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Photometric Decomposition of 3 Early-Type Dwarf Galaxies in the Virgo Cluster

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Abstract.

Equivalent profiles of IC 783, IC 3328 and IC 3653, derived from HST and VLT images, are successfully decomposed using the classical two-component method of Kormendy (1977). Clearly distinguished are a bulge and a faint exponential disk, embedded in the spheroidal component. The blue-light profiles of IC 3328 and IC 3653 point to existence of a very bright compact nucleus.

1 Introduction

The significant advance in observational astronomy during the last decade gave many opportunities to study dwarf galaxies in the Local Universe. An interesting type of such objects are the dwarf ellipticals (dE) and the lenticular dwarfs (dS0). Dwarf ellipticals are usually distinguished from the normal E galaxies by their different morphology and low surface brightness. It is suggested that they are very similar to the fragments from which larger galaxies have formed [9]. Lenticular dwarfs (dS0), introduced by [13], are also objects of low luminosity and surface brightness, but – unlike the case with dEs, – their photometric profile can be sucessfully decomposed into two components: bulge and disk. Thus there is direct observational evidence that dS0s are disky objects. Indeed, there is still no clear morphological distinction between dE and dS0 galaxies; very recently, [12] unify both in a common type, labeled 'early-type dwarfs' (dE), and introduce the tern dEdi for those of them with disky features. Their analysis is based on an extensive study of the Virgo cluster, using multiband photometric data from the Sloan Digital Sky Survey.

Hundreds of dEs populate the nearby Virgo cluster. This nearest rich (~ 2500 galaxies) giant cluster is gravitational center of the Local supercluster. At the center of the Virgo cluster are located three giant E galaxies (M 84, M 86 and M 87) – probably formed through a merger of smaller galaxies. Judging on kinematical data, two prominent groupings are distinguished, around M 87 and

M 86. Some authors differentiate five main groups: V1 (M 87), V2 (M 49), V3 (M-cloud), V4 (M 59) and V5 (W-cloud) (see *e.g.* [5]). Objects of the present study are three early-type dwarf galaxies, revealing disk features, members of three different groups of the Virgo cluster (Table 1).

Table 1. General data on the chosen galaxies. Abbreviations: CE95 [5], B – barred galaxy, R – galaxy with a ring (classification: Leda database).

IC number	RA (J2000)	DEC (J2000)	Classification NED	Classification Leda	Membership (CE95)	DM [mag]	B_T [mag]
IC 783	12:21:38.78	+15:44:42.7	SAB(rs)0	S0-a (B)	V1 (M 87)	31.46	14.94
IC 3328	12:25:57.81	+10:03:12.8	dE,N	E-S0 (R)	V2 (M 49)	30.98	14.49
IC 3653	12:41:15.72	+11:23:13.5	E3	S0	V4 (M 59)	29.90	13.93

The galaxy IC 783 was originally classified as type S0 [4] because of suspected disk component. A research of its circumnuclear region ($r_{gc} < 20''$) revealed existence of a two-component spiral structure, possibly with ring or bar ([1, 2]). Spiral structure was discovered also in IC 3328 by [10] – it is strongly winded, compact and centered in the galaxy center. The nucleus is well pronounced and therefore IC 3328 was classified as 'dwarf elliptical nucleated' (dE,N), although [10] argue that it is most probably dS0. In contrast to the former two galaxies, IC 3653 is classified as a normal elliptical (*cf.* [8]). However, its morphology and photometric features are typical for dwarf ellipticals [15]. There is no observational indication that it possesses a disk.

2 Data Analysis

In the present work we use high-quality images from the FORS1 archive (VLT) and the ACS Virgo Survey (HST). The FORS1 images have been taken in the red broadband filter R, with typical resolution of $0\farcs2$ per pixel, and we processed them preliminary to remove the bias and to perform a flat field correction. The HST images have been taken with the Wide Field Channel (WFC) of the Advanced Camera for Surveys (ACS), which allows an image scale of $0\farcs05$ per pixel. The used broadband F475W and F850LP filters are characterized by high throughput and correspond respectively to g' and z' filters in the Sloan Digitized Sky Survey system. The objects, covered by the ACS Virgo Survey, were a subset of 100 galaxies from the Virgo Cluster Catalog (VCC) with morphological types of E, S0, dE, dE,N, dS0 or dS0,N [6].

In a previous work we performed surface photometry of the chosen three galaxies [7]. The applied methods confirmed the existence of disky structures in IC 783 and IC 3328 and indicated possible disk in IC 3653. Therefore, a careful photometric decomposition is required for quantitative structure analysis of this galaxies. We applied a decomposition procedure, using the classical two-

component method of [11]. It was originally invented to study the radial light distribution in galaxies with well pronounced spheroid component, clearly dominating in large central regions. As one can see from the presented profiles, the case with our objects is different (see especially Figures 3 and 4). Nevertheless, Kormendy's method is successful when approximating radial surface brightness distribution $\mu(r)$ of the components by means of Sersic's law [14]:

$$\mu_{\rm bul}(r) = \mu_{\rm bul}(0) + 1.086\ (r/h_{\rm bul})^{N_{\rm bul}},$$
$$\mu_{\rm disk}(r) = \mu_{\rm disk}(0) + 1.086\ (r/h_{\rm disk})^{N_{\rm disk}},$$

where h is a scaling factor and N is exponential-power decimal number, typically in range [0,2]. (In the scientific literature, the index N is usually written in the form $1/n$.) Up to ten iterations of the procedure are sufficient to obtain appropriate solution. Generally, the cases when $N < 1$ represent profiles with concave shapes, usual for the galactic bulges. The most concave shapes, intrinsic for cD ellipticals, are characterized by $N \sim 0.25$ (de Vaucouleurs law). The case $N = 1$ corresponds to Freeman's model, considered as typical for the disks of intermediate and late type galaxies. The models when $N > 1$ represent various convex shapes and the case $N = 2$ gives Gaussian shape. The radial profiles of small ellipticals, the bulges of late type galaxies as well disks of early type galaxies in the sample of [11] may be modeled with $N > 1$.

3 Results and Discussion

The one-dimensional photometric profiles were obtained by use of the program package *pleinpot*, developed at the Observatory of Lyon, and are shown with filled symbols in Figure 1–5. The parameters of the bulge and disk Sersic fits are given in Table 2.

The results of IC 783 reveal a well pronounced disk, reaching to the outer regions of the galaxy. The steep bulge profile indicates strong concentration of the spherical component toward the bright nucleus (Figure 1). However, we point out some uncertainty in the estimates of $N_{\rm bul}$ and $h_{\rm bul}$ due to unusually high central luminosity. (The problem is even more severe in case with the z' image of IC 3328; see below.) Thus the extension of dominating spherical component still

Table 2. Decomposition with Sersic profiles of IC 783 and IC 3328.

Galaxy	d (μ=25)	Disk	Parameters of Sersic law fits					
	[arcsec]	[kpc]	$N_{\rm bul}$	$\mu_{\rm bul}(0)$	$h_{\rm bul}$	$N_{\rm disk}$	$\mu_{\rm disk}(0)$	$h_{\rm disk}$
IC 783 (R)	131.2	12.45	0.958	18.04	0.688	1.011	19.45	13.07
IC 3328 (g')	54.2	4.13	0.272	12.26	<0.001	1.341	20.54	9.46
IC 3328 (z')	58.2	4.43	0.930	21.31	0.674	1.193	20.80	9.37
IC 3328 (R)	80.2	6.11	0.970	17.66	0.450	1.128	19.44	9.42

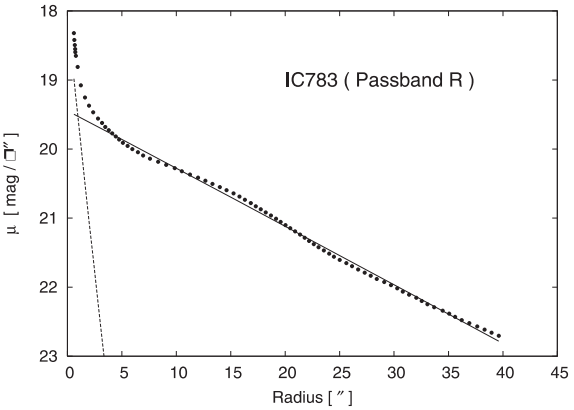

Figure 1. Decomposition of the radial surface brightness distribution (large dots) of IC 783 in R filter. Sersic fits of the bulge (dotted) and disk (solid) are shown.

needs to be clarified. At galactocentric distances > 5 arcsec disk component is dominant. As seen from a brief look at Figure 3 in [2], our disk profile covers the region of spiral arms and the unidentified central structure (bar or ring). The transition between arms and central structure occurs at $r_{gc} \sim 12$ arcsec where light bend in the profile is observed (Figure 1).

Photometric profiles of IC 3328 in g' and z' are also clearly decomposed into bulge and disk. The comparison between the two decompositions surprisingly shows different behaviour in the circumnuclear region (*cf.* Figures 2 and 3). Impressive is the extremely bright nucleus, seen in g' passband, that almost disappears in z'. Existence of foreground object is not a plausible explanation in

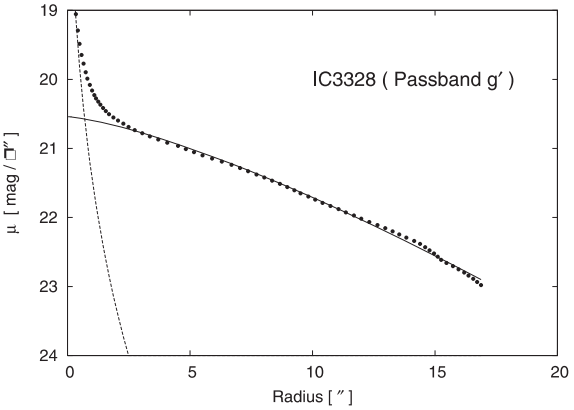

Figure 2. The same like Figure 1 but for IC 3328 (g' filter). The symbols are the same.

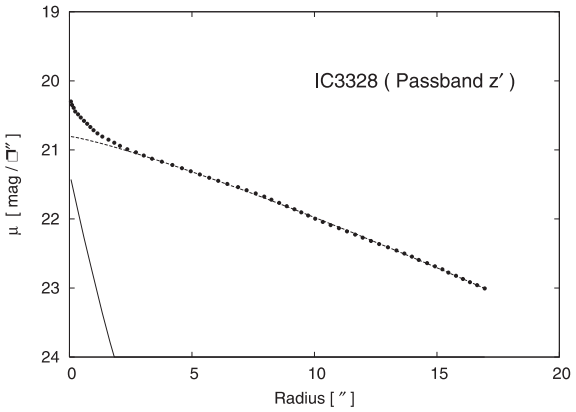

Figure 3. The same like Figure 1 but for IC 3328 (z' filter).

view of the short life and small spatial density of luminous OB stars. Moreover, similar behavior is observed in case with IC 783 – although its nucleus is not that bright. If the nucleus of IC 3328 is really very bright in blue light, it may be speculated that it harbors young, compact stellar cluster(s). The disk component is blue ((g'-z')$\lesssim -0.2$), revealing no color gradient with the galactocentric distance. Taking into account that the disk is purely stellar, this behaviour indicates lack of huge, non-axisymmetric concentrations of massive stars. Indeed, the surface photometry of [10] (see Figure 1 there) clearly shows regular spiral structure, with uniform light distribution, reaching nearly to the galaxy center.

Decomposition of radial surface brightness profile of IC 3328, using ground-based (VLT) and obviously deeper observations in R passband, indicates also

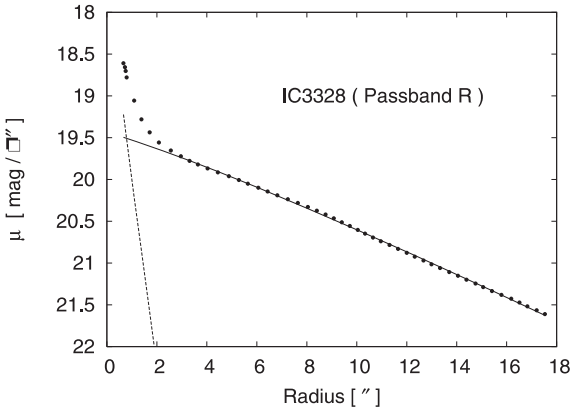

Figure 4. The same like Figure 1 but for IC 3328 (R filter).

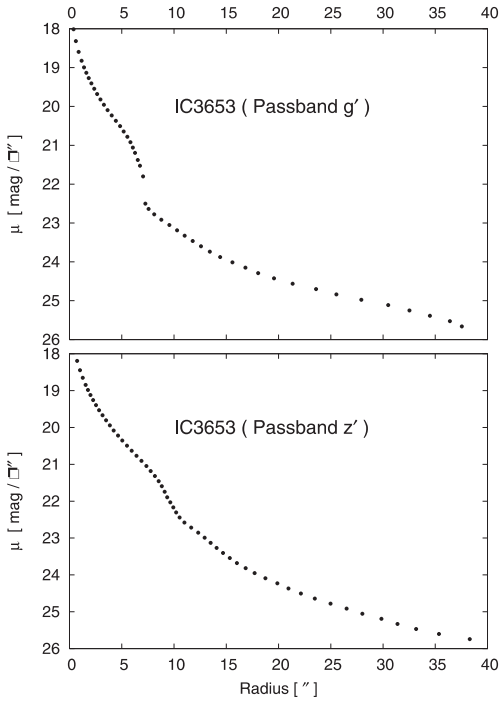

Figure 5. Radial brightness profile of IC 3653 in g' and z' filters.

lightly concave bulge profile and lightly convex disk profile (Figure 4). In all 4 decompositions, we found nearly flat, Freeman type profiles of the bulge and the disk – as one can expect when considering dwarf galaxies.

Photometric profiles of IC 3653 in g' and z' cannot be decomposed through the method of [11]. The profiles in the inner 10″ have mixed concave-convex shape that cannot be approximated by Sersic law. Probably this indicates a more complex central structure which we intend to study by use of other approaches. Surface photometry techniques, applied by us recently, give no clear indication for existence of disky structure [7].

Acknowledgments

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