The orientation of rich galaxy clusters

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We present an analysis of spatial orientations of galaxies in 377 optically selected rich Abell clusters (Abell et al., 1989) with redshift $z < 0.2$. We investigated the relation between angles that give information about galaxy angular momenta and the number of members in each structure.

1 Introduction

One of the most important aim of cosmology and modern extragalactic astronomy is to solve the problem of structure formation. There are many theoretical models describing scenarios of structure formation (Peebles, 1969; Zel'dovich, 1970; Sunyaev & Zeldovich, 1972; Doroshkevich, 1973; Shandarin, 1974; Dekel, 1985; Wesson, 1982; Efstathiou & Silk, 1983; Bower et al., 2006). The crucial goal is to discriminate among different models of galaxy formation. An investigation of the orientation of galaxies in clusters is regarded as a standard test of theories of galaxy and large-scale structure formation. An interesting problem emerges in the case of dependence of the alignment on the mass of the structure. Godłowski et al. (2005) suggested that the alignment of galaxies in a cluster should increase with the richness of cluster. The suggestion made by those authors was already confirmed by Aryal et al. (2007) (based on the series of papers by Aryal & Saurer 2004, 2005, 2006 and Godłowski et al. 2010). Therefore, in this paper we checked if the alignment of galaxies in clusters depends on the number of their constitutive members.

2 Observational data

We selected all Abell clusters from Abell/ACO Catalogue (Abell et al., 1989) with galactic latitude $b > 40°$, richness class ≥ 1, and with redshifts $z < 0.2$ (Struble & Rood, 1999). Therefore, 377 Abell clusters remained to be analysed. The area covering $2 \times 2\,\mathrm{Mpc}^2$ ($h = 0.75$, $q_0 = 0.5$) around each cluster was extracted from DSS (digital sky survey). We obtained catalogues of galaxies, considering objects within the magnitude range of $(m_3,\ m_3 + 3)$ in the studied area, where m_3 is the magnitude of the third brightest galaxy, applied the FOCAS packages to the regions extracted from DSS. Each catalogue contains information about the right ascension and declination of each galaxy, galaxy coordinates, x and y, on the photographic plate, instrumental magnitude, object area, galaxy ellipticity and the position angle of the major axis of the galaxy image.

3 Method of investigation

In this method, we analysed the distribution of galactic position angles p and the galaxy's inclination i with respect to the observer line of sight. Two possible orientations of the galaxy plane were determined, which gave two possible directions

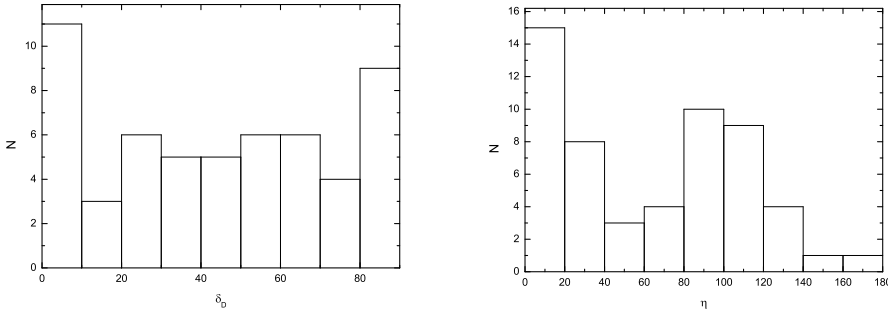

Fig. 1: Left: Distribution of the δ_{D} angles for cluster A756. Right: Distribution of the η angles for cluster A756.

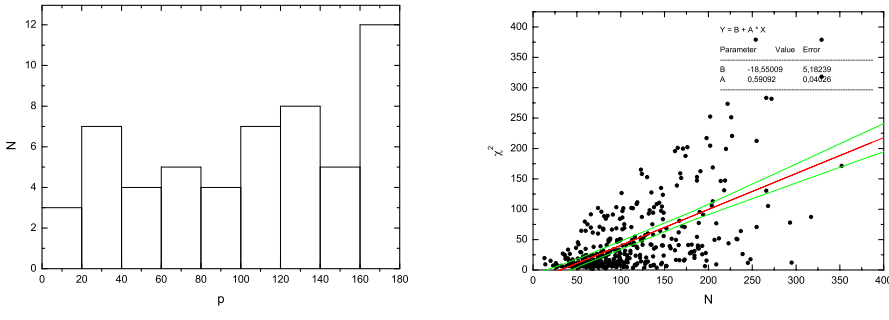

Fig. 2: Left: Distribution of the position angles for cluster A756. Right: Relation between the number of galaxies in the cluster N and the value of analysed statistics χ^2 for δ_{D} angles.

perpendicular to the galaxy plane. For each galaxy, two angles are determined: δ_{D} – the angle between the normal to the galaxy plane and main plane of the coordinate system and η – the angle between the projection of this normal onto the main plane and the direction toward the zero initial meridian. On the Fig. 1 both panels, and Fig. 2 left panel, we show the distribution of the δ_{D} angle, η angle and position angle of galaxies for one example cluster – ACO 756. In order to detect non-random effects in the distribution of the investigated angles, we carried out χ^2 statistical test. We found that the values of the statistics increase with the amount of the galaxies members (e.g. Fig.2 right panel), which is equivalent to the existence of a relation between anisotropy and the number of galaxies in a cluster.

4 Conclusions

We analysed the alignment of galaxies belonging to 377 Abell clusters. Using statistical test, we confirmed the suggestion of Godłowski et al. (2005, 2010) that non-randomness of galaxy orientations in clusters increases significantly with cluster richness. Such confirmation follows from the analyses of all three investigated angles. The observed dependency of alignment of galaxies in clusters on the richness of the cluster leads to the conclusion that the angular momentum of the cluster increases

with the mass of the structure – $J \sim M^{\frac{5}{3}}$ (Wesson, 1979, 1983; Carrasco et al., 1982; Brosche, 1986).

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