EXTENDED RADIO EMISSION IN CLUSTERS OF GALAXIES: RECENT WESTERBORK OBSERVATIONS

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Whether galaxy clusters, in addition to a number of radio sources associated with *individual* cluster members, have an extended radio emitting region designated as cluster halo is in an interesting way related to several questions concerning cluster characteristics:

i) do relativistic electrons leak out of active cluster galaxies and accumulate; how do they propagate in the cluster;
ii) what is the strength and topology of the intracluster magnetic fields;
iii) is there an association between radio-synchrotron and either inverse Compton or free-free X-ray emission;
iv) what static thermal pressure helps to confine the discrete extended (head-tail) radio sources in clusters.

The observations are problematic, especially for the nearby clusters for which the expected angular sizes of the cluster haloes are of the order of 30' arc:

i) single dish telescopes have the best brightness sensitivity but blend discrete sources due to lack of resolution;
ii) aperture synthesis telescopes are insensitive to extended emission due to missing short spacings (for the Westerbork Synthesis Radio Telescope at 610 MHz $\theta_{max} \approx 30'$);
iii) the galactic foreground continuum and its polarization is difficult to separate from suspected cluster emission.

We present results for five clusters studied with the WSRT:
1) In the Coma cluster a radio halo (Coma C) has been detected (Jaffe et al. 1976; Valentijn, 1977). Assuming a Gaussian brightness distribution for the halo at 610 MHz a flux of 1.2 ± .5 Jy and a F.W.H.M. diameter of 33' was found. Additional single dish WSRT observations proved the strong polarized signal from the direction of Coma to be galactic foreground radiation. If the X-ray emission from Coma is at least 75% thermal, as indicated by Fe-line emission, then the intracluster magnetic field must be at least 10^{-7} Gauss to keep the inverse Compton X-rays below the permitted level. Compare this value with $H_{eq} = 4.10^{-7}$ Gauss.

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2) In the Perseus cluster Gisler and Miley (1978) found no evidence at 610 MHz for whole cluster emission. NGC 1275 does have its own radio halo on a 5' scale (see also Miley and Perola, 1977), whose morphology is similar to, possibly identical with that of the extended X-rays source centred on NGC 1275 (Gorenstein et al. 1977). According to an inverse Compton interpretation of the X-rays, the X-ray to radio surface brightness ratio would imply a magnetic energy density $\sim$ 500 x below the radio-deduced equipartition value, so this X-ray component is most probably thermal.

3) In the Hercules cluster no extended radio halo has been detected. Two wide angle radio trails (NGC 6061 and NGC 6034) have been mapped (Valentijn and Perola, 1977; van Breugel and Valentijn, 1978). In order to confine the expansion of these tails by a dense and hot intracluster medium a lower limit on the product $\rho T_7 > 10^{-5}$ (10^7 K cm^{-3}) is derived.

4) In A2256 there appear four to six radio trails in the 610 and 1415 MHz maps and in addition there is eccentrically located cluster emission not identifiable with individual galaxies (Bridle and Fomalont, 1976; Bridle et al. 1978). The galaxies in A2256 represent a normal radio luminosity function.
Values of $\rho T_7 > 5.10^{-4}$ (10^7 K cm^{-3}) are derived from static thermal confinement of the tailed radio sources. This set of quantities and especially the relatively low spectral index $\alpha(1415, 610) = 0.7$ for the very extended component implies particle reacceleration over extensive volumes and may indicate the presence of a strong intracluster magnetic field.

5) A1314 contains several radio trails (Vallée and Wilson, 1976; Wilson and Vallée, 1977; Vallée, 1977). There is no evidence for a cluster halo.

The limited range of surface brightness sensitivity of the WSRT defines the actual range of ρT_7 derived from observables from 10^{-5} to 10^{-3} (10^7 K cm^{-3}). Uncertainty in the electron to nuclear energy ratio η adds an uncertainty $\eta^{4/7}$. The density and pressure estimates in individual cases are therefore only indicative and uncertain by a factor of ten.

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DISCUSSION

Ginzburg: If you observe high radio brightness in the central regions of a cluster of galaxies, you can estimate, making a number of assumptions, what the intensity of the radio halo in the cluster should be. What is your view on this question?

van der Laan: My views on this question are not related to the observations which I have presented. It is my view that extended "halo" sources in clusters may be detected in low frequency radio surveys. The cosmic ray electron component is expected to suffer severe synchrotron, inverse Compton and adiabatic losses which conspire to steepen the spectrum of the halo emission. These sources would not be observable at the wavelengths at which we have made our observations. There is no contradiction between the observation of intense radiation from the central regions and the absence of a cluster halo.