31st ASI Meeting
ASI Conference Series, 2013, Vol. 9, pp 53 – 57
Edited by Pushpa Khare & C. H. Ishwara-Chandra

A study of the triaxial mass models and their projected properties

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Abstract. We study the projected properties of some triaxial mass models. We develop a methodology to use ensemble of mass models to study the orientations of elliptical galaxies and intrinsic shapes of very flat elliptical galaxies. We attempt the orientation and shape estimates using photometric data alone. The orientations and intrinsic shapes are given by a Bayesian probability distribution. We apply the method to infer the orientation and shape of a galaxy, using the ellipticities and the difference in the position angles at two suitably chosen points from the profiles of the photometric data. We find the expectation values and most probable values constitute a summary of the shape of galaxies. The expected as well as most probable values of the short to long axial ratios of our calculation agree extremely well with the values reported by other workers.

Keywords : galaxies : photometry - galaxies : structure

1. Introduction

Intrinsic shapes and orientations of the individual elliptical galaxies have been investigated by e.g. Binney (1985), Tenjes et al. (1993), Statler (1994) and Bak and Statler (2000). These authors have used the kinematica and photometric data, and have used the triaxial models. It was shown analytically that the projected density distribution is stratified on similar and co-aligned ellipses (Binney 1985). Statler (1994) uses (apart from the kinematial data) a constant value of ellipticity, which is an average over a suitably chosen range of the radial distances, for the shape and the orientation estimates. A complementary problem was attempted by Chakraborty et al. (2008), wherein variation in the intrinsic shapes of the light distribution of elliptical galaxies

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was investigated by using triaxial models, which exhibit ellipticity variation and position angle twist. These models are fixed by assigning the values of axial ratios (p_0, q_0) and (p_∞, q_∞) at small and at large radii, respectively. These axial ratios are related to triaxialities T_0 and T_∞, respectively, at small and large radii.

2. Models

A triaxial generalization of Dehnen's spherical density distribution $\rho(r)$ (Dehnen, 1993) is made triaxial by considering the distribution $\rho(r)$ is given by

$$\rho(M) = \frac{(3-\gamma)M_0 b}{4\pi PQ} M^{-\gamma}(b+M)^{-4+\gamma}, \qquad (1)$$

where M_0 is the mass of the model, and $0 \leq \gamma < 3$. These models are presented in Chakraborty (2004) and are modified in Chakraborty and Diwakar (2011). We shall refer to these models as **$\mathbf{M^2}$ models**.

Another form of triaxial generalization of Dehnen's model is presented in deZeeuw and Carollo (1996), the density distribution of the form

$$\rho \quad = \quad f(r) - [g(r) + g_1(r)]Y_2^0 + [h(r) + h_1(r)]Y_2^2, \qquad (2)$$

In above, $f(r)$, $g(r)$, $h(r)$ and the parameters $r_1..r_4$ are the same as in deZeeuw and Carollo. $g_1(r)$ and $h_1(r)$ are introduced in Chakraborty and Diwakar (2011). We shall refer to these as **fgh models**.

3. Orientations

The observed data are obtained from R-band photometry of Peletier et al. (1990) and Franx et al. (1989). While using this data to calculate the probability of orientation and shape, we consider the uncertainty of 0.02 in ellipticities, and the uncertainty of $1^o.0$ in position angles both at R_{in} and R_{out}.

We now apply the methodology based on Bayesian statistics described in Statler (1994). The list of elliptical galaxies alongwith the observed data used in the models is presented in Chakraborty and Diwakar (2011) and Table 1 presents the statistical summary of the orientation estimates of ten galaxies. Fig. 1 presents the plots of the posterior probability distribution $\mathcal{P}$ of the orientation as a function of polar coordinates (θ', ϕ') of the line of sight, for NGC 7619. Here, we use M^2 models with $\beta = 0.2, 1.0$, and 5.0 and fgh models with $\alpha = 0.0, 2.5$ and 5.0 and take the unweighted sum of the probability over all these models. The probability is shown in dark-grey shade : darker the shade, higher is the probability. The white contour encloses 68% of the total probability which can be interpreted as 1σ error bar.

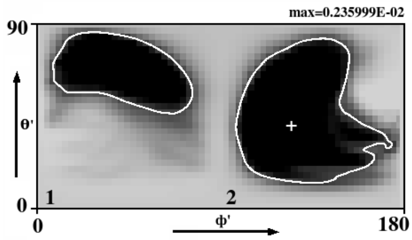

Figure 1. Plot of the posterior probability distribution $\mathcal{P}$ as a function of (θ', ϕ') for NGC 7619 in octants (1, 2). Plus marks the location of the maximum probability.

Table 1. Summary of the orientation estimates.

Galaxy	θ'_p	ϕ'_p	$< \theta'_p >$	$< \phi'_p >$	HPD
NGC 1052	79.5	139.5	58.7	87.6	34.1%
NGC 1407	13.5	127.5	40.0	93.4	33.0%
NGC 2986	31.5	118.5	46.4	93.8	27.4%
NGC 3379	16.5	88.5	40.6	90.0	55.3%
NGC 4261	35.5	91.5	43.7	90.4	46.6%
NGC 4374	67.5	175.5	44.4	79.0	26.5%
NGC 4486	73.5	10.5	49.4	75.6	11.0%
NGC 4551	88.5	142.5	54.0	88.3	45.6%
NGC 5638	16.5	37.5	44.5	84.3	17.0%
NGC 7619	40.5	106.5	50.7	95.5	27.9%

4. Intrinsic shapes of very flat elliptical galaxies

The elliptical galaxies of our present investigation are very flat, with ellipticity typically around 0.3 or more. The morphological classification of NGC 720, 2768 and 3605 are $E5/E3, E6/E5$ and $E4/E5$ respectively, from $RC2$ catalogue. We use the ensemble of M^2 models, with $\beta = 5.0, 2.5, 1.0, 0.5$ and 0.2. Integrating the marginal posterior density over all possible values of T_0 and T_∞, and taking unweighted sum over all models, we obtained shape estimates $\mathcal{P}$ as a function of (q_0, q_∞). Fig. 2 presents the shape estimate of the galaxy NGC 720 and Table 2 presents the statistical summary of the shape estimate of the galaxies NGC 720, NGC 2768 and NGC 3605.

Table 2. Statistical summary of the intrinsic shape estimates of the galaxies.

Galaxy	q_{0p}	$q_{\infty p}$	$\|T_d\|$	$< q_0 >$	$< q_\infty >$	$< \|T_d\| >$	HPD
NGC 720	0.68	0.38	0.41	0.56	0.40	0.41	19.2%
NGC 2768	0.68	0.28	0.22	0.62	0.33	0.39	8.5%
NGC 3605	0.68	0.43	0.16	0.60	0.41	0.37	16.6%

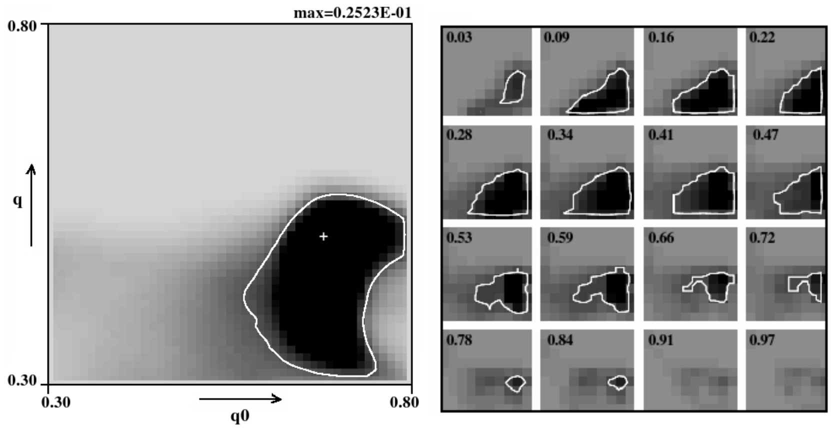

Figure 2. Left: Plot of marginal posterior density ($\mathcal{P}$) as a function of $q_0, q_\infty(= q)$, summed over various values of (T_0, T_∞). Right: three dimensional plot of MPD ($\mathcal{P}$) as a function of $q_0, q_\infty, |T_d|$, for NGC 720. Values of $|T_d|$ are constant in each section. In each section, q_0 goes from the left to right hand side from 0.25 to 0.75, and q_∞ runs between the same values from the bottom to the top.

5. Results and discussions

We have demonstrated that photometry can be used to obtain constraints on the orientations of the light distribution of elliptical galaxies, especially for the galaxies with large position angle difference. We have obtained possible orientations of ten elliptical galaxies. We have presented the intrinsic shapes of 3 very flat galaxies. The specific feature of these estimates is the choice of the lover limit of q_0 and q_∞. We find that these galaxies are little rounder inside (average value of $< q_0 >\sim 0.6$), but very flat outside (average value of $< q_\infty >\sim 0.3$).

Acknowledgements

I would like to thank the coordinator, IUCAA reference centre and Pt. Ravishankar Shukla University, for the technical support.

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