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ALMA observations towards G023.01−00.41

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Abstract. We want to understand whether or not young stars, with masses of tens of Solar masses, can form in the disk accretion scenario. This challenge requires to resolve the spatial morphology of gas and dust within a few 1000 au of a massive young stellar object, and to measure the gas kinematics with respect to the star. Also, because the gas kinematics near the young star can be a mixture of rotating, expanding, and infalling motions all together, to separate each velocity component it is necessary to map the emission of various gas tracers, as well as to image the circumstellar gas at different distances from the star. With this in mind, we made use of the Atacama Large Millimeter Array (ALMA) at wavelengths near 1 mm, with the aim to image the dense molecular gas in the vicinity of a well-known O-type young star. We previously observed this source with the Submillimeter Array (SMA), at scales of about 0.1 pc, with the Karl G. Jansky Very Large Array (VLA), at scales of the order of 1000 au, and with the Very Long Baseline Array (VLBA) and European VLBI Network (EVN), at scales of a few au.

1. Introduction

G023.01−00.41 is a luminous ($4 \times 10^4\,L_\odot$) star-forming region at an hot molecular core (HMC) stage, which stands out among the strongest Galactic CH_3OH maser sources, and shows a unique CH_3OH maser fountain spouted from its HMC center. The star-forming region has an accurate distance measurement of $4.59^{+0.38}_{-0.33}$ kpc, determined through the trigonometric parallax of its maser emission (Brunthaler et al. 2009). In the past years, we have performed an observational campaign towards G023.01−00.41 with the most sensitive interferometric facilities available to date (Sanna et al. 2010, 2014, 2015, 2016), including: the SMA at 230 and 345 GHz (half power beam width, HPBW, of $3'' - 0.7''$), the VLA at 8, 22 and 45 GHz (HPBW of $0.3'' - 0.1''$), the VLBA at 1 and 22 GHz (HPBW of $14 - 1$ mas), and the EVN at 6 GHz (HPBW of 8 mas). We made use of this large dataset of observations to provide a comprehensive picture of the outflowing gas from the HMC, and to eventually pinpoint the driving source of the outflow (Fig. 1). Knowing the star position and the outflow direction, we obtained ALMA observations in cycle 3, with the aim to study the gas kinematics in the direction perpendicular to the outflow axis. We targeted high density molecu-

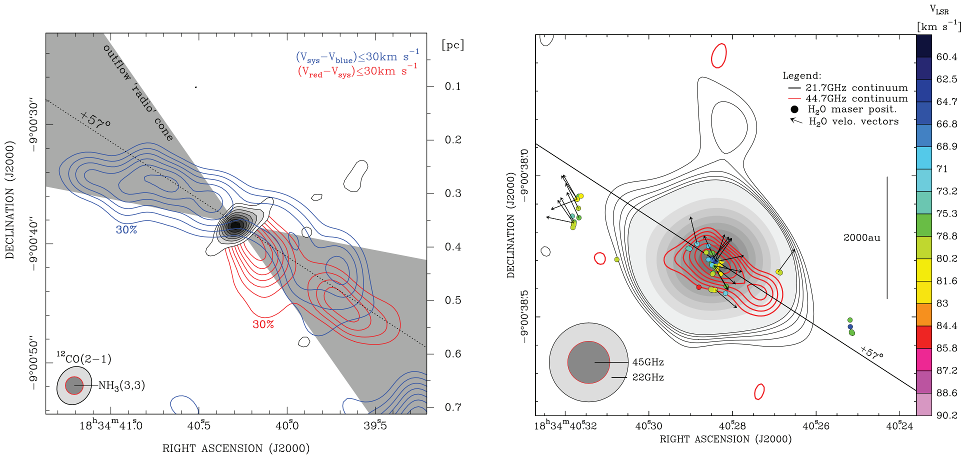

Fig. 1. Outflow emission driven by an O-type young star in the star-forming region G023.01−00.41 (adapted from Sanna et al. 2016). **Left:** Spatial morphology of the ^{12}CO (2–1) outflow emission observed with the SMA across several tenths of parsec (right scale). To outline the compact component of the outflowing gas, CO contours start at 30 % of the peak emission, for the blue and red-shifted emission separately, and increase by 10 % steps. We detected CO gas (LSR) velocities up to 30 $\mathrm{km\,s^{-1}}$ from the rest velocity of the central core. Grey contours at the center of the bipolar outflow show the distribution of warm and dense NH_3 gas heated by the central star. NH_3 contours start at 4 σ by 1 σ steps (Codella et al. 1997). For comparison, the grey shadow marks the opening angle of the radio jet emission detected near the massive star (right panel). Synthesized beams are drawn at the bottom left corner. **Right:** Spatial morphology of the radio (free-free) continuum emission within a few 1000 au from the massive young star (yellow star). These observations were conducted with the VLA at both 22 GHz (black contours and grey tones) and 45 GHz (red contours). Contours start at 3 σ by 1 σ steps. The ionized gas clearly outlines the route (position angle of +57°) of the jet emission at the base of the large-scale molecular outflow. The 22.2 GHz H_2O maser cloudlets (spots) detected with the VLBA, together with their proper motions (arrows), mark shocked gas layers associated with the jet expansion (Sanna et al. 2010). Maser positions have been corrected for the apparent motion of the source (at variance with Sanna et al. 2016). The color of each spot indicates the gas LSR velocity as given by the color bar. In this panel, we plot the star position determined through our new ALMA observations. Synthesized beams are drawn at the bottom left corner.

lar tracers in band 6, with a linear resolution of several 100 au, and a line sensitivity of 1 K per spectral channels of a few 0.1 $\mathrm{km s^{-1}}$. The final goal of these observations has been to provide clear proof of gas rotation in the vicinity of an O-type young star.

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