Distribution of Matter in Spheroidal Stellar Systems: Intrinsic and Projected Dynamical Properties

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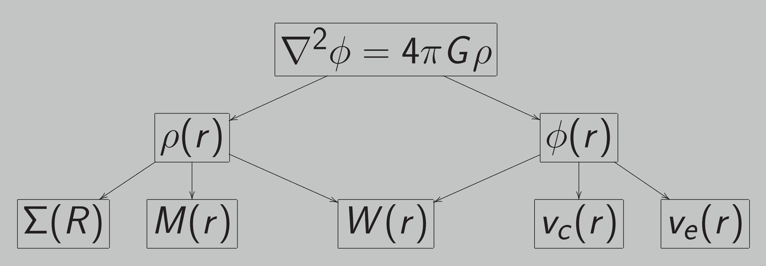
Introduction

This work aims to study several distributions of matter that represent spheroidal stellar systems. Our goal is to determine which is the most suitable profile for different dynamic systems. Different distributions of matter correspond to different dynamic properties such as circular speed, escape velocity, potential energy, integrated mass, total mass. Thus, we solved the basic equations of potential theory to 13 different pairs density-potential and projected them in the line of sight as to compare to measured parameters of elliptical galaxies. In this work, we compare the surface photometry of 27 early-type galaxies of Virgo Cluster with the analytical results from different mass profiles. We introduce preliminary results which associate the tridimensional mass distribution that, once projected, best represents the mass distribution from every galaxy from the sample.

Mass Model and Dynamical Properties.

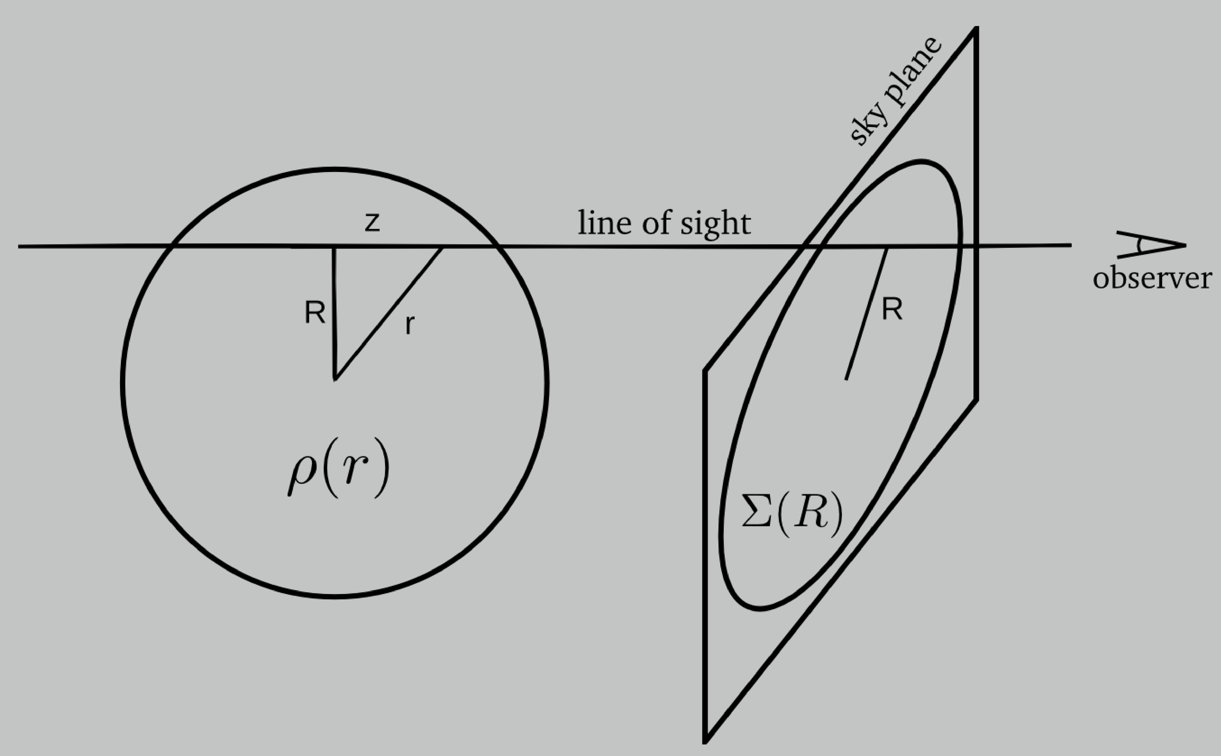


Where the density $\rho(r)$ is the source of potential $\phi(r)$;
$\Sigma(R)$ is the distribution of projected matter;
$M(r)$ is the mass accumulated in the galaxy. If $r \to \infty$ will be the total mass;
$v_c(r)$ is the circular speed and $v_e(r)$ is the escape velocity;
$w(r)$ is the potencial energy.

Projected Mass Density

A galaxy with three-dimensional distribution of matter, gives rise to a two-dimensional distribution of matter projected on the plane of the sky.

$$\Sigma(R) = 2\int_R^\infty \frac{\rho(r')rdr}{\sqrt{r^2 - R^2}} \qquad I(R) = \frac{1}{\gamma}\Sigma(R) \qquad \gamma = \frac{M}{L}$$



Projected Mass Densities for 10 models

Hubble

$$\rho_{HU}(r) = \frac{\rho_0}{(r^2 + a^2)^{3/2}} \qquad \Sigma_{HU}(R) = \frac{2a^3}{a^2 + R^2} \tag{1}$$

Jaffe

$$\rho_J(r) = \rho_0 \frac{a^4}{3r^2(a+r)^2} \qquad \Sigma_J(R) = \frac{a^2(\sqrt{R^2 - a^2}(a^2\pi + 2aR - \pi R^2) + 2R(R^2 - 2a^2)ArcSec(\frac{R}{a}))}{3R(R^2 - a^2)^{3/2}} \tag{2}$$

NFW

$$\rho_{NFW}(r) = \rho_o \frac{a}{r(r+a)^2} \qquad \Sigma_{NFW}(R) = 2a^3\left(\frac{1}{R^2 - a^2} - \frac{aArcCos(\frac{a}{R})}{(R^2 - a^2)^{3/2}}\right) \tag{3}$$

Plummer

$$\rho_P(r) = \frac{\rho_0}{(r^2 + a^2)^{5/2}} \qquad \Sigma_P(R) = \frac{4a^5}{3(a^2 + R^2)^2} \tag{4}$$

Pseudo Isothermal

$$\rho_{PI}(r) = \rho_0\left(\frac{1}{r+a}\right)^2 \qquad \Sigma_{PI}(R) = 2a^2\left(\frac{a}{a^2 - R^2} + \frac{R^2 ArcCos(\frac{a}{R})}{(R^2 - a^2)^{3/2}}\right) \tag{5}$$

Singular Isothermal

$$\rho_{IS}(r) = \rho_0\left(\frac{a}{r}\right)^2 \qquad \Sigma_{IS}(R) = \frac{\pi a^2}{R} \tag{6}$$

With Nucleus.

$$\rho_{WN}(r) = \rho_0\left(\frac{1}{r+a}\right)^4 \qquad \Sigma_{WN}(R) = \frac{a^3(a\sqrt{R^2 - a^2}(2a^2 + 13R^2) - 3(4a^2R^2 + R^4)ArcSec(\frac{R}{a}))}{3(a^2 - R^2)^3\sqrt{\frac{R^2}{a^2} - 1}} \tag{7}$$

Hernquist

$$\rho_{HE}(r) = \rho_0 \frac{2a}{3r(r+a)^3} \qquad \Sigma_{HE}(R) = \frac{2a^3(-3a\sqrt{R^2 - a^2} + (2a^2 + R^2)ArcSec(\frac{R}{a}))}{3(a^2 - R^2)\sqrt{R^2 - a^2}} \tag{8}$$

Finite homogeneous

$$\rho_{HF}(r) = \rho_0\theta(a - r) \qquad \Sigma_{HF}(R) = 2\sqrt{a^2 - R^2} \tag{9}$$

Power Law

$$\rho_{LP}(r) = \rho_0\left(\frac{a}{r}\right)^\alpha \qquad \Sigma_{LP}(R) = \frac{\sqrt{\pi}\left(\frac{a}{R}\right)^\alpha R\Gamma[\frac{1}{2}(\alpha - 1)]}{\Gamma(\frac{a}{2})} \tag{10}$$

Sérsic (reference)

$$\Sigma_{SS}(R) = I_n \exp\left\{-b_n\left[\left(\frac{R}{R_n}\right)^{1/n} - 1\right]\right\} \tag{11}$$

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Fit to Virgo Galaxies

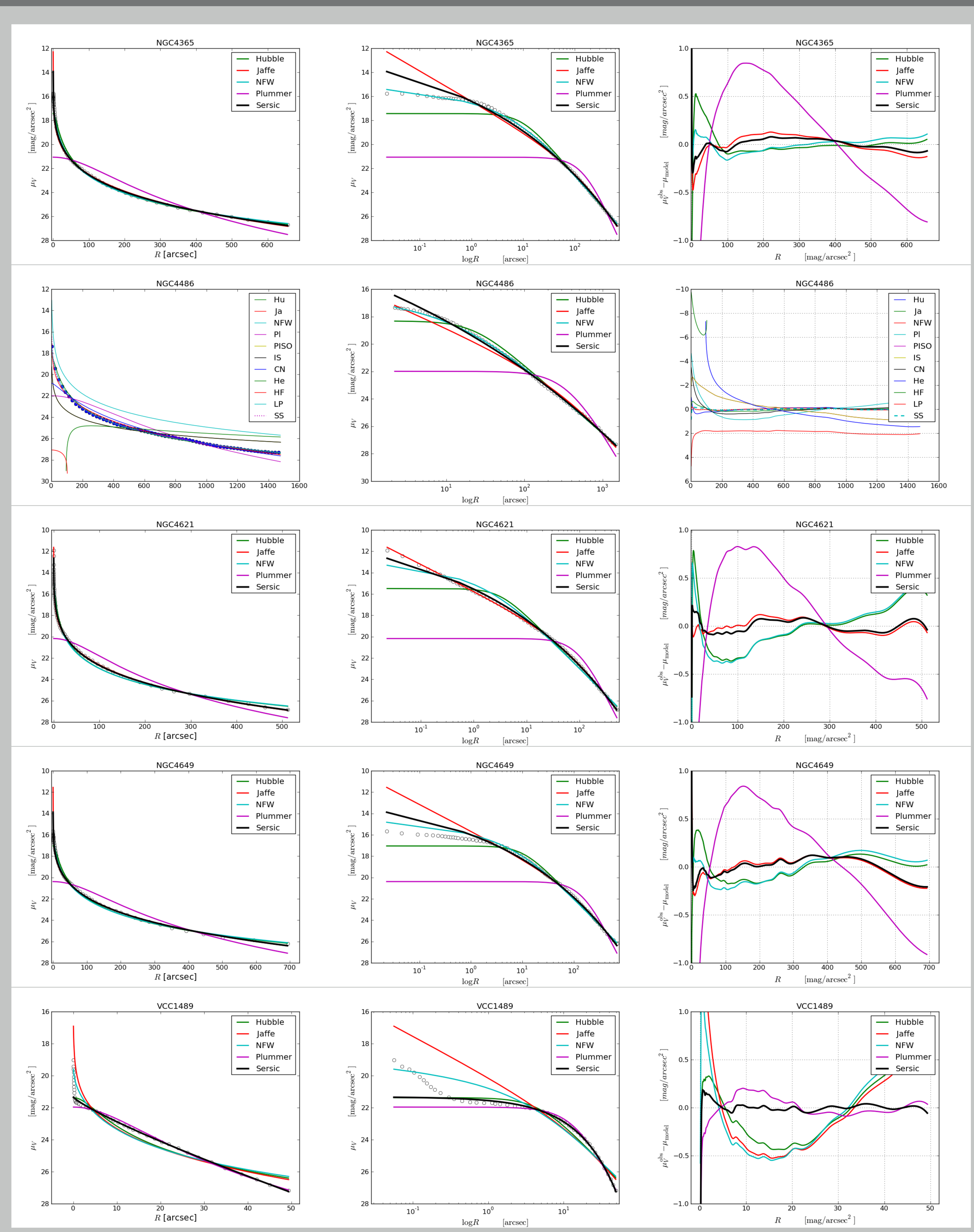

Figure 1: Surface luminosity profile for 5 galaxies in Virgo Cluster. Points are measurements from Kormendy (2009). Solid lines are projected models (see text.)

Fit to the Kormendy (2009) Virgo Sample

Bold values are best fit among models (except Sersic's)

Table 1: Reduced $\chi^2 \times 10^{-3}$

	Sersic	Hubble	Jaffe	Navarro-F-W	Plummer	Pseudo-Isot.	Isothermal	Nucleated	Hernquist	Finite Homog.	Power Law
NGC 4261	5	6	8	**3**	33	36	36	44	60	94	38
NGC 4318	12	34	28	35	**20**	64	64	81	39	88	492
NGC 4365	5	7	10	**3**	33	38	38	25	70	108	156
NGC 4374	3	8	**4**	7	30	42	42	33	74	111	161
NGC 4382	6	17	**13**	17	26	50	50	44	84	123	285
NGC 4387	4	27	20	29	**16**	61	61	101	50	132	723
NGC 4406	8	15	14	**11**	27	35	35	18	67	110	50
NGC 4434	4	30	**14**	54	22	68	68	86	54	96	285
NGC 4458	8	18	**8**	16	28	50	50	91	44	114	167
NGC 4459	5	17	**10**	17	26	51	51	55	75	110	160
NGC 4464	5	42	24	56	**19**	81	81	83	68	154	143
NGC 4467	6	20	**16**	22	19	52	52	66	89	80	109
NGC 4472	4	8	12	**7**	30	40	41	17	70	116	615
NGC 4473	2	9	**3**	10	31	50	50	51	75	110	50
NGC 4478	5	34	24	52	**17**	71	71	92	54	98	430
NGC 4482	8	25	23	26	**15**	50	50	68	30	73	1372
NGC 4486 A	3	31	22	33	**17**	69	69	89	68	134	316
NGC 4486 AK	4	31	20	33	**19**	70	70	91	70	135	188
NGC 4486 B	3	38	80	40	**18**	79	79	89	116	107	105
NGC 4486	6	8	11	**6**	36	35	35	24	56	106	10
NGC 4489	11	27	**19**	28	22	59	59	80	42	85	63
NGC 4515	6	21	**10**	43	28	60	60	82	49	87	309
NGC 4551	5	32	22	50	**16**	102	66	86	48	92	147
NGC 4552	5	8	9	**4**	36	40	40	34	71	108	236
NGC 4564	8	17	**12**	16	24	43	43	61	35	118	212
NGC 4570	16	29	26	28	**25**	56	56	72	50	91	241
NGC 4621	3	13	**3**	11	33	48	48	40	80	117	155
NGC 4636	3	**10**	12	56	28	31	31	18	65	105	33
NGC 4649	6	**6**	12	**6**	32	42	42	26	74	11	74
NGC 4660	6	22	**11**	22	27	60	60	82	57	12	280
VCC 1087	7	**11**	17	12	15	-	25	62	49	51	748
VCC 1185	8	**14**	87	15	15	-	31	45	40	90	388
VCC 1199	6	32	20	33	**18**	68	68	81	49	93	390
VCC 1355	7	**9**	17	12	13	24	24	51	43	75	57
VCC 1407	5	16	16	87	**15**	42	42	45	30	113	58
VCC 1431	5	26	72	28	**11**	54	53	70	56	126	106
VCC 1440	3	11	**4**	79	27	43	43	64	47	109	63
VCC 1489	5	15	70	65	**7**	33	33	66	25	56	80
VCC 1545	3	12	**11**	63	20	40	40	79	40	88	365
VCC 1627	4	29	65	60	**17**	103	65	104	109	93	369
VCC 1828	5	**12**	17	15	13	32	32	68	54	67	262
VCC 1871	7	35	24	103	**14**	69	69	108	84	129	251
VCC 1910	8	27	26	56	**13**	53	53	66	80	126	151

Conclusions

We have compared the surface photometry of 27 early-type galaxies from the Virgo Cluster with 10 projected theoretical mass density profiles. From 10 profiles studied, only the Hubble, Jaffe, Navarro-Frenck-White and Plummer density models provide a reasonable description, once projected, of the observed luminosity profile. The residuals for these models are comparable to those of the Sérsic law, considered the standard description of light profiles of early-type galaxies. The results can be used to classify galaxies according to their mass distribution. Besides, the analysis gives observational support for theoretical dynamical models, since one may infer from it the galaxy tridimensional mass distribution. The following stage will be apply this analysis to a sample of 40 000 of early-type galaxies from the SPIDER survey to invetigate if the mass distribution among galaxies is multimodal and how the mass distribution correlates with another structural parameteres.

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