Cosmological Implications of the Casimir Energy Density

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Abstract

In this article, we analyse some unspecific details which are significant in certain experiment related to Casimir effect. At the "point of closest approach", as the Casimir force equals the Coulombic force, we can calculate the static energy density. Also, identical phenomena occurs in the cosmological H and HeI Rydberg atoms. Since our model is notinflationary, in spite of the marked contrast between both scales, by extrapolation, utilizing a dynamical expression for this microscopic magnitudes, we can obtain the Cosmological Constant. Due to its intensives form, these finding are fascinating, since from a specific microscopic empty cavity, we can equalize its expansive energy density with respect to the cosmological energy density.

Key Words: Cosmology; Cosmological Constant; Dark matter; Dark energy; Casimir effect; Rydberg atoms; Empty space.

1 Introduction

The existence of a kind of intrinsic energy which gives origin to the empty space, comes from its experimental discovery (Casimir; 1948) in relation with the attractive force between parallel plates. Thereafter, about the origin of this "mysterious" energy, the earliest ambitious speculation there were by the same Casimir. However, the "apparent beauty of this model" were convincingly "refuted" (Boyer; 1968) based on pure and profuse mathematical arguments without offering any physical alternative. And so, the thing after 70 years despite the different techniques, ways of measurements, surfaces, designs and stratagems, until the present, the Casimir effects reminds limited to the measurements of "forces" in terms of "distances". (A brief summary of these historical antecedents was considered by Milonni; 1993 and Lamoreaux; 2007).

2 Formulation of the density of energy

2.1 Conversion of force into energy density

In the plane - plane geometry, the areas of both planes are L^2, and the pressure is independent of the extension of the areas. But in the sphere-plane geometry, when the radius of curvature is relatively high, (10 - 15 cm), this surface can be considered approximately as a plane. However the spherical surface causes an optical dispersion, which geometrically can be corrected by the factor 2 [1]. Then, for the two system the Casimir pressure is expressed by

[1] Ratio between hemisphere surface / circle surface= $\frac{2\pi R^2}{\pi R^2} = 2$

plane - plane **plane - sphere**

$$\rho = \frac{\pi^2 \hbar c}{240 d^4} = 1.30 \times 10^{-18}\,\mathrm{erg\,cm}\; d^{-4} \qquad \rho = \frac{\pi^2 \hbar c}{120 d^4} = 2.60 \times 10^{-18}\,\mathrm{erg\,cm}\; d^{-4} \tag{1}$$

At the point of closest separations, $d = 6.0 \times 10^{-5}$ cm, the static density of energy is $0.20\, erg\, cm^{-3}$. For the micro electromechanical MEMS devices, the Casimir force and the Coulombic force are expressed by the following equations.

$$F_{Cas} = \frac{\pi^3 \hbar c R}{360 d^3} = 2.73 \times 10^{-20}\,\mathrm{dyn\,cm^3}\; d^{-3} \tag{2}$$

$$F_{Coul} = \frac{\pi \varepsilon_0 R V^2}{d} = 5.15 \times 10^{-10}\,\mathrm{dyn\,cm}\; d^{-1} \tag{3}$$

Being $R = 0.01\,\mathrm{cm}$; $\varepsilon_0 = 7.97 \times 10^{-2}$ (dimensionless in c g s); $V = 0.136V$ ($1V = 3.333 \times 10^{-3}\,\mathrm{cm}^{1/2}\,\mathrm{g}^{1/2}\,\mathrm{s}^{-1}$)
In all MEMS systems (Chan and similar) at the "point of closest approach" (7.6×10^{-6}cm) the Casimir force ($\sim 7.0 \times 10^{-5}$ dyn) is equal to the Coulombic force at 136 mV. This point, marks a limit, due to the fact that in all experiments a constant is obtained when the different results are derived in the form of energy density. Then, we can infer that all these "coincident" results, obeys the fact that are measurements of a constant of nature (Table 1).
The Casimir energy density within the boundaries of any microscopic cavity appears from an initially attractive interaction, which then, at the point of closest separation begins to have a repulsive perturbation. Reaching this balance, allows us to register the *static* energy density.
If we consider in Eqts. (2) and (3) as $2R^2$ to be the effective area of the sphere, the static Casimir and the Coulombic pressure are:

$$\rho_{Cas} = \frac{\pi^3 \hbar c}{720 R d^3} = 1.36 \times 10^{-16}\,\mathrm{erg}\; d^{-3} \tag{4}$$

$$\rho_{Coul} = \frac{\pi \varepsilon_0 V^2}{2Rd} = 2.57 \times 10^{-6}\,\mathrm{dyn\,cm^{-1}}\; d^{-1} \tag{5}$$

e.g $d = 7.57 \times 10^{-6}$ cm; $\rho_{Cas} = 0.314\,\mathrm{erg\,cm^{-3}}$; $\rho_{Coul} = 0.337\,\mathrm{erg\,cm^{-3}}$

Reference	Geometry	Sphere radius cm	Closest sep cm	Static Ener. Dens. ρ_{S_t} erg cm^{-3}	Dynamic dens. ρ_{de} g cm^{-3}
Sparnaay; 1958	plane - plane	—	$\sim 5.0 \times 10^{-5}$	∼0.21	$\sim 7.80 \times 10^{-30}$
Lamoreaux; 1997	plane - sphere	11.5	6.0×10^{-5}	0.20	7.50×10^{-30}
Roy - Mohideen; 1999	plane - sphere	0.01	6.5×10^{-6}	0.50	1.90×10^{-29}
Chan; 2001	plane - sphere	0.01	7.6×10^{-6}	0.31	1.10×10^{-29}
Bressi; 2002	plane - plane	—	5.0×10^{-5}	0.21	7.50×10^{-30}
Lisanti; 2005	plane - sphere	0.01	7.6×10^{-6}	0.31	1.10×10^{-29}
Iannuzzi; 2007	plane - sphere	0.01	7.0×10^{-6}	0.40	1.50×10^{-29}
Capasso; 2007	plane - sphere	0.01	7.5×10^{-6}	0.32	1.44×10^{-29}
Kim; 2009	plane - sphere	15.1	5.0×10^{-5}	0.41	1.50×10^{-29}
Sushkov; 2011	plane - sphere	15.6	7.0×10^{-5}	0.11	4.06×10^{-30}
Average				0.296	1.12×10^{-29}

Table 1: The results of static energy density ρ_{st} is obtained from Eqts. (1) and (5). The dynamic energy density or dark enegy ρ_{de} is obtained from Eqts. (28), (29) and (30)

3 Cosmological considerations

3.1 Kinematics implications of H_0

Theorically, 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 second of paralax, given by the diameter of the terrestrial orbit around the Sun, is an anthropic scale unit, and physically unmeaning by itself. On the other hand, if this unit is replaced by the radius of the gravitational collapse, it may 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_n).

When the Universe radius was 6.37×10^{24} cm = 2.64 Mps = R_G with a Planck's blackbody distribution curve corresponding to a temperature of $\sim 5,250$°K, there still existed a fraction of photons in a thermic state equivalent to $\sim 165,000$°K, whose number was the same as the whole population of baryons.

Starting from these conditions, the collapse of gravitation is produced; all the matter and radiation which up to that epoch was in an undiferenciated state, 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 km s^{-1}.Mps^{-1} means second^{-1}; then, as the cosmological space progresses, the Hubble expansion rate will decrease continuously, until it reaches the present time value of $H_0 = 75.4$ $\mathrm{Km\,s^{-1}}$ $\mathrm{Mps^{-1}}$ (Table 2).

m_Λ/m_M	R_U cm	$H(\mathrm{Km\,s^{-1}}Mps^{-1})$	z	Temp.(°K)
1,965	6.40×10^{24}	1.5×10^5	1,920	5,250
1,310	1.01×10^{25}	1.0×10^5	1,280	3,350
983	1.28×10^{25}	1.5×10^4	960	2,625
—	—	—	—	—
7.86	1.60×10^{27}	600	7.68	21.00
6.55	1.92×10^{27}	500	6.40	17.50
5.63	2.24×10^{27}	428	5.55	15.00
4.90	2.56×10^{27}	375	4.80	13.10
—	—	—	—	—
1.025	1.23×10^{28}	75.5	0	2.73*

* Present age

Table 2: The numerical results obtained from Eq. (11) show that the expansion rate is c when the radius of the Universe is $R_G = 2,060$Mps. Making use of this scale, the expansion rate progresively decreases up to the present value of $75.5\mathrm{Km\,s^{-1}\,Mps^{-1}}$.

3.3 Non inflationary origin and evolution of the repulsive dark energy

All the 3.12×10^{87} photons of the CMB radiation (Eq. 18) 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 $4,000$°K the electrons and the hydrogen nucleus will still be at the plasma state. The N_γ 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 $T \sim 6 \times 10^9$°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 $T > 2 \times 10^{12}$°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. $\left\{ \begin{array}{l} 1/4N(p^+ + e^- + \nu_{\mathrm{neutrino}} \to n^0) \\ 1/4N(p^- + e^+ + \nu_{\mathrm{antineutrino}} \to n^0) \end{array} \right\} N/2$ 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 $T = 1.62 \times 10^{32}\,^\circ$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).

3.4 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 $R_G = 1.032$ Mps (gravitational collapse) and R_U^0 (present time radius) we have

$$H_0 = \frac{c}{(z+1)R_G} = \frac{v}{R_G} = 2.45 \times 10^{-18}\,\mathrm{s}^{-1} \tag{6}$$

being $v = 7.8 \times 10^6\,\mathrm{cm\,s}^{-1}$; $R_G = 3.19 \times 10^{24}$ cm

$$H_0 = \frac{c}{R_U^0} = 2.45 \times 10^{-18}\ \mathrm{s}^{-1} \tag{7}$$

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

Equalizing (6) with (7) and reordering, we find the following dimensionless scale

$$2\frac{v}{c} = \frac{1}{z+1} = \frac{v}{H_0 R_U^0} = \frac{R_G}{R_U^0} \tag{8}$$

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

$$2\frac{v}{c} = \frac{T}{T_G} \tag{9}$$

Since H_0 defines the present Hubble expansion rate, and H defines a value of the Hubble constant at different epoch, we may extend (8) in the following way:

$$2\frac{v}{c} = \frac{1}{z+1} = \frac{v}{HR_U} = \frac{R_G}{R_U} = \frac{T}{T_G} = \left(\frac{8m_\Lambda}{M_V}\right)^{1/2} \tag{10}$$

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

$$m_\Lambda = \frac{M_V v^2}{2c^2} = \frac{M_V}{8(z+1)^2} = \frac{M_V v^2}{8H^2 R_U^2} = \frac{M_V R_G^2}{8R_U^2} = \frac{M_V T^2}{8T_G^2} \tag{11}$$

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_Λ 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 $R_G = 1.032$ Mps referential point, is coincident with the withdrawal of the protogalaxies after gravitational collapses.

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 $H_0 t_0 \simeq 1$. Table 2 and 3 illustrate theses properties.

4 The extension of the cosmological space

4.1 Energy constraint

All terms of the Eq. (11) 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 hegemoneously expansive. Up to the $R_G \sim 2.032$Mps, the gravitation collapses, and as it implies a force exerted, this makes a continuous decrease of $m_{de} = M_V v^2/2c^2$. 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:

$$\text{Expansive energy} = F_{\text{grav}} L_{\max} \tag{12}$$

As $F_{\text{grav}} L_{\max}$ is the potential energy U, it determines that the expansive energy (kinetic K) be depressed continuously up to the equilibrium limit given by $1/2K = U$, which constraints the Universe extension ($L_{\max}$).

$$L_{\max} = \frac{M_V v^2}{ZG {m_U^0}^2} R_U^2 \tag{13}$$

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

Being $N_b = 5 \times 10^{79}$ and $m_U^0 = 8.35 \times 10^{55}$ g

$K = m_{de} = M_V v^2/2c^2$ (dynamic mass of the vacuum or dark energy) and $U = m_M = 2G{m_U^0}^2/c^2 R_U$ (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 The cosmological constant problem. Physical meaning of the cosmological term

The cosmological constant Λ, 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 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. (13) is

$$L_{\max} = \frac{M_V v^2}{2G {m_U^0}^2} R_U^2 \tag{14}$$

Multiplying both terms of (14) by $\frac{4\pi R_U c^2}{3}$ and reordering

$$\frac{3c^2}{8\pi R_U\, L_{\max}} = \frac{G\rho_M\, m_U^0 c^2}{M_V\, v^2} \tag{15}$$

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

$$\Lambda = \frac{1}{{L_{\max}}^2} = \frac{-8\pi}{3\,c^2} G\,\rho_\Lambda \simeq \frac{8\pi}{3c^2} G\,\rho_M \tag{16}$$

As $c^2/{L_m}^2 \simeq {H_0}^2$

$${H_0}^2 = \frac{-8\pi\, G\,\rho_\Lambda}{3} \simeq \frac{8\pi\, G}{3} \rho_{m_U^0} \simeq \frac{8\pi\, G\,\rho_M}{3} \tag{17}$$

For $H_0 = 2.44 \times 10^{-18}\mathrm{s}^{-1}$; $\rho_\Lambda = 1.10 \times 10^{-29}\mathrm{g\,cm}^{-3}$

5 Static energy density of the empty space

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 the annihilation of matter-antimatter particles (Isasi; 2012).

The total number of these photons is a constant of nature:

$$N_\gamma = \left(\frac{2\pi R_U}{5\lambda_{CMB}}\right)^3 = 3.18 \times 10^{87};\ \text{e.g. } R_U^0 = 1.23 \times 10^{28}\mathrm{cm} \quad \text{(for present radius)} \tag{18}$$

Hence, the number of photons per cm^3 is

$$n_\gamma = \frac{6\pi^2}{(5\lambda_{CMB})^3} = \frac{3}{4\pi}\left(\frac{kT_{CMB}}{\hbar c}\right)^3,\ k = 1.38 \times 10^{-16}\mathrm{erg}K^{-1} \tag{19}$$

e.g at present time $T = 2.73\,°\mathrm{K}$; $\lambda_{CMB} = 0.105\,\mathrm{cm}$; $n = 408\,\mathrm{photons\,cm}^{-3}$

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

$$\rho_{st} = 102(m_p^+ + m_p^- + m_e^- + m_e^+)c^2 \simeq 204\, m_p^\pm c^2 = 0.31\,\mathrm{erg\,cm}^{-3} \tag{20}$$

Since: $(m_p^\pm + m_e^\pm) \simeq m_p^\pm$

This value is the static density of energy of the vacuum at present time. The vacuum is ubiquitous and an active element which permeates all the universe.

The static density of energy at any temperature below 1×10^{9}°K is

$$\rho_{st} = \frac{1}{2} n_\gamma\, m_p^\pm\, c^2 = \frac{3 m_p^\pm}{8\pi\, c}\left(\frac{kT}{\hbar}\right)^3 = 0.015\,\mathrm{erg\,cm}^{-3}\,°\mathrm{K}^{-3} T^3 \tag{21}$$

5.1 Dynamic repulsive cosmological density (dark energy)

After the gravitational collapse, at temperature below 5, 250°K, the dynamical density is:

$$\rho_{de} = \frac{1}{2} n_\gamma m_p^\pm \frac{v^2}{2c^2} = \frac{3m_p^\pm v^2}{16\pi c^2} \left(\frac{kT_{CMB}}{\hbar c} \right)^3 \tag{22}$$

As the temperature $T_G = 5,250°\mathrm{K}$ marks a point of departure from the gravitational collapse, this temperature can be considered as a constant. Then, according to $v^2/2c^2 = T_{CMB}^2/8T_G^2$, we have:

$$\rho_{de} = \frac{1}{2} n_\gamma m_p^\pm \frac{T^2}{{T_G}^2} = \frac{3m_p^\pm {T_{CMB}}^5}{64\pi {T_G}^2} \left(\frac{k}{\hbar c} \right)^3 = 7.5 \times 10^{-32}\,\mathrm{g\,cm^{-3}\,°K^{-5}} T^5 \tag{23}$$

6 Cosmological H and He highly excited Rydberg atoms

6.1 Thermic equilibrium between the CMB radiation and the Rydberg atoms

The cosmological space acts as an entity, since it expands by itself as an active element (dark energy). This phenomenon from the recombination, becomes clear by stretching the N_γ photons of the CMB radiation which permeates the whole cosmological space in a homogeneous form.

In the halos of galaxies, the intergalactic medium and the medium between clusters and interclusters, the undetectable dark matter is formed by highly excited Rydberg hydrogen atoms at $n = 80 - 90$; $Z = 1$, and by helium Rydberg atoms $Z = 1.34$, at $n = 110 - 120$ which are in perfect thermic equilibrium with the CMB radiation. These Rydberg atoms can by detected by its gravitational effect as dark matter.

According to Bohr's formulation for H and He atom:

$$T = \frac{\Delta E}{k} = \frac{Z^2 m_e e^4}{2\hbar k} \left(\frac{1}{n_i^2} - \frac{1}{n_j^2} \right) \tag{24}$$

$$\mathrm{For} H_{n_i} \leftrightarrows H_{n_j} \frac{\Delta E_H}{k};\ Z = 1,\ \mathrm{result} T = 157,100°\mathrm{K} \left(\frac{1}{n_i^2} - \frac{1}{n_j^2} \right) \tag{25}$$

In the same way for $He_{n_i} \leftrightarrows He_{n_j}$; $Z = 1.34$ we have:

$$T = 282,130°\mathrm{K} \left(\frac{1}{n_i^2} - \frac{1}{n_j^2} \right) \tag{26}$$

As a representative example, in the Milky Way halo, there are 3,200 photons of the CMB radiation for one hydrogen Rydberg atom and 12,800 CMB radiation photons for one Rydberg He atom.

Hydrogen Rydberg atom				Helium Rydberg atom			
n_i	n_j	Temp. °K	λ_{CMB} rad cm	n_i	n_j	Temp. °K	λ_{CMB} rad cm
76	80	2.65	0.109	103	107	2.85	0.101
77	81	2.55	0.113	104	110	2.77	0.104
78	82	2.46	0.117	105	111	2.69	0.107
78	83	3.02	0.096	106	112	2.62	0.110
79	84	2.91	0.099	107	113	2.55	0.113
80	85	2.80	0.103	107	114	2.95	0.098
81	86	2.70	0.107	108	115	2.85	0.101
82	88	3.08	0.094	109	116	2.78	0.104
83	88	2.52	0.114	110	117	2.71	0.106
83	89	2.97	0.097	111	118	2.64	0.109

Table 3: According to Equations (25) and (26) we have some illustrative results for H and He Rydberg atoms. λ_{CMB} radiation is obteined by use of the Eq. (29) T. $\lambda_{CMB} = 0.28804$°K cm.

6.2 Dynamical form of the energy density

The transition from the radiative era, to the gravitational era, occurs after the baryonic mass surpasses the mass-energy of the radiation at 5, 250°K. At this epoch, the first clumps were formed and this point marks the initial time of the Hubble parameter. The radio between the Hubble constant at the present time, with respect its value at the gravitational collapse and other directly related parameters are equal to

$$Y_D^2 = \frac{H_0^2}{2H^2} = \frac{v^2}{2c^2} = \frac{T_{CMB}^2}{8T_G^2} = \frac{R_G^2}{8R_U^2} = \frac{1}{2(z+1)^2}$$

The square of these ratios, defines the dynamical relativistic factor of the empty space in expansion. At present time ${Y_D}^2$ is

$${Y_D}^2 = \frac{1}{2}\left(\frac{75.4\text{km}\,\text{s}^{-1}\text{Mps}^{-1}}{c\ \text{km}\,\text{s}^{-1}\,\text{Mps}^{-1}}\right)^2 = \frac{1}{8}\left(\frac{2.73°\text{K}}{5,250°\text{K}}\right)^2 = \frac{1}{8}\left(\frac{6.2\times10^{24}\text{cm}}{1.23\times10^{28}\text{cm}}\right)^2 = 3.15\times10^{-8} \quad (27)$$

6.3 Expression of the dynamic density for the Rydberg atoms and Casimir experimental results

The dynamic empty space density registered by the Casimir system of measurement is:

plane - plane

$$\rho_{Cas} = \frac{\pi^2\,\hbar\,{Y_D}^2}{240\,c\,d^4} = 4.80\times10^{-47}\,\text{g}\,\text{cm}\;d^{-4} \quad (28)$$

For $d = 5\times10^{-5}$cm $\quad \rho_{Cas} = 7.80\times10^{-30}$g cm^{-3}

plane - sphere

$$\rho_{Cas} = \frac{\pi^2\,\hbar\,{Y_D}^2}{120\,c\,d^4} = 9.75\times10^{-47}\,\text{g}\,\text{cm}\;d^{-4} \quad (29)$$

For $d = 6\times10^{-5}$cm $\quad \rho_{Cas} = 7.50\times10^{-30}$ g cm^{-3}

plane - microsphere

$$\rho_{Cas} = \frac{\pi^3 \, \hbar \, {Y_D}^2}{720 \, R \, c \, d^3} = 5.02 \times 10^{-45} \, \text{g} \; d^{-3} \tag{30}$$

For $d = 7.6 \times 10^{-6}$cm $\quad \rho_{Cas} = 1.10 \times 10^{-29}$ g cm^{-3}

Since the Casimir devices are classical macroscopic system, then, their measurement gives continuous results.

Temp °K	v (cm/s)	R_U (cm)	m_M (g)	m_{de} (g)	ρ_{de} (g cm^{-3})
4,000	1.14×10^{10}	8.4×10^{24}	1.30×10^{59}	1.91×10^{62}	7.70×10^{-14}
105	3.0×10^{8}	3.2×10^{26}	3.35×10^{57}	1.32×10^{59}	9.50×10^{-22}
10.5	3.0×10^{7}	3.2×10^{27}	3.35×10^{56}	1.32×10^{57}	9.50×10^{-27}
2.73	7.8×10^{6}	1.23×10^{28}	8.50×10^{55}	8.90×10^{55}	1.10×10^{-28}
1.05	3.0×10^{6}	3.2×10^{28}	3.35×10^{55}	1.32×10^{55}	9.50×10^{-32}

Table 4: m_{de} is the dynamic relativistic mass of the vacuum; m_M is the relativistic gravitational mass (Sect. 4.1); ρ_{de} is obtained from Eq. (23).

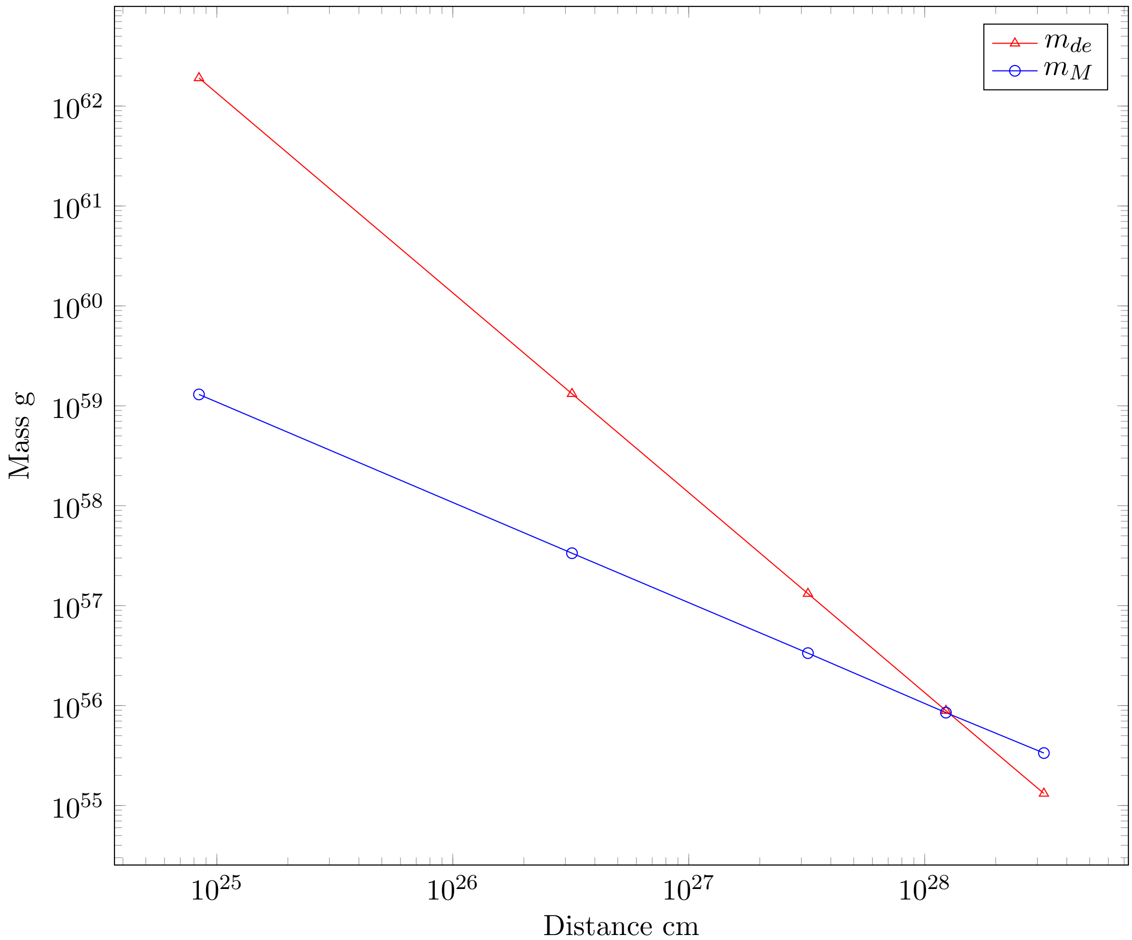

Figure 1: The red line represent the relativistic dynamical mass of the vacuum, m_Λ. The blue line, represent the relativistic gravitational mass, m_M. The numerical values are from Table 4.

7 Conclusions

In natural science, particularly in any branch of the inflationary 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 inflationary "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. In this respect, a new interpretation of the experimental results of the Casimir effect, is a proof of this.

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