Cosmic Masers: Proper Motion toward the Next-Generation Large Projects
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Multiple scales of view for outflow driven by a high-mass young stellar object, G25.82–W1

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Abstract. We are investigating the extended outflow from G25.82–W1, which is one of the members of the high-mass protocluster G25.82–0.17. The aim is to study the star-forming environment of G25.82–W1. To identify the outflow, we obtained CO $2-1$ data using the Atacama Large Millimeter/submillimeter Array.

We have identified several spatial and spectral outflows, including: 1) an extended N1–S1 CO outflow, driven by a high-mass young stellar object (HM-YSO) named G25.82–W1; 2) an elongated SE–NW outflow powered by G25.82–W2; 3) a compact and curved N2–S2 CO outflow originating from G25.82–E; and 4) a pair of knotty lobes centered on G25.82–W.

Furthermore, the innermost region of the N1–S1 CO outflow, traced by the 22 GHz H_2O maser, reveals a complex spatial and velocity structure within a 2" from its launching point.

To accurately calculate the properties of the N1–S1 CO outflow, we have utilized an accurate distance measurement of $d = 4.5$ kpc, derived from the annual parallax of the H_2O masers. The outflow rate and force are comparable to those observed in outflows from other HM-YSOs. The physical properties of the N1–S1 CO outflow follow a trend connecting the low and high-mass regimes, supporting the idea that the star-forming mode in G25.82–W1 is likely a scaled-up version of low-mass star formation.

Keywords. ISM: kinematics and dynamics - ISM: jets and outflows - stars: formation - stars: massive

1. Introduction

G25.82–0.17 is one of the high-mass star-forming regions where high-mass protocluster formation is in progress (Kim *et al.* 2020). For simplicity, hereafter, we will refer to G25.82–0.17 as G25.82. Multiple 1.3 mm continuum sources have been revealed in G25.82 through observations conducted by the Atacama Large Millimeter/submillimeter Array (ALMA), indicating the presence of young stellar objects (YSOs) at different evolutionary stages. Among the YSOs in this region, G25.82–W1 is classified as a high-mass YSO (HM-YSO) having a disk-outflow system. Our aim is to understand the star-forming environment of G25.82–W1 through the analysis of multi-scale views of the outflow from this target.

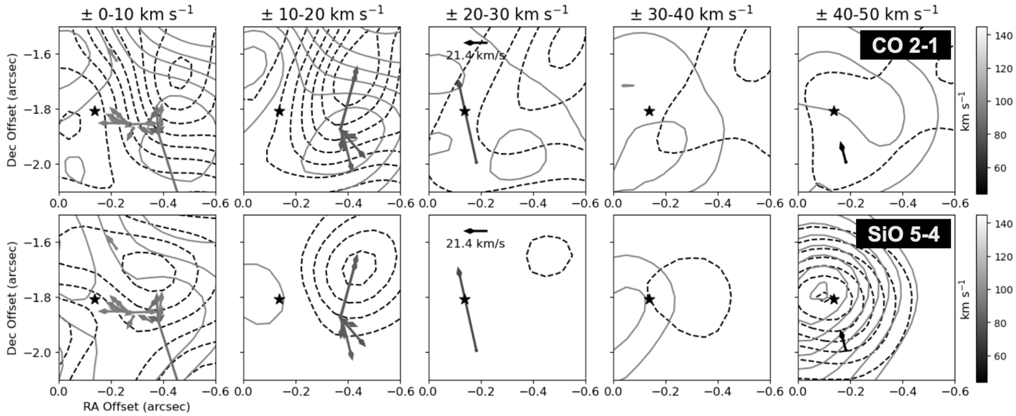

Figure 1. Proper motions of the H_2O masers are shown along with channel maps of CO 2–1 and SiO 5–4. A star indicates the position of G25.82–W1. Each contour map represents the integration of emission over 10 km s^{-1} velocity intervals. The velocity offset from the systemic velocity (93.7 km s^{-1}; Wienen *et al.* 2012) is presented in the upper left corner of each panel. Dashed contours represent the blue-shifted components, while solid contours represent the red-shifted components. In the upper panels, dashed contours are set at [20, 40, 80, 160]σ with 1σ =5.2 mJy beam^{-1}· km s^{-1}, while solid contours are set at [20, 40, 80, 160, 320]σ with 1σ =5.0 mJy beam^{-1}· km s^{-1}. Contours in the lower panels are set at [20, 35, 50, 65, 80, 95, 110, 125]σ with 1σ =3.4 mJy beam^{-1}· km s^{-1} for dashed lines, and 1σ =3.7 mJy beam^{-1}· km s^{-1} for solid lines.

2. Observation and Results

Observations: To investigate the 3D velocity structure of the outflow, H_2O maser monitoring observations were carried out toward G25.82 using two VLBI arrays: VLBI Exploration of Radio Astrometry (VERA) and KaVA (Korean VLBI Network (KVN) and VERA array).

While masers are effective for tracing velocity fields with high resolution, they can only provide sparsely distributed spatial structures. Therefore, it is crucial to study the outflow structures traced by thermal lines in order to bridge the gap between central HM-YSOs and the distribution of maser emissions in the outflows. Through complementary observations, it is also possible to derive quantitative physical properties. For these reasons, we also analyzed CO data, a well-known outflow tracer, obtained using the ALMA.

Results: An extended CO outflowing gas extending in the north-south direction is identified, driven by G25.82–W1 (referred to as the N1–S1 CO outflow). The total velocity range is from 5.9 to 178.6 km s^{-1}. The morphology of both the blue- and red-shifted lobes is characteristic. In the case of the blue-shifted lobe, it is launched toward the west from G25.82–W1 and then extends to the north, while the red-shifted lobe is initially driven toward the east and propagates to the south. The root of the N1–S1 CO outflow is likely connected to the H_2O maser outflow.

In total, 31 H_2O maser features were identified. Most of the identified H_2O maser features have blue-shifted velocities or velocities similar to the systemic velocity of G25.82 (93.7 km s^{-1}; Wienen *et al.* 2012). They are all located within approximately 2” from G25.82–W1.

As shown in Figure 1, H_2O maser features exhibit a close spatial association with the blue-shifted component of the larger-scale outflows observed in CO 2–1 and SiO 5–4 emissions. Dominant proper motions of H_2O maser features are observed in the north-south and east-west directions, where the E–W CO distribution and N1–S1 CO outflow

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coexist. This suggests that H_2O maser features are tracing the innermost region of the N1–S1 CO outflow.

We also fitted the measured absolute positions of the maser features to calculate the annual parallax. The combined parallax is 0.222 ± 0.021 mas, corresponding to a distance of $4.5^{+0.47}_{-0.39}$ kpc. This is comparable to the kinematic distance of 5 kpc from a previous study (Green & McClure-Griffiths 2011). The outflow properties of the N1–S1 CO outflow follow a trend that connects the low and high-mass regimes, supporting the idea that the star-forming mode in G25.82–W1 is likely a scaled-up version of low-mass star formation.

References

Kim, Jungha, Hirota, T., Kim, K., *et al.* 2020, *ApJ*, 896, 127
Green, J. A., & McClure-Griffiths, N. M., 2011, *MNRAS*, 417, 2500
Wienen, M., Wyrowski, F., Schuller, F., *et al.* 2012, *A&A*, 544, A146