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The Properties of Nearby Galaxy Structures

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Abstract. We constructed the statistically uniform catalogue of 6188 galaxy structures, having at least 10 members in the structure field. These structures were extracted through the application of the Voronoi tessellation to Muenster Red Sky Survey which is a catalogue of galaxies based on scans of 217 ESO plates in the region covering about 5000 square degrees. We found that the shape of structures projected on the celestial sphere is different for rich and poor structures, which can reflect condition during their formation. Recent (for $z < 0.18$) weak dynamical evolution of galaxy clusters is observed. The distributions of position angles of ten brightest galaxies in structure are isotropic. The position angle of the brightest cluster member tend to be align with the parent cluster major axis only in the case of BM type I clusters, this is clusters containing cD galaxy.

1. Introduction

In the seventies of the twentieth century three theories of galaxy structure origin called "scenarios" have been proposed. These are: adiabatic, isothermal and turbulent scenarios. The type of density perturbation, its amplitude and mass scale were the main differences among them. In the adiabatic scenario (Zeldovich 1970) both matter and radiation are perturbed conserving entropy per baryon, while in isothermal perturbation (Peebles 1968) temperature and radiation density are constant, only matter forms clumps. Vortex motion involves both matter and radiation perturbations. These pictures gave different masses of newly forming protostructures. In the isothermal scenario low mass clumps are formed firstly, subsequently due to gravitational clustering large scale structures are built up. In the adiabatic picture the great massive protostructures were developed. The asymmetric collapse of matter produces flat structures called "pancakes", which fragmentation lead to the origin of galaxies. Several studies show that the phase of adiabatic perturbation is necessary in galaxy origin (Sahni et al. 1998). The hybrid models in which both types of density perturbations are taking under consideration started to be very common. When dark matter is considered some kind of its perturbation must be taken into account. Both isothermal and adiabatic in hybrid scenario can be considered (van de Weygaert & Bond 2008).

The various numerical simulations also shed some light into processes and possible results of interactions. In the standard Cold Dark Matter and ΛCDM scenarios structures are formed in the hierarchical manner. This is due to gravitational interaction: smaller structures merge into greater ones. Accretion of material eventually occur preferentially along a filamentary structure in which larger aggregations of matter are embedded. Virialisation of matter might led to more spherical distribution. Therefore, the ellipticity should increases with redshift (Hopkins et al. 2005). Observations show that great axes of galaxy clusters should point to each others (Binggeli 1982; Flin 1987; Plionis 1994). The orientation of galaxies in structures is expected when large scale protosupercluster formes before galaxies do, and after that fragmentation led to the origin of smaller structure, like clusters and finally galaxies. However, it was shown, that in the case of hierarchical clustering, as well as ΛCDM models (Faltenbacher et al. 2005; Wray et al. 2006) the alignment can be observed. The analysis of galaxy planes distribution shows that alignment is weaker either in clusters containing giant cD galaxy or less massive clusters (Aryal & Saurer 2006a,b).

The general conclusions of all theoretical investigations point out that the intrinsic shape of structures, angular momenta of galaxies and structures contain evidence of the formation history of large scale structures. Therefore the study of properties of large scale structure is necessary for better understating the origin and evolution of galaxies.

The alignment of galaxies is important also from other points of view. The gravitational lenses as well as cosmic shear produce alignment. The knowledge of intrinsic alignment of galaxies in clusters is necessary for correct distinguishing among the results of these effects. Having to our disposal a catalogue of nearby structures we would like to study in details properties of these structures which allows one to made a good comparison with similar objects located far away, these are older objects. Such comparisons permit to separate the primordial properties from the influence of evolution.

2. Observational Data

The PF Catalogue of galaxy structures (Panko & Flin 2006) serves as observational basis of our investigations. The PF Catalogue contains information on 6188 structures having at least 10 members in the over dense region. The PF Catalogue is the result of application of the Voronoi tessellation technique (VTT hereafter) (Ramella et al. 1999, 2000) for cluster detection to the Muenster Red Sky Survey (MRSS). This technique is completely non-parametric and therefore, sensitive to both symmetric and elongated clusters, allowing correct studies of non-spherically symmetric structures. Moreover, it is cluster finding algorithm in which non-uniform galaxy background is correctly treated (Ramella et al. 2000, 2001). PF structures were found in MRSS as overdensity regions using the VGCF (Voronoi Galaxy Cluster Finder) an automatic package for the identification of galaxy clusters in two-dimensional galaxy catalogues (Ramella et al. 2001).

Determination of the cluster shape and position angle of the structure major axis in PF Catalogue was performed using the standard covariance ellipse method for positions of galaxies within the magnitude limit m_3, $m_3 + 3^m$, where m_3 is the magnitude of the third brightest galaxy situated within overdensity regions (Panko & Flin 2006). MRSS is a large-sky galaxy catalogue covering an area of about 5000 square degrees on the southern hemisphere and it is complete down to the magnitude $r_F = 18.^m3$. 217 ESO Southern Sky Atlas R Schmidt plates with galactic latitudes $b < -45°$ were digitized with the two PDS microdensitometers of the Astronomisches Institut at Muenster. The classification of objects into stars, galaxies and perturbed objects was done with an automatic procedure with a posterior visual check of the automatic classification. The external calibration of the photographic magnitudes was carried out by means of CCD sequences. The MRSS contains positions, red magnitudes, radii, ellipticities and position angles of about 5.5 million galaxies (Ungruhe et al. 2003). The resulting catalogue of structures is statistically complete for galaxies brighter than $r_F = 18.^m3$. Moreover, poor and rich structures were found using the same procedure.

3. Results and Discussion

At the first step of investigations we analysed the ellipticity of galaxy structures. We divided our sample of structure into groups, according to number of member galaxies. It was clear that the distributions of ellipticities depend on the structure richness. In Fig. 1 some examples of these distributions are given. Using Kolmogorov - Smirnov test we compared the similarity of the distribution of ellipticities in structures with different number of members. Table 1 lists the value of the Kolmogorov - Smirnov statistics. At the significance level $\alpha = 0.05$ the $\lambda_{cr} = 1.358$. If $\lambda < \lambda_{cr}$ than two samples are extracted from the same population. From the Table 1 follows that only clusters having 50 and more members are taken from the same population. We studied also the distributions of position angles of the brighter galaxies in clusters. We found isotropic distribution starting from the brightest galaxies, through the second brightest galaxy until the tenth brightest member. We investigated also isotropy of the distribution of the acute angle being the difference between the position angle of the cluster PA_g and the three brightest cluster members PA1, PA2 and PA3. All distributions were isotropic. The only anisotropic difference was in the case of BM I clusters (Fig.3). The brightest galaxies tend to be aligned with the major axis of the parent cluster. We checked also the relation between redshift and ellipticity of the structure. The redshifts were determined using $m_{10} - z$ relation. We found weak, but statistically significant relation between discussed parameters. Nearer clusters have smaller ellipticities (Fig.2).

4. Conclusions

We obtained statistically uniform and complete sample of galaxy structures. This low redshift sample constitute very good observational basis for study properties of nearby galaxies (Kim et al. 2002). Observed properties should be compared with both theoretical prediction of numerical simulations and structures located at higher redshifts. Our result shows that the distribution of structure ellipticities clearly depends on the structure richness. This richness - ellipticity dependence can reflect the conditions during formation of structures. It is possible that greater ellipticity of less numerous, i.e., less massive structures reflect the fact, that these structures are less evolved. We observed also recent dynam-

Table 1. The result of statistical analysis

	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	>100
10-20	3,7354	6,2565	7,2929	6,6493	6,1754	5,7794	4,5407	4,4379	7,4503
21-30		3,1015	4,5013	4,6979	4,5504	4,9033	3,0930	3,8179	6,3343
31-40			1,6189	2,4571	2,5490	3,1751	1,6852	2,6718	3,8782
41-50				1,3196	1,5201	2,2652	0,9619	2,0691	2,5903
51-60					0,6179	1,1031	0,1750	1,2746	1,0271
61-70						0,8063	0,2955	1,0595	0,8441
71-80							0,8065	0,4377	0,2852
81-90								1,0573	0,6658
90-100									0,6831

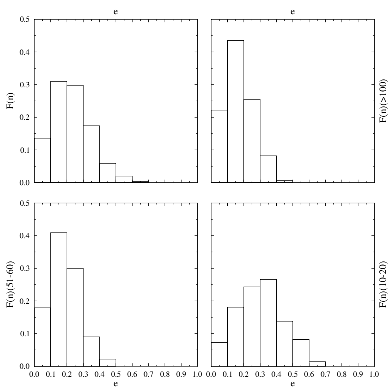

Figure 1. The distribution of ellipticities for all 6188 structures in the PF Catalogue (upper left panel), very rich clusters (upper right panel) and structures with richness: $51 - 60$ and $10 - 20$ objects respectively (lower panels)

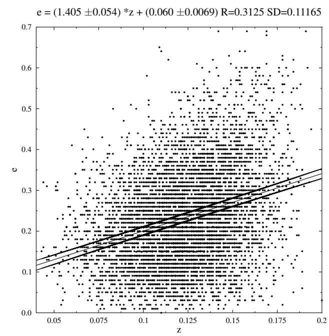

Figure 2. The redshift-ellipticity relation

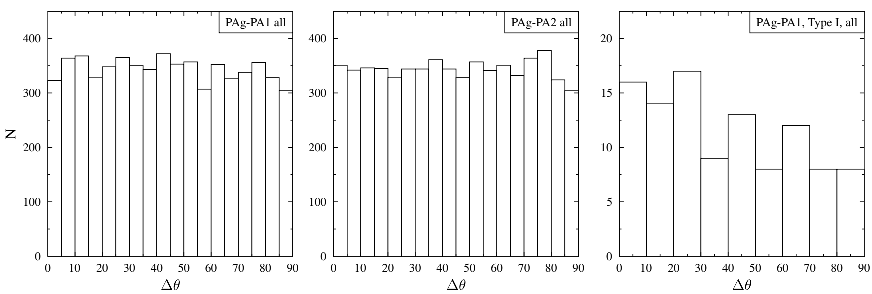

Figure 3. The difference between structure and galaxy position angles

ical evolution of structures, this is their virialisation (Plionis 2002; Biernacka 2007). It is possible that this virialisation is mainly due to more massive structures. The change of ellipticity with redshift is expected in ΛCDM, but only low redshift region was examined. We investigated the distributions of position angles of i-th (i=1-10) brightest galaxy in structures. These distributions were isotropic. Also the differences between position angle of the i-th galaxy in the cluster and parent structure were checked. The distributions were isotropic too. Only in the case of Bautz-Morgan type I cluster the difference was anisotropic. The cD galaxies tend to be aligned with the major axis of the parent cluster. This result supports investigations pointing out the special role of this galaxies in cluster evolution (Fuller et al. 1999).

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