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Radio Sources and Their Environment

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Abstract. The properties of radio sources in and outside of Abell clusters are reviewed. The properties of sources in and out of Abell clusters are shown to be surprisingly similar. However, sources in dense cluster cores do not fit this pattern and, as in Virgo A (M87), have a significant, sometimes dominant input of energy into the "cooling core" environment.

1. Introduction

The relationship between radio galaxies and their environment is much too large a topic for a short presentation at a Joint Discussion. Thus we will cover only two aspects of this large subject: 1) the statistical properties of radio sources in and out of rich clusters and 2) the impact of radio jets on dense cluster cores.

2. Statistics of Radio Galaxies

The images we make of radio sources are supposedly snapshots of one epoch in the constantly changing appearance of each source. Thus, like stars, in order to understand the phenomena we are seeing we need to study moderately large, complete samples so that we see sources in all stages of their evolution. For this reason, we have explored three complete samples of radio galaxies: the VLA Abell cluster sample (Ledlow & Owen 1995, 1996), the Bologna radio galaxies (Fanti et al. 1987) and the Wall and Peacock sample with $z < 0.3$ (Wall & Peacock 1985). We have studied the sample using three observables (absolute radio luminosity, absolute optical luminosity, and radio linear size). Using these three variables we find no significant difference in the properties of the cluster and non-cluster samples (Ledlow, Owen, & Eilek 2000). This seemingly strange result appears to be saying that radio sources in very different environments have the same properties. However, another possibility is that radio sources cataloged to be in rich clusters live in similar environments as those not associated with rich cataloged clusters. The latter conclusion is consistent with recent X-ray/optical

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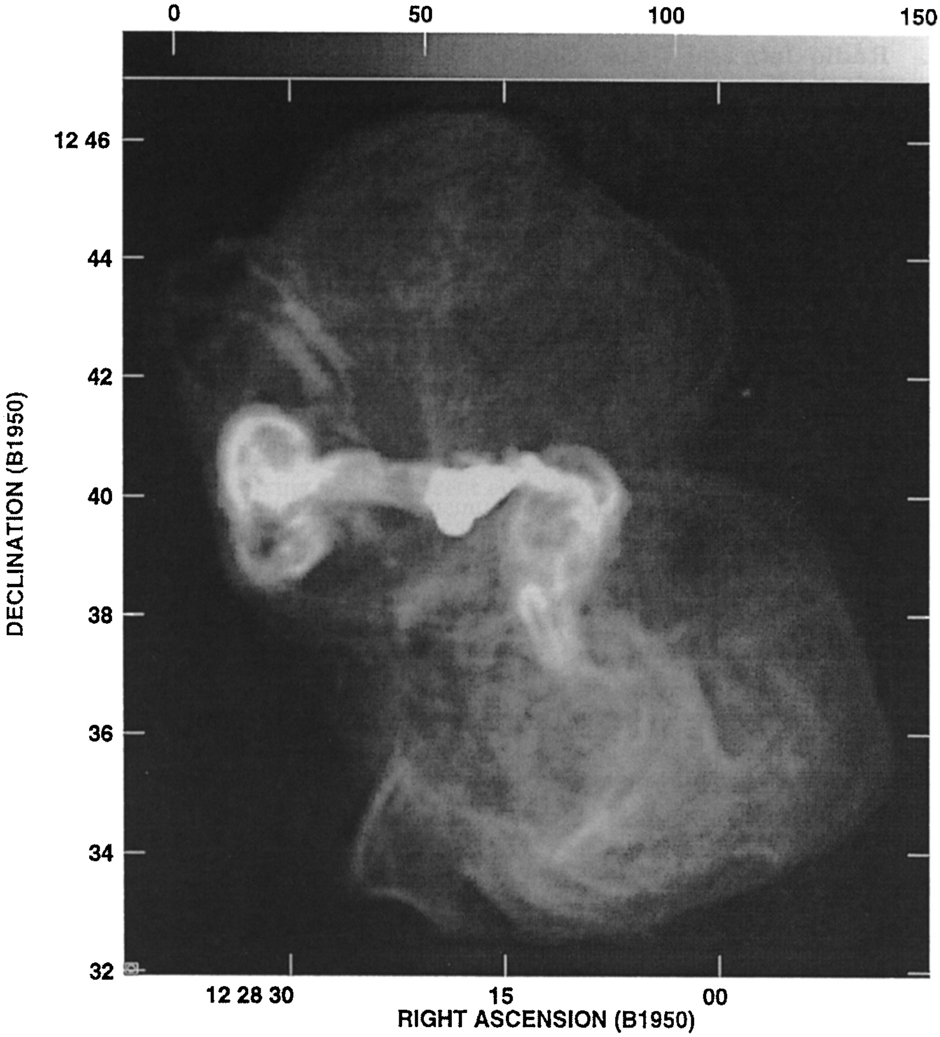

Figure 1. M87 image at 90cm. This image shows the structure of the "halo" extending over 70 kpc. The saturated, triangular region near the center of the image contains the famous 2 kpc jet and the inner lobes.

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studies of nearby, non-Abell cluster radio galaxies, which find that the majority of these sources (especially the FR I's) live in environments only slightly less dense and rich than those found in Abell clusters. (e.g. Miller et al. 1999; Worrall & Birkinshaw 2000). Thus radio galaxies appear to be markers of similar external environments.

3. Radio Jets and Dense Cluster Cores

The recent VLA image of Virgo A (Figure 1), in the dense core of the Virgo cluster, reveals a much more complex situation than previous, lower fidelity images (Owen, Eilek, & Kassim 2000). The image suggests that the smaller scale outflow, as seen in the famous M87 optical/radio jet, in fact extends out radially to scales of 40 kpc. This scale is approximately the same as is the region which is modeled as a "cooling flow" based on the X-ray images of the center of the cluster. Based on the disturbed appearance of the halo, we believe that most of this power is deposited in the local gas. Models of the energy flux in the jet typically are $\sim 10^{44}$ ergs s^{-1}. The X-ray luminosity from the 70 kpc region is $\sim 10^{43}$ ergs s^{-1}. Thus there appears to be more energy being deposited in this region by the flow originating in the central black hole than being radiated away in X-rays. Therefore, this part of the cluster appears to be heating right now rather than cooling.

However, M87 may well be in an unusual period of activity as we currently observe it. This heating phase may only last $\sim 10^8$ years or so. We find that the two bubbles of radio emission would take about this long to be inflated at 10^{44} erg s^{-1}. If the source is a transient, we would expect X-ray cooling to dominate when the black hole was not active. Other "cooling cores" very often have detectable radio emission but at a large range of power levels. We may well be observing these clusters in the variety of states which the activity in the central black hole can produce. Thus the central parts of rich clusters may be a continuing battle between the cooling losses from the hot, intracluster medium which extends over Megaparsecs and the energy gains from the comparatively tiny black hole in the cluster core.

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