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Evidence for Strong Intracluster Magnetic Fields in the Early Universe

J. Xu[1], J. L. Han[1]
[1] National Astronomical Observatories, Chinese Academy of Sciences
e-mail (speaker): xujun@nao.cas.cn

Magnetic fields in galaxy clusters have been observed and studies in past few decades.[1] Direct evidence for intracluster magnetic fields is the presence of diffuse radio halos and relics in galaxy clusters through which a roughly strength of a few microGauss is estimated under the minimum energy hypothesis. An alternative way to investigate magnetic fields in the intracluster medium (ICM) is the statistical study of Faraday rotation measures (RMs) of radio sources within or behind galaxy clusters, which shows the RM excess for the contributions from the ICM with an amplitude from a few to a few tens of rad m^{-2}.[2]

It is not known if there is any evolution of intracluster magnetic fields at different cosmological epochs. Statistical studies of the redshift evolution of net RMs contributed by the ICM is the key to the puzzle. Previous statistics of RMs were generally made for the whole contribution on the path from the observer to the sources, so only a marginal dependence of redshift was found.[3,4,5] Differences in Faraday rotation measures of an embedded double radio sources, i.e., a pair of lobes of mostly Fanaroff-Riley type II radio galaxies, are free from the Faraday rotation contributions from the interstellar medium inside the Milky Way and the intergalactic medium between radio galaxies and us, and hence provide a novel way to estimate average magnetic field within galaxy clusters

We have obtained a sample of 627 pairs whose RMs and redshifts are available in the most updated RM catalogs and redshift databases. The RM differences of the pairs are derived. Figure 1 shows statistically large RM differences for pairs of redshifts at $z > 0.9$, indicating the average intracluster magnetic fields as strong as about 4 μ G, comparable to the intracluster field strength in nearby galaxy clusters. Such a strong magnetic field in the early universe makes a big challenge on the theories of generation of cosmic magnetic fields.

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References

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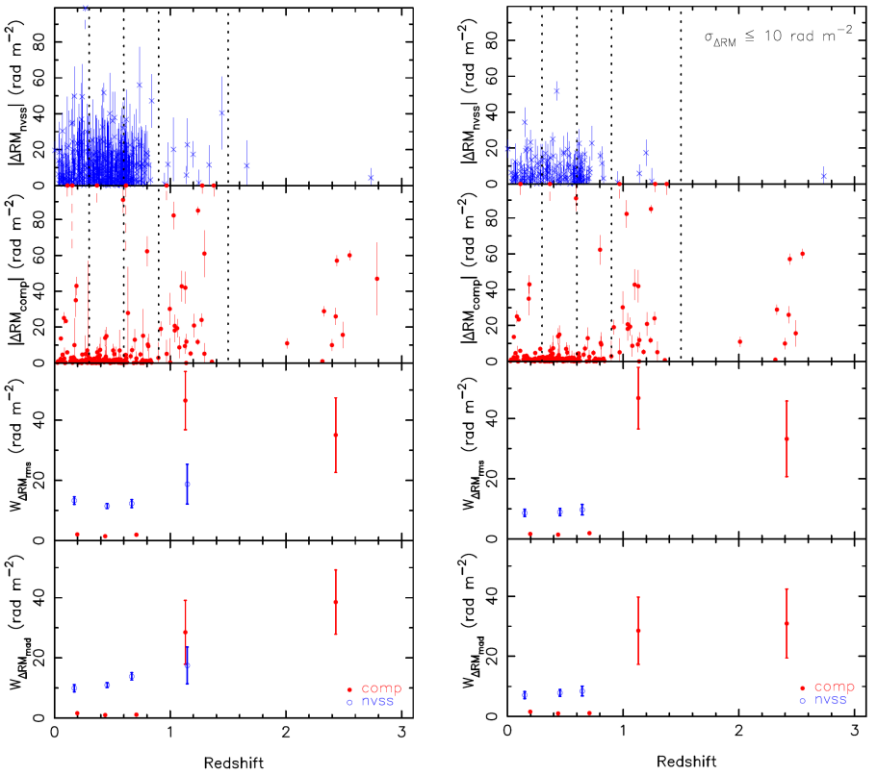

Figure 1. Distribution of absolute values of RM differences | Δ RM| and the data dispersions as a function of redshift for 387 NVSS pairs and 197 pairs of compiled data with LS<1Mpc, |b|>10°, and z<3 (left), and the same plots for pairs with a formal Δ RM uncertainty less than 10 rad m-2 (right). The dispersions of the | Δ RM| distribution are calculated with a Gaussian fitting with a characteristic width $W_{\Delta RM}$ or simply taken as the median absolute values.