Is the negative vacuum energy around galaxies a possible candidate for dark matter?

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Abstract
In this short communication we point out to the possibility that the clouds of the negative vacuum energy around galaxies may have the same effect as dark matter. These clouds amplify the force acting on the baryonic matter around galaxies changing their dynamical and kinematical properties. Inserting the density of the baryonic matter into field equations of the cosmic quaternionic field for the present time yields the negative cosmological constant which is approximately equal to the density of the baryonic matter of galaxies. Due to the effect of the negative vacuum energy on moving cosmical objects the effective total masses of galaxies assume several times larger values as their baryonic masses. ¹

1 Introduction

The recent astronomical observations [1] [2] [3] [4] give increasing support for the accelerating and flat universe which consists of a mixture of a small part of the baryonic matter about one third non-relativistic dark matter (DM) and two thirds of a smooth component, called dark energy (DE). In this communication, we put forward the thesis that DM is a type of the negative vacuum energy concentrated around galaxies which can be modelled by negative cosmological constant Λ whose value can be determined by means of the field equations of the cosmic quaternionic fields.

In the literature, DE is theoretically modelled by many ways, e.g. as (i) a very small cosmological constant (e.g.[10]) (ii) quintessence (e.g.[11]) (iii) Chaplygin gas (e.g.[12])

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(iv) tachyon field (e.g.[13] [19] [20]) (v) interacting quintessence (e.g.[14]), quaternionic field (e.g.[15]), etc. It is unknown which of the said models will finally emerges as the successful one.

Another fundamental problem being faced to cosmology is that of the nature of DM, which is supposed to exist because of dynamical astronomical measurement but we have not yet detected it. Astronomers found that one third of the universe’s mass is made up of unknown matter that is invisible to telescopes but have gravitational effects on the baryonic matter [16]. Lacking evidence of direct detection, the presence, nature, and quantity of DM must be inferred from the kinetic and distribution properties of baryons. In the literature, many sophisticated candidates of DM have been proposed which can be divided up into two categories. Some authors proposed that DM consists of a kind of matter substance, e.g. of the massive particles (WIMPs) which stems from extensions to the standard model of particle physics, such as supersymmetry and extra-dimensional theory. Other assume that DM represents the relics of primordial black holes (see, e.g.[17]). On the other side, several authors try explain the kinematic effects assigned to DM by modifying of Newton’s law of gravitation (see,e.g. [18]).

In what follows, we will show that clouds of negative vacuum energy around galaxies enhance the gravitation force acting on cosmological objects which has a similar effect on their rotation curves as if one would add to their baryonic mass densities an additional masses. These 'additional masses' could represent the corresponding DM seemly concentrated around galaxies.

2 The field equations for the cosmic quaternionic field

In a recent article [5], Λ has been interpreted as the field energy of the cosmic quaternionic field (called Φ-field, for short). The field equations for the Φ-field can be written in the following form (c=1)

$$\partial_i F_{ij} = J_j, \quad (1)$$

where $J$ is the 4-current of ordinary matter with the components $J_j = k\rho v_j \ (j=1,2,3)$ being the components of space velocity and $\rho$ is the matter density; $J_0 = k(\epsilon_{self} + \rho)$ where $\epsilon_{self}$ is the energy density of the Φ-field. $F_{ij}$ has only diagonal components $F_{ii} = \Phi, \ i = 1,2,3, \ F_{ii} = -\Phi, \ i = 0,$ and $F_{ij} = 0, \ i \neq j$. The field variable $\Phi$ has the dimension of field strength and its square has the dimension of energy density. In the differential form the field equation (1) becomes (c=1)

$$\nabla \Phi = k\vec{J} = k\rho \vec{v}, \quad v_i, i = 1,2,3 \quad (2a)$$

and

$$-\frac{\partial \Phi}{c \partial t} = k_0 (\epsilon_{self} + \rho), \quad i = 0 \quad (2b)$$
where $\epsilon_{\text{self}}$ is the energy density of the $\Phi$-field given as [6]

$$\epsilon_{\text{self}} = \frac{\Phi^2}{8\pi}.$$ 

If one writes Newton’s law of gravitation in the symmetrical form

$$F = -\frac{(q_g)^2}{r^2} = -\frac{Gm}{r^2},$$

then the quantity $q_g = \sqrt{Gm}$ can be understood as the 'gravitational charge', assigned to the mass $m$ [8] [7]. Next, we will use gravitational charges when formulating the field equations of the cosmic quaternionic field. Since the r-h-side of Eqs.(2a) and (2b) oughts to have the dimension of gravitational charge we set for the coupling constants $k$ and $k_0$ as

$$k = \sqrt{G}, \quad k_0 = 8\pi\sqrt{G}.$$

Inserting $k$ and $k_0$ into Eqs. (2a) and (2b) we have

$$\nabla\Phi = \sqrt{G}\vec{J} = \sqrt{G}\rho\vec{v}, \quad v_i, i = 1, 2, 3 \quad (2a')$$

and

$$-\frac{\partial\Phi}{\partial t} = 8\pi\sqrt{G}(\epsilon_{\text{self}} + \rho), \quad i = 0. \quad (2b')$$

These equations are first-order differential equations whose solution can be found given the source terms. According of the boundary conditions we distinguish three types of solutions of Eqs. (2a') and (2b'):

(i) For $\rho = 0$, the only source of the $\Phi$-field is its own energy density, i.e. $\epsilon_{\text{self}} = \Phi^2/8\pi$. Assuming the spacial homogeneity of the $\Phi$-field and the absence of any ordinary matter then the field variable $\Phi$ will be dependent only on time $t$. Therefore, Eqs.(2a) and (2b) become

$$\nabla\Phi = 0 \quad (3a)$$

and

$$-\frac{d\Phi}{dt} = 8\pi\sqrt{G}\Phi^2. \quad (3b)$$

The solution of (3b) has a simple form

$$\Phi(t) = \frac{1}{\sqrt{G}(t + t_0)}.$$ 

where $t_0$ is the integration constant given by the boundary condition.

(ii) For $|\vec{v}| \ll c$ and $\rho \neq 0$ we have

$$\nabla\Phi \approx 0 \quad (4a)$$

and

$$-\frac{d\Phi}{dt} = 8\pi\sqrt{G}\left(\frac{\Phi^2}{8\pi} + \rho\right). \quad (4b)$$
For the present time $t \approx 10^{10} \text{yr}$, the derivation of $d\Phi/dt$ become approximately equal zero and Eq. (4b) turns out to be

$$8\pi\sqrt{G}\left(\frac{\Phi^2}{8\pi} + \rho\right) = 8\pi\sqrt{G}(\Lambda + \rho) \approx 0.$$ \hfill (5)

The field energy density of the cosmic quaternionic field $\Phi/(8\pi)$ for ($t_0 = 0$) is

$$\Lambda = \frac{\Phi^2}{8\pi} = \frac{\lambda}{8\pi}\left[\frac{1}{\sqrt{Gt}}\frac{1}{\sqrt{Gt}}\right].$$

From Eq.(5) it follows

$$\Lambda \approx -\rho.$$ \hfill (7)

For a weak gravitation field of the spherically symmetric galaxy the acceleration of a cosmic object is given as [21]

$$\ddot{R} = -\frac{G\int_0^R \rho(r)r^24\pi dr}{R^2} + \frac{R\lambda}{3}.$$ \hfill (8)

Keeping in mind that $\lambda = 8\pi G\Lambda$ and $\Lambda \approx -\rho$, respectively, we have finally

$$A = \ddot{R} = A_1 + A_2 = -\frac{G\int_0^R \rho(r)r^24\pi dr}{R^2} - \frac{8\pi GR\rho}{3}.$$ \hfill (9)

We see that the first and second term in Eq. 8 represents the gravitation acceleration and the acceleration due to negative cosmological constant, respectively. Equaling the centripetal and the acceleration $A$, the velocity of the rotational curves as a function of $\rho$ and $R$ becomes

$$v_R = \sqrt{\frac{G\int_0^R \rho(r)r^24\pi dr}{R} + \frac{8\pi G\rho R^2}{3}}.$$ \hfill (10)

For example, consider a galaxy with the mass distribution $\rho = \text{const} = \rho_0$. The velocity of the rotational curve $v_R$ is

$$v_R = \sqrt{\frac{G\int_0^R \rho_0(r)r^24\pi dr}{R} + \frac{8\pi G\rho_0 R^2}{3}} = R\sqrt{G\left(\frac{4\pi\rho_0}{3}\right)(1 + 2)}$$

while without the presence of the negative vacuum energy this velocity is

$$v_1 = R\sqrt{G\left(\frac{4\pi\rho_0}{3}\right)}.$$  

We see the presence of the negative vacuum energy is the same as if the density of galaxy were $3\rho_0$, i.e. as if the total mass of galaxy would increases. The clouds of negative vacuum energy around galaxies behaves as DM. Yet, this does not excludes that also other components of DM exists.
3 Consequences

It is generally believed that most of energy and matter in our universe is of unknown nature to us, therefore to explain the nature of DM is one of the major fundamental challenges of present astrophysics. In this communication we have attempted to show that the cloud of the negative vacuum energy around galaxy whose density is approximately equal to $\rho$ has the same effect as DM occurring in them.

From what has been said so far the following points are worth of mentioning

(i) The clouds of negative vacuum energy around galaxies has the same effect as presence of additional mass in them.

(ii) The density of the negative vacuum energy is approximately equal to the mass density of galaxies.

(iii) The whole kinematics of star motion in galaxies is given by their baryonic mass distribution.

(iv) It seems probable that DM does not exists per se, but DM could just be some type of vacuum energy concentrated around galaxies (see also [23]).

(v) The density of the negative vacuum energy can be determined by means of field equations of the cosmic quaternionic field.

The aim of this short communication was only to outline the basic idea of a possible new interpretation of dark matter. Many important issues remained open and may be eventually solved by the future detailed theory and its application to a realistic model of galaxies.

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