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A blind survey of the 6.7 GHz methanol maser line

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Abstract. A blind survey for 6.7 GHz methanol maser emission has been made with the 32 m Toruń radio telescope. The survey consists of 4,800 spectra on an equilateral triangular grid pattern with each grid point separated by 4$'$.4 covering a field of ~21 deg^2 at galactic longitudes 20° to 40° and galactic latitudes ±0°.52. The average sensitivity was 1.6 Jy and the spectral resolution was 0.04 km s^{-1}. A total of 99 sources were detected, 28 of which were not found during previous searches of IRAS-selected ultracompact HII regions. The peak flux density of new detections is usually lower than 30 Jy. About half of the methanol masers have no IRAS counterparts within a radius of 2$'$. The nature of these sources is unclear.

1. Introduction

Searches for the 6.7 GHz methanol maser emission from known star-forming regions associated with OH and H_2O masers and/or ultracompact HII (UCHII) regions resulted in detection rates of 65–90% (Menten 1991; Caswell et al. 1995). Many new methanol sources have been detected towards IRAS-selected candidate UCHII regions (e.g. Schutte et al. 1993; van der Walt, Gaylard, & MacLeod 1995; Walsh et al. 1997; Slysh et al. 1999; Szymczak, Hrynek, & Kus 2000). These observations showed that the 6.7 GHz methanol transition is a powerful tracer of sites of recent or ongoing massive star formation.

Unbiased surveys of selected areas along the Galactic plane (Caswell 1996; Ellingsen et al. 1996) enabled considerable progress towards obtaining a complete population of CH_3OH maser sources. The survey by Ellingsen et al. showed that many 6.7 GHz methanol sources are not associated with IRAS sources and some may be associated with sources with colours well outside the colour ranges of UCHII regions. It is likely that systematic surveys can be successful in finding methanol masers associated with different kinds of objects. In this paper we report the preliminary results of a blind survey of an area along the Galactic plane readily accessible to the Toruń radio telescope.

2. Observations

The observations were made between 2000 February and October with the 32 m radio telescope of the Toruń Centre for Astronomy. The half-power beamwidth (FWHM) of the telescope was 5$'$.5 at 6.7 GHz. We used a dual-channel cooled

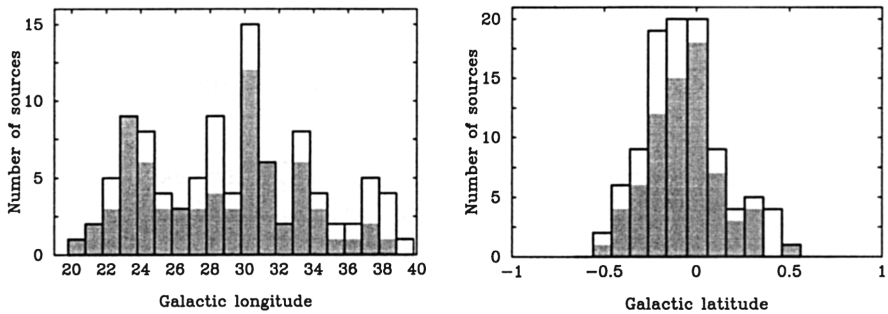

Figure 1. Number of methanol masers as a function of galactic longitude (left) and galactic latitude (right). The shaded and blanked bars represent known and new sources, respectively.

HEMT receiver to measure simultaneously two opposite circular polarizations. The system temperature was about 60 K on cold sky. The backend was a 2^{14} channel spectrometer. We used it in two parts of 4096 channels each with a bandwidth of 4 MHz, yielding a velocity resolution of 0.04 $\mathrm{km\,s^{-1}}$ and a velocity coverage of $\pm 90\,\mathrm{km\,s^{-1}}$. The data were taken in total−power position switching mode. The system was calibrated continuously against a noise diode of known temperature. This calibration was checked by continuum measurements of 3C123 and Vir A and is thought to be accurate to 15%.

The Galactic plane was surveyed over a strip 20−40° wide in longitude and $\pm 0\overset{\circ}{.}52$ wide in latitude using an equilateral triangular grid pattern (4,800 points) with each grid point separated by $4\overset{\prime}{.}4$ (about 0.8 FWHM). The 3σ noise level after 10 min on-source integration and averaging the two polarizations was about 1.6 Jy. New detections were confirmed and their positions were measured by taking spectra on a NSEW grid, at positions separated by half the FWHM from the nominal positions.

3. Results

We have detected 99 methanol sources, 28 for the first time. About 25 of 71 known sources were discovered previously with the 32 m telescope in a survey of 1399 IRAS selected candidate star-forming regions. The Galactic distribution of methanol sources is not uniform. The number of masers significantly drops at higher galactic longitudes; at $35° < l < 40°$ the number of detections is a factor of 2.5 lower than at $30° < l < 35°$. The highest number of sources was detected near $l = 32°$. A second maximum in the source counts was seen at $l \approx 23°$. The distribution of new detections in galactic longitude is nearly uniform. There is a strong concentration of masers towards the Galactic plane; about 70% of the sources lie within the galactic latitude range of $\pm 0\overset{\circ}{.}2$. New masers are significantly biased towards negative galactic latitudes. At least three clusters of maser sources were found. They contained 2 or 3 sources within a region of less than $4'$. The velocity structure of emission in a cluster suggested that the objects can be related to a common centre of activity.

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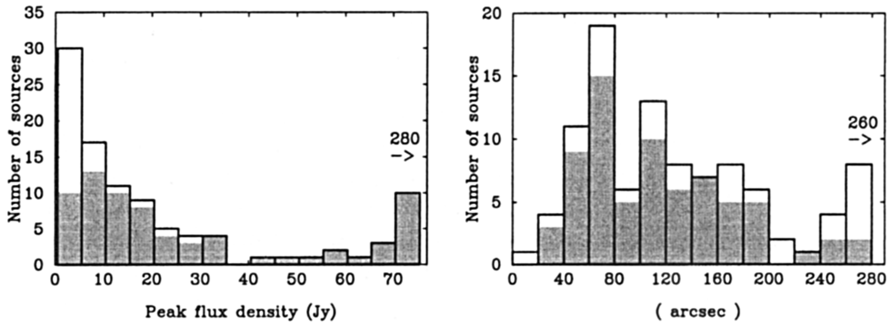

Figure 2. Histograms of methanol maser sources versus the peak flux density (left) and the angular separation of methanol source to the nearest IRAS source (right). The shaded and blanked bars represent known and new sources, respectively. The last bar in the left-hand histogram indicates the number of sources with the peak flux density higher than 280 Jy. The last bar in the right-hand histogram indicates the number of sources separated from IRAS sources by more than 260″.

The detected masers were relatively weak sources. The peak flux density of 71 methanol sources was lower than 35 Jy (Fig. 2). There are only 10 sources with a peak flux density higher than 280 Jy and all of them were previously known. The 24 new sources had a peak flux density below 10 Jy.

We measured the angular separation of each methanol source from the nearest IRAS source (without checking whether each IRAS source satisfies the criteria required for a candidate UCHII region, Wood & Churchwell 1989). A total of 55 sources, including 12 new detections, are within 2′ of IRAS counterparts. Of the 28 new methanol sources, 18 (64%) have no IRAS counterpart within 2′ of the IRAS position. It is somewhat unexpected that 28 out of 71 known sources (39%) also are not associated with IRAS sources within 2′. In the region we have surveyed, 15 sources, including 10 new masers, have no IRAS counterpart within 3.′5. This group of sources without any obvious association with known IRAS objects deserves further investigation.

4. Discussion

We carried out a complete 6.7 GHz methanol survey covering galactic longitudes 20°to 40°and galactic latitudes ±0.°52. Ellingsen et al. (1996) performed a systematic survey within a similar range of galactic latitude but at $l = 325° - 335°$. They found 50 masers above a peak flux density of 2.3 Jy. There are 60 sources in the region at $l = 25° - 35°$, which is symmetric about the Galactic centre relative to the region surveyed by Ellingsen et al.. Taking into account the slightly higher sensitivity of our survey, this implies a comparable number of masers in both regions. This supports the estimate of the number of detectable methanol masers in the Galaxy made by Ellingsen et al. (1996) by extrapolation from the number of sources in the region $325° < l < 335°$.

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The present survey provides evidence that there are 28 known methanol sources which are more than $2'$ offset from IRAS sources. It is likely that these masers are not associated with IRAS sources or the IRAS positions are severely confused. We found a group of 15 weak sources which have no IRAS counterpart within $3\farcm5$. Ellingsen et al. (1996) also found a significant fraction of 6.7 GHz methanol masers which cannot be detected in IRAS selected surveys. As these sources are weak, one can suppose that they are very distant massive star-forming regions, where other indicators of star-forming activity are too weak to be detected. Another possibility is that they are associated with less massive objects or objects at very early stages of evolution (Ellingsen et al. 1996). This group of the methanol masers needs more extensive investigations to clarify its origin.

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