Cosmic Masers - from OH to H_0
Proceedings IAU Symposium No. 287, 2012
R.S. Booth, E.M.L. Humphreys & W.H.T. Vlemmings, eds.

doi:10.1017/S1743921312006916

325 GHz Water Masers in Orion Source I

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Abstract. Radio Source I in the Orion BN/KL region provides the closest example of high mass star formation. It powers a rich ensemble of SiO and H_2O masers, and is one of only three star-forming regions known to display SiO maser emission. Previous monitoring of different SiO masers with the VLBA and VLA has enabled the resolution of a compact disk and a protostellar wind at radii <100 AU from Source I, which collimates into a bipolar outflow at radii of 100-1000 AU (see contribution by Greenhill *et al.*, this volume). Source I may provide the best case of disk-mediated accretion and outflow recollimation in massive star formation. Here, we report preliminary results of sub-arcsecond resolution 325 GHz H_2O maser observations made with the SMA. We find that 325 GHz H_2O masers trace a more collimated portion of the Source I outflow than masers at 22 GHz, but occur at similar radii suggesting similar excitation conditions. A velocity gradient perpendicular to the outflow axis, indicating rotation, supports magneto-centrifugal driving of the flow.

Keywords. ISM: individual (Orion KL) - ISM: jets and outflows - stars: formation - masers

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1. Introduction

Massive stars affect the composition of the ISM and regulate star formation in molecular cloud complexes, thereby playing an important role in the evolution of galaxies. However, the detailed structures and processes involved in massive star formation remain largely uncharacterised. We have therefore embarked on a high-angular resolution study of massive, nearby YSO radio Source I in Orion BN/KL (d=414±7 pc; Menten *et al.* 2007). Using VLBI, it has been possible to map vibrationally-excited SiO maser emission of Source I at radii between 10-100 AU at 19 epochs over 2 years (around 20% of the crossing timescale) with a resolution of 0.1 AU (Matthews *et al.* 2010). The resulting movie has revealed a rotating and expanding flow that brackets an elongated 7 mm continuum source we interpret as arising from an ionized disk (Reid *et al.* 2007; Goddi *et al.* 2011). At radii >100 AU, proper motions of maser spots from the SiO vibrational ground state indicate a collimated, slow (18 km s^{-1}) outflow along the direction of the Source I rotation axis.

2. Observations and Results

Our 325 GHz water maser data towards Orion Source I were taken on November 30^{th} 2006 with the Submillimeter Array (SMA) in the extended configuration using 6 antennas. This configuration provided maximum baselines of 220 meters corresponding to a resolution of $0.6''$ at 325 GHz. The resolution in velocity was 0.37 km s^{-1}. We used CASA to calibrate the data. 3c279 and 0528+134 served as the bandpass and the gain

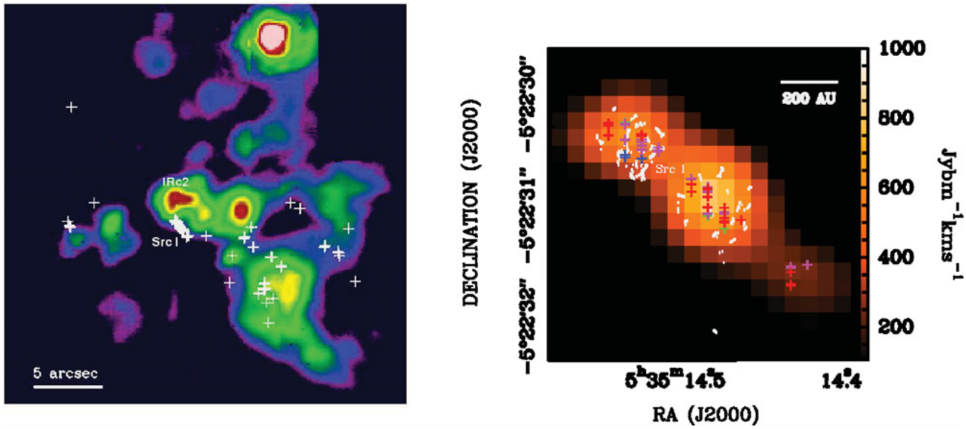

Figure 1. *Left*(Fig. 1a): Orion BN/KL 12.4 μm Gemini mosaic overlaid with fitted positions of 325 GHz H_2O maser emission (white crosses) observed using the SMA. Source I is marked by the clustered maser features south of IRc2; *Right*(Fig. 1b): Comparison of 22 GHz H_2O positions (VLA 1983, 0.1" resolution; Greenhill *et al.* 1998, white dots) with 325 GHz maser spot positions (SMA 2006, crosses). Background color scale is the 325 GHz moment 0 image.

callibrator respectively and flux calibration was performed using Titan. We used the strongest maser feature at 15.3 km s^{-1} to apply self-calibration to the data.

We imaged the 325 GHz H_2O maser emission and identified over 120 components in an area of 15 $''$ around Source I (Figure 1a).The maser features associated with Source I trace a bipolar, collimated outflow for which we estimate a collimation angle of $\sim$40^o and a position angle of $\sim$60^o. The two outflow lobes display almost the same velocity distribution, spanning from -6 to 25 km s^{-1}, indicating the outflow axis lies close to the sky plane. There is a velocity gradient across the lobes perpendicular to the outflow axis which we interpret as rotation. Therefore magnetic fields may play a role in launching and shaping the outflow. We compared the fitted 325 GHz maser positions with the 22 GHz H_2O positions observed with the VLA in 1983 (Greenhill *et al.* 1998; Figure 1b). 325 GHz emission traces a more collimated region than that probed by 22 GHz masers. 22 GHz H_2O masers are excited in shocks with densities of $\sim$10^9 cm^{-3}, while models disagree on the conditions required to pump 325 GHz masers (10^6 cm^{-3}, Cernicharo *et al.* 1999; 10^9 cm^{-3}, Yates *et al.* 1997). We find that both transitions are excited at similar radii from Source I, suggesting similar excitation conditions for 22 GHz and 325 GHz H_2O masers in the Source I outflow.

References

Cernicharo, J., Pardo, J. R., González-Alfonso, E., *et al.* 1999, *ApJ*, 520, 131

Goddi, C., Humphreys, E. M. L., Greenhill, L. J., Chandler, C. J., & Matthews, L. D. 2011, *ApJ*, 728, 15

Greenhill, L. J., Gwinn, C. R., Schwartz, C., Moran J. M., & Diamond, P. J. 1998, *Nature*, 396, 650

Matthews, L. D., Greenhill, L. J., Goddi, C., *et al.* 2010, *ApJ*, 708, 80

Menten, K. M., Reid, M. J., Forbrich, J., & Brunthaler, A. 2007, *A&A*, 474, 515

Reid, M. J., Menten, K. M., Greenhill, L. J., & Chandler, C. J. 2007, *ApJ*, 664, 950

Yates, J. A., Field, D., & Gray, M. D. 1997, *MNRAS*, 285, 303

https://doi.org/10.1017/S1743921312006916 Published online by Cambridge University Press