The X-ray Universe 2008, Granada, Spain, 27 - 30 May 2008
A conference organized by the XMM-Newton Science Operations Centre

Nature of X-ray Sources in the Outskirts of Clusters of Galaxies

M. Hüdaverdi[1], E. N. Ercan[1], F. Gök[2], G.I. Gün[3]

1- Boğaziçi University, Physics Department, Bebek, 34342, Istanbul

2- Akdeniz University, Physics Department, Dumlupinar Boulevard, 07058, Antalya

3- Çanakkale Onsekiz Mart University, Physics Department, Terzioglu Campus, 17100, Çanakkale

Abstract

Three nearby (z<0.08) clusters of galaxies (A194, A1060, A2255) have been analyzed for the X-ray point source properties with XMM-Newton data. More than 100 sources are detected from cluster fields by a multi-band detection technique. The source properties are studied by individual spectral fitting and constructing a cumulative log(N)&log(S) for a flux limit of $F_x > 1 \times 10^{-14} erg cm^{-2} s^{-1}$. The results are compared with the properties of field galaxies from Lockman-Hole. About 3 σ excess of X-ray sources was found from the cluster regions. The optical follow-up sources from A2255 field are further observed by TUG 1.5 m telescope of RTT-150. Considering the luminosity range of the sources in our study ($L_X > 10^{40}$ erg/s) the X-ray emission from accretion processes are taken into account rather than thermal processes of hot halo. Since cluster regions are highly populated with galaxies which are surrounded by high density ICM, clusters are the places with very high probability of galaxy collisions and close encounters. These physical conditions may disturb the equilibrium of individual galaxies with the surrounding gas of fuel and may trigger accretion onto LMXBs, fuel AGNs and awake black-holes. Regarding also the distribution of sources within the clusters, we notice that the brighter sources are likely to reside in the cluster outskirts. Based on our study results, infall induced AGN activities and quenching of point-like emissions by high dense cluster core are discussed.

Keywords: clusters: galaxies: individual: Abell 194, Abell 1060, Abell 2255 − X-rays

1 Introduction

Clusters of galaxies are the largest gravitational entities of the universe. They are formed from the gravitational collapse of the galaxies and the subgroups which is recurrent and still ongoing event at the present epoch. Samples of galaxies extracted from a certain cluster are subject to the same selection effects because they all accomodate at the same redshift. Cluster centers come to dynamical equilibrium prior to outer regions. Consequently the substructral features vanish in the center. Whereas the cluster outskirts are dynamically complex regions populated by galaxies moving towards the cluster potential. Understanding the undergoing physics in these regions between the virialized cluster cores and the widespread field is specially important.

Early optical surveys suggest that active galaxies in clusters are overpopulated. The conventional portrait of clusters shows overdensities of galaxies as expected. The recent X-ray results (e.g. [1]) on *Chandra* and *XMM-Newton* data reveal higher fractions of point sources toward clusters of galaxies compared to blank fields. Refs. [2] and [3] conducted systematic analysis of X-ray source populations and found significant excess from cluster fields.

In order to understand environmental effects of high-density Intra-cluster medium (ICM) on galaxies, we selected three clusters, dominated by point-like structures not buried into the ICM diffuse emission. In this work, we report X-ray and optical observational results of galaxies from the outskirts of A194, A1060 and A2255. Assuming H_o=75 km s^{-1} Mpc^{-1} and cosmological deceleration parameter of q_0=0.5, the luminosity distances to A194, A1060 and A2255 are found to be 73 Mpc, 46 Mpc, 348 Mpc, and an angular size of 1 arcmin corresponds to 20.5 kpc, 13 kpc and 97.8 kpc, respectively.

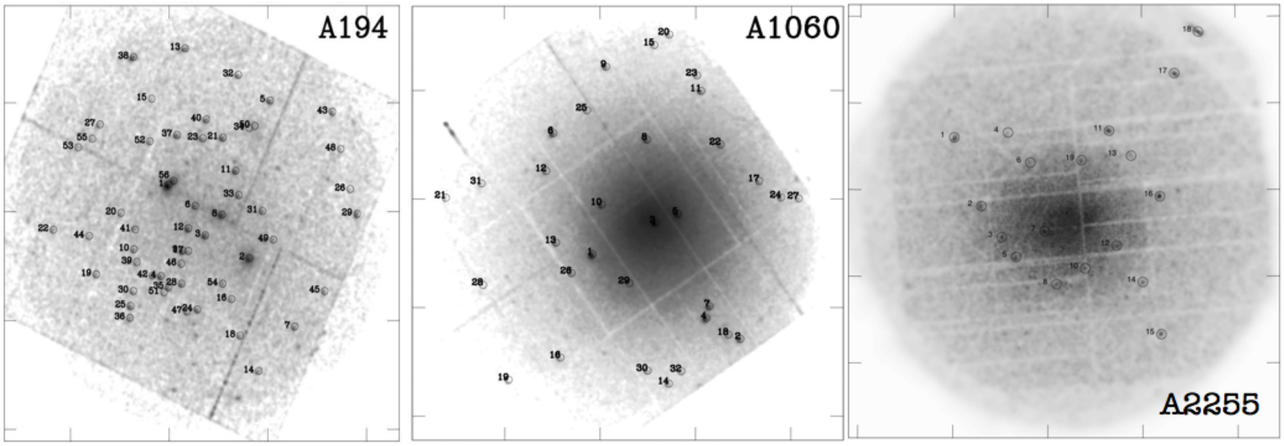

Figure 1: A194, A1060 and A2255 adaptively smoothed, merged 0.3-10 keV EPIC images. The circles indicate the locations of the detected point sources.

2 Data Analysis

We use X-ray data obtained by *XMM-Newton* observations which cover a major portion of the cluster emission with large collecting area. The routine filtering and cleaning steps are applied as described in [4]. Data are clipped above and below 2.7σ of the average count rate and cleaned events are produced.

2.1 Source Detection

We applied a multi-band source detection on the EPIC images in the soft band of $0.3-1$ keV (S), medium band $1-1.6$ keV (M), and hard band $1.6-10$ keV (H). Principally, the diagnosis of absorption effects and power-law emission is intended. This selection also splits the counts equally which is statistically more favorable. The final lists are prepared with the SAS command "SRCMATCH". With the source detection routines mentioned above, the final merged lists contain 56, 32 and 18 point sources for A194, A1060, and A2255 respectively. The Lockman Hole observations are used as reference field for comparison. Figure 1 display the detected sources on 0.3-10 keV mosaic images.

2.2 log(N)-log(S)

Using the definition of the sum of the inverse areas of all sources brighter than flux S, $N(>S)$, is defined as the cumulative number per square degree, the relation between number and flux is derived. Figure 3 shows comparison of the obtained log(N)-log(S) plot for A194, A1060, A2255 and that of the Lockman Hole measured by [5]. The characteristic of the solid angle is the same for the clusters and the field: the survey area decreases with flux. In clusters, due to extended emission, faint sources can not be detected easily in the center, thus they rise at the outskirts. Whereas, in the field there is no extended emission to bury faint sources. A significant ($\sim 3\sigma$) X-ray source excess is found from cluster fields relative to the Lockman Hole.

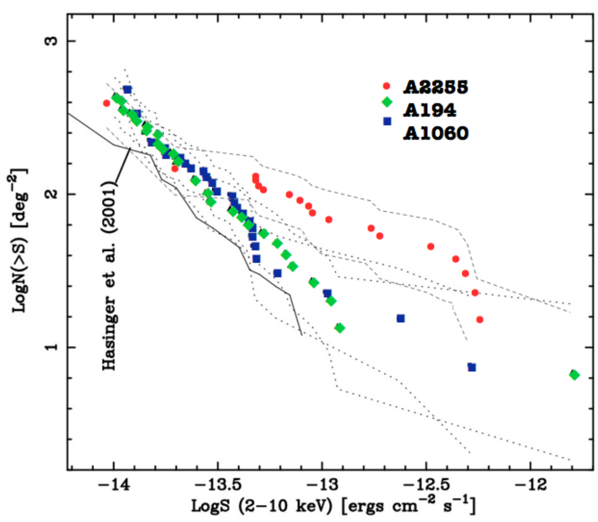

Figure 3: Log(N)-log(S) of the X-ray selected sources from 3-clusters field (filled-boxes) compared with the field of Lockman Hole (solid broken line) by Ref. [5]. The line shows the power-law model ([4]). The dotted lines show 1σ confidence level of statistical constrains and 10% calibration errors.

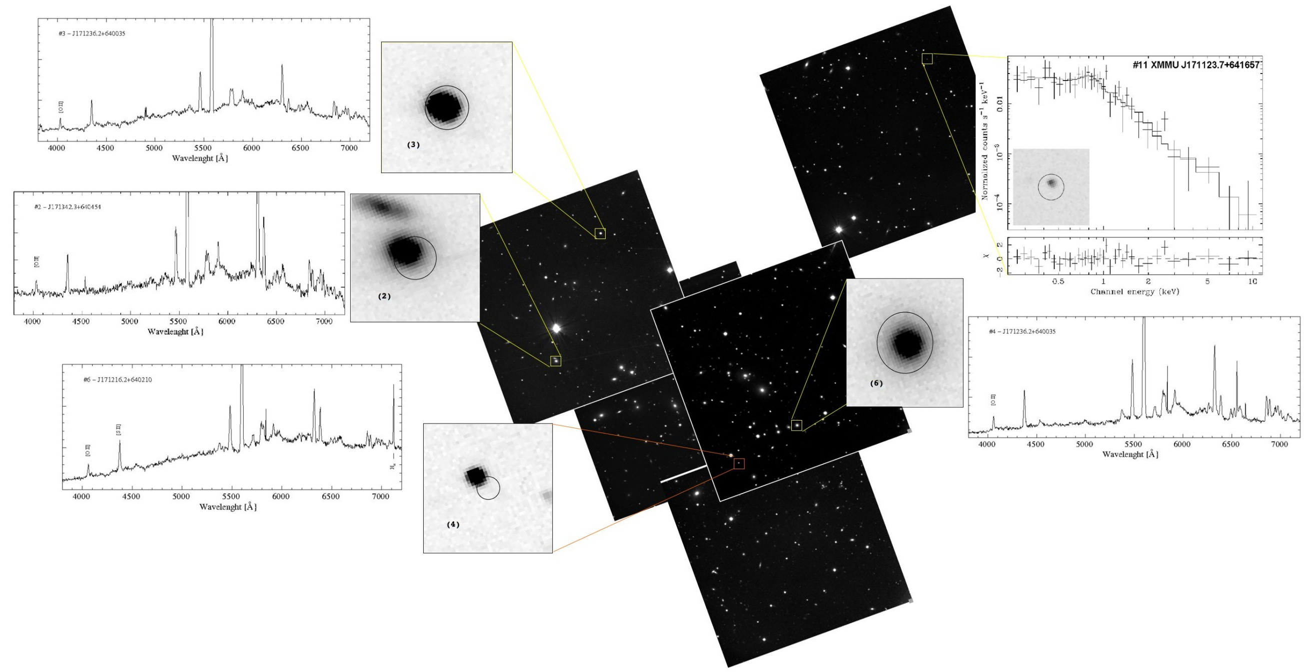

Figure 2: A2255 TUG optical observation. Black (white) images are RTT-150 B band images, shows A2255 central (zoomed) sources. The spectra are obtained from TFOSC spectrometer on TUG, except top-right. The top-right is X-ray spectrum of the pointed source.

2.3 TUG observation of A2255

Optical observations of Abell 2255 were performed with 150 cm Russian-Turkish Telescope (*RTT-150*). The telescope is located at Bakirlitepe Mountain, Antalya, south of Turkey. The source was observed using the ANDOR photometer and *TFOSC* spectrometer. The raw data were reduced using standard procedures as described by Ref. [9]. The CCD size is 2048×2048 pixels at 0.24 arcsec pixel^{-1} resolution. The intended area was covered with 5 pointings. The exposure time was 1500 sec for each frame in using Johnson B, R filters. The optical spectrometric data are taken by *TFOSC*. Its optical design is similar to the FOSC series. For this study the grism #15 is used, which provides the maximal light efficiency and the widest spectral range (3230-9120 $\AA$). Obtained spectral resolution is $\sim 8\AA$. We acquired 900 s for each source. Wavelength calibration was performed using Neon lamp. Reduction of spectroscopic data was done with IRAF.

3 Discussion and Conclusion

We have presented the nature of X-ray detected sources in the fields of nearby, poor clusters of galaxies A194, A1060 and A2255. A total of 106 X-ray sources have been detected (56, 32 and 18 respectively) by the PN camera. The excess of the X-ray sources at F_X=1×10^{-14} ergs cm^{-2} s^{-1} is estimated as $\sim3\sigma$ based on the log(N)-log(S) plot. Considering the luminosity range of our sample, LMXB and AGNs are evaluated. The results suggest an elevated X-ray emission or higher population from the cluster sources. The scenario was infall induced AGN activity. When the sources enter ICM, they get brighter. As they proceed towards the core, they are thought to loose their fuel by ram pressure stripping and get fainter.

This work is supported by TUBITAK contract No.106T310. The authors also acknowledge partial support from Boğaziçi University Research Foundation via code 06HB301. The work made use of the Turkish National Observatory (TUG) data and are supported by projects RTT150.06.20 and RTT150.05.017.

References

[1] Cappi, M., Mazzotta, P., Elvis, M., et al. 2001, ApJ, 548, 624

[2] Cappelluti, N., Cappi, M., Dadina, M., et al. 2005, A&A, 430, 39

[3] Ruderman, J. T., Ebeling, H. 2005, ApJ, 623, 81

[4] Hudaverdi M., H. Kunieda, T. Tanaka et al. 2006, PASJ, 58, 931

[5] Hasinger, G., Altieri, B., Arnaud, M., et al. 2001, A&A, 365, L45

[6] Aslan Z., Bikmaev, I. F., Vitrichenko, É. A., 2001, AstL. 27, 398