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/S1743921323002089

Water maser flare and potential accretion burst in NGC 2071-IR

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Abstract. We monitored 22 GHz water masers in NGC 2071-IR using the Hartebeesthoek 26-m telescope and identified a significant flare (up to 4722 Jy) originating from the 14.4 $\mathrm{km\,s^{-1}}$ feature associated with the protostellar core NGC 2071-IRS1. To determine if the maser flare resulted from an accretion burst, we analyzed related signatures such as simultaneous flaring of other maser species and an increase in infrared luminosity. Near-infrared (Ks-band) observations conducted on 28 December 2019 during the flare, using the Kanata/HONIR telescope, exhibited a 0.2 magnitude increase in comparison to the 2MASS magnitude obtained from observations conducted on 10 October 1999. However, our findings indicate that the flare was attributed to mechanisms other than an accretion burst.

Keywords. Masers, stars: formation, ISM: jets and outflows, ISM: individual objects (NGC 2071)

1. Introduction

The NGC 2071-IR is a star-forming region in the Orion B molecular cloud which is associated with low and intermediate-mass protostars and it hosts protostars (IRS 1 and IRS 3) driving high-velocity bipolar outflows (Cheng *et al.* 2022). Accretion bursts are characterized by a rapid increase in protostellar accretion rate and an increase in luminosity (Stamatellos *et al.* 2011). Accretion burst can drive H_2O maser flares (Bayandina *et al.* 2022) and long-term monitoring observations enable the detection of flares (Burns *et al.* 2022). We used the Hartebeesthoek Radio Astronomy Observatory's (HartRAO) 26-m radio telescope to monitor the 22 GHz H_2O masers in NGC 2071-IR from January 2019 to May 2022 and detected a strong flare in November 2019. During the flare, the Kanata/HONIR telescope made near-infrared observations which revealed the Ks-band magnitude increased by 0.2 mag compared to the 2MASS magnitude. Although short-term water maser flares indicate physical changes in the associated star-forming regions, our understanding of the mechanisms underlying these flares still remains incomplete.

2. An accretion burst in NGC 2071-IR?

The $V_{LSR} = 14.4\,\mathrm{km\,s^{-1}}$ feature peaked at 4722 ± 4 Jy on MJD 58837. The flare profile exhibited a gradual rise over 341 days and a rapid decay over 79 days. By comparing the features in the HartRAO spectra with the interferometric spot maps shown in Figure 1,

https://doi.org/10.1017/S1743921323002089 Published online by Cambridge University Press

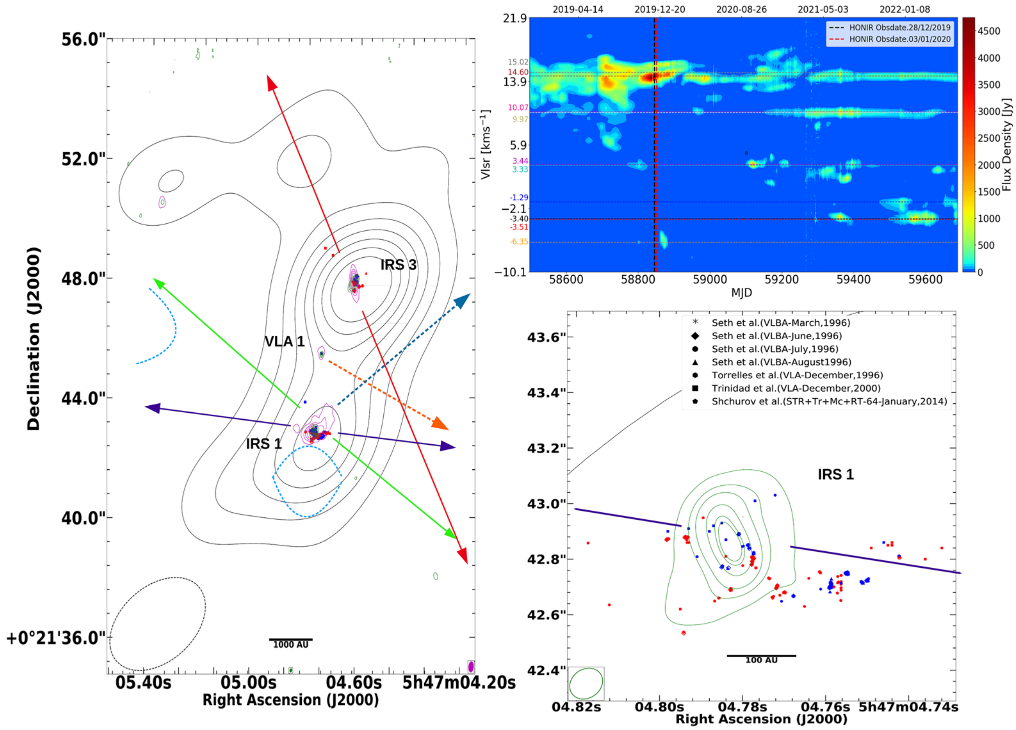

Figure 1. (*Top right*) Dynamic spectra of water masers. The vertical lines represent the Kanata/HONIR observations and the horizontal lines indicate the velocities of the main features. (*Left*) The layout of NGC 2071-IR region with ALMA 0.8 mm continuum (green contours) and the 3.6 cm VLA continuum (magenta contours) overlaid on the ALMA-ACA 0.8 mm continuum (black contours). The arrows represent the outflows in the region and their respective directions, with dashed arrows indicating potential or inferred outflows. (*Bottom right*) A zoom-in on NGC 2071-IRS1. The maser positions from the studies listed in the legend of the bottom right image are coloured blue or red to indicate blue-shifted or red-shifted masers with respect to the cloud velocity (9.5 km s^{-1}).

we determined that the flared feature is associated with IRS 1. Overlaying the water maser positions onto the IRS 1 dust emission revealed a maser distribution that resembles an outflow shell, resembling a "water spout" (Burns *et al.* 2015). To gain insights into the possible mechanism behind the flare, we studied the structure and morphology of the NGC 2071-IR region using archival millimetre and sub-millimetre observations from ALMA and the VLA.

Although significant increases in water maser flux density and luminosity characterize an accretion burst, the attained increment levels by the flare (4722 Jy) and luminosity (0.2 mag) are not significant in this context. Furthermore, the flare profile (gradual rise and sharp decay) deviates from the expected profiles observed in accretion burst sources, which typically exhibit an exponential rise followed by a gradual or steep decay (MacLeod *et al.* 2018). Moreover, the expected increase in luminosity during an accretion burst is typically by a factor of 5 ∼ 10 (Audard *et al.* 2014). Considering the multiple outflows observed in the region (Figure 1 *left*), shocks resulting from the collision of entrained ejecta in the outflow with the ambient cloud may provide a better explanation for the flare.

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We acknowledge funding from DARA (Development in Africa with Radio Astronomy: Newton Fund -UKs (STFC grant ST/R001103/1) and support from HartRAO and the M2O.

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