

An unlikely radio halo in the low X-ray luminosity galaxy cluster RXCJ1514.9-1523

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ABSTRACT

Aims. We report the discovery of a giant radio halo in the galaxy cluster RXCJ1514.9-1523 at $z=0.22$ with a relatively low X-ray luminosity, $L_{X[0.1-2.4\text{keV}]} \sim 7 \times 10^{44} \text{ erg s}^{-1}$.

Methods. This faint, diffuse radio source is detected with the Giant Metrewave Radio Telescope at 327 MHz. The source is barely detected at 1.4 GHz in a NVSS pointing that we have reanalyzed.

Results. The integrated radio spectrum of the halo is quite steep, with a slope $\alpha = 1.6$ between 327 MHz and 1.4 GHz. While giant radio halos are common in more X-ray luminous cluster mergers, there is a less than 10% probability to detect a halo in systems with $L_X \leq 8 \times 10^{44} \text{ erg s}^{-1}$. The detection of a new giant halo in this borderline luminosity regime can be particularly useful for discriminating between the competing theories for the origin of ultrarelativistic electrons in clusters. Furthermore, if our steep radio spectral index is confirmed by future deeper radio observations, this cluster would provide another example of the very rare, new class of ultra-steep spectrum radio halos, predicted by the model in which the cluster cosmic ray electrons are produced by turbulent reacceleration.

Key words. radiation mechanism: non-thermal – galaxies: clusters: general – galaxies: clusters: individual: RXCJ1514.9-1523

1. Introduction

Hot, X-ray emitting gas is the dominant constituent of the intra-cluster medium (ICM) in galaxy clusters. The ICM is also permeated by magnetic fields and ultra-relativistic particles, whose energy densities and dynamical effects are still uncertain. The presence of these non-thermal components is evidenced by giant, faint synchrotron radio halos, detected in the central $\sim \text{Mpc}$ regions of a number of massive clusters (e.g., Ferrari et al. 2008, Cassano 2009, Venturi 2011 for reviews). Unlike radio galaxies, these diffuse, cluster-scale radio sources lack any optical identification and are associated directly with the ICM, in good spatial coincidence with the distribution of the hot, X-ray emitting gas. They are produced by electrons with Lorentz factor $\gamma \gtrsim 1000$ spinning in large-scale μG magnetic fields. Their radio spectra are steep, with spectral indices $\alpha > 1$ (we adopt $S_\nu \propto \nu^{-\alpha}$, where S_ν is the flux density at the frequency ν).

Observations show that radio halos are not common in galaxy clusters. Large halos are found in only $\sim 1/3$ of the most massive and X-ray luminous clusters (e.g., Giovannini et al. 1999, Kempner & Sarazin 2001, Venturi et al. 2008, Cassano et al. 2008), and become even rarer in less massive systems. The rest of the clusters seems to form a distinct population of *radio-quiet* systems (Brunetti et al. 2007, 2009).

Clusters with and without a giant halo appear segregated in terms of their dynamical state: halos are located exclusively in merging systems, while clusters without radio halos are typically

more relaxed (e.g., Buote 2001, Cassano et al. 2010, and references therein). Few exceptions are known, where a radio halo is not present in a merging system, typically with relatively low X-ray luminosity ($L_X \lesssim 8 \times 10^{44} \text{ erg s}^{-1}$; e.g., Cassano et al. 2010, Russell et al. 2011).

The halo-merger connection suggests that the energy necessary to generate radio halos – through acceleration of particles and amplification of magnetic fields – is provided by cluster mergers. Although the origin of radio halos is still debated (e.g., Brunetti et al. 2008, Pfrommer et al. 2008, Donnert et al. 2010, Keshet and Loeb 2010, Brown and Rudnick 2011, Jeltama and Profumo 2011), current observations (e.g., Cassano 2009, and references therein) appear to favour models where the giant halos are caused by merger-driven turbulence that reaccelerates relativistic particles (*reacceleration model*; Petrosian 2001, Brunetti et al. 2001). In line with present data, these models predict that halos are more probably found in massive clusters and become quite rare in systems with mass $\lesssim 10^{15} M_\odot$ (i.e., $L_X \lesssim 7 - 8 \times 10^{44} \text{ erg s}^{-1}$) at intermediate redshift ($z \sim 0.2 \div 0.5$; Cassano et al. 2008).

Here, we report the discovery of a giant radio halo in RXCJ1514.9-1523, a galaxy cluster at $z=0.22$ with a relatively low X-ray luminosity, $L_{X[0.1-2.4\text{keV}]} = 7.2 \times 10^{44} \text{ erg s}^{-1}$ (Böhringer et al. 2004).

We adopt the ΛCDM cosmology with $H_0=70 \text{ km s}^{-1} \text{ Mpc}^{-1}$, $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$. At the redshift of RXCJ1514.9-1523, this gives a scale of $1'' = 3.59 \text{ kpc}$.