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REPRESENTATION OF THE CONVEX RADIAL PROFILES OF GALACTIC DISKS BY MEANS OF SERSIC FORMULA: GALAXIES M 31, M 33, LMC, SMC AND M 83

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Abstract

Iterative one-dimensional decomposition technique for radial galactic profiles in the spirit of Kormendy (1977) is presented and applied on the profiles of nearby galaxies. Both the bulge and disk components are modelled by the Sersic (1968) formula. The free parameters of the model – central brightness, scale length and optimal exponential number N=1/n are derived by internal iterative procedure. The total magnitudes of the bulge and the disk components are derived by numerical integration. The method is applied for decomposition of 22 published profiles of nearby galaxies and for estimation of the errors of their parameters. A hint of correlation is found between the disk exponential number or the disk central brightness, on the one hand, and the total luminosity of the disk, on the other hand. The disks of the big galaxies Milky Way and M 31 show convex shape with some depressed central brightness, while the disks of the dwarf galaxies SMC and LMC show almost exponential shapes with peak of the central brightness. The galaxy M 33 is an intermediate case.

1. Introduction

Usually, the structures of the galaxies are investigated by decomposition of their radial profiles into bulge and disk components. It is deemed that there is no strong physical basis for such a procedure, but this approach is an universal way for describing and comparison of galaxies by means of a small number of well defined parameters. Generally, the objective here is to represent quantitatively the Hubble sequence (de Vaucouleurs 1959a, Freeman 1970, Kormendy 1977, Bagget et al.1998, Simard et al. 2002, Balcells et al. 2003).

On the base of ≈30 profiles of nearby galaxies, Freeman (1970) introduced in use the exponential shape of radial disk profiles as a first approximation, known till now as "Freeman Law". It is considered that the exponential shape of the bright part of the disks may be understood from theoretical point of view (Freeman 1970, Mo et al, 1998, Reshetnikov 2000). However, it is known that the disk scale lengths of exponential disks, derived by different authors, show discrepancies by factor of two (Knapen and van der Kruit 1991), and that the disk scale length does not correlate with the Hubble type (van der Kruit, 2002). Moreover, the deep profiles of galactic disks have convex shapes and Freeman Law is in fact a very rough approximation. Generally, the truncation of the surface brightness of the outer part of the disks may be explained by decreasing the star forming rate, due to insufficient matter concentration or/and lack of reasons for disk instabilities (Bottema 1993, Geressen et al. 1997, Bizyaev and Zasov 2002).

The models of truncated shapes of disk profiles were introduced by van der Kruit and Searle (1981ab) and were applied widely by Barteldrees and Dettmar (1994) by means of a special parameter - cut-off radius. However, when the deepness of the observation increases, the cut-off radius increases, too. For this reason, Pohlen et al. (2000) introduced a presentation of the disk shape with two exponents - inner, corresponding to the Freeman disk, and outer, more steep. The deep observations of 3 face-on galaxies, up to ~29 mag/arcsec^2 in R band of Pohlen et al. (2002) supported this "double exponent model".

Another possibility to describe disk shapes is to use a smooth model of the convex shape of the disk. Fig.1a shows the deep profile of the edge-on galaxy ESO 189-G12 and the respective edge-on view of its face-on exponential model, reproduced from the paper of Barteldrees and Dettmar (1994). The inconsistency between the exponential model in the periphery of the profile is very large - > 2.5 mag or > 10 times in intensity. A parabolic fit of the general shape of the profile is also shown in Fig.1a and it shows that the outer part of the profile is close to parabola. Fig.1b shows the major axis profiles of the galaxies M 31 and M 33 from the papers of de Vaucouleurs (1958, 1959a). The outer parts of these profiles are well fitted by parabolas, too.

After visual analysis of ~ 150 deep major axis profiles of edge-on galaxies, given in the papers of van der Kruit and Searle (1981ab), Karachentsev et al (1992), Barteldrees and Dettmar (1994), Pohlen et al. (2000), we found that 80% of the profiles have parabola-like shapes (Stanchev et al. 2003). In the other 20% of the cases, the profiles seem to be approximately exponential, i.e. they are particular cases of parabola.

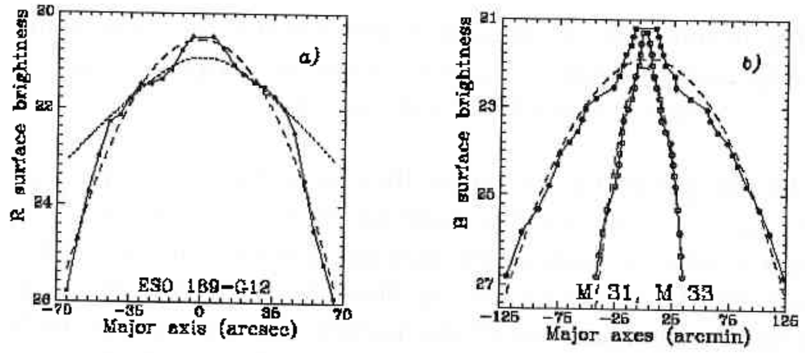

Fig. 1 a) Deep major axes profile of the edge-on galaxy ESO 189-G12 (solid line), the edge-on view of the respective exponential model of the bright part of the disk (dotted line) (Barteldress & Dettmar 1994) and the general shape of the profile, modelled by parabola (dashed line); b) - deep major-axis profiles of galaxies M 31 and M 33 (de Vaucouleurs 1958; 1959b) (solid lines), and their general shapes, modelled by parabolas (dashed lines).

Let us assume that in the magnitude scale, the edge-on disk profile is parabola. Therefore, in the intensity scale, the profile must be Gaussian. However, notice, if the edge-one major-axis disk profile is just Gaussian, than the respective face-one radial disk profile must be again just Gaussian, and the radial disk profiles in magnitudes must be the respective parabola. Obviously, the Gaussian model of the radial face-on profile, which allows simple presentation of the integral of the total luminosity, is very attractive. However, the nature of galactic disks seems more complicated and we introduced flexible modelling of the convex disk profiles, based on the formula of Sersic (1968) (see Part 2). The possible presence of galactic bar is not accounted for in this paper.

The goals of the presented work are: (i) to introduce a one-dimensional decomposition fitting method in the spirit of Kormendy (1977), but including derivation of optimal Sersic exponential degrees both for the bulge and the disk, (ii) to apply this method on numerous published profiles of nearby galaxies, including deriving the fundamental shape and magnitude parameters and (iii) to give an empiric estimations for the standard errors of the derived amplitude parameters.

2. The models and the method of decomposition

It is well known that the apparent profiles of an elliptical galaxy or the bulge of a spiral galaxy may be described by the formula of Sersic

(1968). The formula may be presented in two ways - in linear scale, i.e. in intensities I_R, and in magnitude scale, i.e. in surface brightness, μ_R:

(1) $I_R = I_0 \exp(-(R/H)^N)$ or $\mu_R = \mu_0 + C R^N$

The free parameters in (1) are the central intensity I_0 (or the central brightness $\mu_0 = -2.5 \log I_0$), the scale length $H = (1.0857/C)^{1/N}$) and the exponential number N, which describes the curvature of the profile. These parameters may be derived from the observations by the MLS, applying decomposition techniques. Notice that usually, the exponential number N is noted as 1/n, but following Lauberts and Valentijn (1989) we prefer notation, which are simpler in interpretation of the dependences and correlations with the participation of log N.

The Sersic formula (1) is able to present various shapes of profiles. The case N=1/4, which is known as "1/4 Law" of de Vaucouleurs (1948), describes the profiles of giant ellipticals. N≈1/2 corresponds to the profiles of big ellipticals or bulges of early type spirals. N≈1 corresponds to some ellipticals and bulges of late type galaxies. N≈2 corresponds to some dwarf ellipticals and to some bulges of the very late type galaxies. Generally, the shape of the bulge changes smoothly with Hubble type of the galaxy (Andredakis et al. 1995, Graham 2001). Notice also that N=1 represents just Freeman's (1970) exponential law and N=2 represents just the Gaussian function.

The model (1) may be completed by higher order terms and named "second order Sersic formula" (2) and "third order Sersic formula" (3):

(2) $I_R = I_0 \exp(-(R/H_1)^N-(R/H_2)^{2N})$ or
$\mu_R = \mu_0 + C_1R^N + C_2R^{2N}$

and

(3) $I_R = I_0 \exp(-(R/H_1)^N-(R/H_2)^{2N}-(R/H_3)^{3N})$ or
$\mu_R = \mu_0 + C_1R^N + C_2R^{2N} + C_3R^{3N}$.

Generalizations (2) and (3) of the Sersic formula include two or three scale length parameters The connections between the parameters C_k and H_k have the same form as in case (1).

Different shapes of radial profiles of galaxies are presented in Fig.2. The solid curves that represent different radial shapes of bulges and disks are modelled by formula (1). The dashed curves that represent disks with central depression are modelled by formula (2).

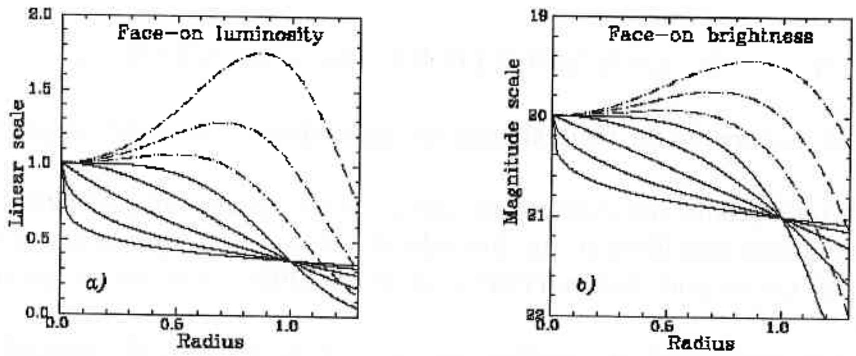

Fig. 2 Examples of models of bulge or disk radial profiles. The solid lines represent 5 shapes of radial profiles of "normal" bulges or disks, modelled by the Sersic formula (1) for N = ? , ? ., 1, 2 and 4, with I_0 = H = 1. The dashed lines represent 3 shapes of convex disk profiles with central depression, modelled by the second order Sersic formula (2), with different parameters. The profiles are presented in arbitrary intensity (a) and magnitude (b) scales.

The third order Sersic formula (3) is very useful, too. Our experience shows that it describes very well the general radial profile of galaxy with bulge and disk components. The value of N is usually between 0.5 and 1. Moreover, the inflex point between the bulge and disk, where the shape of the profile changes from concave to convex type, is usually the natural dividing point between the bulge and disk parts of the profile, necessary for the decomposition. We note that the same point, derived by means of the usual 3-rd order polynomial, corresponding to (3) with N=1, lies usually rather far from the bulge. Formula (3) may describe also various shapes of ring-like disks. For example, if C_2=0 complies with the formula of Kormendy (1977) for disk with exponential outer part and sharp inner truncation.

Having the estimation of the free parameters in (1), the total intensity I_T of the object (bulge or the disk) may be derived by integration along the polar angle and the radius:

∞

$$\text{(4)} \qquad I_T = b/a\, I_0\, 2\pi\, H \int_0 \exp(-(R/H)^N)dR$$

Here *b/a* is the apparent axial ratio of the object. The total intensity may be written using the gamma function Γ (van der Kruit and Searle 1981ab; Barteldrees and Dettmar 1994):

$$\text{(5)} \qquad I_T = b/a\, I_0\, 2\pi\, H/N\, \Gamma(1/N) = b/a\, I_0\, 2\pi\, H\, \Gamma(1/N+1).$$

In practice, in the general case, we apply direct numerical integration of (4).

More details and connections between the system of parameters of de Vaucouleurs and these in the formula of Sersic (1) are given f.e. in the papers of Ciotti and Bertin (1999), Graham (2001) and the references therein.

For analysis of 1D profiles, we created an iterative decomposition procedure like that described by Kormendy (1977), which fits both the bulge and disk profiles from formula (1). Applying formulae (2) or (3) in some special cases is also possible. The number of main iterations of the disk and bulge fitting is usually < 10. In each case of fitting, the optimal exponential numbers are derived by iterative gradient method. The number of these "inner" iterations is usually < 50. As a special case of the procedure, the exponential numbers of the bulge and/or disk models may be fixed in advance by the user. In the applications presented here, we discuss only the models with optimal exponential numbers. The total computing time for one profile with 100–200 points, for computer of the class of Pentium 1 is up to 2 seconds.

In the case of smooth profile without prominent bar the results of the decomposition do not depend strongly on the choice of the dividing point. In these cases, the inflex point of the 3-rd order model (3) may be used automatically. In more complicated or "noised" cases, we execute the procedure sometimes, searching for the dividing point that gives the minimum RMS of the restored profile. Where needed, the decomposition procedure may remove automatically a few "noised" points close to the dividing point.

The results of the process in the presented work are the parameters μ_0, H and N, according to formula (1), both for the bulge and the disk, as well as the total magnitudes of the bulge, disk and galaxy by formula (4). The estimation of other parameters is derived, too (see Part 4). We note that the values of N and H do not depend on the Milky Way extinction. The other parameters are estimated in two cases - with and without extinction correction of the profile.

3. The profiles and their decompositions

The nearby galaxies M 31, M 33, LMC and SMC play fundamental role in the knowledge about the Universe and the presented decomposition technique is applied first on their profiles. Additionally, a profile of the galaxy M 83 and a model of the Milky Way are included for comparison.

The basic parameters of the galaxies, collected from NED and LEDA, are given on Table 1, as follows: the galaxy name, the Hubble type, the distance modulus DM, the Milky Way foreground extinction in B-band A_B, the total apparent B-magnitude B_T, the total colour index $(B-V)_T$, the apparent blue diameter at surface brightness level 25 mag/arcsec^2 d_{25}, the apparent axial ratio *a/b,* the total B-magnitude, corrected for foreground and internal extinction $B_{0,C}$, the respective colour index $(B-V)_{0,C}$, and the respective corrected apparent diameter $d_{0,C}$.

Table 1. Basic data about the galaxies adopted from data bases NED and LEDA

Galaxy	Type	DM	A_B	B_T	$(B-V)_T$	d	*a/b*	$B_{0,C}$	$(B-V)_{0,C}$	$d_{0,C}$
M 31	Sb	24.43	0.46	4.36	0.92	186.2'	3.02	3.24	0.73	195.0'
M 33	Sc	25.06	0.18	6.29	0.56	66.0'	1.66	5.73	0.47	67.6'
LMC	SBm	19.66	0.26	0.90	0.51	647.7'	1.17	0.51	0.43	676.1'
SMC	SBm	18.41	0.20	2.75	0.45	371.5'	2.21	2,21	0.36	380.2'
M 83	SBc	29.57	0.29	8.53	0.66	14.1'	1.10	8.17	0.58	14.8'

Because of the large apparent sizes of the galaxies M31 and M 33, accurate CCD observations have not been made yet. For this reason, we have used available data: (i) the equivalent (elliptically averaged) profiles and the photometry sections along the axes and the direction Ease-West in B band, published by de Vaucouleurs (1958, 1959b), (ii) the equivalent profiles of M 31 in the U, B, V and R_C bands of Walterbos and Kennicutt (1988), and (iii) the photometry sections along the major of M 31 and M33 axis in Gunn r-band of Kent (1987). The data for the central part of M 33 of de Vaucouleurs (1959b) are completed by the data of Kent (1987) in the Gunn g-band. We have used the rough relation $B \approx g + 0.6$, derived from the data about the center of M31 of de Vaucouleurs (1958) and Kent (1987). The profiles of M 83 and the model of the Milky Way are used from the paper of Freeman (1970). We account for the foreground extinction through the relations A_U=1.26 A_B, A_V=0.77A_B, A_R=0.62A_B and A_I=0.45A_B (Schlegel et al., 1998).

The graphs of the decompositions of the profiles of M 31 and M 33 into bulge and disk components are shown in Fig.3-6. The convex shapes of the disks and their good representation by the Sersic formula (1) can be seen well. The convex shape is not well enough prominent only in the case of M 33, in Fig.5b, because the used profile of Kent (1987) is obviously not deep enough.

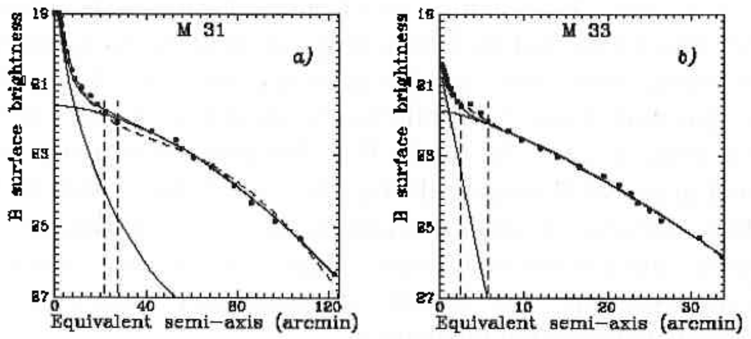

Fig. 3 Decomposition of the equivalent profiles of the galaxies M 31 (a) and M 33 (b) by data of de Vaucouleurs (1958, 1959b) in B band. The solid curves represent the shapes of the bulge, disk and restored profile. The dashed curves represent the fit of the whole profile with the polynomial (3). The vertical lines represent the last used point of the bulge and the first used point of the disk; the points between the vertical lines are not used in the decomposition.

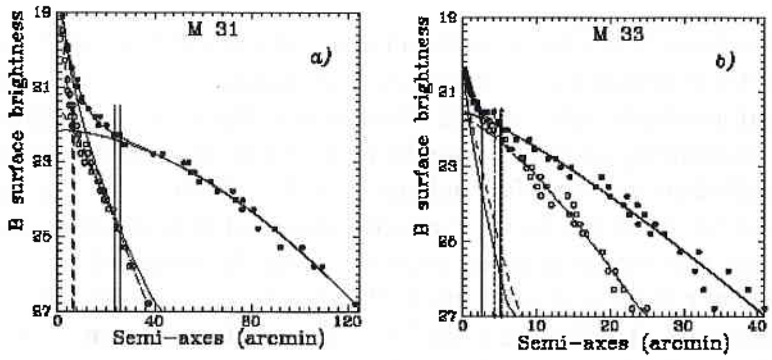

Fig. 4 Decomposition of the major axis profiles (dots, solid lines) and minor axis profile (circles, dashed lines) of the galaxies M 31 and M 33 by data of de Vaucouleurs (1958, 1959b) in B band. See also the caption of Fig.3.

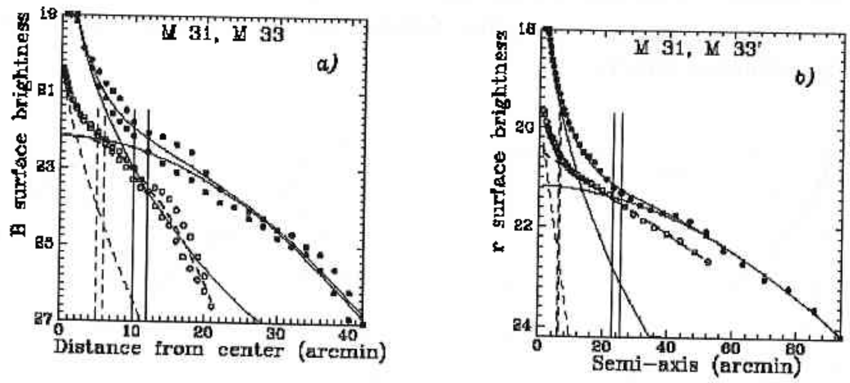

Fig. 5 a) Decomposition of the East-West sections of M 31 (dots, solid lines) and M 33 (circles, dashed lines) by data of de Vaucouleurs (1958, 1959b); b) Decomposition of the major (dots, solid lines) and minor (circles, dashed lines) axes profiles of the galaxy M 31 by data of Kent (1987) in r band. For better comparison, the abscissa data of M 33 is multiplied by factor of 3. See also the caption of Fig.3.

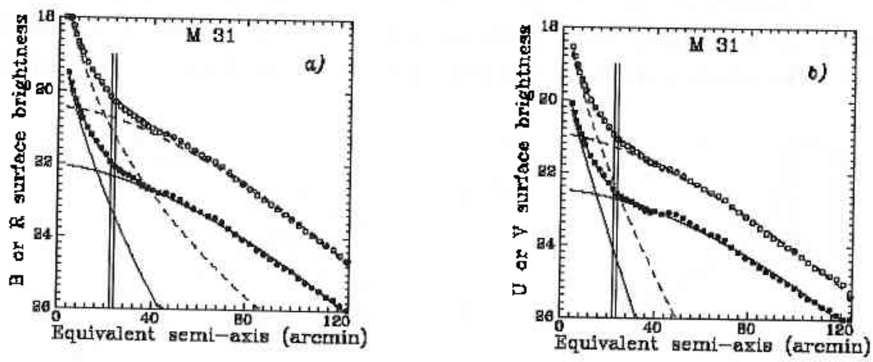

Fig. 6 Decomposition of the equivalent axis profiles of the galaxy M 31 by data of Walterbos and Kennicutt (1988): a) in B band (dots, solid lines) and R band (circles, dashed lines); b) in U band (dots, solid lines) and V band (circles, dashed lines). See also the caption of Fig.3.

The profiles of the LMC and SMC are presented in Fig.7. The disk parts of these galaxies are almost exponential, even LMC shows concave disk profile. We note that the LMC is the galaxy with the largest apparent size on the sky, which is the most difficult for surface photometry at low brightness levels. In the cases of LMC and SMC, two processings of the data are made – with decomposition into bulge and disk, and without, only by fitting the whole profile by the Sersic formula (1). The results are very close (see Parts 4 and 5).

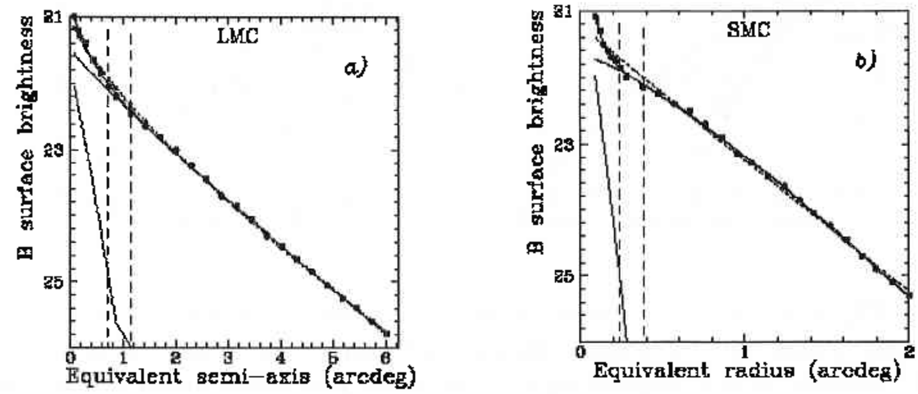

Fig. 7 Decompositions of equivalent profiles of the galaxies LMC (a) and SMC (b) by data of de Vaucouleurs (1960). The dotted lines show the fit of data by the Sersic formula (1) without decomposition.

Profiles of the SB galaxy M 83, as well as a model of the mass density of the Milky Way, published by Freeman (1970) are presented in Fig.8. The convex shape of the disk parts of the profiles is well represented.

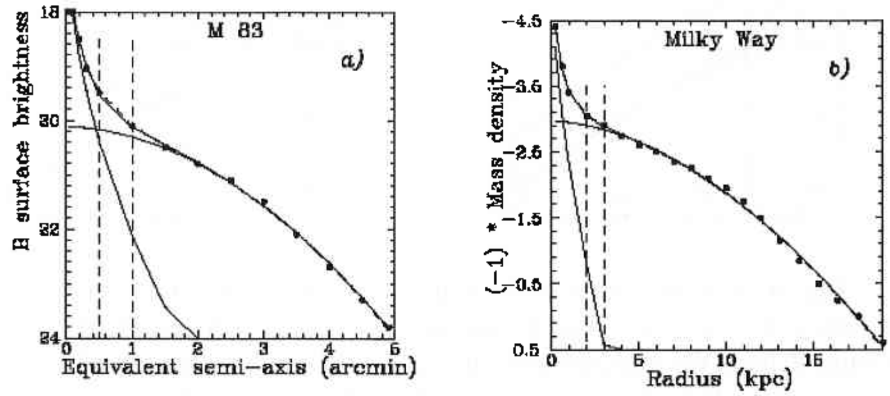

Fig. 8 Decomposition of the profiles of M 83 (a) and of the Milky Way model (b), from the graphs published by Freeman (1970).

The decompositions shown in Figs.3-8 are used to derive the shape, si e and magnitude parameters of the galaxies discussed in Parts 4 and 5.

4. Results about the shape and size parameters

The results from the decompositions are presented on Table 2, as follows. RMS is the standard error of the restored profile, N_b and N_d are the exponential numbers of the bulge and disk, respectively, $\mu_{0,b}$ and $\mu_{0,d}$ are the apparent central brightness of the bulge and disk, H_d is the scale si e of the disk, log H_d/H_b is the logarithm of the ratio of the scale si es of the disk and the bulge, d_{25} is the estimated diameter of the disk profile at 25 mag/arcsec^2, obtained from the intrinsic profile, $d_{25,0}$ is the diameter at the same level, but obtained after preliminary subtraction of the galactic extinction from the profile data and source in the referenced paper.

Table 2. Shape and si e parameters of the bulge and the disk

Galaxy	Band	RMS	N_b	N_d	$\mu_{0,b}$	$\mu_{0,d}$	H_d	log H_d/H_b	D_{25}	$D_{25,0}$	Source
M 31	B	0.11	0.32	1.75	14.72	21.65	52.8'	3.26	185.1	201.4	1
M 31	U	0.07	0.90	1.66	19.31	22.51	59.0'	2.01	194.8	220.5	2
M 31	B	0.05	0.64	1.57	17.95	22.07	54.2'	1.45	203.5	228.2	2
M 31	V	0.05	0.68	1.48	17.15	20.96	48.5'	1.32	235.9	245.9	2
M 31	R	0.04	0.44	1.58	14.98	20.46	52.3'	2.07	258.2	268.9	2
M 31	r	0.05	0.41	1.82	15.12	21.16	53.7'	2.60	214.6	223.6	3
M 33	B	0.06	0.99	1.36	20.55	21.74	12.8'	1.14	57.5	59.8	4
M 33	r	0.02	0.93	1.01	15.80	20.48	8.8'	1.08	71.9	73.7	3
M 31	B	0.12	0.52	1.75	17.13	22.17	53.8'	1.97	185.8	202.5	1a
M 31	B	0.16	0.24	1.30	9.29	21.87	11.5'	4.87	51.9	57.7	1b
M 31	B	0.26	0.40	1.96	14.81	22.21	19.9'	2.51	64.2	69.4	1c
M 33	B	0.23	0.73	1.22	20.26	21.55	10.9'	1.32	56.4	58.8	4a
M 33	B	0.17	0.85	1.35	20.49	21.74	7.6'	0.92	34.6	36.0	4b
M 33	B	0.21	0.72	2.10	20.27	22.15	10.9'	1.09	34.5	35.5	4c
LMC	B	0.02	1.16	0.92	20.84	21.48	81.0'	0.66	576.0	624.0	5
LMC	B	0.07	-	0.78	-	21.02	54.0'	-	576.0	630.0	5d
SMC	B	0.03	1.10	1.25	20.24	21.64	45.0'	0.98	204.0	234.0	5
SMC	B	0.10	-	0.99	-	21.21	31.8'	-	228.0	240.0	5d
M 83	B	0.06	0.50	1.90	16.18	20.12	2,6'	1.90	11.3	11.7	6

Milky Way - 0.61 1.78 - - 9.9 kpc 1.68 - - 6

Sources of data: 1 - de Vaucouleurs (1958); 2 – Walterbos and Kennicutt (1988);

3 - Kent (1987); 4 - de Vaucouleurs (1959b); 5 - de Vaucouleurs (1960); 6- Freeman (1970). The notations 'a','b' and 'c' correspond to the photometry sections along the major axis, minor axis and the direction east-west in the respective works, the notation 'd' corresponds to parameters, derived without decomposition, as a result of fit of the whole profile by means of (1).

Table 2 shows that the standard error (RMS) of the restored equivalent profiles is small, while the photometry sections of M 31 and M 33 are significantly noised. The errors of the derived photometry parameters of galaxies are due mainly to the data incompleteness and/or the errors of the magnitude scale zero point. For this reason, the theoretical standard deviations of the parameters, estimated only based on the application of the MLS, is underestimated, but comparison of the results, obtained from different data sets may give empiric error estimation.

The values of N_b, $\mu_{0,b}$ and log H_d/H_b depend strongly on the completeness of the data about the central part of the galaxy and they show significant differences (see also the discussion of Graham, 2001). The estimations of the disk parameters N_d and $\mu_{0,d}$ depend mainly on the deepness of the profiles. In the cases of the most deep profiles – these along the direction East–West for M 31 and M 33, we derive $N_d \approx 2$, corresponding to the Gaussian function. The disk size parameters – H_d, D_{25}, and $D_{25,0}$ have various estimations, too. In the cases of LMC and SMC, both methods, with decomposition and with general fit only, show approximately exponential disks and relatively high central brightness. In the case of the Milky Way, only the shape parameters N_b, N_d, H_d and log H_d/H_b are derived.

Table 2 contains numerous estimations of shape and size parameters about M 31 and M 33 and gives possibilities for estimation of their mean values and the standard errors. The results are collected in Table 3 where the notations of the parameters and the sources are the same as in Table 2. In the greatest number of cases, the average of two estimations, using equivalent profiles and major axis profiles, is given. For N_b and $\mu_{0,b}$, suggesting that the axis ratio of the bulge is just unit, we include in the estimation also the profiles along the minor axes and the directions East-West, using all data of de Vaucouleurs (1958, 1959b). The mean values from the data of Walterbos and Kennicutt (1988) about M 31 are given for comparison.

Table 3. Mean values and errors of the shape and size parameters of M 31 and M 33

Galaxy	Band	N_b +/-	N_d +/-	$\mu_{0,b}$ +/-	$\mu_{0,d}$ +/-	H_d +/-	log H_d/H_b +/-	D_{25} +/-	$D_{25,0}$ +/-	Source
M 31	B	0.37	1.75	13.99	21.91	53.3	2.62	185.4	202.0	1
		0.12	0.10	3.32	0.37	1%	0.90	0.3%	0.2%	
M 31	UBVR	trend	1.57	trend	trend	53.5	1.71	trend	trend	2
		-	0.07	-	-	8%	0.38	-	-	
M 33	B	0.82	1.29	20.39	21.64	11.8	1.23	57.0	59.4	4
		0.13	0.10	0.15	0.13	11%	0.13	1%	1%	

The estimation of the N_b of a distant galaxy depends strongly on the resolution, the completeness of the data, etc. In the cases of M31 and M33, the most nearby spiral galaxies, these effects are not strongly revealed. The data of Kent (1987) occur also close to the data of de Vaucouleurs (1958)

(Table 2). The error of the estimation of N_b may be considered < 0.15. However, the data of Walterbos and Kennicutt (1988) shows well manifested trend - the value of N_b decreases from U band toward R band from 0.9 to 0.4. Obviously, in comparison with the R band, in the U band, the bulge of M31 seems more truncated, with shape of the equivalent profile near to exponential. Generally, the values of N_b for M31 and M33 on Table 3 (as well as those of M83 and the Milky Way on Table 2) correspond well to the dependence "log n_b – Hubble type" and "log n_b – log (D/B)" of Andredakis et al. (1995) and Graham (2001) (n=1/N and D/B is the disk-to-bulge luminosity ratio). Here, these values are log $(1/N_b)$ = 0.43 +/- 30% for M31 and log $(1/N_b)$= 0.09 +/- 25% for M33. Generally, the relative error of the values of log n_b or log N_b may be considered <30%.

Generally, the value of N_d depends on the inclination of the galaxy - the most convex shapes of the disks are visible in the cases of the edge-on galaxies (see f.e. Pohlen et al 2000). The value of N_d depends also on the deepness of the observation. Here the most convex profiles, with $N_d \approx 2$, are visible in the cases of the miost deep observations - along the EW directions of M 31 and M33 of de Vaucouleurs (1958, 1959b). No significant dependanse of N_d on the photometry band in Walterboss and Kennicutt (1988), but their mean value - N_d =1.57 +/- 0.07 - is lower, then in the data of de Vaucouleurs (1958) - N_d = 1.75 +/- 0.10. Generally, the error in the estimation of log N_d may be considered to be <10%.

The central bulge brightness $\mu_{0,b}$ is very poorly defined, especially in cases of small N_b. Our estimation of $\mu_{0,b}$ for M 31 is very uncertain. In the case of M33, the estimation of $\mu_{0,b}$ seems to be better, within an error of 0.15 mag. The intrinsic values of $\mu_{0,d}$ depend strongly on the inclination angle of the galaxy and/or position angle of the section. Here, for M31 and M33 we obtain estimations with different uncertainties. The used material is not sufficient for good estimation of the error of $\mu_{0,d}$, but we assume the error to be <0.3 mag. The error of log H_d/H_b seems to be <30%. Table 4 shows also that the scale length may be estimated within a standard error <2% and the error of the diameters at low isophote levels is less - ≈1%.

5. Results about the total magnitudes

The estimations of the total magnitudes of the bulges, disks, the sum of bulge plus disk, as well as the D/B ratio, may be derived from the equivalent profiles only. The respective results are presented on Table 4, as follows: m_{lim} is the limiting surface brightness magnitude of the published photometry data, m_b ,m_d and m_T are the total magnitudes of the bulge, disk and the sum of the bulge and disk, estimated by the formula (2), m_{b0}, m_{d0}

and m_{T0} are the same total magnitudes, but estimated upon extraction of the respective foreground extinction, and $\log(D/B)_{T0}$ is the respective disk-to-bulge luminosity ratio. The sources of data: the same as with Table 2.

Table 4. Magnitude parameters derived from the equivalent profiles

Galaxy	Band	m(lim)	m_b	m_d	m_T	m_{b0}	m_{d0}	m_{T0}	$\log(D/B)_{T0}$	Source
M 31	B	26.8	9.83	3.94	3.93	9.37	3.48	3.47	2.36	1
M 31	U	26.2	5.18	4.09	3.75	4.61	3.52	3.18	0.44	2
M 31	B	26.0	5.30	3.84	3.58	4.84	3.38	3.12	0.58	2
M 31	V	24.6	4.16	2.96	2.64	3.81	2.60	2.30	0.48	2
M 31	R	25.4	4.82	2.30	2.20	4.52	2.00	1.90	1.01	2
M 31	r	24.2	6.55	2.95	2.91	6.59	2.65	2.62	1.57	3
M 33	B	25.8	9.82	5.97	5.94	9.64	5.79	5.76	1.54	4
M 33	r	24.7	9.58	5.34	5.32	9.48	5.33	5.30	1.66	3
LMC	B	25.8	4.76	1.19	1.15	4.50	0.93	0.89	1.43	5
SMC	B	25.3	6.54	3.01	2.98	6.34	2.81	2.76	1.42	5
M 83	B	23.8	11.97	7.42	7.41	11.68	7.13	7.12	1.82	6

Table 4 show that the total magnitudes of the bulges of M 31 and M 33, as well as the respective disk-to-bulge ratios are poorly derived. In the case of disks, as well of total magnitudes when the contribution of the bulge is small, the accordance of the results is better. In R-band, the different deepness of the profiles and different photometry systems for M31 make the total magnitudes much different.

The galaxy M31 has large apparent size and its photometry investigations are very difficult. Here, we may compare the total magnitudes and colours from some sources. According the LEDA, the data about M31 are B_T = 4.36 mag, $(U\text{-}B)_T$ = 0.50 and $(B\text{-}V)_T$ = 0.92. Walterbos and Kennicutt (1988), applying the "1/4 law model" for the bulge and exponential model for the disk, derived from their equivalent profiles B_T = 5.21 mag, $(U\text{-}B)_T$ = 0.34 and $(B\text{-}V)_T$=0.74. Using the data of Walterbos and Kennicutt (1988) and decomposing the profiles with optimal polynomial degrees, we obtain B_T =3.58 mag, $(U\text{-}B)_T$ = 0.17 and $(B\text{-}V)_T$ = 0.94. The large differences between total magnitudes and color indexes, derived from the different data and methods underline again the problem with the accurate photometry of M31 and M33. Our results in B and R bands are collected in Table 5, where the notations are the same as in Table 4.

Table 5. Mean values and errors of the magnitude parameters of M31 in B and R bands

Galaxy	Band	m_b +/-	m_d +/-	m_T +/-	m_{T0} +/-	$\log(D/B)_{T0}$ +/-	Source
M31	B	7.65	3.89	3.76	3.30	1.47	1,2
		3.20	0.07	0.25	0.25	1.26	
M31	R,r	5.68	2.62	2.56	2.26	1.29	2,3
		1.22	0.46	0.50	0.51	0.40	

Based on available data about M31 and M33, we consider the error of the estimations of the total magnitudes of the disks or the whole galaxies to be about 0.5 mag.

6. Conclusions

In the presented paper, we present the results about the photometry parameters of nearby galaxies upon decomposition of their profiles into bulge and disk components, accounting for the convex shape of the disk profiles. We should expect that this method does not overestimate the central disk brightness and that it will provide for more real estimation of the total disk brightness. Therefore, we must expect a hint of some "scaling relations" between disk luminosity or size and its shape parameters.

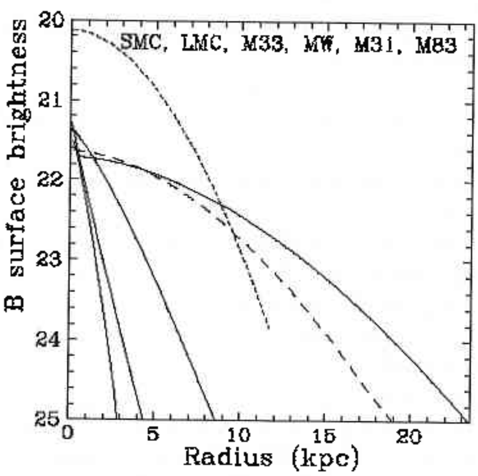

Fig. 9 Comparison of the disk models of the galaxies. The solid curves, from left to right, correspond to the galaxies SMC, LMC, M33 and M31. The model of the Milky Way disk, shifted arbitrarily along the ordinate axis is shown by dashed curve. The disk of the SB galaxy M83, modelled not accounting for the presence of bar, is shown by dotted line.

The true shapes of the disks of the galaxies, included in the presented work, are shown in Fig.9. We see that the disks of the giant galaxies, M31 and the Milky Way, display well manifested convex shapes (or depressed central brightness), while the disks of the dwarf galaxies SMC and LMC display almost exponential shapes with high central brightness. M33 is an expected intermediate case. However, we include M83 to show that the situation is more complicated. The disk of M83, having approximately the size of M33, seems to be very bright and very convex. The reason may be in the fact, that the profile of the SB galaxy, M83 is decomposed not accounting for the presence of bar.

Generally, the central brightness and the exponential number of the disk shape seem to be potential photometric indicators of the galaxy's gigantism. This conclusion should be confirmed or rejected based on rich and uniform number of disk profiles.

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ПРЕДСТАВЯНЕ НА ИЗПЪКНАЛИТЕ РАДИАЛНИ ПРОФИЛИ НА ГАЛАКТИЧНИТЕ ДИСКОВЕ ЧРЕЗ ФОРМУЛАТА НА СЕРСИК: ГАЛАКТИКИТЕ М 31, М 33, LMC, SMC И М 83

Цветан Георгиев

Резюме

Представена е итеративна едномерна декомпозиционна процедура за профили на галактики в духа на Корменди (1977) и е приложена за близки галактики. Компонентите на балджа и диска се моделират чрез формулата на Серсик (1968). Свободните параметри на модела – централната яркост, мащабният размер и оптималният експоненциален показател – се получават чрез итеративна градиентна процедура. Тоталните звездни величини на диска и балджа се получават чрез числено интегриране. Методът е приложен за декомпозиция на 22 публикувани профила на близки галактики и за оценки на грешките на техните параметри. Намерен е намек за корелация между дисковия експоненциален показател и централната яркост на диска от една страна и тоталната светимосг на диска от друга. Дисковете на големите галактики – Млечния път и М31 показват изпъкнали профили с понижена централна яркост, докато дисковете на галактиките джуджета – LMC и SMC имат почти експоненциални профили с пикове на централната яркост. Галактиката М33 е междинен случай.