

Chemical and Kinematic Stratification of the HL Tau Outflow seen by ALMA and JWST

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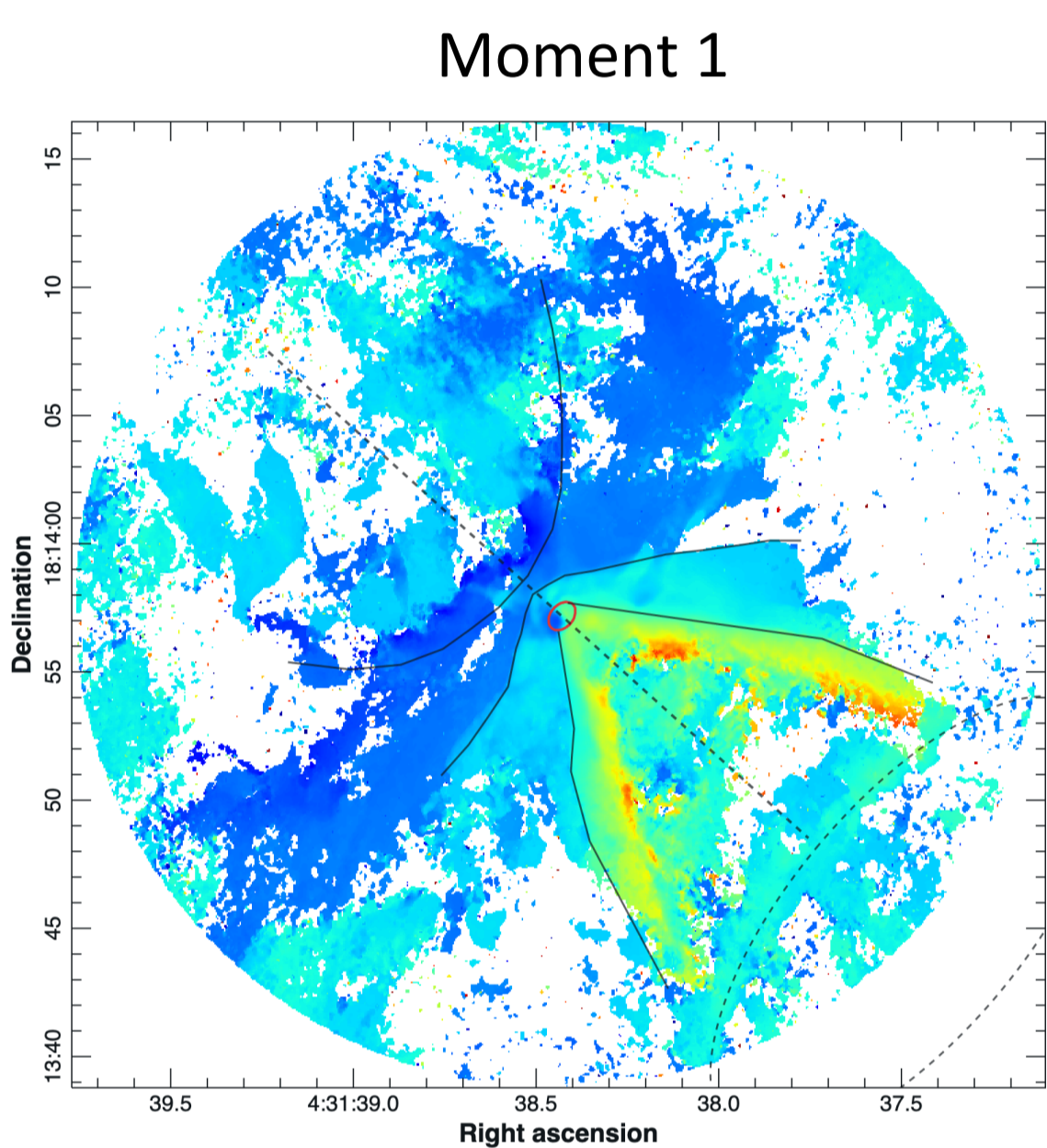
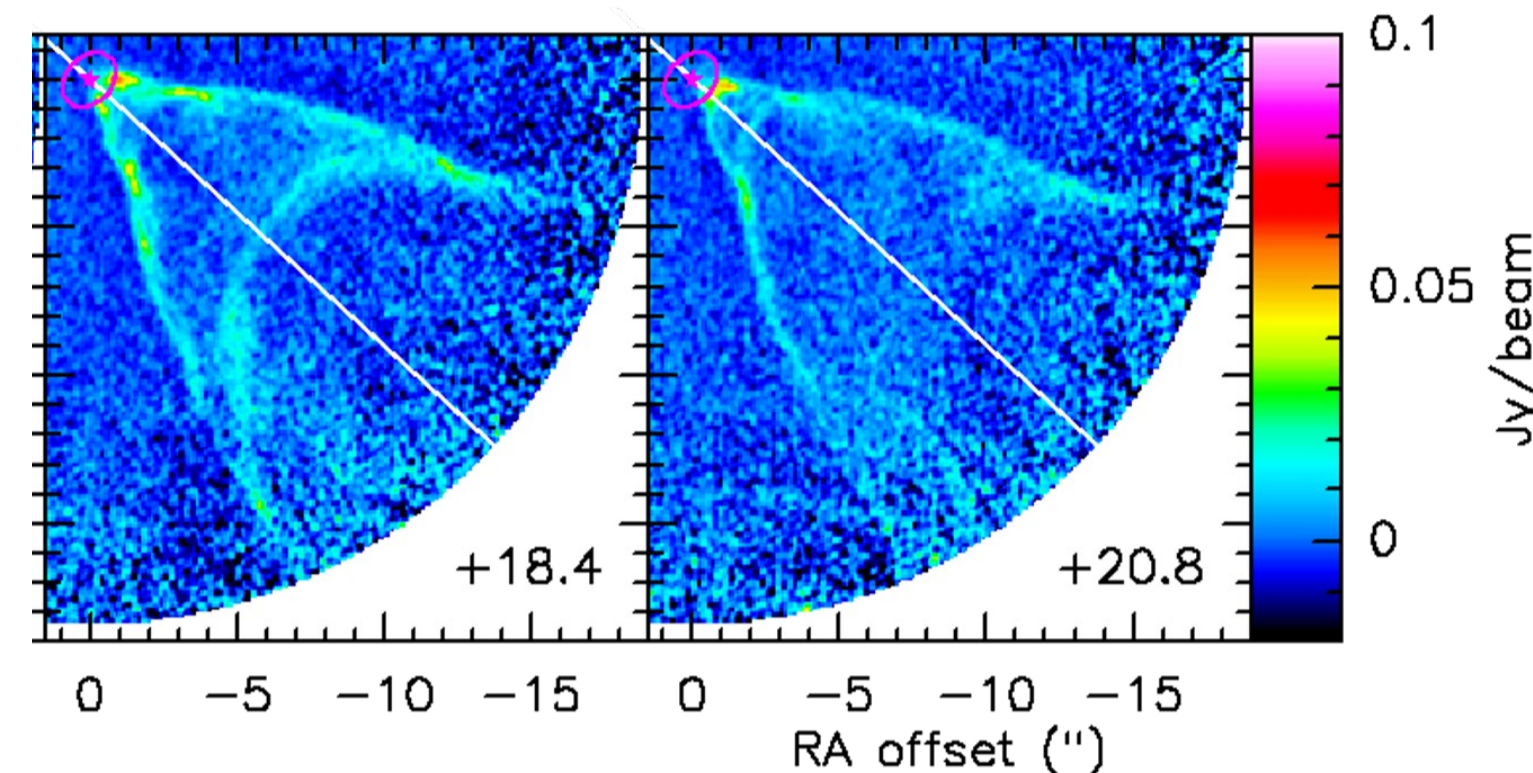
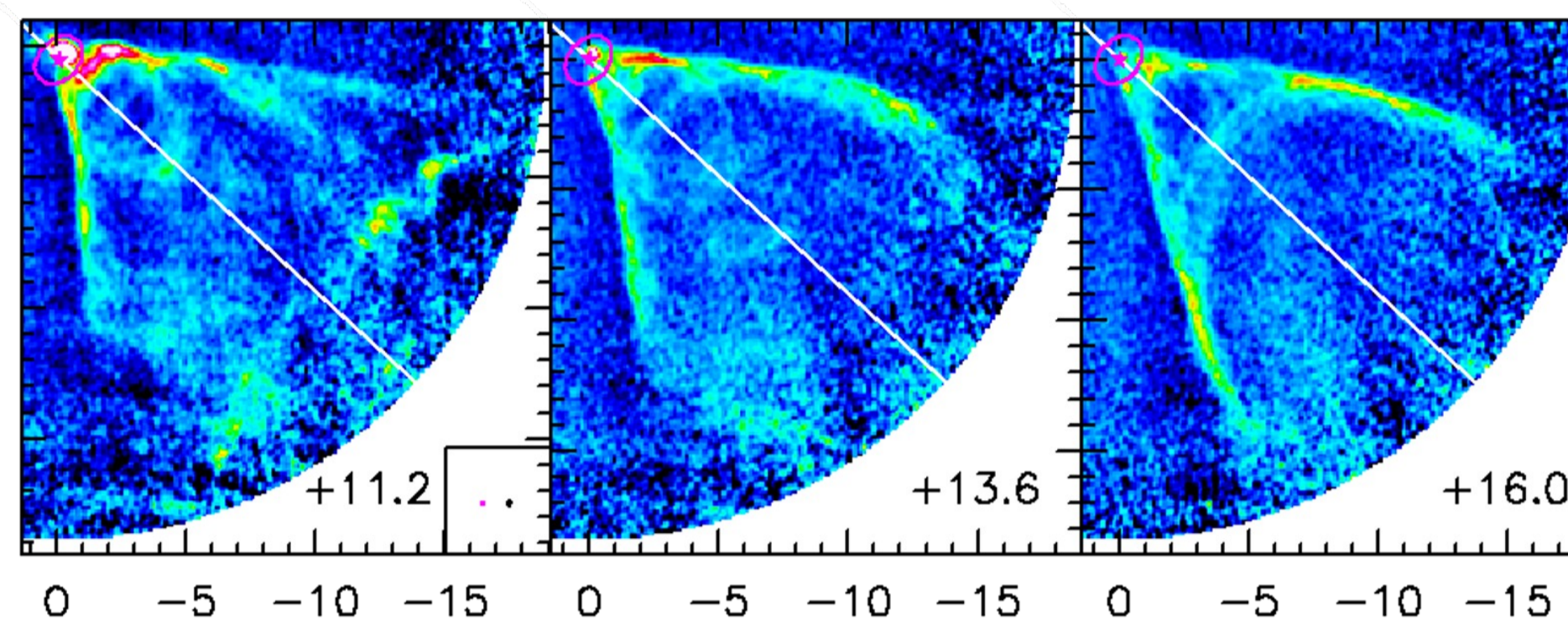
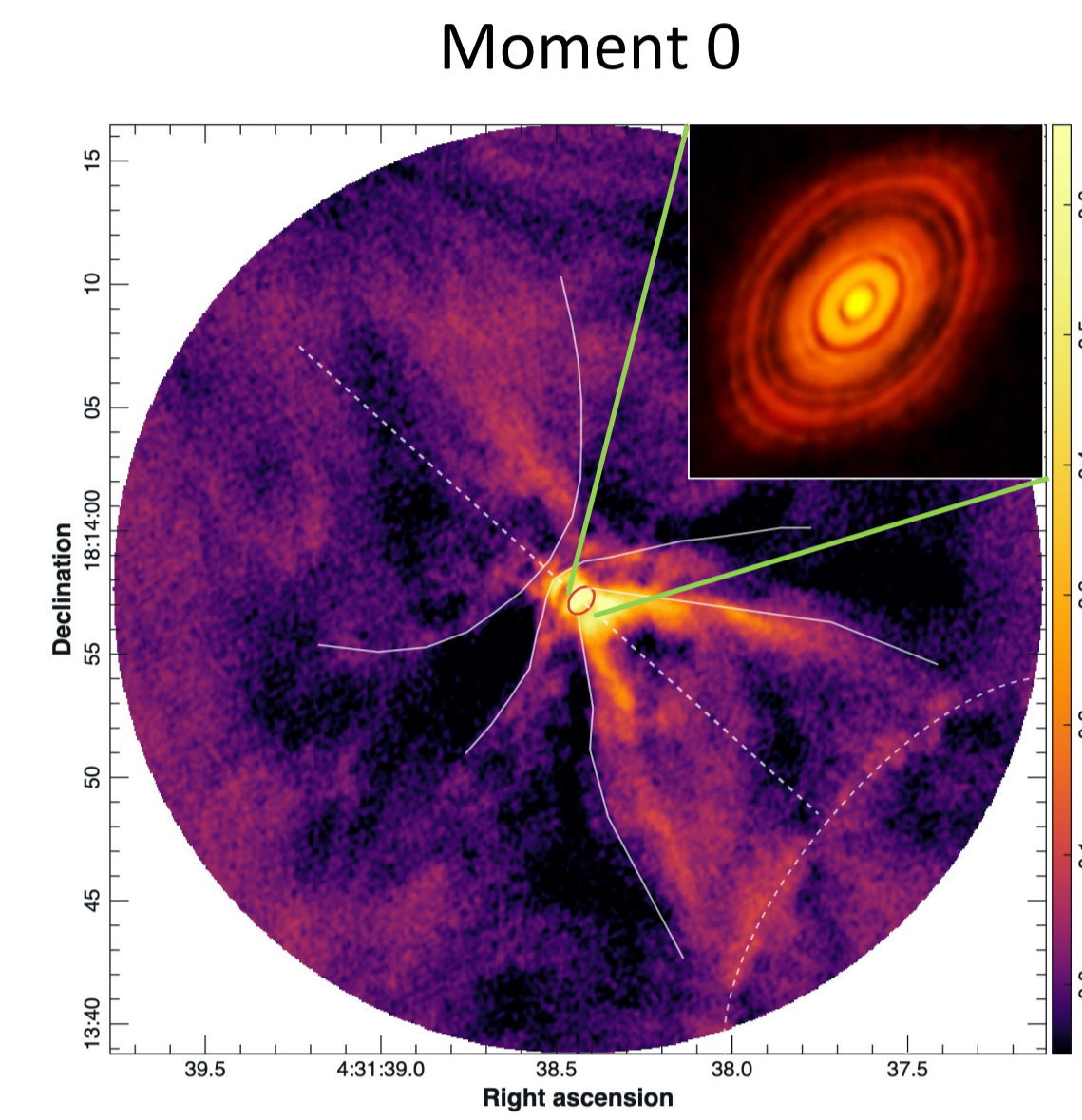
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ALMA: Nested shells in CO

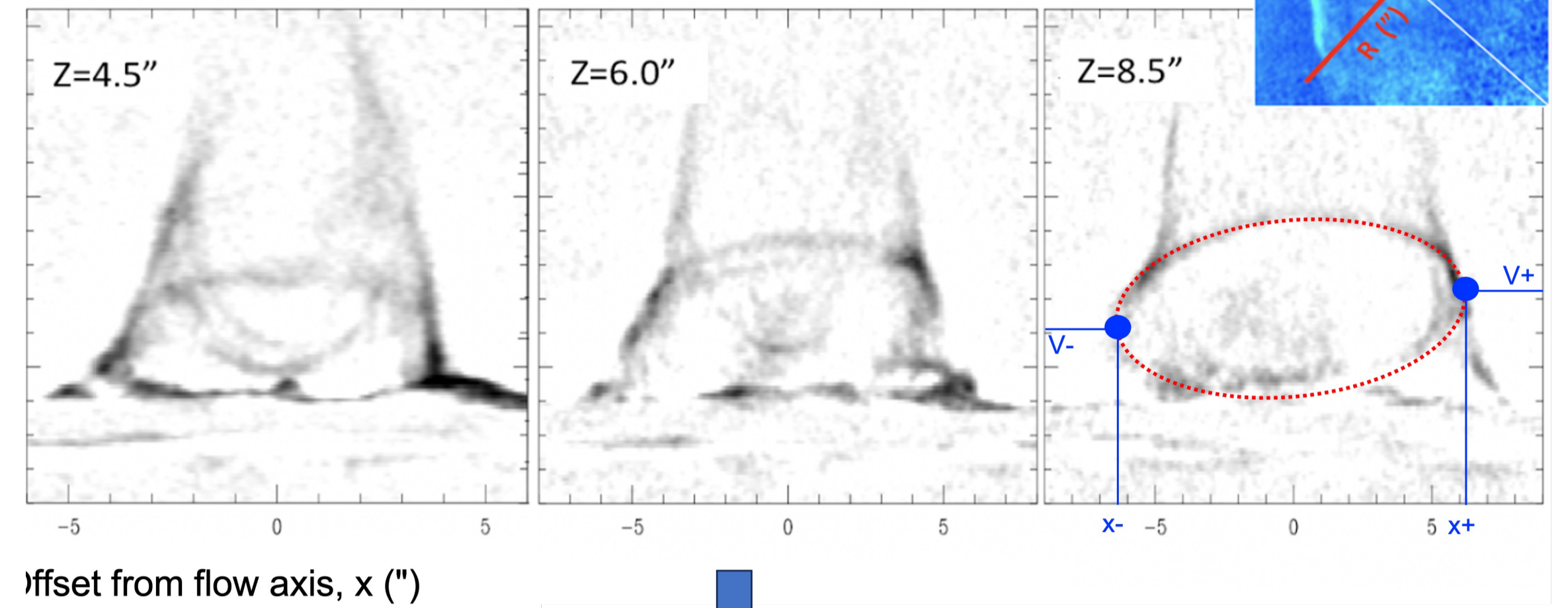
CO(J=2-1) observations of HL Tau molecular wind from HL Tau reveal a **system of arcs and bubbles** interpreted as **nested shells originated from the disk** (Bacciotti, Nony et al 2025)

We followed and fitted these features ... in the *channel maps*

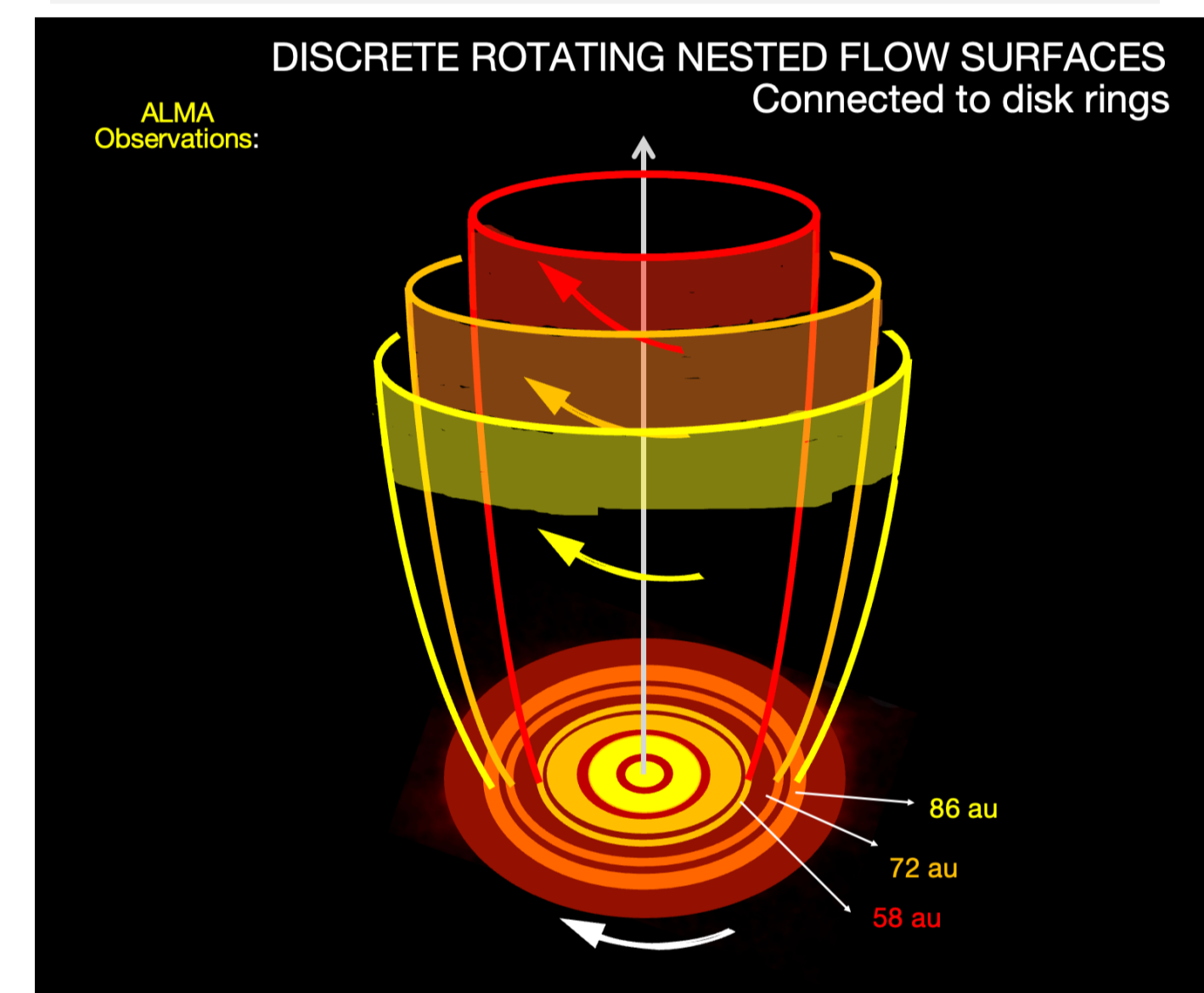
... in *Position-Velocity diagrams*



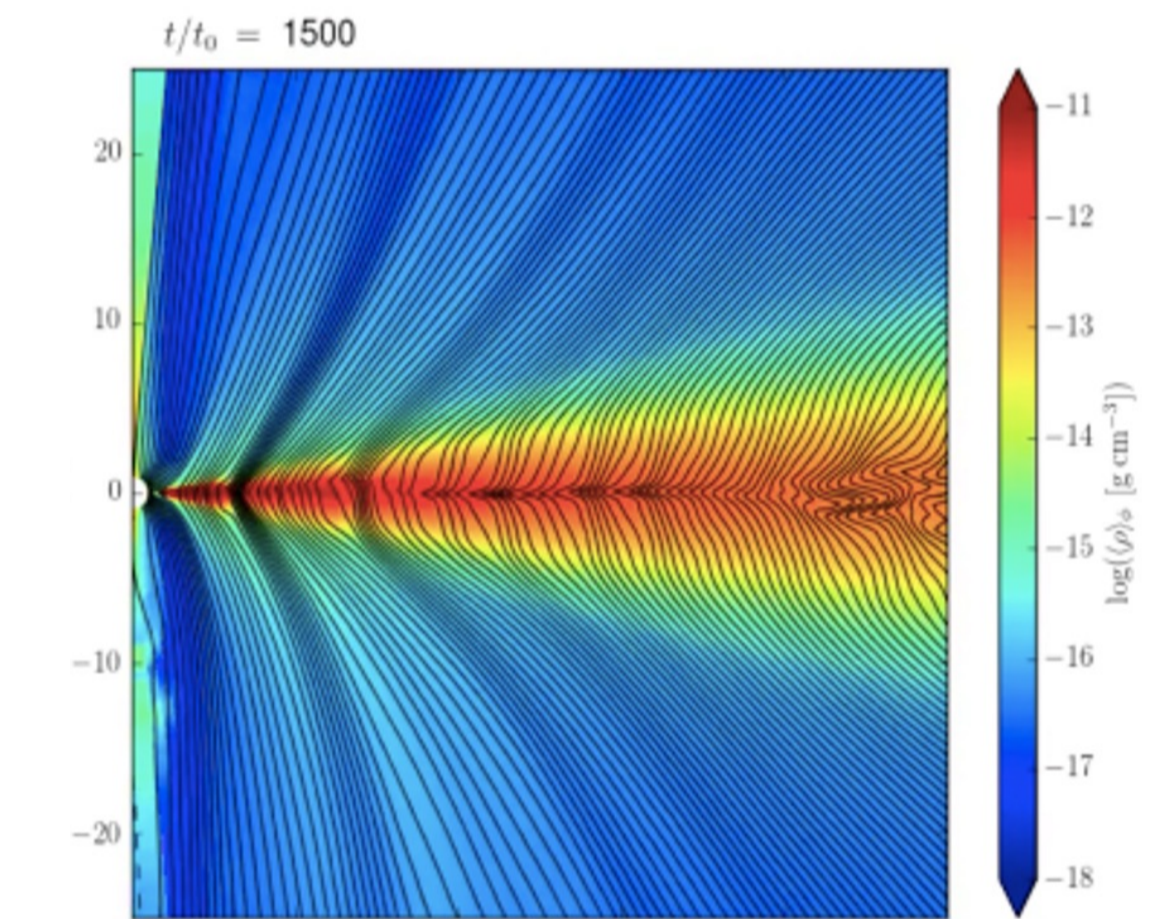
Measurements of **rotation** in the transverse PV



emission from the disk region with substructures



in line with MHD models forming rings without planets

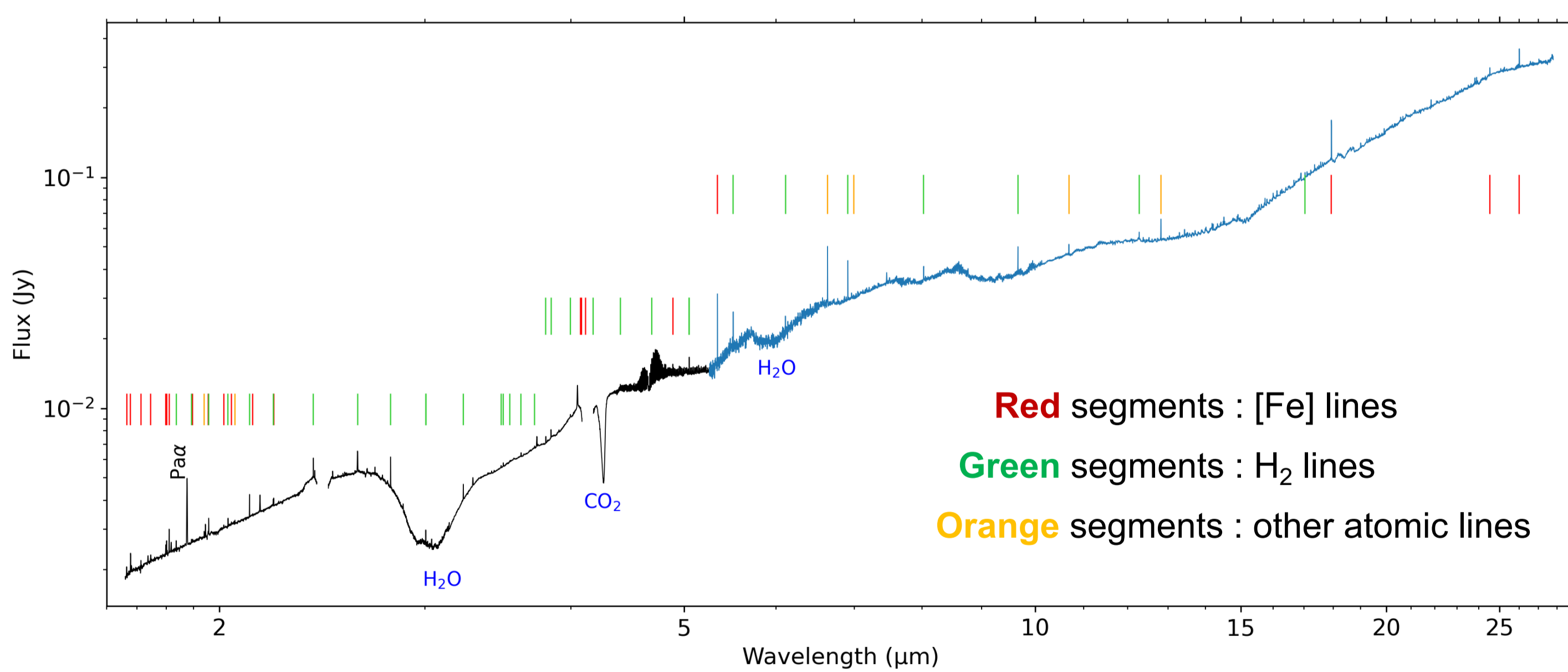


Red-shifted lobe detected $V_{\text{rad}} = 3$ to 20 km/s
Blue-shifted lobe detected $V_{\text{rad}} = -4$ to -10 km/s

Suriano et al. 2019

JWST: A stratified wind

NIRSpec + MIRI (1.66 – 28 μm) mosaics of the red-shifted lobe of HL Tau outflow reveal a **stratified wind** shining in numerous **atomic, H₂ and CO lines** (Nony, Bacciotti et al. in prep.)

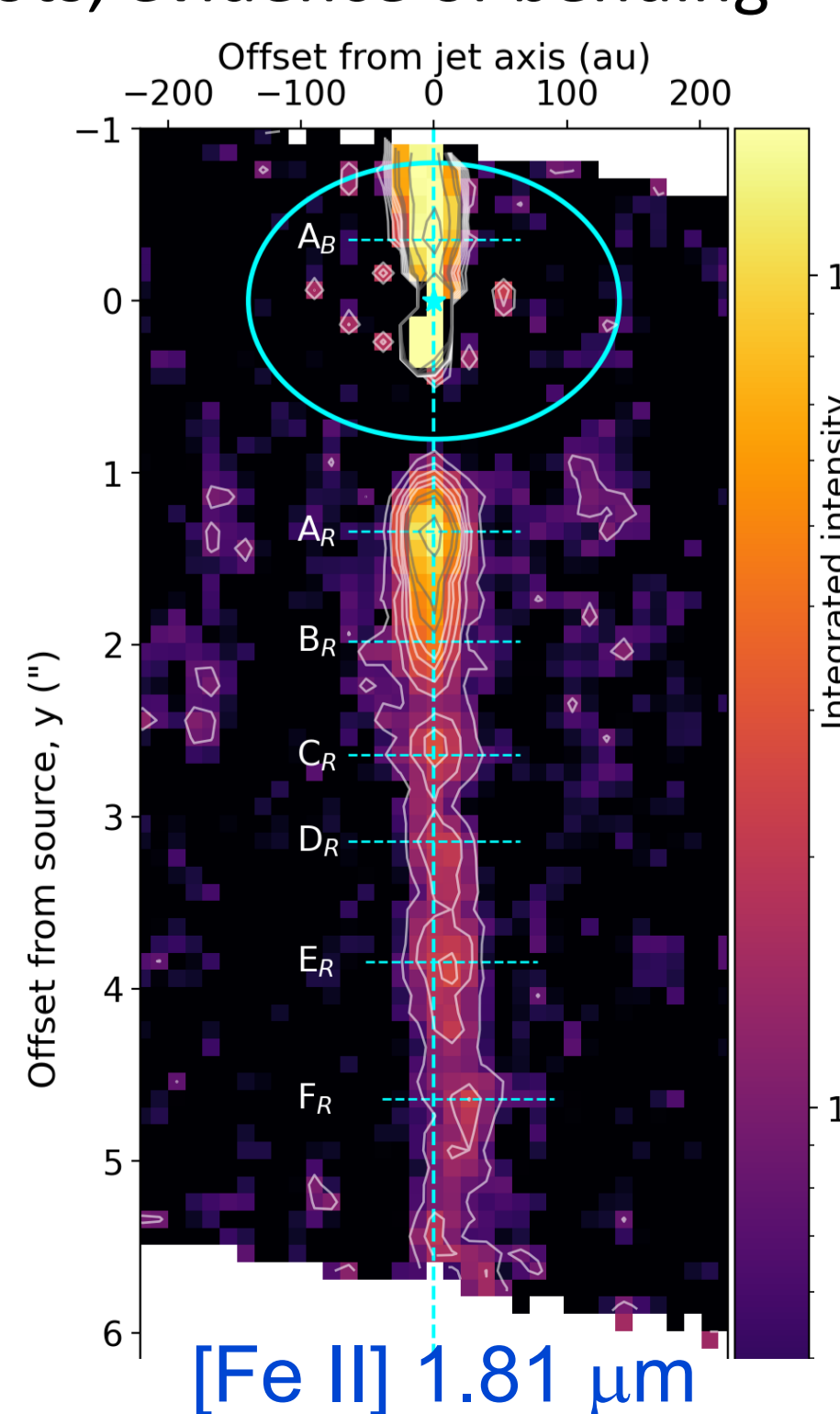


Combined spectrum at position of brightest jet knot

Atomic jet:

Red $V_{\text{rad}} = 160$ km/s

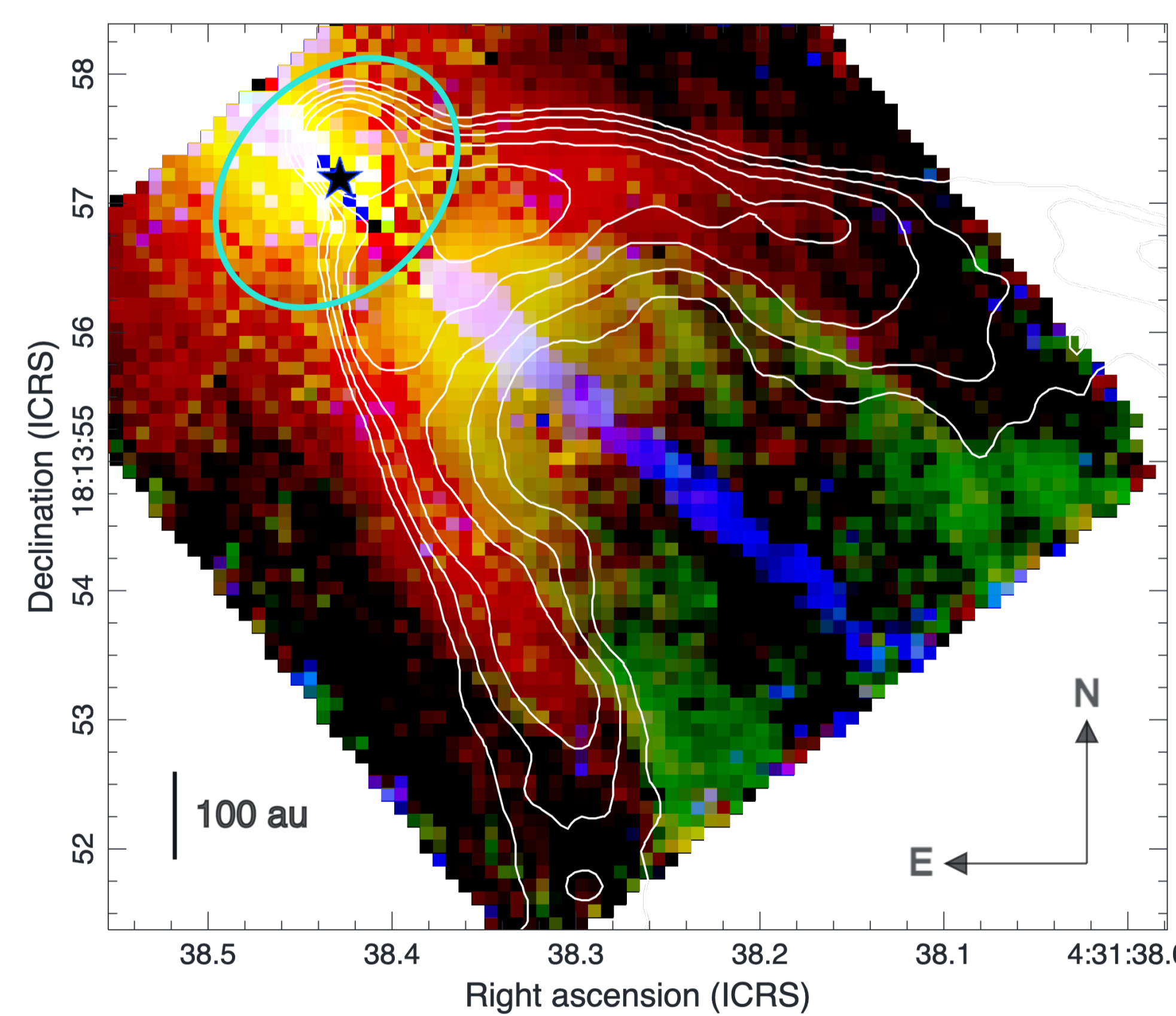
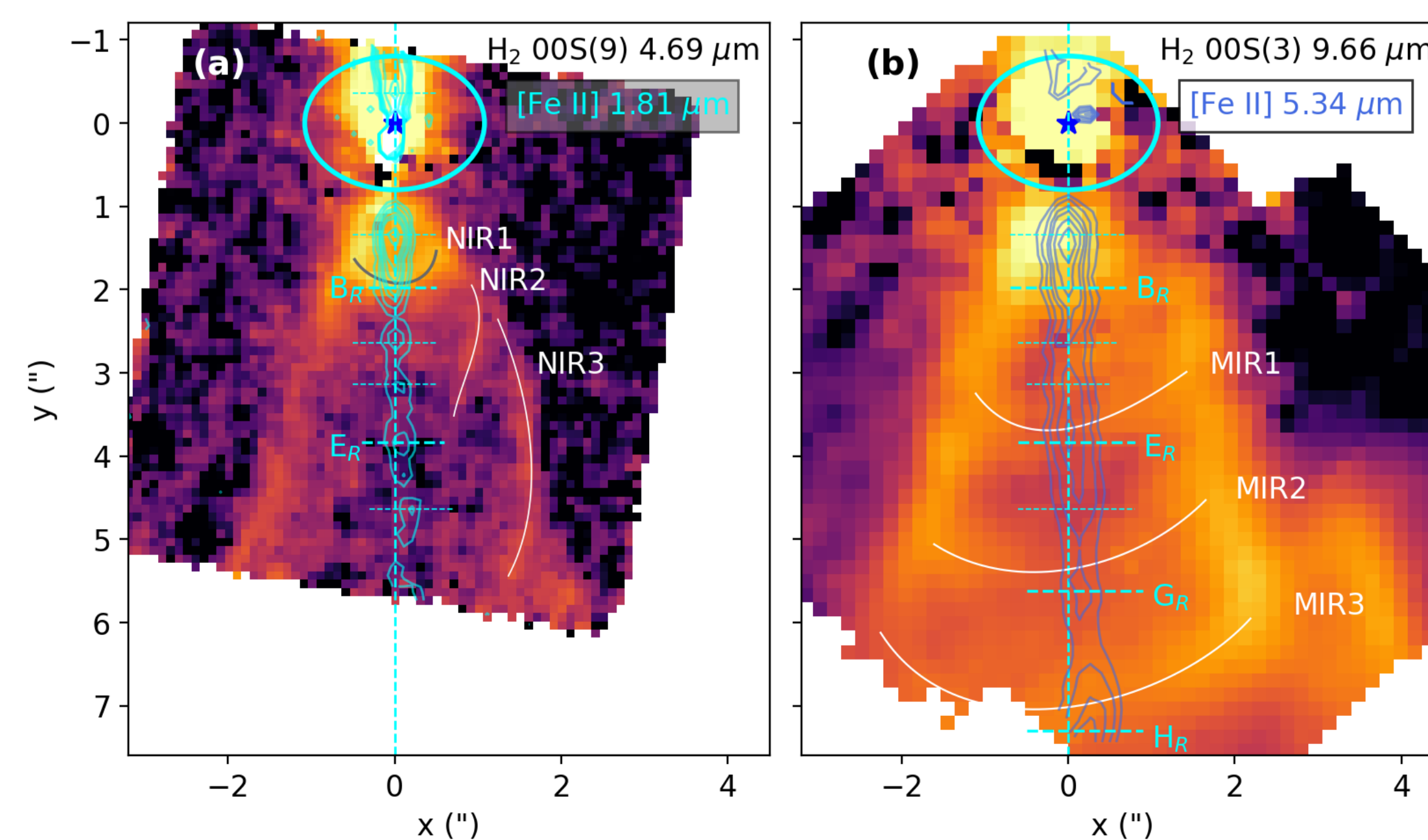
Detected in [Fe II], [Ni II], [Mn II], [Ar II], [Ne II]
8 knots, evidence of bending



H₂ wind

Red $V_{\text{rad}} = 45$ km/s

Detected in transitions of $v=0-0$ S and $1-0$ O, S, Q
arcs substructures: signatures of jet bow shocks?



from JWST NIRSpec :

- Blue: [Fe II] 1.81 μm
- Green: H₂ 00 S(9) 4.7 μm
- Red: CO ($v=1-0$) rovib P2-P6 around 4.7 μm

from ALMA :

- Cyan ellipse : 1.3 mm continuum at 20σ (disk)
- White contours: ¹²CO(J=2-1) at 1.3 mm

warm CO wind

Red $V_{\text{rad}} = 35$ km/s

¹²CO detected in transitions from $v_{\text{up}} = 1$ to 3
Cospatial with the cold CO(J=2-1)

