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TURKISH NATIONAL OBSERVATORY (TUG) VIEW OF CLUSTERS OF GALAXIES

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Abstract. We present the results of the optical observations of clusters of galaxies trough photometric observations with RTT150 telescope. We have selected a sample of 10 nearby (z < 1.2) Abell clusters from the northern sky. Properties of the extended X-ray intra-cluster medium (ICM) are studied using *Chandra* and XMM-*Newton* archival data. Considering possible relations of X-ray and radio plasma, the extended radio halo and jets are studied. The intent of our observations is to map galaxy densities in the optical band and to define sub-clustering if there is any. The X-ray (temperature and metal distributions) and radio features, combined with galaxy distributions are used to diagnose morphology, structure and evolutional history of the clusters.

1. INTRODUCTION

Clusters of galaxies are the largest gravitational entities of the Universe. They are formed from the collapse of individual field galaxies, groups, small or large-scale structures. The existence of sub-structures clearly indicate mergers. Mergers are recurrent events and still ongoing in the present epoch. Thus, cluster formation is still active in nearby Universe. These large scale dynamics generate turbulent motions of ICM plasma, accelerate particles by driving them to relativistic speeds and lead to large-scale (300-600 kpc) areas of radio emission. They do not have an obvious galaxy counterpart, as opposed, to radio galaxies which have AGN counterpart. Diffuse radio emission falls into two categories: (i) Radio halos are centrally located in the cluster, relatively regular in shape, and unpolarized, (ii) Radio relics are peripherally located, fairly elongated, irregular and often highly polarized. Therefore, radio properties of clusters are strong indicators of mergers and dynamical evolution of clusters. As for the optical bands, galaxies can be studied individually. Samples of galaxies extracted from a certain cluster are subject to the same selection effects because they all accomodate at the same redshift. Cluster center arrives to dynamical equilibrium before the outer regions. Consequently, the substructral indications vanish in the core. 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. Although early optical surveys suggest that active galaxies in clusters are relatively lower than the field (Dressler et al. 1985), the conventional portrait of clusters shows overdensities of galaxies as expected. The recent X-ray results on *Chandra* and XMM-*Newton* data reveal higher fractions of point sources toward clusters of galaxies compared to blank fields. As data for more clusters become available, it is concluded that the brighter galaxies are likely to be located in the outskirts of clusters ($R \sim 1$ Mpc), which is naturally attributed to the infall-related fueling of active nuclei. This work is part of a more general program aiming at understanding morphology of clusters and member galaxies from nearby (Abell) clusters. In order to understand environmental effects of high-density Intra-cluster medium (ICM) on galaxies, we have selected different (faint to bright) morphological systems. To interpret possible physical relation between X-ray and radio plasma, density and pressure profiles are studied (e.g. A194, A2634). We asssume the Hubble constant H_0=75 km s^{-1} Mpc^{-1} and cosmological deceleration parameter of q_0=0.5, The quoted uncertainties for the best fit parameters of spectral fittings are given for 90% confidence range, unless otherwise stated.

2. OBSERVATIONS AND DATA REDUCTION

The log of X-ray and optical observations is shown in Table 1. On-source archival data is used, off-set observations are ignored for X-ray analysis. Concerning the statistics we prefer to study longer exposures (> 10000 ksec).

2. 1. X-RAY DATA

We analysed the X-ray data obtained from *Chandra* and XMM-*Newton* archival data, covering entire cluster emission with ∼3 arcmin offset from the X-ray peak. ACIS camera and analysis software CIAO 4.0 is used for *Chandra*. The three EPIC instruments, the two MOSs and the PN were used for XMM-*Newton*. We processed the observation data files and created calibrated event files using the SAS version 7.0.0. The event lists were generated from the observation data files (ODF) by the tasks EMCHAIN and EPCHAIN.

2. 2. OPTICAL DATA

The optical observations of Abell clusters were performed using 150 cm Russian-Turkish Telescope (*RTT-150*). The telescope is located at Bakirlitepe Mountain (2500 m), 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 Aslan et al. (2001). The photometric data were taken with ANDOR CCD. The CCD size is 2048 × 2048 pixels at 0.24 arcsec pixel^{-1} resolution. The intended area was covered with multi-pointing if the interested area was larger than FOV ($8.2' \times 8.2'$). The exposure time was 1500 sec for each frame using Johnson B, R filters. The instrumental magnitudes were found using DAOPHOT[1] aperture photometry tasks in IRAF[2]. These instrumental magnitudes were then calibrated using field standard stars in the USNO A2.0[3] catalog.

[1]Dominion Astrophysical Observatory Photometry package

[2]IRAF is distributed by the National Optical Astronomy Observatories (http://iraf.noao.edu/), which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

[3]United States Naval Observatory Astrometric Standards

Table 1: Log of X-Ray (XMM-*Newton* and *Chandra*) and Optical (TUG) observations.

Source	Mission	Date	α (2000)	δ (2000)	Exp. (sec)
Abell 1589	XMM-*Newton*	2003.06.18	12:41:13.56	+18:34:40.10	17412
	TUG	2008.06.23	12:41:17:73	+18:34:41.50	1500
Abell 1750	XMM-*Newton*	2001.07.29	13:30:49.36	-01:50:09.30	17412
	TUG	2006.05.31	13:30:48.28	-01:50:09.57	1500
Abell 0194	XMM-*Newton*	2002.12.23	01:25:47.35	-01:23:55.20	22549
	TUG	2008.06.23	01:25:44.60	-01:22:24.50	1500
Abell 2029	*Chandra*	2004.01.08	15:10:56.10	+05:44:38.00	78910
	XMM-*Newton*	2002.08.25	15:10:51.64	+05:44:22.10	23569
	TUG	2008.06.24	15:10:56.19	+05:44:49.50	1500
Abell 2034	*Chandra*	2001.05.05	15:10:11.71	+33:29:11.80	54700
	XMM-*Newton*	2003.08.01	15:10:06.38	+33:30:19.50	26413
	XMM-*Newton*	2006.01.02	15:10:16.90	+33:30:18.30	32009
	TUG	2008.06.23	15:10:15.24	+33:29:44.10	1500
Abell 2063	*Chandra*	2005.03.29	15:23:05.30	+08:36:31.90	17040
	Chandra	2002.12.23	15:23:05:30	+08:36:31.90	14350
	XMM-*Newton*	2005.02.17	15:23:05.39	+08:36:32.30	21516
	TUG	2008.06.24	15:23:05.34	+08:36:38.50	1500
Abell 2241	XMM-*Newton*	2003.01.28	16:59:49.31	+32:36:44.90	18453
	XMM-*Newton*	2002.08.19	16:59:38.76	+32:36:48.80	13447
	XMM-*Newton*	2002.08.21	16:59:38.69	+32:36:45.70	12838
	TUG	2008.06.24	16:59:36.37	+32:37:14.50	1500
Abell 2255	*Chandra*	2000.10.21	17:12:41.50	+64:04:08.00	39940
	XMM-*Newton*	2002.10.22	17:12:40.90	+64:02:55.80	21292
	TUG	2007.07.19	17:13:40.99	+64:06:04.40	1500
Abell 2304	XMM-*Newton*	2003.06.30	18:20:08.48	+68:58:24.70	18054
	XMM-*Newton*	2003.04.25	18:20:19.36	+68:58:18.40	15854
	XMM-*Newton*	2003.03.25	18:20:24.29	+68:57:49.20	12808
	TUG	2008.06.24	18:20:35.90	+68:55:21.80	1500
Abell 2634	*Chandra*	2004.08.31	23:38:29.40	+27:01:53.10	50160
	XMM-*Newton*	2002.06.22	23:38:32.39	+27:02:44.00	11545
	TUG	2008.06.24	23:38:32.88	+27:00:23.50	1500

3. SOURCES

ABELL 1589: It is a nearby cluster (z=0.0725), locates at a distance of 729 Mpc. ICM gas has an average temperature of 5.44 keV, luminosity of $L_X = 2.4 \times 10^{44}$ erg/s. The main elongation of the X-ray plasma is in the north-east to south-west direction, but small perturbations in other directions can also be seen clearly. Temperature distribution produced from XMM-*Newton* data (Fig. 1: left panel) is in north to south direction. In the middle (Fig. 1) *Chandra* 0.2-8.0 keV image is displayed. Optical R-filter RTT150 observations (Fig. 1: right panel) clearly show that the cD elliptical perfectly coincides with the X-ray peak. This strongly indicates that the merger effects are dominant at the outskirts and have not reached the central region yet.

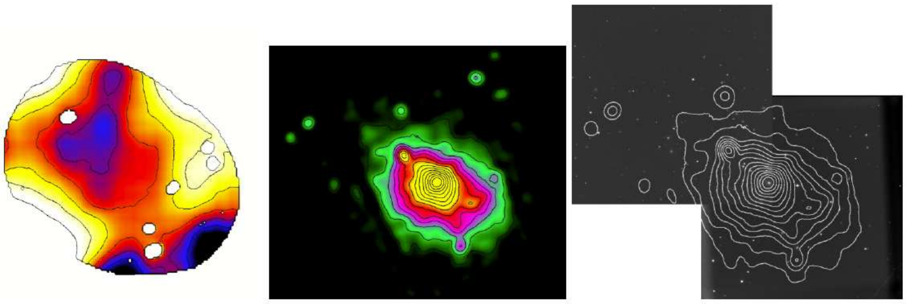

Figure 1: Abell 1589: Temperature, *Chandra* X-ray, TUG optical images.

ABELL 1750: It is a binary cluster at 345.5 Mpc away (z=0.0852), Fig. 2. Temperature map shows hot gas in between A1750-N and A1750-S, which is heated by X-ray plasma shocked by mergers (Belsole et al. 2004). We have detected 81 X-ray sources from the field. The numbers are significantly higher compared to the field galaxy counts. The source activities are probably triggered by the merger.

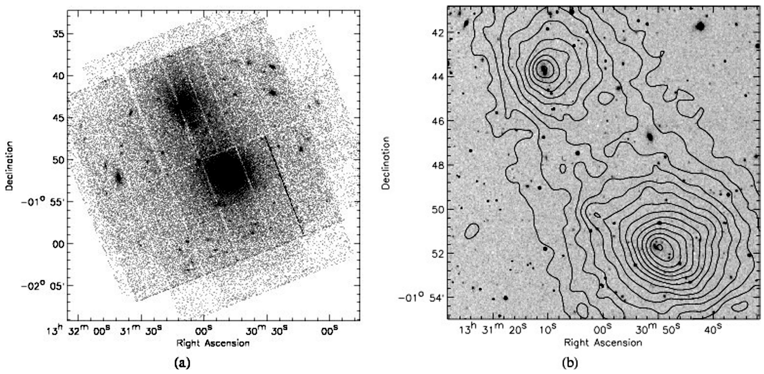

Figure 2: (a) EPIC 0.3-7.0 keV, (b) X-ray contours overlaid on optical image.

ABELL 194: The cluster is very faint in X-rays. It is nearby source (z=0.0180). A194 also known with large scale ($\sim$1 Mpc) radio emission (see Fig. 3). The bright galaxies are linear. ICM has an average temperature of 2.7 keV. Temperature map shows that radio lobes coincide with hot regions ($\sim$ 3.5 keV). This is likely due to shock heating of ICM by relativistic radio jets. A detailed analysis for pressure and density distribution is required to understand X-ray and radio connection.

ABELL 2029: The cluster locates at a distance of 310 Mpc (z=0.0767). The extend X-ray ICM elongates in north-east to south-west direction (Clarke at al. 2005). The central region is observed with single pointing by TUG (Fig. 4). It contains a large BCG galaxy IC1101 which coincides with the X-ray peak. The central galaxy also hosts wide-angle-tail radio source PKS 1508+059. The X-ray and radio connection is studied by Clarke et al. (2005) in detail. The distribution of bright galaxies is aligned with ICM elongation which is likely the direction of the cluster formation (Fig. 4). The system is quite relaxed on a large scale, but sub-structures in the center are evident.

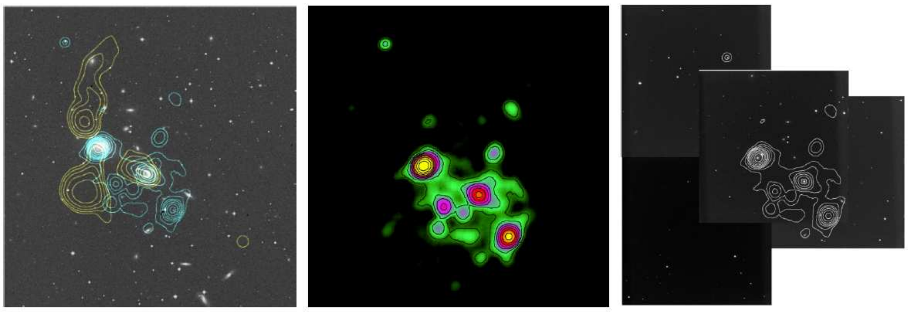

Figure 3: A194: (i) Optical DSS image with XMM-*Newton* (X-ray) and VLA (radio) contours, (ii) soft X-ray and (iii) TUG observations of 4-pointings overlaid by X-ray contours.

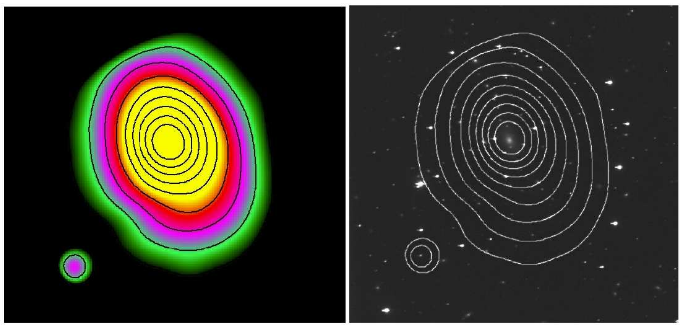

Figure 4: Abell 2029 *Chandra* X-ray and TUG optical (R-filter) observation.

ABELL 2034: It is a nearby cluster at 458 Mpc (z=0.1130). The cluster seems relaxed (Fig. 5). The X-ray peak is off-axis with cD galaxy $\sim$1 arcmin. There is a slight elongation from north to south. A detailed analysis for the cluster is presented by Bozkurt et al. (2008) in these Proceedings.

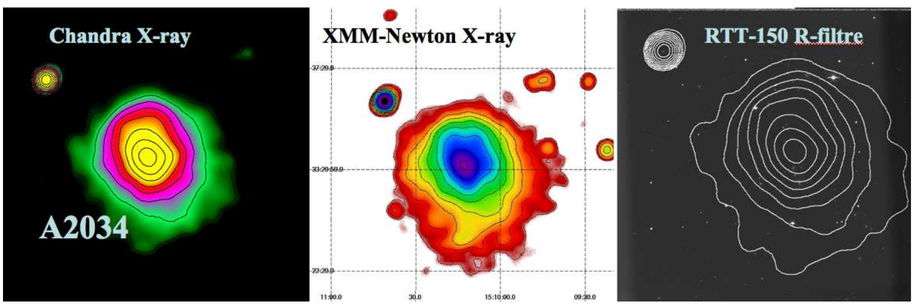

Figure 5: X-ray (*Chandra*, XMM-*Newton*) and TUG optical observation of A2034.

ABELL 2634: This is a centrally concentrated of richness class I, nearby (126.5 Mpc, z=0.0312) cluster of galaxies (Fig. 6). X-ray properties of member galaxies are studied by Sakelliou and Merrifield (1998) in detail. Based on their result, the X-ray emission can be explained by the usual population of X-ray binaries. In this work, we combine temperature distribution and radio jet propagation in the ICM, see Fig. 6 right panel. The figure shows how the radio jets move through cooler parts of the ICM. Based on the definition of pressure $P \sim nkT$, where n is the electron density, T is the temperature, one can estimate that the mechanism is ruled by density and pressure properties of the X-ray plasma.

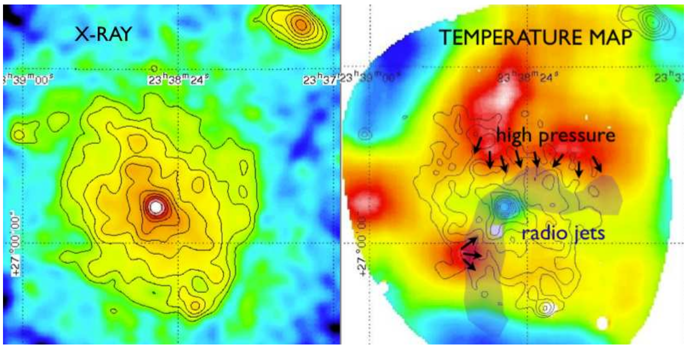

Figure 6: A2634, Interaction of X-ray plasma and Radio Jets.

Acknowledgments

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