.3001×10^{-27}. The experimental coefficient found by [8] Bressi, *et al.* is $1.22 \pm 0.18 \times 10^{-27}$. For a typical value of $l = 200$ [nm], the minimum Casimir pressure is amplified by $\eta \sim 6.3\times 10^{10}$. Based on this model, the maximum scope of the $l_{\max}$ Casimir Effect between two plates is ~0.1 [mm], because at any greater distance the pressure would be below the minimum value of P_{cmb}^0 at our position in the universe. **Figure 5** shows the Casimir zero pressure and the photon gas pressure relative to the age of the universe.

In brief, with this model we note that photon pressure in the CMB (~1.291×10^{-11} [Pa]) at our position, t_0, provides a possible explanation for the Casimir effect, as the photons produce an amplified pressure of that value. This leads to the following question: If the Casimir effect is generated by photons in the CMB,

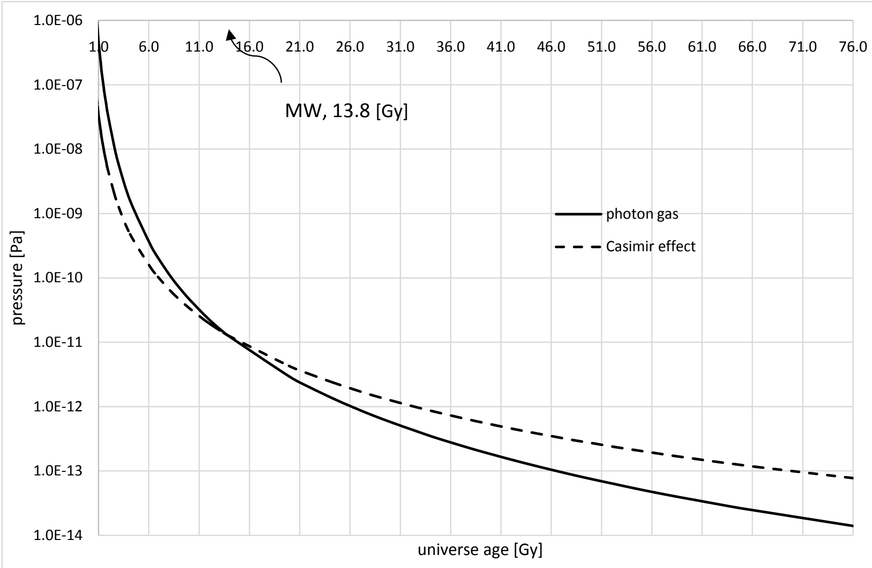


Figure 5. Photon Pg and Casimir P_c^0 (energy density) from 1 [Gy] to 76.1 [Gy].

how is it that in laboratory experiments, in the total absence of CMB photons, when they are not physically in the presence of experimental setups, their effects are nevertheless measured by the instruments? The first part of the answer could be that the universe has stored the presence of the original photons in "memory". This helps us to partially understand how this effect is found in many types of experiments and phenomena [9]: It is a fundamental characteristic of our universe, where the effects of CMB photons are stored as some sort of property of spacetime in the form of energy which we put into action and measure in diverse experimental setups with more or less pronounced amplification effects.

3. A Possible Baryonic Matter-Free Zone Caused by Proton and Electron Time Lags

This model shows that, assuming that recombination ends when the temperature drops below ~3000 [K], recombination occurred much later than the previously assumed, or ~69.2 [My] rather than ~380,000 years. Now, if we calculate the redshift, z, at recombination, taking into account an age of 76.1 [Gy] (2.39 × 10^{18} [s]) for the universe, we find a redshift value that is closer to observations, or z_{comb}~1100 [10]:

$$z_{comb} = \frac{ct_\Omega}{r_{comb}} - 1 = \frac{c \times 2.399 \times 10^{18}}{\left(\frac{3V_{comb}}{4\pi}\right)^{1/3}} - 1 \sim \frac{7.173 \times 10^{26}\,\mathrm{m}}{\left(\frac{3\left(1.172 \times 10^{72}\,\mathrm{m}^3\right)}{4\pi}\right)^{1/3}} - 1$$

$$= \frac{7.173 \times 10^{26}\,\mathrm{m}}{6.541 \times 10^{23}\,\mathrm{m}} - 1 \sim 1095$$

Or still:

$$z_{comb} = \frac{t_\Omega}{t_{comb}} - 1 = \frac{76.09\ \mathrm{Ga}}{0.06919\ \mathrm{Ga}} - 1 \sim 1098$$

This is a surprising result, as it matches the sequence between the temperature drop to the recombination level, around 3000 [K], and the time period associated with recombination with the estimated age of the universe. Moreover, the redshift is calculated according to the scale factor for the universe, and not that of the MW; therefore, it applies to the entire universe rather than a one-time object within the universe. Indeed, during recombination, free photons end up on this last scattering surface, travelling in all directions, including that of expansion at the same speed as the physical boundary of the universe, c, (we chose $H = 1/t$). That is why CMB photons appear as omnipresent gas in all directions and close to us. Finally, such a late recombination time allows solving the horizon problem paradox from a standpoint of the last scattering surface dimension. Indeed, the diameter of the universe at recombination was ~138 [My], making it possible to estimate the dimension of the last scattering surface with the equation for the angular dimension of a structure relative to redshift, z, and Sitter's apparent angular dimension $\Delta\theta$. For an apparent angular dimension of this last scattering surface, which covers the entire celestial half-sphere ($\Delta\theta = \pi$), we can solve for d or t:

$$d = ct = \frac{2c}{H_0}\left[1 - \frac{1}{\sqrt{1+z}}\right]\frac{\Delta\theta}{1+z}$$

$$\begin{aligned} t &= 2\left[1 - \frac{1}{\sqrt{1+z}}\right]\frac{\Delta\theta}{1+z}t_0 \\ &= 2\left[1 - \frac{1}{\sqrt{1+1100}}\right]\frac{\pi}{1+1100}\times 4.35\times 10^{17}\,[\mathrm{s}] \\ &= 2.408\times 10^{15}\,\mathrm{s} = 76.3\,[\mathrm{My}] \end{aligned}$$

Then, a smaller value than the diameter of the universe at recombination, or:

$$d_{comb} = 2r_{comb} = 2ct_{comb} = 138\,[\mathrm{My}]$$

We can see that the last scattering surface is included in the universe at that time, which suggests that the inflation mechanisms may no longer be in play, at least from the standpoint of the physical dimensions of the original CMB.

A possible zone of empty matter due to the time lag during photon and electron and the electrostatic force acting before recombination, around 69.2 [My], can be estimated. Indeed, prior to the creation of baryonic matter, only photons can be observed. We begin with the calculation at the time of protons, $t_{pr} = 9.939\times 10^{-13}\,[\mathrm{Gy}]$ (advent of the baryon mass). Using an expanding sphere of matter from before recombination at 69.2 [My], well before the formation of structures, and a mean value of $\bar{\beta} = 0.998$, or the relativist value used at the time of proton creation, such a sphere of free protons and electrons, when entered into the expansion equation, yields:

$$\begin{aligned} t_{pr}^{0} &= \frac{t_\Omega}{t_1}\frac{r_1}{c} + \frac{t_1}{t_\Omega}\bar{\beta}\left(t_\Omega - t_1\right) = \frac{2.399\times 10^{18}}{2.181\times 10^{15}}\frac{9.397\times 10^{12}}{c} \\ &\quad + \frac{2.181\times 10^{15}}{2.399\times 10^{18}}\times 0.998\left(2.399\times 10^{18} - 2.181\times 10^{15}\right) \end{aligned}$$

$$t_{pr}^{0} = 2.177 \times 10^{15}\,\mathrm{s} = 69.0\,[\mathrm{My}]$$

How can that t_{pr}^{0} value be interpreted? First, that zone is not observable because it is prior to recombination (69.2 [My]). However, it closely corresponds to the typical range of a time period called recombination (~−200,000 years). Indeed, protons and neutrons appear approximately 666 days before electrons. At that time, the electrostatic repulsive force of protons is dominant and much greater than gravity (10^{42} times greater). This repulsive action of protons, which pushes them towards the physical boundary of the universe, can be estimated. Indeed, assuming that the minimum energy principle applies at this time period of the universe, which is much greater than Planck time ($t_p = 10^{31}$), the electrostatic energy difference between an evenly distributed proton configuration in the volume at the time of electrons vs. evenly distributed protons around the perimeter, is:

$$W_e^V - W_e^S = \frac{1}{2}\iiint_V \rho_e V^* \mathrm{d}V - \frac{1}{2}\iiint_S \sigma V^* \mathrm{d}S = \frac{3Q^2}{20\pi\varepsilon_0 R} - \frac{Q^2}{8\pi\varepsilon_0 R} = \frac{Q^2}{40\pi\varepsilon_0 R}$$

where:

$\rho_e = \rho_{cte}$: the volumic density of proton charge in the R-radius sphere

σ : the surface density of proton charge at r radius (at electron time)

V^* : the electric potential

Q: the total charge of protons, $Q = n_{pr} q$

Note that the minimum energy is for the proton configuration around the perimeter of the volume at electron time. The mean speed of proton motion towards the perimeter, discounting the effects of gravity force, which is much smaller than the Coulomb force, can be estimated using the proton motion equation with energy conservation and work done:

$$W_e^V - W_e^S = \int_0^R \overline{F}\mathrm{d}r = \int_0^R m\overline{a}\mathrm{d}r = \int_0^R \rho V\overline{a}\mathrm{d}r = \int_0^R \rho V\ddot{\overline{r}}\mathrm{d}r = \frac{Q^2}{40\pi\varepsilon_0 R}$$

With the last two expressions and derivation, we get:

$$\frac{\mathrm{d}}{\mathrm{d}r}\left[\int_0^R \rho V\ddot{\overline{r}}\mathrm{d}r\right] = \frac{\mathrm{d}}{\mathrm{d}r}\left[\frac{Q^2}{40\pi\varepsilon_0 r}\right]$$

$$\rho V\ddot{\overline{r}} = \frac{-Q^2}{40\pi\varepsilon_0 r^2}$$

Finally, for $r_p(t)$, which represents the average position of proton motion towards the perimeter during electron production, we get the following differential equation:

$$\ddot{\overline{r}}_p = \frac{-Q^2}{\rho V 40\pi\varepsilon_0 r^2} = \frac{-3Q^2}{\frac{M_t}{V_t}4\pi 40\pi\varepsilon_0 r^5} = \frac{-3Q^2}{\frac{3M_t}{4\pi R^3}4\pi 40\pi\varepsilon_0 r^5}$$

$$= \frac{-Q^2 R^3}{40\pi\varepsilon_0 M_t r^5} \sim \frac{-Q^2 R^3}{40\pi\varepsilon_0 n_{pr} m_p r^5}$$

$$\ddot{\bar{r}}_p \sim \frac{-n_{pr}^2 q^2 c^3 t_{pr}^3}{40\pi\varepsilon_0 n_{pr} m_p r^5} = \frac{-n_{pr} q^2 c^3 t_{pr}^3}{40\pi\varepsilon_0 m_p r^5} = \frac{-5.51\times 10^{114}}{r^5} = \frac{A}{r^5}$$

Solving this equation for $\bar{r}_p(t)$:

$$\bar{r}_p(t) \sim \left(\frac{-9A}{2}\right)^{1/6} t^{1/3} = 1.67\times 10^{19} t^{1/3}$$

To find out if the protons reach the boundary of the sphere during the time period before the creation of electrons, the mean speed of the protons moving towards the perimeter can be estimated, $\dot{r}_p(t)$, relative to the speed of the boundary, with is equal to *c*. If that speed is greater than *c*, then the protons are travelling close to c and at the boundary of the universe during the time $t = t_{el} - t_{pr} \sim 666\,[\mathrm{d}]$. Solving for the mean speed of protons ($t = t_{el}$), we get:

$$\dot{r}_p(t) = \frac{1}{3}\left(\frac{-9A}{2}\right)^{1/6} t^{-2/3} = \frac{5.59\times 10^{18}}{t^{2/3}} = \frac{5.59\times 10^{18}}{t_{el}^{2/3}}$$

$$= \frac{5.59\times 10^{18}}{\left(5.75\times 10^7\right)^{2/3}} = 3.75\times 10^{13} \sim c^5$$

Indeed, the protons would be at the boundary at the time of electron production. Then, during electron production, even if the ionization energy of photons inhibits proton-electron recombination, they would be in a state of convergent acceleration, which would partly allay the absence of protons in that part of the universe. However, the high m_p/m_e mass ratio means that possible lack of baryonic matter cannot be compensated and will remain permanent in a large area around the beginning. This has significant repercussions on the development and distribution of mass. Indeed, the protons, are at the periphery while the electrons in the volume are moving towards the protons but the neutrons stay distributed in the volume. Based on the calculations, there could be an area with a diameter of ~135 [My] and a boundary of ~200,000 years in depth at the limits of the observable horizon, with no baryonic matter except possibly neutrinos and other neutral particles. Such a possible baryonic matter-free zone could be the result of repulsive Coulomb force between protons, corresponding to the 666-day time lag or phase lag period between the creation of protons and electrons. That possible empty space of matter is not caused by gravity, as it acts on and creates areas of low mass density with very few galaxies or other structures, like the various areas of less matter space we can observe. This original less baryonic matter zone, if we could detect it, would point us towards the beginning of the universe, which would, of course, put into question the idea that there is no preferred position for the universe, or one of the foundations of the cosmological principle.

4. Cosmological Constant Λ Estimated Values

The Friedmann equation (FLRW metric) for an isotropic universe made up of matter in the presence of energy associated with the cosmological constant can be written in relation with the terms that contribute to the expansion or contraction of the universe, H, with gravity, G, the existence of energy other than baryonic through Λ and the space curvature, k, or:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G\rho}{3} + \frac{\Lambda c^2}{3} - \frac{kc^2}{a^2}$$

where the scale factor is a [-], k is the space curvature, [m^{-2}] and ρ, the density of conventional mass [$\text{kg}\cdot\text{m}^{-3}$]. In this form, the equation represents the expansion of the universe expressed with the Hubble constant. In this model, we consider and assess the evolution of conventional energy (photon gas and mass-energy equivalence). An expression for the cosmological contant, Λ, can be obtained using the Friedmann equation. Indeed, assuming the existence of mass-energy equivalence (non-baryonic), represented by constant Λ, along with zero acceleration ($H = 0$) of that mass-energy equivalence, that equation, which represents the non-baryonic residual volumic mass-energy equivalence of the universe, is written as:

$$\frac{E_{\text{conventional}} - E_{\text{mass-energy}}}{V} = \frac{E_\Lambda}{V} = \frac{m_\Lambda c^2}{V} = \rho_{e\Lambda} c^2 = \left|\frac{3kc^4}{a^2} - \frac{c^4\Lambda}{8\pi G}\right|$$

With space curvature k (closed if $k > 0$, flat if $k = 0$ and open if $k < 0$):

$$k = \left[\frac{a^2 8\pi G\rho}{3c^2} + \frac{a^2\Lambda}{3}\right] - \left[\frac{a^2H^2}{c^2}\right]$$

The effects of each term of the equation are clearly seen. The first term is the closing effect caused by gravity, G, via mass density, ρ; the second is the closing effect caused by the residual mass-energy equivalence (non-baryonic) via cosmological constant Λ; and the last term is the opening effect, or expansion, caused by an unknown element, but represented by the Hubble constant. **Figure 6** shows that the space curvature, k (equation $k(H)$), in relation to the other variables: ρ, Λ and $H = 1/t$. The value of k today, time t_0, is very close to zero, but slightly negative (open).

$$k(t_0) \sim -5.6\times10^{-53}\left[\text{m}^{-2}\right]$$

The transition between a closed and open universe around 3 [Gy] is clear.

An oft-mentioned expression for the cosmological constant is found in the following equation (with space curvature, k, considered to be zero), which represents the existence of a non-baryonic volumic energy density in the universe:

$$\rho_{\Lambda e} = \rho_\Lambda c^2 \sim \frac{c^4\Lambda}{8\pi G}$$

The model estimates this residual conventional energy density from the mass created at time t, with the equation below. Indeed, all the variables in this equation are conventional type (positive pressure and positive volume). There are no new-type variables that could translate the existence of a form of energy other than conventional:

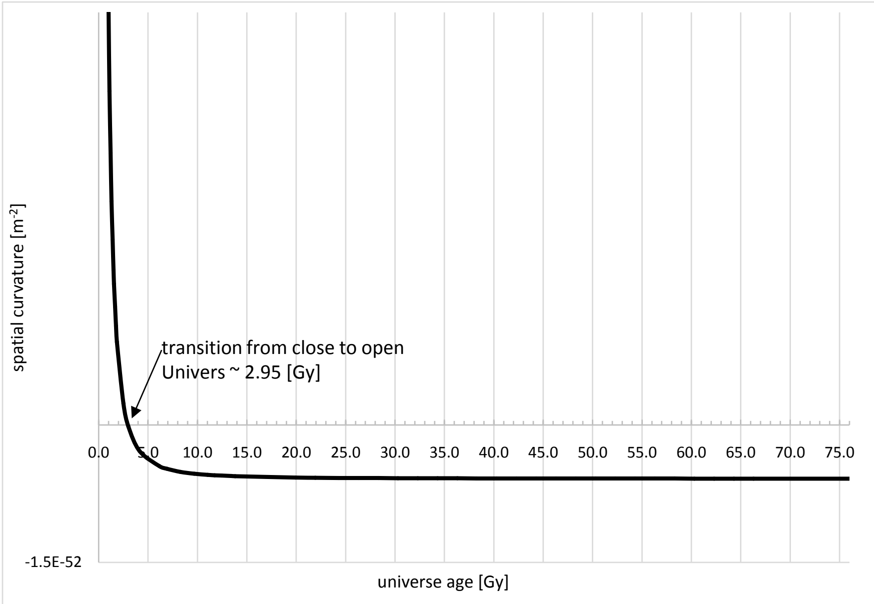


Figure 6. Spatial curvature k from 69 [My] to 76.1 [Gy].

$$\rho_{\Lambda e}c^2 = \frac{E_{\text{conventional}} - E_{\text{equivalence } m\text{-}E}}{V} = \frac{3PV - \frac{M_T c^2}{\sqrt{1-\beta^2}}}{V}$$

$$= \left[\frac{4\sigma T^4}{c}\right] - \left[\frac{4\sigma \frac{M_T c^2}{\sqrt{1-\beta^2}}}{3c^4 \psi k_b t^3}\right]$$

where $\psi = \frac{64}{3}\pi^2 \zeta(3)\left(\frac{k_b}{hc}\right)^3 \sim 8.497\times 10^7 \left[\text{m}^{-3}\cdot\text{K}^{-3}\right]$.

With the equation below, two dominant terms at different times are found for the expression of the cosmological constant, by virtue of the dominator, which reduces in t^4 for the first term, and t^3 for the second. Hence, the first dominant term for the beginning of expansion can be written as Λ_{rad}, and the second, Λ_{mass}, for the time period that comes later with the creation of the baryonic mass until today, at time t_0. Moreover, the second term, which contains the mass generated over time, shows that the constant can undergo relatively quick variations:

$$\Lambda(t) = \Lambda_{\text{rad}} - \Lambda_{\text{mass}} \sim \left[\frac{8\pi G}{c^4}\right]\left[\frac{4\sigma T^4}{c}\right] - \left[\frac{8\pi G}{c^4}\right]\left[\frac{4\sigma \frac{M_T c^2}{\sqrt{1-\beta^2}}}{3c^4 \psi k_b t^3}\right]$$

$$= \left[\frac{32\pi G\sigma T^4}{c^5}\right] - \left[\frac{32\pi G\sigma \frac{M_T c^2}{\sqrt{1-\beta^2}}}{3c^8 \psi k_b t^3}\right]$$

This predictive equation for Λ, often written Λ_{eff}, has the following characteristics: When $t \to t_p$, $\Lambda = \Lambda_{rad} \to 10^{70}$, and inversely when $t \to t_\Omega$, $\Lambda = \Lambda_{rad} - \Lambda_{masse} \to 10^{-58}$; at $t = t_0$ (13.8 [Gy]), we get the value 6.7 × 10^{-54} [m^{-2}], which is in the order of magnitude of the oft-mentioned value: <10^{-52} [m^{-2}] [11] [12]. This value varies greatly throughout the age of the universe. Moreover, the constant is not a true constant; indeed, it varies with the age of the universe, that is to say the effects of expansion and the production of mass, or the decrease of non-massive energy in the universe.

In the beginning, during the primitive formation of large structures like galaxies over a time period of about 0.2 to 2 [Gy], the energy is mostly in the form of radiation (over 90% of the energy is radiation), and for this period of a few [Gy], the second term, which depends on total mass, M_T, is far less important. **Figure 7** shows the $\Lambda_{mass}/\Lambda_{rad}$ ratio.

Therefore, the $\Lambda_{mass}/\Lambda_{radiation}$ ratio at our time, t_0, is equal to ~ 0.163. It is interesting to note that the ratio obtained is in the same order of magnitude as this mentioned for baryonic matter to that of dark matter $\Omega_{\text{barionic}}/\Omega_{\text{dark}} \sim \dfrac{0.0457}{0.2693} \sim 0.169 \quad (h = 0.7)$ [13]. For a universe where radiation is dominant, during the formation of large structures (<2 [Gy]), a simplified expression can be used for the cosmological constant (**Figure 8**):

$$\Lambda \sim \Lambda_{\text{rad}} = \left[\frac{32\pi\sigma T^4}{P_p}\right] = \left[\frac{64\pi^6}{15}\right]\left[\frac{k_b^4 G}{h^3 c^7}\right] T^4 = 1.57\times10^{-58} T^4$$
$$= \left[\frac{64\pi^6}{15}\right]\left[\frac{k_b^4 G}{h^3 c^7}\right]\left[T_\Omega^4 t_\Omega^4\right]\frac{1}{(-t+b)^4}$$

For $t_\Omega = 76.1\,[\text{Gy}]$ and $T_\Omega = 2.7\,[\text{K}]$ and $H = 1/t$ and b~0, for Λ_{rad} and Λ_{mass} we get:

$$\Lambda_{\text{rad}}(t > b)_{(\text{for universe age } 76.1\text{ Gy})}$$
$$= \frac{k_\Lambda}{(-t+b)^4} = \frac{2.8854\times10^{17}}{(-t+b)^4} = \frac{2.8854\times10^{17} H^4}{(-1+bH)^4} = 2.8854\times10^{17} H^4$$

$$\Lambda_{\text{mass}}(t \ge t_{pr})_{(\text{for universe age } 76.1\text{ Gy})}$$
$$= \frac{\left[\dfrac{32\pi G\sigma \dfrac{M_{pr}c^2}{\sqrt{1-\beta^2}}}{3c^8\psi k_b}\right]}{t^3} = \frac{1.0806\times10^{-1}}{t^3} \sim 1.0806\times10^{-1} H^3$$

Finally, we get an approximative expression for the cosmological constant, taking only the proton mass into consideration:

$$\Lambda(b \le t < t_{pr}) = 2.88\times10^{17} H^4 \left[\text{m}^{-2}\right]$$
$$\Lambda(t \ge t_{pr}) = 2.88\times10^{17} H^4 - 1.08\times10^{-1} H^3 \left[\text{m}^{-2}\right]$$

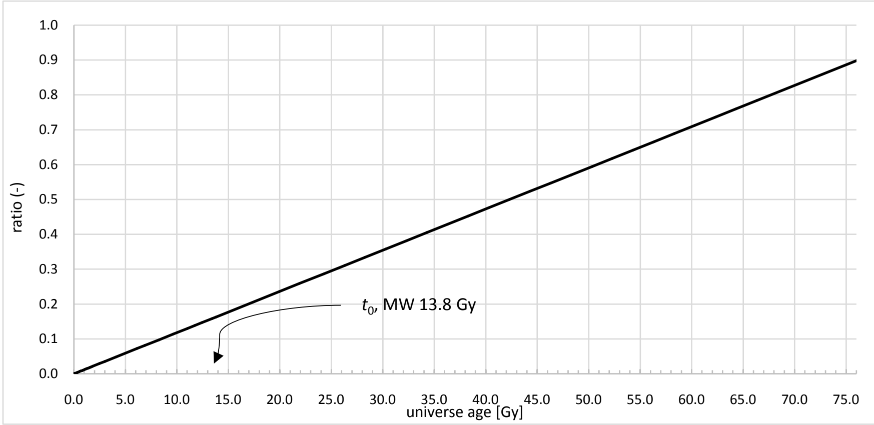


Figure 7. Ratio of $\Lambda_{\text{mass}}/\Lambda_{\text{radiation}}$.

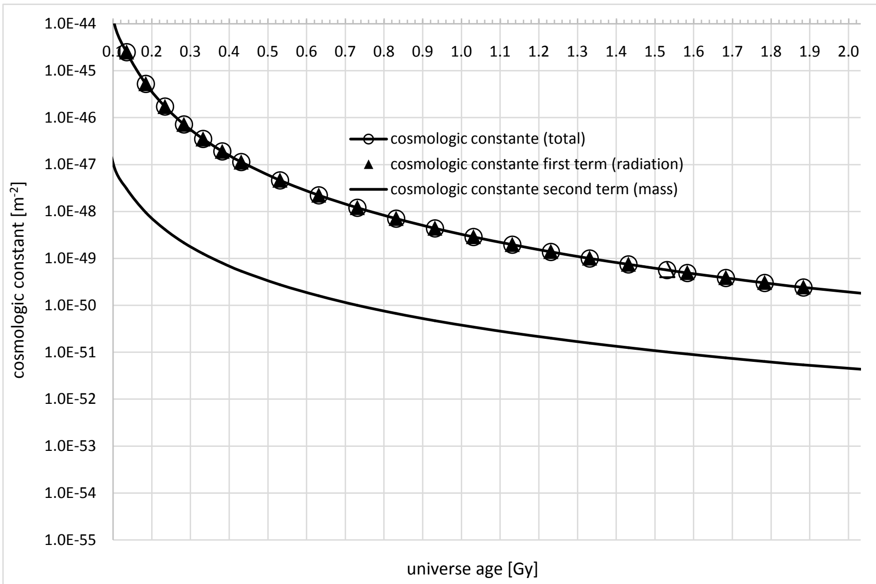


Figure 8. Cosmologic constanteΛfrom 69 [My] to 2 [Gy].

After manipulation, another expression for Λ_{rad} is found:

$$\Lambda_{\text{rad}} = \left[\frac{8}{r_u^2}\right]\left[\frac{P_u}{P_p}\right] = \left[\frac{8G}{c^5 r_u^2}\right]\left[P_u\right] = \left[\frac{8H^2}{\dot{r}_u^2}\right]\left[\frac{P_u}{P_p}\right]$$

The above equation contains a scale factor that varies inversely with the radius of the universe, r_u^2, modulated by a power ratio, or the quotient of output power of the universe, P_u, taken as a blackbody at T, time t, and Planck power P_p. This clearly shows that the cosmological constant diminishes relative to the squared radius and dissipated energy of the universe, leading to the great variation of the two factors combined, scale and energy. These two variations of magnitude (squared scale factor and dissipated energy) lead to the great variation of the constant. Indeed, the only variation of the energy factor (P_u/P_p) leads to a variation of ~10^4, and that of the squared radius, to a variation of ~10^{126}. In brief, it is principally the expansion of the universe that leads to the reduction of the constant. For a static universe, the ratio of the powers is equal to 1, and the radius remains constant, meaning that the cosmological constant would truly be a constant. The following correlation is sometimes reported:

$$D_u = 2r_u \sim \frac{1}{\sqrt{\Lambda}}$$

In this model the expression is:

$$D_u = 2r_u = \frac{\sqrt{\dfrac{32P_u}{P_p}}}{\sqrt{\Lambda}}$$

For $t = 13.8$ [Gy], the constant of the numerator is:

$$\sqrt{\frac{32P_u}{P_p}} = \sqrt{\frac{32\left(7.66\times10^{50}\right)}{3.629\times10^{52}}} \sim \sqrt{0.54} = 0.74$$

Another value for Λ is suggested by [14] Carmeli *et al.*:

$$\Lambda = \frac{3}{c^2t^2} = 2.2642\times10^{-52}\left[\mathrm{m}^{-2}\right]$$

where $\tau = 12.16$ [Gy]. In this model, we get the following form:

$$\Lambda = \frac{\frac{8G}{c^5}P_u}{c^2t^2} = \frac{0.137}{c^2t^2} = 9.9\times10^{-54}\left[\mathrm{m}^{-2}\right]$$

If different Planck quantities are used, the following expression can be used for the constant:

$$\Lambda_{\mathrm{rad}} = 8\left[\frac{P_u}{r_u^2}\right]\left[\frac{t_p^3}{m_pl_p^2}\right] = 8\left[\frac{P_u}{r_u^2}\right]\left[\frac{1}{cF_p}\right]$$

Also, this expression is for the beginning when $t \to t_p$:

$$\Lambda\left(t_p\right) = \frac{32\pi G\sigma T_p^4}{c^5} = \frac{16\pi^4}{15}\frac{c^3}{Gh} = \frac{\frac{8\pi^3}{15}}{l_p^2} = 6.33\times10^{70}\left[\mathrm{m}^{-2}\right]$$

Figure 9 and **Figure 10** show the graph for Λ. For the entire duration of the simulation, or 76.1 [Gy], the cosmological constant varies by a factor of $\sim10^{128}$; or by 10^{70} at $t \to t_p$ until 10^{-58} for $t = 76.1$ [Gy].

In brief, those expressions for space curvature and energy density (non-baryonic) can be obtained by substituting the cosmological constant equation:

$$k(H) = a^2\left[\frac{k_\Lambda}{3(-1+bH)^4}H^4 + GM_t\frac{2-\frac{\pi^4}{4\zeta(3)}}{c^5}H^3 - \frac{1}{c^2}H^2\right]$$
$$\sim a^2\left[9.61\times10^{16}H^4 + 3.04\times10^{-3}H^3 - 1.11\times10^{-17}H^2\right]$$

where $t \geq t_{pr}$

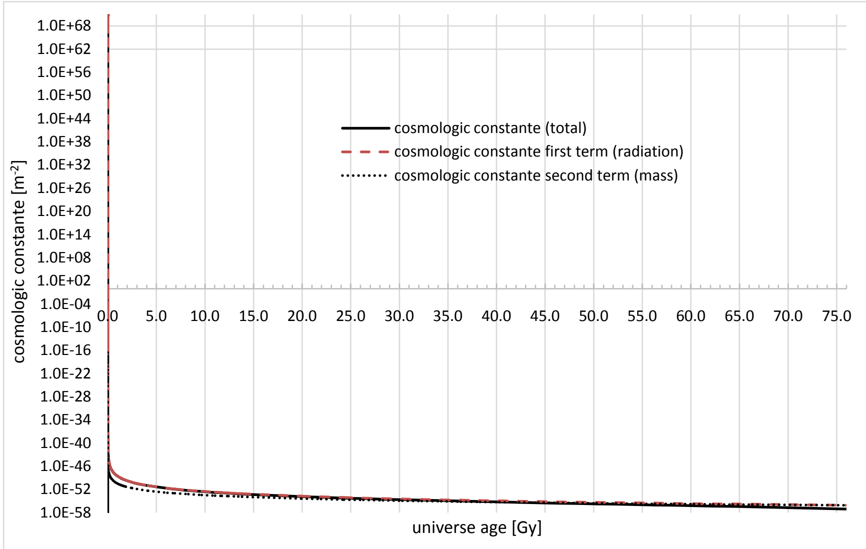


Figure 9. Cosmologic constant $\Lambda = \Lambda_{rad} + \Lambda_{mass}$ from 1 tp to 76.1 [Gy].

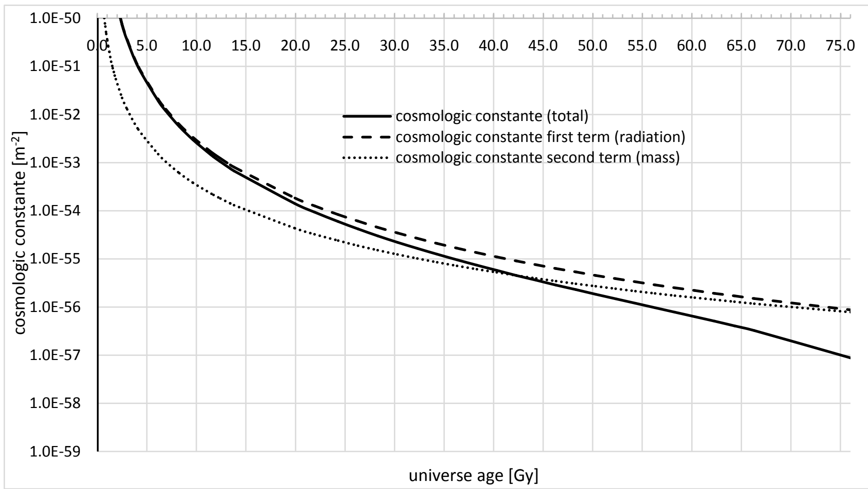


Figure 10. Cosmologic constante $\Lambda = \Lambda_{rad} + \Lambda_{mass}$ from 1 tp to 76.1 [Gy].

The space curvature equation yields $k = 0$ for $t = 2.95$ [Gy], or the transition from closed to open universe. This closely corresponds with the value found for deceleration transition, q, around 2 [Gy] (Figure 1). That these two values are relatively close is promising in terms of model constancy.

As concerns energy density, we find two distinct contributions: one associated with radiation and the other, with mass (for $b\sim 0$, valid for $t > 10^{-13}$ [s]):

$$\rho_{\Lambda e}(H) = \rho_{\Lambda e}^{\text{rad}} + \rho_{\Lambda e}^{\text{mass}} = \frac{c^4 k_\Lambda}{8\pi G(-1+bH)^4} H^4 - \frac{\pi^3 M_t}{120\zeta(3)c} H^3$$
$$\sim 1.38\times 10^{60} H^4 - 3.98\times 10^{41} H^3$$

Figure 11 and Figure 12 show energy density in association with the cosmological constant relative to the age of the universe. For Planck time t_p, we get an energy density of $\sim 10^{113}$ [J m^{-3}], while for t_0 (13.8 [Gy]) that number drops to $\sim 10^{-11}$ [J·m^{-3}]; a reduction factor of $\sim 10^{124}$!

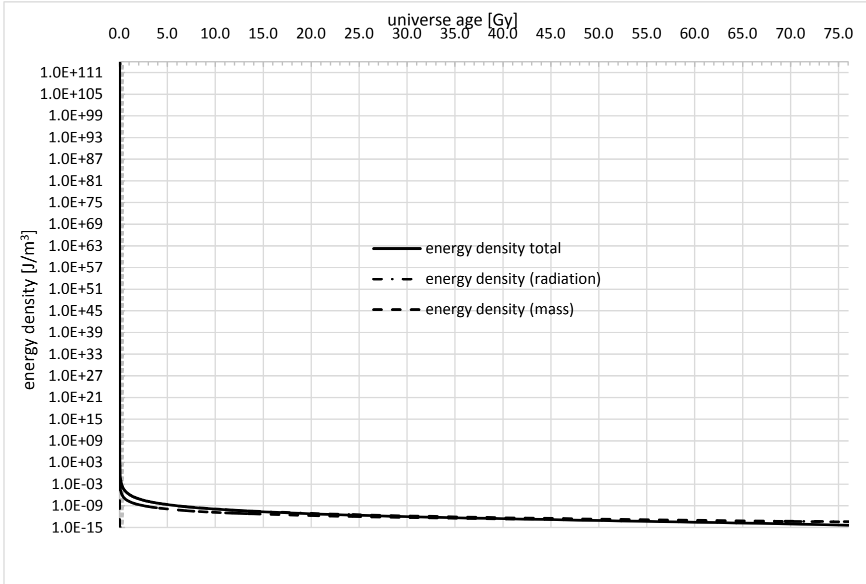


Figure 11. Energy density $\rho_{\Lambda e}$ of cosmologic constant Λ from $1 t_p$ to 76.1 [Gy].

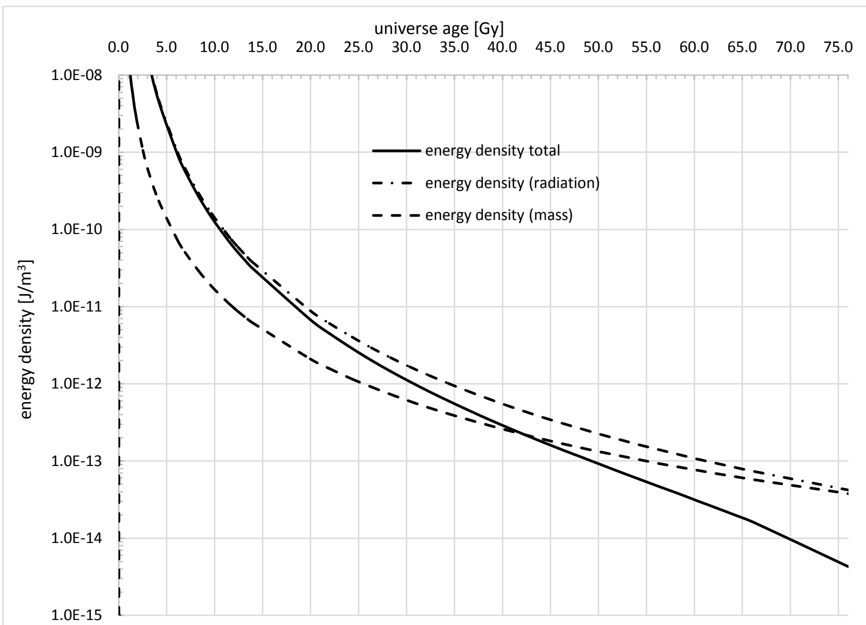


Figure 12. Energy density $\rho_{\Lambda e}$ of cosmologic constant Λ from $1 t_p$ to 76.1 [Gy].

The expression for energy density at t_p can be written as:

$$\rho_{\Lambda e}\left(t_p\right) = \frac{\pi^3}{15}\frac{c^7}{G^2 h} = \frac{\pi^2}{15} P_{pres} \sim 3\times10^{113}\left[\mathrm{J}\cdot\mathrm{m}^{-3}\right]$$

After a few algebraic manipulations, the following expression is obtained, yielding the energy density variation from the beginning, t_p, until today, t_0 (13.8 [Gy]).

$$\frac{\rho_{\Lambda e}\left(t_0\right)}{\rho_{\Lambda e}\left(t_p\right)} = \left(\frac{T_\Omega}{T_P}\right)^4 \left(\frac{\zeta(3)}{\zeta(4)}\right)^4 \frac{1}{\left(5+W_0\left(-5e^{-5}\right)\right)^4}$$

$$\frac{\rho_{\Lambda e}(t_0)}{\rho_{\Lambda e}(t_p)} \sim 1.081 \times 10^{-3} \left(\frac{T_\Omega}{T_P}\right)^4 \sim \left(\frac{1.202}{\frac{\pi^4}{90}}\right)^4 \frac{1}{4.965^4} \left(\frac{2.728}{1.41 \times 10^{32}}\right)^4 \sim 1.2 \times 10^{-124}$$

In short, as concerns energy density variation in the universe, we find a ratio to the power of four between temperature variation and Planck temperature variation, with a multiplication factor.

Finally, the Friedmann equation can be written according to the different terms of the equation in the form of an equivalent volumic mass. This highlights the relative contribution of the terms:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}(\rho_m + \rho_\Lambda + \rho_k)$$

The expressions of equivalent volumic mass in the equation are as follows:

$$\rho_m = \frac{M_t}{V}$$

$$\rho_\Lambda = \rho_r = \frac{E_\gamma - E_M}{c^2 V} = \frac{2.7 N k_b T - M_t c^2}{c^2 V} = \frac{3PV - M_t c^2}{c^2 V}$$
$$= \frac{3P}{c^2} - \rho_m = \frac{4\sigma T^4}{c^3} - \rho_m = \frac{\Lambda c^2}{8\pi G}$$

$$\rho_k = \frac{-3kc^2}{8\pi G a^2}$$

We can see that the volumic mass associated with the cosmological constant, Λ, is equivalent to that of photon gas minus the baryonic mass. Therefore, the cosmological constant reveals the existence of radiation energy. As concerns space curvature, we get a value that can turn negative according to the value of the curve (closed universe). This is important data because it is the only term that can become negative and act in opposition to gravity and mass-energy equivalence. If we express volumic masses based on the critical value corresponding to $\Lambda = k = 0$, or a flat universe whose only energy comes from mass, we get:

$$\rho_{cri} = \frac{3H^2}{8\pi G}$$

With

$$\Omega_m = \frac{\rho_m}{\rho_{cri}}, \quad \Omega_\Lambda = \frac{\rho_\Lambda}{\rho_{cri}}, \quad \Omega_k = \frac{\rho_k}{\rho_{cri}}$$

In the Friedmann equation:

$$H^2 = \left(\frac{\dot{a}}{a}\right)^2 = \frac{8\pi G}{3}(\Omega_m + \Omega_\Lambda + \Omega_k)\rho_{cri}$$

Figure 9 and Figure 10 show the values for ρ_i and Ω_i calculated according to the age of the universe.

Figure 13 shows the equivalent densities. Here, the contribution of curvature is negative for age below 2.9 [Gy], a closed universe, as already discussed with the q curve (deceleration). Then, that value of curvature increases rapidly to about 4 [Gy]. Thereafter, all values decrease in monotonic fashion and at different rates. Note that the total value is very close to the critical value, but always smaller.

Figure 14(a) shows the values of associated contributions as they relate to critical density. We can see that curvature, k, is the key factor that can explain sustained expansion of the universe. We know that the contribution of mass along with the cosmological constant, are based on conventional energy (mass-energy, radiation). In the case of space curvature, k, that form of energy cannot be so easily explained.

5. The Energy form of the Friedmann Equation

To determine the type of energy behind the expansion of the universe, the Friedmann equation can be expressed in terms of energy. Indeed, if all the terms of the equation are multiplied by $c^5G^{-1}H^{-3}$, we get:

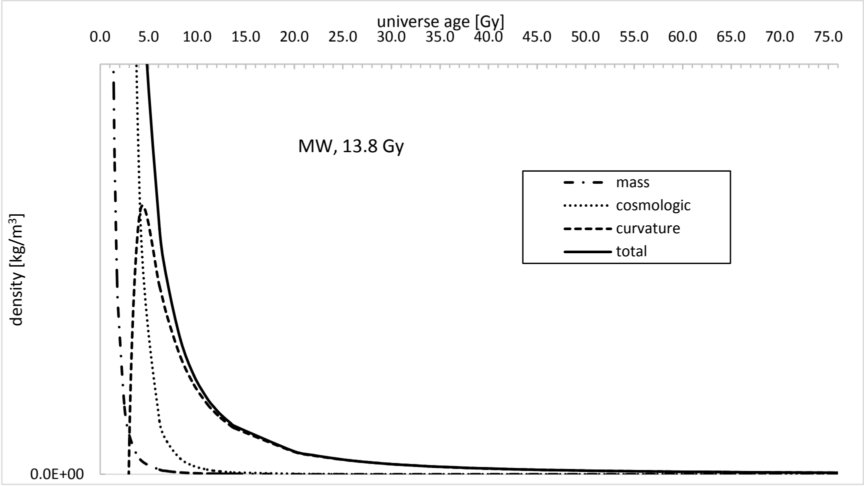
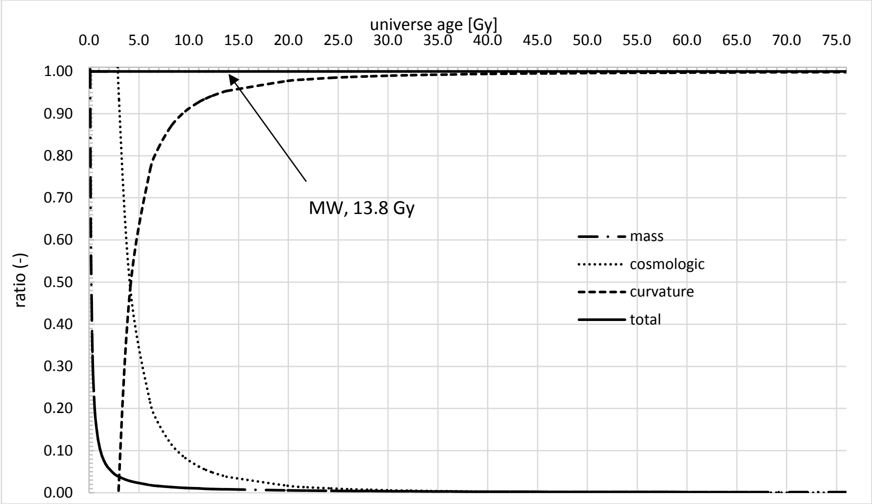
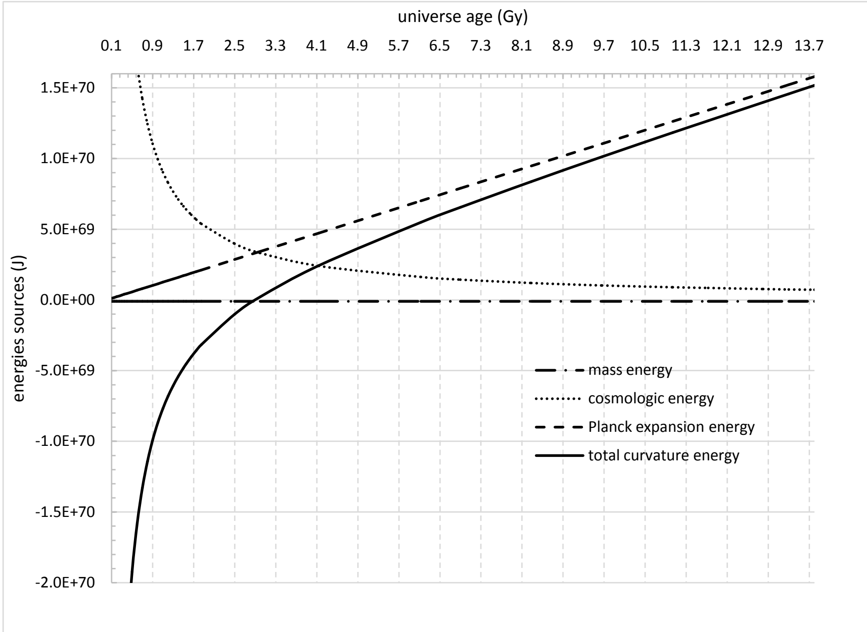


Figure 13. Equivalent densities ρ of Friedmann eq. terms from 100 [My] to 76.1 [Gy].



(a)



(b)

Figure 14. (a) Ratio of densities Ω of Friedmann eq. terms from 100 [My] to 76.1 [Gy]; (b) Energies sources from 100 [My] to 13.8 [Gy].

$$\left(\frac{c^5}{GH^3}\right)H^2 = \left(\frac{c^5}{GH^3}\right)\frac{8\pi G\rho_m}{3} + \left(\frac{c^5}{GH^3}\right)\frac{\Lambda c^2}{3} - \left(\frac{c^5}{GH^3}\right)\frac{kc^2}{a^2}$$

$$\frac{c^5}{GH} = \frac{c^5}{H^3}\frac{8\pi\rho_m}{3} + \frac{c^7}{GH^3}\frac{\Lambda}{3} - \frac{c^7}{GH^3}\frac{k}{a^2}$$

Let us express density with total mass and radius using the Hubble-Lemaitre law for the boundary ($c = Hr$), as:

$$\rho_m = \frac{M}{V} = \frac{M}{\frac{4\pi}{3}r^3} = \frac{3M}{4\pi r^3} = \frac{3MH^3}{4\pi c^3}$$

Finally, we get an expression of the Friedmann equation in the form of energy:

$$\frac{c^5}{GH} = 2Mc^2 + \frac{c^7}{GH^3}\frac{\Lambda}{3} - \frac{c^7}{GH^3}\frac{k}{a^2}$$

$$E_{\text{Planck}} = E_{\text{mass}} + E_{\text{radiation}} + E_{\text{curvature}}$$

Let us express the energy associated with curvature as:

$$E_{\text{curvature}} = E_{\text{Planck}} - E_{\text{mass}} - E_{\text{radiation}}$$

$$E_{\text{curvature}} = \frac{P_{\text{Planck}}}{H} - 2Mc^2 - \frac{c^7}{GH^3}\frac{\Lambda}{3}$$

$$E_{\text{curvature}} \sim \frac{P_{\text{Planck}}}{H} - 2Mc^2 - \frac{c^7}{G}\frac{k_\Lambda H}{3}$$

$$E_{\text{curvature}} \sim \frac{F_{\text{Planck}}c}{H} - 2Mc^2 - \frac{c^7}{G}\frac{k_\Lambda H}{3}$$

where: $k_\Lambda = 2.88\times10^{17}\left[\mathrm{s}^4\cdot\mathrm{m}^{-2}\right]$, $M \sim 7.53\times10^{50}\left[\mathrm{kg}\right]$,
$P_{\text{Planck}} = 3.629\times10^{59}\left[\mathrm{W}\right]$

A positive energy result represents an open universe, while a negative result means a closed universe. In the above equation, note that both positive and negative results are possible according to the values of the terms. The first term, open, is Planck power multiplied by cosmic time. The second term, closed, is a constant of total energy associated with mass (50% energy, 50% kinetic, $\overline{\beta} = \sqrt{3/4}$), and the third term, closed, is the energy associated with radiation (via Λ), which decreases with the increase in cosmic time. The transition from a closed universe to an open one is for $E_{\text{curvature}} = 0$. We get the following positive root:

$$H = 1.054\times10^{-17}\left[\mathrm{s}^{-1}\right]$$

$$t = \frac{1}{H} = 3.00\left[\mathrm{Gy}\right] \quad (z \sim 3.6)$$

In the above equation, if the mass is increased by a factor of 10 or 50 the transition from close to open is delayed by 590 [My] or 4.1 [Gy] (at 3.59 [Gy] or 7.1 [Gy]). We see the impact of the mass on the transition.

In short, with the Friedmann equation and the assumptions of this model, we find that energy of unknown origin is acting on the expansion of the universe through an enormous power that is equal to Planck power P_P multiplied by cosmic time. That expansion energy E_{curv} is not directly expressed in a model variable. Moreover, it is positive via Planck power, which represents conventional energy acting in opposition to gravity F_G (or E_{mass}) and cosmological gravity force F_Λ ($E_{\text{radiation}}$ or E_Λ). The expansion power is not associated to mass (baryonic) or radiation (photonic via Λ). This unknown energy of expansion is possibly contained in a potential form available in the volume and at the frontier of the universe that acts by an expansion effect of space in the manner of stretching of space. This Planck power P_P can be expressed by the Planck force F_P multiplied by c. In this model, we consider that the frontier of the universe moves at speed c. It is seen that the idea of an internal and external force (multiverse) of the magnitude of Planck force acts at the boundary to stretch the space at speed c.

One can determine the expression of the volume expansion force of the universe $\vec{\boldsymbol{F}}_{\text{exp}}$ using the theorem of divergence in spherical coordinates knowing the expansion force at the border $\vec{\boldsymbol{F}}_{\text{Planck}}$.

$$\vec{\boldsymbol{F}}_{\text{Planck}} = F_{\text{Planck}}\boldsymbol{e}_r$$

if one accepts that spherical symmetry applies to the scale of the universe:

$$\iiint_{V_{\text{universe}}} \vec{\nabla}\cdot\vec{\boldsymbol{F}}_{\text{exp}} = \oiint_{S_{universe}} \vec{\boldsymbol{F}}_{\text{Planck}}\cdot\mathrm{d}\vec{\boldsymbol{S}}$$

$$\int_0^{r_U}\int_0^{2\pi}\int_0^{\pi}\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2F_{\text{exp}}\right)r^2\sin\theta\mathrm{d}\theta\mathrm{d}\varphi\mathrm{d}r = r_U^2F_{\text{Planck}}\int_0^{2\pi}\int_0^{\pi}\sin\theta\mathrm{d}\theta\mathrm{d}\varphi$$

The solution found with the divergence theorem is:

$$\vec{\boldsymbol{F}}_{\text{exp}} = F_{\text{Planck}} \boldsymbol{e}_r$$

The result found is remarkable. Indeed, we find that a constant Planck force acts at all points of space, radial direction outwards to realize the expansion of the universe. Of course, the result found brings more questions than answers. At first glance, however, the result seems logical and presupposes energy associated with space itself. A summary calculation, based on the work PdV done by this Planck force to create space, shows that for every m^3 of space in our position (MW) the energy used to create space is worth ~1.8 × 10^{-9} [J·m^{-3}]. However, at the beginning of the Planck era, this space creation energy was worth ~1.1 × 10^{113} [J·m^{-3}].

Finally, for comparison, this total expansion energy can be estimated with the spherical symetry.

$$E_{\text{curvature}} = \int_V \mathrm{d}E_{\text{curv}} = \int_0^{r_U} \vec{\boldsymbol{F}}_{\text{Planck}} \cdot \boldsymbol{e}_r \mathrm{d}r = F_{\text{Planck}} r_U = F_{\text{Planck}} ct = \frac{F_{\text{Planck}} c}{H}$$

We find the same result for an empty universe (without total mass and radiation energy E_{mass} and $E_{\text{radiation}}$). Figure 14(b) shows the evolution of diferents energies function of cosmic time from 100 [My] to 13.8 [Gy]. Mass energy value is ~1.04 × 10^{68} [J]. We see that the universe becomes open at ~3 [Gy]. Subsequently, the curves become almost monotonous until 76.1 [Gy].

6. Age of the Universe from the Friedmann Equation

The values obtained from the model for our position (a_0 = 1) are (see Figure 14(a)):

$$\Omega_{m0} \cong 0.00632$$

$$\Omega_{\Lambda 0} \cong 0.03995$$

$$\Omega_{k0} \cong 0.95373$$

The age of the universe is estimated from the integral of Fridemann's equation taking into account that the cosmological constant is identified with the total energy of the universe E_Λ (non-massic), *i.e.*:

$$t_\Omega = \int_0^t \mathrm{d}t = \int_0^a \frac{t_0}{\sqrt{\frac{a_0^4 \Omega_{\Lambda 0}}{a^2} + \frac{a_0^3 \Omega_{m0}}{a} + \frac{a_0^2 \Omega_{k0}}{1}}} \mathrm{d}a$$

Note that the exponent of $\Omega_{\Lambda 0}$ is 4 as electromagnetic energy compared to 1 in the usual case. We find the following expression for the integral:

$$t_\Omega = \frac{a t_0}{\Omega_{k0}} \sqrt{\frac{\Omega_{\Lambda 0}}{a^2} + \frac{\Omega_{m0}}{a} + \frac{\Omega_{k0}}{1}} - \frac{t_0 \Omega_{m0}}{2\Omega_{k0}^{3/2}} \ln\left[2\sqrt{a^2 \Omega_{k0}^2 + a_{k0} \Omega_{m0} + \Omega_{k0} \Omega_{\Lambda 0}} + 2a\Omega_{k0} + \Omega_{m0}\right] + C$$

The value of the C constant can be estimated with the parameters estimated at

$a = a_0 = 1$ or $t_\Omega = t_0$. It is possible to find:

$$C = t_0 - \frac{t_0}{\Omega_{k0}}\sqrt{\frac{\Omega_{\Lambda 0}}{1} + \frac{\Omega_{m0}}{1} + \frac{\Omega_{k0}}{1}}$$

$$+\frac{t_0\Omega_{m0}}{2\Omega_{k0}^{3/2}}\ln\left[2\sqrt{\Omega_{k0}^2 + \Omega_{k0}\Omega_{m0} + \Omega_{k0}\Omega_{\Lambda 0}} + 2\Omega_{k0} + \Omega_{m0}\right]$$

$$C = t_0 - 1.0485t_0 + 4.5885\times 10^{-3}t_0 = -0.04391t_0$$

For $t_0 = 13.8$ [Gy], we find, $C = -0.605$.

Now we have already estimated that the age of the universe is ~76.1 [Gy] with the Casimir effect or a value of the scale factor $a = 5.51$. For this scale factor and the equation found for the age of the universe, we find:

$$t_\Omega = \frac{5.51t_0}{\Omega_{k0}}\sqrt{\frac{\Omega_{\Lambda 0}}{5.51^2} + \frac{\Omega_{m0}}{5.51} + \frac{\Omega_{k0}}{1}}$$

$$-\frac{t_0\Omega_{m0}}{2\Omega_{k0}^{3/2}}\ln\left[2\sqrt{5.51^2\Omega_{k0}^2 + 5.51\Omega_{k0}\Omega_{m0} + \Omega_{k0}\Omega_{\Lambda 0}} + 2\times 5.51\Omega_{k0} + \Omega_{m0}\right] - 0.605$$

$$t_\Omega = 77.958 - 0.142 - 0.605 = 77.21\,[\mathrm{Gy}]$$

In summary, we find that the solution of Friedmann's equation with the parameters estimated at our position a_0 gives an age approximately similar to that estimated with the Casimir effect. This result is interesting because it shows a relatively good match of the model with regard to the estimation of the age of the universe by 2 different methods.

7. Some Comparison with Some Data from the ΛCDM Model

The Table 2 below shows some of the major differences between this model and the ΛCDM model [13]. The numbers are averages over a time period ranging from $z = 0$ to $\sim z_{re}$ (~7.70), or ~1.5 [Gy] to 13.8 [Gy]. Variations in values were left out for easier comparison. Indeed, Planck measurements are from different times in the past of the universe, thus confirming that they are, at least partly, time-related averages. The table shows three main differences: First, the estimated age of the universe is greater. The MW is situated at cosmic time 13.8 [Gy]; second, the baryonic mass is 11 times smaller; and third, dark energy associated with Λ is in fact radiation energy, which is very large at the beginning. Moreover, if the total energy associated with dark matter in added up in the ΛCDM model, dark energy and radiation ($\Omega_{cdm} + \Omega_\Lambda + \Omega_r$), we get ~0.950, which is quite similar to the radiation value, Ω_Λ, of the model (0.968).

Finally, in the beginning, the energy associated with space curvature, k, is relatively small compared to radiation. That energy is of unknown origin and possibly acting at the boundary. As concerns the curvature of space, k, the energy source is not identified. However, in this version of the model, that energy form does not behave like mass-energy equivalence, as is the case with the cosmological constant.

Table 2. Some comparison between this model AΛΩ and ΛCDM model.

Description	Symbol	ΛCDM	AΛΩ	Comments
Age of the universe (cosmic)	t_Ω [Gy]	13.799 (obs.) 46	13.799 (obs.) 76.1	The MW is at cosmic time 13.8 [Gy]
Total density parameter	Ω_{tot}	1	1	
Hubble constant	H_0 [km·s^{-1}·Mpc^{-1}]	67.4 ± 0.5	70.9	$H_0 = 1/t\left[s^{-1}\right]$
Baryonic density	Ω_b	0.0486	0.03045	Less baryonic matter
Dark matter density	Ω_{cdm}	0.2664	0	Dark matter is not a parameter of the model
Matter density	Ω_m	0.315	0.03045	Baryonic matter only
Dark energy density	Ω_Λ	0.685	0	Mass and/or photon energy only, except for curvature k
Radiation energy density	Ω_r or Ω_Λ	$\Omega_r = 10^{-5}$	$\Omega_\Lambda = 0.96893$	The cosmological constant represents radiation energy
Curvature energy density	Ω_k	+0.001 ± 0.002	+0.00062	Curvature energy is of unknown origin
Cosmic neutrino mass	m_ν [eV]	$\Sigma m_\nu \leq 0.12$	≤48 × 10^3 [eV]	The cosmic neutrino is estimated with the muonic neutrino with β SN1987A

8. Cosmological Gravity Force, F_Λ

For the time period when radiation was dominant, a central force associated with Λ_{rad} can be determined using mass-energy equivalence. Indeed, we know the value for Λ_{rad} via the evolution of energy in the universe. Let us assume an element with mass m in rotation according to a Kepler model in a central gravity field of mass M. Another attractive force is a work around mass m, this time associated with the non-baryonic energy density, which acts through mass-energy equivalence of the interior sphere whose boundary is determined by the rotation radius, r, of mass m. That central force has been suggested by several authors, including [15] Martin. However, after mathematical elaboration, they note that the force is repulsive, and not attractive. This can be explained through mathematical calculations using the cosmological constant, which predicts a repulsive rather than attractive effect when placed on the left side of the general relativity equation.

In this model, we consider that the force is attractive simply through mass-energy equivalence, which can also be achieved with the General Relativity Theory (see below), meaning that a positive energy mass is associated with a positive energy, such as the energy of photons associated with constant Λ, and that energy mass exerts an attractive force on surrounding masses the same way the inertial mass (baryonic) does. What's more, the notion of mass-energy (or electromagnetic) was addressed initially by [16] Langevin, a contemporary of Einstein.

$$m_{\text{energetic}} = m_{\text{inertial}} = m_{\Lambda} = \frac{E_{\Lambda}}{c^2} = \rho_{\Lambda} V = \frac{c^2 \Lambda r^3}{6G}$$

We can see that the mass-energy associated with the cosmological constant (photon gas) depends on a zone demarcated by the assumed radius, r. The full action of this force is unknown, but it is gravitational, meaning that this cosmological gravity force acts together with conventional gravity and that other such couplings are possible. This can partially explain the issues with the cosmological constant, Λ. In fact, that gravity force can be put into action in the general relativity equation through the existence of the cosmological constant, as put forth by Einstein but for a different reason than the static universe he proposed. Indeed, the cosmological constant was later added by Einstein as an opposing force to gravity. Therefore, when the term $\Lambda g_{\mu\nu}$ is moved to the right-hand side, the side of the energy-momentum tensor, we get a repulsive effect associated with Λ:

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

With the signature of the metric tensor (+, −, −, −), the energy-momentum tensor can be expressd as:

$$T_{\mu\nu}^{\text{total}} = T_{\mu\nu}^{\text{baryonic}} - \rho_{\Lambda e} g_{\mu\nu}$$

In this case, the resulting force is repulsive, as Einstein wanted. However, it is also possible to make the effects of that energy appear directly in the energy-momentum tensor as a source of additional mass-energy through the mass-energy principle, as:

$$T_{\mu\nu}^{\text{total}} = T_{\mu\nu}^{\text{baryonic}} + T_{\mu\nu}^{\text{mass-energy}}$$

$$T_{\mu\nu}^{\text{total}} = T_{\mu\nu}^{\text{baryonic}} + \frac{E_{\Lambda}}{V} g_{\mu\nu}$$

$$T_{\mu\nu}^{\text{total}} = T_{\mu\nu}^{\text{baryonic}} + \rho_{\Lambda e} g_{\mu\nu} = \rho_m c^2 + \frac{c^4 \Lambda}{8\pi G} g_{\mu\nu}$$

Hence, the energy density component of the tensor, T^{00}, is entirely positive:

$$T^{00} = \rho_m c^2 + \frac{c^4 \Lambda}{8\pi G} = \rho_{m+\Lambda} c^2$$

The solution for the spherical geometry is found in the Newton equation for low velocities:

$$\nabla^2 \Phi = 4\pi G \rho_{m+\Lambda} = 4\pi G \left(\rho_m + \frac{c^2 \Lambda}{8\pi G} \right) = 4\pi G \rho_m + \frac{c^2 \Lambda}{2}$$

The potential being:

$$\Phi = -\frac{Gm}{r} + \frac{c^2 \Lambda r^2}{12}$$

A potential in r^2 is said harmonic and the equation of the trajectory of a mass m' in harmonic potential is a closed curve like that Newtonian in r^{-1} (Bertrand's problem). The acceleration of a mass m' in this field is expressed as the gradient of potential Φ:

$$\boldsymbol{a} = -\nabla\Phi\boldsymbol{e}_r = -\frac{\partial\Phi}{\partial r}\boldsymbol{e}_r = -\frac{\partial\left(-\frac{Gm}{r}+\frac{c^2\Lambda r^2}{12}\right)}{\partial r}\boldsymbol{e}_r$$

$$\boldsymbol{a} = -\frac{Gm}{r^2}\boldsymbol{e}_r - \frac{\Lambda}{6}c^2 r\boldsymbol{e}_r$$

We can see that, at this time, solving the equation predicts an attractive force associated with constant Λ and of the same type as the baryonic mass. The r term can be related to the Hooke ellipse. Moreover, it is surprising to note here that at the beginning of the formation of the structures of the universe the two forces in kr^{-2} and kr acted simultaneously which, certainly would be likely to reconcile, if it were possible Newton and Hooke. It would make sense to call the potential found NcH for Newton-cosmological-Hooke. Finally, in a detailed form, the NcH potential is expressed as:

$$\Phi(m,r,H) = -\frac{Gm}{r} + \frac{c^2 k_\Lambda}{12}H^4 r^2$$

Then, solving the equation for low velocities (Newton) includes one mass contributors (baryonic) and one energy (k_Λ, cosmological). The geometric variable r of the structure and the time factor of formation of the structure H. At this time, we can see that expansion of the universe is not caused by dark energy associated with Λ, but by another effect seen earlier, the energy associated with curvature, k. If that choice had been made, the force derived by [15] Martin would be attractive.

Finally, based on this approach, we can see that the cosmological constant must be included in Einstein's equation because it represents non-baryonic energy in the universe, but the sign for the term $\rho_{\Lambda e}g_{\mu\nu}$ on the right-hand side of the equation must be positive, which provides a possible explanation for the additional attractive gravity effects associated with the positive energy of constant Λ. At this time, expansion of the universe can be attributed to energy associated with curvature, k, as stated earlier. A similar potential has been proposed by Farnes [17], but the sign of the term in r^2 is negative which forces to consider the existence of a negative mass to produce a positive attraction force. The existence of the negative mass, although possible in theory, has not been observed until now.

Therefore, assuming this notion of mass-energy, and according to Newton's law of attraction for that mass, m_Λ, the central attractive force associated with the mass-energy equivalence can be written as:

$$|F_\Lambda| = \frac{Gm_\Lambda m}{r^2} = \frac{G(\rho_\Lambda V)m}{r^2} = \frac{G\left(\rho_\Lambda 4\pi r^3\right)m}{3r^2}$$

$$= \frac{4\pi G(\rho_\Lambda)rm}{3} = \frac{4\pi G}{3}\left(\frac{c^2\Lambda}{8\pi G}\right)rm = \frac{\Lambda}{6}c^2 mr$$

The force can be expressed in relation to the age of the universe:

$$F_\Lambda = \frac{\Lambda}{6}c^2 rm = G\left(\frac{16\pi\sigma T_\Omega^4 t_\Omega^4}{3c^3}\right)\frac{rm}{t^4} = G\left(\frac{16\pi\sigma T_\Omega^4 t_\Omega^4}{3c^3}\right)mrH^4$$

For $T_\Omega = 2.7\,[\mathrm{K}]$, $t_\Omega = 76.1\,[\mathrm{Gy}]$, and $t = t_0 = 13.8\,[\mathrm{Gy}]$, we get;

$$F_\Lambda = 4.82\times 10^{-36}\,mr$$

This attractive force can be attributed to the cosmological constant, which translates conventional energy density that is not in the form of conventional baryonic mass. Moreover, the force of gravity, which varies in r, is active everywhere on the same basis as baryonic mass gravity. Note that such a force has never been detected around us because the cosmological constant is extremely small today (~10^{-54}). However, at the time of primitive galaxy formation, the cosmological constant was much greater (Λ~10^{-48} at t~0.5 [Gy]). Also, when we include the great galaxy or cluster radii, we will see that cosmological gravity played a large part in galaxy rotation. For comparison purposes, let us calculate the ratio between the cosmological gravity and Newton's force for the solar system:

$$\frac{F_\Lambda}{F_G} = \frac{\frac{\Lambda c^2 mr}{6}}{\frac{GMm}{r^2}} = \frac{\Lambda c^2 r^3}{6GM}$$

$$= \frac{\left(6.73\times 10^{-54}\right)\times\left(2.99\times 10^{8}\right)^2\times\left(149.6\times 10^{9}\right)^3}{6\left(6.67\times 10^{-11}\right)\times\left(1.98\times 10^{30}\right)} = 2.53\times 10^{-24}$$

For the earth, with small g_Λ, the force assumes the following value:

$$F_\Lambda = \frac{\Lambda}{6}c^2 rm = \frac{\left(6.73\times 10^{-54}\right)\times\left(2.99\times 10^{8}\right)^2\times\left(6378\times 10^{3}\right)}{6}m$$

$$= g_\Lambda m = 6.39\times 10^{-31}\left[\mathrm{m\cdot s^{-2}}\right]m$$

Note that the value for g_Λ is much too small to be detectable by current instruments. However, over the first billion years, let us calculate the ratio of the cosmological gravity to the force of gravity for the universe with a critical volumic mass of $3H^2/8\pi G$:

$$\frac{F_\Lambda(1Gy)}{F_G(1Gy)} = \frac{\frac{\Lambda(1Gy)c^2 mr}{6}}{\frac{GMm}{r^2}} = \frac{\Lambda(1Gy)c^2 r^3}{6GM} = \frac{\Lambda(1Gy)c^2}{8\pi G\rho_{cri}}$$

$$= \frac{2.88\times 10^{-49}c^2}{8\pi G\left(1.79\times 10^{-24}\right)} \sim 8.6$$

Note that the attractive effect of cosmological gravity is huge and greatly surpasses that of gravity alone during the formation of great structures like galaxies. At 500 [My], the ratio was ~34. **Figure 15** and **Figure 16** show the mean ratio F_Λ/F_G for the time period starting at proton time t_{pr}. Note that the cosmological gravity makes it possible for the great structures like galaxies to form much faster than simply under gravity. This notion of additional force to gravity could provide a possible explanation for the production of primitive black holes at the very beginning of the universe ($6 < z < 30$) (Lupi, Colpi, Devecchi *et al.*, 2014). Indeed, the ratio F_Λ / F_G is ~54 aound 400 [My], which may accelerate the accumulation of mass beyond the Eddington limit.

Today, those effects are potentially limited to the great structures, such as galaxy clusters or superclusters, as it increases with an increase in radius. The time period when cosmological gravity was greater than gravity alone can be determined with:

$$F_\Lambda \geq F_G$$

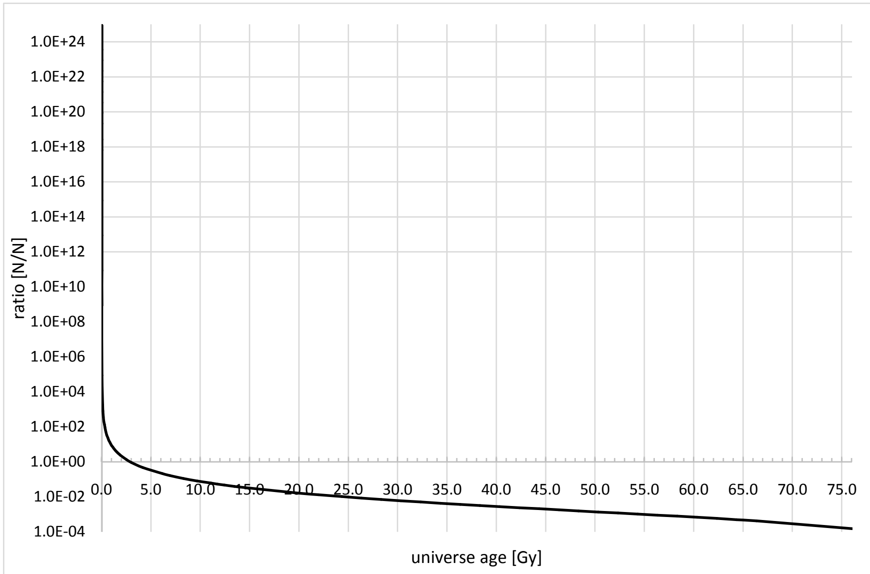


Figure 15. Ratio of F_Λ / F_G from $1 t_p$ to 76.1 [Gy].

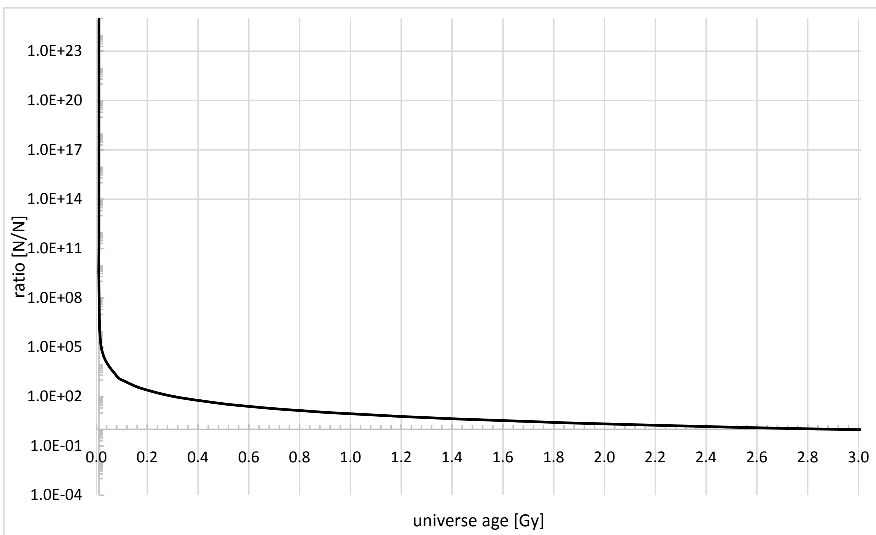


Figure 16. Ratio of F_Λ / F_G from $1 t_p$ to 3 [Gy].

$$\frac{\Lambda}{6}c^2 rm \geq G\frac{Mm}{r^2}$$

$$\Lambda \geq \frac{8\pi G}{c^2}\rho \sim 1.87\times 10^{-26}\rho$$

where ρ is the volumic mass of matter in the zone concerned. For the entire universe at critical density, we get:

$$\Lambda \geq \frac{8\pi G}{c^2}\rho_c \geq \frac{3H^2}{c^2}$$

With the expression derived for the cosmological constant, we get the following expression, which yields the cosmic time at which cosmological gravity was greater than gravity force alone:

$$\alpha H^4 - \varepsilon H^3 \geq \frac{3H^2}{c^2}$$

With the values for α and ε already obtained, cosmic time is found to be:

$$t_{\text{cosmic}} \leq 2.89\,[\text{Gy}]\ \ (z \geq 3.77)$$

Therefore, cosmological gravity is the dominant force beyond gravity alone for a time period of ~2.9 [Gy].

This cosmological gravity force may have an impact on the different concepts used in cosmology as the Eddington limit, the Jeans radius. For the first ~3 [Gy], the values obtained from the concepts can be adapted using the adapted Newton gravitation constant G^{Λ} to take intoaccount this cosmological force of a structure mass M and radius r by substituting G with the adapted one.

$$G^{\Lambda}(H) = \left(1 + \frac{\Gamma H^4 r^3}{M}\right)G$$

With: $\Gamma = \frac{c^2 k_{\Lambda}}{6G} \sim 6.47\times 10^{43}\left[\text{kg}\cdot\text{s}^4\cdot\text{m}^{-3}\right]$

This expression of $G^{\Lambda}(H)$ was proposed repeatedly by many authors as part of a family of models called: Dark matter, dark energy dynamical scalar field (quintessence) [19]. The general form of the equation proposed is:

$$G(\alpha) = \left(1 + 2\alpha^2(\varphi)\right)G$$

The value mentioned for α compatible with the CMB is ($0 < \alpha < 0.06$). We find this value of α for the MW.

$$\alpha(\varphi) = \sqrt{\left(\frac{\Gamma H_0^4 r^3}{2M}\right)} \sim \sqrt{\left(\frac{6.47\times 10^{43}\times 2.29\times 10^{-184}\times 6,478\times 10^{203}}{2\times 2.97\times 10^{41}}\right)} \sim 9\times 10^{-4}$$

The model proposes a very small modification of the G value which depends mainly on the r^3 size of the structure in question. This small change in G could be a part of the search for a new metric $f(R)$ gravity theory models. A large number of $f(R)$ gravity models have been proposed to explain different cases where the GR theory appears to be less accurate in predicting observations. In a near futur, the observations and measurments of gravitational waves GW with the development of more sensitive sensors will determine whether or not the GR theory will be a definitive, or not, theory of gravity as it has been formulated in 1916 [20].

According to the author, while that force is negligible today on our scale, it was central to the formation of our universe and the great structures within it.

9. Conclusion

The model proposed herein sheds light on the importance of the cosmological constant, Λ, which acts as a dominant gravitational force in the early universe when considered a source of energy in the GR equation. The model does not consider the existence of energy other than photons. In other words, the notion of dark energy, dark matter (non-baryonic) is not specifically addressed in the model, although the existence of some baryonic dark matter is accepted. The model questions certain elements of the cosmological principle, that is the idea that there is no preferred position. The model assumes that the MW occupies a precise location (cosmic time 13.8 [Gy]), and not a central one in this universe of possible ~76 [Gy] cosmic age. Moreover, we do not have sufficient data from cosmological observations to claim with the assurance that the universe is the same in all directions and, more specifically, to the high values of z, excluding the CMB, which appears in the early universe before the formation of the structure that we observe, which in turn is subject to a different chronology. Indeed, the observed percentage of this universe is extremely low, especially as concerns galaxies. If the number of galaxies is an estimated $\sim 2 \times 10^{12}$, less than $\sim 10^{-6}$ percent have been indexed (90,000 galaxies) (Vipers, 2016). The model can partially describe the rotation of certain galaxies without recourse to dark matter (halo), but rather uses the cosmological gravity effect, which has a heavy impact during the early formation period (part 3). Finally, the model described herein seems interesting for several reasons, but further development is required before its foundations can be validated (complete particle generation, atoms, fusion, etc.). The model is still one among many, fine tuning and improvements are to be expected.

Funding Statement

Funding for this article was supported by the University of Quebec at Chicoutimi.

Acknowledgements

The author would like to thank the members of his family, especially his spouse (Danielle) who with patience to bear this work as well his children (Pierre-Luc, Vincent, Claudia), for their encouragement to persevere despite the more difficult periods. Also, a big thank to Mrs. Nadia Villeneuve of UQAC who has prepared the article and references in an acceptable version. Finally, thanks to the

University of Quebec at Chicoutimi and to the colleagues of the Department of Applied Sciences for their supports in the realization of this work.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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