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New detections of H_2O maser sources on the 13.7 m radio telescope of Purple Mountain Observatory*

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Abstract. Observations of H_2O maser sources on the 13.7 m radio telescope of Purple Mountain Observatory from 1990 Aug. to 1994 Jan. are summarized. For searching new water masers, the total number of search candidates is about 360, with 110 objects detected. Among them are 96 new detections. A list of the new detections and their spectra are presented.

Key words: masers — radio lines: general; ISM; stars

1. Introduction

Masers are often detected from star formation regions and evolved stars. In addition to providing a good laboratory for study of maser processes, the intense maser emissions have been used as probes of the structures, dynamics and physical conditions of their surroundings. Among various galactic masers from different masing species and transitions, the 22 GHz H_2O maser emission (the rotational transition between $6_{16} - 5_{23}$ levels) is most spectacular, with its high intensity, great variability and wide velocity range.

Since the first detection of the line (Cheung et al. 1969), much observational and theoretical work has been done, as documented by many excellent review papers (e.g. Reid & Moran 1981; Cohen 1989; Elitzur 1992; Anderson & Genzel 1993; Bowers 1993), and the present number of known galactic H_2O maser sources has been increased to more than seven hundred in the northern sky. The most comprehensive catalog of H_2O maser sources north of −30 deg was compiled by the Arcetri group (Comoretto et al. 1990 and Brand et al. 1993).

Since the 22 GHz system of the 13.7 m telescope of Purple Mountain Observatory was put into operation in 1990, systematic observations of H_2O maser sources have been taken on the telescope. In addition to some monitoring programs, most of the observing time was spent on surveys towards CO outflows, compact HII regions, late-type stars and bright IRAS sources (e.g. Sun et al. 1995; Wu et al. 1995).

In several observing runs from August 1990 to January 1994, the total number of candidates for new water masers was about 360, with 110 objects detected. Among them 96 are new detections.

2. Observations

All observations were made with the 13.7 m telescope of Qinghai Station, Purple Mountain Observatory, located at Delingha, Qinghai Province, West China (37°22′4N, 3200 m above sea level).

The antenna of the telescope is a radome-enclosed classic Cassegrain type. The surface accuracy of the main dish is 0.2 mm. At the water maser frequency (22.23508 GHz was used for the rest frequency of the line), the HPBW of the telescope is 4.′2, the antenna aperture efficiency measured by continuum observations of the planet Venus is 0.48, including the absorption of the radome, equivalent to a flux temperature ratio of 38 Jy K^{-1}. The pointing accuracy of the telescope calibrated and checked by five point observations of strong continuum point sources is 20″.

The 22 GHz receiver front end is composed of a cooled Schottky mixer and a 1.4 GHz FET IF amplifier together with a phase-locked Gunn local oscillator. The system temperature of the telescope is around 300 K. The

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* Table 1 and Fig. 1 are only available in electronic form at the CDS via anonymous ftp to cdsarc.u-strasbg.fr (130.79.128.5) or via http: //cdsweb.u-strasbg.fr/Abstract.html

spectral back end is a high resolution 1024-channel AOS with a channel bandwidth of 12 KHz and equivalent velocity resolution of 0.16 km s^{-1}.

The noise diode is a secondary temperature calibrator calibrated at the beginning of each observing run by hot and cold black bodies. The stability of the noise diode output was checked regularly by observations of the continuum calibration sources.

Unless the sources had rich spectral features and wide frequency coverage (for which position switching mode was used), most observations were made in frequency switching mode. The typical integration time was 10 minutes on Signal and Reference respectively. For survey observations, several scans of spectral data were usually accumulated.

Before observing the source, calibration observation (switching on and off the noise diode) was usually done in the vicinity of the source position to get the gain curve of the AOS: $G(i) = \mathrm{TC} * P_{\mathrm{off}}(i)/(P_{\mathrm{on}}(i) - P_{\mathrm{off}}(i))$, where TC is the calibration temperature of the temperature calibrator, $P_{\mathrm{on}}(i)$ and $P_{\mathrm{off}}(i)$ are the channel outputs of AOS when the noise diode is on and off respectively. The system noise and the passband effect (including the response of AOS itself) are removed, and the temperature scale is given by the standard relation: $T(i) = G(i) * (S(i) - R(i))/R(i)$.

At 22 GHz, the elevation dependence of the antenna gain is not apparent, so the temperature scale was converted directly to the flux scale by multiplying the flux temperature ratio of 38 Jy K^{-1}. Usually the atmospheric attenuation at zenith (ATTN) was determined by the continuum sky dip observation, and the effect of atmospheric absorption was corrected by multiplying a factor of $\exp(\mathrm{ATTN} * \sec(Z))$. We estimate that the final error in flux scale of our spectral data is about 20%.

All spectral data are stored on tape and disk in a format conforming to the POPS package specifications. POPS is the data reduction package developed by NRAO (Tuscon), kindly provided to Purple Mountain Observatory and replanted to the PDP-11 data reduction computer by the engineers of the observatory.

Owing to the limited memory size of the original computer for data reduction, it is difficult to process the whole frame of 1024 AOS data points by using POPS. Therefore, a program is run on the computer to convert the format of the data file from POPS to Drawspec, and transfer the data to a personal computer. The data are then reprocessed with Drawspec. Drawspec is a compact data reduction package running on PC, developed by Dr. Liszt (NRAO) and kindly provided by the author. Possible systematic errors of velocity have been corrected before data reduction, and the velocity accuracy of the data is estimated to be better than 1 km s^{-1}. The data reduction with Drawspec consists essentially of 3 steps. First a polynomial fit to the baseline is removed in each scan of the spectrum and all related scans added together, the rms noise is computed for the final accumulated spectrum. Second, a suitable number of gaussians are fitted to the lines to evaluate the peak intensity and the central velocity of the strongest component. Finally, the integrated intensity of the gaussian components is computed.

3. The new detections

The new detections and their spectra are compiled in Table 1 and shown in Fig. 1.

For most sources in Table 1, at least two observations at different times were taken. We report here only the spectrum with higher signal/noise ratio. Owing to the complexity of the H_2O spectral features and also the rather low signal/noise ratio of the weak sources detected, only the most significant parameters have been included in the table. The items of the table are:

Column 1: name of the source,

Columns 2, 3: right ascension and declination (1950.0),

Column 4: class of the source,

Column 5: flux density (Jy) of the strongest component in the spectrum,

Column 6: peak velocity (km s^{-1}) with respect to the LSR,

Column 7: noise level of the spectrum σ (Jy),

Column 8: integrated flux (Jy km s^{-1}) computed over the velocity interval related to the strongest component of the spectrum,

Column 9: date (yymmdd) of observation.

The source is considered to be detected if the strongest component in the spectrum is greater than 4 times the noise level of the spectrum and has been confirmed by additional observations. It is also checked that there is no strong nearby maser source, to rule out the possibility of strong sources seen in the antenna sidelobes. We have also followed the general rule to consider positions with a separation less than half of HPBW as a single source.

The atlas of spectra of Fig. 1 (flux density in Jy versus velocity in km s^{-1}) contains only those sources where at least one spectral feature was detected.

The sources that have been detected on the 13.7 m telescope independently but already reported by Brand et al. (1994) and Xiang et al. (1995) are not included in Table 1.

4. Discussion

The rms (Jy) distribution of the new detections is given in Fig. 2a, which shows a cut-off at ~ 3 Jy corresponding to the theoretical sensitivity of our telescope for on-source integration time of one hour.

The peak flux density distribution of the new detections is given in Fig. 2b, which has a cut-off around 15 Jy and a peak around $20 \sim 25$ Jy. 49 of the new detections are tentatively classified as Star Formation Region, and others are classified as Star (Palagi et al. 1993). Almost all

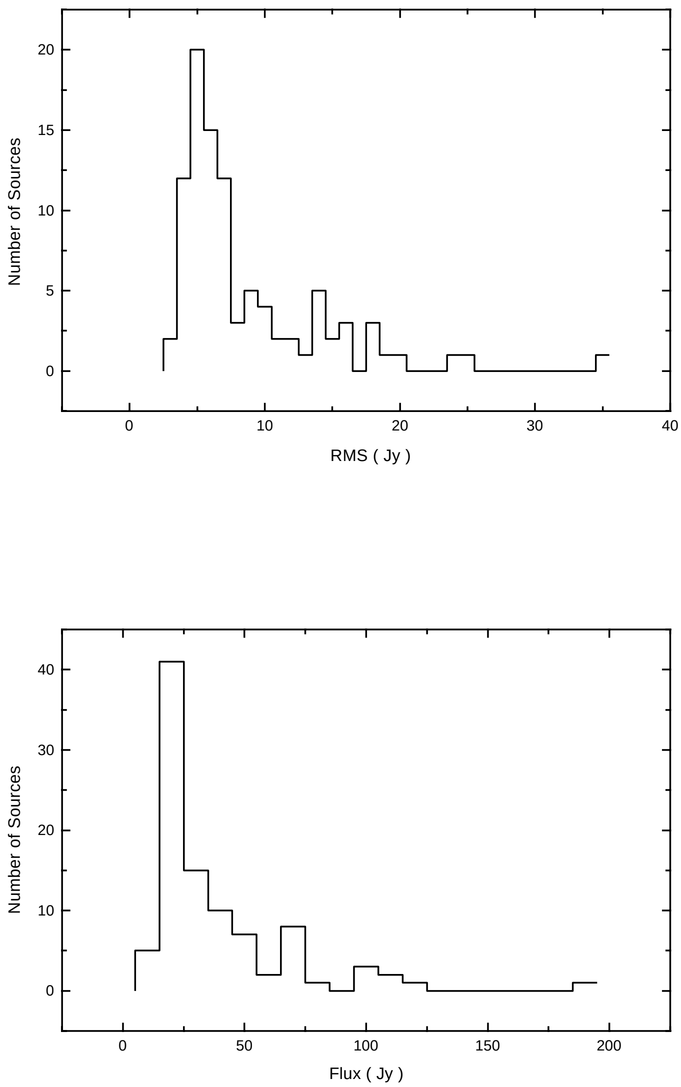

Fig. 2. a) Distribution of 1σ rms noise; **b)** Distribution of peak flux density of the new detections

of our newly-detected sources are associated with IRAS sources. In terms of the logarithm of the IRAS fluxes ($[f_n] = \log(f_n)$, with $n = 12, 25, 60, 100$), Wouterloot & Walmsley (1986) proposed the criteria for the H_2O maser in star formation regions: $[f_{25}] - [f_{12}] = 0.5 \sim 1.1$, $[f_{60}] - [f_{25}] = 0.4 \sim 1.7$, $[f_{100}] - [f_{60}] = -0.1 \sim 0.5$. 87% of the newly-detected sources classified as SFR are inside this boundary. The distribution in the infrared color-color diagram of our newly-detected stellar masers is also in accordance with that of the 274 known stellar maser sources listed in the catalogues of the H_2O maser sources compiled by the Arcetri group.

Among our new detections listed in Table 1, a few evolved stars with IRAS low resolution infrared spectral class 4n and even a few standard carbon stars are included. These results may appear in contrast with current models of C-rich stars. It is well-known that the chemical classes of evolved stars are usually classified as O-rich, C-rich, and S-type, and the composition of the atmosphere and circumstellar envelope of these objects depends strongly on the chemical class to which they belong. Usually, oxygen-bearing molecules other than CO are relatively rare in the atmospheres and the circumstellar envelopes of C-rich stars, and the detection of OH, H_2O, or SiO maser emission is considered to be the indicator of O-richness of these stars. In fact, until now the dominant chemistry of many objects is not well-known, and the discrimination of the chemical properties of their circumstellar envelopes is by far not straightforward. For examples, detections of OH or H_2O masers from some J-type carbon stars are reported (Little-Marenin 1986; Willems & de Jong 1988; Barnbaum et al. 1991; Nakada et al. 1991; Engels 1994), and generally explained by the existence of O-rich envelopes surrounding C-rich stars. Wood et al. (1983) found that the infrared properties of two LPV(long period variable) carbon stars in SMC switch between the O-rich and carbon star groups as they vary.

However, the detection of an H_2O maser from a standard carbon star is unusual and is worthy to be investigated, although the signal to noise ratio in some of our detections is not very high and more sensitive observations are needed for further confirmation.

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