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Distribution of Baryonic and Dark Matter in Spiral Galaxies

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Abstract: In the present paper, the distributions of baryonic and dark matter are derived for 24 northern sky spiral galaxies. The baryonic mass surface density profile is derived, and the component of the galaxies' observed rotation due to the baryons (stars and gas) is computed. Thus, the baryonic rotation curve of each sampled galaxy is separated from the observed rotation curve given in data base (Stapehane Courteau).

Key Words: Baryonic Matter, Dark Matter, Surface Brightness Profile, Rotation Curve.

I. INTRODUCTION

Kinematics and dynamics of spiral galaxies are main issues to uncover in field of astronomy. It is claimed that dynamics of spiral galaxies can be explained on the basis of Modified Newtonian Dynamics (Milgrom 1983, Bekenstein 2004, Moffat 1995). However, mainstream physicists do not consider it and believe that introduction of Dark Matter is enough to explain the rotation dynamics of all type of spiral galaxies. Kinematics of spiral galaxies is studied using statistical models like Power Law Hypothesis (Roscoe, 1999) and Universal Rotation Curve (Persic, Salucci & Stel 1996). Here, in the present paper, we are applying some mathematical techniques to understand the behavior of rotational kinematics of northern sky spiral galaxies.

II. SURFACE MASS-DENSITY DISTRIBUTIONS OF BARYONIC MATTER

To measure a galaxy's radial surface mass-density distribution, a color – M/L relation is applied to its surface brightness profiles. These relations show a relatively tight correlation between optical color of a galaxy and its stellar mass-to-light ratio (M/L). This relation is composed of the optical color with the largest wavelength baseline and the reddest near-infrared band. The surface brightness profile for each galaxy is then multiplied by the galaxy's M/L profile to derive a radial surface mass-density profile. For those galaxies with a significant bulge component, bulge-disk decomposition is performed. A characteristic B-R color is adopted for each component based on the average colors of the bulge and disk. The variation in B-R color from galaxy-to-galaxy for bulge and disk components suggested strongly that bulge/disk decomposition is required, combined with good photometry to set the M/L for each component of each galaxy. However, within a galaxy, systematic variations within the disk component have a much smaller effect upon the derived stellar rotation curves.

I assume that a galaxy any Hubble Type Sb, Sc & Sbc galaxy has a gas mass that is typically $M_{HI}/L_B = 0.32$ (Roberts & Haynes 1994) and hence does not greatly affect their baryonic mass.

III. BARYONIC ROTATION CURVES

Baryonic rotation curves are calculated for each galaxy from their radial baryonic surface mass-density distributions. They are plotted in figures 5.1 – 5.4 as lines consisting stars. This calculation is done with the help of MATLAB software package, which calculates rotation curves assuming that spiral galaxy is composition of an exponential disk with spherical bulge in central region. Exponential disks in this calculation are assumed to have a scale height of 0.3kpc, which is typical of bright spirals.

IV. OBSERVED ROTATION CURVES

Spectroscopic observations were made at Lick Observatory using the ultra violet (UV) Schmidt Cassegrain Spectrograph on the Shane 3.0m telescope (Miller & Stone 1987) and at Las Campanas with the Modular Spectrograph on the 2.5m du Pont telescope. Table 1 summarizes the main characteristics of both instrumental setups. A total of 453 Hα spectra, including repeats, were collected at Lick and Las Campanas. Only ten spectra showed no measurable signal. The final collection of Rotation Curves includes measurements for 304 galaxies, 62 of them were observed more than once. Eight galaxies were observed twice as a consistency check between Lick and Las Campanas. Minor axis rotation curves for 6 galaxies were also observed to verify the lack of significant velocity gradients. In the present dissertation 24 galaxies are selected to study radial distribution of Baryonic and Dark matter.

V. DARK MATTER ROTATION CURVES

For each galaxy, baryonic rotation curve derived in section 1 is compared with its observed rotation curve from the literature to derive a “dark matter rotation curve”. At those radii where a galaxy's observed rotation speed is faster than that derived from its baryonic component, the additional gravitational component is assumed to be due to dark matter. A dark matter rotation curve is derived as the square root of the difference of the squares of the observed velocity and the baryonic velocity at each radius (Binney & Tremaine 1987). Dark matter rotation curves for each of the galaxies are plotted as lines of vertical dash marks in Figures 1 - 4. In doing this, it is assumed that the halos of galaxies are axially symmetric and that the disk and halo are aligned.

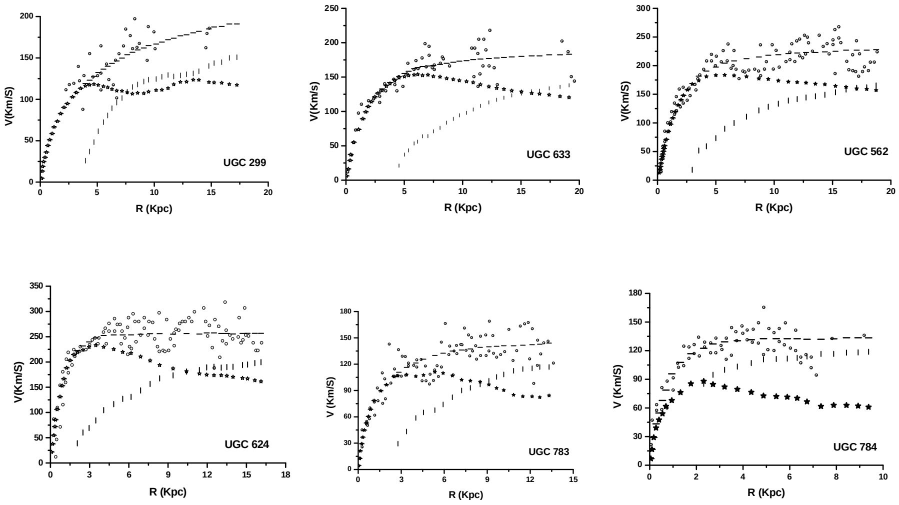


Figure 1: Observed rotation curves (open circles, dashed lines for models), baryonic rotation curves (stars), and dark matter rotation curves (vertical dash marks) for each galaxy in the sample (continued).

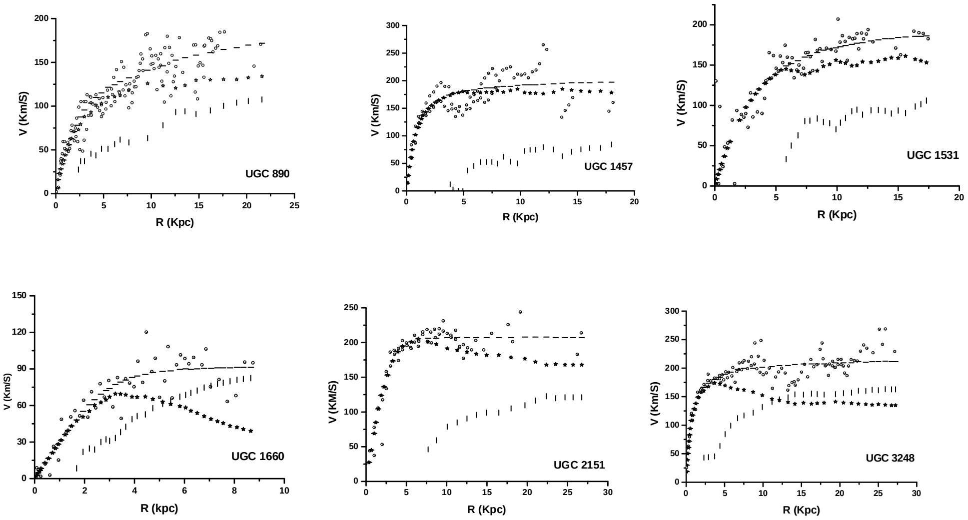
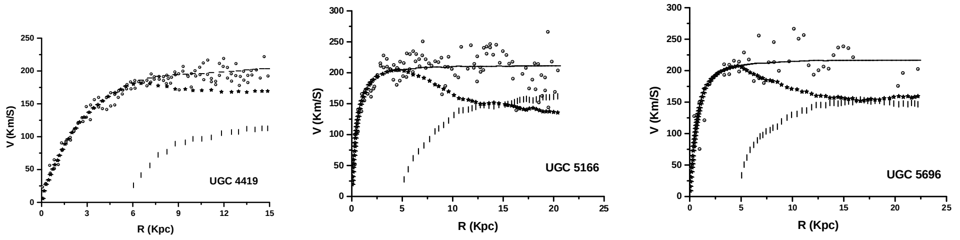


Figure 2: Observed rotation curves (open circles, dashed lines for models), baryonic rotation curves (stars), and dark matter rotation curves (vertical dash marks) for each galaxy in the sample (continued).



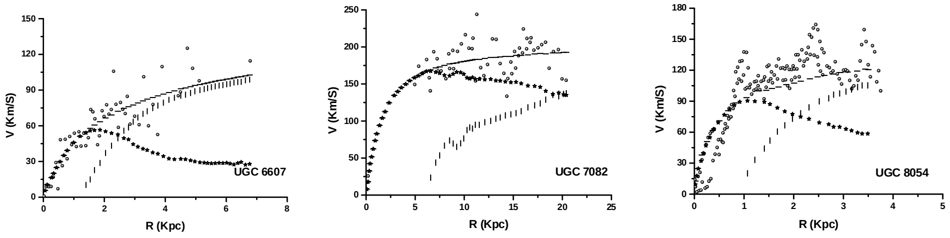


Figure 3: Observed rotation curves (open circles, dashed lines for models), baryonic rotation curves (stars), and dark matter rotation curves (vertical dash marks) for each galaxy in the sample (continued).

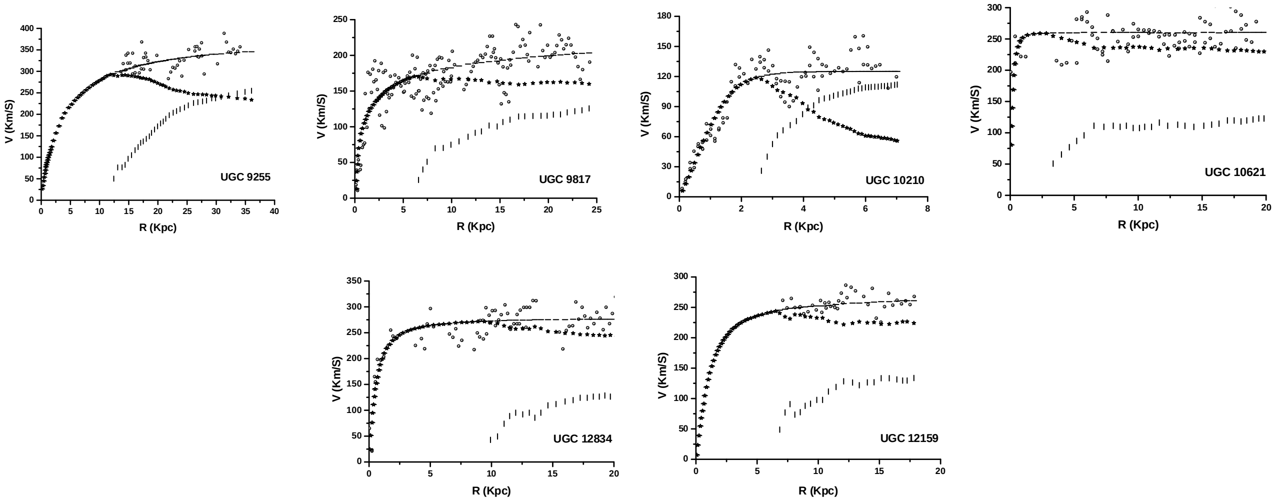
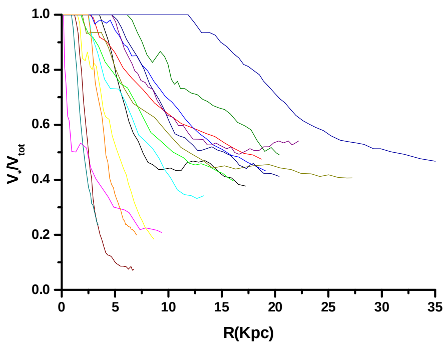


Figure 4: Observed rotation curves (open circles, dashed lines for models), baryonic rotation curves (stars), and dark matter rotation curves (vertical dash marks) for each galaxy in the sample.

VI. RADIAL DISTRIBUTION OF BARYONIC AND DARK MATTER

In figures 1 – 4 observed rotation curves are dominated by baryonic matter in the inner parts of galaxy. Beyond this inner region, baryonic mass falls off as dark matter begins to dominate. However, some galaxies are dark matter dominated throughout. From these figures, one can determine the general trend that faster rotating galaxies (which tend to be more massive and brighter) are dominated by baryonic matter in their inner regions. In some galaxies, the distribution of luminous matter suddenly falls, whereas in some galaxy it decreases slowly. In some galaxies at a certain radius denoted by R_X (cross over radius), the amount of Dark Matter and Luminous Matter is equal and as we go further away, dark matter dominates the rotation curves.



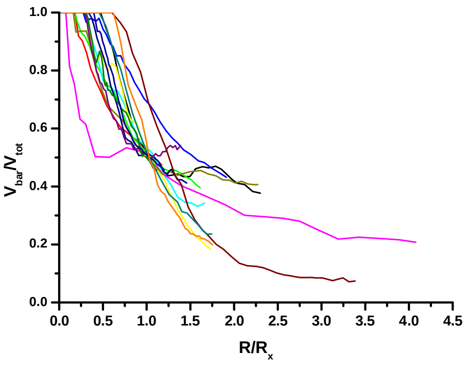


Figure 5: Distribution of dark and baryonic Matter. **Figure 6:** distribution of dark and baryonic Matter.

In Figure 5 $\beta(r) = V_{bar}/V_{tot}$ is plotted against versus R (radius) and in figure 6 $\beta(r)$ is plotted versus R/R_X (radius in units of R_X) for those galaxies in which an R_X is observed. This choice of radial coordinate causes the curves to overlap at $r = R_X(\beta(r) = 0.5)$, and thus allows for a better comparison of their radial behavior. When $\beta(r) = 1$, the baryonic matter of a galaxy accounts for its entire observed rotation curve, $\beta(r) = 0.5$ at $r = R_X$, and $\beta(r) = 0$ where the dark matter accounts for its entire observed rotation curve. Figure 5 shows that the contribution of Dark Matter suddenly increases in smaller galaxies whereas it increases slowly in larger galaxies. In the above figure the area where $\beta \geq 0.9$, denotes the region in which a galaxy is dominated by baryons. The area in the figure where $\beta = 0.5$ denotes the radii beyond which the galaxy is dark matter dominated. It is observed in figure 5 that the radius where the dark matter onsets varies from galaxy to galaxy with an intrinsic scatter. An examination of the region in figure where $\beta < 0.5$ (or, equivalently where $r = R_X > 1$) shows the manner in which the galaxies become increasingly Dark Matter dominated.

Mass and luminosity of galaxy exhibit a correlation with V_{max}, which means greater the luminosity faster the velocity. It can be calculated that high luminous galaxies are large in size and have high rotational velocity at any radius.

UGC Nan of Galaxy	Observed	Baryonic		Dark Matter	
	Vmax	Vbar max	R at Vbarmax	Rx	V at Rx
299	205.684	123.57392	13.4171	7.5	108
562	267.386	183.49825	5.75835	16	161
624	317.872	233.0326	3.47129	10	180
633	217.617	153.95809	6.15039	15	128
783	168.657	111.0594	5.34704	8	99
784	165.117	87.97439	2.31362	2.3	87
890	184.522	134.0047	21.60079	NA	NA
1457	264.682	184.9825	9.73522	NA	NA
1531	206.692	161.2631	15.60347	NA	NA
1660	119.943	69.61583	3.23479	5	62
2151	243.501	205.31	6.47482	NA	NA
3248	268.237	174.1123	3.70823	12	141
4419	224.224	181.3446	6.54349	NA	NA
5166	265.653	204.361	4.69388	14	150
5696	266.106	207.608	4.67713	16	151
6607	124.94	56.55122	1.8599	2	50
7082	243.685	167.4476	6.58312	20	135
8054	163.983	121.028	3.43	2	75
9255	387.853	292.233	11.8492	31	240
9817	242.8	170.497	6.13743	NA	NA
10210	160.243	118.846	2.47357	4	88
10621	313.526	258.857	2.82209	NA	NA
12159	286.015	243.75	6.52003	NA	NA
12834	318.847	271.795	9.42387	NA	NA

Table 1: Parameters Derived From Observed, Baryonic Matter, and Dark Matter Rotation Curves

VII. CONCLUSION

On the basis of figures 1 – 4 one can determine the general trend that faster rotating galaxies (which tend to be more massive and brighter) are dominated by baryonic matter in their inner regions. In some galaxies, the distribution of luminous matter suddenly falls, whereas in some galaxy it decreases slowly. In some galaxies at a certain radius denoted by R_X (cross over radius), the amount of Dark Matter and Luminous Matter is equal and as we go further away, dark matter dominates the rotation curves. Figure 5 shows that the contribution of Dark Matter suddenly increases in smaller galaxies whereas it increases slowly in larger galaxies. It is clear from the present study that type-2 (Sb) galaxies have maximum radius from 10Kpc to 35Kpc and also have high value of V_{max} (maximum velocity) and brighter compare to other types. Mass and luminosity of galaxy exhibit a correlation with V_{max}, which means greater the luminosity faster the velocity. It can be calculated that high luminous galaxies are large in size and have high rotational velocity at any radius.

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