Another Cosmological Constant to Solve More Problems of Our Cosmological Models

MueizGaferKamalEldeen

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mueizphysics@gmail.com

Abstract

A simple analysis based on mathematical arguments shows that adding another well-defined term to the cosmological constant can solve more problems of our cosmological models.

Introduction

In the presence of the concept of quantum vacuum zero-point energy, the unceasing desire of physicists for linking together quantum mechanics and general relativity which was strongly excited by the reintroduction of the cosmological constant was shocked by the great discrepancy between the values of the cosmological constant and the vacuum energy which led to more concern about other possibilities about the cosmological constant.

The aim of this paper is to offer one of these possibilities which resolve among other problems about our cosmological models the problem of the cosmological constant.

The New Term

We have Einstein's field equation with the cosmological constant:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + g_{\mu\nu} \Lambda = kT_{\mu\nu}$$

Now let us add in addition to the ordinary cosmological constant the quantity : ($k\,T_{\mu\nu}^{average}$) where ($T_{\mu\nu}^{average}$)is the average stress-energy tensor of the universe:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R + g_{\mu\nu} \Lambda = kT_{\mu\nu} - k\,T_{\mu\nu}^{average}$$

Let us first apply the field equation to the whole homogenous and isotropic universe :

$$R_{\mu\nu}^{global} - \frac{1}{2} g_{\mu\nu} R^{global} + g_{\mu\nu} \Lambda = k\,T_{\mu\nu}^{average} - k\,T_{\mu\nu}^{average} = 0$$

This gives :

$$g_{\mu\nu}\Lambda = -R_{\mu\nu}^{global} + \frac{1}{2} g_{\mu\nu} R^{global}$$

Thus the field equation can be written in the following form:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R - R_{\mu\nu}^{global} + \frac{1}{2} g_{\mu\nu} R^{global} = kT_{\mu\nu} - k\, T_{\mu\nu}^{average(global)}$$

Which appear more beautiful if we use Einstein's Tensor :

$$G_{\mu\nu} - G_{\mu\nu}^{global} = kT_{\mu\nu} - k\, T_{\mu\nu}^{global}$$

This new form of the field equation can be more familiar if we consider the analogy with the field equation which relate the topology and the elasticity factor in different regions in the surface of a spherical balloon with slightly different values of elasticity factors across its surface which also contains two global constants that represent the average elasticity factor and the global radius of the balloon.

The appearance of the quantity($k\, T_{\mu\nu}^{average}$)in the field equation has no practical impact on the local application of the field equation inside or near heavy bodies because of the small value of the present average stress-energy tensor of the universe while it leads to totally different result in the application of the field equation to the universe as a whole as will be shown.

The Flatness Problem and the Cosmological Constant Problem

Because of the existence of the term ($k\, T_{\mu\nu}^{average}$) subtracted from the right-hand side of the field equation ($kT_{\mu\nu}$) it is clear that any homogeneous distribution of matter and energy throughout the universe cannot affect the geometry of the universe because in this case the contribution of this distribution on the stress-energy tensor in every region is equal to its contribution on the average stress-energy tensor of the universe and thus the right-hand side of the field equation is not affected by such a distribution regardless of its density.

The independence of the large-scale geometry of the universe from the average density of matter eliminates *the flatness problem* because the concept of the critical density becomes meaningless.

This can also take away the difficulty known as *the (old) cosmological constant problem* which can be summarized in the following question : Why does the *zero-point energy* of the vacuum not cause a large cosmological constant ? What cancels it out ? The answer is simply: Because the zero-point energy is distributed homogeneously throughout the space and thus its contribution to the two terms of the right-hand side of the field equation cancel out each other and so it cannot affect the curvature and thus can be omitted from the field equation.

The addition of this term to the field equation also offers a simple answer to the question why the value of the cosmological constant is comparable to the present mass density of the universe which is called *the new cosmological constant problem.*

Let us apply the field equation in empty space far from heavy bodies :

$$R_{\mu\nu}^{far\ empty\ space} - \frac{1}{2} g_{\mu\nu} R^{far\ empty\ space} + g_{\mu\nu}\Lambda = -k\, T_{\mu\nu}^{average}$$

$$g_{\mu\nu}\Lambda = -R_{\mu\nu}^{far\ empty\ space} + \frac{1}{2} g_{\mu\nu} R^{far\ empty\ space} - k\, T_{\mu\nu}^{average}$$

The present value of the curvature of the empty space far from heavy bodies is very small and thus:

$$g_{\mu\nu}\Lambda \quad \sim \quad k\, T_{\mu\nu}^{average}$$

Other Implications and Results

The field equation with the new term is:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R - R_{\mu\nu}^{global} + \frac{1}{2} g_{\mu\nu} R^{global} = kT_{\mu\nu} - k\, T_{\mu\nu}^{average}$$

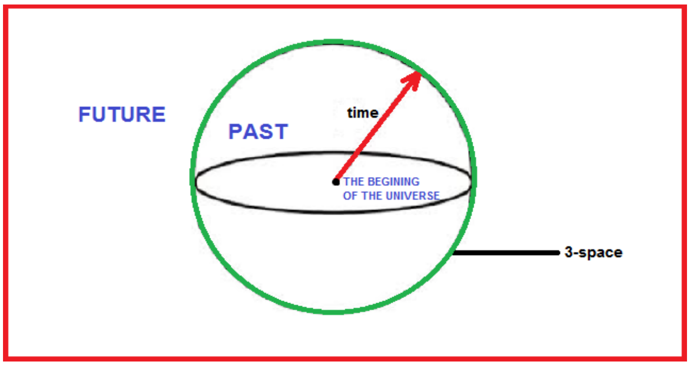
Taking the trace of both sides by contracting with $g^{\mu\nu}$ and rearranging the terms one gets :

$$R^{global} + k\rho^{global(\,average)} = k\rho + R$$

To make this equation useful we have to determine the quantity ($R^{global} + k\rho^{global}$) which is not so difficult practically but of course it must also be something which could be determined theoretically which depends on our cosmological model.

Take for example the following cosmological model:

According to this model the space-time is a 4-sphere in which the 3-dimensional surface represents the 3-space of the universe and the radius represents the time .



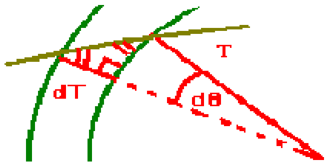
As a result of this relation between the *time* and the *3-space* we have to stop thinking about a single direction of time when we are exploring distances comparable to the radius (age) of the universe .The idea that the time dimension in any point in the 3-space is the line from the center to that point represents the main feature of this model which distinguishes it from the existing ones.

According to this model the quantity (R^{global}) can easily be determined by the radius of the universe.

Now let us see how this model can be used to understand some facts and explain some observational data :

Hubble's Law and red shift : The world line of light (c = 1) as it travel through the 4-dimensional space-time between the source of light and the observer is a logarithmic spiral (tends to straight line in large values of the age of the universe) this is because it keeps making an angle (Π / 4) with the 3-dimensional surface in every time because the speed is equal to the tangent of this angle.

Thus the relation between the time of emission (T*e*) and the time of observation (T*o*) and the angle between the world lines of the observer and the source (ɵ) can be obtained as follows :



We have : (*d*T = T *d*ɵ) then by integration (from T = T*e* to T = T*o*) we arrive at the important result:

T*o* = T*e* (e^ɵ)

The red-shift (z) resulted from this relation between the time of emission and the time of observation is :

z = (e^ɵ) - 1

This relation *{ z = (e^ɵ) - 1}* agree with Habble's law and can also be used to explain red-shift data claimed to be results of accelerated expansion (which is impossible according to this model) such as supernova observations and thus introduce another source for red-shift other than movement and gravitational field.

The Large-scale Universe is Homogeneous and Isotropic : This can be thought of as a natural result of the shape of the *3-space* in this model , because there is no preferred region or direction in a spherical surface.

Horizon Problem : The problem with the standard cosmological model that different regions of the universe have not contacted each other (according to the standard model) but have the same physical properties is known as the horizon problem . The cosmic background radiation which fills the space between galaxies is precisely the same everywhere.

This model provides a simple explanation to this homogeneity. According to the equation of the world line of light from this model *{* T*o* = T*e* (e ^ *ɵ*) *}* all the radiation emitted from a source whose world line is at angle (nΠ) *}*

with our world line reaches us at time (T*o* = T*e* (e ^ n Π) from all direction. This provides us with a simple explanation for cosmic background radiation.