



The Need for High Short-baseline Sensitivity

Mapping Kinematics and Chemistry from Envelope to Disks

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East Asian ALMA Community Workshop: ALMA2040 Science and Technology Perspectives

Star and Planet Formation Laboratory, RIKEN

July 17, 2026

Credit:

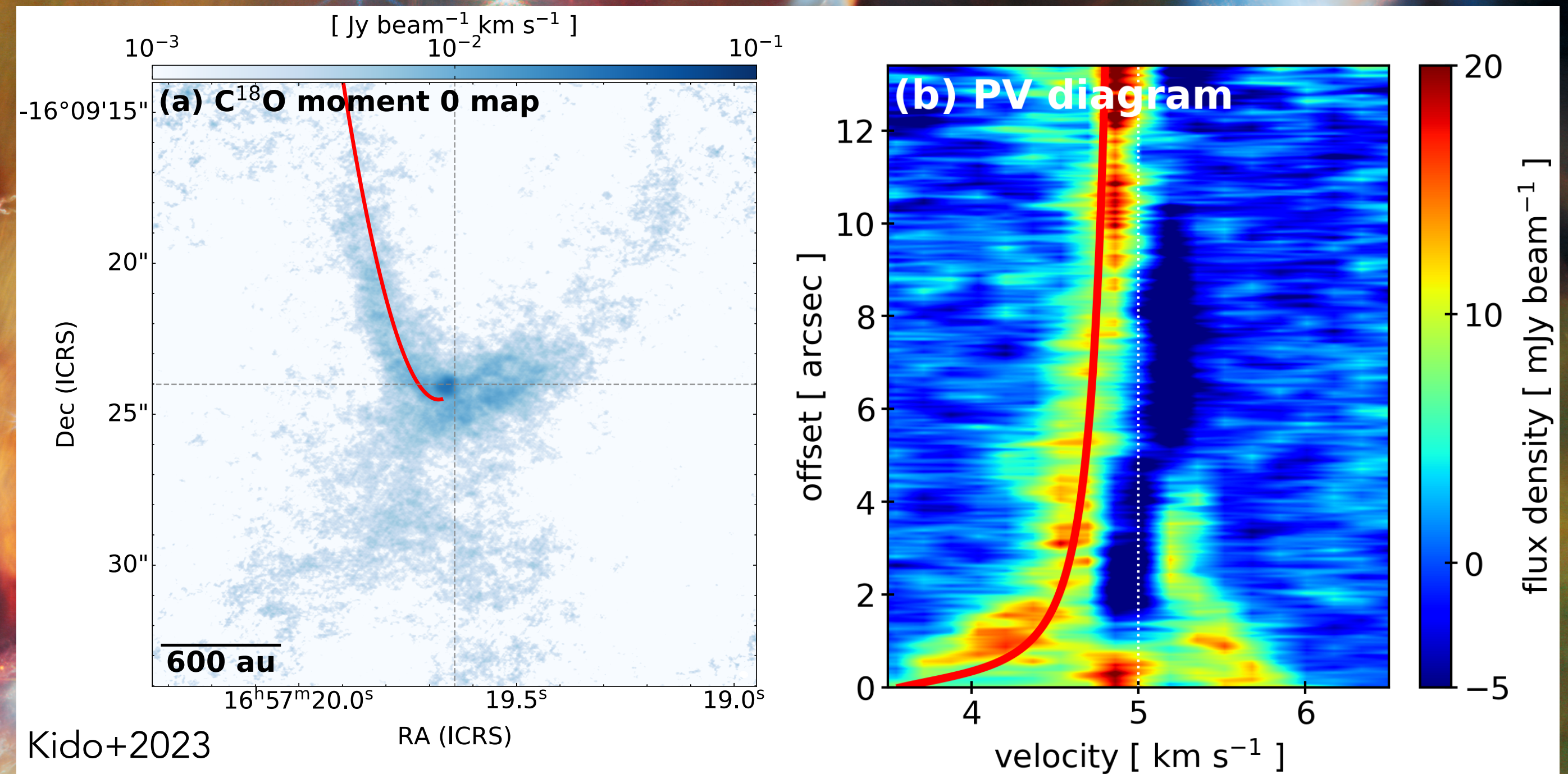
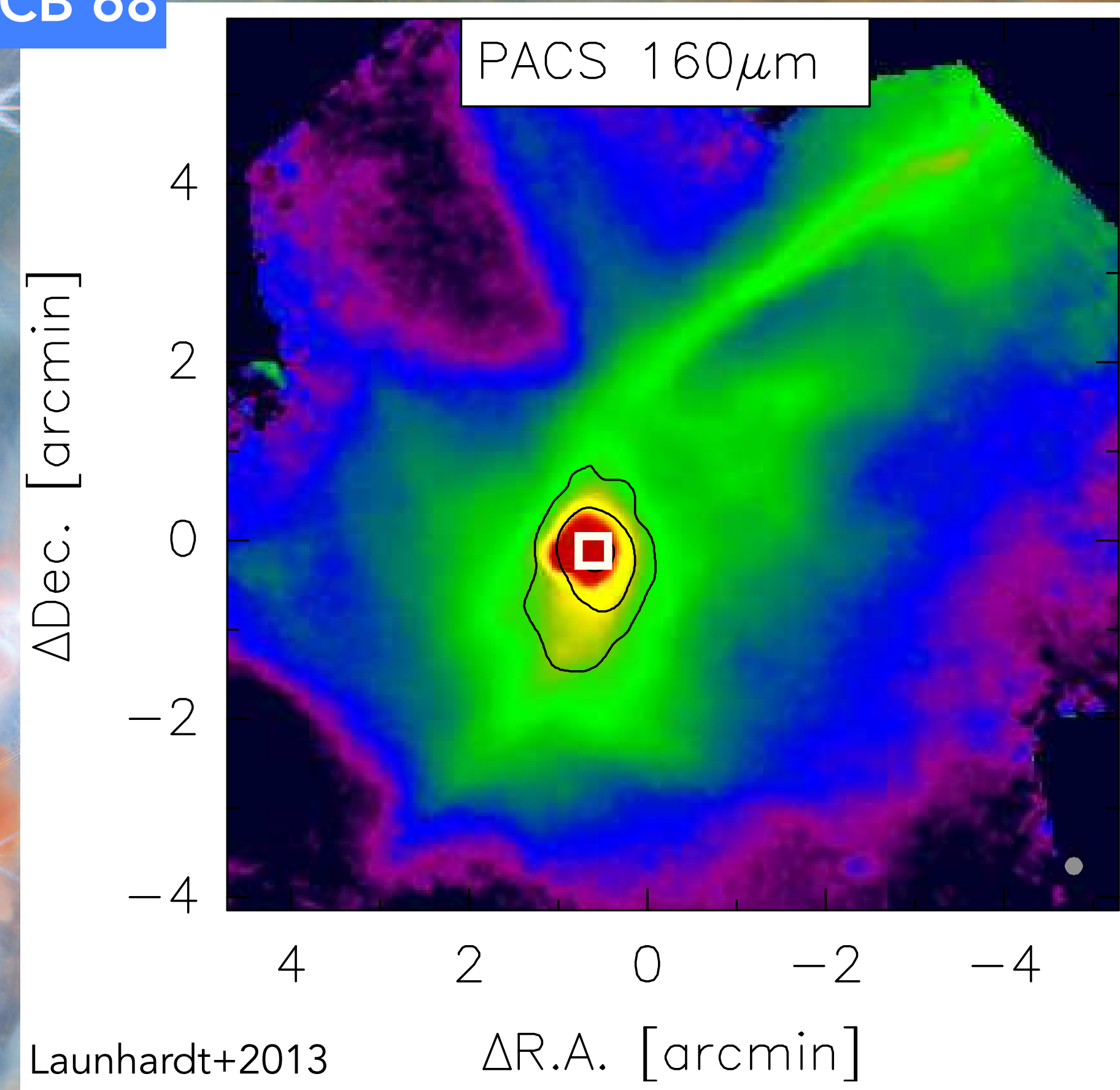
ESA/Webb, NASA & CSA, T. Megeath, M. Zamani (ESA/Webb)

Acknowledgement: M. H. Özsağ

Star formation understood via dynamic and chemistry

We observe gas motions and compositions of dust and gas to infer star & planet-forming processes

CB 68



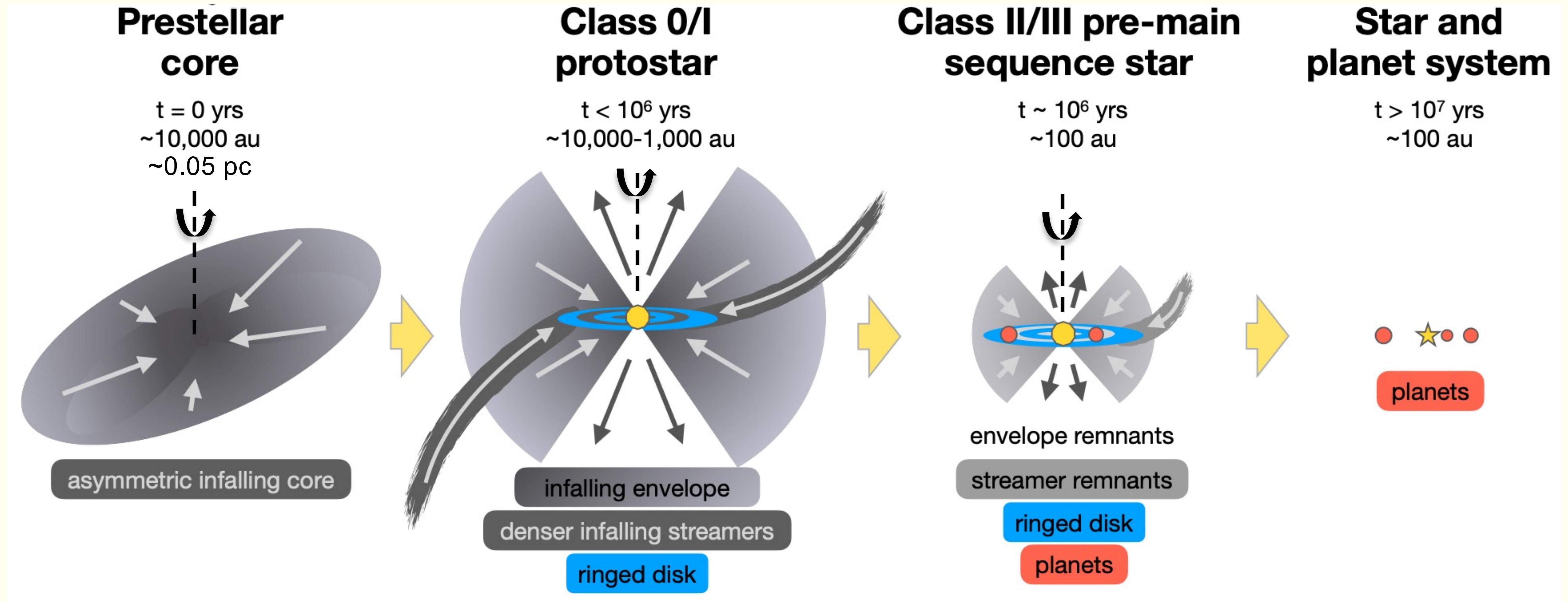
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Evidence of asymmetric and filamentary infall

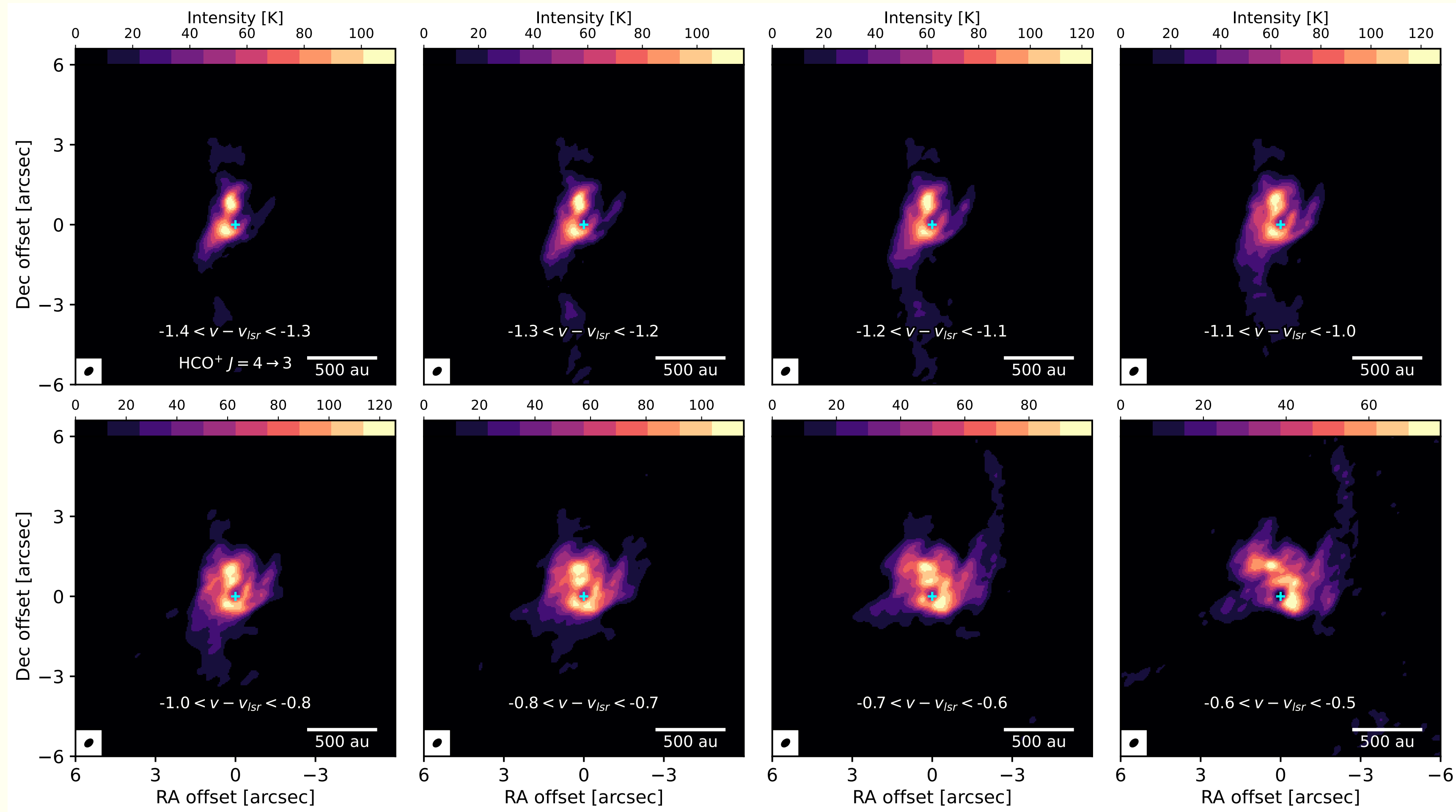
"Streamer" starts to be found in many sources, but its properties remain difficult to measure



Pineda+2023 (PPVII)

Filaments in a Class 0 protostar BHR 71

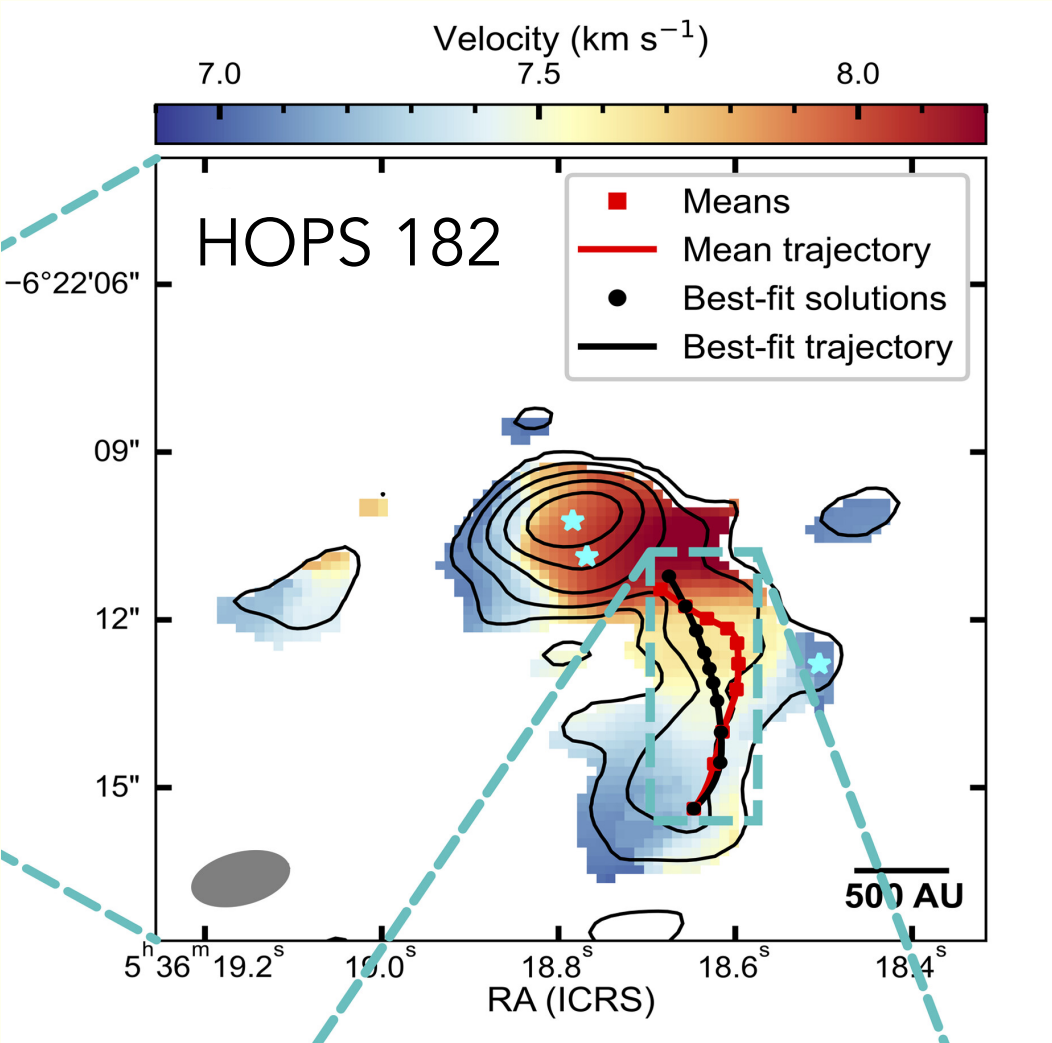
Multiple streamer-like structures seen in HCO^+ as extended emission close to source velocity



Yang+ in prep.

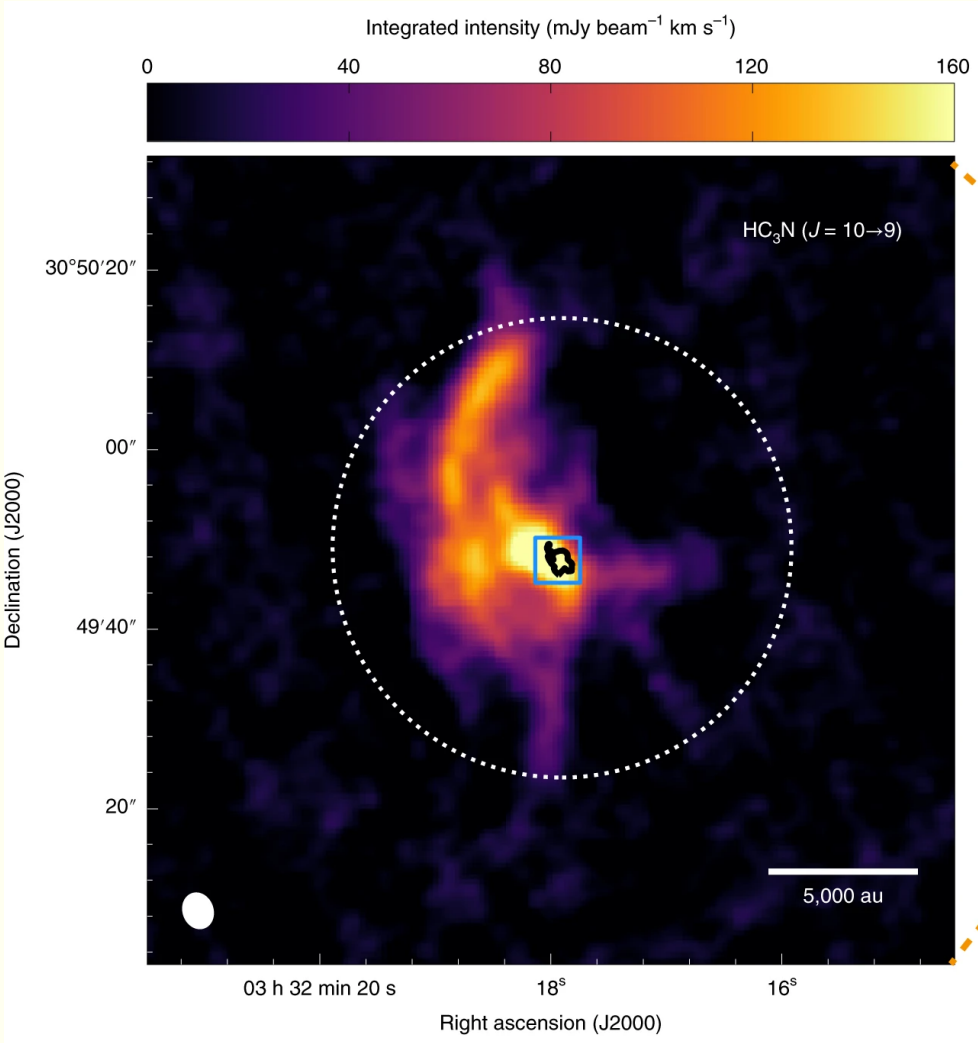
Chemistry of the streamers

C¹⁸O



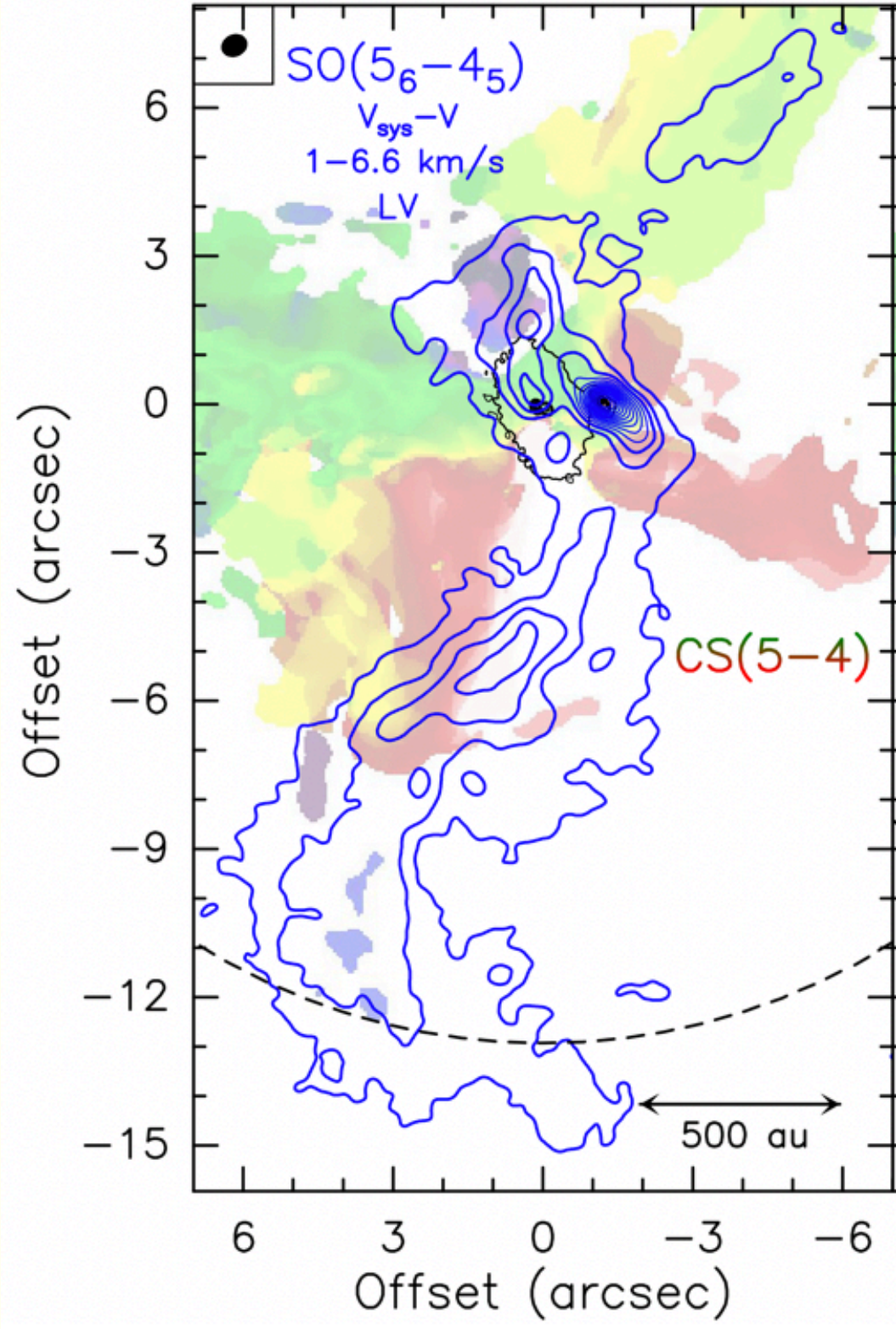
Huang+2026

HC₃N



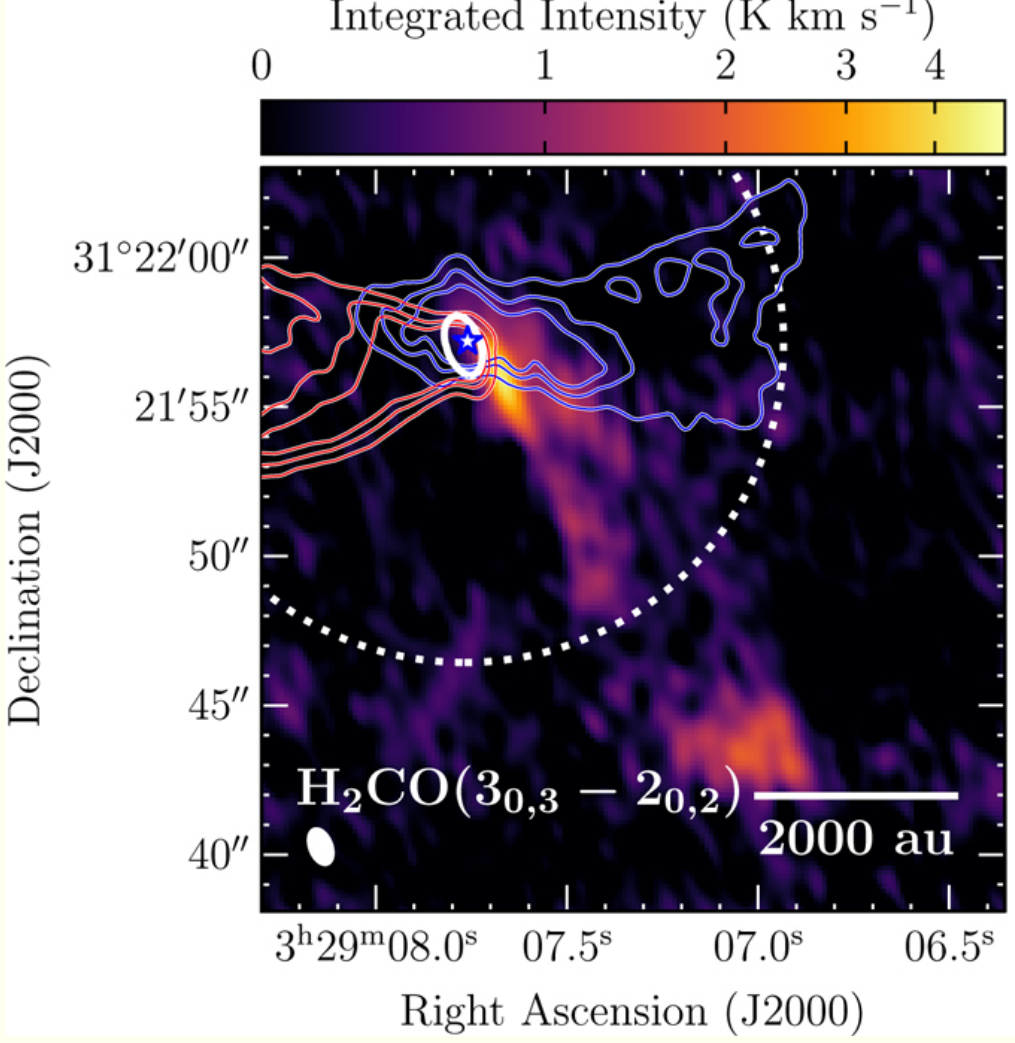
Pineda+2020

SO



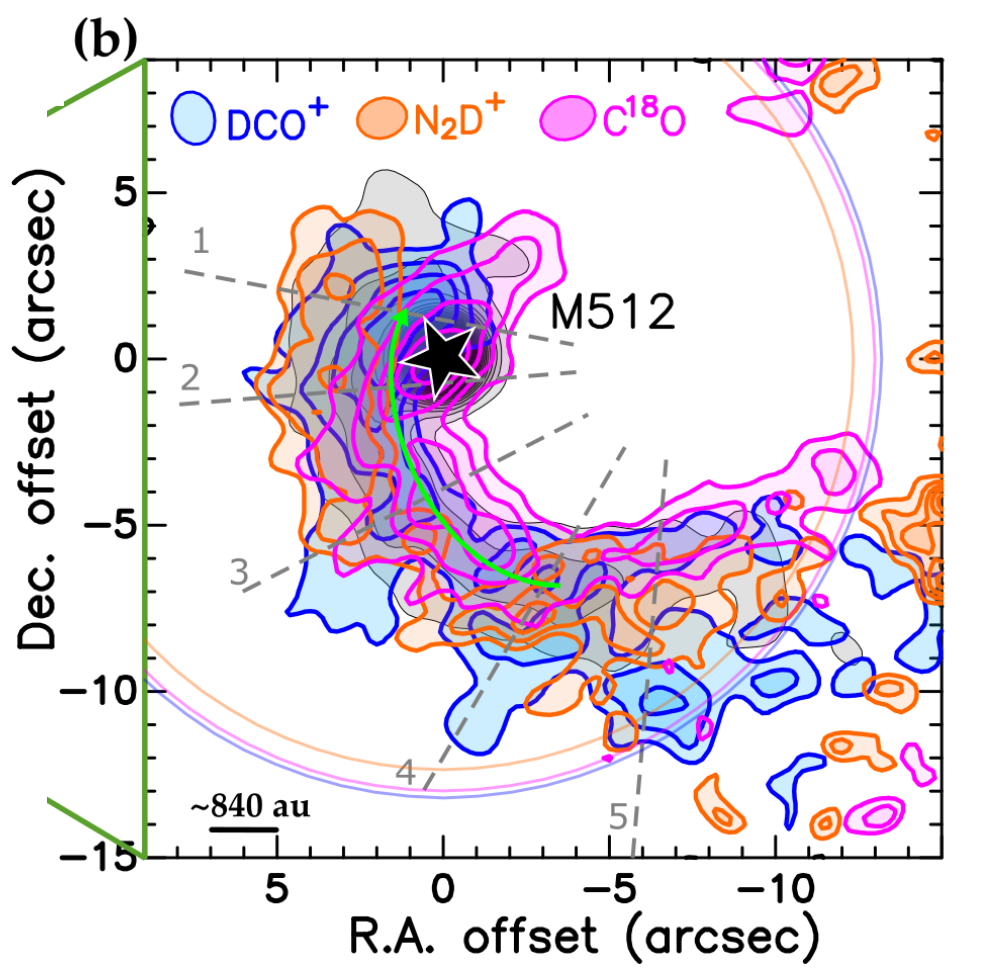
Codella+2024

H₂CO



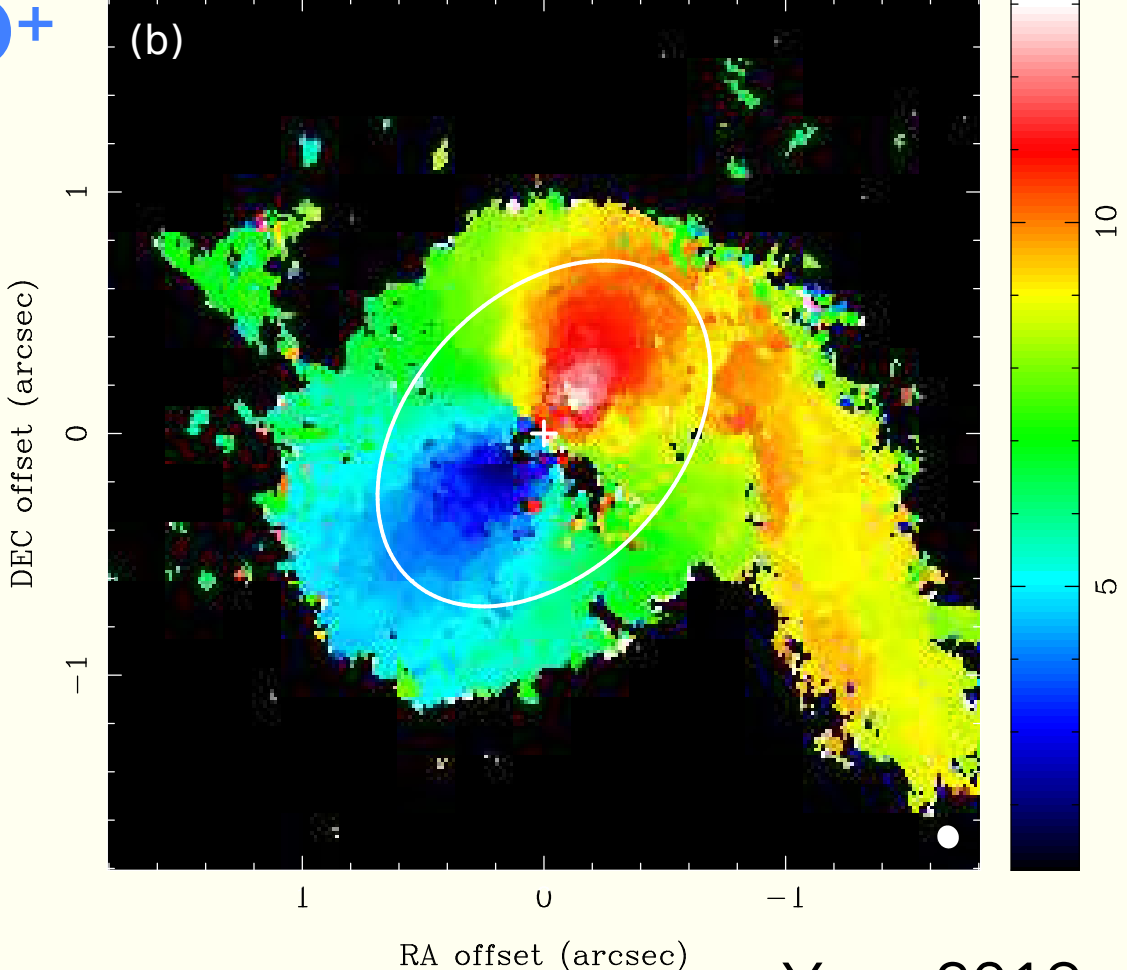
Valdivia-Mena+2022

DCO⁺
N₂D⁺



De Simone+2026

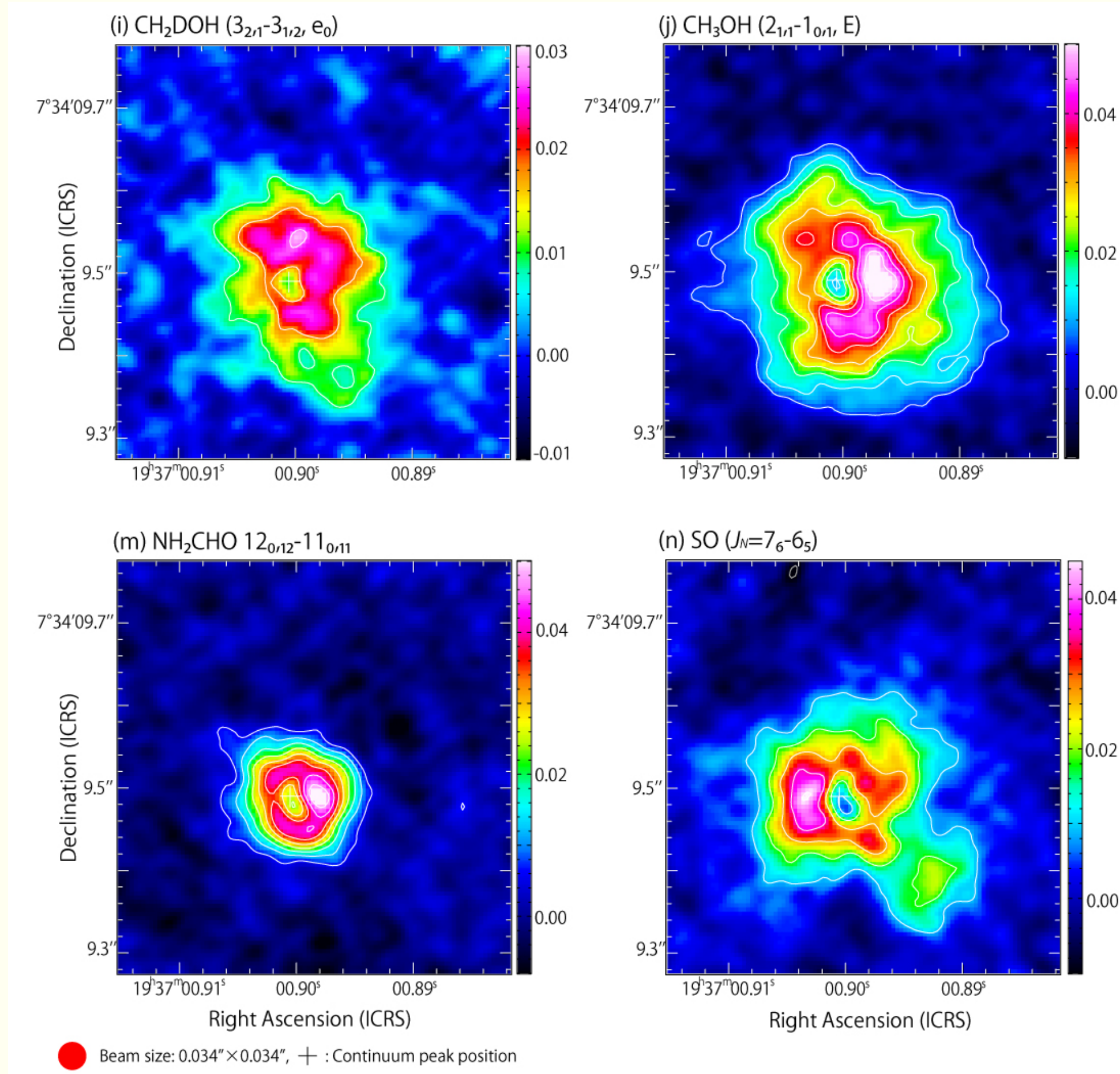
HCO⁺



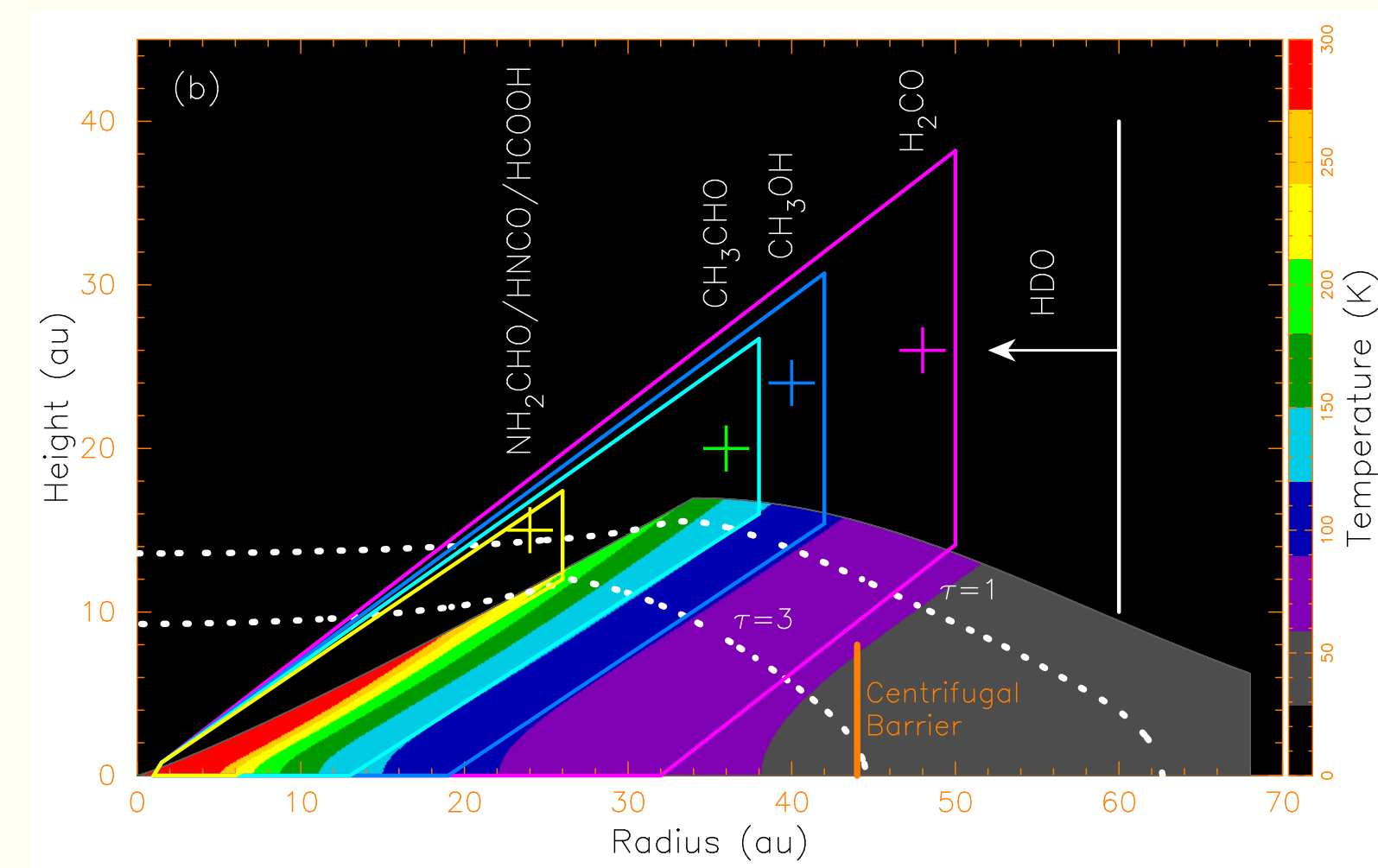
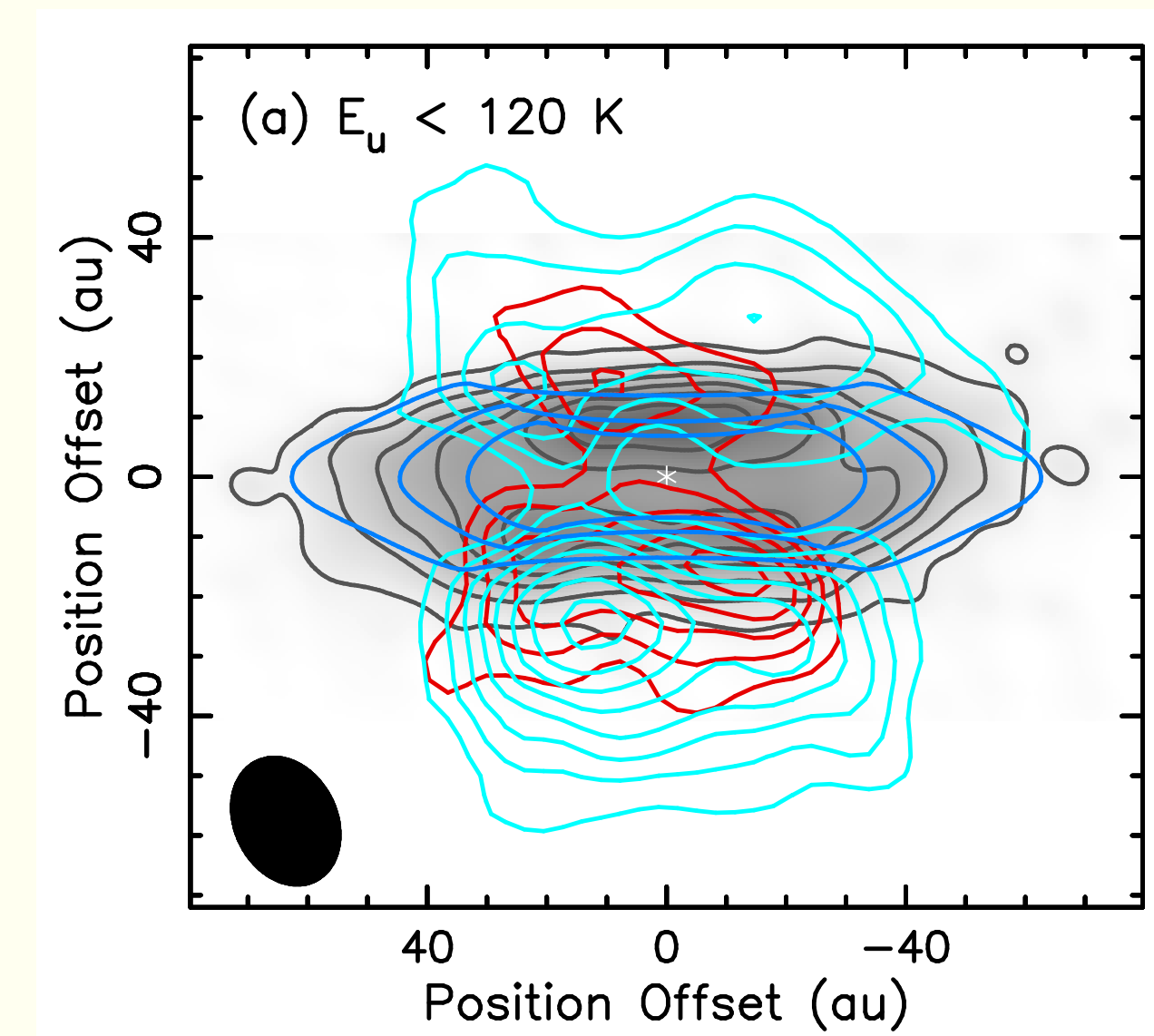
Yen+2019

Chemical diversity in compositions and morphology

High-resolution observations show potentially diverse extents of complex species



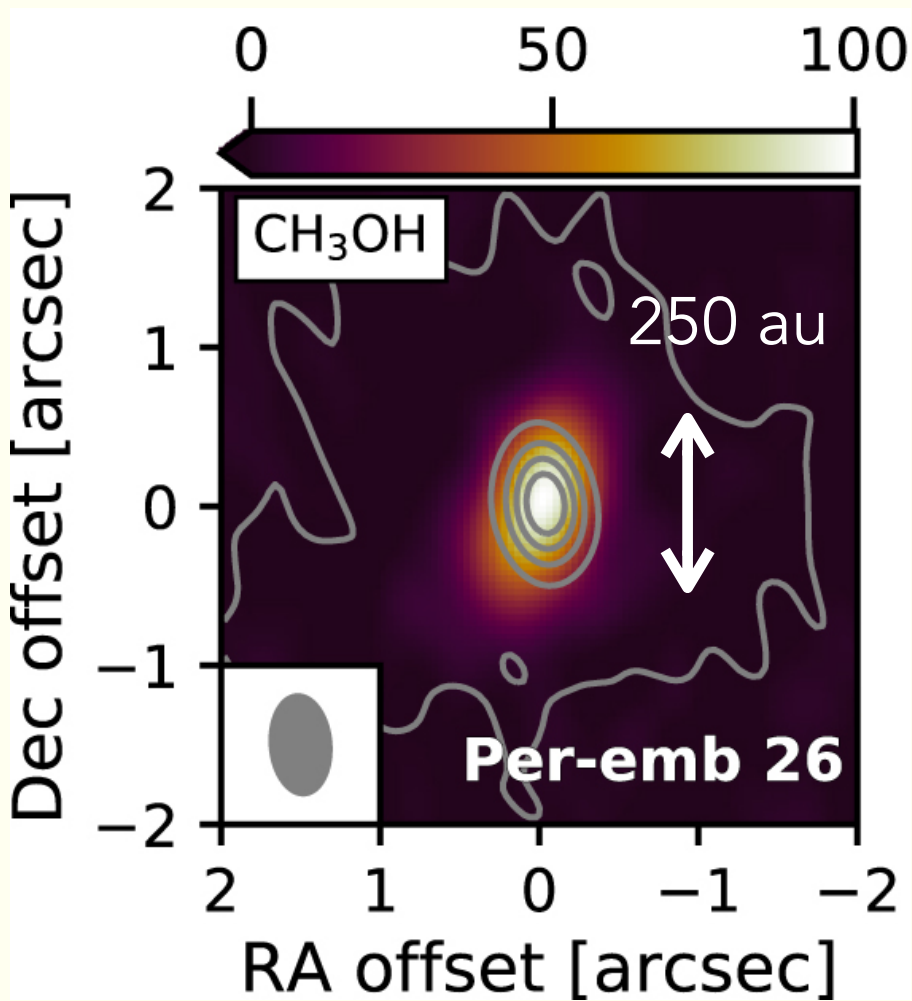
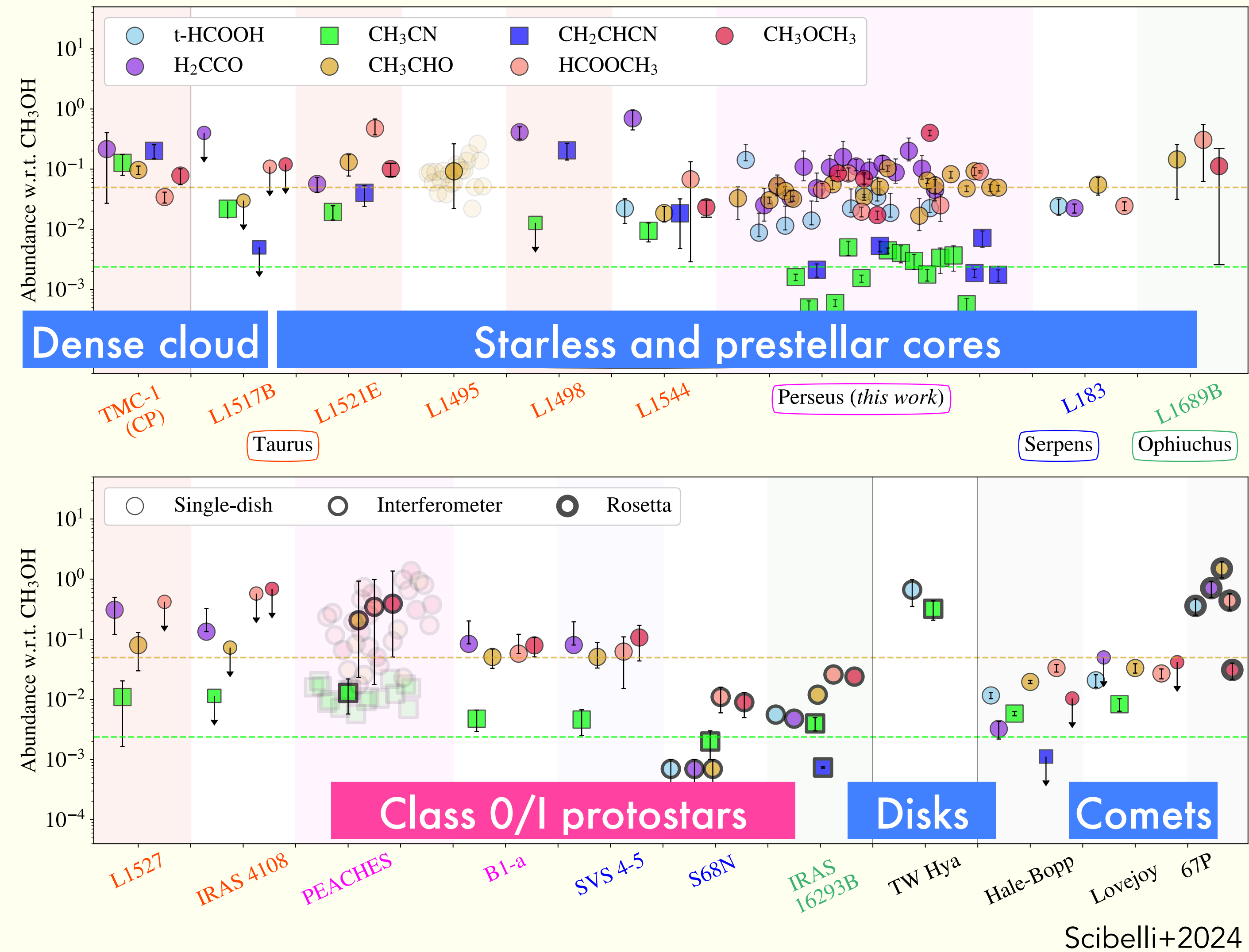
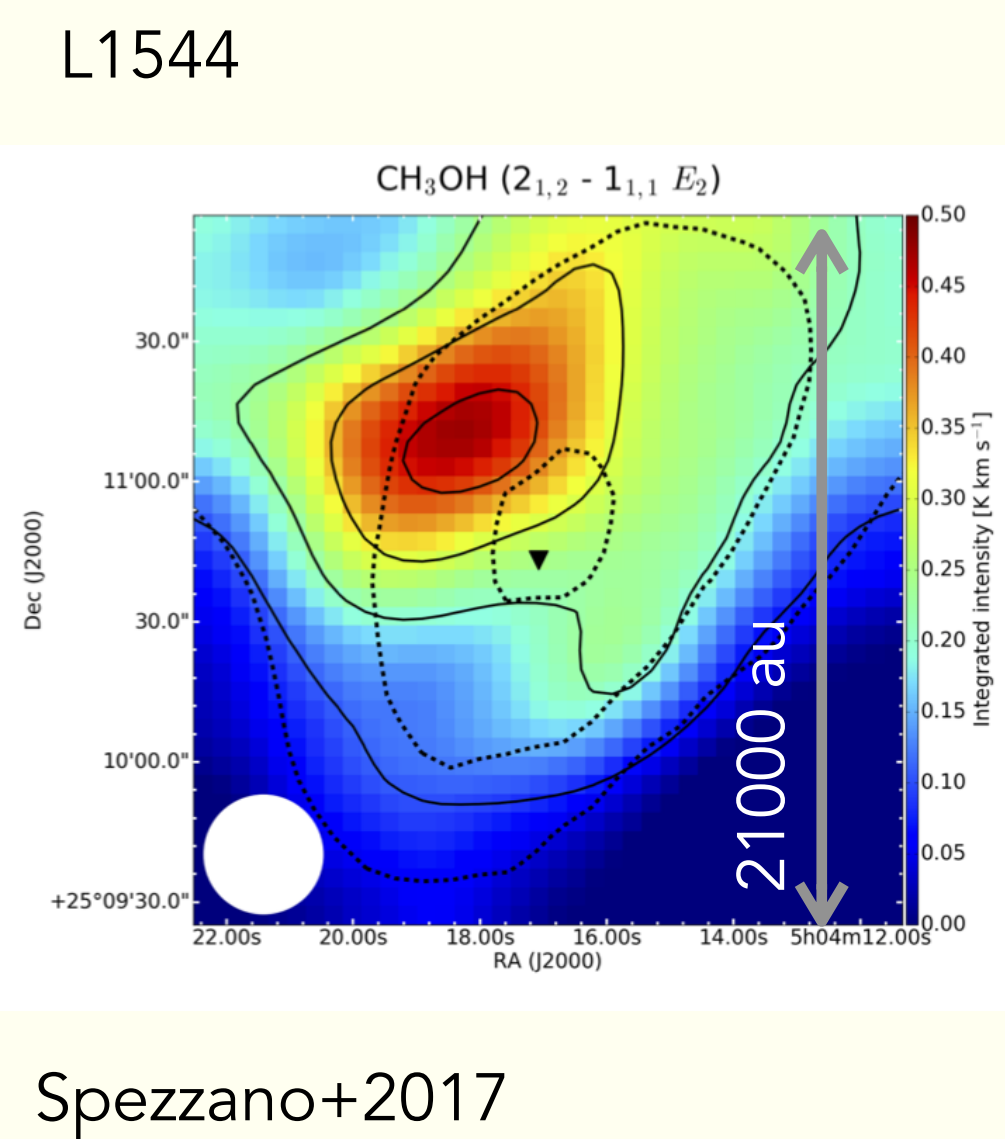
Okoda+2022



Lee+2022

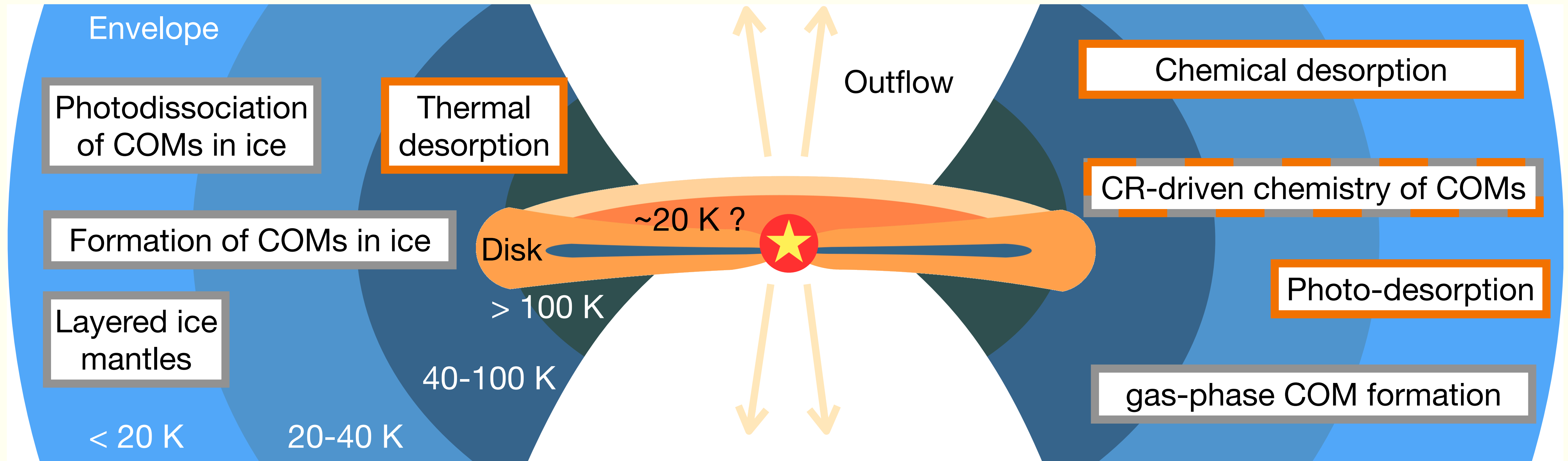
Cold vs. hot molecular emission & envelope vs. disk

Connected molecular distributions from cores to disks.



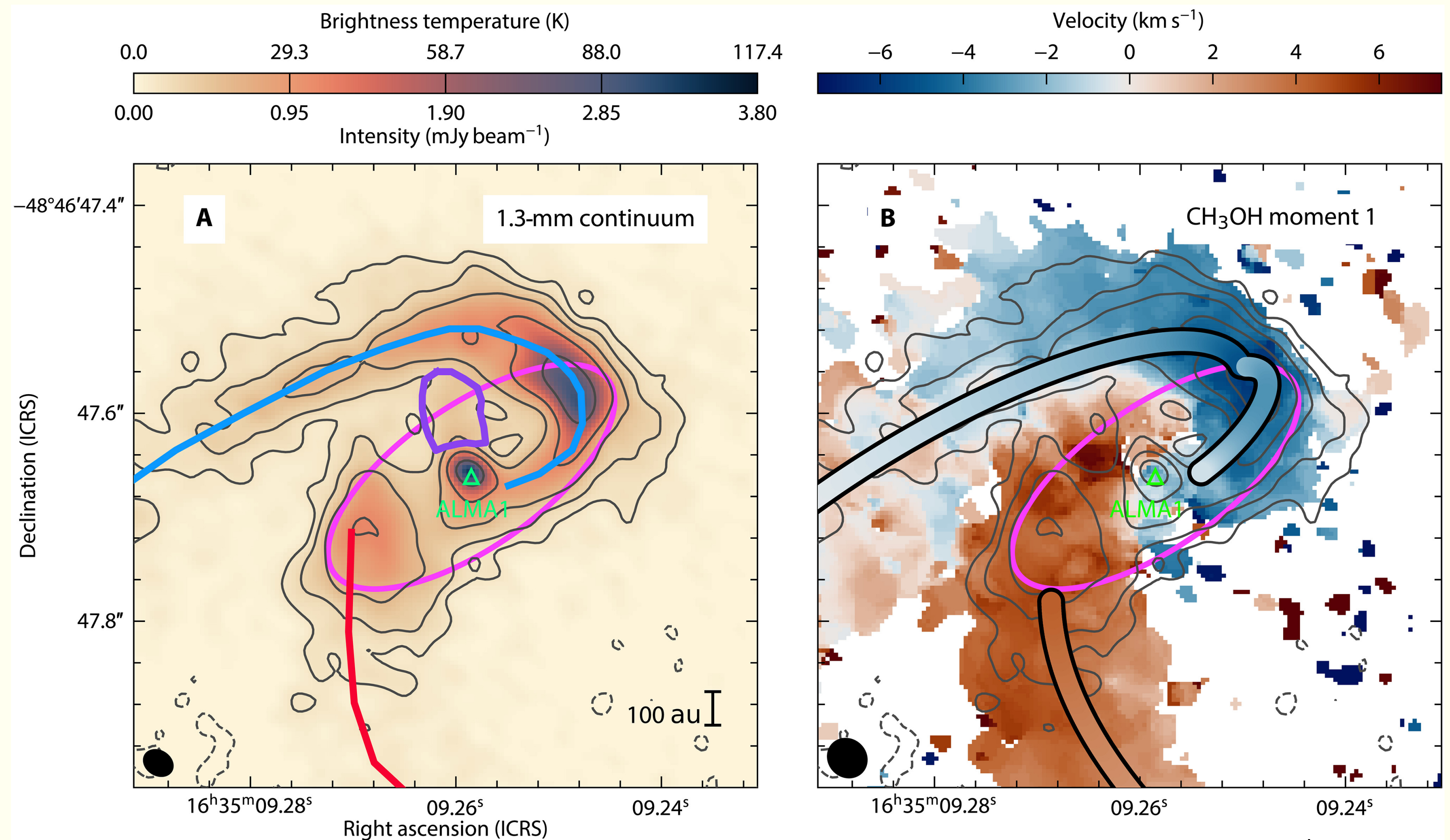
Inseparable interplay of chemistry and dynamics

Chemistry determines the available tracers throughout star formation



Direct detection of streamer-fed disks

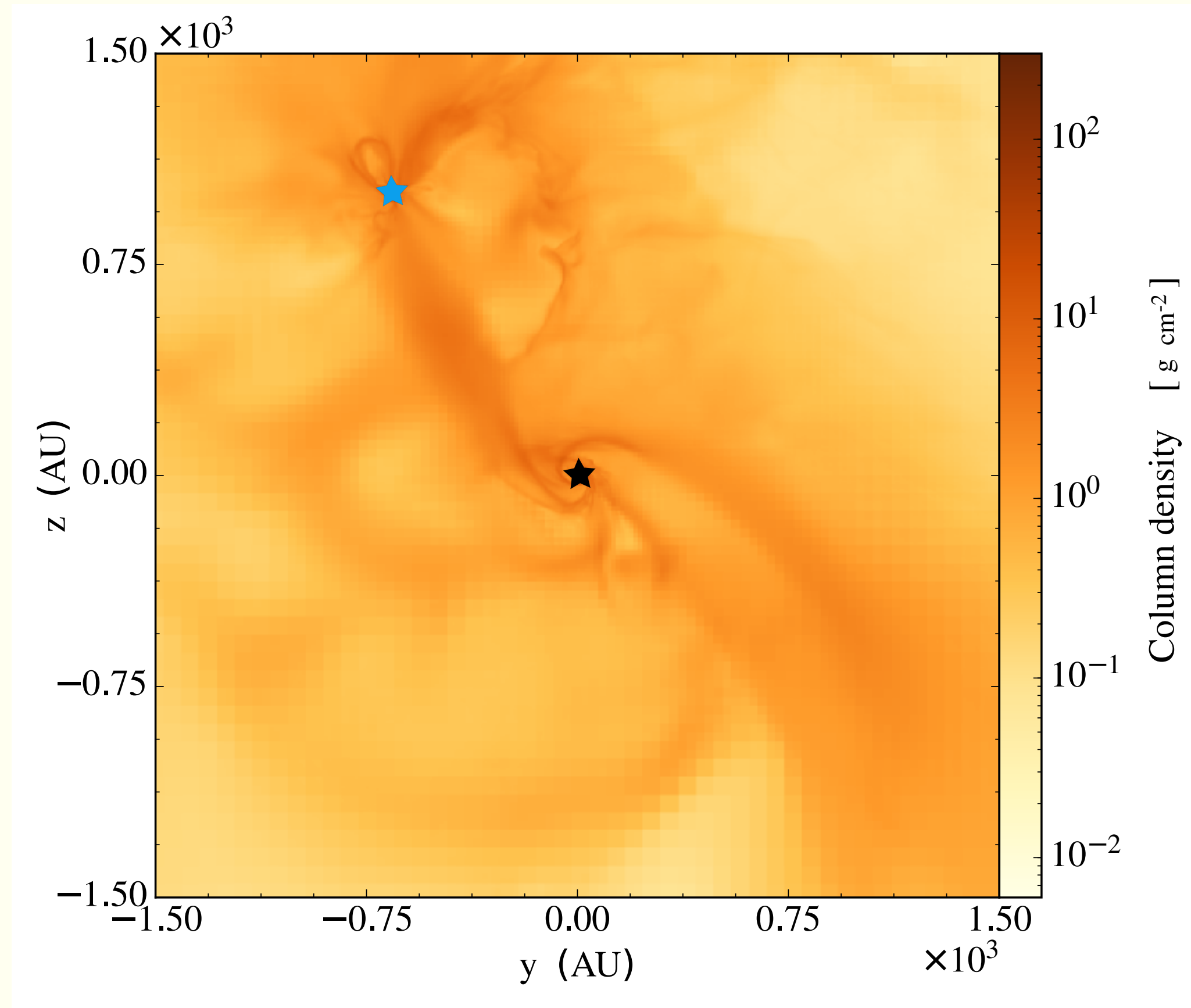
CH₃OH filaments feeding a disk in a massive protostar



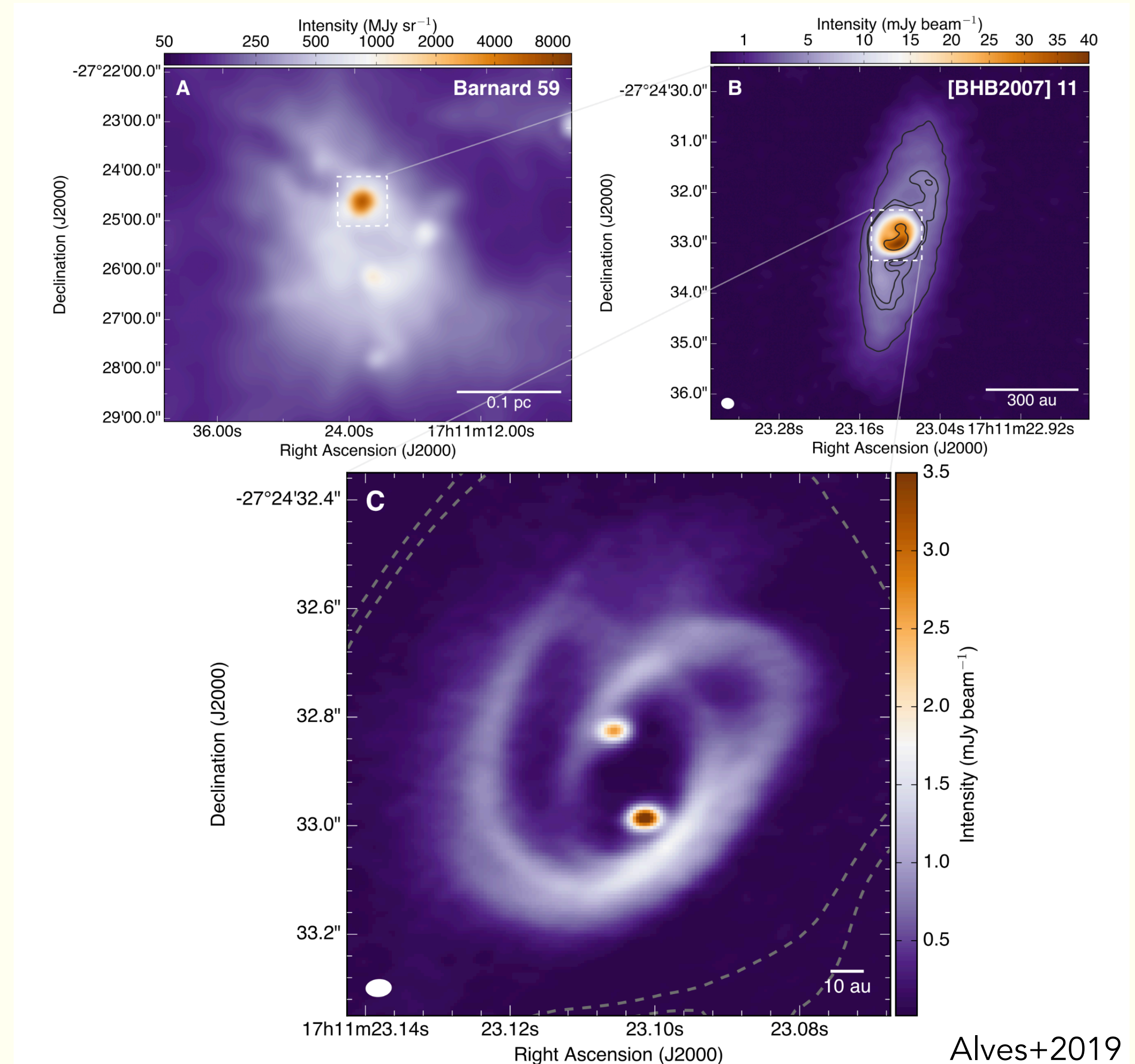
Olguin+2024

The need for short-baseline sensitivity and image fidelity

We need to probe $\sim 1000\text{-}10000$ au scale along with the <10 au resolution



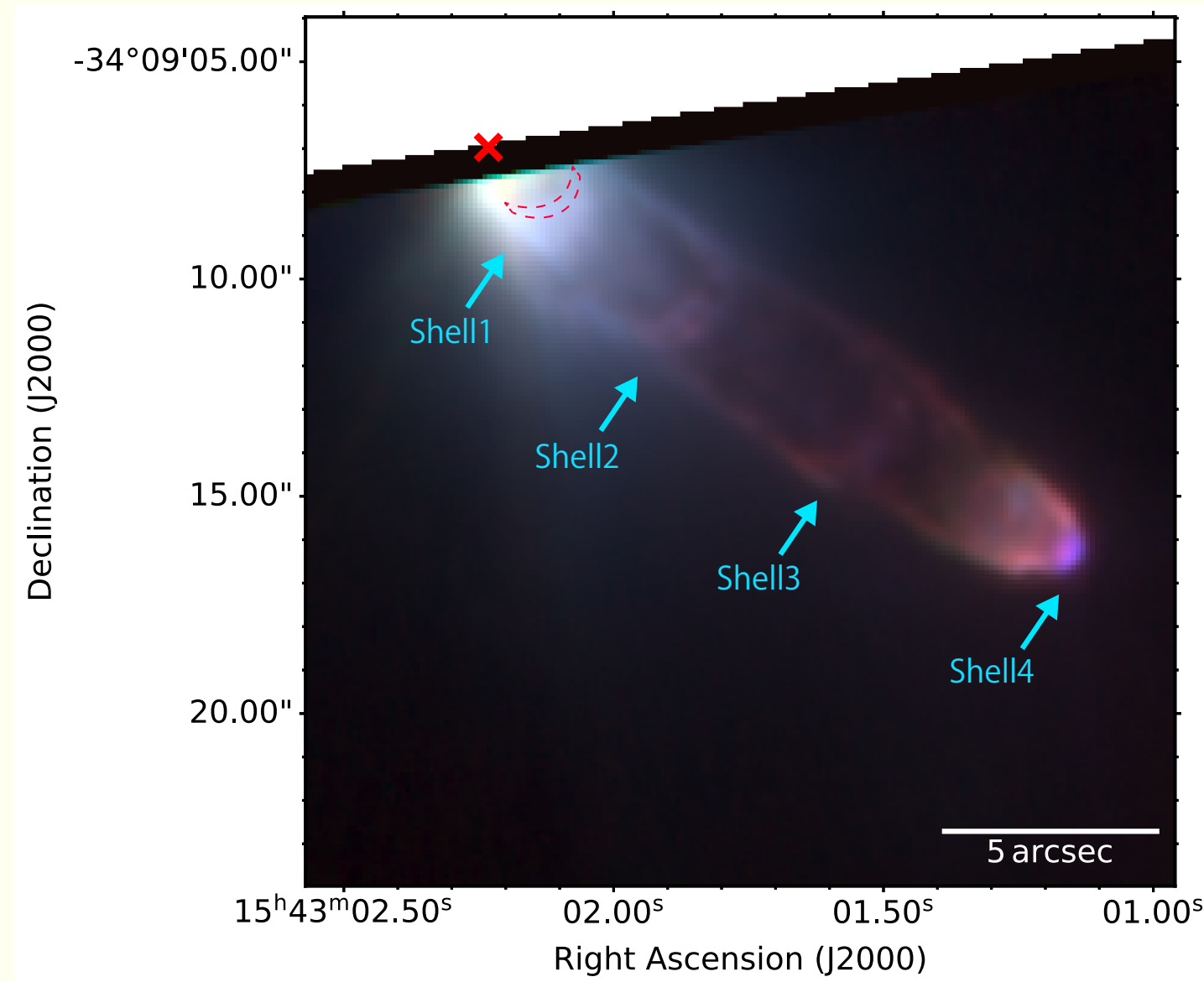
Kuffmeier+2019



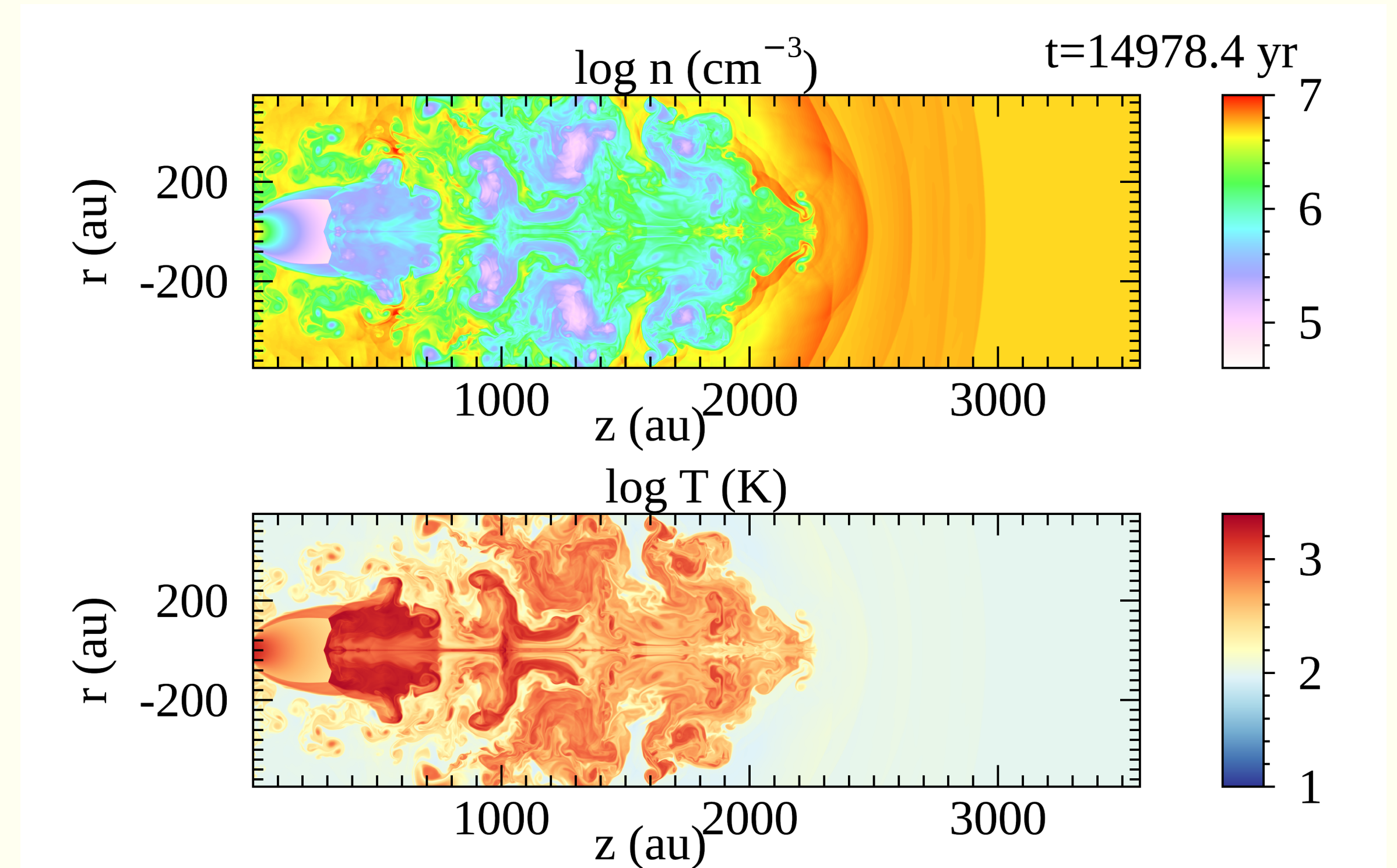
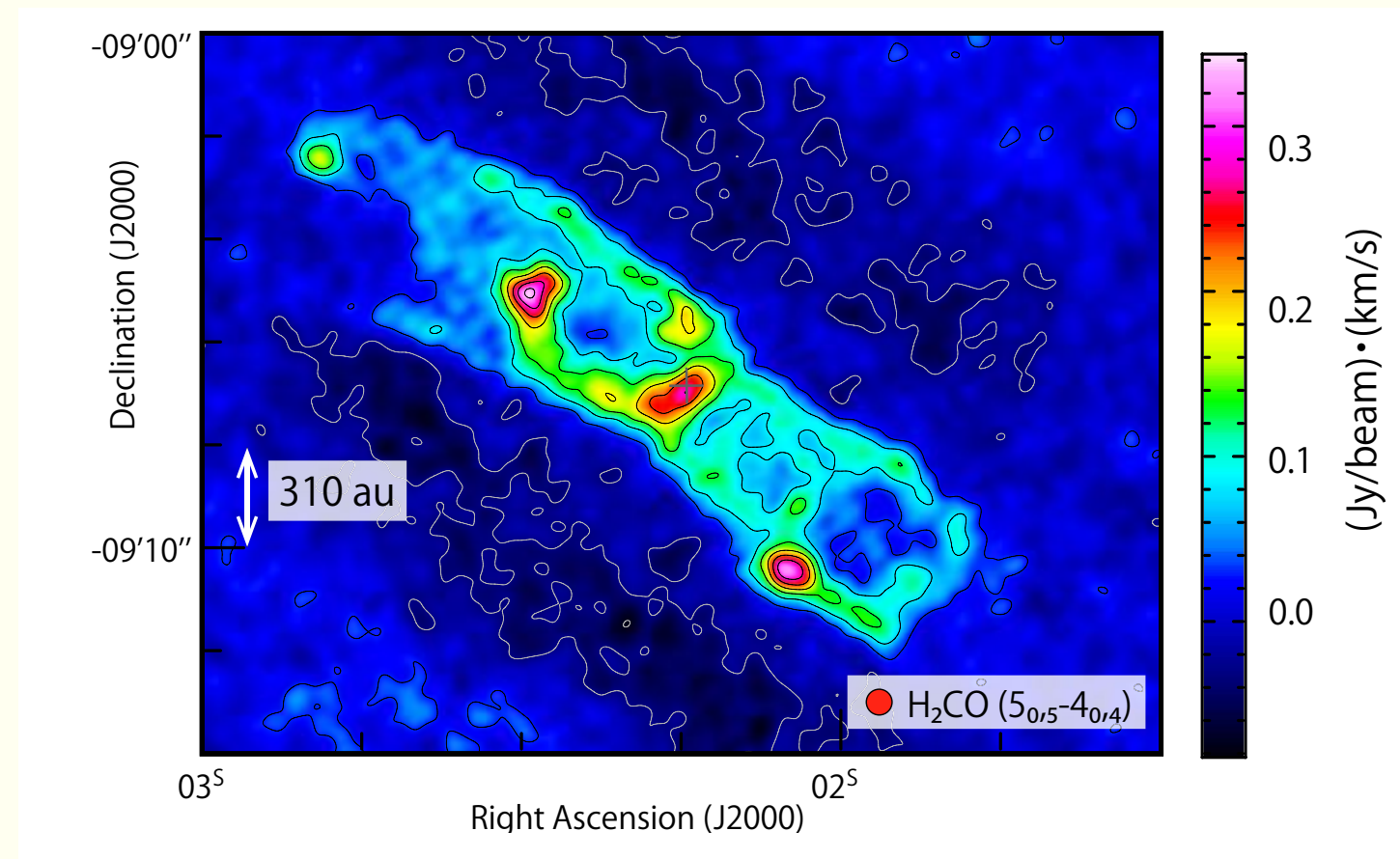
Alves+2019

Outflows also requires high-resolution and large MRS

To compare with IR images, sensitivities at multiple spatial scales are required



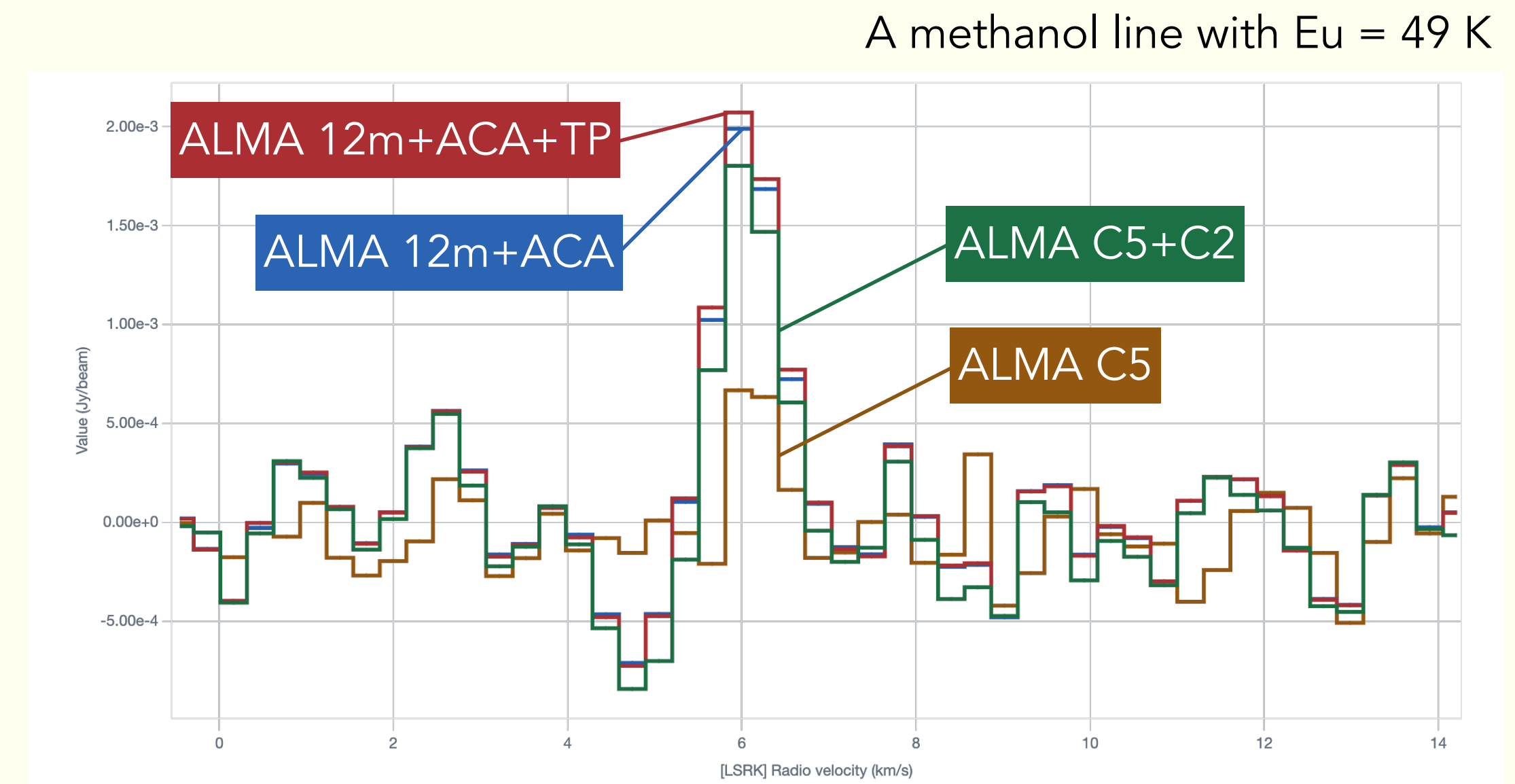
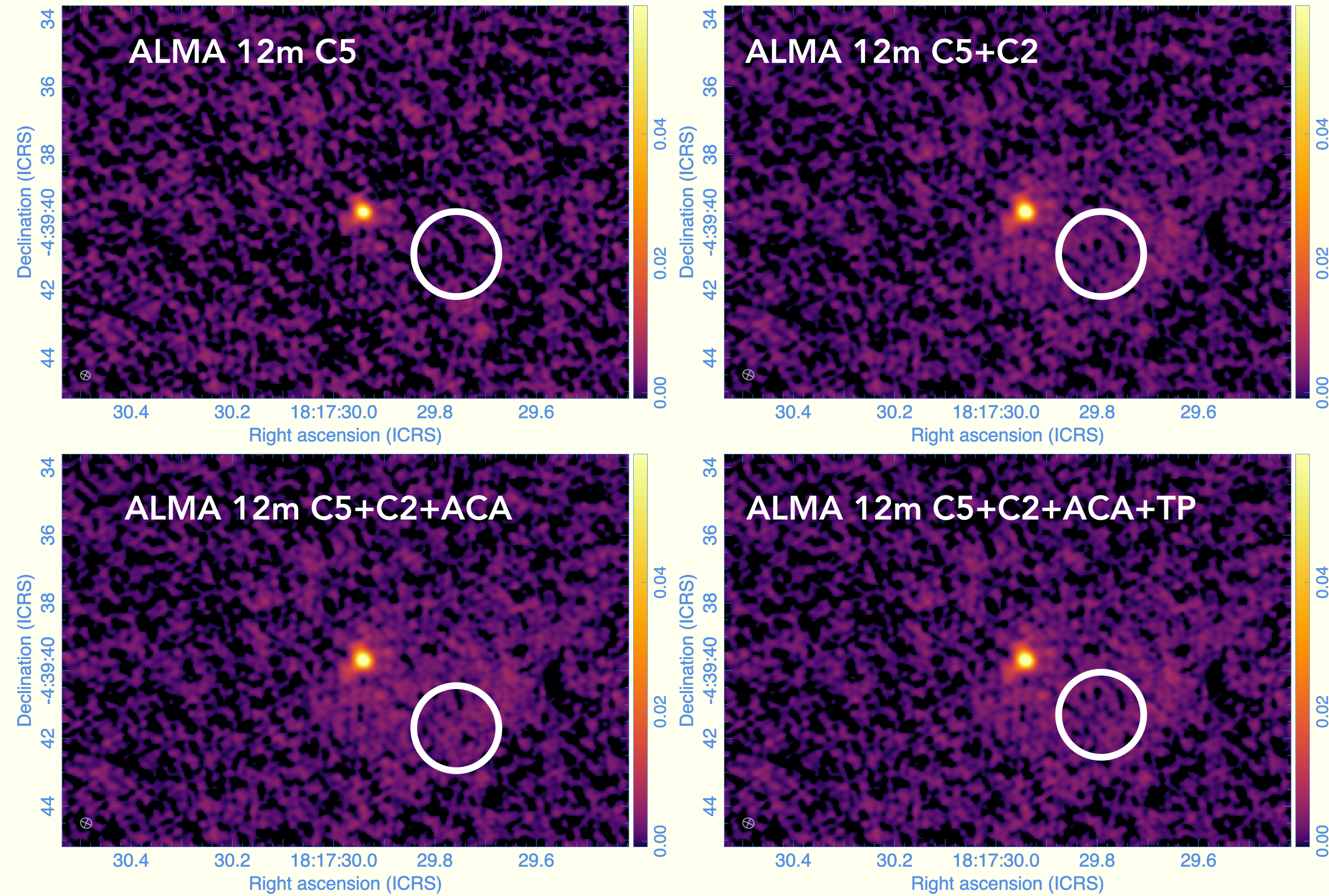
Okoda+2025



Hanawa+2025

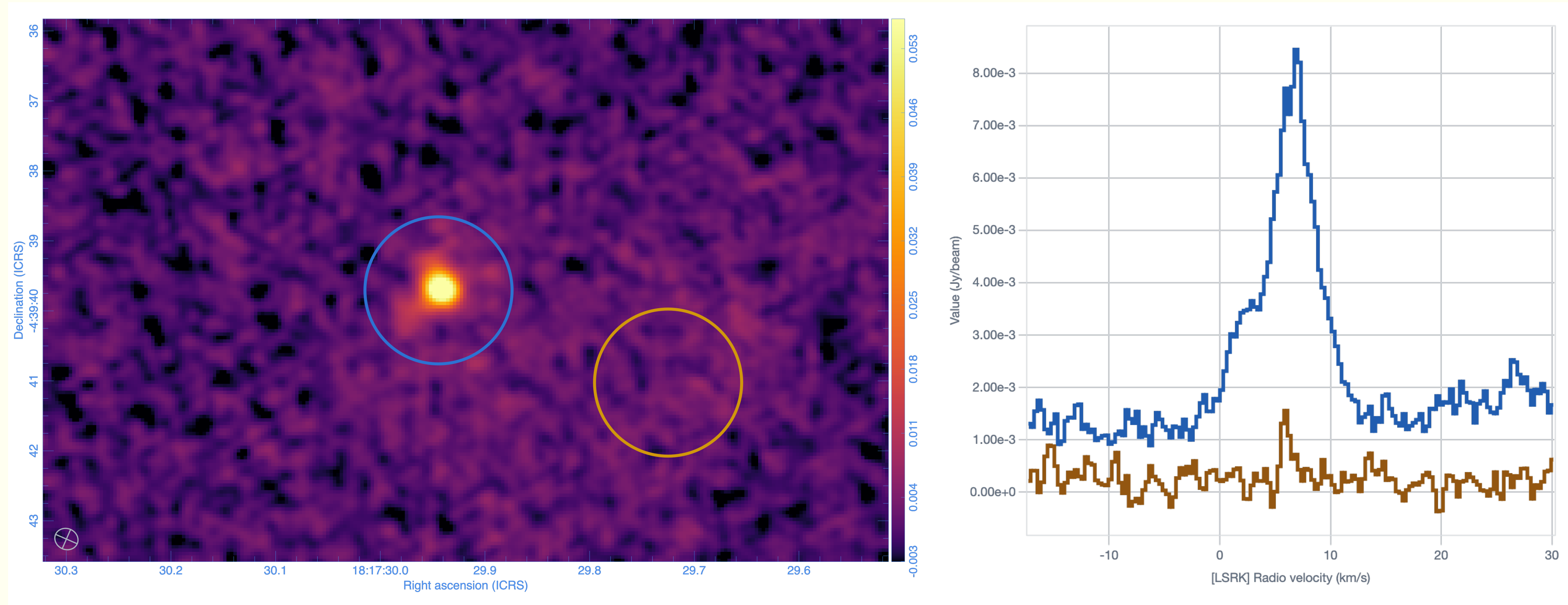
Limitations in the current ALMA capabilities

A complete census of emission from envelope to disk scale requires multiple configurations



Limitations in the current ALMA capabilities

Extended emission is clearly detected spectrally but its morphology is ill-constrained

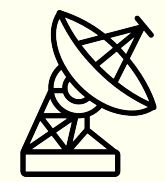


How can ALMA2040 meet this challenge?

Probing structures connecting envelopes to disks requires
high resolution, high line sensitivity, and good short-baseline coverage



A resolution sufficient to resolve the region where infall and accretion interacts
 $\sim 1 \text{ au} = 3 \text{ mas}$ at 300 pc



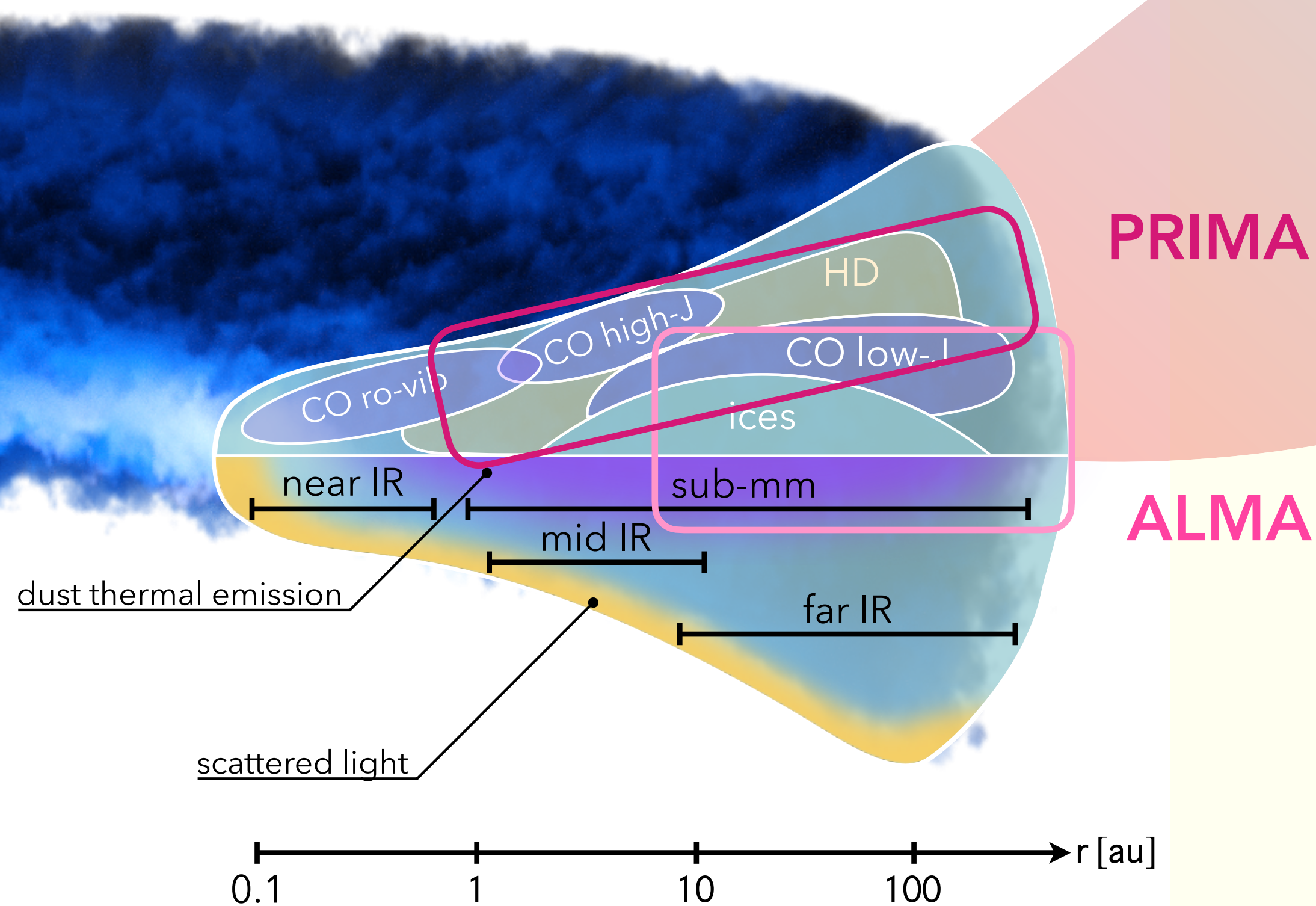
A significantly improved line sensitivity
10x better than current ALMA = more collecting area + wide bandwidth for stacking



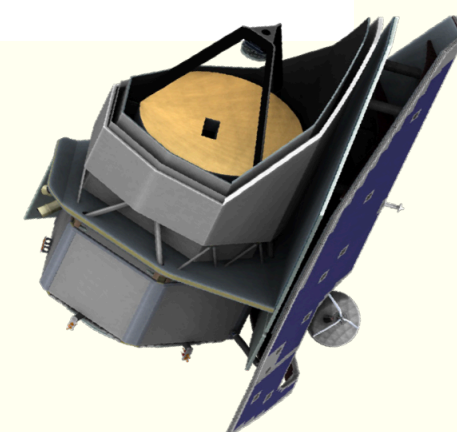
A sufficient uv coverage to probe the thousands au scale with good sensitivity
MRS > 5''-10'' with a sensitivity similar to the current 12m array

A synergetic path to ALMA2040 with PRIMA

PRIMA is a far-IR telescope aims to launch at 2032, surveying the gas and water mass in disks



- Accurate disk mass measurements for understanding the impact of asymmetric infall and the interplay of outflows and accretion.
- Available water vapor mass to probe the role of icy pebbles in disks.
- Mission timeline from 2032-2037+, perfectly situated to be a pathfinder for high-resolution, planet-forming protostellar systems to be targeted by ALMA in 2040s.



FIRESS to obtain $R \sim 100$ and $R \sim 1000 \sim 10000$ s spectra at 24-235 μm

PRIMAger can cover 25-250 μm with $R \sim 4$ & polarimetric imaging

Summary and future outlook

- Discoveries of asymmetric infalling filaments and their potential effects on the ongoing star/disk/planet formation connects the large-scale (thousands au) and disk-scale (1-10 au).
- A complete understanding requires observations of multiple molecular tracers at multiple spatial scales.
- For organic species, in addition to the compact hot corinos, extended emission does exist but it is often filtered out in interferometric observations.
- ALMA capabilities with **10x line sensitivity, milli-arcsec spatial resolution, and good sensitivity at MRS of 5"-10"** would be ideal for connecting dynamics and chemistry from envelopes to disks