The New Molonglo Radio Survey

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Abstract. The Sydney University Molonglo Sky Survey (SUMSS) is a deep imaging survey of the southern radio sky at 843 MHz. Over the next few years, it will cover 8000 square degrees of sky south of declination $-30°$. The survey's resolution (43 arcsec) and sensitivity (3σ detection limit 3–5 mJy) are similar to those of the northern NRAO VLA Sky Survey (NVSS). Some of the scientific problems which can be tackled with such a survey include the clustering of faint radio sources, identification of diffuse and giant sources, and the space distribution and evolution of star–forming galaxies. SUMSS data will be made publicly available as the survey progresses.

1 Introduction

The most powerful radio galaxies act as 'beacons' which can be seen to enormous distances, so radio surveys have played a key role in developing our understanding of the high–redshift universe. Most of what we know about distant radio galaxies comes from studying those detected in 'classic' radio surveys with detection limits of 1 Jy or more. However, such sources are relatively rare (the well–studied 3CR catalogue has only 298 extragalactic sources; Spinrad et al. 1985) and their radio luminosities are often so extreme that observations of the underlying galaxies are strongly affected by the presence of an active nucleus.

Large–area radio–source surveys at mJy levels offer some significant advantages for cosmological studies. Not only do they yield such large numbers of sources that detection of large–scale structure is possible (Cress et al. 1996), they also sample objects which lie at similar redshifts to the Jy–level sources but are 100 to 1000 times less radio–luminous. Thus they provide much more representative probes of galaxy formation and evolution. Furthermore, mJy–level surveys also probe a second cosmologically–significant radio source population, that of star–forming galaxies, which are extremely rare in the strong–source surveys.

A new generation of large–area radio imaging surveys (see Table 1) is now mapping the whole sky with unprecedented sensitivity. Only two of these, the NRAO VLA Sky Survey (NVSS) and the Sydney University Molonglo Sky Survey (SUMSS) cover the southern hemisphere, and only SUMSS covers the region south of declination $-40°$. Here we describe the SUMSS survey, which began in mid–1997, and discuss some of the science which can be done with the survey data.

	FIRST	NVSS	SUMSS	WENSS
Frequency (MHz)	1400	1400	843	325
Area (deg^2)	10,000	33,700	8,000	10,100
Resolution	$5''$	$45''$	$43''$	$54''$
Detection limit	1 mJy	2.5 mJy	3.5 mJy	15 mJy
Coverage	$\delta > +22°$	$\delta > -40°$	$\delta < -30°$	$\delta > +30°$
Sources/deg^2	90	60	50	21
Reference	(a)	(b)	(c)	(d)

Table 1. Large–area mJy–level radio surveys currently in progress. References: (a) Becker et al. 1995; (b) Condon et al. 1998; (c) This paper, Bock et al. 1998; (d) Rengelink et al. 1997.

2 The Sydney University Molonglo Sky Survey (SUMSS)

The survey uses the Molonglo Observatory Synthesis Telescope (MOST), a 1.6 km east–west cylindrical parabolic reflector which is operated by the University of Sydney and located near Canberra, Australia. In 1996, the telescope was upgraded to provide a $2\overset{\circ}{.}7$ diameter field of view (for more details, see Large et al. 1994 and Bock et al. 1998).

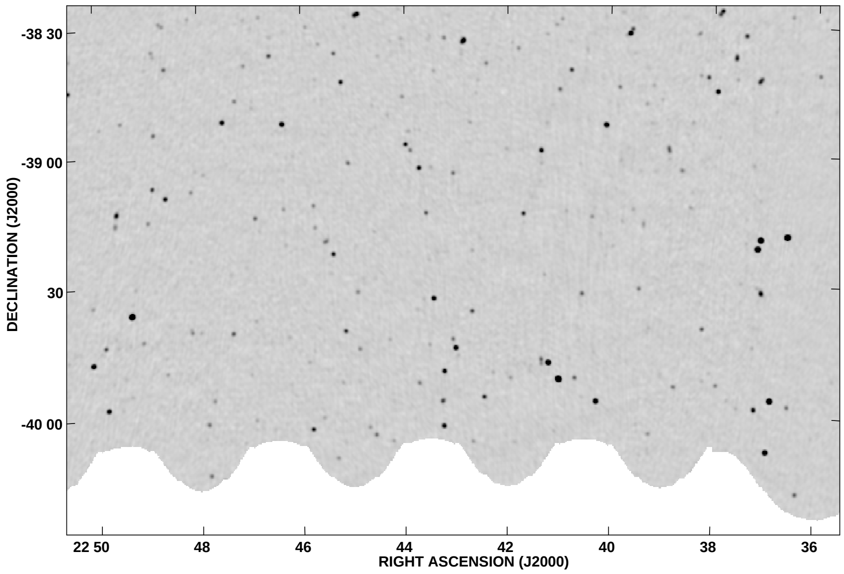
Table 2 summarizes some characteristics of synthesis observations with the MOST in its wide–field mode. Each full synthesis observation takes 12 hours and, because it is an east–west array, the MOST performs best at declinations south of $-30°$. The SUMSS will therefore cover the declination region $-30°$ to $-90°$.

The rms noise in individual MOST images is a combination of thermal noise and source confusion from both the main beam and sidelobes of the MOST. First results from the survey data show that at southern declinations (near $-70°$), the rms noise in a single wide–field image is typically 0.7–1.0 mJy/beam near the centre, rising to 1.0–1.2 mJy/beam near the edges of the field. Further north (at declination $-35°$), the rms noise level is higher (as expected), with a typical value of 1.5 mJy/beam near the centre, rising to 2.5 mJy/beam at the edges. For SUMSS data, the final survey images will be formed into $4° \times 4°$ mosaics to recover uniform sensitivity in the overlap regions.

Frequency	843 MHz (36 cm)
Bandwidth	3 MHz
Polarization	Right–hand circular (IEEE)
Declination range (12 hr synthesis)	$-90° \leq \delta < -30°$
Synthesized beam (FWHM)	$43'' \times 43''\mathrm{cosec}\lvert\delta\rvert$
Image area	Elliptical, $163' \times 163'\mathrm{cosec}\lvert\delta\rvert$
Noise after 12 hr (1σ)	0.7–1.5 mJy/beam
Dynamic range (typical)	250:1

Table 2. Key characteristics of individual SUMSS observations

NVSS (1.4 GHz)



SUMSS (843 MHz)

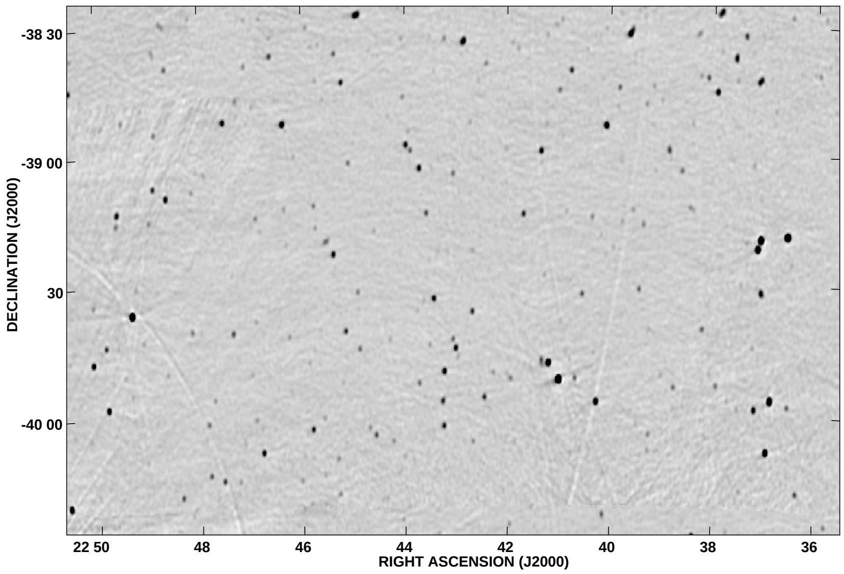


Fig. 1. NVSS and SUMSS radio images of the $6\,\mathrm{deg}^2$ ESO Imaging Survey (EIS) field centred at (J2000) 22 42 54 -39 28 00. The southern limit of the NVSS survey at declination $-40°$ is responsible for the gaps in the top image.

Figure 1 shows radio continuum images from the NVSS (1.4 GHz) and SUMSS (843 MHz) for a 6 $\deg^2$ region overlapping one of the ESO Imaging Survey (EIS) fields. The two surveys are well matched in sensitivity and resolution, and overlap in the declination zone $-30°$ to $-40°$.

There are 2713 SUMSS field centres south of declination $-30°$, each with a fully–synthesised area of $2\overset{\circ}{.}7 \times 2\overset{\circ}{.}7\mathrm{cosec}(\delta)$ $(= 7.3\,\mathrm{cosec}\delta\ \deg^2)$ at declination δ. We use hexagonal close packing for the survey field centres, and the rate of progress (i.e. area added to that already surveyed) is 4.4 square degrees per field. The survey observations are made at night to reduce the effects of solar interference. We can therefore cover about 1000 $\deg^2$/year. The survey began in mid–1997, and our aim is to complete the 1118 fields with Galactic latitude $|b| > 30°$ by mid–2000. The entire southern–sky survey is nevertheless a long–term project which will take up to eight years to complete.

3 The faint radio source population

Deep radio surveys of a few small areas of sky at 1.4 GHz (Windhorst et al. 1985, Condon 1984; see also Condon 1992) show that there are two astrophysically distinct populations of extragalactic radio sources. Over 95% of the sources above about 50 mJy are classical radio galaxies and quasars (median redshift z$\sim$1) powered by "active galactic nuclei" (AGN), while the remaining sources are identified with star–forming galaxies (median z$\sim$0.1). The fraction of star–forming galaxies increases rapidly below 10 mJy, and below 1 mJy they begin to be the dominant population.

In a poster paper presented at this meeting, Jackson & Wall (1998) predict the radio source population mix at 843 MHz as a function of flux density. Their work suggests that at the lowest flux densities probed by SUMSS (3–5 mJy), about 20% of sources will be associated with star–forming galaxies and the remainder with various kinds of AGN (FR I and FR II radio galaxies, quasars and BL Lac objects).

4 Science with the new survey

While some important science can be tackled with the SUMSS data alone, the value of the survey will be enormously enhanced when it is combined with data at other wavelengths.

¿From the SUMSS data alone, we can study the clustering of faint radio sources on scales of a few hundred Mpc. If we can tie the SUMSS and NVSS data together effectively (using the overlap zone at $-30°$ to $-40°$ declination), then we will also be able to produce the deepest–ever 'all–sky' radio image.

In the overlap zone we can also combine the NVSS and SUMSS data to measure a radio spectral index between 843 MHz and 1.4 GHz. Figure 2 shows the results for a small region near the South Galactic Pole. About 2–3% of sources appear to have very steep spectra ($\alpha < -1.6$), and are candidate ultra–steep spectrum (USS) sources. Many of these are likely to be very distant (e.g. Röttgering et al. 1997a).

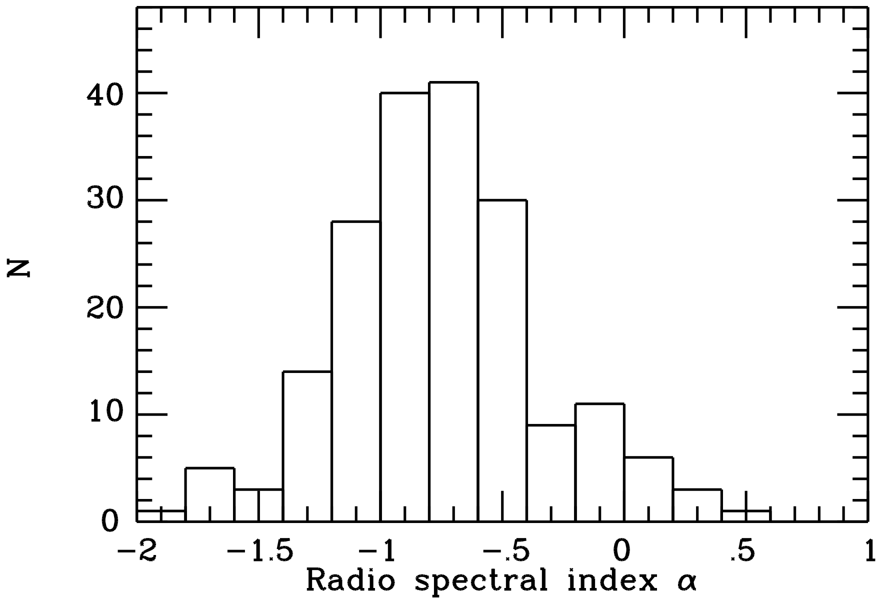


Fig. 2. Radio spectral index distribution for 195 radio sources with S_{843} >10 mJy observed by both SUMSS and NVSS in the South Galactic Pole region. The spectral index $\alpha^{1.4}_{843}$ has a median value of −0.8.

Because of its good coverage of short spacings in the (u, v) plane, the MOST is more sensitive to large–scale, diffuse radio emission than other synthesis telescopes. SUMSS should therefore be efficient at detecting Mpc–scale diffuse radio sources like the giant cluster source A3667 (Röttgering et al. 1997b).

The SUMSS radio positions are accurate enough (typical rms errors of 1–2 arcsec for flux densities above 5 mJy) that unambiguous optical identifications can be made from digitized sky survey (DSS) data. The identification rate is about 30% down to a limiting magnitude of $b_J \sim 22$. Deep CCD data (e.g. from the ESO Imaging Survey) should increase the identification rate to as high as 80–90%.

With follow–up optical spectroscopy we can distinguish AGN from starburst galaxies, measure redshifts, construct luminosity functions and study the evolution of different radio–source populations. We are currently collaborating with the 2dF Galaxy Redshift Survey team (see Colless 1998, this meeting) to obtain spectra of the 2% of their target galaxies which are also NVSS or SUMSS radio sources. This will ultimately yield about 5000 spectra of radio–detected galaxies brighter than $b_J \sim$19.5. We also plan to carry out a deeper 2dF study in a smaller area of sky to probe fainter radio–source counterparts down to $b_J \sim$22.5. Galaxies fainter than this will probably require 8 m class telescopes for follow–up.

The SUMSS data are well–suited to multi–wavelength studies, such as cross–identification with X–ray or infrared catalogues. The SUMSS images and data catalogue will be made publicly available as the survey proceeds, and we welcome collaboration with other groups. Examples of possible collaborative projects could be deeper radio observations of fields which will be studied in detail at other wavelengths, requests for specific areas or objects to be observed early in the survey, or follow–up of targets of opportunity such as X–ray transients.

I would like to acknowledge the efforts of my colleagues in the SUMSS team at the University of Sydney (Duncan Campbell–Wilson, Lawrence Cram, David Crawford, Gene Davidson, Ralph Davison, Anne Green, Richard Hunstead, Carole Jackson, Michael Large, Vincent McIntyre, Bruce McAdam, Barbara Piestrzynski, Gordon Robertson, Tony Turtle, Jeff Webb and Michael White), who have made this survey possible.

References

Bock, D., Large, M.I., Sadler, E.M. (1998). In preparation.
Becker, R.H., White, R.L., Helfand, D.J. (1995). ApJ 450, 559.
Colless, M.M., 1998. This meeting.
Condon, J.J. (1984). ApJ 287, 461.
Condon, J.J. (1992). ARA&A 30, 575.
Condon, J.J., Cotton, W.D., Greisen, E.R., Yin, Q.F., Perley, R.A., Taylor, G.B., Broderick J.J. (1998). AJ, in press.
Cress, C.M., Helfand, D.J., Becker, R.H., Gregg, M.D., White, R.L. (1996). AJ 473, 7.
Jackson, C.A. & Wall, J.V., 1998. This meeting.
Large, M.I., Campbell–Wilson, D., Cram, L.E., Davison, R., Robertson, J.G. (1994). PASA 11, 44.
Rengelink, R.B., Tang, Y., de Bruyn, A.G., Miley, G.K., Bremer, M.N., Röttgering, H.J.A., Bremer, M.N. (1997). A&AS 124, 259.
Röttgering, H.J.A., van Ojik, R., Miley, G.K., Chambers, K.C., van Breugel, W.J.M., de Koff, S. (1997a). A&A 326, 505.
Röttgering, H.J.A., Wieringa, M.H., Hunstead, R.W., Ekers, R.D. (1997b). MNRAS 290, 577.
Spinrad, H., Djorgovski, S., Marr, J., Aguilar, L. (1985). PASP 97, 932.
Windhorst, R.A., Miley, G.K., Owen, F.N., Kron. R.G., Koo, D.C. (1985). ApJ 289, 494.