Astron. Astrophys. 227, L37–L39 (1990)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

Two wide-velocity H_2O masers

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Received October 19, accepted October 24, 1989

Summary. VLA observations are presented for two H_2O maser sources with wide (>50 kms^{-1}) velocity spread. In 351.78-0.54 the H_2O masers form a ring, while in 0.54-0.85 they are located on a line. In both sources maser spots with velocities near that of the ambient gas are spread over 3-4", while the red- and blue-shifted masers are more tightly grouped. The distribution and kinematics of the H_2O masers in these sources suggest the presence of a disc or ring of material surrounding a massive young star in an early evolutionary phase.

Key words: Star formation - masers

1. Introduction

The formation of a massive star is often signalled by strong maser emission in the 22 GHz water vapour line. The H_2O masers appear as unresolved spots, sometimes spread over several arc seconds and covering from ~10 to >100 kms^{-1} in velocity. Hydrogen densities of ~10^9 cm^{-3} are needed to account for the intensities measured, and temperatures of several hundred degrees are required to populate the maser levels. These conditions, along with the small observed size of the maser spots, suggest that the maser emission arises in dense clumps of molecular gas surrounding a massive young star. The energy necessary for exciting maser action in these clumps may come from collisions.

Recently, Forster and Caswell (1989) mapped 74 galactic maser sources with ~1" resolution in both the OH and H_2O lines. They found that the OH and H_2O masers are closely associated physically, but that they occur in separate zones with different kinematics. The OH masers occur in rather well-organized systems, probably associated with an evolving HII region, while the H_2O masers occur in more scattered groups showing little coherent behaviour. The H_2O masers are interpreted as fragments of material ejected from the star at the end of the accretion phase of massive star formation.

In order to investigate the kinematics of water masers further, two sources from the Forster and Caswell survey were re-observed at the VLA with higher angular and velocity resolution than in the original study. These sources were chosen because their large velocity spread and angular size allow them to be easily resolved both spatially and in velocity, and because the characteristics of their maser emission suggest that these sources are in a very early stage of evolution.

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2. Observations and data reduction

The observations were made on 6 June, 1986 while the VLA was in its largest (A-array) configuration. The H_2O maser sources were observed in two different correlator configurations, one covering a large velocity range and the other providing higher velocity resolution over a smaller range. The sources were observed for ~10 minutes in each configuration, and were preceded by short calibration observations. The source and calibrator positions, observed central velocities, and the correlator parameters are given in Table 1.

Table 1

Source	Type	RA (1950)	DEC	Velocity
351.78-0.54	H_2O maser	17 23 20.32	-36 06 44.0	-5.0 kms^{-1}
0.54-0.85	H_2O maser	17 47 03.83	-28 53 39.5	20.0
1519-273	calibrator	15 19 37.25	-27 19 30.3	0.0

Bandwidth	Channels	Antennas	Vel. Range	Vel. Resolution
6.250 MHz	64	18	84 kms^{-1}	1.32 kms^{-1}
3.125	128	13	42	0.33

Data analysis was carried out using standard AIPS (Astronomical Image Processing System) software. The uv data were self-calibrated using antenna-based gains derived from a single strong maser in each field. The self-calibrated maps were cleaned and restored using a circular Gaussian beam of ~0.2" FWHM. The rms noise in a channel map with little or no maser emission was 100-200 mJy. In channel maps containing strong masers, dynamic range limited the detection of weak sources to ~7 per cent of the peak intensity. Positions and velocities were determined for all maser spots with intensity greater than ~1Jy which were also above the dynamic range limit.

§ the Australia Telescope National Facility is operated in association with the Division of Radiophysics by CSIRO

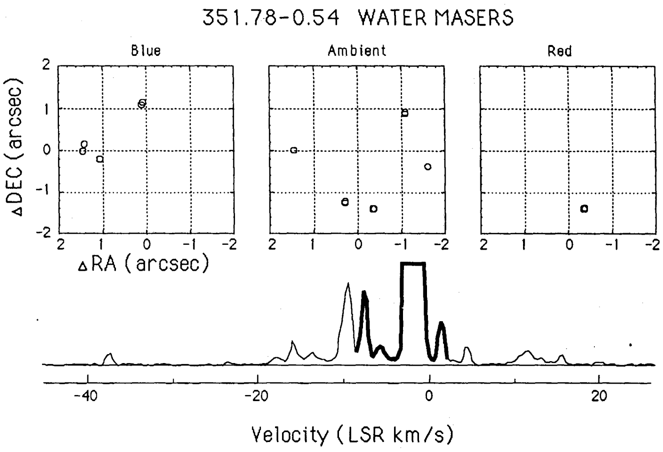

Fig. 1. VLA spot maps of the blue-shifted (<-9 kms^{-1}), ambient velocity (-9 to +2 kms^{-1}), and red-shifted (>2 kms^{-1}) water masers in the source 351.78-0.54. The H_2O spectrum obtained with the Parkes telescope shows the ambient velocity range in bold outline; the strongest feature in this spectrum has been clipped

3. Results

Spot maps of the blue-shifted, ambient velocity, and red-shifted water masers in 351.78–0.54 are shown in Figure 1. The total velocity range of maser features extends from -38 to +22 kms^{-1}. We define an ambient velocity range extending from -9 to +2 kms^{-1}, which encompasses the full extent of the (J,K = 2,2) ammonia line, 12 GHz methanol masers, and most of the 1665 MHz OH maser emission. A Parkes telescope spectrum is shown below the spot maps for reference (Marshall 1987). The Parkes spectrum is similar to that measured at the VLA, and shows the same spectral features.

In 351.78–0.54, water maser emission occurs in six compact groups arranged in a ring of ~3" diameter. Maser spots with velocities lying within the ambient range are found in five of the six groups. The blue-shifted masers in the velocity range -15 to -9 kms^{-1} occur in the eastern-most group (ΔRA = 1.4", ΔDEC= 0"). This group also contains emission at velocities within the ambient range. The most blue-shifted feature at -38 kms^{-1} is located just below and to the right of this group. Maser spots with velocities in the range -20 to -15 kms^{-1} are located in the most northern group. This is the only group which does not exhibit any emission in the ambient velocity range. The red-shifted masers with velocities >2 kms^{-1} are all located in the southern-most group. Ambient velocity masers are also present within this group.

The distribution of maser spots in 0.54–0.85 is shown in Figure 2. A Parkes telescope spectrum showing maser features extending from -28 to +60 kms^{-1} is given below the spot maps. The complete Parkes spectrum contains many more maser features than those shown, with velocities extending from -80 to +95 kms^{-1}. The velocity range of the VLA data covers -22 to +62 kms^{-1}; thus all maser features shown in the Parkes spectrum, with the exception of the feature at -28 kms^{-1}, are represented in the VLA spot maps. Although precise positions for maser features outside the VLA velocity range are not available, single-dish mapping at Parkes indicates that the total maser emission in 0.54–0.85 is confined to an area of diameter <5".

The maser spots in 0.54–0.85 mapped at the VLA are distributed along a diagonal line ~4" in extent, and ambient velocity masers are found over the full extent of this line. In this source we define the ambient velocity range as 6 to 23 kms^{-1}, which includes the main OH lines and the full width of the NH_3, CO and HCN lines. One maser spot in this range (13 kms^{-1}) lies 1.3" south of the centre. In contrast, the blue- and red-shifted masers are both tightly grouped near the centre of the line. The two high-velocity groups do not coincide precisely, and neither extends further than ~0.3" from the centre.

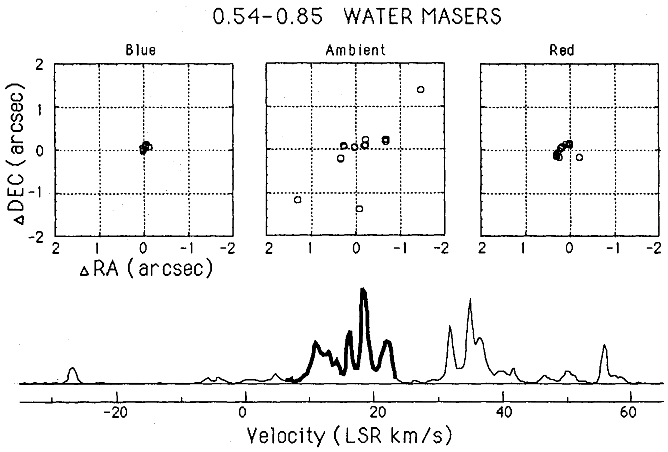

Fig. 2. VLA spot maps of the blue-shifted (<6 kms^{-1}), ambient velocity (6 to 23 kms^{-1}), and red-shifted (>23 kms^{-1}) water masers in the source 0.54-0.85. The H_2O spectrum obtained with the Parkes telescope shows the ambient velocity range in bold outline. The blue-shifted feature at –28 kms^{-1} is outside the range of the VLA data, and is not represented in the spot maps

4. Discussion

The two maser sources 351.78–0.54 and 0.54–0.85 exhibit many similarities and some interesting differences. Assuming that these sources lie at the near kinematical distance inferred from their ambient velocities, both sources are located ~2 kpc from the sun. Thus the total extent of H_2O maser emission shown in Figures 1 and 2 is 30–40mpc (~10^{17} cm). Neither source has a strong compact HII region at the position of the masers, although a very weak continuum source was detected near 351.78–0.54 by Fix et al. (1982) and 0.54–0.85 lies in a region of extended HII emission. Both sources have a wide velocity spread in their H_2O maser emission, covering ~60 kms^{-1} in 351.78–0.54, and ~175 kms^{-1} in 0.54–0.85. In both cases the water masers with velocities near that of the ambient gas are spread over a larger area than the blue- or red-shifted masers.

A striking difference between these two sources is the circular arrangement of H_2O masers in 351.78–0.54 and the linear arrangement in 0.54–0.85. The location of the blue- and red-shifted maser groups in these two sources is also different, being on opposite sides of the ring in 351.78–0.54, and nearly coincident at the centre of the line in 0.54–0.85. While entirely different in aspect, the maser distributions in these two sources share a similar symmetry. In both cases a line can be drawn through the centre of the overall maser distribution which intersects both the blue- and the red-shifted groups. This symmetry is reminiscent of an expanding ring geometry. An expanding ring model would reproduce the observed distributions qualitatively if it were observed edge-on in 0.54–0.85 and more nearly face-on in 351.78–0.54. A bipolar flow could also produce this symmetry; however, in addition, the large spatial extent of the ambient velocity masers would require a more general expansion.

Owing to their compact size, wide velocity spread, and lack of a strong compact HII region, these water maser sources are in an early expansion phase according to the evolutionary scenario proposed by Forster and Caswell (1989). The symmetrical geometry and kinematics exhibited by the maser sources 351.78–0.54 and 0.54–0.85 suggest that a ring or disk geometry may be influencing the expansion.

Acknowledgement. I gratefully acknowledge the help of Max Komesaroff, who took part in the observations and data reduction but, sadly, died before a first draft of this paper was written.

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