On the reason of cosmological constant problem and its solution

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Abstract:

Quantum field theory's energy density of vacuum corresponds to the cosmological constant. We found, calculation of its numerical value is based on Planck unit which assumes, the gravity is as strong as the strong nuclear force is. We argue, this assumption is the reason of very high predicted value of it and cosmological constant problem emerges. Here we modified this assumption and got correct value of it and apparently cosmological constant problem is vanished.

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Introduction

Cosmological constant first appeared in Einstein's field equation of general relativity to achieve the static solution of universe which holds back the cosmological objects from moving outward [1,2]. After the discovery of Hubble's expanding universe, its interesting story started. It comes in limelight and become entity of scientific interest after the current observation, which indicates the universe is not only expanding but also this expansion is accelerated [3,4]. Physicist believes, interpretation of this constant may sheds lights on understanding the large scale structure of universe and its fate [5,6]. It is a dimension-full entities as it has (length)$^{-2}$ dimension.

Quantum field theory suggests this constant arises because of existence of vacuum fluctuation and it corresponds to vacuum energy density or zero point energy [7,]. However, its value is calculated and reported, the observed value is over 120 orders of magnitude smaller than the calculated value. This discrepancy is called cosmological constant problem in particle physics and gravitation [8]. There are many proposed theory to meet this problem, still this problem persists and continually annoying physicists, it becomes the factor of other problems, the so called mother of all problems. Its description may be found somewhere else, its needless to describe all proposed theories here.

Here we take this unsolved problem of physics thoroughly and proposed its solutions. We didn't put forward any new theory or any new equation instead we refine the old existed equation, which is the equation that facilitates us to calculate the energy density of vacuum. This manuscript is mainly organized of three parts, in the first part we will asses why the cosmological constant arises, the second part is all about the proposed solution of this problem and at last we draw exclusive conclusions.

The reason of cosmological constant problem

To solve any problem, first of all we need to know why that particular problem emerges. In this case, we can find the reason by assessing; why the conventionally existed theory can't give its value, what is observed today. Or we can say, what are the shortcomings of those calculations? To answer these all questions, we will review the theory or equation which calculates its value theoretically.

As we mentioned earlier, the Quantum Field Theory suggests the existence of vacuum fluctuation which leads to the specific energy of vacuum and that is called energy density of vacuum technically and it is correspond to the cosmological constant [9,10]. An elucidated mathematical expression for energy density of vacuum is given below,

$$\rho = \frac{c^7}{G^2 h} \tag{1}$$

Where, used all constants holds its usual meanings and its accepted numerical values, apparently it is equal to followings, if we take, $\boldsymbol{E} = \boldsymbol{F} \times \boldsymbol{r}$ and $\boldsymbol{\rho} = \frac{\boldsymbol{E}}{\boldsymbol{r}^3}$

$$F = \frac{r^2 c^7}{G^2 h} \tag{2}$$

Where, a new variable r is the space or distance. Now, comparing it with Newton's classical gravitational force, it will deduce to Planck length or mass,

$$l_{pl}^2 = \frac{Gh}{c^3} \tag{3}$$

$$m_{pl}^2 = \frac{hc}{G} \tag{4}$$

These are ultimately Planck unit and these are based on following basic relation or assumption,

$$Gm^2 = hc \tag{5}$$

however one can say, the mathematical expression for calculation of energy density of vacuum or cosmological constant is basically based on the Planck unit and it is not able to calculate the theoretical value of cosmological constant, as we know from the discrepancy between its calculated value and observe value. However, there is strong reason to believe, this assumption is wrong and we need to modify it to make it consistent with physical observations.

Apart to it, if we divide it by r^2 we will get,

$$G\frac{m^2}{r^2} = \frac{hc}{r^2} \tag{6}$$

We recognize the first term as well known the classical gravitational force.

The second term has more significance, it has the same dimension as the force has, however, we believe, this term shows the mathematical expression to calculate some kind of force which is quantized, since it is quantized itself thus it shows a quantum of force. Besides, it also follows the inverse square law of force. We apply this expression to calculate the theoretical numerical amount for strong nuclear force [12]. There is only one variable and that is the ***r***, which we will take as the size of nucleus.

If we substitute the ***r*** as the size of nucleus, we will get the numerical amount of it about the order of ***10⁴ N***, for the same the amount of gravitational force is order of ***10⁻⁴³ N*** thus one can easily conclude, the strong nuclear force is really strong in nature comparison to the classical gravity. From the observation it is clear that, gravity is not equal to the strong force, clearly, the Planck relation assumes that the gravity is as strong as the strong nuclear force. We doubt, this assumption is the hardcore reason of prediction of high value of vacuum energy density and it emerge as cosmological constant problem.

From above discussion we can say, the Planck unit is not consistent with the physical or experimental observations in at least two fronts,

1. It is used to calculate the energy density of vacuum and it gives its wrong values
2. It doesn't explain the existence of gravitational coupling constant i.e. it doesn't gives, at what order gravity is weak to the strong nuclear force.

Thus we conclude that, Planck unit is dimensionally balanced but the theoretical calculations based on it are not consistence with physical or experimental observations. Besides, it gives arise the so called cosmological constant problem. If we want to meet these challenges, we need to correct this assumption. In upcoming paragraph we will meet this theoretical challenge. We will propose a hypothesis to correct or modified it.

Correction in Planck unit

From preceding paragraphs, we know that, Planck unit is dimensionally balanced but the result what we got from this is extremely different to the observed one, thus one can reason ultimately, there must be some additional dimensionless or numerical quantities, this will help us to get the right of desired entities. However, its modification is urgently needed to make it consistent with existing theories.

This can be done by writing following empirical mathematical expressions for force balance, that is,

$$\frac{hc}{r^2} \times \frac{m_p^2 c^3}{h} = G\frac{m^2}{r^2} \times \frac{c^4}{G} \tag{7}$$

The used constant and variable hold its usual meanings and its accepted values; the new variable m_p is the mass of proton. We called this a force balance equation because one can see there is four distinct form of force and it is dimensionally balanced as well. It can also be written as,

$$\frac{hc}{r^2} = G\frac{m^2}{r^2} \times \frac{\frac{c^4}{G}}{\frac{m_p^2 c^3}{h}} \tag{8}$$

if we substitute the numerical values of used all constants and we assume m_p themass of proton is also a constant, however, we will get followings expressions,

$$\frac{hc}{r^2} = 10^{+39} G\frac{m^2}{r^2} \tag{9}$$

one can see, this is a modified form of Planck unit if we divide it by r^2 and we notice there is an additional numerical constant, what we desire to make it consistent with the observations. We also recognize it as the gravitational coupling constant [13]. It shows the gravity is less less weaker to strong nuclear force. This is an alternative way to derive the gravitational coupling constant theoretically.

Now, the Planck unit is modified by adding additional numerical constant thus we will get modified form of Planck's mass and length as given below,

$$m_{pl}^2 = \frac{hc}{10^{+39}G} \tag{10}$$

$$l_{pl}^2 = \frac{10^{+39}Gh}{c^3} \tag{11}$$

If we substitute the value of all used constant we will get the Planck's mass as the mass of proton and Planck's length as the size of nucleus respectively. However we conclude that there is no existence of speculative Planck's mass and length that is so called shortest possible length.

Now we come to the central question's solution, when we use this modified Planck unit, we will get the mathematical expression to calculate the energy density of vacuum, as given below,

$$\rho = \frac{c^7}{(10^{+39})^3 G^2 h} \tag{12}$$

from above the numerical value will be $\rho = 10^{-11} J/_{m^3}$, while its observe value is $\rho = 10^{-9} J/_{m^3}$ and one can say the predicted value is comparable to its currently observed value[2,3,14]. Cosmological constant problem is solved now.

Conclusion:

We arrive at the conclusion that, the Planck unit is dimensionally balanced but quantitatively not as we notice form the assessment of cosmological constant problem. However, modification of this relation is mandatory to make it compatible with the physical observation. From modified form of it, we found the Planck mass and length are nothing but these qualities are just well known proton mass and nucleus radii. This modification will alter all the predictions which are based on Planck's units such as derived Planck units and hawking temperature etc.

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