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The low-frequency radio emission in galaxy clusters

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Abstract. Larger scale structures in the Universe are formed by massive Galaxy clusters that grow via mergers of smaller clusters and galaxy groups. Multiple frequency radio emissions arising from such massive clusters were investigated in this work, in order to study the nature of low frequency non-thermal emission that are generated within their ongoing merger events. To probe further, the non-thermal and thermal components of the intra cluster medium and their interaction during cluster collisions, Chandra X-ray data was used. GMRT data presented on 5 massive clusters in this paper reveals the presence of diffuse radio structures in the form of *halos*, *relics* and *mini-halos* in these systems. Furthermore, we discuss the statistical properties of radio power at 1.4 GHz and X-ray luminosity in galaxy clusters and highlight the importance of contribution from LOFAR and SKA in this field.

1. Summary

We present results from low frequency GMRT observations on 5 clusters chosen from the MAssive Cluster Survey (MACS) and investigate the presence and morphological distribution of the non-thermal radio emission in the form of *halos*, *mini-halos* and

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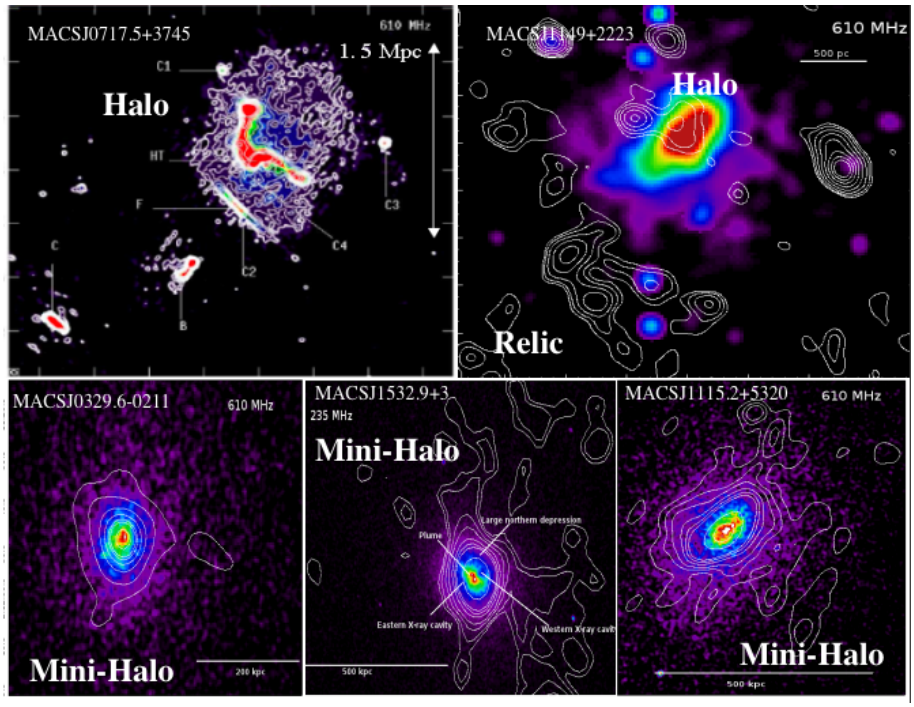

Figure 1. GMRT contours overlaid on Chandra X-ray data for (top left to bottom right) MACSJ 0717.5 + 3745, MACSJ1149 + 2223, MACSJ0329.6 − 0211, MACSJ1532.9 + 3 and MACSJ1115.2 + 5320.

relics in these systems (Feretti et al. 2012). Radio *halos* are mainly present in clusters that show dynamically disturbed centers in X-rays, whereas *mini-halos* are present in relaxed cool core clusters (Giacintucci et al. 2011). Centrally placed Mpc-scale giant halo was detected in MACS J0717.5+3745 and Mpc-scale central halo with double relic structure placed at the periphery of the X-ray emission was detected in MACS J1149+2223 downto 610 MHz (Pandey-Pommier et al. 2013a, 2013b, 2014, Bonnafede et al. 2012, vanWeeren et al. 2009). In the case of MACSJ0329.6-0211, MACSJ1532.9+3 and MACSJ1115.2+5320, mini-halos of size $\leq$ 500 kpc were detected down to 610 MHz, ref. Fig. 1 (Pandey-Pommier et al. 2014). The correlation between halo radio power at 1.4 GHz and X-ray luminosity plane is already known to show bimodality in its distribution suggesting that radio halos are transient phenomenon connected with merging clusters (Cassano et al. 2008). Thanks to our deep observations with high sensitivity ($\sim$ 45μJy at 610 MHz) we have managed to provide better upper limits to the radio power at 1.4 GHz and X-ray luminosity plot by detecting the most powerful radio halo in MACSJ0717.5+3745 and most steep radio halo in MACSJ1149+2223. In the case of mini-halos our results further confirm the hypothesis that there exists an intrinsic scaling between the radio power and the X-ray luminosity by providing positive detections to the fit (Kale et al. 2013). It is important

to note that this correlation is poorly constrained due to less available statistical data, as *mini-halos* are rare events (Kale et al. 2013). Thanks to upcoming high sensitivity facilities with large collecting areas like LOFAR (10-240 MHz) and SKA (70 MHz - 10 GHz), operating at low frequencies, it will be possible to detect many such steep spectrum sources (Cassano et al. 2012).

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