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Abell 2029 Clusters of Galaxies:
Analysis of X-Ray Point Sources

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Özet In order to understand the nature of point like structures in the cluster vicinity, we have analyzed Abell 2029 X-ray archival data of XMM-Newton and Chandra. 16 sources are detected by *wavedetect* algorithm with a 4σ selection threshold. Each source emission is further characterized by power-law plasma model individually. Critical parameters are estimated for point-like plasma. Four sources (#1, #2, #9 and #16) are reported to be very bright in X-Ray ($L_X = 10^{42} ergs/sec$). The brightness of the cD source (#16) as having very violent complex physical environment and being contaminated by extend ICM, found to be reasonable. The other bright sources locate at the outer regions ($> 1Mpc$) of A2029. Based on our very limited sample, we support the previous suggestion on triggered emission as the galaxies fall into the gravitational potential of the cluster.

1 Introduction

The nature of point-like structures (AGNs) in clusters provides critical implications for their growth, triggering and/or suppression of emission as being extremely dense Intra-cluster medium (ICM) environment. One important question, which is also the main motivation for this work, is how galaxies evolve, and why the population is different in clusters. Numerous observations show that fraction of elliptical and S0 galaxies are higher than spirals. Recent studies also report than spiral are likely to evolve elliptical in clusters (Kutdemir et al. 2010). These physical mechanisms include ram-pressure stripping of interstellar matter (ISM) by ICM, evaporation of galactic plasma by hot ICM, tidal effects due to cluster gravitational potential, galaxy harassment and mergers. These processes may trigger and fuel AGNs by accelerating accretion onto central black

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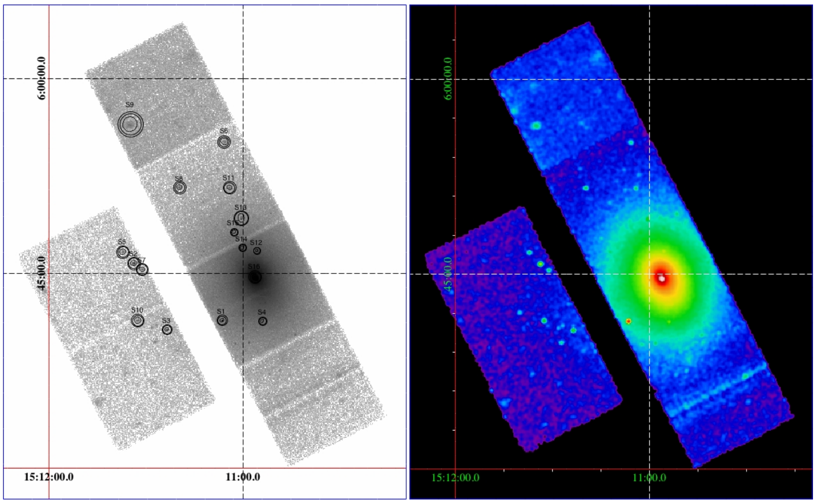
hole in galaxies. In our study of cluster AGNs, we investigate the properties of X-ray point sources from Abell 2029 field. Abell 2029 is located at a redshift of $z = 0.0767$ and known with its large central cD galaxy IC1101. It is one of our clusters of 10-sample for our survey of AGN properties within the clusters of galaxies. Throughout the work we assume a flat universe and the cosmological parameters as: $(\Omega_M, \Omega_\Lambda, h) = (0.3, 0.7, 0.7)$ where $H_0 = 100h$ km s^{-1} Mpc^{-1}.

2 Observations and Data Reduction

A2029 was observed 10 times with ACIS detector on the *Chandra*. However, the late 7-observation was pointed at the ∼10 arcmin offset and having an exposure of less than 5000 ksec and The other observations have 10 ksec and 20 ksec exposure times. We exclude observations with low statistics to avoid sophistication of mosaic data analysis that would bring into this work and considered only the 78.9 ksec of January, 2004 observation (OBS-ID=4977) for clarity. Figure 1 left-panel show *Chandra* raw image before background and exposure correction. The geometrical shape and the gaps are due to ACIS chip configuration. The right-panel is all-band 0.3-10 keV image after background subtraction, psf and exposure correction. The X-ray plasma is elongated along a north-east to south-west direction. To detect X-ray sources that are potential X-ray AGNs in



Şekil 1. *Left* : Chandra raw image before background and exposure correction. Black circles are the locations of detected sources. *Right* : 0.3-10 keV image after background subtraction, psf and exposure correction

the cluster, we applied the wavelet-detection algorithm, *wavdetect* of the Ciao

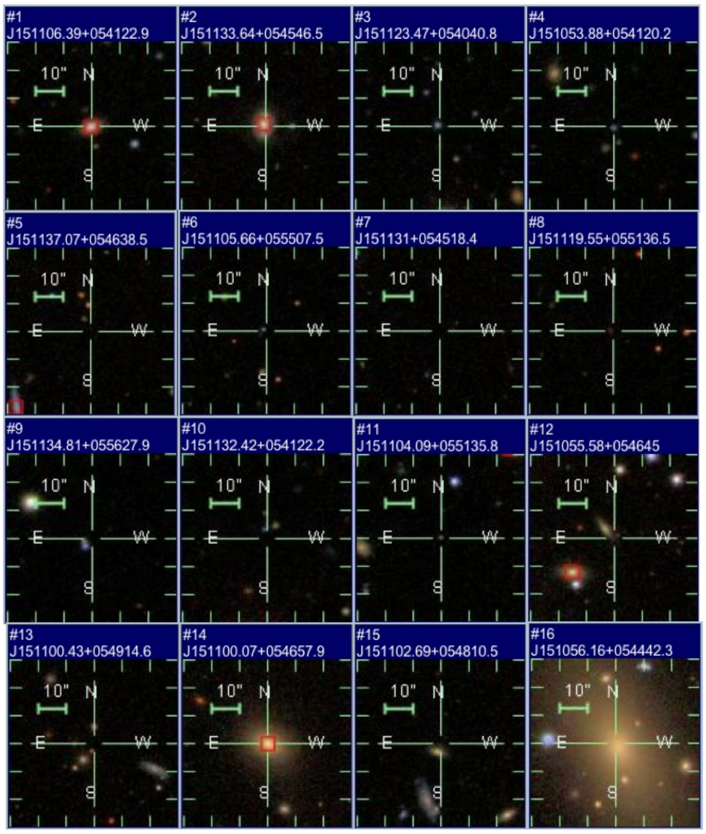
4.2 version. Considering the source position, strong ICM as background, and the chip properties source detection and flux significance, we construct limiting sensitivity map to see our analysis limits. For example, a faint-source at offset at outskirts can be detected with higher confidence, than a bright-source at cluster center buried into dense ICM. For our analysis we concentrated on sources with at least 15 broad (0.3-8 keV) X-ray counts. We detect a total of 16 sources including the cD galaxy. The source locations are circled in Figure 1, They can also be seen clearly at 3σ gaussian smoothed image. We used XSPEC, version

Çizelge 1. Source summary with coordinates, flux and luminosity values within [2-10] keV and [0.3-8] keV, and photon indices. Γ(=2.0) is fixed for #14 and #15.

SRC	RA	DEC	$F_X[2-10]$	$L_X[2-10]$	$F_X[0.3-8]$	$L_X[0.3-8]$	PhoIndex
#1	227.77665	5.6897132	7.3055e-13	0.1076e+44	9.5112e-13	0.1355e+44	2.08714
#2	227.89018	5.7629169	8.1052e-14	0.1158e+43	1.0722e-13	0.1511e+43	1.59985
#3	227.84781	5.6780181	5.2222e-14	0.7523e+42	6.0472e-14	0.8497e+42	1.78010
#4	227.72454	5.6889562	1.2608e-14	0.1887e+42	2.9013e-14	0.4196e+42	2.22801
#5	227.90447	5.7773780	1.6091e-14	0.2383e+42	3.2009e-14	0.4608e+42	2.08584
#6	227.77361	5.9187684	1.0694e-14	0.1620e+42	2.9667e-14	0.4310e+42	2.39607
#7	227.87918	5.7551219	2.1782e-14	0.3145e+42	3.2120e-14	0.4560e+42	1.74593
#8	227.83149	5.8601394	3.5132e-14	0.5018e+42	4.6414e-14	0.6541e+42	1.59795
#9	227.89505	5.9410897	2.4641e-14	0.3736e+42	6.9185e-14	0.1005e+43	2.40570
#10	227.88512	5.6895183	2.0527e-14	0.3032e+42	3.9148e-14	0.5628e+42	2.05079
#11	227.76707	5.8599446	1.1593e-14	0.1706e+42	2.1325e-14	0.3061e+42	2.00398
#12	227.73161	5.7791876	2.8975e-14	0.4244e+42	3.0309e-14	0.4280e+42	2.35602
#13	227.7518	5.8207341	2.6506e-14	0.3786e+42	3.5013e-14	0.4934e+42	1.59775
#14	227.75033	5.7827556	3.5066e-15	0.5158e+41	6.1157e-15	0.8765e+41	2.00000
#15	227.76124	5.8029260	5.9474e-15	0.8654e+41	6.6965e-15	0.9436e+41	2.00000
#16	227.73401	5.7451035	2.3073e-12	0.3443e+44	3.5851e-12	0.5142e+44	1.34372

12.6.0 software to fit a spectral model to the extracted spectra. We extracted the spectra from $30''$ circles. The background for each spectrum was obtained from a ring (between $45''$-$60''$) from outside the source region. Finally, extracted spectra were rebinned so that each channel had a minimum of 25 counts. The net count rates are fit by a power-law model with a Galactic absorption column along the line of sight N_H=3.25 × 10^{20} cm^{-20}. The best fitted values of important parameters is given at Table1. Here, we focus on the sources brighter than

$L_X = 10^{42}$ ergs/sec at 0.3-10 keV band, which are #1, #2, #9 and #16. We also inspected possible optical counterparts at the source coordinates. Figure2 shows $1' \times 1'$ clipped regions of SDSS R-filter images. Only 4 sources are accompanied with a galaxy in optic band brighter than M=-20. Considering both X-ray and optical brightness of the sources only 3 sources (#1, #2 and #16) are $L_X > 10^{42}$ ergs/sec and brighter than M=-20, we classify them as AGN.



Şekil 2. The SDSS optical counterparts of detected X-ray point sources.

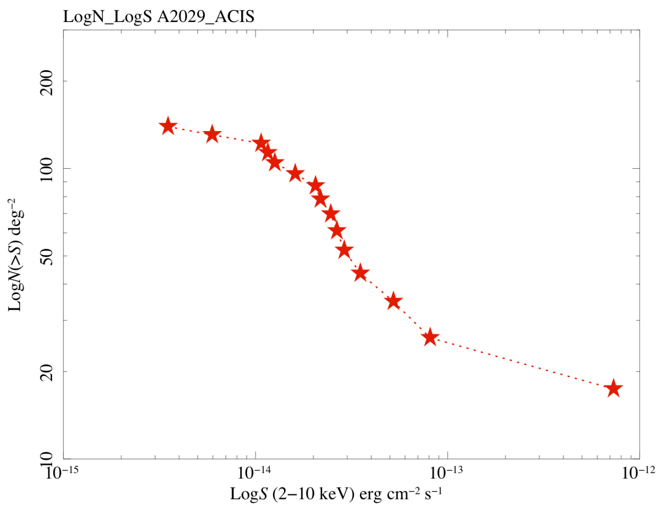
3 Discussion and Summary

We constructed logN-logS curve in 0.3-10 keV band in order to understand characteristics of galaxy density. The sum of the inverse areas of all sources brighter than flux S, N(> S), is defined as the cumulative number per square degree.

Using the integrated formula of source numbers in units of $\deg^{-2}$:

$$N(>S) = \sum_{i=1}^{n} \frac{1}{\Omega_i}(deg^{-2}) \tag{1}$$

where n is the detected source number and Ω_i is the sky coverage for the flux of the i-th source, the relation between number and flux is derived. Figure3 shows the result for A2029. The faint source ($< 10^{-14}$ergs sec^{-1}cm^{-2}) density is comparable with that of the field results (Hasinger et al. 2001). But the sources brighter than $\sim 2 \times 10^{-14}$ergs sec^{-1}cm^{-2} X-ray source density is significantly higher. The study shows that A2029 harbors 3 bright X-ray sources with active



Şekil 3. log(N)-log(S) of the identified sources of our samples.

galactic nuclei, in which the X-ray emission is probably triggered by violent ICM environment. The weakness of our work is the lack of redshift information for all X-ray sources. Our result is based on the assumption that all X-ray point sources are in the gravitational potential of the A2029. After all, we are definitely aware of poor statistics for making a concrete conclusion. However, we extend our work by increasing the cluster sample as the future action. This work is supported by TUBITAK Science Project #109T092.

Kaynaklar

Kutdemir, E., Ziegler, B. L., Peletier, et al. 2010, A&A, **V 520**, 1–74
Hasinger, G., Altieri, B., Arnaud, M., et al. 2001, A&A, **365**, L45