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Detection of 6 new 107 GHz methanol masers

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1. Introduction

Like water masers, methanol masers occur in regions of massive star formation. But unlike water masers, they seem to be exclusively associated with massive young stellar objects (MYSO). More importantly, recent high resolution spatial distribution studies of 6.7 GHz methanol masers by Norris et al. (1993) suggest that unlike H_2O masers which are spherically distributed around the MYSO, methanol masers may occur in the disks around them. If this is true it will become an important tool to study disk dynamics and lead to more reliable estimation of central masses. Since the high-resolution studies have been done only on a handful of sources, we undertook a statistical study of the deviation of methanol maser velocities from that of the dense core (and presumably the disk-YSO system), traced by CS $2 \rightarrow 1$ and compared it with a similar distribution derived from velocities of water masers. In addition, we also undertook a systematic survey for the first time of 33 southern massive YSOs with a view to detect the methanol transition at 107 GHz. The basic motivations for this search were : a) If methanol masers are located in the disks, different transitions with different energies are likely to be excited at different radii along the disk. Therefore, a systematic study of their position and velocity can enable us to understand the disk kinematics. b) The inner galaxy has higher incidence of methanol masers compared to the outer galaxy. The galactic metalicity gradient has been invoked as its cause. However, there is a more natural explanation : there is more incidence of massive star formation in the inner galaxy than in the outer. Moreover, since the 6.7 GHz methanol maser is mostly saturated, it is less sensitive to metalicity effects. But, mm-wave transitions are unlikely to be saturated and hence can serve to be a good probe of metalicity effects. c) The southern galaxy seems to be undergoing a burst of star formation; not only there is more number of MYSO in the south, but most of the luminous ones are also found there. But, no mm-wave methanol survey had been conducted in the southern galaxy (the only one survey had been limited to the northern half).

2. Analysis, observations and results

Top two panels of Fig 1 shows the distributions of deviations of water and methanol maser velocities from those of the cores given by the CS spectra. Clearly the distributions are very similar with FWHM of 8 km/s. Since the water masers are known to be isotropically distributed, this would suggest the same for methanol masers too, except for the fortuitous situation wherein the keplerian velocities at the locations of methanol masers also happen to be 4 to 8 km/s. If this were the case, given the masses of the YSO $\gtrsim 10\ M_{\odot}$, this would constrain their locations to be in the range of 3-10 milli-pc.

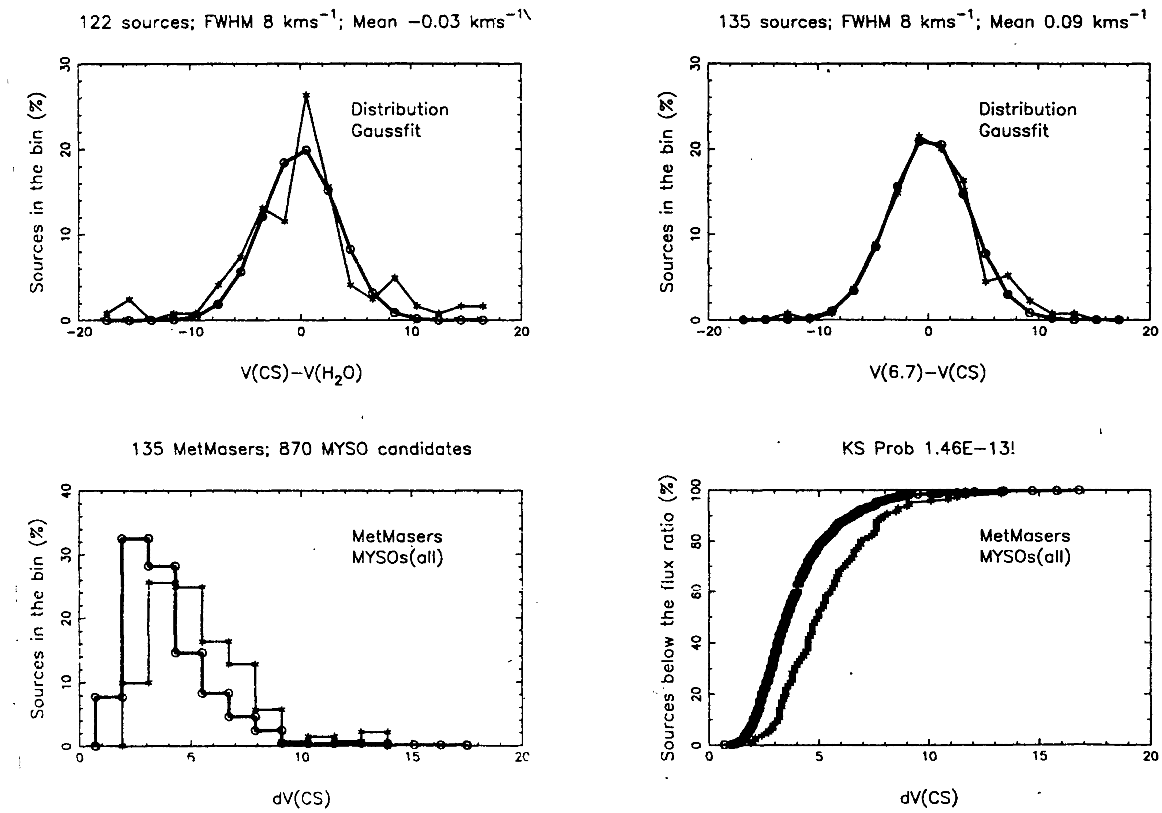

Figure 1.

The bottom two panels of Fig 1 show the distribution of CS line-widths (both density and cumulative distributions) for sources with and without methanol masers. Clearly, the two populations have distinct distributions with the sources with methanol masers having systematically larger line widths. This supports the idea that such sources have outflows and the methanol masers may be shock excited at the interface between the disk and the outflowing gas.

We used the 22m Mopra antenna to survey 33 MYSOS for 107GHz methanol masers and detected 6 new ones, for the first time in the southern galaxy. The properties of these sources have been tabulated at the end and the Fig 2 shows the 6 spectra along with gaussian fits. Fig 3 shows the time-variability in the case of IRAS05327-0526 and two undetected lines in IRAS05327-0524.

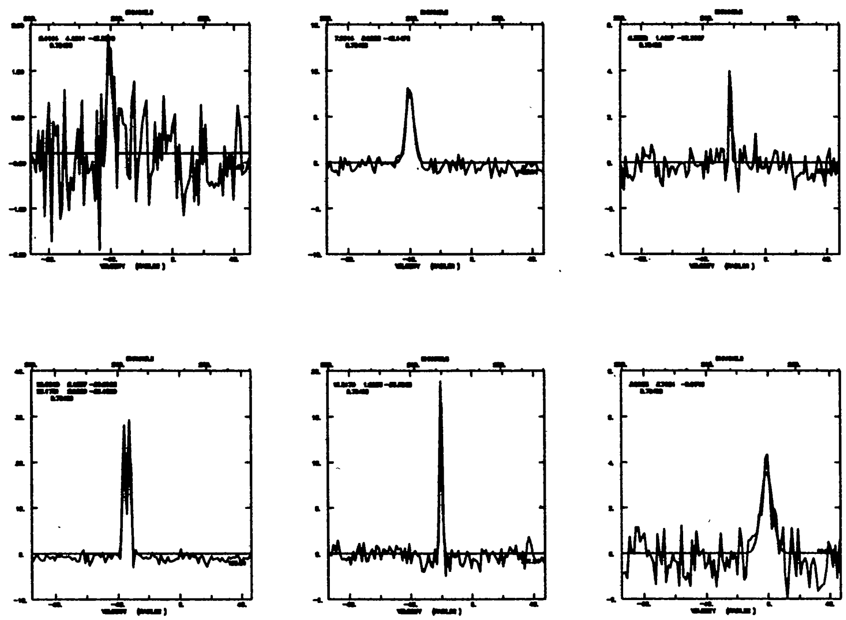

Figure 2.

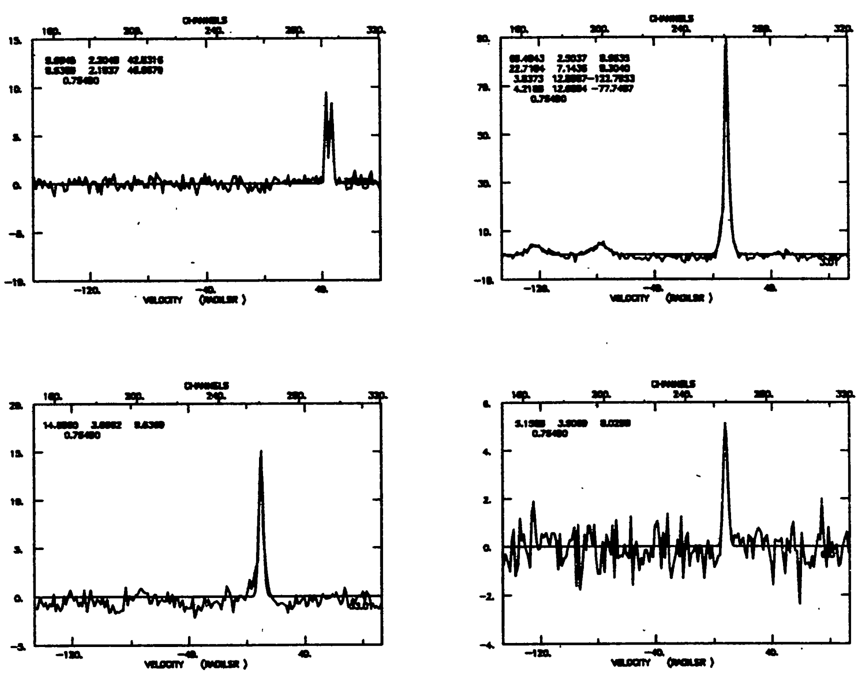

Figure 3.

Conclusions

1. The similarity in the distribution of velocity offsets of methanol and water masers with respect to the carbon-monosulphide line that traces the dense, embedding cores suggests that the methanol too may be distributed spherically like water, rather than in the disk. Even if it is distributed in the disk, its keplerian distance has to be in the range 3 to 10 milli-pc from the central object.

2. Sources that have methanol masers have systematically larger CS line-width relative to those without. This suggests them to have outflow activity. Since methanol masers are presumably shock-excited, they may originate at the disk-stellar-wind interface at the base of the outflows.

3. In searching for further ways to confirm and exploit the disk origin of the methanol masers, we have discovered 6 new mm-wave methanol masers in our search towards 33 southern star-forming regions. This has doubled the known mm-wave methanol masers and will permit them to be studied as a special group.

4. Line-strengths of the mm-wave methanol masers do not correlate strictly with the strengths of 6.7 GHz masers. One of the sources shows large time-variability in line strength (IRAS05327-0526; Fig 3). We have also discovered 2 additional broad lines, from an unknown species, in IRAS05327-0524.

Properties of newly discovered mm-wave methanol sources

IRAS NAME	S_{12}	S_{25}	S_{60}	S_{100}	$S_{6.7}$	$V_{6.7}$	S_{107}	V_{107}	V_{CS}	T_{CS}	dV
13079-6218	28.3	249.7	3167	8164	400	-37.0	2.4	-40.8	-41.0	4.7	7.5
15520-5234	16.0	538.0	10780	16380	363	-44.0	8.0	-40.1	-42.3	7.4	5.5
16019-4903	1.5	65.0	401	431	109	-24.0	4.0	-22.4			
13079-6218	28.3	249.7	3167	8164	400	-37.0	2.4	-40.8	-41.0	4.7	7.5
15520-5234	16.0	538.0	10780	16380	363	-44.0	8.0	-40.1	-42.3	7.4	5.5
16019-4903	1.5	65.0	401	431	109	-24.0	4.0	-22.4			
16484-4603	9.9	192.0	3444	5347	1460	-35.0	29.0	-38.1	-43.4	2.5	4.5
							29.2	-32.5			
16533-4009	26.4	471.3	7136	13290	544	-17.5	19.2	-20.3			
17233-3606	4.5	228.8	8787	20400	246	1.5	3.6	-1.0	-3.4	7.8	7.1