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The Submilliarcsecond Structure of Quasars and AGN

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Abstract. VLBA observations of 130 quasars and AGN made at 15 GHz with submilliarcsecond resolution show a variety of structures, most of which appear linear.

1. Introduction

We have used the VLBA at 15 GHz to image the structure of 130 strong compact AGN and quasars. The good two-dimensional coverage of the VLBA allows us to image sources as far south as −20 degrees declination with good image quality and even further south for a few strong sources. Many of these sources, particularly those with $\delta < +35°$, have not been previously imaged with milliarcsecond resolution. This is the shortest wavelength and the highest angular resolution which has been used to image a large sample of radio sources. Generally our observing frequency is above the synchrotron self-absorption cutoff frequency; thus our observations penetrate further into the nuclear regions than VLBI observations made a lower frequencies.

Our goals are to classify and study the morphological characteristics of compact quasars and AGN; to examine the relation, if any, between radio structure and luminosity, spectra, optical counterparts, and redshift; to search for structures that might indicate gravitational minilensing; and to find unresolved or nearly unresolved sources that might be used as calibrators for the VLBA.

2. Observing Procedures

The observations were made during six observing sessions between 1994 and 1997. In order to optimize the (u,v) coverage, we observed each source over a wide range of hour angle. All data taken below 10 degrees elevation at any antenna were deleted, as were data from any antenna taken during periods of excessively bad weather when the excess sky temperature exceeded 75 degrees, or was changing very rapidly due to heavy rain or thick cloud cover.

We observed with a bandwidth of 64 MHz using one-bit samples and LHC polarization. Each source was observed for four to five minutes once each hour for a range of eight hours. Thus we observed three such groups per day for a total integration time on each source of about 40 minutes. The rms noise in each image was typically about 300 microJy, about that expected from the nominal system temperatures of 60−100K and antenna gain of about 0.1 K/Jy.

The observed fringe visibilities were initially calibrated in amplitude using the nominal gain curves determined for each antenna. All of the fringe fitting,

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editing, calibration, were done using the NRAO AIPS package. The initial imaging was carried out using the Caltech DIFMAP package in an automated mode.

With this automated procedure we nearly reached theoretical noise for most sources. For about ten percent of the sources which had unusually complex structure, were sufficiently strong, or otherwise had inadequate (u,v) coverage, the above procedure did not result in noise-limited images. For these sources we made further iterations of the CLEAN self-cal loop using manually determined parameters. For a few sources, we used the self-calibrated data determined from DIFMAP to image each source using the AIPS task IMAGR with a Robustness factor 0 which gives a good compromise between resolution and sensitivity.

3. Summary of Results

Our images have a nominal resolution of 0.5 milliarcseconds and a dynamic range typically of the order of 2000. They are available on the World Wide Web at *http://www.cv.nrao.edu/~azensus/2cmsurvey.*

Most of the sources show the canonical core-jet morphology. In many cases there is significant curvature, and in some cases multiple bends are seen along the jet structure. Frequently, these bends are observed across a remarkably small region of a few parsecs or less. Most of the jets may be described by a small number of apparently discrete components, but in some cases there appears to be a continuous distribution of radiation. Usually the structures are unresolved along the direction perpendicular to the jet, but there are a few sources with broad plumes. About ten percent of the sources contain only a single component with any secondary feature at least a thousand times weaker. A few sources appear to have a complex morphology including in one case (1323+321) an apparent double helix structure.

We find no obvious difference in morphology between sources which are strong gamma-ray emitters and those that are not. Peak brightness temperatures are typically of the order of 10^{11} K. For $0.5 < z < 3$, there is no apparent dependence of overall angular size with redshift, consistent with the earlier result of Kellermann (1993) and Gurvits (1994), and with that expected for values of the deceleration parameter, $q_o > 0$.

Second, third, and in some cases fourth-epoch observations of these sources show that our sample, which is approximately flux limited, includes many sources with appreciably slower apparent velocities than those seen in the earlier superluminal studies, which were apparently biased toward the more rapidly moving sources. This agrees with the results of Vermeulen (1995)

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