Bipolar outflow tracing by 22 GHz H_2O masers toward W49 N star-forming region measured with KaVA

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Abstract

We report the updated results of proper motion of 22 GHz H_2O masers which were carried out with KaVA toward the star forming region (SFR) W49 N. The data were observed for 3 epochs during February - May 2017. The number of maser features found in each epoch are 263, 268, and 310 features, respectively. LSR velocities are between -300 to +300 km s^{-1}. The strongest flux is mainly about +0.8 km s^{-1} and its highest flux density ~10,000 Jy. Another strong feature is at the high blue-shifted LSR velocity [-80:-90] km s^{-1} in every epoch. The averaged proper motions in east-west and north-south directions are (-0.352,+0.889) mas yr^{-1}, respectively. All proper motion of features followed a clear pattern, similar to a bipolar outflow, which were tracing the expanding structure from its centre.

Introduction

W49 North (W49 N or G043.16+0.01) is a region inside the high-mass SFR, W49A. It is the most luminous and complex SFR with H_2O masers in our Galaxy (Cheung et al. 1969; Burke et al. 1970). An H_2O maser parallax distance of $11.11^{+0.79}_{-0.69}$ kpc has been measured (Zhang et al. 2013). De Pree et al. (2000) identified nine distinct ultracompact sources in W49 N which were calculated from the low-resolution 7mm image e.g. A, B1, B2, C, D, F, G1, G2a, and G2b. Mostly, the H_2O maser emission in W49 N is found closely associated with the G1/G2 sources and strongest flux is observed around there. Many previous works have been discussed and proposed that the maser emission arises from an outflow centre near the G region, e.g., Gwinn et al. (1992), Honma et al. (2004), and Zhang et al. (2013). Liu et al. (2015) suggested an extremely energetic outflow which is traced by the HCN v2=1 (3-2) line, and the most energetic molecular outflows in the Milky Way. In this work, we will report the morphology of a bipolar outflow which is traced by 22 GHz H_2O masers with KaVA telescopes.

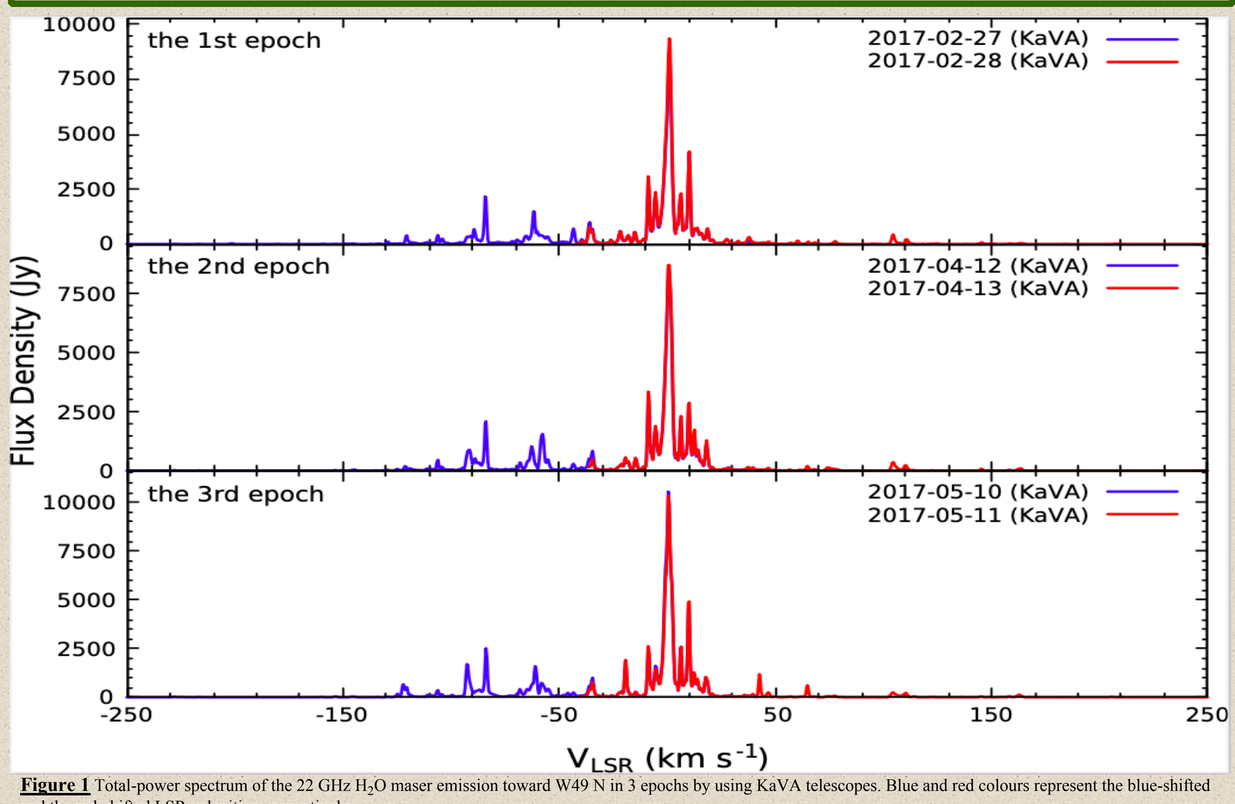

Figure 1 Total-power spectrum of the 22 GHz H_2O maser emission toward W49 N in 3 epochs by using KaVA telescopes. Blue and red colours represent the blue-shifted and the red-shifted LSR velocities, respectively.

Total-power spectrum

The 22 GHz H_2O masers in W49 N were observed by using KaVA telescopes for three epochs i.e. 27-28 February 2017, 12-13 March 2017 and 10-11 May 2017 (hereafter called the 1st, the 2nd and the 3rd epoch, respectively). The LSR velocities are between -300 to +300 km s^{-1}. Its total-power spectrum in each epoch was measured by using the **POSSM** task in AIPS and plotted as shown in Figure 1. Blue and red colours represent blue-shifted and red-shifted emission, respectively. We found the strongest flux was mainly at the centre of group (i.e. 0-1 km s^{-1}), and the highest flux density was ~10,000 Jy. Numerous of strong features were found at the high blue-shifted LSR velocity [-50:-100] km s^{-1} in every epoch. Almost blue-shifted were more favoured and stronger than red-shifted features.

Summary

Current updated results of 22 GHz H_2O masers toward W49 N star-forming region are presented, they were observed by KaVA telescopes during February - May 2017. Number of maser features were increased during the flare event from July 2017 to November 2018. All proper motions of maser features were moving out from its centre and tracing a bipolar outflow morphology with wide open angle ~60-65 degrees to a skyplane. However, we need to add the precession and rotation condition into this model for further improving.

References

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Number of H_2O maser features and their distributions

The number of maser features were found 263, 268, and 310 features, respectively. These features tended to increase, especially in the 3rd epoch which had the highest number during the observation period. These results were in good agreement with the previous work of Volvach et al. (2019) in which they found significant flares of the 22 GHz H_2O maser emission during July 2017 until November 2018. The pointing and phase-tracking center position of the target source, W49N is taken to be RA(J2000) = 19h 10m 13.41s, Dec(J2000) = +09º06'14.3". All position offsets in this report corresponded to the strongest spot and the same spot in each epoch. We plotted only the subset of features which were found from all three epochs as shown in the panel (a) of Figure 2. Their distribution offsets are in a region of size 16 arcsec^2. One maser feature was separated by about (-1.8,0) arcsec. The arc-region was marked inside the dashed box of panel (b) and magnified as shown in panel (c). Mostly the features with red-shifted and blue-shifted LSR velocities were found on the eastern and western part, respectively.

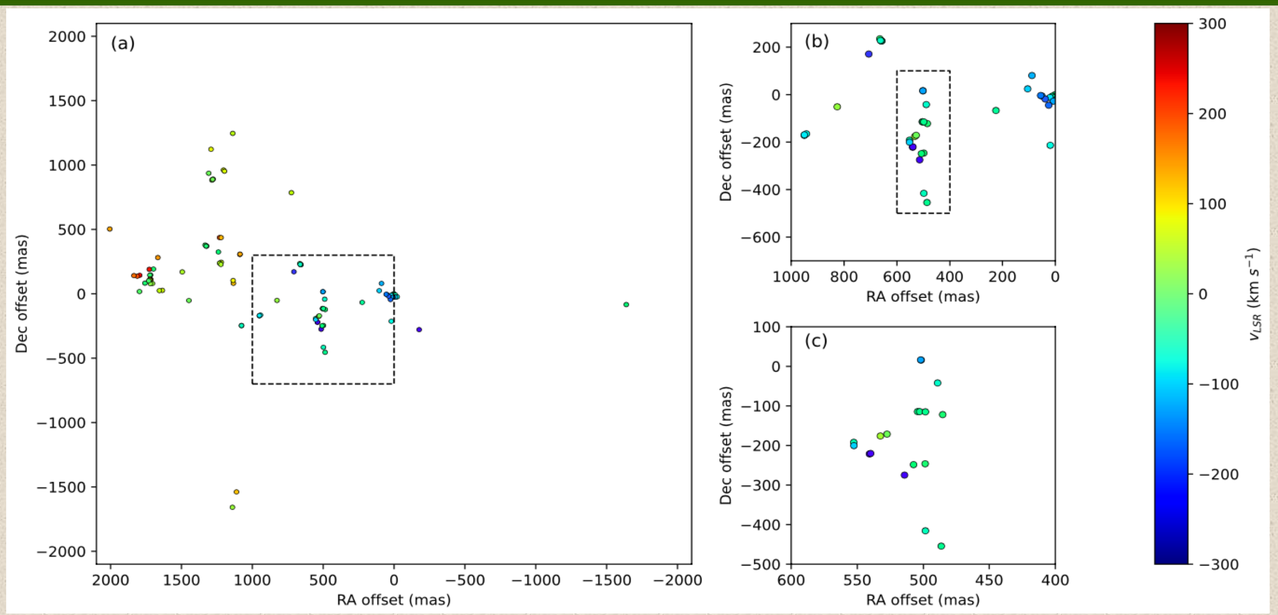

Figure 2 Panel (a) shows the distribution of 22 GHz H_2O maser features toward W49 N which were found in all three epochs and observed by KaVA telescopes. The position offsets were corresponded to the strongest spot in each epoch. Colour shades on the right legend represent the strength of LSR velocities (in the unit of km s^{-1}). The arc-region is inside the dashes box of panel (b) and zoomed in as shown in panel (c).

Proper motions

Figure 3 shows the proper motions of 22 GHz H_2O maser features which were observed by KaVA telescopes during three epochs. The lengths and directions of vectors represent the magnitude of proper motions and direction in RA and Dec. offset, respectively. The colour shades are the averaged LSR velocities in each moving feature. Only 102 features are classified as moving features, identified from all three epochs. All feature distributions were similar to the bipolar outflow structure with 60-65 degrees inclination angle to the plane of the sky. This is strongly supported by previous works e.g. Gwinn et al. (1992) and Zhang et al. (2013). We found mostly the features have been being move out from their weighted position. Proper motion of some features were moving more than 6 mas yr^{-1} around the arc-region and the most eastern part of region.

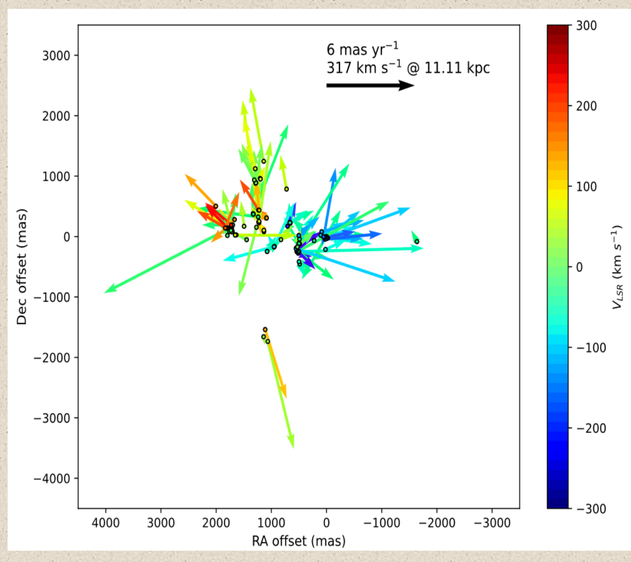

Figure 3 The proper motions of 22 GHz H_2O masers were observed by KaVA telescopes during 3 epochs. Their lengths of arrows are given on the top right of figure which show the strength of proper motion. Colour shades on the right legend represent the strength of LSR velocities (in the unit of km s^{-1}).

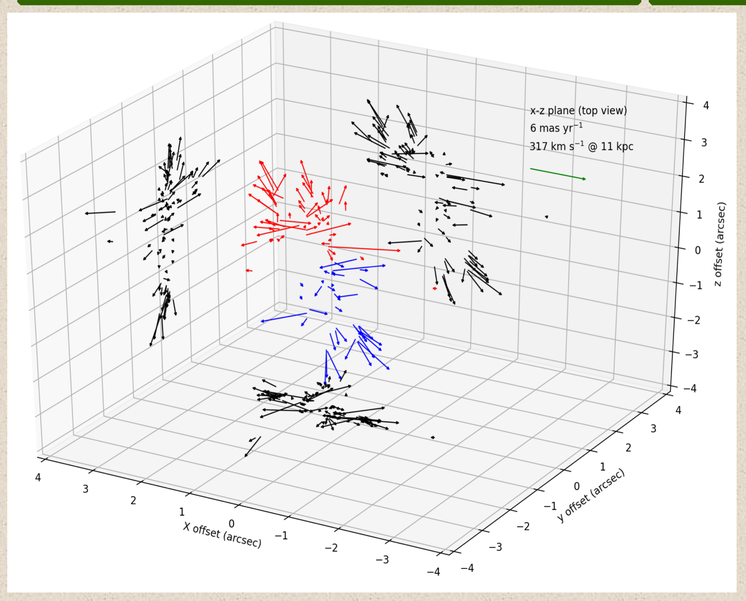

Figure 4 The proper motions of 22 GHz H_2O masers were observed by KaVA telescopes during 3 epochs in 3 dimensions. Red and blue colours represent the quantity of Doppler velocity offset v_{0z} relative to the local standard of rest are more than 0 km s^{-1} and lower than 0 km s^{-1}, respectively. Black arrows are projected in 2D plane.

Modelling of bipolar outflow

According to the limitation of LSR velocities and deep details in parameters which have been used in Zhang et al. (2013), we therefore found that we could more easily compare our results with previous modelling which was performed by Gwinn et al. (1992). We adapted the expanding model without rotation into our results with 4 flow parameters (two velocity parameters and 2 powers). After correcting the accuracy of maser positions with observations by Zhang et al. (2013), we got the solutions, e.g. the position offsets x_0, y_0 relative to the position of strongest spot in each epoch +0.8 km s^{-1} is (+0.378940, -0.254073) arcsec. Velocity offsets (v_{0x}, v_{0y}, v_{0z}), a fitting distance and z-positions were also computed.

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