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LOCAL ELLIPTICAL GALAXIES: SOME ASPECTS OF THEORY VS. OBSERVATIONS

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SUMMARY: In this paper we analyse on, the sample of the local elliptical galaxies, some predictions of various cosmological theories. We start with the sample of ellipticals described in Samurović (2007b) and confront the established concentration parameters and mass-to-light ratios of these objects with various cosmological models, i.e. models given by Navarro, Frank and White (NFW) (1996, 1997) and Burkert (1995), respectively. We find that the bright galaxy (NGC 5846), for which the sum $\alpha+\beta$ is high, can be reasonably modelled by the NFW models. The Burkert model provides rather good predictions of the dark matter content at one effective radius. There is an indication that bright ellipticals ($M_B \lesssim -21.0$) are more dark matter dominated that the fainter ones ($M_B > -21.0$).

Key words. Galaxies: kinematics and dynamics – Galaxies: elliptical and lenticular, cD – Galaxies: structure – dark matter

1. INTRODUCTION

The problem of dark matter in elliptical (in general, early–type) galaxies remains one of the biggest unsolved questions in the contemporary extragalactic astronomy and cosmology (see Samurović 2007a, Chapter 1, for details). Although many details are still lacking, it seems that a general picture emerges and in an extremely rough description it can be expressed in the following way: it appears that dark matter does not dominate in the inner regions (outside ∼2–3 effective radii, R_e) (Samurović and Danziger 2005), but at larger distances (beyond $\sim 3-4R_e$) it starts playing a more important role, but its contribution varies from case to case.

It was found by van der Marel (1991), on a sample of 37 bright ellipticals, that the typical mass-to-light ratio in elliptical galaxies in the B-band is: $M/L_B = (5.95 \pm 0.25)h_{50}$, i.e. $M/L_B = 8.33 \pm 0.35$ for $h = 0.70$ (the value of the Hubble constant used in this paper).

It must be stressed that the sample of elliptical galaxies explored to large distances from the center (beyond 3 R_e) remains disappointingly small. This, however, does not prevent us to already draw some conclusions regarding the dynamics and kinematics of ellipticals. In Samurović (2007b, hereafter S07) we presented the sample of 11 ellipticals for which we had the estimate of the mass-to-light ratio beyond $\sim 4R_e$ and calculated the values of the (α, β) parameters (see below). In the present paper we shall focus on three galaxies from this sample, to which we added NGC 5846, and compare the available observational results with the predictions of two different theoretical approaches: Navarro, Frenk and White (NFW) model (1996, 1997) and the Burkert model (Burkert 1995, Salucci and Burkert 2000, Boriello, Salucci and Danese 2003, hereafter B03).

We do not consider the problem of rotation of the ellipticals, because it is beyond the province of this paper. The newly announced two-dimensional spectroscopic survey `ATLAS`^{3D} should provide a magnitude limited sample of 260 nearby early-type galaxies important in the study of slow and fast rotators (Emsellem et al. 2007).

The plan of the paper is as follows: In Section 2 we present the sample which we use in this paper. In Section 3 we describe some theoretical aspects of the analysis of elliptical galaxies in the framework of different cosmological models. In Section 4 we compare the observational data for the galaxies in our sample with the theoretical predictions. Finally, in Section 5 we discuss our findings and present the conclusions.

2. THE SAMPLE

In S07 we presented the table which included the details necessary for the calculation of the (α, β) parameters as given in the paper by Tortora, Cordone and Piedipalumbo (2007) which are used in the calculation of the total mass-to-light ratio, Υ, of the given elliptical galaxies at given radius:

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

where Υ_0 is a scaling M/L ratio, r_0 is a reference radius (taken to be an effective radius, R_e, radius which encompasses half the total light of a given galaxy) and (α, β) are the logarithmic slope parameters. It can be seen from Eq. (1) that the scaling M/L ratio is equal to $\Upsilon(r_0) \times 2^{-\beta}$, where $\Upsilon(r_0)$ is the mass-to-light ratio at the reference radius, r_0. In S07 we arrived at the conclusion that higher value of the sum $\alpha + \beta$ suggests higher dark matter content. In Table 1 below we present four galaxies with the relevant observational data: galaxies NGC 821, NGC 3379 and NGC 4494 were already presented in S07. We here added NGC 5846 for which we have data out to 3.2 R_e (as given in Napolitano et al. 2005). Although the data for NGC 5846 do not extend out to $\sim 4R_e$, as required in S07, we included it here because of the newly available observational results and theoretical predictions related to this galaxy. We have calculated, as described in detail in S07, the (α, β) parameters and we found $\alpha = 0.30 \pm 0.05$ and $\beta = 0.30 \pm 0.05$, for $\Upsilon_0 = 9.0$ (see Fig. 1). The meaning of the lines in Fig. 1 is the same as in S07: the solid line is the observed mass-to-light ratio of NGC 5846 and the dashed lines represent upper and lower limits to the fitted value of the mass-to-light ratio, calculated using Eq. (1). It is obvious that in the inner part of this galaxy (for the radius between 0.5 and 1 R_e) the fit is not perfect, but beyond $\sim 1R_e$ the trend of the mass-to-light ratio indicates that dark matter starts to dominate. The obtained sum $\alpha + \beta = 0.6$ strongly suggests the existence of dark matter beyond $\sim 1.5R_e$. The reason for building this sample is a recently published paper by Napolitano et al. (2007) (hereafter N07) which contains data regarding these four galaxies based on the new observations which used planetary nebulae (PNe) (see also the paper by Douglas et al. 2007 related to NGC 3379). Note the misprint in Napolitano et al. (2005) (but not in N07) for the absolute magnitude in the B-band of NGC 5846: it should read (see the HyperLeda database), $M_B = -21.3$.

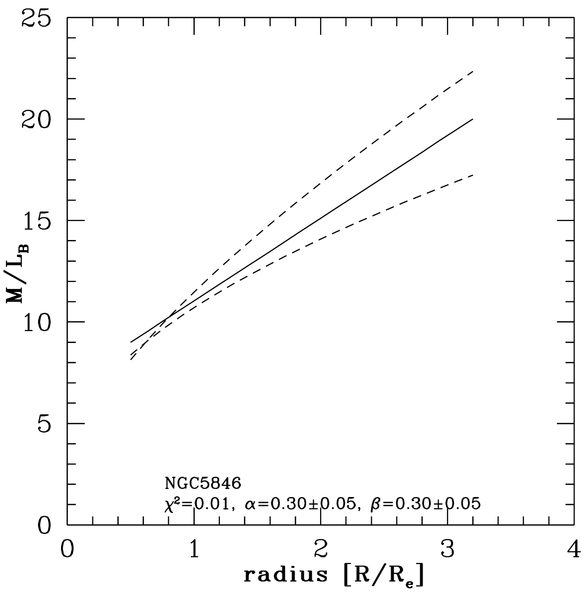

Fig. 1. *Mass-to-light ratio of the galaxy NGC 5846 in the B-band. Radius is given in units of effective radius (see Table 1). Solid line is an observational one and two dashed lines indicate upper and lower limits to the modelled mass-to-light ratio (see text for details). The line based on the slope parameters* $\alpha = \beta = 0.30$*, is between the limits.*

Table 1. Observational data for the 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 821	E2	25.5	-20.6	6.2	50	2.5	0.5	8.4	0.4	4.8	13.1	3.9
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 4494	E1	18.0	-20.7	4.3	49	0.3	0.5	3.9	0.4	3.9	5.5	1.7
NGC 5846	E1	26.3	-21.3	8.0	63	0.0	0.5	9.0	1.0	3.2	20.0	6.0

NOTES – Col. (1): Designation of the galaxy. Col. (2): Type of the galaxy from HyperLeda catalog (`http://www-obs.univ-lyon1.fr/hypercat`). Col. (3): Distance based on SBF measurements (Tonry et al. 2001) rescaled from $h = 0.74$ to $h = 0.70$. Col. (4): Magnitude in the B-band. 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 $\Upsilon_{\rm out}$.

3. THEORETICAL ASPECTS

According to the currently accepted cosmological paradigm, ΛCDM (cold dark matter, CDM plus a cosmological constant) structure grows hierarchically; small objects collapse first and merge in a continuous hierarchy to form more and more massive objects. The CDM model however faces two main difficulties: (i) the problem of cuspy cores – in this model the rotation curves of haloes are peaked more strongly than what is observed and (ii) this model predicts large quantities of small dwarf galaxies which are not observed.

In this Section we consider two models: Navarro, Frenk and White (NFW) model based on the CDM cosmology and Burkert model based on the observations which suggest that dark haloes are more diffuse than the luminous component and that their densities flatten at small radii.

Navarro, Frenk and White (NFW) models

Navarro, Frenk and White (NFW) (1996, 1997) models based on N-body simulations of hierarchical collapse and merging of CDM haloes produce an universal density profile:

$$\rho_{\rm NFW}(r) = \frac{\rho_s}{(r/r_s)(1+r/r_s)^2}, \tag{2}$$

where r_s is the inner characteristic length-scale, which corresponds to the radius where the logarithmic slope of the profile is equal to -2.

As shown in B03, the NFW mass profile can be expressed as:

$$M_{\rm NFW}(r) = M_{\rm vir}\frac{A(r,r_s)}{A(c,r_s/R_e)}, \tag{3}$$

where $A(x,y) \equiv \ln(1+x/y) - (1+y/x)^{-1}$ for any pair of variables, (x,y) and $M_{\rm vir}$ is the halo virial mass.

In general, one can define the concentration parameter $c_{\rm vir} \equiv r_{\rm vir}/r_s$, where $r_{\rm vir}$ is the halo virial radius (see Bullock et al. 2001).

One of the most important results of the CDM theory is the fact that the halo concentration correlates well with the virial mass. Namely, low-mass haloes are denser and more concentrated that high-mass haloes. Wechsler et al. (2002) in their numerical experiments found that at redshift $z = 0$ the following relation holds;

$$c(M_{\rm vir}) \simeq c_{11}\left(\frac{M_{\rm vir}}{10^{11}M_\odot}\right)^{-0.13}, \tag{4}$$

where $c_{11} \simeq 20.8$. Judging from the Fig. 17, in Wechsler et al. virtually no haloes are found below $c_{\rm vir} \sim 10$.

One can also define the total dark-to-light-traced mass ratio as $\Gamma_{\rm vir} \equiv M_{\rm vir}/M_*$, where M_* is the total cumulative mass traced by star light, and can be written, for the Hernquist (1990) distribution, as:

$$M_*(r) = M_*\frac{(r/R_e)^2}{(r+R_e+k)^2}, \tag{5}$$

where $k \simeq 0.55$ (see Samurović 2007a, Chapter 2.1.1). Various cosmological observations (cosmic microwave background anisotropy) suggest that there is an absolute lower limit, $\Gamma_{\rm vir} \simeq 8$.

Burkert models

Driven by the observational results which suggest that dark haloes are more diffuse than the luminous component and that their densities flatten at small radii, we provide here, in a similar fashion as above, some formulae based on the mass density by Burkert (1995). The Burkert's purely phenomenological density distribution has the form:

$$\rho_{\rm dm}(r) = \frac{\rho_0 r_0^3}{(r+r_0)(r^2+r_0^2)}, \tag{6}$$

where ρ_0 and r_0 are free parameters which represent the central density and a scale radius, respectively and "dm" denotes dark matter. It should be noted that this profile resembles the NFW profile at large radii (for $r \gtrsim 0.02 R_{\rm vir}$, see Bullock et al. 2001). From Eq. (6) the mass profile can be written as:

$$M_{\rm B}(r) = M_e \frac{B(r, r_0)}{B(1, r_0/R_e)}, \qquad (7)$$

where, for any pair of variables (x, y), $B(x, y) \equiv -2\arctan(x/y) + 2\ln(1 + x/y) + \ln[1 + (x/y)^2]$ and M_e is the dark mass within R_e (see B03).

4. COMPARISON OF THE OBSERVATIONS AND THEORETICAL PREDICTIONS

In this Section we apply the concepts presented in Section 3 on the observed galaxies from our sample and confront these theoretical expectations with the observational results (or, more precisely, with the modelling results based on the observations). The observational results from N07 were obtained by modelling the dark halo of a given galaxy as a standard NFW halo using $c_{\rm vir}$ and $M_{\rm vir}$ as free parameters. Such a dark halo was included in the Jeans equation (see e.g. Samurović 2007a, Chapter 2.1.1).

B03 presented an interesting approach to the modelling of dark matter in ellipticals with the usage of the fundamental plane (FP) (Djorgovski and Davis 1987, Dressler et al. 1987). The FP provides the correlation between the effective radius, central velocity dispersion and the mean effective surface brightness. It is assumed that the virial theorem is the main constraint to the structure of elliptical galaxies. B03 forced different models to the FP. They found that, for the application of the $H + NFW$ model (stellar bulge with a Hernquist profile embedded in a dark spherical NFW halo) on their sample of 221 early-type galaxies, they need "to keep $\Gamma_{\rm vir}$ unacceptably low or to decrease the halo concentration well below the value currently predicted by simulations in ΛCDM cosmology". Their best-fit model is in fact consistent with no dark matter at all: $\Gamma_{\rm vir} = 2 \pm 4$ and they exclude values of $\Gamma_{\rm vir} \gtrsim 10$ at 95 per cent confidence level (CL). When they recover the FP they put a small amount of dark matter inside $1R_e$ and lower the concentration parameter to ~ 5. It is interesting that this is just what is observed in the case of three galaxies from our sample: NGC 821, NGC 3379 and NGC 4494 (see column (2) of Table 2 and Fig. 2). It is worth repeating that this is well below the predictions from the numerical simulations (see column (9) of Table 2). On the other hand, for NGC 5846 the agreement is better and the observational and theoretical estimates are similar (see Fig. 2).

In order to compare the NFW and Burkert models, we used equations (3) and (7) to calculate the mass at the virial radius using the observational results found in N07. We used the value of the virial radius found for the NWF model and insert it into the Burkert model in order to estimate the value of the concentration parameter of the Burkert model. Since $M_e \approx 0$ for NGC 821 and NGC 4494 (see Table 2, column (12)) the estimates for these two galaxies could not be given. For NGC 3379 using $r_{\rm vir} = 220$ arcsec we found that, in order to have the theoretically preferred estimate of the concentration index of 17.3, one should have $M_{\rm vir}/M_e \approx 2.4$ and $r_0 = 13$ arcsec. For NGC 5846 using $r_{\rm vir} = 630$ arcsec, in the same way, we found that for the theoretically preferred estimate of the concentration index of 11.8, $M_{\rm vir}/M_e \approx 10$ and $r_0 = 53$ arcsec. Both of these ratios are well below the estimates based on N07: 14 and 222 for NGC 3379 and NGC 5846, respectively.

It is worth recalling that a contrary trend occurs for dwarf elliptical galaxies, where faint (low-mass) objects are more dark matter dominated than bright (large-mass) objects.

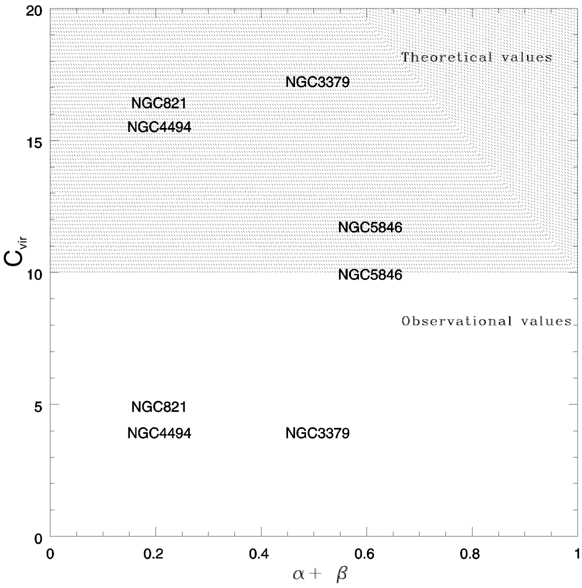

Fig. 2. *Values of the sum $\alpha + \beta$ vs. the value of the $c_{\rm vir}$ parameter for the NFW model: observed values of $c_{\rm vir}$ for the given galaxies are below 10, and the theoretical predictions are all above 10, in the hatched region.*

In B03 there is also a detailed analysis of the $H + B$ (stellar bulge with a Hernquist profile now embedded in a Burkert dark halo) mass model. The authors provide two formulae for their fits of the total mass-to-light ratio in the Gunn r-band:

$$\Upsilon_r = (5.3 \pm 0.1)\left(\frac{L_r}{L_*}\right)^{(0.21 \pm 0.03)}, \qquad (8)$$

$$\Gamma_e \equiv \frac{M_{\rm dm}}{M_*} = 0.29 \pm 0.06\,, \qquad (9)$$

at 68 per cent CL. It is important to stress that here Υ_r (and also Υ_B, see below) represents *only* the stellar contribution to the total mass-to-light ratio. B03 modelled Υ_r as $\Upsilon_r \equiv M_*/L_r = \Upsilon_{r*}(L_r/L_*)^\alpha$ where Υ_{r*} and α were free parameters. We transformed Eq. (8) to the B-band to make a comparison with our previous results (we used $L_*^r = 2.7\times10^{10}L_\odot^r$ from Blanton et al. 2001, $L_B^* = 2.45\times10^{10}L_\odot^B$ from Binney and Merrifield 1998 and the data from Jørgensen, Franx and Kjœrgaard 1995 and Buzzoni 2005; see `http://www.ucolick.org/~cnaw/sun.html` for the absolute magnitude of the Sun in several bands) and the obtained results are given in Table 2 in columns (10) and (11). The estimate for Γ_e based on Eq. (9) is given in column (12). We take the total mass-to-light (dark plus stellar) from Table 1 (see Figs. 1 and 2 from S07) and the stellar contribution from column (10) from Table 2. In Table 2. we also present other theoretical aspects of the galaxies from our sample: columns (2)–(5) are taken from N07, columns (6)–(8) are calculated as given in Section 2 above, column (9) is based on Eq. (4) and columns (10) and (11) are based on Eq. (8). They represent: $c_{\rm vir}$ is a dark halo concentration at virial radius, $M_{\rm vir}$ is virial mass at $r_{\rm vir}$ expressed in $10^{11}M_\odot$, fraction of dark-to-luminous matter, $f_{\rm vir} = M_{\rm dm}/M_*$, β_* parameter describes the nonspherical nature of the stellar velocity dispersion $\beta_* = 1 - \overline{v_\theta^2}/\sigma_r^2$, (see Chapter 2 of Samurović 2007a for details). The quantity $c_{\rm vir}^{\rm th}$ is the theoretical estimate of a dark halo concentration parameter at virial radius (as given in Eq. (4)) and is related to the NFW models, whereas the quantity in column (12), Γ_e is related to the Burkert models.

From Table 2 one can see that Burkert model predicts in some cases realistic estimates of the dark matter content at $1R_e$ (very close to the observed value for NGC 3379, somewhat lower than the observed value for NGC 5846 and a negligible value for NGC821) while in the case of NGC 4494 it fails because this galaxy has apparently anomalously low mass-to-light ratio (see the typical value given by van der Marel 1991).

We did not compare the quantities at the virial radius in view of the problem of determine the total mass of a given galaxy at large radii (see B03). But since NFW and Burkert models resemble each other at large radii, as said above, one may expect similar predictions from both approaches. Here we note, for example, that in the case of the galaxy NGC 1399 Richtler et al. (2004) found that a NFW halo with $c_{\rm vir} = 15$ provides a good fit to the observed data at large distances from the center (see also Fig. 6 from Samurović and Danziger 2006).

There is a hint that brighter galaxies ($M_B \lesssim -20.5$) are more dark matter dominated (at large distances from the center, i.e. beyond $\sim 3R_e$) than the fainter galaxies ($M_B > -20.5$) (see N07). In our small sample, the brightest galaxy has the largest mass-to-light ratio at the outermost point which implies the highest fraction of dark matter there ($\sim 3.2R_e$). Note, however, that for NGC 4494 ($M_B = -20.7$) the measured mass-to-light ratio is extremely small: at $\sim 3.9R_e$, $\Upsilon_B = 5.5$. Also, as presented in S07 (see also Samurović 2006, Samurović 2007a) for NGC 5128 at $\sim 15.1R_e$, the mass-to-light ratio is low, $\Upsilon_B = 13.8$; this galaxy belongs to the brighter group since $M_B = -21.0$. So, if we want to make more accurate division at this stage, it seems that galaxies with $M_B > -21.0$ show lower amounts of dark matter beyond $\sim 3R_e$ (see also Table 1 in S07; only for NGC 1700, $M_B = -21.7$, do we have rather small mass-to-light ratio, $\Upsilon_B = 7.8$ at $4.6R_e$).

Table 2. Data based on theoretical considerations for the sample of the elliptical galaxies with M/L measurements

Galaxy	$c_{\rm vir}^{\rm obs}$	$M_{\rm vir}(10^{11}M_\odot)$	$f_{\rm dm}$	$\beta_*(4R_e)$	α	β	Υ_0	$c_{\rm vir}^{\rm th}$	Υ_B	$\Delta\Upsilon_B$	Γ_e
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
NGC 821	5	6.0	6	-0.1	0.2	0.0	9	16.5	8.6	0.3	0.00
NGC 3379	4	4.2	5	0.3	0.6	-0.1	6	17.3	7.7	0.3	0.28
NGC 4494	4	9.1	9	0.3	0.1	0.1	4	15.6	8.6	0.3	0.00
NGC 5846	10	80	16	0.0	0.3	0.3	9	11.8	9.8	0.2	0.07

NOTES – Col. (1): Designation of the galaxy. Col. (2): Dark halo concentration at $r_{\rm vir}$ (value based on the observations from N07). Col. (3): Virial mass at $r_{\rm vir}$ expressed in $10^{11}M_\odot$ (from N07). Col. (4): Fraction of dark-to-luminous matter, $f_{\rm dm} = M_{\rm dm}/M_*$ at the virial radius (from N07). Col. (5): β_* parameter which describes the nonspherical nature of the stellar velocity dispersion (from N07, see text for details). Col. (6): best-fitting value of the α parameter from Eq. (1). Col. (7): best-fitting value of the β parameter from Eq. (1). Col. (8): best-fitting value of the scaling mass-to-light ratio from Eq. (1). Col. (9): Dark halo concentration at $r_{\rm vir}$ (value based on the CDM simulations from Eq. (4)). Col. (10): Mass-to-light ratio of the stellar component in the B-band. Col. (11): Error of Υ_B. Col. (12): Dark to stellar mass ratio within $1R_e$.

5. CONCLUSIONS

In this paper we presented a sample of four galaxies for which we have enough data to compare the observationally based quantities with the theoretically calculated ones. From the sample taken from S07 we took three galaxies (NGC 821, NGC 3379 and NGC 4494) to which we added fourth one (NGC 5846) for which some new observational data were recently published (N07). We compared the observational data with the theoretical predictions based on the NFW and Burkert cosmological models. Our results are as follows:

(1) The galaxies for which the sum $\alpha + \beta$ is high (more exactly, the galaxy NGC 5846 from our present sample; as shown in S07 this is a possible indication of high dark matter content), there is a hint that the discrepancy between the values of concentration parameter $c_{\rm vir}$ is smaller than in the cases for which this sum is small (NGC 821 and NGC 4494) when the discrepancy is large. The low values of $c_{\rm vir}$ for the NFW models were also noticed by the authors of B03 who forced these models to the fundamental plane.

(2) The Burkert models provided reasonable agreement with the observational data. In the analysis of the dark matter fraction, the estimate of the quantity $\Gamma_e \equiv \frac{M_{\rm dm}}{M_*}$ at $1R_e$ was practically equal to the theoretical prediction for NGC 3379, somewhat lower than the observed value for NGC 5846 and negligible—no dark matter within $1R_e$—for NGC821. In the case of NGC 4494 the prediction fails because this galaxy has apparently anomalously low mass-to-light ratio (at $3.9R_e$ the mass-to-light ratio is $\Upsilon_B = 5.5$). It is interesting to compare the NFW and Burkert approaches here: while the NFW models provide reasonable agreement for one galaxy only (the most luminous one, NGC 5846) the Burkert models provide a reasonable agreement with fainter galaxies too. The sample is obviously still too small to draw firm conclusions, but the results obtained here suggest that more observations of ellipticals which span a large interval of luminosities are needed (see also the conclusion below).

(3) Since our sample is small, we can only have a hint that brighter galaxies ($M_B \lesssim -21.0$) are more dark matter dominated (at large distances from the center, i.e. beyond $\sim 3R_e$) than the fainter galaxies ($M_B > -21$). The same conclusion can be reached by analyzing Table 1 from S07.

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ЛОКАЛНЕ ЕЛИПТИЧНЕ ГАЛАКСИЈЕ: НЕКИ АСПЕКТИ ТЕОРИЈЕ У ПОРЕЂЕЊУ СА ПОСМАТРАЊИМА

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У раду су на узорку локалних елиптичних галаксија анализирана предвиђања различитих космолошких теорија. Пошли смо од узорка елиптичних галаксија који је описан у раду Samurović (2007b) и упоредили параметре концентрације и односе маса-сјај ових објеката у различитим космолошким моделима, тј. у моделима Навара, Френка и Вајта (Navarro, Frenk and White, NFW) (1996, 1997) и Буркерта (Burkert 1995). Нашли смо да за сјајну галаксију (NGC 5846), за коју је збир $\alpha + \beta$ висок, NFW модели дају задовољавајуће слагање са посматрањима. Буркертови модели предвиђају прилично добро допринос тамне материје на јединичном ефективном радијусу. Постоји индикација да у сјајним елиптичним галаксијама ($M_B \lesssim -21.0$) постоји више тамне материје него у слабијим ($M_B > -21.0$) елиптичним галаксијама.