Accretion shocks in the disk of DG Tau and HL Tau

ALMA-DOT VI

On arXiv today!

A. Garufi, L. Podio, C. Codella, D. Segura-Cox, … J. Pineda, … L. Testi

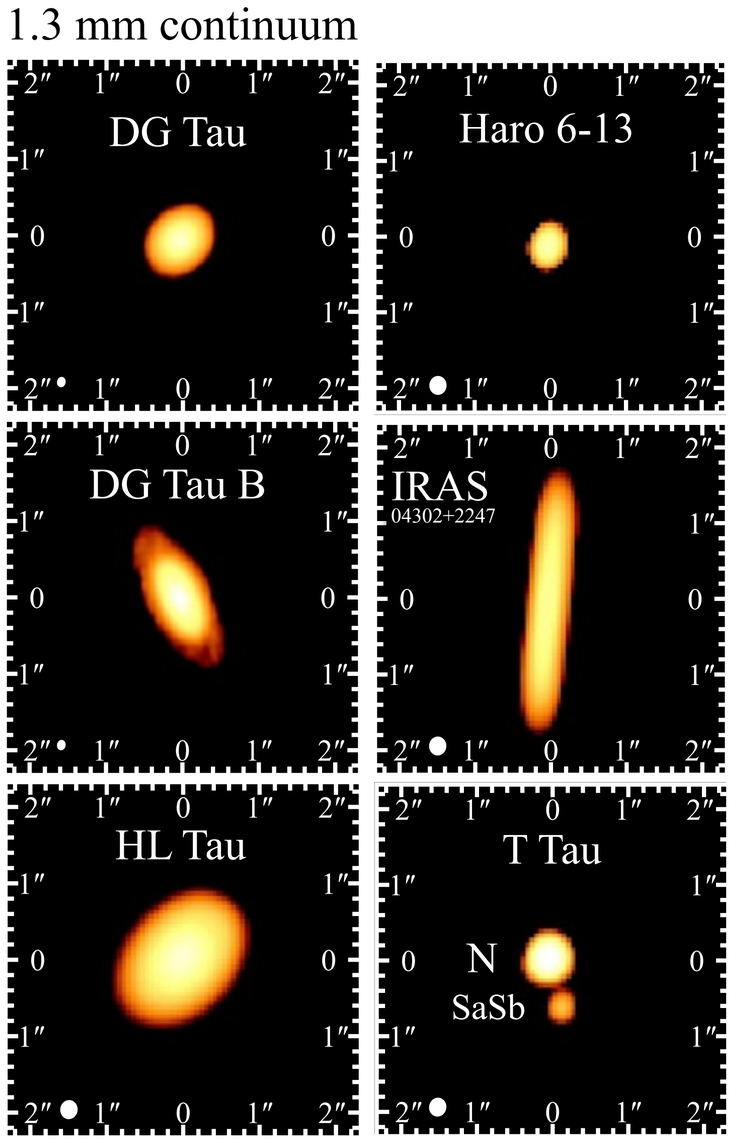
ALMA chemical survey of disk-outflow sources in Taurus (ALMA-DOT)

ALMA Cycle 4, 5, 6 in Band 5, 6, 7, and 9 of six **Class I**

PI: L. Podio

with: A. **Garufi**, C. Codella, F. Bacciotti, D. Fedele

and: C. Favre, E. Bianchi, C. Ceccarelli, L. **Testi**, S. **Facchini**, A. **Miotello**, R. **Teague**, D. **Segura-Cox**, J. **Pineda**, and many others…

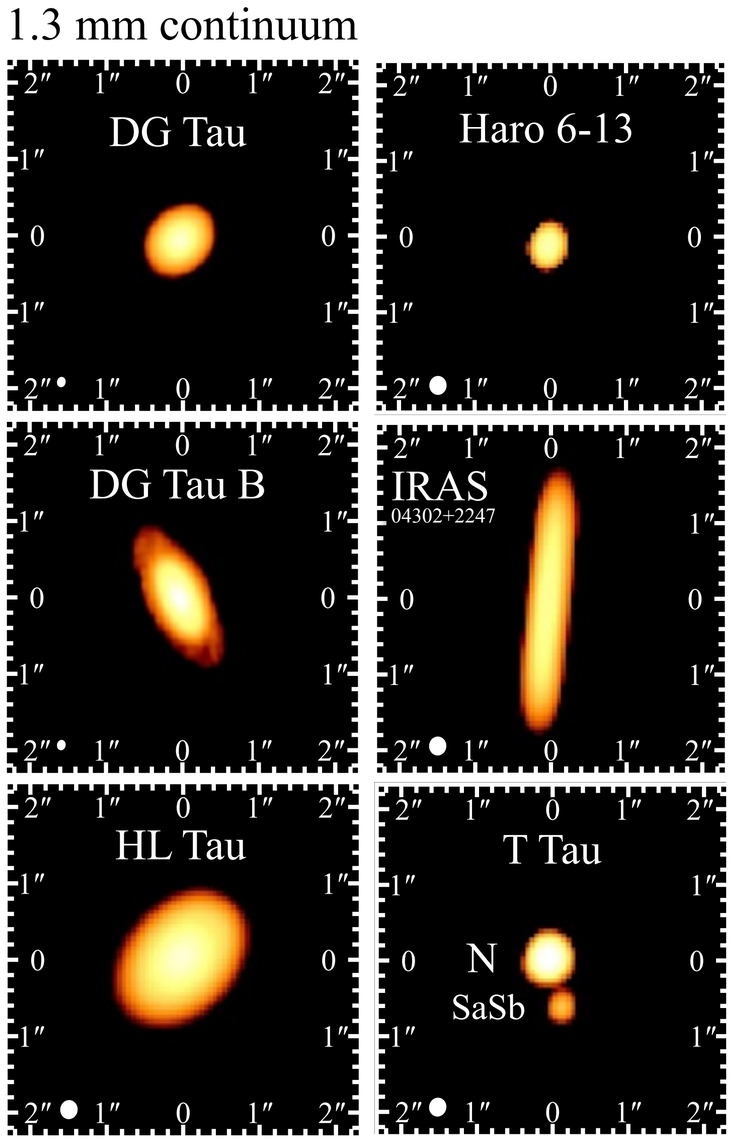


ALMA chemical survey of disk-outflow sources in Taurus (ALMA-DOT)

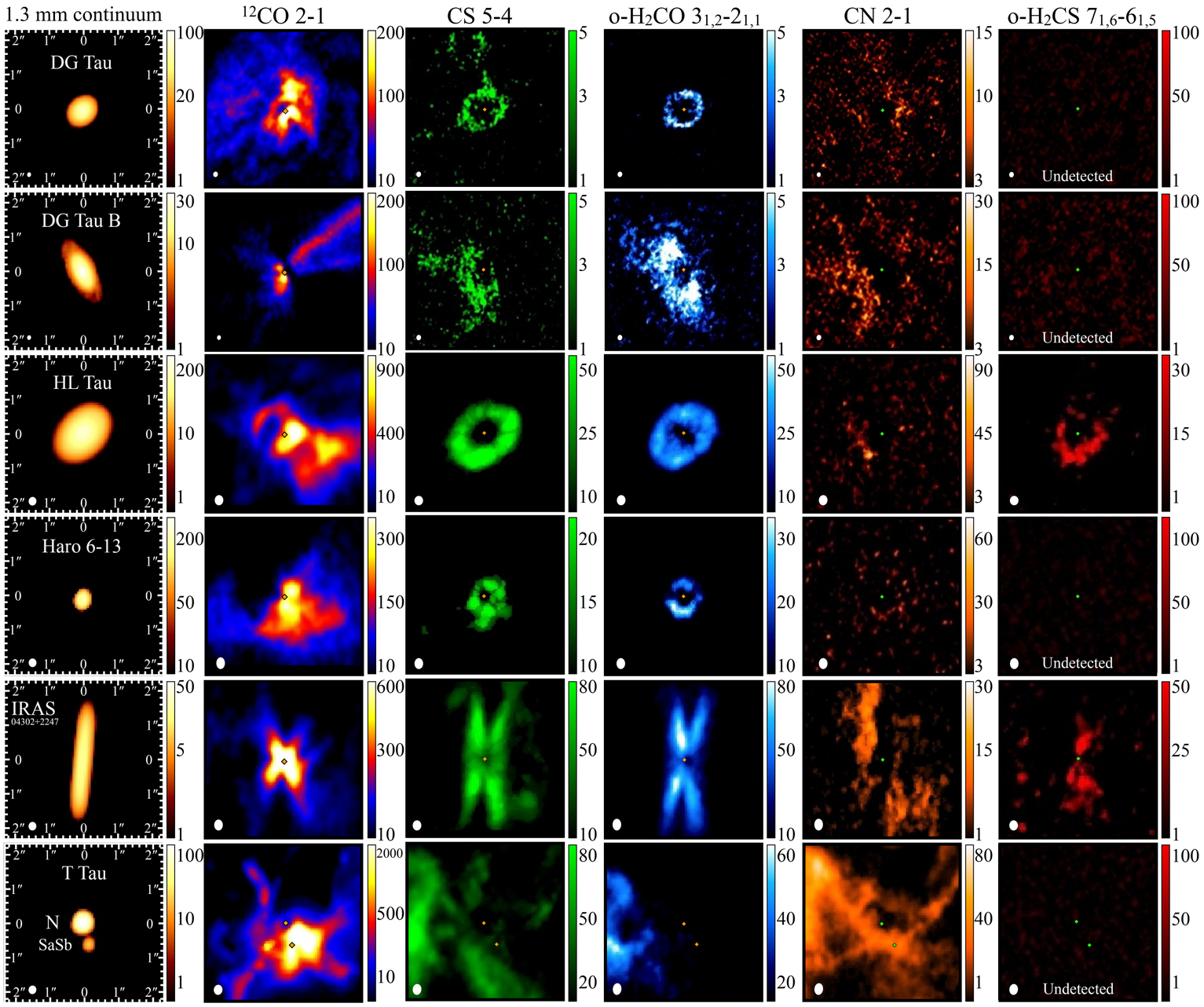
1. Imaging the young gaseous disks of Class I with multiple molecules other than ^{12}CO

2. Imaging outflows, envelope, streamers, and other structures around the disk

3. Detect and characterize simple organic molecules (formaldehyde, methanol)



ALMA-DOT V: Overview (Garufi et al. 2021a)



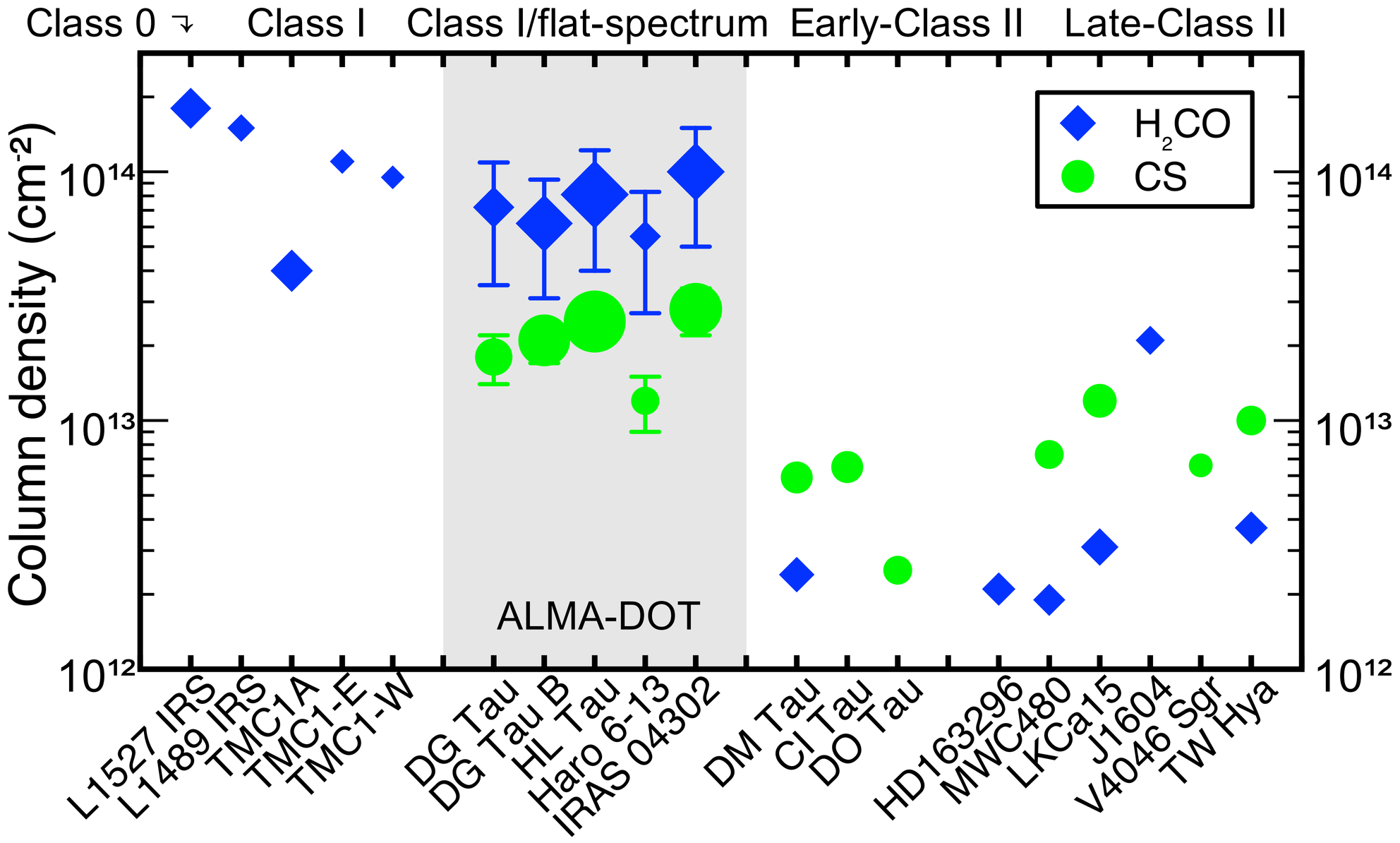
1. ^{12}CO traces outflow and envelope

2. H_2CO and CS are good disk tracers, and look very similar

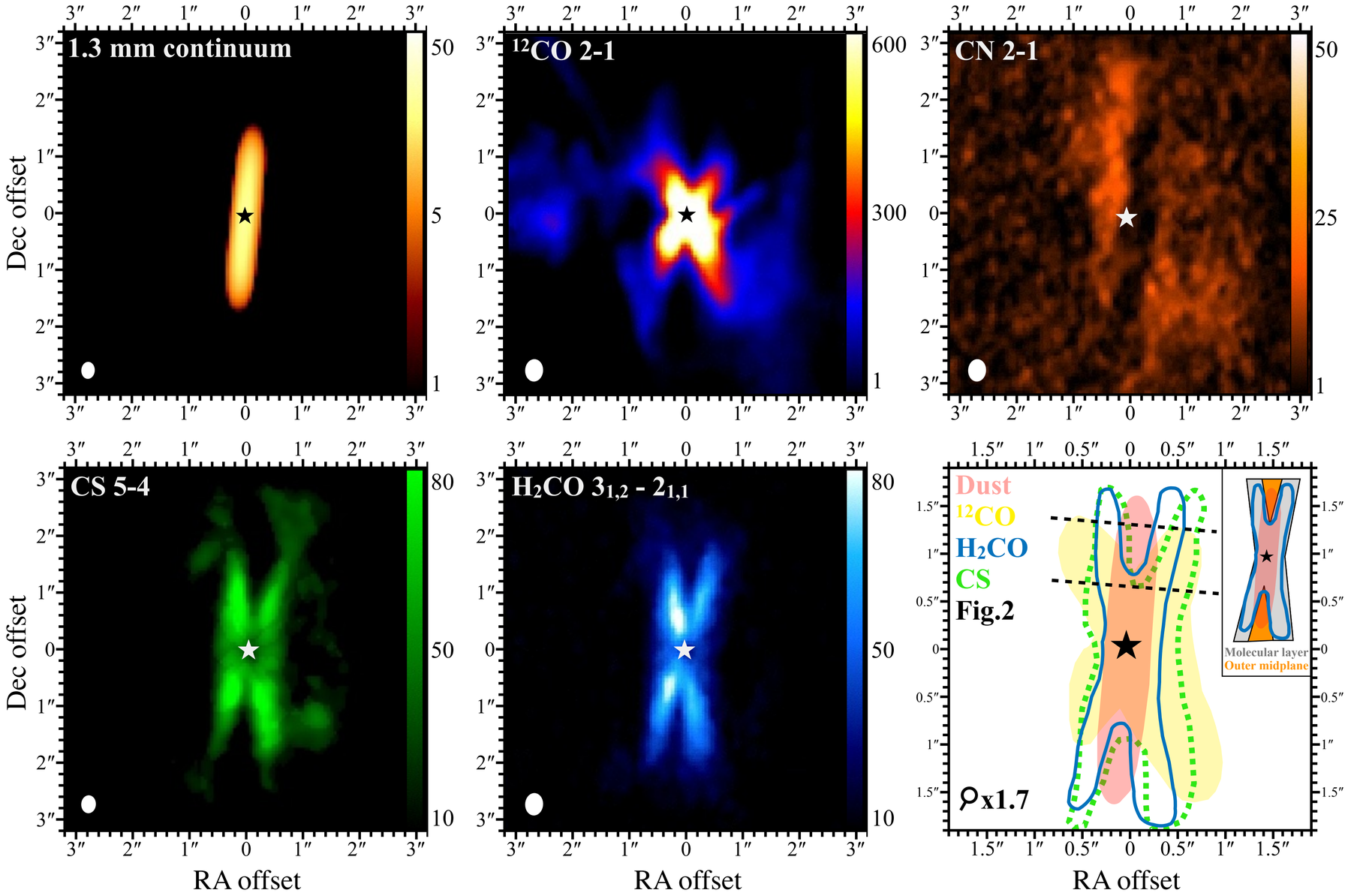
3. CN is detected only from the dust edge outward

4. H_2CS and CH_3OH are also detected in 2 and 1 sources

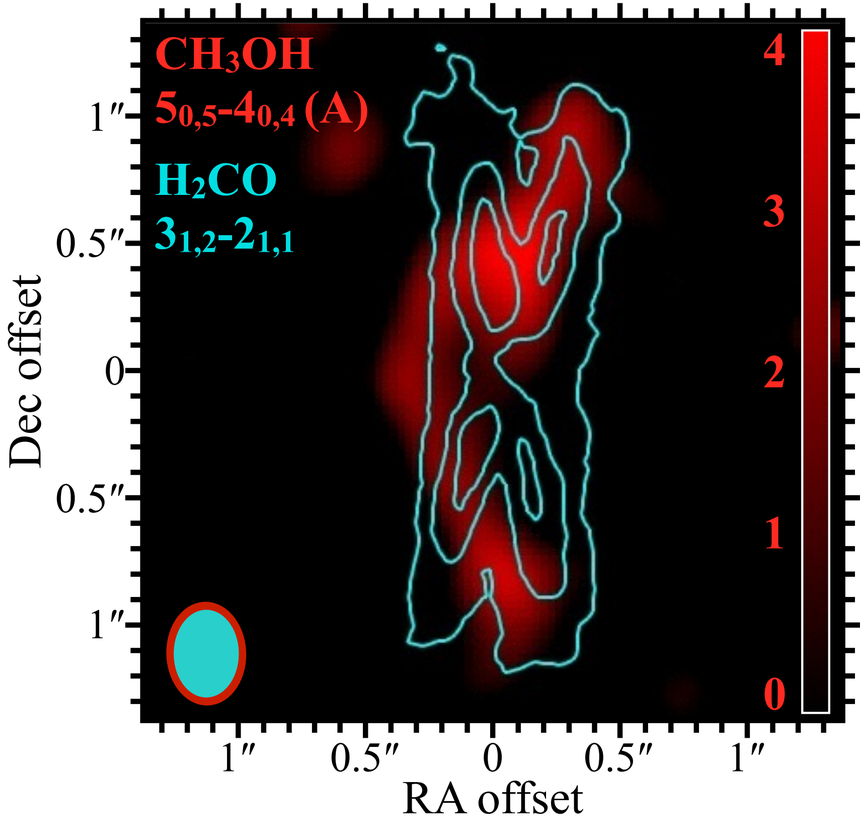
ALMA-DOT V: Overview (Garufi et al. 2021a)

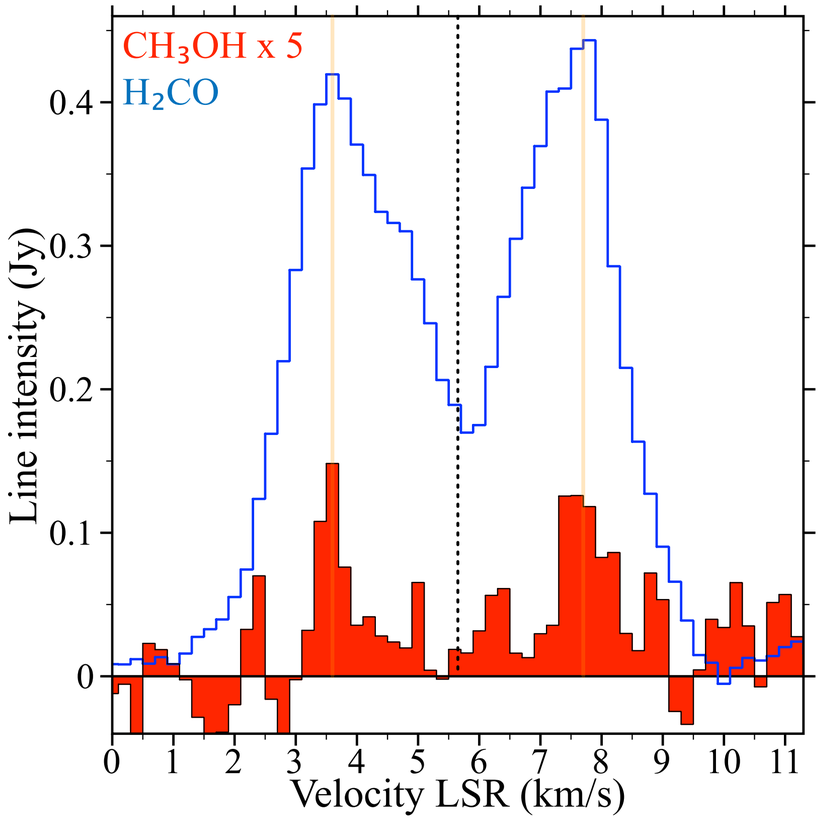


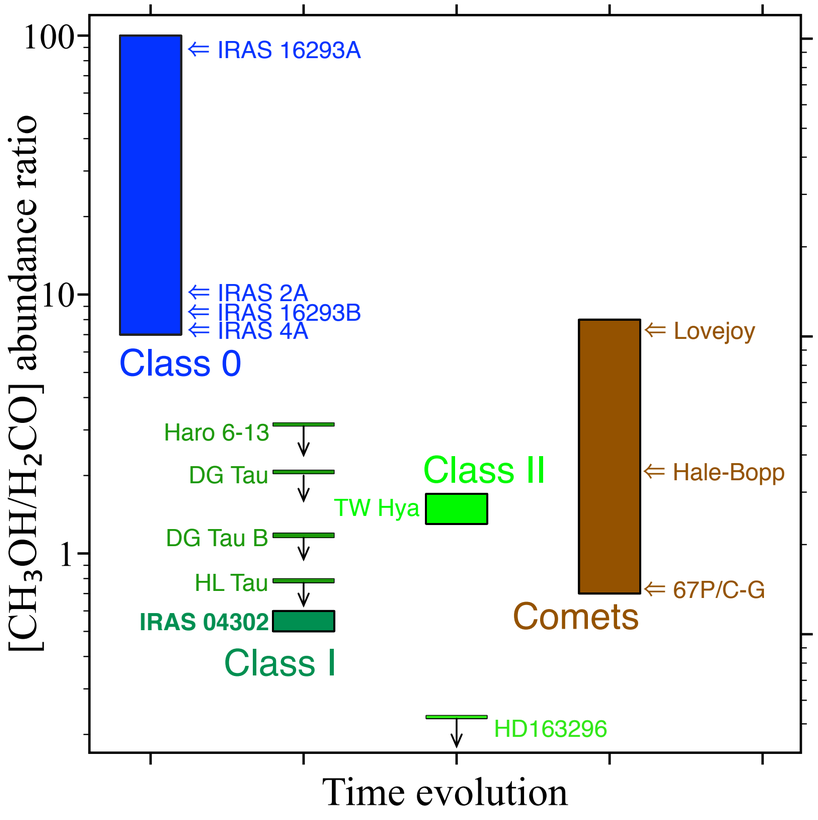
ALMA-DOT II: Vertical stratification
(Podio et al. 2020a)



ALMA-DOT II: Vertical stratification
(Podio et al. 2020a)



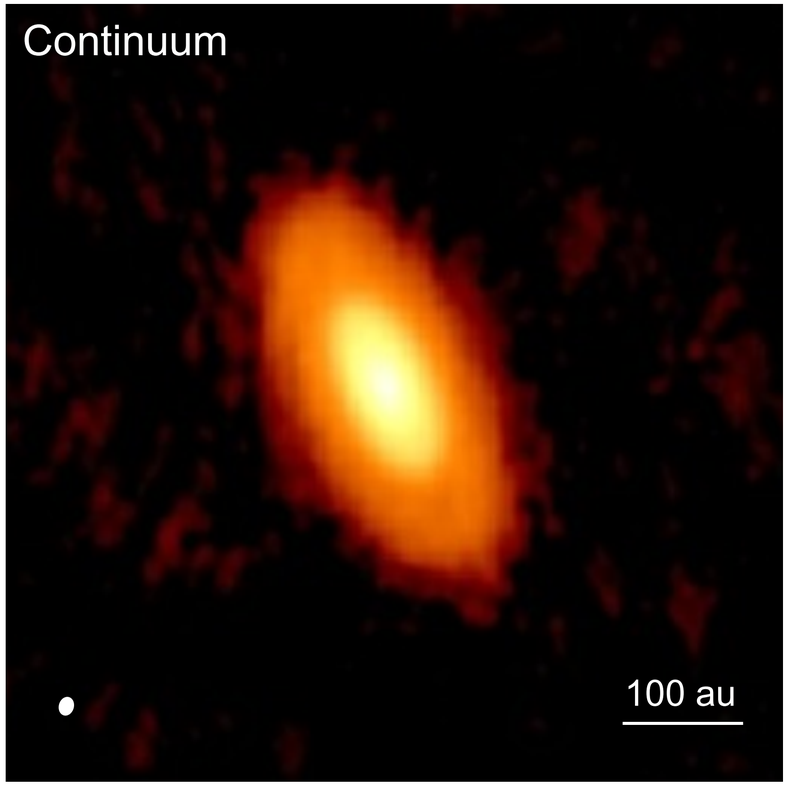


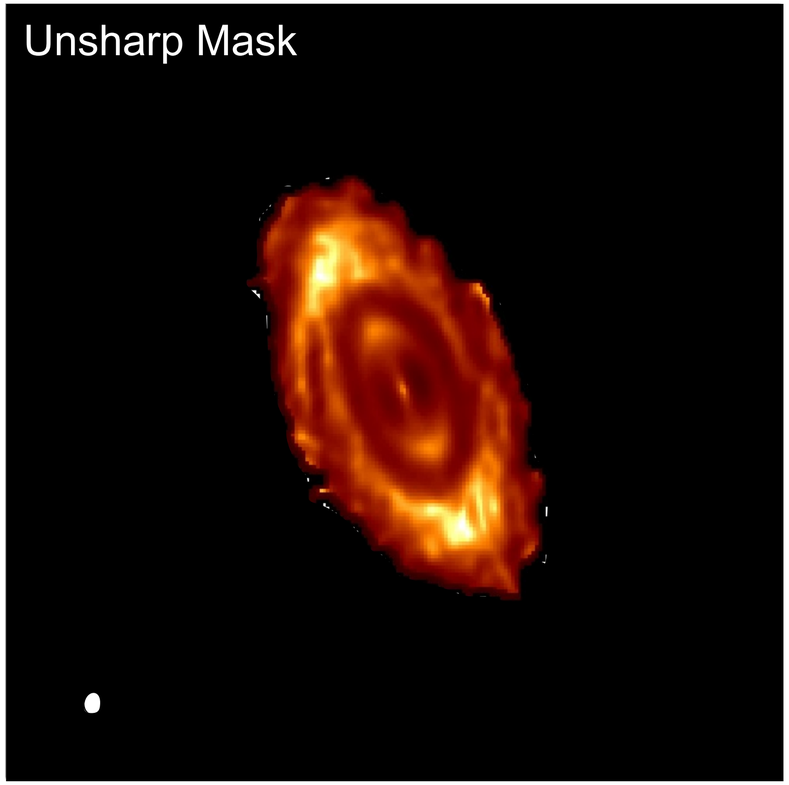


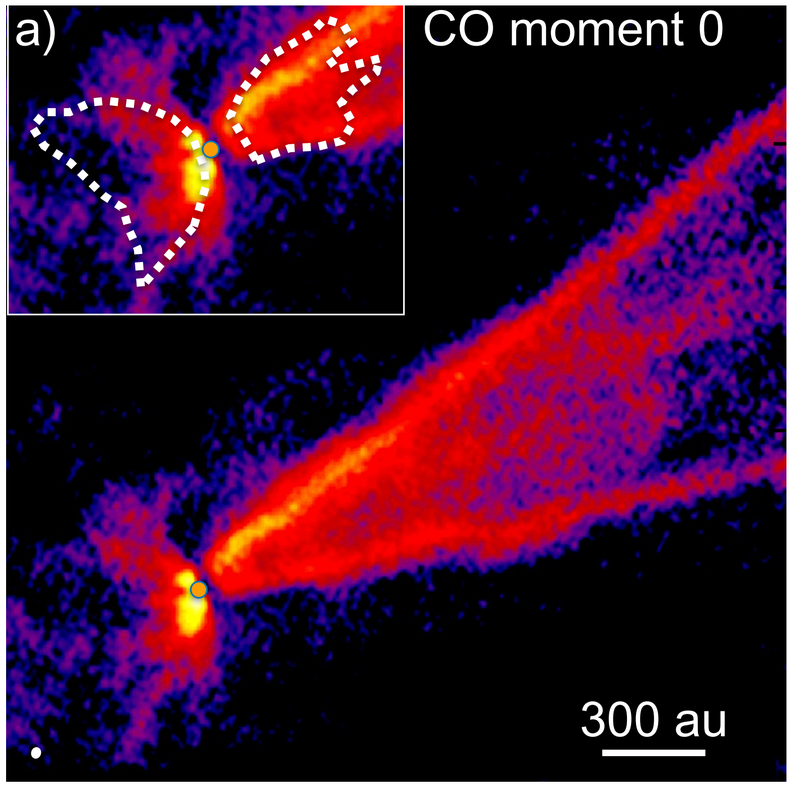
Methanol is tentatively detected for the first time in a Class I.

The ratio with formaldehyde is low (0.5-0.7).

ALMA-DOT I: Early disk sub-structure
(Garufi et al. 2020a)

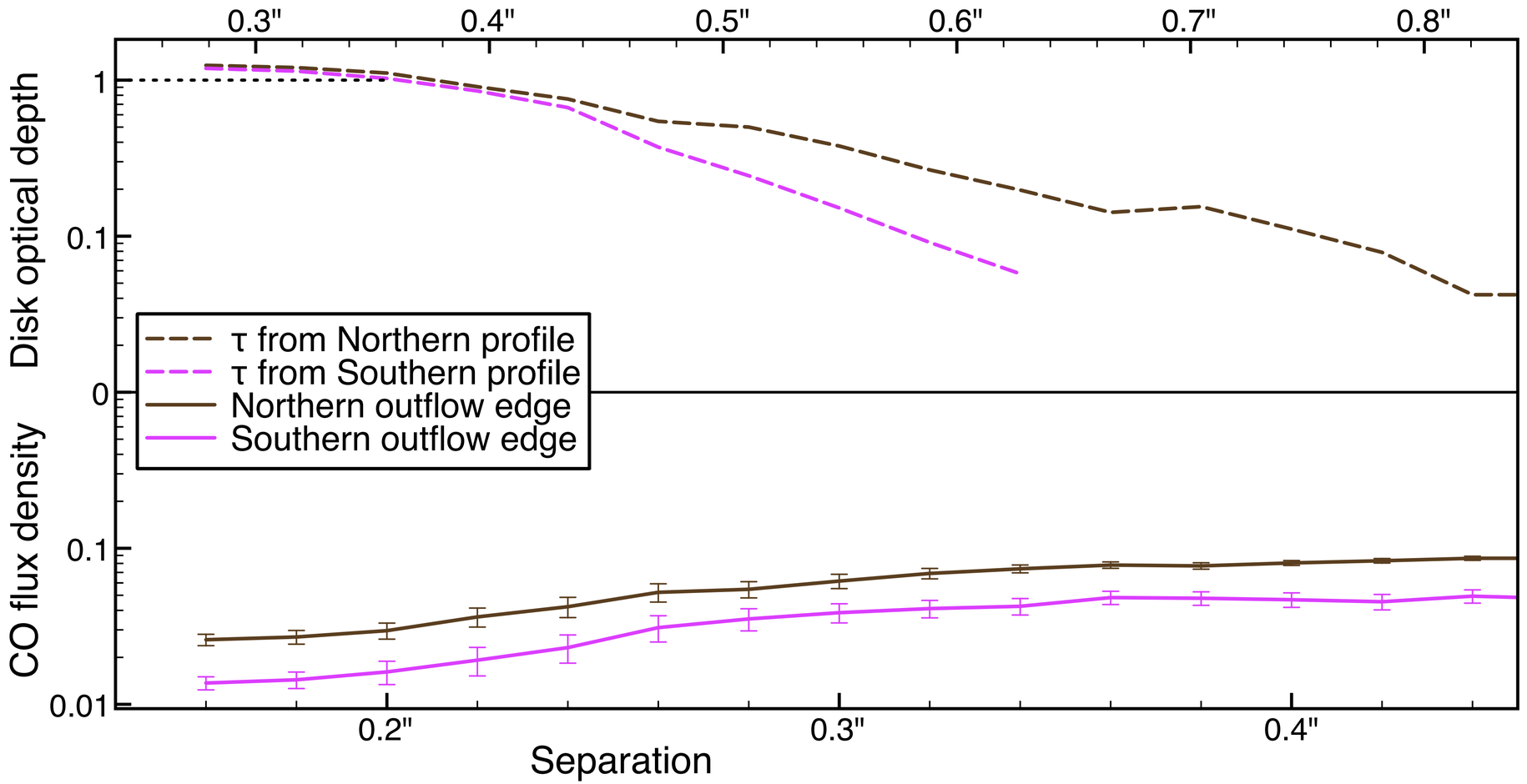


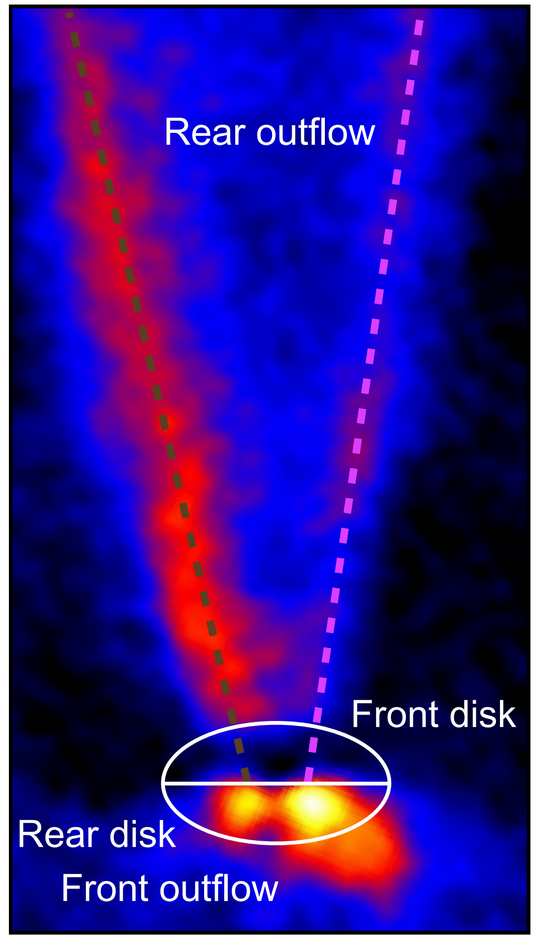




Disk radial discontinuities and a possible spiral are detected at a moderately high resolution (20 au)!

ALMA-DOT I: Early disk sub-structure
(Garufi et al. 2020a)

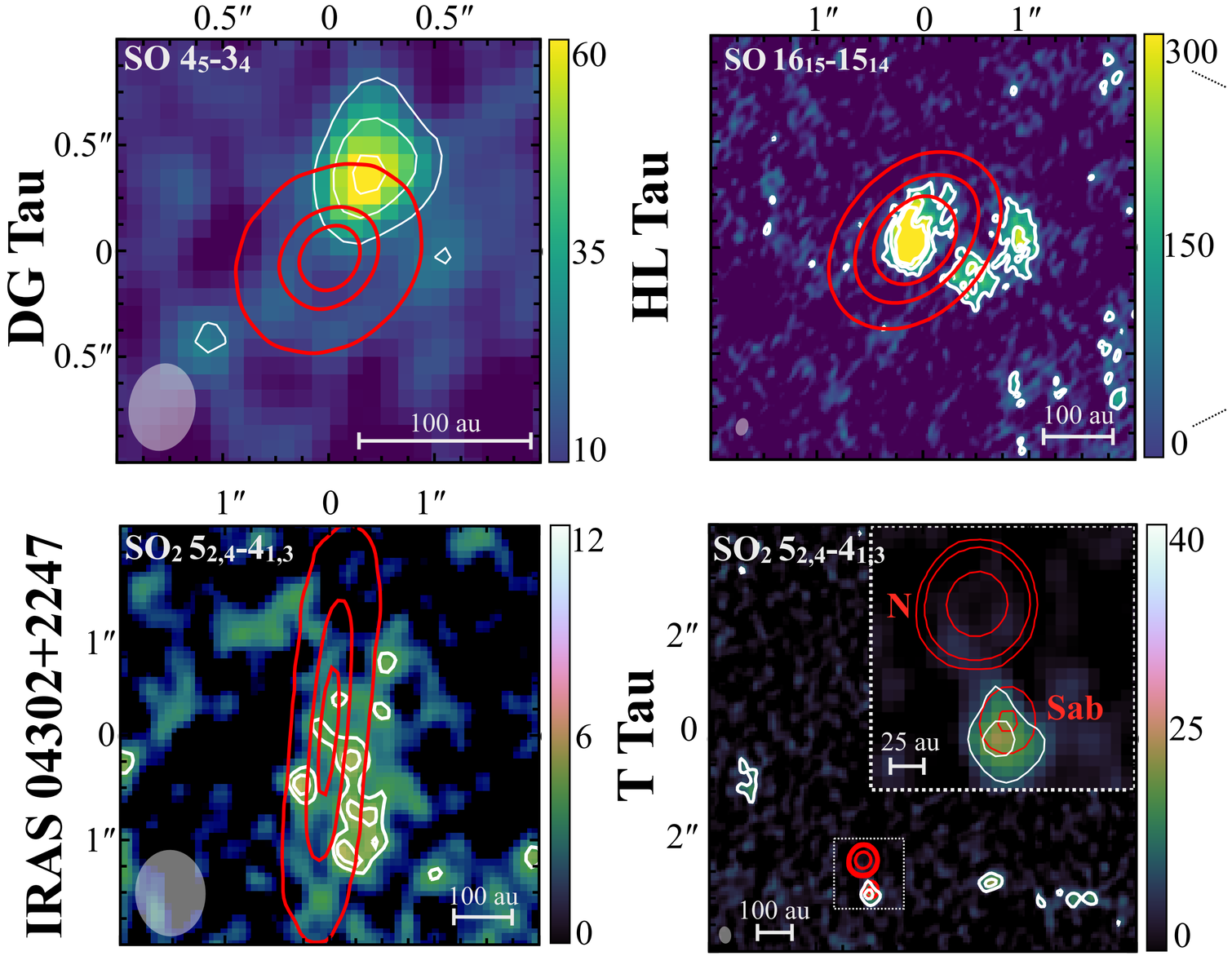




From the occultation of the rear-side outflow, the disk is constrained optically thick out to 50 au.

ALMA-DOT VI: Accretion shocks
(Garufi et al., on the arXiv today)

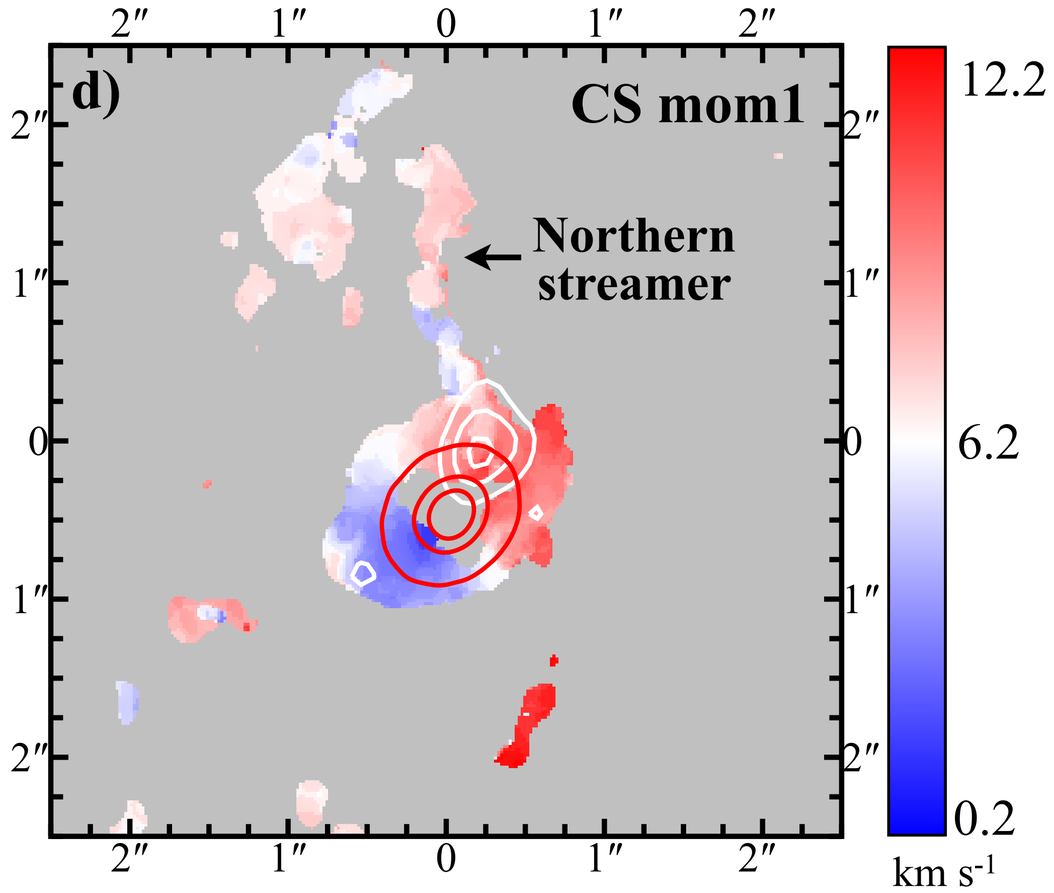
ALMA-DOT VI: Accretion shocks
(Garufi et al. 2021b)



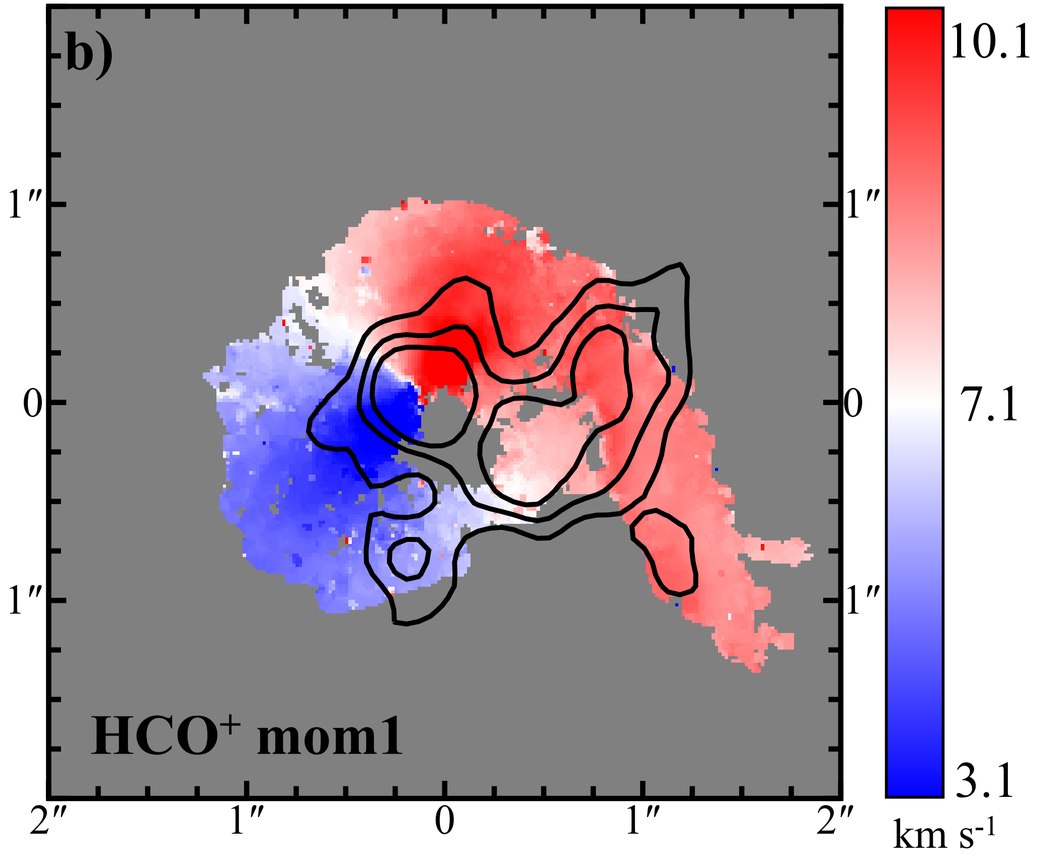
SO and SO_2 emission is detected in specific disk regions

These molecules are desorbed from grains to the gas phase by localized process.

ALMA-DOT VI: Accretion shocks
(Garufi et al. 2021b)

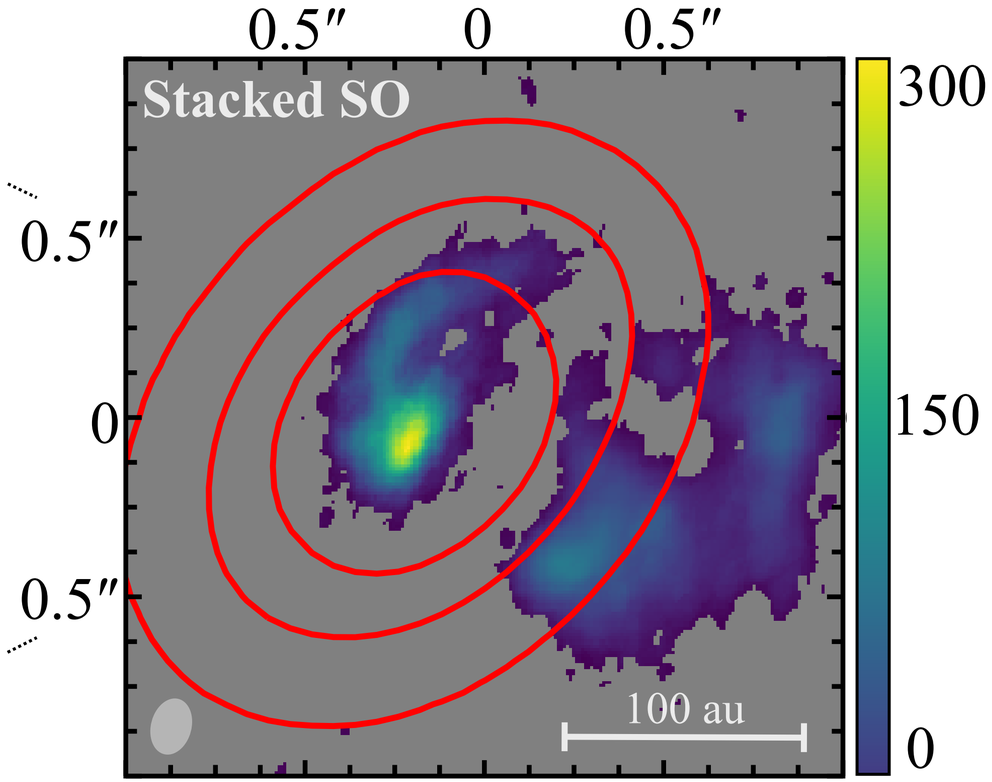


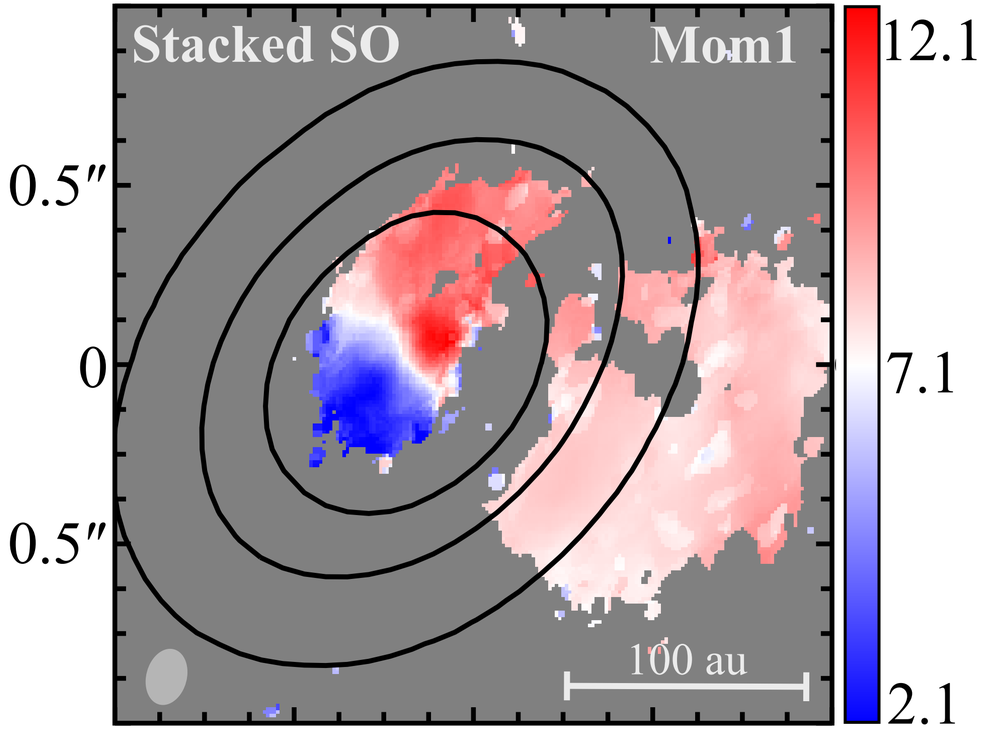
See Yen et al. (2019)



The SO and SO_2 emission is co-spatial with the intersection between disks and streamers indicating shocks.

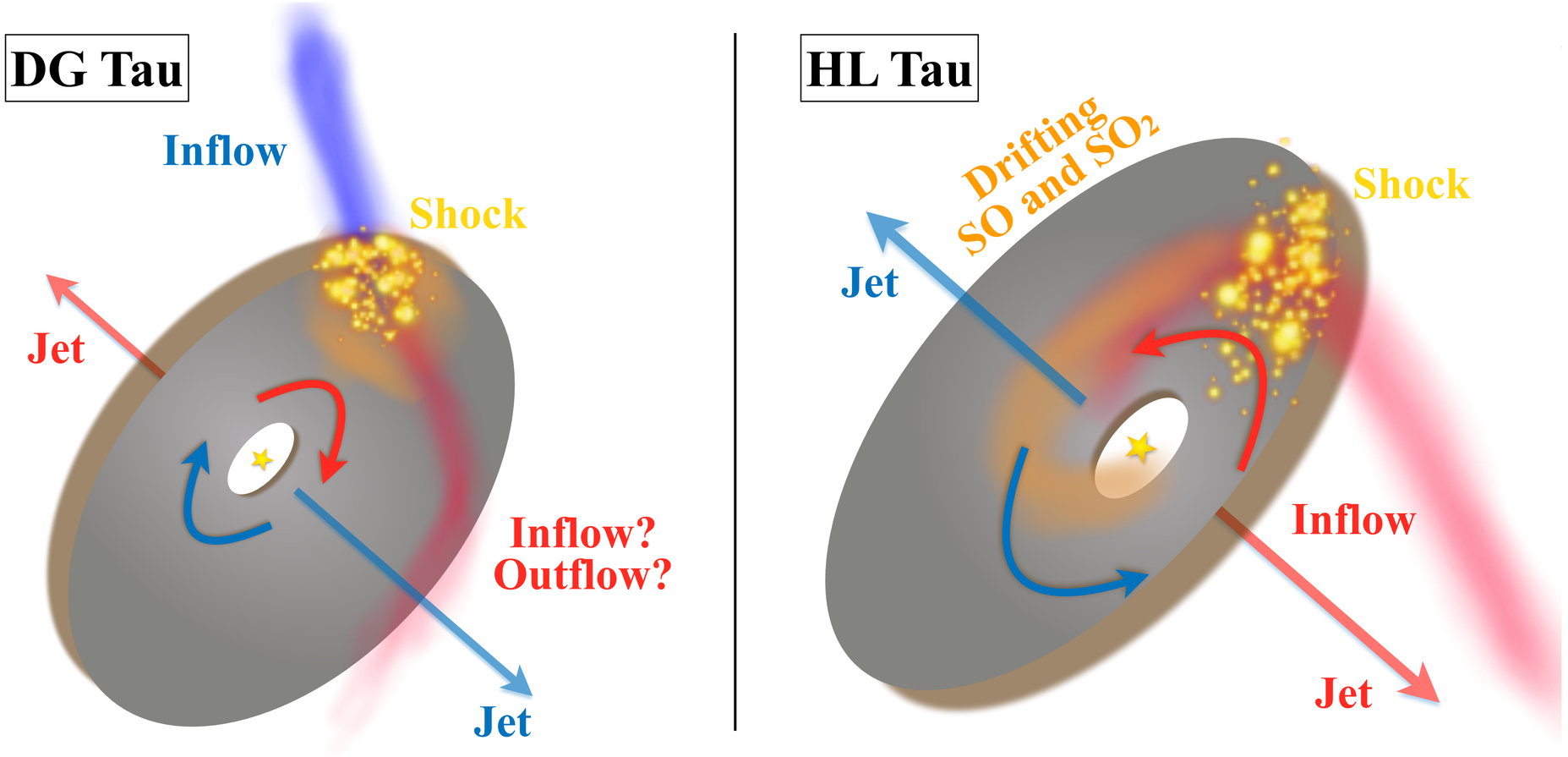
ALMA-DOT VI: Accretion shocks
(Garufi et al. 2021b)





HL Tau also shows an inner component in a spiral-like shape

ALMA-DOT VI: Accretion shocks
(Garufi et al. 2021b)



SO and SO_2 molecules in HL Tau are released in the shock and accrete inward in a few hundred years.

Conclusions

ALMA-DOT probed the chemistry of young, embedded sources: gas-dust interplay, nature of molecular emission, vertical stratification, abundance ratios of key-molecules etc.

Late accretion occurring through streamers impacts the disk properties in specific regions that can be probed by shock-tracers.