The Parkes-MIT-NRAO Southern Sky Survey at 4850 MHz

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Abstract: During 1990 we surveyed the southern sky using a multi-beam receiver at frequencies of 4850 and 843 MHz. The half-power beamwidths were 4 and 25 arcmin respectively. The finished surveys cover the declination range between +10° and -90°, essentially complete in right ascension, an area of 7.3 steradians. Preliminary analysis of the 4850 MHz data indicates that we will achieve a five sigma flux density limit of about 30 mJy. We estimate that we will find between 80,000 and 90,000 new sources above this limit. This is a revised version of the paper presented at the Regional Meeting by the first four authors; the surveys now have been completed.

1. Introduction

The Parkes-MIT-NRAO survey of the southern sky is a collaboration between institutions in Australia and the USA, using the ATNF Parkes radio telescope facility and the NRAO-developed 7-beam receiver. The primary aim of the project was to survey the whole sky south of -36° declination at a frequency of 4850 MHz to a 5σ flux density limit of 30 mJy. Secondary aims of this project were to extend the survey from -36° declination as far north as time permitted, and to make a concurrent 843 MHz survey using a separate, off-axis receiver. This latter survey will provide a valuable point on the radio spectrum of sources particularly when combined with the 408 MHz data of the Molonglo Reference Catalogue (Large et al. 1981) and existing Parkes catalogues (Shimmins et al. 1966, Bolton et al. 1979 and references therein). The low-frequency Molonglo survey contains 12,141 sources to a 408 MHz flux density limit of 700 mJy and covers 7.85 sr; it is essentially complete to 1 Jy and contains 7347 sources to this limit. The significance of this Parkes survey at 843 MHz will be in its contribution to the analysis and interpretation of a southern sky survey which will be made at the same frequency using the Molonglo Observatory Synthesis Telescope (MOST) as described in Robertson (1991).

The 4850 MHz survey complements the survey of Condon et al. (1989) at the same frequency. The northern survey was made with the NRAO Greenbank 91-m radio telescope in 1987 October. It covered 6.0 sr of sky in the declination range 0° to +75° at a frequency of 4850 MHz with a resolution of 3.7 by 3.3 arcmin. Their rms map noise is about 5 mJy and about five times greater than the rms confusion level. There are 10,000 sources per steradian stronger than 25 mJy and their rms position uncertainties in each coordinate range from 10 arcsec for the strongest sources to 30 arcsec for the weakest sources observed near the Sun. A smaller-area survey of Bennett and collaborators (Bennett et al. 1986) covered 1.87 sr and contains 5974 sources to a flux density limit of 50-100 mJy (depending on declination) at 5000 MHz, extending from declination 0° to +20°.

A southern extension to -40° declination is in progress using the NRAO 43-m radio telescope also at Greenbank. This overlap will enable reliable completeness estimates to be made on the two independent northern and southern surveys. Our survey was made using the same NRAO 7-beam 4850 MHz receiver as has been used for these northern surveys.

The only existing large-area, high-frequency radio survey in the same total area as covered by this new survey is that of Bolton and collaborators (Bolton et al. 1979 and references therein) which contains around 8200 sources to a 2700 MHz flux limit of about 250 mJy corresponding to about 160 mJy at 5000 MHz for sources of average spectral index.

2. The Equipment

The National Radio Astronomy Observatory (NRAO) lent us its 7-beam receiver made specifically for the northern survey (for fuller details see Condon et al. 1989). The receiver was mounted at the prime focus of the Parkes 64-m radio telescope. The receiver consists of 14 low-noise HEMT (high electron mobility transistor) channels fed in pairs from the seven feeds. The seven feeds were arranged in a hexagonal pattern. Each feed had a half-power beamwidth (HPBW) of 4.1 arcmin. Each receiver had a typical system temperature of around 35 K and a bandwidth of 600 MHz. The receiver was oriented in such a way that the beams made seven parallel tracks on the sky separated by approximately 1 HPBW. This gave us a scan which was 28 arcmin wide. Each feed had two oppositely circularly polarised channels which provided two independent views of the same portion of sky. In general, these two outputs were simply averaged to provide a lower noise level. However, they also provided useful redundancy in the event that only one of the channels from a beam was operational because of technical problems.

The 843 MHz receiver also had two channels but with orthogonal linear polarisations. Typical system temperatures were about 100 K and the bandwidths were around 20 MHz. The half-power beamwidth of the telescope for the 843 MHz survey was similar to the width of a scan from the 7-beam receiver, permitting a well sampled survey also to be made at this lower frequency.
3. The Observations
The 4850 MHz survey required calibration for pointing, relative gains of the beams as a function of zenith angle, and flux density. Sources with accurately known positions were observed intensively before the start of the survey on both the southern and northern meridians and occasionally throughout the survey observations. Similarly, we observed the radio sources PKSB 0521–365 and PKSB 1921–293 [nomenclature following that recommended by the IAU (Dickel et al. 1987)] using all 16 receiver channels and over the total range of zenith angles covered in the survey to produce individual gain versus zenith angle curves for each channel. Finally, we established a flux density scale using the source PKSB 0915–118 (Hydra A) for which we have assumed a total flux density of 13.5 Jy at 4850 MHz and 66.0 Jy at 843 MHz.

The main survey was made by scanning the telescope north and south along the meridian (HA (hour angle) = 0) at a rate close to 11 degrees per minute under control of the master equatorial guidance system. Both the north-going and south-going scans had to be started at precise sidereal times to ensure correct coverage of the sky. In order to obtain proper Nyquist sampling, a second set of scans was made, displaced from the first set by 0.5 HPBW. The sets of north- and south-going scans provided two independent, fully sampled surveys of the southern sky. The survey was done in two sessions, 1990 May 29 – 1990 July 2 and 1990 October 31 – 1990 November 25, and in a variety of sections. The primary survey covered the declination range –36° to –83.5° and a second strip covered the range –38.5° to –30°. In November, as well as many ‘mopping-up’ scans, the far north was covered from +11° to +10° declination.

The zenith strip, with a declination range of –29° to –37°, was covered in the June session and a slightly larger region –26° to –40° was repeated in the November session. These zones required a special observing technique since they pass close to the Parkes zenith (Dec = –33°). We observed this zone by scanning in both HA and Dec but at a constant orientation.

Polar scans were made from –88.3° to –89.8° declination.

The receiver gains or noise tube calibrations changed between the June and the November runs, but the antenna gain remained consistent between the two runs. The standard error introduced by application of the antenna gain curve is estimated to be 1.6%.

After application of the antenna gain curves and receiver gain to Hydra A, the residual standard error on the reduced flux density of Hydra A was only 0.9%.

While the observations were being made, we were able to display data from any, or all, of the 16 channels. This permitted us to monitor the degradation of the signal caused by weather (which mainly affected the 4850 MHz data) or by locally caused impulsive interference (which mainly affected the 843 MHz data). We were also able to check that the telescope was detecting the known, stronger sources at the expected times, positions and strengths since each strong radio source was likely to be encountered by several of the beams giving confirmation of a strong source detection, and indicating that the survey was proceeding satisfactorily.

4. Discussion
The reduction, evaluation and display of the data from the PMN 4850 MHz survey will be completed by the end of 1991. However, we can indicate a few of the preliminary results. In a small test area covering 0.11 sr in the RA range 22–23 h and declination range –36° to –88° (epoch and equinox 1990.45) we find a standard error in the peak flux density of between 5 and 8 mJy and an overall positional accuracy of ±25 arcsec in RA and ±20 arcsec in declination. Overall the positions should be an improvement on earlier Parkes surveys as the southern position calibrator grid has improved in the last 15 years (White et al. 1991 and references therein). We expect that further analysis will indicate that these errors are flux-density dependent in a similar manner to the 2700 MHz Parkes surveys and as was found for the northern survey by Condon et al. (1989).

The test area contains 1367 sources stronger than 25 mJy. The composite Parkes database (PKSCAT90, Wright and Otrupcek 1990) of the same region contains 131 sources (with flux densities above 250 mJy at 2700 MHz). The new survey finds all but one of these sources. We suggest that this source is missing because it is now very weak at both 2700 and 5000 MHz or it has an unusually steep radio spectrum or a combination of these two possibilities. Wedge maps have been generated for this test area and the increase in source density of a factor of about 10 over the 2700 MHz Parkes survey is immediately apparent. The source density calculated for the sources in our test area is 12 400 ± 340 sr−1. This is similar to the northern survey figure of 10 000 sr−1 stronger than 25 mJy.

Table 1 of Kellermann and Wall (1987) lists some earlier small-area 5000 MHz source surveys. Maslowksi et al. (1984) find a source density of 10 761 sr−1 to 30 mJy; Owen et al. (1983) find a source density of 6956 sr−1 to 35 mJy; Wall et al. (1982) using Parkes data obtain a source density of 6463 sr−1 to 32 mJy; six deep Parkes selected regions (Downes et al. 1986) with a limiting flux density of 100 mJy at 2700 MHz cover a similar area of 0.075 sr and contain 178 sources, implying a source density of only about 2400 sr−1 to 60 mJy at 5000 MHz. Already our preliminary results are indicating a significant incompleteness in some of these earlier small-area surveys.

5. Conclusion
Our preliminary analysis suggests that the PMN survey has attained its goal of making a complete, deep, high-frequency survey of the whole of the southern sky. However, because of the confusion by extended structure the analysis of the Galactic plane data will be done separately and reported later. We have established a significant overlap zone with the area surveyed by Condon and collaborators in the northern hemisphere. Even our preliminary results are indicating a significant incompleteness in some earlier small-area surveys.

We have also produced a confusion-limited survey at 843 MHz over the same region, and the results of this survey will be described in a future paper.

Acknowledgements
We would like to thank Andrew Chambers, Leonie Coulcher, Reece Gulhot, Tom Martin, Brett McArdle, Petra Nott, Sarah Pickett, Michael Russell, Leonie Thornton and Richard Willet (Year 9 high school students from a variety of schools in Australia gaining vocational experience) for their assistance with the observing.

The Australia Telescope National Facility is operated in association with the Division of Radioophysics by CSIRO. We thank the NRAO for the loan of its receiver and technical support. The National Radio Astronomy Observatory is operated by Associated Universities Inc. under contract with the National Science Foundation.


Wright, A. E. and Otrupcek, R., 1990. PKSCAT90 is an ATNF/CSIRO internal publication, available from the authors on request.