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THE PECULIARITIES IN O-TYPE GALAXY CLUSTERS

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ABSTRACT. We present the results of analysis of $2D$ distribution of galaxies in galaxy cluster fields. The Catalogue of Galaxy Clusters and Groups PF (Panko & Flin) was used as input observational data set. We selected open rich PF galaxy clusters, containing 100 and more galaxies for our study. According to Panko classification scheme open galaxy clusters (O-type) have no concentration to the cluster center. The data set contains both pure O-type clusters and O-type clusters with overdence belts, namely OL and OF types. According to Rood & Sastry and Struble & Rood ideas, the open galaxy clusters are the beginning stage of cluster evolution. We found in the O-type clusters some types of statistically significant regular peculiarities, such as two crossed belts or curved strip. We suppose founded features connected with galaxy clusters evolution and the distribution of DM inside the clusters.

Keywords: Galaxies: clusters: morphological types.

1. Introduction

The fundamental problem of modern extragalactic astronomy and cosmology is the scenario of structure formation. The most popular concordance ΛCDM model describes the Universe as a spatially flat, homogeneous and isotropic in a large scale. In the model large-scale structures of Universe were formed from the primordial adiabatic, nearly scale invariant random fluctuations (Silk, 1968; Peebles & Yu, 1970; Sunyaew & Zeldovich, 1970). Modern simulations, from well quoted *Millennium Simulation* (Springel et al., 2005) to *Illustris Project* (Vogelsberger et al., 2014, Artale et al., 2017), show complex structure of sheets and filaments with clusters of galaxies at the intersections of this filamentary structure. The comparison the results with observation data give us the way to reliable scenario.

Galaxies in the galaxy clusters were and remain the confident optical markers of structure of clusters and their components. The features of distribution of galaxies inside the cluster can be described as the morphological type of the cluster. From the beginning time of galaxy clusters study they were divided to types according some schemes. Panko (2013) summarized the classical schemes, including both famous Bautz – Morgan (1970), Rood – Sastry (1971) ones and less popular López-Cruz at al. (1997) and López-Cruz & Gaztanaga (2001) approach. Improved and integrated scheme (Panko, 2013) allows to assign the morphological types corresponding to cluster “concentration” (from C – compact, to I – intermediate, and O – open), “flatness signs” (L – line or F – flat, and no symbol if no indication of “flatness sign” is present) and the role of bright galaxies (cD or BG, if the bright cluster members role is significant). Other peculiarities are noted as P. “Flatness signs” can correspond to filamentary substructure or preferential plane in cluster. The designations can be combined, for example CFcD or ILP. Note, the clusters CL-type were not found (Panko, 2013). The fact can be understanding taking into consideration the direction of evolution of galaxy clusters from O-type (independently from “flatness signs”) to C-type (Struble & Rood, 1982). This way of evolution is confirmed by increase the ellipticity with redshift for low-redshift galaxy clusters and groups (Biernacka et al., 2009). According to ellipticity determination (Panko & Flin, 2006) the “flatness signs” – belts and strips – can be connected with DM distribution inside the clusters and/or between nearest large-scale structures, as was founded by Dietrich et al. (2012) for A222 and A223 clusters. Some years before hot gas filament connecting both clusters was traced in X-ray by Werner et al. (2008). The compound filamentary structure of DM inside the cluster can be reflected in regular peculiarities, in particulary as crossing belts or curved strips. We supposed such regular peculiarities can by founded in clusters with all types of concentration and select open galaxy clusters as observational data for first step of our study.

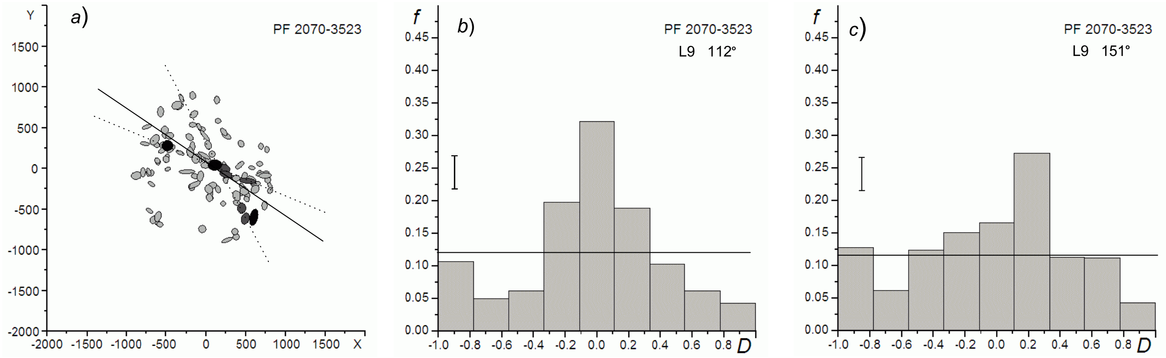

Figure 1: The map of galaxy cluster PF 2070-3523 with crossing $L9$ belts (a), dotted lines note the directions for first (112°) and second (151°) belt, solid line shows the direction of main axe of cluster. The panels (b) and (c) show the weighted densities in the bands across the belt for both cases, solid line corresponds to mean weighted density, vertical bar illustrates the SD.

2. Observational Data and Mapping

Our study based on "A Catalogue of Galaxy Clusters and Groups" (Panko & Flin 2006, hereafter PF). The PF Catalogue was constructed on Münster Red Sky Survey Galaxy Catalogue (Ungrue et al. 2003) as the observational basis. The full information in the PF Catalogue contains the list of galaxies in the cluster field for each PF galaxy cluster. Information for galaxies includes RA_{2000} and Dec_{2000}, r_F magnitude, major and minor axes and positional angle of major axis of galaxy best-fitted ellipse accordingly to MRSS (Ungrue et al. 2003).

We created the "The Cluster Cartography set" (Panko & Emelyanov, 2015, hereafter CC) for quick detail study of morphology of galaxy clusters. The cluster map is constructed in rectangular coordinates recalculated into arcseconds. The symbols on the map illustrate the galaxy shape and orientation in the projection on the celestial sphere, but size of symbol corresponds to galaxy magnitude; calculation bases on MRSS data. Additional brightest galaxies can be marked by darker shades of gray (Fig. 1, b and Fig. 1, c).

CC allows us to find the overdense regions as circles on case of C- and I-types of clusters or as belts/strips for L and F clusters. In the last case the clusters is divided to N bands. N can be 3, 5, 7, 9 or 11 and the width of each band is $1/N$ part of diameter of cluster. The numbers of galaxies in the bands are recalculated to weighted densities of galaxies (Panko & Emelyanov, 2015). It allows to describe overdense features as $L11$ or $L9$ for L-clyster and $F7$ or $F5$ for F-clusters (the numeral part corresponds N).

The map of PF 2070-3523 with crossing belts is shows in Fig. 1, a. Note the direction of major axis is in concordantly with directions of the belts (solid and dashed lines in Fig. 1, a). The distributions of waited density of galaxies for two $L9$ belts are shown in Fig. 1, b and Fig. 1, c. The central maximum in Fig. 1, b is significant, the cluster can be attributed to $F7$ type also. The case shown in Fig. 1, c corresponds to second overdense strip, so classification $L9$ is valid, without regard to asymmetry of histogram.

3. The Types of Peculiarities in Open Galaxy Clusters

The PF Catalogue contains 453 rich galaxy clusters without "boundary effects" connected with bounds of MRSS. Their previous classification was made by Panko and Gotsulyak (in preparation), and 254 PF galaxy clusters were attributed to O-type. The list was the observational base of present study. All clusters were mapped by CC. Common distribution open clusters according to subtypes is presented in Table 1. 6 clusters from 254 have feebly marked concentration to the center (last lines in Table 1) without peculiarities.

Table 1: Open PF galaxy clusters

Type	Number	BG	P
O	153	7	33
OF	59	6	5
OL	21	3	8
OLxF	15	5	5
IO	1		
OI	5		
All	254 (248)	21	51

For 153 pure O-type clusters 7 ones have peculiarities connected with positions of brightest galaxies (BCM). For example in PF 0016-3529 the brightest

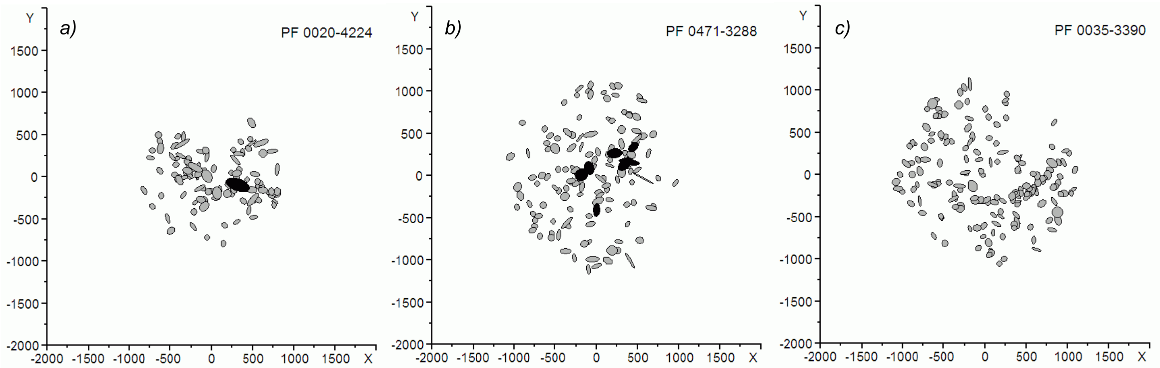

Figure 2: The examples of crossed belts, enhanced the orientation of the brightest galaxy (a), the positions of brightest galaxies (b)and curved strip (c) in open galaxy clusters.

galaxy placed in the center of clusters and difference in magnitudes between first and second BCM is $0^m.4$. Certainly, it is not *cD* galaxy, but the situation is not usual for *O*-type. In PF 0020-4224 (Fig. 2, *a*) the brightest galaxy is on the cross of two belts and have difference with second BCM $1^m.4$. Formally the difference notes to *cD* definition for PF 0020-4224. More, the alignment of brightest galaxy along to the main belt in the cluster notes to especial role of the brightest galaxy in PF 0020-4224 evolution. In *OL* and *OF* cluster peculiarities in BCM positions were found in 6 and 3 cases correspondingly. Another case BCM peculiarities we can illustrate in Fig. 1, *a* and Fig. 2, *b*: positions of tree and more BCM are connected with overdense regions. Crossed belts in open clusters were found in 15 cases and we recognized theirs as significant subtype. We suppose it reflects the *DM* filaments inside the cluster. Another types of peculiarities, Y-form overdense region (PF 0017-6446)or curved strips (Fig. 2, *c*). Other peculiarities connect with weak seen overdense regions with BCM.

4. Conclusion

We found the significant regular peculiarities in open galaxy clusters. More than 1/3 of cluster in our input list have filamentary substructure, both rectilinear and curved. We found 15 galaxy clusters with crossed overdense belts attributed to special type of peculiarity. Other peculiarities are rare, however Y-type overdense regions are confirmed by positions of BCM. We suppose the founded features note to nonuniform distribution of *DM* in the open clusters. The direction of overdense region must be connected with the orientations of galaxies in it. On the other hand, preferential directions connect with positions of nearest neighbors, and we can trace large-scale structure around galaxy clusters.

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