From the Big Split of the primal cosmic “Substance” to a five-component vacuum with positive and negative energy densities

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Abstract: This study considers the asymmetric self-division of a preexisting substance at zero-energy as the seeding and nucleation for the cosmic inflation driven by Friedmann equations. This split creates two unsymmetrical constituents that provide the potential energy required for activating the universe expansion and the emergence of three other vacuum ingredients. This expansion model corresponds to a vacuum containing five components, two with positive and three with negative energy densities, including a negative cosmological variable Λ(t). In this model dark energy and dark matter, as identified by the ΛCDM framework, seem to accurately fit the sum of two components.

1- Introduction

The preexisting conditions that triggered the so-called Big Bang is one of the unsolved mysteries in physics [1]. It more or less corresponds to the point zero of the unidirectional arrow of time as manifested in our dimension. Indeed, the ΛCDM framework describes the evolution of the universe since the Big Bang (+ the Planck time), and the cosmic inflation that followed. This is in fact the classical answer to avoiding the mathematical singularity associated with the Big Bang theory and to the violation of the first law of thermodynamics.

In this context, the existence of a primal “substance” (for lack of appropriate terminology), that would asymmetrically divide itself and create potential energy from the two new constituents is appealing. As the matter of fact, asymmetric cleavage creating two charged species from a neutral entity is common in electrical phenomena and electrochemistry. Likewise, the remarkable asymmetric stem cell division that leads to two daughter cells with distinct fates is well documented in molecular biology [2]. Further, the existence of a primal substance avoids the Big Bang singularity issue, and takes on the “filling” principle of the negative pressure space in the inflationary process.

The asymmetric self-division of the primal substance necessarily requires the creation of both positive and negative mass-energies in order to obey overall neutrality, and to conform with the total energy of the universe which is zero. Therefore the universe requires polarization, and symmetry, which seems to be an intrinsic characteristic of this cosmos. Everything in the universe appears to exist along with its opposite counterpart, electrical charges, magnetic poles, numbers, categories, properties, etc., and these opposites make up the dynamic unity of the universe. Coincidentally, the existence of negative mass has regain interest in the last few years, within general relativity framework [3], or bimetric theory [4-5].

This article considers the self-division of a preexisting substance within the cosmological inflation theory governed by Friedman equations, cascading down to the creation of baryons and what is known as dark matter (DM) and dark energy (DE). In this framework, the number of constituents of the vacuum energy becomes five due to the presence of those two extra components arising from the split of the primal substance. The objective of this study is to evaluate the time-dependent fraction $I_i(t)$ of each constituent (i), as well as each contribution factor χ_i to the total vacuum density parameter Ω(t). It is important to realize that the contribution factor χ_i is a positive or negative scalar characteristic of the vacuum constituent (i) itself, whereas the fraction $I_i(t)$ is time-dependent and characterize the abundance of the particular constituent (i) within the vacuum composition. As a consequence, the availability of an adequate function R(t) will be required in order to determine the pair ($I_i(t)$, χ_i) for each of the five vacuum components.

In this context, it is considered that the initiation of the inflation process requires a seeding/nucleation. This nucleation sets off the creation of spacetime and the transparency process of the vacuum, as well as the emergence of the five vacuum fluids into a preexisting fluid of a different equation of state (EOS).

This study will cover the following:

➔ Construction of a simple mathematical function R(t) modeling the average cosmic inflation of a spherical universe in the euclidean space, while obeying some established cosmological constraints. The derivative will produce the time-variable Hubble parameter H(t) and therefore the total energy density parameter Ω(t) expressed by [6]:

$$\Omega(t)=\left(\frac{H(t)}{H_o}\right)^2=\frac{\rho(t)}{\rho_c}=\sum_{i=1}^{5}\Omega_i(t) \qquad (1)$$

with ρ(t) being the total density at time t, ρ_c the critical density and H_o the Hubble constant.

➔ Determination of the 5 density parameters $\Omega_i(t)=\rho_i(t)/\rho_c$ with i=1-5, given a number of constraints that will be detailed further. The 5 constituents of the vacuum are the 2 initial components arising from the self-division of the preexisting substance, and the 3 components emerging later on the time scale. It will be found that those three constituents are not straight equivalent to the three vacuum constituents of the ΛCDM theory (baryons, DM and DE / cosmological constant)

➔ Evaluation of the cosmological variable Λ(t), which will come out negative and variable, and dominating the expansion of the vacuum, therefore better described as a negative quintessence-like fluid, or cosmological variable.

➔ A conclusive discussion about the astonishing mechanism developed by the universe to go from zero-energy to zero-energy, while creating sustainable baryonic matter and complexity in between the two zeros, despite the second law of thermodynamics. Obviously, this is only possible if:

- negative mass-energy is present to balance out positive mass-energy of ordinary matter and maintain both neutrality and zero total energy in the universe
- negative pressure is generated to drive the inflationary process
- both negative and positive energies are continuously created to compensate dilution from the vacuum expansion
- a positive entropy must arise to compensate the negentropic process associated with the creation of vast ordered structures and complexity in the observable cosmos

2- A stretched exponential function to model the average cosmic inflation

The search for a simple function $\log_{10}(R)=f(t)$ to model the cosmic inflation of a spherical universe in the euclidean geometry led to a stretched exponential function of the form:

$$\log_{10}(R)= \alpha - \beta*\exp[-(t/\gamma)^k] \qquad 1<k<2 \qquad (2)$$

The following constraints were imposed:

- The curvature k=0, as observed by the ΛCDM model, and the universe is considered flat. In this case, the inflation rate will eventually slow down drastically and the universe will continue expanding at a very slow rate. This does not necessarily mean that it could not eventually collapse.
- At present-time the expansion is accelerating and the acceleration is exponential
- The current estimated radius of the observable universe is ~ 5 10^{23} km, understanding that the whole universe could be larger.
- Nucleation at t=0 implies $R_{t=0} > 0$
- The ratio $\mathrm{Log}(R_\infty)/\mathrm{Log}(R_{t=0})$ was limited to ~ φ^7, which was found very compatible with the actual observable universe, with φ being the ubiquitous golden mean $\varphi=(1+\sqrt{5})/2$

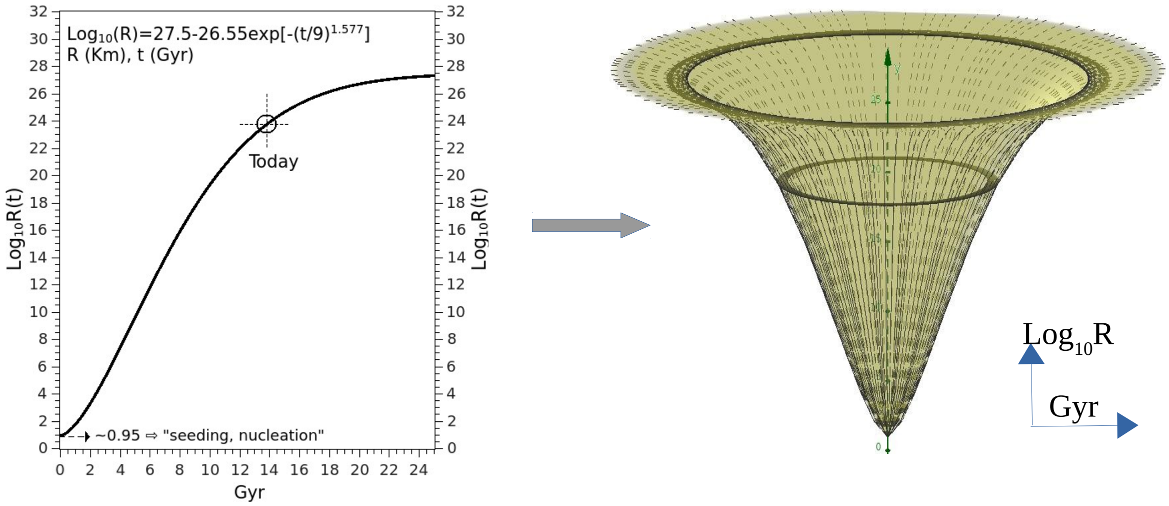
The function found is expressed below and is graphed in Fig. 1

$$\log_{10}R(t)=27.5-26.55*\exp\left(-\left(\frac{t}{9}\right)^{1.577}\right) \qquad \text{with t in Gyr and R in km} \qquad (3)$$

Coincidentally, the factor 1/9 seems exact, and the exponent 1.577 is equivalent to (1+γ) with γ being the Euler-Mascheroni constant. The nucleation radius can be readily found at $\log_{10}(R_{t=0})\approx0.95$. As time goes by, the radius of the universe eventually plateaus, meaning that the expansion rate drastically slows down (reaching 0 at t > 30 Gyrs) after an impressive accelerated expansion (Fig. 2). As a result, the Hubble parameter H(t) will eventually be driven down to zero, and so will the total energy density ρ(t). In fact it is the sum of positive and negative energy densities $\rho(t)=\rho_+(t)+\rho_-(t)$ that will slow down to zero when both energies balance out.

However, the total density of the universe must be maintained positive in between the two zeros so that both the observable and the observer can emerge, dependently arising from the same principles and from the same source, the vacuum. What would be the purpose of an observable universe without observers? As in the words of Andre Linde:"..*The universe and the observer exist as a pair… The moment you say that the universe exists without any observers, I cannot make any sense out of that. I cannot imagine a theory of everything that ignores consciousness… In the absence of observers, our universe is dead.."* [7].

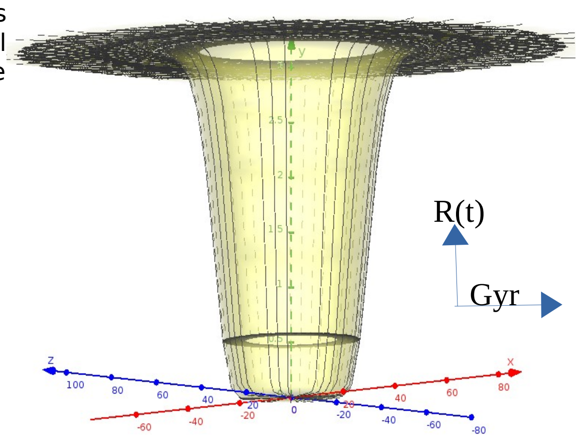
Figure 1: $Log_{10}R(t)$ vs time (Gyr)



The nucleation initiates the inflation process and provides a non-zero radius at t=0. Thus, it does not require a mathematical singularity such as in the Big Bang model. The nucleation is intrinsic to the nature of the two constituents emerged from the asymmetric self-division of the preexisting substance. Thus the function R(t) is expressed in (4), and is graphed in Fig. 2.

$$R(t) = 10^{U} \text{ with } U = 27.5 - 26.55 * \exp\left(-\left(\frac{t}{9}\right)^{1.577}\right) \quad (4)$$

Figure 2: R(t) ($x10^{27}$ km) vs Gyr



Above and beyond the numerical accuracy of the function R(t), the model in Fig. 2 reveals undeniable trends, particularly the exponential acceleration of the cosmic inflation, in accordance with the predictions of the ΛCDM model.

Further, the formula R(t) provides the following characteristics:
- $R_{t=0} \simeq 8.9$ km (nucleation radius)
- $R_o \simeq 5.9 \times 10^{23}$ km
- $R_\infty = 10^{27.5}$ km
- $\text{Log } R_\infty / \text{Log } R_{t=0} \simeq \varphi^7$
- $\text{Log}(R_\infty/R_o) \simeq 2\varphi \text{Log}(10)$

3- Expansion rate and Hubble parameter

The average expansion rate is simply dR/dt which provides the following expression in kms^{-1}

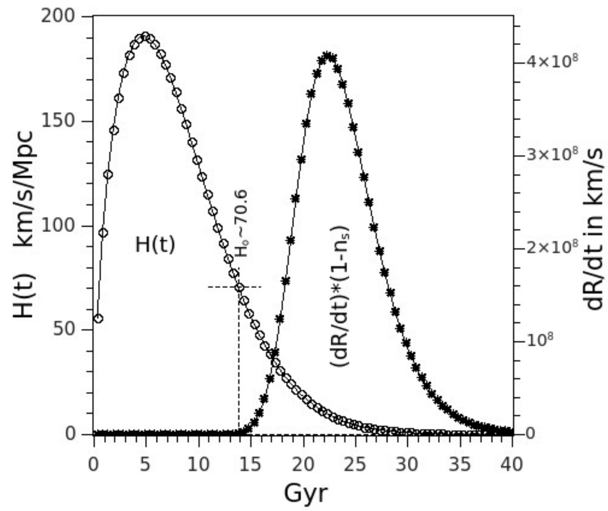
$$dR/dt = 10.73(t/9)^{0.577} \exp\left(2.3U - (t/9)^{1.577}\right)/3.15 \times 10^{16} \quad (5) \quad \text{with U defined in (4)}$$

This formula may provide values of $\dot{R}>c$ in the euclidean space expansion. However, it is recognized that expansion rates exceeding c are not incompatible with general relativity, which enables distant entities to recede from each other at speeds >c [8]. If special relativity excludes objects from moving faster than c with respect to a local frame of reference, it cannot apply when spacetime curvature becomes significant or when distances becomes very important as in cosmology.

Unexpectedly, the Hubble parameter was found to fit the formula:

$$H(t)=\frac{dR}{Rdt}(1-\tilde{k}) \text{ with } \tilde{k}\simeq 0.96 \quad (6)$$

Figure 3: Expansion rate $\dot{R}(t)$ and Hubble parameter H(t)



No rational was found for the factor $(1-\tilde{k})$, but it seems to be required in order to obtain the observed value for H_o. However, it could naturally relate to the scalar spectral index n_s=0.966±0.004, (the most recent estimated value [9]). The scalar spectral index is connected to the hypothetical scalar field believed to be responsible for the cosmic inflation, and describes how density fluctuations vary with scale [10]. So it shall not be surprising that $\dot{R}(t)$ be dependent on n_s since H(t) depends on density in Friedmann equations. Using a value n_s=0.962 provides H_o=70.6 Km/s/Mpc. It should be noted that coincidentally 2Logφ=0.9624.. Applying this factor to $\dot{R}(t)$ in equation (5) provides an expansion rate today of $\dot{R}_o\simeq 1.3\times10^6$ km/s in the euclidean space expansion, therefore ~ 4 times c.

The Hubble parameter is graphed in Fig. 3 with the expansion rate corrected by the factor $(1-\tilde{k})$ as discussed above. Of interest is the quasi Gaussian shape of the expansion rate. The accelerated expansion seems to peak around 22-23 Gyr. On the other hand, H(t) already peaked at ~5 Gyr and has continuously decreased ever since, despite the accelerated expansion. This is due to the fact that R increases faster than $\dot{R}$. The Hubble parameter eventually slows down to zero, contrary to the ΛCDM model which predicts a lower bound for H(t) at around 57 Km/s/Mpc [11]. This difference is mainly caused by the absence of negative mass-energy in the ΛCDM model.

4- The energy density ρ(t)

Knowing H(t), it becomes straightforward to determine the total energy density ρ(t) from Friedmann first equation, assuming a curvature k=0, and a cosmological variable Λ (t)

$$(\frac{\dot{a}}{a})^2 = H(t)^2 = \frac{8\pi G\rho(t)}{3} + \frac{\Lambda(t)c^2}{3} \qquad (7)$$

With a critical density $\rho_c=3H_o^2/8\pi G$ and a total density parameter $\Omega(t)=\rho(t)/\rho_c$ we can write

$$(\frac{H(t)}{H_o})^2 = \frac{\rho(t)}{\rho_c} + \frac{\Lambda(t)c^2}{8\pi G\rho_c} = \frac{\rho(t)}{\rho_c} + \frac{\rho_\Lambda(t)}{\rho_c} = \Omega(t) + \Omega_\Lambda(t) = \sum_1^n \Omega_i(t) \qquad (8)$$

Assuming Λ(t) as a non-specific contributor to the total density parameter with a density

$$\rho_\Lambda(t) = \frac{\Lambda(t)c^2}{8\pi G} \quad (9) \quad \text{we obtain} \quad \Lambda(t) = \frac{8\pi G\rho_\Lambda(t)}{c^2} \quad (10)$$

In equation (7), the contribution from radiations Ω_{rad} is neglected for the sake of simplicity. As the matter of fact, if the universe is considered as a blackbody at temp °K, the total energy density can be estimated by the following formula:

$\rho(T)=\sigma T^4$ with $\sigma=7.56\times10^{-16}$ $Jm^{-3}K^{-4}$ (11)

Today at 2.73°K, $\rho_{rad}\simeq 4.7\times10^{-31}$ Kgm^{-3}, which is ~1.8×10^{-4} ρ_c. (12)

Therefore radiation contribution to the total density will be neglected over the entire time scale, although it might not be totally right around zero, when radiation energy was dominant.

The evolution of the energy density in the universe is expressed through $(H(t)/H_o)^2=\rho(t)/\rho_c=\Omega(t)$ with ρ(t) being the sum of positive and negative energy densities:

$$\rho(t)=\rho_{+}(t)+\rho_{-}(t) \quad (13)$$

This total energy density appears to have reached a maximum when the universe was ~4.8 Gyrs old, and has been decreasing ever since. When positive and negative energies balance out, the total density will be zero, which does not mean the universe will be depleted from energy.

Remarkably, the total energy density parameter curve Ω(t) in Fig. 4 was found very similar to the well known shape of a typical blackbody emission spectrum. As the matter of fact, the overlay of the total density parameter Ω(t) and the CMB/FIRAS monopole spectrum is astonishing, as shown in Fig. 5. The similarity extends down to the X scales, regardless of the scale units (Gyr vs cm^{-1}). This similarity may express some further insight as to the vibrational nature of the vacuum (due to the relation time-period-frequency), or the forces that has been driving the universe expansion, or some kind of fractal relationship. Also of interest is the maxima $\Omega(t)_{max}\simeq 7.3$ occurring around 4.8 Gyrs.

Figure 4: Ω(t) vs. time

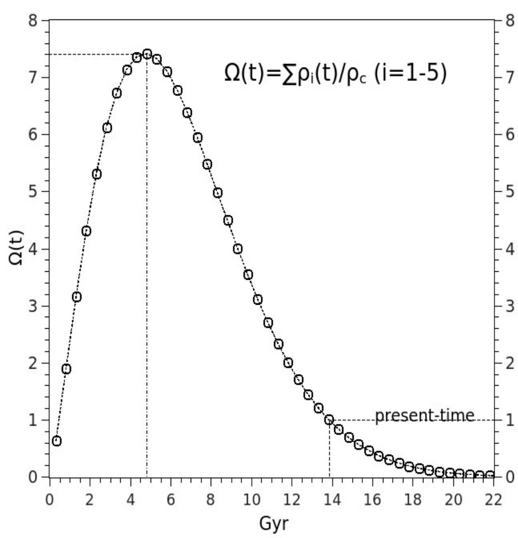
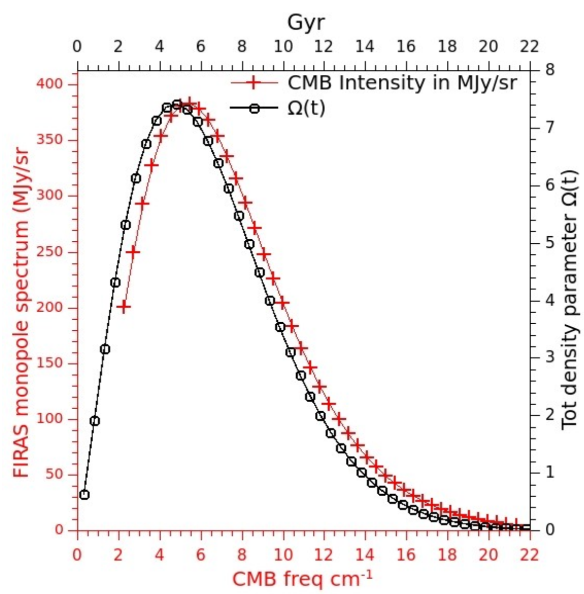


Figure 5: Ω(t) and CMB - (Data from [12]



5- A vacuum made from five constituents. Fractions and contribution factors of individual constituents to the total energy density.

As discussed earlier, the asymmetric self-division of the preexisting substance led to the emergence of two unsymmetrical constituents and therefore potential energy. In turn, those two newly created constituents $I_1(t)$ and $I_2(t)$ will contribute to the birth of the three other ingredients. Those three essential ingredients will be referred as $I_3(t)$, $I_4(t)$, and $I_5(t)$ in Fig. 6.

These five constituents $I_i(t)$ are believed to be the building blocks of the observable and non-observable universe (in addition to radiation). In this picture, baryonic matter will be further identified as $I_5(t)$, and the cosmological variable Λ(t) will turn out to be $I_3(t)$. In the other hand, what the ΛCDM framework identifies as DE and DM will be, in reality, the combination of 2 other $I_i(t)$. Those possible combinations will be determined further.

Now if we make the following statements, with $I_i(t)$ being the fraction or the abundance of constituent (i) then we can write:

$$\sum_{i=1}^{5} I_i(t)=1 \quad \text{(or 100 if working in \%)} \quad (14) \qquad \text{and} \qquad \Omega_i(t)=\frac{\rho_i(t)}{\rho_c}=\chi_i I_i(t) \quad (15)$$

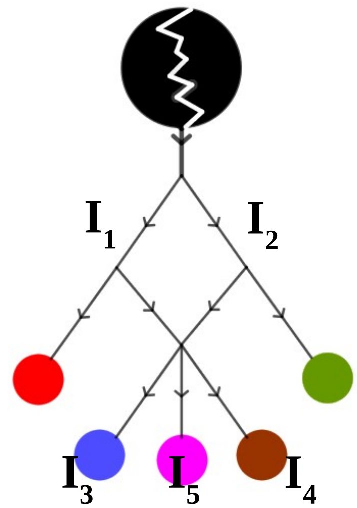
with χ_i being the positive **or** negative contribution factor of $I_i(t)$ to the total energy density ρ(t).

Then, the equation (8) can then be written:

$$\left(\frac{H(t)}{H_o}\right)^2 = \sum_{i=1}^{5} \chi_i I_i(t) \quad \chi \in \mathbb{R} \qquad (16)$$

Figure 6 depicts the asymmetric self-division of the primal substance, propagation, and emergence of $I_3(t)$, $I_4(t)$, and $I_5(t)$. Coincidentally, the early part of Fibonacci sequence can be found in the diagram as 0,1,1,2,3,5 with 0 assigned to the void.

Figure 6: From the primal substance to the five vacuum constituents



The five combinations $(I_i(t),\chi_i)$ i=1-5 can be determined from graphical correlation in accordance with equation (16). This will of course lead to a multitude of possible scenarios. However, a number of constraints will drastically restrict the possibilities. Those restrictions are the following:

- Neutrality of the primal substance implies that χ_1 and have opposite signs
- At $t \simeq 0$ the sum $I_i(0)+I_2(0)=1$ (or 100%), I_3, I_4, and I_5 emerge later on the time scale at the Y=0 line
- The sum $I_i(t)+I_2(t)+I_3(t)+I_4(t)+I_5(t) = 1$ (or 100%) for any value of (t)
- At time t_o (present-time) the constituent $I_5(t)$ (baryons) should be around 4-5%.
- One constituent, $I_3(t)$ or $I_4(t)$, would exponentially grow with time and eventually dominate the vacuum composition. Let's refer to this constituent as $I_3(t) = \Lambda(t)$
- The combination of $I_3(t)+I_i(t)$ with i=1,2, or 4 could make up the DE from the ΛCDM model (~70% @ t_o)
- The combination of two other constituents $I_j(t)+I_k(t)$ could make up the DM from the ΛCDM model (~26% @ t_o), with j and k # i above.
- I_1 and I_2 arisen from the division of the original substance have a strong attraction to each other and continuously try to reunite.

A number of scenario have been obtained through a computed curve fitting/correlation program, and all of them presented both positive and negative energy density contribution factors χ_i. What appeared as the most probable and realistic scenario was retained, and this scenario is presented in Fig. 7 in the following page. The scenario selected clearly requires positive and negative energy densities, and shows the following characteristics:

➔ A long period of latency from t=0 taken as the split of the primal substance, to the emergence of the three sub-constituents $I_3(t)$ + $I_4(t)$, and $I_5(t)$.

➔ The functions $I_3(t)$ and $I_4(t)$ start simultaneously on the time scale @ around 2.2 Gyrs and they both are negative contributors to the total energy density ρ(t). The domination of $I_3(t)$ is exponential and explicit, and seems to level off at around 69%. It appears to be the natural candidate for the cosmological variable Λ(t). This constituent $I_3(t)$ has a relatively small negative contribution to ρ(t). At the present-time, the fraction $I_3(t_o)$ is ~56%. Determination of the today value $\Lambda(t_o)$ can be deducted from equations (10) and (15):

$$\Lambda(t_o) = \frac{8\pi G \rho_\Lambda(t_o)}{c^2}$$ with $\rho_\Lambda(t_o) = \Omega_3(t_o)\rho_c = \chi_3 I_3(t_o)\rho_c$ obtained from the exponential function $I_3(t)$ in Fig. 7 @ t_o=13.8 and in accordance with Table 1. Hence $I_3(t_o)$=0.555 and χ_3= –7.5 which provides

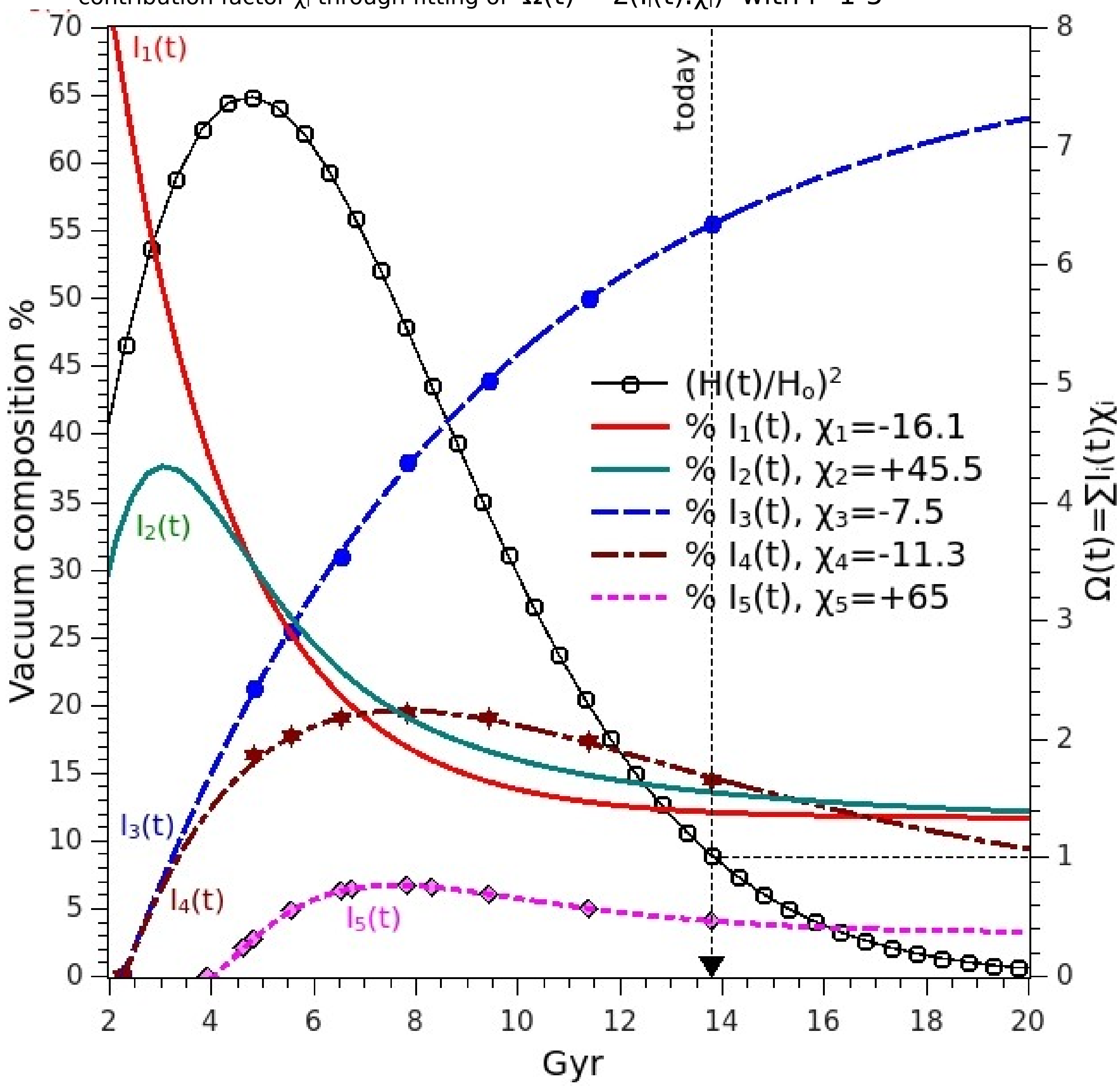
$$\Lambda(t_o) \simeq -6.7 \times 10^{-52}\ m^{-2} \qquad (17)$$

given $\rho_c = +8.62\times10^{-27}$ kg/m^3 , $G=6.674\times10^{-11}$ m^{3}kg^{-1}s^{-2} and $c=2.998\times10^8$ ms^{-1}. This value obtained for $\Lambda(t_o)$ is negative, but in the same order of magnitude as that provided by ΛCDM (≈ 1.10×10^{-52} m^{-2}) [13]. Negative values for Λ have been proposed in other studies [14].

➔ The function $I_5(t)$ was easily attributed to baryons, and emerges with the strongest positive energy density contributor (χ_5=+65) as one could logically expect. Baryon formation seems to begin @ ~4 Gyrs and eventually follows an asymptotic limit around 3.3%. The creation of baryons needs to be continuous in order to compensate for the cosmic expansion and preserve a stable level. This continuous creation of baryons has already been suggested [15].

➔ The two initial constituents $I_1(t)$ and $I_2(t)$ have strong and opposite contributions to the total energy density, χ_1=–16.1 and χ_2=+45.5 respectively. This huge distinction may reveal additional information about the origin of potential energy at the beginning of the universe. As expected, the fate of $I_1(t)$ and $I_2(t)$ is also driven by their strong mutual attraction and their tendency to reunite. This attraction is explicit in Fig 7.

Figure 7: Graphic determination of the functions $I_i(t)$ and associated energy density contribution factor χ_i through fitting of $\Omega(t) = \Sigma(I_i(t).\chi_i)$ with i=1-5



➔ The various parameters found from the correlation/fitting exercise in Fig. 7 are summarized in Table 1 below. From the contribution factors χ_i described in this table, the evolution with time of all the density parameters $\Omega_i(t)$ can be graphed, creating the dynamics of the vacuum composition. This graph is presented in Fig. 8.

Table 1: Summary of parameters found (t_o=present-time)

Constituents →	$I_1(t)$	$I_2(t)$	$I_3(t)$ $\Lambda(t)$	$I_4(t)$	$I_5(t)$ Baryons	Sum
χ_i=contribution factor of $I_i(t)$ to total $\Omega(t)$	–16.1	+45.5	–7.5	–11.3	+65	NA
$I_i(t_o)$ in fraction	0.121	0.135	0.555	0.147	0.041	0.999
$\Omega_{i,o} = \rho_i(t_o)/\rho_c$	–1.95	+6.14	–4.16	–1.66	+2.67	+1.04
$\rho_i(t_o)$ in Kg/m^3	-1.7×10^{-26}	$+5.3\times10^{-26}$	-3.6×10^{-26}	-1.4×10^{-26}	$+2.3\times10^{-26}$	$+8.9\times10^{-27}$
$\Lambda(t_o)$ in m^{-2}			-6.7×10^{-52}			

➔ In Fig. 9 the fraction of constituent $I_3(t)$ has been graphed as a function of the scaling factor $a(t)=R(t)/R_o$, more specifically as a function of Log(a). In this way, the resulting exponential function gives directly access to the power of a(t) used in the following expression derived from Friedmann equation, expression well known in the concordance ΛCDM model:

$$\left(\frac{H}{H_o}\right)^2 = \sum_{i=1}^{n} \Omega_{i,o}\, a^{-k_i} \qquad (18)$$

In this equation, $\Omega_{i,o}$ is the density parameter of constituent i at t_o, a is the scaling factor at time t, and k_i the power exponent of a(t) relative to constituent i. The ΛCDM model predicts for the cosmological constant the exponent $k_\Lambda = 0$, meaning that Λ is constant over time and therefore independent of the scaling factor. It is found in this study that k_Λ=0.0156, therefore close to zero but not exactly zero.

Figure 8: Graph showing the evolution of the 5 density parameters $\Omega_i(t)$

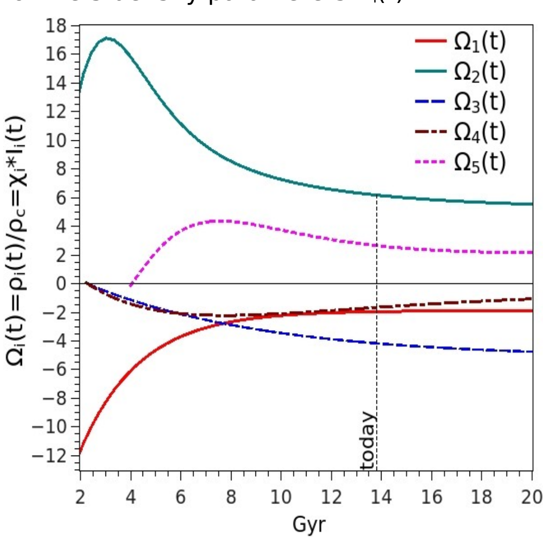
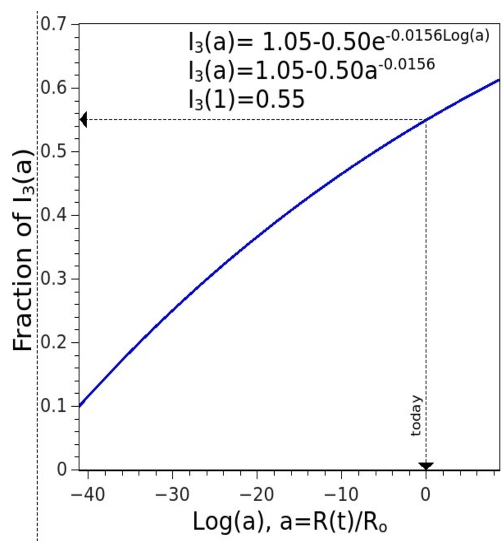


Figure 9 : Fraction $I_3(t)$ vs. Log(a)



➔ In this study, the cosmological variable Λ(t) was easily identified as $I_3(t)$ due to its specific exponential growth over time. However, what the ΛCDM model attributes to DE and DM might be a combination of 2 constituents, due to the fact that the number of cosmic constituents is now 5 instead of 3 in the ΛCDM model. A close look at Table 1 reveals 3 possible combinations, which are summarized in Table 2 below. Amazingly, all three combinations are close to the published data for DE and DM, around 0.69 and 0.26 respectively. Although none of the combinations can be favored at this time, proceeding by elimination suggests that scenarios B and C are the closest to these values. Further $I_2(t)$ is positive therefore closer to the characteristics of DM than to DE. In consequence we are left with the most probable combination C, where DE is the sum of two negative contributors, while DM is the sum of one negative and one positive contributor.

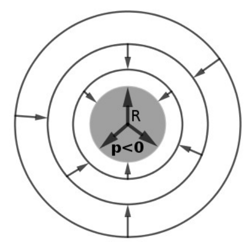
Table 2: Correspondence with DE and DM from the ΛCDM model

Scenario #	Dark Energy (DE)	Sum	Dark Matter (DM)	Sum
A	$I_3(t_o)+I_1(t_o)$	0.676	$I_2(t_o)+I_4(t_o)$	0.282
B	$I_3(t_o)+I_2(t_o)$	0.690	$I_1(t_o)+I_4(t_o)$	0.268
C	$I_3(t_o)+I_4(t_o)$	0.702	$I_1(t_o)+I_2(t_o)$	0.256
ΛCDM	DE	0.69	DM	0.26

6. The vacuum pressure p(t)

Of great interest is the evolution of the total vacuum pressure p(t). Friedmann acceleration equation is usually expressed in the following form:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) + \frac{\Lambda c^2}{3} \qquad (19)$$



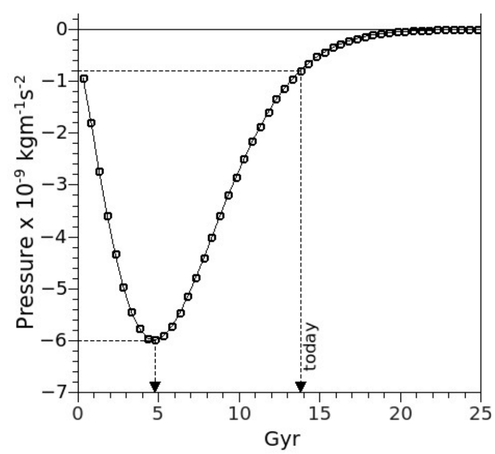
which can be rewritten as

$$\dot{H} + H^2 = \frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(\rho + \frac{3p}{c^2}\right) \qquad (20)$$

Therefore the expression of p(t) can be rearranged in the following form

$$p(t) = -\frac{c^2}{4\pi G}\dot{H}(t) - \left(\frac{c^2}{4\pi G} + \frac{\rho_c c^2}{3H_0^2}\right)H(t)^2 \qquad (21)$$

Fig 10: p(t) vs Gyr



The function p(t) is graphed in Fig. 10. When compared to the equation of state (EOS) of a perfect fluid $w=p/\rho c^2$, with w being the EOS parameter, it is found a value consistent with w= –1. Then we can write

$p(t) + c^2 \rho(t) = 0$ then

$$p(t) + c^2[\rho_+(t) + \rho_-(t)] = 0 \qquad (22)$$

The vacuum pressure minimum value was found = -6×10^{-9} $kgm^{-1}s^{-2}$. At present-time (t_o), the vacuum pressure $p(t_o)$ is found at -0.8×10^{-9} $kgm^{-1}s^{-2}$.

Negative pressure in inflationary theory implies that the expansion results from “filling up” the negative pressure space. However, some kind of external substance is required to occupy that space, and the primal substance maybe the substance playing that function.

7. Conclusion

The assumption of the existence of a primal “substance” making up the initial void has some advantages: it wipes out of the mathematical singularity associated with the Big Bag theory, and does no longer need to infringe the first law of thermodynamics. Further, it is perfectly compatible with the cosmic inflation theory.

The preexistence of this substance at zero-energy requires an asymmetric self-division in order to create potential energy and polarization of the universe. In turn, the two daughter substances provide the seeding/nucleation that initiates inflation and creation of spacetime. They also provide the roots for the emergence of the other constituents of the vacuum, essentially radiation, baryons, and what is known today as DE and DM. Under the assumption of a 5-constituent vacuum, DE and DM fit closely the partial sums of 2 constituents.

The total energy of the universe must remain zero at all time, and this is generally a common consensus. However, maintaining the total energy at zero requires the existence of negative mass-energy density to balance out the observable baryonic matter. Together with the modeling of the inflation radius through a simple function R(t), it was found that the vacuum energy is made from 2 positive and 3 negative energy densities, which includes a negative cosmological variable $\Lambda(t)$.

Figure 11: $\Omega_+(t)$ and $\Omega_-(t)$ vs Gyr

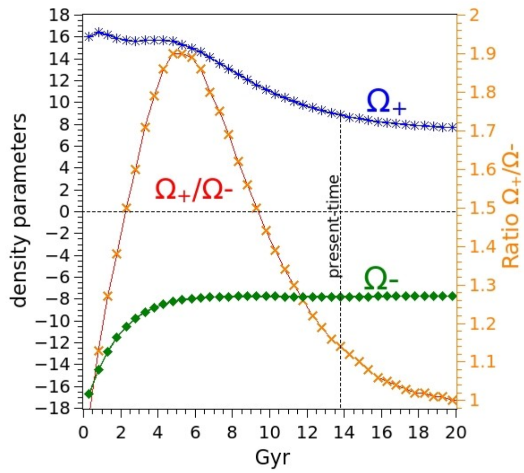


Fig. 11 depicts the ratio of positive to negative energy densities parameters $\Omega_+(t)/\Omega_-(t)$. This ratio peaked at around 5.5 Gyrs with a value $\Omega_+/\Omega_- \approx 1.9$. At the present-time, the ratio $\Omega_+(t_o)/\Omega_-(t_o) \simeq 1.14$.

The accomplishment of the universe at generating baryons from a primal substance at zero energy is a remarkable achievement. When positive and negative energies eventually cancel out ($\Omega_+/\Omega_-=1$), then the overall energy density goes back to zero, as shown in Fig 10. Meanwhile "stable" baryonic matter was created, and with baryons come atoms, molecules and the impressive variety of manifested forms called living beings, with various degrees of consciousness. These living beings, or observers, are equipped with sophisticated senses that allow observation, which can even make the wave function to collapse causing particles to appear [16]. This of course recalls the anthropic principle of cosmology, first introduced in the scientific literature in 1974 by Brandon Carter. This principle considers the fine-tuning of the universe designed for emergence of intelligent life. Could the beginning of the universe be animated with "intention"? As Freeman Dyson wrote: "*As we look into the universe, and identify the many accidents of physics and astronomy that have worked together to our benefit, it almost seems as if the universe must in some sense have known we were coming"* [16]. As such, it's rather difficult to imagine the universe violently destroyed in a Big Rip or a Big Crunch, in light of that implied "intention". But as A. Ijjas, P. Steinhardt and A. Loeb wrote in a 2017 Scientific American article: *"Inflation is such a flexible idea that any outcome is possible".*

The other fundamental question is of course the evolution of entropy with time, which at first does not seem to obey the 2nd law of thermodynamics. As the matter of fact, if we consider the energy of the preexistence substance at zero, then the corresponding entropy ought to be maximum. Obviously the self-division of the primal substance creates negentropy, and so does the cosmic inflation leaving behind complexity and highly organized structures such as galaxies, clusters, stars, etc. and intelligent life. Therefore in order to balance this negative entropy, positive entropy must be created in order to obey the 2nd law of thermodynamics. Looking at the overall picture, this positive entropy could well be the information entropy of the universe, given the enormous amounts of bits of information circulating across the cosmic web at any given time. Of course, this affirmation echoes the holographic principle, first described in the 1990's by 't Hooft and Susskind [17]. Therefore the following would make sense:

$$S_{total} = S_{thermodynamics} + S_{information}$$

Finally, this paper shows that the existence of negative mass-energy in the vacuum is compatible, with a flat universe with curvature k=0, not necessarily with k=-1 [18]. But the most amazing fact is that positive and negative mass-energies can coexist in the vacuum without annihilation. This may have to do with the unusual interaction between positive and negative particles, usually referred as "run away" motion. This behaviour could create the right conditions so that the probability of collision between (+) and (-) mass particles is considered non-existent. Astonishingly, J.M. Souriau demonstrated that negative mass is equivalent to reversing time [19].

7. References

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