Probing the Inward Motion in the Class 0 Protostar NGC 1333 IRAS 4A with ALMA

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Although gravitational collapse has been widely accepted from the theoretical viewpoints of star formation, the observational study of infall motions is usually a challenge. A major issue is that such kinematic features at relatively low velocity are easily contaminated by other star formation activities. The inverse P-Cygni line profile, i.e., the redshifted self-absorption of spectral lines, obtained from high-resolution interferometric observations is recognized as a more robust probe of infall motions. Here we report ALMA observations towards the Class 0 protostar NGC 1333 IRAS 4A to explore its inward motion down to a scale of 50 AU, sufficient to resolve the kinematics of the proto-binary system IRAS 4A1 and 4A2. With previous known inverse P-Cygni profile seen in one H2CO transition, IRAS 4A has been identified as an ideal object for probing infall motions, although the possibility of the absorption features being caused by an unrelated foreground absorption layer can not be completely ruled out. Thanks to the flexible spectral capability, we simultaneously capture five H2CO transitions with various energy levels, which presumably trace different layers of infall motions. Our ALMA results demonstrate strong evidence of accretion toward 4A2 region. We extract with radiative transfer models the physical parameters of the infalling gas from the observed spectra, and discuss whether the spatial distribution of infall speed is consistent with free-fall, and explore the role of forces other than gravity (such as magnetic field) in the collapse dynamics.