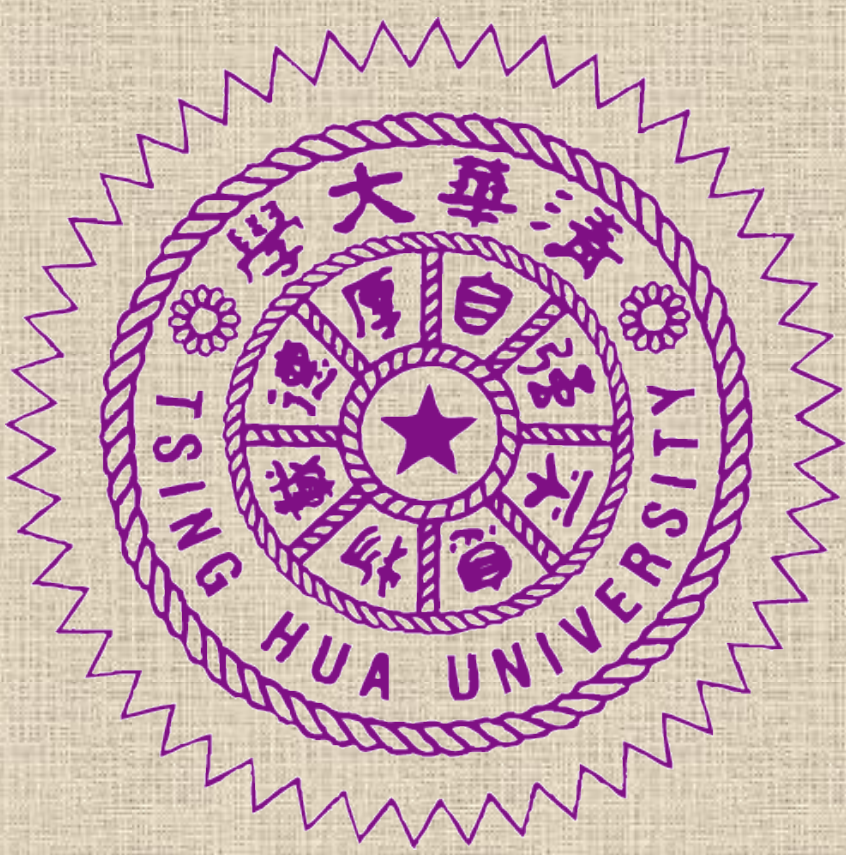


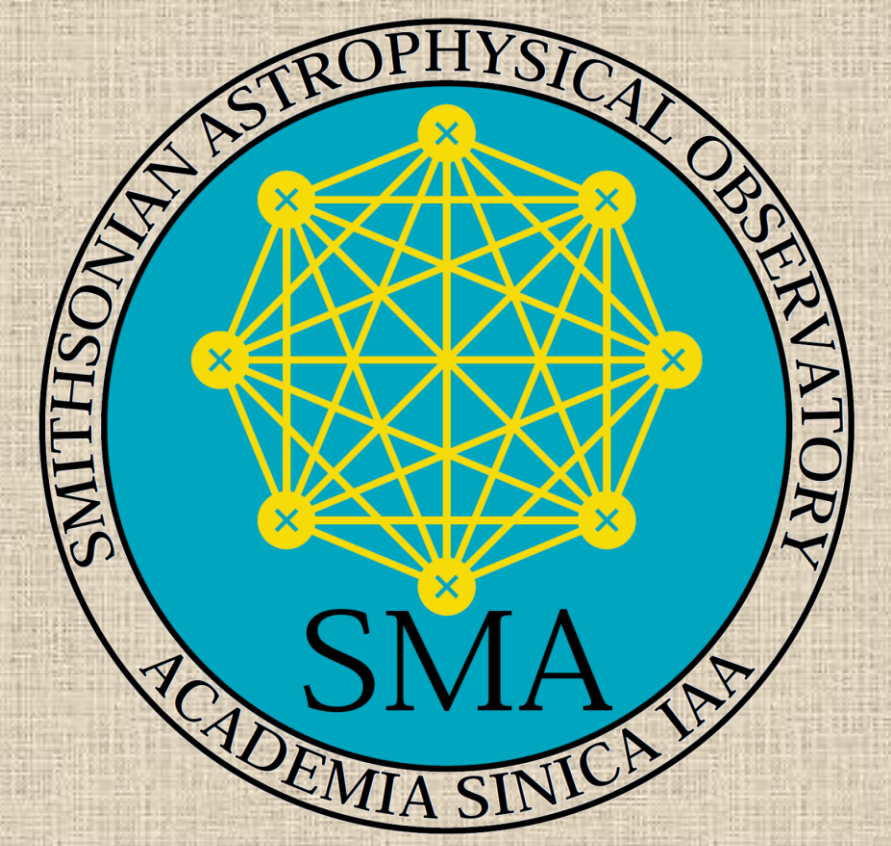
Extreme High Velocity Components in Quadrupolar Outflow of NGC 1333 IRAS 2A



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Abstract - We have mapped a quadrupolar outflow of NGC 1333 IRAS 2A with the Submillimeter Array in CO (2-1) and SiO (5-4) at an angular resolution of 3". The quadrupolar outflow consists of an extended north-south outflow and a collimated east-west outflow. Our observations newly discovered extreme high velocity (EHV) components (≥ 20 km/s) within a north-south wide-angle cavity. These jet-like EHV components are detected near the YSO and outflow vertexes and imply a jet axis along the presumable cavity shell. On the other hand, the east-west outflow shows a bow-shock delineated by standard high velocity ($\lesssim 20$ km/s) CO emission and an off-axis EHV component in the west lobe. In the southern EHV component, two distinct kinematic features show an outflow overtaking process with an interface coincided with nearby shocked H₂ emission. Considering shock dynamics of these EHV components, we witnessed an ongoing jet interaction with earlier ejected materials and surrounding envelop.

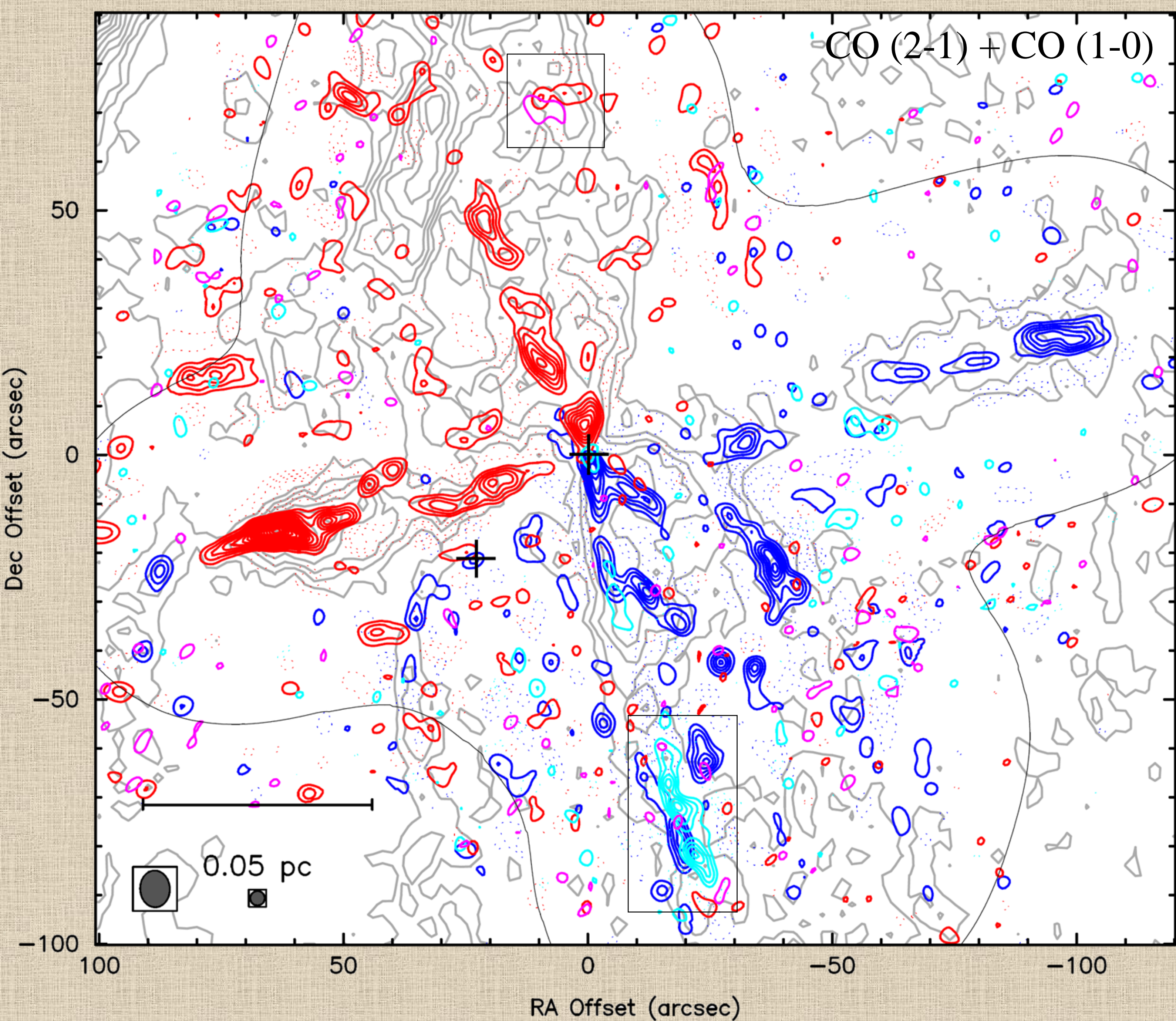


Figure 1 – SMA CO (2-1) integrated map for SHV (red and blue contours) and EHV (magenta and cyan contours) components overlaid with BIMA CO (1-0) integrated map for SHV components (grey contours). The cross marks indicate the position of mm sources, IRAS 2A (center) and IRAS 2B.

Outflow Morphology

Quadrupolar outflow driven by a low mass Class 0 protostar, NGC 1333 IRAS 2A ($d \sim 220$ pc), shows a collimated east-west outflow and an extended north-south outflow in BIMA CO (1-0) integrated map (Fig. 1, grey contours; Engargiola et al. 1999). Our SMA CO (2-1) observations discovered jet-like extreme high velocity (EHV) components ($V_{LSR} \geq 20$ km/s) out of standard high velocity (SHV) components ($V_{LSR} \lesssim 20$ km/s) along each outflow directions with an angular resolution of $\sim 3''$ (Fig. 1, color contours). Near the outflow vertex and YSO, each components shows a secondary line profile with peak velocity offset of ~ 40 km/s in CO spectrum, which is the way to identify EHV components (Bachiller et al. 1999). Central EHV component is observed in multiple line emissions (Fig. 3) while the other components show only CO (2-1) emission. In addition, these EHV components are well aligned with nearby IRAC 4.5 μ m emissions (Fig. 2 & 3, grey scale) which is thought to be indicative of shock activity.

Shock Dynamics

In the southern EHV component, two distinct kinematic features are found with a velocity jump at the interface (Fig. 2c; black arrow). We suggest that the faster upstream component is in the process of overtaking the slower downstream component and generating a shock of wide velocity spread (Fig. 2d). A shocked H₂ emission also locates near this hypothesized shock interface. On the other hand, the northern EHV component shows a large velocity spread (Fig. 2b) without obvious velocity difference (Fig. 2a). This blob is most likely a post-shock gas clump and agree well with a nearby shocked H₂ emission.

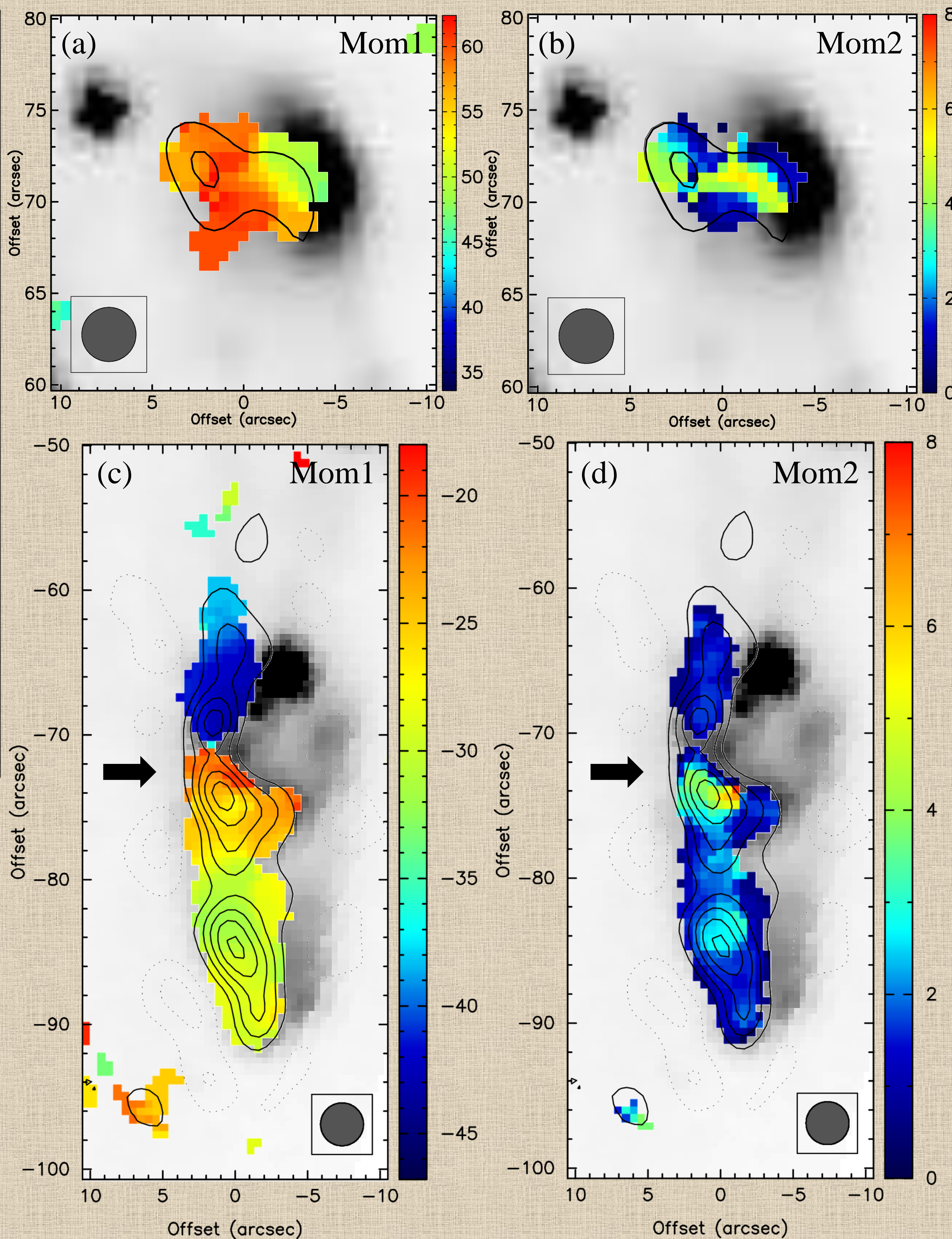
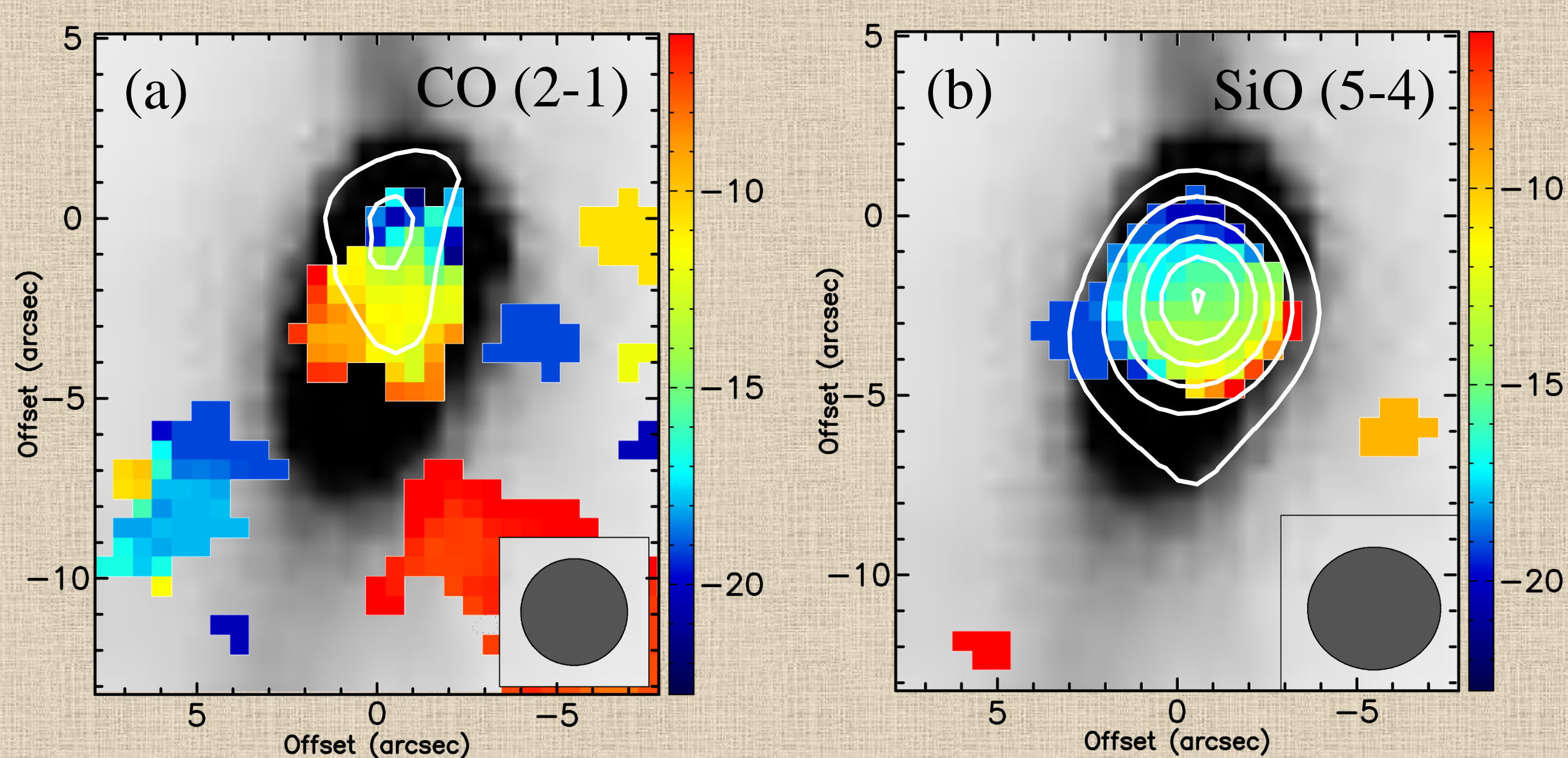


Figure 2 – (a) & (c) : CO (2-1) intensity-weighted mean velocity (moment 1) maps of northern (rotated by -7°) and southern EHV (rotated by -15°) components. (b) & (d) : CO (2-1) intensity-weighted velocity dispersion (moment 2) maps of northern and southern EHV components. Black arrow indicates the interface of velocity jump.

Ongoing Jet Activity

In the central EHV component, a blue-shifted wide velocity spread are presented with a nearby shocked H₂ emission (Fig. 3). This component implies a new outflow activity near the YSO without any kinematic interpretations due to an unresolved structure. Considering these EHV components along north-south direction, we suggest an ongoing jet activity with a jet axis aligned with presumable CO (1-0) cavity shell.

Summary

Our SMA observations mapped quadrupolar outflow of NGC 1333 IRAS 2A with two newly discovered EHV components near the north-south outflow vertexes. We suggest an outflow overtaking process in the southern component and a post-shock gas clump in the northern component. The central component, on the other hand, implies a new outflow activity near the central YSO. Considering shock dynamics of each EHV components, we witnessed an ongoing jet interaction with earlier ejected materials and surrounding envelop.

References

1. Bachiller, R., & Tafalla, M. 1999, The Origin of Stars and Planetary Systems (NATO ASI C, 540; Dordrecht: Kluwer), 227
2. Engargiola, G., Plambeck, R.L., 1999, In: The Physics and Chemistry of the Interstellar Medium, Ossenkopf V., Stutzki J., Winnewisser G. (eds.), Herdecke: GCA-Verlag, 291

Figure 3 – (a) : CO (2-1) moment one map of central EHV component (rotated by -15°). (b) : SiO (5-4) moment one map of central EHV component.