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Chapter

A ROLE OF ZERO POINT ENERGY IN THE UNIVERSE EXPANSION

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ABSTRACT

The hot Big-Bang predicts a rate of space expansion without reacceleration, which however is observable. In order to adequate the classic treatment to this problematic, it was analyzed the dimensional evolution of space. Is was concluded that the structure of voids and filaments could be predicted under the assumption that gravitational interactions given place to filament formation allowed that weakened internal gravity could no longer oppose the distention of the voids. The resulting effect would be reacceleration of the space expansion. Therefore, we treated the continuous generation of the Zero Point Energy (ZPE) in the formulation of the expansionary process as the time function term exceeding the effect of gravity. Using a superior limit, for the ZPE of 10% of the critic density and a universe density of 40%, the resulting calculation predicts re-acceleration at 4400 million years after the Big-Bang. It is assumed that ZPE accumulation as a function mainly of the volume-voids evolution, which could be related to the process of elongation and multiplication of Cosmic Microwave Background (CMB).

Keywords: dark energy, Universe expansion, CMB, critical density, voids, ZPE

INTRODUCTION

The present work studies the chronology lapse from the Era of Last Dispersion to the present, and is centered in the evolution of voids as a function of temperature. The latter, parameter gives a homogenous character to the space-time. Thus, De Broglie's wavelength relationship to emission temperature, dimensions quantum properties like radiation pressure and zero point energy (ZPE). However, the universe geometry of the universe shows a heterogeneous distribution of matter-energy, which would turn the finding of iterative geometrical parameters a complex task to achieve.

The observations, theory and computers simulations indicate that the amount of matter in the universe is only 30 percent of the amount necessary to support a flat geometry of the universe, the latter, requires a critical density of $\rho_0 \approx 8.588 \times 10^{-10}$ J/m^3 [1]. However, the same combination of data indicates that the universe is flat. The observations and measurements of ordinary matter in the universe indicate a value of density of around 5% with respect to the critic. Also, a contribution of radiation of the 0,005% is considered, a 0,3% of hot dark matter and a 25% of cold dark matter [2] [3] [4].

In order to increase this value of density, the non-observed dark energy, was proposed to contribute to the Hamiltonian balancing kinetic versus gravity potential. If the hypothesis of dark energy it's not accepted, the relation of kinetic versus gravity would not be in balance, and therefore the universe would show an open geometry. However, it could be postulated a system that would maintain such a balance at lower density than the one generally accepted [5] [6]. ZPE was evaluated [7] at the predicted lower density requirement because indirect measurements consider its superior limit value in the universe of about 10% of critical density [8].

RESULTS

Seeking a mechanism leading to flat geometry at 40% of critical density, 30% in the form of matter and 10% in the ZPE, it was calculated quantum expansion independently of gravitation. This system corresponds with the quantum effect photon multiplication and elongation in the voids. The latter, are so large that we can assume that their interior is free of any relevant gravity by surrounding galactic filaments.

Since the voids volume largely surpass the volume of matter in the galactic filaments Cosmic Microwave Background (CMB) [9] homogeneity is preserved when temperature evolution is evaluated in the sum of the voids volume [10] [11].

The relationship of photon elongation with space expansion [6] [12] is not only sustainable by the CMB describable like a continuum of decreasing energy. Additionally, recent observations of train of photons emanated from supernovas show that the one from a galaxy with redshift 0.5, last less time than the one released by a galaxy at redshift 1 [9] [13].

Hence is possible to evaluate independently of gravitation and matter distribution, the photon elongation within the CMB system as the large scale thermodynamic parameter of the expansion [14] [15] [16].

1. CMB System and the Parameter of the Expansion

The volume of the galaxies has a much lower magnitude that the one occupy by voids, accordingly the evolution of the universe expansion could be related to that of the voids and because that one implies photon-elongation, the latter control space-expansion.

The totality of the universe could be idealized as galaxies immersed in a CMB-system, with a volume which could be individually open but could be treated as close to evaluate cosmological events. The associated CMB spectrum evolves in parallel to expansion parameter $a_{(t)}$, according to time t : $\frac{a_0}{a} = \frac{\lambda_0}{\lambda}$, where the sub-index "0" refers to the present. The λ-elongation of the CMB quantum system becomes a thermodynamic continuum.

The process of photon-multiplication coupled with wavelengths elongation results in CMB localization on the increasing space-time continuum. Hence, the domain space-time-energy relates to a quantum expansion from individual local events, possible related to Spontaneous Parametric Down Conversion (SPDC).

CMB-photon multiplication is equivalent to a SPDC quantum event, the minimum action related with the process of space increment everywhere but specially at voids and the events sum to conform universe expansion. This treatment allowed by the quantum scale could then dimension photon multiplication in terms independent of gravitational features.

Accordingly a photon γ become divided $\gamma \rightarrow \gamma_2 + \gamma_2$, conserving initial *E*, $E = \frac{1}{2}E + \frac{1}{2}E = E_2 + E_2$, duplicating De Broglie's wavelength $\lambda \rightarrow 2\lambda$ decreasing energy $\frac{1}{2}E = \frac{hc}{2\lambda}$. This treatment allows simulation to account for photon number and the coupling of λ-elongation expansion parameter.

The increment $\Delta\lambda$ produced an increment in the confining volume $\Delta V = \frac{\pi}{6}\Delta\lambda^3$. This changes increments ZPE within the voids $\Delta E_{ZPE} = \rho_V \, \Delta V$, where ρ_V is the vacuum density which remain constant along the chronology.

2. The Equations for the Dynamics of Universe Expansion

The dynamic could be described by three independent equations with three parameters: energy density $\varepsilon_{(t)}$, pressure $P_{(t)}$ and the expansion parameter $a(t)$ [17] [18].

$$\left(\frac{a'_{(t)}}{a_{(t)}}\right)^2 = \frac{8\pi G}{3c^2}\varepsilon_{(t)} - \frac{kc^2}{R_0^2 a_{(t)}^2} \tag{1}$$

$$\varepsilon'_{(t)} + 3\frac{a'_{(t)}}{a_{(t)}}\varepsilon + 3\frac{a'_{(t)}}{a_{(t)}}P = 0 \tag{2}$$

$$P = \omega\varepsilon \tag{3}$$

Assuming flat universe $k = 0$ simplify equation (1) $\left(\frac{a'_{(t)}}{a_{(t)}}\right)^2 = \frac{8\pi G}{3c^2}\varepsilon_{(t)}$. Resolving this system to satisfies the three parameters. Substituting with (3) within (2) generates the differential equation $\varepsilon'_{(t)}+3\frac{a'_{(t)}}{a_{(t)}}(1+\omega)\,\varepsilon_{(t)}=0$, solving by the separate variable method $\frac{d\varepsilon}{\varepsilon}=-3\,(1+\omega)\,\frac{da}{a}$ and $\varepsilon_{i(a)}=\varepsilon_{i,0}\times a^{-3(1+\omega)}$ (4). Thus replacing with (4) in (1) results $\left(\frac{a'_{(t)}}{a_{(t)}}\right)^2=\frac{8\pi G}{3c^2}\varepsilon_{i,0}\times a_{(t)}{}^{-3(1+\omega)}$, and $\frac{a'_{(t)}}{a_{(t)}}=\xi\ a^{-\frac{3}{2}(1+\omega)}$ (5), where $\xi=\left(\frac{8\pi G}{3c^2}\varepsilon_{i,0}\right)^{1/2}$ is scalar.

3. Densities Evaluation

Radiation density ε_r within the voids is regarded as only dependent of temperature $\varepsilon_r=\frac{8\pi^5k^4T^4}{15\,h^3c^3}$, its uniform distribution; at the cosmological large scale allows treatment as an adiabatic system.

Matter density ρ_m chronologically becomes a function of the cosmological red shift z, $\frac{\rho_m}{\rho_{m_0}}=\left(\frac{a_{(t_0)}}{a_{(t)}}\right)^3=(1+z)^3$, where the sub-index 0 indicates the present. Radiation density increases at a faster rate $\frac{\rho_r}{\rho_{r_0}}=\left(\frac{a_{(t_0)}}{a_{(t)}}\right)^4=(1+z)^4$. The additional exponent reflex that λ is proportional of expansion parameter $a_{(t)}$ and this one to the red shift $\frac{a_{(t_0)}}{a_{(t)}}=1+z$. The relative proportion between densities $\frac{\rho_m}{\rho_r}=\frac{\rho_{m_0}}{\rho_{r_0}}(1+z)^{-1}$, where in relationship to the present $\frac{\rho_{m_0}}{\rho_{r_0}}\approx 10^4$ and $1+z=T/T_0$, hence $\rho_m=10^4\frac{T_0}{T}\rho_r$. Density in energy terms is $\varepsilon=\rho\,c^2$, accordingly to $\varepsilon_m=10^4\frac{T_0}{T}\varepsilon_r$.

Since vacuum density or ZPE constant $\rho_v=\text{constant}$ [19], in energy terms $\varepsilon_v=\text{constant}$ and the value of the vacuum energy E_V becomes only dependent of the space volume V, hence expansion increments the accumulation of ZPE.

Table 1. Composition of the universe. Calculations for several ZPE levels were done the only included correspond to maximal contribution of 10% of critical density:

$$\varepsilon_v=0.1\,\varepsilon_0\approx 8.588\times10^{-11}\ \text{J/m}^3$$

Matter-energy	Particles	Mass o energy [eV]	Particle number	Total with regard to a flat universe
Ordinary Matter	Protons, electrons	10^9	1.85×10^{78}	5%
Radiation	Photons CMB	6.3×10^{-5}	3.78×10^{87}	0.005%
Hot dark matter	Neutrinos	≤1	3.175×10^{87}	0.3%
Cold dark matter	Particles super-symmetric?	10^{11}	10^{77}	25%
ZPE	¿?	¿?	¿ ?	10%

4. The Pressure Parameter in the Resolution of the Dynamics Equations

The density $\varepsilon_{(t)}$ and pressure $\mathrm{P}_{(t)}$ are additive quantities in equation (3) $\mathrm{P} = \sum \mathrm{P}_i = \sum \omega_i \varepsilon_i$, the total pressure becomes the sum of all partial pressures radiation, matter and vacuum $\mathrm{P}_T = \mathrm{P}_r + \mathrm{P}_m + \mathrm{P}_\mathrm{v}$, where the general terms $\mathrm{P}_{(t)} = \mathrm{P}_T$.

Radiation pressure equal one third of radiation density $\mathrm{P}_r = \frac{1}{3}\varepsilon_r$, the scalar factor omega $\omega = \frac{1}{3}$. The vacuum pressure $\mathrm{P}_\mathrm{v} = -\varepsilon_\mathrm{v}$, when $\omega = -1$. The matter pressure $\mathrm{P}_m = \frac{\mathrm{v}^2}{3c^2}\varepsilon_m$, where v is the average speed of the particles with mass within the universe, with a velocity much lower than that of *c*, $\mathrm{v} << c$, the factor $\mathrm{v}^2/3c^2$ tends to cero $\frac{\mathrm{v}^2}{3c^2} \to 0$, thus $\omega \to 0$.

However, if $\frac{\mathrm{v}^2}{3c^2} \neq 0$, the expression of velocity $\mathrm{v}^2 = \frac{k\mathrm{T}}{\mu}$ allows $\mathrm{P}_m = \rho\frac{k\mathrm{T}}{\mu}$, where μ is the average mass of particles and T the average temperature. Numerically, the calculation shows that $\mu = 1\mathrm{MeV}$ and $\mathrm{T} = 10\,\mathrm{K}$, thus $\mathrm{v}^2 = \frac{1.38\times10^{-23}\mathrm{J/K}\times10\mathrm{K}}{1\mathrm{MeV}\times1.783\mathrm{Kg/MeV}}$ and $\mathrm{v} \approx 8\times10^3\ \mathrm{m/s}$.

Accordingly, $\mathrm{P}_T = \frac{1}{3}\varepsilon_r + \frac{\mathrm{v}^2}{3c^2}\varepsilon_m - \varepsilon_\mathrm{v}$, with $\varepsilon_m = 10^4\frac{\mathrm{T}_0}{\mathrm{T}}\varepsilon_r$, hence $\mathrm{P}_T = \frac{1}{3}\varepsilon_r + \frac{\mathrm{v}^2}{3c^2}10^4\frac{\mathrm{T}_0}{\mathrm{T}}\varepsilon_r - \varepsilon_\mathrm{v}$. At 10% of critical density of $\varepsilon_\mathrm{v} = 0.1\varepsilon_\mathrm{c}$ equivalent to $\varepsilon_\mathrm{v} = 8.58834\times10^{-11}\mathrm{J/m^3}$; and radiation density $\varepsilon_\mathrm{r} = \frac{8\pi^5k^4\mathrm{T}^4}{15h^3c^3}$.

5. The Expansion Parameter

The contribution of partial pressures to total $\mathrm{P}_T = \sum \mathrm{P}_i = \sum \omega_i \varepsilon_i$ could be replaced by a system of equivalent pressure with only one kind of particles $\sum \omega_i \varepsilon_i = \bar{\omega}\,\varepsilon_T$, where ε_T the total density is use for this work and $\bar{\omega}$ is the value that verifies equality, at 40% of critical $\varepsilon_T = 0.4\,\varepsilon_\mathrm{c}$, with $\varepsilon_\mathrm{c} = 8.40043\times10^{-10}\,\mathrm{J/m^3}$.

Table 2. the value of omega ω at the dominant density. Reacceleration of the universe expansion at red shift of z=1.7 implicate a temperature of T=7.357 K, at present measure in CMB T=2.725

Dominant energy	ω	Temperature [K]
Radiation	1/3	10^{32} –3000
Matter	0	3000–7,357
CMB–Voids	–1	7,357–Present

Calculating $P_T = \frac{1}{3}\varepsilon_r + \frac{v^2}{c^2}\varepsilon_m + \varepsilon_v = 0.4\,\bar{\omega}\,\varepsilon_c$, where pressure of mass tends to zero $\frac{v^2}{c^2}\varepsilon_m \to 0$. Assuming that ZPE of 10%, $\varepsilon_v = 0.1\varepsilon_c$, hence $\frac{1}{3}\varepsilon_r - 0.1\varepsilon_c = 0.4\,\bar{\omega}\,\varepsilon_c$, which in temperature parameter becomes $\frac{1}{3}\frac{8\pi^5 k^4 T^4}{15 h^3 c^3} - 0.1\,\varepsilon_c = 0.4\,\bar{\omega}\,\varepsilon_c$, final solution is $\bar{\omega} = -0.24996 \approx -0.25$.

Replacing in the equation $\frac{a'_{(t)}}{a_{(t)}} = \xi\, a^{-\frac{3}{2}(1+\omega)}$ (5), its is obtain $\frac{a'_{(t)}}{a_{(t)}} = \xi\, a^{-9/8}$, integrated $\int a^{1/8} da = \xi \int dt$, with solution is $\frac{8}{9} a^{9/8} = \xi\, t$. Clearing the parameter $a = \frac{3}{4}\frac{3^{7/9}}{2^{2/3}}(\xi\, t)^{8/9}$ is obtain an expansion rate as $\frac{a_0}{a} = \left(\frac{t_0}{t}\right)^{8/9}$, that relate to red shift is $\frac{a_0}{a} = \left(\frac{t_0}{t}\right)^{8/9} = 1 + z$. Present time t_0 estimated between 4.27921×10^{17} and 4.37388×10^{17} seconds.

Reported observations calculated reacceleration for a redshift $z \approx 1.7$ [9]. Introducing this value allows determining the time *t* of acceleration of expansion.

Thus for the lower value 4.27921×10^{17} s, becomes $\left(\frac{4.27921\times10^{17}}{t}\right)^{8/9} = 1+1.7$, and the time $t = 1.39984\times10^{17}$, or 4400 million light years after the Big-Bang.

The higher value 4.37388×10^{17} s, $\left(\frac{4.37388\times10^{17}}{t}\right)^{8/9} = 1+1.7$, and the time $t = 1.43081\times10^{17}$, or 4500 million light years after the Big-Bang.

The average value $t_0 = 4.32655\times10^{17}$ s, $\left(\frac{4.32655\times10^{17}}{t}\right)^{8/9} = 1+1.7$, and the time $t = 1.41533\times10^{17}$ s, or 4480 million light years after the Big-Bang.

6. The Expansion by Spontaneous Parametric Down Conversion Parameter

For this treatment the radiation pressure terms are replaced by SPDC-produce by the De Broglie density energy quantum or photon CMB as a function of either λ or T.

The photon energy $E_\lambda = \frac{hc}{\lambda}$, applying the derivate operator for λ becomes $\frac{dE_\lambda}{d\lambda} = -\frac{hc}{\lambda^2}$. The differential for ZPE is dependent of the volume differential $dE_v = \varepsilon_v\, dV$. The differential for total energy within the voids and excluding baryons particles $dE_T = dE_\lambda + dE_v$.

The volume generate by the λ-De Broglie equals $V = \frac{\pi}{6}\lambda^3$, and the differential $dV = \frac{\pi}{2}\lambda^2\, d\lambda$, assuming that λ correspond to a diameter. Thus the differential for total energy $dE_T = -\frac{hc}{\lambda^2} d\lambda + \varepsilon_v \frac{\pi}{2}\lambda^2\, d\lambda$. Integrating $E_T = \frac{hc}{\lambda} d\lambda + \varepsilon_v \frac{\pi}{6}\lambda^3$ which is to be expressed as a function of temperature becomes $E_T = k\,T + \frac{\pi}{6}\frac{h^3 c^3}{k^3 T^3}\varepsilon_v$.

Voids total density $\varepsilon_T = \frac{6}{\pi}\frac{k^4 T^4}{h^3 c^3} + \varepsilon_v$, where $\varepsilon_{dB} = \frac{6}{\pi}\frac{k^4 T^4}{h^3 c^3}$ De Broglie density $\varepsilon_r = \frac{8\pi^5 k^4 T^4}{15 h^3 c^3}$ and the relation $\frac{\varepsilon_r}{\varepsilon_{dB}} = \frac{4\pi^6}{45}$, $\varepsilon_r = 85.5\times \varepsilon_{dB}$.

Thus, total pressure $P_T = \frac{1}{3}\varepsilon_{dB} + \varepsilon_v = 0.4\,\bar{\omega}\,\varepsilon_c$, accordingly $\varepsilon_{dB} = \frac{45}{4\pi^6}\varepsilon_r$ it is obtain $\frac{1}{3}\frac{45}{4\pi^6}\varepsilon_r - 0.1\varepsilon_c = 0.4\,\bar{\omega}\,\varepsilon_c$, or in temperature terms $\frac{2}{\pi}\frac{k^4 T^4}{h^3 c^3} - 0.1\varepsilon_c = 0.4\,\bar{\omega}\,\varepsilon_c$, and solution $\bar{\omega} = -0.24999 \approx -0.25$. The prediction of expansion rate of the universe based in the λ-De Broglie reach similar conclusions to the one based in the previous treatment: $\frac{a_0}{a} = \left(\frac{t_0}{t}\right)^{8/9}$.

7. Chronology of the Expansion Parameter

The results obtains under the treatments 5 and 6, allows to chronological asses the Eras according the predominance of the density parameter yielding similar dates for re-acceleration.

Hence, also predicting that on a further away time the expansion parameter would maintain a constant tendency for the dissipative state of the density potential. The latter, may manifest the coupling between volume increase and ZPE accumulation at related constant rates. The scattering of electromagnetic zero point radiation by accelerating particles may confer inertia. The latter at the Compton frequency of a particle could lead to a mass equivalence: $\lambda_B = h/p$ [7].

Table 3. Chronology as a function of the dominant density. Eras could be characterized as a function of density from the starting of re-acceleration 4400-4500 million light years after the Big-Bang

Dominant Periods		Radiation		Matter		CMB–Void		Future
Time	[s]	5.4×10^{-43}	1.2×10^{13}	1.2×10^{13}	1.415×10^{17}	1.415×10^{17}	4.33×10^{17}	$t\to\infty$
	[light-years]	×	$3,8\times10^5$	$3,8\times10^5$	4.5×10^{10}	4.5×10^{10}	1.372×10^{10}	
Temperature [K]		1.41×10^{32}	3000	3000	7.3575	7.3575	2.725	$T\to0$
Red Shift: z		$z\to\infty$	1100	1100	1.7	1.7	×	×
Expansion Parameter		×	×	$\frac{a_0}{a} = \left(\frac{t_0}{t}\right)^{2/3}$		$\frac{a_0}{a} = \left(\frac{t_0}{t}\right)^{8/9}$		$\frac{a_0}{a} = k$
Ratios		×	×	$c\int_{1.2\times10^{13}}^{1.415\times10^{17}} \left(\frac{10^{17}}{t}\right)^{2/3} dt$		$c\int_{1.415\times10^{17}}^{4.326\times10^{17}} \frac{4.33\times10^{17}}{t} dt$		$c\int kdt$
Hubble		×	×	$H_0 = 2/3t_0$		$H_0 = 1/t_0$		×

8. Universe Flatness

The photon multiplication in the voids allows inferring a thermal uniformity according to the evolution state of CMB spectrum along the universe chronology. CMB fluctuations may show disregard able values with the mean value of temperature smoothing by the photon multiplication, which gives substance to evaluate a total density for the universe and to calculus finding it lower than critical.

DISCUSSION

ZPE conforms a minimal potential unable to participate in thermal equilibrium an allowing a sustainable dissipation of the potential created by radiation density and allowing the theoretical formulation of a thermodynamic open system between inflation and ZPE.

The arrow of time became conformed by the dissipation of the potential from photons of higher to many more of lower energy by mechanisms like SPDC or other which allow decreasing potential but conservation of energy at lower levels. Accordingly, these processes become irreversibly integrated [20] and maintained away from equilibrium by a dissipative potential [21].

CONCLUSIONS

The chronology increase in volume of voids exerts a pressure that would reinforce the local gravity of filaments attraction of cold and hot matter. The formation of cumulus and super-cumulus, when draining voids of particles, favors and reinforces the joint action of ZPE-CMB distending the space. Thus, the adiabatic CMB-system allows formulating parameters of temperature-density and red shift, in relation to ZPE time-dependent accumulation.

The universe in expansion and with flat curvature could be defined by the cosmological parameter of critical energy density. This one, is generated from kinetic versus gravity the relationship, and has been postulated with a priori requirement of preserving the concept that at the great scales the distribution of matter in the Universe would be homogenous. The data for conceptual fitting leads to calculate a 70% contribution of dark energy to critical density, in order to compensate the insufficient energy-mass content within the observable Universe. Dark energy has not been described physically. Alternatively, ZPE accumulation is a process leading to an inertial force capable to contribute to the driving of space expansion.

Introducing voids evolution allows inferring that the effect of gravity could become less and less significant, because the continuous increment of void volume, restricts in their enclosed space how far could reach the influence of gravity.

The λ-elongation was assayed by a simulation of the mechanisms of SPDC, this one show that the evolution of the CMB radiation spectrum is consistent with the Big-Bang coupling of cooling with expansion.

The chronology after the Last Dispersion Era allows to described expansion of the universe by the evolution of voids, integrating the quantum structure with the continuum of non-equilibrium open thermodynamics of the universe [20] [21], and by ignoring the distribution of matter since filament occupy a much smaller volume than voids.

The results of the sections 5 and 6 create a chronological order as a function density, which allows the calculation of the reacceleration Era. Hence, it naturally predicts that the expansion parameter "*a*" defines a relationship $a_0 / a = k$ and appears link to the accumulation of ZPE.

Accordingly to results either the quantum treatments by photon elongation or by elongation plus SPDC could produce a chronology for the evolution of voids. Hence, allowing the perspective of a quantum integrated Universe under a thermodynamic continuum. Thus, results predict expansion reacceleration at 4400 million light years after Big Bang, which is close to the observational value.

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