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Research Paper

An appraisal of Milgrom's fitting formula by the antigraviton-graviton theory

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Abstract

On one hand, the Wong's antigraviton-graviton theory (AGT), which may also be called a new quantum gravity theory, predicts that at the limit of infinite radius, the effective acceleration is proportional to the square root of the Newtonian gravitational acceleration. Thus it partially supports Milgrom's fitting formula (MIFF). On the other hand, our AGT discovers that the definition of the critical acceleration as a universal parameter by MIFF is not adequately valid.

Keywords: *Cosmology: Theory, Dark Matter, Galaxies: Kinematics And Dynamics, Gravitation, Large-Scale Structure Of Universe.*

1. Introduction

According to Newton's second law of motion, $F = ma$ where F is the force acting on a mass m , and a is the acceleration produced. In 1983, the first alternative model to the dark matter hypothesis, called Modified Newtonian Dynamics (MOND), was proposed by Milgrom, who suggested an ad hoc modification of the second law: when the acceleration is much smaller than a universal critical acceleration a_o , force becomes proportional to the square of acceleration; but if the acceleration is much larger than a_o , force is proportional to acceleration as usual. Milgrom emphasized that MOND "does not constitute a theory", and can at most be interpreted as an "effective working formula", which has "limited applicability" [1]. Astronomical data of galaxies, galactic clusters and superclusters have given considerable empirical support to Milgrom's fitting formula (MIFF). In the following, we shall derive an acceleration formula in the limit of infinite distance, according to the Wong's antigraviton-graviton theory (AGT) [2], which may also be called a new quantum gravity theory, and compare it with MIFF.

2. Theory

According to our AGT [2] , when the radius R is less than or equal to the gravitational scale-length R_o , Newtonian gravity theory (NGT) is correct. Thus the centripetal acceleration of a star which is at a radius of R_o from the galactic center is

$$a_o(R_o) = G_n M(R_o)/R_o^2 , \qquad (1)$$

where $M(R_o)$ is the central mass at the radius R_o . According to NGT, the centripetal gravitational acceleration at any radius R is

$$a_n(R) = G_n M(R)/R^2 , \qquad (2)$$

where $M(R)$ denotes the central mass at the radius R. In reference [2], it has been shown that the effect of the cooperation of antigravitons with gravitons is that the central mass $M(R)$ has been amplified by an amplification factor of

$$\mu(R) = \cosh[R/\lambda(R)]/\cosh(1) . \qquad (3)$$

Hence, according to our antigraviton-graviton theory (AGT), using eq. (3), the centripetal acceleration at radius R is

$$a_q(R) = \frac{G_n M(R) \times \mu(R)}{R^2} . \qquad (4)$$

In reference [2], it has also been shown that the distance dependence of the expectation value of the graviton wavelength is

$$\lambda_A(R) = R_o\left[1 + \frac{(R/R_o) - 1}{1 + \ln(R/R_o)}\right] . \qquad (5)$$

From eq. (5), it can be shown that

$$R \to \infty, \lambda_A \to \frac{R}{\ln(R/R_o)} \qquad (6)$$

Eq. (6) yields

$$R \to \infty, \frac{R}{\lambda_A} \to \ln(R/R_o) \qquad (7)$$

$$R \to \infty, \cosh(R/\lambda_A) = \cosh[\ln(R/R_o)] = 0.5(R/R_o) \qquad (8)$$

Using eq. (3) and eq. (8), we obtain

$$R \to \infty, \ \mu(R) \to \frac{R}{2R_o \cosh(1)} . \qquad (9)$$

Substituting eq. (9) into eq. (4), we have

$$R \to \infty, a_q(R) \to \frac{G_n M(R)}{2\cosh(1) R_o R}. \quad (10)$$

From eq. (1), (2) and (10), we get

$$R \to \infty, a_q(R) \to \frac{\eta}{\sqrt{2\cosh(1)}} \sqrt{a_o(R_o) a_n(R)} = \frac{\eta\sqrt{a_o(R_o) a_n(R)}}{1.756747}, \quad (11)$$

where η is defined as the mass ratio

$$\eta = M(\infty)/M(R_o). \quad (12)$$

In reference [2], we have shown that R_o is equal to 0.5π times the radius of its radial centre of mass (RCM). In order to estimate η, let us take the approximation that the mass distribution of a galaxy (including both stars and gas) can be represented by an exponential function with a photometric scale-length R_{ph}, it can be shown by integral calculus that the RCM is equal to $2R_{ph}$. Therefore,

$$R_o = \pi R_{ph}. \quad (13)$$

Combining eq. (12) and (13), and using the formula for the calculation of mass for an optically thin model [3], it can be shown that

$$M(R_o)/M(\infty) = 0.9567861 \text{ (7 sig. fig.)}. \quad (14)$$

Thus the reciprocal η is equal to 1.045166 (7 sig. fig.). Substituting this value of η into eq. (11) we obtain

$$R \to \infty, a_q(R) \to 0.5949438\sqrt{a_o(R_o)a_n(R)} \approx 0.59\sqrt{a_o(R_o)a_n(R)} \text{ (2 sig. fig.)}. \quad (15)$$

Eq. (15) is calculated to 2 significant figures, as the above approximation, of using a single photometric scale-length R_{ph} in representing the galactic mass distribution, usually cannot attain accuracy better than about 3 per cent.

3. Discussion

From the above, our AGT found out that, for each spiral galaxy, when the radius reaches the gravitational scale-length R_o, the acceleration attains a critical value a_o, below which NGT is exact; but above which, NGT no longer applies. And a_o is found to be the centripetal acceleration of a star which is at a radius of R_o from the galactic center, i.e. $a_o = a_o(R_o)$. Eq. (15) is very similar to Milgrom's fitting formula [MIFF], namely

$$R \to \infty, a_{miff}(R) \to \sqrt{a_{o,miff}\, a_n(R)}, \quad (16)$$

where $a_{miff}(R)$ $a_{o,miff}$ is the acceleration predicated by MIFF, and $a_{o,miff}$ is the universal critical acceleration assumed by MIFF. Although eq. (15) predicts that at the limit of infinite radius, the effective acceleration is proportional to the square root of the Newtonian acceleration $a_n(R)$ [1]; yet according to our AGT, the parameter a_o is defined as the acceleration at the gravitational scale-length R_o. Consequently, the value of a_o depends on the mass distribution of the individual galaxy. This definition of a_o is different from MIFF, according to which $a_{o,miff}$ is a universal constant. For a sample of nine spiral galaxies, Begeman, Broeils and Sanders found that the value of $a_{o,miff}$ depends on each individual galaxy and the statistical average of $a_{o,miff}$ is $1.21\times10^{-10}\,\mathrm{m\,s^{-2}}$, with a dispersion of 0.27 (about 22%) [4].

This relatively large dispersion suggests that the interpretation of our AGT is more accurate than that of Milgrom's definition of the critical acceleration ($a_{o,miff}$). Nevertheless, as much empirical support has been given to the ad hoc MIFF by galaxies, galactic clusters and superclusters, a similar support may be expected for our AGT, which is a gravitational theory derived from special relativity theory and quantum theory.

4. Conclusion

On one hand, since our AGT predicts that at the limit of infinite radius, the effective acceleration is proportional to the square root of the Newtonian acceleration a_n, it partially supports MIFF. On the other hand, our AGT discovers that the definition of the critical acceleration ($a_{o,miff}$) as a universal constant by MIFF is not adequately valid.

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