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ASTRONOMY AND ASTROPHYSICS

A Comparison of Radio and X-Ray Morphologies of Four Clusters of Galaxies Containing Radio Halos

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Abstract. Several clusters of galaxies contain cluster wide, central, diffuse radio halo sources. From a morphological point of view the diffuse radio emission seems to be connected to the X-ray emission of the cluster. To quantify the similarity in the radio and X-ray brightness, we performed an analysis of the radio and the X-ray emission for four clusters of galaxies containing radio halos (Coma, Abell 2255, Abell 2319, Abell 2744). Our study leads to a linear relation between the radio and the X-ray surface brightness in two clusters (A2255, A2744). In Coma and A2319 the radio and the X-ray brightness can be related with a sub-linear power law. Implications of these findings within simple radio halo formation models are briefly discussed.

Key words: Cosmology: diffuse radiation – Radiation mechanism: non-thermal – Radio continuum: general – Galaxies: clusters : general – Galaxies: intergalactic medium – Magnetic Fields

1. Introduction

The presence of cluster-wide magnetic fields and relativistic electrons in cluster of galaxies can be directly demonstrated by the detection of radio halos residing in the center of some clusters of galaxies. Radio halos are diffuse, and cluster wide radio emission regions. They are very likely related to the intra-cluster medium (ICM) as a whole and not to a particular galaxy.

The physical mechanism producing the radio-synchrotron emitting relativistic electron population is not yet determined. However it is clear from cooling time arguments that it has to operate within the ICM, in order to explain the large extensions ($\simeq$ 1Mpc) of radio halos.

In general, the clusters containing radio halos are characterized by the presence of recent merger process, which are probably the energy source of the relativistic electrons. Moreover, they show high X-ray luminosity and therefore high temperature and large mass (Feretti 2000).

Several suggestions for the mechanism transferring energy into the relativistic electron population have been made (see Enßlin (2000) for a recent review): in-situ acceleration of relativistic electrons by plasma and by shock waves, particle injection from radio galaxies, acceleration out of the thermal pool, secondary electrons resulting from hadronic collisions of relativistic protons with the ICM gas protons, and combinations of these processes.

It is therefore important to develop observables which allow a discrimination between these models. Important observables used so far in the literature are: the global radio spectral index, the emission and spectral index profile, the total radio emissivity and its correlation to cluster parameters as temperature or X-ray luminosity.

It is the purpose of this paper to present a new observable: the comparison of the radio and the X-ray surface brightness in clusters containing radio halos. Its suitability is demonstrated by the striking similarities of the radio halo morphology and the thermal X-ray emission of halo clusters. These morphological similarities indicate an energetical relation between the thermal gas and the relativistic plasma. This observable is straightforward to determine from observational data or any theoretical model and does not depend on any assumptions.

Intrinsic parameters are calculated with $H_0 = 50\,\mathrm{kms}^{-1}\mathrm{Mpc}^{-1}$ and $q_0 = 0.5$.

2. Data Analysis

So far, the similarity of the radio halo and the X-ray morphology of the clusters was only pointed out in the literature (Deiss et al. 1997, Feretti 1999, Liang et al. 2000) but not used to constrain models. Here we present the first deeper analysis of the relation between the radio and the X-ray brightness distribution. We provide such an analysis for four clusters: Coma (Abell 1656), Abell 2255, Abell

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