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A Symmetric Ring Galaxy Model Explains the Rotation Curve of Galaxies

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Abstract

This paper proposes a symmetric ring galaxy (SRG) model based on the general structure of galaxies. Based on this model, we have obtained results that are consistent with the actual observation results of the galaxy rotation curve, thus solving the problem of inconsistency between the observation results of the galaxy rotation curve and the expected results, which has long plagued the astronomical community. This article also analyzes the root causes of the problem of galaxy rotation curves, and finds that the main reason is that people use unrealistic galaxy models and incorrect calculation methods. Therefore, the dark matter hypothesis and gravitational correction theory that explain the problem of galaxy rotation curves have lost their theoretical basis, and the correctness of these theories undoubtedly faces serious challenges and profound doubts.

Keywords: Galaxy rotation curve, modified Newtonian dynamics, dark substance, symmetric ring galaxy (SRG) model

1. Introduction

The Galaxy Rotation Curve (RC) is a curve that describes the relationship between the rotational speed of a star around a galaxy and the distance between the star and the center of the galaxy. In 1939, Babcock studied the RC of M31 and found that the rotational speed outside the galaxy was almost constant (Babcock, H. W., 1939). Subsequently, Oort (1940) and Volders (1959) conducted research on the RCs of NGC3115 and M33, respectively, and reached similar conclusions. With the continuous accumulation of observational data, American astronomer Vera Rubin published a far-reaching paper in 1980, confirming that in over 100 galaxies, the rotational velocity of peripheral stars in the galaxy remains almost unchanged (Rubin, V. C., Ford, W. K. J., & Thonnard, N., 1980). Due to the dense mass of the core region of a galaxy, its rotation can be approximated as rigid body rotation, so the rotation speed will rapidly increase with the increase of the rotation radius. After leaving the dense region of the galaxy's core, according to Newton's law of gravity, the farther the star is from the center of the galaxy, the slower its rotational speed will be. However, actual observation results show that the rotation speed of stars in the edge region of the galaxy did not decrease as expected, but instead showed a relatively stable rotation curve, which is known as the "flat rotation curve" (as shown in Figure 1). The inconsistency between actual observations and theoretical predictions of galaxy rotation curves has attracted widespread attention, and various explanations have emerged.

The earliest explanation proposed and accepted by most astronomers is the dark matter model (Oort, J.H., 1932; Zwicky, F., 1933; Smith, S., 1936; Oort, J.H., 1940; Kahn, F. D., & Woltjer, L., 1959; Begeman, K.G. *et al*., 1991; Sofue, Y.&Rubin, V., 2001; Chemin L., *et al*., 2011). This model assumes the existence of an invisible substance that surrounds the visible galactic disk of spiral galaxies in a spherical shape, forming a so-called dark matter halo. The total mass of these dark matter is greater than that of visible galactic disks, providing additional gravity to the stars at the edge of the galaxy, preventing a decrease in rotational speed. However, although many experiments are striving to find dark matter particles that only interact through gravity and do not participate in electromagnetic interactions, there have been no exact detection results so far. In addition, although the dark matter hypothesis can roughly explain the observational results of galaxy rotation curves, it cannot analyze the details within it. Therefore, the dark matter hypothesis still has many controversies. In order not to introduce controversial dark matter, Milgrom (1983) proposed a modified Newtonian dynamics (MOND) theory. This theory suggests that the strength of gravity varies at different scales, and assumes that when the gravitational acceleration is less than a specific threshold, Newton's law of gravity needs to be replaced by MOND (Robert, H.&Stacy, S., 2002). Although this theory performs well in certain aspects, such as fitting the rotation curve of galaxies and explaining the distribution of mass with luminosity, it is mainly based on mathematical modifications and does not provide an explanation of the specific mechanism. In addition, it lacks a solid theoretical foundation in physics and its explanations of other phenomena appear farfetched, so many people hold a reserved attitude towards it.

Newton's theory of gravity has been verified by a large number of experimental observations, and this theory is correct and logical. We cannot easily make corrections that lack physical basis just to explain the rotation curve of galaxies. This article aims to construct a brand new model based on Newton's gravitational theory to explain the rotation curve of the Milky Way galaxy, replacing the dark matter hypothesis and MOND theory.

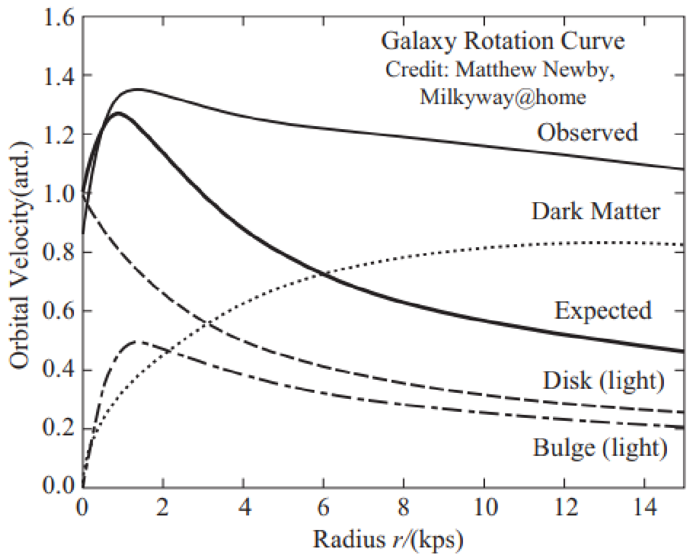

Figure 1. Galaxy rotation curve (from Zheng et al. 2022)

2. The Structure of Galaxies and the Establishment of Galaxy Models

Galaxies are usually composed of billions of stars, and their distribution in space is basically uniform. They rotate around the center of the galaxy to form a disk like structure, generally consisting of spiral galaxies and elliptical galaxies. By making any straight line in the galactic disk that passes through the center of the galaxy, many stars can be found almost symmetrically on both sides of the center of the galaxy (Figure 2A, B). Based on this, we can establish a symmetric ring galaxy (SRG) model (Figure 2C): divide the galaxy into four parts: the central core, dense region A, intermediate region B, and marginal region C. The central region is a spherical or rod-shaped structure, while the A, B and C regions are circular structures. In Zone A, due to the dense mass of stars, their rotation around the center of the galaxy approximates that of a rigid body. Therefore, in Zone A, stars farther away from the center of the galaxy have a higher rotational speed. In Zone B or Zone C, the distribution of stars is relatively dense, and the rotation radii do not differ significantly. Therefore, the rotation speed of stars in the same area is basically the same.

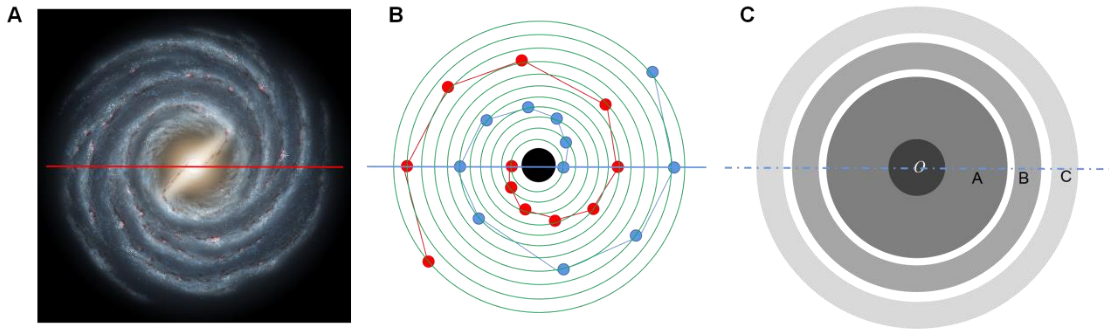

Figure 2. Galactic Structure and Galaxy Model

3. Analysis of the Forces and Rotational Velocities of Stars in the Galaxy Model

This article only considers the analysis of the forces and rotational velocities of stars in the B and C regions. Due to the circular structure of the B and C regions, the rotation speed of stars in the same region is basically the same. Therefore, we can consider the B and C regions as a whole, that is, the circular rotation around the center of the galaxy.

Assuming the total mass of the central core of the galaxy and region A is M, the total mass of region B is m_b, and the total mass of region C is m_c. The radius of the circle in Zone B is r_b, and the radius of the circle in Zone C is r_c. The distance between the circles in Zone B and Zone C is d. So, the centripetal force of the B region circle rotating around the center of the galaxy is the gravitational force between B and A regions minus the gravitational force between B and C regions:

$$F_b = G\frac{Mm_b}{{r_b}^2} - G\frac{m_b m_c}{d^2} \tag{1}$$

The centripetal force of the C region circle rotating around the center of the galaxy is the gravitational force between C and A regions, plus the gravitational force between C and B regions:

$$F_c = G\frac{Mm_c}{{r_c}^2} + G\frac{m_b m_c}{d^2} \tag{2}$$

According to the relationship between centripetal force and rotation speed

$$F = m\frac{v^2}{r} \tag{3}$$

The rotational speed of the circle in Circular B can be obtained as

$${v_b}^2 = \frac{F_b r_b}{m_b} = \frac{GM}{r_b} - \frac{Gm_c}{d^2} r_b \tag{4}$$

The rotational speed of Circular C is

$${v_c}^2 = \frac{F_c r_c}{m_c} = \frac{GM}{r_c} + \frac{Gm_b}{d^2} r_c \tag{5}$$

From equations (4) and (5), it can be seen that the rotation speed v_c of stars in the edge region does not decrease sharply compared to the rotation speed v_b of stars in the middle region as the distance from the center of the galaxy increases, because v_b needs to be subtracted from $\frac{Gm_c}{d^2} r_b$, while v_c needs to increase $\frac{Gm_b}{d^2} r_c$. After this fluctuation, the difference between the two is not significant. According to our simple galaxy model, the expected stellar rotation speed obtained under the Newtonian gravitational framework is consistent with the actual observation results.

4. Discussion

The generally default galaxy model is shown in Figure 3A. In this model, each star independently rotates around the center of the galaxy, and its centripetal force is equal to the gravitational force of the galaxy's center of mass on the star. People classify the center of the galaxy and the total mass of all stars as the mass M of the galaxy's center of mass, while the center of the galaxy is assumed to be the center of mass of the galaxy. Then, use the following formula to calculate the speed at which the star rotates around the center of the galaxy:

$$v = \sqrt{\frac{GM}{r}} \tag{6}$$

Therefore, it is believed that calculating the rotational speed of a star around the center of a galaxy only depends on the mass M of the galaxy's center of mass and the distance r from the star to the center of the galaxy. Due to $r_c > r_b$, it is expected that the rotation speed of star C in the edge region should be significantly lower than that of star B in the middle region (i.e. $v_c << v_b$). However, the actual observation results are not so significant, and the difference between the two is not significant (i.e. $v_c \approx v_b$). This is the famous problem of galaxy rotation curves. In order to explain that the rotation speed of stars in the edge region is greater than actually observed, it is assumed that the mass M of the galaxy's center of mass may be greater than the visible mass, and it is speculated that there is invisible "dark matter" in the galaxy. This is the basis for the dark matter hypothesis. Milgrom (1984) speculated that Newtonian mechanics theory may not be applicable to large-scale galaxy space, thus proposing the MOND theory.

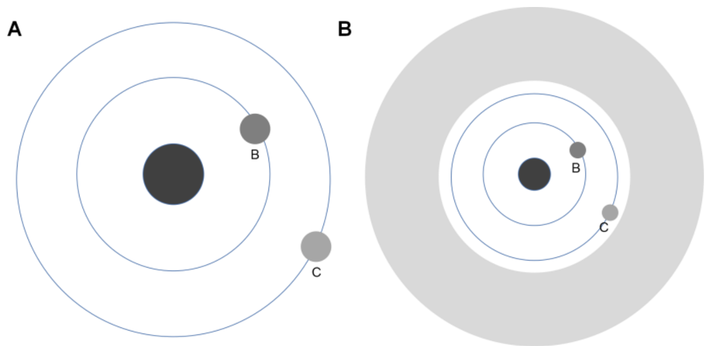

Figure 3. People's default galaxy model and hypothetical dark matter distribution

However, the galaxy model (Figure 3A) used to calculate the rotational speed of stars is not realistic. This model is actually a stellar system model similar to the solar system and does not conform to the usual spiral galaxy structure. In a solar system, the mass of stars accounts for the vast majority of the total mass (the sun accounts for 99.86% of the total mass), while the distribution of planets is often scattered and uneven. However, in spiral galaxies, the distribution of stars is basically symmetrical relative to the center of the galaxy, so the distribution is roughly uniform.

We constructed a symmetric ring galaxy (SRG) model based on the true structure of spiral galaxies such as the Milky Way (Figure 2). We simply divide the galaxy into four parts: the central core, dense region A, intermediate region B, and marginal region C. By calculating the rotational speeds of the B-zone ring and the C-zone ring, we obtained the conclusion that v_b and v_c are approximately equal. When calculating the gravitational force on the B-zone ring, we do not calculate the gravitational force on the B-zone ring from the center of mass M of the galaxy, but rather the gravitational force between the B-zone ring and the A-zone minus the gravitational force between the B-zone ring and the C-zone ring. Similarly, the gravitational force on the C-zone ring is the force between the C-zone ring and the A-zone ring, plus the force between the C-zone ring and the B-zone ring. This fully demonstrates that as long as the correct galaxy model is adopted and the correct gravity calculation method is used, we can fully explain the galaxy rotation curve based on Newton's gravity theory, and there is no problem of inconsistency between theoretical expectations and actual observations.

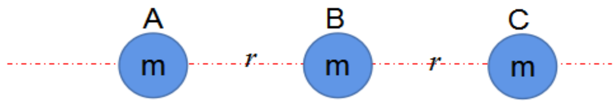

Figure 4. A simple ABC model of gravity

The real problem is not Newton's law of universal gravitation itself, but people often make mistakes when applying it. For example, if three objects A, B, and C with a mass of m are arranged in a straight line, and the distance between AB and BC is r (Figure 4), then different calculation methods will obtain different results for the gravitational force on A or C. If the gravitational force on A is calculated based on the distance from the centroids of B and C to A, or if the gravitational force on C is calculated based on the distance from the centroids of A and B to C, then

$$F_A = F_c = G\frac{m\times 2m}{(1.5r)^2} = \frac{8Gm^2}{9r^2} \tag{7}$$

If B is regarded as the center of mass of three objects, and the gravitational force acting on A or C is the gravitational force between it and the center of mass, then

$$F_A = F_c = G\frac{m\times 3m}{r^2} = \frac{3Gm^2}{r^2} \tag{8}$$

If the gravitational forces between A and B, A and C are calculated separately, then their combined forces are calculated; Or calculate the gravitational forces between C and B, C and A respectively, and then calculate their combined forces, then

$$F_A = F_c = G\frac{m^2}{r^2} + G\frac{m^2}{(2r)^2} = \frac{5Gm^2}{4r^2} \tag{9}$$

Obviously, since the three objects of ABC are completely discrete, they do not meet the necessary prerequisite for calculating the center of mass, that is, the distribution of matter must be continuous. Therefore, the first two calculation methods are incorrect. The second method also mistakenly regards its own mass as a part of the centroid mass, and then calculates the gravitational force between itself and the centroid mass. The correct approach for calculating the gravitational forces between multiple discrete objects is to calculate the gravitational forces between each object separately and then calculate their combined forces. Therefore, only the third method is correct.

It can be seen that when people use equation (6) to estimate the speed of a star's rotation around a galaxy, they actually consider the center of the galaxy as the center of mass, and consider the centripetal force of the star's rotation around the center of the galaxy as the gravitational force between the star and the center of mass of the galaxy. This processing method clearly makes errors similar to equations (7) or (8). Our proposed symmetric ring galaxy (SRG) model divides galaxies into four simple regions and roughly calculates the gravitational forces between multiple discrete objects using a method similar to equation (9). The results are in good agreement with actual observations. If we partition galaxies more and more finely, then the rotational speeds of various regions within the galaxy will be estimated more accurately.

In the dark matter model, the purpose of introducing dark matter is to increase the mass M of the galaxy's center of mass, thereby increasing the stellar rotation speed in the edge region. However, this approach ignores the fact that as the total mass of the galaxy's center of mass increases, the rotation speed of stars in the edge region increases, and the rotation speed of stars in the middle region also correspondingly increases. Therefore, the overall trend of the expected galaxy rotation curve will not change. Moreover, people believe that dark matter is mainly distributed in the regions of galaxy halos, and even speculate that galaxy halos are composed of dark matter (Figure 3B). It is speculated that the mass of dark matter in the galaxy cluster where the Milky Way is located is about ten times greater than that of visible matter (Robert, H.&Stacy, S., 2002), so the mass of dark matter in the galaxy halo is much greater than the mass of visible matter in the galaxy (including all galaxy stars and galactic cores). This mass distribution structure of galaxies, dominated by external masses, clearly cannot concentrate the mass of galaxies at the center of the galaxy and form its center of mass. Therefore, the stars in the galaxy will not be able to rotate around the center of the galaxy as usual, but will instead be pulled by the strong gravitational pull of dark matter into the dark matter halo. The purpose of introducing dark matter is indeed to maintain the validity of Newton's law of gravity, but ironically, dark matter often does not follow Newton's law of gravity.

5. Conclusion

This paper establishes a simple symmetric ring galaxy (SRG) model based on astronomical observations of galaxy structure. Based on this model, this paper analyzes the forces and rotational velocities of stars in the middle and edge regions of galaxies. Under the framework of Newton's law of gravity, we have obtained results that are consistent with the actual observation results of galaxy rotation curves, thus solving the problem of inconsistency between the observation results of galaxy rotation curves and the expected results, which has long plagued the astronomical community. The emergence of this problem actually stems from people using the wrong galaxy model and calculation method, which did not consider the symmetrical distribution of stars in the galaxy or the interaction between stars in different regions. They mistakenly regarded the center of the galaxy as the center of mass of the entire galaxy and believed that the gravitational force on the star was equal to the gravitational force between it and the center of mass of the galaxy. Therefore, the dark matter hypothesis and MOND theories have lost their theoretical basis, and the correctness of these theories will inevitably be seriously questioned and challenged. This study provides important insights and reflections on the methodology for solving physics problems.

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