

# On the Origin and Physical Nature of the Cosmological Vacuum

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## Abstract

In the present manuscript, we consider the origin of the cosmological space, and the Cosmological Constant as a consequence of the annihilation of the matter - antimatter at the very beginning of the big bang. Since the cosmological expansion creates the space, the cosmological vacuum is considered as a very hegemonic entity which is the locus where all the objects create the events. Certainly,  $N$  units of masses in conjunct are required to produce an equilibrium between the gravitational phenomena of the matter in bulk and each coulombic interaction between protons and electrons within the nuclear and atomic contour in all astrophysical (e.g. stars) or cosmological entities (e.g. galaxies). The "dark matter" is considered to be formed by highly excited H and HeI Rydberg's atoms in equilibrium with the CMB radiation.

**Keywords:** Cosmology; Cosmological Constant; Dark Matter; Dark Energy; Hubble Constant; CMB radiation.

## 1 Introduction

The empty space, understood as a "physical vacuum" within the microscopic contour of an isolated atom, as well as the macroscopic space, extends this later one to the limit know as the Universe are subjected to an equivalent physical formalism. This spatial equivalence is a generalized property, and is sustained despite of the marked contrast between both magnitudes.

The significative scale difference between both extremes gives rise to the following properties which have relativistic significance.

1. An observer in the macrospace of the Universe lacks of simultaneity between the phenomenon and the observation, but has the possibility of registering the past events *i.e.* he is able to see a wide interval in the Universe history.
2. On the other hand, the same observer, from his macroscopic referential framework, is placed outside of the microcosmos; so that the experiments that reveal the nature of an isolated atom (excluding the inherent quantum uncertainty) present a practically simultaneous interaction in an unlimited reproducible way and unequivocal exactitude.
3. In both experiments (macroscopic and microscopic) all the information to justify the indistinguishability of both contours and its equivalence, is provide by means of the comparison of atomic spectrum originated in the laboratory with respect to the spectrum registered by the same elements with cosmological redshifts.

4. Every and any massive units (*e.i.* atom) within the Universe, causes the gravitational interaction (at the event horizon) with all the remainder massive unities. As the  $N$  unities of mass-energy are the total mass of the Universe gravitational field, the sum of these unities can be considered as a single mass unity.
5. Likewise, every and any single quantum unity (atom or wave) interacts quantumly in reversible equilibrium within the Universe (at the event horizon) with any other quantum unity of the remainder Universe. As the  $N$  quantum unities mark the whole spatial contour, this whole structure can be considered as a single spatial unity.
6. The Universe is a closed system, which expands adiabatically. Correspondingly, any contour of macrospace (open system) interacts with the surrounding by means of absorption or emission of exactly measurable amounts of energy. The redshifted photons due to the cosmological expansion, and the eigenstates excitation interval of an atom, would have the same energy and space scale proportions, which links both systems. In Section 2.2 we analyze these implications.

## 2 Microspace vacuum and macrospace vacuum

### 2.1 Relativistic meaning of the spectral lines

For an electron pertaining to an isolated hydrogen atom, when  $n = 1$  and  $v = c/137$  ( $v \ll c$ ), the Lorentz relativistic expression may be stated in the following form

$$m_0(1 + \delta) = m_0 \left( 1 + \frac{v^2}{c^2} \right)^{1/2} \simeq m_0 \left( 1 + \frac{v^2}{2c^2} \right) \quad (1)$$

When this single electron evolves from a state ( $i$ ) towards a state ( $j$ ), there is within the empty contour of the atom a mass increase of  $\Delta m$

$$m_i = m_e (1 + \delta_i) \quad (2)$$

$$m_j = m_e (1 + \delta_j) \quad (3)$$

$$\Delta m = m_i - m_j = m_e (\delta_i - \delta_j) \quad (4)$$

Taking into account  $\delta = v^2/c^2 = \alpha^2/n^2$ , being  $\alpha$  the Sommerfeld constant, and as this relationship expresses the relativistic quantum ratio in electromagnetic emission (or absorption), we can insert it in (1) and (4)

$$\Delta m = m_e \left( \frac{v_i^2}{2c^2} - \frac{v_j^2}{2c^2} \right) = \frac{m_e \alpha^2}{2} \left( \frac{1}{n_i^2} - \frac{1}{n_j^2} \right) \quad (5)$$

Since  $\alpha = e^2/\hbar c$ , we have

$$\Delta m = \frac{m_e e^4}{2\hbar^2 c^2} \left( \frac{1}{n_i^2} - \frac{1}{n_j^2} \right) \quad (6)$$

As with the expansion, the kinetic energy  $K$  diminishes and the potential energy  $U$  increases, this means that the potential energy is equivalent to the space<sup>1</sup> that has been created. Likewise, the spectral process of emission or absorption is an interaction between a microbubble of energy (atom) and the macrospace. In this process, both entities always exchange simultaneously the same quantum unit of energy. The absorption lines expresses the mass-energy quantity proceeding from the exterior space, and the emission lines are equivalent to the mass-energy transferred to the macrospace when the electron falls down to an inferior quantum level.

This correlativity of mass-energy and space-time reciprocal exchange is the foundation for establishing the equivalence between both vacuum contours: the microspace “vacuum” mass-energy and the macrospace “vacuum” mass-energy (Section 2.2).

From the Equations (1) and (6) it is evident that as the atomic radius increases, the electron energy decreases and  $\Delta m$ , which means the mass equivalent of the empty atomic space between  $n_i$  and  $n_j$  increases too.

Likewise, according to Bohr’s formalism, the electron “velocity” is  $v_i$  for  $n_i = 1$  and  $r_i = a_0$  (Bohr radius). When the atom is excited or “expands”,  $v$  decreases inversely and linearly in terms of the Bohr’s radius:  $v = \hbar/(m_e n a_0)$ .

As the velocity depression is also parametrized with respect to a scale unit ( $a_0$ ), it allows us to establish the following formalism:

$$\frac{v_j}{v_i} = \frac{a_0}{r_j} = \frac{1}{n_j^2} \quad (7)$$

## 2.2 Cosmological expansion and the hydrogen atom excitation

According to Eq.(7) it may be deduced that the relativistic mass of a photon emitted or absorbed for any transition is inversely proportional to the ratios of the corresponding stable orbits.

Consequently

$$\frac{m_i}{m_j} = \frac{r_j}{a_0}, \quad r_j = 4a_0, 9a_0, \dots, n^2 a_0 \quad (8)$$

Also the following proportions are valid:

$$\frac{m_i}{m_j} = \frac{E_i}{E_j} = \frac{T_i}{T_j} = \frac{r_j}{a_0} = \frac{n_j^2}{n_i^2} = \frac{\lambda_j}{\lambda_i} \quad (9)$$

This means, that the relativistic interactive photons mass-energy is directly proportional to the relativist temperature, and inversely proportional to the atomic radius. Even though it is certain that the expansion of the Universe operates in a continuous form, it is a particular congruence that the information of the event was provided by quantum transitions of atomic emissions systems. If for a practical convenience, we change the sign of these transitions, and instead of emission, it would correspond to the excitement of an electron of an isolated hydrogen atom. Here, its eigenvalues would have the same scale proportions in their spatial development as the cosmological values expressed as redshift or temperature of the CMB radiation.

This correspondence, is due to the equivalence between the energetic mechanism itself that originates the radiation (quantum states) associated to the size of the atoms, and the size of the Universe in expansion.

It is because of that

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<sup>1</sup>The space is equivalent to mass or energy

$$z + 1 = \frac{\lambda_{obs}}{\lambda_{em}} = \frac{R_U^0}{R_{em}} = \frac{n_j^2}{n_i^2} = \frac{T_{em}}{T_{obs}} \quad (10)$$

Where  $z$  is the measurement of the cosmological expansion;  $R_{em}$  and  $R_U^0$  are the respective Universes radii when light was emitted, compared with the present radius.

For a transition  $n_i = 1$  to  $n_j = 2$ , the atomic radius is 4 times greater,  $\lambda_{obs}$  for  $n = 2$  is 4 times larger too. If  $z = 3$ , it means that the Universe was 4 times smaller  $R_{em} = R_U^0/4$ , or what is the same, the wavelength emitted was a quarter of the observed  $\lambda_{em} = \lambda_{obs}/4$ .

As the monodimensional parameters of cosmological expansion have the same proportion as those of atomic excitation states, it means that the energetic implications of both vacuum contours are identical, despite of their scale magnitudes.

Thus, due to the cosmological expansion, the Lyman alpha line shift of the atomic hydrogen spectra, coincides with the ratio between the two atomic radii which generates this transition Eq. (10). E.g., for  $z = 3$  the Lyman alpha line is shifted to a cosmological expansion with a factor 4. Likewise, when an isolated hydrogen atom originates a photon of  $\lambda = 1,216\text{\AA}$ , the electron has a quantum transition from  $n_j = 2$  to  $n_i = 1$ , due to a spatial transition of  $4a_0 \rightarrow a_0$ . Although we have adopted the intense Lyman alpha line, the same properties for any other electronic transition can be verified.

### 2.3 Underlying Astrophysical and Cosmological Implications from the Millikan Experiment

The Millikan experiment consist in the execution of several experiments sistematically integrated in only one instrument. To carry out this experiment in atmospheric pressure does not mean any failure, since it would be impossible to carry it out in the vacuum. In the same way, when the bouyance and the viscous force are substracted this leads to a vacuum formal situation.

$$O = F_{grav} + F_{elect} + F_{visc} + F_{bouy}$$

The analysis of some unspecific details from this Millikan's outstanding experiment (Millikan, 1911, 1913); (Townsend, 1897) reveals us implications as valuable as the direct observations of the phenomena. Then, in all cases the connection between the terrestrial gravitation, the electron's charge unit and the Coulombic field was derived from:

$$F_G = E_V \cdot n \cdot e = \frac{GM_{\oplus} \cdot m_d}{R_{\oplus}^2} = g_{\oplus} \cdot m_d \quad n: \text{ number of electrons} \quad (11)$$

This indicates that the gravitational potential on the droplet mass is equivalent to the electrical potential on the droplet charge.

Suppose that the droplet remains immobile, being  $n = 1$ ;  $E_V = 5,000 \text{ volt} \times \text{cm} \times 3.333 \times 10^{-3} \text{ cm}^{1/2} \cdot \text{g}^{1/2} \cdot \text{s}^{-1} = 16.67 \text{ esu} \cdot \text{cm}^{-3}$ ;  $m_d = 8.17 \times 10^{-12} \text{ g}$ ;  $M_{\oplus} = 5.697 \times 10^{27} \text{ g}$ ;  $G = 6.67 \times 10^{-8} \text{ cm}^3 \cdot \text{g}^{-1} \cdot \text{s}^{-2}$  and  $R_{\oplus} = 6.378 \times 10^8 \text{ cm}$ . From these results it follows that  $e = 4.80 \times 10^{-10} \text{ cm}^{3/2} \cdot \text{g}^{1/2} \cdot \text{s}^{-1} (\text{esu})$ .

This equation is an illustrative expression in the most simplified form of the experiment. As the mass of electrons in our terrestrial contour is irrelevant, the experimental stratagem was to bond the units of changes to a heavy body. By removing the application of the Stokes' Law and using only the correction for the atmosphere bouyancy, the result is equivalent to the mass of a motionless droplet in the vacuum. Since the intensity of the electrical field  $E_V$  exerted on the droplet is independent of its position, consequently this approach is depending solely on their effective mass.

The Eq.(11) expressed in its energetic form can be extrapolated in two opposite directions as far as the most extremes physical limits. On one side, the gravitational field can be as big as the sun (Sect. 5.6), or galaxy, or the whole universe. This causes the total suppression of the droplet mass which was solely an experimental artifice, remaining to own electron mass and its units of change (e.g. Eq. 48). Otherwise, this can leads an electrostatic field as a big as the Coulombic field of two opposite units of charges in the distance of one atomic radius or lesser, as the relativistic distance of the classical electron radius.

## 2.4 Macrocosm and microcosm moments of interaction

I view of these preliminary antecedents of equivalence - which link the gravitational field with the Coulombic field - it is possible to relate the atomic and subatomic universe, to the cosmological Universe. In order to accomplish this, we will connect both scales through their corresponding moments of interaction (Law of the Lever). Then, the moment between the microscopic and macroscopic magnitudes can be made equal and be superimposed in the following way:

$$\begin{aligned} \text{Energy A} &= \text{Energy B} \\ F_G \times L_{max} &= F_{coul} \times r_e \end{aligned} \quad (12)$$

The “classical electron radius”  $r_e$ , physically has an entirely relativistic signification of equivalence between mass, radial distance and the unit of change. This constant  $r_e$ , is the radial separation between two electrical changes when the Coulombic potential of energy is equivalent to the electron relativistic mass  $m_e c^2 = e^2/r_e$ . The gravitational interaction between a proton and an electron in the in the domain of  $r_e$  is  $F_G = Gm_p m_e / (2\pi^2 r_e^2)$ . As in this conditions  $F_{coul} = e^2/r_e^2 = m_e c^2 / r_e$  we can substitute it in the Eq. (12) and resolve for  $L_{max}$ .

$$L_{max} = \frac{2\pi^2 r_e e^2}{Gm_p m_e} = \frac{2\pi^2 r_e^2 c^2}{Gm_p} = 1.26 \times 10^{28} \text{ cm} = 1.36 \times 10^{10} \text{ Ly} \quad (13)$$

Being:  $L_{max}$  Universe critical radius; electron charge  $e = 4.8 \times 10^{-10} \text{ cm}^{3/2} \text{ g}^{1/2} \text{ s}^{-1}$ ; electron mass  $m_e = 9.11 \times 10^{-28} \text{ g}$ ; proton mass  $m_p = 1.673 \times 10^{-24} \text{ g}$ ; gravitational constant  $G = 6.67 \times 10^{-8} \text{ cm}^3 \text{ g}^{-1} \text{ s}^{-2}$ ; classical radius  $r_e = 2.82 \times 10^{-13} \text{ cm}$ .

It is evident the critical radius  $L_{max}$  established in this way is a constant, because it was originated by means of constants. Nevertheless, as  $L_{max}$  is a superior limit, it is accomplished when the expansive energy is the same as the potential energy. As the generalized state of expansion continues, this limit in the present has not been reached.

## 2.5 Critical number of protons

A microspace contour, and all the whole Universe contour are complementary when these opposite extremes are represented by means of a limited energy bubble with a well defined critical radius in its spherical surface. This makes it possible to determine another critical parameter, which can be found applying the Principle of Correspondence (Bohr, 1929) about Eq.(13). Its result lead to the obtainment of the number of baryons  $N_b$  and the critical mass  $m_U^0$ .

Multiplying and dividing Eq. (13) by  $N$ , being  $N$  a constant

$$L_{max} = \frac{2\pi^2 r_e^2 N c^2}{Gm_p N} = \frac{R_U^2 c^2}{Gm_U^0} \quad (14)$$

$$\text{as } m_U^0 = m_p N_b \text{ and } L_{max}^2 = 4\pi^2 r_e^2 N_b \quad (15)$$

from which we obtain the Schwartzchild Radius <sup>2</sup>.

$$L_{max} = \frac{2GM}{c^2}; \quad M = m_U^0 \quad (16)$$

The equations (14) and (15) show that  $N_b$  represent the critical number of baryons. Therefore:

$$N_b = \left( \frac{L_{max}}{2\pi r_e} \right)^2 = \left( \frac{\pi r_e c^2}{G m_p} \right)^2 = \left( \frac{\pi e^2}{G m_p m_e} \right)^2 = 5.08 \times 10^{79} \quad (17)$$

The critical baryon density is:

$$\rho_b = \frac{3N_b m_p}{4\pi R_U^3} = \frac{3}{4\pi} N_b m_p \left( \frac{H_0}{c} \right)^3 = 1.09 \times 10^{-29} g \cdot cm^3 \quad (18)$$

The Principle of Correspondence is clearly expressed in the Eq.(17) when microphysics scale gets connected with cosmological scale through the  $N_b$  constant.

The ratio of interaction between two units of changes, with respect to the intensity of its gravitational field is  $7.13 \times 10^{39}$  times greater. It signifies that  $7.13 \times 10^{39}$  units of mass are required to produce a gravitational field of the same intensity as a single pair of units of change. These assertion and principles can be applied to other very extensives or massive forms: galaxies formation, the structure of the Sun and stars (Sect. 5.5, Sect. 5.6)

### 3 The Hubble constant

#### 3.1 Kinematics implications of $H_0$

Theoretically, the Hubble constant is defined as a parameter established by the speed of the cosmological expansion within a scale unit (Misner *et al*; 1972).

$$H = \frac{\dot{R}}{R}$$

Starting from this constant, the following parameters can be deduced: a) Linear recession law:  $v = dl/dt = \dot{l} = \dot{R}l/R$  being  $l$ , the mean distance between two referential physical points (*i.e.* galaxies). b) Hubble time  $t_H = l/v = H^{-1}$  where  $t_H$  is the time from the present referential position, extrapolated to zero distance between galaxies moving at the recession rate observed today. c) Hubble length  $L_H = c/H$ , where  $L_H$  is the top distance, which is attained by use of the linear recession law when  $v$  is extrapolated to  $c$ .

#### 3.2 The origin of $H_0$

One microsecond of parallax, given by the diameter of the terrestrial orbit around the Sun, is an anthropic scale unit, and physically unmeaning by itself. The origin of  $H_0$  must be marked by a physic unit of scale transcendent and significant as the radius of the gravitational collapse, it may

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<sup>2</sup>The scale  $4.10 \times 10^{17} \text{s} : 1.23 \times 10^{28} \text{cm} : 8.36 \times 10^{55} \text{g}$ , is the same as Schwartzchild scale in Natural Units 1s :  $3 \times 10^{10} \text{cm} : 2 \times 10^{38} \text{g}$ .

allow us the acquisitions of physical implications which are comparative to the atomic referential radius as unit of scale (*i.e.*  $a_0$  or  $r_e$ ).

When the Universe radius was  $6.37 \times 10^{24}$  cm = 2.064 Mps =  $R_G$  with a Planck's blackbody distribution curve corresponding to a temperature of  $\sim 5,250^\circ\text{K}$ , there still existed a fraction of photons in a thermic state equivalent to  $\sim 166,000^\circ\text{K}$ , whose number was the same as the whole population of baryons (Sect. 5.3).

Starting from these conditions, the collapse of gravitation is produced; all the matter and radiation which up to that epoch was in an undifferentiated state of plasm, undergoes a 3-d granular packing condensation. The development of these clumps is a fundamental point of reference: the history of the cosmological expansion begins with the withdrawal of these formations, in order to mark the initial time of  $H_0^{-1}$ .

Since kilometer and megaparsec are units of distance, the dimensions  $\text{km s}^{-1}\cdot\text{Mps}^{-1}$  means  $\text{second}^{-1}$ ; then, as the cosmological space progresses, the Hubble expansion rate will decrease continuously, until it reaches the present time value of  $H_0 = 75.4 \text{ Km s}^{-1} \text{ Mps}^{-1} = 156 \text{ Km s}^{-1} (2.064 \text{ Mps})^{-1}$  (Table 1).

At the present the observational determination of  $H_0$  shows acceptable precise values and by means of different methods converges within  $H_0 = 73.8(\pm 3.1) \text{ Km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}$  (Riess, 2011);  $H^0 = 73(\pm 2)(\pm 4) \text{ Km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}$  (Freedman - Madore, 2010);  $H^0 = 73.9 \text{ Km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}$  (Bonamente, 2006);  $H_0 = 76.5 \text{ Km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}$  (Holanda, 2011);  $H_0 = 74.3 \text{ Km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}(\pm 2.1)$  (Freedman - Madore, 2012).

### 3.3 Dynamic implications of $H_0$

Taking into account the Cosmological Principle, and considering  $H_0$  for a simultaneous time (unobservable) for any point in all the extension of the space, we may establish the dynamic state of the Universe from the radiative transition, to baryonic up to present time. Thus, for the extremes  $R_G = 2.064 \text{ Mps}$  (gravitational collapse) and  $R_U^0$  (present time radius) we have

$$H_0 = \frac{c}{(z+1)R_G} = \frac{v}{R_G} = 2.45 \times 10^{-18} \text{ s}^{-1} \quad (19)$$

being  $v = 1.56 \times 10^7 \text{ cm s}^{-1}$ ;  $R_G = 6.37 \times 10^{24} \text{ cm}$

$$H_0 = \frac{c}{R_U^0} = 2.45 \times 10^{-18} \text{ s}^{-1} \quad (20)$$

where  $R_U^0 = 1.225 \times 10^{28} \text{ cm}$

Equalizing (19) with (20) and reordering, we find the following dimensionless scale

$$\frac{v}{c} = \frac{1}{z+1} = \frac{v}{H_0 R_U^0} = \frac{R_G}{R_U^0} \quad (21)$$

Any value from the linear recession law is comparable to whatever intensive property of a system *i.e.* it is similar to the absolute temperature used universally as an indicator of the thermic state, or as a measure of energy for any system.

Then

$$\frac{v}{c} = \frac{T_G}{T} \quad (22)$$

Since  $H_0$  defines the present Hubble expansion rate, and  $H$  defines a value of the Hubble constant at different epoch, we may extend (21) in the following way:

$$\frac{v}{c} = \frac{1}{z+1} = \frac{v}{HR_U} = \frac{R_G}{R_U} = \frac{T}{T_G} = \left(\frac{m_\Lambda}{M_V}\right)^{1/2} \quad (23)$$

$M_V$  is the mass of the cosmological vacuum (Sect. 4.3).

Raising to square all this dimensionless terms and reordering, we find

$$m_\Lambda = \frac{M_V v^2}{c^2} = \frac{M_V}{(z+1)^2} = \frac{M_V v^2}{H^2 R_U^2} = \frac{M_V R_G^2}{R_U^2} = \frac{M_V T^2}{T_G^2} \quad (24)$$

These proportions express the dynamic state of the Universe unquestionably. The term  $M_V v^2/c^2$ , the same as the other terms, represents the relativistic  $m_\Lambda$  mass-energy equivalence of the space in expansion.

Despite of the different methods for the determination of the Hubble constant, and the implications of the Universe age, for us,  $H_0^{-1}$  as well as  $t_0$ , are not independent quantities, since we consider for  $H_0$  a clear point of departure. This  $R_G = 2.060$  Mps ( $6.40 \times 10^{24}$  cm) referential point, is coincident with the withdrawal of the protogalaxies after gravitational collapses (Sect. 5.1).

The Hubble time is an indicator of the cosmological age through the expansion rate in relation with the  $R_G$  referential interval of distance. Hence, the present value of  $H_0^{-1}$  means the duration of the expansion from  $R_G$  until now. For this reason, the  $t_0 =$  age, determined on the basis of the antiquity of the oldest objects, plus its time of formation, is the same as  $t_0 \simeq H_0^{-1}$ , as likewise  $H_0 t_0 \simeq 1$ .

## 4 The extension of the cosmological space

### 4.1 Energy constraint

All terms of the Eq.(24) determine the main implication of the Hubble parameter, because it establishes the dynamic index (scale factor) of the relativistic kinetic energy of the global expansion, prevailing for any point in space in a simultaneous time (Cosmological Principle).

In the initial evolutive process, because of  $E_\Lambda > E_G$  and  $m_\Lambda > m_M$ , the Universe was hegemonously expansive. Up to the  $R_G \sim 2.064$ Mps, the gravitation collapses, and as it implies a force exerted, this makes a continuous decrease of  $m_\Lambda = M_V v^2/c^2$ . Thus, the space expansion range can be established by means of the ratio between the expansive energy and the restrained force (Planck, 1926).

Slightly modifying the mechanical equivalent of heat, we have:

$$\text{Expansive energy} = F_{\text{grav}} L_{\text{max}} \quad (25)$$

As  $F_{\text{grav}} L_{\text{max}}$  is the potential energy  $U$ , it determines that the expansive energy (kinetic  $K$ ) be depressed continuously up to the equilibrium limit given by the virial  $2K = U$ , which constraints the Universe extension ( $L_{\text{max}}$ ).

$$L_{\text{max}} = \frac{M_V v^2}{G m_U^0} R_U^2 \quad (26)$$

$$m_U^0 : \text{critical mass} = N_b m_p (\text{constant})$$



Being  $N_b = 5 \times 10^{79}$ ;  $m_U^0 = 8.35 \times 10^{55}$  g and  $M_V$ : mass of the vacuum  $2.64 \times 10^{63}$  g (Sect. 4.3).

$2K = m_\Lambda = M_V v^2 / c^2$  (dynamic mass of the vacuum) and  $U = m_M = G m_U^0{}^2 / c^2 R_U$  (gravitational mass).

Considering  $R_G$  as the starting point, for any historic value of  $R_U$ , the results are always  $L = 1.23 \times 10^{28}$  cm =  $1.32 \times 10^{10}$  ly.

## 4.2 Physical meaning of the cosmological term

The cosmological constant  $\Lambda$ , was designed exclusively for static model of universe. Its origin, was from an arbitrary *ad-hoc* constant of integration, and its negative sign, gives it the meaning of a repulsive “*antigravity*”. Because of its static non-expansive nature, its implementation is ineffective for any previous stage in the evolution of the universe. Moreover, this repulsive term acts only on the space itself, but not acting on the matter. For this properties, it does not gravitates.

As a consequence of its static origin, this term is not virialized. Then, the Eq.(26) is

$$L_{\max} = \frac{M_V v^2}{2G m_U^0{}^2} R_U^2 \quad (27)$$

Multiplying both terms of (27) by  $\frac{4\pi R_U c^2}{3}$  and reordering

$$\frac{3c^2}{8\pi R_U L_{\max}} = \frac{G \rho_{m_U^0} m_U^0 c^2}{M_V v^2} \quad \text{Being } \rho_{m_U^0} = \frac{3m_U^0}{4\pi R_U^3} \quad (28)$$

At present time  $R_U^0 \simeq L_{\max}$ , and  $m_U^0 \simeq m_\Lambda \simeq \frac{M_V v^2}{c^2}$ . Then

$$\frac{\Lambda}{3} = \frac{1}{L_{\max}^2} = \frac{-8\pi}{3 c^2} G \rho_\Lambda \simeq \frac{8\pi}{3 c^2} G \rho_{m_U^0} \quad (29)$$

As  $c^2 / L_{\max}^2 \simeq H_0^2$

$$H_0^2 = \frac{-8\pi G \rho_\Lambda}{3} \simeq \frac{8\pi G \rho_{m_U^0}}{3} \quad (30)$$

For  $H_0 = 2.44 \times 10^{-18}$  s<sup>-1</sup>;  $\rho_\Lambda = 1.10 \times 10^{-29}$  g cm<sup>-3</sup>

This means definitely, that the origin of the cosmological constant proceed from the referential energy of the vacuum  $m_\Lambda$ .

## 4.3 Origin and evolution of the repulsive $\Lambda$ cosmological term

All the photons of the CMB radiation vibrate in all possible directions through a symmetric axis. But, as they have their origin in the annihilation of almost the same quantity of matter-antimatter, they are formed from  $N_\gamma/2$  pairs of polarized waves. This polarization still remains after the inverse thermoionization (recombination) because the recombinant electron also collapses in atoms with two possible quantum states. Likewise, the electrons of the hydrogen atoms and He too, show two equal quantum states and emit polarized photons in both pairs.

Because the great supremacy of the  $N_\gamma/2$  pairs of polarized waves, and despite of the perturbations provoked by the  $N_b$  baryons, this scheme remains invariant through all the cosmological evolution. Therefore, from the present conditions, if we fix an inverse sequential order towards a collapse on the space itself (gravitational implosion), it will show the following phases:

- a - When the temperature is higher than  $4,000^\circ\text{K}$  the electrons and the hydrogen nucleus will still be at the plasma state. The  $N_\gamma$  photons of the CMB radiation keep their polarity, taking into account that they are  $1/2N_\gamma(-)$  and  $1/2N_\gamma(+)$ .
- b - For the electrons' threshold temperature  $T \sim 6 \times 10^9^\circ\text{K}$  and  $R_U \sim 2.6 \times 10^{19}$  cm, 1/4 photons (-) and 1/4 photons (+) collapses as 1/4 electrons and 1/4 positrons.
- c - When  $R_U \sim 1.6 \times 10^{16}$  cm and  $T > 2 \times 10^{12}^\circ\text{K}$  (neutron's threshold temperature) other 1/4 photons (+) plus 1/4 photons (-) collapse as 1/4 protons and 1/4 antiprotons, their final result being  $N/2$  neutrons.  $\left\{ \begin{array}{l} 1/4N(p^+ + e^- + \nu_{\text{neutrino}} \rightarrow n^0) \\ 1/4N(p^- + e^+ + \nu_{\text{antineutrino}} \rightarrow n^0) \end{array} \right\} N/2$  neutrons  
Where  $N/2 = 1.6 \times 10^{87}$  neutrons, and the constant  $M_V = 2.6 \times 10^{63}$  g is the **mass intake from the empty space**.
- d - Finally, this  $N/2$  neutrons coalesces to give  $\sim 1.2 \times 10^{68}$  Planck's "particles" when  $R_U = 6.4 \times 10^{-11}$  cm and  $T = 1.62 \times 10^{32}^\circ\text{K}$ .

In a cyclic, or periodic Universe, the Planck state was not an initial *ex-nihilo* big bang starting point, instead, it was a crossing point for a new cycle. As at this point, there is not a preexistent surface, the Universe does not rebound on it, but it passes across itself, and expands toward any 3d points of space. Then, the former inward gravitational implosive falling energy was shifted to an opposite outward acceleration. This accelerative expansion, in fact, was simultaneously canceled by an equal attractive gravitational field ( $g = 0$ ). Consequently, the origin of the cosmological expansion was produced exclusively from matter-antimatter annihilation (dark energy).

Both opposite interactions were still unchanged until the gravitational baryonic collapse, which started at 2.064 Mps (Sect. 3.2).

#### 4.4 Photons number density of the CMB radiation

The energy spectrum of the CMB radiation registered at present, whose mean wavelength is 0.105 cm, represents a huge magnified copy of the photons produced by annihilation of  $m_p^\pm$  and  $m_e^\pm$  (matter - antimatter particles).

The number of photons  $\eta_\gamma$  of the CMB radiation per  $\text{cm}^{-3}$  may be easily calculated from the Wien's Law.

$$T \cdot \lambda_{CMB} = \frac{2\pi \hbar c}{5k} \quad \text{Reordering} \quad \frac{2\pi}{5\lambda_{CMB}} = \frac{kT}{\hbar c} \quad (31)$$

In order to obtain it, is only necessary to apply in both terms the sphere formula:

$$\eta_\gamma = \frac{6\pi^2}{(5\lambda_{CMB})^3} = \frac{3}{4\pi} \left( \frac{kT_{CMB}}{\hbar c} \right)^3 \quad (32)$$

e.g.  $T_{CMB} = 2.73^\circ\text{K}$  and  $\lambda_{CMB} = 0.105\text{cm}$ ;  $\eta_\gamma = 408 \text{ photons}\cdot\text{cm}^{-3}$ .

Otherwise, the Universe photons number  $N_\gamma$  is a constant of nature since  $T_{CMB} \cdot R_U$  and  $R_U/\lambda_{CMB}$  are constants:

$$N_\gamma = \left( \frac{2\pi R_U}{5\lambda_{CMB}} \right)^3 = \left( \frac{kT_{CMB}R_U}{\hbar c} \right)^3 = 3.12 \times 10^{87} \quad (33)$$

This equality shows the invariance of  $N_\gamma$  throughout the evolution of  $R_U$ .

Multiplying the Eq. (32) by  $kT/c^2$ , we can arrive to the Universe density of the CMB radiation in  $\text{g}\cdot\text{cm}^{-3}$ .

$$\rho_{CMB} = \frac{3}{4\pi} \frac{(kT_{CMB})^4}{\hbar^3 c^5} \quad (34)$$

#### 4.5 Dynamic repulsive density of the empty space

Because of its expansive origin (from annihilation of matter-antimatter particles) the cosmological vacuum is a repulsive ‘‘antigravitational’’ entity. Then, at the present temperature of the CMB radiation (2.73 °K), the vacuum density of energy is equivalent to

$$\rho_{vac} = 102 (m_p^+ + m_p^- + m_e^- + m_e^+) \cdot c^2 = 204 m_p^\pm \cdot c^2 = 0.31 \text{ erg}\cdot\text{cm}^{-3}$$

$$\text{Since: } (m_p^+ + m_p^-) \simeq m_p^\pm \text{ and } 204 = \frac{1}{2} 408$$

The vacuum energy density at any temperature below  $1 \times 10^9$ °K is

$$\rho_{vac} = \frac{1}{2} \eta_\gamma \cdot m_p^\pm \cdot c^2 = \frac{3m_p^\pm}{8\pi c} \left( \frac{kT}{\hbar} \right)^3 = 0.015 \text{ erg} \cdot \text{cm}^{-3} \cdot \text{°K}^{-3} \cdot T^3 \quad (35)$$

After the gravitational collapse, at the temperature bellow 5,250 °K, the vacuum dynamical density in  $\text{g}\cdot\text{cm}^{-3}$  is:

$$\rho_\Lambda = \frac{1}{2} \eta_\gamma \times \frac{1}{2} m_p^\pm \cdot \frac{v^2}{c^2} = \frac{3m_p^\pm \cdot v^2}{16\pi c^2} \left( \frac{kT_{CMB}}{\hbar c} \right)^3 \quad (36)$$

As the temperature  $T = 5,250$ °K marks a point of departure from the gravitational collapse, by use of the Eq.(22), we have:

$$\rho_\Lambda = \frac{1}{4} \eta_\gamma \cdot m_p^\pm \cdot \frac{T_{CMB}^2}{T_G^2} = \frac{3m_p^\pm \cdot T_{CMB}^5}{16\pi T_G^2} \left( \frac{k}{\hbar c} \right)^3 = 7.5 \times 10^{-32} \text{ g} \cdot \text{cm}^{-3} \cdot \text{°K}^{-5} \cdot T^5 \quad (37)$$

## 5 Structure Formation

### 5.1 Beginning of the baryonic epoch

A gaseous homogeneous system with a certain temperature can be gravitationally merged from a plasma state and forms a condensation of matter when the gravitational potential energy rises over the internal thermic energy  $E_G > E_T$  (Jeans, 1902). Specifically, a proof particle confined in a gravitational field shows the formation of clumps of radius  $R$  when:

$$\begin{aligned} \text{Gravitational Potential Energy} &> \text{Expansive Energy} \\ \text{Attractive Force} \times R &> \text{Expansive Energy} \end{aligned} \quad (38)$$

At this epoch, despite of the dominant expansion of the cosmological space, the first structures can be formed by means of the attractive potential. This is because the hegemonic cosmological constant is only related with the space itself, but does not acts on the attractive gravitational effect

Time seg.	Temp. °K	$R_U$ cm	$z$	$\rho_b$ g·cm <sup>-3</sup>	$\rho_\Lambda$ g·cm <sup>-3</sup>	$\rho_\gamma$ g·cm <sup>-3</sup>	H Km·s <sup>-1</sup> $R_G^{-1}$	H Km·s <sup>-1</sup> Mps <sup>-1</sup>
$2.13 \times 10^{14}$	5,250	$6.40 \times 10^{24}$ *	1,920	$7.74 \times 10^{-20}$	$3.00 \times 10^{-13}$	$2.30 \times 10^{-21}$	$3.0 \times 10^5$	$1.50 \times 10^5$
$3.34 \times 10^{14}$	3,350	$1.01 \times 10^{25}$	1,280	$1.97 \times 10^{-20}$	$3.16 \times 10^{-14}$	$3.82 \times 10^{-22}$	$2.0 \times 10^5$	$9.69 \times 10^4$
$4.27 \times 10^{14}$	2,625	$1.28 \times 10^{25}$	960	$9.68 \times 10^{-21}$	$9.35 \times 10^{-15}$	$1.44 \times 10^{-22}$	$3.0 \times 10^4$	$1.45 \times 10^4$
—	—	—	—	—	—	—	—	—
$5.33 \times 10^{16}$	21.00	$1.60 \times 10^{27}$	7.68	$4.96 \times 10^{-27}$	$3.06 \times 10^{-25}$	$5.89 \times 10^{-31}$	1,200	581
$6.40 \times 10^{16}$	17.50	$1.92 \times 10^{27}$	6.40	$2.87 \times 10^{-27}$	$1.23 \times 10^{-25}$	$2.84 \times 10^{-31}$	1,000	484
$7.47 \times 10^{16}$	15.00	$2.24 \times 10^{27}$	5.55	$1.88 \times 10^{-27}$	$5.70 \times 10^{-26}$	$1.53 \times 10^{-31}$	856	415
$8.55 \times 10^{16}$	13.10	$2.56 \times 10^{27}$	4.80	$1.28 \times 10^{-27}$	$2.90 \times 10^{-26}$	$2.92 \times 10^{-32}$	750	363
—	—	—	—	—	—	—	—	—
$4.10 \times 10^{17}$ **	2.73	$1.23 \times 10^{28}$	0	$1.09 \times 10^{-29}$	$1.13 \times 10^{-29}$	$1.68 \times 10^{-34}$	156	75.5

\* Gravitational collapse      \*\* Present time

Table 1: The numerical result obtained from Eq.(23) show that the expansion rate is  $c$  when the radius of the universe is  $R_G = 6.40 \times 10^{24} = 2.060$  Mps. Making use of this scale, the expansion rate progressively decreases up to the present value of  $156 \text{ km}\cdot\text{s}^{-1}\cdot(2.064 \text{ Mps})^{-1}$  or  $75.5 \text{ km}\cdot\text{s}^{-1}\cdot\text{Mps}^{-1}$ . By use of the Eqts. (18) and (37),  $\rho_b$  and  $\rho_\Lambda$  are obtained. Using the Eq.(53) or  $1/H$ , time is accomplished.

associated with the matter. Therefore, the initial gravitational interaction makes the beginning of the baryonic era (Sect. 5.3).

The transition from an universe dominated by radiation to an universe dominated by matter occurs after  $\rho_m \gg \rho_{CMB}$  radiation. At this epoch, the universe was  $\sim 2,000$  times smaller than the present. Reached these conditions, one can say that it was the beginning of the gravitational era and the end of the era of radiation. For this transition we adopts a temperature of  $5,200^\circ\text{K}$ , which correspond to the beginning of the baryonic epoch and the called “recombination” (negative thermoionization) of the hydrogen and HeI atoms.

As the photons even by far, they are the least massives of all components, but because of their great number, they represent together with the electrons the extremes entities which mark the limiting temperature for the formation of these clumps.

Consequently, both for the electrons and the photons, the expansive energy is

$$\frac{1}{2}m_e\bar{v}^2 = \frac{3}{2}kT \quad (39)$$

For an electron, the translation energy for degree of freedom on the zero point is  $3kT/2$ . Likewise, for the same electron, the attractive force within a clump contour is

$$F_a = \frac{GM_L m_e}{R_L^2} \quad (40)$$

being  $M_L$ : clump mass and  $R_L$ : clump radius. Combining Eq. (39) and (40) in (38) we have

$$R_L = \frac{2GM_L m_e}{3kT} = \frac{2GN_L(m_p + m_e)m_e}{3kT} \quad (41)$$

where  $N_L$  is the particles pair number. If we multiply both members by  $4\pi R_L^2/3$  and reordering, we have Eq. (42) in terms of the average density  $\bar{\rho}$

$$R_L = \left( \frac{9kT}{8\pi G m_e \bar{\rho}} \right)^{1/2} \quad (42)$$

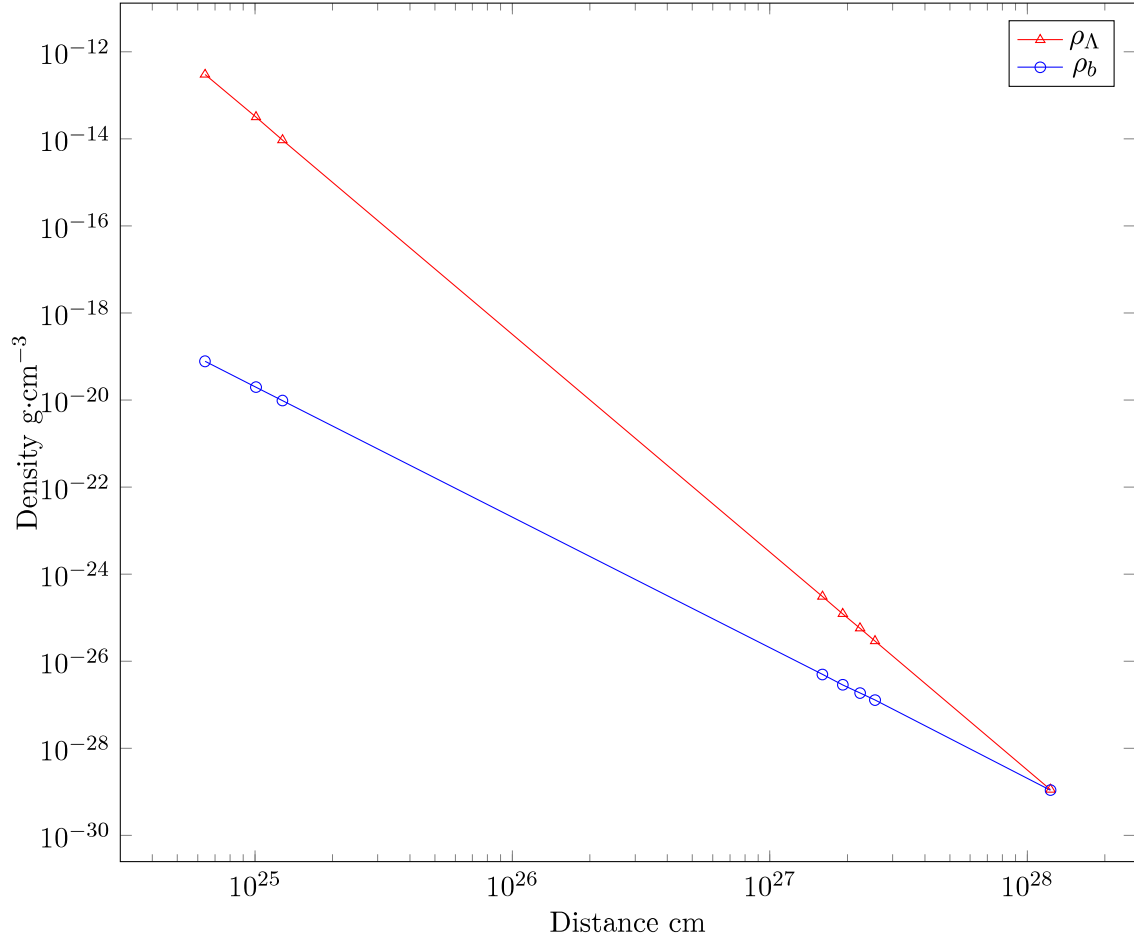


Figure 1: The red line represent the dynamical density of the vacuum  $\rho_{\Lambda}$ . The blue line represent the density of the baryonic matter  $\rho_b$ . The numerical values are from Table 1.

Although the formalism of the big bang has the significance of the realization of a generalized expansion process, once the lumps are formed they will not dissipate, but opposite occurs: within their contour they can collapse to produce minor structures (stars) as well as they can associate among themselves to form new conjuncts (cumulus). In both cases, when these new structures originate, and due to the simultaneous effect produced by the progressive expansion, the rarefying increases in the surrounding, which makes the process not fully efficient, and a significative mass remains in a dark (baryonic) form.

## 5.2 Numerical calculation

For the formation of a clump of gas (protogalaxy) in a fluid with a mass density of  $\bar{\rho} = 7.74 \times 10^{-20}$  g·cm<sup>-3</sup>, the mean kinetic energy of a proof plasma particle (*i.e.* an electron) corresponds to the thermic state determined by a Planck's distribution curve. As in the fluid, the number of photons is about  $10^8$  : 1 times the number of nucleus and electrons, when the temperature is  $\sim 5,250^\circ\text{K}$ , yet there exist as many photons in a thermic state correspondig to  $167,000^\circ\text{K}$  as the whole population of free electrons. That is the reason why the gravitational fusion or gravitational collapse (Sect. 5.3) starts just when the Universe has a radius of 2.064 Mps ( $6.40 \times 10^{24}$  cm) and  $E_G \gg E_T$ .

Using Eq.(42) we may obtain the lumps radius in the fluid fluctuation. The result is  $R_L = 1.37 \times 10^{21}$  cm.

The mass of this lump may be calculated by equating and reordering Eq.(40) and Eq.(42)

$$M_L \left( \frac{3}{4\pi\rho} \right)^{1/2} \left( \frac{3kt}{2Gm_e} \right)^{3/2} = 7.74 \times 10^{44} \text{ g} = 3.9 \times 10^{11} M_\odot \quad (43)$$

The mass of this protogalaxy coincides with the massives old galaxies observed at the present time (Marchesini, 2010) (Wiklind, 2007). Owing to the physical constraint imposed by the Eq.(42) and the restriction of space within its general contour (2.064 Mps) the three dimensional (3-d) close packing makes an individual size considerably inferior (1/40) than the present one. Since the galaxies do not increase their extension in synchrony with the generalized cosmological expansion of the space, they will reach their normal size when the dynamic equilibrium is accomplished , after the stars formation, up to the present time.

Adjusting the Eq.(14) we can get the present radius

$$R_{Gx} = \frac{8\pi^2 N_b r_e^2 v^2}{GNm_p}$$

If  $N_b = 4.67 \times 10^{68}$ ;  $v = 3.07 \times 10^7 \text{ cm s}^{-1}$ ;  $R_{Gx} = 2\pi r_e (2N_b)^{1/2} = 5.33 \times 10^{22}$  cm.

$$\text{Also } R_{Gx} = \frac{GM_{Gx}}{v^2} = 5.34 \times 10^{22} \text{ cm} = 56,000 \text{ Ly.}$$

### 5.3 The start of the baryonic age. Energy and temperature

The temperature for the fixed number of  $N$  particles in a certain volume is a measure of their (kinetic) energy. That is the reason why the energy for a certain quantity is always an extensive property. On the other hand, the absolute temperature for degree of freedom, similarly pressure and density are intensive properties and independent of the mass. Thus, the Boltzmann constant  $k$ , for a Kelvin degree determines the mass or energy of  $1^\circ\text{K}$  for one freedom degree (particle or photon). If  $m = kT/c^2$ , and  $T = 1^\circ\text{K}$ , result  $m_\gamma = 1.533 \times 10^{-37} \text{ g (fd)}^{-1}$ .

This means that the average of energy for each freedom degree, multiplied by the total number of photons or particle, will allow us to establish the energy of whole system. Then,  $N$  elements are required for producing an equivalent behavior between the gravitational potential of the matter in bulk and the coulombic potential of the individual atoms.

For the present universe with a present Hubble constant  $H_0 = 75.4 \text{ Kms}^{-1} \text{ Mps}^{-1}$ , the mean mass of all the photons was equal to the critical gravitational mass when  $T = 167,000^\circ\text{K}$  and  $R_U = 6.4 \times 10^{24}$  cm.

$$T = \frac{m_U^0 c^2}{k N_\gamma} = 167,000^\circ\text{K}$$

Being  $m_U^0 = 8.35 \times 10^{55} \text{ g}$  and  $N_\gamma = 3.15 \times 10^{87}$ . In order to calculate the effective temperature in which the beginning of the baryonic age is produced, the scale established in Eq. (23) is used.

$$2.73^\circ\text{K} \cdot R_U^0 = T_G \cdot 6.4 \times 10^{24} \text{ cm}$$

since  $R_U^0 = 1.23 \times 10^{28} \text{ cm}$ ,  $T_G = 5,250^\circ\text{K}$ .

The discordance between the initial baryonic radius  $R_G = 2.0 \times 10^{23} \text{ cm}$  for  $T = 167,000^\circ\text{K}$  and  $R_G = 6.37 \times 10^{24} \text{ cm} = 2.064 \text{ Mps}$  for  $T_G = 5,250^\circ\text{K}$  takes place, because in the plasma there

is a great excess of photons with respect to the number of baryons ( $\sim 10^8 : 1$ ) and this determine that the baryonic age was produced considerably later.

Finally, it must be added that the process of galaxies formation is not fully efficient (just 0.003 to 1) and most of the cosmic material is gas and dark matter.

#### 5.4 Physics of the Stars. Gravitational and Coulombic Connection

The stars are self-regulated active systems formed by multiple large spherical layers of condensation of gas. For its operation, the mass of gas is bounded by an upper critical temperature and pressure which is required to produce the nuclear reaction in the core. But this upper mass is not unlimited, because the supermassive stars are unstable. Given these definitions, we will consider in our analysis the two extremes that make the operation of a star: the core and the photosphere.

In the star photosphere a large number of atoms, mainly H and He are in hydrostatic identical intensity balance respect to two superposed and opposite fields. The outward force due to the temperature and an inward force provoked by the gravitational field of the total mass of all the individual atoms. Simultaneously the electrons of these individual atoms are also in balance respect two superposed forces: the outward force due to this same temperature and the inward quantum forces produced by by the attractive Coulombic field of the nucleus.

It is certain that  $N$  units of masses in conjunct are required to produce the equivalence between the gravitational phenomena of the matter in bulk and each individual coulombic interaction between photons and electrons within its atomic contour. These  $N$  units of mass determines all the physical properties of one star. The total mass defines its types, size luminosity, temperature and their lifetime. Besides being only mass dependent to establish their particular characteristic, all stars for their operation use the same physical principles, which basically works as a self-regulating thermostat.

#### 5.5 Temperature of the core and the solar photosphere

It is a well defined property that the solar core is directly linked to the nuclear phenomena and the temperature of the nuclear reactions are regulated by the pressure. In the other extreme, the temperature of the photosphere is controlled by the pressure and the emission of the excited atoms. According to this mechanism of balance, both opposite extremes, the radius of the core and the radius of the photosphere remain constant. Therefore, it is remarkable that both temperature are in a simple way directly connected to the respectives mass of the protons and electrons.

$$T_c = \frac{4GM_\odot m_p}{27kR_c} = 1.56 \times 10^7 \text{K} \quad R_c = 1.55 \times 10^{10} \text{cm} \quad (44)$$

$$T_\odot = \frac{4GM_\odot m_e}{9kR_\odot} = 5,660 \text{K} \quad R_\odot = 6.96 \times 10^{10} \text{cm} \quad (45)$$

Dividing the Eq.(44) by the Eq.(45) we have:

$$\frac{R_\odot}{R_c} = \frac{3m_e T_c}{m_p T_\odot} \quad (46)$$

$$\text{since } T_c = \frac{3m_p T_\odot}{2m_e}; \quad R_c = \frac{2}{9} R_\odot \quad (47)$$

The Eq.(47) is an expression of the mechanism of self-regulation (thermostat) for to sustain the equilibrium of the star in terms of the radius and temperature of the core and the chromosphere.

## 5.6 Photosphere Temperature

In the core, all atoms are totally ionized to form solely nuclei and free electrons. Upon ascending towards the surface the temperature falls gradually, resulting at the end the recombination of atoms. This phenomena occurs principally in the photosphere which is the solar surface where the light is emitted. Then the solar radius is referred to the distance from its center to the photosphere. In the same way the energy of the gravitational field on the mass of any free electron expressed in the Eq. (45) is equal to the mean blackbody energy of the emission spectrum for  $\sim 5,700^\circ\text{K}$ .

$$E = \frac{Z_{eff} \cdot e^2}{2n^2 a_0} \cong \frac{4GM_\odot m_e}{9R_\odot} \quad (48)$$

Obviously, at the first sight by applying directly this relationship, both extremes are irreconcilables, since inevitably it gives for  $n$  a non entire number, because of there are many multiples quantum transitions from different elements.

Being that

$$a_0 = \frac{\hbar^2}{m_e e^2} \quad (49)$$

Replacing (49) in (48)

$$E = \frac{Z^2 m_e e^4}{2n^2 \hbar^2} \quad (50)$$

The temperature  $5,700^\circ\text{K}$  of the solar spectrum is originated mainly from  $N$  excited atoms of H, He, Mg, Ca, Na, K, Fe, etc, which emit 8% of UV radiation; 40% visible; 50% of IR and 2% of far IR radiation. Likewise, in accordance to the experimental spectrum, the maximum irradiation corresponding to a blackbody for a temperature of  $5,770^\circ\text{K}$ .

## 6 Time - temperature relationship

### 6.1 Expansive ideal gas of photons

Since the whole cosmological space is a black body contour full of radiation and a very repulsive-expansive bubble of energy, the ideal gas equation as a kinetic expression is a suitable tool to resolve this problem directly.

$$V = \frac{N_\gamma kT}{\rho_\gamma c^2} \quad (51)$$

As the relation volume to radius is

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

Substituting  $\rho_\gamma$  by Eq. (34), and dividing by  $c$

$$t = \frac{\hbar}{kT} N_\gamma^{1/3} \quad (52)$$

If  $N_\gamma = 3.12 \times 10^{87}$  (Eq. 33), it means

$$T = 1.12 \times 10^{18} \text{s} \cdot ^\circ\text{K} \cdot \text{t}^{-1} \quad (53)$$



## 6.2 Time - temperature from microphysics

Finally, we will make use of parameters proceeding from microphysics solely, in particular, the Coulombic total energy of the electrons in the Rydberg states for the H - HeI cosmological atoms. The binding energy of these electrons are:

$$\begin{aligned} H^1 &: 13.6\text{eV} \text{ (157, 900°K)} \\ H_e I &: 24.6\text{eV} \text{ (285, 600°K)} \end{aligned}$$

The abundance by atom of H - He is: 16 H<sup>1</sup>:1 He<sup>4</sup>.  
Thus, the effective value of  $Z^2$  is given by

$$Z_{eff}^2(H^1 + HeI) = 0.9375 \times 1^2 + 0.0625 \times 1.341^2 = 1.050 \quad (54)$$

The origin of the photons of CMB radiation and the cosmological expansion, was produced solely from matter antimatter annihilation (Dark Energy). In consequence, at the same rate as the empty cosmological space increases, the following intensive properties decrease synchronically in a regressive general development.

- i The matter-antimatter empty space density (the space itself).
- ii The  $n_\gamma$  photon number density of the CMB radiation.
- iii The total energy density in the Rydberg H - He microstates.

For the last point, the balance begins from the gravitational collapse, and continues after the recombination in higher Rydberg microstates until the present time. Then, it can be said that the Rydberg H - He atoms behave as micro-barometers in thermodynamic equilibrium with the CMB radiation.

Thus, the average energy in the empty contour for these electrons can be expressed by the following constant.

$$E_{Ryd}(H^1 - He^4) = \frac{Z_{eff}^2 \cdot m_e \cdot e^4}{2\hbar^2} = 14.25 \text{ eV} = (165, 500^\circ\text{K}) \quad (55)$$

This constant is totally independent form any particular quantum levels in the history of the Rydberg (H - HeI) atoms evolution. Then, in all stages of the cosmological expansion, the ratio between the energy within the empty contour of Rydberg atoms with respect to the energy of a proton-antiproton, allows us to obtain  $\eta$  (baryon to photon ratio). The last assertion is consequence of the origin of the empty space and the CMB radiation, since both entities proceeds from the annihilation of protons-antiprotons.

$$\eta = \frac{Z_{eff}^2 \cdot m_e}{2m_p^\pm} \cdot \left(\frac{e^2}{\hbar c}\right)^2 = \frac{Z_{eff}^2 \cdot m_e \cdot \alpha^2}{2m_p^\pm} = 1.55 \times 10^{-8} \quad (56)$$

Now, it is possible to find  $N_\gamma$  multiplying  $1/\eta$  by the baryon number  $N_b$  (Eq. 17)

$$N_\gamma = \left(\frac{2\pi}{\alpha Z_{eff}}\right)^2 \cdot \frac{e^2}{Gm_p m_e} \cdot \frac{e^2}{Gm_e^2} = 3.18 \times 10^{87} \quad (57)$$

From this equation, it is clear that the photons number  $N_\gamma$  of the CMB radiation is a result of the ratio in the Coulombic interaction between the electron-proton and the electron-electron, with

respect to the gravitational interaction of its masses. This ratio, is invariant from any quantum state and the number of interactive particles. It should be noted, that  $N_\gamma$  is deduced entirely from physical constants, which are not subject to any direct cosmological observation. Thus, we have again the same result as the expressed in the preceding equation.

$$t = \frac{\hbar}{kT} \cdot N_\gamma^{1/3} = 1.12 \times 10^{18} \text{ s} \cdot \text{K} \cdot \text{T}^{-1}$$

In the intergalactic and intercluster medium, the undetectable dark matter is formed by ionized and highly excited H Rydberg atoms at  $n \simeq 220$ ;  $Z = 1$  and HeI,  $n \simeq 240$ ;  $Z = 1.34$  which has the same density of energy as the cosmological empty space. At  $2.73^\circ\text{K}$ ,  $1 \text{ m}^3$  of the cosmological space is totally pervaded with  $4.08 \times 10^8$  photons of the CMB radiation, 6 H atoms and 0.4 atom of HeI. As the inner vacuum density of these atoms is the same as the vacuum cosmological density, they are the components of the “hidden” mass. Also, as the energy of these Rydberg hydrogen-like electrons are permanently in an exact balance with respect the energy of the CMB radiation, such Rydberg atoms are always transparent to this radiation.

## 7 Conclusions

In natural science, particularly in any branch of the physics, it is extremely hard to construct a scientific framework on basis of generalized hypothetical and enigmatic unknown forms of matter-energy. Hence, it is very unusual, as in the cosmological “standard model”, it is considered as a natural fact, that  $\sim 95\%$  of the matter-energy (near the whole) is in unknown hidden form.

Cosmology requires particles, radiation, space and energy; likewise, atomic physics and astrophysics require the same components. Since atomic physics and astrophysics do not make use of any hidden form of matter-energy, the theoretical cosmology must be free of these artifices. Given these failures, another physics, independent of the dogmas by the hegemonic standard model, would be essential and imperative.

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