L1448N: Kinematic Models of a Gravitationally Unstable Disk

Nickalas Reynolds (OU); John Tobin (OU); Patrick Sheehan (OU); Leslie Looney (Illinois); Dominique Segura-Cox (MPE); Kaitlin Kratter (Arizona); Zhi-Yun Li (Virginia); Claire Chandler (NRAO);Michael Dunham (SUNY-Fredonia); Robert Harris (Illinois); Laura Perez (U. Chile); Carl Melis (UCSD); Sarah Sadavoy (CfA); Erin Cox(Illinois)

L1448 IRS3A+B Continuum

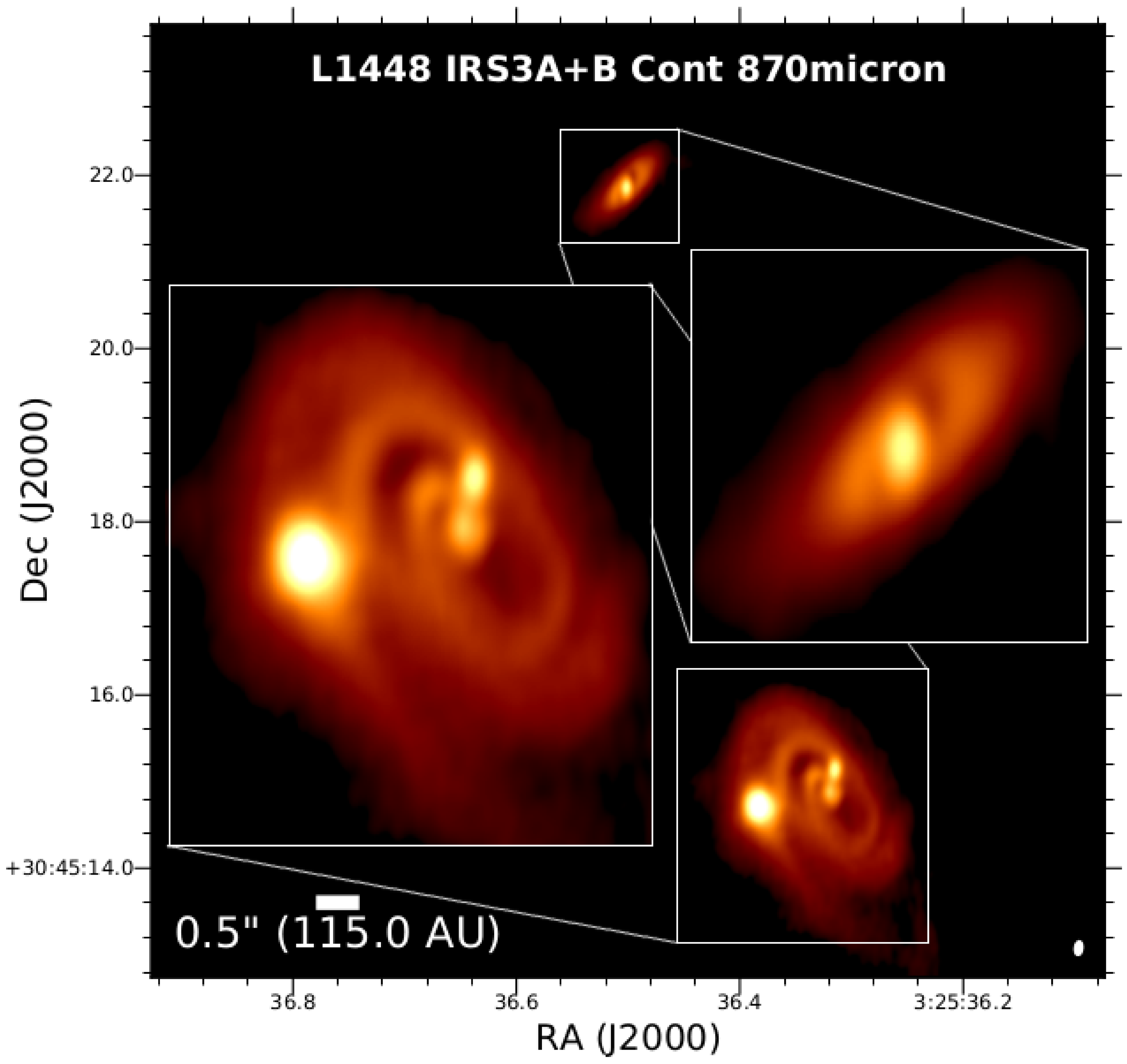

Figure 1: Robust 0.5, IRS3B exhibits multiple spiral arm structure, originating from the inner binary (~60 AU) and extended to the embedded tertiary source (~180 AU). The wide companion IRS3A also has spiral arm structure. The blue crosses represent protostar positions and the green crosses represent kinematic centers based on modelling. Lower-right is the synthesized beam width ($0.11'' \times 0.05''$).

Introduction

During the VLA Nascent Disk and Multiplicity (VANDAM) survey, a compact (<200 AU) triplet was discovered, L1448 IRS3B. However, the exact formation mechanism and evolution steps of these close (<500 AU) multiple systems is not completely understood. Close multiple systems can be produced from massive disks that become gravitationally unstable. Massive disks are thought to be formed via the build up of in-falling material from the collapsing protostellar envelope. When massive enough, the self-gravity of the disk can trigger the formation of spiral structure and fragmentation. ALMA Cycle 4 observations resolved spiral structure originating from an inner (~60 AU) binary with a third protostellar companion embedded within one of the arms whose velocity is consistent with the Keplerian rotation of the disk. A wide companion (~1800 AU), IRS3A, was also within the field of view, revealing its own spiral structure, but the major axis of the disk around IRS3A is orthogonal to the axis of the disk around IRS3B. We have modeled these two sources using RADMC-3D to further explore the stellar and disk parameters. We have found IRS3B inner protostars consistent with a mass of $\sim 0.9 M_\odot$ and IRS3A consistent with $\sim 1.4 M_\odot$.

Conclusion

We present the results of our kinematic models for the high spectral and spatial resolution of the L1448 IRS3A+B system. The circumbinary disk is gravitationally unstable at the radius of the tertiary IRS3B companion and as evident by the low binary mass, more unstable than was previously calculated [Tobin et al. 2016]. Coupling the tertiary's location within the region of gravitational instability and it's orbit falls within the plane of the disk, this supports the tertiary forming with the structure. Holistic modelling is critical for understanding the formation mechanisms and evolution timelines for protostellar objects. L1448 IRS3A+B could further provide unprecedented insight into the evolution of gravitationally unstable disks and compact companion systems.

Results

Kinematic Parameters							
Position	SM[1] ($M_\odot$)	V_{sys} ($km\,s^{-1}$)	i	pa	DR[2] (AU)	FD[3] (Jy)	DM[4] ($M_\odot$)
IRS3A	1.4	5.17	70	210	2.0×10^{-3}	1.8×10^{-1}	0.00038,0.0026
IRS3B	0.9	4.75	70	120	1.8×10^{-3}	1.67	0.0048,0.0056

[1]: Stellar Mass, [2]: Disk Radius, [3]: Continuum Flux Density, [4]: Disk Mass estimated from continuum by hand vs model

Kinematic Models

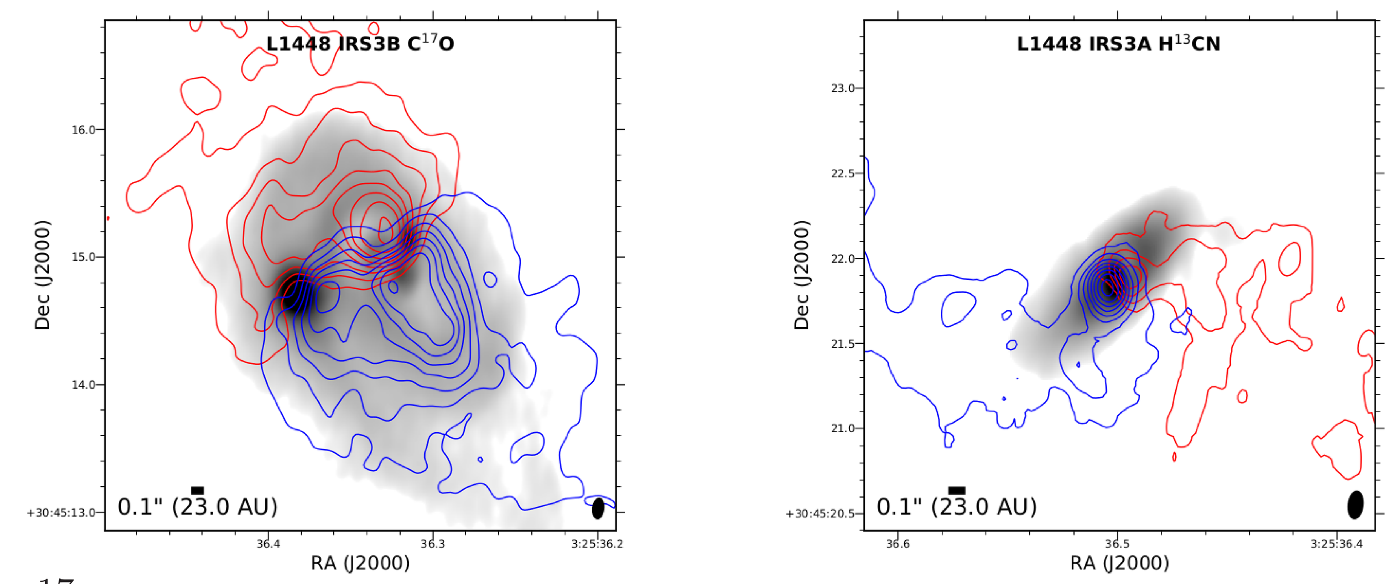

Figure 2: $C^{17}O$ ($J = 3 \rightarrow 2$) blue and red-shifted (blue and red contours, respectively) integrated intensity maps overlaid on the continuum image. The contours are at 10 sigma and increase in 8 sigma intervals. The system velocity is $V_{sys} \sim 4.75$ km s^{-1}. Beam size ($0.25'' \times 0.19''$).
$H^{13}CN$ ($J = 4 \rightarrow 3$) blue and red-shifted (blue and red contours, respectively) integrated intensity maps overlaid on the continuum image. The contours are at 3 sigma and increase in 5 sigma intervals. The system velocity is $V_{sys} \sim 5.2$ km s^{-1}. Beam size ($0.25'' \times 0.16''$).

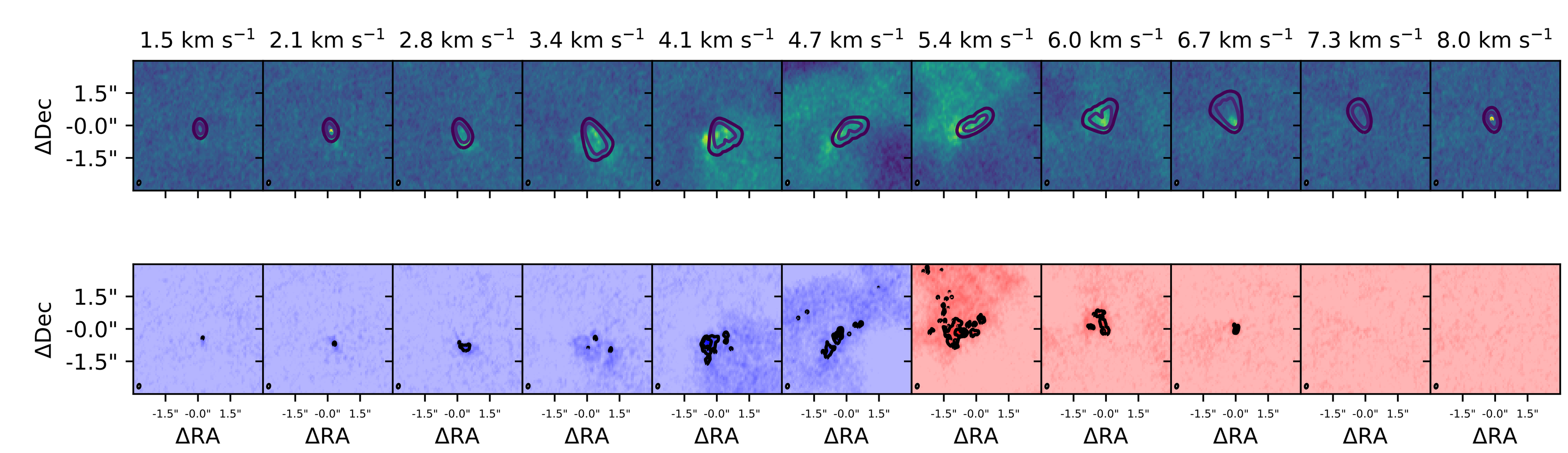

Figure 3: Top row, L1448 IRS3B $C^{17}O$, the model is shown as contours overlaid on the channel maps. Bottom row, the residuals of the model and the data, blue and red-shifted (blue and red contours, respectively) at 10 and 15 σ. This is indicative of the tertiary source shaping disk. The synthesized beam size is represented in the lower-right in each panel ($0.25'' \times 0.19''$).

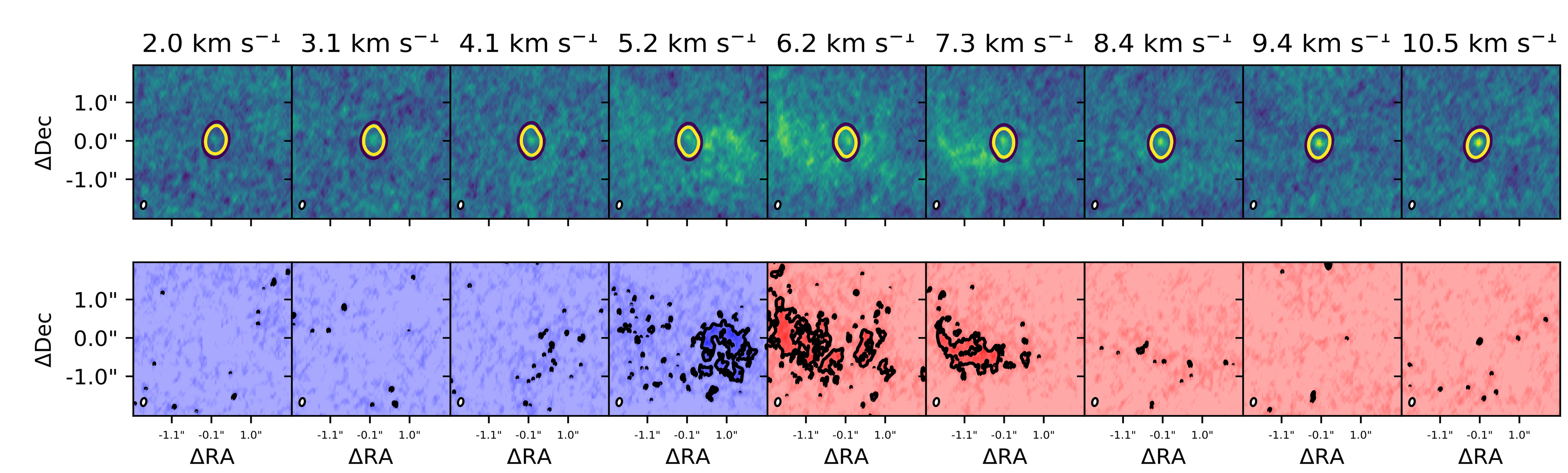

Figure 4: Top row, L1448 IRS3A $H^{13}CN$, the model is shown as contours overlaid on the channel maps. Bottom row, the residuals of the model and the data, blue and red-shifted (blue and red contours, respectively) at 6 and 9 σ. The residuals come from the large scale structures in the environment and are not strongly coupled with the disk. The synthesized beam size is represented in the lower-left in each panel ($0.25'' \times 0.16''$).

PV Diagrams

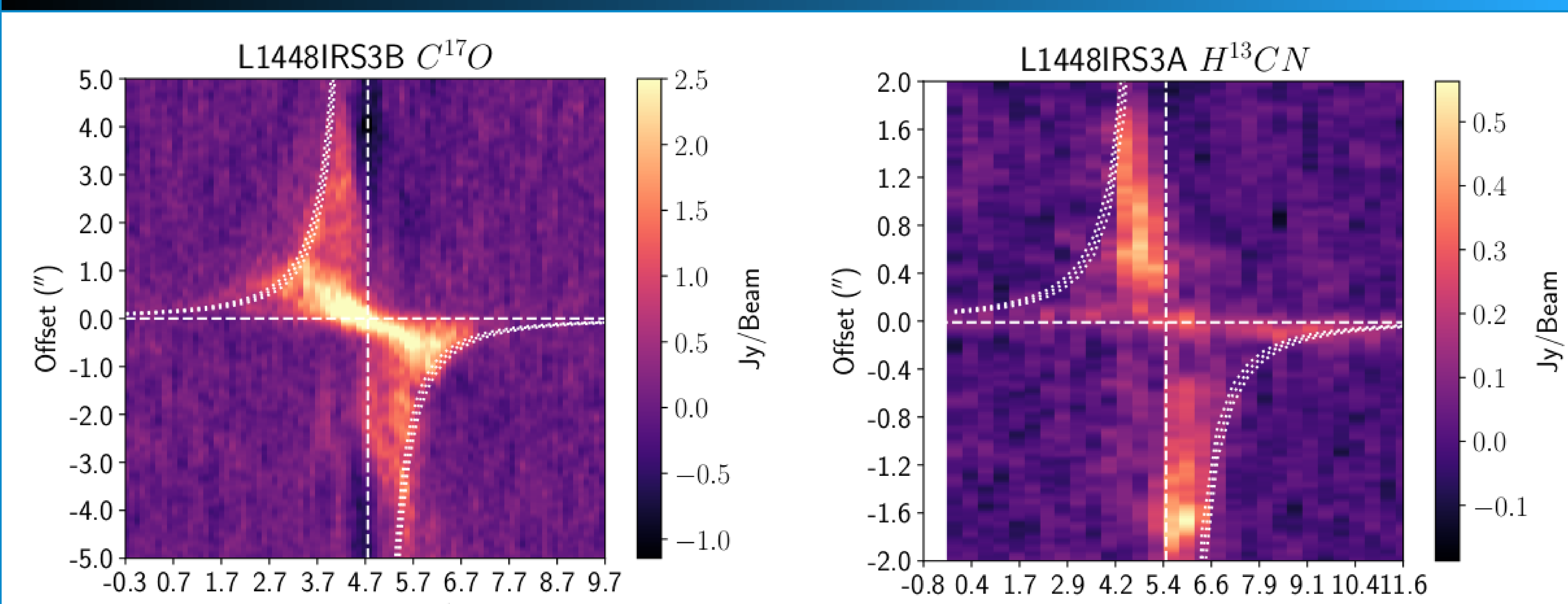

Figure 5: Position-Velocity Diagrams: Left-Column: IRS3B $C^{17}O$ with the dotted lines corresponding to $0.8 \pm 0.1 M_\odot$. Right-Column: IRS3A $H^{13}CN$ with the dotted lines corresponding to $1.5 \pm 0.2 M_\odot$. Both are consistent with the parameters yielded by the RADMC-3D models.

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Contact Information

[Web] *nhn.ou.edu/~reynolds* **[SRT]** *nhn.ou.edu/srt*
[Email] *nickreynolds@ou.edu*
[Github] *github.com/nickalaskreynolds*