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Study of the intrinsic parameters of some mass models of elliptical galaxies

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Abstract. Determination of intrinsic shapes of individual elliptical galaxies using photometry is an important problem because the number of galaxies with good photometry is many more than those with good kinematics. We determine the intrinsic shapes and prior density which is called as flat prior reported by Chakraborty et al. (2008) and Singh & Chakraborty (2009). Our results are presented as plots showing the intrinsic shapes of the galaxies as a function of (q_0, q_∞) for 2 and $(q_0, q_\infty, |T_d|)$ for 3 dimensional shapes, where q_0 and $q_\infty (= q)$ are the short to long axial ratios at small and at large radii and $|T_d|$ is the absolute value of the triaxiality difference, defined as $|T_d| = | T_\infty - T_0|$. The probability is shown in grey scale: darker is the region higher is the probability.

Keywords : galaxies: general – galaxies: fundamental parameters – galaxies: photometry

1. Introduction

Statler and his coworkers (e.g. Statler 1994) have used kinematical data along with photometric data for constraining 3-dimensional shapes of elliptical galaxies, Fasano (1995) has given another important method for constraining the shapes of galaxies wherein he uses only photometric data. Statler (1994) uses a constant and average value of ellipticity. He uses pair of the shape parameters, namely, the short to long axial ratio c_L of the light distribution and the triaxiality T_M of the mass distribution. We allow all possible values of the axial ratios, and investigate the shape described by four parameters $(q_0, T_0, q_\infty, T_\infty)$, where T_0 and T_∞ are the triaxialities at small and at large radii, respectively. We use the ellipticities ϵ_{in}, ϵ_{out} and the position angle

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difference $\Theta_{out} - \Theta_{in}$ at two suitably chosen points R_{in} and R_{out} from the profiles of the photometric data of the galaxies.

2. Models

We consider triaxial model of form

$$\rho(r, \theta, \phi) = f(r) - g(r)Y_2^o(\theta) + h(r)Y_2^2(\theta, \phi) , \tag{1}$$

where (r, θ, ϕ) are the spherical coordinates. The functions $Y_2^0 = \frac{3}{2}\cos^2\theta - \frac{1}{2}$ and $Y_2^2 = 3\sin^2\theta\cos 2\phi$ are the usual spherical harmonics. These models exhibit ellipticity variations and isophote twists in their projections (de Zeeuw & Carollo 1996; Chakraborty & Thakur 2000). We shall refer to these models as fgh models. We now have another form of triaxial generalization as presented in Chakraborty (2004), with r replaced by M, $M^2 = x^2 + y^2/P^2 + z^2/Q^2$ with varying axial ratios $P^{-2}(M)$ and $Q^{-2}(M)$. We shall now refer to these models as M^2 model. To modify the fgh model, we consider the density same as in de Zeeuw & Carollo, (1996). To modify the M^2 model, we redefine $P^2(M)$ and Q^{-2} in terms of (q_0, q_∞) with α and β parameter. The parameter α and $\beta > 0$ alters the values of (P, Q) in the intermediate region.

3. Methodology for the determination of intrinsic shapes of elliptical galaxies

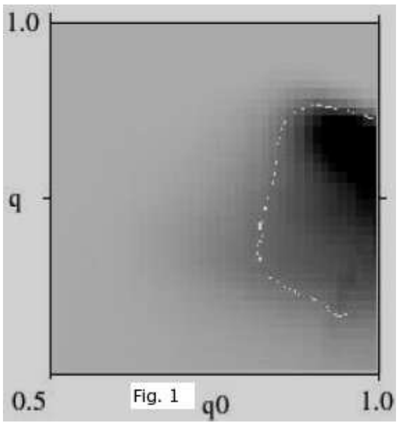
The likelihood of obtaining the observed data from the model is given by

$$\mathcal{L}(\mathbf{o}_{ob}, \mathbf{o}_{cal}) = \mathcal{N} exp\{-\sum_{j=1}^{N} \frac{(o_{ob}^j - o_{cal}^j)^2}{2\sigma_j^2}\}, \tag{2}$$

where $\mathcal{N}$ is the normalization factor, and σ_j is the error in o_{ob}^j. The probability (posterior density) of obtaining the data is the product of the likelihood and the parent distribution (prior density). It is necessary that the likelihood be a sharply peaked function, so that the probability is relatively insensitive to the parent distribution. This is called a 'likelihood-dominated' posterior density. Integrating the posterior density over the 'uninteresting' parameters (θ', ϕ') one obtains the marginal posterior density P. Here, (θ', ϕ') are the viewing angles.

4. Variation in the intrinsic shapes of individual elliptical galaxies

We use the ensembles of the models to investigate the intrinsic shapes. The data are obtained from R-band surface photometry of Peletier et al. (1990). Fig.1 shows that



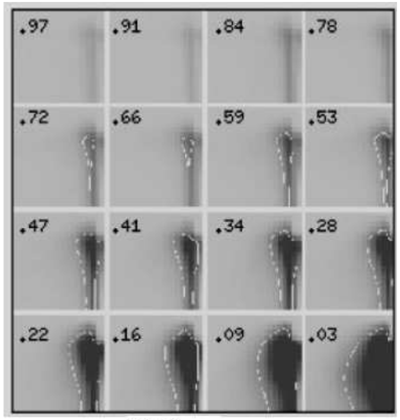
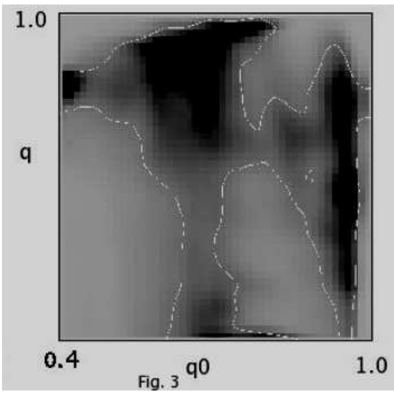


Fig. 2



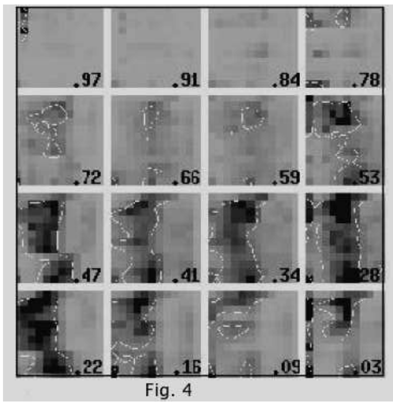


Figure 1. Plot of marginal posterior density (MPD) as a function of $q_0, q_\infty (= q)$ where q_0, $q_\infty (= q)$ are the axial ratios at small and at large radii, summed over various values of (T_0, T_∞). **Figure 2**. 3-dimensional plot as a function of $q_0, q_\infty, |T_d|$, for NGC 3379. Values of $|T_d|$ are constant in each section. q_0 and q_∞ run as in Fig.1. **Figure 3**. 2-dimensional plot of the distribution as a function of q_0, q_∞. **Figure 4**. 3-dimensional plot of the distribution as a function of $q_0, q_\infty, |T_d|$ for 20 galaxies using modified prior.

Table 1. Summary of the 3-dimensional shape estimates using flat and modified prior

Galaxy	$< q_0 >$	$< q_\infty >$	$< \|T_d\| >$	q_{0P}	$q_{\infty P}$	$\|T_{dP}\|$	Type	Prior
NGC 3379	0.88	0.72	0.29	0.93	0.78	0.03	RF	Flat
NGC 3379	0.81	0.70	0.26	0.93	0.78	0.03	RF	Modified

the axial ratios at small and at large radii are well-constrained. Although, T_0 and T_∞ are not constrained, we find that the triaxiality difference T_d is constrained indicating that marginal posterior density (MPD) is higher for smaller T_d (Chakraborty et al. 2008). We find that NGC 3379 is rounder inside and flatter outside and NGC 4589 is flatter inside and rounder outside in Table 1.

5. Distribution of the intrinsic shapes of elliptical galaxies

The shapes $\mathcal{P}(q_0, q_\infty)$ and $\mathcal{P}(q_0, q_\infty, |T_d|)$ as calculated using a flat prior for 20 galaxies are superimposed over each other to obtain the distribution. This is regarded as a modified prior. Shapes of 20 galaxies are recalculated using this prior. Superimposing these over each other, we obtain the distribution shown in Figs 3 & 4. This iterative procedure is due to Bak & Statler (2000).

6. Conclusions and future prospects

We find variations in the intrinsic shapes of elliptical galaxies, using photometric models exhibiting ellipticity variations and position angle twists. Our results on flattening agree well with the previous results given in the literature. We determine the intrinsic shapes of the light distribution of 20 elliptical galaxies by using a flat and modified prior. We find that axial ratios at small and at large radii are well-constrained shape parameters. However, the triaxiality can not be constrained by photometry. We find constraints only in the absolute value of the difference in triaxialities. As a future programs, we would like to determine the intrinsic shapes of large number of elliptical galaxies using high order residual terms. Also we would like to study the velocity field.

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