Galaxy Rotation Curve of Triangulum Galaxy (M-33) By Using New Quantum Gravity Theory

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1. Introduction:

Figure: 1

Messier 33 (M-33) also known as the Triangulum Galaxy is a famous spiral galaxy located in the small northern constellation Triangulum. The Triangulum Galaxy is the third largest galaxy in the Local Group of galaxies after the Andromeda Galaxy and the Milky Way.

With a diameter of about 60,000 light year, the Triangulum galaxy is the third largest member of Local group of galaxies of 40% the size of Milky Way. The Triangulum may be home to 40 billion stars as compared to 400 billion of the Milky Way and 1 trillion stars of Andromeda Galaxy.

2. **Mass Distribution In Triangulum Galaxy (M-33):**

There are four luminous components that could contribute to the gravitational field of galaxy.

A) Stellar Disk: - A thin disk is the main stellar component of galaxy since the central bulge is very small and can be completely neglected. The M-33 is extremely blue galaxy having $(B\text{-}V)_T = 0.46$ (de Vaucouleurs at al.1991). The total blue luminosity in the units of blue solar luminosity is $L_B = 4.2 \times 10^9\ L_\odot$. (Sandage &Tamman 1981). The total stellar mass of the galaxy is $7 \times 10^9\ M_\odot$ approximately.

B) Atomic Gas: - Most of the gaseous mass in M-33 is in the form of neutral atomic hydrogen. The high sensitivity observation of M-33 made with the Arecibo 305m radio telescope have allowed to draw a detailed map of the spatial extent of neutral gaseous component down to a limiting column density N_{HI} = 1-2 x 10^{19} cm^{-2}. The total H_1 mass is estimated to be 1.8 x 10^9 M⊙ (assuming D = 0.7mpc) 25 per cent of which resides in the outer disk.

As a part of Arecibo Galaxy Environment Survey (GES), it has been observed the neutral hydrogen (GTI) gas in and around the nearby Local group of galaxy M-33 to a greater depth than previous observations.

C) Warm Ionized Gas: **-** If the background ionizing radiation accounts for the sharp H_I fall off seen in the outer disk around 3 x 10^{19} cm^{-2} (Corbelli & Salpeter, 1993). A similar amount of ionized gas is expected to lie above and below the whole H_I disk since this is exposed to the same background radiation field. If we take a column density of ionized gas equal to $3x10^{19}cm^{-2}$(σ_{HII} = 0.26 M⊙ pc^{-2}) throughout the H_I disk ,we have an H_{II} mass of 1.9 $x10^8$. This is only a rough estimate since radiation and gravity from stellar disk has been neglected, but it agrees with the surface density of ionized gas detected in the outer parts of NGC 253 (Bland Hawthorn, Freeman & Quinn 1997) and above the disk of NGC 891 (Dettmar 1992) since the detailed radial distribution of warm ionized gas is unknown and its estimated mass is only 10 percent of the H_I mass, we shall neglect its contribution to gravitational potential.

D) Molecular Gas: - M-33 is known to be a galaxy deficient in molecular gas. Maps of the diffuse CO component and the intereferometric studies show that molecular gases are not dominant component of global gas mass fraction, although individual large molecular complexes with masses of order of 10^{5-6} M⊙ are prominent in the nuclear region (eg. Young & Scoville 1982; Wilson& Scoville, 1989) within the first kilo parsec, the derived H_2 column density is radially constant and of the same order of the H_1 density but at larger radii it drops rapidly. At 2.5 kpc the H_2 mass is 6 x 10^7 M⊙ about half of the HI mass. Therefore the molecular contribution to the potential well is small and it is reasonable approximation to consider the H_2 surface density of same order of the K- band stellar scale length Rd and molecular gas as a small part of mass which we shall find for stellar disk.

The Triangulum galaxy (M-33) is a thin flat disk having no dominant bulge. Hence the mass model consist of thin flat disk having different mass densities.

3. **Mass distribution model for new theory:**

For the purpose of mathematical calculations I have considered M-33 as the flat circular disk having constant surface mass density. In this model of M-33 galaxy we have taken the combined mass of all baryonic matter is equal to 9 x 10^9 M⊙. The higher value of stellar mass is taken because there is no strong relation between luminosity and mass. The stellar mass in the region beyond radial extent of 20 x 10^3ly is neglected because the total mass in this region is less than 10% and negligible.

Also the atomic gas in the region within R < 20 x 10^3 ly, is only taken into consideration. The total mass of atomic gas in this region is equal to 2 x 10^9 M⊙. The atomic gas in the region where R > 20 x 10^3 ly is neglected, because the total mass of atomic gas in this region is less than 25% and negligible.

The contribution to the gravitational potential of the mass in the region where R > 20 x 10^3 ly is very less and negligible. The total baryonic mass of the M-33 galaxy is 9 x 10^9 M⊙ up to the radial extent of 20 x 10^3 ly.

4. **Calculation of rotational velocities according to new quantum gravity theory:**

The rotational velocities (V_{th}) are calculated using the mass model and new quantum gravitational theory. Rotational velocity (V_{th}) at different radial distance from the center of galaxy are calculated. The rotational velocities are tabulated as given below. The table no.1 shows the calculated theoretical rotational velocity and observed rotational velocity. Table also shows the ratio between the calculated theoretical rotational velocity (V_{th}) and the observed rotational velocity (V_{ob}).

Table No.1

SR. NO.	Distance from center of galaxy in kly	Theoretical velocity (V_{th})in km/s	Actual Observed velocity (V_{ob}) in km/s	Ratio between V_{th} and V_{ob}
1	5	49.344	70.5	0.699
2	10	72.681	89.2	0.8148
3	15	94.630	100.3	0.9434
4	20	117.75	109.00	1.080
5	21.5	116.02	108.91	1.065
6	25	114.7	110.46	1.038
7	29.4	116.17	113.93	1.019
8	30	116.53	114.48	1.017
9	32.81	118.54	117.18	1.011
10	36.56	121.80	121.69	1.001
11	40	125.12	124.69	1.003
12	44.12	129.32	129.14	1.001
13	48.125	133.50	133.48	1.0001
14	50	135.48	135.50	0.9998
15	52	137.59		-----
16	54	139.69		-----

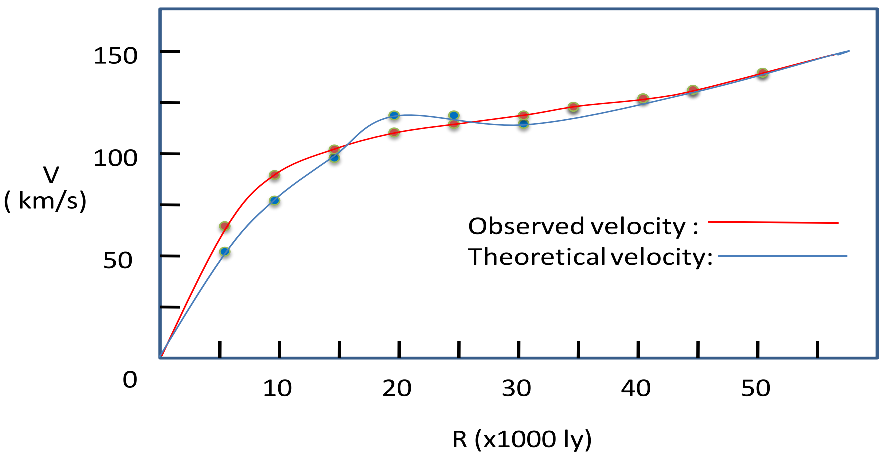

Figure: 2

As seen from figure: 2, there is more difference between observed velocity V_{ob} and theoretical velocity V_{th} in the region from centre of galaxy to the edge of stellar disk. The theoretical velocities on the edge of the disc are neglected because theoretical values on the edge of disc are very high compared to the observed rotational velocities. Also the actual M-33 galaxy is not a flat disc with uniform surface mass density. M33 is a spiral galaxy with non-uniform mass density. So it is necessary to neglect high theoretical velocities (Vth) on the edge of disk. The rotational velocities as predicted by this new theory at distances of 52 kly and 54 kly are 137.59 km/s and 139.69 km/s respectively. Any observations confirming to these predicted values will prove this theory.

5. Comparison between observed and theoretical rotational velocities:

It is observed that the theoretical rotational velocities curve form a cusp at the radius of 20 x 10^3ly. This is a dominant and most important aspect of new quantum gravitational theory. The halo cusp problem cannot be solved by dark matter hypothesis. Inability to solve halo cusp problem is main drawback of dark matter hypothesis. This new quantum gravitational theory solves the halo cusp problem of rotation curve of galaxy.

Second important aspect is that new theory predicts slowly increasing rotation curve at a large distances from the centre of galaxy. Observational evidences shows that most of the galaxies are having the slowly rising rotation curves. There is a good agreement between rotation curve derived from new theory and actual observed rotation curve.

6. Major aspects of new quantum gravitational theory:

The new quantum gravity theory is based on baryonic matter only. This new theory is not based on the dark matter. Hence the existence of dark matter is rejected. The new theory is different from Newton's gravitational theory or any other gravitational theory postulated at present. The new theory is non-relativistic theory in which space and time are constant and not related to each other. This theory is a quantum gravity theory in which gravity is made up of small quantas.

7. Predications using new gravitational theory:

1) According to new theory, the rotational velocities of the galaxy should be slowly increasing. This is in close agreement with the rotational curve of the most of the galaxies.

2) When the two or more galaxies are gravitationally interacting, then the rotation curve will be nearly constant or very slowly decreasing. This is an observed fact that the rotation curve of some of the galaxies are nearly flat or decreasing.

3) According to new theory, the rotation curve will have flat or decreasing zone after the halo cursp. The rotation curve of most of the galaxies have flat or decreasing zone after halo cusp. This is a dominant feature of rotation curve of large galaxy having large central bulge at their center.

References:-

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3) Olivia C Keenan, Jonathan I. Davies, Rhys Taylor and Robert F Minchin:-The structure of Halo Gas around M33.
4) Wikipedia:- Galaxy rotation curve (January 2017)

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