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The extended GMRT Radio Halo Survey and the follow-up of Planck clusters

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Abstract. Extensive radio surveys of galaxy clusters are key to solving the long standing puzzles regarding the origins of the diffuse radio emission from the intra-cluster medium (ICM). These diffuse sources are termed as radio halos and radio relics and are manifestations of the relativistic electrons and the magnetic fields in the ICM. The Extended GMRT Radio Halo Survey (EGRHS) is a deep radio survey of bright galaxy clusters at 610 and 235 MHz with the GMRT designed to study the statistical properties of radio halos and relics in the galaxy clusters. We summarize the statistical results from this survey and present two candidate diffuse sources detected in Abell 2552 and Z5247. In addition to this, we have undertaken a follow up of Planck clusters with the GMRT and the Jansky Very Large Array. A radio halo has been discovered in the cluster Plck171.9-40.7 and a relic in the cluster Plck200.9-28.2. Our sensitive 610 MHz image of the cluster MACSJ1149.5+2223 shows that an earlier claimed relic is in fact a radio galaxy.

Keywords : radio continuum: general – galaxies: clusters: individual: Plck171.9-40.7, Plck200.9-28.2, MACSJ1149.5+2223

1. Introduction

The intra-cluster (ICM) is dominated by the hot ($\sim 10^7 - 10^8$ K) thermal plasma, but also contains relativistic particles and magnetic fields. The relativistic electrons and magnetic fields in the ICM lead to diffuse synchrotron sources that are detected in the radio band. These are broadly classified into radio halos, radio relics and mini-halos

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(see Feretti et al. 2012, for a review). Radio halos are ∼ Mpc in extent, centrally located, unpolarized radio sources. Radio relics are arc-like, elongated sources at the peripheries of the clusters. The radio halos and relics have been found to be mainly associated with ongoing merging activity in clusters (e.g. Cassano et al. 2010). The turbulence injected at cluster cores during mergers is currently believed to play a major role in the generation of radio halos and the radio relics have been found to be consistent with the scenario of accelerated electrons at the outgoing merger shocks (see Brunetti & Jones 2014, for a review).

In order to understand the occurrence properties and nature of these sources, we have undertaken radio observations of a large number of galaxy clusters with the GMRT. We present the recent results from the Extended GMRT Radio Halo Survey and the GMRT observations of clusters detected by the Planck satellite.

2. Extended GMRT radio halo survey

The first radio survey of a well defined sample of galaxy clusters, tailored to probe the redshift range where bulk of the radio halos are expected based on models to make robust statistical studies was the GMRT Radio Halo Survey (GRHS)(Venturi et al. 2007, 2008). We are carrying out an extension of it, called the Extended GMRT Radio Halo Survey (EGRHS). The GRHS and EGRHS samples were selected from the REFLEX and eBCS cluster catalogs based on X-ray luminosity ($L_{X[0.1-2.4keV]} > 5 \times 10^{44}$ erg s^{-1}), redshift (0.2-0.4) and declination ($> -30^{\circ}$) constraints. The GRHS and EGRHS together consist of 67 galaxy clusters. Most of these clusters (∼ 50) lacked sensitive radio data and were observed with the GMRT at 610 MHz and/or at 610-235 MHz (dual band simultaneous observations).

In the first part of the EGRHS we present the results based on the analysis of 12 galaxy clusters. Diffuse radio emission was not detected in the EGRHS sub-sample of 11 clusters. A mini-halo was detected at 610 MHz in RXJ 1532.9+3021 (see , S. Giacintucci et al. in this proc.). Based on the information regarding the presence of radio halos in a sub-sample of 48 clusters, the radio halo fraction, (f_{RH}) is 23%. When the clusters are divided into two X-ray luminosity bins separated at 8×10^{44} erg s^{-1}, the lower luminosity bin has $f_{RH} \sim 11\%$ and the high luminosity bin has ∼ 31%. Among the cool-core clusters selected from the GRHS+EGRHS sample, ∼ 50% contain mini-halos (see Kale et al. 2013, for details).

An important part of this survey are the stringent upper limits on the detection of radio halo emission obtained by injection of model radio halos in the radio data. The upper limits allow us to see the bimodality in the distribution of clusters in the $P_{1.4GHz}-L_X$ (radio halo power versus X-ray luminosity) plane. A weak or no bimodality was seen in the case of mini-halos in cool-core sub-sample – this result requires further investigation with a larger sample.

We have recently found candidate diffuse radio emission in two of the EGRHS

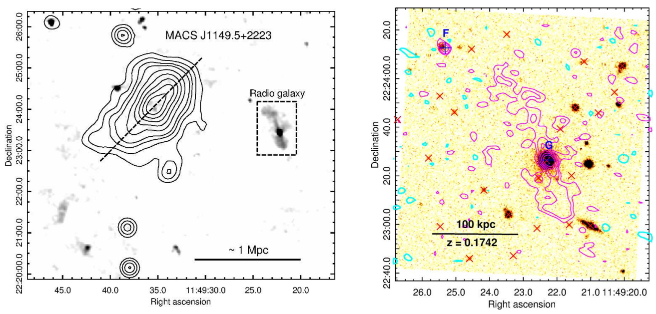

Figure 1. Left: The X-ray emission (Chandra obs ID03589) from the cluster in contours overlaid on the 610 MHz image in grey-scale. The possible merger axis is shown by the dashed line. Right: The high resolution 610 MHz emission in contours starting at 90μJy beam^{-1} overlaid on SDSS r-band image.

clusters. The 610 MHz analysis on A2552 shows hints of diffuse radio emission. The emission is not cluster-wide but is offset toward northwest of the cluster. The cluster Z5247 is a merging cluster based on the morphology with two peaks in the X-ray surface brightness. The cluster contains a dominant galaxy with tail-like radio emission. There is evidence for a radio halo in the central region of the cluster. In addition, an intriguing relic-like elongated diffuse radio source with no optical identification is detected towards east of the cluster. It is also detected in the NVSS and has a steep spectrum ($\alpha \sim 1.6$) ($S_\nu \propto \nu^{-\alpha}$, where α is the spectral index). between 610 and 1400 MHz. The radio emission from both A2552 and Z5247 are being investigated to learn their nature.

3. Follow-up of selected Planck clusters

The Planck satellite has detected a large number of galaxy clusters using the Sunyaev-Z'eldovich effect (SZ) (Planck Collaboration et al. 2011, 2013). The most massive and hot clusters were among the first detections of the Planck satellite. About 51 new clusters were also discovered. The clusters from the Planck Early SZ catalog (Planck Collaboration et al. 2011) were examined in the NVSS (1.4 GHz NRAO VLA Sky Survey) and candidate diffuse sources were shortlisted and observed with the GMRT at 610 and 235 MHz.

The GMRT observations of the cluster Plck171.9-40.7 (Plck171, hereafter) confirmed the presence of a radio halo (Kale 2013; Giacintucci et al. 2013). Among other newly detected clusters with the Planck satellite, we have discovered a radio relic in the cluster Plck200.9-28.2 (Plck200, hereafter). These two clusters were further observed with the JVLA with the new 1-2 GHz broadband receiver in 2013.

The cluster MACSJ1149.5+2223 (z=0.544, MACSJ1149, hereafter) was also observed with the GMRT. A double radio relic system that is offset from the merger axis and a central radio halo have been claimed to be detected in this cluster by Bonafede et al. (2012) using GMRT 325 MHz observations. In our high resolution ($\sim 4''$) images at 610 MHz we find that the western relic is in fact a foreground radio galaxy, containing core, jets and lobes at z=0.174 (Fig. 1).

4. Summary

We have presented recent results from the Extended GMRT Radio Halo Survey (EGRHS) and from the GMRT observations of Planck clusters. Statistical results based on the first part of the analysis of the GRHS+EGRHS are available (Kale et al. 2013). The fraction of radio halos is $\sim$ 23% in the analysed sub-sample. In the cool-core sub-sample of GRHS+EGRHS, $\sim$ 50% contain mini-halos. Among the recently analysed 610 MHz data, we have found candidate diffuse radio emission in the clusters Abell 2552 and Z5247.

Clusters in Planck Early SZ Cluster catalogue with candidate diffuse features in the NVSS were observed with the GMRT at 610 and 235 MHz. We discovered a radio halo in Plck171 and a radio relic in the cluster Plck200. We have also imaged these clusters with the JVLA at 1-2 GHz and mapped the diffuse emission in detail. Our 610 MHz observations of the cluster MACSJ1149 show that the earlier claimed western radio relic is a radio galaxy with a core, two sided-jets and lobes.

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