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Why Zeldovich Failed to Estimate the Precise Value of Cosmological Constant in Planck Unit?

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Abstract

To meet the cosmological constant problem, we studied the Zeldovich's proposed solution and evaluated here why he estimated the theoretical value of this constant larger by over 120 orders of magnitude in Planck mass; by theoretically deriving his empirically proposed equation thoroughly. We reported that the mathematical expression of Planck unit is numerically imbalanced thus its numerically incorrect expression, therefore, in this unit he predicted its extreme value and cosmological constant problem persisted there. A modification in this unit has been suggested, subsequently it modified the Zeldovich's proposed expression and this modified expression estimated the precise value of this cosmological constant later. These findings imply that if the mathematical expression of Planck unit was correct he would have estimated the precise value of this constant alone.

Keywords

Cosmological Constant, Vacuum Energy, Planck Unit

1. Introduction

Observational result shows that universe is not only expanding but also this expansion is accelerating itself [1]. To explain this phenomenon, it has been presumed that some kind of mysterious energy does exist which impose a negative pressure and drive this expansion away. Therefore, it is hypothesized that this mysterious energy is cosmological constant which corresponds to vacuum energy density or dark energy [2]. Here, vacuum energy density and cosmological constant have been used interchangeably.

Quantum mechanics (QM) attempted to estimate its theoretical value by assuming that zero point energy (ZPE) might be giving rise this vacuum energy and summed all ZPE of ground state but estimated value is larger by 120 orders of magnitude to observed value; this disagreement is known as cosmological constant problem in physics [2].

So far, many other theories have been propounded to estimate its value, its brief introduction can be found in Ref [3] [4] and references therein. Still this disagreement exists in a range between 46 and 120 orders of magnitude [5] [6]. A recent solution has been proposed in a different perspective e.g. see Ref. [7] [8].

In the wake of this discrepancy, Zeldovich comes up with a different approach and believed that instead of ZPE the quantum fluctuations of empty space might be reason behind the origin of this energy and empirically proposed an equation to estimate its theoretical value, his emulated expression is written as below (interested reader may refer to Ref. [3] for his argument to writing that expression)

$$\rho_E \sim G\frac{m^6c^4}{h^4} \tag{1}$$

where, all used constants hold its usual meanings and values. The mass m is only used variable here. If we take this mass m as Planck mass, it corresponds to,

$$\rho_E \sim \frac{c^7}{G^2h} \tag{2}$$

substituting the numerical value of all used constant, its numerical value is about 10^{112} J/m^3 but observed value is 10^{-9} J/m^3, thus estimated value is still larger by over 120 orders of magnitude and problem persisted constantly.

Notwithstanding, from Equation (1) he estimated its value only larger by 9 orders of magnitude in pion mass but there is no clear reason or explanation to take this mass. Furthermore, this expression was emulated empirically; there isn't its theoretical derivation from any established theory, however, it is believed that QM can't predict its precise value which is a serious failure of this theory. To make compatible the quantum theory with cosmological constant; this disagreement must be explained thoroughly.

In this rapid communication, to meet the long standing cosmological constant problem, we revisited the Zeldovich's idea by asking a more subtle question; why pion mass gives relatively small value and why Planck mass/unit gives extreme value of vacuum energy density or cosmological constant? And, to investigate the reason behind it, we independently derived his empirically proposed equation by using a novel approach while inferring that neither classical nor quantum form of energy can explain this vacuum energy instead it might be another form of energy; a quantum-gravitational form of energy in someway. Coincidently, we found, the derived expression is same as the expression what was empirically proposed by him, so we able to explain and unravel why cosmological constant problem persisted in his idea and what might be its possible solutions.

2. Derivation of Quantum-Gravitational Form of Energy

On order to accomplish the objective, we empirically proposed a force balance equation which interrelate the quantum and classical force as written below,

$$\frac{hc}{R_Q^2} \times \frac{m_Q^2 c^3}{h} = \frac{c^4}{G} \times G \frac{m^2}{R^2} \tag{3}$$

where all used constants holds its usual meanings. The variable m stands for mass and R for space. To differentiate the space associated with quantum of force has been denoted as R_Q and R for classical space; in same fashion the mass associated with quantum mechanics as m_Q while mass associated with classical mechanics denoted as m only.

Theoretically, it shows a balance between quantum and classical force so we named it "Force Balance Equation" (hereafter we abbreviate it as "FBE").

The LHS of this FBE denotes a quantum of force and it can be able to estimate the theoretical value of strong nuclear force if we replace R_Q with size of nucleus and m_Q with mass of pion or proton respectively [9]. Rest part of FBE denotes a classical force and these are well known in fundamental physics, it doesn't need descriptions more.

This FBE is in consistence with other existing theory; it can be seen if we derive the relative strength of quantum of force/strong nuclear force to gravitational force from our proposed FBE, it gives us,

$$\frac{hc}{R_Q^2} = \left(\frac{hc}{Gm_Q^2}\right) G \frac{m^2}{R^2} \tag{4}$$

where

$$K = \frac{hc}{Gm_Q^2} \tag{5}$$

a constant quantity, it's value is nearly 39 orders of magnitude if we take m_Q as mass of proton, it suggest strong force is stronger to gravity by 39 orders of magnitude in quantity and this quantity is gravitational coupling constant itself.

Since, mass and space are only used variable in FBE which consists from quantum and classical force. Thus, a quantum relation between these variables will be,

$$R_Q = \frac{h}{m_Q c} \tag{6}$$

similarly, a classical relation as followings,

$$R = \frac{Gm}{c^2} \tag{7}$$

it has only gravitational constant.

Now, one can observed from FBE that the quantum force possess only Planck constant whereas classical force has only gravitational constant, however, on order to derive an expression of force which possess both constant *i.e.* a quantum-gravitational form of force we presumed that the mass/space associated with quantum mechanics is same, equal, replaceable and interchangeable with the mass/space associated with classical mechanics.

Here, initially we assumed that all the variables of FBE a quantum entity and substituted the quantum relation between mass and space in it *i.e.* Equation (6) in Equation (3); it doesn't give any new expression. But, when we assumed all the variables as classical entity and substituted the classical relation between the mass and space in FBE *i.e.* Equation (7) in Equation (3), it gives,

$$\frac{hc^5}{G^2m^2}\times\frac{R^2c^7}{G^2h}=\frac{c^4}{G}\times\frac{R^2c^8}{m^2G^3} \tag{8}$$

its just inverted form of FBE (hereafter we call it "inverted FBE") and first two expressions are the desired quantum-gravitational form of force.

These two expressions are only relevant to the objective of this article therefore the description of rest terms is discarded intentionally. Yet, it is worthy to describe the last terms of this FBE which denotes a new form of gravitational force; which is just inverted form of classical gravity. Its importance and role played in physics is to be discussed somewhere else.

A notable fact is that this "inverted FBE" is in Planck unit [10] because while deriving the desired quantum-gravitational force terms we presumed that mass/space are equal in classical and quantum mechanics and once we take it equal it originates the Planck mass/length/unit obviously.

The first quantum-gravitational force term of "inverted FBE" is just inverse of quantum of force and equivalent to Hawking temperature [11], if we take $E=F\cdot R$ where E denotes energy and R is space and $E=k_BT$ where k_B is Boltzmann constant and T is temperature.

Subsequent quantum-gravitational force terms corresponds to Zeldovich's expression for cosmological constant in Planck unit as written in Equation (2) if we take again $E=F\cdot R$. This is the systematic derivation of his empirically proposed equation and it interprets that cosmological constant is nothing but just a quantum-gravitational form of quantum of force. It means, it's nothing but just a quantum-gravitational energy density of vacuum itself.

But only problem is, as discussed in preceding sections, this expression can't predict the precise value of vacuum energy density instead estimate value is extreme large. It hints, this expression is numerically incorrect somehow and we can proof it from inverted FBE if we calculate the relative strength of strong force to gravity, it gives us followings,

$$\frac{R^2c^7}{G^2h}=\left(\frac{Gm^2}{hc}\right)\frac{R^2c^8}{m^2G^3}=\left(\frac{1}{K}\right)\frac{R^2c^8}{m^2G^3} \tag{9}$$

it says, strong force is weaker to gravity by 10^{39} order of magnitude and this contradict the observational results and defy the result what we obtained from Equation (4) because strong gravity is not observed by any experiment till date. It implies that this inverted FBE and subsequently the Zeldovich's expression for vacuum energy density is numerically incorrect notwithstanding its dimensionally balanced.

To our understanding, we obtained this incorrect expression because while deriving it we presumed that classical mass/space is equal to quantum mass/space. This presumption might not be correct. Therefore, to meet this problem, it needs to discriminate the quantum space/mass and classical mass/space, which is neither equal nor interchangeable at all in any respect. Since, these entities are dimensionally equal thus it will be numerically not equal so there exists any dimensionless quantity which relates these entities in both mechanics.

3. Modifications of Planck Unit

On this ground, a correct relation between these entities can be derived if we compare the quantum and classical form of energy which is dependent of space only as written below,

$$\frac{hc}{R_Q} = \frac{Gm^2}{R} \tag{10}$$

numerically, it gives us followings,

$$R_Q = \frac{hc}{Gm^2} R = KR \tag{11}$$

this suggests, a dimensionless constant terms interrelate the space in classical and quantum mechanics. From this assertion, the correct mathematical expression of Planck unit from Equation (6), (7) and (11) will be,

$$m_{pl}^2 = \frac{hc}{GK} \quad \text{and} \quad R_{pl}^2 = \frac{GhK}{c^3} \tag{12}$$

it modified the well-established and accepted mathematical expression of Planck unit.

4. Derivation of Correct Mathematical Expression for Zeldovich's Expression

Further, in this scenario, the correct expression of "inverted FBE" will be derived by substituting Equation (11) and (12) in Equation (3) which gives us followings,

$$\frac{hc^5}{G^2 m^2 K^2} \times \frac{R^2 c^7}{G^2 h K^2} = \frac{c^4}{G} \times \frac{R^2 c^8}{m^2 G^3} \tag{13}$$

its modified form of "inverted FBE" and this modification is valid since it gives the relative strength of quantum force to gravity similar to Equation (4).

Here, it first terms is correct expression for Hawking temperature with some modifications by taking again $E = F \cdot R$ where R is from Equation (11) and $E = k_B T$ where k_B is Boltzmann constant and the temperature T is as written below,

$$T = \frac{hc^3}{Gmk_B}\left(\frac{1}{K}\right) \tag{14}$$

this suggests, Hawking predicted extreme high temperature; observed temperature will be as low as by factor of *1/K i.e.* $1/10^{39}$ orders of magnitude in quantity. Since, this temperature is not measured by experimental set up till date thus our prediction needs confirmation.

In same manner, the second terms is correct expression for Zeldovich's proposed equation for cosmological constant in terms of modified Planck unit by taking $E = F \cdot R$ where R is from Equation (11), however, the energy density of vacuum will be,

$$\rho_E = \frac{c^7}{G^2 h K^3} \tag{15}$$

substituting the K from Equation (11) it reduce to Equation (1), it suggests there is no existence of Zeldovich's expression for vacuum energy in Planck unit, however, there is no cosmological constant problem at all in this perspective.

5. Conclusions

In summary, Zeldovich's proposed equation for cosmological constant is actually quantum-gravitational energy density of vacuum which is quantum-gravitational form of quantum of force; and this force is mediated by pion thus in this mass it predicts its relatively small value. But, the mathematical expression of Planck unit is numerically incorrect so that in this unit he predicted its extreme value and the cosmological constant problem persisted unnecessarily there.

This conclusion also invokes that, if the mathematical expression of Planck unit is numerically incorrect therefore all those predictions which are based on this unit must be numerically incorrect. This conclusion might have viable impact on other branches of physics where this unit is frequently used to predict the theoretical value of other physical entities. Along with the cosmological constant, the Hawking temperature is such other physical entity where its theoretical value prediction is based on this unit, however, Hawking might also have predicted its incorrect temperature; the actual temperature will be something else, future research recommended in this area.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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