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Nuclear Steep Point Amplitude and Mass Distribution

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Abstract

We investigate the characteristics of rotation curves of massive spiral galaxies Sb, SBb, Sc and SBc influenced by mass distribution in self environment of the galaxy. Images of galaxies in luminous range of EMW spectrum (4680Å – 6450 Å) are taken up for this study. This study reveals sharp negative slopes following long flat region in rotation curves of galaxies with highly significant spiral arms. For galaxies with slightly significant spiral arms, we notice approximately zero slopes followed by long flat region. For galaxies with negligible signature of spiral arms, we notice positive slope lacking nuclear steep rise without flat region.

Keywords: Galaxy, rotation curve.

Introduction

The “rotation curve” of a galaxy is a graph plotted between the orbital velocity of the stars or gas in the galaxy on y-axis and the distance from the centre of the galaxy on x-axis. Stars orbit around the centre of the galaxies at a constant speed over a large range of distances from the centre of the galaxy. According to the various observations they revolve much faster than would be expected by Newtonian gravity. In 1959, Louise Volders demonstrated that spiral galaxy M33 does not spin as expected according to Keplerian dynamics [1] a result which was extended to many other spiral galaxies during the late 1960s and early 1970s[2]. Vera Rubin together with fellow staff member Kent Ford, announced that most stars in spiral galaxies orbit approximately at the same speed. Subsequent to this, numerous observations have been made that do indicate the violation of Newtonian gravity in various parts of the cosmos. Stars and gas in the disk portion of a spiral should orbit the center of the galaxy similar to the way in which planets in the solar system orbit the sun. Based on this, it would be expected that the average orbital speed of an object at a specified distance away from the majority of mass distribution would decrease inversely with the square root of the radius of the orbit. Galaxy rotation curves are flat to the greatest extent they can be measured. At the time of discovery of the discrepancy, it was thought that most of the mass of galaxy had to be in the galactic bulge, near the center. Precise observations have delineated the undulations in this overall flat structure. Rotation curves are principal tools used to understand dynamics of galaxy. There is a direct relation between rotation curves and mass models for galaxies. Rotation curve of galaxy depends on the overall distribution of mass throughout the galaxy. Information traced out from the rotation curve and surface photometry of related galaxy, enables one to construct a detailed dynamical model of the galaxy [3, 4]. The shape of a rotation curve is determined by the relationship among three principle components: bulge, disk and dark halo. Thus it is used to infer mass distribution in the disk and halo particularly for spiral one. Recent numerical cosmological calculations within the framework of the CDM scenario indicate that the properties of a dark halo, are probably just the ones that determine the shape of the rotation curve in the outer regions of the galaxy [5]. The purpose of the present note is to investigate the rotation curves of spiral galaxies in various mass distributions in self environments.

Table 1: (a) Name of the galaxies (b) Slope at nuclear steep point region (c) Associated angle with slope (d) Absolute magnitude and (e) Surface brightness [8].

Group	Name	Slope	Angle(ϴ)	Absolute Magnitude	Surface Brightness
1	NGC 3031	-1.75	-60	-21.54	21.27+/-0.39
	NGC 1097	-3.33	-73	-21.22	21.52+/-0.62
	NGC 6946	-5.16	-79	-20.89	23.03+/-0.39
	NGC 5236	-8.66	-83	-20.67	21.03+/-0.39
	NGC 2841	-3	-71	-20.84	21.48+/-0.39
2	NGC 2403	0.083	4	-19.65	21.68+/-0.39
	NGC 3198	0.3	18	-20.48	22.75+/-0.39
	NGC 5055	0.05	2	-21.2	21.35+/-0.28
	IC 342	0.4	21	-20.62	21.35+/-0.39
	NGC 3672	0.2	11	-20.59	21.85+/-0.39
3	NGC 3495	1.1	48	-20	21.23+/-0.39
	NGC 4062	1	45	-19.55	22.78+/-0.39
	NGC 2708	2.1	64	-20.1	21.99+/-0.39

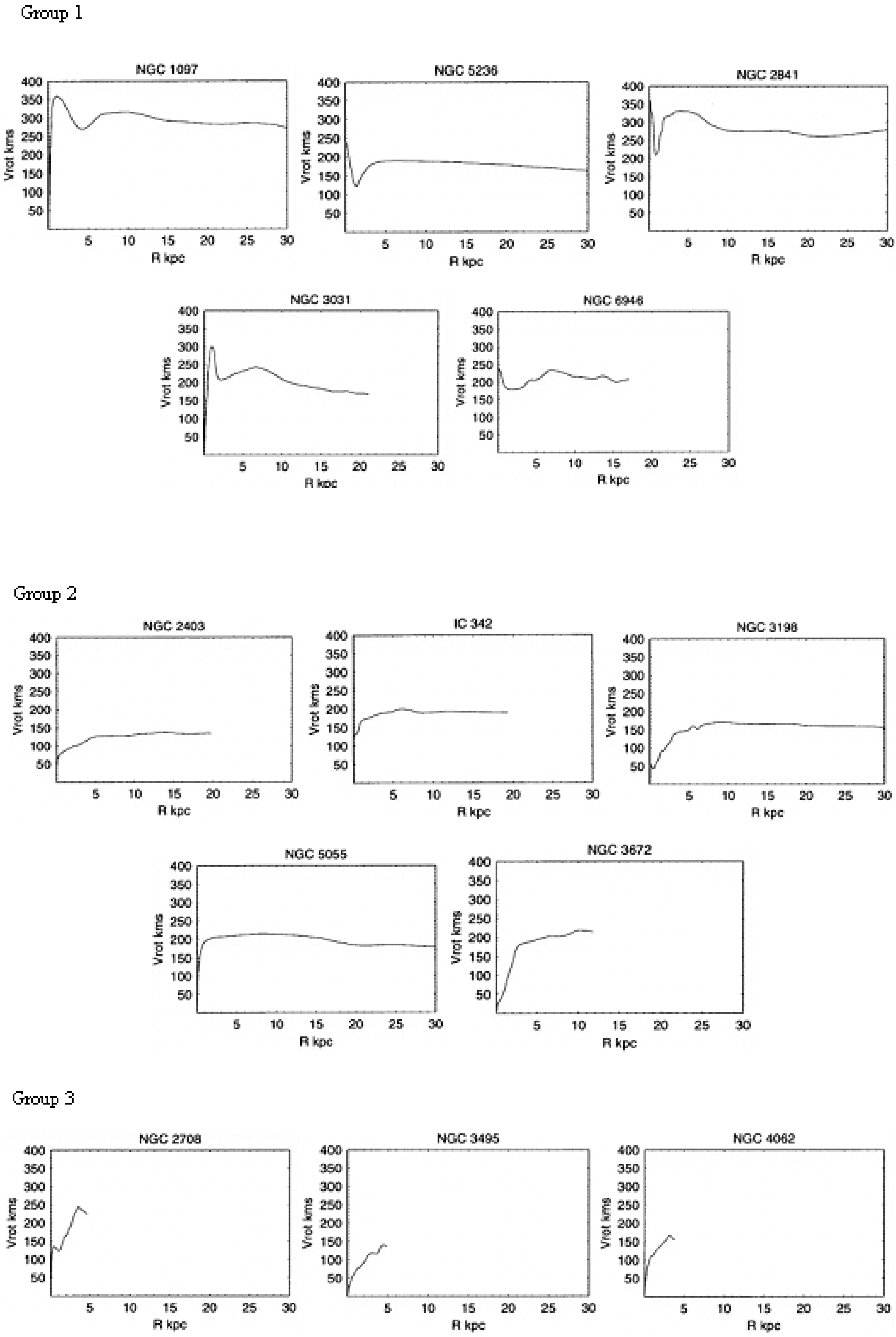


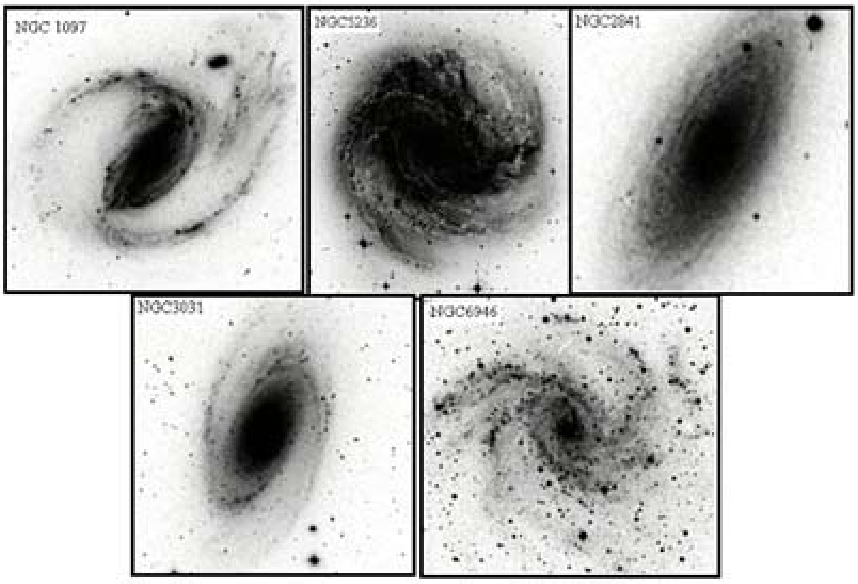
Figure 1: Rotation curves of galaxies under study [6].

Samples

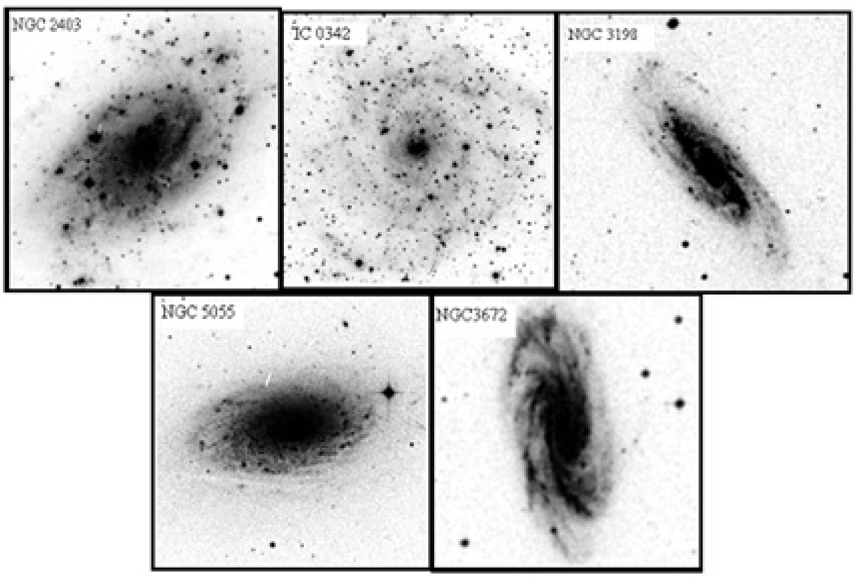
Highly accurate, extended rotation curves of 13 spiral galaxies are considered as a sample for the present paper, which are described by Sofue et al. [6]. Rotation curves of galaxies are shown in figure (1), under group (1), group (2) and group (3). These samples include giant galaxies, comparable to or even bigger than the Milky Way in size. Images are taken from Nasa Extragalactic Database (NED) [7] within range of visible spectrum

Images: Images of galaxies under study [7]

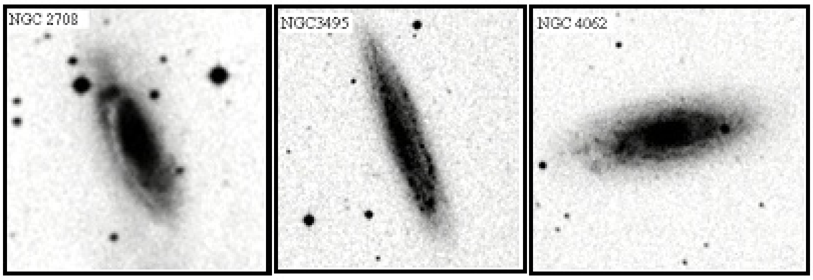
Group 1



Group 2



Group 3



(4680Å − 6450Å). Images of galaxies are shown in figure (2) under group (1), group (2) and group (3). According to Hubble categorization the galaxies are Sb, SBb, Sc and SBc spirals. In table 1, surface brightness and absolute magnitude are taken from Hypercat Lyon/Meudon Extragalactic Database [8]. Brightness and absolute magnitude in three groups is under our study are approximately same.

Analysis and interpretation

Graphs and images of the chosen sample of 13 spiral galaxies are studied to investigate influence of mass distribution in spiral arms on nuclear steep rise region. This study infers correlation between mass distribution of galaxies and shapes of their rotation curves.

Primarily this study includes three groups of galaxies. Precise study of their rotation curves and images reveals the following: Rotation curves of galaxies with sharp negative slopes following long flat region are revealed in galaxies where spiral arms are highly significant. Rotation curves of galaxies with approximately zero slopes followed by long flat region are noticed in galaxies where spiral arms are slightly significant. Rotation curves of galaxies with positive slope lacking nuclear steep rise without flat region are noticed in galaxies where signature of the spiral arms is negligible. We could reach to these conclusions on the basis of images of galaxies and their rotation curves.

I Group

The nature of rotation curve in nuclear steep rise region decides the group. In the first group slope is negative which means that the curve falls rapidly up to some extent just after steep nuclear rise. Five galaxies exhibit this feature and form the first group. Rotation curves of all the members of first group show rapid fall just after nuclear steep rise. Rotation curves of galaxies NGC1097 and NGC3031 start from zero and acquire maximum velocity denoted here as nuclear steep point amplitude. Rotation curves of NGC2841, NGC5238 and NGC6946 show velocity increment toward the center indicating existence of a massive black hole, which shows nuclear steep rise.

In case of galaxies NGC5236 and NGC2841 velocity increment towards center and behavior of slope are nearly same. These similarities are also exhibited by images. Bulge region is relatively large and massive in comparison to disc region.

Disc region shows involvement of spiral arms extensively. There is lack of broad secondary maxima in NGC5236 and it may be due to arm separation towards the outskirt region of the galaxy whereas NGC2841 exhibits broad secondary maxima and its image does not show arm separation towards out skirt region.

Rotation curves of NGC1097 and NGC3031 are nearly same. Their images are also very similar. There exists relatively broad and massive bulge followed by very clear spiral arms. NGC 3031 shows sharper slope than NGC1097. Reason may be that in NGC3031, there is continuity between bulge and arms of disk like NGC 2841. In NGC1097 arms are clearly separated from bulge.

The rotation curve of NGC6946 shows sharp slope like rest of the members of the group but followed by many maxima and minima. Image of the galaxy is different from rest of the members. However their spiral arms are conspicuous as in the case of other members of this group.

II Group

In second group again, five galaxies are taken up. All the members of group do not show nuclear steep rise. Rotation curves start from zero and rise upto an extent followed by long flat region. There are approximately zero slopes in nuclear steep rise region which is around 5kpc in case of most of the rotation curves. First maxima (nuclear steep rise) and secondary maxima overlap each other and form long flat region which either increases or decreases toward the outskirt region. Images of member galaxies of the group show that their spiral arms are not as clear as in the case of first group. This may be the reason behind lack of negative slope in nuclear steep rise region.

III Group

Three galaxies are taken up as members of third group. In this group, rotation curves show neither nuclear steep rise nor flat region. If we look for slope around nuclear steep rise region, it is positive. This means that curve rises even after nuclear steep point. Images of the member galaxies also confirm that the spiral arms influence nuclear steep rise.

Discussion

On the basis of this study, galaxies are divided according to the nature of the curve in nuclear steep rise region. With sharp negative slope in nuclear steep rise region there is extensive direct signature of spiral arms. With approximately zero slopes, arms are not highly significant. In the group of positive sharp slope, signature of arms is not conspicuous. This study clearly points towards correlation between distribution of matter and respective rotation curves. Besides, the presence of spiral arms is related with nuclear steep point. When arms are noticeably separated from bulge, slope is sharper than for the case where arms are not clearly separated from bulge. Where arms are not very significant, rotation curves show zero slope. Third group galaxies where arms are slightly significant show positive slope. Relative size of bulge region in comparison of disc influences width and amplitude of secondary maxima. Thus luminous mass distribution decides shape of rotation curve upto an extent. Shape of the outskirt region may be influenced by presence of Dark matter in halo but central rotation curve and curve upto middle of the disk should be due to result of luminous mass distribution within the galaxy.

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