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Dark Energy Attenuation Based Modification of Newton's Law of Gravity: A Theoretical Support to Milgrom's MOND Concept

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Abstract

The Concept of MOND (Modifying Newtonian Dynamics) was proposed by Mordehai Milgrom as a possible way to reconcile the difference between the experimentally observed high values and the calculated values using Newton's Law of Gravity for the dynamical parameters of orbiting stars in a galaxy, without having to introduce the concept of dark matter. Milgrom's MOND concept challenges the need for dark matter to account for the above difference. The experimentally observed velocity rotation curves of stars in a galaxy show that for small values of r (distance of the star from the centre of the galaxy), the velocity observed (V_O) for the orbiting star fairly agrees with values (V_N) calculated using Newton's law of gravity. But as r increases, the difference between V_O and V_N gradually increases. For very large values of r, V_O increases with a constant slope. Finally, V_O becomes fairly constant with distance. The above features of V_O cannot be explained by Newton's law of gravity. Milgrom successfully showed that the above features can be explained by modifying Newton's law of gravity as $F = \frac{GMm}{r^2 \mu}$ where μ is a function just added by Milgrom without a supporting theory behind and is assumed to have certain special properties to suit the purpose. In this paper, it is shown that when the attenuation of dark energy by the space medium is taken into account, Newton's law of gravity gets modified with a correction term in it. This correction term surprisingly gives rise to the required properties of the function μ added by Milgrom to the existing conventional law of gravity. The work presented here therefore can be considered as a theoretical support for the successful phenomenological scheme proposed by Milgrom.

Keywords

Dark Matter, Dark Energy, MOND, Alagar-Uma Mass formula, Axioms for Space

1. Introduction

The abnormally high experimental values (Krumm *et al.* [1], Salpeter *et al.* [2], Bosma [3], Rubin *et al.* [4]) observed for the dynamical properties associated with the motion of stars in a galaxy which are unexplainable by Newton's Law of Gravity pose (Faber *et al.* [5], Rood [6]) a great challenge to the astrophysicists and make them consider the following three possibilities.

1) There exists a large quantity of unseen matter (Dark matter) in a galaxy, which boosts the values for the above-mentioned dynamical parameters beyond what would be expected on the basis of the visible mass alone.

2) Instead of requiring the existence of dark matter, the second possibility is that Newton's law of gravity needs a suitable modification and by this modification, the experimentally observed values for the dynamical parameters of stars in a galaxy can be accounted for.

3) There are scholars who need a modification of Newton's law of gravity and also require the presence of dark matter to explain the above experimentally observed dynamical parameters of the motion of stars in a galaxy (Oliver Pignard [7]).

The first possibility leads to dark matter hypothesis and the second possibility leads to MOND proposed by Mordehai Milgrom (Milgrom [8] and Bekenstein *et al.* [9]).

As for the first possibility, the extra mass required to explain the difference is termed as dark matter (Missing mass or Hidden mass). For the past four decades various theories have been proposed regarding the nature of dark matter. As of today, there is no experimental support for the presence of any kind of dark matter. As an alternative approach, Mordehai Milgrom's MOND scheme modifies Newton's law of gravity to fit the experimental data without invoking dark matter. As a mere assumption, Milgrom replaces Newton's law $F = \frac{GMm}{r^2}$ by $F = \frac{GMm}{r^2 \mu}$ where the function μ is tailored to suit the experimentally observed values.

Milgrom assumes that the acceleration a of a test particle in a gravitating system is given by

$$a = \frac{g_N}{\mu\left(\frac{a}{a_0}\right)}$$

where g_N is the conventional gravitational acceleration and a_0 is a characterised constant for a given galaxy with the dimension of acceleration. The function

$\mu\left(\frac{a}{a_0}\right)$ is so constructed that it has the following requirements.

For $\frac{a}{a_0} \gg 1$, $\mu \cong 1$ and $a = g_N$

For $\frac{a}{a_0} \ll 1$, $\mu = \frac{a}{a_0}$ and $a = \frac{g_N}{\left(\frac{a}{a_0}\right)}$

Milgrom's work, spanning over a few decades has met with a fair success and gained a good reputation among the current astrophysicists. However, his assumptions regarding the function μ and its properties do not stem from a theory.

To quote Milgrom [8]: "Successful as it may be, MOND remains at present as a limited phenomenological theory. By phenomenological, I mean that it has not been motivated by, and is not constructed on fundamental principles". This observation of Milgrom provides a strong motivation for the work presented in this paper.

2. Dark Energy and Its Attenuation

Ever since Newton deduced his law of gravity from Kepler's laws of planetary motion, the problem of deriving the gravity formula from suitable axioms has posed a great challenge to the physics community. As Richard Feynman remarked: "No machinery has ever been invented that 'explains' gravity without also predicting some other phenomenon that does not exist." (Richard Feynman [10]). Further there is a famous statement of Newton: "I do not pretend to know the cause of gravity……" (Newton's Letter to Richard Bentley, 1692). About two decades ago, one of us (Alagar Ramanujam *et al.* [11]), working on the premise that gravity is not attraction (Higgs [12], Peebles *et al.* [13], Andrew Janiak [14], Padmanabhan [15], Eric Verlinde [16], Davis *et al.* [17], Bernal Thalman [18]) but a phenomenon arising out of the interplay between the compressive Space pressure on every object and the dark energy emitted by the object trying to mitigate the compressive pressure, obtained a formula for the mass *(M)* of a macro object as

$$M = \beta A(C - R) \tag{1}$$

where A is the surface area of the object, C is the Space pressure on the object, R is the dark energy repulsive flux emitted by the object and β is a universal constant.

The above Alagar-Uma Mass formula, was obtained from a set of axioms (Alagar Ramanujam *et al.* [11]) framed for the primordial Space in which the universe is floating. The axioms are:

1) Space is all-pervading and is of potential Energy and Consciousness. It has the property of self-compression and continually exerting compressive pressure on every system in it.

2) Self-compression results in the formation of infinitesimal spinning quanta of Space, called "formative dust". Due to the surrounding compression, dust is forced into the formation of discrete groups known as fundamental particles; every group

of dust formed by the surrounding compressive pressure of Space has a spin and hence becomes a source of a diverging radial field with a repulsive force at every space-time point.

Using the above mass formula, Alagar Ramanujam *et al.* ([19], [20], [21], [22]) and Vijay [23] succeeded in obtaining the first ever derivation of Newton's law of gravity.

In this paper, their derivation is revisited taking into account the attenuation of the dark energy, emitted by the objects due to its absorption by the Space medium.

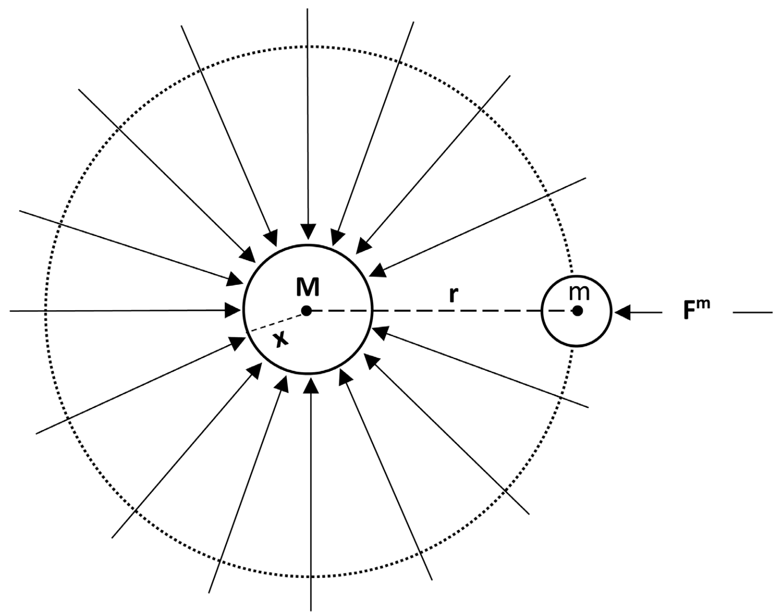

Figure 1. Space pushes m towards M.

Let M be the mass of the supermassive object at the centre of a galaxy with surface area A and m be the mass of a star orbiting around it at a distance r. Let C be the compressive pressure on M due to Space. The compressive thrust AC acting on the mass M from all directions is the same as the compressive thrust acting on the imaginary sphere of radius r. It is the compressive thrust that permeates through the imaginary sphere of radius r, finally arrives on the object M (**Figure 1**). So, the compressive pressure (C_r) due to space on the unit area of the imaginary sphere will be $\left(\frac{AC}{4\pi r^2}\right)$.

The intensity of the total repulsive flux AR emanating from the object M will go on decreasing with the distance r due to the attenuation by the Space medium.

Let $f(r)$ be the amount of repulsive flux absorbed by the Space of volume $\frac{4\pi}{3}\left(r^3 - x^3\right)$, where x is the radius of the central massive object. Then $\left(AR - f(r)\right)$ will be the repulsive total flux that will pass through the imaginary sphere.

So, the repulsive pressure at the distance r will be given by

$$R_r = \frac{AR - f(r)}{4\pi r^2} \tag{2}$$

In view of this, the net inward pressure at the distance r will be

$$p_r = (C_r - R_r) = \frac{AC - (AR - f(r))}{4\pi r^2} \tag{3}$$

As r increases, $f(r)$ will increase reaching a maximum at $r = r_0$ when the total repulsive dark energy flux AR is completely absorbed.

Hence, we write

$$f(r) = \frac{4\pi}{3}(r^3 - x^3)t \tag{4}$$

$$f(r_0) = \frac{4\pi}{3}(r_0^3 - x^3)t = AR \tag{5}$$

where t is the flux absorbed by unit volume of the Space.

The force F^m on the orbiting star of mass m will be

$$F^m = Kmp_r \tag{6a}$$

where K is a proportionality constant whose value depends on the nature of the material of the mass m. The dimension of K will be $[L^2\ M^{-1}]$.

Combining Equations (3) and (6a), for the force acting on m we have

$$F^m = Km\left(\frac{AC - (AR - f(r))}{4\pi r^2}\right)$$

$$= Km\left(\frac{A(C-R) + f(r)}{4\pi r^2}\right)$$

By using Equation (1), we get

$$F^m = Km\frac{M\beta^{-1} + f(r)}{4\pi r^2}$$

$$F^m = KmM\beta^{-1}\frac{1 + \beta(M)^{-1} f(r)}{4\pi r^2}$$

Taking $\left(\frac{K}{4\pi\beta}\right)$ as G, we have

$$F^m = GmM\frac{1 + \beta(M)^{-1} f(r)}{r^2}$$

From Equation (4),

$$F^m = GmM\frac{1 + \beta(M)^{-1}\left(\frac{4\pi}{3}\right)(r^3 - x^3)t}{r^2}, \quad r < r_0$$

$$F^m = GmM\frac{1 + \omega(r^3 - x^3)}{r^2} \tag{6b}$$

where $\omega = \frac{4\pi t\beta}{3M}$ is a characteristic factor of the galaxy under consideration. Its dimension is [L^{-3}]. Dimension of G is [L^2 M^{-1}] [LT^{-2}] = [L^3 M^{-1} T^{-2}].

The action-reaction equality of F^m and F^M (force acting on the mass M) demands that,

$$F^m = F^M = F = \frac{G}{r^2}\left\{M + \omega_1\left(r^3 - x^3\right)\right\}\left\{m + \omega_2\left(r^3 - y^3\right)\right\} \tag{7}$$

Where $\omega_1 = \frac{\beta 4\pi t_1}{3}$; $\omega_2 = \frac{\beta 4\pi t_2}{3}$ and y is the radius of the mass m. t_1 and t_2 are the repulsive flux from M and m respectively, absorbed by unit volume of the Space.

Equation (7) shows that the modified gravity force law between any two masses, here M and m, has a correction term and hence differs from the usual Newton's law of gravity. With this correction term taken into account, Equation (7) is termed here as Vethathirian Law of Gravity (VLG). In what follows the consequences of this extra correction term is discussed in detail.

If the absorption of the repulsive dark energy flux by the Space medium between the super massive object M and the star m is not taken into account, then t_1 and t_2 will be zero and in that case Equation (7) reduces to the usual Newton's law of gravity. Thus, the attenuation of the dark energy flux by the Space gives rise to a modification to the existing Newton's law of gravity.

3. Theoretical Support to Milgrom's MOND Concepts

A concept of great significance brought out in this paper is the following: Every object emits dark energy waves in Space and once emitted their intensity gradually decreases due to the gradual absorption of the dark energy waves by the Space medium. Due to this attenuation the derived expression given in Equation (7) becomes different from the traditional Newton's law of gravity. As a first application of the modified Newtonian law of gravity, it is shown below that the correction term $\left(1+\omega\left(r^3 - x^3\right)\right)$ in Equation (6b) meets the requirements of the function μ of Milgrom as expressed in the Introduction. This amounts to a theoretical support to Milgrom's MOND concept.

From Equation (6b) we can write for the modified acceleration of an orbiting star in the galaxy as

$$a^m = g^n\left(1+\omega\left(r^3 - x^3\right)\right)$$

$$a^m = \frac{GM}{r^2}\left(1+\omega\left(r^3 - x^3\right)\right) \tag{8}$$

where $g^n\left(=\frac{GM}{r^2}\right)$ is the Newtonian acceleration of the star at a distance r from the centre of the galaxy and a^m is the acceleration of the star according to the modified Newtonian law of gravity. Since a^m will always be greater than g^n, Equation (8) has the potential to explain the abnormally high experimental values for the accelerations of the stars.

To speak in the language of Milgrom we have

$$a^m = g^n\left(1+\omega\left(r^3 - x^3\right)\right),\ r < r_0$$

$$a_0^m = g_0^n\left(1+\omega\left(r_0^3 - x^3\right)\right) \text{ where } g_0^n = \frac{GM}{r_0^2}$$

$$\frac{a^m}{a_0^m} = \frac{g^n\left(1+\omega\left(r^3 - x^3\right)\right)}{g_0^n\left(1+\omega\left(r_0^3 - x^3\right)\right)} \tag{9}$$

As r decreases, Equation (9) shows that $\frac{a^m}{a_0^m}$ tends to become a very large quantity and a^m approaches g^n since $\omega\left(r^3 - x^3\right)$ decreases. This property of Equation (9) supports Milgrom's requirement that for large values of $\left(\frac{a}{a_0}\right)$, $\mu\left(\frac{a}{a_0}\right)$ tends to 1, so that $a = g^n$.

For large values of r beyond the value of r_0, since the correction term $\omega\left(r^3 - x^3\right)$ becomes maximum and remains the same, we have from Equation (9),

$$\frac{a^m}{a_0^m} = \frac{r_0^2}{r^2},\quad r > r_0.$$

Let us consider a distance r in the periphery area of the galaxy such that

$$r^2 = r_0^2\left(1+\omega\left(r_0^3 - x^3\right)\right)$$

For the above distance r, which is far greater than r_0, $\left(\frac{a^m}{a_0^m}\right)$ will be extremely small. Substituting for r^2 in Equation (8) we get

$$a^m = \frac{GM}{r_0^2} = \frac{GM}{\left(\frac{a^m}{a_0^m}\right)r^2} = \frac{g^n}{\left(\frac{a^m}{a_0^m}\right)} \tag{10}$$

Thus Equation (10) supports Milgrom's another requirement expressed by him as follows. For small values of $\left(\frac{a}{a_0}\right)$, $\mu\left(\frac{a}{a_0}\right)$ tends to $\left(\frac{a}{a_0}\right)$ so that

$$a = \frac{g^n}{\left(\frac{a}{a_0}\right)}$$

Since the requirements of Milgrom's function $\mu\left(\frac{a}{a_0}\right)$, are shown to flow from the correction term, the work presented here may be considered as a theoretical support to Milgrom's work. It is our view that all his results based on his function $\mu\left(\frac{a}{a_0}\right)$, are physically possible and worth considering.

4. Discussion & Conclusion

Around 1980, it was confirmed that, the experimentally absorbed values for the dynamical parameters of the orbital motion of stars in the periphery of the galaxy, exceeds the corresponding values calculated by the Newtonian Law of Gravity. As a possible explanation for this discrepancy, the hidden mass or the dark matter hypothesis was introduced. According to this hypothesis, much of the mass in a galaxy is in unabsorbed form and if one takes the unabsorbed dark matter into account, the above discrepancy will not be there. However, there is no as yet any experimental confirmation regarding the existence of dark matter.

As an alternative to the hidden mass hypothesis, Mordehai Milgrom proposed a concept called MOND concept. The work of Milgrom shows that, if a certain modified version of the Newtonian Law of Gravity, is used to describe the motion of stars in a galaxy, the observational results are reproduced with no need to assume the hidden mass. Milgrom modifies Newtonian Law of Gravity by introducing a function μ. Requiring the function to have a specific set of properties, he has developed a very successful phenomenological scheme to explain the experimentally absorbed high values without the necessity to introduce dark matter. Though highly successful, his phenomenological scheme has no theory behind it. This paper offers a theory from which Milgrom's function μ becomes derivable with its specific properties.

Derivation of Newton's law of gravity presented here is a first of its kind. As already mentioned, gravity is considered here not as an attraction, but a phenomenon arising out of an interplay between compressive pressure due to Space on the object and the dark energy repulsive pressure emanating from the object. The attenuation of dark energy by the Space medium gives rise to a correction term to the existing Newton's law of gravity. It is this correction term that lends a theoretical support to the work of Milgrom, spread over four decades, to explain the abnormally high experimental values for the dynamical parameters of the orbiting stars in a galaxy, without any necessity to introduce dark matter.

The Vethathirian Law of Gravity obtained here has a potential to modify the expressions for the Schwarzschild metric due to an isolated mass M. The Schwarzschild line element is well known in General theory of relativity and is given below.

$$\mathrm{d}s^2 = \left(1 - \frac{2\varnothing}{c^2}\right)\mathrm{d}t^2 - \left(1 - \frac{2\varnothing}{c^2}\right)^{-1}\mathrm{d}r^2 - r^2\left(\mathrm{d}\theta^2 + \sin^2\theta \mathrm{d}\Phi^2\right)$$

where $\varnothing$ is the Newtonian Potential $\left(\frac{GM}{r}\right)$.

Since the Vethathirian Law of Gravity is different from Newtonian Law of Gravity, the Vethathirian potential will be different from the Newtonian potential. In view of this, the potential $\varnothing$ in the above expression has to be replaced by a new expression for the potential to be obtained from Vethathirian Law of Gravity. This work will be a further application of Vethathirian Law of Gravity and the same is in progress (Alagar Ramanujam *et al.* [24]).

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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