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LUMINOSITY PROFILES OF dE AND dS0 GALAXIES IN THE VIRGO CLUSTER

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ABSTRACT

We investigated the structural parameters of a sample of 30 dwarf galaxies (15 dEs and 15 dS0s) in the Virgo Cluster using *i*-band images from the Sloan Digital Sky Survey Data Release 4. Among 28 galaxies for which surface brightness profiles were derived from ellipse fittings, 23 galaxies had a single component that was adequately described by a generalized Sérsic function with a shape parameter ranging from n=0.5 to 2, while 5 galaxies (2 dEs and 3 dS0s) had bulge and disk components that were fitted by a generalized Sérsic function and an exponential function, respectively. Since the majority of dwarf galaxies in the present sample had a single component, it seems likely that genuine dS0 galaxies that have disk and bulge components are quite rare in the Virgo Cluster. The similarity in structural parameters of genuine dS0 galaxies in the Virgo Cluster with those of Magellanic-type galaxies implies that the progenitors of dwarf lenticular galaxies in the Virgo Cluster were most likely Magellanic-type galaxies if dS0s are harassed late-type spirals.

Key words : galaxies: structure — galaxies: morphology — galaxies: dE, dS0

I. INTRODUCTION

Dwarf galaxies are considered the building blocks of larger galaxies in the CDM cosmogony (White & Frenk 1991; Navarro & White 1993). Although there is no clear distinction between 'dwarf' galaxies and 'normal' or 'giant' galaxies, the term 'dwarf' is generally applied to galaxies fainter than $M_B \simeq$ -18 (Ferguson & Binggeli 1994). These galaxies are the most numerous in the universe, but they are difficult to observe outside the local universe because of their low surface brightness.

Among dwarf galaxies, dwarf elliptical galaxies (dEs) and dwarf lenticular galaxies (dS0s) are especially interesting because they have common properties but different origins (Aguerri et al. 2005). The dE and dS0 galaxies are gas-poor systems with old stellar populations, though some in the Virgo Cluster have bars or spiral arms (Jerjen et al. 2000; Barazza et al. 2002). The colors and global scales of dS0 galaxies in the Coma Cluster are similar to those of dE galaxies, but the scale length of the innermost parts of dS0 galaxies is similar to that of late-type spiral galaxies, implying different origins for dE and dS0 galaxies (Aguerri et al. 2005).

As noted by Sandage & Binggeli (1984), a morphological classification of dEs and dS0s encounters a subtle problem owing to similarities in apparent shape and photometric properties. This difficulty is well known for their giant cousins (E and S0 galaxies), but it is greater for dwarfs due to their intrinsic small size. This is the reason why dS0 galaxies were ignored until Sandage and Binggeli (1984) introduced them into the morphological classification of dwarf galaxies in the Virgo Cluster. The surface brightness profiles of dS0 galaxies have two components, bulge and disk (Sandage & Binggeli 1984; Binggeli & Cameron 1991), while those of dE galaxies have a single component that is adequately described by a generalized Sérsic function (Sérsic 1968) with a shape parameter n≈1-2 (Barazza et al. 2003; Graham & Guzmán, 2003). Thus, it seems plausible that a detailed analysis of the surface brightness profiles of dE and dS0 galaxies might lead to a better classification of their morphological types.

The origin of dS0 galaxies in the Virgo Cluster may differ from that of dS0 galaxies in the Coma Cluster because the formation and evolution of galaxies is thought to be affected by their environment. Interactions with neighbor galaxies and inter-galactic medium in the Coma Cluster are supposed to be stronger in the Coma Cluster due to the presence of higher densities and deeper potentials. It would therefore be interesting to determine whether the scale lengths of dS0s in the Virgo Cluster are different from those of Coma Cluster dS0s, since their scale lengths are closely related to those of the progenitors if the harassment scenario applies to the origin of dS0s in the Virgo and Coma clusters.

Thus, the primary aim of the present study is to obtain photometric properties that may be relevant to a consideration of the origin of dS0 galaxies in the Virgo Cluster. For this purpose, we analyze a sample of dE

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TABLE 1.
LIST OF SELECTED GALAXIES

OBJECTS	TYPE	NUCLEUS	$\alpha_{00}(hh\ mm\ ss)$	$\delta_{00}(dd\ mm\ ss)$
IC 0781	*dS*0	*n*	12 20 03.3	+14 57 41
IC 0794	*dE*	*n*	12 28 08.6	+12 05 36
IC 0810	*S*0?		12 42 09.1	+12 35 49
IC 3032	*E*?		12 11 07.7	+14 16 30
IC 3097	*dE*	*n*	12 17 01.1	+09 24 27
IC 3167	*dSB*0	*n*	12 20 18.8	+09 32 43
IC 3303	*dS*0	*n*	12 25 15.2	+12 42 53
IC 3305	*dE*	*n*	12 25 14.5	+11 50 59
IC 3331	*dS*0	*n*	12 26 05.3	+11 48 44
IC 3358	*dE*	*n*	12 26 54.3	+11 39 50
IC 3363	*dE*		12 27 03.1	+12 33 39
IC 3393	*dE*	*n*	12 28 41.7	+12 54 57
IC 3413	*dS*0	*n*	12 29 22.5	+11 26 02
IC 3435	*dS*0	*n*	12 30 39.8	+15 07 47
IC 3437	*dE*	*n*	12 30 45.9	+11 20 35
IC 3443	*dE*		12 31 15.7	+12 19 54
IC 3459	*dSB*0		12 31 56.0	+12 10 26
IC 3486	*dE*	*n*	12 33 14.0	+12 51 28
IC 3492	*E*?		12 33 19.8	+12 51 13
IC 3501	*dE*		12 33 51.6	+13 19 21
IC 3518	*dS*0	*n*	12 34 31.3	+09 37 24
IC 3586	*dS*0		12 36 54.8	+12 31 12
IC 3607	*dE*		12 38 32.2	+10 22 36
IC 3612	*dS*0		12 39 04.7	+14 43 52
IC 3637	*dS*0 *pec*		12 40 19.6	+14 42 54
IC 3773	*dS*0		12 47 15.3	+10 12 12
IC 3779	*dE*	*n*	12 47 20.3	+12 10 00
NGC 4366	*dE*	*n*	12 24 47.0	+07 21 11
NGC 4436	*dE*/*dS*0	*n*	12 27 41.2	+12 18 57
NGC 4640	*dS*0	*n*	12 42 57.7	+12 17 12

and dS0 galaxies in the Virgo Cluster using i-band images from the Sloan Digital Sky Survey Data Release 4 (SDSS DR4). It is also important to determine the fraction of misclassified dEs and dS0s, since the morphology of a galaxy is one of the basic parameters that relates to its formation and evolution.

This paper is organized as follows. In section 2, we detail observational data and provide a brief introduction of data reduction. The results of the present study are given in section 3, and a discussion of the morphology and origin of dS0 galaxies is presented in section 4. The conclusions of the present paper are given in the final section.

II. OBSERVATIONAL DATA AND DATA REDUCTION

(a) Data Selection

We used i-band images for 30 Virgo Cluster members from the SDSS DR4. The pixel size of images was $0.396''$/pixel, which is smaller than the mean seeing size of $\sim 1.5''$. Objects were selected from the catalog of dwarf galaxies in the Virgo Cluster of Sandage & Binggeli(1984) and Binggeli & Cameron(1991) for dS0 galaxies and Binggeli & Cameron(1991), Pierini(2002), Binggeli, Sandage & Tammann(1985) for dE galaxies. Since dS0 galaxies are rarer than dE galaxies, we first selected most of the bright dS0 galaxies and then randomly selected dE galaxies to gather a similar number of galaxies for the two types. There were 20 dS0 galaxies in Binggeli & Cameron's list and 21 dS0 galaxies in Sandage & Binggeli's list. Because of difficulties in their identification, 7 of them were omitted and 12 of them were excluded because they were not classified as dS0 galaxies in NED(NASA/IPAC Extragalactic Database). There were 7 galaxies in Sandage & Binggeli's list which overlapped with Binggeli & Cameron's list, and we assumed as dE, N for one galaxy(NGC 4436) which was classified as dE6/dS0, N. In the case of dE galaxies, 16 galaxies were selected from the catalog of Binggeli & Cameron (1991), Pierini (2002), and Binggeli, Sandage, & Tammann (1985). Through data analysis process, IC 3305 and IC 3607 were excluded because of error for ellipse fitting. The basic parameters of the selected galaxies are listed in Table 1. We adopted a distance to the Virgo Cluster of 16 Mpc(Okon et al. 2002; van Driel et al. 2005; Giovanelli, R. et al. 2005).

(b) Data Reduction

SDSS DR4 provides flat-fielded images that allow the omission of pre-processes relevant to CCD images. The images were subtracted and divided by the sky frames, which were obtained by fitting the sky regions surrounding the galaxy images in order to obtain the galaxy light distribution, expressed in units of local sky level:

$$I_{rel}(x,y) = \{I_{obs}(x,y) - I_{sky}(x,y)\}/I_s$$

where I_s is the average background local sky intensity. Due to the low S/N ratio in the outer parts of the galaxy, we applied a Gaussian beam filter type smoothing using SPIRAL in order to apply heavy smoothing to the outer part of the galaxy and light smoothing to the bright inner part.

III. LUMINOSITY DISTRIBUTION OF DWARF GALAXIES

(a) Isophotal Maps

We present isophotal maps of the sample galaxies in Fig. 1 to show the morphology of galaxies in detail. An inspection of these isophotal maps reveals 8 galaxies (IC 3167, IC 3413, IC 3435, IC 3459, IC 3518, IC 3586, IC 3612, and NGC 4640) that seem to have bulge and disk components. We selected IC 3167, IC 3586 and NGC 4640 for their varying position angles in the central regions, IC 3413 and IC 3435 for their pronounced bulge components, IC 3459 for its bar-like structure, and IC 3518 and IC 3612 for the outer rectangular isophotes. All of these galaxies are classified as dS0 galaxies according to Sandage & Binggeli(1984). Thus, about 50% of galaxies that are classified as dS0 galaxies are recovered by a visual inspection of isophotal maps. However, as shown in Fig. 4, only two of these galaxies (IC3435 and IC 3586) are found to be genuine dS0 galaxies that have two components according to the profile analysis.

(b) Ellipse Fittings

We applied ellipse fittings to derive elliptically averaged surface brightness profiles. Ellipse fitting fits the concentric ellipses to the isophotes of galaxies. We used a modified version of the ellipse fitting program written by Tod Lauer. This ellipse fitting yields profiles of position angle and ellipticity along the major axis, as well as surface brightness profiles. Profiles of surface brightness, position angle and ellipticity are presented in Fig. 2.

The ellipticity tends to increase with the radius until r ≈ 5″-10″ and thereafter remains constant, except for IC 3413, IC 3437 and IC 3486, which show an ever-increasing tendency. The small ellipticity near the center (r ≤ 3″) is due to smoothing by atmospheric seeing with a mean FWHM of about 1.5″. However, the smooth increase of ellipticity from the seeing dominated regions (r ≤ 3″) to r≈10″ observed in 10 galaxies (IC 0794, IC 3097, IC 3303, IC 3363, IC 3393, IC 3459, IC 3779, NGC 4366, NGC 4436, NGC 4640) seems to reflect an intrinsic structure since most of these galaxies are nucleated dwarfs ('dE, N' or 'dSB0, N'). Only one galaxy (IC 3459) is a non-nucleated dwarf (dSB0), but it has a central bar. Thus, the luminosity of the inner regions where ellipticity varies smoothly is dominated by their nuclei, which are mostly round.

The position angles are nearly constant for most of the galaxies if we ignore the small changes of position angle within r ≈ 5″. This indicates that most of the dE galaxies do not have a triaxial structure because the position angle should vary with radius in triaxial systems (Lauer 1985). IC 3097 and IC 3413 show noticeable changes in position angles, but they also show different patterns. Whereas IC 3097 shows a smooth change within r ≈ 9″, IC 3413 shows an abrupt change at r ≈ 6″. This abrupt change of position angle seems to be caused by the existence of small ellipticity (< 0.1) due to round bulge, and is therefore not a real feature. However, the smooth change of the position angle in IC 3097 seems to be caused by a real feature, such as a triaxial bulge or bright nucleus.

(c) Profile Decomposition

Surface brightness profiles of dE galaxies are adequately represented by the Sérsic profile (1968):

$$\mu(r) = \mu_e + 2.5b_n[(r/r_e)^{1/n} - 1]$$

where r_e is the effective radius, which encloses half of the total luminosity of the profile, μ_e the effective surface brightness, and n the profile shape parameter. We used the approximate solution $b_n = 0.868n - 0.142$ of Caon et al. (1993) in fitting a Sérsic profile to the observed surface brightness profiles. In the case of dS0 galaxies, which are characterized by the coexistence of bulge and disk components, we assumed a Sérsic profile for the bulge component and an exponential profile for the disk component.

Since we do not know *a priori* whether a galaxy has a single component, we first assumed that all galaxies have a single component and then fitted Sérsic profiles to the observed surface brightness profiles to determine whether an extra component is present in central regions. If the residuals from this fit (taking into account photometric errors in surface brightness profiles) were

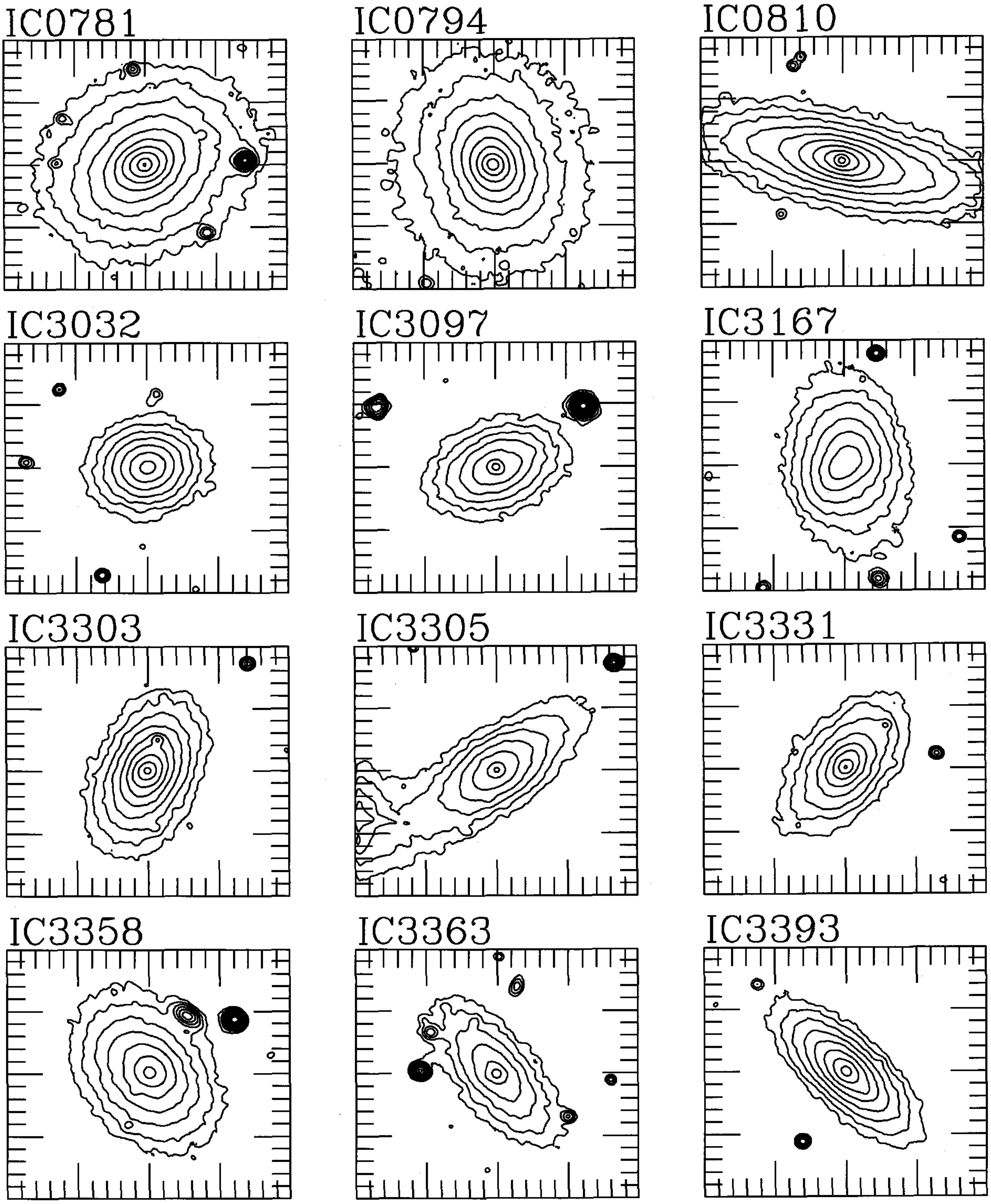
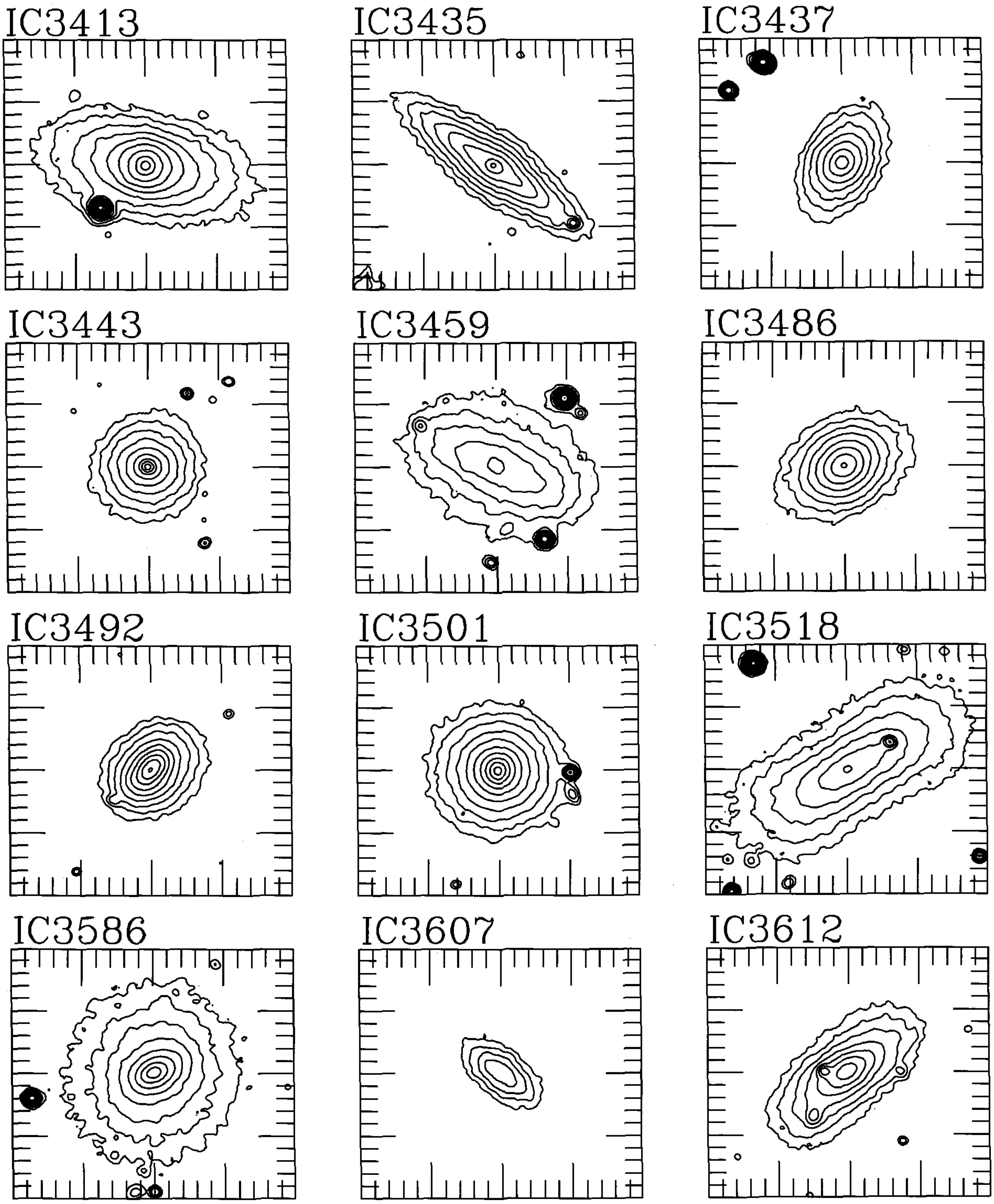


Fig. 1.—Isophotal maps of 30 dE/dS0 galaxies. The interval of isophotes is 0.5 mag/arcsec^2 and the outermost isophote is 5 mag fainter than the sky surface brightness. North is situated in the top direction and east is to the left. The dimension of the isophotal maps is 40 arcseconds in one dimension.



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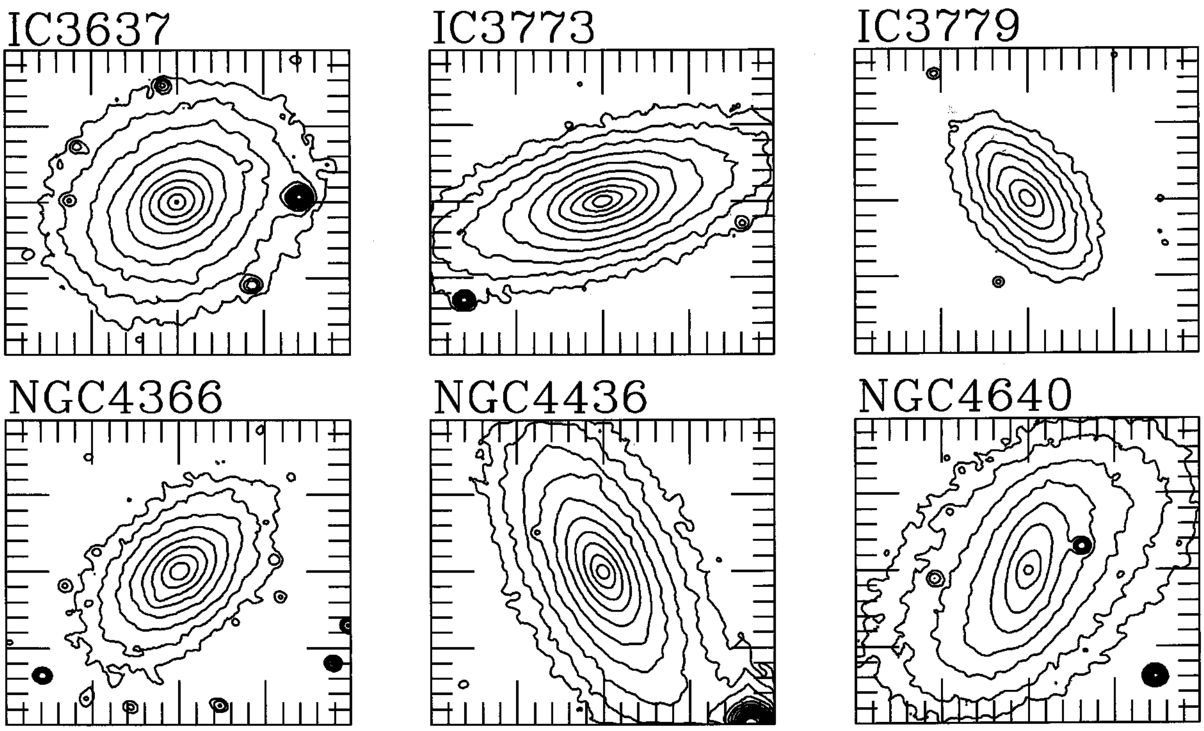


Fig. 1.—continued.

larger than 0.2 mag/arcsec^2, then those galaxies were fitted with two components (Sérsic + exponential) on the assumption that they possessed bulge and disk components. The shape parameter n (often called a Sérsic index) for the best-fitted profile was determined using a χ^2 minimizing technique by varying n from 0.5 to 5 with Δn=0.5.

For the disk luminosity profile, we used a form of exponential function as introduced by Freeman (1970):

$$\mu(r) = \mu_0 - 1.0857r/r_0,$$

where μ_0 is the central surface brightness and r_0 the scale length of the disk. Since we did not obtain the zero point of the photometry, the effective surface brightness μe and disk central surface brightness μ_0 can not be directly compared with other values.

Fig. 3 shows surface brightness profiles of galaxies that are classified as dE galaxies (Sandage & Binggeli 1984; Binggeli & Cameron 1991) with the resulting functions. As shown in Fig. 3, two galaxies (IC 3443, IC 3501) have bulge and disk components. This means that the success rate of visual inspection of galaxy morphology is 85.7% for dE galaxies if we assume that profile decomposition provides a true morphology of galaxies. Fig. 4 shows that the outcome is not as promising for dS0 galaxies: 11 of the 14 dS0 galaxies were found to have a single component. The success rate is therefore only 21.4% for dS0 galaxies. 8 of 11 galaxies (IC 0781, IC 3167, IC 3303, IC 3331, IC 3413, IC3435, IC 3518, NGC 4640) have nuclei that are confused with bulges. IC 3459 has a bar-like feature that makes the shallow gradient in the luminosity profile in the central region ($r < 12''$). Due to this shallow gradient, the surface brightness of IC 3459 was well fitted by a single Sérsic profile with a small shape parameter n=0.5. The morphology of IC 3612 seems to be confused as dS0 galaxy by the rectangular shape of the outer isophotes and IC 3637 has a peculiar morphology.

The Sérsic index of single-component galaxies is 1.61 $\pm$ 0.84. This value is consistent with the Sérsic index of dE galaxies (n$\approx$1-2) as determined by Barazza et al. (2003) and Graham & Guzmán (2003). It is interesting to note that the Sérsic index of dS0 bulges is very close to n=1. That is, the Sérsic index of a dS0 bulge is the same as that of dS0 disks because the exponential function is the same as the Sérsic profile with n=1. We summarized the derived Sérsic index and scale parameter of single-component galaxies in Table 2, and corresponding values for two-component galaxies in Table 3.

The average effective radius of two-component galaxies was 0.41 $\pm$ 0.16 kpc, but the average effective radius of one-component galaxies with a Sérsic index equal to 1 was 1.49$\pm$0.38 kpc. This large difference is expected because the effective radius of two-component galaxies is defined by the radius that has half of the bulge luminosity, while the effective radius of one-component galaxies is defined by the radius that encloses half the

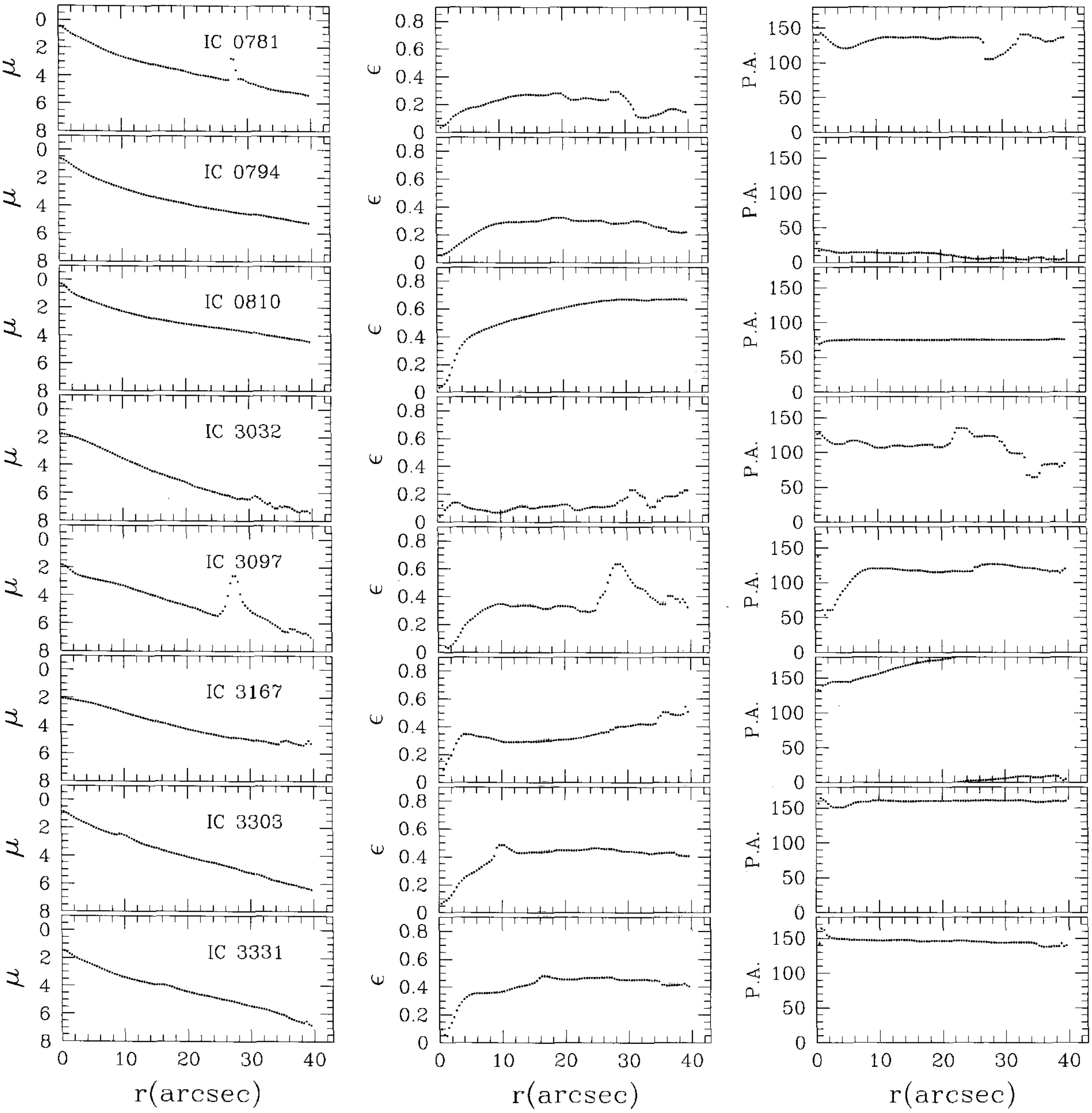


Fig. 2.—Surface brightness, ellipticity and position angle profiles of 28 dE/dS0 galaxies. Surface brightness is relative to sky surface brightness.

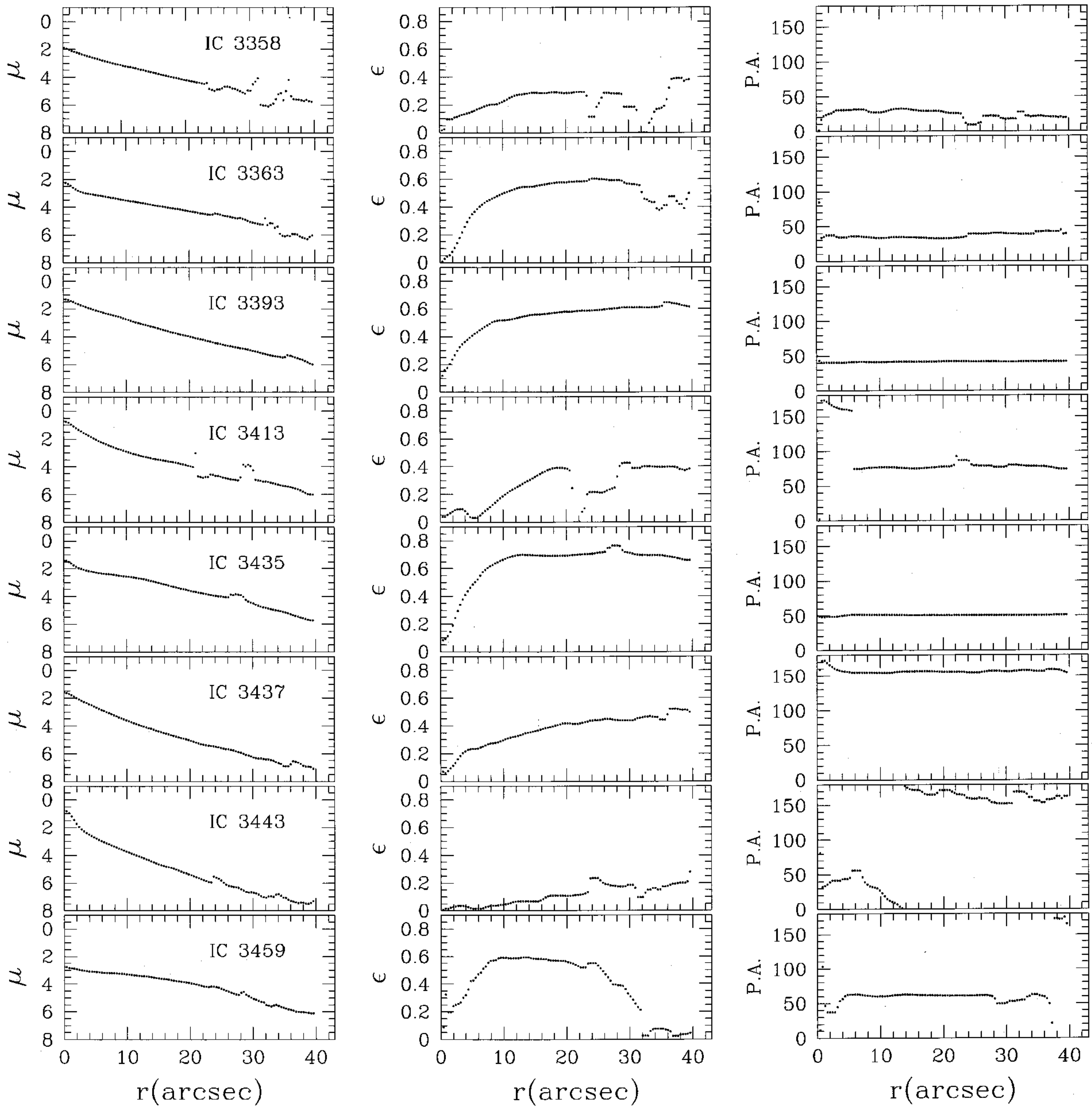
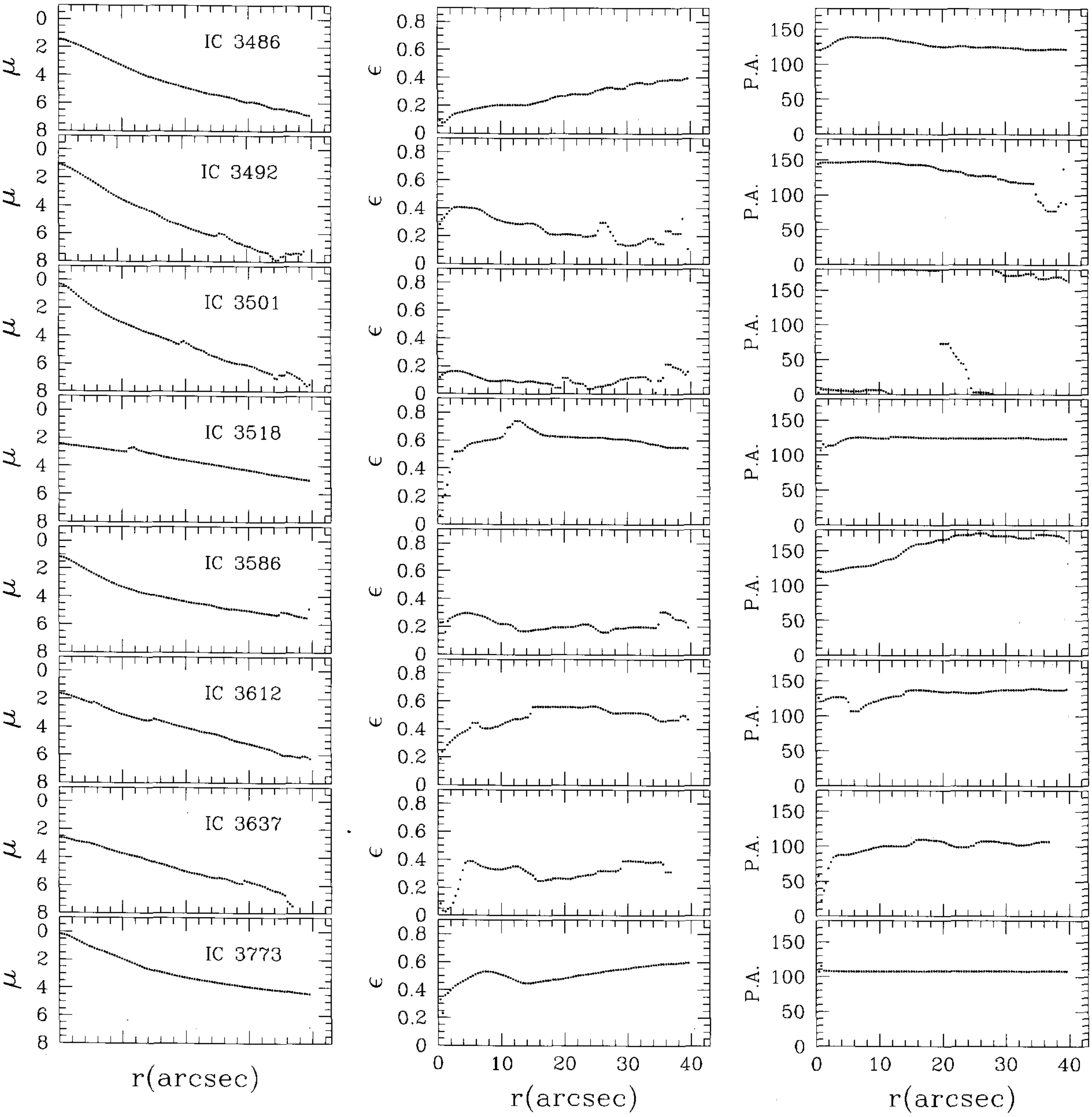


Fig. 2.—continued.



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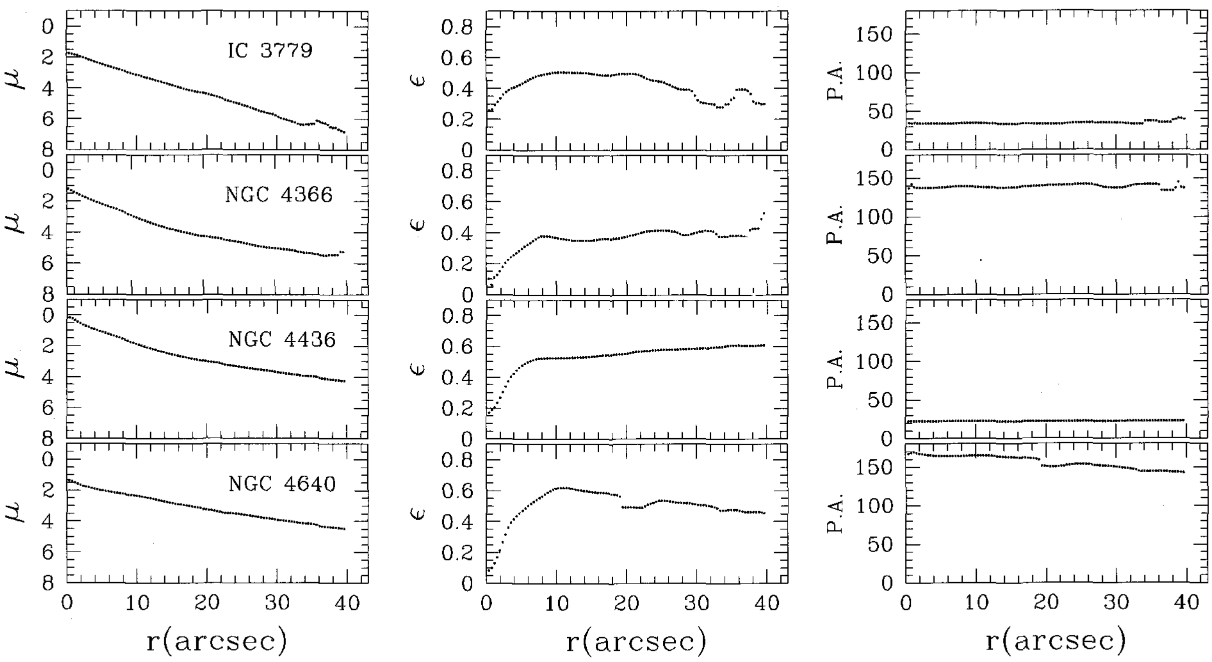

Fig. 2.—continued.

luminosity of the whole galaxy. The average scale length of two-component galaxies (r_0) was 1.19±0.62 kpc.

The fraction of nucleated dwarf elliptical ('dE, N') galaxies in the present sample is 0.67, revealing that 10 of 15 dwarf elliptical galaxies have nuclei. Among these galaxies, two (IC 3097, IC 3363) have profiles showing a central excess of light after subtraction of the Sérsic profile from the observed profiles. We assumed that this excess light is attributable to the bright nuclei.

We derived B/D ratios for 5 dS0 galaxies using the following relation (Kodaira et al. 1986):

$$\log(B/D) = -0.4(\mu_e - \mu_0) + 2\log(r_e/r_0) + 0.557$$

where μ_0 and μ_e are the effective brightness of the bulge and the central surface brightness of the disk, respectively, and r_e and r_0 are the bulge effective radius and disk scale length, respectively. Although absolute calibration of photometry was not made in the present study, this equation is valid since μ_0 and μ_e were derived from the luminosity distribution relative to the sky brightness. We list log(B/D), B/D, μ_0 and μ_e values for dS0 galaxies in Table 4.

IV. DISCUSSION

(a) Accuracy of Visual Classification of dE and dS0

There is a large fraction of sample galaxies whose visually classified morphologies differ from those expected from profile decomposition. Among 14 galaxies classified as dE galaxies, 12 galaxies (85.7%) were found to have a single component and luminosity profiles that were adequately described by the Sérsic function with a shape parameter n=1.61 ± 0.84. In the case of dS0 galaxies, only 3 of the 14 galaxies (21.4%) were found to have two components. Thus, there is substantial confusion regarding morphology determined by the visual inspection of photographic plates (Sandage & Binggeli 1984 ; Binggeli & Cameron 1991). This confusion is greater with dS0 galaxies since more than 70% of dS0 galaxies were found to be dE galaxies on the basis of profile decomposition. The present statistics, based on a sub-sample of dE and dS0 galaxies in the Virgo Cluster, does not represent the accuracy of the visual classification of galaxies in the Virgo Cluster. However, the uncertainty in the classification of dS0 galaxies in the Virgo Cluster is thought to be not much different from the present statistics since the present sample includes more than half of the dS0 galaxies in the Virgo Cluster.

The confusion between dE and dS0 galaxies is not lessened even if we use color images in the morphology classification because their colors are very similar (Ann et al. 2006). Thus, if a morphological distinction between dE and dS0 galaxies is crucial to a understanding of their origin and evolutionary history, it is much better to use morphology derived from profile decomposition.

(b) Origin of dS0 Galaxies

Various mechanisms have been proposed for the origin of dE galaxies, among which the harassment sce-

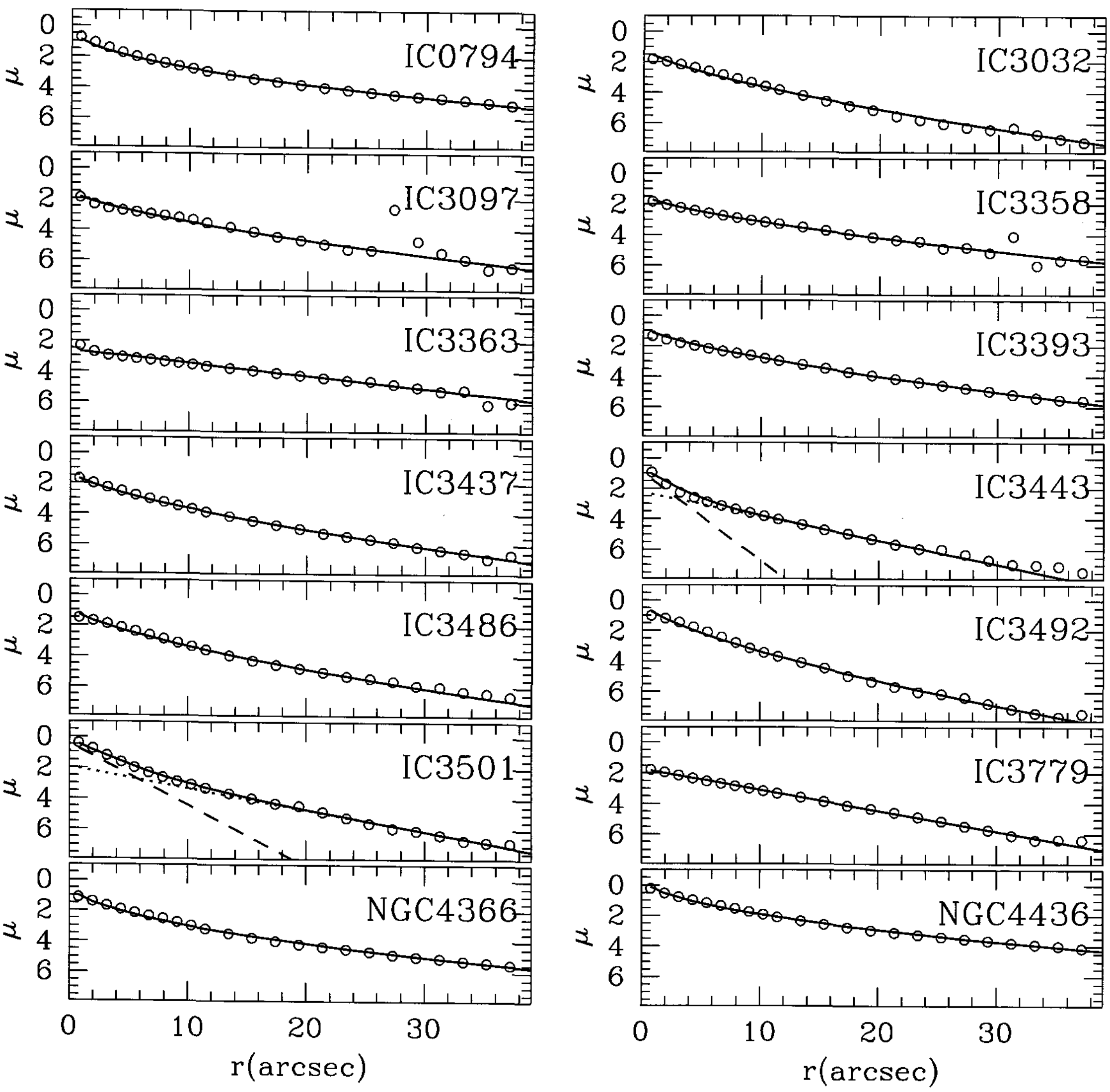

Fig. 3.—Surface brightness profiles of dE samples. In the case of two-component galaxies, the bulge is fitted to a Sérsic profile and the disk is fitted to an exponential profile. The dashed-line represents the bulge component and the dotted-line represents the disk component. Combined profiles are represented by solid lines.

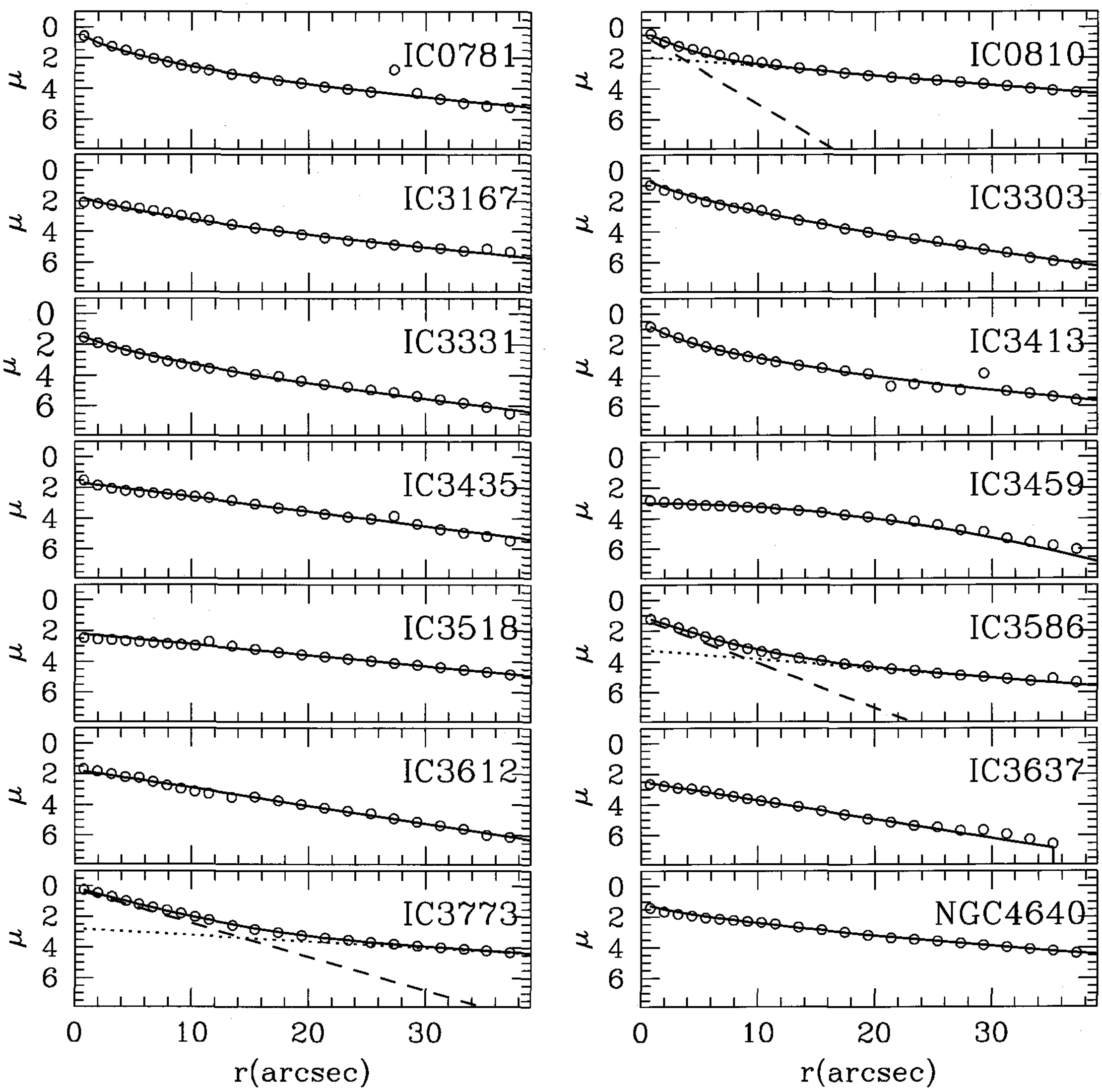

Fig. 4.—Surface brightness profiles of dS0 samples. In the case of two-component galaxies, the bulge is fitted to a Sérsic profile and the disk is fitted to an exponential profile. The dashed-line represents the bulge component and the dotted-line represents the disk component. Combined profiles are represented by solid lines.

TABLE 2.
PHOTOMETRIC PARAMETERS OF ONE-COMPONENT FITTED GALAXIES

OBJECTS	TYPE	SÉRSIC INDEX	$r_e(arcsec)$	$r_e(kpc)$
IC 0781	*dS0*	2.0	21.38	1.66
IC 0794	*dE*	2.0	24.56	1.91
IC 3032	*E?*	1.5	12.27	0.95
IC 3097	*dE*	1.5	17.54	1.36
IC 3167	*dSB0*	1.5	22.53	1.75
IC 3303	*dS0*	1.5	13.29	1.03
IC 3331	*dS0*	1.5	16.11	1.25
IC 3358	*dE*	1.5	21.12	1.64
IC 3363	*dE*	1.0	22.30	1.73
IC 3393	*dE*	1.5	16.79	1.30
IC 3413	*dS0*	2.0	19.56	1.52
IC 3435	*dS0*	1.0	18.99	1.47
IC 3437	*dE*	1.5	13.77	1.07
IC 3459	*dSB0*	0.5	17.08	1.32
IC 3486	*dE*	1.5	12.29	0.95
IC 3492	*E?*	1.5	8.41	0.65
IC 3518	*dS0*	1.0	25.62	1.99
IC 3612	*dS0*	1.0	15.60	1.21
IC 3637	*dS0*	5.0	14.81	1.15
IC 3779	*dE*	1.0	13.50	1.05
NGC 4366	*dE*	2.0	21.00	1.63
NGC 4436	*dE*	2.0	26.18	2.03
NGC 4640	*dS0*	1.5	30.60	2.37

TABLE 3.
PHOTOMETRIC PARAMETERS OF TWO-COMPONENT FITTED GALAXIES

OBJECTS	TYPE	SÉRSIC INDEX	$r_e(arcsec)$	$r_e(kpc)$	$r_0(arcsec)$	$r_0(kpc)$
IC 0810	*dS0*	1.0	4.00	0.31	17.6	1.36
IC 3443	*dE*	1.0	3.14	0.24	6.92	0.54
IC 3501	*dE*	1.0	4.58	0.36	7.84	0.61
IC 3586	*dS0*	1.0	6.27	0.49	17.9	1.39
IC 3773	*dS0*	1.0	8.22	0.64	26.3	2.04

TABLE 4.
EFFECTIVE BRIGHTNESS, DISK CENTRAL BRIGHTNESS, LOG(B/D) AND B/D VALUES FOR dS0 GALAXIES

OBJECTS	μ_e	μ_0	$\log(B/D)$	B/D
IC 0810	2.28	1.91	-0.88	0.13
IC 3443	2.76	2.26	-0.33	0.47
IC 3501	2.25	1.95	-0.03	0.93
IC 3586	3.02	3.23	-0.27	0.54
IC 3773	2.02	2.78	-0.15	0.71

nario seems to be applicable to dS0 galaxies (Aguerri et al. 2005). On the basis of deep CCD photometry of dE and dS0 galaxies in the Coma Cluster, Aguerri et al. (2005) showed that there is a similarity between the scale length of the bulges of dS0 galaxies and that of late-type spiral galaxies, suggesting that dS0 galaxies are harassed late-type spirals.

In the harassment scenario, the disk scale length, the bulge to disk ratio (B/D), and the effective radius of bulges may resemble those of late-type spiral galaxies if the disks of late-type spirals are not affected substantially during the harassment process. If this is the case, comparison of disk scale length and B/D ratios of dS0s with those of late-type spirals can provide an observational test for the origin of dS0 galaxies.

The mean disk scale length of 5 two-component galaxies is 1.19 ± 0.62 kpc. While it is somewhat smaller than that of late-type spiral galaxies in the Virgo Cluster (1.68 ± 0.69 kpc) (Kodaira et al. 1986), it is consistent with values of 0.4 - 2.4 kpc for faint late-type galaxies (mainly Magellanic irregulars) (Smoker et al. 1999). Thus, Virgo dS0 galaxies identified by

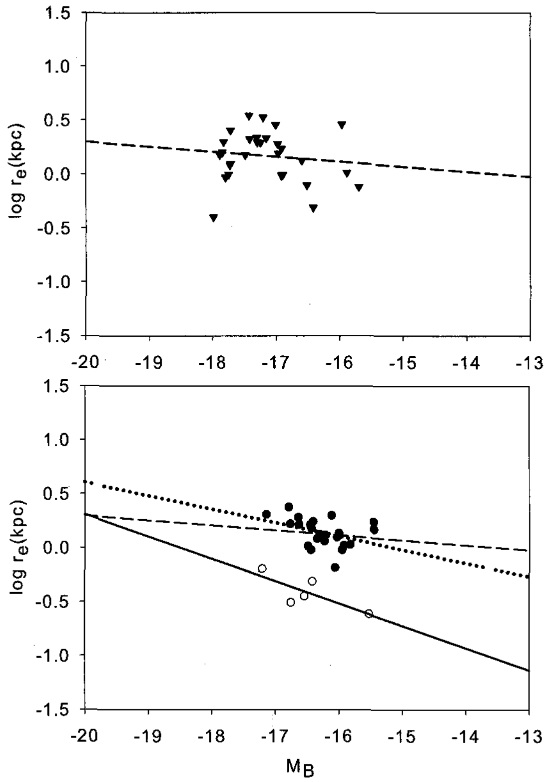

Fig. 5.—Effective radius as a function of M_B. The dE and dS0 galaxies identified by profile decomposition in the present study are represented by filled circles and open circles, respectively (bottom panel). The dS0 galaxies in the Coma Cluster (Aguerri et al. 2005) are indicated by filled triangles (top panel). The solid line and dotted line are the least-squares solutions of dS0 galaxies and dE galaxies in this study, respectively. The long dashed line is the least-squares solution of dS0 galaxies in Aguerri et al. (2005).

profile decomposition cannot have evolved from bright late-type spiral galaxies that survive at the present time. But they can be harassed Magellanic-type galaxies. Whereas the disk scale length of dS0 galaxies is somewhat smaller than that of late-type spiral galaxies in the Virgo Cluster, their B/D ratios are similar: 0.56 $\pm$ 0.30 for dS0 galaxies and 0.67 $\pm$ 0.86 for late-type spirals. Thus, dS0 galaxies cannot be distinguished from late-type spirals in the Virgo Cluster on the basis of a B/D ratio.

As shown by Aguerri et al. (2005, see their Fig. 14), the relation between effective radius and absolute magnitude of dS0 galaxies in the Coma Cluster is similar to that for late-type spirals, though it differs somewhat for dEs and dS0s. As shown in Fig. 5, we found a similar relation for our dS0 galaxies but with a systematically smaller effective radius for a given M_B. This difference in effective radius and slightly brighter luminosity for the Coma dS0s might be due to the different environments. The dS0 galaxies in the Coma Cluster evolved from more massive late-type spirals than those of the Virgo Cluster because galaxies in a more dense environment (Coma Cluster) suffer greater harassment than those in a less dense environment (Virgo Cluster). Therefore, even if harassment is the main mechanism accounting for the origin of dS0 galaxies in both clusters, the progenitor galaxy may be different.

V. CONCLUSIONS

We obtained the structural parameters of dwarf galaxies in the Virgo Cluster by elliptical fitting. The galaxies were classified into two types according to the results of profile decomposition. There is a large difference between morphology determined by the visual inspection of photographic plates (Sandage & Binggeli 1984; Binggeli & Cameron 1991) and that expected from profile decomposition. $\sim$ 14% of dE galaxies were found to be dS0 galaxies and $\sim$ 80% of dS0 galaxies were found to be dE galaxies.

The B/D ratio of dS0 galaxies in the Virgo Cluster is similar to that of late-type spiral galaxies in the Virgo Cluster, but the disk scale lengths of dS0 galaxies in the Virgo Cluster are slightly smaller than those of late-type spiral galaxies in the Virgo Cluster. The effective radius of bulges of dS0 is also systematically smaller than that of Coma Cluster dS0s or late-type spiral galaxies. Thus, there seems to be no evidence supporting the harassment scenario for the origin of dS0 galaxies if we assume that the present population of late-type spirals is a typical progenitor of dS0s. However, it is possible that dS0s in the Virgo Cluster are harassed late-type galaxies that are similar to Magellanic-type galaxies.

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