ON THE DETERMINATION OF GALAXY STRUCTURE ELLIPTICITY

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ABSTRACT. We discuss factors influencing the determination of the observed shape of galaxy clusters when the covariance ellipse method is involved. The analysis of 377 Abell clusters show that at greater distances from the cluster center the ellipticity is rather smooth. There were no statistical differences among ellipticities when the cluster center was located at the brightest cluster member, the third brightest galaxy, the mean as well as the median values of galaxy coordinates. Moreover, we show that for rich galaxy clusters the distribution of ellipticities is the same for two totally different cluster samples.

Key words: galaxy clusters, properties;

1. Introduction

Galaxies form different structures, some are less, some are more numerous. The shape of the structure is an important parameter. Various scenarios of galaxy origin predict different shape of structures. One of the most popular method of finding the intrinsic, three dimensional shape of structure is based on the observed, projected, this is two dimensional shape of structure. Before going into the problems dealing with inversion of the distribution of the apparent shape of galaxy clusters we would like to concentrate on the first stage of investigation, this is on the determination of the observed shape of galaxy clusters. There are several methods of shape determination. The most popular is fitting the covariance ellipse; inertia tensor method and Minkowski functionals can be regarded as some other ones. Our paper is oganised in the following manner. Section two describes the applied method of analysis, this is standard covariance ellipse method, while section three presents our observational data. The main results of our work are given in section four, while conclusions ends the paper.

2. The covariance ellipse method

We used covariance ellipse method (Carter & Metcalfe, 1980) to obtain galaxy cluster ellipticity. The method is based on first five moments of the observed distribution:

$$M_{10} = \frac{1}{N} \sum_i x_i \tag{1}$$

$$M_{01} = \frac{1}{N} \sum_i y_i \tag{2}$$

$$M_{20} = \frac{1}{N} \sum_i x_i^2 - \left(\frac{1}{N} \sum_i x_i \right)^2 \tag{3}$$

$$M_{02} = \frac{1}{N} \sum_i y_i^2 - \left(\frac{1}{N} \sum_i y_i \right)^2 \tag{4}$$

$$M_{11} = \frac{1}{N} \sum_i x_i y_i - \frac{1}{N^2} \sum_i x_i \sum_i y_i \tag{5}$$

where x_i and y_i are galaxy coordinates. The centroid of the contour is: $x_0 = M_{10}$, $y_0 = M_{01}$. The semi - principal axes are the solution λ_u and λ_v of the quadratic equation:

$$(M_{20} - \lambda^2)(M_{02} - \lambda^2) - M_{11}^2 = 0, \tag{6}$$

the eigenvalues of the matrix of moments of the distribution. The cluster ellipticity is given by:

$$e = 1 - \sqrt{\frac{1 - \epsilon}{1 + \epsilon}} \tag{7}$$

where

$$\epsilon = \frac{\sqrt{(M_{20} - M_{02})^2 + 4M_{11}^2}}{M_{20} + M_{02}} \tag{8}$$

3. Observational data

We selected all Abell clusters with galactic latitude $|b| > 40°$ and Richness Class≥ 1. In such way we obtained 1238 clusters. We take all clusters with redshift $z < 0.2$ determined by Struble & Rood, (1999). In such manner our sample contains 377 Abell clusters. For each of these clusters the area covering 2x2 Mpc on the sky ($h = 0.75$, $q_0 = 0.5$) was extracted from DSS. A catalogue contains objects within the magnitude range m_3, $m_3 + 3$ where m_3 is the brightness of the third brightest galaxy in the investigated area. The catalogues were obtained applying FOCAS packages to DSS. Afterwards, the automatically obtained catalogues were visually corrected. Each catalogue contains information about right ascension, declination of galaxies, x and y galaxy positions on the photographic plate, instrumental magnitude, area of object, ellipticity and position angle.

The PF Catalogue (Panko & Flin, 2006) served as a second source of data. The catalogue contains 6188 structures having more than 10 members. These structures were extracted from Münster Red Sky Survey galaxy catalogue (MRSS hereafter). MRSS is the result of a large-scale galaxy survey in the red spectral region, covering an area of 5,000 square degrees, and forming one of the largest coherent data base for cosmological investigations in the southern hemisphere (Ungruhe et al., 2003).

We selected the Voronoi tessellation technique (VTT hereafter) for cluster detection (Panko and Flin, 2004), Icke and van de Weygaert (1987), Ramella et al. (1999, 2001). This technique is completely non-parametric, and therefore sensitive to both symmetric and elongated clusters, allowing correct studies of non-spherically symmetric structures with non-uniform galaxy background (Kim et al., 2002). The search of over dense region was made using the procedure *kiang*, the corn of the VGCF (Voronoi Galaxy Cluster Finder), an automatic package for the identification of galaxy clusters in photometric, two-dimensional galaxy catalogues (Ramella et al., 1999)

For each structure in our catalogue, further analysis was carried out individually. The structures with at least 10 galaxies in the considered area were included to our catalogue. For galaxies in brightness lying inside the magnitude limits m_3, $m_3 + 3^m$, calculations were carried out. For each structure, the covariance ellipse was inscribed, considering only galaxies above the mentioned magnitude limit. This allows us to determine the ellipticity and the position angle of the structure.

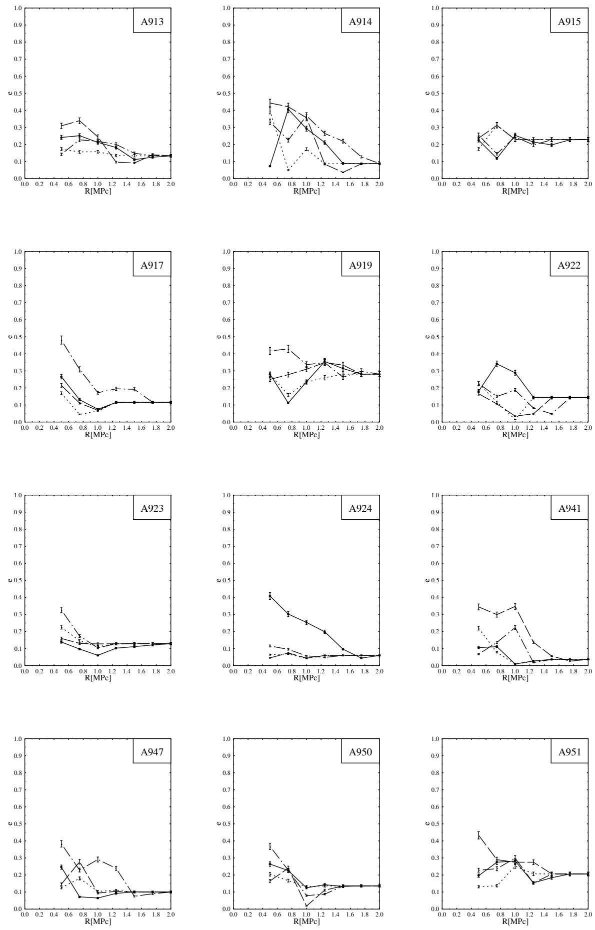

Figure 1: The change of the cluster ellipticity with the distance from the cluster center.

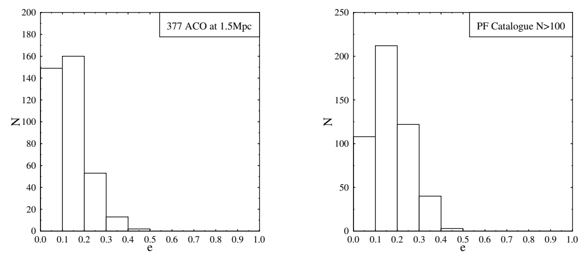

Figure 2: The ellipticity distribution for 377 ACO clusters ($R = 1.5Mpc$), the mean coordinates of galaxy positions accepted as cluster center and ellipticity distribution for structures having more than 100 members in the PF Catalogue.

Table 1: The statistics of cluster center influence

The λ statistcs for K-S test for $R = 1.5$Mpc

	The brightest galaxy	third brigtest	median	mean
The brightest galaxy	X	0.137	0.780	0.876
third brightest	0.137	X	0.932	0.823
median	0.780	0.932	X	0.109
meana	0.876	0.823	0.109	X

The λ statistcs for K-S test for $R = 1.75$Mpc

	The brightest galaxy	third brigtest	median	mean
The brightest galaxy	X	0.069	0.151	0.069
third brigtest	0.069	X	0.178	0.082
median	0.151	0.178	X	0.041
mean	0.069	0.082	0.041	X

The λ statistcs for K-S test for $R = 2.0$Mpc

	The brightest galaxy	third brigtest	median	mean
The brightest galaxy	X	0.041	0.041	0.041
third brigtest	0.041	X	0.055	0.041
median	0.041	0.055	X	0.000
mean	0.041	0.041	0.000	X

4. Results

We used covariance ellipse method (Carter & Metcalfe, 1980) to obtain galaxy cluster ellipticity. It is well known that ellipticity depends also on the distance from the cluster center (e.g. Carter & Metcalfe (1980), Flin (1984), Trevese et al. (1992), Struble & Ftaclas (1994)). The influence of this fact was checked studying the cluster ellipticity at various distances from the cluster center. We calculated the ellipticity in circular rings for the distance range from 0.5 Mpc to 2 Mpc with the step 0.25 Mpc. We used four methods for cluster center determination: the mean position of all galaxies, the brightest galaxy in the cluster, the third brightest galaxy in the cluster and the median of galaxy coordinates. For these four galaxy cluster center determinations we calculated ellipticities at distances described above (Fig. 1). For the significance level $\alpha = 0.01$ (the critical value $\lambda_{0.01} = 1.627$) the Kolmogorov - Smirnow test confirmed the similarity of the distributions. The Table 1 present the values of the Kolmogorov - Smirnow test statistics for various centers at $r \geq 1.5 Mpc$.

The observed ellipticity distributions for structures with various number of members, as given in PF Catalogue are different. Using the Kolmogorov - Smirnow test we found that the distribution of cluster ellipticities in the case of 377 ACO clusters and very rich galaxy clusters, this is containing 100 and more members in the PF Catalogue are identical at the confidence level $\alpha = 0.01$.

5. Conclusions

The main goal of this work was to check the influence of different factors to the determined projected ellipticity of galaxy cluster. The ellipticity of projected galaxy clusters depends on the radial distance from the cluster center. In projection, close to the center, clusters are more elongated than at greater distances. Moreover, the changes of ellipticity nearby the center are great, the parameter is noisy. At greater distance from the center the run of ellipticity is usually quite smooth. Therefore, we decided to use in all analyses cluster ellipticity determined at 1.5 Mpc. We checked also the ellipticity distribution at greater radii (r=1.5 Mpc and 2 Mpc), but we do not find statistically significant differences. The influence of the adopted cluster center is negligible. This conclusion is based on the analysis of the ellipticity distributions at greater distances from the cluster center, when four different cluster centers were considered, namely: the brightest cluster galaxy, the third brightest member, the average and the median of galaxy coordinates. We checked the distribution of ellipticities for various structures in the PF Catalogue. These distributions strongly depend on the structure richness. For rich clusters, the distributions of ellipticities in both data set were identical.

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