RADIO POLARISATION STUDIES OF GALAXIES AT Z > 2

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We present some interesting results from a radio study of 17 radio galaxies at z >2, selected from a complete sample of Molonglo sources with $S_{408} > 0.95$ Jy for which optical identifications and spectroscopic redshifts are being obtained in a major observational programme (Kapahi *et al.* 1995).

Observations and results : The 17 galaxies were mapped using the VLA at 1.4, 4.8 and 8.3 GHz with the highest resolution of $\sim 0.3''$ at 8.3 GHz. The integrated spectra are generally quite steep and convex in many sources, steepening to $\alpha \geq 1.2$ ($S \propto \nu^{-\alpha}$) at the highest frequency. Most of the sources have a double structure with sizes ranging up to $22''$. Unresolved radio cores, coincident with the optical galaxies, are detected at the mJy or sub-mJy level in most cases. Several sources also show one-sided jet-like features. Surprisingly, most of the cores appear to have steep spectra between 5 and 8.3 GHz!

Large rotation measures (RM) of a few 100 rad/m^2 are common in these sources; several show RMs of over 1000. The galaxy 1138-252, at z = 2.17, has an RM of 5700. The polarisation at 15-20 GHz (emitted) is typically 5-10%. Most sources show strong depolarisation by 5 GHz (emitted), probably as a result of beam depolarisation. The asymmetry in the radio lobe properties in most sources is, perhaps, a pointer to the irregular and clumpy nature of their environment.

Steep spectrum cores : Eight of the 12 cores detected in the sub-arcsecond images at both 4.7 and 8.3 GHz have a steep spectral index ($\alpha > 0.5$) with $\alpha_{med} = 0.75$. This is in sharp contrast to the flat spectra ($\alpha < 0.5$) of the cores (believed to arise from superposed spectra of syn-

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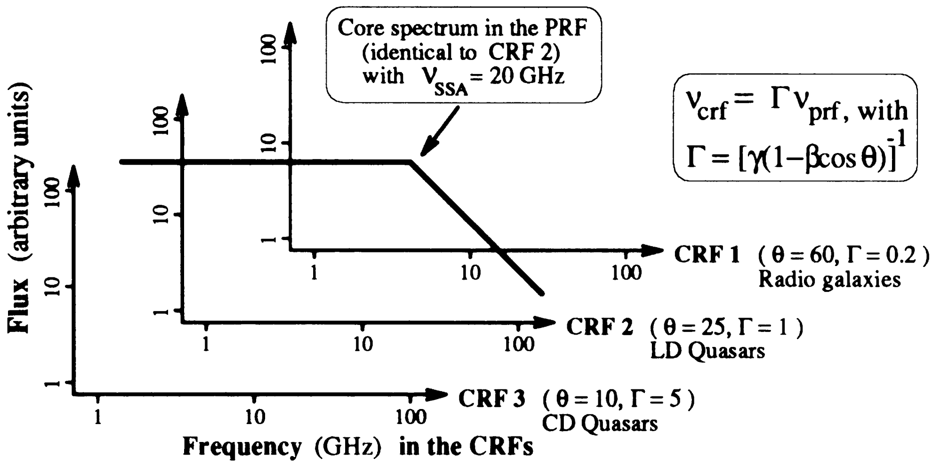

Figure 1. Relationship between the cosmological (**crf**) and the plasma (**prf**) rest frames.

chrotron self-absorbed components) of almost all extended radio sources at lower z and core-dominated quasars (CDQ) at all redshifts.

We identify the steep spectra of cores in high z galaxies with the optically thin synchrotron emission at frequencies above the turn-over of the smallest component in the core. The relation between the frequencies in the cosmological rest frame (**crf**) of the galaxy and the rest frame of the emitting plasma in the relativistic jet (**prf**) is shown in figure 1. Relativistic motion in the cores would lead to a blueshift in objects viewed close to the jet axis and a redshift in objects viewed perpendicular to it. In the context of galaxy-quasar unification (Barthel 1989), the synchrotron turn-over should therefore occur at higher frequencies in the **crf** as one goes from radio galaxies to lobe dominated quasars (LDQ) to CDQs. Indeed, CDQs are known to turn over at ~50-75 GHz (Gear *et al.* 1994) while some LDQs do so at ~20 GHz (Antonucci *et al.* 1990) in the **crf.** The corresponding value for our galaxies is estimated to be ~ 5 GHz which explains why only high z galaxies appear to have steep spectrum cores at the observed frequencies of 5-10 GHz.

We derive physical parameters of the "smallest component" radiating in the cores of these sources using the observed turn-over parameters and the doppler factors. Using $\gamma \sim 5 - 15$ and the typical viewing angles for galaxies and quasars in Barthel's scheme, we obtain a size of ~1 parsec, magnetic field of ~1 gauss and electron density of ~1000 cm^{-3} for the cores of both galaxies and quasars. While these numbers are only order of magnitude estimates, the similar values for quasars and radio galaxies argue for similar physical phenomena and conditions in their cores.

We emphasize that the physical size derived is over a 100 times smaller

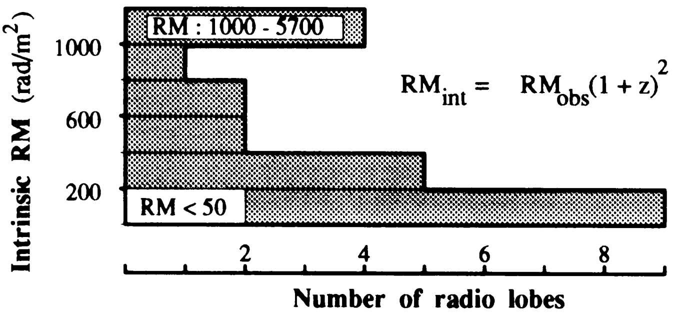

Figure 2. Histogram of the intrinsic RM of the lobes of high z galaxies.

than the telescope resolution. This phenomenon is therefore very useful for probing radio galaxy cores, most of which are too faint for VLBI studies.

Large rotation measures : Sources at low z typically have RMs of a few 10 rad/m^2. Only 2 radio lobes in our sample have RM < 50 (another 4 are consistent with RM < 50 within 1σ errors). Five of the 13 galaxies with a measured RM have RM > 800; the corresponding fraction at low z is $\leq 5\%$. The low z galaxies with large RMs are predominantly in dense x-ray clusters with cooling flows, apart from a few which are compact steep spectrum sources (Taylor *et al.* 1992). The one common feature in high RM sources at all z appears to be a dense environment.

After considering various possibilities for the Faraday material responsible for the RM (from our Galactic ISM to plasma within the radio lobes), we suggest that the most promising option, within the constraints of existing models of galaxy formation, is the dense and magnetized hot gas in the intracluster medium interacting with the bow shock of the radio hotspot. A cluster scale Faraday screen with aligned magnetic field (due to a cooling flow), as has been invoked for lower z objects, is another possibility, though less compelling as it is not clear if there is sufficient time for a cooling flow to start by $z \geq 2.5$. However, both these models require magnetic fields of a few μ *gauss* correlated over scales of a few kiloparsec threading the intracluster medium by $z = 3$. An explanation for the high RMs at high z must necessarily deal with questions regarding the origin of the magnetic field and may have implications for models of galaxy and cluster formation.

References

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