FIRST RESULTS FROM THE VLA FIRST SURVEY

R.H. BECKER AND M.D. GREGG
IGPP, LLNL, L-413 Livermore, CA 94551-9900
D.J. HELFAND AND C.M. CRESS
Columbia University, 538 West 120th Street NY, NY 10027
R.L. WHITE
STScI, 3700 San Martin Drive, Baltimore, MD 21218
AND
R. MCMAHON
IoA, Madingley Road, Cambridge, CB3 0HA, U.K.

Abstract. The VLA *FIRST* survey is now in its second year. We have completed mapping over 1500 deg^2 of the North Galactic Cap and present here the catalog of the 138,000 radio sources detected therein. We discuss the statistics of this new catalog including the two-point angular correlation function for all radio emitters, present our optical identification of 24,000 sources using the APM catalog, and report followup studies on radio variability, X-ray source identification, and our bright quasar sample.

1. Introduction

Our survey to collect Faint Images of the Radio Sky at Twenty-cm, *FIRST*, began in April of 1993. Using the VLA in its B configuration, we have completed two seasons of observations and are about to embark on a third. The observations consist of 165 s snapshots on a hexagonal grid of overlapping pointings; 11,000 such grid pointings have been collected to date covering 1,555 deg^2 of the north Galactic cap between 28 deg and 42 deg north. The individual images are weighted and combined to yield the final coadded survey images which are archived at the NRAO and the STScI. The images have a mean rms of 0.13 mJy and pixel sizes of 1.8″. The intent is for the

R. Ekers et al. (eds.), Extragalactic Radio Sources, 499–502.

completed survey to cover the 10,000 $\deg^2$ region of the proposed Sloan Digital Sky Survey.

We have recently published a comprehensive description of the *FIRST* survey (Becker, White, and Helfand 1995a). Today (14 October 1995), we are releasing a source catalog containing over 138,000 sources which have been extracted from these images. The catalog is essentially complete for point sources with peak flux densities > 1 mJy. Extensive astrometric checks have demonstrated systematic position errors of $< 0.05''$ and 90% confidence error circles of $< 1''$ for all sources down to the survey limit. Morphological information on sources with sizes $> 2''$ is also included. The catalog is available from the www site http://sundog.stsci.edu/.

2. The 1994 Catalog

The best way to place this catalog in context is through comparisons with other existing astronomical catalogs. For example, we have made a detailed comparison between the *FIRST* catalog and the APM catalog of optical objects from the POSS I. These comparisons have confirmed the subarcsecond accuracy of the radio positions, and have allowed us to find optical counterparts for $\sim 24,000$ radio sources, by far the largest set of radio identifications in existence. For offsets of $\leq 1''$, the false matching rate is only 2%. In general, we find that 17% of the radio sources have optical counterparts to the plate limit of the POSS I ($E = 20.0$). The color and morphological information available in the APM catalog allow ready classification for many of the counterparts: blue stellar counterparts have a high probability of being quasars, while red, extended objects are typically radio galaxies at redshifts less than 0.3.

The *FIRST* catalog also contains counterparts to 17% of the X-ray sources in the *ROSAT* WGACAT, providing arcsecond positions for over 1000 serendipitous X-ray emitters which fall in the 190 PSPC pointings covered by the *FIRST* survey to date. This reduction by a factor of 10^2 to 10^3 in the error circle areas for this faint set of X-ray sources will be of great value in optical identification programs. We have also performed comparisons to various stellar catalogs; a description of our successful efforts to find new stellar radio sources is presented in Becker et al. (1995b).

3. The FIRST Bright QSO Survey

A year ago we initiated a program to identify optically bright QSOs detected by the *FIRST* survey. The QSO candidates were identified by comparing the *FIRST* catalog with the APM catalog. Our original selection criteria included all objects brighter than 17.5 mag on the E plate of the POSS I which were classified as stellar in appearance on either plate and

which were within 2 arcsec of a *FIRST* radio source. These criteria selected 219 QSO candidates from the 1993 survey area (305 deg^2). To date we have obtained spectra of 151 of the objects; another 25 were readily classified from the literature. Of these 176 objects, there are 69 QSOs, 2 blazars, 32 narrow line galaxies, 41 normal galaxies, and 32 stars. Despite the bright magnitude limit, only 15 of the 69 QSOs found in this 300 deg^2 region had been catalogued previously. Two of the new objects are brighter than 15 (one of which is at a redshift of 0.9), suggesting that the *FIRST* bright quasar survey will be a rich source of targets for HST and FUSE to use in absorption line studies.

An analysis of these initial results indicates that, for the coming observing season, we can define a more stringent set of criteria for the bright QSO search that will be 70% efficient and 95% complete by requiring a 1.1 arcsec match between radio and optical objects, and by excluding objects redder than O-E of 2.0. In the next year the number of QSOs from this project should increase by a factor of 5.

4. Large Scale Structure

The two-point angular correlation function for optical galaxies has been used for twenty years to explore the large scale structure of the Universe. Attempts to calculate this correlation function for radio catalogs have been frustrated by the low source surface density and the large range of redshifts characteristic of a flux-limited radio samples. Peacock and Nicholson (1991) did find a signal for luminous low-redshift radio galaxies, and Kooiman et al. (1995) have found a marginally significant correlation using the 6cm Greenbank survey. The fifty-fold improvement in sensitivity and angular resolution offered by the *FIRST* catalog makes it a logical choice with which to pursue a study of the large-scale structure of the Universe by applying angular correlation function analysis.

We have begun such an effort, and the preliminary results are reported in Cress et al. (1995). Based on the narrow ($\sim 3°$) strip from the 1993 dataset alone, a highly significant correlation function was detected on scales from several arcminutes to several degrees with a slope $\gamma \sim 0.9$, slightly larger than, but marginally consistent with, the value observed for optical galaxy samples. One of the more interesting results of this analysis was the higher correlation amplitude observed for a sample of radio doubles. Whether this result is a consequence of the fact that these resolved sources are, on average, closer, or are, in fact, more highly clustered remains uncertain. We are now extending this work to the new 1500 deg^2 dataset, as well as exploring the use of model radio luminosity functions to derive the 3-D spatial correlation function from these data.

5. Variable Radio Sources

The grid of pointings for the *FIRST* survey is so dense that almost all sources detected by the survey are observed at least twice, allowing us to search for variability in the radio sky. The *FIRST* observations are taken along a single declination strip per observing session with sessions generally separated by 1 to 7 days. Hence the survey samples two time scales, 3 minutes between adjacent fields at the same declination, and several days between fields in neighboring declination strips. Using conservative selection criteria, we have found approximately 400 sources (0.3% of the total) which appear to vary by more than 25%. Strong confirming evidence for the unusual nature of these objects comes from an examination of the optical counterparts of these putative variables. While only 17% of all *FIRST* sources have APM counterparts, the variable sources have counterparts at over twice this rate, and the magnitude distribution is skewed toward bright magnitudes. There is no way that an error in the radio data could produce a positive correlation with the optical sky. Followup observations are planned.

6. Summary

The unique combination of positional precision, depth, and angular resolution provided by FIRST affords us the opportunity to pursue a wide range of scientific programs. In addition to the bright quasar survey, the study of rapid variability, and the analysis of the two-point correlation function described above, a number of other projects are in progress. We are currently obtaining images and spectroscopy of fields containing bent head-tail radio sources in a search for high redshift clusters, examining gravitational lens candidates found in our images, and following up blank *IRAS* fields in a search for high-redshift starburst galaxies. A much larger set of projects can certainly be envisioned, and we hope that our prompt public release of the images and catalogs from *FIRST* will stimulate interest in pursuing them among members of the broader astronomical community.

References

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