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The Multi Wavelength Study of the two Unique Radio Galaxies Hercules A and 3C 310 - The story so far

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Abstract. We are studying the two unique powerful radio galaxies Hercules A and 3 C310. We are trying to determine whether the unusual and similar structure and behaviour of these two radio galaxies originate in a similar fashion or not. In other words we try to find why these sources have so many similarities and are so different from double lobed AGNs. This research is being made by using multi-wavelength observations across the electromagnetic spectrum.

1. Introduction

Hercules A (z=0.154, e.g. Gizani & Leahy, 1999) and 3C 310 (z=0.054, van Breugel & Fomalont, 1984) are two powerful radio galaxies with a similar and unique behaviour: Both sources appear with double optical nuclei (3C 310: Chiaberge et al., 1999, Hercules A: Baum et al., 1996) and have similar absolute magnitude (≈ -23.5) at the R-band (Owen & Laing, 1989). 3C 310 is smaller.

Both radio sources are classified as FR1.5 (Hercules A: Dreher & Feigelson, 1984; 3C 310: Owen & Laing, 1989). 3C 310 is less powerful than Hercules A. They have no compact hot spots and consist of sharply-bounded lobes. They are probably the only two radio galaxies that show large multiple circular radio features (ring-like structures) that are interior to the lobes and not just phenomena of the boundaries. The projected magnetic field follows the edges of these features. They are highly polarized and steep spectrum sources of similar steepness. The ring-like structures and other high brightness features have much flatter spectra than the surrounding diffuse lobes. This may indicate that we are witnessing a renewed outburst from the active nucleus. Their lobes present asymmetries with respect to brightness, depolarization and spectral index. Hercules A has a weaker radio core with a steep spectrum. New high resolution VLBI observations (see Gizani & Garrett, these proceedings) have also revealed possible misalignment between the pc and kpc-scale jets of both sources.

They are the hosts of clusters of galaxies (Hercules A: Feigelson & Berg, 1983, 3C 310: Jenkins et al. 1977). 3C 310 has a lower X-ray luminosity than Hercules A. For both sources the X-ray emission is centered on the radio core. The brightness profile can be described well if we assume contribution from a point source (e.g. Gizani & Leahy, 1999, Hardcastle & Worrall, 1999). While the intra-cluster medium in both the Hercules A and 3C 310 clusters (of type Abell and Zwicky respectively) has a similar temperature, it seems to be denser towards the center for the Hercules A cluster (e.g. Leahy & Gizani, 1999). The hydrogen column density towards Hercules A is higher than towards 3C 310 almost by a factor of two.

The thermal pressure of the Hercules A cluster is larger than of the 3C 310 cluster and hence the confinement of its lobes by the intra-cluster medium is greater. The cluster thermal pressure at the distance of the radio lobes is typically an order of magnitude larger than the lobe minimum pressure for both radio galaxies (Leahy & Gizani, 1999).

2. Multi-wavelength observations

2.1. Radio

We have studied the kpc-scale environment of the extragalactic radio source Hercules A in terms of the intracluster magnetic field (see Gizani & Leahy, 1999 for example). We have also mapped the Faraday rotation field at high resolution (1.4 arcsec). We have found that Hercules A exhibits a strong depolarization asymmetry: The depolarization is mainly caused by a centrally condensed medium (probably the X-ray emitting gas) in which Hercules A is embedded at $\simeq 50°$ to the line of sight. The western weak jet and associated lobe is behind the bulk of the depolarizing gas while the bright eastern jet and lobe are in front. The extended X-ray emission is elongated along the radio galaxy axis and there is a weak nuclear component. The estimated temperature of the cluster is kT=2.45 keV and the central electron density is $n_\circ \simeq 7.8 \cdot 10^{-3}$ cm^{-3} which reveals a hot, dense environment. We have estimated a central value of the magnetic field to be $3 \lesssim B_\circ(\ \mu\mathrm{G}) \lesssim 9$ (see Gizani & Leahy, 1999 for example).

In addition we are studying the spectral ageing of the source. For this reason we have taken high resolution 400 cm and 90 cm VLA data using the Pie Town link (Gizani, Cohen & Kassim in prep.).

We have observed the central region of Hercules A at 18 cm using the EVN-MERLIN array (see Gizani et al. 2001 for example, also Gizani & Garrett these proceedings).

There are no high resolution radio observations of 3C 310. In order to make a similar analysis as for Hercules A, we are going to reprocess the existing observations by van Breugel & Fomalont, 1984 combined with new radio observations which we are planning to make.

As for Hercules A, the core of 3C 310 is unresolved with the VLA. It is very weak, but stronger. We are probing the pc-scale environment of 3C 310 with the global VLBI and MERLIN (see Gizani & Garrett, these proceedings).

We have also made HI observations of each radio galaxy with emphasis on their nuclear region using the Westerbork array (Gizani & Morganti in prep.). Due to the weak core of Hercules A, the declination of the source as well as interference we have been unable to detect any HI absorption against its central engine and/or its lobes. A possible HI absorption has been observed against the southern lobe of 3C 310 at the area of the ring-like feature with an optical depth of 0.8%. We have already requested more time in order to confirm this.

2.2. Infrared

As powerful radio galaxies, Hercules A and 3C 310 are expected to be strong emitters in the infrared. For both radio sources we have planned near-infrared observations of the host and of the ring-like features. The infrared observations will provide an accurate measure of the shape of the spectrum, in order to constrain the nature of acceleration mechanism in the ring-like features, which make them shine so bright in the radio just like hot spots do.

2.3. Optical

The optical imaging and spectral observations will allow the study of the ionized gas in the accretion disk fuelling the massive black hole. We also need to explain some of the observed depolarization of Hercules A. In addition studying the properties of the possible narrow/broad emission line (H_α for example) of both radio galaxies we will study their nuclear region. For 3C 310 it is tempting to see if there are any optical features like for example the possible rings of obscuration found on Hercules A (Baum et al., 1996).

2.4. X-ray

The XMM observations are going to give us a good estimate of the temperature of the cluster gas and quantify the X-ray emission of both radio galaxies. Since there are no high resolution data on 3C 310, Chandra data are going to clarify the ambiguous X-ray emission and also, for example, measure accurately pressure and density as a function of radius from the core and identify interactions between the X-ray and radio emission at the area of the radio rings.

3. Conclusions

We are studying the two radio galaxies Hercules A and 3C 310 as they are exceptional cases. Both radio sources have a similar behaviour and many differences from the usual morphology and characteristics of double radio sources associated with active galactic nuclei.

This study is being made using multi-wavelength observations across the electromagnetic spectrum. Their combination will reveal the physical mechanisms that take place interior and exterior to the source i.e. in the central engine, in the galactic environment and in the intra-cluster gas.

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