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PHENOMENOLOGICAL APPROACH TO THE MODELLING OF ELLIPTICAL GALAXIES: THE PROBLEM OF THE MASS-TO-LIGHT RATIO

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SUMMARY: In this paper the problem of the phenomenological modelling of elliptical galaxies using various available observational data is presented. Recently, Tortora, Cardona and Piedipalumbo (2007) suggested a double power law expression for the global cumulative mass-to-light ratio of elliptical galaxies. We tested their expression on a sample of ellipticals for which we have the estimates of the mass-to-light ratio beyond ~ 3 effective radii, a region where dark matter is expected to play an important dynamical role. We found that, for all the galaxies in our sample, we have $\alpha + \beta > 0$, but that this does not necessarily mean a high dark matter content. The galaxies with higher mass (and higher dark matter content) also have higher value of $\alpha + \beta$. It was also shown that there is an indication that the galaxies with higher value of the effective radius also have higher dark matter content.

Key words. galaxies: kinematics and dynamics – galaxies: elliptical and lenticular – galaxies: structure – dark matter – galaxies

1. INTRODUCTION

The problem of dark matter in elliptical (early-type) galaxies can be assessed by using different methodologies: observational, theoretical, computational (see e.g. Samurović 2007 for a detailed review). Each of these methodologies has its advantages and drawbacks. For example, observations of integrated stellar spectra of ellipticals below $\sim 2-3$ effective radii (R_e) can provide good insights about kinematics and dynamics, but above ~ 3 R_e the observations are still very rare, because of the time needed to collect high quality long-slit spectra in these outer faint regions. Theoretical and computational efforts suffer from the lack of knowledge about orbits in ellipticals and are, in principle, computationally very expensive. New observations based on tracers, such as planetary nebulae (PNe) and globular clusters (GCs) in ellipticals, can provide the insights about the mass in outer regions but much more observed tracers per galaxy is needed if one wishes to obtain detailed kinematics in outer regions where dark matter should exceed the luminous one.

One possible approach to the problem of dark matter would be to adopt an approach which is intermediate between observations and theory: a phenomenological one. Such an attempt should be strongly based on all available observational results (in the case of ellipticals: integrated stellar spectra, X-rays, tracers such as PNe and/or GCs, gravitational lensing, to name a few), without dealing with the still poorly known aspects of dark matter physics. Such an approach can in principle provide insights and predictions related to some fundamental parameters of the galaxies in question. In this paper we examine the problem of the total cumulative mass-to-light ratio of ellipticals based on different observational techniques.

We remind the reader that several correlations between basic structural parameters of elliptical galaxies are known to exist (see Binney and Merrifield 1998, Sec. 4.3.4, for details): for example, surface brightness – effective radius relation (see Fig. 4.43 in the aforementioned book), stating that more luminous ellipticals have lower surface brightnesses. Another example is the Faber–Jackson relation saying that more luminous ellipticals have larger central velocity dispersions. Yet another example of a correlation of parameters in elliptical galaxies is the so-called fundamental plane (FP); ellipticals populate a three-dimensional manifold in the space of their observable quantities: effective radius, R_e, effective surface brightness (mean surface brightness within R_e), and central velocity dispersion σ.

Very recently, Kassin et al. (2007) introduced a new kinematic estimator called $S_{0.5}$ defined as $S_{0.5} = \sqrt{0.5V_{\rm rot}^2 + \sigma_g^2}$, where $V_{\rm rot}$ is the rotational velocity and σ_g is the gas velocity dispersion. Their results suggest that there may exist a physical connection between the Tully-Fisher relation (valid for spirals) and the already mentioned Faber-Jackson relation. Interestingly, their sample of galaxies cover redshifts between 0.1 and 1.2 and no detectable evolution of the slope in the $\log M_*$–$\log S_{0.5}$ relation, which connects the stellar mass and the $S_{0.5}$ estimator, was seen. Their results seem to imply that absolute changes in the inner baryon structures are small.

The typical mass-to-light ratio in elliptical galaxies is given by van der Marel (1991). In a sample of 37 bright ellipticals he found that the average mass-to-light ratio in the B-band in solar units (it is understood that solar units are used throughout this paper) is: $M/L_B = (5.95 \pm 0.25)h_{50}$ thus $M/L_B = 8.33 \pm 0.35$ for $h_0 = 0.70$ (the value of the Hubble constant used in this paper). A correlation which he found states that the mass-to-light ratio is correlated with the total luminosity: $M/L_B = 3.84 h_{50}(L_B/L_{*,B})^{0.35}$, where $L_{*,B} \equiv 3.3 \times 10^{10} h_{50}^{-2} L_\odot$.

The plan of the paper is as follows: In Section 2 we provide basic theoretical facts related to the phenomenological aspects of the mass-to-light ratio of ellipticals. In Section 3 we present the sample which we use and provide related observational details. In Section 4 the computational results are given, and finally, in Section 5 we provide discussion of the obtained results and the conclusions.

2. THEORETICAL CONSIDERATIONS

In a recent paper Tortora, Cardone and Piedipalumbo (2007, hereafter TCP07) suggested a double power law formula for the global cumulative mass-to-light (hereafter M/L) ratio. Their ansatz can be expressed as:

$$\Upsilon(r) \equiv \frac{M(r)}{L(r)} = \Upsilon_0 \left(\frac{r}{r_0}\right)^\alpha \left(1 + \frac{r}{r_0}\right)^\beta, \qquad (1)$$

where Υ_0 is a scaling M/L ratio, r_0 is a reference radius (in this paper taken to be an effective radius, R_e, radius which encompasses half the total light of a given galaxy) and (α, β) are slope parameters. The main purpose of the present paper is to find these two parameters for different observed galaxies (see below). The case for which $(\alpha, \beta) = (0, 0)$ is obviously the one with a constant mass-to-light ratio, i.e. $\Upsilon(r) = \Upsilon_0$. As noted by TCP07, a model without dark matter will thus be obtained by setting zero values for the two slope parameters and so the mass-to-light ratio becomes: $\Upsilon(r) \simeq \Upsilon_*$, where Υ_* is related to the stellar component of a given elliptical.

For the details regarding the constraints on the slope parameters the reader is referred to TCP07. Here, for the sake of clarity we only provide the essential expression:

$$\max(\gamma - 2, -\beta) \leq \alpha \leq \min(\gamma, 1 - \beta). \qquad (2)$$

The hatched area permitted by these two constraints is given in Fig. 4. We note that in this paper the widely used Hernquist (1990) model of the luminosity density is used which means that $\gamma = 1$ is always used (see TCP07 for details).

3. SAMPLE OF GALAXIES AND OBSERVATIONAL INFORMATION

In our previous works (Samurović and Danziger 2005, 2006, Samurović 2006, and also in Samurović 2007) we have shown that there is no need for dark matter in ellipticals interior to $\sim 2 - 3R_e$. Beyond this region dark matter starts to play more important role (see, for example cases of NGC 1399 and NGC 5128, two galaxies with different properties but with an increased dark matter content). Therefore, in order to study phenomenology of the ellipticals with dark matter, we decided to build a sample of ellipticals for which we have estimates of M/L ratios beyond $\sim 3R_e$. We started with the sample of Napolitano et al. (2005) eliminating the galaxies for which the observations do not extend beyond $\sim 3R_e$. Whenever it was possible, we used our own estimates of the M/L ratio (the case of NGC 1399, NGC 3379 and NGC 5128; regarding NGC 5128 see also the discussion below); we have also added the galaxy IC 1459 for which we had different observational data (see below for details). The final sample consisted of 11 elliptical galaxies with established M/L gradients and presented in Table 1. In this Table we list two values of the mass-to-light ratio of a given galaxy: one at the given inner point ($r_{\rm in}$) and the other at some given outer point ($r_{\rm out}$). It is obvious that all galaxies show more or less steep gradient in their mass-to-light ratio, and therefore $(\alpha, \beta) \neq (0, 0)$ in all the cases.

Table 1. Sample of the elliptical galaxies with M/L measurements

Galaxy	Type	D [Mpc]	M_B	R_e [kpc]	R_e [arcsec]	a_4	$r_{\rm in}$ [R_e]	$\Upsilon_{\rm in}$	$\Delta\Upsilon_{\rm in}$	$r_{\rm out}$ [R_e]	$\Upsilon_{\rm out}$	$\Delta\Upsilon_{\rm out}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
NGC 221	E3	0.9	-16.5	0.2	46	0.0	0.1	2.8	0.2	5.6	4.8	2.8
NGC 821	E2	25.5	-20.6	6.2	50	2.5	0.5	8.4	0.4	4.8	13.1	3.9
NGC 1399	E1/cD	21.1	-21.4	4.3	42	0.1	1.0	8.3	0.8	11.4	45.0	8.0
NGC 1700	E4	52.0	-21.7	3.5	14	0.4	0.5	4.0	0.4	4.6	7.8	0.8
NGC 3379	E1	11.2	-20.1	2.0	55	0.2	1.0	6.0	1.0	4.0	12.0	1.0
NGC 3384	E5/S0	12.3	-19.8	1.5	25	1.0	0.5	4.1	0.4	5.8	7.4	2.2
NGC 4472	E2	17.2	-22.0	8.7	104	-0.3	0.5	8.0	0.3	4.5	28.5	8.6
NGC 4486	E3/cD	17.0	-21.7	7.8	95	0.0	0.5	5.3	0.4	4.8	30.0	4.5
NGC 4494	E1	18.0	-20.7	4.3	49	0.3	0.5	3.9	0.4	3.9	5.5	1.7
NGC 5128	S0	3.84	-21.0	6.6	309	-0.5	1.0	5.1	1.2	15.1	13.8	3.6
IC 1459	E3	24.2	-20.8	3.9	33	0.0	1.0	7.5	2.5	5.0	16.0	2.5

NOTES – Col. (1): Name of the galaxy. Col. (2): Type of the galaxy after HyperLeda catalog (`http://www-obs.univ-lyon1.fr/hypercat`). Col. (3): Distance from SBF measurements (Tonry et al. 2001) rescaled from $h = 0.74$ to $h = 0.70$. The distance to IC 1459 was determined using heliocentric radial velocities from the NED archive (`http://nedwww.ipac.caltech.edu`). The distance to NGC 5128 is taken from the paper by Rejkuba (2004); the mass-to-light ratio of this galaxy is based on Samurović (2006); see text for details. Col. (4): Magnitude in the B-band from HyperLeda catalog. Col. (5): Effective radius expressed in kiloparsecs. Col. (6): Effective radius expressed in arcsecs. Col. (7): Isophote shape parameter, a_4. Col. (8): Inner radius at which the mass-to-light ratio ($\Upsilon_{\rm in}$) is established. Col. (9): Mass-to-light ratio at $r_{\rm in}$ in the B-band. Col. (10): Error of $\Upsilon_{\rm in}$. Col. (11): Outer radius at which the mass-to-light ratio ($\Upsilon_{\rm out}$) is established. Col. (12): Mass-to-light ratio at $r_{\rm out}$ in the B-band. Col. (13): Error of $\Upsilon_{\rm out}$.

The basic data regarding the galaxies from the sample are given in Napolitano et al. (2005), and we here present only some additional details which are either newer and/or not present in the aforementioned paper. In Table 1 we present basic features of the galaxies in the sample: type, distance, magnitude in the B-band, effective radius, a_4 parameter (fourth harmonic deviations from ellipse), inner and outer radii and the corresponding mass-to-light ratios.

NGC 1399: This galaxy was the subject of a detailed comparative study related to its mass-to-light ratio based on different tracers (Samurović and Danziger 2006) where GCs and X-rays were used to trace the total mass out to ~ 10 arcmin ($= 14.3 R_e$). However, in the outermost regions there exists a strong discrepancy between the estimates based on X-rays and GCs (still without satisfactory explanation), and, therefore, in the present paper we decided to take as the last measured point the value of the M/L ratio at 8 arcmin ($= 11.4 R_e$). We note that interior to this point, the increase of the total M/L ratio is well approximated by a linear fit (see Fig. 6 in Samurović and Danziger 2006).

NGC 3379: This is a very interesting galaxy in the sense that the amount of dark matter which it contains was considered very low (see Ciardullo, Jacoby and Dejonghe 1993, Romanowsky et al. 2003). In 2005 a paper by Dekel et al. appeared, in which the low velocity dispersion observed in this galaxy was attributed to a domination of radial orbits. Very recently, Douglas et al. (2007) using the same instrument (Planetary Nebulae Spectrograph, PN.S) as Romanowsky et al. (2003) observed 214 PNe (191 are ascribed to NGC 3379 and 23 to the companion galaxy NGC 3384). They conclude that the amount of dark matter in this galaxy is low, a result at odds with the results of Dekel et al. (2005). In the present paper we decided to take as the upper limit of the total M/L ratio at 4 R_e ($\simeq 220$ arcsec), $\Upsilon_B = 12$ (based on the X-rays and temperature $T_X = 0.26$ keV, see Samurović and Danziger 2006, Samurović 2007). This is in agreement with the result obtained by Pierce et al. (2006). The upper limit, based on the Jeans modelling, permitted by Romanowsky et al. is $\Upsilon_B \lesssim 12$ (at 220 arcsec) and corresponds to a radially-biased model. We used the effective radius $R_e = 54.8$ arcsec found in Capaccioli et al. (1990) which we verified using the curve of growth.

NGC 3384: As noted above, this galaxy is a companion to the galaxy NGC 3379. Sluis and Williams (2006) estimated recently the M/L of this galaxy, $\Upsilon_B \sim 11$, but concluded that this result "is likely an overestimate". The value used at the outer limit in the present paper is the one found in Napolitano et al. (2005): $\Upsilon_B = 7.4$.

NGC 5128: This galaxy was also the subject of a detailed comparative study: in Samurović (2006) we studied the total mass (and the total mass-to-light ratio in the B-band) of this galaxy using X-rays, GCs and PNe. The value of the inner mass-to-light ratio is given in Table 1 using all of these three mass tracers. The outer mass-to-light ratio at the outer limit is based on the PNe alone because these ob-

jects provided an estimate of the mass-to-light ratio at the outermost point of NGC 5128 (at $\sim 15R_e$, $\Upsilon_B \sim 14$). As noted in Samurović (2006), there is a discrepancy between this result and the one based on the X-rays: the reason for it is not clear at the present time, although some explanations, such as lack of hydrostatic equilibrium in these regions, were proposed. Very recently, a new detailed study of NGC 5128 by Woodley et al. (2007) appeared in which a kinematical and dynamical study of the halo of this galaxy based on 340 GCs and 780 PNe is presented. They inferred a total mass based on PNe equal to $1.0 \pm 0.2 \times 10^{12} M_\odot$ (interior to 90 kpc). They also discussed the possible reasons for the discrepancy between this result and the result obtained in Samurović (2006). In the present paper we will not address this issue because it is beyond the scope of our paper (we refer the reader to a detailed discussion in the paper by Woodley et al.) but instead we simply take Woodley et al. value of the total mass (corresponding to $M/L_B \sim 24$, at r_{out}, for the distance used in the present paper) and calculate the slope parameters (α, β).
IC 1459: This galaxy was the subject of a detailed kinematical and dynamical study in Samurović and Danziger (2005). We used high quality long-slit spectra and found that interior to $\sim 3R_e$ dark matter does not play an important role in this galaxy. We also found that between one and three effective radii, this galaxy shows radial anisotropies. The inner value of the mass-to-light ratio given in Table 1 at $\sim 1R_e$, $\Upsilon_B \sim 7.5$ is calculated using the modelling of the kinematics based on the integrated stellar spectra. The upper value $\Upsilon_B \sim 16$ at $\sim 5R_e$, comes from the X-ray methodology, using the temperature $T_X = 0.6$ keV.

4. COMPUTATIONAL RESULTS

In order to compute the slope parameters (α, β) given by Eq. (1) we have written a least-squares code in FORTRAN which varies the slope parameters and fits Eq. (1) to the observed values of the mass-to-light ratio of a given galaxy. We have calculated the χ^2 values in each case, and present the results in Figs. 1 – 3 and Table 2.

We adopted the following procedure: first for each galaxy we tabulated 20 "observational" (i.e. based on the 2 observed values of the mass-to-light ratio at r_{in} and r_{out} assuming a linear relation between them) equidistant points (experiments were also made with different numbers of points but the results were the same) which describe the mass-to-light ratio as a function of radius. Then we search for the fit using Eq. (1) by varying the slope parameters, keeping the scaling mass-to-light ratio (Υ_0) constant at the same positions (same 20 equidistant points). As a reference radius, r_0, as already mentioned in Section 2, we have used the effective radius, R_e. We repeat the procedure for different values of the scaling constant: in Figs. 1 – 3 and in Table 2 we present only the best fitting results. It is interesting to note that the scaling constant which provides the best fit in all the cases is always close, if not identical, to the lower limit of the total mass-to-light ratio (Υ_{in}).

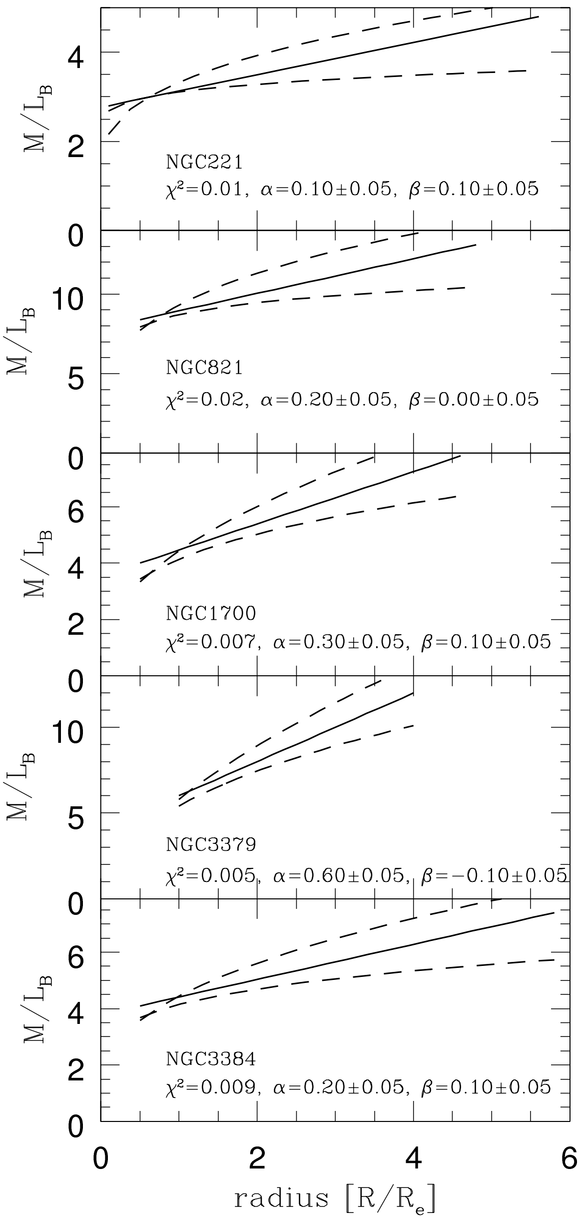

Fig. 1. *Mass-to-light ratio of the first part of the used sample of galaxies (*NGC 221, NGC 821, NGC 1700, NGC 3379 *and* NGC 3384*) in the B-band. Radius is given in units of effective radius and for individual galaxies can be found in Table 1. Solid line is the "observational" one and the two dashed lines indicate upper and lower limits to the modelled mass-to-light ratio (see text for details). The line based on the slope parameters from Table 2 is between the limits.*

In Figs. 1 – 3 we plotted with the solid lines the observed mass-to-light ratios and with the dashed lines upper and lower limits to the fitted values of the mass-to-light ratios. The fit obtained using the values (α, β) presented in Table 2 is between the two limits. The positions of the galaxies in the (α, β) space is given in Fig. 4.

The calculated values of the slope parameters α and β populate the hatched permitted region in Fig. 4 as given by relations (2). The constraints from these relations were imposed while searching for the best fit. We note, however, that we also searched for the solution without imposing them: in such a case a solution can also be reached but it was of poorer quality (much higher χ^2 values). It is also obvious from Fig. 4 that all 11 galaxies fill the right-hand part of plot: they all have $\alpha > 0$. Only 3 galaxies (NGC 3379, NGC 1399 and NGC 5128) have negative β parameter. Note that the smallest value of $\beta = -0.6$ is found for NGC 5128: this galaxy most probably has surprisingly low amount of dark matter in its outer parts (Peng et al. 2004). Note that NGC 5128 is the only galaxy for which we have plotted two separate cases: one based on the estimate from Samurović (2006) (panel "a" in Fig. 3) and the other one based on the estimate from Woodley et al. (2007) (panel "b" in Fig. 3). As one can see the results for the slope parameters (α, β) are very similar, although the reduced χ^2 value is much better in the first case. Since in Tables 1 and 2 we presented data based on the mass inferred in the paper by Samurović (2006) only, here we note that in the case "b" we have $\Upsilon_0 = 6$ (the same value as in the case "a"). The galaxy NGC 1399 for which the amount of dark matter is much higher also has a negative β parameter, albeit higher ($\beta = -0.3$). What all galaxies have in common is the positive sum of α and β. According to TCP07 this is a "strong evidence for dark matter". Our sample is biased in the sense that the selection criterion was the existence of the mass measurements beyond $3R_e$ and this is a region where dark matter starts to become dynamically important. It is worth mentioning that, in spite of the aforementioned selection criterion, there are 4 galaxies for which the total mass-to-light ratio is below 8 (in the B-band) indicating low amount of dark matter even beyond $\sim 3R_e$. Hence one can conclude that the condition $\alpha + \beta > 0$ is a *necessary* condition, but it is not a *sufficient* condition for the existence of dark matter. In general, we note that the galaxies with high mass-to-light ratios have high $\alpha + \beta$ values. To claim the existence of dark matter, it seems that additional constraints are necessary: *(i)* the mass-to-light ratio in the B-band should be $\Upsilon_B > 8$ and *(ii)* the value of the effective radius is probably important—it can be seen that the galaxies with higher *physical* value of the effective radius (column 5 in Table 1) have higher total masses (and higher total mass-to-light ratio) and therefore higher dark matter content. Although it is obvious that there are exceptions and that the sample is rather small, one can see that the galaxies for which $R_e > 4$ kpc have higher mass-to-light ratios. The notable exception is NGC 3379, but the mass content of this galaxy is still highly problematic (see Douglas et al. 2007). Therefore, the result regarding the connection between the effective radius and the total mass should be taken as an indicative and not a conclusive one.

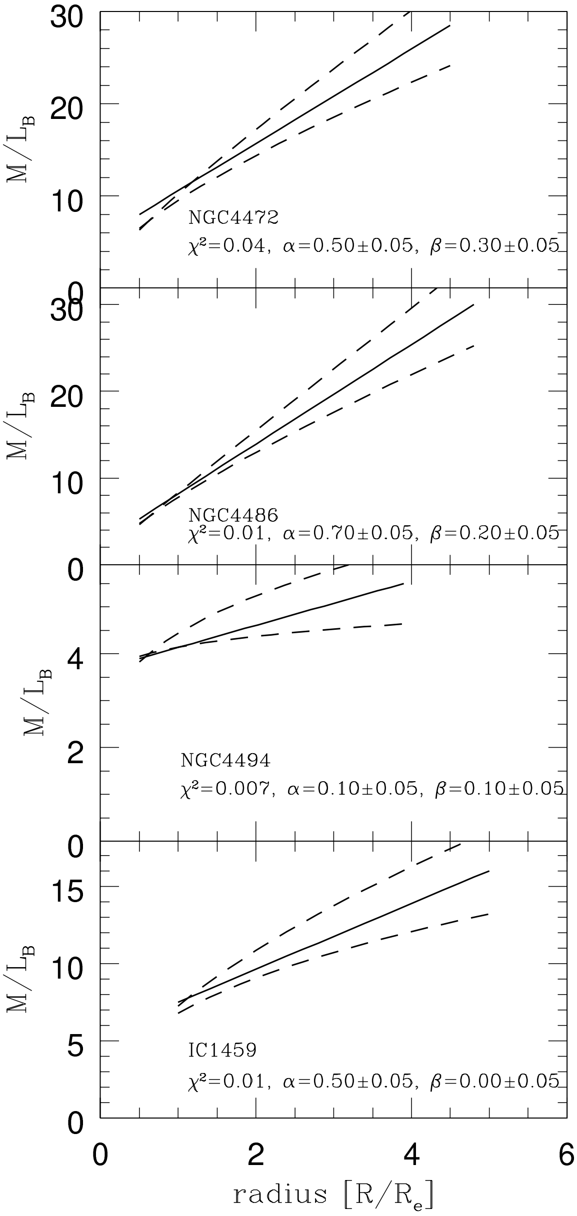

Fig. 2. *Mass-to-light ratio of the second part of the used sample of galaxies (*NGC 4472, NGC 4486, NGC 4494 *and* IC 1459*) in the B-band. Radius is given in units of effective radius and for individual galaxies can be found in Table 1. The explanation of the plotted lines is same as in Fig. 1.*

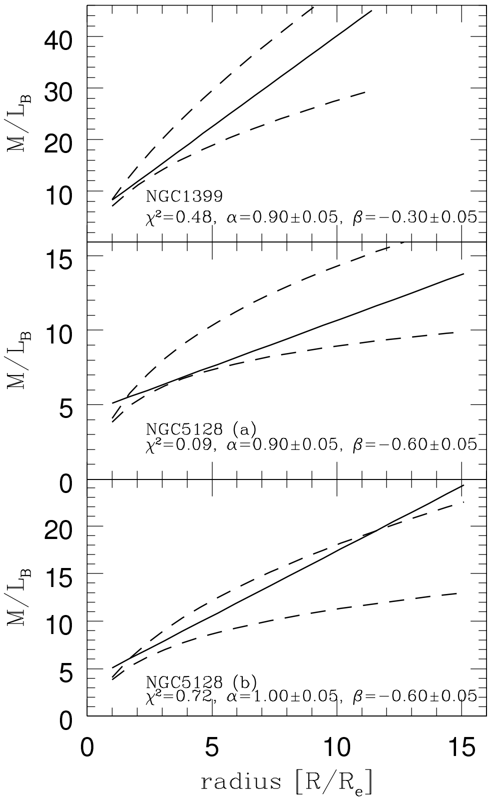

Fig. 3. *Mass-to-light ratio of the third part of the used sample of galaxies (*NGC 1399 *and* NGC 5128*) in the B-band. For the galaxy* NGC 5128 *two different cases were presented: the mass-to-light ratio in the case "a" is based on the paper by Samurović (2006) and in the case "b" the mass-to-light ratio is based on the paper by Woodley et al. (2007), see text for details. Radius is given in units of effective radius and for both galaxies can be found in Table 1. Note the different scale for radius with respect to Figs. 1 and 2. The explanation of the plotted lines is same as in Fig. 1.*

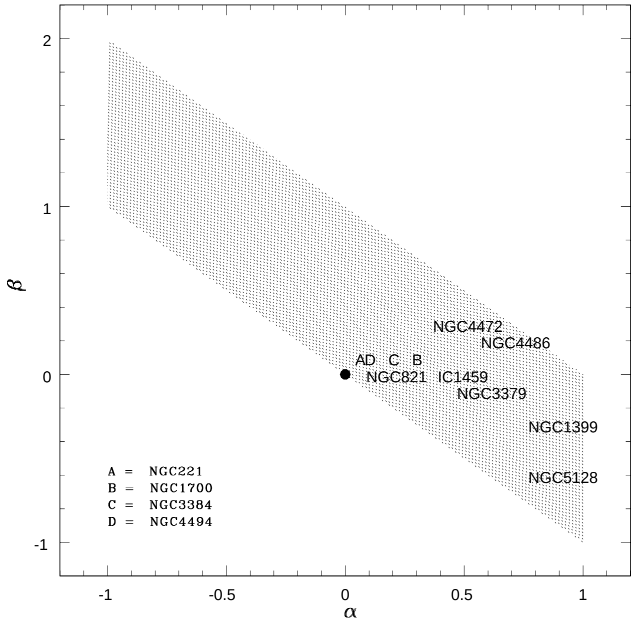

Fig. 4. *Calculated values of the slope parameters α and β for the sample of ellipticals used in this paper. The hatched region is a zone permitted by theoretical considerations and is based on relations (2), assuming the Hernquist (1990) model of the luminosity density. To avoid overlapping of the names of four galaxies their names were abbreviated to four different letters, as indicated on the left-hand side of this Figure. Big black dot stands for $(\alpha, \beta) = (0, 0)$, the case of the constant mass-to-light ratio.*

Table 2. Best fit values of the slope parameters (α, β) for the galaxies in Table 1.

Galaxy (1)	α (2)	β (3)	Υ_0 (4)	χ^2 (5)
NGC 221	0.10 ± 0.05	0.10 ± 0.05	3	0.01
NGC 821	0.20 ± 0.05	0.00 ± 0.05	9	0.02
NGC 1399	0.90 ± 0.05	-0.30 ± 0.05	10	0.48
NGC 1700	0.30 ± 0.05	0.10 ± 0.05	4	0.007
NGC 3379	0.60 ± 0.05	-0.10 ± 0.05	6	0.005
NGC 3384	0.20 ± 0.05	0.10 ± 0.05	4	0.009
NGC 4472	0.50 ± 0.05	0.30 ± 0.05	8	0.04
NGC 4486	0.70 ± 0.05	0.20 ± 0.05	7	0.01
NGC 4494	0.10 ± 0.05	0.10 ± 0.05	4	0.007
NGC 5128	0.90 ± 0.05	-0.60 ± 0.05	6	0.09
IC 1459	0.50 ± 0.05	0.00 ± 0.05	7	0.01

NOTES – Col. (1): Name of the galaxy. Col. (2): Best-fitting value of the α parameter with formal error. Col. (3): Best-fitting value of the β parameter with formal error. Col. (4): Best-fitting value of the scaling mass-to-light ratio. Col. (5): Best-fitting value of the reduced χ^2 parameter. The fits for NGC 5128 are based on the mass inferred by Samurović (2006); see text for details.

5. CONCLUSIONS

In this paper we applied a phenomenological approach to the modelling of the mass-to-light ratio of elliptical galaxies. It was shown that such an approach is very useful in the study of ellipticals, because it provides a connection between different crucial observational parameters thus permitting to reveal the properties of these objects. One of the possible applications of the results obtained in this paper could be, for example, in the analysis of numerical simulations of galaxy formation and evolution.

We built a sample of 11 elliptical galaxies for which we have various observations (and mass determinations) beyond ~ 3 effective radii. We applied a formula recently suggested by Tortora et al. (2007) which provides a relation between the total mass-to-light ratio and the radius, giving thus a possibility to investigate the properties of dark matter distribution in ellipticals. We calculated the slope parameters α and β and the scaling mass-to-light ratios for the galaxies from our sample and reached the following conclusions:

(1) We showed that the best-fitting results are obtained when scaling mass-to-light ratio (Υ_0) is close to the value obtained near the inner radius: for example for the galaxy NGC 1399 at $r_{\rm in}$ $\Upsilon_{\rm in} = 8.3$ and $\Upsilon_0 = 10$.

(2) We found that all the galaxies from our sample populate the region for which $0 < \alpha < 1$ and $-0.6 \leq \beta \leq 0.3$. The galaxy with the lowest value of β is NGC 5128, $\beta = -0.6$. This is the galaxy for which a small contribution of dark matter was estimated (see e.g. Peng et al. 2004, Samurović 2006; see also Woodley et al. 2007).

(3) We found that for all the galaxies in our sample $\alpha + \beta > 0$ but this does not indicate strong contribution of dark matter (see the example of NGC 221, at $r_{\rm out} = 5.6R_e$, $\Upsilon_0 = 4.8$, $\alpha + \beta = 0.1 + 0.1 = 0.2$). On the other hand, for the galaxy with the highest dark matter contribution, NGC 1399, at $r_{\rm out} = 11.4R_e$, $\Upsilon_0 = 45$, $\alpha + \beta = 0.9 - 0.3 = 0.6$. This might suggest that higher value of $\alpha + \beta$ suggests higher dark matter content.

(4) We note that there is an indication that the galaxies with higher effective radius have a greater probability to have higher dark matter content. Bertin et al. (1994) found that for galaxies which have $R_e > 8$ kpc one can argue in favor of dark matter. Note that this value was calculated for $h_0 = 0.50$, whereas in this paper we have used $h_0 = 0.70$, which after rescaling gives the boundary value of the effective radius ≈ 5.7 kpc. One of the results of this paper is that this value can be even lower: for example, NGC 1399 has $R_e = 4.3$ kpc along with a high dark matter content.

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REFERENCES

Bertin, G., Bertola, F., Buson, L.M., Danzinger, I.J., Dejonghe, H., Sadler, E.M., Saglia, R.P., de Zeeuw, P.T. and Zeilinger W.W.: 1994, *Astron. Astrophys.*, **292**, 381.
Binney, J.J. and Merrifield, M.R.: 1998, Galactic Astronomy, Princeton Univ. Press, Princeton, NJ.
Capaccioli, M., Held, E.V., Lorenz, H. and Vietri, M.: 1990, *Astron. J.*, 99, 1813.
Ciardullo, R., Jacoby, G.H. and Dejonghe, H.G.: 1993, *Astrophys. J.*, **414**, 454.
Dekel, A., Stoehr, F., Mamon, G.A., Cox, T.J. and Primack, J.R.: 2005, *Nature*, **437**, 707.
Douglas, N.G., Napolitano, N.R., Romanowsky, A.J., Coccato, L., Kuijken, K., Merrifield, M.R., Arnaboldi, M., Gerhard, O., Freeman, K.C., Merrett, H.R., Noordermeer, E. and Capaccioli, M.: 2007, *Astrophys. J.*, accepted, preprint `astro-ph/0703047v1`
Hernquist, L.: 1990, *Astrophys. J.*, **356**, 359.
Kassin, S.A., Weiner, B.J., Faber, S.M., Koo, D.C., Lotz, J.M., Diemand, J., Harker, J.J., Bundy, K., Metevier, A.J., Phillips, A.C., Cooper, M.C., Croton, D.J, Konidaris, N., Noeske, K.G. and Willmer, C.N.A.: 2007, *Astrophys. J.*, accepted, preprint `astro-ph/0702643v1`
Peng, E.W., Ford, H.C. and Freeman, K.C.: 2004b, *Astrophys. J.*, **602**, 685.
Pierce, M., Beasley, M.A., Forbes, D.A., Bridges, T., Gebhardt, K., Faifer, F.R., Forte, J.C., Zepf, S.E., Sharples, R., Hanes, D.A. and Proctor, R.: 2006, *Mon. Not. R. Astron. Soc.*, **366**, 1253.
Rejkuba, M.: 2004, *Astron. Astrophys.*, **413**, 903.
Romanowsky, A.J., Douglas, N.G., Arnaboldi, M., Kuijken, K., Merrifield, M.R., Napolitano, N.R., Capaccioli, M. and Freeman, K.C.: 2003, *Science*, **5640**, 1696.
Samurović, S. and Danziger I.J.: 2005, *Mon. Not. R. Astron. Soc.*, **363**, 769.
Samurović, S. and Danziger, I.J.: 2006, *Astron. Astrophys.*, **458**, 79.
Samurović, S.: 2006, *Serb. Astron. J.*, **173**, 35.
Samurović, S.: 2007, Dark Matter in Elliptical Galaxies, *Publ. Astron. Obs. Belgrade*, **81**.
Sluis, A.P.N. and Williams, T.B.: 2006, *Astron. J.*, **131**, 2089.
Tonry, J.L., Dressler, A., Blakeslee, J.P., Ajhar, E.A., Fletcher, A.B., Luppino, G.A., Metzger, M.R., Moore, C.B.: 2001, *Astrophys. J.*, 546, 681.
Tortora, C., Cardone, V.F. and Piedipalumbo, E.: 2007, *Astron. Astrophys.*, **463**, 105 (TCP07).
van der Marel, R.P.: 1991, *Mon. Not. R. Astron. Soc.*, **253**, 710.
Woodley, K.A., Harris, W.E., Beasley, M.A., Peng, E.W., Bridges, T.J., Forbes, D.A. and Harris, G.L.H.: 2007, *Astron. J.* accepted, preprint `astro-ph/0704.1189v1`

ФЕНОМЕНОЛОШКИ ПРИСТУП МОДЕЛИРАЊУ ЕЛИПТИЧНИХ ГАЛАКСИЈА: ПРОБЛЕМ ОДНОСА МАСА-СЈАЈ

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Оригинални научни рад

У раду је обрађен проблем феноменолошког моделирања елиптичних галаксија користећи различите расположиве посматрачке податке. У скорашњем раду, Tortora, Cardone and Piedipalumbo (2007) су предложили израз за глобални кумулативни однос маса-сјај за елиптичне галаксије. У раду смо тестирали њихову формулу на узорку галаксија за који поседујемо процене односа маса-сјај на удаљеностима већим од 3 ефективна радијуса, тј. у областима у којима се очекује да тамна материја игра значајну динамичку улогу. Нађено је да се за све галаксије у узорку добија $\alpha + \beta > 0$, али и да то не значи обавезно висок удео тамне материје у њима. Галаксије које имају већу масу (и већи удео тамне материје) имају такође и вишу вредност збира $\alpha + \beta$. У раду је такође показано да за галаксије са већим ефективним радијусом постоји већа вероватноћа да је удео тамне материје у њиховом саставу већи.