A WIDER VIEW FROM THE SOUTH

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1. Introduction

Wide-field capabilities have been installed recently on the 3.9-m Anglo-Australian Telescope, the Australia Telescope National Facility 64-m dish at Parkes and the University of Sydney Molonglo Observatory Synthesis Telescope (MOST). These will enable a number of large-scale surveys to be undertaken, complementing and in some cases surpassing what is being achieved in the North. This paper summarises the principal technical features of the new wide-field capabilities. It also outlines the main properties and the major science goals of several surveys that commenced in 1997. Additional details of the Molonglo survey are presented, to illustrate the ways in which it complements the NVSS and WENSS surveys.

2. 2dF at the Anglo-Australian Observatory

The AAO has traditionally played a leading role in the development and exploitation of multiple-object fibre spectroscopy. The first common-user system on the 3.9 metre Anglo-Australian Telescope (AAT) was called FOCAP (Gray 1986). It relied on manual insertion of fibres into a drilled aperture plate, and could accommodate up to 63 fibres over a $40'$ Cassegrain field. Today, the FLAIR system on the UK Schmidt Telescope has 90 fibres available for manual placement over the 40 deg^2 Schmidt field (Parker & Watson 1995). FOCAP was replaced in 1987 by AUTOFIB (Parry & Sharples 1988), which included a robotic fibre postioner for 65 fibres over the $40'$ Cassegrain field.

In 1989 the AAO commenced work on a major enhancement to its capacity for multiple-object fibre spectroscopy at the AAT. A new wide-field corrector was built, with the capability of sub-arcsecond optical imaging over a $2°$ diameter field of view at prime focus. A robotic fibre positioner places up to 400 fibres within this field. Dedicated high-throughput spectrographs then acquire up to 400 spectra simultaneously, while another 400 fibres are being positioned by the robot ready for the next exposure (Taylor 1995). The system has entered its final commissioning phase, and is now routinely making scientific observations. Up-to-date reports and examples of recently acquired data are available.[1].

The power and flexibility of the 2dF system imply that it will be used for a large variety of astronomical observations. There will be many relatively small observing programs (requiring, say, up to 1000 spectra of objects lying in the 2° field) that will be completed with great efficiency. However, the major part of the time available to 2dF over the next few years will be devoted to two large-scale redshift surveys, one concentrating on galaxies and the other on quasars. The large galaxy survey (Colless 1997) will acquire a total of 250,000 redshifts for galaxies brighter than $B = 19.7$ lying in more than 600 fields which cover an area of 1700 $\deg^2$. The quasar redshift survey (Smith *et al.* 1996) will examine the spectra of over 25,000 candidate QSOs, selected on the basis of their ultra-violet excess and covering an area of 750 $\deg^2$. The outcomes of these surveys will be homogeneous datasets valuable for addressing a wide range of questions in cosmology.

3. Parkes 21 cm multi-beam facility

The Australia Telescope National Facility has constructed and commissioned a 21 cm feed system with 13 receivers at the Parkes radio telescope. The feeds have a system temperature of 23.5 K. They are located in a new prime focus cabin and disposed to form beams with an angular resolution of $14'$ separated by $\sim 28'$. Nyquist sampling of the image plane is achieved by interleaving observations across the direction of scanning. The on-line correlator produces measurements of flux density in all 13 channels and 2 polarisations simultaneously, with a spectral resolution of 16 km s^{-1} and a velocity range 0–14,000 km s^{-1}. An important feature of the new system is its use of AIPS++ for data acquisition, reduction and analysis.

The Parkes multi-beam facility has recently commenced regular observing and a report on its status is regularly updated.[2] Several major H I surveys are planned, including an all-sky survey (initially $\delta < 0°$) with a limiting sensitivity (5σ, 600 s) of approximately 20 mJy per 13 km s^{-1} channel (corresponding to $M_{\rm HI} \sim 10^6 d^2$ $M_\odot$ for a velocity width of 200 km s^{-1} and distance d in Mpc). A deeper survey of the zone of avoidance will also be made, along with a sensitive wide-band search for pulsars in the 1.4 GHz continuum.

4. Molonglo Observatory Synthesis Telescope

The Molonglo Observatory Synthesis Telescope (MOST) is an Earth-rotation synthesis radio telescope operated by the University of Sydney. The reflector comprises two 800×12 m^2 east-west cylindrical paraboloids (called 'arms') separated by a 15 m gap. Each arm is divided into 44 electrically independent elements (called 'bays'), and each bay is correlated with all 44 bays of the other arm to form a total of 64 real-time fan beams. Over the past three years each bay has been re-equipped

[1] http://www.aao.gov.au/2df
[2] http://www.atnf.csiro.au/Research/multibeam/multibeam.html

with a set of 4 low-noise HEMT preamplifiers and digital phasing circuits which allow time-shared observations of an array of up to 896 fan beams separated by $11''$, corresponding to a $2\overset{\circ}{.}7$ diameter field of view (Large *et al.* 1994). Relevant technical specifications of the MOST are listed in Table 1 (see also Robertson 1991).

TABLE 1. Technical specifications of the MOST

Centre frequency	843 MHz (36 cm)
Bandwidth	3 MHz
Polarization	RHC (IEEE)
Declination range for full HA	$-90°$ to $-30°$
Synthesized beam	$43'' \times 43''\,\mathrm{cosec}(\delta)$
Field size (no time sharing)	$23' \times 23'\,\mathrm{cosec}(\delta)$
Field size (max time sharing)	$164' \times 164'\,\mathrm{cosec}(\delta)$
Noise after 12 h (1σ)	0.4–1.2 mJy beam^{-1}
Surface brightness sensitivity	0.3–0.9 K (1σ)
Dynamic range (typical)	250:1

The fan beam responses recorded by the MOST are reconstructed by the back-projection algorithm (Crawford 1984, Cram and Ye 1995) to form an image of the radio brightness distribution. Because the aperture of the MOST is almost filled, the image contains Fourier components with a wide range of angular scales, and has low sidelobes. Figure 1 illustrates the image quality achievable for a complex region of the Galactic plane. CLEANing and self-calibration may be applied to MOST images, although the algorithms differ from those used in distributed-antenna arrays such as the VLA and the ATCA.

4.1. SYDNEY UNIVERSITY MOLONGLO SKY SURVEY (SUMSS)

When it operated as the 'Mills Cross' at 408 MHz, the Molonglo radio telescope was engaged in a number of surveys, the largest of which was published as the Molonglo Reference Catalogue (MRC: Large *et al.* 1981). Since conversion to 843 MHz, the telescope has been used with a $70'$ field to survey the southern Galactic plane ($|b| < 1\overset{\circ}{.}5$; Whiteoak & Green 1996), the Magellanic Clouds (Ye & Turtle 1991) and several 'selected areas' such as the SGP and UKST Field 287 which has been the target of very deep optical studies (Hawkins & Véron 1996, McNally 1996). These surveys have been the first step in many investigations of southern radio sources.

The new wide-field capability of the MOST provides an opportunity to completely survey the southern sky to limits much deeper than previous surveys, and this is now being done. As shown in Table 2, the Sydney University Molonglo Sky Survey (SUMSS) will reach limits comparable with those of the major northern hemisphere WENSS and NVSS surveys now under way. One difference between

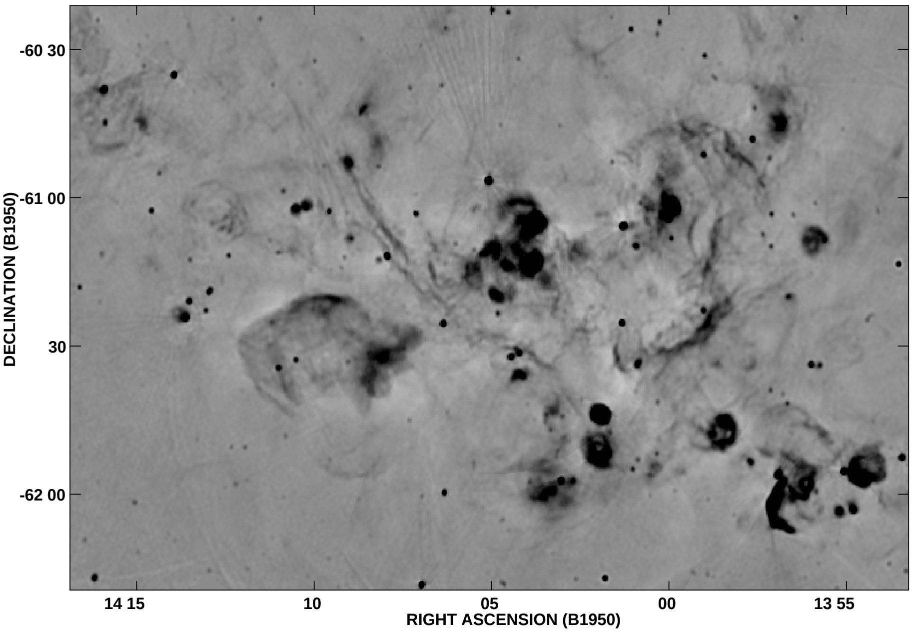

Figure 1. MOST mosaic of 70′ field observations of a $2\overset{\circ}{.}8\,(\alpha) \times 2\overset{\circ}{.}0\,(\delta)$ region of the Galactic plane centred at $l = 312°$, $b = 0°$. The greyscale range is from -50 to $+60$ mJy/beam.

the northern surveys and the SUMSS will be the sensitivity of the latter to extended low surface brightness emission, of special significance in that part of the survey lying near the Galactic plane.

TABLE 2. Comparison of the new large area radio surveys

	WENSS	NVSS	SUMSS
Frequency	325 MHz	1400 MHz	843 MHz
Area (sq. deg.)	10,100	33,700	8,000
Resolution ($''$)	$54 \times 54\,\mathrm{cosec}(\delta)$	45	$43 \times 43\,\mathrm{cosec}(\delta)$
Detection limit	15 mJy	2.5 mJy	<5 mJy
Coverage	$\delta > +30°$	$\delta > -40°$	$\delta < -30°$
Sources per sq. deg.	21	60	>40

To compare the potential of the NVSS and SUMSS surveys, we present in Figure 2 images made of the Fornax cluster as part of the NVSS and as a mosaic of 70′ MOST fields. We have also used parallel observations made near the SGP to examine the spectral indices of a total of 195 sources with $S_{843} > 10$ mJy identified in a mosaic of 70′ fields made by the MOST in an area also surveyed in the NVSS. The derived spectral indices are fully consistent with previous work despite the relatively small frequency baseline.

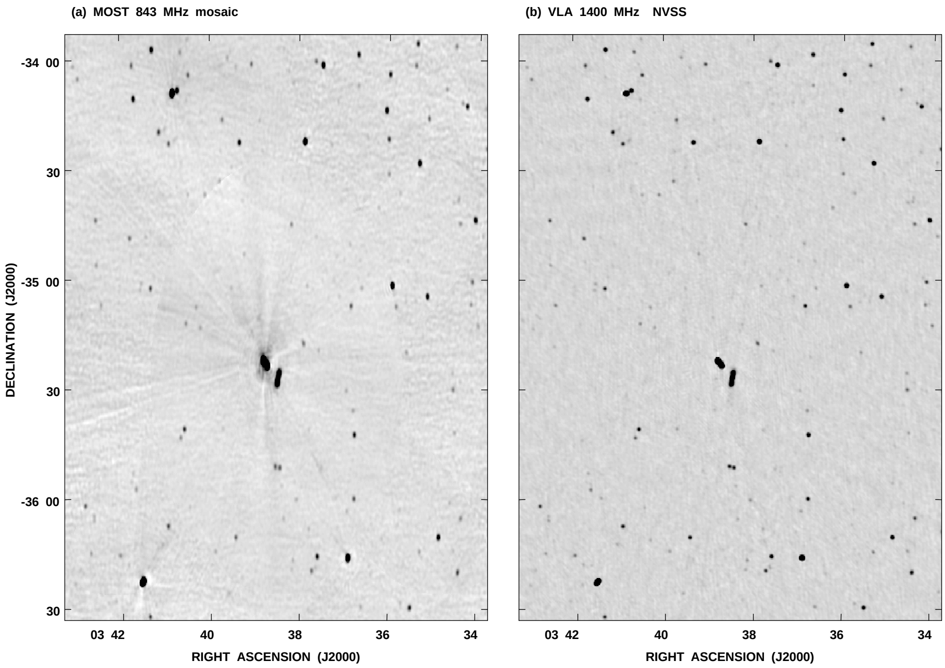

Figure 2. (a) MOST and (b) NVSS mosaic images of the Fornax cluster region. The MOST image was formed from seven separate 70′ images but would be covered now in a single wide-field observation.

It has already been established (Hunstead 1991) that the limiting positional accuracy of MOST is well below 1″. A preliminary assessment of the accuracy of MOST positions at survey-level flux densities was obtained by comparing the positions of sources in the Marano deep field at $-55°$ (Gruppioni *et al.* 1996) obtained using the Australia Telescope Compact Array (ATCA) and the MOST in its 70′ mode. In Figure 3, we show the formal position errors in a four-fold sum of MOST images from the AIPS task VSAD. The ATCA/MOST comparison suggests that these error estimates are conservative. From this we expect that SUMSS positions will be uncertain by no more than 1″ for sources brighter than 20 mJy, increasing to ~2″ at 10 mJy and 3–5″ at 5 mJy. These values will permit reliable optical identifications of sources close to the survey limit, at least at high Galactic latitude.

Figure 4 (derived from Windhorst 1984) illustrates the expected outcome of searches for optical counterparts of sources detected in the SUMSS. We plan to press the SUMSS survey close to its sensitivity limits, even to the extent of ob-

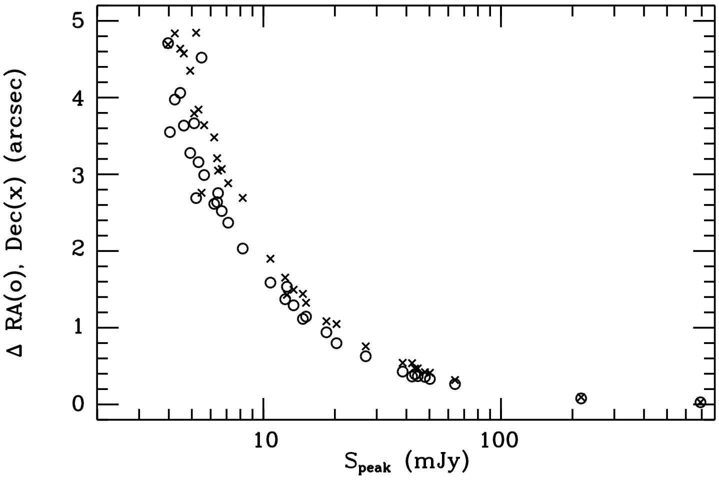

Figure 3. Formal position errors in α and δ for MOST observations of sources in the Marano field. These errors are confirmed by direct comparison with ATCA positions (Gruppioni *et al.* 1996) for sources in common. Our expected calibration error is $\sim 0\farcs5$.

serving many fields twice over, in order to explore the blue 'starburst' galaxy population.

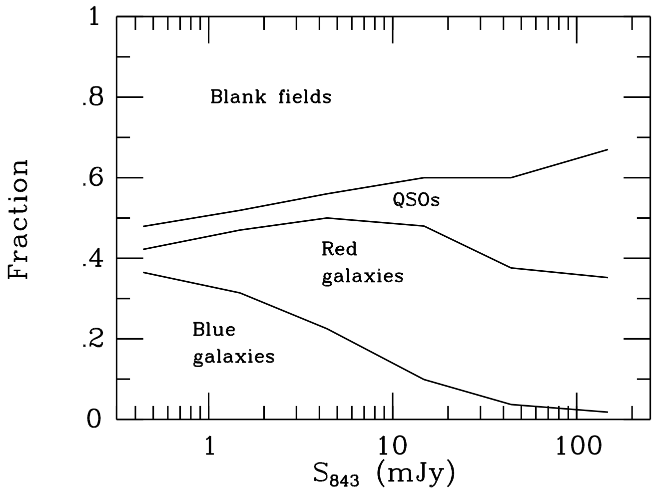

Figure 4. Predicted fractions of the different classes of optical identifications on 4-m plates as a function of flux density at 843 MHz [adapted from Windhorst (1984) assuming a median spectral index $\alpha = -0.75$, where $S_\nu \propto \nu^\alpha$].

The team conducting the SUMSS survey plans to make the data publicly available on the WWW as the survey proceeds. We would welcome collaborations, especially in multi-wavelength follow-up studies, and will be in a position to respond to requests for early observations of fields of particular interest to other astronomers. Further details regarding the MOST and the SUMSS survey may be found at our web site.[3]

5. Prospects

The surveys outlined above will each increase by large factors the numbers of catalogued southern objects. For a significant fraction of these objects, the surveys (taken together) will provide very useful multi-wavelength information which will be supplemented with targeted programs on other telescopes. The databases will be valuable resources for studies of Galactic problems, as well as key problems in extragalactic astronomy, such as large-scale structure and the formation and evolution of galaxies and clusters.

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[3] http://www.physics.usyd.edu.au/astrop/