# FINDING THE MISSING REMNANTS: A LOW FREQUENCY VLA SURVEY OF THE GALACTIC PLANE FROM $\ell$ = +4° to +23°

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## Abstract

Predictions of the Galactic supernova remnant (SNR) rate and statistical studies of the current Galactic SNR census both indicate that there should be many more SNRs in our Galaxy than are currently known ($\sim$ 230). This paucity of SNRs is likely due in part to selection effects, which are most severe toward the inner Galaxy where the diffuse non-thermal Galactic plane emission coupled with the thermal emission from H II regions causes the most confusion. We present a high-resolution, high dynamic range survey of the Galactic plane from $\ell$ = +4° to +23° ($b = -1.^\circ5$ to $1+.^\circ5$) using 330 MHz observations with the Very Large Array (VLA). At this frequency we exploit the non-thermal spectra of SNRs while our high angular resolution allows us to separate them from the diffuse Galactic emission. We present a number of newly discovered SNRs from the initial stages of the survey, together with supporting evidence from archival X-ray, infrared, and radio data.

## 1 Introduction

Low frequency observations of the Galactic plane are an essential tool to explore the environments of two energetically important constituents of the Galactic medium: supernova remnants and H II regions. Supernova explosions have a profound effect on the morphology, kinematics, and ionization balance of galaxies, and possibly trigger new generations of star formation. However, based on statistical studies of predicted supernova remnant (SNR) rates, there should be many more SNRs in our Galaxy ($\sim$ 1000; Li et al., 1991; Tammann, Loeffler & Schroeder, 1994; Case & Bhattacharya, 1998) than are currently known ($\sim$ 230; Green, 2002). This lack is likely the result of selection effects acting against the discovery of old, faint, large remnants, as well as, very young, small remnants due to poor sensitivity and spatial resolution at low frequencies where SNRs are brightest (c.f. Green 1991). These missing remnants are thought to be concentrated toward the inner Galaxy where the diffuse emission from the Galactic ridge emission causes the most confusion. A complete census of Galactic SNRs is essential to understand the star formation history of our Galaxy.

We are engaged in a long term project to utilize the 74 and 330 MHz systems at the VLA to image the inner Galactic plane at low frequencies. This project is proceeding on two fronts: (1) Survey the inner Galactic plane from $\ell = -15°$ to +55°, $b = \pm5°$ at 74 MHz with $\sim 60''$ resolution in order to constrain the low energy end of SNR spectral energy distributions, and explore the low density ionized interstellar medium via free-free absorption toward SNRs. (2) Image the plane at 330 MHz from $\ell$ = +4° to +23°, $b = \pm1.5°$ with high resolution ($\sim 30''$) and surface brightness sensitivity (rms $\sim$ 5 mJy beam$^{-1}$). The resulting images from these projects will improve upon existing surveys below $\lesssim$ 1 GHz by several orders of magnitude in both resolution and sensitivity and will approach the same level as existing centimeter wavelength surveys. These proceedings present the first results from the 330 MHz imaging project.

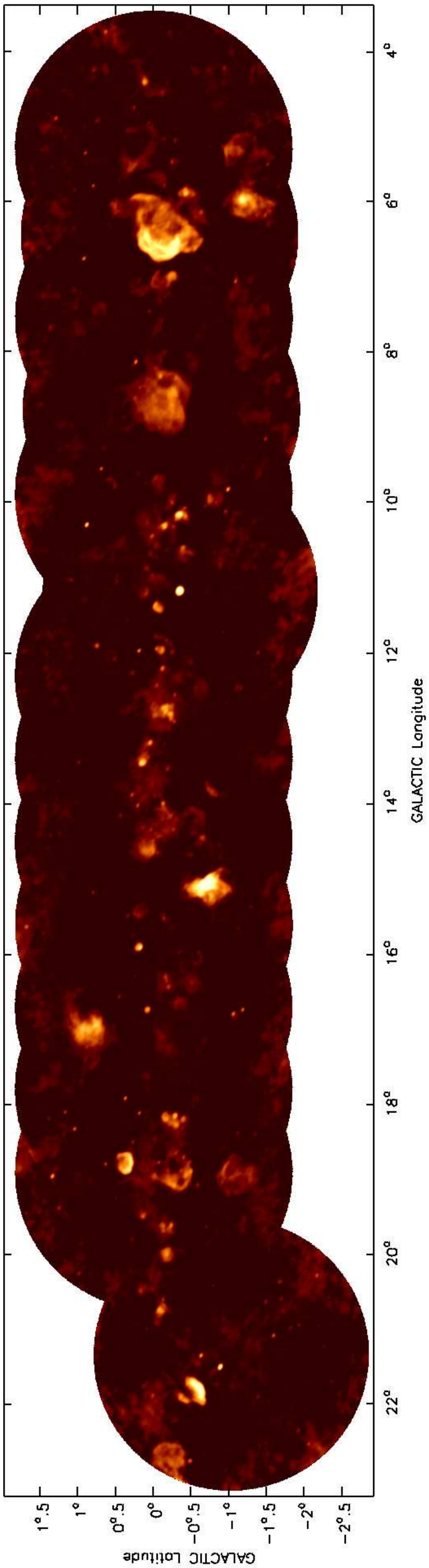


Figure 1: Left: VLA C+D configuration mosaic at 330 MHz composed of 14 pointings. The resolution is $3' \times 2'$ and the rms noise is $\sim$ 50 mJy beam$^{-1}$. When the second epoch of C configuration data and the B configuration data are added we expect a final resolution of $\sim 30''$ and an rms noise of $\sim$ 5 mJy beam$^{-1}$. This image already surpasses previous survey images of this region below 2 GHz, in either resolution (Bonn) or sensitivity (NVSS).

### 1.1 Hasn't this been done?

Couldn't existing lower frequency surveys be used for this purpose? No! Previous single dish surveys like the Bonn 1.4 GHz and 2.6 GHz surveys (while sensitive) had fairly poor resolution, $9'\!.4$ and $4'\!.3$, respectively (Reich et al., 2001; Reich, Reich & Furst, 1997). The 408 MHz survey by Haslam et al. (1982) has a resolution of 0.85 degrees. These resolutions are insufficient to discern SNRs in confused regions. Conversely, the NVSS 1.4 GHz survey with $45''$ resolution has poor sensitivity to extended structures due to missing short spacings and the snapshot nature of the survey.

## 2 Preliminary results

Figure 1 shows our D + Epoch I C configuration 330 MHz mosaic. This mosaic consists of 14 individual pointings, three of them from the VLA archive. The B configuration data are in hand and the Epoch II C configuration data will be observed this spring. From this low resolution image we have already compiled more than 20 new SNR candidates.

Figure 2 shows a higher resolution B+C+D configuration 330 MHz image of the region near $\ell = 18^\circ\!.8$ with two of our new SNR candidates indicated. A comparison of the 330 MHz continuum shown in Figure 2 is compared to Midcourse Space Experiment (MSX) 8 $\mu$m data in Fig. 3. Both the known and new SNRs are anti-correlated with dust emission, while the H II regions are well correlated with strong 8 $\mu$m emission. Such comparisons are a powerful tool for distinguishing thermal and non-thermal emission.

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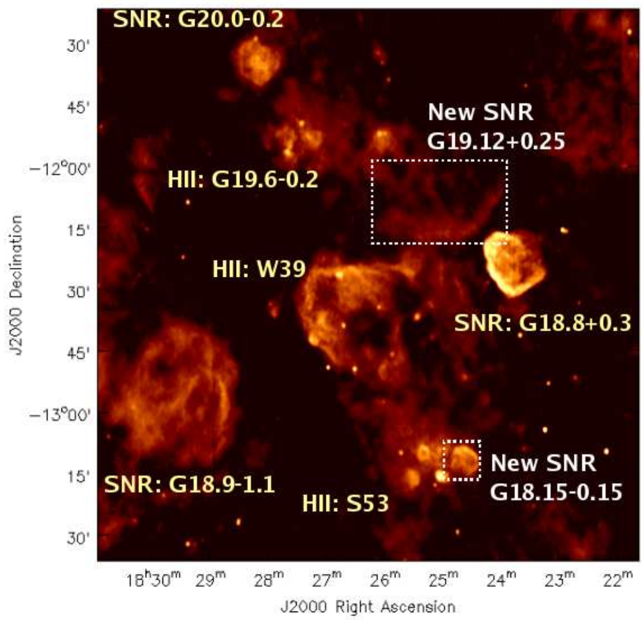


Figure 2: VLA B+C+D configuration image at 330 MHz of the region near $\ell = 18^\circ\!.8$. The resolution is $45'' \times 35''$ and the rms noise is $\sim$ 10 mJy beam$^{-1}$. Several of the brighter known sources are identified in yellow, while the dashed boxes indicate the location of two new SNR candidates.

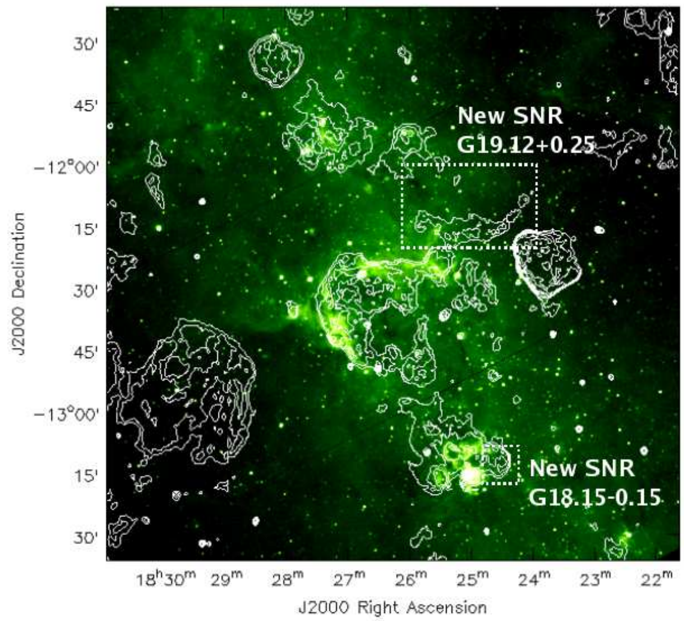


Figure 3: MSX 8 $\mu$m emission with the 330 MHz continuum contours from Figure 2 superposed. The resolution of the MSX data is $20''$. Note the anti-correlation of strong dust emission and the known and new SNRs.

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