

The 658 GHz Vibrationally Excited H₂O Maser in Orion Source I

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We carried out an observational study of the 658 GHz vibrationally excited H₂O maser line ($v_2 = 1, 1_1, 0-1_{0,1}, E_l = 2329$ K) toward a massive protostar candidate Source I in the Orion KL region using the Atacama Large Millimeter/Submillimeter Array (ALMA) in cycle 0 [1]. The observation was carried out at ALMA band 9 with the longest baseline length of 385 m, which achieved the spatial resolution of $0.28'' \times 0.25''$.

The 658 GHz H₂O line is found to be emitted from a compact structure with the size of ~ 100 AU (Figure 1). The source structure is elongated along the northeast-southwest direction parallel to the low-velocity (18 km s^{-1}) molecular outflow (Figure 1). The most remarkable feature is a velocity gradient along the northwest-southeast direction, which is perpendicular to the outflow axis and the source elongation suggesting a rotating structure. A spectral profile shows an asymmetric structure with the brighter red-shifted component as seen in other H₂O lines [2] and SiO masers [3] (Figure 2). The observed flux density and the compact structure suggest a high brightness temperature of $> 2 \times 10^4$ K, which is consistent with a strong maser emission.

These basic properties suggest that the 658 GHz H₂O line is most likely emitted from the base of the northeast-southwest low-velocity (18 km s^{-1}) molecular outflow ejected from a rotating disk around Source I. Our results demonstrate that the vibrationally excited H₂O line at 658 GHz could be a unique tracer of hot molecular gas close to the central protostar as proposed for another submillimeter H₂O line at 321 GHz [2] and the 43 GHz SiO masers [3].

References

- [1] Hirota, T., Kim, M. K., Honma, M.: 2016, *ApJ*, **817**, 168.
- [2] Hirota, T., et al.: 2014, *ApJ*, **782**, L28.
- [3] Kim, M. K., et al.: 2008, *PASJ*, **60**, 991.

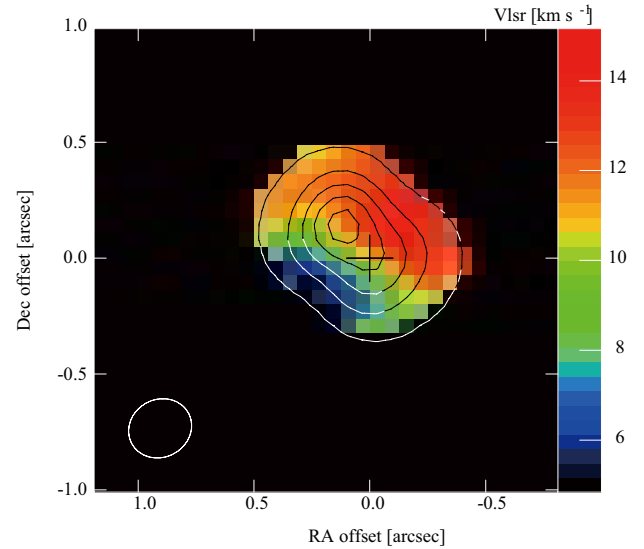


Figure 1: Moment 0 (contour) and 1 (color) maps of the 658 GHz H₂O line emission. The contour levels are 10 %, 30 %, 50 %, 70 %, and 90 % of the peak intensity of $3923 \text{ Jy beam}^{-1} \text{ km s}^{-1}$. A black cross corresponds to the position of Source I determined by the continuum emission. A synthesized beam size is shown at the bottom-left corner. Position offset is measured with respect to the continuum peak.

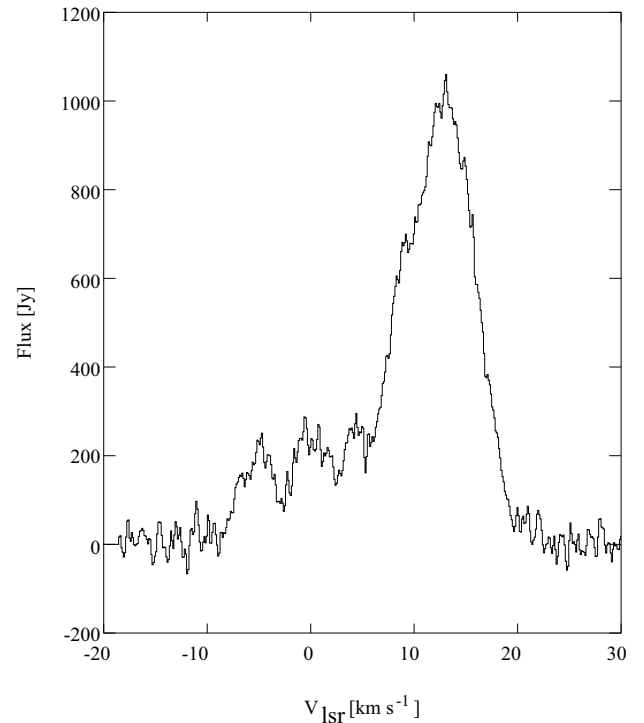


Figure 2: Spectrum of the 658 GHz H₂O line.