Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
Proceedings IAU Symposium No. 380, 2024
T. Hirota, H. Imai, K. Menten, & Y. Pihlström, eds.
doi:10.1017/S1743921323003162

Spatio-kinematics of water masers in the HMSFR NGC6334I before and during an accretion burst

Jakobus M. Vorster[1,2], **James O. Chibueze**[2,3,4], **Tomoya Hirota**[5,6] and **Gordon C. MacLeod**[7,8]

[1]University of Helsinki, Finland,

[2]North-West University, South Africa, email: jakobus.vorster@helsinki.fi

[3]Department of Mathematical Sciences, University of South Africa, Roodepoort, South Africa,

[4]University of Nigeria, Nigeria,

[5]National Astronomical Observatory of Japan, Japan,

[6]SOKENDAI (The Graduate University for Advanced Studies), Japan,

[7]The Open University of Tanzania, Tanzania,

[8]SARAO Hartebeesthoek Astronomical Observatory, South Africa.

Abstract. In 2015, the high-mass star-forming region NGC6334I-MM1 underwent an accretion burst. Using VERA, we monitored 22 GHz water masers before and during the accretion burst to observe the changes in the maser spatial and velocity distributions in the region. The masers in CM2-W2 and MM1-W1 displayed variability that could be attributed to the accretion burst. The bright masers in CM2-W2 were found to better trace the shock structure as the epochs progressed. The mean 3D speeds derived from the proper motions were 50 km/s and 54 km/s for the pre-burst and burst epochs respectively. High-velocity proper motions were found at the southern edges of the N-S ($\sim$80 km s^{-1}) and NW-SE ($\sim$150 km s^{-1}) bipolar outflows. The precise mechanism of the flaring of the water masers due to the accretion burst has yet to be investigated.

Keywords. masers, stars: formation, ISM: jets and outflows

1. Introduction

The high-mass star-forming region NGC6334I recently underwent a period of high-mass accretion (Hunter *et al.* 2017). This accretion burst was accompanied by the flaring of multiple maser species, such as 6.7 GHz methanol and 22 GHz water masers (MacLeod *et al.* 2018). High-resolution VLBI observations of the evolution of water masers during the rapid onset of the accretion burst give information on the time dependence of the water masers, which is influenced by the burst's evolution.

2. Observations and Data Reduction

We conducted seven observations of 22 GHz water masers in NGC6334I with the VLBI Exploration for Radio Astrometry (VERA) array. The observations were done before and during the burst on 2014.72, 2014.90, 2015.08, 2015.28, 2015.88, 2016.11 and 2016.19. The spectral resolution was 0.4 km s^{-1} and the beam size was 1.3×3.3 milliarcseconds. The data were calibrated and imaged with standard imaging techniques

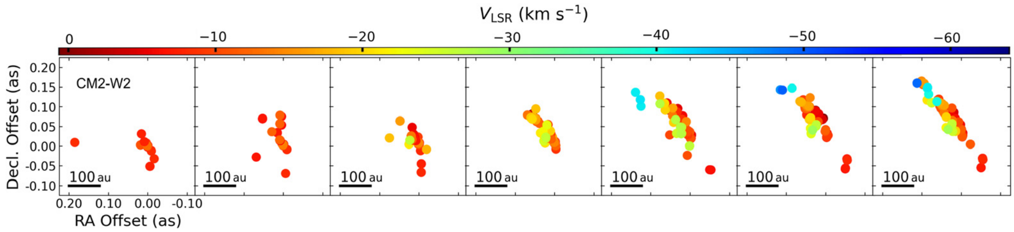

Figure 1. Top: Water maser positions and radial velocities over all seven observed epochs in CM2-W2.

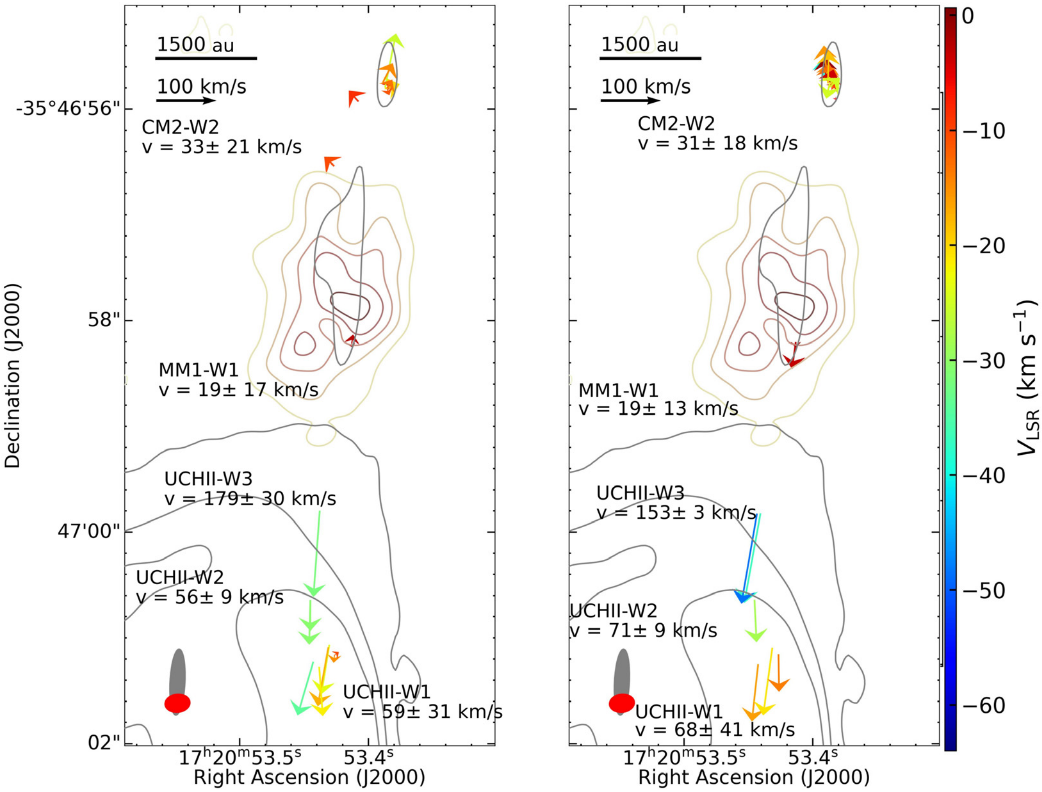

Figure 2. Proper motions of water masers in NGC6334I before (2014.7 − 2015.3) and during (2015.9 − 2016.2) the accretion burst. The mean velocities of each region is shown in black text. The brown contours represent the ALMA 1.3 mm continuum and the grey contours the JVLA 5 cm continuum, as in Brogan *et al.* (2018).

with the Astronomical Image Processing System (AIPS). The data were self-calibrated on the brightest persistent maser spot. Proper motions were calculated by identifying persistent groups of maser spots showing a Gaussian spectral distribution, which were termed maser features. The position of the feature in each epoch was calculated with the flux-weighted mean position of the spots in the feature.

3. Results and Discussion

Figure 1 shows the positions of maser features in CM2-W2, the northern bow shock, 2800 au from the accretion bursting source MM1B (Chibueze *et al.* 2021). The maser features trace a bow shock structure more clearly as the burst progresses. The linear

https://doi.org/10.1017/S1743921323003162 Published online by Cambridge University Press

size of the maser feature at (0,0) of Figure 1 also increased with the accretion burst. The brightening of the feature was also seen in its spectral distribution. Figure 2 shows the proper motions. of maser appearing to trace the bipolar outflow in NGC6334I. New high-velocity features were excited in the southern regions.

The 22 GHz water masers are understood to be collisionally pumped in turbulent and shocked regions (Hollenbach *et al.* 2013). The changes in the large ($\sim$ 100 au) and small scale ($\sim$ 1 au) spatial distribution of the masers indicate that the variability in the masers can be attributed to the accretion burst rather than hydrodynamic variability which is intrinsic to water masers. Investigating the precise mechanism of how the burst affected the water masers requires three observations to be explained: The better tracing of the bow shock, the increase of the linear size of single features and the dramatic flare observed in single dish monitoring observations.

Supplementary material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S1743921323003472

References

Brogan, C.L., Hunter, T.R., Cyganowski, C.J., *et al.* 2018, *ApJ*, 866, 87
Hunter, T.R., Brogan, C.L., MacLeod, G.C., *et al.* 2017, *ApJ*, 837, L29
MacLeod, G.C., Smits, D.P., Goedhart, S., *et al.* 2018, *MNRAS*, 478, 1077
Hollenbach, D., Elitzur, M. and McKee, C.F. 2013, *ApJ*, 773, 70
Chibueze, J.O., MacLeod, G.C, Vorster, J.M., *et al.* 2021, *ApJ*, 908, 175

https://doi.org/10.1017/S1743921323003162 Published online by Cambridge University Press