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Mathematical Description of the Rotation of Spiral Galaxies Linearly Dependent on the Distance of Dark Energy

Dr. Vasiliy K. Balkhanov

Institute of Physical Materials Science of the Siberian Branch of the Russian Academy of Sciences, Ulan-Ude City, Russia

***Correspondence author**

Dr. Vasiliy K. Balkhanov
Institute of Physical Materials Science of the Siberian Branch of the Russian Academy of Sciences
Ulan-Ude City
Russia

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Abstract

The article explains why astrophysicists had to enter a dark mass and dark energy. We just assumed that the amount of dark energy increases linearly with distance from the center of the galaxy. This assumption, apparently, makes best describe rotary rotation curves of spiral galaxies.

Keywords: spiral galaxies, dark energy

Introduction

The rotation is the center of the Galaxy

From observations [started Zwicky F. (1933, Helvetica Phys. Acta, 6, 110); continue, for example, Persic M., Salucci P., Stel F., 1996, MNRAS, 281, 27)]. It was found that the actual speed of rotation is approximately constant, experiencing only minor fluctuations. In the year 1959 Louise Volders demonstrated that spiral galaxy M33 (Triangle) does not spin as expected according to Newtonian dynamics. In 70-ies of the last century the result was spoken to many other spiral galaxies. Currently known thousands of rotational curves, and they all show in favor of the existence of the unknown nature of the mass in the Halo of the Galaxy, tenfold higher than a lot of stars in the Galaxy's disk, see for example, Figure 1 and [[Lukash & Mikheeva, 2010; Dergachev, 2013; Zasov et al., 2017; Lilly, 1981].

The initial plot rotation curve can be explained as follows. Center of the Galaxy is a dense cluster of stars of various natures, crystal gravitational attraction. The rotation of such a dense clusters can be thought of as a rigid body rotation. The latter means that each segment, as well as a solid body, rotates with the same angular velocity Ω. Multiplying Ω the distance from the center of the Galaxy r, get rotary speed V_θ, with which the center revolves around a plot:

$$V_\theta = \Omega r \tag{1}$$

Figure 1 shows that, indeed, such a linear pattern on the initial site has been observed for almost all galaxies.

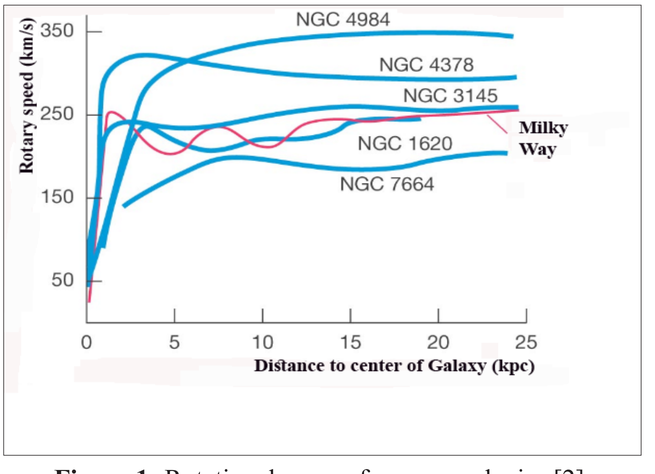

Figure 1: Rotational curves for some galaxies [2].

Kepler rotation. Description of the Schwarzschild metric

Away from the center of the star are more freely, and each of them is moving on its own. To remain in orbit, the centrifugal acceleration V^2_θ/r the stars must be compensated by gravitational attraction to the center of the Galaxy with the acceleration λ/r^2, where is $\lambda = \gamma M(r)/c^2$ (This is Newton's law). In here $M(r)$ - the mass of the galaxies inside the orbit radius r, γ - Newton's gravitational constant, c – the speed of light. Thus, equating

$$\frac{V_\theta^2}{r} = \frac{\lambda}{r^2},$$

find rotary speed of rotation of the stars according to Newtonian dynamics:

$$V_\theta = \sqrt{\frac{\gamma M(r)}{r c^2}} \tag{2}$$

This speed is shown in Figure 2 in the form of a dotted line and is called Kepler.

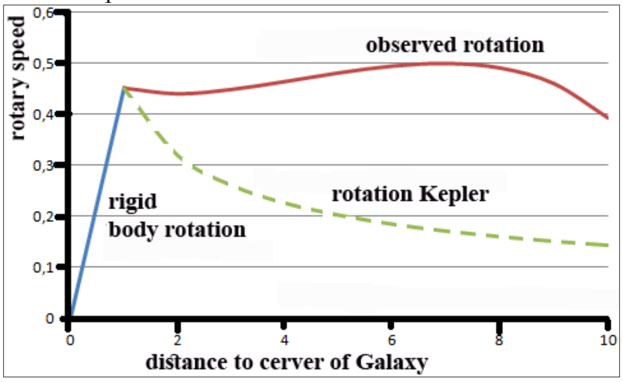

Figure 2: The observed rotational speed, described by the formula (9). Speed and distance are in relative units.

The general theory of relativity explained the result (2). Using the Schwarzschild metric and condition geodesy the trajectory of stars, find

$$V_\theta = \sqrt{\frac{\gamma\, M(r)}{r\, c^2}\left(1 - \frac{2\gamma\, M(r)}{r\, c^2}\right)} \qquad (3)$$

This expression is obtained as follows. As regard the rotation only, so variation in radial coordinates δr in the Schwarzschild metric can be omitted. Given the variation of azimuth angle δ ѳ,for square variation metric δS^2 have,

$$\delta S^2 = \left(1 - \frac{2\lambda}{r}\right)\delta t^2 - r^2\, \delta\, \vartheta^2 \qquad (4)$$

Condition surveying in the following form [4]:

$$\delta S = B\left(1 - \frac{2\lambda}{r}\right)\delta t$$

Excluding the variation with it metrics δS, (4) find

$$r^2\, \delta\, \vartheta^2 = \left(1 - \frac{2\lambda}{r}\right)\left[1 - B^2\left(1 - \frac{2\lambda}{r}\right)\right]\delta t^2$$

Where the rotational speed of the stars around the Galactic center:

$$V_\theta = \frac{r\, \delta\, \theta}{\delta\, t} = \sqrt{\left(1 - \frac{2\lambda}{r}\right)\left[1 - B^2\left(1 - \frac{2\lambda}{r}\right)\right]} \qquad (5)$$

In the absence of a gravitational field, no rotation will not be star may fly out of this Galaxy. This means that when λ = 0 must be $V_o = 0$. But from (5) to λ = 0 should be $V_\theta = \sqrt{1 - B^2}$. And to make it $V_o = 0$, we are must put $B = 1$. Thus, defined constant B. Now for the rotational speed of the (5) get general relativistic expression (3).

Dark mass and dark energy

On the one hand the result of (3) clarifies the classical expression (2). On the other hand, if $\lambda = const$, then get updated dotted line in figures 1 and 2. But over the 70 years of observations, it was found that the actual speed of rotation is approximately constant, experiencing only minor fluctuations. This speed is shown in Figure 2 in the form of a horizontal continuous wavy line. To fix the looming dilemma, recall that $\lambda = \gamma M / c^2$, and to the mass M of the Galaxy, first of all, you can always add a lot M_Λ, that call dark matter, because of its nature as long as nothing is known. And, secondly, to add the equivalent mass of dark energy E_Λ, i.e. replace $M \rightarrow M + M_\Lambda + E_\Lambda / C^2$. In such a way that the ratio (3) described the curves in figures 1 and 2, it was necessary to specify mass $M(r)$. The most simple way, followed by Astrophysics, it injected a dark matter with mass M_Λ, and dark energy E_Λ. So, that $\gamma M(r)/c^2$ is replaced with the following expression:

$$\frac{\gamma\, M(r)}{c^2} + \frac{\gamma\, M_\Lambda}{c^2} + \frac{\gamma}{c^2}\frac{E_\Lambda}{c^2} \qquad (6)$$

Here you can enter the usual way the density of dark matter p_Λ, so the mass of dark matter will $M_\Lambda = \frac{4}{3}\pi\, \rho_\Lambda\, r^3$, and Einstein's constant cosmology

$$\Lambda = \frac{8}{3}\frac{\pi\gamma\, \rho_\Lambda}{c^2}$$

Then let's make an assumption, the result of which will be the best agreement calculated rotational speeds are observed. That is, suppose that the dark energy E_Λ linearly rising from the center of the Galaxy:

$$E_\Lambda = W_\Lambda r \qquad (7)$$

On the possibility of such patterns indicates that dark energy per unit length W_Λ from dimensional considerations, turns out to be a proportional combination of fundamental constants:

$$W_\Lambda = \frac{c^4}{\gamma} = 1.2 \cdot 10^{44} \text{ Joule/m} \qquad (8)$$

Will make the following comment. Dependency (7) indicates that the dark energy as would be squeezed out from the center of the Galaxy. It can be assumed that the formation of galaxies and just the Halo is due to the fact that dark energy obeys the patterns (7).

Substituting all our results in formula (3), for a rotational speed get the following expression:

$$V_\theta = \sqrt{\left(\frac{\lambda}{r} + \frac{1}{2}\Lambda\, r^2 + \frac{\gamma\, W_\Lambda}{2c^4}\right)\left(1 - \frac{2\lambda}{r} - \Lambda\, r^2 - \frac{\gamma\, W_\Lambda}{c^4}\right)} \qquad (9)$$

This relationship is represented by a wavy line in Figure 2. See quality satisfactory agreement with the curves in Figure 1.

Conclusion

We told how Astrophysics with the need to come to the introduction of dark matter and dark energy. Installed the result (8) for the rotational speed of the various parts of spiral Galaxies. By varying the three constant -λ, ʌ and W_Λ, you can achieve the best consent formula (9) measured with a rotational pattern. Also identify their signs. For interested researchers define these three permanent for each Galaxy could be the beginning of a great independent scientific work.

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