Revealing of convex disk profiles in LSB galaxies

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Abstract. The radial brightness profiles of 38 disk-dominated low surface brightness (LSB) galaxies, 12 taken from Romanishin et al. ([1983], RSS83) and 26 taken from Sloan Digital Sky Survey (Abazajian [2004], SDSS), were investigated. The profiles were decomposed into bulge and disk components using Kormendy's [1977] method. In our approach both the bulge and the disk profiles were fitted through Sersic's [1968] formula. Thus the convexity of the disk profile is expressed in terms of the exponential power number in the formula, without introducing the concept of a cut-off radius of the disk (Georgiev [2005]). We found that the convexity of the RSS83 disk profiles correlates with the luminosity of the bulge. Such a correlation was not found for the SDSS profiles, probably due to the low resolution of the profiles. We found also for both samples that the convexity of the disk profiles correlates with the ratio of the scale lengths of the disk and the bulge. We interpreted these correlations as indirect evidences, as in the case of normal galaxies, that more massive LSB galaxies have more convex disk profiles.
Key words: galactic disks; galaxies – structure; galaxies – fundamental parameters

Изявяване на изпъкнали дискови профили в LSB галактики

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Изследвани са радиалните яркостни профили на 38 дисково-доминирани галактики с ниска повърхностна яркост (LSB) - 12 взети от Romanishin et al. ([1983], RSS83) и 26 взети от Sloan Digital Sky Survey (Abazajian [2004], SDSS). Профилите са декомпозирани на компоненти на балджа и диска по метода на Kormendy [1977]. В нашия подход профилите и на балджа и на диска се фитират по формулата на Sersic [1968]. Изпъкналостта на дисковия профил се изразяма чрез експоненциално-степенния показател във формулата, без въвеждане на концепцията за радиус на обрязване на диска (Georgiev [2005]). Ние намерихме, че изпъкналостта на дисковия профил при RSS83 галактиките корелира със светимостта на балджа. Такава корелация при SDSS профилите не бе намерена, вероятно поради ниската резолюция на профилите. Ние намерихме още, че при двете извадки изпъкналостта на дисковия профил корелира с отношението на мащабните дължини на диска и балджа. Ние интерпретираме тези корелации като непреки свидетелства, че както при нормалните галактики по-масивните LSB галактики имат по-изпъкнали дискови профили.

Introduction

There have been many surface brightness profile decompositions done since 1977, when John Kormendy proposed his iterative procedure. In most cases authors preferred to use a simple exponential model for fitting the disk component, despite the multiple examples of convex profiles. The widely discussed truncation of the disk profiles could be apparent because of the convexity of the profile. Following some results and considerations of Pohlen et al. [2002], Jarret et al. [2003], etc. (see Georgiev [2005] and references therein), we tried to give an account of possible disk profile convexity in the case of LSB galaxies. Following the early applying of this approach to the profiles of normal galaxies (Georgiev [2005]), here we fit the disk profile again with Sersic's [1968] formula.

Sersic's formula may be presented in linear form as $I_R = I_0 \exp(-(R/H)^N)$, or in magnitude form as $\mu_R = \mu_0 + C\,R^N$. Here I_0 (or $\mu_0 = -2.5 \log I_0$) is the central surface brightness, H is the radial scale length (then $C = (1.087\,H)^{(1/N)}$) and N is the exponential power number, instead of $1/n$ in the original Sersic's formula. The value of N describes the shape of the profile in a more simple way than $1/n$. In magnitude representation the cases $N < 1$, $N = 1$ and $N > 1$ correspond to concave, flat and convex profiles, respectively.

In this paper we present the results of the decompositions of the brightness profiles of 38 LSB galaxies. The profiles in Johnson's B and R filters for 12 such galaxies were taken from the paper of Romanishin et al. [1983] (hereafter RSS83). These galaxies are relatively close to our Galaxy and their bulge profiles are weakly degraded by the limited resolution of the observation. The profiles from RSS83 are deep, in some cases below 28 B-magnitude level. The photometry, even carried out on photographic plates, is assumed reliable. A part of the results on RSS83 galaxies are published in Deshev et al. [2006].

The profiles of the other 26 galaxies are extracted from the SDSS photometry data in g' and r' filters. The photometric system g' takes intermediate place between broad B and V bands and the r' band is close to the broad R band. The typical depth of the profiles is about 26 g' magnitude level. The galaxies in this SDSS data set are distant and their bulge profiles are heavily degraded by the seeing. That prevents from clear comparison between the results presented here and in other investigations. However, the homogeneity of the SDSS profiles is attractive for more general conclusions and here we check our approach on a limited sample of objects.

Additional data, needed for this investigation, was taken from NED and Hyper Leda databases. The distances to the galaxies were estimated roughly by means of the Hubble constant. By this reason and because of uncertainties in the photometry of the faint peripheral parts of the galaxies, we cannot use accurate absolute magnitudes of the galaxies and their components. A fuller presentation of the data and the results is given in Deshev [2006].

Results

The results acquired from the decompositions of LSB galaxy profiles confirm what was observed in the profiles of normal galaxies.

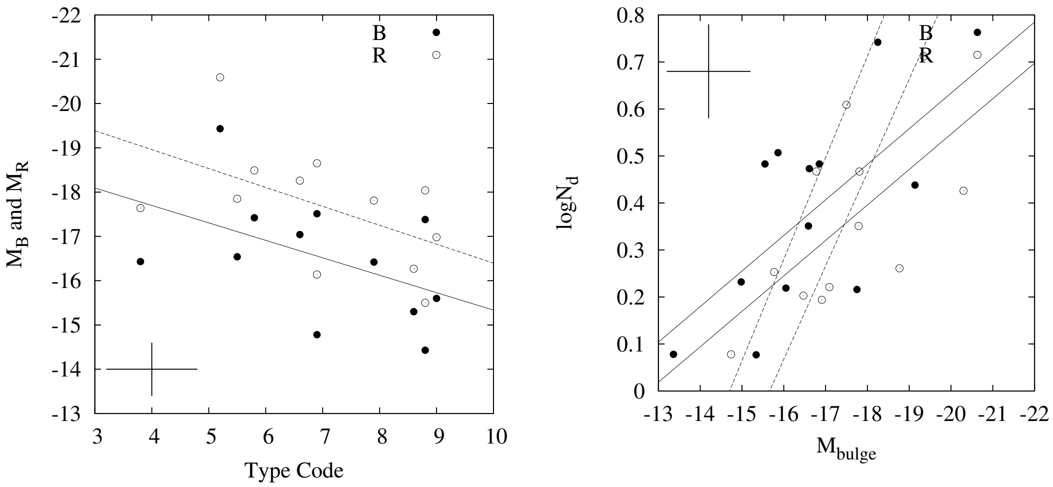

Fig. 1. Correlations in the data taken from the profiles of RSS83 galaxies. Left: Absolute magnitude plotted against morphology type code. Solid and dashed lines show the regressions for B and R magnitudes with standard errors 1.3 mag and 1.2 mag, respectively. Right: Exponential power number for the disk profile N_d plotted against the absolute magnitude of the bulge M_{abs}. Solid and dashed lines show the standard and reverse regressions, respectively. The cross shows the average uncertainties.

In Fig. 1 two correlations for the galaxies in the sample RSS83 are presented. In the left part of Fig. 1 the absolute magnitude and the morphology type code are compared. This graph shows the known fact that early type galaxies generally have higher luminosities. However, the most early galaxy in the sample - UGC 6922 - seems to be a dwarf galaxy. In the right part of Fig. 1 the exponential power numbers N_d for the disks are plotted against the total luminosity of the bulges in these galaxies. The bulge luminosity is calculated from the model of the bulge profile, derived after the decomposition procedure. In spite of the uncertainties with the absolute magnitudes, one can easily see that when the bulge is getting brighter and more massive the disk is fitted with a greater exponential number, i.e. it appears more convex. The tendency shown in Fig. 1 is found to be independent of the color, with a standard deviation of 0.155 for the R data and 0.168 for the B ones. Why in these, in general earlier type, galaxies the disks should obey greater convexity is yet to be understood. A similar correlation is found in the dataset from SDSS but with greater deviations, caused probably by the uncertainties in the calculated bulge luminosities.

One distance independent parameter, derived from decompositions, is the ratio of the scale lengths of the disk and bulge profiles of the galaxy H_d/H_b. It is known that the profiles of more massive bulges, inherent to the more massive galaxies, have more concave shapes, i.e. typically shorter scale lengths H_b. On the other hand we have previous evidences, that more massive disks, inherent again to more massive galaxies, have more convex profiles, i.e. typically longer scale lengths. Therefore we can expect that the ratio H_d/H_b must correlate with the total luminosity of the galaxy. However, the mathematical task of the decomposition is in principle not correct and the derived values of H_d and H_b are not entirely independent. Though, the ratio H_d/H_b correlates with the luminosity of the galaxy and it is worth to be considered.

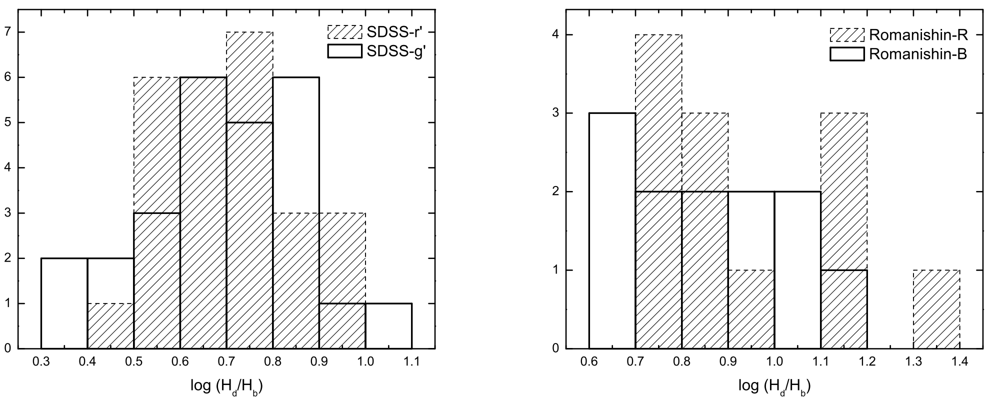

Fig. 2. The distributions of the ratio of the scale lengths of the disk and the bulge profiles (left - SDSS, right - RSS83). The bluer color is shown with solid line.

In Fig. 2 the distribution of this ratio is given for both datasets. One can say all data peak around $log(H_d/H_b) = 0.7$ or $H_d/H_b = 5$. In the shorter wavelengths the distribution is smoother and the peak is woolly. A similar behavior of this ratio is found by de Jong [1996] and Courteau et al. [1996], although they fitted disk profiles with an exponential function (as flat shape). The distribution of the RSS83 galaxies, shown in the right part of Fig. 2, is bimodal.

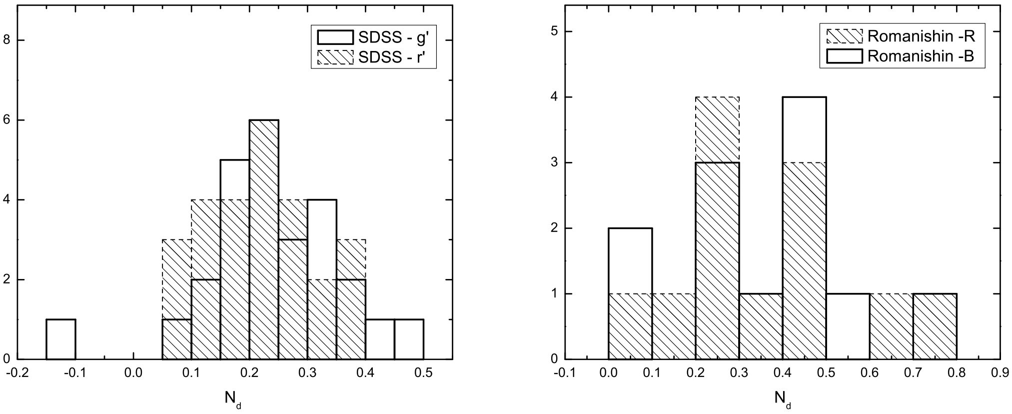

Fig. 3. The distribution of the exponential power number of the disk profiles in both datasets (left - SDSS, right - R83

Better pronounced bimodality can be seen in Fig. 3, showing the distribution of the exponential power number for the disks of the two datasets. Earlier the investigations of the color gradients in the disks showed that the scale length gets larger, when observed in shorter wavelength. Although this tendency can hardly be ascertained from Fig. 2, where it could be suspected in a woolly distribution. Because in our approach both the scale length and the exponential power number are definitive for the shape of the given component, and not only for its size, the similarities in Figs 2 and 3 are not surprising.

Other distance independent parameters are the exponential power numbers of the models of the disk and bulge. In the presented sample the most common value for $\log N_d$ is 0.25 ($N_d = 1.8$). This agrees very well with the visual impression from the profiles published by Karachentsev et al. [1992], Barteldrees & Dettmar [1994], Pohlen et al. [2000], Kregel, van der Kruit & de Grijs [2002], where the most common shape of the radial surface brightness distribution of the disks (in magnitudes) is like a parabola (with N_d=2, that is the Gaussian function in a linear scale).

In Fig. 4 the ratio of the scale lengths of the disk and the bulge is plotted against the exponential power number of the disk. The correlation between both parameters is tight. For the SDSS dataset the standard deviations are 0.10 for the g' data and 0.06 for the r' data. Although the deviations are greater in the other dataset, the correlation is clearly visible. The discrepancy in the distribution of the scale length ratio is found to correlate with the shape of the disks.

Conclusions

As it was shown before, the LSB galaxies, like normal galaxies, have typically convex disk profiles. In the case of normal galaxies this convexity is found to correlate with the total luminosity of the galaxy (and with the morphological type code, see Georgiev [2007]). In spite of the disadvantages of the available profiles, this paper gives evidences that the same correlations must exist also for the LSB disk galaxies.

It is known that the ratio of the scale lengths of the disk and the bulge concentrates around certain values, when both profile parts are fitted with exponential functions (de Jong [1996] and references therein). A similar behavior of this ratio is found here, when both parts are fitted with Sersic's [1968] exponential power formula. An important result is the correlation between the exponential power number of the disk with the

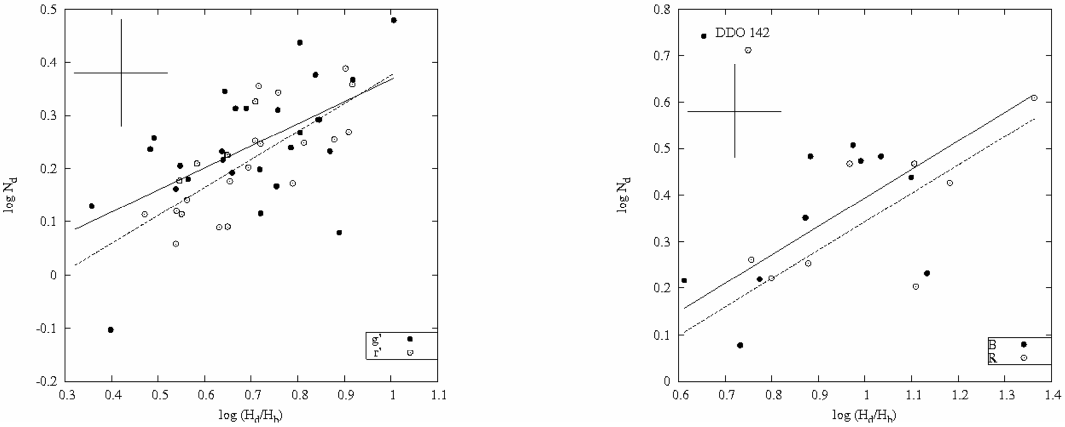

Fig. 4. The ratio of the scale lengths of the disk and the bulge profiles for both datasets plotted against the exponential power number of the disk shape (left - SDSS, right - R83). In the sample of R83 DDO 142 is excluded from the fit. The graph is taken from Deshev et al. [2006]

luminosity of the bulge, and with the total luminosity of the galaxy. If such a correlation is narrow enough, it may be calibrated as a distance indicator.

The convex disk profiles, modeled here and in the previous papers, are not surprising. They are predicted by the results of the multiple hydrodynamical simulations of galaxy formation. These simulations show the insufficient gas density for star formation as the main reason for apparent truncation of the disk profile and the smoother and flatter appearance of the disk profiles of the late type galaxies can be a result of long term evolution and radial mass redistribution. Clearly, deeper observations of a larger sample of galaxies are needed to give a proof to this.

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