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A Search for High-velocity Gas Associated H_2O Masers and Ultracompact HII Regions

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Abstract With the objective of studying the relationships between high-velocity gas and water maser emissions the results of a search from 95 IRAS sources for high-velocity gas associated with star forming molecular clouds are reported. 21 sources have been identified as molecular outflow candidates.

Key words: HII regions – ISM: jets and outflows – stars: formation – masers

1 INTRODUCTION

A violent molecular outflow is a basic component of star formation process. Such outflows are observed over a wide range of wavelength from the ultraviolet to the radio, resulting from the interaction of highly supersonic stellar winds with the ambient material and the wind ejection takes place in the vicinity of a newly formed star. Outflows are produced by stars of all masses, but current outflow theories are predominantly based on observations of nearby, low-mass outflow systems. This is partly because low-mass young stellar objects (YSOs) are far more abundant than high-mass ones and formation of massive stars occurs in distant ($> 1\,\mathrm{kpc}$), dense stellar clusters. So the identification of the driving source is rather difficult.

Shepherd & Churchwell (1996) surveyed high velocity gas (HVG) in 122 massive star formation regions and found that 90% of their sample are associated with HVG (full width greater than $15\,\mathrm{km\ s^{-1}}$), which are generally substantially higher than for low mass outflow sources.

Based on the far-infrared spectra of known ultra-compact HII regions, Wood & Churchwell (1989) established a two-color criterion that characterizes these objects, $\log(F_{25}/F_{12}) > 0.57$ and $\log(F_{60}/F_{12}) > 1.30$.

With the aim of studying the relationship between H_2O masers and CO HVG, we chose a sample of H_2O masers for high-velocity molecular emission observation from the catalogues of

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Comoretto et al. (1990), Brand et al. (1994), Palumbo et al. (1994), Codella et al. (1995), and Han et al. (1998). All of our sources are already IRAS sources. Our selection criteria were the following: (1) $\delta \geq -10$; (2) Spectrum increasing from 12 to 100μm; (3) Colors: $\log(F_{25}/F_{12}) > 0.57$ and $\log(F_{60}/F_{12}) > 1.30$.

2 OBSERVATIONS

The observations of the $J = 1 - 0$ transition of ^{12}CO were made with the 13.7 m telescope at the Qinghai Station of Purple Mountain Observatory, United Radio Astronomy Laboratory of Chinese Academy of Sciences, from 2000 March 1 through March 31. This antenna is located in the Gobi desert, a very dry and arid region at 3200 m above sea level in western China. The beam size at frequency 115 GHz is $54''$. The pointing and tracing accuracy is better than $10''$. A cooled super-conducting mixer and a FET IF-1 were employed. Its double-side band system temperature is less than 250 K. The acoustic-optical spectrometer provides 1024 channels for a total band widths of 170 MHz. The frequency resolution is 255 kHz. The antenna efficiency is $55\% - 65\%$ depending on the elevation. The Observations were made in position-switching mode. The integration time is 4 minutes. The RMS is ~ 0.20 K and the absolute calibration for flux density was about 20%.

3 RESULTS AND DISCUSSION

CO emission was detected towards 95 H_2O maser sources and the observational data of the new outflow candidates detected are tabulated in Table 1. The first three columns give the IRAS source name and their 1950 equatorial coordinates. Column 4 gives the antenna temperature T_a^*. Columns 5 and 6 list the $V_{\rm LSR}$ and the peak velocity of the H_2O maser emission $V_{\rm H_2O}$. Columns 7 to 8 are the measured half-power widths (FWHM) estimated from a Gaussian fit to the line core, and the measured full width (FW) of the ^{12}CO ($J = 1 - 0$) line at $T_a^* = 200$ mK.

Table 1 Main Parameters of the Newly Detected Outflow Candidates

IRAS Name	R.A. (1950) (h m s)	Dec (1950) (° ′ ″)	T_a^* (K)	$V_{\rm LSR}$ (km s^{-1})	$V_{\rm H_2O}$ (km s^{-1})	FWHM (km s^{-1})	FW (km s^{-1})
03414+3200	03 41 28.0	32 00 00	13.8	8.2	21.8	2.2	11.3
06006+3015	06 00 41.4	30 15 04	8.1	–8.1	–35.1	5.7	19.1
06046–0603	06 04 42.2	–06 03 28	6.4	11.2	···	3.8	11.3
18265+0028	18 26 32.6	00 28 35	3.5	6.0	5.3	6.1	17.4
18316–0602	18 31 39.0	–06 02 07	5.1	40.1	45.2	9.9	38.3
18421–0404	18 42 10.1	–04 04 38	6.7	89.7	63.1	6.5	26.1
19213+1732	19 21 22.9	17 23 06	5.2	67.3	–26.8	3.7	8.7
19216+1658	19 21 37.7	16 58 06	2.9	1.5	···	6.4	11.3
19227+1721	19 22 45.8	17 21 34	6.7	3.5	···	5.6	16.5
19325+1925	19 32 33.8	19 25 03	4.1	39.1	–11.0	7.1	15.7
19410+2336	19 41 04.2	23 36 54	12.5	21.9	26.4	5.9	24.4
19411+2306	19 41 10.1	23 06 47	11.1	28.1	···	4.8	20.0
19474+2637	19 47 28.7	26 37 37	8.5	18.3	20.5	2.1	7.8
20051+3435	20 05 09.4	34 35 50	5.6	10.6	···	5.3	13.1
20081+3122	20 08 09.9	31 22 42	6.2	11.1	15.1	6.4	13.9
20160+3636	20 16 03.5	36 36 09	3.8	0.8	···	4.9	15.7
20215+3725	20 21 35.6	37 25 15	4.3	–2.2	5.5	4.8	11.3
20243+3853	20 24 20.6	38 53 36	4.4	7.6	···	3.4	14.8
20306+3749	20 30 41.8	37 49 19	3.5	–4.5	···	4.6	13.1
20350+4126	20 35 04.8	41 26 02	6.8	–3.4	23.1	6.0	22.6
22142+5206	22 14 14.5	52 06 33	4.5	–37.5	–20.5	3.1	10.0

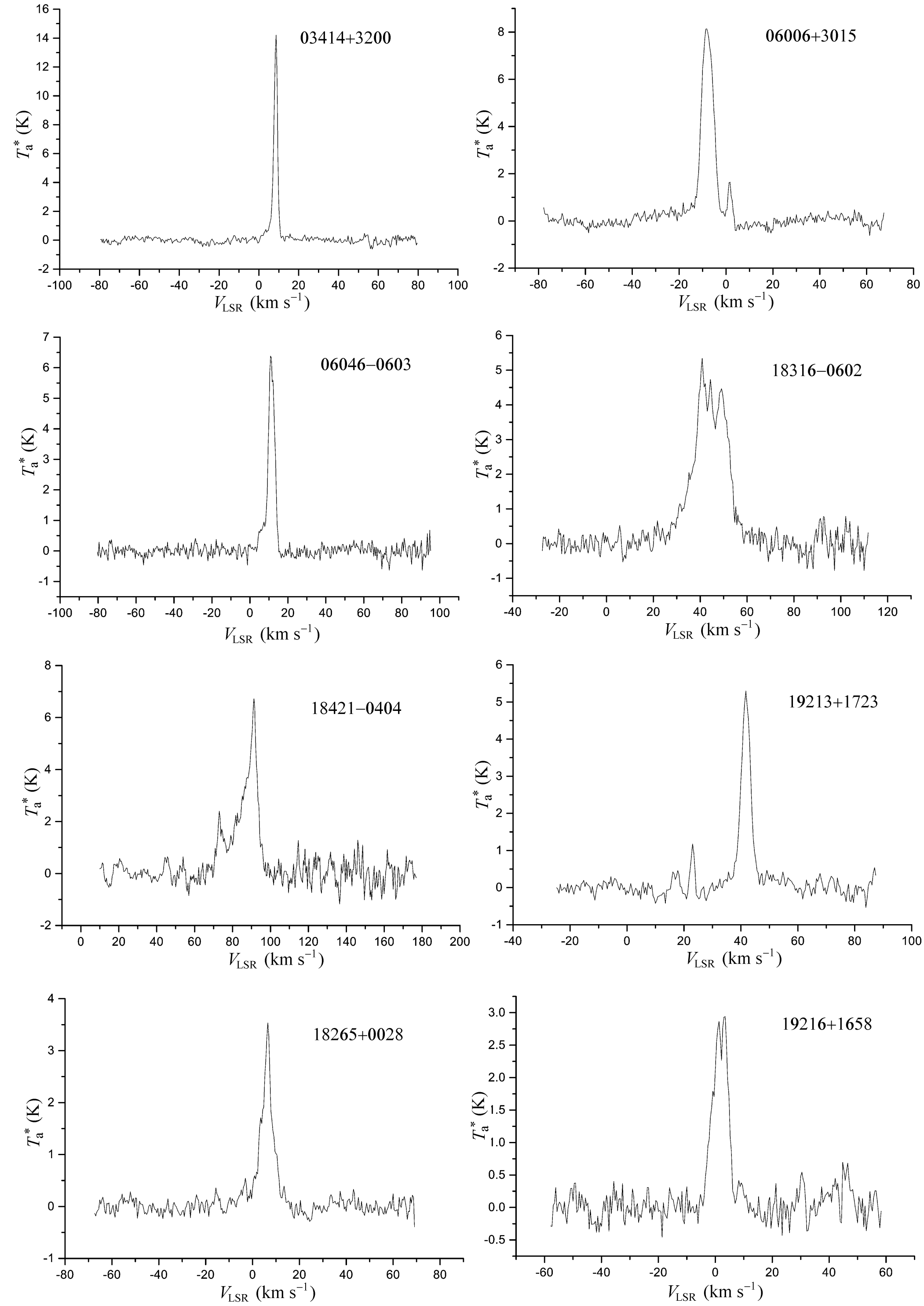

Fig. 1 ^{12}CO ($J = 1 - 0$) Profile of the new outflow candidates

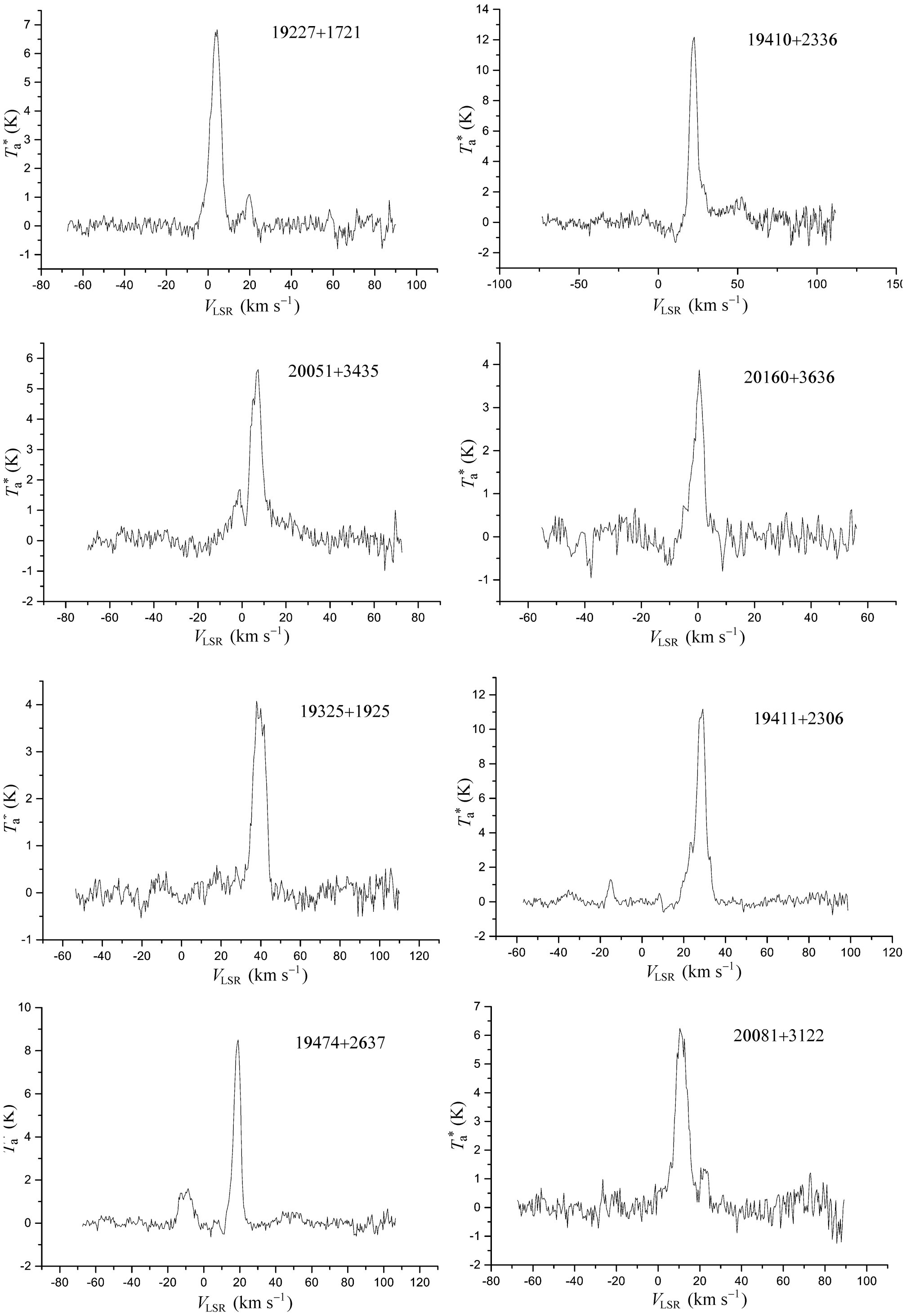

Fig. 1 (Continued)

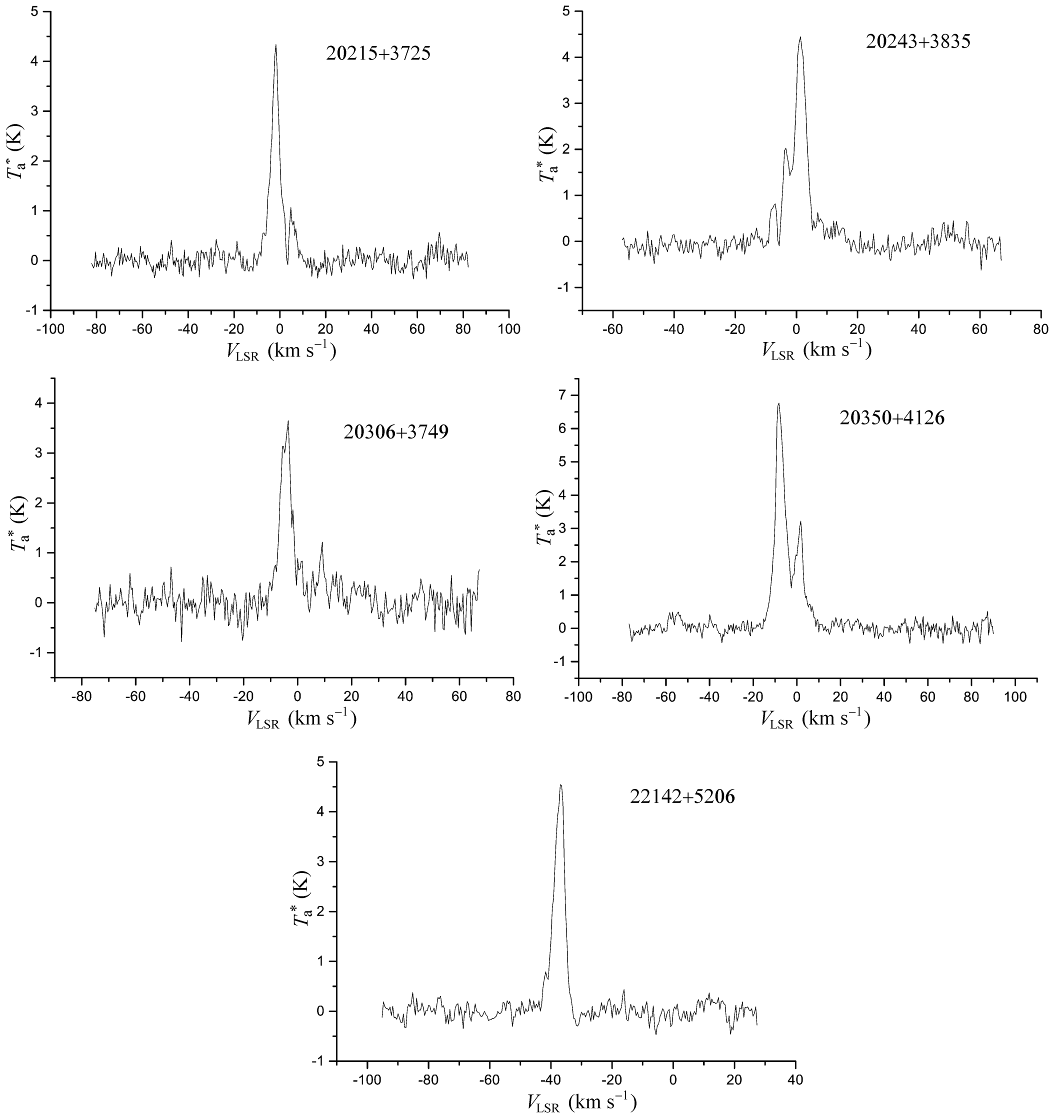

Fig. 1 (Continued)

The CO spectra in most of our sources show broad line wings. Almost 45% of the sources have FWs greater than 15 km s^{-1}. We regard a source as an outflow candidate if it satisfies the following criteria: (1) FW is larger than the full width obtained from a Gaussian fit to the line core, (2) FW is in general greater than 15 km s^{-1}, and (3) it has high velocity wings. We found that 21 of our sample satisfied the criteria; these are shown in Fig. 1. Seven of them have been mapped and the results show that the excess high velocity emission is indeed produced by outflows.

By comparing the H_2O and CO velocities given in Table 1 one can see that in most cases the peak velocity of the H_2O maser emission is close to that of the CO emission. This suggests that the masers are associated with the CO molecular cloud. We also found that some H_2O

masers have a large velocity difference relative to the CO molecular clouds ($> 30\,\mathrm{km\ s^{-1}}$). First, this suggests that the H_2O masers may stem from independent directions because masers can in principle occur in either outflows or disks (Greenhill et al., 1998), and the velocity of masers from outflows or disks can be very different. If a maser occurs in a disk, its average velocity should be close to that of the ambient gas and masers occur ring in outflows can acquire larger velocities (relative to the CO peak) from being accelerated. In addition, the masers may stem from outflow in different directions. Observations show that H_2O maser velocities can increase from about 20 to $200\,\mathrm{km\ s^{-1}}$ in the outflow (Gwinn, et al., 1992, Gwinn, 1994). When a stellar wind strikes some denser material low velocity features may be produced; higher velocity features can be produced when it strikes a relatively less dense ambient material. As a result, both low or high velocity maser features may appear. Again, infalling protostellar envelopes or expanding compact HII regions may also shock dense gas and produce maser emission (Leppänen, et al., 1998, Furuya et al., 1999). Finally, the masers may originate in clump-clump collisions. If collisions take place among clumps at sufficient relative velocities, the powerful energy can excite H_2O maser emission (Tarter & Welch, 1986). For masers caused by different mechanisms as mentioned above their velocities can be very different. Thus, although the masers are associated with the same CO cloud, a large velocity dispersion can exist among them.

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