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Research Paper

Source of Energy for creation of Universe, Minimum possible length and resolution of Hubble tension

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Abstract— Big Bang inflationary cosmological model doesn't explain the source of energy responsible for creation of our universe. If the universe is assumed to be created by a quantum vacuum fluctuation, uncertainty principle permits creation of maximum energy of ~10^{-8} kg in Planck time whereas total energy due to matter/vacuum in the universe is more than ~10^{54} kg. Thus, instantaneous creation of such huge energy of the universe from complete emptiness violates the law of conservation of energy. However, this problem can be solved if, by considering negative gravitational potential energy, net energy of the universe can be mathematically proved to be equal to zero right from the beginning of the universe to till date. In other words, gravitational potential energy (whose sign is negative) can be the source of all positive energy due to matter and vacuum. In this article, we derive the necessary condition required in any cosmological model to make net energy of the universe equal to zero. Then, we show that the recently published new cosmological model based on quantization of zero-point field satisfies this necessary condition for zero-energy universe whereas Big-Bang inflationary model doesn't. Thus, law of conservation of energy is satisfied in new model during creation of the universe from complete emptiness. It is also brought out to the notice that zero energy universe is possible only if smallest possible length in nature is, $l_{min} = l_p(\pi/2)^{1/2} \approx 2.0\times10^{-35}$ m which is of the order of Planck length. Finally, some unique features of the new cosmological model are stated and Hubble constant tension is resolved.

Keywords — Conservation of Energy, Creation of universe, Minimum length, Planck length

1. Introduction

The mechanism of the creation of our universe is still an unsolved mystery. The most accepted model i.e. Big Bang theory hypothesizes that all the matter and radiation in the Universe was stored at a point called Big Bang singularity [1] and suddenly it started expanding about 13.8 billion years ago making up the universe as we see now. But, then question arose why did it expand instead of collapsing into a black hole in spite of its initial extremely high energy density. At this point, Alan Guth's cosmic inflation theory [2] came into rescue which proposed that all the matter and radiation of the universe were created by decay of potential energy of the initial false vacuum constituted by the inflaton scalar field which had repulsive gravity. However, the most important question still remains, where did the energy of the false vacuum come from at first place? Steinhardt's cyclic universe model [3] proposes an eternal series of oscillations of the universe, each beginning with a Big Bang and ending with a Big Crunch. Even this model doesn't answer what was the initial source of energy for the cyclic universe.

One possible way to identify the initial source of energy is that our universe might have been created from a quantum vacuum fluctuation. However, since uncertainty principle permits creation of a maximum energy of ~0.02mg in a Planck time of ~5.4 ×10^{-44} s by quantum fluctuation, a natural question arises, what was the source of energy for creation of all the matter in the universe which is about ~10^{54} kg including the dark matter? An elegant solution proposed by Krauss [4] is that if we prove the net energy of the universe to be zero by considering negative gravitational potential energy, then we can identify the gravitational potential energy as the source of all positive energy represented by matter, radiation and dark (or vacuum) energy. However, Krauss [4] had to assume flatness of space to prove the zero-energy universe i.e. in his theory zero-energy universe is a consequence of flatness. Since as per standard cosmology, the space became flat only after rapid inflation, the question about the source of energy before inflation remains unanswered.

Carroll [5] has argued, Einstein's field equation doesn't imply conservation of energy due to matter and radiation in expanding space-time and hence source of energy may not be required at all. But, if we closely look, Einstein's theory of gravity is a geometric theory and considers only positive energy (matter/radiation) in its energy-momentum tensor, not the negative gravitational potential energy. That's why energy conservation appears to be violated in his theory. In Einstein's theory, one uses curvature of space-time to calculate the dynamics of physical bodies. The role of gravitational potential energy is replaced by the curvature of space-time. So, in general relativity, "covariant divergence" (not the "ordinary divergence") of energy-momentum tensor is equal zero. Covariant divergence includes a term related to curvature. Hence, we can say that the gravitational potential energy is stored in the form of curvature of space-time. For example, an apple falling from a height gains kinetic energy because the gravitational potential energy becomes more and more negative. From Newtonian perspective, potential energy reduces because of gravitational interaction between apple and earth, whereas from Einstein's perspective, potential energy reduces because of change in curvature of space-time between apple and earth. Thus, concept of gravitational potential energy is perfectly valid in general theory of relativity and law of conservation of energy is supposed to be satisfied in a true cosmological model.

Now let's analyze the situation just at the instant when the universe was created. Few researchers bring Noether's theorem to argue that, as there was a time asymmetry between "before" and "after" the creation, energy was not conserved and all the energy just appeared from nothing without need of a source. But, truly speaking, Noether's theorem states that time symmetry leads to energy conservation. It doesn't say that time asymmetry leads to energy non-conservation. So, if we can construct a cosmological model that conserves energy even at the time of its creation, that will be more appealing. This energy conservation is possible during the creation of universe from nothing only if net energy of the universe (including positive matter/vacuum energy and negative gravitational potential energy) is proved to be zero right from the beginning to till date.

In this article, we derive the necessary condition required to be satisfied in any cosmological model to make net energy of the universe equal to zero without using flatness of space as an assumption. Then, we examine whether the recent cosmological model [6] (developed by quantization of zero-point fields in a closed universe) and standard Big-Bang inflationary (ΛCDM) model satisfy this condition or not. It is found that net Zero-Energy universe is possible only in new cosmological model.

We also bring out to the notice of reader that new cosmological model gives the exact value of smallest possible length in nature. Although earlier researchers have speculated that minimum possible length might be of the order of the Planck length, its exact value was not predicted [7-8]. In the new model, total energy of the universe can be zero (leading to conservation of energy during creation of the universe) only if the minimum possible length becomes equal to a specific value given in section-3. Finally, we present a discussion on unique features, verifiability and possible resolution of Hubble tension in the new cosmological model.

2. Methodology (Requirement for a Zero-energy universe)

Just like in a 3-D space, surface of a balloon (2-sphere) is two dimensional and isotropic, in a 4-D space, surface of a 3-sphere is three dimensional and isotropic. Following this idea originally proposed by Einstein [9], let's consider our universe to lie on the surface of such a 3-sphere existing in a 4-D space. If we put dots on the surface of a balloon and expand it, the dots will move away from each other. Similarly, galaxies in our universe lying on the surface of expanding 3-sphere, recede away from each other. Even if our universe is closed, its spatial curvature cannot be detected by us as our space freely expands under gravitation just as an observer freely falling in a gravitational field cannot detect the curvature of space-time. Mathematically, as shown in the recent paper [6], observed flatness of space is due to the fact that total energy density (due to vacuum, matter and radiation) comes out to be exactly equal to the critical density, $u = \frac{3c^2H^2}{8\pi G}$. For such a spherical universe, as average intergalactic separation of galaxies is much more than the Schwarzschild radius, we can use the Newtonian expression for gravitational potential energy (not the general relativistic expression [10-11]) which is given by,

$$U_{grav} = -k\,G\,\frac{M^2}{R} \tag{1}$$

Where M is mass equivalent of total energy due to vacuum, matter and radiation, R is radius of universe, G is universal gravitational constant and k is the proportionality constant depending upon geometry of universe and the minus sign indicates that gravitational potential energy is negative.

To get a net zero-energy universe by cancellation, magnitude of (negative) gravitational potential energy must be same as the positive energy in the form of vacuum, matter and radiation. So,

$$|U_{grav}| = Mc^2$$

Or $$kG\frac{M^2}{R} = Mc^2$$

$$\Rightarrow \qquad M \;\alpha\; R \tag{2}$$

Thus, zero-energy universe is possible only in a continuous creation model where total energy due to vacuum, matter and radiation is directly proportional to the radius of the universe. Since, volume 'V' of space increases as,

$$V \;\alpha\; R^3 \tag{3}$$

Dividing Eq. (2) and (3), the requirement for zero-energy universe can be stated in terms of Energy density of space $\rho = M/V$ as,

$$\rho \;\alpha\; \frac{1}{R^2} \tag{4}$$

3. Results and discussion

A. Testing of different cosmological models

Surprisingly, total positive energy U due to vacuum, matter and radiation in the recently published new cosmological model [3] naturally (by quantization of zero-point fields) comes out to be directly proportional to the radius of the universe, $U = \frac{3\pi^2 c^4 R}{2\beta^2 G}$ (where β is a constant of the order of unity and when R is much greater than Planck length) agreeing with the condition given by Eq. (2). Total energy density u in the new model is inversely proportional to square of radius of universe ($u = \frac{3c^4}{4\beta^2 G R^2}$) agreeing with the required condition given by Eq. (4). That's why the net energy of the universe including gravitational potential energy could be zero in the new model and law of conservation of energy could be satisfied starting from beginning of the universe.

In contrast, in standard inflationary ΛCDM (Dark energy Cold Dark Matter) model of cosmology, dark/vacuum energy density is assumed to be *constant* (which means energy due to vacuum is directly proportional to R^3) and matter energy density is assumed to vary as $1/R^3$ (which means total matter energy is constant). These contradict Eq. (2) and (4). So, standard model cannot lead to a zero-energy universe and hence law of conservation of energy cannot be satisfied during creation of universe from complete emptiness.

In the new model [6], just at the time of creation, universe was an empty bubble of space of radius $R_i = \frac{l_p}{\sqrt{8\pi}} \approx 3.22 \times 10^{-36}\, m$ (where l_p is Planck length) containing only vacuum energy due to zero-point field having energy allowed by uncertainty principle. When the space gradually expanded due to negative pressure of vacuum as per Einstein's field equations, magnitude of the positive energy due to vacuum, and matter/radiation energy and magnitude of negative gravitational potential energy increased simultaneously neutralizing each other to keep net energy at zero level. Today, we see a huge amount of (positive) energy of $\sim 10^{54}$ kg due to vacuum, matter and radiation as compared to the initial Planck energy of $\sim 10^{-8}$ kg because radius of universe has also increased from initial value of $\sim 10^{-36}$m to present value of $\sim 10^{26}$m (Note that both mass and radius have undergone change by *same factor i.e.* 10^{62} and this is in agreement with the new model that predicts the positive energy of universe to be proportional to the radius of universe).

B. Smallest possible distance predicted by new cosmological model

In the new cosmological model [6], since the space is closed and spherical, circumference becomes integer multiple of wavelength of zero-point wave leading to quantization of the zero-point fields. Counting all possible modes of zero-point field, we found the vacuum energy density (or dark energy density) to be, $u_{vac} = \frac{c^4}{2\beta^2 G R^2}$ where β is a constant which defines the smallest possible distance or "cut off wavelength" by relation, $l_{min} = \lambda_{min} = \beta l_p$ (l_p is Planck length). Using the expression for u_{vac} in work done during expansion of the universe, sum of matter and radiation energy density came out to be, $u_{matter+rad} = \frac{c^4}{4\beta^2 G R^2}$.

In the later part of the new model, it was shown, to make the magnitude of (negative) gravitational potential energy equal to the sum total of (positive) vacuum, matter and radiation energy, another parameter γ needed to be equal to 2. This γ was related to β by relation, $\gamma = \sqrt{2\pi}/\beta$.

So, putting $\gamma = 2$, value of β comes out to be,

$$\beta = \sqrt{\frac{\pi}{2}}.$$

Thus, exact value of minimum possible length in nature, as per the new theory, is,

$$l_{min} = l_p\sqrt{\frac{\pi}{2}} \tag{5}$$

Numerical value of the above comes out to be,

$$l_{min} \approx 1.25 \times l_p \approx 2.0 \times 10^{-35} m.$$

So, first (massless) particle of the universe which appeared by excitation of the zero-point field with wavelength equal to the minimum possible length l_{min} must have the energy of

$$E = \frac{hc}{l_{min}} = \sqrt{8\pi} \times m_p c^2 \approx 6.11 \times 10^{19}\, GeV.$$

This is also the maximum possible energy of any particle in nature.

C. Some unique features of the new model and resolution of Hubble tension

In the new model [6], using the R dependent expressions for energy density of vacuum and density of matter-plus-radiation in Friedman equations, it is found that the vacuum (or dark) energy density and matter-plus-radiation energy density can be expressed in terms of Hubble's constant by relations $u_{vac} = \frac{c^2 H^2}{4\pi G}$

and $u_{matter+radiation} = \frac{c^2 H^2}{8\pi G}$

whose numerical values come out to be ~ 5.6×10^{-10} J/m^3 and ~2.8×10^{-10} J/m^3 respectively (taking H = 70 kms^{-1}Mpc^{-1}). These predictions agree well with the observational data. In the new model, the universe in the form of 3-sphere was found to be expanding at double the speed of light ($\frac{dR}{dt} = \gamma c = 2c$). This does not violate the special theory of relativity as it is the speed of 3D space in infinite 4D space whereas special relativity limits the velocity of particles in 3D space to the speed of light. So, radius of universe at any time

't' is given by, $R = 2ct$ and putting it in Eq. (4), we get $\rho \ \alpha \ \frac{1}{t^2}$. This inverse square dependence of energy density with time can be verified in future by collecting cosmic data at different ages of the universe (we can look very far to know the past state of universe).

An interesting feature of the new model is that total energy density due to vacuum, matter and radiation comes out to be, $u = \frac{3c^2H^2}{8\pi G}$ which is equal to the critical density required to explain the observed flatness of space. Thus, in contrast to conventional cosmological theory, new model doesn't need fine tuning or inflaton field having a specific potential energy distribution to prove flatness.

Recently, Hubble constant tension has been a hotly debated topic in astrophysics. The value of Hubble constant ~ 67.4 ± 0.5 km-s^{-1}/MPc predicted by standard Big-Bang inflationary model using CMB (cosmic microwave background) data is in 4.4σ tension with the locally determined value ~74 ± 1.42 km-s^{-1}/MPc based on Cepheid-supernovae (Type Ia) data [12-14]. However, this problem does not arise in case of new cosmological model. This can be understood as follows. In the new model, the radius of universe increases at constant rate of 2c. So, the Hubble constant is given by,

$$H = \frac{dR/dt}{R} = \frac{2c}{2ct} = \frac{1}{t} \quad (6)$$

Thus, in new model, Hubble's constant is ***exactly*** equal to the reciprocal of the age of the universe.

Taking the age of universe to be approximately same as age of the oldest star (Methuselah or HD 140283) i.e. 13.7±0.7 billion years [15] and putting it in Eq. (6), the present value of Hubble's constant in new model comes out to be ~71.3 ± 3.6 km-s^{-1}/MPc which agrees well with the value ~74 ± 1.42 km-s^{-1}/MPc directly measured from Cepheid-Supernovae Ia [14].

4. Conclusion

In this article, we have derived the required condition for creation and evolution of a zero-energy universe from empty space and thereby obeying the law of conservation of energy. This condition dictates that the total positive energy must be directly proportional to the radius of universe or in other words energy density must be inversely proportional to the square of radius (1/R^2 dependence) so that total positive energy due to vacuum, matter and radiation is exactly cancelled by the negative gravitational potential energy. Thus, positive energy of the universe is created at the cost of making gravitational potential energy more and more negative. The new cosmological model [6] satisfies these criteria of zero energy universe along with correct prediction of dark energy and matter energy whereas standard model doesn't. It is also brought out to the notice that zero energy universe is possible in the new model only if smallest possible length in nature is $l_{min} = l_p\sqrt{\pi/2} \approx 2.0 \times 10^{-35} m$ which is of the order of the Planck length. This value bears significance in QED, quantum gravity and string theory. Taking this minimum distance as wavelength, maximum energy of a (mass-less) particle comes out to be $\approx 6.11 \times 10^{19}\ GeV$ which might have appeared at the time of creation of the universe. Finally, some unique features of the new cosmological model have been highlighted in this paper and Hubble constant tension arising in standard cosmological model is resolved.

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Reference

[1] Matts Roos, *Introduction to cosmology*, (John Wiley & Sons, 2015)
[2] P. J. Steinhardt, N. Turok, "Cosmic Evolution in a Cyclic Universe", *Physical Review D*. **65** (12): 126003 (2002)
[3] Alan H Guth, "Inflationary universe: A possible solution to the horizon and flatness problems", *Phys. Rev. D*, 23(2), 347-356, (1981)
[4] Lawrence M. Krauss, *A universe from nothing* (Free Press, New York, 2012)
[5] Sean Carroll, "Energy is not conserved", *Discover*, February 23 (2010) (https://www.discovermagazine.com/the-sciences/energy-is-not-conserved)
[6] Biswaranjan Dikshit, "A new cosmological model based on quantization of the zero-point field", *Canadian Journal of Physics*, **100**, 218–225 (2022)
[7] Ronald J. Adlera, "Six easy roads to the Planck scale", *American Journal of Physics*, **78**, 925 (2010)
[8] Ahmed Farag Ali, Saurya Das and Elias C. Vagenasb, "Discreteness of space from the generalized uncertainty principle", *Physics Letters B*, **678**, 497–499 (2009)
[9] A. Einstein, "Kosmologische Betrachtungenzurallgemeinen Relativitäts theorie", Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften Berlin, 142-152 (1917)
[10] Biswaranjan Dikshit, "Derivation of general relativistic gravitational potential energy using principle of equivalence and gravitational time dilation", *Canadian Journal of Physics*, **99**, 951–953 (2021)
[11] Pavel Voracek, "Relativistic gravitational potential and its relation to mass-energy", *Astrophysics and Space Science*, **65**, 397-413 (1979)
[12] Weikang Lin, Katherine J. Mack, and Liqiang Hou, "Investigating the Hubble Constant Tension: Two Numbers in the Standard Cosmological Model", *The Astrophysical Journal Letters*, **904:L22**, 1-9 (2020)
[13] Planck Collaboration: N. Aghanim et al., Planck 2018 results, *Astronomy & Astrophysics*, **641,** A6, 1-67 (2020)
[14] Adam G Riess, S Casertano, W Yuan, L M Macri, and D Scolnic, "Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics beyond ΛCDM", *The Astrophysical Journal*, **876:85** (2019)
[15] O. L. Creevey et al, "Benchmark stars for Gaia Fundamental properties of the Population II star HD 140283 from interferometric, spectroscopic, and photometric data", *Astronomy and Astrophysics*, **575,** A26 (2015)

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