Cosmic MASERs: From Protostars to Blackholes
IAU Symposium, Vol. 206, 2002
V. Migenes and M. J. Reid, eds

VLA observations of H_2O and OH (1612 MHz) maser emission towards OH 231.8+4.2

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Abstract. We present Very Large Array (VLA) observations of H_2O and OH (1612 MHz) maser emission toward the protoplanetary nebula OH 231.8+4.2. The H_2O observations show two features at V_{LSR} of 23.1 and 44.5 km s^{-1}, coinciding in position within error with the SiO (v=1; J=2-1) maser position from Sánchez Contreras et al. (2000). The H_2O and SiO masers are most likely tracing the position of QX Pup, the Mira near the center of OH 231.8+4.2. This position is, however, clearly offset by $\sim1''$ from the axis of the bipolar outflow traced by the OH maser emission. These results suggest the presence of a binary system: one invisible star powering the bipolar outflow and the other, the Mira star QX Pup, associated with the H_2O and SiO masers. This scenario requires that the two stars have evolved at very similar rates.

1. Introduction

OH 231.8+4.2 is a well studied protoplanetary nebula (PPN) located at a distance of $\sim$1500 pc (Bowers & Morris 1984; Kastner et al. 1992; Shure et al. 1995). It is characterized by a bipolar reflection nebula with a position angle of $\sim20°$, with HH-like objects at the poles (Cohen et al. 1985; Reipurth 1987; Sánchez Contreras et al. 2000). The spatial distribution and kinematics of the molecular emission in this source seems to follow the bipolar outflow with the blueshifted gas to the NE and the redshifted gas to the SW (Sánchez Contreras et al. 1997; 2000). Cohen (1981) reports an excess of blue continuum emission suggesting the presence of a warm companion star in OH 231.8+4.2, but until now no other evidence for binarity has been presented. The OH 1667 MHz and the near-infrared continuum emission toward OH 231.8+4.2 show variability indicative of an evolved AGB star (Feast et al. 1983; Bowers & Morris 1984; Kastner et al. 1998). The central star in this PPN has been classify as M9 III (Cohen 1981; Feast et al. 1983), and direct images (3.8 μm) of the central star identify it as the Mira variable QX Pup (Kastner et al. 1998). The OH 1667 MHz maser emission exhibits an axisymmetric distribution interpreted originally by Morris, Bowers & Turner (1982) as a disk with an ellipsoidal density structure. New observations of the 1667 MHz maser emission by Zijlstra et al. (2001) show the presence of an equatorial disk of $\sim5''$ in diameter in expansion and the presence of an outflow aligned in the same direction as the optical one (position angle of $\sim20°$), with the NE lobe blueshifted and the SW lobe redshifted (see also Chapman 2001 in these proceedings). It is known that H_2O and SiO masers are not expected to be observed in post-AGB stars (Lewis 1989; Gómez et al. 1990). OH 231.8+4.2 shows a bipolar morphology, optical line emission and shocks which are indicators of a star that recently entered the post-AGB phase (Sánchez Contreras et al. 2000). We present high angular resolution maser observations that suggest that a binary system may be present in this object.

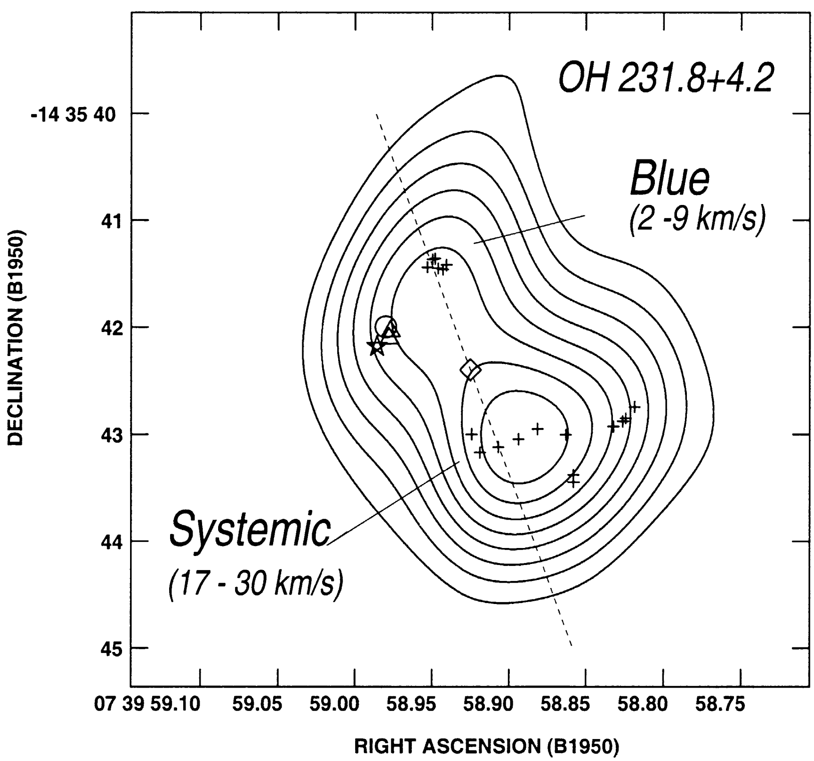

Figure 1. The contours show the velocity integrated OH 1612 MHz maser emission. Contours are 20, 30, 40, 50, 60, 70, 80, and 90 % of 1.1 Jy beam^{-1} km s^{-1}. The peak position of OH 1612 MHz in each single channel was plotted with a cross. The diamond marks the centroid of the OH 1667 MHz emission (Zijlstra 2001). The peak positions of the H_2O masers are marked with triangles, the SiO position by Sánchez Contreras et al. (2000) is plotted with a circle and the estimated position for the Mira star by Kastner et al. (1998), is marked with a star.

1.1. OH (1612 MHz)

The OH (1612 MHz) and H_2O (22235 MHz) observations were made using the Very Large Array (VLA) of the National Radio Astronomy Observatory (NRAO)[1] during 1991 July 25 and 1992 May 19, respectively.

Figure 1 shows the velocity integrated OH 1612 MHz maser emission in contours. The peak position of each single maser component is plotted with a cross. We have found that the OH 1612 MHz maser emission is spatially distributed in three main groups: at the north with blueshifted velocities (2 – 9 km s^{-1}), at the south with systemic velocities (17 – 30 km s^{-1}), and a third group of weak OH masers at the east with velocities between -24 to 40 km s^{-1}, a close up of these weak masers is shown in Figure 2. Tracing a line from the NE blueshifted masers passing through the centroid of the OH 1667 MHz position, $\alpha(1950) = 07^h\ 39^m\ 58^s.925$; $\delta(1950) = -14°\ 35'\ 42''.4$, given by Zijlstra et al. (2001) we obtain a position angle of ~20°, similar to the position angle of the optical outflow in the plane of the sky.

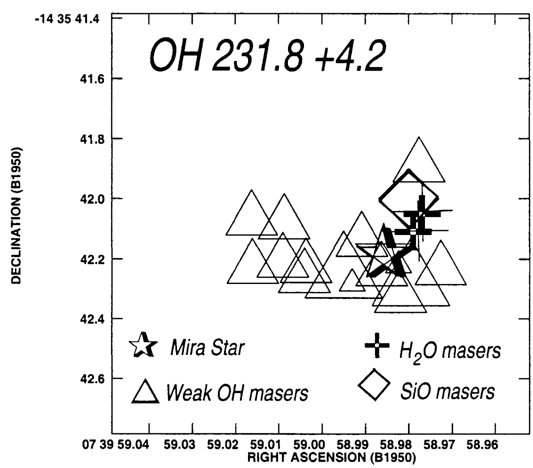

Figure 2. A close up of the weak OH 1612 MHz masers (triangles) and the H_2O masers (crosses) where the SiO (diamond) and the Mira (star) positions are also plotted.

1.2. H_2O maser emission

The H_2O profile shows two main components at V_{LSR} of 23.9 and 45.0 km s^{-1}, located at $\alpha(1950)= 07^h39^m58^s.98 \pm 0^s.01$; $\delta(1950)= -14°35'42''.1 \pm 0''.1$, coinciding in position within $0''.2$ with the SiO (v=1; J=2-1) maser position from Sánchez Contreras et al. (2000) and the estimated position for the Mira star (Kastner et al. 1998). Figure 2 shows a close up of the third group of weak OH 1612 MHz masers. The positions of the H_2O masers, the SiO maser, and

[1]NRAO is a facility of the National Science Foundation operated under cooperative agreement by Associated Universities, Inc.

the Mira star are also plotted. The position defined by the H_2O and SiO maser emission is offset from the axis of the outflow (see Figure 1). Recently, VLBA observations of the v=1-2 J=1-0 SiO maser emission by Desmurs et al. (2001 these proceedings) present evidence of a compact disk with a diameter of a few milliarcsec. We believe that this compact disk is associated with the Mira star.

2. Discussion and Conclusions

The OH 1612 MHz maser distribution clearly suggests the presence of two stars, one associated with the Mira star, the H_20, and the SiO maser emission and the second one related with the powering source of the bipolar outflow. Assuming that we have two stars in OH 231.8 + 4.2 the minimal distance between the Mira and the axis of the bipolar outflow is about $0\overset{''}{.}7$ which at the distance of 1500 pc give us a separation of ~1000 AU, too large for binary models (10 - 100 AU) that could produced the observed bipolar morphology. In conclusion we believe that OH 231.8+4.2 has a binary system where both stars are evolving with very similar timescales. There is at least a related case in the literature, KjPn8, where López et al. (2000) have argued for the presence of a binary with components of very similar mass. More observations are needed in order to confirm the evidence of a binary system at the core of OH 231.8 + 4.2.

YG and LFR acknowledge the support from DGAPA, UNAM, and CONACyT, México.

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