Deviations of the Surface Brightness Distribution in Isolated Elliptical Galaxies

Omar Basil Mohammad Saleh
Department of Physics / College of Education
University of Mosul

Received 11 / 03 / 2012 **Accepted** 02 / 05 / 2012

الملخص:

تم في هذا البحث، دراسة منحنيات السطوع السطحي لـ 48 مجرة اهليجية معزولة. حيث تم استخدام نموذج – $r^{1/n}$ ومطابقته مع منحنيات المجرات المعزولة للمديات الشعاعية الوسطى $0.1\leq\left(\frac{R}{R_e}\right)\leq1.5$. من خلال الحصول على أفضل ملائمة مع المنحنيات، تم الحصول على منحنيات الانحرافات بين الأرصاد والنموذج المعتمد. وبينت النتائج إن الانحرافات هي مماثلة إلى الدراسات السابقة، وعلى ضوء نتائج البحث اتضح إن الانحرافات لا تعتمد على محيط بيئة المجرة سواء إن كانت معزولة أو غير معزولة، وبالتالي مثل هذه النتائج تؤدي إلى فهم اكبر لتطور وتركيب البنية للمجرات الاهليجية.

Abstract:

In this paper, we present the surface brightness profiles of 48 isolated elliptical galaxies. we have adopted the $r^{1/n}$ – law to the observed surface brightness profiles of the adopted sample of isolated elliptical galaxies for the intermediate radial range $0.1\leq\left(\frac{R}{R_e}\right)\leq1.5$. From best fitting profile. The results showed that the deviations are similar to previous studies, and the deviations do not depend on the surrounding environment of the galaxies, whether that were an isolated or not. Such results might be very useful to understand the structure and evolution of elliptical galaxies.

1. Introduction:

A more recent result is that the surface brightness profile of elliptical galaxies frequently deviates from the $r^{1/4}$ – law, the "universal"

$r^{1/n}$ – law (equation 1) has provided the best fit in many instances (Caon et al. 1993). The parameter n takes values typically between 1 and 15, and is related to the effective radius and to the absolute magnitude of the galaxy (Trujillo et al. 2001).

$$\mu(R)=\mu_e+1.0857b_n\left[\left(\frac{R}{R_e}\right)^{1/n}-1\right] \quad \ldots (1) \quad \text{(Sersic, 1968)}$$

where μ_e is the surface brightness at the effective radius R_e that encloses half of the total light of the model, the constant b_n is defined in terms of the parameter n which describes the 'shape' of the light profile, a good approximation is $b_n \approx 2n-0.327$ for $1 \le n \le 15$ (Trujillo et al., 2001).

The study of Isolated elliptical galaxies important to driven the processes of the structure and evolution of galaxies (Pamela et al., 2004). Isolated elliptical galaxies provide a useful control sample, typically found in highly clustered regions of the universe. There are two kinds of isolated elliptical, low environmental density and close companions (Jack, 2009). Karachentseva (1973) was chosen his catalogue (KIG) about 1000 isolated galaxies with m_B< 15.7 from the Zwicky et al. (1957) catalogue which is known to be biased against surface brightness galaxies. Colbert et al. (2001) has studied 30 isolated early-type galaxies, selected from the Third Reference Catalog (RC3; de Vaucouleurs et al. 1991) catalogue. Galaxies were selected to have no catalogued neighbours within 1 h^{-1} 100 Mpc (where $h = H_0/100\ km\ s^{-1}\ Mpc^{-1}$) and ±1000 $km.s^{-1}$. However, some of the target galaxies themselves had luminosities only slightly greater than the catalogue limit. This means that some candidate isolated galaxies actually have nearby neighbours of quite similar luminosity. Reda et al. (2004) defined a 36 nearby isolated early-type galaxies, his isolation criteria have no comparable-mass neighbours within radial velocities V < 9000 km s^{-1}, 2 B-band magnitudes, 0.67 Mpc in the plane of the sky and 700 km s^{-1} in recession velocity. Karachentseva et al. (2010) presented a list of 75 isolated late-type dwarf galaxies with criteria have no neighbors with a relative radial velocity difference of less than 500 km/s or projected separations within 500 kpc. These were selected from ~ 2000 dwarf galaxies with radial velocities in Local Group V_{LG} < 3500 km/s within the volume of the Local super cluster. In previous studies of the deviation of the light profiles, Burkert (1993) has studied the intermediate axis surface brightness distribution of elliptical galaxies, He has shown that the $r^{1/4}$ – law provides an excellent fit to the observed brightness distribution within the radius range $0.1R_e \le R \le 1.5R_e$, with mean deviations $<\delta\mu>$ smaller than 0.1 mag $arcsec^{-2}$ and the maximum deviations smaller than 0.2 mag $arcsec^{-2}$. Younis (2000a,b) has studied the systematic deviation from the $r^{1/4}$ – law for two samples of elliptical galaxies and he found that the mean deviation are less than 0.12 mag arcsec^{-2}, for one sample and less than 0.09 mag.arcsec^{-2} for the other. Recently, Younis and Basil (2011), have studied the surface brightness profiles of 46 elliptical galaxies, belong to Coma Cluster of galaxies have been fitted by $r^{1/n}$ – law for the intermediate radius range $0.1R_e \le R \le 1.5R_e$. The mean deviations <δμ> found to be less than 0.03 mag arcsec^{-2}. The deviation profiles between the observations and the adopted models show that the maximum negative deviation found to be around the reduced radius of 0.86, while the maximum positive deviation were found to be around the reduced radius of 0.96. The crossing points between the adopted models and the observed surface brightness profiles were found to be around the reduced radius 0.65, 0.83 and 1.0.

In this work, has been adopted the Deviations of the Surface brightness distribution in Isolated Elliptical galaxies to drive the photometry parameter, were analyzed the surface brightness distribution of 48 isolated elliptical galaxies with the model proposed by $r^{1/n}$ – law for the radial range $0.1 \le \left(\frac{R}{R_e}\right) \le 1.5$, 43 galaxy selected from data published by Fasano and Bonoli, (1989) and 5 galaxy from Reda et al. (2004).

2. Data selection and Reduction:

Our sample content a 43 galaxy was selected from a published paper by (Fasano & Bonoli, 1989), these galaxies was selected from the UGC (Uppsala General Catalog of Galaxies) catalogue (Nilson, 1973), the galaxies are calssified as ellipticals in catalogue. The observation were done with 1.82 m telescope in Asiago (Ekar), Italy. The scale (CDD) was 0.290 arcsec.pixel^{-1} and the filed size format of 385 × 578.

For the 5 galaxy from Reda et al. (2004), candidate isolated early-type galaxies was taken from the Lyon-Meudon Extragalactic Data Archive (LEDA). From this catalogue Reda selected galaxies that the following criteria: (i) morphological type $T \le -3$; (ii) Virgo corrected recession velocity $V \le 9000$ km s^{-1}; (iii) apparent magnitude $B \le 14.0$; the observation of galaxies in the B- band and R-band images were obtained using the 3.9 m Anglo-Australian Telescope, with a pixel scale of 0.229 arcsec.pixel^{-1} giving a field of view of 30.6 × 30.6 arcmin^2.

Figure (2) shows the distribution of these galaxies as a function of their absolute magnitude M_B. Here in this papers, it has adopted the Sersic law ($r^{1/n}$ – law) to determine the fitting between $r^{1/n}$ – law and the observed surface brightness profiles of the adopted sample of isolated elliptical galaxies for the intermediate radial range $0.1 \le \left(\frac{R}{R_e}\right) \le 1.5$, this range cover more than 60 % of the total luminous mass which provides a good representation of the distribution of the visible matter (Burket 1993).

The effective radius R_e for the adopted radial range was determined in a self-consistent method. The first estimated value for the R_e was derived from the $r^{1/n}$ – law using the ***lsqcurvefit*** function of the ***MatLab package***.

$$\mu(x) = \mu_o + 1.0857 b_n \left(\frac{R}{R_e} \right)^{1/n} \qquad \dots (2)$$

Where $b_n \cong 2n - 0.327$, $\mu_o = \mu_e - 1.0857 b_n$

For this new value of R_e a new range of radius is updated as $0.1\, R_e^{1/n} \le R^{1/n} \le 1.5\, R_e^{1/n}$ then the procedure of the fitting is repeated to updated the value of R_e and then the range of radius until converged R_e was obtained. For each galaxy of the adopted sample, the deviation profiles $\delta\mu(x)$ from the best fitting $r^{1/n}$ – law and the mean deviation $< \delta\mu >$ were determined using the following two equations

$$\delta\mu(x) = \mu(x) - \mu_s(x) \qquad \dots (3)$$

$$< \delta\mu > = \frac{1}{\sqrt{N}} \left[\sum_i^N \left(\mu(x_i) - \mu_s(x_i) \right)^2 \right]^{\frac{1}{2}} \qquad \dots (4)$$

Where $\mu(x)$ is the observed surface brightness profiles, $\mu_s(x)$ is the best fitting $r^{1/n}$ – law to the surface brightness profiles, and N is the total number of the data points within the radial range

4. Results and Discussion:

Figure (1) shows the observed surface brightness profiles, the best fitting $r^{1/n}$ – law, and their deviation from its models for the 48 isolated elliptical galaxies. All galaxies of the sample in figure (1) contains a top and bottom figure. The top of the figure shows the surface brightness and their best fitting and bottom figure shows the deviations from the $r^{1/n}$ – law, the deviation profiles shows 65% of the sample have a negative deviation (i.e. the surface brightness of the galaxy brighter than $r^{1/n}$ – law) and 35 % of the sample have a positive deviation (i.e. the surface brightness of the galaxy fainter than $r^{1/n}$ – law) at the inner parts of galaxy (small radii). The derived parameters are listed within table (1): Column 1 - 13, name of galaxy, type of galaxy, absolute magnitude (M_B), mean deviation $<\delta\mu>$, effective radius of the intermediate range radii (R_e), shape parameter (n), the radial position at reduce radius of the first crossing point (r'_{C1}), the radial position of the second crossing point (r'_{C2}), the radial position of the third crossing point (r'_{C3}), the position of the top of the hump (r'_{p+}), the maximum positive deviation (p_+), the position of the bottom of the dip (r'_{p-}), and the last column is maximum negative deviation (p_-).

Figure (3) shows the distribution of the isolated elliptical galaxies as a function of their mean deviation <δμ>, the most of the galaxies were found to be less than (0.035) mag.arcsec^{-2}. Figure (4) shows the position of the top of the hump of the deviation profiles for the sample which is found at the reduced radius $r'_{p+} = 0.95$, while figure (5) shows the bottom of the dip of the deviation profiles for the sample of galaxies which is found to be at the reduced radius $r'_{p-} = 0.81$. The radial position of the crossing points (r'_c) (i.e. the points at which the deviations change their signs) have been found for each galaxy. The first crossing points, the second and the third, for all galaxies of the sample found to be around the reduced radius $r'_{C1} \cong 0.63$, $r'_{C2} \cong 0.8$ and $r'_{C3} \cong 0.95$ see figure (6,7,and 8).

Although the sample that chosen in this study, consists of isolated galaxies, the results showed that the deviations between the observed and the models proposed for the sample's galaxies found to be similar to the previous results, therefore the deviations do not depend on the surrounding environment of the galaxies.

5. References:

1) **Burkert, A., (1993)** "*Do Elliptical Galaxies Have $r^{1/4}$ Brightness Profiles?*". Astro. & Astrophys., 278, 23-28.
2) **Caon, N., Capaccioli, M., D'Onofrio, M., (1993)** "*On The Shape Of The Light Profiles Of Early-Type Galaxies*". Mon. Not. Roy. Astro. Soc., 256, 1013.
3) **Colbert, J. W.; Mulchaey, J. S.; Zabludoff, A. I.** (2001), "*The Optical and Near-Infrared Morphologies of Isolated Early-Type Galaxies*", A. J., 121, 808C.
4) **De Vaucouleurs, G., De Vaucouleurs, A., Corwin JR., Buta R. Paturel G. and Fouque P. (1991)** "*third Reference Catalogue of Bright galaxies*". RC3, M 0000d.
5) **Fasano, G. & Bonoli, C. (1989)** "*Isophotal twisting in isolated elliptical galaxies* " A&AS, 79, 291F.
6) **Jack Sulentic, (2009)**, "*Isolated Galaxies History of Research and Ideas Over the Past 40 Years*", International Conference on Isolated Galaxies, May 12th – 15th, Granada, Spain.
7) **Karachentseva V. E., (1973)**, "*The Catalogue of Isolated Galaxies*" Astrof. Issledovanija Byu. Spec. Ast. Obs., 8, 3 k.
8) **Karachentseva V. Karachentsev I., Sharina M., (2010)**, "*isolated dwarf galaxies in the local supercluster and its surroundings*", Astrophysics, Vol. 53, No. 4.
9) **Nilson, P., (1973)**, "*Uppsala General Catalogue Of Galaxies*" Acta Universitatis Upsalienis, Nova Regiae Societatis Uppsalienis, Series V: A Vol. 1.

10) **Pamela M., Christian E., Michael N., 2004**, "*early-type galaxies in extremely isolated environments: typical ellipticals?*", Astro. J. 127: p3213-3234.

11) **Reda, F., Forbes. D., Beasley, M., O'Sullivan, E., Goudfrooij, P. (2004)**, "*The photometric properties of isolated early-type galaxies*", Mon. Not. Roy. Astro. Soc., 354, 851R

12) **Sersic, J. L., (1968)** *Atlas de Galaxias Australes (Cordoba: Observatorio Astronomico, Universidad de Cordoba)*

13) **Trujillo, I., Aguerri, J. A. L., Cepa, J., Gutierrez, C. M., (2001)** "*The Effects of Seeing On Sersic Profiles*". Mon. Not. Roy. Astro. Soc., 321, 269-276.

14) **Younis, S. M., (2000a)** "*Systematic Deviations From $r^{1/4}$ ed Vaucouleurs Law In Elliptical Galaxies*". J. Edu. Sci., 41.

15) **Younis, S. M., (2000b)** "*Surface Brightness Profiles In Early-Type Galaxies: A Study Of The Small Deviations From The $r^{1/4}$ Law*". J. Edu. Sci., 42, 77.

16) **Younis, S. M., Basil O. M., (2011)** "*Deviations of the Light Distribution from the Sersic's model in Elliptical galaxies*". J. Edu. Sci., 24.

17) **Zwicky F. et al. (1957)**, "*Catalog of Galaxies and Clusters of Galaxies*" V.1 1-6 California Inst. Tech. Pasadena.

Table (1)

galaxy	Type*	$-M_B$ * (mag.)	<δμ> mag arcsec^{-2}	X_e arcsec	n	r'_{C1}	r'_{C2}	r'_{C3}	r'_{P+}	P+	r'_{P-}	P-
NGC 7796	E (cD)	20.93	0.0270	45.049	5.662	0.667	0.740	0.844	0.699	0.0416	0.789	-0.0289
ESO 318-G021	E?	20.94	0.0279	35.109	7.956	0.694	0.777	0.863	0.817	0.0384	0.733	-0.0387
NGC 2865	E3-4	20.83	0.0231	21.069	3.891	0.671	0.843	1.027	0.773	0.0330	0.917	-0.0349
NGC 821	E6	20.82	0.0356	5.223	1.880	0.485	0.779	1.134	0.955	0.0478	1.231	-0.0739
ESO 153-G003	E	21	0.0183	54.028	8.398	0.739	0.779	0.837	0.940	0.0300	0.869	-0.0284
UGC 236	E	19.88	0.0204	5.336	2.693	0.682	0.813	0.964	0.890	0.0340	0.766	-0.0361
UGC 741	E	20.84	0.0281	8.279	5.121	0.732	0.818	0.921	0.868	0.0430	0.785	-0.0379
UGC 881	E	20.97	0.0140	13.805	4.863	0.776	0.871	0.959	0.909	0.0206	1.036	-0.0226
UGC 1030	E	19.23	0.0293	6.783	2.288	0.589	0.899	1.125	0.982	0.0494	1.215	-0.0464
UGC 1043	E	19.26	0.0375	8.599	2.279	0.673	0.887	1.098	0.974	0.0702	0.788	-0.0503
UGC 1503	E	20.46	0.0302	8.218	1.147	0.541	0.847	1.141	1.289	0.0463	0.749	-0.0416
UGC 1543	E	21.07	0.0378	19.304	3.522	0.561	0.779	0.947	1.079	0.0446	0.859	-0.0602
UGC 1788	E	22.05	0.0258	13.706	2.496	0.577	0.677	0.799	1.067	0.0406	0.985	-0.0484
UGC 2022	E	19.54	0.0403	7.968	2.515	0.502	0.679	0.855	0.797	0.0415	0.577	-0.0870
UGC 2656	E	19.87	0.0398	9.513	2.808	0.536	0.674	0.836	0.603	0.0643	0.754	-0.0508
UGC 2717	E	20.13	0.0126	17.523	6.215	0.741	0.822	0.901	0.975	0.0291	0.960	-0.0218
UGC 2957	E	21.12	0.0151	231.43	11.21 5	0.630	0.673	0.726	0.702	0.0317	0.663	-0.0205
UGC 3307	E	19.23	0.0375	9.615	4.574	0.657	0.895	1.024	0.961	0.0601	1.052	-0.0619
UGC 3646	E	21.41	0.0399	15.605	4.080	0.593	0.759	0.943	0.651	0.0586	0.864	-0.0491
UGC 4782	E	21.31	0.0319	6.206	1.626	0.676	0.859	1.202	1.374	0.0438	0.753	-0.0359
UGC 5705	E	17.90	0.0384	9.489	2.289	0.552	0.795	1.049	0.663	0.0591	0.908	-0.0585

galaxy	Type*	$-M_B$ * (mag.)	<δμ> mag arcsec^{-2}	X_e arcsec	n	r'_{C1}	r'_{C2}	r'_{C3}	r'_{P+}	P+	r'_{P-}	P-
UGC 5955	E	17.30	0.0138	9.476	2.776	0.602	0.782	0.945	1.076	0.0170	1.124	-0.0168
UGC 6159	E	17.49	0.0229	206.13	12.529	0.688	0.713	0.754	0.732	0.0396	0.699	-0.0350
UGC 6504	E	21	0.0375	10.824	4.381	0.649	0.805	1.011	0.936	0.0415	0.702	-0.0626
UGC 6671	E	21.48	0.0358	4.994	2.518	0.588	0.753	0.966	0.848	0.0376	0.602	-0.0588
UGC 6810	E	20.64	0.0211	12.853	6.191	0.710	0.923	1.012	1.032	0.0190	0.977	-0.0248
UGC 7115	E	20.87	0.0425	8.731	5.189	0.733	0.872	1.006	0.933	0.0460	0.759	-0.0533
UGC 7224	E	20.72	0.0276	22.898	7.049	0.699	0.763	0.631	0.924	0.0374	0.965	-0.0480
UGC 7681	E	18.73	0.0197	17.153	1.835	0.454	0.743	1.021	0.906	0.0301	0.574	-0.0249
UGC 7767	E	18.11	0.0350	5.444	2.461	0.579	0.783	1.039	0.882	0.0343	1.095	-0.0479
UGC 7838	E	19.72	0.0334	14.714	1.447	0.380	0.655	1.014	0.771	0.0473	0.753	-0.0484
UGC 7988	E	21.21	0.0236	12.101	3.897	0.616	0.704	0.850	0.929	0.0324	0.785	-0.0291
UGC 8376	E	23.09	0.0296	9.955	2.888	0.545	0.736	0.976	0.849	0.0311	0.611	-0.0475
UGC 8453	E	22.64	0.0327	13.169	5.138	0.661	0.749	0.893	0.815	0.0462	0.962	-0.0485
UGC 8779	E	22.74	0.0250	11.279	4.126	0.566	0.664	0.814	0.731	0.0364	0.592	-0.0404
UGC 9070	E	18.13	0.0228	25.573	4.564	0.629	0.784	0.936	0.957	0.0588	0.887	-0.0326
UGC 9278	E	20.32	0.0380	11.752	4.970	0.638	0.715	0.819	0.981	0.0597	0.874	-0.0518
UGC 10103	E	20.63	0.0347	6.043	4.188	0.691	0.849	0.992	1.144	0.0391	0.728	-0.0613
UGC 10352	E	20.98	0.0258	2.798	1.784	0.643	0.785	0.911	0.806	0.0313	0.757	-0.0532
UGC 10410	E	21.25	0.0347	12.288	4.329	0.625	0.731	0.911	0.793	0.0329	0.665	-0.0658
UGC 10467	E	19.70	0.0169	12.570	2.873	0.621	0.869	1.109	1.184	0.0227	1.019	-0.0250
UGC 10595	E	18.71	0.0230	14.968	5.603	0.709	0.811	0.929	0.755	0.0412	0.866	-0.0278
UGC 10695	E	22.84	0.0179	25.015	3.736	0.559	0.732	0.959	1.011	0.0253	0.886	-0.0175
UGC 10827	E	21.22	0.0283	23.688	6.279	0.614	0.686	0.843	0.814	0.0201	0.629	-0.0392
UGC 10836	E	21.39	0.0188	32.874	5.655	0.613	0.676	0.761	0.717	0.0292	0.639	-0.0313
UGC 11605	E	20.83	0.0358	20.868	5.601	0.652	0.765	0.920	0.869	0.0246	0.685	-0.0503
UGC 12002	E	19.86	0.0231	13.177	3.032	0.557	0.803	1.079	1.100	0.0417	0.910	-0.0307
UGC 12733	E	21.57	0.0231	25.989	4.114	0.574	0.721	0.806	0.679	0.0291	0.773	-0.0428

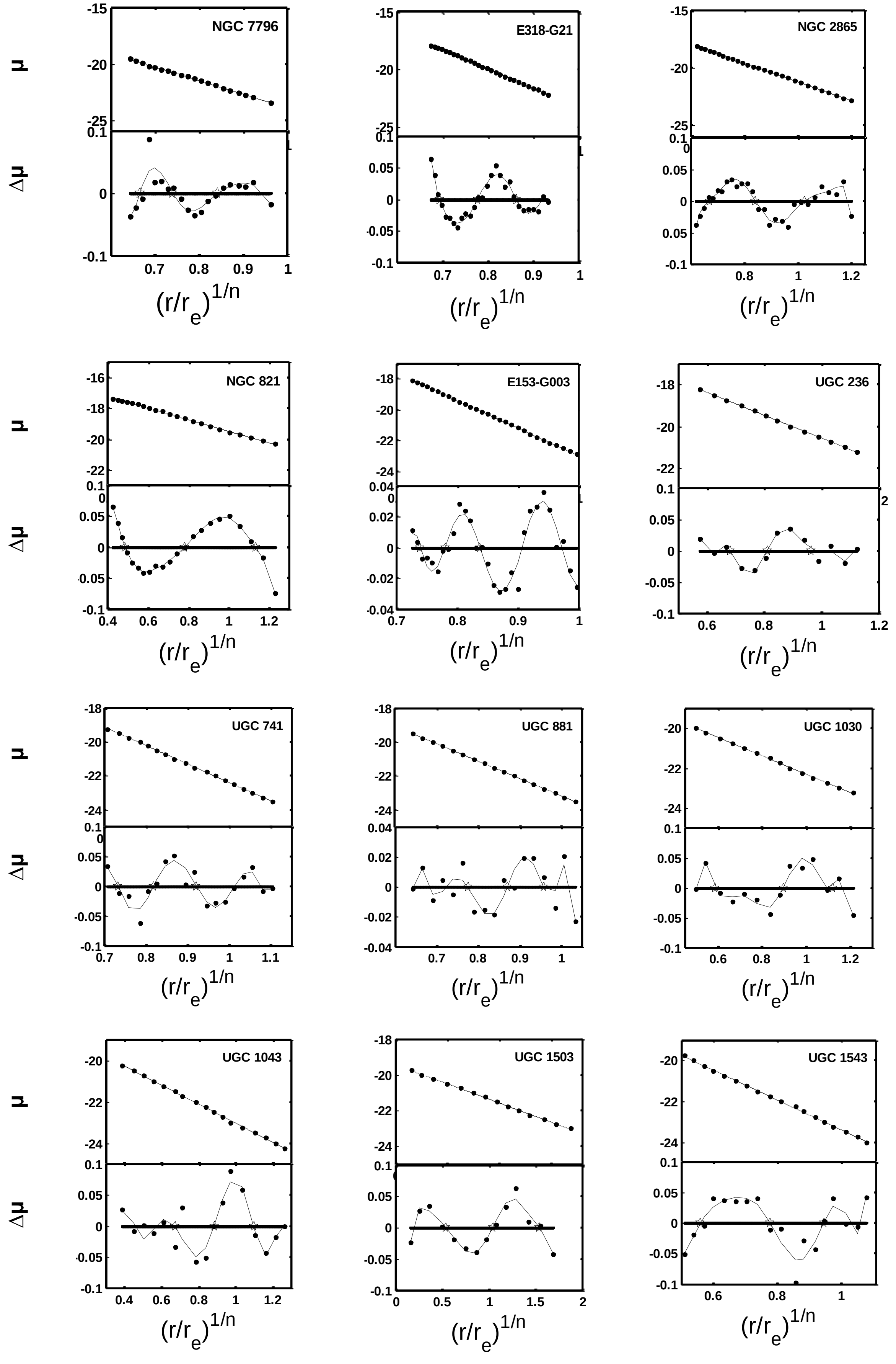
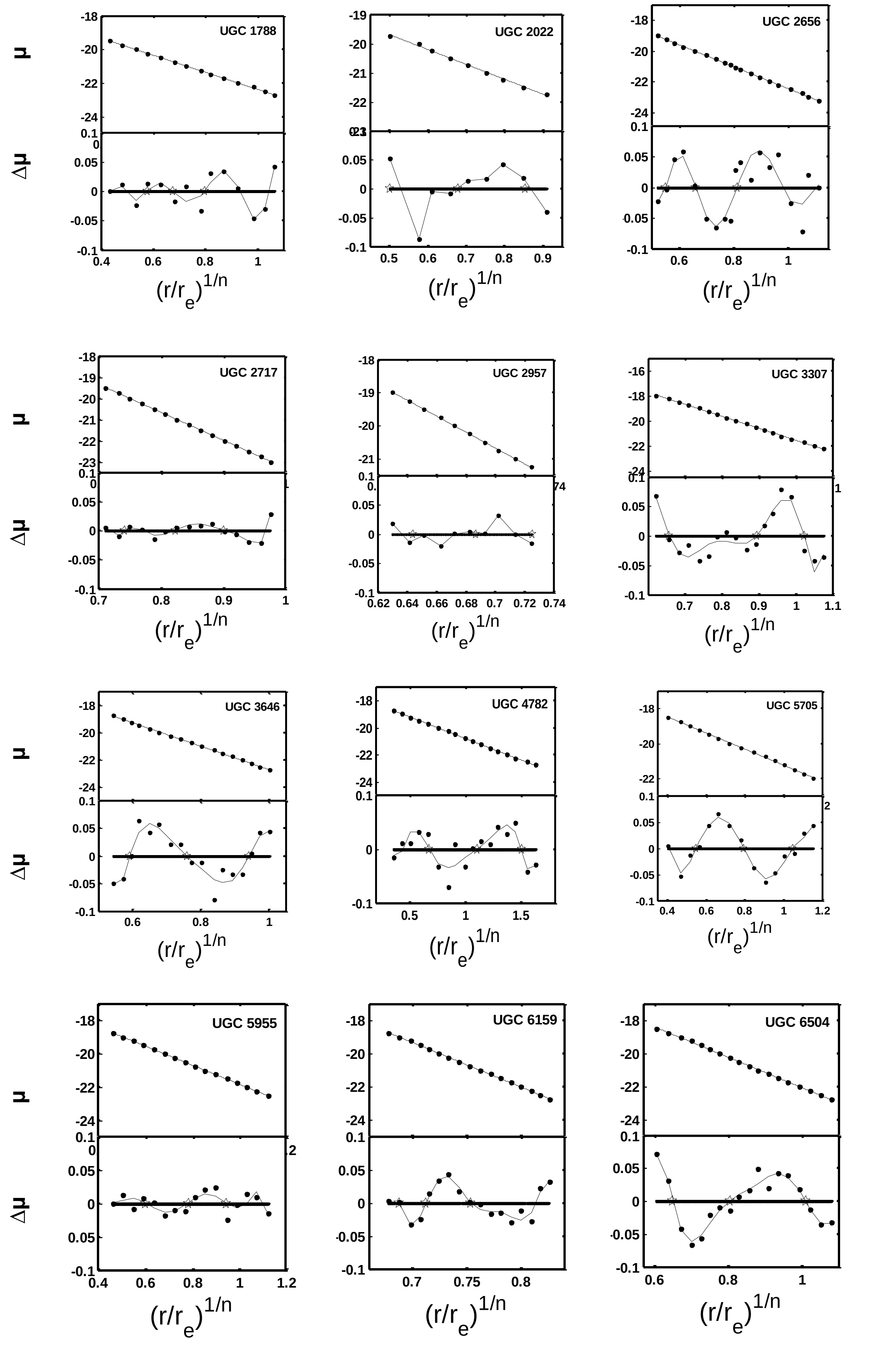
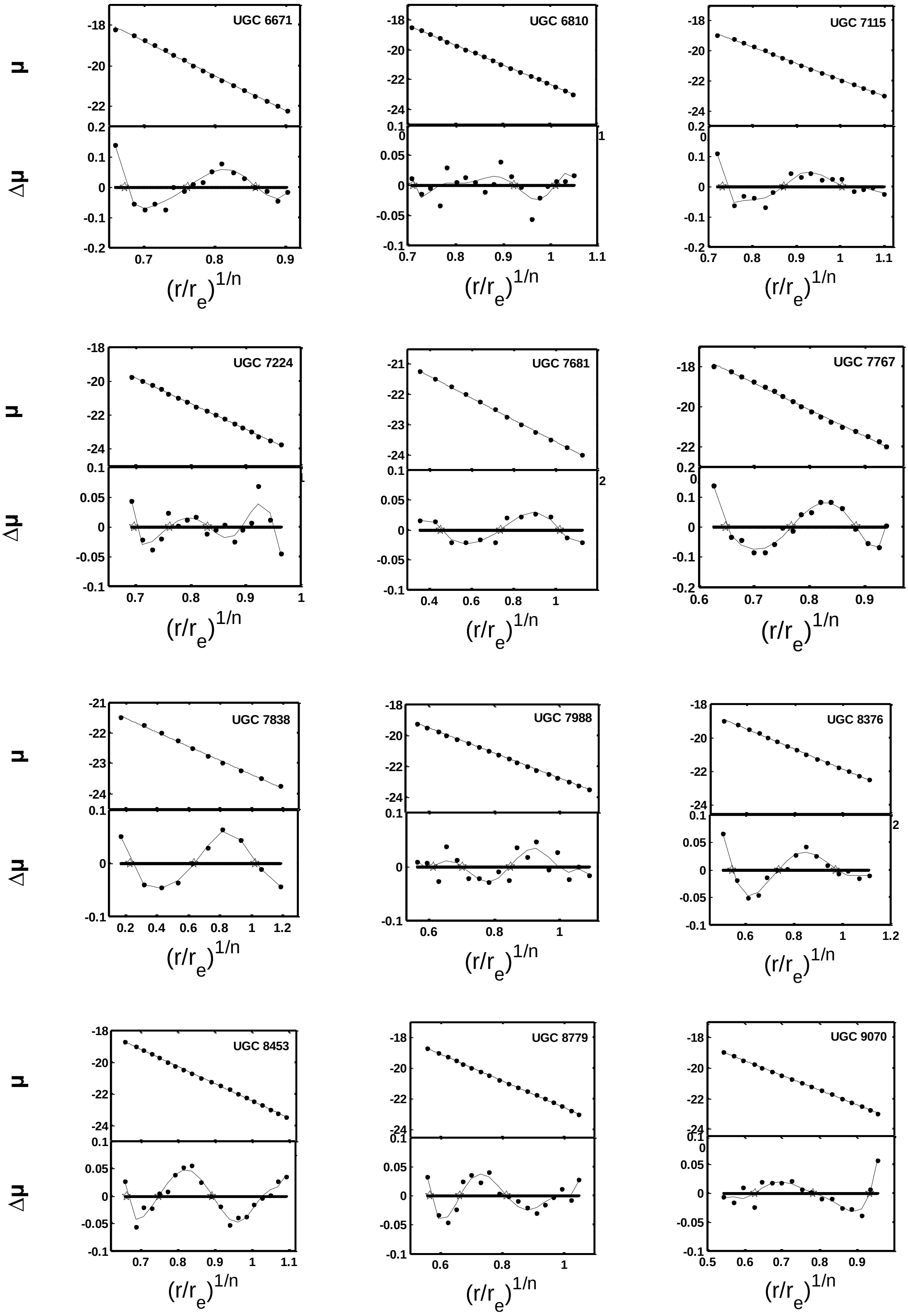


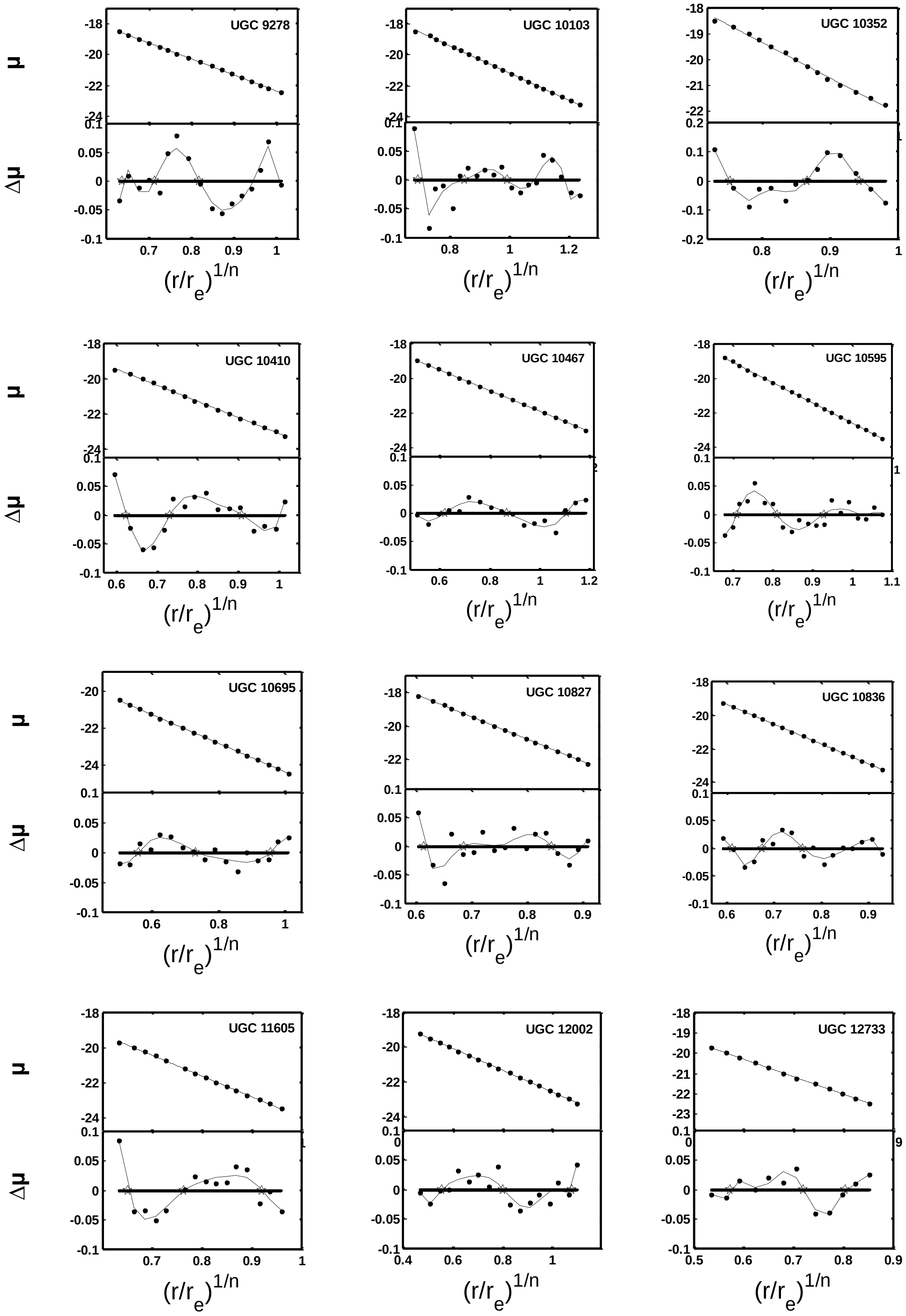
Figure (1): represent the surface brightness profiles (μ) and its deviations (Δμ) agents radius range of $r^{1/n}$ for isolated elliptical galaxies: the point is the observations, solid line is the $r^{1/n}$ - law



Complement – Figure (1)



Complement – Figure (1)



Complement – Figure (1)

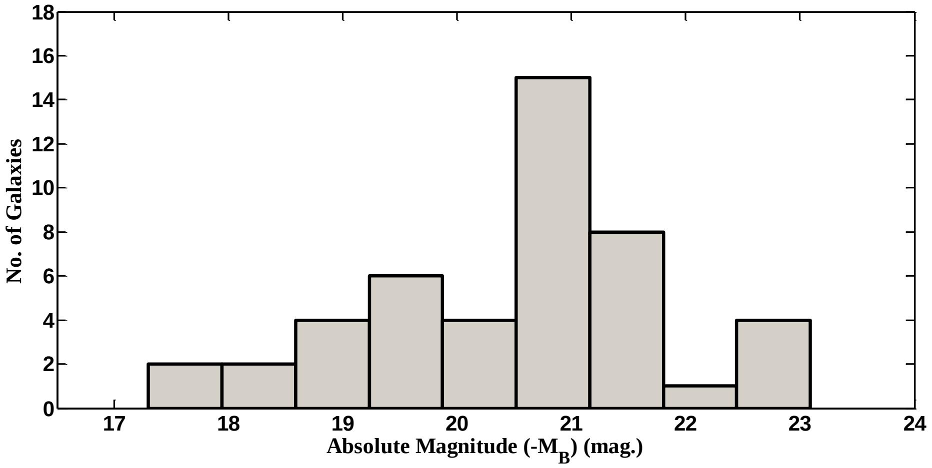


Figure (2): The distribution of the isolated elliptical galaxies as a function of their absolute magnitude

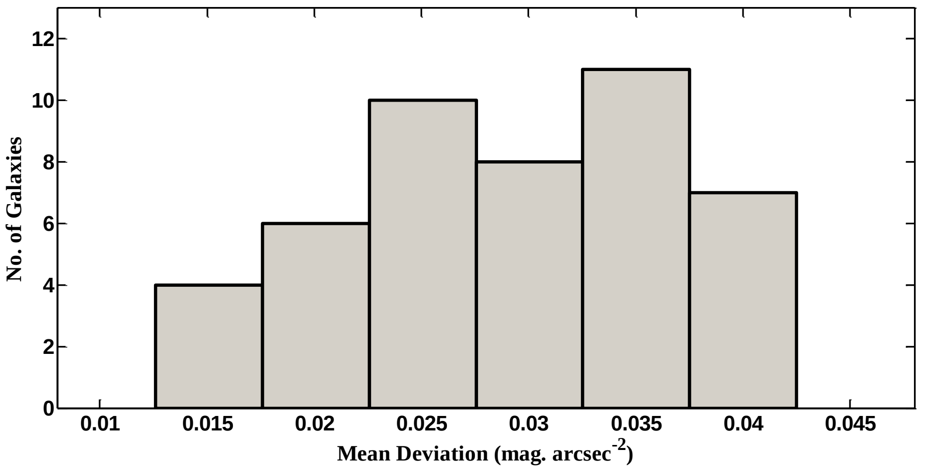


Figure (3): the number of isolated Elliptical galaxies is shown as a function of their mean deviations <δμ>

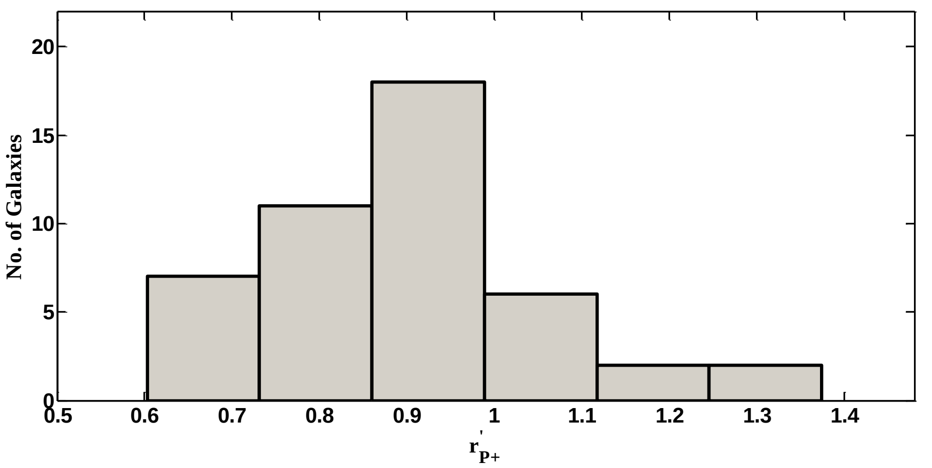
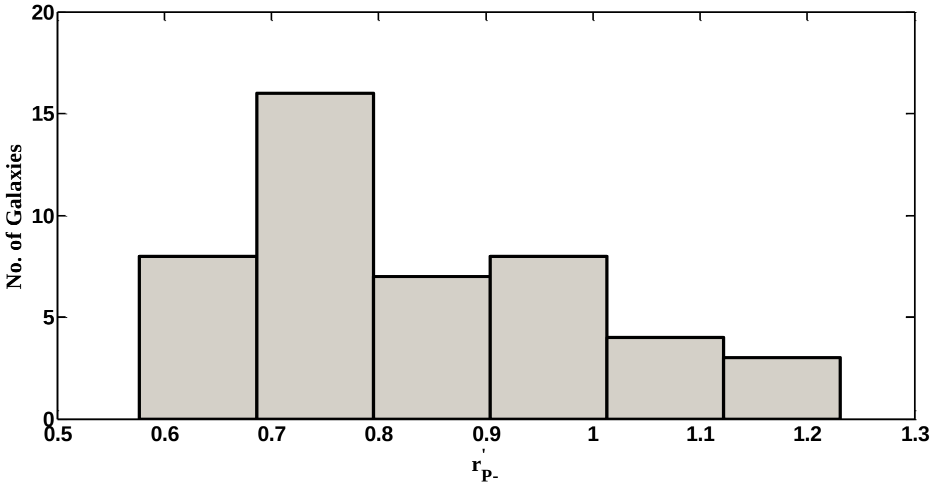


Figure (4): The radial position of the maximum positive deviation (top of the hump) r'_{P+}



Figure(5): The radial position of the maximum negative deviation (Lower point) r'_{P-}

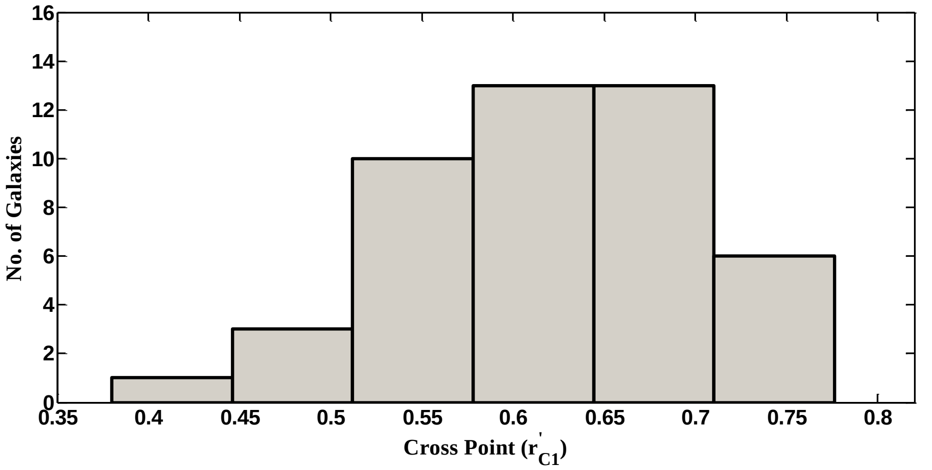


Figure (6): The radial position of r'_{C1}

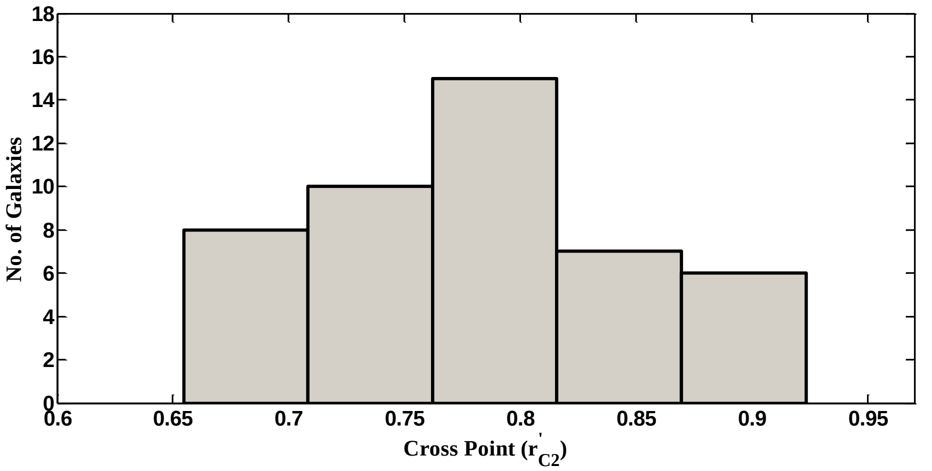
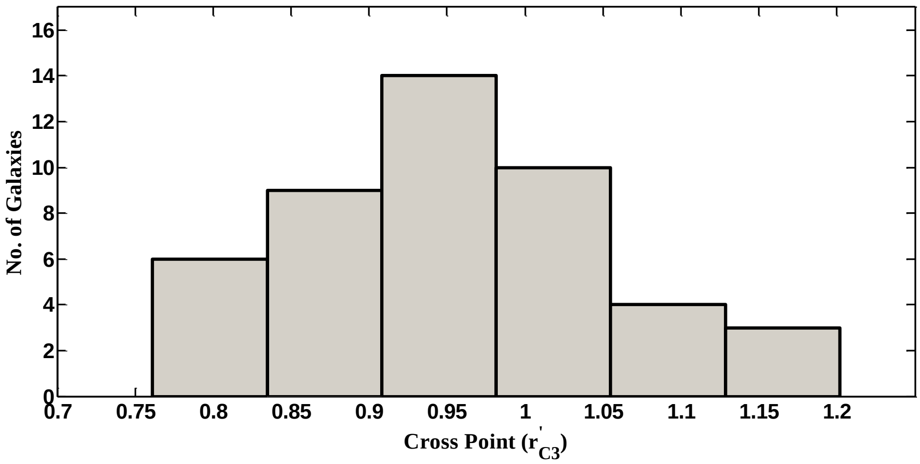


Figure (7): The radial position of r'_{C2}



Figure(8): The radial position of r'_{C3}

Table (2)

Deviation Parameters	Burkert (1993)*	Younis (2000a)*	Younis (2000b)*	Younis & Basil (2011)**	The present research**
$<\delta\mu>$	0.1	0.12	0.09	0.03	0.035
r'_{p+}	----	----	0.85	0.96	0.95
r'_{p-}	0.8	0.8	0.75	0.83	0.81
r'_{C1}	----	----	----	0.65	0.63
r'_{C2}	----	----	----	0.83	0.8
r'_{C3}	----	----	----	1.0	0.95

*** = Deviation Parameters were derived by $r^{1/4}$ – law**
**** = Deviation Parameters were derived by $r^{1/n}$ – law**