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The Rotation Speeds of Galaxies Can Be Predicted Without Dark Matter

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Abstract

In many galaxies, it has been observed that the rotation speed curve rises from the galactic center and reaches its maximum at a distance of several kpc, beyond which it is almost flat to the edge of the galaxy disc. If the rotation speed is determined only by the gravity of the stars, it should be smaller toward outside like the Solar system. So, it is thought that the rotation speed curve becomes flat due to the heavy halo component made of dark matter. However, considering that there are more than 100 billion stars in the galaxy and the spiral galaxy has a convex lens-like shape, I devised a bicone model of the galaxy and calculated the rotation speed curve. Then I found that the rotation speed curve is almost flat to the edge of the galaxy disc as observed. It shows that it is not necessary to assume the existence of dark matter in the galaxy. This is what Henri Poincaré predicted in his book in 1908, when he considered that there were around 1 billion stars in the galaxy.

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Introduction

In 1908 Henri Poincaré stated in his book " Science et méthode" that the galaxy has around 1 billion stars, so the kinetic theory of gas can be applied as a model of the galaxy and that there are no dark substances, not as much as glowing substances anyway [1]. In 1933 Fritz Zwicky observed optically the total brightness and the orbital speed of the galaxy in the Coma Cluster and that he explained the "missing mass" to be necessary 400 times more [2,3]. In the 1970's Vera Rubin calculated the mass from the observation of the rotation speed of the galaxy using the equation of the equilibrium of centrifugal force and gravity, and found that there are about 10 times as many substances as optically observable substances [4]. Since there are more than 100 billion stars in the galaxy, I devised the bicone model of galaxy so that I can calculate the speeds of the stars in the galaxy like as the measured value and I can predict the rotation speed of the galaxy without Dark Matter [5-12]. It is possible to clearly show that there is no problem in galaxy rotation.

Galaxies in the Universe

It was thought that there were 200 billion galaxies in the observable universe, but in 2016 a study reported that there are at least 2 trillion galaxies in the Universe.

The Great Debate about the Size of the Universe

In 1920 Harlow Shapley and Heber Doust Curtis held a public debate entitled "The Size of the Universe". This debate had a great influence on astronomers and was called "The Great Debate" [13]. Shapley said, "Our galaxy is about 300,000 light-years in diameter, and spiral galaxies are in our galaxy like globular clusters". Curtis said, "The size of our galaxy is about 20,000 light-years in diameter, spiral galaxies are other galaxies similar to our galaxy".

Hubble Classification and the rotation of the Galaxy

In 1926 Edwin Hubble proposed a method of classifying galaxies by their morphology [14,15]. There are elliptical galaxies, lenticular galaxies, spiral galaxies, barred spiral galaxies, and irregular galaxies that do not fit into any of them. Bertil Lindblad, a professor at the Royal Swedish Academy of Sciences and director of the Stockholm Observatory since 1927, observed the movement of stars in the Galaxy and stratified them in consideration of the movement of the Sun within the Galaxy, and showed that stars in the Galaxy are revolving around the center. In the "Hubble Classification" spiral galaxies are divided into Sa type (the one with the tightest arms wrapped around) and Sd type (the one with the arms wide open). A spiral galaxy with open arms has a small bulge, which is a bulging area in the center of the galaxy, and a large bulge has a characteristic that the arms are wrapped around it.

The Milky Way Galaxy

The spiral arms of the Milky Way galaxy form a logarithmic spiral like all other spiral galaxies. And the Milky Way galaxy has an angle of about 12 degrees for a logarithmic spiral. The total mass of the Milky Way galaxy is estimated to be about 1.26 trillion times that of the Sun.

A convex lens-like shape

Near the center of the galaxy is a dense bulge of relatively old stars, surrounded by a galactic disc of about 100,000 light-years in diameter consisting of young stars and interstellar medium [16]. The thickness of the galactic disc is about 15,000 light-years at the center and about 1,000 light-years at the periphery, and it has a convex lens-like shape. The Milky Way galaxy where humans are, has a central core (bulge), which is said to have a supermassive black hole about 2.6 million times the mass of the Sun. The galactic disc with a diameter of about 100,000 light-years (50,000 light-years from the galactic center) has spiral arms, and most of the stars and interstellar medium are present in this part.

A Spherical Galactic Halo

Further outside the bulge and disc, there is a spherical galactic halo with a diameter of about 250,000 to 400,000 light-years, consisting of about 130 globular clusters. The halo spreads out in a spherical shape, and the gravity from the center of the galaxy works almost evenly according to the distance, and a small number of celestial bodies also exist. At the innermost part of the halo, globular clusters are distributed in a spherical shape with a diameter of about 300,000 light-years (150,000 light-years from the galactic center). Generally, celestial bodies existing in halos are older and have less metal than discs. There is an ionized gas on the outside.

The center of the Milky Way galaxy and the type of galaxy

The center of the Milky Way galaxy is located about 30,000 light-years away from the Sun in the direction of Sagittarius, and there is a strong radio source called Sagittarius A [17-19]. It is certain that there is a supermassive black hole in the center of Sagittarius A (Sagittarius A*). The Milky Way galaxy is a barred spiral galaxy classified as SBbc by the Hubble Classification and is thought to contain about 200 to 400 billion stars.

Observed rotation speed of the Milky Way galaxy

As with many galaxies, the Milky Way galaxy has a mass distribution in which the orbital speeds of stars in the galaxy are approximately the same regardless of the distance from the center. Excluding the central bulge and outer edge, the typical speed of galaxy stars is about 210 to 240 km/s. Therefore, the orbital period of a typical star is simply proportional to the length of its orbit. This is very different from the case where celestial bodies with different orbits have different orbital speeds depending on their orbits, such as Kepler motion in the Solar system where most of the mass is concentrated in the center of the system. It takes about 225 to 250 million years for the Solar system to orbit in the Milky Way galaxy, and it is thought that it has made about 20 to 25 orbits revolution since the birth of the Solar system. The orbital speed of the Solar system is about 217 km/s.

Orbital speeds in the Solar system and the Milky Way galaxy

The Solar system and the Milky Way galaxy system are the same as rotating bodies. Therefore, I can calculate the rotation speeds for both systems.

Revolution speed of each Planet in the Solar system

The following formula can be obtained from equation of Mathematics 1. in Methods, that is equilibrium equation between centrifugal force and gravity of the Sun.

$$v = \sqrt{(GM/r)}$$

		Mass of the sun (kg)		1.9891E+30				
		Gravitational constant		6.6743E-11				
		Mass (kg)	Orbital period (year)	Average revolution radius (km)	Average orbital speed (km/s)	Centrifugal force (mv^2/r)	Gravity of the sun (GmM/r^2)	Calculated orbital speed v=sqrt(GM/r) (km/s)
0	Sun	1.99E+30						
1	Mercury	3.30E+23	0.241	57910000	47.36	1.28E+22	1.31E+22	47.88
2	Venus	4.87E+24	0.615207	108208930	35.02	5.52E+22	5.52E+22	35.03
3	the Earth	5.97E+24	1	149597871	29.78	3.54E+22	3.54E+22	29.79
4	Mars	6.42E+23	1.881	227920000	24.07	1.63E+21	1.64E+21	24.13
5	Jupiter	1.90E+27	11.86155	778412010	13.07	4.17E+23	4.16E+23	13.06
6	Saturn	5.69E+26	29.53216	1426725400	9.67	3.73E+22	3.71E+22	9.65
7	Uranus	8.69E+25	84.25301	2870990000	6.80	1.40E+21	1.40E+21	6.80
8	Neptune	1.02E+26	164.79	4495060000	5.43	6.72E+20	6.73E+20	5.43
	Total mass	1.99E+30						

Table 1. Calculated orbital speeds in the Solar system

Table 1 shows calculated orbital speeds in the Solar system, compared with actual speeds. Average orbital speed is nearly equal to calculated orbital speed, as showed in Table 1. The biggest difference is at the nearest to the Sun, that is Mercury. Figure 3 shows the orbital speeds vs. revolution radius of the planets in the Solar system.

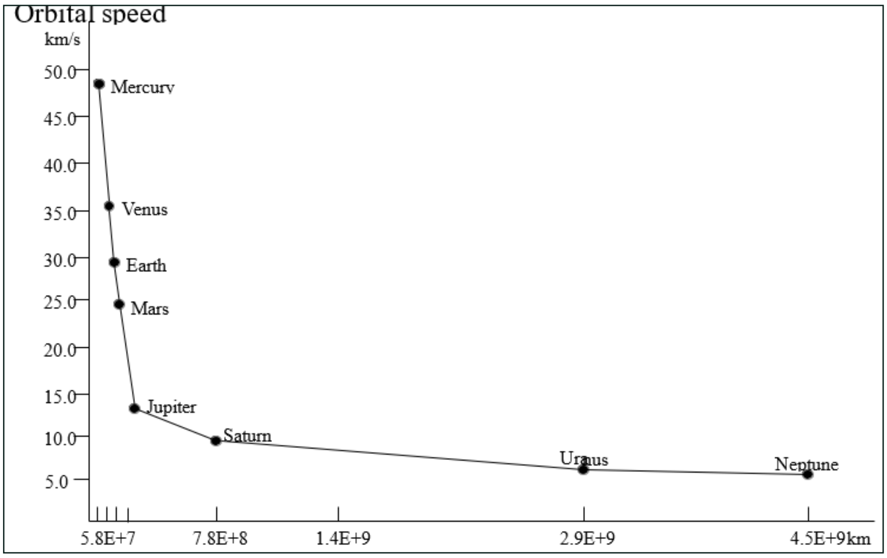

Figure 3: Orbital speeds vs. revolution radius in the Solar system

Rotation speed of the Milky Way galaxy by using the bicone model
I devised the bicone model in order to calculate rotation speed of the galaxy.

Difference between the Solar system and the Milky Way Galaxy

The Solar system and the Milky Way galaxy system are the same as rotating bodies. The big difference is the distribution of their masses. The main component of the Solar system is the Sun, which accounts for 99.86% of the total mass. On the other hand, in the Milky Way galaxy system, the central black hole has about 2.6 million solar masses, but since there are about 200 billion stars in total, the central black hole has only 0.0013% of the total galaxy mass.

Similarity of the Solar system and the Milky Way Galaxy

However, since the Solar system and the Milky Way galaxy are similar rotating bodies, the speed of each orbit can be calculated by the equation of equilibrium between centrifugal force and gravitational force. This is the same as calculating the orbital speed of an artificial satellite in Earth's orbit. The reason is that all the masses inside the orbit cancel the internal force each other, and only the external force of the system acts as a centripetal force on the flying object in the orbit toward the center of gravity due to all the stars inside the orbit, which form the central force. This produces the same effect as the gravitation on the Earth. Therefore, I can derive the same equation in the galaxy as before.

$$v_G = \sqrt{(GM_G/r_G)}$$

v_G: Speed of the orbit in the galaxy
G: Gravitational constant
MG: masses of all stars inside the orbit including the mass of center black hole
r_G: radius of the orbit in the galaxy

Calculation for the revolution speed of the Sun in the Milky Way galaxy

In order to calculate the orbital speeds in the galaxy I devised bicone model of the galaxy showed in Figure 1 and Figure 2. The Solar system is assumed to be at 28125 light-years from the center of the Milky Way galaxy. The volume ratio is calculated by dividing the volume of the bicone inside the orbit by the volume of the bicone of the entire galaxy. The volume of bicone is calculated by adding partial cone volume to partial cylinder volume. By multiplying the total mass of the galaxy by the volume ratio, I can get the masses inside the orbit. This assumes that the stars of solar mass are evenly distributed within the bicone model. Then I can get the speed of the Solar system in the Milky Way galaxy as the following calculation.

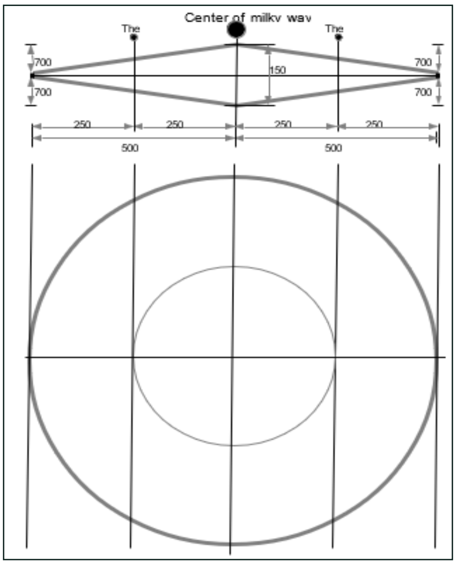

Figure 1: The bicone model of galaxy

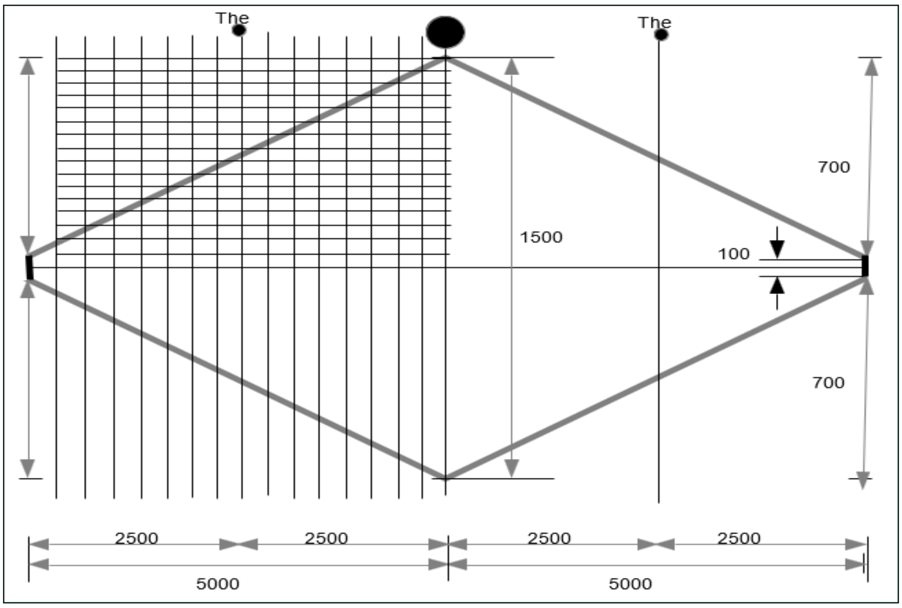

Figure 2: Bicone model for calculation

Calculation method for the orbital speeds in the galaxy

The radius is divided into 16 and the orbital speed is calculated at each location. The volume of the divided bicone is calculated by adding the cylinder and cone of that radius by multiplying the respective heights by their bottom areas. To calculate the total mass within the volume inside that radius, I assume that stars of the same mass as the Sun are evenly distributed. The mass within that volume is calculated by the ratio of the total volume of the Milky Way galaxy with a radius of 50,000 light-years to the inner volume of the radius. The orbital speed at that radius is equivalent to thinking that the total mass inside it is in the center of the Milky Way galaxy. This is the same as assuming that the total mass of the Earth is at the center of gravity of the Earth. Therefore, the same formula as the calculation of the orbital speeds of the planets in the Solar system can be applied to the calculation of the orbital speeds in the Milky Way galaxy.

Light-yeas: 9.4605284×10^{15} m represented by L_y below.
π: 3.14159265

Half of total volume of the galaxy bicone:
$\pi(50000L_y)^2(500L_y) + (\pi(50000L_y)^2 (7000L_y))/3$
$= 1.884229\times10^{61}\,m^3$

Half volume inside the orbit of the Solar system:
$\pi(28125L_y)^2 (7000\times7/16+500)\, L_y + (\pi(28125L_y)^2 (7000\times9/16)\, L_y)/3$
$= 1.025784\times10^{61}\, m^3$

Then volume ratio = 0.544405

Total number of stars with solar masses in the Milky Way galaxy:
1.7336×10^{11} in order to derive orbital speed of 217 km s^{-1} at the orbit of the Sun.

Total masses of stars inside the orbit of the Solar system:
$M_G = (1.7336\times10^{11}\times 0.544405 + 2.6\times10^6) \times 1.9891\times10^{30}$

The mass of the Sun: 1.9891×10^{30} kg
$G = 6.67430 \times10^{-11}\, m^3\, kg^{-1}\, s^{-2}$

Therefore, the revolution speed of the Solar system in the Milky Way galaxy is calculated as below.

$$v_G = \sqrt{(G \times M_G / 28125L_y)} \;/\; 1000 = 217 \text{ km s}^{-1}$$

Radius of the Milky Way galaxy (light-years)		π		
	50000	3.14159265		
Mass of Black Hole in the center (M⊙)		Light-years (m)		
	2600000	9.46053E+15		
Orbital speed of the Sun (km/s)		Total number of stars in the Milky Way		
	217	1.7336E+11		
Orbital period of the Sun (years)		1 / 2 volume of the Milky Way galaxy (m^3)		
	250000000	1.884229E+61		

Partition of bicone model for calculation	Radius of the orbit (light-years)	Volume of cone + cylinder	Volume ratio	Orbital speed v=sqrt(GM/r) (km/s)
1/16 of radius	3125	1.872539E+59	0.009938	88.02
2/16 of radius	6250	7.187088E+59	0.038143	121.87
3/16 of radius	9375	1.548904E+60	0.082204	146.07
4/16 of radius	12500	2.632379E+60	0.139706	164.90
5/16 of radius	15625	3.923674E+60	0.208238	180.07
6/16 of radius	18750	5.377327E+60	0.285386	192.43
7/16 of radius	21875	6.947879E+60	0.368739	202.51
8/16 of radius	25000	8.589868E+60	0.455882	210.63
9/16 of radius	28125	1.025784E+61	0.544405	217.00
10/16 of radius	31250	1.190632E+61	0.631893	221.79
11/16 of radius	34375	1.348986E+61	0.715935	225.10
12/16 of radius	37500	1.496300E+61	0.794118	226.98
13/16 of radius	40625	1.628027E+61	0.864028	227.47
14/16 of radius	43750	1.739622E+61	0.923254	226.58
15/16 of radius	46875	1.826538E+61	0.969382	224.30
16/16 of radius	50000	1.884229E+61	1.000000	220.58

Tab.2 Orbital speed of the Milky Way galaxy (km/s)

Calculation Result

Table 2 shows the orbital speeds in the Milky Way galaxy by the bicone model. Looking at the calculation result, it is consistent with the observation result that is "The typical velocity of a star in the galaxy is about 210 to 240 km s-1. Therefore, the orbital period of a typical star is simply proportional to the length of its orbit". The number of stars in the Milky Way galaxy is said to be 200 to 400 billion, but in this calculation result at a radius of 28125 light-years near the orbit of the Sun, an orbital speed of 217.00 km s-1 requires only 173.36 billion stars of the solar mass in the entire galaxy. Therefore, it may be less than the traditional prediction for number of stars. Also, since there is no dark matter, the total mass of the Milky Way galaxy will be considerably less than previously predicted. Figure 4 shows the orbital speeds vs. revolution radius of the stars in the Milky Way galaxy.

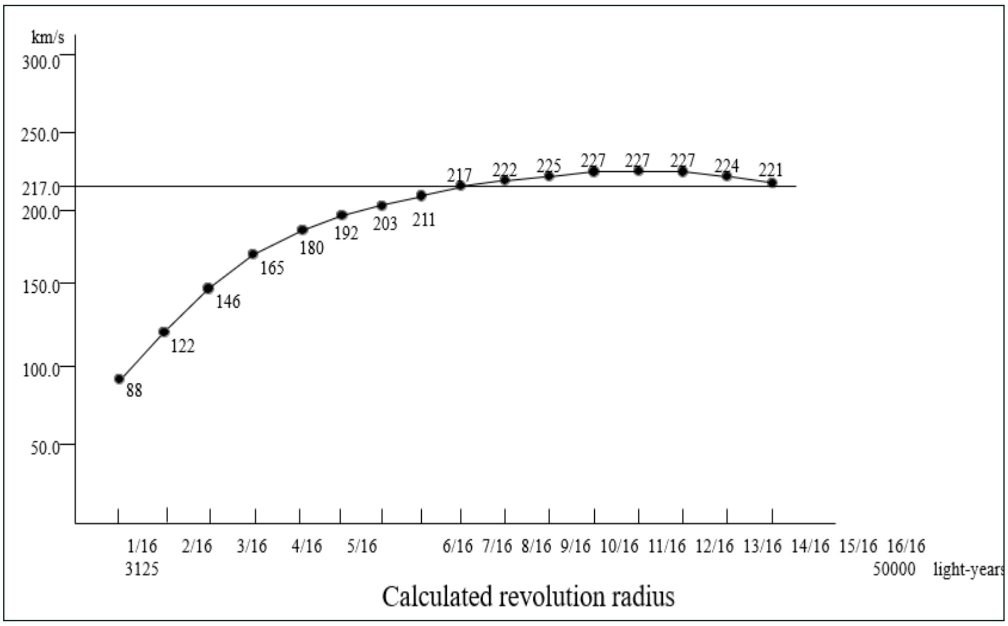

Figure 4: Orbital speeds vs. revolution radius in the Milky Way galaxy

Validity of the bicone model

I came up with the bicone model because the spiral galaxy has a convex lens shape, but I think that the model approximation does not apply where there is a huge black hole in the center of the galaxy and the mass is concentrated [20]. Even so, I think it is a good approximation that the orbital speeds of stars in the galactic disk are almost the same regardless of the length of the radius. And that is consistent with Henri Poincaré's description in 1908, that there are probably no dark substances from the kinetic theory of gas.

Conclusion

The bicone model of galaxy allow the orbital speed of the galaxy's rotation to be calculated for each length of radius, but the question is how close this bicone model is to the actual galaxy. In this model, the mass inside of the orbit is calculated by the volume ratio assuming that the stars with the same mass as the sun are distributed at the same density inside the bicone, so if it is observed that the mass density distribution is high near the galactic center, it is necessary to reflect it in the calculation of the orbital speed to improve the accuracy. Even so, it is no longer necessary to assume the existence of Dark Matter, because it is not a particular problem that the orbital speed calculation has been called the galaxy rotation problem, but the normal rotational motion of spiral galaxies using the bicone model. In the future, the rotation speed of the galaxy can be predicted more accurately by improving the observation accuracy of the number of stars in the galaxy and its distributed mass density.

Methods

Mathematics

Equilibrium equation between centrifugal force and gravity of rotating body

Centrifugal force of object with circular orbit is

mv^2/r m: mass of object
v: orbital speed
r: radius from the Sun

Gravity of the Sun is

GmM/r^2 G: Gravitational constant
M: mass of the Sun

Orbital speed is derived as follows.

$$v = \sqrt{(GM/r)}$$

Acknowledgments

I was able to get great suggestions from two people when considering the rotational movement of the galaxy. Akio Kubo is the president of the small and medium sized machining company which I work for. We were able to have meaningful discussions about the typhoons and strait swirls that occur around us how they happen and also, he taught me how to control the rotational speed of the lathe. Mr. Kensuke Maeda is my neighbor and is familiar with agriculture and fisheries. When someone put the liquor bottle upside down, the liquor runs down to the ground. I got useful suggestions from him as to why the liquor spins at that time. I came up the idea that the rotation of galaxies is in the middle point between the rotation of the lathe and the rotation of the liquor.

Author Contributions

Noboru Kubo, proposing ideas, writing articles, Adjusting many references

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