86 GHZ SIO MASER SURVEY OF LATE-TYPE STARS IN THE INNER GALAXY

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Abstract We present observations of 86 GHz (J=2-1, v=1) SiO maser emission in the Inner Galaxy. Using the IRAM 30m telescope, we targeted late-type stars selected from the ISOGAL and MSX catalogues, in order to measure radial velocities of a large number of stars. Our 255 new measurements double the number of maser line-of-sight velocities known toward the inner Galaxy. Combining our measurements with those from other surveys, in particular OH maser surveys, will allow a kinematic analysis of the stellar orbits in the inner Galaxy. Analyzing the colours and luminosities of OH and SiO maser emitters also yields new clues on the conditions under which different masers may occur.

Keywords: stars: stars: late-type – masers – Galaxy: kinematics and dynamics

Introduction

Maser emission from circumstellar envelopes of mass-loosing late-type stars is often strong enough to be detected throughout the Galaxy. Masers can indicate the line-of-sight velocities of the respective stars to within a few km s^{-1}. Frequently detected maser lines are from OH at

1.6 GHz, H_2O at 22 GHz, and SiO at 43 GHz and 86 GHz (e.g. Habing, 1996).
Until recently, only a few hundred stellar line-of-sight velocities, mainly from OH/IR stars, were known toward the inner Galaxy ($30° < l < -30°$ and $|b| < 1$). This number is too small to allow for a good multicomponent analysis of the Galactic structure and dynamics. Obtaining more stellar line-of-sight velocities is therefore an urgent need. We are therefore conducting a search for 86 GHz SiO ($v = 1, J = 2 \rightarrow 1$) maser line emission (Messineo et al., 2002) towards late-type stars in the inner Galaxy. This survey is conducted with the IRAM 30m telescope.

1. Source selection

SiO maser emission is detected from several transitions towards oxygen-rich Asymptotic Giant Branch (AGB) stars. However, it occurs more frequently towards M-type Mira stars than towards other AGB stars. Furthermore, the relative strengths of different SiO maser lines are observed to vary with AGB type (Nyman et al., 1993 and references therein), indicating that the SiO maser properties depend on the stellar mass loss rate. The ratio of the SiO maser flux at 43 and at 86 GHz ranges between 2 and 10 in OH/IR stars, but is ~0.4 in Mira stars and in supergiants. Thus, in particular for Mira-like stars, the 86 GHz ($v = 1, J = 2 \rightarrow 1$) SiO maser line is a good handle to measure stellar line-of-sight velocities, complementing previous OH surveys. Mira stars also have the advantage to be more numerous than OH/IR stars.

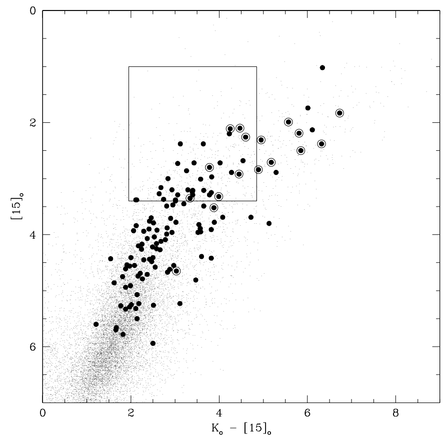

Figure 1 $[15]_o$ versus (K_o − $[15]_o$) ISOGAL-DENIS colour-magnitude diagram (extinction corrected). LPV stars from Glass et al., 2001 are shown as big dots of which the encircled ones mark known OH/IR stars. For comparison, the small dots indicate all the ISOGAL sources within 5 degrees from the Galactic centre. The box defines the region of our sample.

The late-type stars to be searched for maser emission were selected from the combined ISOGAL-DENIS catalogue (Omont et al., 1999) and from the MSX catalogue (Egan et al., 1999) on the basis of colour and

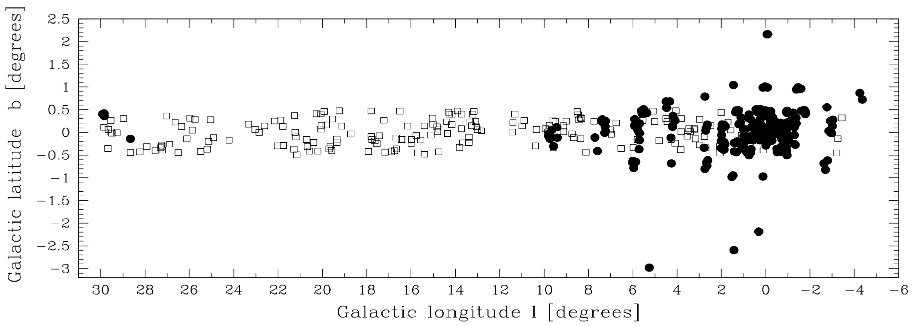

Figure 2. Location of the observed sources, irrespective of detection and non-detections, in Galactic coordinates. The MSX sources are shown as open squares and the ISOGAL sources as filled circles.

magnitude. Analyzing the location of the LPV stars of Glass et al., 2001 in the different ISOGAL-DENIS colour-magnitude diagrams, we found that in the $(K_o - [15]_o)$ versus $[15]_o$ colour-magnitude diagram the LPVs without OH masers separate well from the OH/IR stars (Fig. 1). The OH/IR stars, having 10^2 to 10^3 times higher mass-loss rates than Mira stars, are the brightest objects at 15 μm and have $(K_o - [15]_o)$ colour redder than 4 mag. Therefore, we selected sources from the ISOGAL catalogue by their $[15]_o$ magnitude, and their $(K_o-[15]_o)$ and $([7]_o-[15]_o)$ colours, in a transition region between Mira and OH/IR stars (see Fig. 1). We excluded the brightest and bluest sources, which are most likely foreground stars, and the reddest sources, which likely are either high mass-loss OH/IR stars or young stellar objects. We further excluded sources with $[15]_o > 3.4$, since they are –given the general correlation of SiO maser emission and IR luminosity (Bujarrabal et al., 1987)– likely to show SiO maser emission fainter than our detection limit of 0.2 Jy. For the MSX sources similar selection criteria were applied, and in addition variability information was taken into account.

To avoid duplicating the OH maser line-of-sight measurements, all known OH maser sources were excluded. The search was limited to the Galactic plane between $l = -4°$ and $l = +30°$ and $|b| < 1°$ (Fig. 2); the lower limit in longitude is imposed by the northern latitude of the IRAM 30-m telescope.

2. Results

We observed 441 positions, and detected SiO $(v = 1, J = 2 \rightarrow 1)$ maser lines towards 268 of them, a detection rate of 61%. Because many of these stars we expect to be variable, this detection rate is a lower limit to the actual percentage of 86 GHz SiO maser emitters.

The SiO maser detection rate slightly increases with the mIR flux density at 7 and 15 μm. The detection rate is 71 % for the bright mIR sources at magnitude [15] $\sim$ 1.8 ($\sim$ 3.8 Jy), and decreases to 53 % for the fainter mIR sources, with [15] $\sim$ 3.2 ($\sim$ 1 Jy).

We observed 15 LPVs found by Glass et al., 2001 and detected SiO maser emission from 11 of them (73 %). The fraction of OH-emitting LPVs passing our colour-magnitude selection is much smaller (23 %).

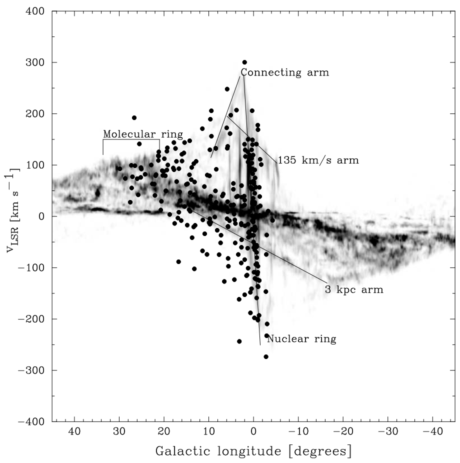

Figure 3 Stellar (l, v) diagram overlayed on the grayscale CO (l, v) diagram from Dame et al., 2001. The SiO 86 GHz masers are shown as dots. Gas features are labelled as in Fig. 1 of Fux, 1999.

The line-of-sight velocities of the 86 GHz SiO maser sources range from -274 to 300 $\mathrm{km\,s^{-1}}$, consistent with previous stellar maser measurements and with the ^{12}CO gas velocities (Fig. 3). An appreciable number of SiO maser sources are far from the CO emission, at negative velocities between $20^\circ > l > 0^\circ$, a range forbidden for pure circular rotation. At longitude 0° the stellar distribution follows the high velocity gas component of the **nuclear disk**; similar results are found by Imai (this volume).

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