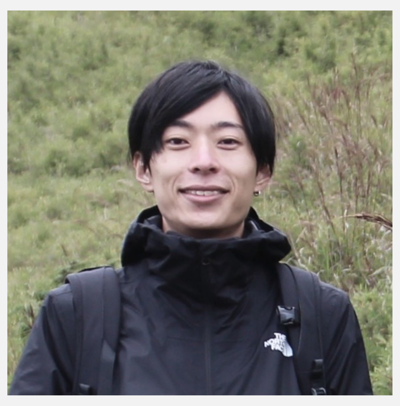
Early Planet Formation in Embedded Disks (eDisk):

Possible Substructure Formation in an Embedded Disk of the Ced110 IRS4 system

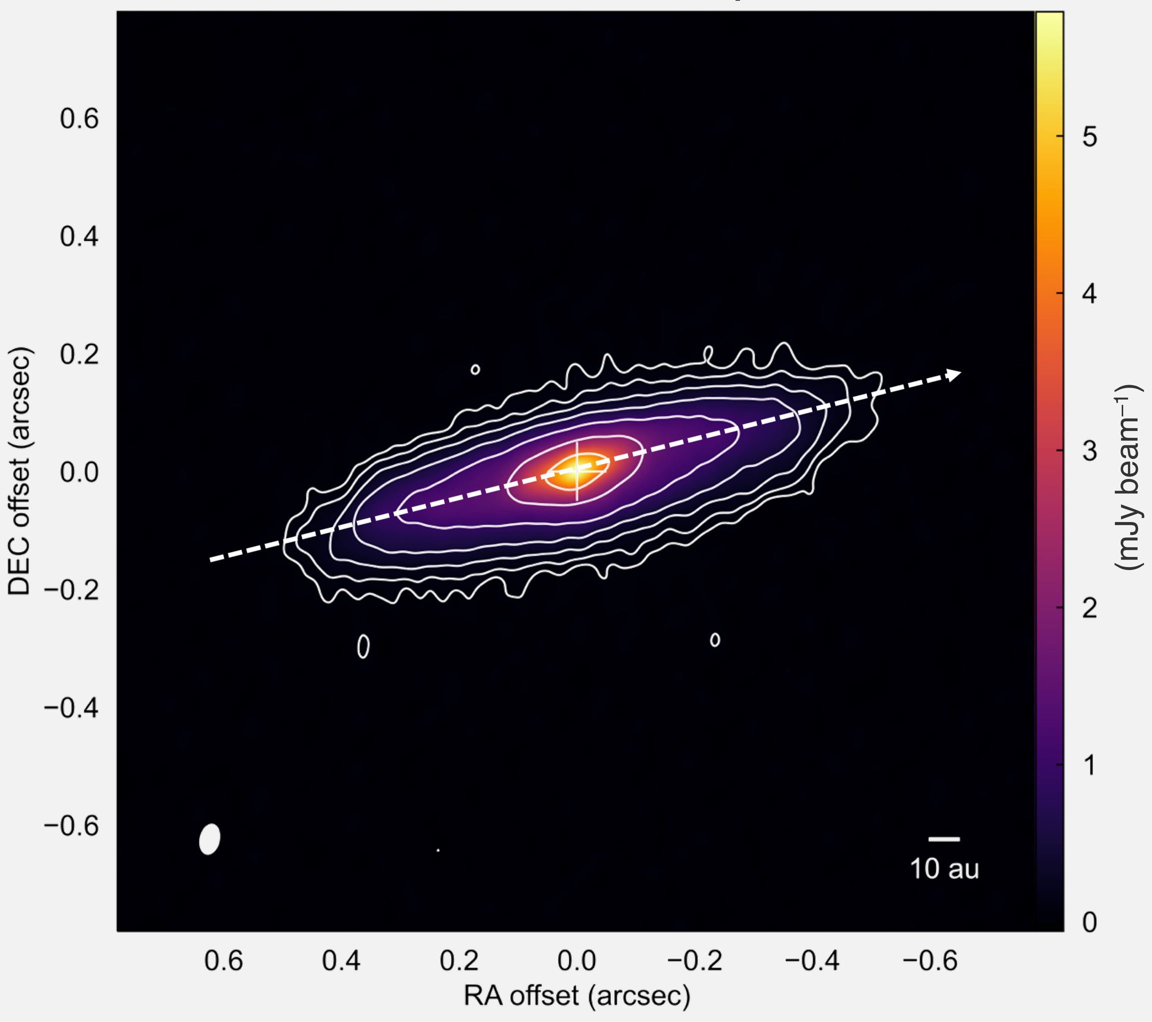
Jinshi Sai (ASIAA) and the eDisk Team

Summary: The ALMA Large program *Early Planet Formation in Embedded Disks (eDisk)* aims to reveal when substructures in protoplanetary disks begin to form by observing 19 embedded disks at spatial resolutions of ~5 au and studying whether they show substructures. In this poster, we present a first-look result of the Class 0/I protostellar system Ced110 IRS4 from the eDisk survey. The 1.3 mm dust continuum tracing a dust disk of Ced110 IRS4A shows no clear gaps or rings, but exhibits bumps along the major axis, which can be interpreted as a shallow, annular structure at a radius of ~40 au. This might suggest a possible substructure formation in the embedded dust disk, although more investigations are required to confirm this as the 1.3 mm continuum emission could be optically thick.

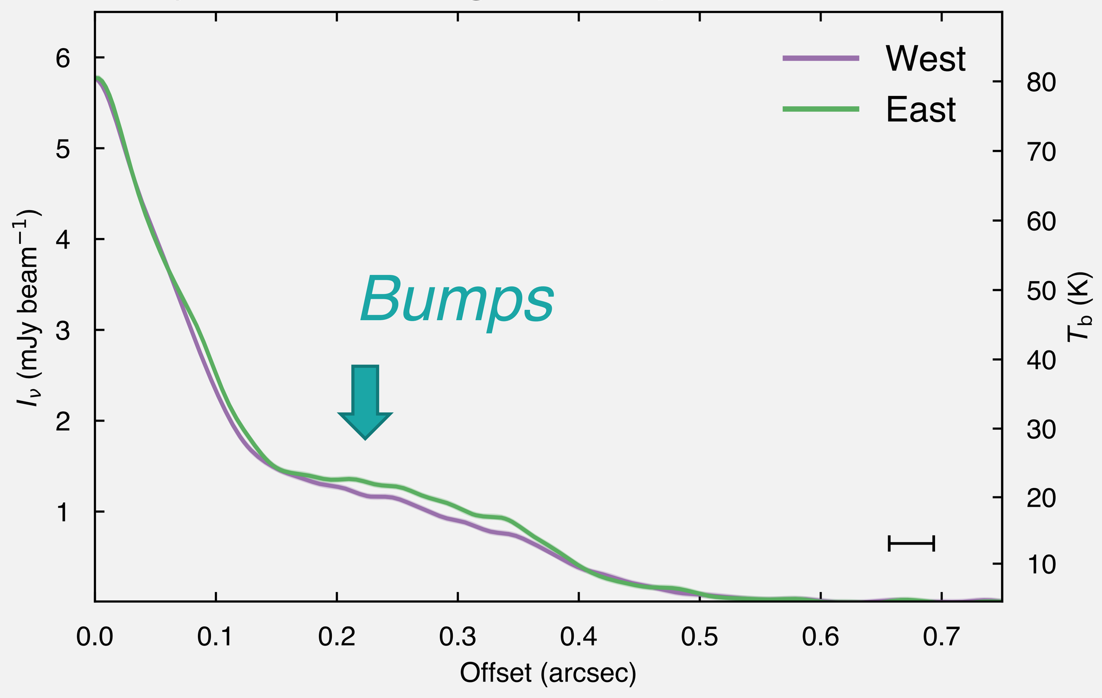


1. Continuum of Ced110 IRS4A Disk

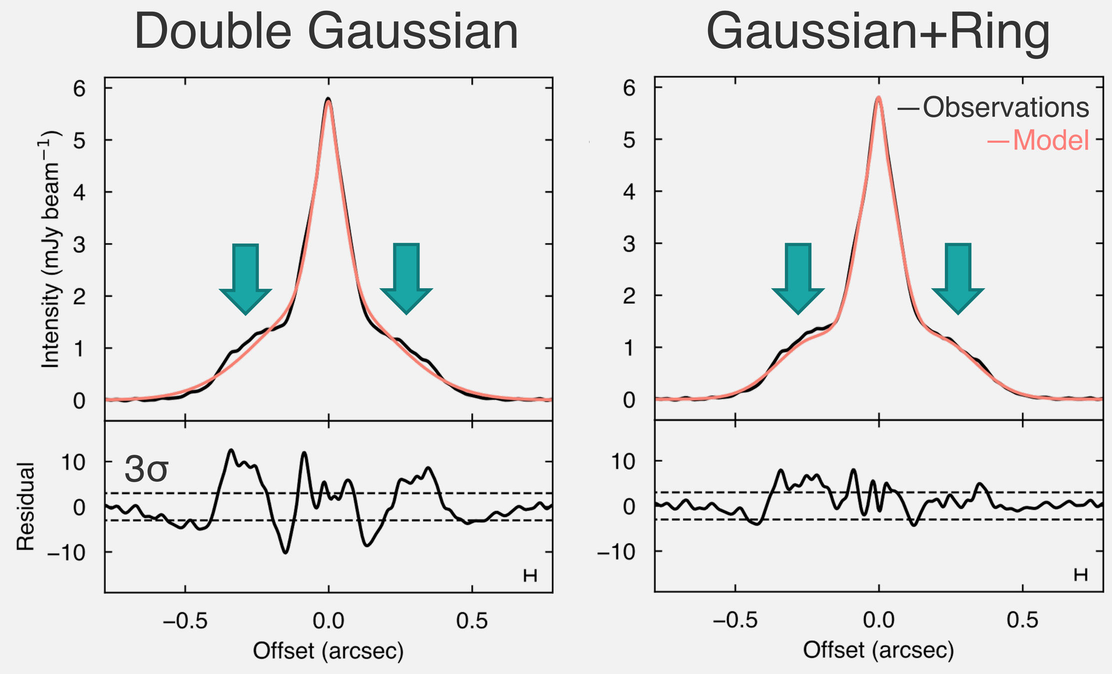
The 1.3 mm Dust Continuum Map



Intensity Profile along the Major Axis



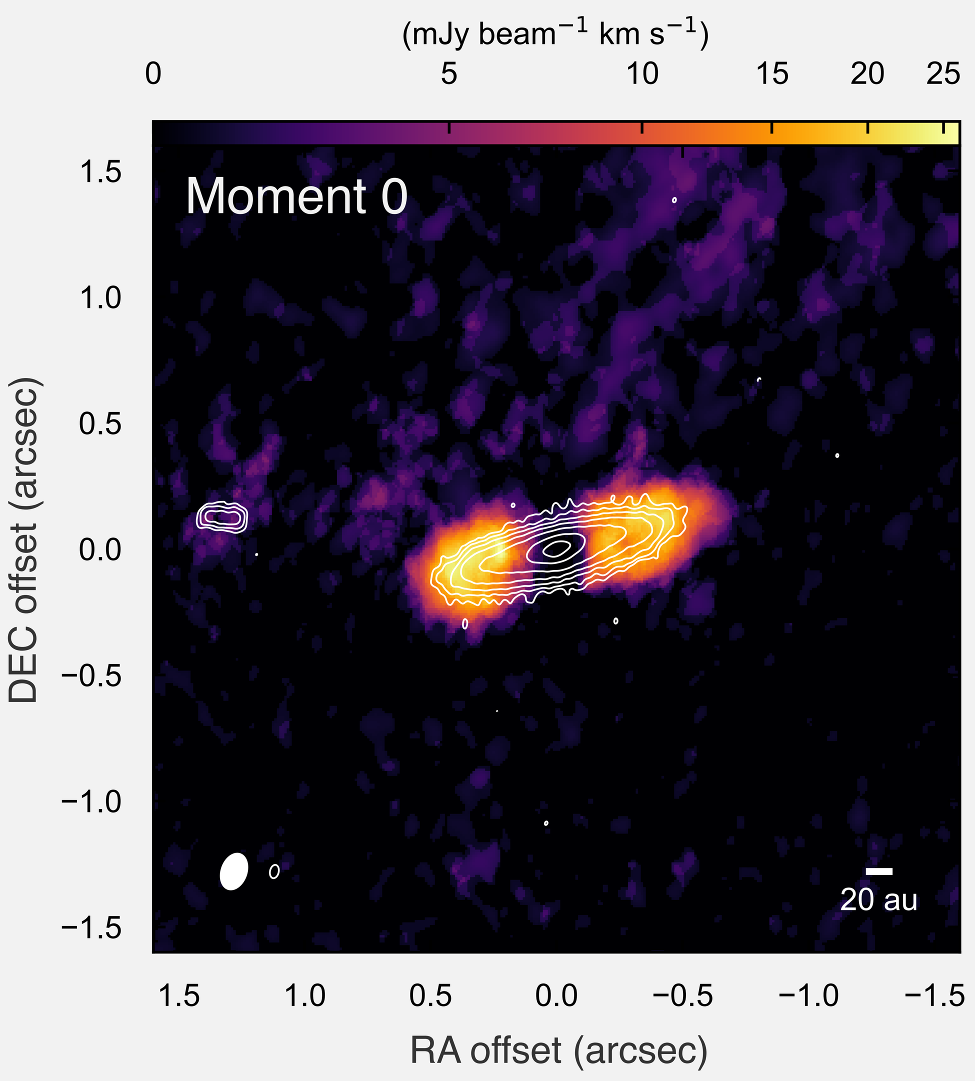
Modeling of the Intensity Distribution

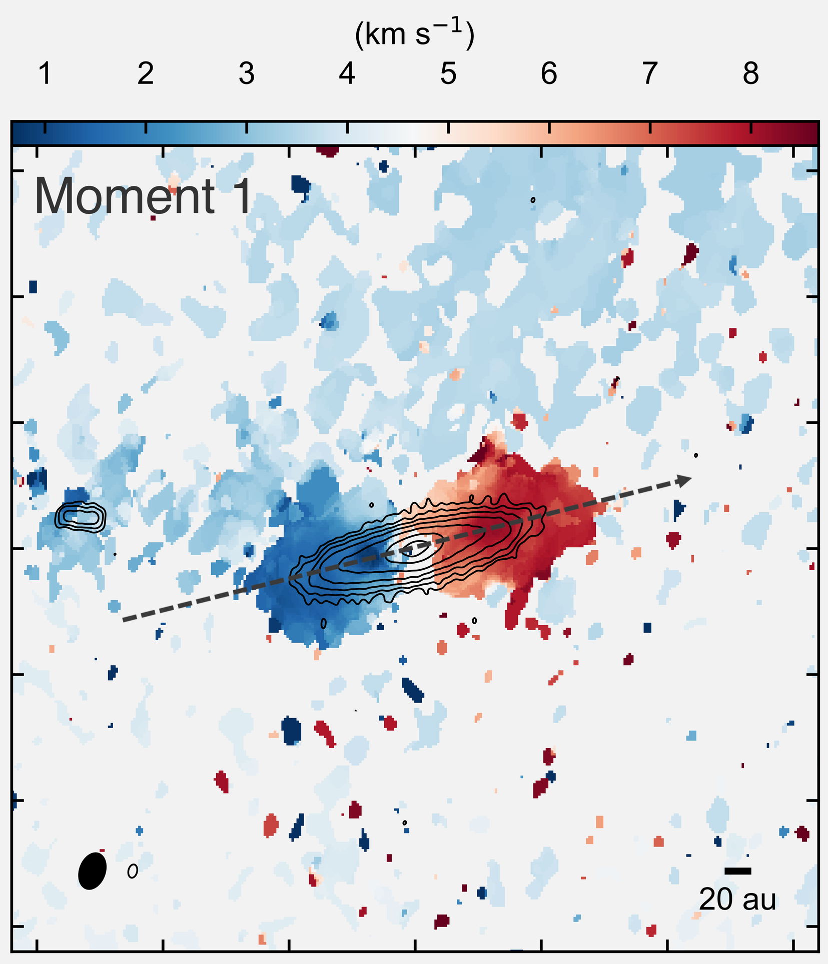


- ✓ *No clear gaps or rings* in the 1.3 mm dust continuum of Ced110 IRS4A
- ✓ *Bumps* along the major axis, which can be interpreted as *a shallow, annular structure at r~40 au*
  - ✓ Might suggest *a possible substructure formation* in the dust disk
- ✓ More observations at longer wavelengths are needed to confirm this, as the 1.3 mm continuum could be optically thick

2. Line of Ced110 IRS4A Disk

C^{18}O J=2–1 Moment Maps

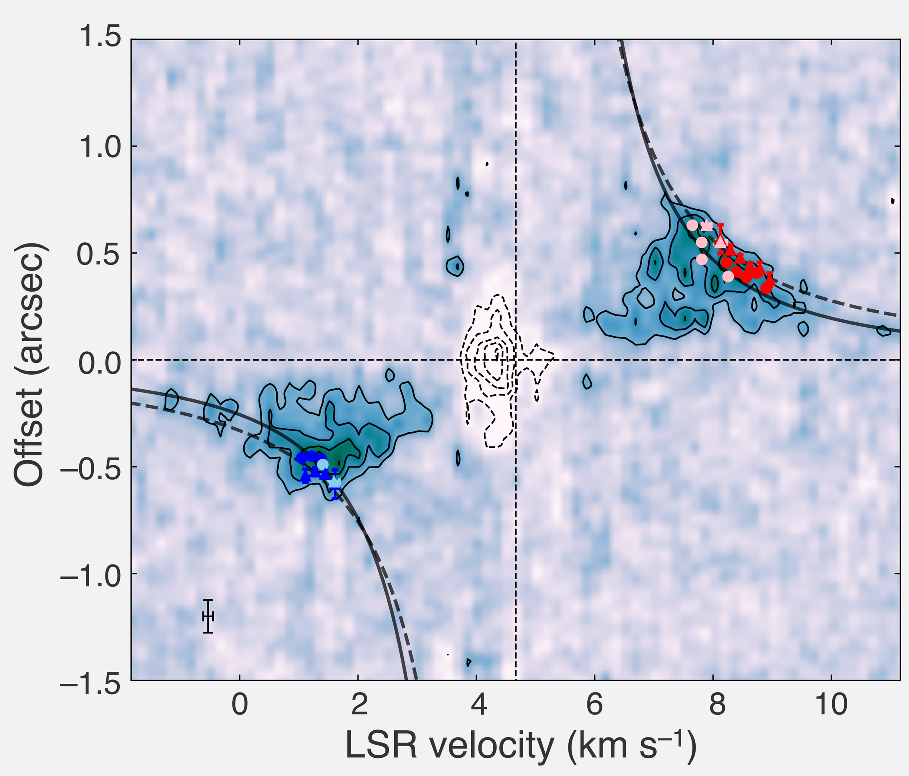




Color: line moment maps
Contour: 1.3 mm continuum map

Rotation Curve Fitting

C^{18}O Position-velocity (PV) diagram



Markers: data points
● Ridge (peak)
▲ Edge (outmost contour)

Lines: best-fit curves
— $v \propto r^{-0.531\pm0.019}$ (ridge)
--- $v \propto r^{-0.669\pm0.070}$ (edge)

How to do the fitting?
We are developing a public code!

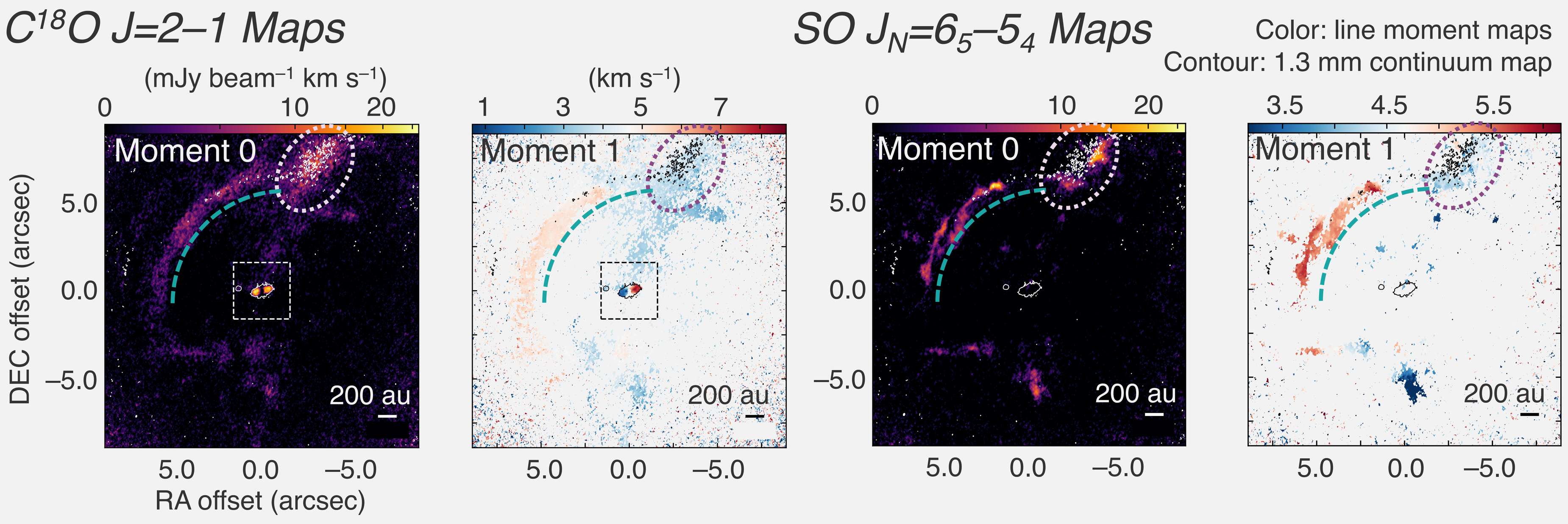
Spectral Line Analysis/Modeling (SLAM)

- ✓ *Clear velocity gradient*, indicating a *rotational motion*
- ✓ The rotational motion is well described by a power-law function of $v \propto r^{\sim -0.5}$, suggesting *a Keplerian disk*
- ✓ Protostellar mass is estimated to be ~1.21–1.45 $M_{\rm sun}$

3. Arc-like Structure

C^{18}O J=2–1 Maps *SO J_N=6_5–5_4 Maps*

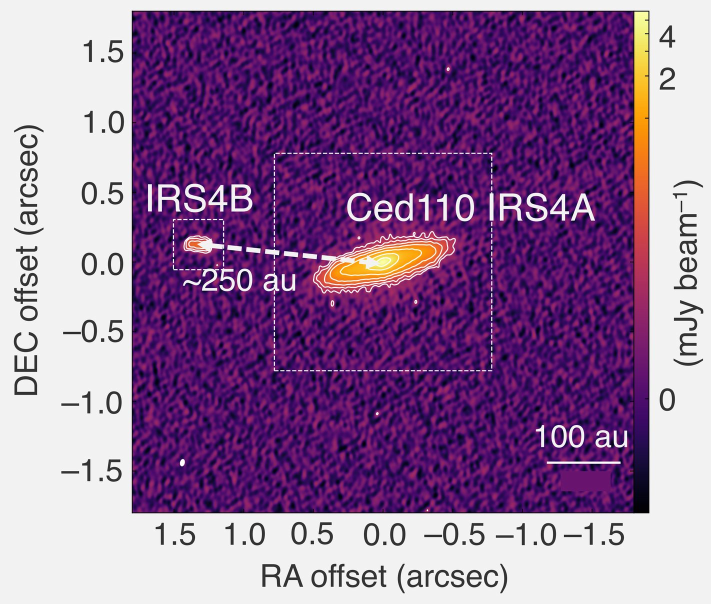
Color: line moment maps
Contour: 1.3 mm continuum map



- ✓ Shocked gas caused by outflow?

4. Binary System

The 1.3 mm Dust Continuum Map



Source	M_* ($M_\odot$)	$V_{\rm sys}$ (km s^{-1})	$M_{\rm disk}$ ($M_\odot$)	$R_{\rm disk}$ (au)	PA$_{\rm disk}$ (°)
Ced110 IRS4A	1.21–1.45	4.67	2.8×10^{-2}	110	104.0 ± 0.4
Ced110 IRS4B	0.02–0.05	2.69	5.6×10^{-4}	30	85.0 ± 2.3

- ✓ Projected separation of ~250 au
- ✓ Large difference in disk and stellar masses
- ✓ Orderd rotational motions
- → Disk fragmentation is preferable?

Target: Ced110 IRS4

- ✓ Class 0/I protostellar system in the Cederblad (Ced) 110 region of the Chamaeleon I dark cloud [d~189 pc; 1]
- ✓ $T_{\rm bol}$~68 K, $L_{\rm bol}$~ 1 $L_{\rm sun}$ [2]

References: [1] Galli et al. 2021, A&A, 646, A46; [2] Ohashi & the eDisk team, submitted to ApJ.

ALMA Observations

Continuum/Line	Frequency (GHz)	Robust	Beam Size	Velocity Resolution (km s^{-1})	RMS (mJy beam^{-1})
1.3 mm continuum	225	0	0.″054 × 0.″035 (−12.5°)	-	0.020
C^{18}O J = 2–1	219.560354	1	0.″153 × 0.″107 (−19.4°)	0.167	1.5
SO J_N = 6_5–5_4	219.949442	2	0.″178 × 0.″127 (−20.9°)	0.167	1.8