DISCRETE X-RAY SOURCES IN GALAXY CLUSTERS

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ABSTRACT. Current studies of extragalactic X-ray sources using data from orbital observatory XMM-Newton are at the front line of X-ray astronomy. Resolution capacity of the observatory instruments enable to detect separate X-ray sources in the close galaxies. In this study we used data from recently published 4XMM-DR9 catalog. This catalog contains 550124 unique sources covering 2,85% of the sky. The main type of extended extragalactic X-ray source is hot halo of galaxy cluster. Such objects are important for astrophysics in the tasks of revealing dark matter distribution, galaxy formation and different cosmology studies.

At the same time, some images of the galaxy clusters contain small scale pointlike X-ray sources scattered around the clusters or their halos. In many cases the nature of such objects is not clear yet and require more detailed studies. Furthermore, energy flux detection threshold of such objects is limited to a great extend not only by the instruments on board of the XMM-Newton observatory but the natural sky background radiation, which is at the level of $10^{-13}\mathrm{W}m^{-2}\mathrm{sr}^{-1}$ both for XMM cameras and the sky background.

Using Hyperleda database we revealed 16 galaxy clusters among the bright XMM sources. Images of the two galaxy clusters demonstrate bright galaxy cores. These clusters are galaxy group NGC 507 and Coma cluster where nucleus of galaxy NGC 4889 was clearly detected. We also analyzed X-ray images of 14 other X-ray clusters but had not found AGNs there.

Out of the above mentioned 16 clusters in the 7 of them we have found 30 pointlike X-ray sources. These sources are presumably mainly AGNs within these clusters. From the other side, they could be also more distant X-ray objects.

Keywords: Galaxiesв's X-ray emission, XMM-Newton, HyperLeda, Active Galaxy Nucleus, galaxy halo, galaxy clusters.

АНОТАЦІЯ. Сучасні дослідження позагалакти-чних джерел рентгенівського випромінення за допомогою даних, які отримані орбітальною обсерва-торією XMM-Newton знаходяться на передовій лінії рентгенівської астрономії. Роздільна здатність приладів обсерваторії дозволяє виявляти окремі джерела рентгенівських променів у близьких галактиках. У цьому дослідженні ми використовували дані нещодавно опублікованого каталогу 4XMM-DR9. Цей каталог містить 550124 унікальних джерел, що охоплюють 2,85% неба. Основним типом протяжного позагалактичного джерела рентгенівського випромінювання є гаряче гало скупчення галактик. Такі об'єкти є важливими для астрофізики в задачах виявлення розподілу темної матерії, утворення галактик та різних космологічних досліджень.

У той же час, деякі зображення скупчень галактик містять точкові рентгенівські джерела невеликого розміру, які розсіяні навколо скупчень або їх гало. У багатьох випадках природа таких об'єктів ще не ясна і вимагає більш детальних досліджень. Крім того, поріг детектування потоку енергії таких об'єктів обмежений не тільки приладами на борту обсерваторії XMM-Newton, але й природним фоном випромінювання неба в рентгенівському діапазоні, яке знаходиться на рівні 10^{-13}Вт·м$^{-2}$ср$^{-1}$ як для XMM камер, так і для фону неба.

Використовуючи базу даних Hyperleda, ми виявили 16 скупчень галактик серед яскравих джерел XMM. Зображення двох скупчень галактик демонструють яскраві ядра галактик. Ці скупчення - група галактик NGC 507 та скупчення Coma, де ядро галактики NGC 4889 було чітко виявлено. Ми також проаналізували рентгенівські зображення інших рентгенівських кластерів проте АЯГ там не було знайдено.

Серед 16 згаданих вище скупчень у 7 ми знайшли 30 точкових джерел рентгенівського випромінювання. Ці джерела, імовірно, в основному є AGN в межах цих кластерів. З іншого боку,

Table 1: Counts of discrete sources in X-ray clusters

N	BCG	Sources
1	6dFGS gJ034253.0-533753	0
2	ESO 156-8	1
3	ESO 383-76	0
4	ESO 444-46	0
5	ESO 444-76	0
6	M 87	1
7	NGC 507	9
8	NGC 708	6
9	NGC 1129	0
10	NGC 1650	2
11	NGC 3311	6
12	NGC 4696	0
13	NGC 4756	5
14	NGC 4761	0
15	NGC 4889	0
16	NGC 5044	0

Fig. 1: NGC4756 and 5 detected point-like X-ray sources

такі точкові джерела можуть бути також і більш віддаленими рентгенівськими об'єктами.

Ключові слова: Рентгенівське випромінення галактик, XMM-Newton, HyperLeda, Активні ядра галактик, Галактичне гало, галактичні кластери.

1. Introduction

X-Ray observations are of a great importance for extragalactic astronomy. A number of different active objects could be currently detected only in X-ray band. During decades of X-Ray observations using orbital observatory XMM-Newton there was established a large data base which is continuously updated and accessible e.g. through Hyperleda database. Recently made available version 4XMM-DR9 (Webb et al., 2020) contains more than 500 thousand sources.

Most of X-ray emitting galaxies are more likely to have AGNs (Tugay & Vasylenko, 2011), but this statement should be verified. Galaxy clusters are another type of extragalactic X-ray sources and at the same time are important tracers of large-scale structure of the universe. Main morphology features of LSS may be characterized by filaments (Tempel, 2013; Tugay, 2014) but the clusters are much more visible especially in X-ray band. Possible coorelation of X-ray clusters orientation with LSS features was considered in (Tugay et al., 2016). For complex LSS studies both optical and X-ray observations are needed as well as data on peculiar motions of the galaxies to a maximum possible sample size (Parnovsky & Tugay, 2005). In the scope of this study the aim of this paper was to analyze X-ray clusters and search for point-like source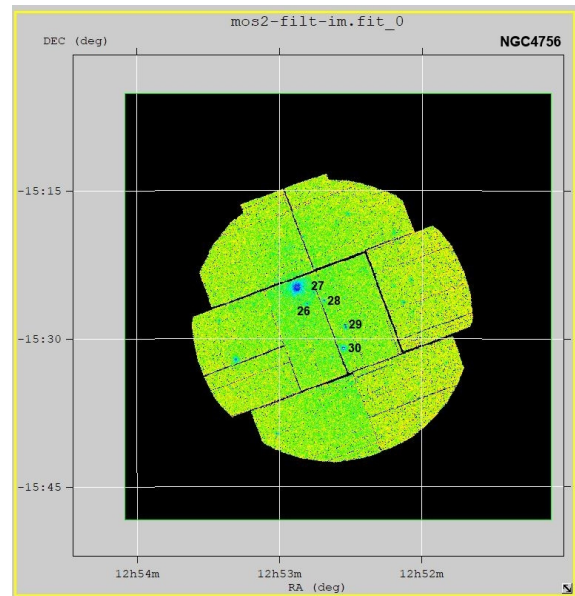s in them. Later we are going to study much more faint X-ray extragalactic sources and compare them with the sources found in this paper.

2. Methodology

XMM-Newton observatory is definitely the best facility to study large samples of X-ray sources. It holds on board three European Photon Imaging cameras (MOS1, MOS2 and PN) capable to obtain images, spectra and lightcurves of the studied objects. MOS1 and MOS2 cameras are suitably designed to build images so in this study we selected their data. Detection energy interval of MOS cameras is in the range of 0.2 keV to 12 keV. To select bright X-ray clusters we used Xgal sample of extragalactic X-ray sources (Tugay, 2014). All sources with $F_X > 10^{-13} W m^{-2} sr^{-1}$ were identified with Simbad data base[1]. 16 clusters were found with at least one X-ray galaxy inside. For data and image processing software we used fits viewer available from NASA High Energy Astrophysics Science Archive Research Center[2]. The list of our sample is presented at Table 1. We refer to each cluster by its brightest galaxy (BCG).

3. Results

Images analysis revealed a number of the point-like sources in a relative angular proximity to the known and reliably identified X-ray sources and their X-ray environment. Such a distance in analysed sample is nearly up to the size of 10' which corresponds to radius

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[1]http://simbad.u-strasbg.fr/simbad/

[2]https://heasarc.gsfc.nasa.gov/docs/software/ftools/fv/
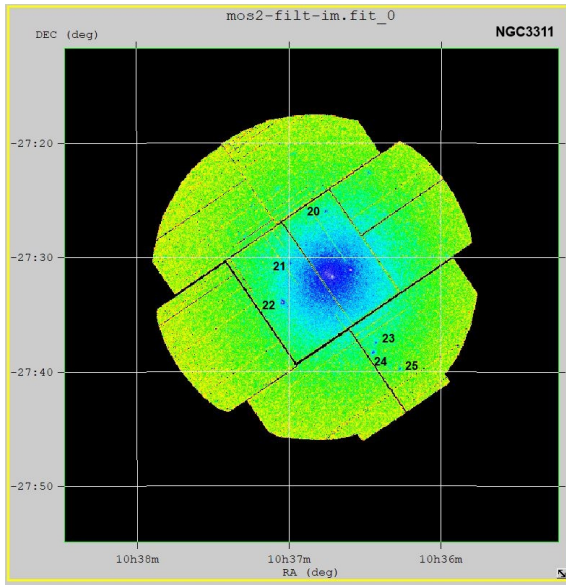
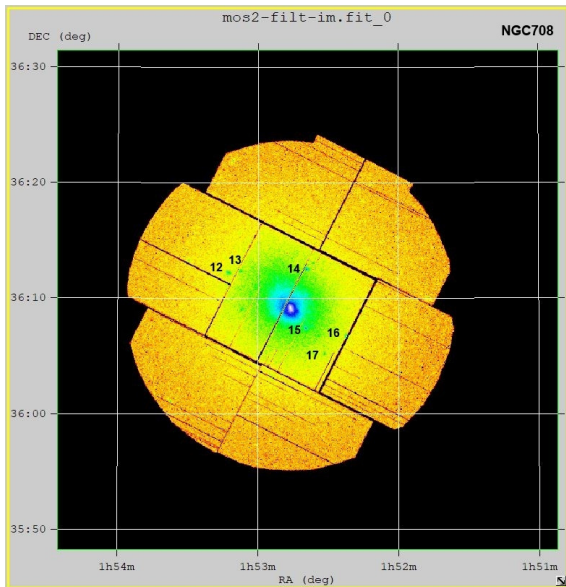Fig. 2: NGC3311 and 6 detected point-like X-Ray sources

Fig. 3: NGC708 and 5 detected point-like X-ray sources

of the largest X-ray haloes. Some examples of the detected point-like sources are presented on Figs. 1 to 3. Numbers of detected sources around each BCG are given in Table 1. Detected point-like X-Ray sources coordinates are given in the Table 2.

4. Conclusion

Performed study of the currently available data enabled to reveal 30 point like X-ray objects around 7 NGC and ESO catalogue objects. Further studies of their nature and properties will be useful for models of galaxy evolution.

Table 2: Coordinates of discrete sources in X-ray clusters

N	BCG	RA	DEC
1	ESO 156-8	3h41m44.20s	-53:42:19.46
2	M 87	12h30m58.47s	12:11:21.96
3	NGC 507	1h23m11.70s	33:27:48.86
4	NGC 507	1h23m24.98s	33:25:24.82
5	NGC 507	1h23m44.86s	33:26:08.52
6	NGC 507	1h23m54.67s	33:23:39.22
7	NGC 507	1h22m58.52s	33:22:47.18
8	NGC 507	1h23m10.95s	33:19:45.88
9	NGC 507	1h23m06.30s	33:19:32.86
10	NGC 507	1h23m07.09s	33:19:23.33
11	NGC 507	1h23m10.99s	33:10:51.15
12	NGC 708	1h53m12.59s	36:12:16.36
13	NGC 708	1h53m07.63s	36:12:25.44
14	NGC 708	1h52m39.13s	36:12:31.65
15	NGC 708	1h52m39.13s	36:07:22.70
16	NGC 708	1h52m22.30s	36:06:46.64
17	NGC 708	1h52m31.96s	36:05:13.71
18	NGC 1650	4h45m11.45s	-15:46:08.04
19	NGC 1650	4h44m52.06s	-15:48:01.20
20	NGC 3311	10h36m45.29s	-27:25:54.45
21	NGC 3311	10h36m59.29s	-27:30:34.85
22	NGC 3311	10h37m02.15s	-27:33:50.38
23	NGC 3311	10h36m25.70s	-27:37:26.24
24	NGC 3311	10h36m26.57s	-27:38:21.70
25	NGC 3311	10h36m16.02s	-27:39:46.20
26	NGC 4756	12h52m48.39s	-15:26:26.79
27	NGC 4756	12h52m45.18s	-15:25:17.28
28	NGC 4756	12h52m41.13s	-15:26:06.48
29	NGC 4756	12h52m32.08s	-15:26:42.14
30	NGC 4756	12h52m33.02s	-15:30:55.24

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