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A Collimated Molecular Jet in W 43A Traced by Water Maser Emission

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Abstract. We present VLBA observations of the spatial and velocity distributions of 22 GHz H_2O and 1612 MHz OH masers in the OH/IR star W 43A. These masers have the same systemic velocity and are, therefore, likely to be associated with the common stellar object. However, the kinematical structures of them are quite different and independent. Most of the H_2O masers are extremely collimated spatially and kinematically. The H_2O maser jet also seems to be precessing . On the other hand, the OH masers exhibit clear arc-shaped structures indicating a spherically-expanding shell with weak collimation. The W 43A jet is very likely to be predominantly composed of hot molecules traced by H_2O maser emission and formed in the immediate vicinity of an unknown star next to another OH/IR star. Such a "molecular jet" is likely to appear only during the short period before a star forms an elongated planetary nebula.

H_2O and OH (1612 MHz) masers in W 43A have been observed using the NRAO's VLBA on three occasions: 1994 June 25, 1994 October 10, and 1995 March 17. The obtained angular and velocity resolutions were 0.5 mas and 0.21 km s^{-1} at 22.2 GHz band and 9 mas and 0.36 km s^{-1} at 1.6 GHz band, respectively. We measured proper motions of 21 H_2O maser features that were detected in two or three epochs. Figure 1 shows the kinematics of the H_2O and OH masers.

Most of H_2O masers in W 43A are concentrated in blue-shifted and red-shifted clusters, both of which are surprisingly spatially collimated with a width of only 20 AU. The two clusters have lengths of 250–350 AU and are separated by 1700 AU. The 3-D motions of the masers indicate a collimated, fast jet-like motion with a 3-D velocity of 145 km s^{-1}. In addition, the direction of the spatial alignments of the water masers in W 43A is shifted slightly by about 10° from both the direction of the cluster separation and the jet direction, implying that the jet is precessing. The observed spatial pattern is consistent with a model to consider a jet with a constant velocity of 150 km s^{-1}, an inclination of 36° with respect to the sky plane, a position angle of 63°, and an axis precession with an angular amplitude of 5° and a period of 55 years.

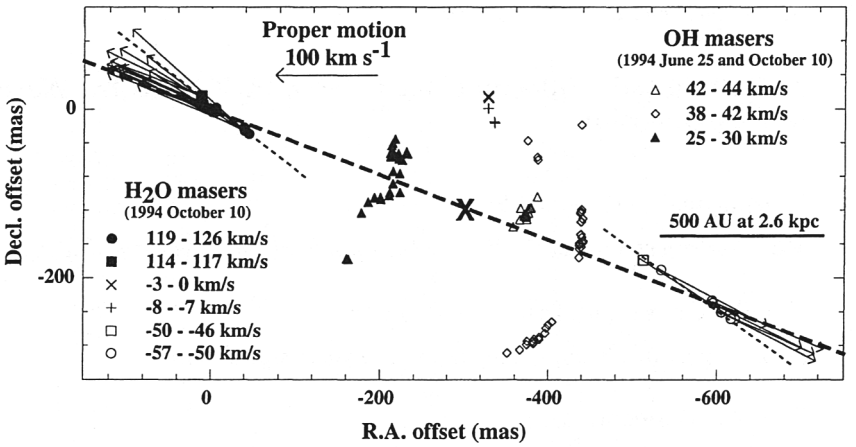

Figure 1. Kinematics of H_2O and 1612 MHz OH masers in W 43A. Arrows show velocity vectors of 21 H_2O masers. A dashed line shows the direction of the jet at a position angle of 69°. Two dotted thin lines show the alignments of maser spots in the individual clusters. A cross shows the estimated location of the central object at ($\Delta\alpha = -296$ mas, $\Delta\delta = -112$ mas) with a systemic radial velocity of $V_{\rm LSR} = 34$ km s^{-1}. The position offsets of the OH masers relative to the H_2O masers were estimated by assuming the common central object at the middle point of the red-shifted and blue-shifted OH masers.

In contrast to H_2O masers, OH masers in W 43A have clear arc-shaped structures that can fit a model of a spherically-expanding shell with a radius of $\sim$500 AU around the star with an expansion velocity of 9 km s^{-1} (e.g. Diamond and Nyman 1988). Usually the morphology and kinematics of H_2O masers are complicated or elongated perpendicular to the directions of the outflows because H_2O masers are excited around shocks between an outflow and the ambient gas cloud. In addition, H_2O masers around an evolved star are located closer to the star than OH masers. From these results, we propose a model of H_2O and OH masers in W 43A as follows. The circumstellar envelope of W 43A is destroyed at closer part from the star at final phase of the OH/IR star stage. The H_2O masers are excited only the tips of a highly-collimated jet with compact clumps simultaneously ejected from the star. Such a collimated jet originating from an OH/IR star is surprising, but can be explained if W 43A contains a binary system; an evolved star and another star generating the OH maser flow and the H_2O maser jet with precession, respectively. The second star is likely to be a unique object that generates such a molecular jet in a short period of evolution prior to a white dwarf.

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References

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