The Alignment of rich ACO galaxy structures

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We analysed the existence of the Binggeli effect in 377 rich ACO (Abell et al., 1989) galaxy clusters taken from Digital Sky Survey I with known morphological types and redshift z<0.2. We searched for an excess of small values of the acute angle $\Delta\theta$, measured as the difference between the direction toward neighbouring clusters and the direction of the cluster position angle. The strongest effect was found for Bautz–Morgan (Bautz & Morgan, 1970, hereafter BM) type I clusters with ellipticities e>0.2.

1 Introduction

Galaxy cluster alignment has been discussed by several authors. The first was Binggeli (1982) who found that galaxy clusters tend to be aligned pointing towards each other. This effect was reported for distances from $10h^{-1}$ Mpc to $150h^{-1}$ Mpc, with the effect decreasing with distance (Struble & Peebles, 1985; Flin, 1987; Rhee & Katgert, 1987; Ulmer et al., 1989; Plionis, 1994; Chambers et al., 2002). The investigation was performed for two different ranges of the electromagnetic spectrum: optical and X-ray. Large-scale computational simulations were made to better understand the processes leading to cluster alignment. Many different cosmological models were considered like the LCDM model (Onuora & Thomas, 2000), where the effect was found for distance up to 30 h^{-1}Mpc; tCDM models where the range of the effect is a factor of two smaller; and SCDM and OCDM models where some alignment effect could be noted when simulations were performed at smaller scales. In the paper by Biernacka et al. (2015) the Binggeli effect was found in rich ACO clusters taken from the PF Catalogue (Panko & Flin, 2006). The effect was found for elongated clusters with ellipticities e≥0.4 for BM type I and III and for structures with separation distance R≤$45h^{-1}$Mpc.

2 Observational basis

The 377 ACO clusters were selected from Digital Sky Survey I with galactic latitude b>40°, richness class ≥ 1 and redshift z<0.2 (Struble & Rood, 1999). The area covering 2 x $2Mpc^2$ around each cluster was extracted. Applying the FOCAS package to DSS I, we obtained catalogues of galaxies, considering objects within the magnitude range (m_3, m_3+3), where m_3 is the magnitude of the third brightest galaxy.

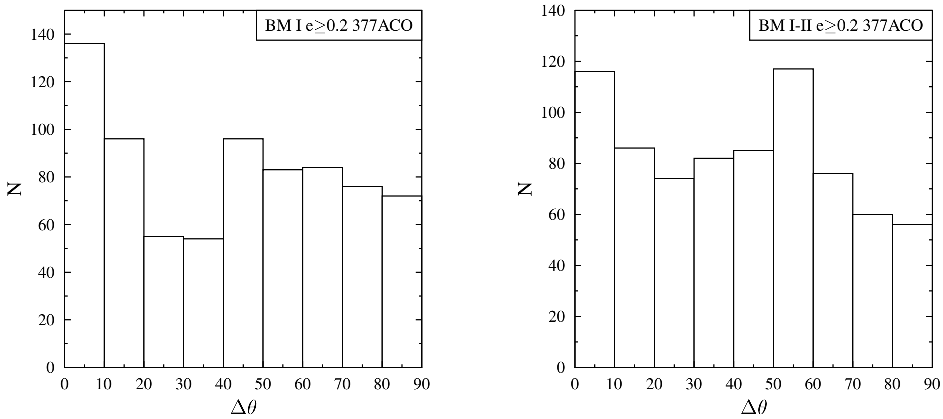

Fig. 1: Binggeli effect for ACO clusters with BM type I and I–II and ellipticity e≥0.2.

The catalogues obtained automatically were visually corrected in order to reduce the classification error.

3 Method

The method used to determine the shape of galaxy clusters (ellipticity and position angle) was the covariance ellipse method (Carter & Metcalfe, 1980). This is based on the first five moments of the observed distribution of galaxy coordinates x_i, y_i. The structure ellipticity was calculated from:

$$e = 1 - \frac{\lambda_2}{\lambda_1}, \tag{1}$$

where λ_i are the semi-major axes of the fitted ellipse. The position angle of the major axis was calculated as:

$$tan2\theta = \frac{2M_{11}}{M_{20} - M_{02}}, \tag{2}$$

where M_{ij} are second statistical moments of the galaxy distribution. The Binggeli effect was checked by studying the distribution of the acute angle $\Delta\theta$ between the direction toward neighbouring clusters and direction of the cluster position angle.

4 Results and Conclusions

We used the Kolmogorov-Smirnov test to investigate the isotropy of the $\Delta\theta$ angles. At a significance level of α=0.05, the value λ_{cr}=1.358. During the analysis of λ values we found statistically significant anisotropy in two cases. The fist one is observed in BM type I with ellipticity $e \geq 0.2$ and λ=1.417, and the second for BM type I–II with the same range of ellipticity and λ=1.376.

- We found the alignment of elongated clusters with e≥0.2. The effect is observed only in the sample containing elongated clusters, because the cluster ellipticity is a not well defined parameter, especially for nearly round clusters.

- The effect was also found in BM type I and type I–II with e≥0.2 (Fig. 1); this was expeceted for BM I due to the special role of CD galaxies during formation.
- It is possible that the origin of galaxy clusters was not a unique, homogeneous process and various factors influenced this process.

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