Astrophysical Masers:
Unlocking the Mysteries of the Universe
Proceedings IAU Symposium No. 336, 2017
A. Tarchi, M.J. Reid & P. Castangia, eds.

doi:10.1017/S1743921318000376

Probing Early Phases of High Mass Stars with 6.7 GHz Methanol Masers

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Abstract. Methanol masers at 6.7 GHz are the brightest of class II methanol masers and have been found exclusively towards massive star forming regions. These masers can thus be used as a unique tool to probe the early phases of massive star formation. We present here the SED studies of 284 methanol masers chosen from the MMB catalogue, which falls in the Hi-GAL range ($|l| \leqslant 60°$, $|b| \leqslant 1°$). The masers are studied using the ATLASGAL, MIPSGAL and Hi-GAL data at wavelengths ranging from 24−870 micrometers. A single grey body component fit was used to model the cold dust emission whereas the emission from the warm dust is modelled by a black body. The clump properties such as isothermal mass, FIR luminosity and MIR luminosity were obtained using the best fit parameters of the SED fits. We discuss the physical properties of the sources and explore the evolutionary stages of the sources having 6.7 GHz maser emission in the timeline of high mass star formation.

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1. Introduction

The 6.7 GHz methanol maser transition is the brightest of class II methanol masers. They have been observed only from high mass star forming regions and have been found to be associated with rapidly accreting massive stars (e.g. Pandian *et al.* 2010). To get a better understanding about the association between high-mass star formation and 6.7 GHz methanol masers, we have determined the SEDs of 284 sources hosting 6.7 GHz methanol masers.

2. Methodology

Our methanol maser sample has been selected from the MMB survey (Green *et al.*2011). We restricted our sample to sources which have been surveyed by Hi-GAL ($|l| \leqslant 60°$ and $|b| \leqslant 1°$) and which have distances available. After eliminating sources that are saturated in Hi-GAL data, extremely crowded fields, and sources with significant uncertainity in their distance (errors $\gtrsim$ 10 kpc), we were left with 284 sources. We have constructed SEDs to these sources from 870 μm to 24 μm using ATLASGAL, Hi-GAL and MIPSGAL surveys. We extracted the fluxes from ATLASGAL and Hi-GAL images using the Hyper package (Traficante *et al.* 2015). Fluxes were extracted at all wavelengths using the same aperture. A single grey body fit was used to model the cold dust emission of SED whereas the warm dust emission was modelled by a black body.

3. Results

The properties of the clumps hosting methanol masers were determined from the SED parameters. The clump mass ranges from 8330 $M_\odot$ to 6 $M_\odot$ with a mean value of approximately 400 $M_\odot$. About 97% of our sources satisfies the criteria $M(r) \geqslant 580 M_\odot \left(\frac{R_{eff}}{pc}\right)^{1.33}$ (Kauffman *et al.* 2010) and can host atleast one massive star. The surface densities range

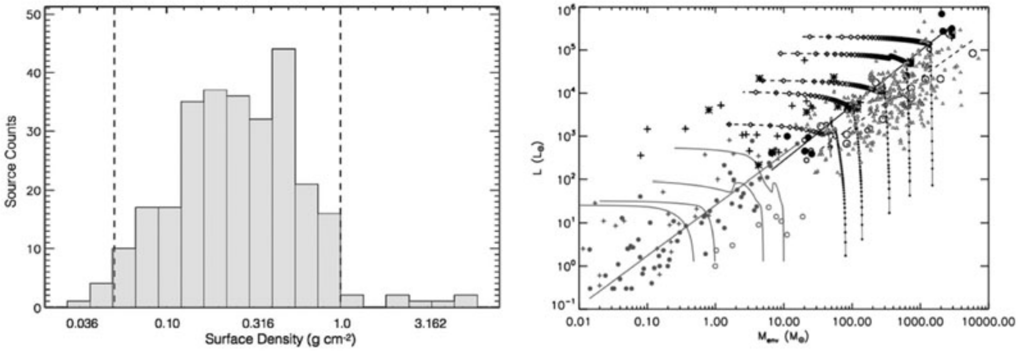

Figure 1. The left panel shows the distribution of surface density of the sources. The two vertical dashed lines are at $\Sigma = 1.0$ and 0.05 g cm^{-2} respectively. The right panel shows the L-M plot with the maser sources being shown as grey triangles.

from 0.03 to 4.8 g cm^{-2} with a mean value of 0.3 g cm^{-2}. Studies by Urquhart *et al.* (2013), show that massive clumps with $\Sigma \gtrapprox 0.05$ g cm^{-2} can form high mass stars. The surface density of 98% of our sources exceeds this threshold. The far infrared (FIR) luminosities range from $10^2 - 10^5$ L$_\odot$ with an average value of 10^3 L$_\odot$. Almost 97% of our sources have luminosities greater than 10^3 L$_\odot$, and are hence likely to host at least one massive star (Walsh *et al.* 2003). The FIR luminosity ($L_{\rm FIR}$) is found to have a weak correlation with the methanol maser luminosity ($L_{\rm mmb}$). A partial-Spearman correlation test was done to remove the dependency of parameters on distance and it yielded a value of 0.52 for $L_{\rm mmb}$-$L_{\rm FIR}$.

We plotted the source luminosity as a function of clump mass (right panel of Fig. 1) to investigate the evolutionary stage of the maser hosts. Also shown in the plot are loci of evolutionary tracks of sources based on the turbulent core model (Molinari *et al.* 2008). In the high mass regime (solid black line in the L-M diagram), the clumps in the lower right region are in early stages of evolution with rapid accretion, whereas those in the upper left are in the envelope clearing phase. According to this model all the sources in our sample lie in the high mass regime with 84% being in the accreting phase and the remaining 16% in the envelope clearing phase. This indicates that majority of our methanol maser sources are in early evolutionary stages, in agreement with that found by Pandian *et al.* (2010).

4. Conclusion

We have constructed SEDs from submillimeter to mid-infrared wavelengths for 284 6.7 GHz methanol masers. The SEDs were fit with grey body models with the dust temperature ranging from 13−35 K. The L-M diagram indicates that the methanol maser sources are at early evolutionary stages with majority of them being in the accretion phase.

References

Green, J. A., & McClure-Griffiths, N. M. 2011, *MNRAS*, 417, 2500
Kauffmann J., Pillai T., Shetty R., Myers P. C., & Goodman A. A. 2010, *ApJ*, 716, 433
Molinari, S., Pezzuto, S., Cesaroni, R., Brand, J., Faustini, F., & Testi, L. 2008, *A&A*, 481, 345
Pandian, J. D., Momjian, E., Xu, Y., Menten, K. M., & Goldsmith, P. F. 2010, *A&A*, 522, A8
Traficante, A., Fuller, G. A., Pineda, J. E., & Pezzuto, S. 2015, *A&A*, 574, A119
Urquhart J. S., Moore T. J. T., & Schuller F. 2013, *MNRAS*, 431, 1752
Walsh A. J., Macdonald G. H., Alvey N. D. S., Burton M. G., & Lee J. K. 2003, *A&A*, 410, 597

https://doi.org/10.1017/S1743921318000376 Published online by Cambridge University Press