DOI: http://dx.doi.org/10.18524/1810-4215.2016.29.84961

X-RAY EMISSION AND ORIENTATION OF SELECTED PF GALAXY CLUSTERS

A.V. Tugay[1], S.S. Dylda[1], E.A. Panko[2]

[1] Astronomy and Space Physics Department, Faculty of Physics, Taras Shevchenko National University of Kyiv, Glushkova ave., 4, Kyiv, 03127, Ukraine, *tugay.anatoliy@gmail.com*

[2] Department of Theoretical Physics and Astronomy, I.I. Mechnikov Odessa National University, Shevchenko Park, Odessa, 65014, Ukraine, *panko.elena@gmail.com*

ABSTRACT. X-ray counterparts for 35 galaxy clusters contained in the PF catalogue of galaxy clusters and groups were found in XMM-Newton archive. 22 ones (all from ACO catalogue) have extended elliptic X-ray haloes appropriate for determination of orientation. Position angles and eccentricities were calculated and compared with cluster orientations optical band.

Keywords: Galaxies: clusters; X-rays: galaxies: clusters.

1. Introduction

The study of morphology of galaxy clusters is important for understanding the large scale structure of Universe. Orientation of galaxies and clusters may give information about clusterisation and cosmologic evolution. The best way to consider orientation of extragalactic objects is the usage of special large and uniform catalog of galaxy clusters. Clusters are also suitable for orientation analysis in X-ray band because they contain a haloes of hot intergalactic gas.

Since (Binggeli, 1984) orientation of galaxies in clusters was the subject of numerous studies. Orientations of galaxies in 247 rich Abell clusters were studied in detail in Godlowski et al. (2010) and Panko et al. (2013) with corresponding statistical analysis and simulations. Orientation of galaxies from compact sample can be numerically described by the distribution of anisotropy parameter. The parameter was calculated for edge-on galaxies in Parnovsky & Tugay (2007) and for nearby galaxy groups in Godlowski et al. (2012). Orientation of galaxies in nearby groups was studied by Pajowska et al. (2012) too.

2. Observational data

Our study in optic band based on PF catalogue of galaxy clusters and groups data. The catalogue contains 6188 structures of southern sky (Panko & Flin, 2006). Orientations and shapes of PF clusters were calculated taking into consideration galaxy $2D$ locations in the cluster field using the covariance ellipse method (Carter & Metcalfe, 1980; Biernacka et al., 2007). To select PF clusters counterparts in X-rays we used Xgal list of all X-ray extragalactic sources observed by XMM-Newton space observatory (Tugay, 2012). Xgal includes 5021 sources and approximately 30% of them are galaxy clusters. In the current study we found PF clusters counterparts in X-rays, calculated their orientations and eccentricities in X-ray band and compared obtained values with optical data, including the anisotropy signs in distribution of galaxies inside the clusters.

3. Method

Cross-correlation of PF and Xgal objects was performed on the base of condition of appearing Xgal source within PF cluster radius. We found 35 Xgal sources counterparts in PF catalogue. To estimate orientation of X-ray halo we selected at XMM images pixels with certain numbers of detected photons (two, three, four etc). Then we approximated each set of pixels with ellipse by the minimal square method and found positional angle PA and eccentricity e. We succeeded to find X-ray orientation for 28 Abell clusters (Abell, Corwin & Olowin, 1989) from PF catalog but 6 of them have no appropriate optical orientation. Common results are presented in Table 1. Table 2 shows PF clusters with X-ray sources that are unappropriate for orientation determination by any reason.

Table 1: Orientation and eccentricities of X-ray PF galaxy clusters.

PF	ACO	PA	PA_X	e_{PF}	e_X
0004-3606	2717	160	36±17	0.29	0.37±0.08
0009-3469	2721	93	12±6	0.23	0.67±0.02
0022-1954	13	102	57±3	0.13	0.64±0.04
0034-2570	22	174	105±7	0.13	0.58±0.17
0042-3308	S 41	163	118±1	0.14	0.60±0.01
0068-2875	2811	119	65±10	0.24	0.48±0.05
0082-2951	S 84	6	58±11	0.17	0.48±0.06
0104-2195	133	65	16±6	0.09	0.55±0.03
0115-4600	2877	179	41±29	0.17	0.29±0.09
0168-5458	2933	70	22±3	0.08	0.75±0.30
0229-4765	S 239	148	198±8	0.16	0.59±0.06
0329-4427	3112	17	12±1	0.14	0.63±0.02
0350-5258	3128	162	139±5	0.14	0.91±0.05
0370-5364	3158	56	11±6	0.11	0.50±0.05
0480-3720	514	61	35±1	0.20	0.67±0.01
0500-3868	3301	43	69±3	0.08	0.48±0.02
2020-5671	3667	39	31±5	0.13	0.74±0.06
2070-3523	3705	122	115±6	0.29	0.47±0.04
2149-5088	3771	0	148±58	0.13	0.62±0.19
2181-3068	3814	60	16±4	0.17	0.50±0.03
2187-1958	2384	167	104±5	0.29	0.81±0.05
2229-3570	3854	27	57±10	0.29	0.41±0.10

3. The general notes on selected clusters

Here are general notes on selected clusters.

A 2717, A 2877, A S 1111. These clusters looks like spherical, but for first and second ones we determined PA.

A 13, A 2811, AO S 84, A S 239, AO 3158, A 3667, A 3771, A 3856. Orientation of cluster core differs from periphery. We didn't determine PA for AC3856.

Double clusters: A 2933, A 3128, A 2384.

Faint clusters: A S 41, A 514, A 3301.

A 3705 - a pair of interacting clusters, but PA was found by X-ray image.

Clusters with undefined orientation or with large differences in optical and X-ray PA are presented in Table 3.

Except for 22 clusters with both optical and X-ray orientation there are 13 PF clusters with X-ray sources for which it is impossible to compare orientations.

4 point X-ray sources were found within PF clusters. No X-ray haloes of galaxy clusters were detected for these systems.

1. PF 0120-3828. BAX 017.9025-38.1867 cluster. X-ray source 2MASXJ00570192-3806028 galaxy (only 3 references in SIMBAD).

2. PF 0093-2244. MCXC J0056.9-2213 cluster. X-ray source RBS139 Seyfert 1 galaxy.

Table 2: PF clusters with X-ray sources not suitable for comparison of orientation.

PF	ACO	PA	PA_X	note
0093-2244	MCXC	131	-	point source
0120-3828	BAX	106	-	point source
0263-5237	3038	146	-	point source
0408-3720	new	180	-	point source
0451-6138	3266	106	-	interacting
0532-2498	Snow 20	24	-	point source
2230-3890	3856	-	50±4	diff. orient.
2256-3778	3888	-	166±6	
2277-5266	3911	-	50±4	
2323-4265	S 1101	-	147±1	
2331-4225	S 1111	-	-	spherical
2378-2816	4038	-	32±6	
2395-3453	4059	-	58±5	

3. PF 0263-5237. Abell 3038 cluster. X-ray source ESO 198-24 Seyfert 1 galaxy.

4. PF 0532-2498. Snow 20 cluster (T.Snow, 1970). X-ray source - IC 411 galaxy (9 references).

PF 0408-3720 cluster was unknown in previous works. In the region of this cluster we found ESO 359-19 Seyfert 1 galaxy.

A 3266 - complex system of interacting clusters unappropriate for orientation estimation in X-rays.

7 PF clusters (bottom of Table 2) have no anisotropy

Table 3: Notes on large differences in orientation. Most of such clusters has near-spherical X-ray halo. Optical orientation of last 5 clusters can not be determined because of their diffuse structure.

PF	ACO	*PA*	PA_X	e_X
0034-2570	22	174	105±7	0.13
0042-3308	S 41	163	118±1	0.14
0068-2875	2811	119	65±10	0.24
0229-4765	S 239	148	198±8	0.16
0350-5258	3128	162	139±5	0.14
0500-3868	3301	43	69±3	0.08
2070-3523	3705	122	115±6	0.29
2149-5088	3771	0	148±58	0.13
2187-1958	2384	167	104±5	0.29
2230-3890	3856	-	50±4	differs
2256-3778	3888	-	166±6	
2277-5266	3911	-	50±4	
2323-4265	S 1101	-	147±1	
2395-3453	4059	-	58±5	

signs in optical band, according to Panko (2013) criteria, so we excluded them from comparison with X-ray data. Specifically, A 3856 shows different orientation of the core and periphery of X-ray halo; A 1111 has spherical halo; other clusters include A 1101, A 3888, A 3911, A 4038 and A 4059.

4. Results and conclusion

Analysis of Table 1 shows that *PA* tend to correlate. Eccentricity is larger in X-rays because visible hot gas halo lies close to the center of cluster in the region of larger potential. The correlation of orientation in two bands leads to issue that galaxies and gas halo in clusters are involved in significant gravitational interaction but the processes of cluster evolution continue in the current cosmological era.

Acknowledgements. This research has made use of NASA's Astrophysics Data System.

References

Abell G.O., Corwin H.G., Olowin R.P.: 1989, *ApJS*, **70**, 1.
Biernacka M., Flin P., Panko E., Juszczyk T.: 2007, *Odessa Astron. Publ.*, **20**, 26.
Binggeli B.: 1984, *A& A*, **107**, 338.
Carter D., Metcalf, N.: 1980, *MNRAS*, **191**, 325.
Godlowski W., Piwowarska P., Panko E., Flin P.: 2010, *ApJ*, **723**, 985.
Godlowski M., Panko E., Pajowska P., Flin P.: 2012, *JPhSt.*, **16**, 3901.
Pajowska P., Godlowski M., Panko E., Flin P.: 2012, *JPhSt.*, **16**, 4901.
Panko E.A.: 2013, *Odessa Astron. Publ.*, **26**, 90.
Panko E., Flin P.: 2006, *JAD.,* **12**, 1.
Panko E., Piwowarska P., Godlowska J., Godlowski W., Flin P.: 2013, *Ap.*, **56**, 322.
Parnovsky S., Tugay A.: 2007, *JPhSt.*, **11**, 366.
Tugay A.V.: 2012, *Odessa Astron. Publ.*, **25**, 142. *http://arxiv.org/abs/1311.4333.*