Cosmic MASERs: From Protostars to Blackholes
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Multi-epoch water maser survey towards low-mass YSOs

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Abstract. We present the results from a series of multi-epoch 22 GHz H_2O maser surveys with the Nobeyama 45 m telescope and the VLA towards low-mass young stellar objects, including all the class 0 sources in the northern sky. Our Nobeyama 45 m survey is the deepest survey – down to an isotopic H_2O luminosity of $\sim 10^{-13} L_\odot$ – performed so far. From this survey, we obtained the following results. (1) Class 0 sources show high H_2O maser activity: our derived detection rates are $\sim$ 38% for class 0, but only $\sim$ 4% for class I sources. (2) Activity of the H_2O masers is more likely related to 100 AU scale ionized jets than to large scale molecular outflows.

1. Introduction

A significant fraction of embedded low-mass young stellar objects (YSOs) are known to exhibit H_2O maser emissions at 22 GHz. Recent maser surveys toward such YSOs have revealed that the H_2O isotropic maser luminosity, L_{H_2O}, correlates well with the source bolometric luminosity, L_{bol} (Wilking et al. 1994). Moreover, the presence of the maser emission is related to that of high-velocity outflowing gas (Felli, Palagi & Tofani 1992), and that of radio continuum emission from ionized gas (Claussen et al. 1996; Meehan et al. 1998). In such YSOs,

the masers appear to be concentrated within several hundred AU of the central stars (Wootten 1989; Chernin 1995; Furuya et al. 1999). Although some H_2O masers seem to be associated with protostellar disks (Fiebig et al. 1996), high resolution VLBI observations have demonstrated that in most cases the masers originate in shocks produced by jets from the protostars (Claussen et al. 1998; Patel et al. 2000; Furuya et al. 2000).

Previous surveys have neglected most of the deeply embedded YSOs: such objects have spectral energy distributions (SEDs) peaking at submillimeter wavelength and are called class 0 sources (Andrè, Ward-Thompson & Barsony 1993). These sources have been proposed as the youngest protostars in a generally accepted evolutionary scheme based on the observed SEDs. At present, 38 low-mass class 0 sources are identified in the northern sky. Class 0 sources are surrounded by a large amount of circumstellar material, and are thought to be accompanied by accretion and gravitational contraction, both of which are believed to contribute significantly to the luminosities of YSOs. They also have powerful collimated bipolar molecular outflows (Bachiller 1996). In contrast, the amount of circumstellar material around class I sources is small, and their molecular outflows are poorly collimated and much less powerful (Moriaty-Scheiven et al. 1994; Bontemps et al. 1996). Consequently, class 0 sources are considered to be the best targets to investigate the masers

2. Observations

In the series of our H_2O maser surveys, we observed totally 260 YSOs including all the class 0 sources detected in the northen sky. Single-dish observations were conducted from May 1996 till March 1999 using the 45 m telescope ($\theta_{\rm HPBW} = 75''$) of the Nobeyama Radio Observatory[1]. The typical sensitivity with a 5-minute integration is 0.1 K in T_A^* (corresponding to 0.12 K in $T_{\rm mb}$ for $\eta_{\rm mb}$ of 0.82, and 0.68 Jy for $\eta_{\rm a}$ of 0.64) with a velocity resolution of 0.5 km s^{-1}. The spectra were obtained using the eight 40 MHz bandwidth accousto-optical apectrometers: the total velocity coverage was 2560 km s^{-1}. We stress that this is the most sensitive maser survey ever conducted. The follow-up VLA obsrevations were performed in 3 epochs from October 1998 till Feburary 2000 using BnC and CnD configurations.

3. Results

Our major results are as follows. (1) Seventeen of thirty-five low-mass class 0 sources ($\delta > -30°$), while only 3 class I sources (GSS30-IRS, YLW 16, and T Tau South) showed the maser emission. (2) The emission was newly detected in B1-IRS, NGC 2024-FIR5, IRAS 05375+0731, Serpens-SMM4, GF 9-2, IRAS 22198+6336, IRAS 22266+6845, and L1204A. (3) We detected extremely high velocity components towards IRAS 20050+2720 (-92 km s^{-1}) and Cep E (-61

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and -38 km s^{-1}) (4) Three class 0 sources (L1448-IRS2, L1448C, and Serpens 68N) previously detcted above our detection limit were not active during our observations. (5) The lowest luminosity source ($L_{\rm bol} \sim 0.3 L_{\odot}$) which showed the masers is GF 9-2.

In order to calculate the detection rates of the masers, we selected class 0, I, and II sources which are nearby (d <440 pc), low-mass ($L_{\rm bol} < 100 L_{\odot}$), and have well-defined bolometric temperatures. All of the class 0 and class I sources were observed with time intervals of less than four months except the periods of the annual shutdown of the telescope (from July till late November in each year). Table 1 shows our derived detection rates of the masers.

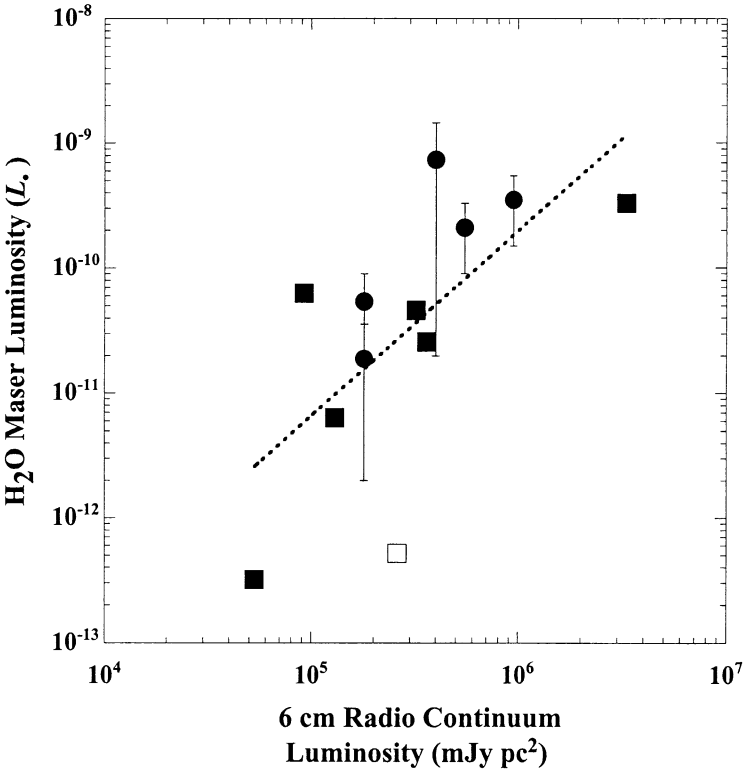

Figure 1. Plot of observed isotropic H_2O maser luminosities (L_{H_2O}) vs. 6 cm radio continuum luminosities ($4\pi d^2 S_{6\rm cm}$). The circles indicate the H_2O masers detected at all the observing epochs: the associated bars indicate the range of the luminosities in our observations. The squares represent the maximum value of the maser luminosities for the sources that have not been detected at one or more epochs. Filled and open symbols indicate class 0 and class I sources, respectively. The best-fit curve of $L_{H_2O} = 2.74 \times 10^{-19} (4\pi d^2 S_{6\rm cm})^{1.48}$ is also shown by a dotted line.

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SED Class	Number of sources	Detection rate (%)
Class 0	28	37.9
Class I	32	4.2
Class II	6	0.0

Table 1. Detection Rates of H_2O Masers. Obviously class 0 sources seem to be favorable sites to excite the H_2O maser emission: the detection rates are $\sim$ 38% for class 0 sources and only $\sim$ 4% for class I.

Felli et al.(1992) reported that L_{H_2O} correlates well with the mechanical luminosity of CO outflows (L_{CO}) in the sample which consists mainly of high-mass stars. However we found that this correlation does not hold for $L_{H_2O} \lesssim 10^{-9} L_\odot$. On the other hand, we found that, even down to $\sim 10^{-13} L_\odot$, L_{H_2O} correlates with the radio continuum luminosity defined as $4\pi d^2 S_{6cm}$ as it can be clearly seen in figure 1. Here, S_{6cm} is the 6 cm continuum flux measured with the VLA and d is the source distance. These results suggest that the H_2O masers in low-mass YSOs are more likely related to the small scale thermally ionized jets than to the large scale moleular outflows.

References

Andrè, P., Ward-Thompson, D., & Barsony, M. 1993, ApJ, 406, 122
Bachiller, R. 1996, ARA&A, 34, 111
Bontemps, S. et al. 1996, A&A, 311, 858
Chernin, L. M. 1995, ApJ, 440, L97
Claussen, M. J. et al. 1996, ApJS, 106, 111
Claussen, M. J. et al. 1998, ApJ, 507, L79
Felli, M., Palagi, F., & Tofani, G. 1992, A&A, 252, 293
Fiebig, D. et al. 1996, A&A, 310, 199
Furuya, R. S. et al. 1999, ApJ, 525, 821
Furuya, R. S. et al. 2000, ApJ, 542, L135
Meehan, L. S. G. et al. 1998, AJ, 115, 1599
Moriarty-Schieven, G. H. et al. 1992, ApJ, 400, 260
Patel, N. et al. 2000, ApJ, 538, 268
Richer, J. S. et al. 1993, MNRAS, 262, 839
Wilking, B. A. et al. 1994, ApJ, 431, L119
Wootten, A. 1989, ApJ, 337, 858

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