Article

Not peer-reviewed version

# Revisiting The Universe Expansion and Dark Energy Problem

John G. Bartzis *

Posted Date: 17 June 2025

doi: 10.20944/preprints202506.1270.v1

Keywords: universe expansion; dark energy; cosmological constant problem; vacuum energy; quantum field theory

*Article*

# Revisiting The Universe Expansion and Dark Energy Problem

**John G Bartzis**

Department of Mechanical Engineering, University of Western Macedonia, Active Urban Planning Zone (ZEP), 50100, Kozani, Greece; bartzis@uowm.gr; Tel.: +302461056710

**Abstract:** The common understanding today is that the Universe is expanding. Although the consensus still favors an accelerating universe, some studies have suggested that when data uncertainties and model assumptions are carefully taken into account, the evidence may not be as strong as initially claimed. This highlights the need for continued scientific scrutiny and more refined analyses. The concept of dark energy has played a catalytic role in cosmic dynamics. The standard cosmological model assumes that dark energy takes the form of a cosmological constant—an energy density that remains constant in space and time. However, this has led also to problems, remaining unresolved today. Trying to be as consistent as possible with the today's state-of-the-art, a new concept is introduced concerning mainly the Hubble parameter treatment and dark energy behavior. Concerning present key findings: (a) indication of a non-accelerated expanding universe dictated by the universe global inflow "Energy Rate (ER)" with a constant expectation value, (b) indication of a universe most likely, born and sustained by the quantum vacuum energy associated with space. The present concept seems to resolve the cosmological constant problem controversy in full alignment with the quantum field theory predictions.

**Keywords:** universe expansion; dark energy; cosmological constant problem; vacuum energy; quantum field theory

---

## 1. Introduction

The general understanding today is that the Universe is expanding and accelerating based on experimental evidence and modeling considerations [1,2]. However there have been reservations questioning the acceleration evidence [e.g. [3,4]) mainly due to data and interpretation uncertainties. One of the key parameters affecting universe expansion is the Hubble Parameter (H), (e.g. [5]), quantifying the rate at which the universe is expanding at any given time (t):

$$H(t) = \frac{\dot{R}(t)}{R(t)} \quad (1)$$

where R(t) is the length scale factor, describing how distances in the universe expand with time.

On the other hand the general relativity formulated by Einstein [6], is the prevailing theoretical framework to describe the Universe evolution and dynamics. More specifically, the Friedman equations are the set of equations in cosmology that govern the expansion of space in homogeneous and isotropic models of the universe. They are derived from **Einstein's field equations** of general relativity under the assumption of the **Friedmann–Lemaître–Robertson–Walker (FLRW)** metric(e.g. [5]). These equations describe the universe expansion, acceleration and energy conservation. A widely used approach to study universe dynamics, is based on the introduction of dark energy [7] described through the cosmology constant(Λ) [6]. In practice, Λ has been introduced into the original Friedmann Equations leading to modification(e.g. [5]).

It is noticed that the nature of dark energy has not been fully understood today and the constant value of Λ although it has been extensively used, it lacks yet adequate global acceptance, In fact, there are findings giving a preference towards a more dynamic behavior of the dark energy (e.g. [8]).

It should be noticed in addition, that quantum theory based on Heisenberg Uncertainty principle, predicts a rather significant energy density for empty space, but astronomical observations show that the energy density associated with the above cosmological constant, is quite small in serious discrepancy with the above quantum field theory ptredictions [9]. It is noticed that this very high discrepancy consists one of the major unresolved problems in cosmology today.

Another major challenge to the standard model is the "Hubble tension"—a significant discrepancy between measurements of the Hubble constant obtained from the early Universe (via cosmic microwave background data) and those derived from the local Universe (using Type Ia supernovae and Cepheid variables) [10]. Despite increasing precision on both fronts, the disagreement persists and has prompted speculation about possible new physics beyond the standard ΛCDM framework.

From the discussion above, it is rather clear that concerning the universe expansion and dark energy problem, there are important open questions that is worth revisiting. The present study pays such a revisit, trying to start from the basics. The ambition of the effort is to be conceptually in agreement with (a) the principle of the Least Action [11], (b) Newton's Third Law of Motion [12] and (c) the logical principle: 'simplicity first'. The whole approach starts with the Hubble parameter considerations and associated hypotheses.

## 2. The Present Approach and the Results

In this work, the Universe spatial curvature is considered flat (k=0). It has been a common approximation since several observations show that universe is very close to flat (e.g. [5]).

### *2.1. The Hubble Parameter and the Total Energy Density*

As mentioned above, the Hubble parameter (H(t)) is given by Equation (1). A range of estimations for the H(t) for present time ($H_0$) based on observation data and their analysis [13,14] is :

$$H_0 \approx (2{,}17 \div 2.37) \times 10^{-18}\ sec^{-1}$$

The above value seems to correlate rather well with the age of Universe ($t_0 \approx 4.4\ x\ 10^{17}$ sec) (e.g. [5]):

$$H_0 \approx \frac{1}{t_0} \approx 2.29 \times 10^{-18} sec^{-1} \quad (2)$$

a value well within the range given above.

It is logical to examine to what degree such an observation might not be a coincidence. Therefore, we are introducing the following two key hypotheses:

<u>1st Key Hypothesis: T</u>he Hubble parameter is proposed to be given for the whole universe time by the following equation.

$$H(t) = \frac{\dot{R}(t)}{R(t)} = \frac{1}{t} \quad (3)$$

where t is the elapsed time after the Big Bang

In consistency with above hypothesis, we introduce the additional key hypothesis.

<u>2st Key Hypothesis:</u> The concept of dark energy remains as the repulsive gravity constituent directly related to the attractive gravity constituents (e.g. matter, radiation). Such a hypothesis introduces a dynamic form of dark energy expressed through the dark energy density ($\rho_{de}$). Thus, the total energy density (ϱ ) consists of the sum of the attractive gravity constituents ($\rho_{ag}$) (mainly matter ($\rho_m$) and radiation ($\rho_{rad}$)) and the repulsive gravity constituent (i.e. dark energy ($\rho_{de}$)) :

$$\rho = \rho_{ag} + \rho_{de} \approx \rho_m + \rho_{rad} + \rho_{de} \quad (4)$$

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 June 2025 doi:10.20944/preprints202506.1270.v1



Equation (4) underlines the assumption that in the present concept, the universe exists due to the balancing coexistence of gravity attractive and gravity repulsing forces. in conceptual agreement with Newton's Third Law of Motion.

The key questions here are : (a) to what degree such a concept meets the reality and (b) can it generate new knowledge useful to lead to new considerations on Universe nature and evolution ?

We concentrate first at the total density evolution.

Let us consider the original first Friedmann equation for the total energy density (ϱ) :

$$(\frac{\dot{R}}{R})^2 = \frac{8\pi G}{3c^2}\rho \quad (5)$$

Equation (5) can be used to estimate the present time value ( $\rho_0$ ) using the $H_0$ value of equation (2).

$$\rho_0 \approx 8.46 \times 10^{-10}\, Joules/m^3 \quad (6)$$

a value rather close to the critical density given in literature (e.g. [5]) : $7.8 \times 10^{-10}\, Joules/sec$

The solution of equation (5) , taken into consideration equation (3), gives the following simple relationship for the total density as a function of time :

$$\frac{\rho(t)}{\rho_b} = (\frac{t}{t_b})^{-2} \quad (7)$$

where $t_b$ is the time when equation (7) starts to apply and $\rho_b$ is the corresponding density.

$\boldsymbol{t_b}$ is most likely to relate to the Planck time scale ( $\boldsymbol{t_{Pl}}$) which is **widely regarded as the transition point** from a quantum gravitational epoch, to a classical, expanding universe **and when the** general relativity starts to apply. In that case, it is plausible to assume $\boldsymbol{t_b \approx t_{Pl}}$ . It is reminded that $\boldsymbol{t_{Pl}}$ is given by the relationship [15].

$$t_{Pl} \sim \sqrt{\frac{h \cdot G}{2\pi c^5}} = 5.39 \times 10^{-44}\, sec \quad (8)$$

We can apply equation (7) with ϱ and t of the present time and estimate $\rho_b$ setting $t_b = t_{Pl}$ as estimated from equation (8), The result has as follows:

$$\rho_b \sim 5.5 \times 10^{112}\, Joules/m^3 \quad (9)$$

We can compare now this value with the Planck energy density scale, Recall that the Plank Energy density scale is given by the relationship :

$$\rho_{Pl} \sim \frac{2\pi c^7}{hG^2} = 4.63 \times 10^{113}\, Joules/m^3 \quad (10)$$

It is clear that $\rho_b$ and $\rho_{Pl}$ are comparable !

This result is quite interesting if one takes also into consideration, that Planck energy density is directly related to the vacuum energy density $(\rho_{QFT})$ arising from quantum fluctuations of fields in space, when confined within the Planck regime. It is derived by summing the zero-point energies of quantum fields up to the Planck scale [16].

$$\rho_b \sim \rho_{pl} \sim \rho_{QFT} \sim 10^{113} Joules\,/m^3 \quad (11)$$

Thus, the above findings have led to the following proposal for the universe energy density estimation:

$$\rho(t) \sim \rho_{Pl} \cdot (\frac{t}{t_{Pl}})^{-2} \sim \rho_{QFT} \cdot (\frac{t}{t_{Pl}})^{-2} \quad (12)$$

It should be underlined that equation (12) is a very important finding since it seems to resolve the controversy of the cosmological constant problem as mentioned above. It is reminded that the vacuum energy density ($\rho_{vac}^{\Lambda}$) derived from observations and the cosmological constant (Λ) is estimated $\rho_{vac}^{\Lambda} \approx 5.96 \times 10^{-10}\, Joules/m^3$ . In other words, instead of $\rho_{vac}^{\Lambda}$ and $\rho_{QFT}$ being comparable, they differ by 122 orders of magnitude.

Preprints.org (www.preprints.org) | NOT PEER-REVIEWED | Posted: 17 June 2025 doi:10.20944/preprints202506.1270.v1



*2.2. The Universe Expansion and Total Energy*

If we differentiate Eq (3) we can derive the second derivative of R(t) expressing the Universe acceleration. We find the interesting result :

$$\ddot{R}(t)=0 \quad (13)$$

Equation (13) marks a significant departure from the present understanding on university acceleration. As discussed before, the latter seems to be widely supported but without full universal acceptance. It is worth noting, that Nielsen et al [3] have revisited the existing evidence for the universe accelerated expansion by analyzing the dataset of Type Ia SuperNovae (SN Ia) [17]. A key conclusion was that the data were quite consistent with a constant rate of universe expansion.

The solution of equation (13) gives the universe expansion:

$$R = c \cdot t \quad (14)$$

Let us recall the original 2nd Friedmann Equation dealing with Universe acceleration:

$$\ddot{R} = -\frac{4\pi G}{3c^2} R(\rho + 3P) \quad (15)$$

This leads to following relation for the pressure:

$$p = -\frac{1}{3} \cdot \rho \quad (16)$$

To what degree equation (16) makes sense, it is discussed later.

First, in order to get the whole picture we consider the Friedmann energy conservation equation

$$\dot{\rho} = -3\frac{\dot{R}}{R}(\rho + P) \quad (17)$$

Recall that the universe total energy ( E ) can be approximated :

$$E \approx \rho \cdot \frac{4\pi}{3} R^3 \quad (18)$$

We differentiate:

$$\frac{\partial E}{\partial t} \approx \frac{4\pi}{3}(\dot{\rho} \cdot R^3 + 3R^2\rho) \quad (19)$$

Substituting $\dot{\rho}$ given by equation (17) , we end up with the following relation regarding universe energy rate (ER):

$$ER = \frac{\partial E}{\partial t} \approx -4\pi \cdot \dot{R} \cdot R^2 \cdot P \quad (20)$$

Equation (20) indicates that the universe energy evolution is controlled by the pressure P and consequently by the factors shaping up this pressure. Negative pressure is directly related to the energy inflow, contributing to the universe expansion.

Substituting now the pressure given by equation (16) in the equation (20), we obtain for the energy rate (ER). :

$$ER = \frac{4\pi}{3} \cdot \dot{R} \cdot R^2 \cdot \rho \quad (21)$$

Taking into consideration equations (5), (14), and (21) we can express and estimate ER as follows :

$$ER \approx \frac{c^5}{2G} = 1.81 \cdot 10^{52}\ \text{Joules/sec} \quad (22)$$

This result is also interesting: ER is a constant. If this is true, energy is pumped into the universe with a constant rate. In other words the universe evolution is characterized by an additional global constant (ER): the expectation value of the universe inflow Energy Rate (ER).

It should be noted , in addition, that the relation (22) is expected to be valid up to the Planck epoch.

Recall that the Planck time scale ( $t_{Pl}$ ) is given by equation (8) whereas the Planck energy scale ($E_{Pl}$ ) is given by the relationship [17] :

 doi:10.20944/preprints202506.1270.v1



$$E_{Pl} \sim \sqrt{\frac{h \cdot c^5}{2\pi G}} \sim 10^9 \; Joules \; (23)$$

The relations (8) and (23) can lead to the following scaling for ER:

$$ER = \frac{c^5}{2G} \sim \frac{E_{Pl}}{t_{Pl}} \; (24)$$

The above relationship , if it is true, is quite significant at least for the following reasons:

(a) The Universe seems to have its roots within its Planck regime exporting vacuum energy at a rate ER.

(b) The expectation value of ER is continuous and constant i.e. another new universal constant dictating the Universe dynamics.

It would be interesting to investige further, whether this vacuum energy is exported to universe in the form of energy 'bursts' with a frequency $1/t_{Pl}$

We are closing this topic by estimating the universe total energy evolution starting fom equation (24) :

$$(E - E_{Pl}) \sim ER \cdot (t - t_{Pl}) \; (25)$$

In obtaining equation (25) we have made the plausible assumption that the initial energy is scaled by the Planck energy $E_{Pl}$.

### *2.3. Universe Composition and Pressure*

We have to go back to equation (16) addressing the pressure vs density relationship. It is reminded that the current state-of-the art suggests that at the present time, the universe is composed mainly by matter and dark energy. Keeping in mind that (a) the present study is concentrating more on setting rather refine the present concept and (b) seeking for first order approximations drawn from the state of the art, we can claim that at the present time the matter energy density ($\rho_{0,m}$ ) is given by the relationship $\rho_{0,m} \approx \frac{1}{3}\rho_0$ , which implies for the dark energy density $(\rho_{0,de})$ :

$$\rho_{0,de} \approx \frac{2}{3} \cdot \rho_0 \; (26)$$

It is widely accepted that the matter related pressure is negligible and therefore, the universe total pressure mainly consists of the dark energy related pressure . Thus, for the present time :

$$P_0 \approx \mathrm{p}_{0,\mathrm{de}} = -w_{0,de} \cdot \varrho_{0,\mathrm{de}} \approx \frac{2}{3} \cdot \rho_0 \; (27)$$

Concerning the value of $w_{de}$, the observation data analysis based on the cosmological constant approximates $w_{de} \approx w_{0,de} \approx -1$

In the frame of the present concept and taking into consideration equations (4) and (27 ) we propose :

$$w_{0,de} \approx -\frac{1}{2} \; (28)$$

It should be noted that there have been data past analyses considering $w_{de}$ as a variable suggesting higher values up to $w_{0,de} \approx 0.8$ [18]. In addition they have been theoretical approaches considering a dynamic behavior of dark energy, like the quintessence (e.g. [19]), in which $w_{de}$ is a variable with values always greater than -1.

Departing from the present time and moving towards the past, the composition is more likely to change the parameter $w_{de}$. Let us express the dark energy content (x) and its $w_{de}$ correction (η) as follows :

$$\rho_{de} = x \cdot \rho \quad w_{de} = -\frac{1}{2} \cdot \eta \cdot \rho_{de} \; (29)$$

Then, the equation (16) after the necessary rearrangements can be expressed as follows:

 doi:10.20944/preprints202506.1270.v1



$$\left(w_{ag} + \frac{1}{2}\eta\right) \cdot x = w_{ag} + \frac{1}{3} \quad (30)$$

where the pressure parameter $w_{ag}$ refers to the attactive gravitation constituent.

It is evident that for the present time: $w_{ag} = 0$ , $\eta = 1$ and $x = \frac{2}{3}$ .

Let us try now to move to the early universe . In this case the main attractive gravity constituent is mainly radiation and $w_{ag} \approx \frac{1}{3}$ .

Let us onsider two options : (a) the parameter $w_{de}$ remains constant i.e. η=1 and x is the variable, and (b) the x remains constant and η becomes variable.

In option (a), we estimate x=0.8 and in the option (b) we estimate η= 4/3 which leads to $w_{de} \approx \frac{2}{3}$.

If the option (a) would have been valid, the indication is that there is a mild decrease of the dark energy content with repect to time, from x=0.8 to 0.7 . If the option (b) would have been valid, the parameter $w_{de}$ decreases with respect to time, from 0.67 to 0.5. The first comment is that both options do not look strange. In fact, options in between could be possible as well. Thus this subject needs further investigation. However an additional comment based on the above exercise, can be made : the key role of the dark energy is to keep the necessary balance, in conceptual line with the 3rd Law of Newton for motion ensuring a sustainable expansion of the universe.

## 3. Concluding Remarks

Revisiting the problem of the universe expansion and dark energy and starting from first principles and introducing two key hypotheses (subsection 2.1), it has opened the way for various interesting and surprising findings that could guide into new considerations and theories concerning the birth of universe, its evolution and its sustainability.

The proposed concept has led to universe energy density predictions (subsection 2.1) up to the Planck epoch, quite comparable with the corresponding vacuum energy density predictions leading to an end of the cosmological constant problem controversy still pending today.

The present results (subsection 2.2) support the theory that the Universe is born and maintained by quantum vacuum energy filling space. Such energy seems to be stable and dictated by a universal constant: the expectation value of the incoming universe Energy Rate (ER). In general terms, the universe seems macroscopically expanding but without acceleration, in conceptual agreement with the fundamental principle of least action.

The Universe composition evolution (subsection 2.3) needs further in depth investigation. The present preliminary analysis does not indicate the existence of excessive amounts of dark energy without excluding some moderately higher values at the early universe. What is also interesting is that the dark energy seems to be the constituent needed to set a sustainable balance between gravity attractive and repulsive forces in conceptual agreement with the 3rd law of Newton for motion.

It should be underlined that this study is a first attempt that needs further considerations aided by old and new observations and further theory ideas and refinements.

## References


1. Riess et al. (1998) Observation evidence from Supernovae for accelerating Universe and a cosmological constant, The Astronomical Journal, 116:1009È1038.
2. Ji, P., L. Shao (2024), Scalar Dark Energy Models and Scalar-Tensor Gravity: Theoretical Explanations for the Accelerated Expansion of Present Universe, arXiv:2406.04954 [gr-qc]
3. Nielsen, J. T. , A. Guffanti & S. Sarkar (2016). Marginal evidence for cosmic acceleration from Type Ia supernovae. *Sci. Rep.* 6, 35596; doi: 10.1038/srep35596
4. Dang D (2025) Questioning Cosmic Acceleration with DESI: The Big Stall of the Universe, arXiv:2504.15635 [astro-ph.CO]

doi:10.20944/preprints202506.1270.v1




5. Maoz Dan (2007) Astrophysics in Nutshell, Princeton University Press
6. **Einstein, A. (1917).** *"Kosmologische Betrachtungen zur allgemeinen Relativitätstheorie." In Sitzungsberichte der Königlich Preußischen Akademie der Wissenschaften (Berlin), 142–152.*
7. Peebles P.J.E , R. Bharat (2003), The cosmological constant and dark energy. Reviews of Modern Physics,75, 559-606.
8. Ro, N. (2025). Dynamical dark energy in the light of DESI 2024 data. Physics of the Dark Universe, 48, 101912.
9. Weinberg, S. (1989). The cosmological constant problem. *Reviews of Modern Physics*, *61*(1), 1–23. https://doi.org/10.1103/RevModPhys.61.1
10. Verde, L., Treu, T. & Riess, A.G. (2019), Tensions between the early and late Universe. *Nat Astron* **3**, 891–895 https://doi.org/10.1038/s41550-019-0902-0
11. Glasscock P. , J. S. and S. Tenenbaum, "Action", *The Stanford Encyclopedia of Philosophy* (Spring 2023 Edition), Edward N. Zalta & Uri Nodelman (eds.), https://plato.stanford.edu/archives/spr2023/entries/action/
12. Newton, I. (1687). *Philosophiæ Naturalis Principia Mathematica*. (Translated by Andrew Motte, 1729). Law III.
13. Planck Collaboration, Planck 2018 results. VI. Cosmological parameters, A&A 641, A6 (2020) https://doi.org/10.1051/0004-6361/2018339101
14. Reiss A. G. et al (2022). A Comprehensive Measurement of the Local Value of the Hubble Constant with 1kms−1Mpc−1 Uncertainty from the Hubble Space Telescope and the SH0ES Team, The Astrophysical Journal Letters, 934 L7 DOI 10.3847/2041-8213/ac5c5b
15. Barrow, J. D. (1983) Natural Units Before Planck Quarterly Journal of the Royal Astronomical Society, Vol. 24, P. 24.
16. Zee, A. (2010). Quantum Field Theory in a Nutshell (2nd ed.). Princeton University Press.
17. Perlmutter, S. et al. (1999) Measurements of Omega and Lambda from 42 high redshift supernovae. Astrophys. J. 517, 565..
18. Brout D *et al* (2022) The Pantheon+ Analysis: Cosmological Constraints, The Astrophysical Journal 938 110 : doi 10.3847/1538-4357/ac8e04
19. Caldwell, R. R., Dave, R., & Steinhardt, P. J. (1998). Cosmological imprint of an energy component with general equation of state. *Phys. Rev. Lett.*, **80**, 1582. DOI: 10.1103/PhysRevLett.80.1582