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Milliarcsecond-Scale Radio Polarimetry of Relativistic Jets in Active Galaxies

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Abstract. MOJAVE (Monitoring Of Jets in AGN with VLBA Experiments) is an ongoing Very Long Baseline Array program to investigate the parsec-scale evolution of relativistic jets associated with active galactic nuclei (AGN). It is currently providing milliarcsecond-resolution, full polarization images at regular intervals of the brightest 133 jets in the northern sky at a wavelength of 2 cm. Our study represents a significant improvement over previous surveys in terms of image fidelity, size, and completeness, and will serve to characterize the kinematics and magnetic fields of AGN jets and determine how these are connected with other source properties.

1. The MOJAVE Program

The NRAO's Very Long Baseline Array (VLBA) has made it possible to now routinely obtain high-quality, milliarcsecond-resolution polarimetric images of compact radio sources at regular intervals. A natural target for polarimetric VLBI studies are radio-loud AGN, many of which have extreme brightness temperatures and substantial linear polarization. The latter is likely associated with synchrotron radiation from a collimated jet that is powered by gravitational infall onto a supermassive black hole. These jets often display superluminal motion, indicating extremely high velocities along paths very close to the line of sight. Polarimetric imaging at regular intervals has revealed that the jets are highly magnetized fluids that respond rapidly to changes in the conditions in their nozzles and in their external environments. Numerical modeling has also shown that they are prone to a variety of fluid instabilities that can lead to twisted, helical ridgelines and oblique shocks in the flow. These directly affect the electric vectors of the jet emission, so observations of the latter can provide useful constraints for relativistic jet simulations. Since June 2002 we have regularly imaged a complete sample of the brightest 133 AGN jets in the northern sky with the VLBA at 15 GHz. Each source is observed approximately once per year, and roughly one-third of the sample has been observed at more than one epoch. All images are available on our project website at www.physics.purdue.edu/astro/MOJAVE.

2. Preliminary Results

The MOJAVE sample contains 93 quasars, 8 radio galaxies, 22 BL Lac objects (which have very weak emission lines or completely featureless optical spectra) and 10 objects with no known optical counterpart. Although BL Lac objects

and radio-loud quasars share many properties and are often grouped together as "blazars", we find their jets to have very distinct linear polarization properties. Assuming that Faraday effects are negligible in the jet regions at 15 GHz, our observations confirm previous findings at other wavelengths (e.g. Cawthorne et al. 1993; Lister 2001), namely that BL Lacs have jet magnetic fields that are preferentially oriented perpendicular to the flow direction, and become more ordered at large distances down the jet. Quasars have a wide range of magnetic field orientations, possibly arising from oblique shocks. The fields also become more ordered with increasing distance down the jet, but at a slower rate than BL Lacs.

2.1. Circular Polarization

Circular polarization (CP) can be produced in AGN jets either as an intrinsic component of synchrotron radiation or via Faraday conversion of linear to circular polarization. If there is significant intrinsic circular polarization, the radio jet must contain (1) a predominately electron-proton plasma and (2) a significant component of unidirectional magnetic field (a magnetic flux) along the line of sight. If the production mechanism is Faraday conversion, the radio jet must contain (1) a large population of low-energy relativistic electrons (and/or positrons) and (2) either some systematic field asymmetry along the line of sight or a small amount of internal Faraday rotation (which also implies at least a small amount of electron-proton plasma and unidirectional magnetic field component; see Wardle et al. 1998).

So far we have detected CP in 10 of 68 jets at a significance of 3 sigma or higher. These detections are being followed up with multi-frequency observations at the University of Michigan Radio Observatory. The nearby jet M87 has -0.5 ± 0.1 % CP located near the apparent origin of the outflow. The jet shows essentially no linear polarization, which is likely due to a very large thermal Faraday screen that affects the linear, but not the circular polarization. M87 may perhaps be analogous to other nearby, low-luminosity AGN (e.g., 3C84, M81, & Sgr A*) which have a similar ratio of high circular to low linear polarization. Unlike more distant, higher luminosity jets, in these nearby sources the VLBI jet may be entirely within the Faraday depolarizing region, which will destroy the linear polarization and leave the CP essentially unaffected (unless the screen is extremely strong). Alternatively, CP may be an intrinsic characteristic of low-luminosity AGN.

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References

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