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Discovery of Three Large HII Regions in the Galactic Plane *

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Abstract We discovered three large HII regions: G148.8+2.3, G149.5+0.0 and G169.9+2.0 in the Sino-German λ6 cm polarization survey of the Galactic plane. They have been identified based on the flat spectral indexes and the strong infrared emission properties.

Key words: radio continuum: general — methods: observational — HII regions

1 INTRODUCTION

HII regions near the Galactic plane are important radio sources. They absorb the background emission of the Galactic plane at low radio frequencies, and can thus be used to estimate the diffuse foreground synchrotron emissivity of the Galaxy (e.g. Roger et al. 1999). At higher frequencies, e.g. 5 GHz, the contribution of HII regions to radio emission can amount to about 9% of the Galactic radio emission (Paladini et al. 2005). HII regions are also key tracers of the structure of galactic spiral arms (e.g. Russeil 2003).

Previous cataloged HII regions are detected in either optical or radio observations. Optical observations (e.g. Sharpless 1959) are subject to the strong obscuration of the interstellar medium in the Galactic plane. This motivated further identification based on radio recombination line observations (e.g. Caswell & Haynes 1987). Most of the candidates were selected from radio continuum surveys (e.g. Altenhoff et al. 1970) which were made decades ago but with poor sensitivity. The radio catalog of HII regions by Kuchar & Clark (1997) was compiled from the 87GB (Condon et al. 1989) and PMN (Condon et al. 1993; Tasker et al. 1994) surveys, and contains only sources with sizes less than 10′. Combining most of the previous data Paladini et al. (2003) made a synthesized catalog of 1442 HII regions.

More recently, several Galactic plane surveys with high resolution and sensitivity have been carried out, such as the Effelsberg 2695 MHz (Reich et al. 1990a; Fürst et al. 1990) and 1408 MHz (Reich et al. 1990b, 1997) surveys, and the Canadian Galactic plane survey (CGPS) at 1420 MHz and 408 MHz (Taylor et al. 2003). All the survey data can be freely accessed via the internet. These surveys have detected a large number of HII regions. There are still many extended radio structures whose nature remains unclear (e.g. Kerton et al. 2007). To identify new HII regions from the extended sources, knowledge of their spectral properties is essential. HII regions have flat spectra while, in contrast, supernova remnants (SNRs) have spectral indexes α around –0.5 ($S_\nu \propto \nu^\alpha$ here S_ν is the flux density at a frequency ν). However, the lack of high quality data at high frequency precludes a definitive study of the spectrum.

We are conducting the Sino-German λ6 cm continuum and polarization survey of the Galactic plane (Sun et al. 2007). This allows us to make further study of the spectra of extended sources by combining the available data and thus to discover new HII regions. A systematic study of all the extended sources is ongoing. In this paper we present the first discovery of three large HII regions.

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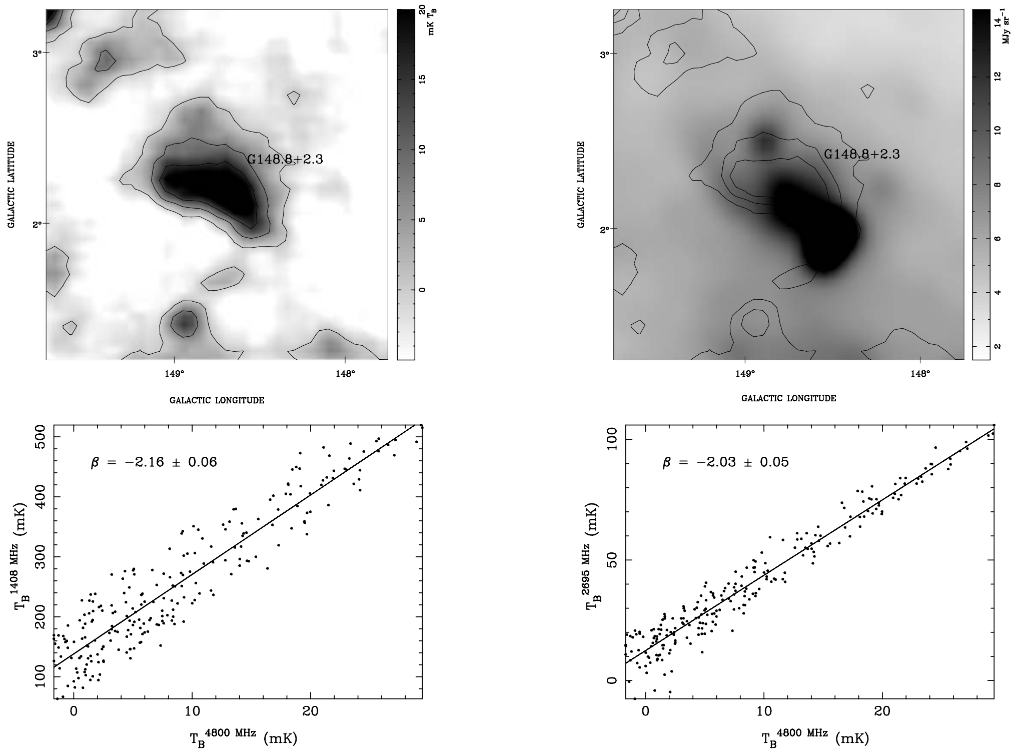

Fig. 1 Results for G148.8+2.3. In the upper left panel the λ6 cm total intensity is shown in both gray image and contours. In the upper right panel the 60 μm intensity is shown in gray image overlaid with the λ6 cm total intensity contours. The contours levels are $2^n \times 3\sigma_{\rm bg}$ ($\sigma_{\rm bg}$ = 2.6 mK $T_{\rm B}$) ($n = 0, 1, 2 \ldots$). TT-plots of 1408 MHz versus 4800 MHz and 2695 MHz versus 4800 MHz are shown in the two lower panels.

2 OBSERVATIONS

The Sino-German λ6 cm polarization survey of the Galactic plane uses the 25 m telescope located at Nanshan station (87°E, 43°N) of the Urumqi Observatory, National Astronomical Observatories, Chinese Academy of Sciences, to observe total power and polarized emissions in the region of $10° < l < 230°$ and $-5° < b < 5°$. The λ6 cm receiving system was constructed at the Max-Planck-Institut für Radioastronomie, Germany, and installed at the telescope in August 2004. A description of the receiving system and the observation technique was presented in Sun et al. (2007). In summary the resolution is 9.′5, the system temperature is about 22 K, the central observation frequency is 4800 MHz and the bandwidth is 600 MHz. The primary calibrator is 3C 286. Its λ6 cm flux density is 7.5 Jy.

The observations in the region $52.^\circ5 \leq l \leq 183.^\circ1$ and $|b| \leq 5°$ have completed by the summer of 2007. Observations in other regions are still going on. Following the processing scheme presented in Sun et al. (2007), we processed the total intensity data of the observed region.

3 THREE LARGE HII REGIONS

Three new HII regions were discovered as shown in Figures 1–3. The spectra and infrared properties clearly indicate they are HII regions (see Table 1).

To obtain an integrated flux density of each source, we subtracted a "twisted" hyper-plane which is defined by the pixel values surrounding the source. A typical error of the flux density of the given object is less than 10%. The parameters of three objects are listed in Table 1. The sizes of these HII regions are estimated from the λ6 cm map.

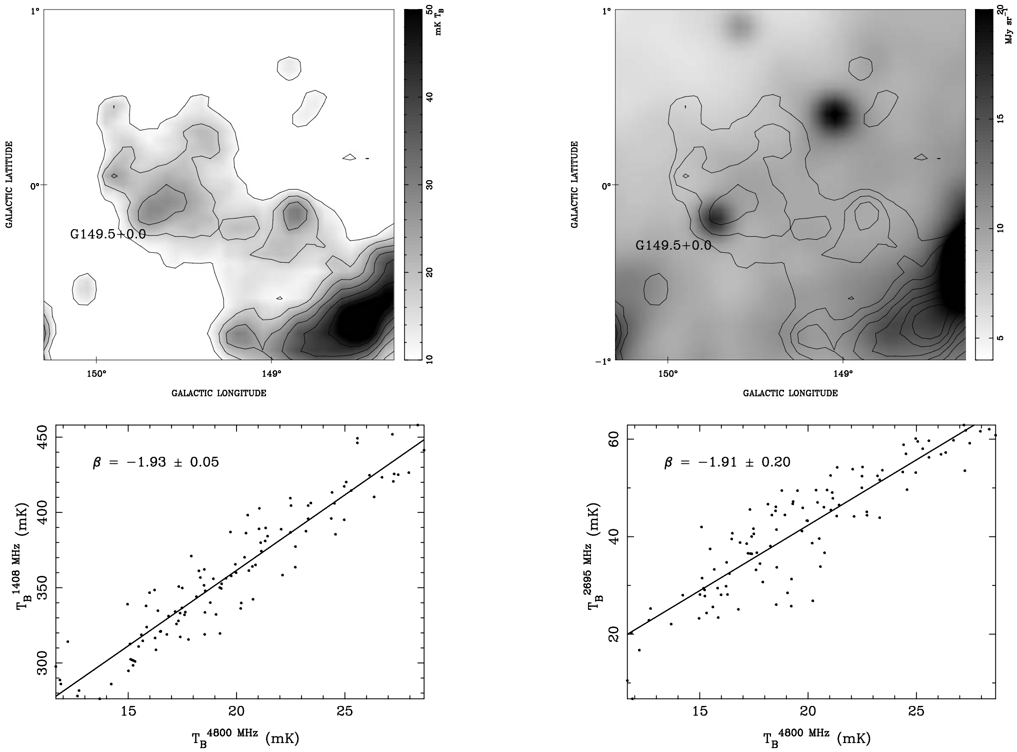

Fig. 2 Same as Fig. 1 but for G149.5+0.0 and $\sigma_{\rm bg}$ = 3.5 mK T_B. The total intensity contours are from 10.5 mK T_B in steps of $2\sigma_{\rm bg}$.

3.1 Spectral Indexes

The spectral index can be obtained by fitting a power-law to the integrated flux densities observed at various frequencies. However, the index could be severely influenced by the uncertainty of the background level particularly for weak and diffuse sources. Nevertheless, after smoothing the maps to the same resolution, one can obtain the spectral index from the distribution of pixel values brightness temperature map at one frequency plotted against those at another frequency (the "T-T plot"). A linear fit yields the brightness temperature spectral index, β. The flux density of a source and its brightness temperature are related via $S_\nu \propto \nu^2 T_\nu$, so the brightness temperatures index can be translated to the flux density spectral index: $\alpha = \beta + 2$.

For every source we first extracted a $2^\circ \times 2^\circ$ map from our λ6 cm data, then we measured the average ($\overline{T}_{\rm bg}$) and variance ($\sigma_{\rm bg}$) of the background emission surrounding the source. The edge of the source is defined by the intensity level $\overline{T}_{\rm bg} + 3\sigma_{\rm bg}$. We also retrieved the corresponding Effelsberg 1408 MHz and 2695 MHz survey data[1]. These data and the λ6 cm data are then smoothed to a common resolution of $10'$ to calculate the TT-plot indexes, $\beta_{1408/4800}$ and $\beta_{2695/4800}$. Note that the TT-plots are made only for pixels belong to the source itself. The indexes are averaged to yield the final spectral indexes by using the errors as weights. The results are shown in Table 1 and Figures 1–3.

All the sources have flat spectra, which mean they are probably either HII regions or crab-like SNRs, but only HII regions have relatively stronger infrared emission. Therefore, we checked the 60 μm far infrared data as following for further identifications.

[1] *http://www.mpifr.de/old_mpifr/survey.html*

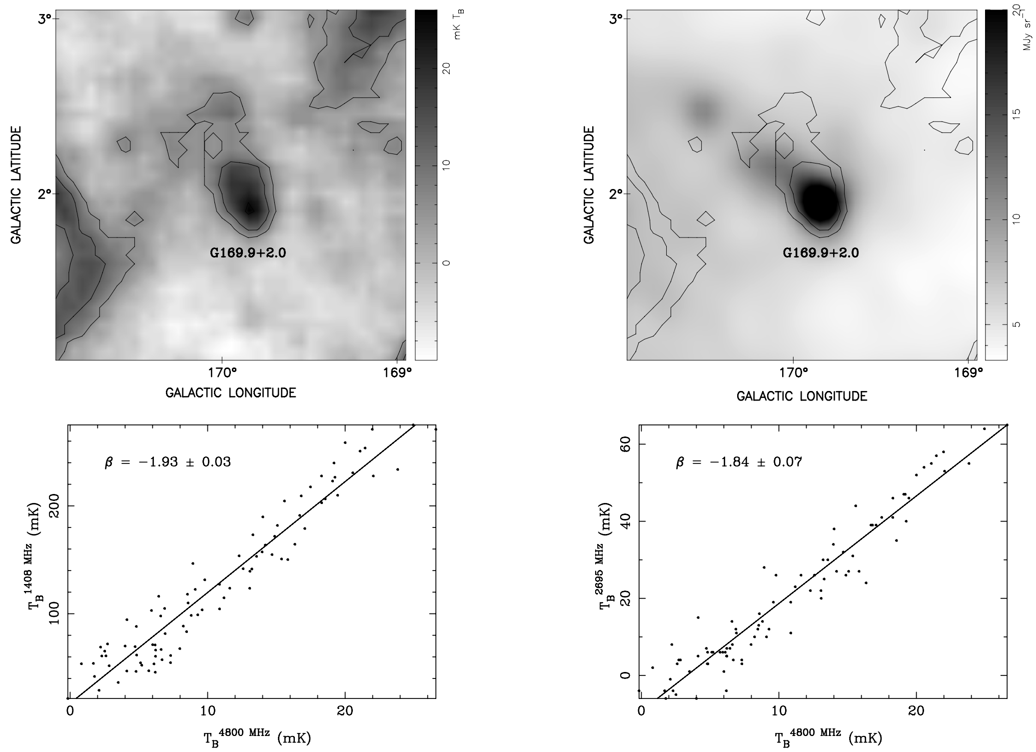

Fig. 3 Same as Fig. 1 but for G169.9+2.0 and σ_{bg} = 2.5 mK T_B.

Table 1 Parameters of Three New HII Regions

Name	Size	S_{4800} (Jy)	$\beta_{1408/4800}$	$\beta_{2695/4800}$	Average α	$R_{60\,\mu m/6\,cm}$
G148.8+2.3	63′ × 40′	1.8 ± 0.2	−2.16 ± 0.06	−2.03 ± 0.05	−0.08 ± 0.04	1317
G149.5+0.0	30′	0.7 ± 0.2	−1.93 ± 0.05	−1.91 ± 0.20	0.07 ± 0.05	672
G169.9+2.0	27′ × 20′	0.4 ± 0.2	−1.93 ± 0.03	−1.84 ± 0.07	0.07 ± 0.03	1800

3.2 Infrared Properties

Fürst, Reich & Sofue (1987) have shown that HII regions have a large ratio between 60 μm and λ11 cm intensity, which is similar to that between the 60 μm and λ6 cm, $R_{60\,\mu m/6\,cm}$. Sun et al. (2007) have found $R_{60\,\mu m/6\,cm} \gtrsim 500$ for HII regions.

The 60 μm infrared images were obtained from the CGPS data archive[2]. All these data have a resolution of about 1′, and we smoothed these data to 10′ to compare with the λ6 cm data. The smoothed infrared images overlaid with the λ6 cm total intensity contours are also shown in Figures 1–3. We found G148.8+2.3, 149.5+0.0 and G169.9+2.0 are strong infrared sources. All three sources have a $R_{60\,\mu m/6\,cm}$ value larger than about 650, as listed in Table 1, confirming them as HII regions.

4 CONCLUSIONS

We identified three new HII regions based on their flat spectra calculated from the λ6 cm, λ11 cm and λ21 cm data and the high ratio between the 60 μm infrared emission and the λ6 cm emission. Our λ6 cm polarization survey of the Galactic plane has a high sensitivity and stability, hence is able to detect weak extended emission. In the near future more new HII regions are expected to be discovered from our survey.

[2] *http://www1.cadc-ccda.hia-iha.nrc- cnrc.gc.ca/cgps/data_structure.html*

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