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ROTATIONAL VELOCITY CURVE OF GALAXY, AND DARK MATTER FOR PHYSICS EDUCATION

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ABSTRACT

The aims of this research are to find experimental evidence that the effect of gravity added beyond ordinary matter cannot be ignored. The research objects of the experiment are 11 students from the Astronomy Couse Graduate School of Tashkent State Pedagogical University. The Research method suggested two cases to justify the application of Newtonian mechanics. Research Results, if the existing theory of gravity is correct as a result of the experiment according to this research method, then the suggestion of dark matter is necessary if the rotation speed of our galaxy remains constant even when moving away from the center. This is Kuhn's normal scientific activity of acquiring the existing theory educationally and solving the problem by the existing theory when a new phenomenon appears.

KEYWORDS: Ordinary Matter, Dark Matter, Rotational Velocity Curve of Our Galaxy, Normal science.

1. INTRODUCTION

One of the greatest intellectual advances of the past millennium was the recognition that all of the laws of nature work the same way in both the laboratory and the cosmos. However, the universe provides higher energies, temperatures, and densities; stronger magnetic and gravitational fields; and much longer observing times than we can hope to reproduce on Earth. Important findings include:

(1) The discovery that nuclear fusion provides the energy source for the Sun and other stars,

(2) Evidence from the Sun and cosmic rays that the three sorts of neutrinos can interchange their identities.

(3) Observations of changes in the orbits of binary pulsars (neutron stars) that provide dramatic confirmation of gravitational radiation, a crucial prediction of Einstein's theory of relativity.

(4) Very tight limits on the extent to which the strengths and other properties of the forces could have changed over billions of years.

(5) The recognition that most of the matter in the universe resides in some mysterious unseen form ("dark matter"), perhaps a new kind of elementary particle, and the recent evidence that a novel form of "dark energy" dominates the dynamics of the cosmic expansion(The National Academy of Sciences Co-chairs Astronomy and Astrophysics Survey Committee ,2001, p.155).

In our research, we aim to contribute to astronomy education for graduate students at teacher training colleges by focusing on (4).

Astronomy education has been reported to be very important for science literacy education in undergraduate schools (National Academy of Sciences, 2001). This study aims to provide a challenging problem by using important astronomy experiments for graduate students of teacher training schools to understand that there are astronomical phenomena that are difficult to explain with our current knowledge, based on this educational necessity.

According to Kuhn (2012, Chapter [VI), discovery begins with the appearance of anomalies, that is, things or situations that are different from what is normal or expected. Recognizing anomalies is considered essential to recognizing novelty. Discovery begins with the recognition of anomalies. It then continues with the exploration of the domain of anomalies. And it ends only when the paradigm theory is adjusted so that the anomalies become what is expected. In short, for Kuhn, anomalies are the basis of scientific discovery and emerge with difficulty and resistance.

The behavior of the planets in the solar system is often called Keplerian rotation. The galaxy is clearly more complex than the solar system. The mass-luminosity distribution obtained from the mass-luminosity relationship measured in the visible or electromagnetic spectrum shows a rotation curve predicted by Keplerian rotation, where the mass is concentrated in the center, as indicated by the cross line B. However, the dot line obtained from the neutral hydrogen spectrum observation is a rotation curve measured in the spiral arms of our galaxy, as indicated by the dot line A. Above all, for an object far from the galactic center to rotate faster than expected, there must be a significant amount of additional mass far from the galactic center.

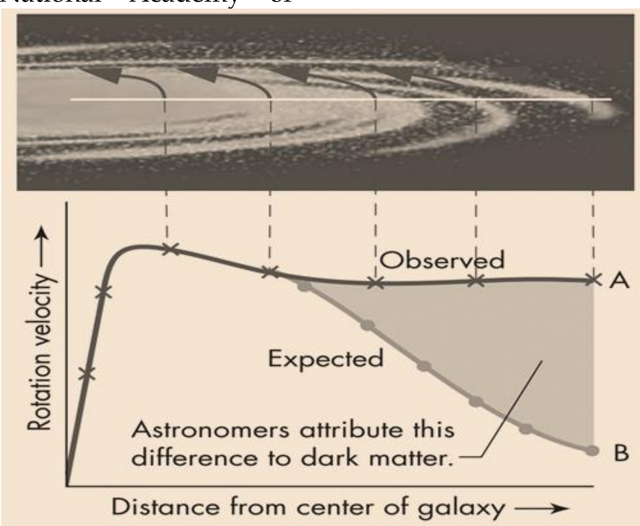


Figure 1: Rotation velocity curve of a typical spiral galaxy: predicted (B) and observed (A). The discrepancy between the curves is attributed to dark matter (Army, & Schneider, 2017, p.468).

The aims of this research are to find experimental evidence that the effect of gravity added beyond ordinary matter cannot be ignored.

The research aims of the experiment are 10 students from the Astronomy Couse Graduate School of Tashkent State Pedagogical University.

Research Q1. How are the rotational velocities (V) of hydrogen clouds calculated respectively?

Research Q2. How is the rotation curve of our galaxy actually expressed?

Research Q3. If the actual rotation curve of our galaxy is different from what we predicted, why?

Research Q4. What are the implications for astronomy education?

2. BACKGROUNDS

When a star rotates around the center of a galaxy, the gravitational force exerted on the star by the galactic mass (Mr) contained in the star's orbit acts as a centripetal force.

Universal gravitational Force = Centripetal Force

$GMr\, m/r^2 = mv^2/ r$, $\therefore Mr= rv^2/G$,.............(1)

If the material of the galaxy is only stars that emit light, the amount of hydrogen cloud is negligible compared to the star, so the total amount of material obtained from the hydrogen cloud and the rotational speed of the star is expected to be the same?

Accordingly, from equation (1),

First case, if all the mass of the galaxy is concentrated in the center, the rotational velocity of the hydrogen cloud is

$v \propto 1/\sqrt{r}$. (Kepler's Motion_)..(2)

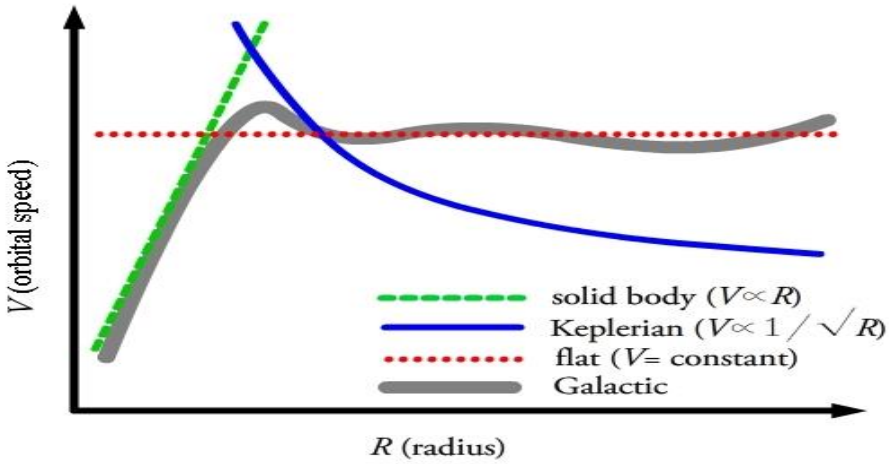
As in the equation above, it undergoes Kepler's motion that decreases inversely proportional to the square root of the distance r to the hydrogen cloud (the blue dotted line(expected) in Figure 1 shows that matter observed with normal brightness is concentrated in the center of the galaxy, and the dotted line in Figure 3 shows that the mass increases in the center of the galaxy and then stops increasing, showing that most of the mass is concentrated in the center of the galaxy.

Another case, when we actually measured the radial velocity of neutral hydrogen clouds, we found that their galactic rotational velocity v is almost constant at a distance from the galaxy.

$M \propto r$, (Non Kepler's Motion, Zeilik, & Gregory, 1998, p.430).. (3)

In other words, this is an observation result that the rotational velocity v does not depend on r (formula (3), and red solid read line in Figure 3). Therefore, We can see that it is widely distributed throughout the galaxy, not just in the center of the galaxy.

This means that there is a large amount of matter outside the galaxy. In addition, it is dark matter that does not emit light. Furthermore, we can know that about 90% of the mass of our galaxy is made of matter that cannot be observed as light, or electromagnetic waves.



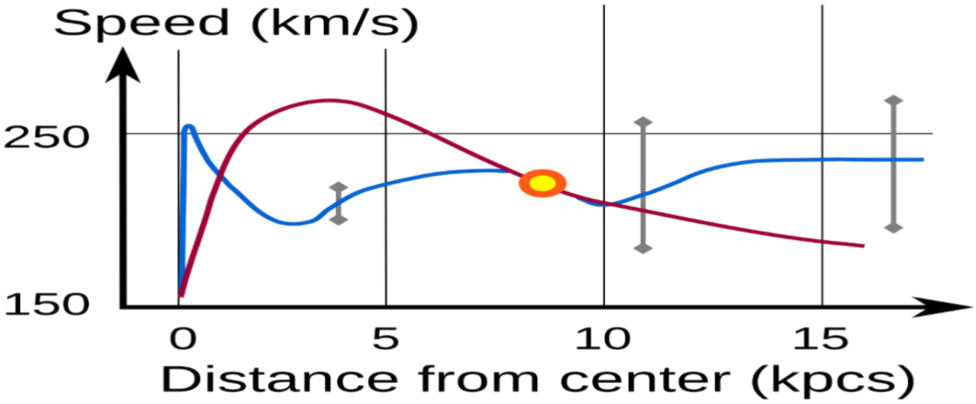


Figure 2: The observed rotational velocity distribution of our galaxy as measured from neutral hydrogen clouds and the predicted rotational velocity from observable matter.(John, et al,, 2004, p. 2; Koupelis, Theo, Kuhn, Karl F. , 2007, p.492).

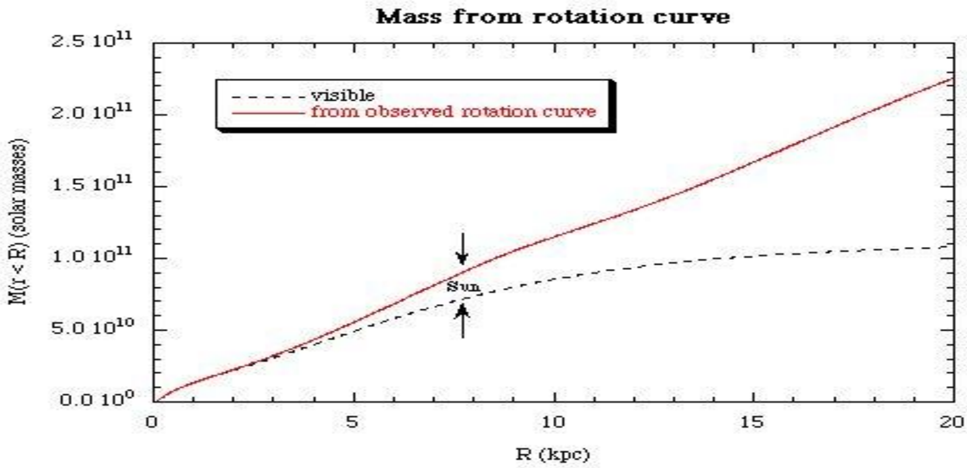


Figure 3: Comparison of the Mass distribution of our Galaxy. (Lee, et al., 2024, p.96).

3. METHODS OF RESEARCH

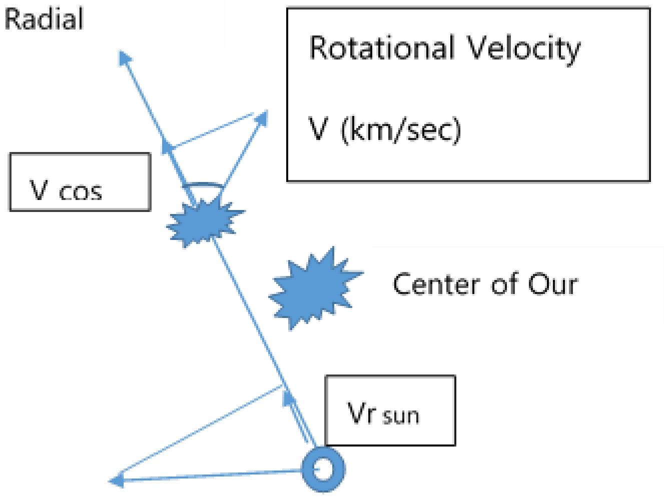
Objects of judgments: 10 graduate students at National Pedagogical University of Uzbekistan, at Tashkent.

3.1. Methods

Figure 4: Represents the positions and rotational speeds of the hydrogen clouds A ~G in the spiral arms of our Galaxy (Lee, et al., 2024, p.98).

Table 1: Distributions The Rational Velocity of Our Galaxy based on hydrogen cloud (Lee, et al, 2024, p.98).

Position	A	B	C	D	E	F	G
Distance from the center of our Galaxy (K pc)	11	5.3	3.3	6.5	14	13	20
Rotation angle of hydrogen cloud based to radial velocity (θ°)	73	53	22	63	75	127	113
Radial Velocity Vr(km/sec)	-25	43	114	10	-33	87	134
velocity of Sun based on observed radial direction Vr,sun (km/sec)	93	93	93	93	93	-220	-220
Rotational Velocity							



Rotational Velocity

Radial velocity of Hydrogen cloud

observed from sun

A

$V_r = V \cos\theta - V_{r,sun}$

Hydrogen cloud

(Rotational velocity) $V = (V_r + V_{r\,sun}) / \cos\theta$ ………………………(4)

Research Q1. Using the equation (4) obtained through the above process, the rotational velocities (V) of hydrogen clouds A ~G positions are calculated respectively.

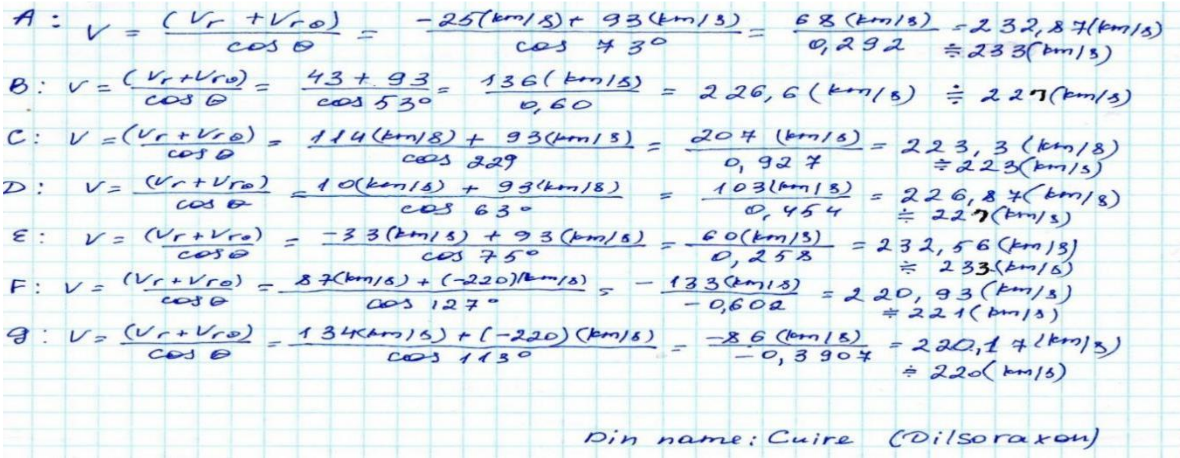


Figure 5: Results of rotational velocity calculated by students based on Table 1, Data, according to formula (4).

4. RESULTS AND INTERPRETATIONS

4.1 Results of Experiment by Graduate Students' Experiment Results, according to (4)

Research Q2. Draw the graph with the x-axis as the distance from the center of the galaxy (kpc) and the y-axis as the rotational validity (km/sec).

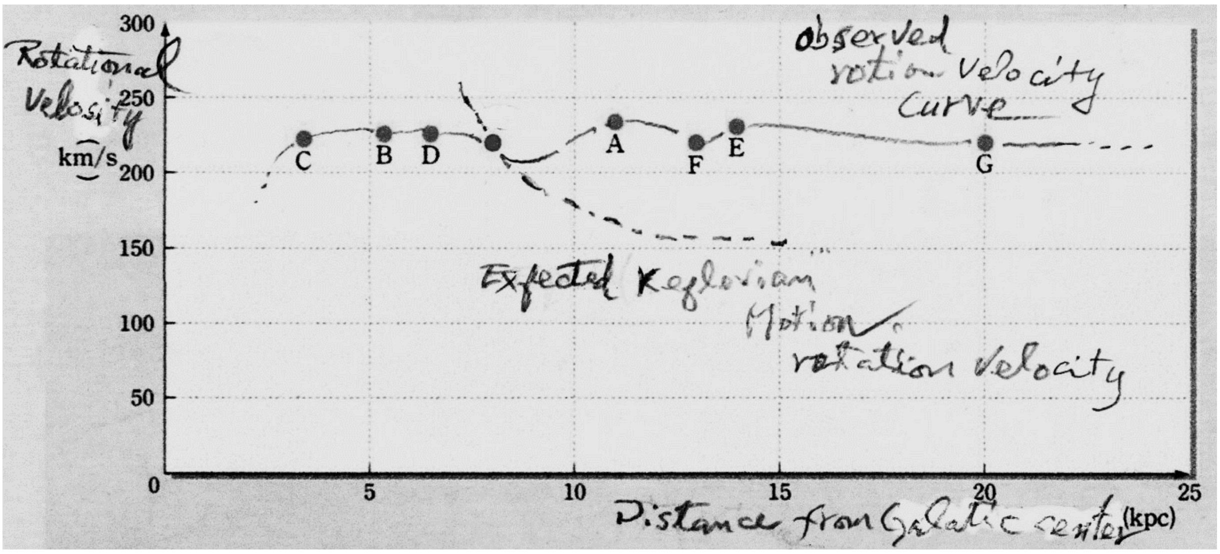


Figure 6: Distribution of Our Galaxy's rotational velocities according to distance from the center of Galaxy based on figure 5 (Graduate Students' Experiment Results). Sun's Rotational Velocity is about 220km/s at 8.5 kpc from the center of Galaxy. The dotted line, Kepler's motion is assumed to be a luminous matter.

Evaluation criteria for and preservice teachers' answers about questions

Evaluation Question 1. There is a Kepler's rotation near the solar system. If that is true, what assumptions are needed?

Answer, first case, if all the mass of the Galaxy is concentrated in the center (5points), the rotation velocity of the hydrogen cloud is Kepler's motion (5 points) in dotted line from Figure 6. (Total 10 points).

Accordingly, from equation (1), first case, if all the mass of the galaxy is concentrated in the center, the rotational velocity of the hydrogen cloud is.

$\boxed{v \sim \frac{1}{\sqrt{r}}}$ (2)(Kepler's motion)

As in the equation above, it undergoes Keplerian motion that decreases inversely proportional to the square root of the distance "r" to the hydrogen cloud.

Question 2. Once outside the solar system, the rotational speed is almost constant. How do you explain that?

Answer, another case, when we actually observed the radial velocity of hydrogens clouds, we found that their rotational velocity is almost constant from outer of Sun at a distance from the center of the Galaxy (5 points). This suggests the presence of dark matter (5points)(total 10 points)

rotational velocity "v" is almost constant at a distance from the galaxy.

$\boxed{M \sim r}$ (3) → Non kepler's motion.

In other words, this is an observation result that rotational velocity v does not depend on r (formula 3), and red solid read line). Therefore, we can see that it is widely distributed throughout the galaxy, not just in the center of the galaxy.

at larger radii. This suggests the presence of dark matter, an unseen mass that extends beyond the visible galaxy. Dark matter provides additional gravitational pull, preventing the expected drop in velocity.

4.2. Interpretations

Research Q3, If the rotation velocity of the hydrogen clouds in our galaxy on the graph does not follow Kepler's rotation, why is that?

Answer> The results of the experiment are based on observations of neutral hydrogen clouds. In the rotational velocity of our galaxy, the rotational velocity is distributed almost uniformly in the section where the distance from the center of the galaxy is about 3 to 20kpc. The reason is that dark matter is distributed in the outer part of our Galaxy.

In terms of experimental data, most of the 10 out of 10 graduate students were able to draw accurate graphs (refer to figure 6)and achieve the learning aims(Question 1, 2).

5. CONCLUSIONS AND SUGGESTIONS

What is the evidence for dark matter in galaxies?

The orbital velocities of stars and, especially neutral hydrogen gas clouds in galaxies do not change much with distance from the center of the galaxy. Applying Newton's laws of gravitation and motion to these orbits leads to the conclusion that the total mass of a galaxy is far larger than the mass of its stars(Bennett, Donahue, Schneider, and Voit, 2017, p.691).

First, if most of the matter that makes up our Galaxy is concentrated in the galactic nucleus, it would be predicted that it would undergo Kepler motion, with the rotational speed decreasing as it moves away from the center.

Second, however, the results of the experiment show that the rotational speed of our galaxy, obtained based on observations of neutral hydrogen clouds, is distributed almost constantly in the range of about 3-20 Kpc from the galactic center.

Third, the reason why the rotational speed is almost constant even when the distance from the galactic center increases is because dark matter occupies most of our galaxy and is distributed on the outskirts of the Galaxy.

Research Q4. What are the implications for astronomy education?

If our law of gravitational attraction is correct, a third component, dark matter, is needed to explain the rotation farther out. The continued use of the law of gravity in science education emphasizes that it is normal scientific activity in Kuhn's paradigm theory that major concepts are difficult to modify. The goal of science education is to acquire existing scientific laws and to develop the ability to solve problems when unexplained phenomena appear.

As an educational implication, Kuhn's normal science, when anomalies arose that challenged the application of Newtonian mechanics, adhered to Newtonian mechanics by adopting new assumptions. It was more important to master existing theories than to ignore them.

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