THE SUBCLUSTERING IN RICH AND POOR cD CLUSTERS OF GALAXIES

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The wavelet analysis of 40 rich and poor galaxy clusters having supergiant cD galaxy shows that the frequency of occurrence of substructure in both type of structure is the same.

INTRODUCTION

The investigation of substructures in galaxy clusters can be useful for study the origin and evolution of large – scale structure. Galaxy clusters are systems in which dynamic play an important role. It is interesting to check the difference between structures containing cD galaxy, which are embedded into rich and poor environments in order to see if the richness of environment, this is the number of galaxies in the vicinity of cD galaxy influences the subclustering properties of galaxy clusters.

Despite of the great progress in the determinations of galaxy redshifts, the 2-D data, this is when galaxy coordinates are available, can still be instrumental in achieving properties of subclustering and testing various theoretical considerations. In this paper we test the frequency of subclustering in poor and rich cD galaxy clusters.

OBSERVATIONAL DATA

There are different sources of our 2-D observational data, but all they came from automatic scans, when the personal bias is not existing.

Automatic scans of plates, taken with the 48-inch Palomar Schmidt Telescope, performed at The Royal Observatory, Edinburgh using COSMOS machine give data for 18 rich clusters [12]. From this paper we selected 12 galaxy clusters classified as cD cluster. The other 8 catalogues of nearby cD clusters were constructed from scans of plates, taken with the same telescope, performed in the Rome Observatory [16, 17, 8, 10].

We analysed galaxies within the magnitude range $m_3, m_3{+}3$, where m_3 is the magnitude of the third brightest galaxy. All galaxies situated within the circle outline from the centre with the radius 1.5 Mpc ($h = 0.75$) were regarded as cluster members.

The 23 poor galaxy clusters MKW/AWM were find by Morgan *et al.* [13] and Albert *et al.* [1]. The photometric data for 16 objects came from Yamagata [19]. This data were obtained scanning plates taken with 105 cm Schmidt telescope of the Kiso Observatory. When there are no data of poor clusters in Yamagata data, there were extracted from Digitised Sky Survey, which is also the result of plates from Palomar Sky Survey. The squares $1^\circ{\times}1^\circ$ centred on the coordinates of the brightest galaxy, *i.e.*, D/cD galaxy, were selected. To the images in the region the FOCAS package was applied for object detection and star/galaxy separation.

The poor cluster data were analysed with magnitude limit $17\overset{m}{.}75$ and galaxy size cutoff ($A > 5$ arcmin). From the sample of 23 poor clusters, we analysed 20 objects, containing D/cD galaxy.

THE METHOD OF ANALYSIS

The existence of substructure in galaxy clusters has bee checked using the wavelet method [4]. The wavelet method is a convolution on a grid of 256×256 pixels between the signal $s(r,a)$ and an analyzing wavelet function $g(r,a)$. We use two-dimensional radial function called the Mexican Hat given by the formula:

$$g(r,a) = (2 - r^2/a^2)\exp(-r^2/2a^2), \tag{1}$$

where r is the distance between the position of a galaxy and a point (x,y) where the wavelet coefficient is calculated and a is a scalelength for the wavelet. The set of the wavelet coefficients resulting from the convolution is given by:

$$w(r,a) = g(r,a) \otimes s(r). \tag{2}$$

Each point in the grid has the corresponding wavelet coefficient connected with it. The usage of different scales a allows one to detect structure having the size comparable to particular value of a. In order to ensure the correct sampling for Mexican Hat we use the scalelength a differentiating one from another with the factor $\sqrt{2}$ [3].

The scales increased from $a = 8$ pixels, through 11, 16, 22, 32, 45 till 64 pixels, which corresponds to the linear scale at the cluster distance in kpc: 125, 172, 250, 344, 500, 703 and 1000 assuming $H_0 = 75$ km/(s Mpc).

The statistical significance of detected substructures, having at least 4 objects, were calibrated using Monte Carlo simulations. The number of points in the simulation is equal to the number of galaxies in real sample. The radial coordinate of points were the same as in the investigated sample, while the angular coordinates were random ones. The reality of substructure was accepted when the probability that it is due the random fluctuation is smaller than 0.001.

For each cluster and each scalelength of the wavelet 1000 simulations were made.

The procedure allows us to detect structures in the field of galaxy cluster studied here, as well as to perform [5] the classification of structures into three types, namely: unimodal, bimodal and complex.

Table 1: Data

Cluster	z	N	a	morph. type
A85	0.0518	643	64	U
A133	0.0604	470	45	B
A151	0.0526	226	32	S
A261	0.0467	519	64	U
A279	0.0797	515	64	U
A496	0.0320	604	45	S
A505	0.0543	244	16	S
A644	0.0704	1376	64	U
A655	0.1245	49	64	U
A754	0.0528	329	16	S
A1413	0.1427	318	16	B
A1650	0.0845	738	16	S
A1651	0.0825	1140	32	S
A1837	0.0376	734	22	S
A2052	0.0348	346	16	S
A2124	0.0654	66	16	S
A2175	0.0978	76	64	U
A2199	0.0303	368	11	S
A2597	0.0852	74	64	U
A2670	0.0745	836	64	U
MKW1	0.0202	51	64	U
MKW2	0.0299	77	11	S
MKW4	0.0196	40	16	S
MKW5	0.0290	62	22	S
MKW6	0.0545	172	64	U
MKW7	0.0289	124	16	S
MKW8	0.0265	68	64	U
MKW9	0.0382	328	11	S
MKW11	0.0224	77	64	U
MKW1s	0.0165	73	11	S
MKW2s	0.0381	69	64	U
MKW3s	0.0453	194	64	U
MKW4s	0.0271	62	64	U
AWM1	0.0272	33	64	U
AWM2	0.0219	50	22	S
AWM3	0.0290	136	64	U
AWM4	0.0338	145	32	B
AWM5	0.0384	142	64	U
AWM6	0.0356	105	8	S
AWM7	0.0290	291	64	U

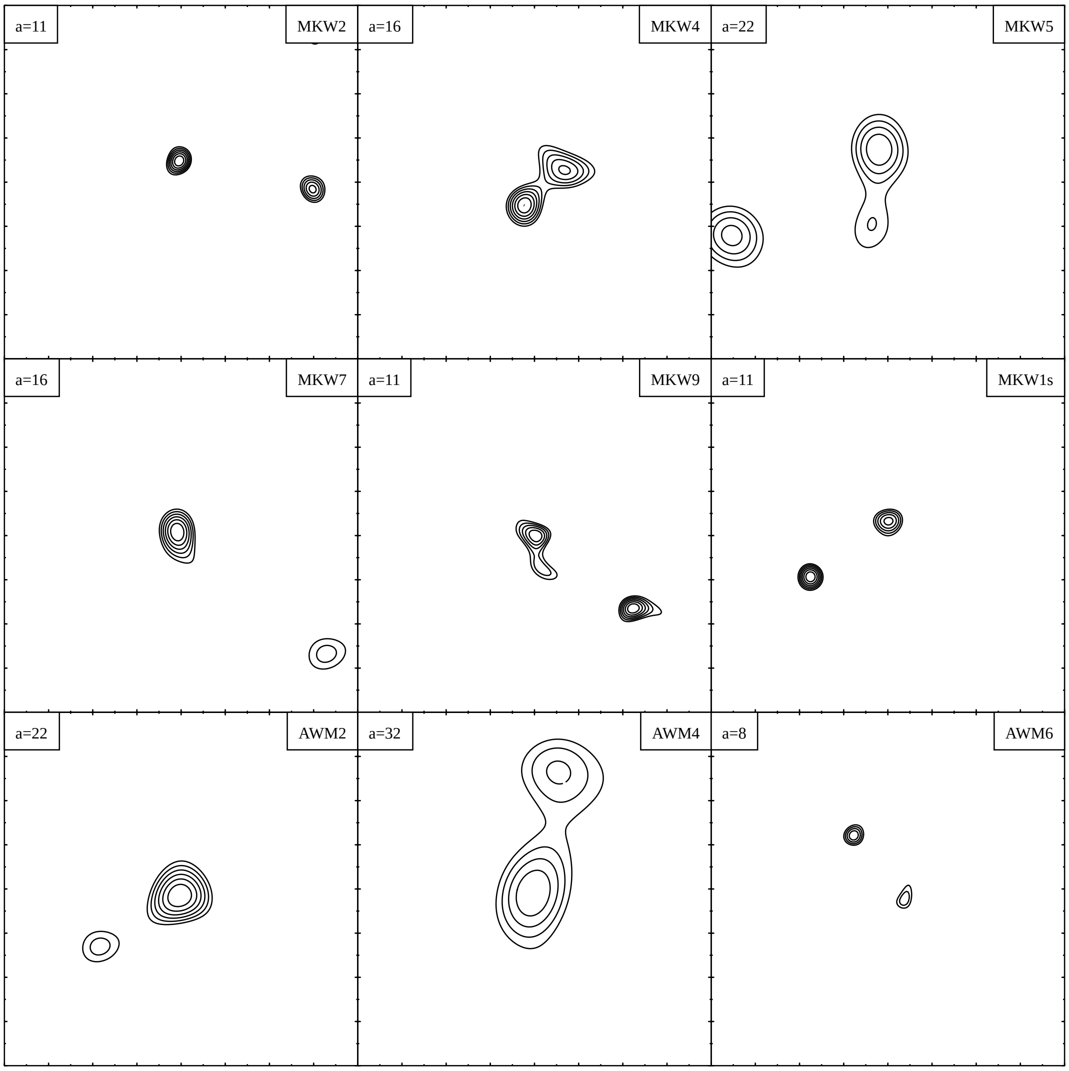

Figure 1: Structures of the investigated poor clusters. The right corner contains the cluster designation, the left one the scalelenght at which significant substructure is observed

RESULT

The result of our analysis is given in Table 1. The first column of Table 1 presents the cluster name, the second the redshift of the cluster z taken from literature, the next one gives the the total number of galaxies N in the field, while the fourth column shows the scalelength a corresponding to the size of detected structure. The last column displays the morphology of the cluster, when letters: U, B and S denote unimodal, bimodal and complex structure of a cluster, respectively. The number of galaxies within structure is smaller than the total number N.

Fig. 1 presents some structures of the investigated poor clusters.

The wavelet analysis allows us to find substructures (in various scalelength a) in 12 objects. This means that the frequency of subclustering in the sample is $12/20 = 0.60$.

The subclustering in 20 MKW/AWM poor clusters containing D/cD galaxy, when checked applying the wavelet analysis too, occurred in the case of 9 structures, which gave the frequency of subclustering $9/20 = 0.45$. The χ^2-test shows that the frequency of subclustering in rich and poor clusters is the same at the significance level $\alpha = 0.001$.

The comparison of Abell clusters with other data for the sample of 12 objects has been performed [12], showing that the change of the morphology type of cluster structure do not influence the estimated frequency of subclustering. The same conclusion is also valid when remaining Abell clusters are compared with other data.

Subclustering in MKW/AWM clusters, based on Yamagata data too, has been checked using adaptive kernel method supplemented by galaxy redshifts for selected galaxies [2]. Beside the discrepancy in the existence of non-existence or substructures in individual cases, the estimations of frequency of occurence of subclustering, as determined from Beers *et al.* [2] is quite comparable with ours, this is 46%.

CONCLUSION

Our statistical analysis is based on 20 Abell clusters of galaxies and 20 poor clusters. The data were derived from automatic scans, which procedure ensured their objectivity.

The wavelet analysis, regarded as very sensitive tool for study the structure properties, applied to poor and rich cluster, yields the lack of difference in substructure occurrence in this two set of data.

If the light traces matter in the same manner in both types of structures, the result shows the same dynamical interaction of objects in poor and rich clusters. This is consistent with the same type of alignment of the dominant brightest cluster galaxies in both rich and poor clusters [7, 9, 15, 11]. This mean that process leading to the formation of D/cD galaxy are independent of the cluster richness.

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