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Properties and structural features of early-type disk galaxies with multi-tier disks

M.A. Ilyina*, O.K. Sil'chenko

Sternberg Astronomical Institute, 13, Universitetskij pr., Moscow 119991, Russia

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The results of photometric decomposition of 85 early-type galaxies are presented. The SDSS r-images are analysed. Double-tier exponential disks are found in all galaxies which are studied; the statistics of disk parameters is analysed.

Keywords: Galaxies: structure, evolution

1 Introduction

The photometric decomposition of disk galaxy images is a long-standing classical topic in studies of galaxy structure. However, the Sloan Digital Sky Survey (SDSS) has provided new possibilities due to its depth and large sky area covered by the observations. The statistics of structure characteristics obtained with the SDSS data for nearby late-type galaxies has been already analysed [1]. Here we present some results for a sample of early-type disk galaxies.

2 Sample

For our decomposition we have selected 85 galaxies satisfying the following criteria:

- the morphological type of S0–Sa, to avoid isophote distortion due to dust;
- disk inclination less than 70°, to avoid degeneracy owing to disk light integration at our line of sight;
- redshift less than 0.03, to provide sufficient metric spatial resolution;
- the absence of large-scale bar (though we do not reject the galaxies with nuclear minibars which do not affect disk parameter determinations).

For these 85 galaxies, the DR7 data of the SDSS imaging [2] have been retrieved. We have chosen r-images because they have the best signal-to-noise ratio for our reddish galaxies. The software used for decomposition is GIDRA (Galaxies Interactive DRAwing) which allows us to build iteratively one-dimensional surface brightness

*Corresponding author. Email: taktonado@gmail.com

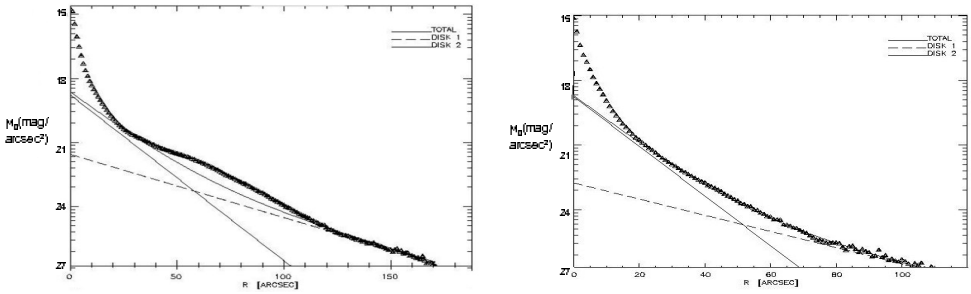


Figure 1 Typical surface brightness profiles in galaxies of our sample: *left* – NGC 4203, so called 'truncated' inner disk which we treat as an exponential disk containing stellar ring; *right* – NGC 4169, so called 'antitruncated', or double-tier, disk fitted by two exponential segments with different scalelength, the outer one being longer.

profiles by averaging counts per pixel over elliptical rings and to construct 2D model maps described by these profiles to subtract them from the images observed [3]. A combination of components tried to fit every galaxy includes a Sersic bulge and two exponential disks with different scalelengths.

3 Results

The most interesting result of the decomposition of 85 early-type disk galaxies is that all of them possess double-tier large-scale disks; it is seen best of all in the band r while in the band g the outer disks with a larger scalelength are sometimes lost among statistical noises due to low surface brightness.

3.1 Classification

By following the classification scheme by Erwin et al. [4], we try to divide all the profiles obtained into 3 groups:

- classical one-scale exponential law; we have no such galaxies in our sample;
- truncated inner disks; they demonstrate a shallow cut-off at some radii; but in our collection of the deep SDSS r-images the truncated inner disks are always followed by outer disks with a larger scalelength (Fig. 1, left); they constitute about 32% of all galaxies;
- antitruncated disks which are a combination of the inner and outer disks with different scalelengths, the outer disks having larger scalelengths (Fig. 1, right); they are a majority, about 68% of all sample galaxies.

Based on the approach by Sil'chenko & Moiseev [5], applied in their paper to the photometric decomposition of the nuclear-ring galaxy NGC 7742, we have suggested that the 'truncated' inner disks may be in fact exponential disks with the ring-like brightness excess at some radius inside them; a close inspection of the images decomposed has confirmed the validity of this approach.

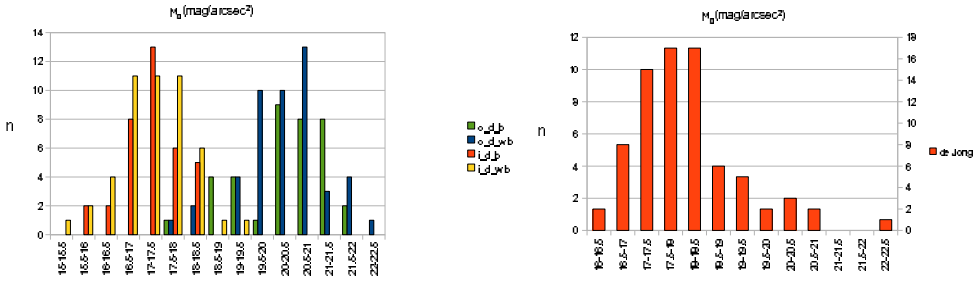


Figure 2 Central surface brightness distributions: *left* – our results, red colour marks inner disks with nuclear bars, yellow colour marks inner disks without nuclear bars, green colour marks outer disks in galaxies with nuclear bars, blue colour marks outer disks in galaxies without nuclear bars; *right* – the results from de Jong [6].

3.2 Statistics of the disk parameters

1. Figure 2 (left) presents the distribution of inner and outer disks over the central surface brightnesses which are determined in this work by the decomposition procedure. The central brightnesses are corrected for the disk inclinations; for the purpose of comparison with the data of de Jong [6], the histograms are shifted to the left by about 3 mag to mimic the K-band measurements (see the SDSS colour transformation equations, [7, 8]). The distribution is strongly bimodal, the inner-disk and outer-disk distributions representing almost non-overlapping, Gaussian-like peaks. Figure 2 (right) shows the similar distribution of the central surface brightnesses for 86 face-on disk galaxies from [6]. De Jong [6] fitted 2d images of the galaxies by a combination of only *two* components, both exponential ones, called 'a bulge' and 'a disk'. From the comparison of the histograms in Fig. 2 one can see that the 'disk' component in [6] corresponds to our inner disks. Obviously, the outer disks of the double-tier ('antitruncated') disk galaxies mostly avoided detection up to recent times due to insufficient depth of the galactic images. Only when the SDSS provided accurate photometry at the level of 27-28 r-mag per square arcsec, the outer disk detections became quite certain.
2. We have considered separately inner and outer disks in galaxies with nuclear bars (43% of the sample) and those without (57% of the sample). As Fig. 2 (left) demonstrates, the distributions of both subsamples over the central surface brightnesses appear to be similar.
3. In Fig. 3 we check the correlation between the central surface brightnesses and exponential scalelengths over a totality of large-scale disks of our sample. Earlier, many authors who probed photometric decomposition of disk galaxies with a single exponential disk found such correlation, in the sense that the more extended disks had lower surface brightness [9–12].However, we noted [13] that this correlation may be an artifact of missing inner and outer disks in one data set. Indeed, the outer disks having larger scalelengths are mostly low surface brightness disks, as we have seen in Fig. 2 (left). But within two subsamples,

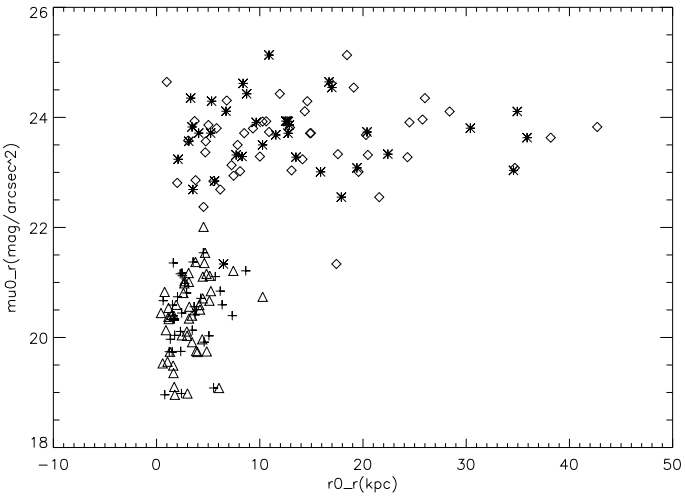


Figure 3 The 'central surface brightness–exponential scalelength' diagram for our galaxies: pluses mark inner disks with nuclear bars, triangles mark inner disks without nuclear bars, stars mark outer disks in galaxies with nuclear bars, diamonds mark outer disks in galaxies without nuclear bars

one of inner disks and the other of outer disks, there is no correlation (Fig. 3). Again in this diagram we cannot distinguish between the galaxies with nuclear bars and the ones without.

4 Conclusions

After having decomposed the SDSS photometric images of 85 early-type disk galaxies lacking large-scale bars, we conclude:

- all early-type disk galaxies in our sample lacking large-scale bars demonstrate double-tier large-scale stellar disks;
- the outer and inner stellar disks probably have a different nature: the central surface brightness distribution is strongly bimodal, with the inner and outer disks having well separated peaks, and at the diagram 'μ_0 vs r_0' the outer and inner disks represent two quite separate point clouds;
- the galaxies with nuclear bars and those lacking them do not separate in any diagram analyzed here; we conclude that the presence of nuclear bars does not relate with any structure re-building at large scales.

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