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Approaches to Describing the Motion of Stars in Galaxies

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Abstract

Only one gravitational interaction is not enough to explain the anomalous high speeds of rotation of stars on the outskirts of galaxies. Therefore, several approaches have been proposed by various authors, including the existence of dark matter, deformation of the gravitational interaction itself at ultra-long distances, modifications of Newton's classical laws, the introduction of additional additive potentials that are weaker than the gravitational interaction, but which decrease with distance relatively "slower" than the actual gravitational interaction. All these approaches make it possible to explain the experimental data on the velocities of stars, but within the limits of the size of the galaxy. For even more distant distances, the accelerated expansion of the Universe is established. So, to explain this, the concept of dark energy was introduced earlier. The approaches proposed earlier cannot fully explain all the features of the motion of galaxies relative to each other. At the same time, the introduction of two additional potential interactions (with the forces $\delta Mm/R$ and $-\beta Mm/R_n$) formally makes it possible to explain most of the experimentally found features of the motion of stars at sub galactic and intergalactic distances.

Keywords: Fundamental interactions • Gravitational potential • Stability of galaxies • Stellar orbital motion

Introduction

Experimental rates of star rotation at the peripheries of galaxies, determined by Rubin VC and Ford Jr. WK [1] in 1970, indicate that gravitational interaction alone is insufficient to explain the dynamic stability of galaxies. They enlisted assumption concerning the existence of Dark Matter (DM), made by Zwicky F [2], who determined using the virial law that the kinetic energy of galaxies motion in Coma Berenices cluster was substantially higher than their potential energy of gravitational attraction for the cluster to be stable. Today these data point to the expansion of the Universe. The idea of DM was necessary just to make the cluster stable [2]. Indeed, DM would allow this cluster to be stable due to gravitational interaction, but this would be so only if DM would not contribute into kinetic energy. In addition, for DM to provide constant star rotation rates at the peripheries of galaxies, its density should increase in a specific manner with distance from the center. In other words, DM distribution over a galaxy should resemble a divergent lens. Therefore, DM should repel from ordinary matter because DM density is minimal in the center. Thus, DM proposed by authors of Rubin VC and Ford Jr. WK [1] and Zwicky F [2] was to possess these paradoxical features. These features were forgotten or taken into account incompletely in the current century. Nevertheless, this approach is still widespread among astrophysicists.

Description

However, undeniable evidence of DM existence has not been obtained yet. In addition, to explain accelerated expansion of the Universe established in 1998 on the basis of data concerning 1a type supernova (S. Perlmutter et al.), DM was supplemented with DE. Astrophysicists have come to a paradoxical conclusion: usual matter accounts for only 4.9% in our Universe, while the rest are invisible dark substances. This situation did not satisfy some astrophysicists, so other hypotheses are also put forward.

Alternative approaches

1) Various methods of Newton's dynamics modification (Milgrom M [3], Bekenstein JD [4] and Wei Li, et al.);

2) Modification of gravitational potential itself, by analogy with Yukawa potential (C. Brando);

3) Assumption concerning strengthening of the interaction between gravitons at the peripheries of galaxies (M. Clark);

4) Introduction of an additional interaction potential that decreases slower that the gravitational potential with an increase in distance (J. Tohline and Sanders RH [5]).

In 2014, Puga VA proposed to supplement Newtonian gravitation potential by two more potentials with the common interaction force [6]:

$$F = M \times m \times (\gamma \times R^{-2} + \delta \times R^{-1} + \varepsilon) \quad (1)$$

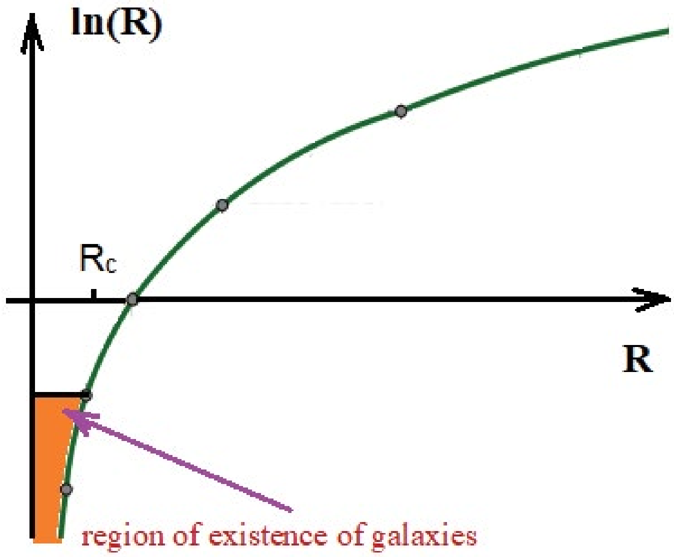

Figure 1. Dependence of the potential energy on the distance R between the bodies interacting with the force F= Mmδ/R (which also corresponds to the attraction of the giant black hole located in the center of the galaxy and the stars of this galaxy).

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He proposed the values for additional constants: $\delta \approx (2.7\pm0.4) \times 10^{-31}$ m^2 $\times$ kg^{-1} $\times$ s^{-2} and $\varepsilon \approx (3.0 \pm 1.0) \times 10^{-51}$ m $\times$ kg^{-1} $\times$ s^{-2}. We propose to supplement the gravitational potential with two more potentials with interaction forces $F=\delta Mm/R$ and $F=-\beta Mm/R_n$, so that the former allows explaining the constancy of star rotation rates at the peripheries of galaxies, while the latter (repulsion potential) allows explaining the accelerated expansion of the Universe [7,8]. The authors are planning in the future to propose the physical mechanisms due to which the additional potentials arise, and to evaluate the values of β and n parameters. The potential energy corresponding to the second term of expression (1) has the following graphic dependence a typical logarithmic function (Figure 1).

Conclusion

Stellars that happen to be at distances above the critical distance, apparently, will not linger in the galaxy in stationary orbits {explained in detail based on the virial theorem}. The region of stability within galaxies is shown in orange. The characteristic critical distance R_c is $\approx 10^{22}$ m. If the traditional gravitational potential {the first term of expression (1)} at any distance allows the formation of orbital motion, then for interaction with the force $F=\delta Mm/R$, orbital motion at ultra-long distances is impossible (at $R > 10^{22}$ m; see Figure 1).

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Conflict of Interest

None.

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