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An All Sky Blind Survey at 20 GHz

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The Australia Telescope Compact Array 20 GHz Survey is a blind survey of the whole Southern Sky at 20 GHz. The survey began in 2004 and we will complete observations of the whole Southern Sky to a flux level of 50 mJy this year.

We have measured the total intensity and polarisation of these sources at 20, 8, and 5 GHz, with near simultaneous observations at the different frequencies. We will discuss the statistics, spectra, polarisation properties and source populations of the AT20G sample. This sample provides valuable information on the foreground source population that affects CMB observations such as Planck.

In this paper we also present ATCA results from a 93 GHz follow-up of a sample of 20 GHz sources. The spectral indices distribution between 20 and 93 GHz are used to estimate the 93 GHz source counts.

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[1] Speaker

PoS(MRU)047

1. Introduction

1.1 Extragalactic Radio Sources

Most of our knowledge of extragalactic radio sources is based on surveys at frequencies below a few GHz. These surveys are dominated by powerful sources with steep spectrum optically thin synchrotron radiating lobes. The flatter spectrum cores in the nuclei of these radio galaxies and QSOs which will dominate at higher frequencies are a minor component of the low frequency surveys. For example, the NVSS survey at 1.4 GHz has 63% lobe dominated sources and only 37% core dominated sources. However, the AT20G bright source survey at 20GHz has 85% cores and only 15% lobes.

1.1.1 Surveys at High frequency

The radio sky above 5 GHz is largely unexplored. Most radio surveys have been conducted at lower radio frequencies for good reasons. For a telescope with diffraction limited field of view, the number of pointings needed for a given survey area scales as ν^2. The radio flux, S, is $\propto \nu^{-0.7}$ for typical radio sources. For a given receiver noise the time needed per pointing to reach a flux level, S, is $\propto S^{-2}$, and hence the survey time scales as $\propto \nu^{3.4}$ for a given collecting area. This means that a 1.2 cm survey takes 240 times as long as a 6cm survey for the same area and source density. WMAP [1] is the first all sky survey at frequencies above 20 GHz. It was made possible by using a small (1.5 m) dish in space and has relatively low point source sensitivity, and took three years integration time (with no bad weather) to reach a flux limit of about 1 Jy.

Table 1: Previous high frequency surveys

Project	Frequency	Number of Sources	Area (sq. deg.)	Flux Limit (mJy)
Taylor et al.2001 [2]	15 GHz	66	60	20
Waldram et al. 2003 (9C) [3]	15 (43) GHz	465	520	25
Hinshaw et al. 2007 [1]	23, 33, 41, 61,94 GHz	323	All sky	1000
Ricci et al. 2004 [4]	18 GHz	126	1216	100
AT20G (-90° to 0°) [5]	20 GHz	5815	20,000	50

2. The ATCA 20 GHz survey: AT20G

The Australia Telescope Compact Array (ATCA) has carried out a radio continuum survey of the entire southern sky at 20 GHz (AT20G) [4, 5, 6]. The wide bandwidth of an analogue correlator [7], originally developed for the Taiwanese CMB instrument AMiBA [8], combined with the fast scanning speed of the ATCA, makes it possible to scan large areas of sky at high sensitivity despite the small (2.3 arcmin) primary beam width at 20 GHz. The survey frequency is 16-24 GHz, with bandwidth of 8 GHz divided into 8 frequency channels.

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The fast-scanning survey measures approximate positions and flux densities for all candidate sources above the detection threshold. Follow-up 20 GHz imaging of these candidate detections is then carried out a few weeks later, using the ATCA and its standard digital correlator. These follow-up images allow us to confirm detections, and to measure accurate positions, flux densities and polarization for the detected sources. Finally, the confirmed sources are also imaged at 5 and 8 GHz to measure their radio spectra, polarisation and angular size. The pilot survey using this technique has been published [4] and more details of the ongoing main survey are included in [5] and [6].

2.1 AT20G Survey Status

The Survey has now been completed for 0° to -90°. The follow-up has been completed to -15°. The Bright source sample -15° to -90°, S_{20} > 500 mJy has been published [5] by Massardi et al and is reported in this symposium. 3 mm observations of a sub sample [9] are also discussed in this symposium. Papers are in preparation on Polarisation, and Galactic ultra compact HII regions and the full sample should be finished in mid 2008.

2.2 Completeness and Reliability

The survey flux limit is 50 mJy. From the comparison with SUMSS and NVSS and analysis of the fraction of 20 GHz sources confirmed in the follow up, we expect high completeness to 70 mJy. The 6352 extragalactic sources detected (declination 0˚ to -90˚) matches the predicted source density [10]. Between 50 and 70 mJy there will be some variability in completeness for different regions of the sky due to variable observing conditions and a completeness mask for the survey will be estimated. Since the AT20G Catalogue includes higher sensitivity follow up observations for all candidate sources, the reliability is essentially 100%.

3. Galactic Plane

The survey includes the galactic Plane which has ten times higher source density due to detection of thermal sources. The interferometer resolves out sources > 1 arc min and is very incomplete for normal HII regions but can be used for a blind survey of compact HII regions and stars.

3.1 Ultra Compact HII Regions

By comparing the AT20G survey with the Molongolo Galactic Plane Survey [11] at 843 MHz we have selected a sample of galactic sources with significant optical depth between 0.8 and 20 GHz. 46 sources with rising spectra and S_{20} > 0.2 Jy were found in the Galactic Plane $|bII|$ < 1.5°. Higher resolution follow up observations have been made at 20 GHz, the H70α recombination line has been measured and data has been compared with Spitzer IR images [12]. Seven of these sources are extra galactic, five are planetary nebula, and 32 are ultra or hyper compact HII regions [13]. Fig. 1 shows one example with a pair of ultra compact HII regions.

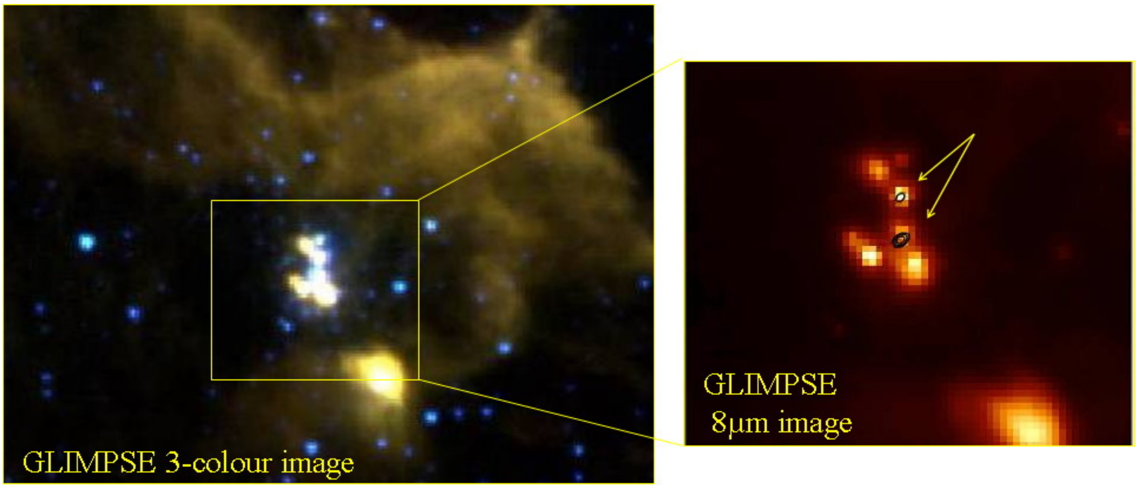

Figure 1. (a) MIR false-colour images of G1235-6302 (b) yellow arrows and 20GHz contours show the two ultra compact HII regions in this MIR complex [13]

4. 20 GHz Source Properties

4.1 Polarization

The polarization properties of sources which are strong at high frequencies are very poorly known [14] yet these sources will be the major impediment to detecting CMB polarization anisotropies. In the AT20G all four Stokes parameters are measured at 20, 8, and 5 GHz for all sources. The median fractional polarisation is 2.5% at 20 GHz, 2.0% at 8 GHz and 1.7% at 5 GHz..

4.2 Size Distribution

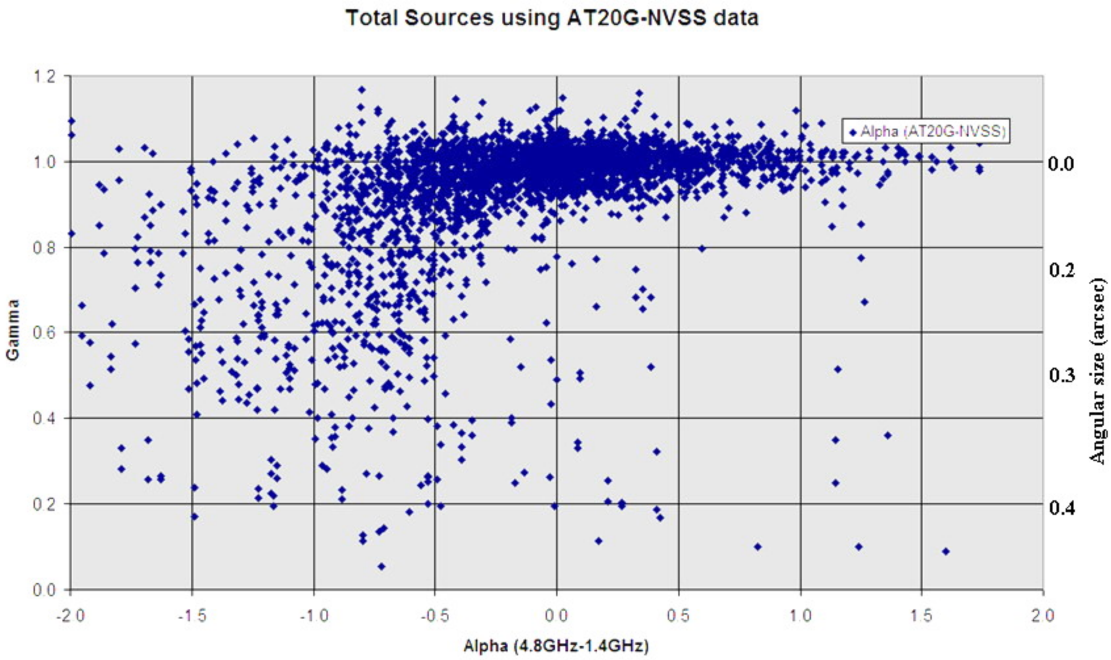

Figure 2. Plot of spectral index (1.4 - 5 GHz) against average visibility amplitude on the 4.5 km baselines for all AT20G sources in common with NVSS and │bII│> 1.5°. The right hand scale indicates the equivalent Gaussian source size [15].

For the survey observations at 20 GHz the ATCA 6 km antenna was included, providing a measurement of the source visibility at long baselines. Sources > 0″.1 in size have significant ($\gamma < 1.0$) visibility on these baselines (Fig. 2). The rapid change in source size for $\alpha < -0.5$ is very clear and consistent with the assumption of two populations [16] although it is also clear that the two populations overlap for $-0.6 < \alpha < -0.3$. The "extended" sources with $\alpha > -0.3$ are a mixture of planetary nebula, core-dominated jet sources, gravitational lenses and binary AGNs [15].

4.3 Radio Spectra

We see a wide variety of spectral shapes, most of which cannot be fitted by a single power-law over the frequency range 1-20 GHz. We can distinguish four main kinds of spectra:

(i) Sources with steep (falling) spectra over the whole range, (ii) Sources with peaked (GPS) spectra, in which the flux density rises at low frequency and falls at high frequency, (iii) sources with inverted (rising) radio spectra over the whole frequency range, (iv) Sources with an upturn in their spectrum, where the flux density is falling at lower frequencies, but then turns up and begins to rise above 5-8 GHz.

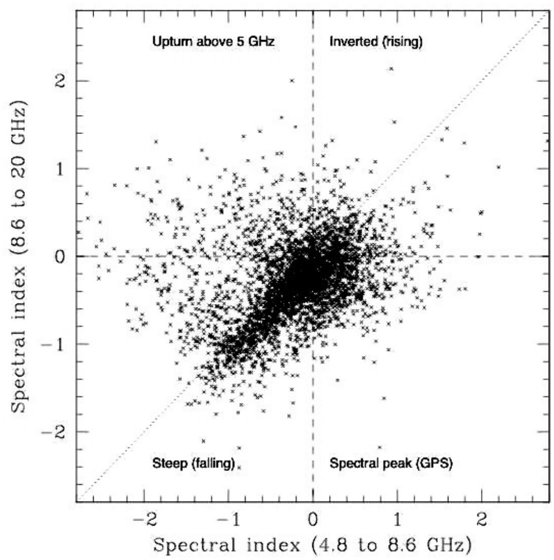

Figure 3. Radio `two-colour diagram' for 3736 extragalactic sources > 40 mJy at 20 GHz

At centimetre wavelengths the radio emission from flat-spectrum ($\alpha > -0.5$; $S \propto \nu^{\alpha}$) objects is dominated by a compact, self-absorbed component, while steep-spectrum objects ($\alpha < -0.5$) are dominated by optically-thin synchrotron emission. The flat- and steep-spectrum populations are usually considered separately when modelling the cosmic evolution of radio sources [16].

As pointed out by Peacock [16] the radio spectral index is only valid as a diagnostic tool if it is measured over a frequency interval small enough that the effects of spectral curvature can be neglected. Because many of the sources in our sample have significant spectra curvature over the frequency range 1-20 GHz, we therefore use a 'radio two-colour' diagram, rather than a single spectral index, to characterize the high-frequency radio-source population. Fig. 3 compares a low-frequency spectral index α_L (which corresponds closely to the spectral index traditionally used to separate flat spectrum and steep spectrum radio sources) with a high-frequency spectral index α_H which measures the spectral shape above 8 GHz.

The dotted line shows the relation for galaxies whose spectra follow a single power-law from 0.8 to 20 GHz. It is clear that only a small fraction of sources fall on or near the dotted line, and that α_L and α_H are not strongly correlated. Over 30% of the sources in

Fig. 3 have flat or inverted spectra between 8 and 20 GHz (i.e. $\alpha_H > 0$), and more than half of these have steep radio spectra below 5 GHz and would not have been predicted as strong 20 GHz sources on the basis of their low frequency spectra. In contrast, many sources with flat or inverted spectra below 5 GHz turn over and become steep above 8 GHz.

5. The Radio Sky at 3mm (See Elaine Sadler this symposium)

5.1 20 GHz v 95 GHz Fluxes

130 extragalactic sources from the AT20G survey were observed at 95 GHz. All fluxes were measured using triple correlations so no phase calibration was required. 90% were detected; only one source has 95 GHz flux greater than that expected from a power law extrapolation. The median spectral index between 20 and 95 GHz is $\alpha = -0.39$ ($S \propto \nu^{\alpha}$). [9]

Almost all sources with rising spectra below 20 GHz turn over between 20 and 95 GHz and there are very few "GPS" sources peaking above 20 GHz. No new population of sources are seen.

5.2 Source Counts at 3mm

We measured the distribution of the 20 - 95 GHz flux ratios for a flux limited sub sample from the AT20G survey, and derived the 95 GHz source counts using the method first described by Kellermann [17]. The result shown in Fig. 4 is in good agreement with Waldram [18] in the region of flux overlap but is significantly lower than De Zotti [10] or Holdaway [19] at flux densities > 100 mJy.

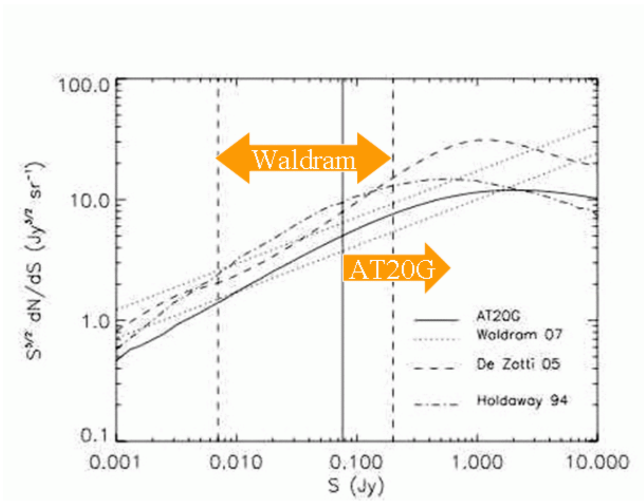

Figure 4. Differential 95GHz source counts

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