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

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Introduction

To use 22 GHz water masers as a tracer for physical processes in HMYSOs, it is important to understand the effects of water masers in time-dependant environments. The current models of 22 GHz water maser emission (e.g. Hollenbach et al. 2013) do not take the effects of radiation from stellar sources into account. Water masers are highly variable, due to their origin in shocked and turbulent gas. The variability in water masers can be grouped into "hydrodynamic variability" (intrinsic) and "pump variability" (external).

In 2015, NGC6334I-MM1B started a period of high accretion analogous to FU Orionis bursts in low-mass stars (Hunter et al. 2017). Single dish monitoring (MacLeod et al. 2018) and 2017 JVLA observations (Brogan et al. 2018) of NGC6334I has found dramatic variability in the water masers. VLBI proper motion observations with KaVA has been done after the accretion burst (early 2016, Chibueze et al. 2021). We did VERA observations with worse sensitivity and angular resolution than the KaVA observations, but with epochs before and after the burst. This allows us to observe the spatial variation of the 22 GHz water masers during the onset of the burst.

Observations

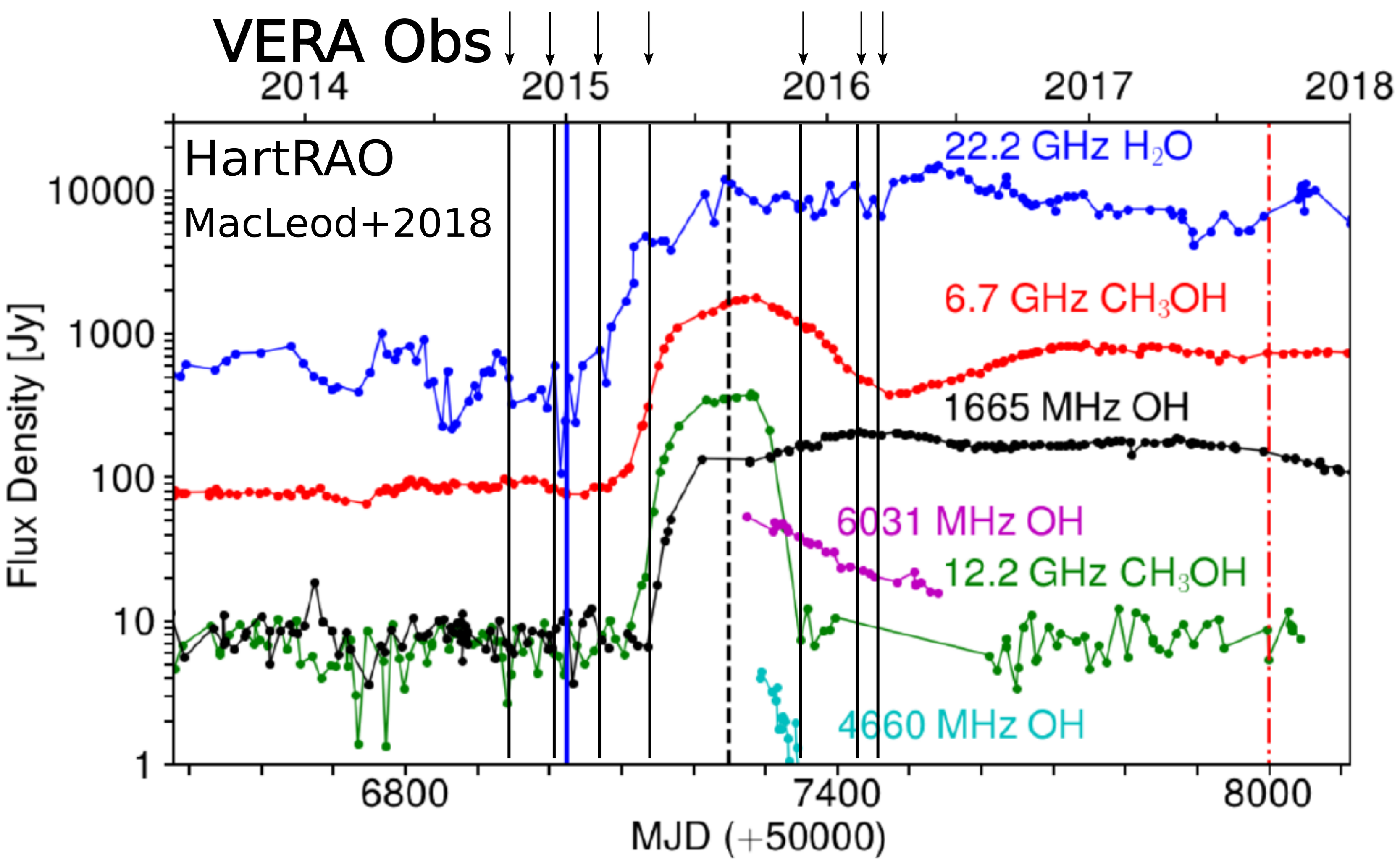

Figure 1: Time series of various maser components as reported in Macleod et al. 2018. **The dates of our VERA observations are shown in the black lines**. The observations cover times before, during and after the onset of the burst.

Results

We detected water masers in CM2-W1, CM2-W2, MM1-W1, UCHII-W1, UCHII-W2, and UCHII-W3 in all epochs. Figure 2 shows zoomed in maser spot maps for the most interesting regions. Changes in the spatial and velocity distributions of the masers is clearly visible. Figure 3 shows the single brightest –7.6 km s^{-1} maser feature over time. The size, brightness and morphology of the maser feature changed over time. Other maser features also had similar changes. Figure 4 shows the proper motions before and after the onset of the accretion burst. There were changes in the mean 3D speed in the UCHII regions, but not significant changes in CM2-W2 and MM1-W1, as shown in the black annotations in Figure 4.

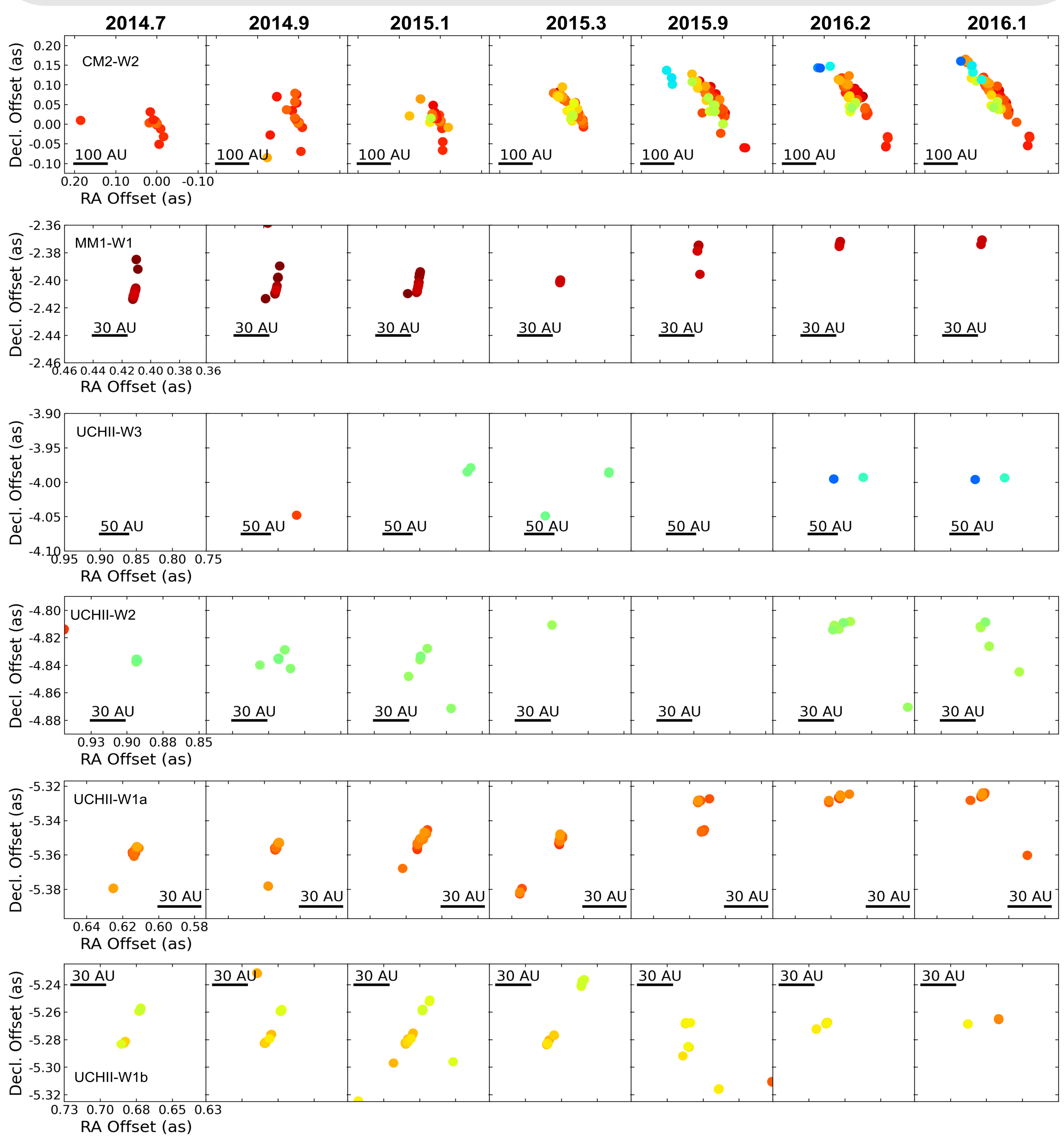

Figure 2: Maser spot distributions for maser spots in various regions. The offsets are in terms of the brightest maser feature in CM2-W2. The colours represent the V_{LSR} according to the colourbar in Figure 4.

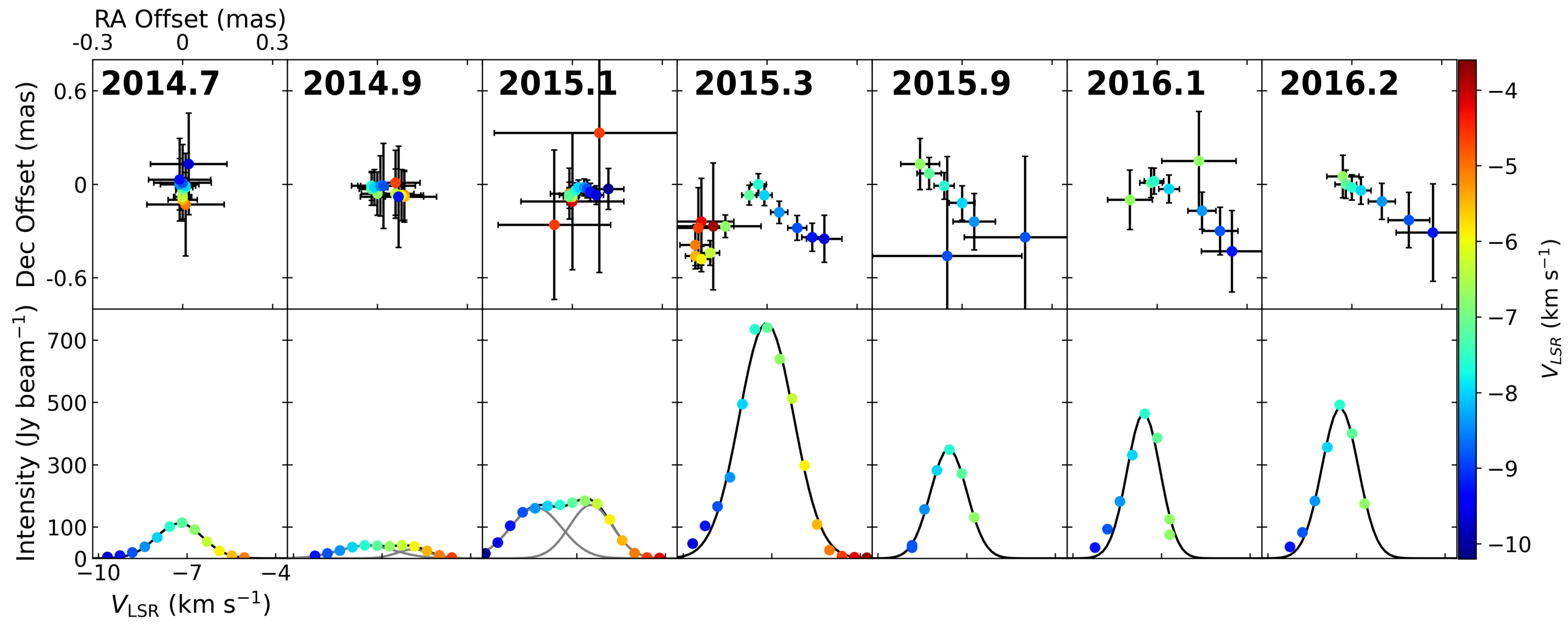

Figure 3: Spatial and spectral distributions of the brightest maser feature (V_{LSR} = –7.6 kms^{-1}) in CM2-W2 over all epochs.

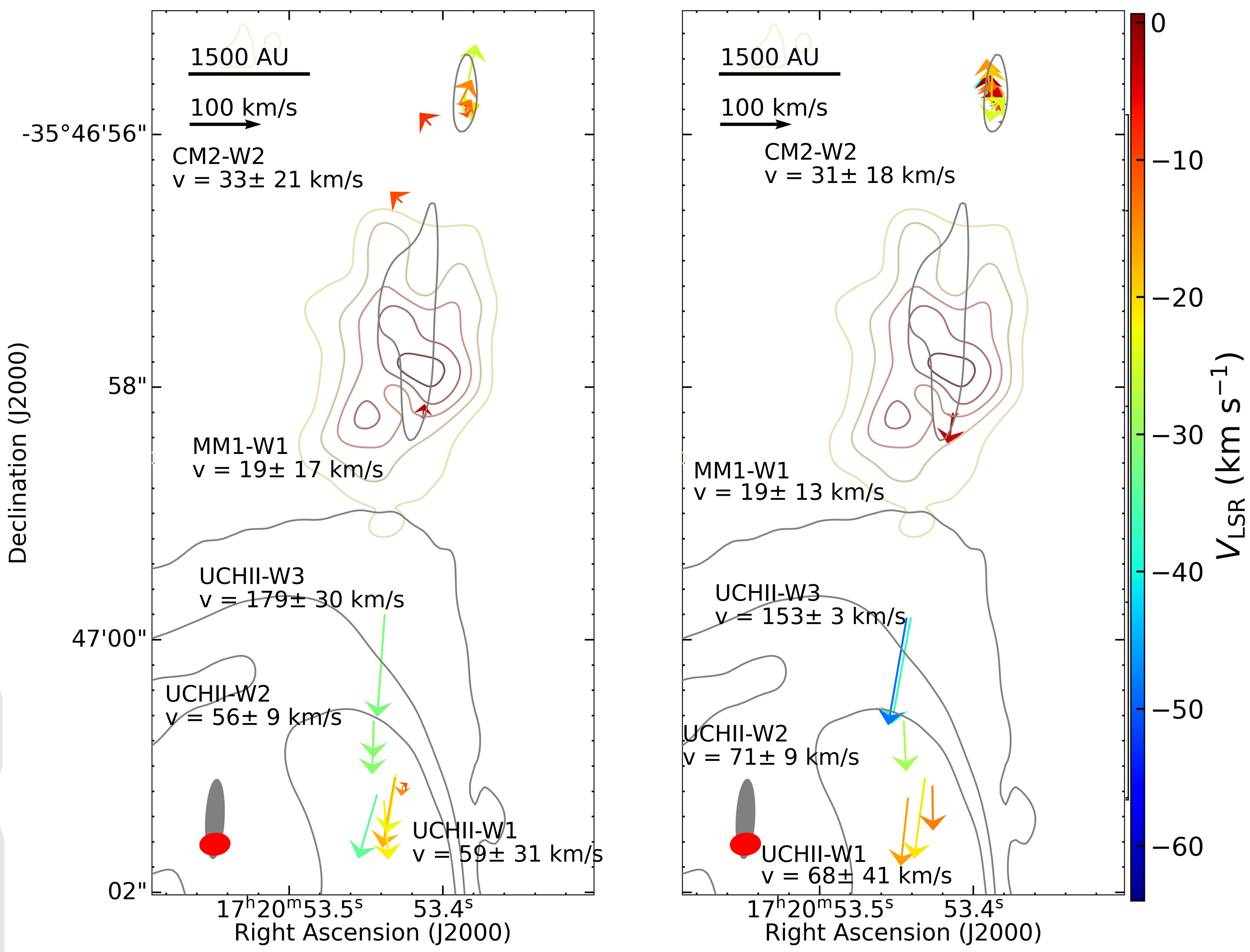

Figure 4: Proper motions of water masers before (2014.7 – 2015.3, left) and after (2015.9 – 2016.2, right) the onset of the accretion burst. The grey contours are JVLA 5 cm continuum and the red contours are ALMA 1.3 mm continuum from Brogan+2018.

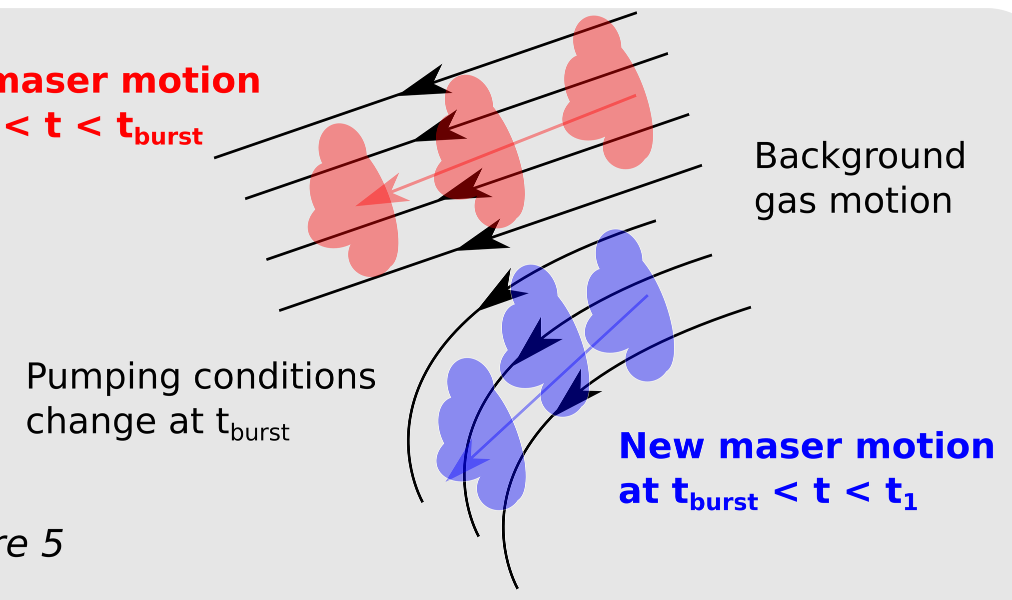

Figure 5

Figure 5 sketches a possible explanation for why the proper motions changed during the accretion burst. Even if the gas motion would not change due the burst, changes in the pumping conditions might cause a different part of the gas to undergo maser action.

Discussion

The change in the CM2-W2 bow shock, the spatial displacement of various maser features (Figure 2), the intrinsic size increase of the brightest feature in CM2-W2 (Figure 3) and the change in the detected proper motions (Figure 4) coincide temporally with the accretion burst (see Figure 1). These changes likely are caused by pump variability induced by the changes in the radiation field due to the accretion burst. At this stage, **there lacks sufficient theoretical explanation** of the flaring and variability of the **collisionally pumped** 22 GHz water masers in NGC6334I. The model of Hollenbach et al. 2013 neglects external radiation fields, and cannot explain the changes in these masers. The explanation proposed by Brogan et al. 2018 assumes radiative heating of the collisional partner H_2 due to the accretion burst, which has not been quantitatively described in HMYSO accretion bursts. The radiative pumping model of water masers by Gray et al. 2022 requires special physical conditions which has not been shown to be the case in this region. In conclusion, proper motions in accretion bursting sources should be lightly interpreted and further theoretical explanation of water masers in time-dependant radiation fields will open avenues for drawing more accurate physical conclusions from 22 GHz water masers.

References

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