Observing Kinematics on AU-scales in B335 with ALMA


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The relationship between outflows and the formation of protoplanetary disks is still not entirely understood. Using ALMA in its longest-baseline configuration, we observed CO isotopologues, SiO, SO2, and CH3OH (in band 6) in the vicinity of the isolated protostar, B335, at a resolution of ~3 au (0.03′′).

We also combined our observations with archival data to produce a high-fidelity image covering scales up to 700 au (7′′). B335 is known to power a large (>104 pc) outflow (HH 119), to still possess a massive envelope, and to demonstrate hot corino chemistry (e.g. “COMs”). B335 is ~100pc away, so 0.01″ ~ 1 au.

Evidence for Rotation

- CH3OH and SO2 trace a rotating region <16 au in diameter centered on the peak.
- LTE analysis of the CH3OH lines gives a temp. of 220±20 K and col. density 6.8±0.1 x 1018 cm⁻².
- From high-velocity 12CO features, the outflow launching radius is estimated to be <0.1 au.

Results

- B335 has a large-scale outflow & cavity, but we do not find any significant evidence for a Keplerian disk down to scales of 3 au!
- CH3OH is detected within 30 au of the cont. peak; SiO also detected close to the peak, but extended along the outflow.
- CH3OH and SO2 trace a rotating region <16 au in diameter centered on the peak.
- LTE analysis of the CH3OH lines gives a temp. of 220±20 K and col. density 6.8±0.1 x 1018 cm⁻².
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ALMA Band 6 observations at longest baselines (2017.1.00288.S), including CO isotopologues (2-1), SiO (5-4), and serendipitously SO2 [22(2,20)-22(1,21)], four lines of CH3OH.

Combined with archival 12CO data from 2013.1.00879.S (ang. res. ~3″) and 2016.1.01552.S (ang. res. ~0.7″ & 1.5″).

Multi-scale cleaning (Briggs, robust = 0.5) took ~800 wall-clock hours; a few channels still did not reach desired cleaning threshold of 3 mJy/beam.

Outstanding Questions

- The region surrounding the cont. peak is optically thick; what would higher-resolution, longer-wavelength observations reveal?
- Large, powerful outflows are typically associated with large, Keplerian disks, but no such disk is seen in B335! What’s going on?
- B335 is young (~10⁴ yr). Are we seeing the first stages of disk formation? Or is B335 an example of magnetic braking in action (e.g. Yen+ 2018, A&A, 615, A58; Maury+ 2018, MNRAS, 477, 2760)?

Acknowledgements: This work made use of data from ALMA projects 2013.1.00879.S, 2016.1.01552.S, and 2017.1.00288.S, and data acquired with the APEX telescope. ALMA is a partnership of ESO, NSF and NINS, together with NRC, MOST and ASIAA, and KASI, in cooperation with the Republic of Chile. The Joint ALMA Observatory is operated by ESO, AUI/NRAO and NAOJ. JPR was supported by the Virginia Initiative on Cosmic Origins (VICO), and by the NSF under grant nos. AST-1910106 and AST-1910675. PB acknowledges support from the Swedish Research Council (VR) through contract 2017-04924.