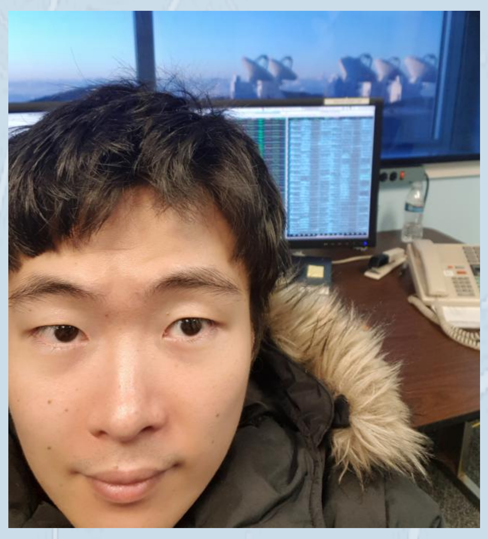
Early Planet Formation in Embedded Disks (eDisk): A first look at the Class 0 protostar IRAS 16253-2429



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Introduction —— protostar at the low-mass end

Protostars at the low-mass end are a key to bridge star formation and BD formation ($< 0.08\ M_{\odot}$). This mass range also includes the majority of stars (Fig. 1).

We aim to obtain a picture of protostars at the low-mass end as a part of the ALMA large program "eDisk". A target, IRAS16253 ($d = 139$ pc), is suggested as such a protostar; however, its central mass is not well constrained in previous works ($0.1\ M_{\odot}$; Tobin+ '12, $0.02\ M_{\odot}$; Yen+ '17, $0.028 - 0.12\ M_{\odot}$; Hsieh+ '19).

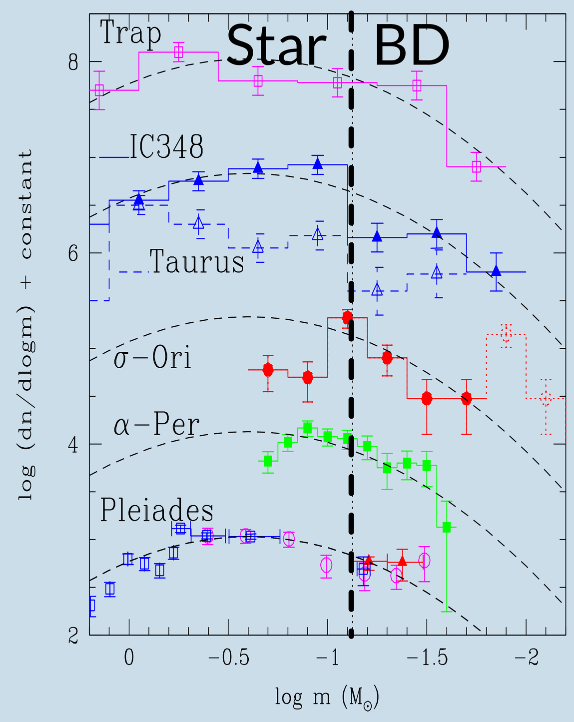


Figure 1. (Chabrier '05) Initial mass function (IMF) for young clusters. The vertical dashed line is at the boundary between hydrogen burning stars and brown dwarfs (BDs).

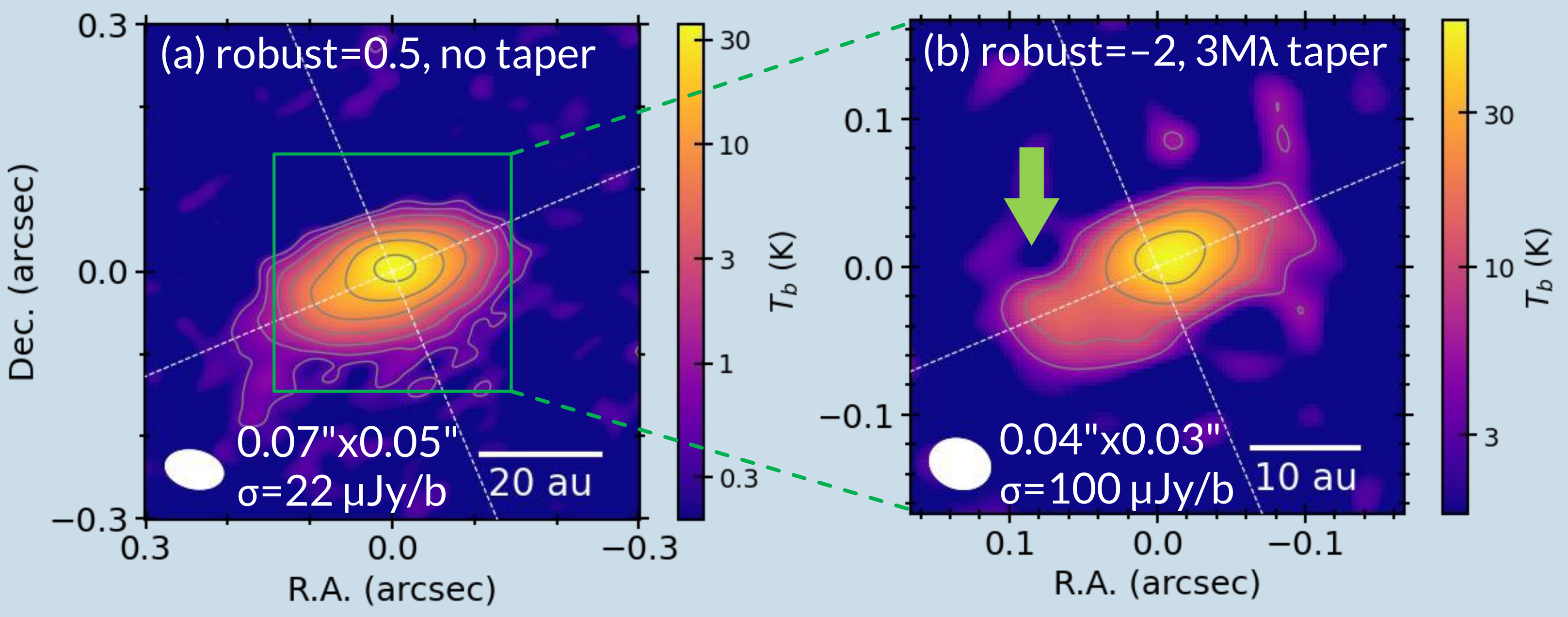


Figure 2. The 1.3 mm continuum images with different robust and taper parameters.

Results —— 1.3 mm continuum (Fig. 2)

- (a) The deconvolved size is 15×6 au (P.A.=113°). $M_{gas} = 1.4\times10^{-3}\ M_{\odot}$ estimated from the flux density at $T = 42$ K.
- (b) The image at a higher angular resolution shows a secondary component at ~14 au from the center along the major axis.

Results —— ^{12}CO, ^{13}CO, C^{18}O $J = 2 - 1$ lines (Fig. 3)

- The ^{12}CO outflow is inclined by $i = 65°$ (Yen+ '17).
- A velocity gradient along the major axis on the <100 au scale.

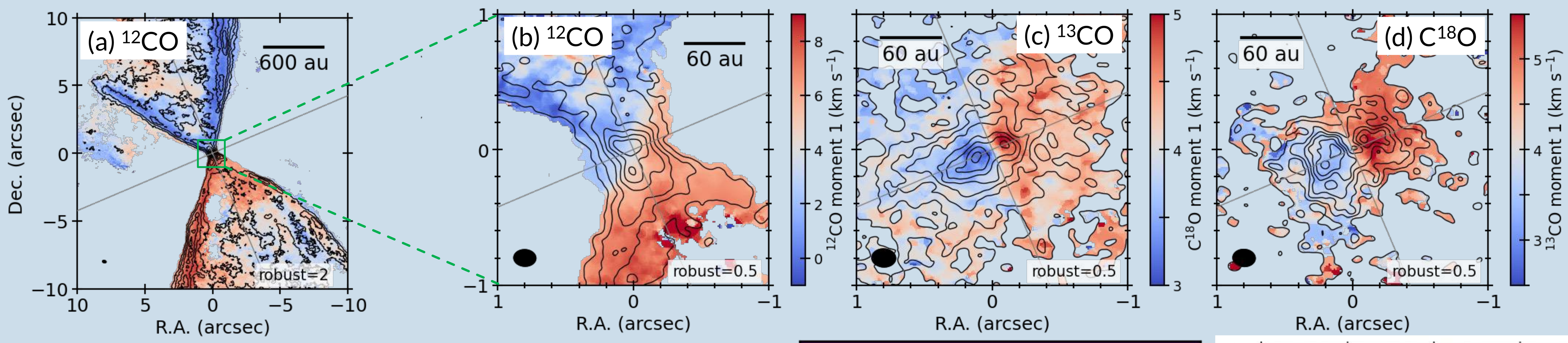


Figure 3. Integrated intensity (contours) and mean velocity (color) maps of CO isotopologue lines.

Discussion —— disk and envelope (Fig. 3)

- We have identified the Keplerian disk ($V_{\rm rot} \propto R^{-0.5}$) for the first time, by applying the edge-ridge method to Fig. 4(a). →M_{*}~0.14 $M_{\odot}$
- The C^{18}O and ^{13}CO emission is consistent with the UCM envelope with the centrifugal radius $R_c = 16$ au (Fig. 4b).

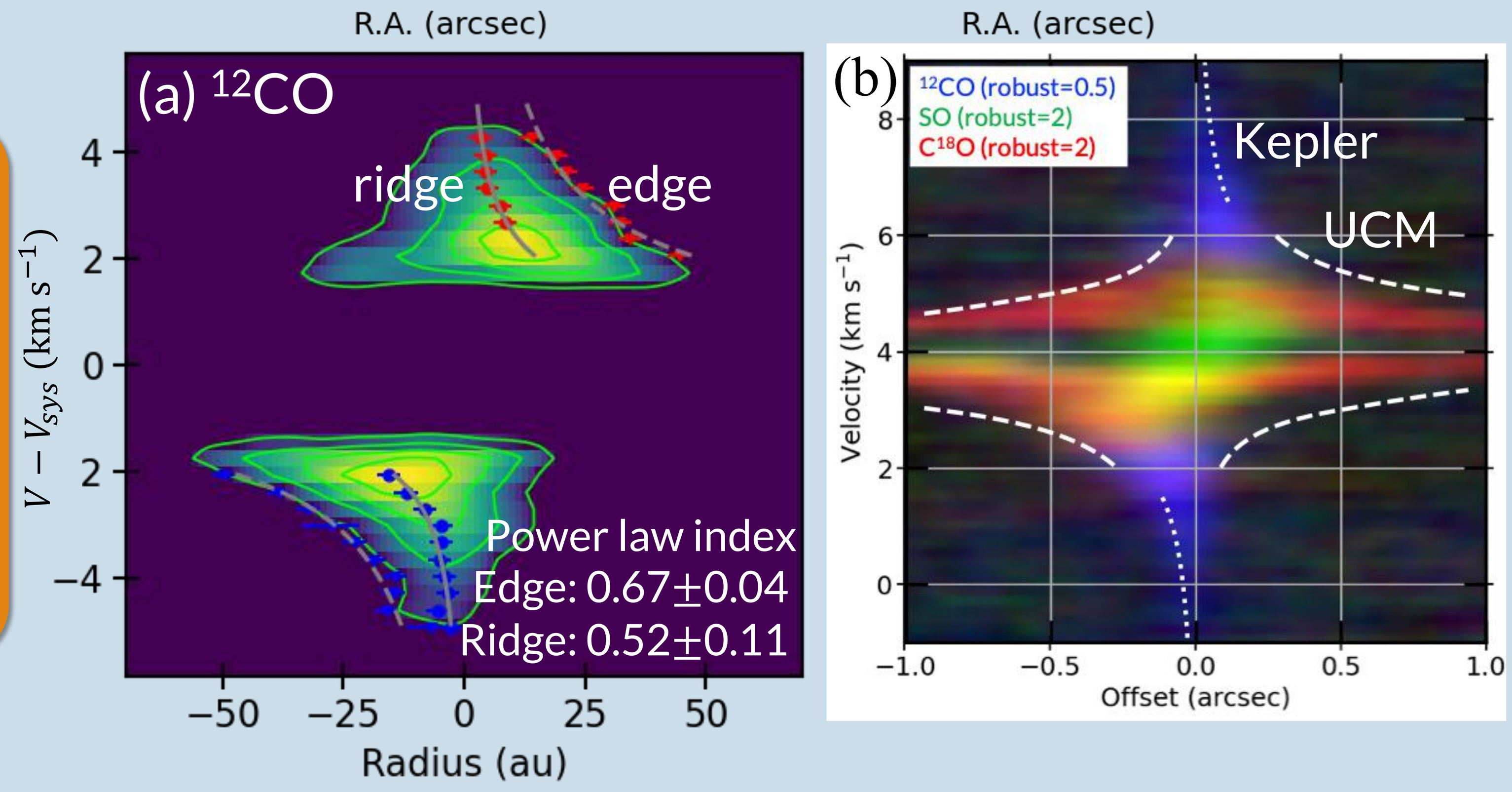


Figure 4. Position-Velocity diagrams along the major axis. (a) Points are ridge and edge radii at each velocity. (b) Dotted line is the Keplerian curve with M_{*}~0.14 $M_{\odot}$. Dashed line is the max velocity of the UCM envelope model (Ulrich '76, Cassen & Moosman '81) with $R_c = 16$ au.

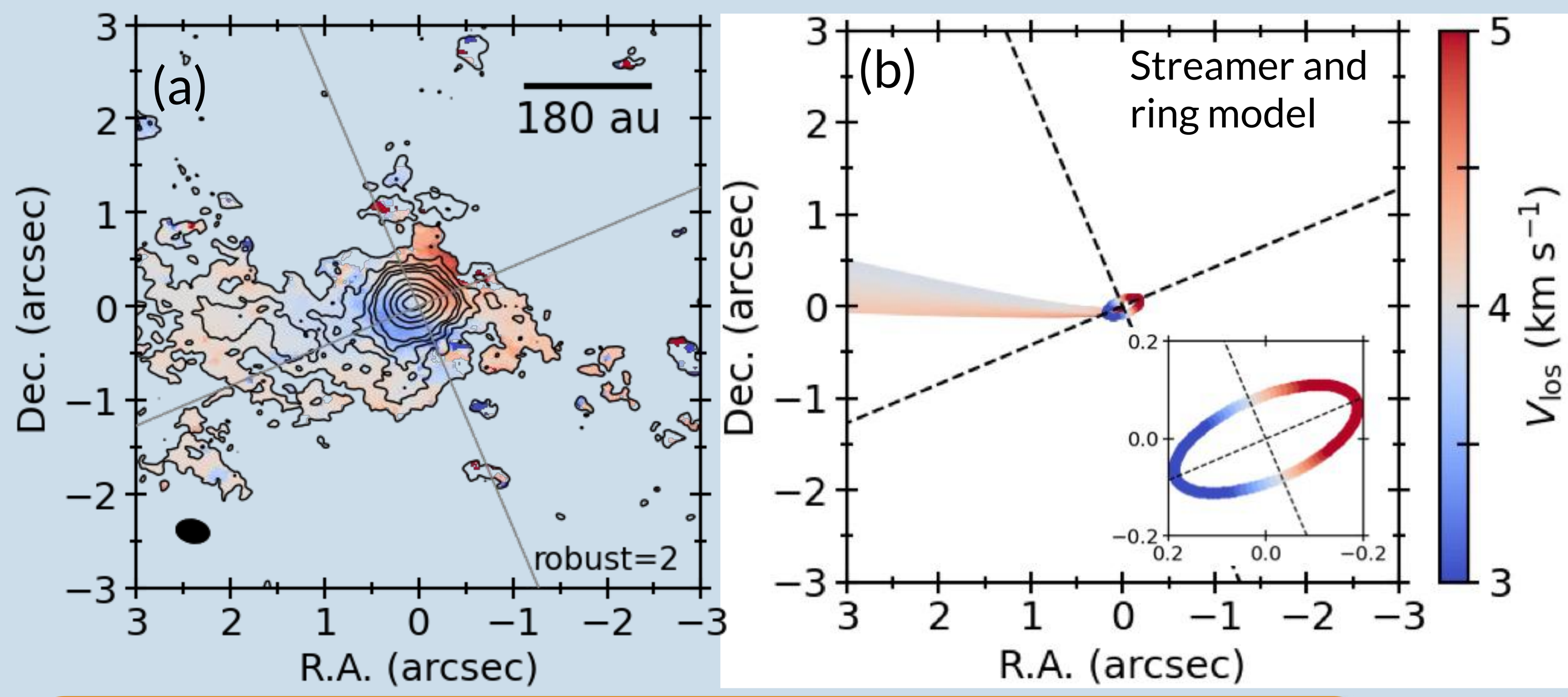
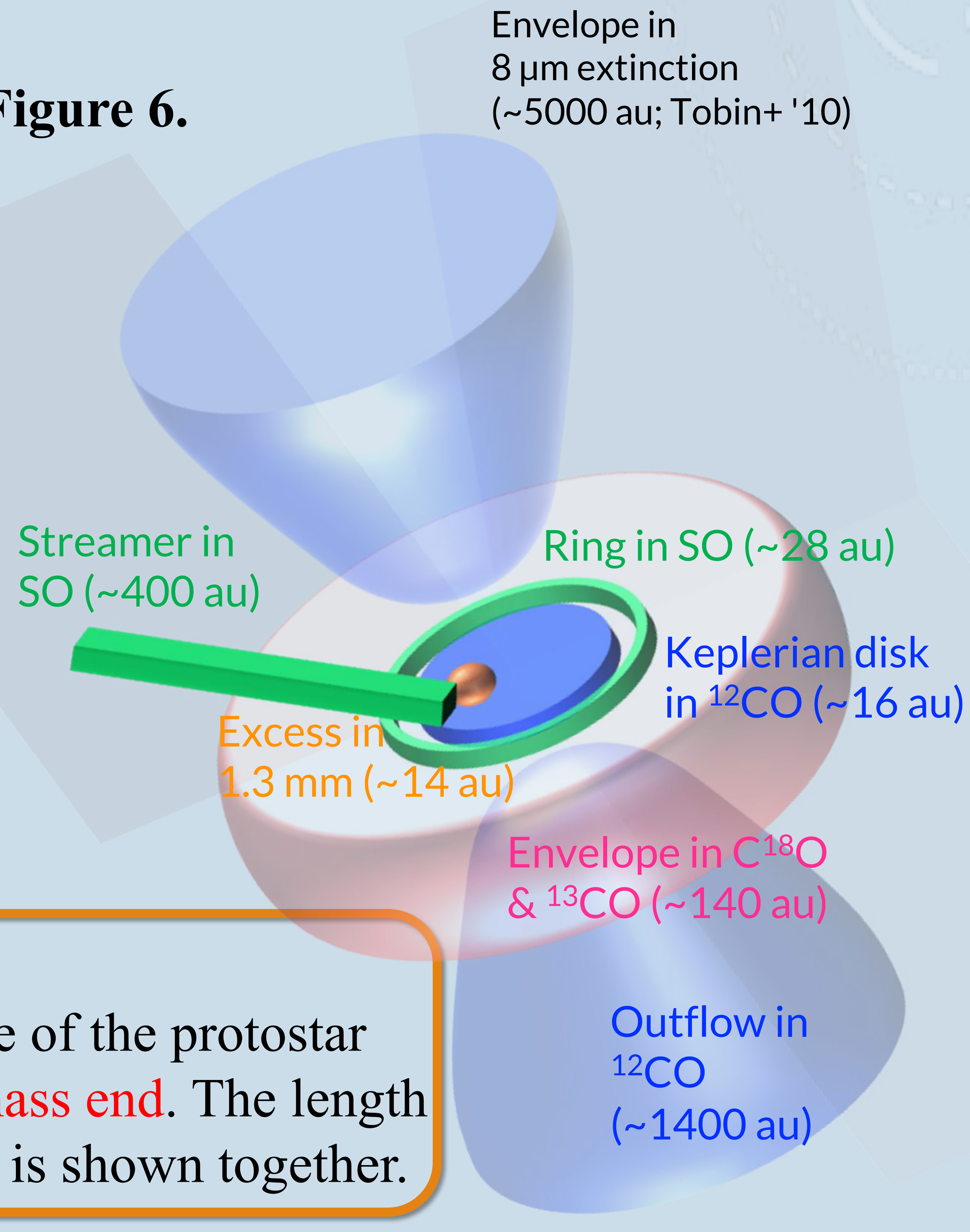


Figure 5. (a) Integrated intensity (contours) and mean velocity (color) maps in the SO line. (b) Line-of-sight velocity of a streamer extracted from the UCM envelope and a ring at $R_{\rm ring} = 28$ au.

Figure 6.



Discussion —— streamer and ring in the SO line (Fig. 5)

- The velocity of a structure extended to the east cannot be explained by the outflow or rotation. A possible interpretation is a ballistic streamer not on the midplane.
- Fig. 4(b) shows a linear velocity gradient in the SO line, implying a ring produced by accretion shock ($R_{\rm shock}$~$1.5R_c$; Shariff+ ' 22).

Conclusions (Fig. 6) ——

We have revealed a picture of the protostar IRAS165253 at the low-mass end. The length or radius of each structure is shown together.

References Cassen & Moosman (1981), Icarus, 48, 353; Chabrier (2005), ASSL, 327, 41; Hsieh et al. (2019), ApJ, 871, 100; Shariff et al. (2022), MNRAS, 514, 5548; Tobin et al. (2010), ApJ, 712, 1010; Tobin et al. (2012), ApJ, 748, 16; Ulrich (1976), ApJ, 210, 377; Yen et al. (2017), ApJ, 834, 178