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# Discovery of supernova remnants in the Sino-German λ6 cm polarization survey of the Galactic plane

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**Abstract.** The Sino-German λ6 cm polarization survey has mapped in total intensity and polarization intensity over an area of approximately 2 200 square degrees in the Galactic disk. This survey provides an opportunity to search for Galactic supernova remnants (SNRs) that were previously unknown. We discovered the new SNRs G178.2−4.2 and G25.1−2.3 which have non-thermal spectra, using the λ6 cm data together with the observations with the Effelsberg telescope at λ11 cm and λ21 cm. Both G178.2−4.2 and G25.1−2.3 are faint and have an apparent diameter greater than 1°. G178.2−4.2 shows a polarized shell. HI data suggest that G25.1−2.3 might have a distance of about 3 kpc. The λ6 cm survey data were also very important to identify two other new SNRs, G152.4−2.1 and G190.9−2.2.

**Keywords.** Radio continuum: ISM – ISM: supernova remnants – Polarization

## 1. Introduction

Supernova explosions have a substantial impact on the interstellar environment. Supernova remnants (SNRs) are post-explosion relics, and are formed when shocks from the explosion sweep up and interact with the surrounding medium. Large-scale radio surveys are ideal hunting grounds for new SNRs. In the most frequently used Galactic SNR catalogue compiled by Dave Green (Green 2009), mainly based on radio continuum observations, there are 274 SNRs. Ferrand & Safi-Harb (2012) recently made a new Galactic SNR catalogue by including new detections from high energy observations. The number of known Galactic SNRs is now 312. This quantity is still far less than the theoretical predictions (e.g. Tammann *et al.* 1994), because of two major limitations: the sensitivity and the angular resolution of the observations.

The Sino-German λ6 cm polarization survey of the Galactic plane (Sun *et al.* 2007, Gao *et al.* 2010, Sun *et al.* 2011, Xiao *et al.* 2011) was conducted between the years 2004 and 2009, observing the Galactic disk in the range of $10° \leqslant l \leqslant 230°$ and $|b| \leqslant 5°$. The angular resolution is 9.5′, and the average sensitivity (1$\sigma$ noise) of the survey is about 0.8 mK $T_b$ in total intensity $I$ and 0.5 mK $T_b$ in linear polarization $U$ and $Q$. Although the angular resolution is coarser in comparison with synthesis telescopes and large single dishes, the system is more suitable for observing SNRs with large extent, and the high sensitivity of the Sino-German survey enables us to discover SNRs as faint as G156.2+5.7, the SNR with the lowest surface brightness until recently. One of the major goals of the λ6 cm survey is to study and identify Galactic SNRs (see Han *et al.* 2013, this volume). In this talk, we present the discovery of two new SNRs G178.2−4.2 and G25.1−2.3 in our λ6 cm survey (Gao *et al.* 2011).

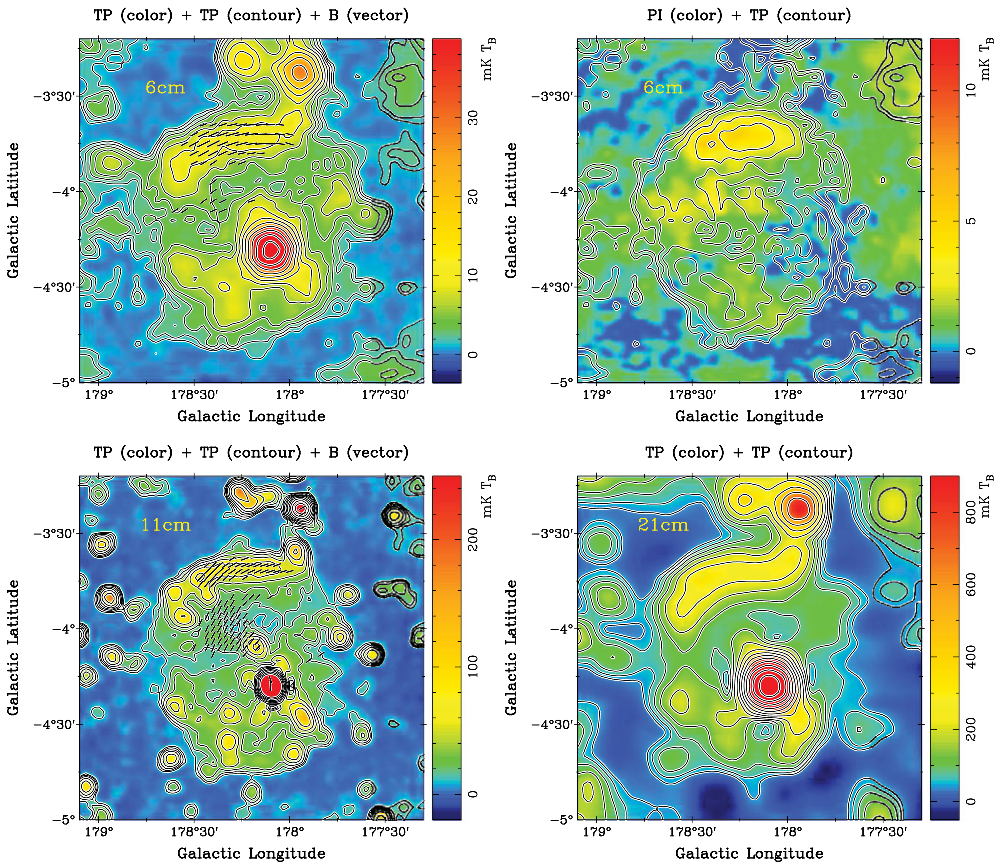


**Figure 1.** Total intensity and polarization intensity images of the new SNR G178.2−4.2 measured at λ6 cm, λ11 cm and λ21 cm. The top right panel shows the total intensity contours after subtracting point sources.

## 2. Identification of two new SNRs

Considering the limitation in angular resolution, we search for shell-type objects as SNR candidate. Shell-type SNRs often appear more extended than the crab-like ones, and are easier to identify due to three characteristics: 1) shell or partial shell structures, 2) associated polarized emission within the shell, and 3) the non-thermal spectrum with a spectral index around $\beta \sim -2.5$ ($S_\nu \sim \nu^\beta$, $\alpha = \beta + 2$), as expected for adiabatic expansion with a compression factor of 4. These are the three criteria for our SNR identifications. Note that polarization may not be detected due to Faraday depolarization. We successfully identified two new shell-type SNRs G178.2−4.2 and G25.1−2.3 in the λ6 cm survey.

G178.2−4.2 is located in the anti-center region of the Galaxy (Fig. 1). It has a circular shape with an apparent diameter of around 1°. A prominent shell is seen in its northern part. The un-related, unresolved double-sided radio source 3C139.2 is near the center of G178.2−4.2. Polarized emission is seen in the northern shell at both λ6 cm and λ11 cm. B-field vectors ($\vec{E}$+90°) are found to be tangential within the shell at λ6 cm. We observed G178.2−4.2 at λ11 cm with the Effelsberg 100-m telescope in March, 2009, and we extracted the λ21 cm data from the Effelsberg λ21 cm survey of the Galactic plane (Reich *et al.* 1997) and the Effelsberg λ21 cm medium latitude survey (Reich *et al.* 2004).

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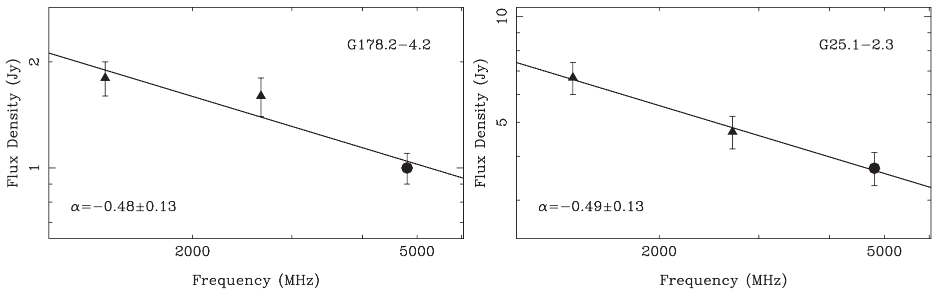


**Figure 2.** Integrated radio spectrum of G178.2−4.2 and G25.1−2.3.

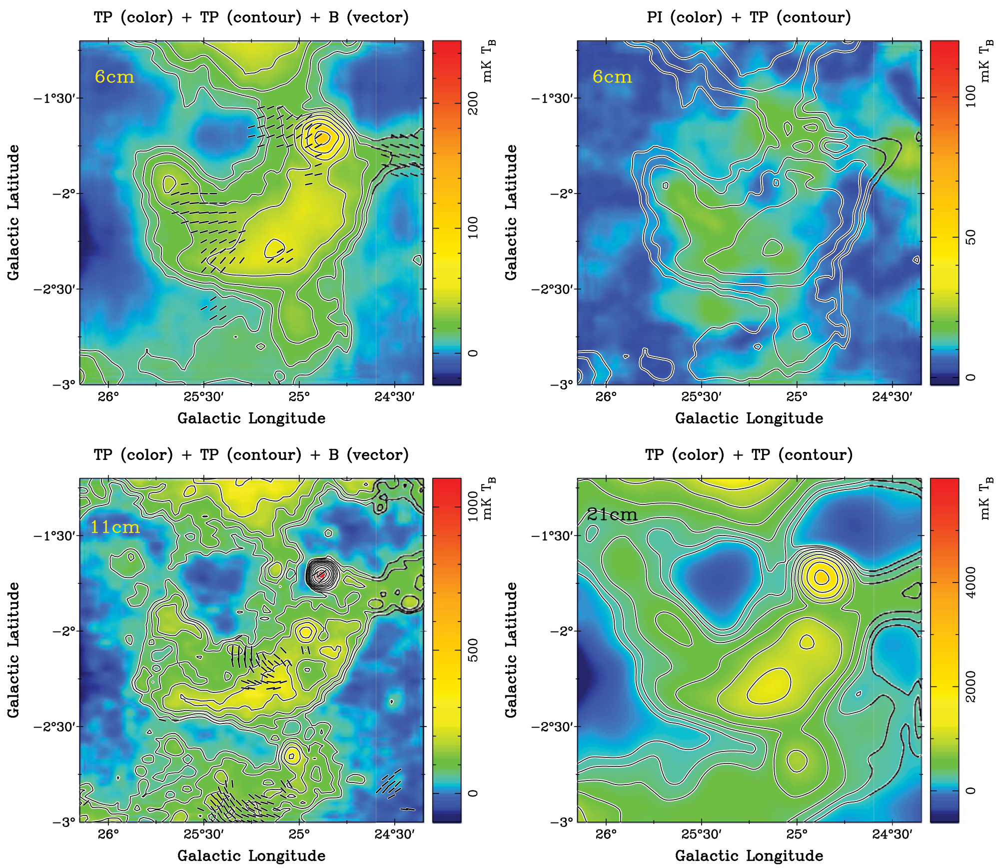


**Figure 3.** The same as in Fig. 1, but for G25.1−2.3.

The flux density is integrated over the same area of G178.2−4.2 at $\lambda$6 cm, $\lambda$11 cm and $\lambda$21 cm, after removing the contribution from extra-Galactic sources and background emission. We measured $S_{6cm} = 1.0 \pm 0.1$ Jy, $S_{11cm} = 1.6 \pm 0.2$ Jy and $S_{21cm} = 1.8 \pm 0.2$ Jy, yielding an integrated spectral index of $\alpha = -0.48 \pm 0.13$ (Fig. 2). This value indicates the non-thermal nature of G178.2−4.2. In summary, the shell structure, the polarized emission and the non-thermal nature strongly indicate that G178.2−4.2 is a SNR. From the integrated flux density, we calculated the surface brightness of the new SNR G178.2−4.2 to be $\Sigma_{1\ \mathrm{GHz}} = 7.2 \times 10^{-23} \mathrm{Wm^{-2}Hz^{-1}sr^{-1}}$. This small value places it among the faintest SNRs known in the Galaxy.

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G25.1−2.3 is found in the inner part of the Galaxy. It is elusive until we filter out the confusion from the strong diffuse Galactic emission. We examined G25.1−2.3 using the data from the Urumqi $\lambda$6 cm survey, the Effelsberg $\lambda$11 cm survey (Reich *et al.* 1990a) and the Effelsberg $\lambda$21 cm survey (Reich *et al.* 1990b), and found that G25.1−2.3 has only one shell curving to the south. Polarization patches are detected within the shell at $\lambda$6 cm and $\lambda$11 cm, but they seem to be un-correlated with G25.1−2.3 (see Fig. 3). We determined that the integrated flux density of G25.1−2.3 is $S_{6cm} = 3.7{\pm}0.4$ Jy, $S_{11cm} = 4.7{\pm}0.5$ Jy, and $S_{21cm} = 6.7{\pm}0.7$ Jy, respectively. The spectrum that we fitted to these data has a spectral index of $\alpha = -0.49 \pm 0.13$ (Fig. 2). SNR G25.1−2.3 has a surface brightness of $\Sigma_{1\ \mathrm{GHz}} = 5.0 \times 10^{-22}\mathrm{Wm^{-2}Hz^{-1}sr^{-1}}$, which makes it one of the fainter SNRs in Green's sample (Green 2009, see his Fig. 1).

From a possibly associated cavity found in the neutral atomic gas, we estimate a distance of 3.1 kpc to the new SNR G25.1−2.3. If this is true, the distance of G25.1−2.3 can explain the absence of polarized emission coming from this object, since polarized emission originated beyond 3 kpc might not be detected at $\lambda$6 cm in this direction of the Galactic plane (Sun *et al.* 2011).

## 3. Other SNRs discovered with the λ6 cm data

Based on high angular resolution synthesis observations, Foster *et al.* (2013) recently identified two other new SNRs, G152.4−2.1 and G190.9−2.2, which are even fainter than G156.2+5.7. The $\lambda$6 cm total intensity and polarization data from the Sino-German $\lambda$6 cm survey were incorporated in their study and provide strong support and evidence for the identifications.

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