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An Alternative to Dark Matter? Part 1: The Early Universe (t_P to 10^{-9} s), Energy Creation the Alphaton, Baryogenesis

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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 $\rho_{\Lambda e}$, age of the universe t_Ω etc. The development of the state equation highlights the importance of not neglecting any of the differential terms given the very large amounts in play that can counterbalance the infinitesimals. Some assumptions were put forth in order to solve these equations. The current version of the model partially explains several of the observed phenomena that raise questions. Numerical application of the model has yielded the following results, among others: Initially, during the Planck era, at the very beginning of Planck time, t_p, the universe contained a single photon at Planck temperature T_P, almost Planck energy E_P in the Planck volume. During the photon inflation phase (before characteristic time ~10^{-9} [s]), the number of original photons (alphatons) increased at each unit of Planck time t_P and geometrical progression~n^3, where n is the quotient of cosmic time over Planck time t/t_P. Then, the primordial number of photons reached a maximum of N~10^{89}, where it remained constant. These primordial photons (alphatons) are still present today and represent the essential of the energy contained in the universe via the cosmological constant expressed in the form of energy E_Λ. Such geometric growth in the number of photons can bring a solution to the horizon problem through $\gamma\gamma$ exchange and a photon energy volume that is in phase with that of the volume energy of the universe. The predicted total mass (p, n, e, and ν), based on the Maxwell-Juttner relativistic statistical distribution, is ~7 × 10^{50} [kg]. The predicted cosmic neutrino mass is ≤8.69 × 10^{-32} [kg] (≤48.7 [keV·c^{-2}]) if based on observations of SN1987A. The temperature variation of the cosmic microwave background (CMB), as measured by Planck, can be said to be partially due to energy variations in the universe ($\Delta U/U$) during the primordial baryon synthesis (energy jump from the creation of protons and neutrons).

Keywords

Cosmological Parameters Numerical Values, Cosmology Early Universe

1. Introduction: Formulation of the Model, Initial Concept

Cosmology fascinates. Sky-watching has forever been an integral part of the human experience. Unfortunately, we do not have all the data we need to fully understand the distant past, what we call the beginning of all things, until today, or even until the so-called end. Nevertheless, we do have numerous findings that allow us to reconstruct, to a greater or lesser extent, the sequence of events from the very beginning, if at all possible, using the laws of physics. The model herein is based on the following key premises, some of which are tested, while others are speculative.

The following are the key premises of the model:

- The macroscopic laws of physics applied after the Planck era;
- At the beginning ($1t_p$, Planck time), all of the energy in the universe was electromagnetic (photons); the conventional photon gas equation of state applies;
- All infinitesimal variations of dr, dT, dP, dV, and similar variables are to be considered and maintained in the elaboration of differentials equations given the large and small quantities involved in the equation terms (e.g. $t_p \sim 10^{-43}[\text{s}]$, $T_p \sim 10^{32}[\text{K}]$);
- The law of conservation of energy applies to universe-size scales;
- The cosmological principle is not necessarily adhered to;
- The Hubble constant of the Hubble-Lemaître law is used to solve the Friedmann equations and find values for $\Lambda(t)$ and $k(t)$.

2. Equation of State for the Temperature, Pressure, Volume

The photon gas equation that applies when photon numbers are high enough to be considered a gas ($N \gg 1$) is written as:

$$PV = \frac{\zeta(4)}{\zeta(3)} k_b NT = f(t)$$

where $f(t)$ represents a function of cosmic time. Observations show that the universe is expanding with time $r(t)$. Expansion of the universe is isotropic ($\dot{r}$ isotropic) and in accordance with the Hubble-Lemaître law. The volume V of space (photon propagation) thus generated is isotropic (large-scale isotropic, $\dot{V}$). The mechanism behind the evolution pattern for V is unknown but, as we will see later, it is represented by the evolution of energy associated with curvature k. It starts with the initial Planck time t_p, and time evolves freely as $t + t_p$. At every step, t_p, V, T and P evolve, but the triggering mechanism for this evolution is unknown. V, T and P evolve in some sort of sequence, which is probably as follows: $t + t_p$, $V + \mathrm{d}V$, $N + \mathrm{d}N$, $T - \mathrm{d}T$, $P - \mathrm{d}P$, $E - \mathrm{d}E$. The expanding volume (spacetime) is a sphere whose radius evolves in line with cosmic time. The Hubble-Lemaître law takes the following simple form:

$$\dot{r} = Hr = r/t$$

In this version, H varies according to cosmic time. We can observe H at t_0, written as $\bar{H}_0$ (~70 [km·s^{-1}·Mpc^{-1}]) [1]. This yields $r = ct + r_\alpha$ as the mean evolution of r over time. The radius can undergo local, spontaneous variations that are different than ct, but the average is still equal to ct.

Let us write the equation of state for photon gas in the form of the variation, freely choosing the negative form of the variations, which allows to denote the possible existence of a singularity at the beginning of the evolution of the universe. Moreover, CMB observations reveal a decay of T:

$$\frac{PV}{T} = \frac{(P - \mathrm{d}P)(V - \mathrm{d}V)}{T - \mathrm{d}T} = f(t)$$

Developing the right-hand side yields:

$$\frac{\mathrm{d}T}{T} = \frac{\mathrm{d}V}{V} + \frac{\mathrm{d}P}{P} - \frac{\mathrm{d}P\mathrm{d}V}{PV}$$

The final term on the right is retained as it contains the potential existence of a singularity at the beginning of the evolution of the universe.

Let us develop V, $\mathrm{d}V$, P and $\mathrm{d}P$:

$$V = \frac{4\pi}{3} r^3 = \frac{4\pi}{3}(ct + r_\alpha)^3$$

$$\dot{V} = \frac{\mathrm{d}V}{\mathrm{d}r}\dot{r} = 4\pi r^2 Hr = 3HV$$

$$\mathrm{d}V = 3HV\mathrm{d}t$$

$$\frac{\mathrm{d}V}{V} = 3H\mathrm{d}t$$

For a photon gas associated with a blackbody considered in a state of equilibrium ($N \gg 1$), radiation pressure is expressed as:

$$P = \frac{4\sigma}{3c} T^4$$

$$\frac{\mathrm{d}P}{\mathrm{d}T} = \frac{16\sigma}{3c} T^3$$

$$\frac{\mathrm{d}P}{P} = 4\frac{\mathrm{d}T}{T}$$

$$\frac{\mathrm{d}P\mathrm{d}V}{PV} = 12H\mathrm{d}t\frac{\mathrm{d}T}{T}$$

Finally, we derive the following specific equation for the evolution of photon gas temperature in a context of expansion of the universe ($N \gg 1$):

$$\frac{\mathrm{d}T}{T} = \frac{H\mathrm{d}t}{-1+4H\widetilde{\mathrm{d}t}}$$

The equation for temperature variations in line with the Hubble constant yields different scenarios of evolution for $T(t)$. First, integration creates a problem since $\mathrm{d}t$ appears in both the numerator and denominator. The presence of $\widetilde{\mathrm{d}t}$ in the denominator is caused by the term $\mathrm{d}V\mathrm{d}P/VP$. If this term is left aside, we get a conventional form of $-H\mathrm{d}t$. Integration can be done by considering the process as a summation along cosmic time t for the numerator $\mathrm{d}t$, with $H/\left(-1+4H\widetilde{\mathrm{d}t}\right)$. Then, the term $4H\widetilde{\mathrm{d}t}$ can be processed in various ways. Moreover, the value of H can vary according to different expansion scenarios. In this version of the model, we assume that the Hubble constant decreases monotonically with time. Let us assume that this term remains constant for the main integration of $\mathrm{d}t$, therefore:

$$T(t) = \frac{a_4}{-t+4\widetilde{\mathrm{d}t}}$$

where, $H = 1/t$, or $\ddot{r}/r = H^2 + \dot{H} = 0$, or still $q = 0$ (for the boundary of the universe).

Note that the acceleration factor q of the boundary of the universe is zero, but we will see later that it is not zero for the mass of the universe.

The equation for T in relation to cosmic time yields interesting characteristics. First, two constants, or unknowns, a_4 and $\widetilde{\mathrm{d}t}$, are required to determine the evolution process of T. Second, $\widetilde{\mathrm{d}t}$ is normally positive, because time is positive and so is $\widetilde{\mathrm{d}t}$. Third, $\widetilde{\mathrm{d}t}$ can be considered a time limit in the flow of time t, which is causal. The smallest $\widetilde{\mathrm{d}t}$ time limit could be a unit of Planck time, t_p.

3. State Equation, Evolution of Photon Gas, Temperature, Volume and Pressure

No data is available on the evolution of temperature in the universe due to the limited time since the beginning of T measurements. CMB temperature has been measured, as well as spatial variation ΔT. We also know Planck temperature, T_p, which is normally considered the maximum temperature of any element. If we take $T(0) = T_p$, [2], which denotes the maximum energy in the universe at positive temperature, we get:

$$T(0) = T_\alpha = T_p = \frac{a_4}{-4\widetilde{\mathrm{d}t}}$$

And then,

$$a_4 = -4\widetilde{\mathrm{d}t}T_p$$

If we assume that the temperature must remain positive at the beginning and all along the cosmic timeline, then the constant a_4 is also positive. This choice of positive temperature is debatable, and a negative temperature at the beginning of the universe leads to a positive temperature after a time delay of $4\widetilde{\mathrm{d}t}$. However, the use of a negative temperature requires the support of an extra element, which is not included in this model.

Let us define the age of the universe as t_Ω, and CMB temperature as T_Ω, or that of the universe as we see it today. Therefore:

$$T(t_\Omega) = T_\Omega = \frac{-4\mathrm{d}tT_p}{-t_\Omega + 4\widetilde{\mathrm{d}t}}$$

The value of $\widetilde{\mathrm{d}t}$ for this condition is:

$$\widetilde{\mathrm{d}t} = \frac{T_p t_\Omega}{4(T_\Omega + T_p)} = b/4$$

To develop an equation for T, we can start with:

$$T(t) = \frac{C_1}{-t+b} = \frac{\frac{T_\Omega T_p t_\Omega}{T_\Omega - T_p}}{-t + \frac{T_\Omega t_\Omega}{T_\Omega - T_p}}$$

Finally, we can assume $(T_\Omega - T_p) \sim -T_p$, then the final expression for T is:

$$T(t) = \frac{-t_\Omega T_\Omega}{-t - \frac{t_\Omega T_\Omega}{T_p}}$$

The equation for T includes a potential singularity for negative T_p, as:

$$t_s = \frac{t_\Omega T_\Omega}{T_p} \sim \frac{2.7\ \mathrm{K}}{1.4\times10^{32}\ \mathrm{K}} t_\Omega \sim 1.93\times10^{-32} t_\Omega$$

For example, for $t_{\Omega\min} = 4.351\times10^{17}$ (13.8 [Gy] from $\bar{H}_0 \sim 70 = (73+66.9)/2$), a singularity is obtained around:

$$t_s = 8.4\times10^{-15}\ [\mathrm{s}]$$

The result is far too removed from the normally accepted value where the inflation of space occurs (~10^{15} removed from the value ~10^{-30} [s] [3].

The most important point to note about this timespan or delay, expressed as $b = -t_\Omega T_\Omega T_P^{-1}$, is the fact that it allows to slow the decrease in temperature down to a characteristic value of ~10^{-14} [s]. We will see that during that delay, the number of photons increases at a quasi-constant temperature and pressure, which allows finding a possible explanation for the event horizon problem.

Photon gas pressure is expressed as ($N \gg 1$):

$$P = \frac{4\sigma}{3c} T^4 = \frac{4\sigma}{3c}\left[\frac{C_1}{-t+b}\right]^4 = \frac{4\sigma}{3c} T_\Omega^4 \left[\frac{t_\Omega}{-t - \frac{t_\Omega T_\Omega}{T_p}}\right]^4$$

Volume is expressed as:

$$V = \frac{\frac{\zeta(4)}{\zeta(3)} k_b NT}{P} = \frac{4\pi}{3}\left(ct + r_\alpha\right)^3$$

At the beginning, the volume is:

$$V(0) = \frac{4\pi}{3}\left(ct + r_\alpha\right)^3 = \frac{4}{3}\pi l_p^3$$

For the number of photons in line with temperature:

$$N = Vn = V\frac{2\zeta(3)}{\pi^2}\left(\frac{2\pi k_b T}{hc}\right)^3 = \frac{4\pi}{3}\left(ct + r_\alpha\right)^3 \frac{2\zeta(3)}{\pi^2}\left(\frac{2\pi k_b T}{hc}\right)^3$$

With $r_\alpha = l_p$ (Planck length).

4. Increase in the Number of Photons (Alphaton)

If the expressions l_p and T_p at $t = 0$ are used, the number of photons at the beginning of the universe, ($t = 0$), is:

$$N(0) = \frac{4\pi}{3} l_p^3 \frac{2\zeta(3)}{\pi^2}\left(\frac{2\pi k_b T_p}{hc}\right)^3$$

$$= \frac{4\pi}{3}\frac{2\zeta(3)}{\pi^2}\left(\frac{hG}{2\pi c^3}\right)^{3/2}\left(\frac{2\pi k_b\left(\frac{hc^5}{2\pi G k_b^2}\right)^{1/2}}{hc}\right)^3$$

$$= \frac{64\zeta(3)}{24\pi} = \frac{8\zeta(3)}{3\pi} = 1.02!$$

The result is not exactly equal to one, and the reason for this is unknown. Of course, the reason behind the existence of the first photon is also unknown! We see that at the beginning, only one photon is present in the original Planck volume. The expression of the number of photons making up the most part of the energy relative to the age of the universe is t_Ω. Expression of the number of photons in relation to cosmic time is:

$$N(t) = \frac{8\zeta(3)}{3\pi}\left(\frac{2\pi k_b T_\Omega}{hc}\right)^3\left[\frac{\left(-cT_p t_\Omega\right)t - \left(l_p T_p t_\Omega\right)}{\left(-T_p\right)t - \left(t_\Omega T_\Omega\right)}\right]^3$$

The cosmic time expression can be used as a progression of n Planck time units, which then yields the following expression of the number of photons in relation to the number of Planck time units:

$$N(nt_p) = \frac{8\zeta(3)}{3\pi}\left(\frac{2\pi k_b T_\Omega}{hc}\right)^3\left[\frac{\left(-cT_p t_\Omega\right)nt_p - \left(l_p T_p t_\Omega\right)}{\left(-T_p\right)nt_p - \left(t_\Omega T_\Omega\right)}\right]^3$$

The above expression of the number of photons relative to time is unusual. Indeed, we find that the number of photons increases according to a geometrical progression of $\sim n^3$ over a characteristic time of $\sim 10^{-9}$ [s] for an age of 76.1 [Gy], up to amaximum where it remains constant. However, the energy necessary to expand the number of photons is not known or at least it is not in the electromagnetic form (photonic). This energy of expanding the number of photons could be identified as the one often mentioned void energy. An important point to emphasize, the model is based on the idea of an original big bang but to the difference that the total energy of the universe is created during this characteristic time of 10^{-9} [s]. In summary, the creation of the universe begins with 1 photon originally at $t = 0$ and subsequently the following photons are created during this period. One can call this period, the inflation of photons and the original photons the Alphaton. We will see how this progression in the number of Alphatons relative to time will make it possible to solve the complex horizon problem.

The expression trends towards a constant number of photons, $\sim 10^{-9}$ [s] ($\mathrm{d}N/\mathrm{d}t = 0$). For $t_\Omega = 76.1\left[\mathrm{Gy}\right]$ (2.39×10^{18} [s]), we get a constant number of photons:

$$N(\infty) = \frac{64\zeta(3)\pi^2}{3}\left(\frac{k_b T_\Omega t_\Omega}{h}\right)^3 \sim 6.42\times 10^{89}\,(\text{constant})$$

The time period when the number of photons increases geometrically, is called the photon epoch (Figure 1 & Figure 2). The process leading to photon inflation is unknownbut at every time increment, the number of photons increases. However, the increase in energy is caused by photon inflation because photon energy remains slightly below Planck energy, E_p, (1.76×10^9 (J)) until time $\sim 10^{-9}$ [s] (Figure 3).

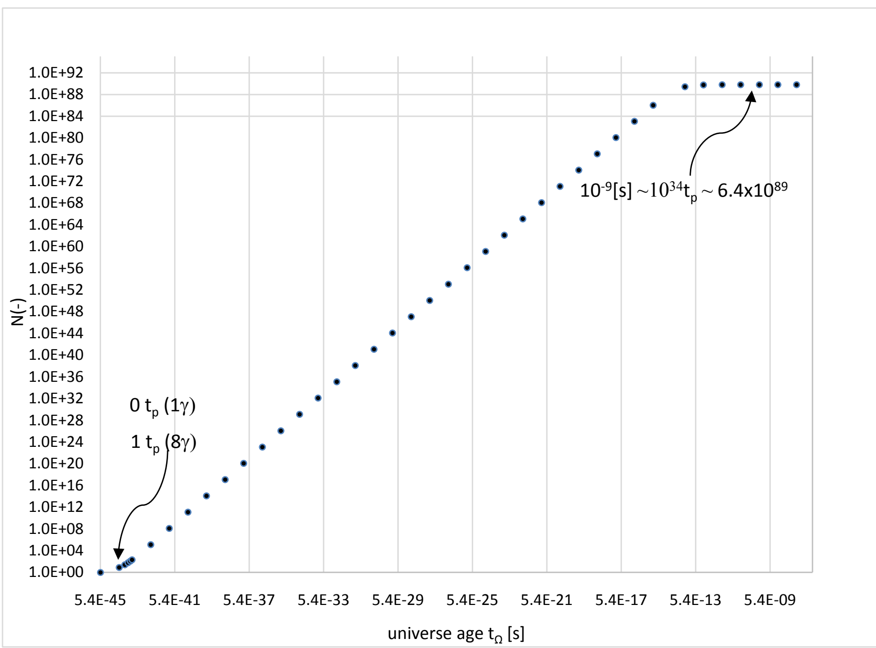

Figure 1. Inflation of photons number from $1t_p$ to 1×10^{-6} [s].

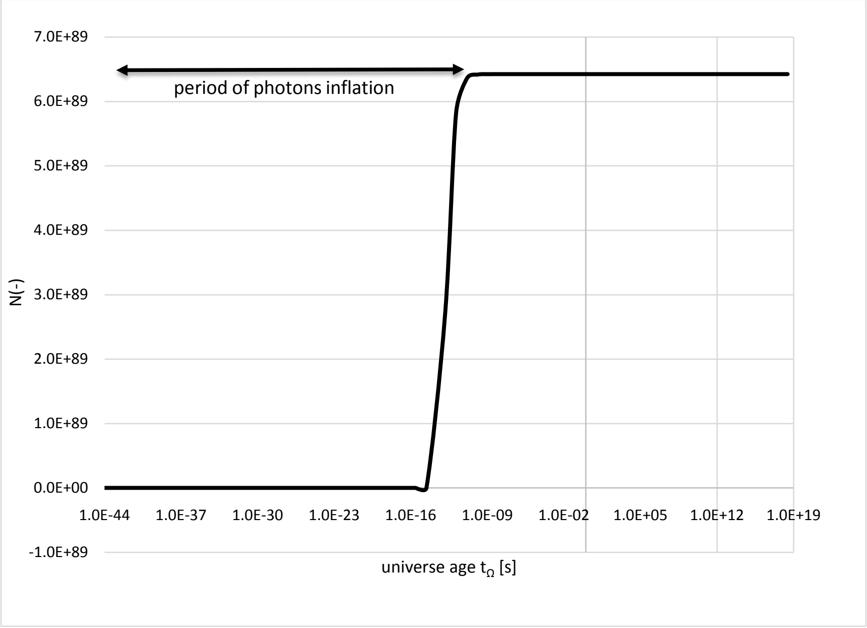

Figure 2. Number of Photons from 1 t_p to 76.1 [Gy].

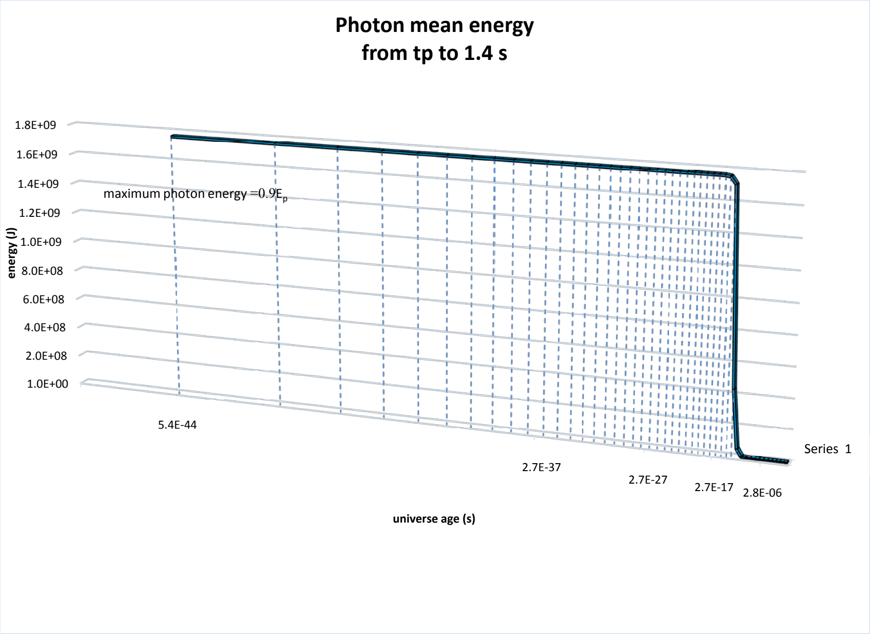

Figure 3. Photon mean energy from 1 t_p to 1.4 [s].

5. Energy Gain

Energy at the beginning of the universe is expressed as the energy of a single photon, the value of which is slightly lower than Planck energy, E_p. For $N = 1$:

$$U(0) = 0.9 N k_b T_p = 0.9 k_b T_p = 0.9 E_p = 0.9 c^2 \sqrt{\frac{ch}{2\pi G}} = 1.76 \times 10^9 \,[\mathrm{J}]$$

From a macroscopic standpoint, we assume that the universe does not undergo energy transfers with other universes. Also, conventional energy is preserved in relation to time.

Photon gas energy in relation to time can be expressed in several equivalent ways for $N \gg 1$:

$$U(t) = 3PV = \frac{4\sigma}{c} T^4 V = 3\frac{\zeta(4)}{\zeta(3)} N k_b T \sim 2.7 N k_b T$$

With the expression for $N(t)$ obtained earlier:

$$U(t) = 2.7 N k_b T = 64\pi^2 \zeta(4) \left(\frac{ct + r_\alpha}{hc}\right)^3 (k_b T)^4$$

It can be written as:

$$U(t) = \left(\frac{64\zeta(4)\pi^2 k_b^4}{h^3 c^3}\right)\left(\frac{(ct + l_p)^3}{(-t+b)^4}\right)(t_\Omega T_\Omega)^4 = U_0\left(\frac{(ct + l_p)^3}{(-t+b)^4}\right)(t_\Omega T_\Omega)^4$$

Or still as:

$$U(n) = \left(\frac{64\zeta(4)\pi^2}{h^3 t_p}\right)\left(\frac{(n+1)^3}{(n+k')^4}\right)(k_b t_\Omega T_\Omega)^4$$

where n is the whole number of Planck time units, t_p, and k' is a constant of universe (CMB temperature is considered constant, as well as the age of the universe, 76.1 [Gy]), therefore:

$$n = t/t_p$$

$$k' = \left(\frac{t_\Omega}{t_p}\right)\left(\frac{T_\Omega}{T_p}\right) = 3.57 \times 10^{11} t_\Omega = 8.57 \times 10^{29}\,[\mathrm{s}] = 2.7 \times 10^{13}\,[\mathrm{Gy}]$$

For $n = 0$, ($N = 1$), we get:

$$U(0) = 0.9 k_b T_p = \left(\frac{64\zeta(4)\pi^2}{3h^3 t_p}\right)\left(\frac{1^3}{(k')^4}\right)(k_b t_\Omega T_\Omega)^4$$

$$= \left(\frac{64\zeta(4)\pi^2 k_b^4 t_p^4}{3h^3}\right) T_p^4 = 0.9 E_p$$

For $t = t_\Omega$, ($N \gg 1$) we get:

$$U(t_\Omega) = \left(\frac{64\zeta(4)\pi^2 k_b^4 t_p^4 k'^4}{h^3}\right)\frac{T_p^4}{t_\Omega} = \left(\frac{64\zeta(4)\pi^2 k_b^4 T_\Omega^4}{h^3}\right) t_\Omega^3$$

Maximum energy is reached for $\dot{U}(t_{\max}) = 0$, or:

$$\frac{3T}{h} + 4\dot{T}\left(\frac{t}{h} + \frac{l_p}{hc}\right) = 0$$

We get:

$$t_{\max} = 3t_s - 4t_p = 3\frac{t_\Omega T_\Omega}{T_p} - 4t_p = 1.93 \times 10^{-32} t_\Omega - 4t_p$$

For $t_\Omega = 76.1\,[\mathrm{Gy}]$, we get:

$$t_{\max} = 1.38 \times 10^{-13}\,[\mathrm{s}] = 2.57 \times 10^{30} t_p$$

And for ($t_\Omega = 76.1\,[\mathrm{Gy}]$):

$$U_{max}(t_{max}) = 3.57 \times 10^{98}\,[\mathrm{J}]$$

Mass has not yet been created at this time because the temperature is in the order of 3.5 × 10^{31} [K]. To get an idea of the sheer magnitude of energy, assuming that the entire mass created is in the order of 10^{52} [kg], with relativistic energy-mass equivalence ($\beta = 0.9$), this corresponds to 2 × 10^{69} [J]; still an infinitissimal fraction of the energy in the universe.

Figure 4 below shows a graph for $U(t)$ at $t_\Omega = 76.1\,[\mathrm{Gy}]$ (2.39 × 10^{18} [s]).

The energy gain, by a factor of 10^{89}, can be explained by the increase in the number of photons, also by a factor of 10^{89}, during time period named photon inflation period, or 1.38 × 10^{-13} [s]. During that photon inflation period, the number of photons increases, but the energy of each photon remains approximately the same as the Planck energy, E_p (Figure 3). Moreover, during that timespan, the temperature, as well as the pressure, remain practically stable at T_p and ~0.2P_p (Figure 5 & Figure 6). Over that time, volume increases by a factor of 10^{86}. Photons are created and this remains unexplained, but this is due to the expansion of the universe volume, V and the availability of unknown energy. Such colossal energy comes from an existing potential which enhances the proliferation of photons, since nothing other than the above equations can predict energy levels. The number of photons increases in a geometrical progression of nearly n^3, where n is the number of Planck time units, t_p.

6. A Possible Solution to the Horizon Problem?

We have seen that the number of photons increases in geometric progression of ~n^3, where n is the number of Planck time units, t_p. Let us find an expression for the volume of the universe in relation to the number of Planck time units, n, the boundary is moving at the speed of light:

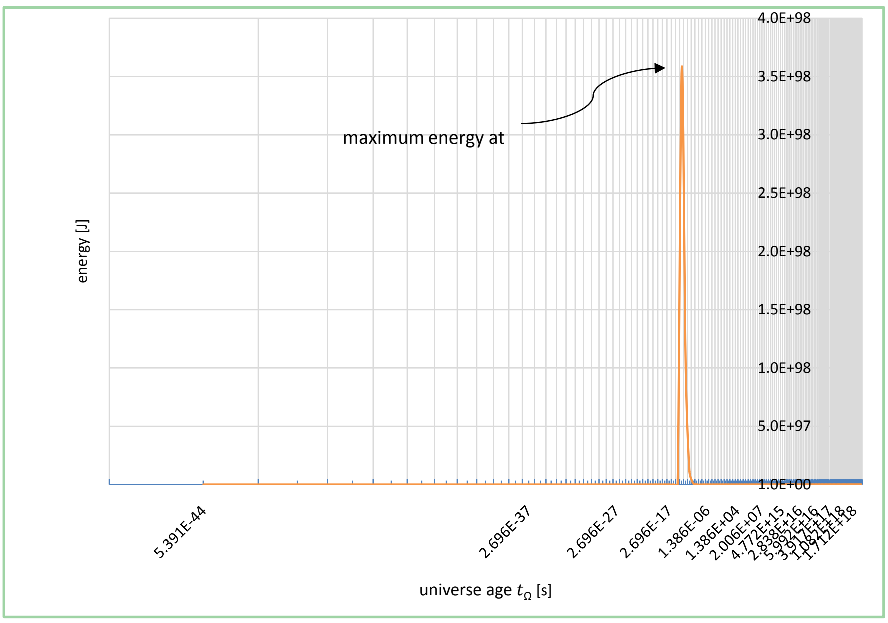

Figure 4. Universe total energy from 1t_p to 76.1 [Gy].

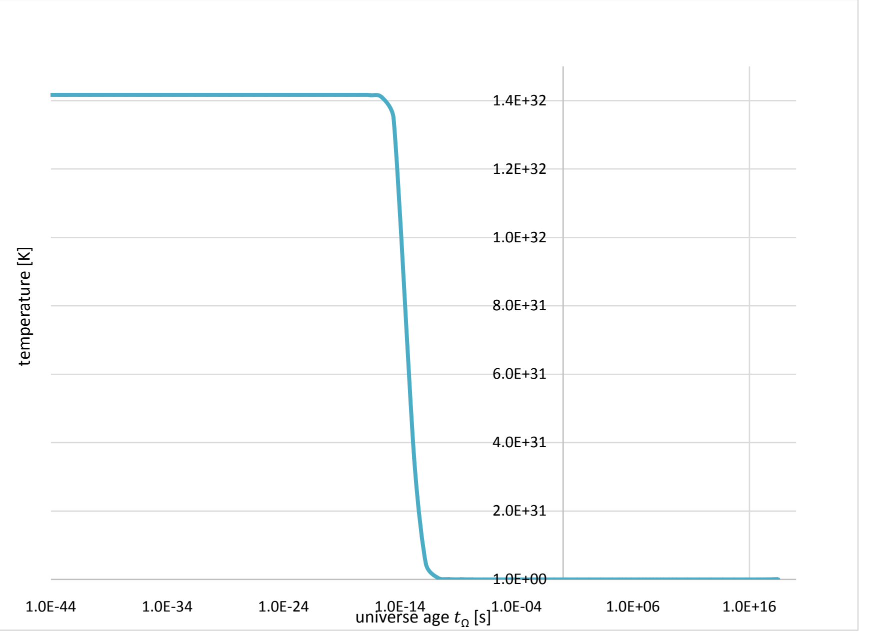

Figure 5. Temperature from $1\,t_p$ to 76.1 [Gy].

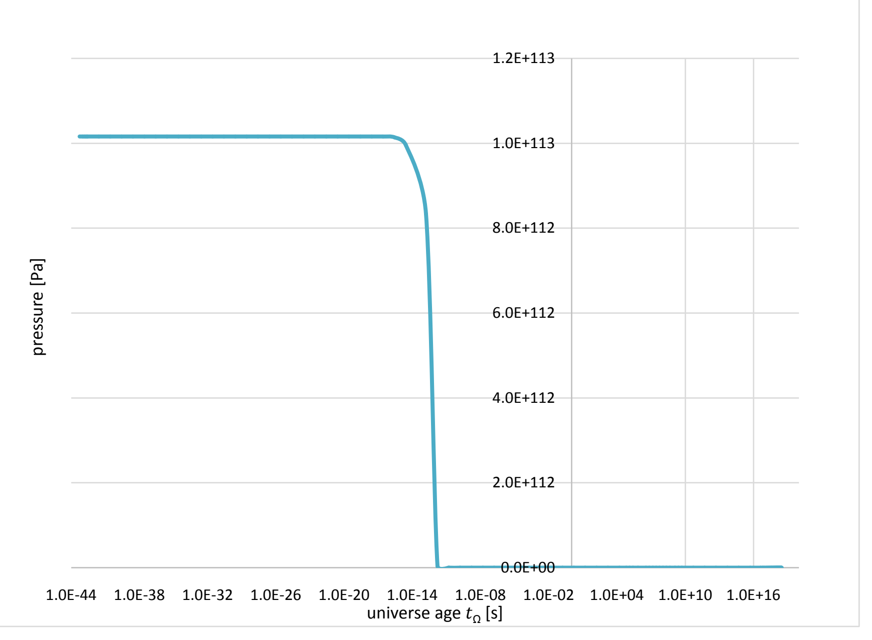

Figure 6. Pressure from $1\,t_p$ to 76.1 [Gy].

$$V\left(nt_p\right)=\frac{4\pi}{3}\left(c\left(n+1\right)t_p\right)^3$$

During the photon inflation period, the volume occupied by photons in relation to their number, N, the Wien's law, and the number of Planck time units can be estimated as:

$$V_\gamma\left(nt_p\right)\sim N\frac{4\pi}{3}\left(\lambda\right)^3=N\frac{4\pi}{3}\left(\frac{\sigma_w}{T}\right)^3$$

With the equation found for temperature T:

$$V_{\gamma}\left(nt_{p}\right)=N\frac{4\pi}{3}\left(\frac{\sigma_{w}}{T}\right)^{3}=N\frac{4\pi}{3}\left(\frac{\sigma_{w}}{\dfrac{-t_{\Omega}T_{\Omega}}{-nt_{p}-\dfrac{t_{\Omega}T_{\Omega}}{T_{p}}}}\right)^{3}$$

Let us express the photon volume quotient to the volume of the universe relative to the number of Planck time units, n, and the number of photons N.

$$\frac{V_{\gamma}\left(nt_{p}\right)}{V\left(nt_{p}\right)}=\frac{N\left(\dfrac{\sigma_{w}}{\dfrac{-t_{\Omega}T_{\Omega}}{-nt_{p}-\dfrac{t_{\Omega}T_{\Omega}}{T_{p}}}}\right)^{3}}{c^{3}\left(n+1\right)^{3}t_{p}^{3}}$$

After manipulation, the expression can be written as:

$$\frac{V_{\gamma}\left(nt_{p}\right)}{V\left(nt_{p}\right)}=\left(\frac{N}{\left(n+1\right)^{3}}\right)\left(\frac{\sigma_{w}}{ct_{p}t_{\Omega}T_{\Omega}T_{p}}\right)^{3}\left(nt_{p}T_{p}-t_{\Omega}T_{\Omega}\right)^{3}$$

In the above expression, the only variables that evolve are the number of Planck time units, n, and number of photons, N. The value of the quotient found for the entire age of the universe is:

$$\frac{V_{\gamma}\left(nt_{p}\right)}{V\left(nt_{p}\right)}\sim 2.06\left(\text{constant}\right)$$

What does this result mean? We have found that the volume occupied by photons, which increases in geometric progression, is always slightly higher than the volume of the universe, and its boundary is moving at the speed of light. Obviously, the value 2 is not accurate because the photons are contained within the volume of the universe. The important value here is the constant. Now, we can imagine the process occurring at every unit of Planck time. The number of photons potentially increases around the volume created (at the boundary?) at every unit of Planck time; the new photons exchange through high-energy photon-photon interactions.

Moreover, at every unit of Planck time, the already existing photons also undergo $\gamma\gamma$ exchange. This $\gamma\gamma$ exchange process is made possible by the quotient between the number of new photons around the boundary of the existing photons at Planck time, prior to the progression from the maximum 8 to the minimum 1, or 8 at the first unit of Planck time, down to near 1 when the number of photons no longer increases, or:

$$\frac{N\left(\left(n+1\right)t_{p}\right)}{N\left(nt_{p}\right)}\sim\frac{8}{1}\left(n=0\right)\rightarrow\frac{10^{89}}{10^{89}}\left(n>10^{34}\left(10^{-9}\left[\text{s}\right]\right)\right)=1\,.$$

This is a very important result, the $\gamma\gamma$ exchange is made possible when the number of photons increases further (ratio →1). This occurs around 10^{-9} [s] after the beginning. Therefore, after that time, the $\gamma\gamma$ exchange remains causal. Moreover, during the photon inflation period, when the $\gamma\gamma$ exchange is not entirely causal, we note that the temperature is steady at Planck temperature (**Figure 6**). Hence, even during the photon inflation period, the information exchange between photons cannot be entirely causal, that information is not necessary from a thermodynamic standpoint because the states of T and P remain more or less constant (**Figure 7**).

This mechanism makes it possible to solve the horizon problem for the photon inflation period, or energy creation period if the high-energy $\gamma\gamma$ exchange principle is accepted. Photon-photon exchange is a fact that has been confirmed at CERN [4]. Photon exchange energy, $\gamma\gamma$, for that experiment was an estimated ~15 - 20 [GeV] while the energy of photons at the beginning was ~$0.9E_p$, or ~10^{19} [GeV]. Of course this goes beyond the purpose of this paper since $\gamma\gamma$ exchange will require much more study. However, the process makes it possible to solve the event horizon problem, as the photon energy volume is always in phase with that of the volume of the universe. In brief, these periods are:

$0 < t < \sim 10^{-16}\,[\mathrm{s}]$ ($z \sim 10^{33}$) (causality, T~constant);

$\sim 10^{-16}\,[\mathrm{s}] < t < \sim 10^{-9}\,[\mathrm{s}]$ ($z \sim 10^{26}$) (partial causality)

$\sim 10^{-9}\,[\mathrm{s}]\left(z \sim 10^{26}\right) < t < t_\Omega$ (causality, N~constant).

The CMB is at z~1100, or well after the start of the causality recovery period. We will see that the last scattering surface of the model is ~69 [My] after the beginning. This leaves ~10^{58} Planck time units to restore causality. It can be reasonably assumed that at recombination time the universe had enough time to recover all of the causality, and that is why we can observe isotropy in the CMB [5].

7. Early Baryogenesis (Protons, Neutrons) and Leptons (Electrons, Neutrinos)

Interactions between photons and matter are complex and beyond the scope of this paper. Moreover, relativistic effects have to be considered as particle speeds approach the speed of light upon creation. In this paper, we describe a creation mechanism for the main particles (p, n, e and ν) to demonstrate the coherence of the model. During early baryogenesis, at very high temperature ($mc^2 \ll kT$), the Maxwell-Juttner M-J (relativist) statistical law is used to predict particle properties (fermions and letpons). Moreover, the presence of antiparticles must be considered, along with the creation-annihilation process. In this paper, we want to estimate the total barionic mass produced at the end of baryogenesis. We are able to estimate the full potential of mass creation in the universe using the mass-energy equivalence, since we are estimating total energy. The following expression is used to find the mass creation potential. Note that here, we assume that the energy in the universe is conventional:

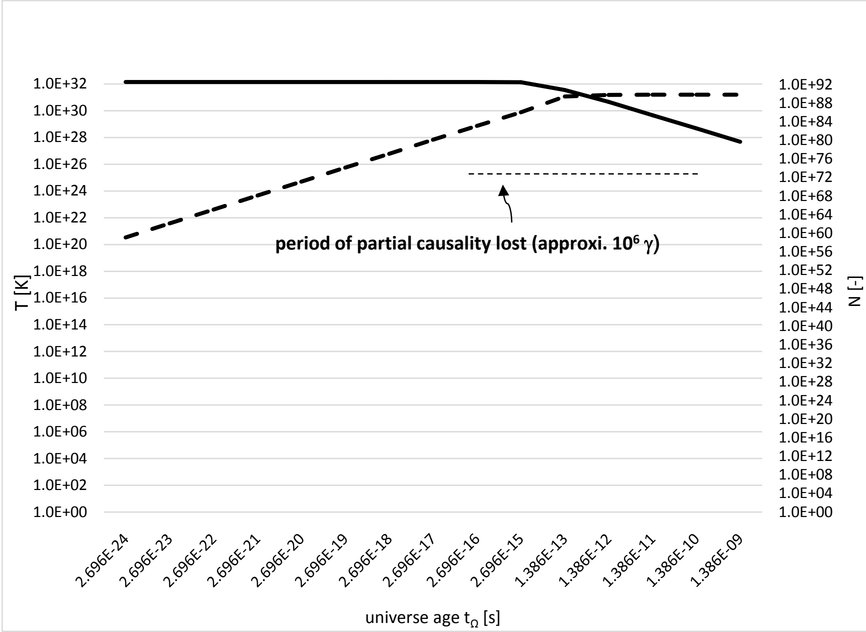

Figure 7. Number of photons and temperature function of cosmic time from 10^{-24} [s] to 10^{-9} [s].

$$M_{pot} = \frac{\sqrt{1-\beta^2}\,U(t_\Omega)}{c^2} = \left(\frac{\sqrt{1-\beta^2}\,64\zeta(4)\pi^2 k_b^4 T_\Omega^4}{c^2 h^3}\right) t_\Omega^3$$

We can see that the mass creation potential is relative to the cube of the age of the universe. For comparison purposes, for a universe aged 13.8 [Gy] ($\beta = 0$), the maximum total mass that can be produced is 4.81×10^{48} [kg], which is~10^4 smaller than the approximate estimated mass of the universe ($10^{52\text{ à }53}$ [kg] [6]. This clearly shows that to maintain this estimated mass, the existence of a source of non-conventional energy, or dark energy, has to be considered. Another possibility is to extend the age of the universe. Evidently, the precise mass of the universe is unknown. Supposing an estimated mass variation factor of $10^2$and conventional energy, we have to assume, based on the above equation, that the universe is much older than 13.8 [Gy] (visible universe ~13.8 [Gy]). Typically, for a mass potential in the order of 10^{50} to 10^{53} [kg], the age of the universe must be somewhere between 37.9 [Gy] and 379 [Gy]. To estimate the volumic quantity of protons and neutrons created, the Maxwell-Juttner statistical distribution is used, as follows [7]:

$$n_{p,n} = \frac{4\pi c m_{p,n}^2 k_b T K_2(\mu)}{h^3} e^{\frac{-m_{p,n}c^2}{k_b T\sqrt{1-\beta^2}}}$$

With: $\mu = \dfrac{m_{p,n}c^2}{\sqrt{1-\beta^2}\,k_b T}$ and $K_2(\mu)$ the modified Bessel function of the second kind. In this distribution, the stop temperature for the definitive creation of protons and neutrons must be specified, as well as the relativistic speed of created fermions. The value of β poses a problem, in fact, a lower value allows to create more mass and conversely also. We will see further from the energetic form of the Friedmann equation that an average value of β can be estimated at $\beta \sim 0.866$. However, the global energy equation imposes a maximum value for beta to $\beta \sim 0.998$ in order to maintain the positive energy balance at the scale of the universe (for the entire cosmic time):

$$\Delta U = U_\gamma - U_M = 2.7N(\infty)k_b T(t_\Omega) - \frac{M_{tot}c^2}{\sqrt{1-\beta^2}} > 0$$

The temperature can be estimated based on the total energy of a proton or neutron at β:

$$\bar{T}_{pr,ne} = \frac{\frac{m_{pr,ne}c^2}{\sqrt{1-\beta^2}}}{k_b} = \frac{C_1}{-t_{pr,ne} + b}$$

This mean photon energy appears at proton and neutron temperature and time, or $t_{pr,ne}$, after the beginning of expansion:

Therefore:

$$t_{pr,ne} = b - \frac{k_b C_1}{\frac{m_{p,n}c^2}{\sqrt{1-\beta^2}}} = \frac{t_\Omega T_\Omega}{T_p} + \frac{k_b T_\Omega t_\Omega}{\frac{m_{p,n}c^2}{\sqrt{1-\beta^2}}} = \left[\frac{T_\Omega}{T_p} + \frac{k_b T_\Omega}{\frac{m_{p,n}c^2}{\sqrt{1-\beta^2}}}\right] t_\Omega$$

For $t_\Omega = 76.1[\text{Gy}] = 2.39\times10^{18}[\text{s}]$ and $\beta = 0.9986$, we find:

$t_{pr} \sim 31345[\text{s}] \sim 0.3627[\text{d}]$ after the beginning of expansion

$$\bar{T}_{pr} = 2.08\times10^{14}[\text{K}]$$

$t_{ne} \sim 31303[\text{s}] \sim 0.3623[\text{d}]$ after the beginning of expansion

$$\bar{T}_{ne} = 2.09\times10^{14}[\text{K}]$$

The creation potential (without annihilation, $\text{p}\bar{\text{p}}$, or disintegration, n) for protons and neutrons at this time is:

$$n_p = \frac{V4\pi c m_p^2 k_b T_{pr} K_2(\mu)}{eh^3} = \frac{16\pi^2 c^4 t_{pr}^3 m_p^2 k_b T_{pr} K_2(\mu)}{3eh^3} = 2.1700\times10^{86}$$

and neutrons:

$$n_n = \frac{V4\pi c m_n^2 k_b T_{ne} K_2(\mu)}{eh^3} = 2.1689\times10^{86}$$

where $\mu = \frac{mc^2}{\sqrt{1-\beta^2}\,k_b T}$.

The creation of neutrons occurs 43 [s] prior to proton fixation, allowing to capture p + n before complete disintegration of the neutrons (881 [s]). To estimate the final number of protons and neutrons, the respective creation and annihilation of antiparticles must be considered. To do so, we assume that baryonic asymmetry prevails according to a normally accepted proportion of one stable baryon created for every 10^9 $p\bar{p}$ and $n\bar{n}$ annihilations [8]. Moreover, neutrons are captured and disintegrate in an accepted proportion of one neutron captured for every four neutrons disintegrated (the calculated ratio is 0.188 for 43 [s] of disintegration time). Then, in a universe aged 76.1 [Gy], we estimate the stable masses to be:

$$M_p \sim 10^{-9}\left(n_p m_p + 0.8 n_n m_n\right) \sim 6.53\times 10^{50}\,[\text{kg}]$$

$$M_n \sim 0.2\times 10^{-9} n_n m_n \sim 7.25\times 10^{49}\,[\text{kg}].$$

However, with the exponential disintegration of neutrons, ~95% of them will still be available for capture (formation of deuterium at *β*) after 43 [s] before the creation of protons.

Also, an equation can be found for the baryon-photon ratio, η_B. Initially assuming that the baryon-photon ratio can be expressed as the proton and neutron creation potential after annihilation and disintegration, expressed in a number of protons (at *β*) only, after manipulation, we get the following equation and a maximum value for the ratio:

$$\eta_B = \frac{n_b\left(t_{pr}\right)}{n_\gamma\left(t_{pr}\right)} \sim \frac{2n_p\left(t_{pr}\right)}{N\left(t_{pr}\right)} = 10^{-9}\frac{\dfrac{2V4\pi c m_p^2 k_b T_{pr} K_2(\mu)}{eh^3}}{64\dfrac{\zeta(3)\pi^2}{3}\left(\dfrac{k_b T_{pr} t_{pr}}{h}\right)^3}.$$

$$= 10^{-9}\frac{\left(1-\beta^2\right)K_2(\mu)}{2e\zeta(3)} = 10^{-9}\frac{\left(1-\beta^2\right)K_2(\mu)}{6.53}$$

The above constant ratio solely depends on *β* associated with protons during (relativistic) creation, and the modified Bessel function of the second kind, $K_2(\mu)$ (Maxwell-Juttner distribution), as well as the numbers, *e*, and Riemann constant, $\zeta(3)$. The value 10^{-9} is the oft-used matter-antimatter annihilation factor, $p\bar{p}$. The maximum value is for $\beta = 0$, or $\mu = 1$ and $K_2(1) = 1.62$. Therefore:

$$\eta_B = 10^{-9}\frac{\left(1-\beta^2\right)K_2(\mu)}{6.53} = 10^{-9}\frac{1.62}{6.53} = 2.48\times 10^{-10}$$

The resulting value of 2.48×10^{-10} is lower than the results of the estimates yielded by the ΛCDM model [9], based on Planck measurements [10]. Indeed, the estimated quotient is not a direct measurement, but rather an estimate that is partly based on ΛCDM model assumptions and observations, or:

$$\eta_B = \frac{n_b}{n_\gamma} = 6.108 \pm 0.038\times 10^{-10}.$$

However, a small change in the oft-stated ~10^{-9} particle-antiparticle annihilation factor and *β* can proportionally change the result.

8. Electrons

The Maxwell-Juttner statistical distribution for electrons:

$$n_{el} = \frac{4\pi c m_e^2 k_b T K_2(\mu)}{h^3} \mathrm{e}^{\frac{-m_e c^2}{k_b T\sqrt{1-\beta^2}}}$$

With: $\mu = \frac{m_e c^2}{\sqrt{1-\beta^2} k_b T}$

This mean energy of photons occurs at stop temperature and electron time, expressed as t_{el}, after the beginning of expansion ($\beta = 0.9986$):

$$\overline{T}_{el} = \frac{C_1}{-t_{el} + b} = \frac{\frac{m_e c^2}{\sqrt{1-\beta^2}}}{k_b} = 1.13 \times 10^{11} [\mathrm{K}]$$

Therefore:

$$t_{el} = b - \frac{k_b C_1}{\frac{m_e c^2}{\sqrt{1-\beta^2}}} = \frac{t_\Omega T_\Omega}{T_p} + \frac{k_b T_\Omega t_\Omega}{\frac{m_e c^2}{\sqrt{1-\beta^2}}} = \left[\frac{T_\Omega}{T_p} + \frac{k_b T_\Omega}{\frac{m_e c^2}{\sqrt{1-\beta^2}}} \right] t_\Omega$$

For $t_\Omega = 76.1 [\mathrm{Gy}] = 2.39 \times 10^{18} [\mathrm{s}]$ and $\beta = 0.9986$, we get:

$t_{el} \sim 5.755 \times 10^7 [\mathrm{s}] \sim 666 [\mathrm{d}]$ after the beginning of expansion.

The electron creation potential (without $\mathrm{e}\overline{\mathrm{e}}$ annihilation) at this time is:

$$n_e = \frac{V 4\pi c m_e^2 k_b T_e K_2(\mu)}{e h^3} = \frac{16\pi^2 c^4 t_{el}^3 m_e^2 k_b T_e K_2(\mu)}{3 e h^3} = 2.1700 \times 10^{86}$$

To estimate the final number of electrons, the respective antiparticle creation and annihilation must be considered. To do so, let us assume that lepton asymmetry prevails according to a proportion of one stable electron created for every 10^9 $\mathrm{e}\overline{\mathrm{e}}$ annihilations.

For $t_\Omega = 76.1 [\mathrm{Gy}]$:

$$M_e = 10^{-9} (n_e m_e + 0.8 n_n m_e) \sim 3.55 \times 10^{47} [\mathrm{kg}]$$

Finally, the following total mass for the creation of electrons, protons and neutrons is achieved:

$$M_t = M_p + M_n + M_e = 7.26 \times 10^{50} [\mathrm{kg}]$$

The ratio of positive (p) to negative (e) charges is strictly equal to one, since the beta disintegration of a neutron produces one proton and one electron. Therefore, the Maxwell-Juttner relativistic distribution predicts an electrically neutral universe in terms of protons, neutrons and electrons. Based on this relativistic distribution and for a specific cosmological model, the following dynamic temperature-time relation must be met during the proton-electron production process. Indeed, the exact mass ratio is known:

$$\frac{m_p(t)}{m_e(t)} = \left[\frac{t_{el}^3 T_{el}}{t_{pr}^3 T_{pr}} \right]^{1/2} = 1836.15$$

Using the above model and equations, along with the Maxwell-Juttner distribution, the dynamic evolution of the model's variables yields a very realistic ratio:

$$\frac{m_p(\infty)}{m_e(\infty)} = 1837.37 .$$

9. Cosmic Neutrinos from SN1987A

Cosmic neutrino mass can be estimated using the above relation. Indeed, cosmic neutrino mass can be expressed according to proton or electron mass, as:

$$\frac{m_\nu(t)}{m_e(t)} = \left[\frac{t_{el}^3 T_{el}}{t_\nu^3 T_\nu}\right]^{1/2}$$

The above equation can be developed with the electron temperature equation along with electron creation time. After some manipulations, we get the following expression for cosmic neutrino mass:

$$m_\nu \sim \left(\frac{k_b\sqrt{1-\beta^2}\, m_{el}^2 T_{el} T_p}{c^2 T_\Omega}\right)^{1/3} \frac{t_{el}}{t_\Omega}$$

The only undetermined variable in the above equation is the mean β of cosmic neutrinos during their creation. The use of β is not an easy choice since this particle is still relatively unknown and has three known states (oscillations). Using β^{SN1987A}, estimated from Stodolsky's observations of SN1987A in [11], ($\beta \le 0.999999998$), the maximum neutrino mass can be expressed as:

$$m_\nu^{\mathrm{SN1987A}} \le 8.69\times10^{-32}\,[\mathrm{kg}] = 48.7\left[\mathrm{keV}\cdot c^{-2}\right]$$

While this is too high a mass for electron neutrinos (<2.5 [eV·c^{-2}]), it fits well for muon neutrinos (≤170 [keV·c^{-2}]).

In addition, this found value is within the estimated limit of Benes [12] for the sterile neutrino mass of SN1987A (10 - 100 [keV·c^{-2}]). Also, Bezrukov [13], from a detailed analysis of the possibilities for the mass of the sterile neutrino, find a value ~3.3 [keV·c^{-2}] that it identifies as a possibility that dark matter is made of sterile neutrinos. However, we will see that the amount of neutrino generated cannot explain the abundance of dark matter predicted by the ΛCDM model (~26%).

This maximum mass is situated between that of the electron neutrino and muon neutrino, or:

$$m_{\nu_e} < m_\nu^{\mathrm{SN1987A}} < m_{\nu_\mu}$$

$$2.5\times10^{-3}\left[\mathrm{keV}\cdot c^{-2}\right] < 48.7\left[\mathrm{keV}\cdot c^{-2}\right] < 170\left[\mathrm{keV}\cdot c^{-2}\right].$$

The resulting mass for cosmic neutrinos is ~10times lower than that of electrons, and their speed is practically the speed of light *c*. Of course, cosmic neutrinos can be found to have different masses depending on the assumptions made for β. The goal here is not to derive precise neutrino mass, which is beyond the scope of this paper. Using the neutrino mass obtained above, the time, temperature, quantity, and total mass of cosmic neutrinos can be achieved using the Maxwell-Juttner distribution:

$$\bar{T}_\nu = \frac{C_1}{-t_\nu + b} = \frac{\frac{m_\nu c^2}{\sqrt{1-\beta^2}}}{k_b} = 8.9\times 10^{12}\,[\mathrm{K}]$$

Therefore:

$$t_\nu = b - \frac{k_b C_1}{\frac{m_\nu c^2}{\sqrt{1-\beta^2}}} = \frac{t_\Omega T_\Omega}{T_p} + \frac{k_b T_\Omega t_\Omega}{\frac{m_\nu c^2}{\sqrt{1-\beta^2}}} = \left[\frac{T_\Omega}{T_p} + \frac{k_b T_\Omega}{\frac{m_\nu c^2}{\sqrt{1-\beta^2}}}\right] t_\Omega$$

For $t_\Omega = 76.1\,[\mathrm{Gy}] = 2.39\times 10^{18}\,[\mathrm{s}]$ and $\beta = 0.999999998$, we get:

$t_\nu \sim 7.315\times 10^5\,[\mathrm{s}] \sim 8.4\,[\mathrm{d}]$ after the beginning

The neutrino creation potential (without $\nu\bar{\nu}$ annihilation) at this time is:

$$n_\nu = \frac{V 4\pi c m_\nu^2 k_b T_\nu K_2(\mu)}{eh^3} = \frac{16\pi^2 c^4 t_\nu^3 m_\nu^2 k_b T_\nu K_2(\mu)}{3eh^3} = 3.19\times 10^{80}$$

Maximum mass of neutrinos (without annihilation), after a few manipulations for $t_\Omega = 76.1\,[\mathrm{Gy}]$, is a cheived by:

$$M_\nu = n_\nu m_\nu \sim 2.77\times 10^{49}\,[\mathrm{kg}]$$

A conclusion can be made here, neutrino mass (without annihilation) represents a maximum ~4.2% of proton mass. Based on the model, cosmic neutrino mass cannot explain the origin of the missing mass. Furthermore, based on the Maxwell-Juttner distribution, cosmic neutrinos appeared before electrons, but after baryons. Another way to proceed involves using the known neutrino mass and look at the creation period and predicted mass, but we still get a predicted neutrino mass that is much smaller than that of baryons.

Let us revisit the total predicted mass of ~7×10^{50}, which is relatively lower (17 to 350 times) than the oft-mentioned total mass of the universe (1.25×10^{52} to 2.5×10^{53}). However, total mass is relative to the age of the universe. Hence, baryon mass could be increased by increasing the age of the universe or by reducing the particle-antiparticle annihilation factor. However, we will see that the so-called missing mass is not that essential to explain galaxy rotation. The mass can be increased, but we will see that the data from the Planck probe give us the mass vs. energy ratio, which allows us to calculate an approximate age of the universe that partly meets the proportions. We will come back to this argument later. With the energy-mass equivalence, when the ratio of total created mass-energy to total universe energy at the time of electron production (around the end of the main leptogenesis) is obtained, we get $\beta = 0.001$, or a low non-relativistic speed of the baryonic mass, but still within the range of velocity for the MW:

$$\frac{E_{\text{mass}}}{E_{\text{total}}} = \frac{\frac{M_t c^2}{\sqrt{1-\beta^2}}}{U(t_{el})} = \frac{6.43\times 10^{67}}{2.72\times 10^{78}} = 2.3\times 10^{-11}$$

This energy ratio confirms that the universe, during early leptogenesis, or at the end of the creation of the particles that make up most of the mass, was vastly influenced by radiation (radiation universe) and that the effects associated with mass, such as gravity, were negligible compared to the electromagnetic impact of photon gas.

Mean total energy of the universe 13.8 [Gy] after the beginning is:

$$U_{\text{total}} \sim 2.05\times10^{69}\,[\text{J}]$$

That energy, when converted to energy-mass equivalence, yields the following mass ($\beta = 0.001$):

$$M_{\text{equi-energy}} = \frac{2.0\times10^{69}\sqrt{1-\beta^2}}{c^2} = 2.23\times10^{52}\,[\text{kg}]$$

The ratio between the baryonic mass and potential energy-mass for the time period ~1 to 13.8 [Gy], which can be observed by instruments like the Planck-probe, would be:

$$\left[\frac{M_t}{M_{\text{equi-energy}}}\right]_{\text{observable}} = \frac{7.26\times10^{50}\,\text{kg}}{2.23\times10^{52}\,\text{kg}} \sim 0.032$$

That energy-matter ratio is smaller than the estimate made from Planck measurements, an estimated ~0.31 (regular and dark matter). However, that ratio was calculated using the ΛCDM model, which includes dark matter and dark energy as parameters. If dark energy is removed from the equation and only the ΛCDM-estimated baryonic mass is considered, the result is closer, or 0.048.

Let us calculate the mean volumic mass of the universe at the end of proton production:

$$\rho_{pr} = \frac{M_{pr}}{V} = \frac{7.26\times10^{50}\,\text{kg}}{\frac{4\pi}{3}r^3} = \frac{7.26\times10^{50}\,\text{kg}}{\frac{4\pi}{3}\left(9.39\times10^{12}\right)^3} = 2\times10^{11}\left[\text{kg}\cdot\text{m}^{-3}\right]$$

Such density is much lower than the approximate density of a proton(~6.7 × 10^{17} [kg·m^{-3}]), showing that the universe could have contained that amount of mass at that time.

We have not yet considered the electrostatic energy associated with protons and electrons. Let us assume that the Coulomb charge was attributed to protons and electrons at the time of baryogenesis and leptogenesis. Indeed, the electrostatic energy of protons and electrons contained in the sphere with a radius of r_{pr} and r_{el} at the time of protons and electrons is quite significant or, respectively:

$$\begin{aligned} E_{pr}^{el} &= \frac{3}{5}k_e\frac{\left(n_{pr}q_{pr}\right)^2}{r_{pr}} \\ &= \frac{3}{5}\times8.987\times10^9\times\frac{\left(3.9\times10^{77}\times1.6021\times10^{-19}\right)^2}{9.39\times10^{12}} \\ &= 2.24\times10^{114}\,[\text{J}] \end{aligned}$$

$$\begin{aligned} E_{el}^{el} &= \frac{3}{5} k_e \frac{(n_{el} q_{el})^2}{r_{el}} \\ &= \frac{3}{5} \times 8.987 \times 10^9 \times \frac{(3.9 \times 10^{77} \times 1.6021 \times 10^{-19})^2}{1.72 \times 10^{16}} \\ &= 1.22 \times 10^{111} [\text{J}] \end{aligned}$$

However, because the quantity of protons, n_{pr}, and electrons, n_{el}, created is identical, we get (including neutron disintegration):

$$n_{pr} = n_{el} = 3.9 \times 10^{77}$$

Therefore, the total charge becomes neutral, and the potential energy disappears in the aftermath of electron production. However, the electrostatic potential remains active for ~666 days, which corresponds to the time difference from the appearance of protons and electrons. We will see that the time difference or delay is the cause of a major so-called baryon-free (empty) zone, except for cosmic neutrinos and others neutral particules.

Thus, the actual baryon-photon ratio for the entire universe ($\beta \sim 0.001$) can be estimated:

$$\eta_B = \frac{n_B}{n_\gamma} = \frac{n_{pr} + n_n}{6.42 \times 10^{89}} = \frac{4.33 \times 10^{77}}{6.42 \times 10^{89}} \sim 6.7 \times 10^{-13}$$

A constant value for the age of the universe after baryogenesis assuming conventional proton and electron half-lives.

This baryon-photon ratio is ~1000 times smaller that the Bernreuther estimate [14]. This is due to the calculated baryon mass, which is 500 to 1000 times smaller, ~10^{50} [kg], than the oft-suggested ~10^{53} [kg].

10. Temperature Variations in the CMB

A possible way to address partially the temperature variations in the CMB is found in variations in the energy of the universe during baryogenesis and leptogenesis. Indeed, when protons, neutrons, and electrons were created, a considerable amount of energy was drawn from the photons for the creation of the particles. That one-time energy shift in the early expansion of the universe (0.362 day for the protons and 666 days for the electrons) surely caused a disruption in the photon gas. Moreover, the creation of matter was likely uniform in the volume, but the energy demand may have caused a local disruption over time for the neutrons, and later for the protons and electrons. Let us calculate that energy disruption for the baryons during baryogenesis, relative to the energy of the universe in the pre-baryon era, and for the electrons, relative to the energy of the universe at that time, or (β of protons, electrons = 0.986 and β neutrinos = 0.999999998):

$$\frac{\Delta E_{\text{baryon}}}{E} = \frac{\Delta E_{M_t}}{E_{\text{total}}} = \frac{(M_p + M_n) c^2}{\sqrt{1 - \beta^2} U(t_{pr})} = \frac{1.25 \times 10^{69} \text{ J}}{9.05 \times 10^{81} \text{ J}} = 1.38 \times 10^{-13}$$

$$\frac{\Delta E_{\text{electron}}}{E} = \frac{\Delta E_{M_t}}{E_{\text{total}}} = \frac{M_e c^2}{\sqrt{1-\beta^2 U(t_{el})}} = \frac{6.12\times 10^{65}\ \text{J}}{7.81\times 10^{78}\ \text{J}} = 9.15\times 10^{-14}$$

$$\frac{\Delta E_{\text{neutrino}}}{E} = \frac{\Delta E_{M_t}}{E_{\text{total}}} = \frac{M_\nu c^2}{\sqrt{1-\beta^2 U(t_\nu)}} = \frac{3.94\times 10^{70}\ \text{J}}{5.0\times 10^{80}\ \text{J}} = 5.88\times 10^{-11}$$

When that energy is put in relation with that of the blackbody, the energy ratio can be expressed in terms of temperature as:

$$\frac{\Delta T_{\text{baryon}}}{T} = \left[\frac{\Delta E_{\text{baryon}}}{E}\right]^{1/4} = \left(1.38\times 10^{-13}\right)^{1/4} \sim 6.1\times 10^{-4}$$

$$\frac{\Delta T_{\text{electron}}}{T} = \left[\frac{\Delta E_{\text{electron}}}{E}\right]^{1/4} = \left(9.15\times 10^{-14}\right)^{1/4} \sim 5.5\times 10^{-4}$$

$$\frac{\Delta T_{\text{neutrino}}}{T} = \left[\frac{\Delta E_{\text{neutrino}}}{E}\right]^{1/4} = \left(5.88\times 10^{-11}\right)^{1/4} \sim 3\times 10^{-3}$$

Following measurements made by Planck, the analysis and explanation of temperature variations in the CMB became priorities. Ever since the initial analyses and Fixsen's synthesis [15], assessments of temperature variations in the CMB continually varied as new interpretations were made and instruments were perfected. Variations sit within a range of values put forth by separate authors. Without going into finer detail, the range of values is as follows:

$$\begin{array}{ccc} \text{Planck, 2016} & & \text{Fixsen, 2009} \\ \dfrac{\pm 27\ \text{mK}}{2.722\ \text{K}} & < \left[\dfrac{\Delta T}{T}\right]_{exp} < & \dfrac{\pm 570\ \mu\text{K}}{2.72548\ \text{K}} \end{array}$$

$$\pm 9.9\times 10^{-3} < \left[\frac{\Delta T}{T}\right]_{exp} < \pm 2.1\times 10^{-4}$$

This shows that baryogenesis and leptogenesis, or variation of energy for the creation of protons, electrons and neutrinos, is in the order of magnitude of the overall temperature variations in the CMB (energy disruption or negative energy jump of the photons during the creation of matter). Could those temperature variations in the CMB be partially caused by successive energy jumps during particle creation, in addition to the vibrational mode of baryons [16]? Moreover, analyses of the variations do not seem to show any anisotropy, except for great empty zones. This supports the notion of isotropic energy variations for the entire volume that is compatible with the creation of a uniform mass in the volume. Finally, because protons, neutrons and electrons, and the particle fusion cycles, occurred at different times and different energy levels for the photons in the photon gas, notable variations $(\Delta T/T)_i$ could be found in the variations of energy spectrum of the CMB in line with the energy levels successively implicated in beryogenesis and leptogenesis, and at successive times for the protons-neutrons, electrons, deuterium, etc.

11. Conclusions

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 (part 2 and 3). Einstein's proposed cosmological constant is used in this model to predict the total energy of the universe rather than as a gravitational balance effect. This colossal energy is worth ~10^{98} [J]. By comparison, the total energy associated with the baryonic mass (~10^{52} [kg]) is worth ~10^{69} [J], a tiny portion of the total energy. The development of the state equation highlights the importance of not neglecting any of the differential terms given the very large amounts in play that can counterbalance the infinitesimals.

The model does not consider the existence of energy other than photons (electromagnetic). 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 provides a possible solution to the horizon problem with the concordance of photon volume with universe volume, the causality recovery period after $z = 10^{26}$ and the last scattering surface $z = 1098$. 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 (part 2 and 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.

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Conflicts of Interest

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

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