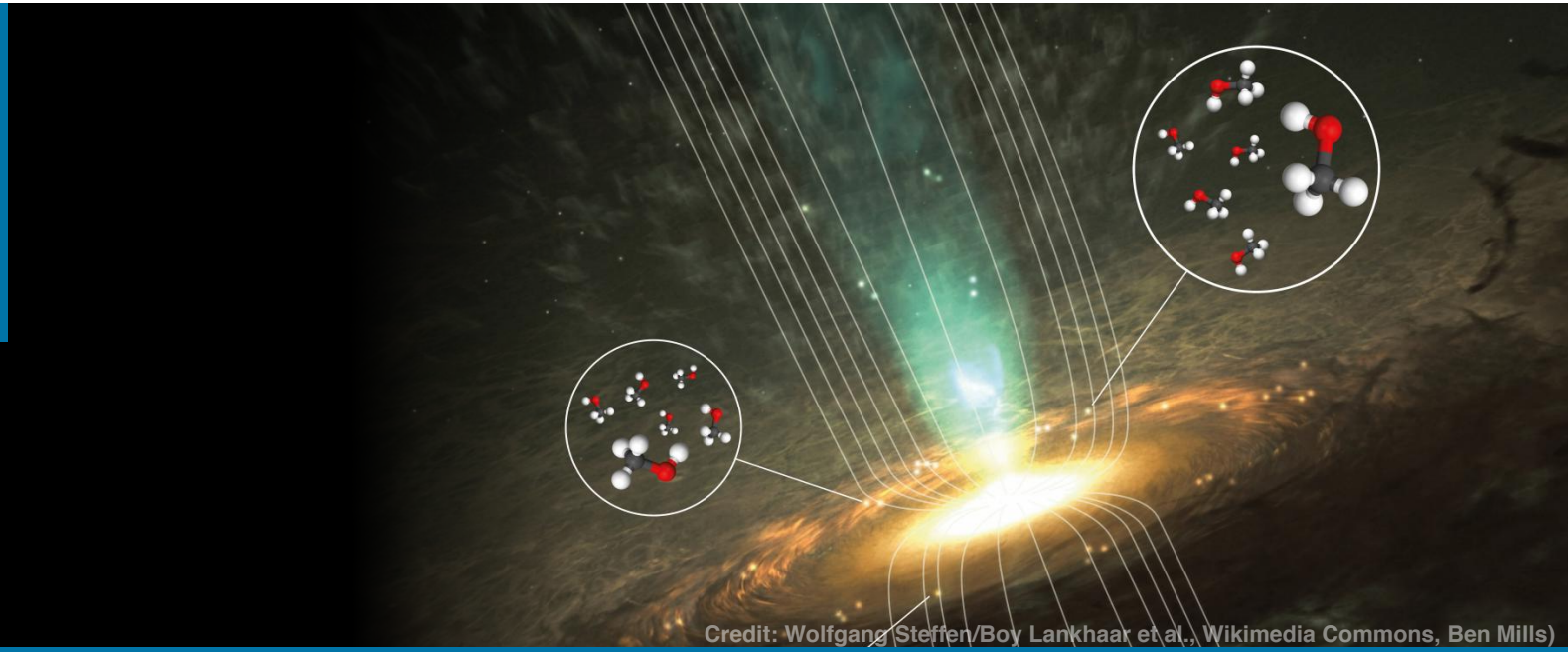
ngvla
Next Generation Very Large Array


Credit: Wolfgang Steffen/Boy Lankhaar et al., Wikimedia Commons, Ben Mills)

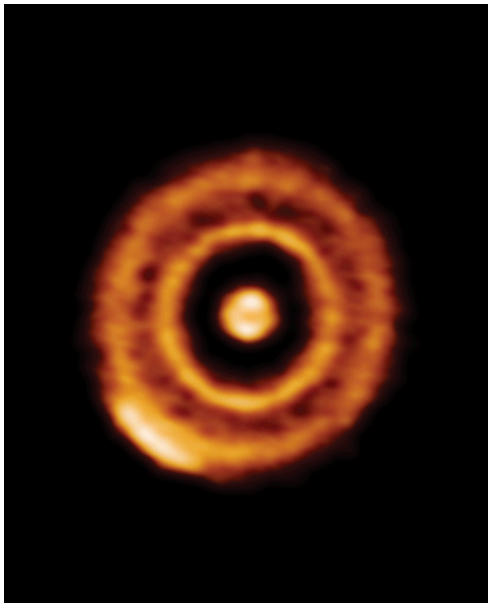
Astrochemistry: Building Potentially Habitable Worlds

Ilse Cleeves, University of Virginia

ngvla.nrao.edu

Outline

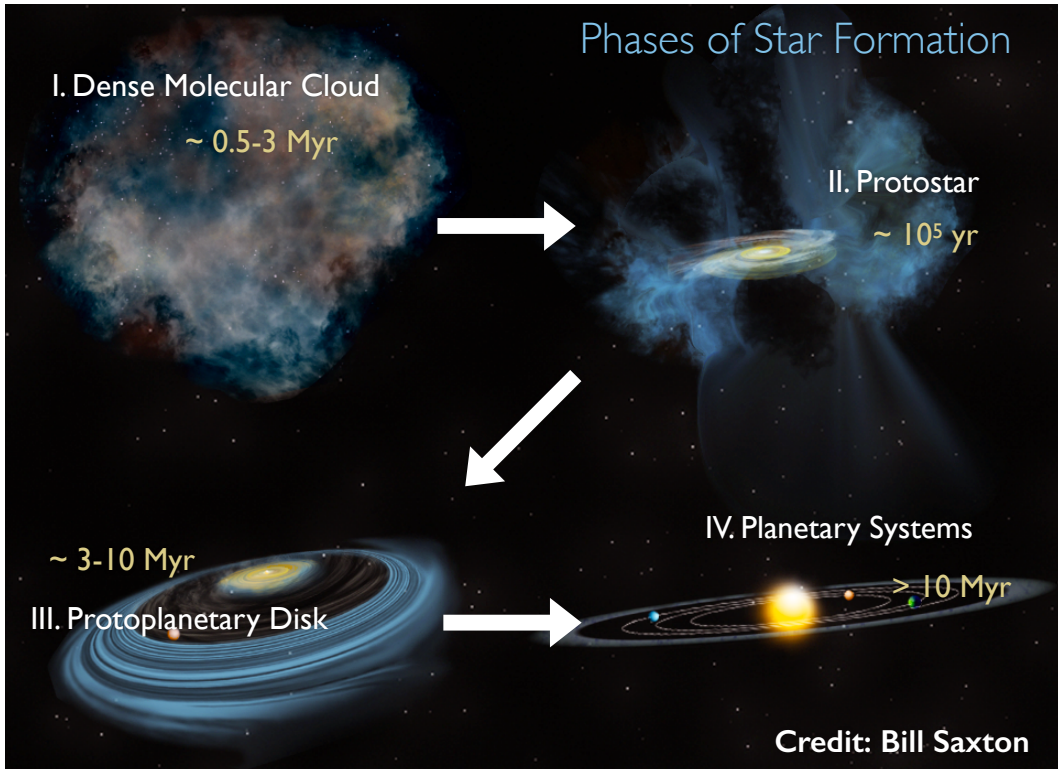
1. Initial chemical conditions for planet formation?
2. Peering through the dust!
3. The chemistry of life: Organics
4. Follow the water (and ammonia)



HD 143006
DSHARP
(PI Andrews)

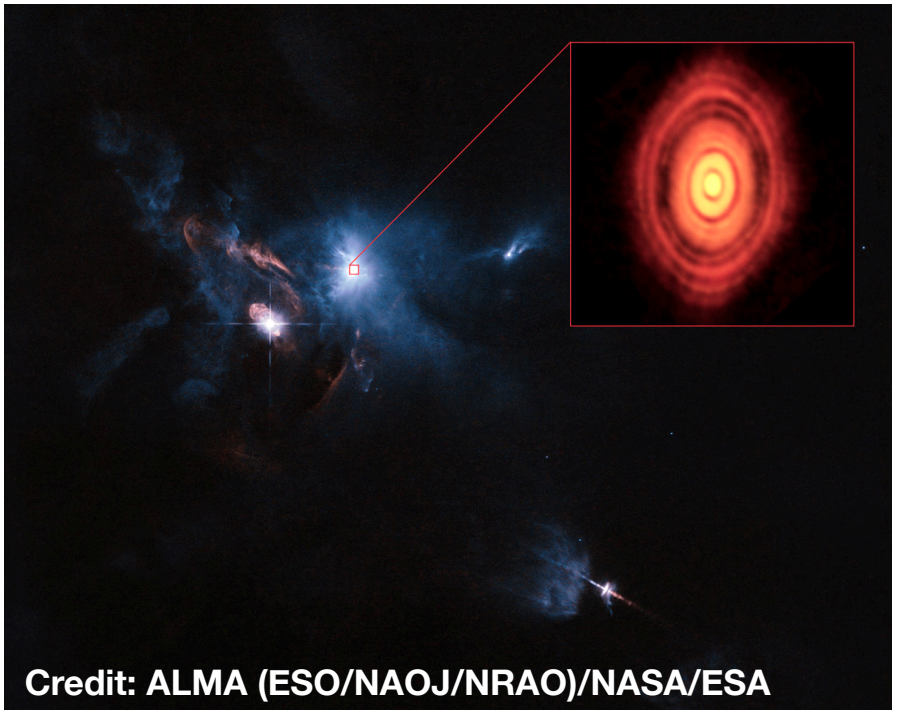
1) The true "initial conditions?"

Historically a divide between protostellar and protoplanetary stages, and it has been unclear how much "legacy" is maintained.



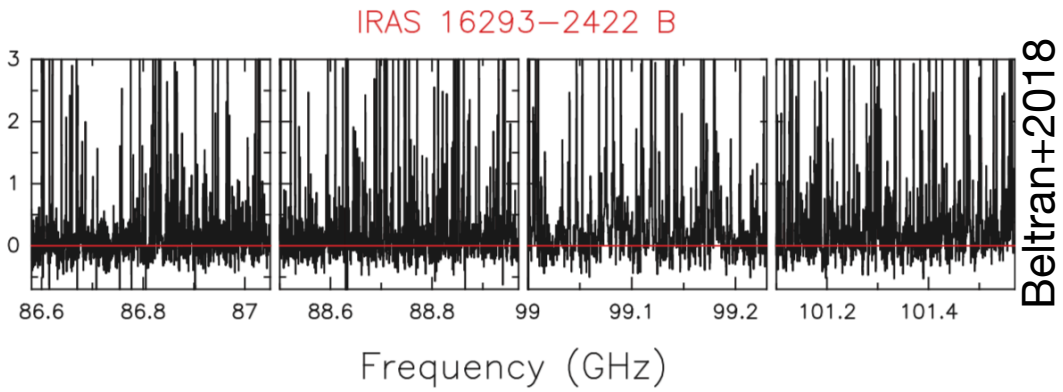
1) The true "initial conditions?"

- HL Tau, highly ringed, but a Class I object!
- If planets, very little time for chemical evolution
- 67/P similar to IRAS 16293 (Drozdovskaya+2018)
- At least half of Earth's ocean water originally primordial (Cleeves+2014)



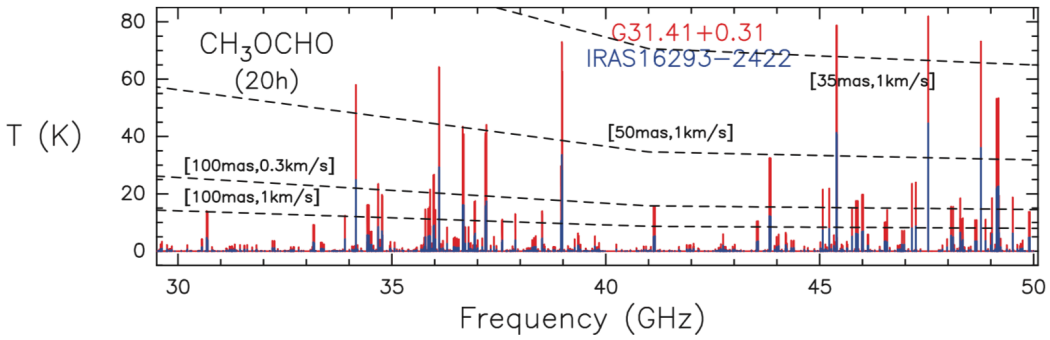
1) The true "initial conditions?"

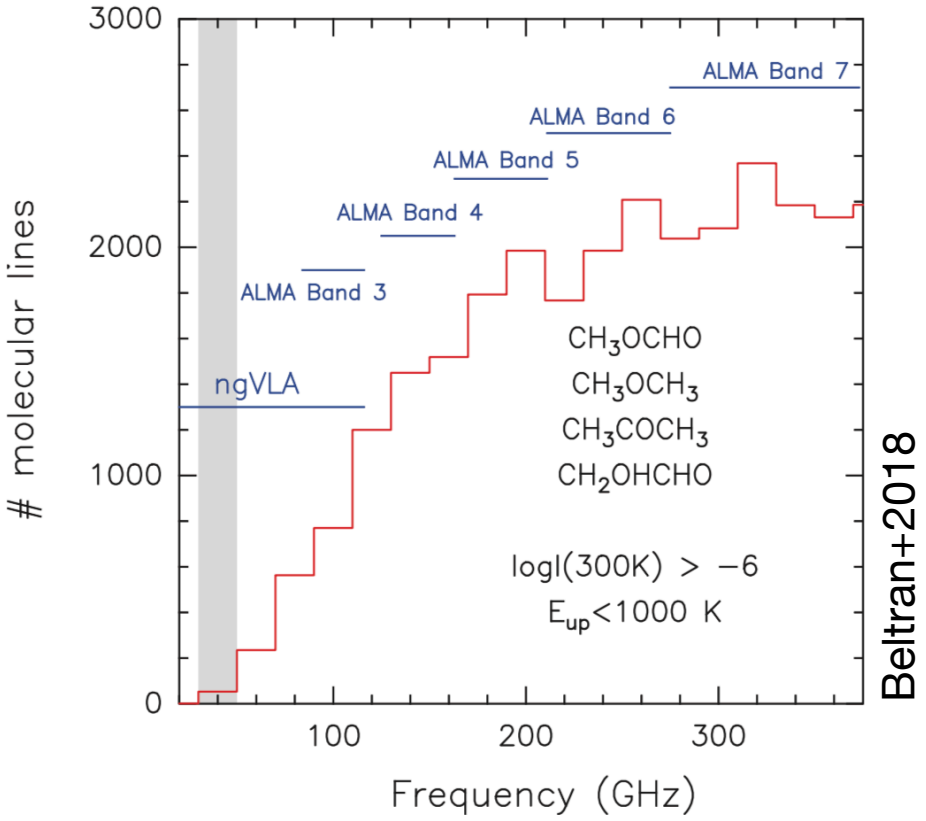
- Important to study the chemistry of interstellar clouds (e.g., McGuire+2018, Beltran+2018 ngVLA chapters)
- At ALMA wavelengths, even Band 3, hampered by line confusion



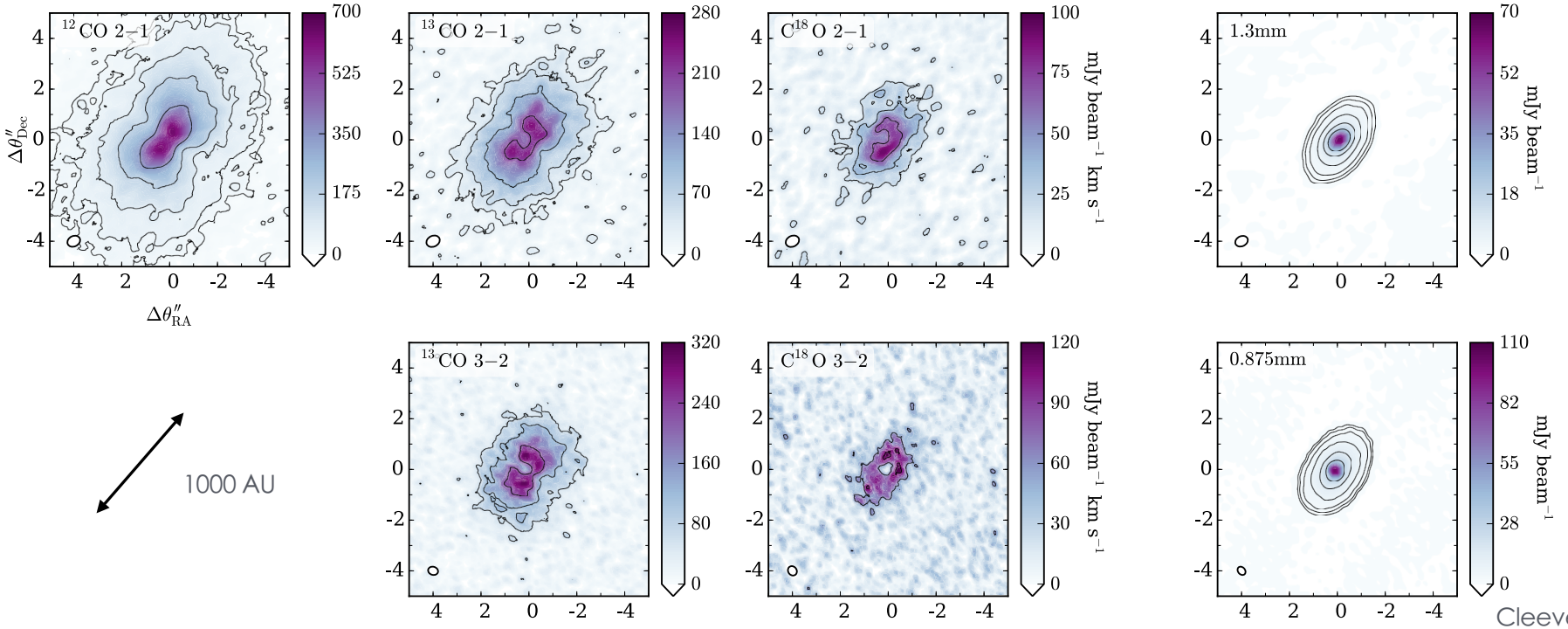
1) The true "initial conditions?"

The sensitivity + lower line density enables better line classification, abundance determination.





2) Peering through the dust



Cleeves et al. 2016c

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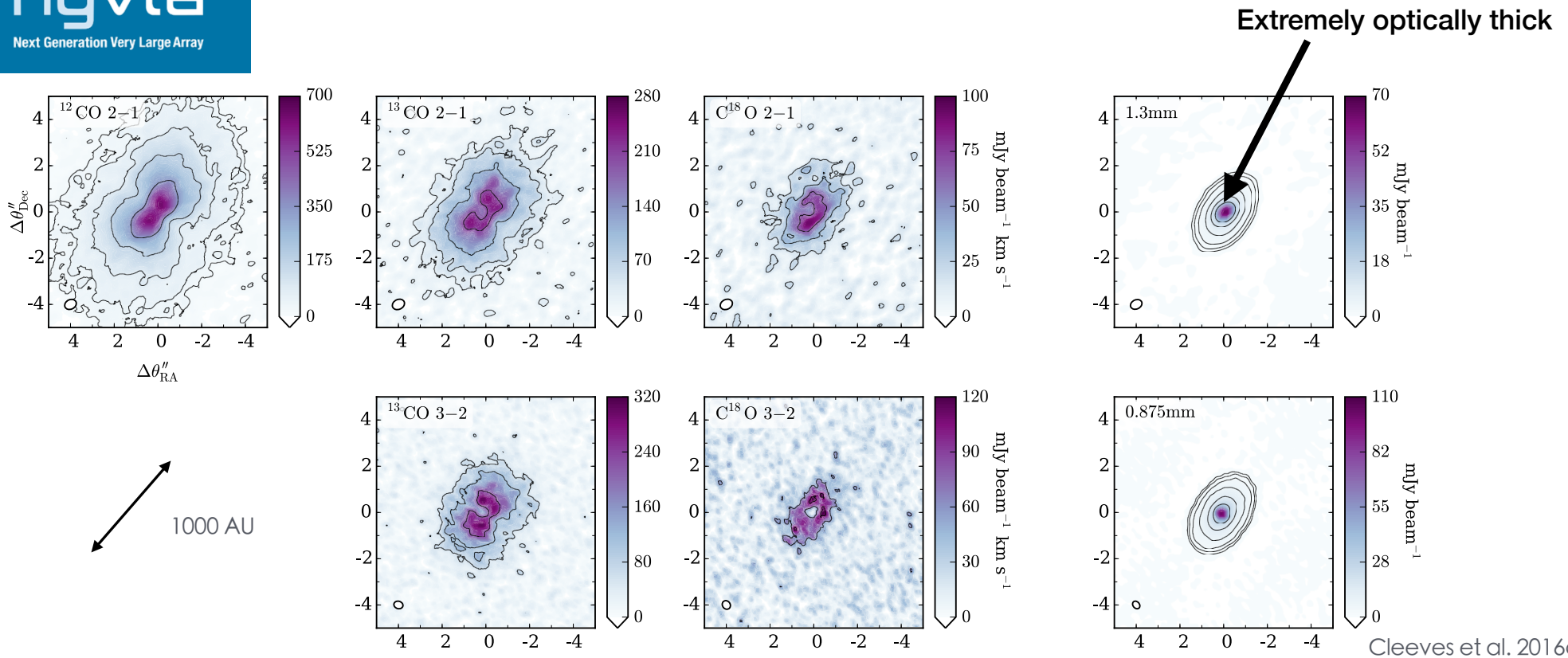
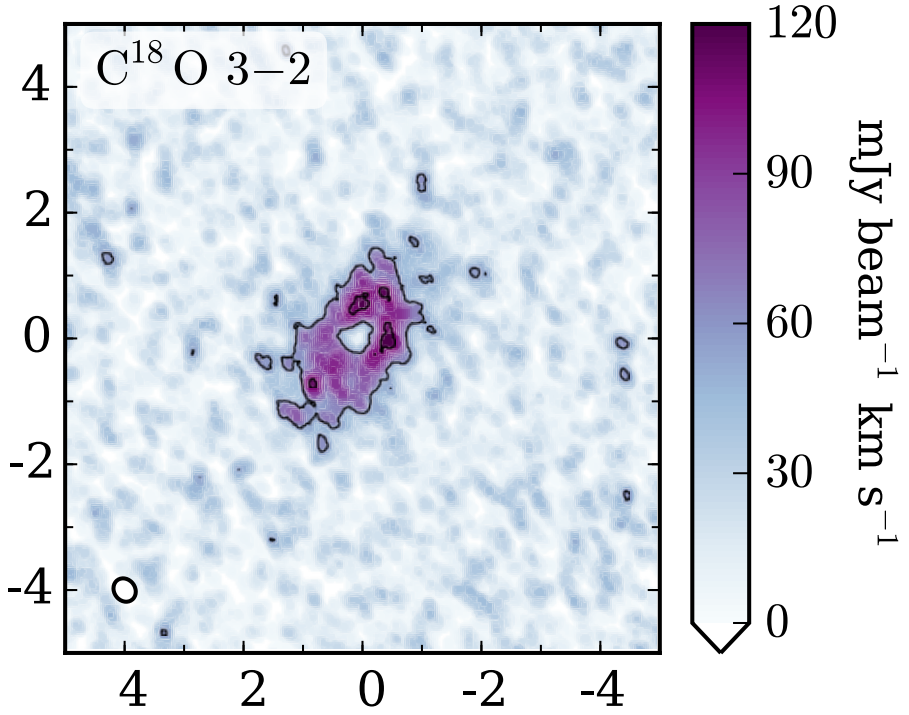


Cleeves et al. 2016c

2) Peering through the dust

IM Lup: continuum is impacting *all* lines observed, and the hole is deeper in the optically thin gas tracers.



Cleeves et al. 2016c

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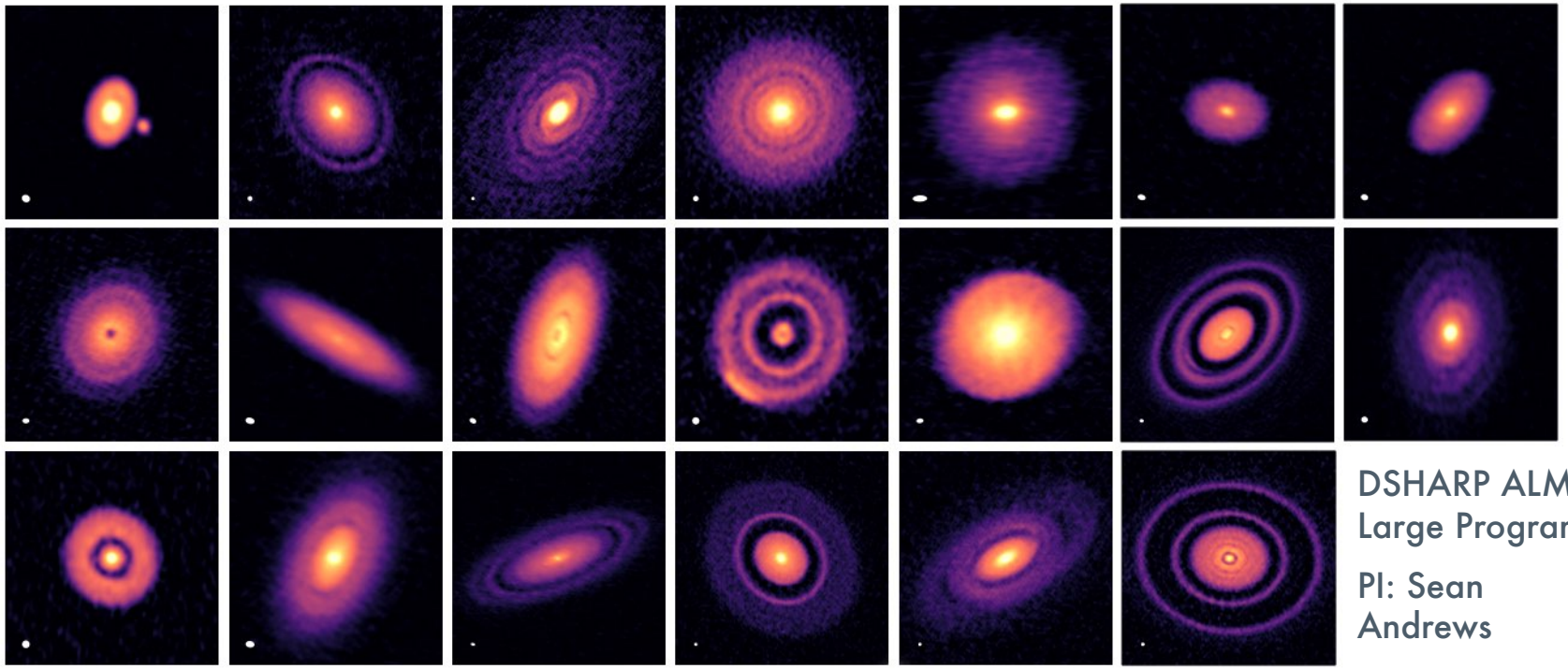
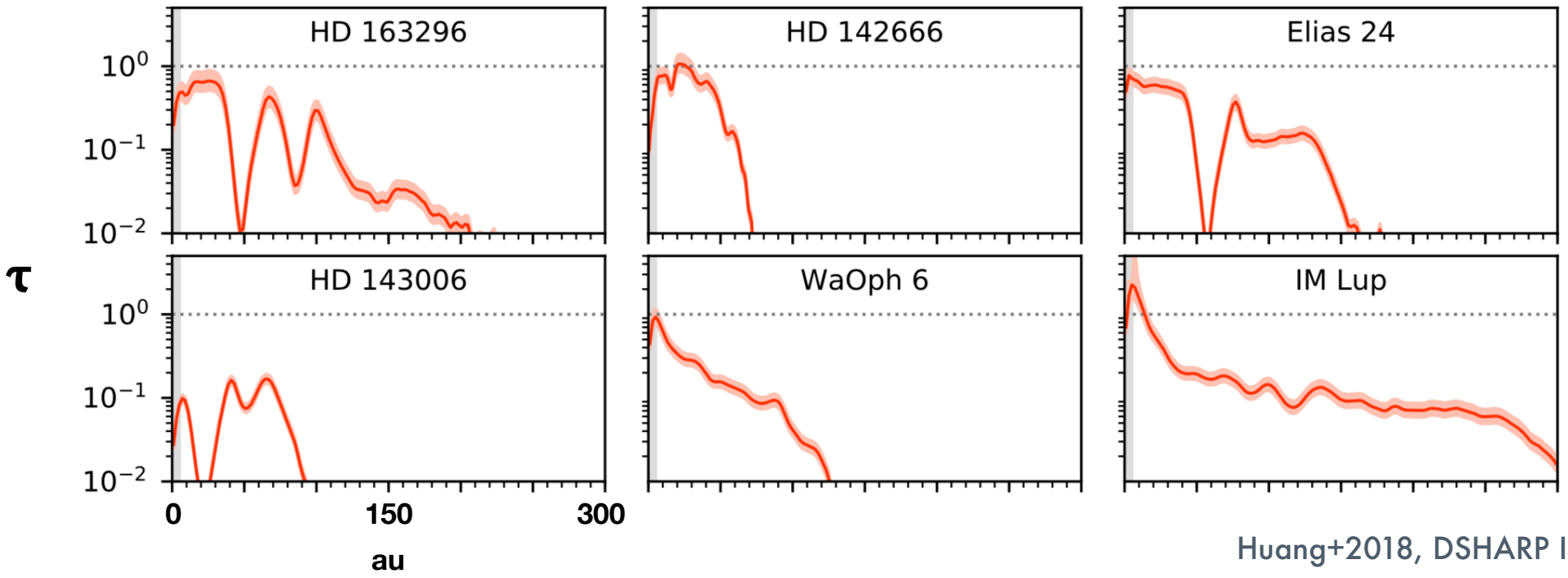


DSHARP ALMA Large Program

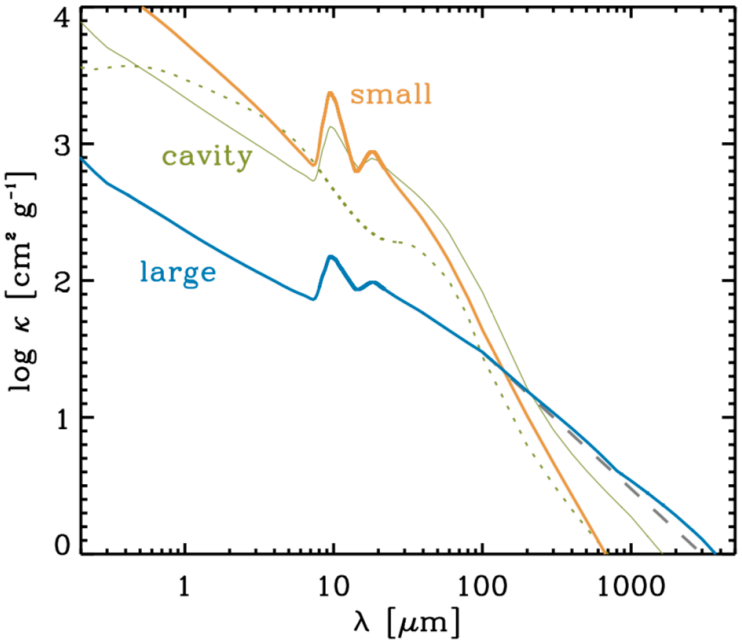
PI: Sean Andrews

2) Peering through the dust



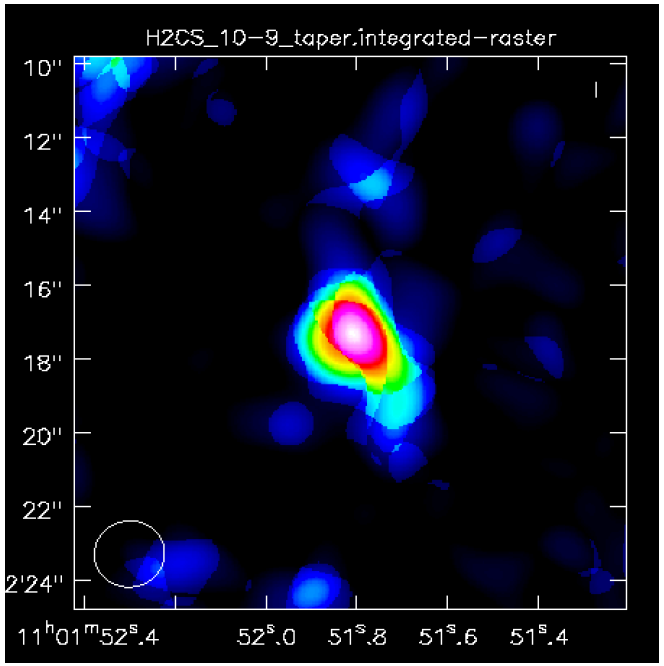
Huang+2018, DSHARP II

2) Peering through the dust



- Using standard disk midplane opacities, up to mm sized (e.g., Andrews+2011)
- ~2.5-3x difference in absorption cross section from 1.25 to 3 mm. Gets us out of optically thick for many of the disks, though not all.

2) Peering through the dust



Kama+in prep

- With sufficient line sensitivity, then there are a host of small molecules that emit
- CS J=1-0 @ 48.99 GHz
- OCS J=1-0 @ 12 GHz (1-0)
  - Or J=4-3 at 48.65 GHz (similar Eu=~5 K)
- H_2CS $2_{1\,2}$ - $1_{1\,1}$ @ 67.654 GHz
- Many transitions of c-C_3H_2, C_2H 1-0 HF at ~ 87 GHz

3) Organics in disks

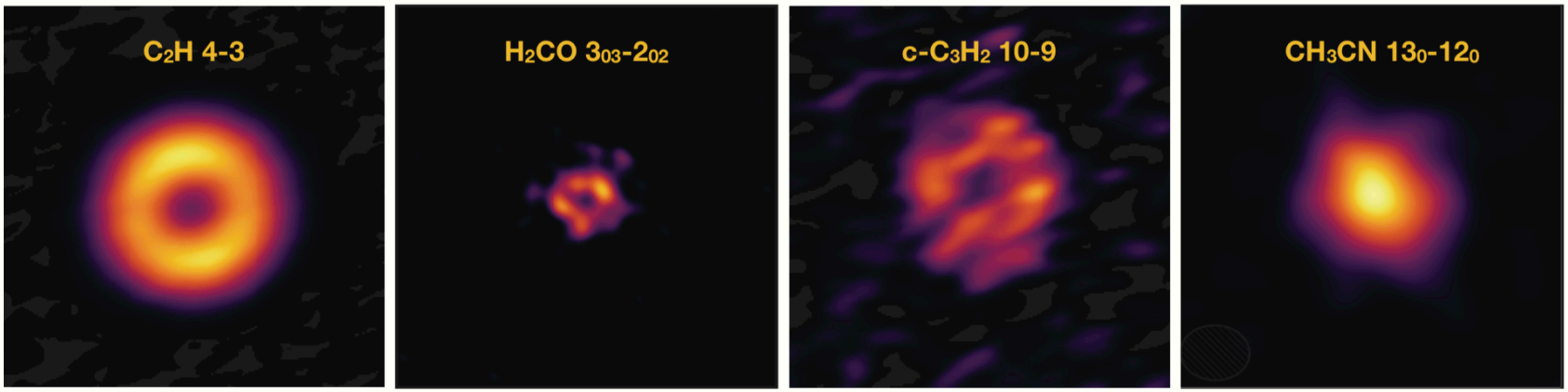


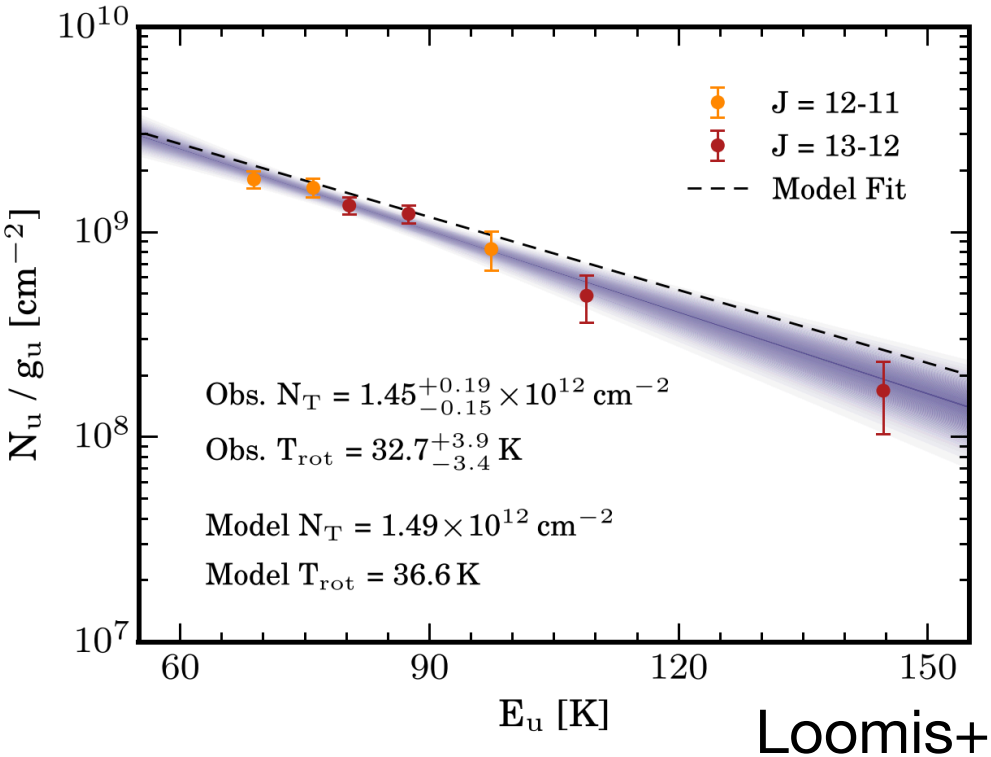
Figure 1. ALMA observations of small and mid-sized organics in the disk around nearby T Tauri star TW Hya. C_2H and c-C_3H_2 observations are from Bergin et al. (2016), H_2CO from Öberg et al. (2017) and CH_3CN from Loomis et al. (2018a). Each panel is $\sim 5'' \times 5''$ and spatial resolutions span $0\farcs4 - 0\farcs8$

3) Organics in disks

- On going debate, do organic ices desorb whole or fragment upon UV absorption? (see also discussion of Ligterink+2018)
- Only products of VUV ice processing were directly detected (H_2, CO, and CH_4) leading to an upper limit of $< 3 \times 10^{-5}$ molecules photon^{-1} photodesorption of intact methanol (see Cruz-Diaz+2016, Bertin+2016).
- Cold organic observations help, Loomis+2018 and in prep.

3) Organics in disks

- ALMA showing cold organics, CH_3CN rotational diagram, two transitions, full k-ladder for each.
- A few beams, temperature profile derived, ~flat

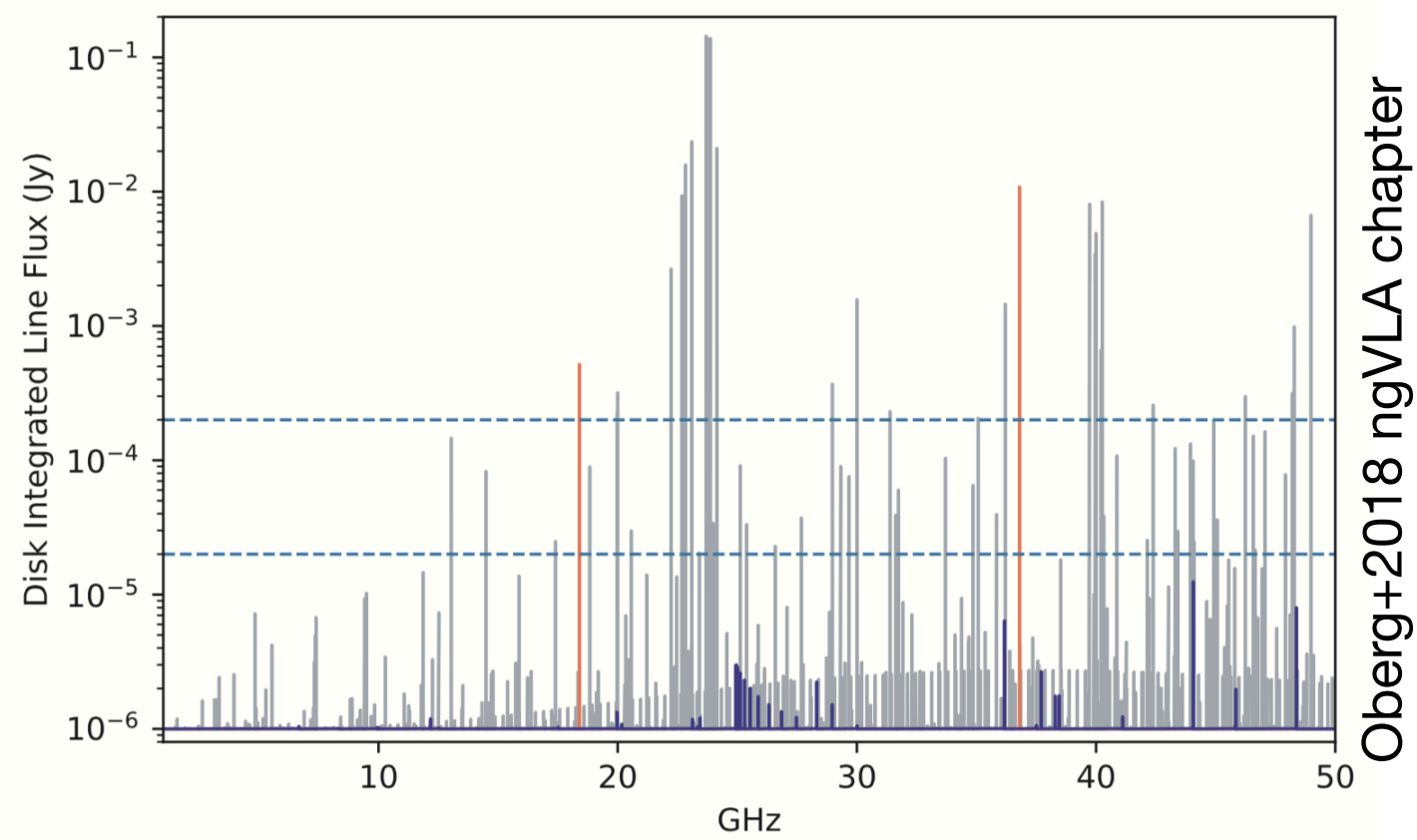


Loomis+2018

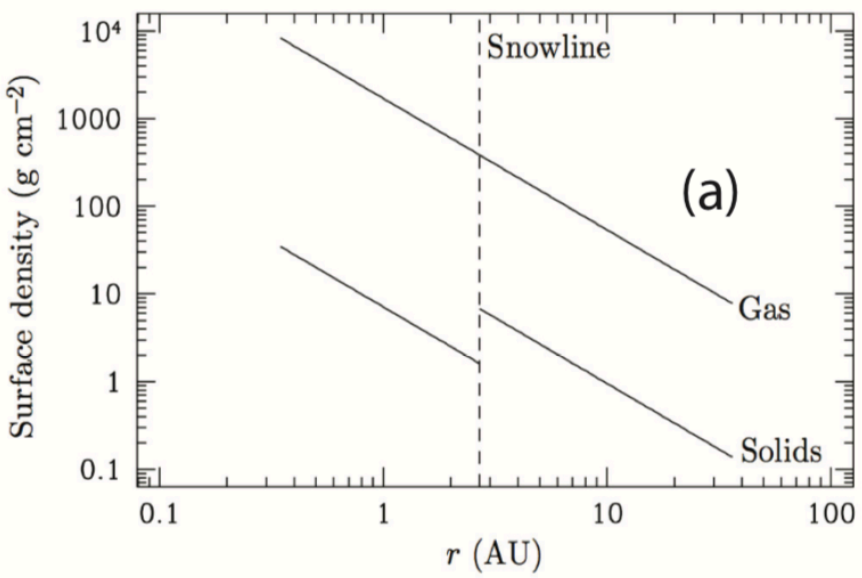
3) Organics in disks

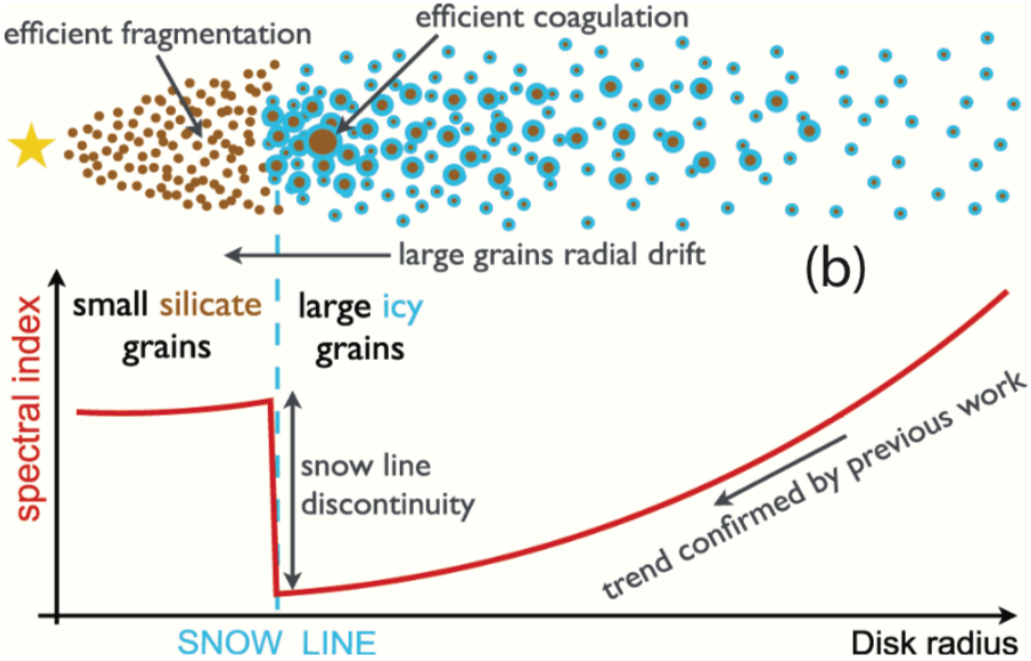
Predicted TW Hya spectra at cm λ.

Using Cleeves+15 TW Hya model output and **Splatalogue** with **astropy**+astroquery



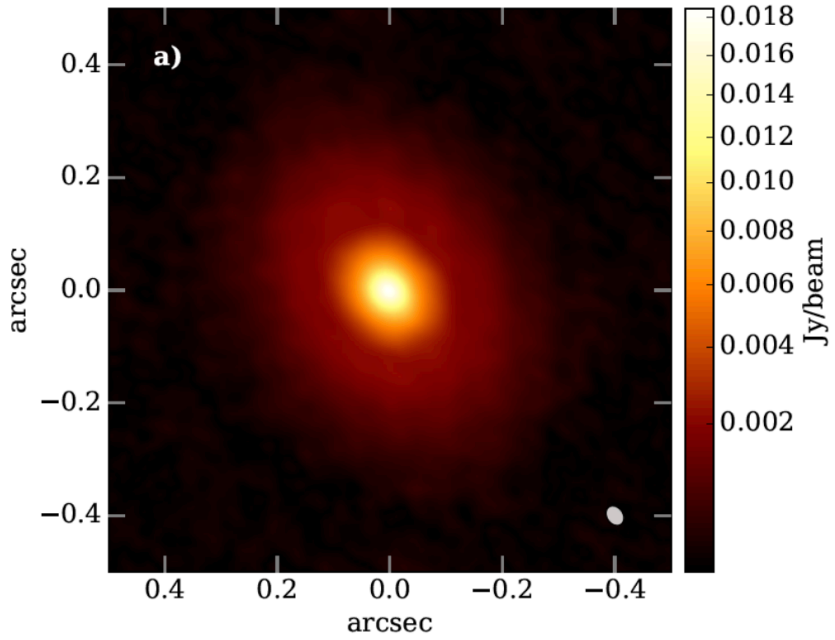
4) Seeking snow lines

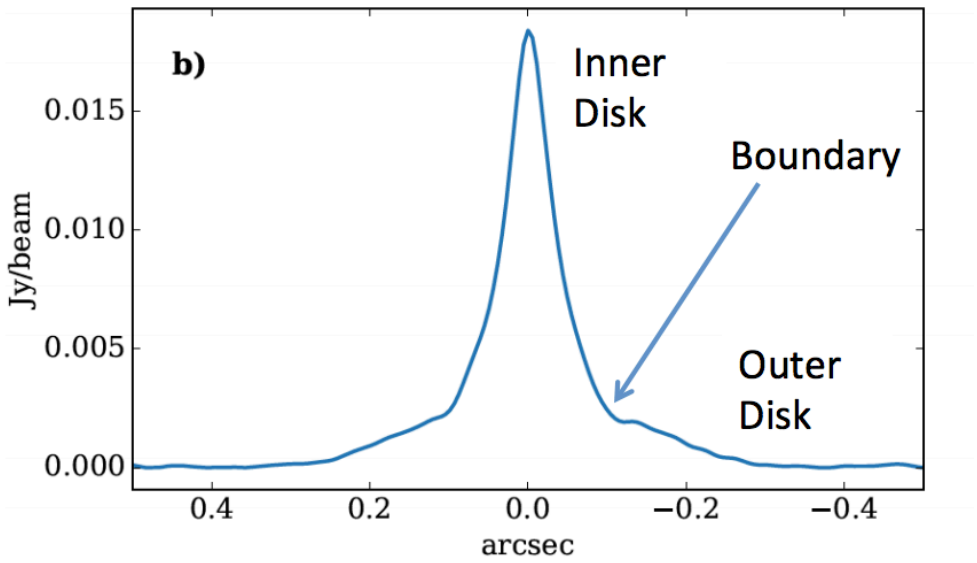




4) Seeking snow lines

V883 Ori





Cieza+2016, Nature

Martin-Domenech+2014

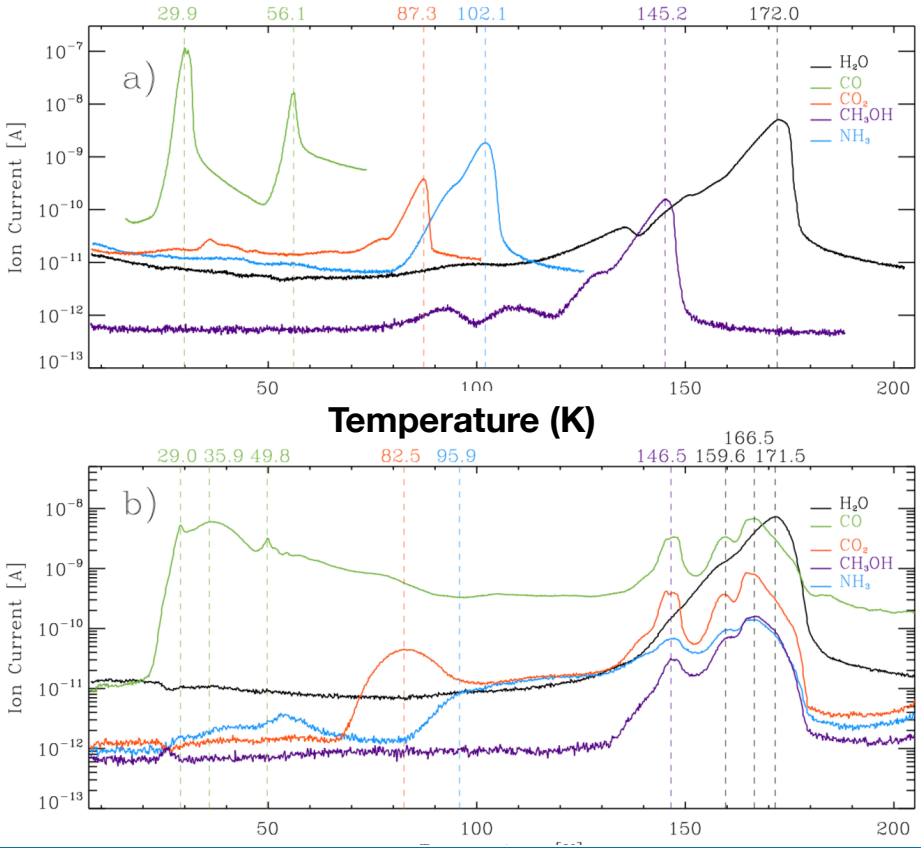
4) Seeking snow lines

However continuum substructure is everywhere, what is water or not?

An alternative is to use NH_3

While pure H_2O and NH_3 ices have different binding energies (Collings+2004)

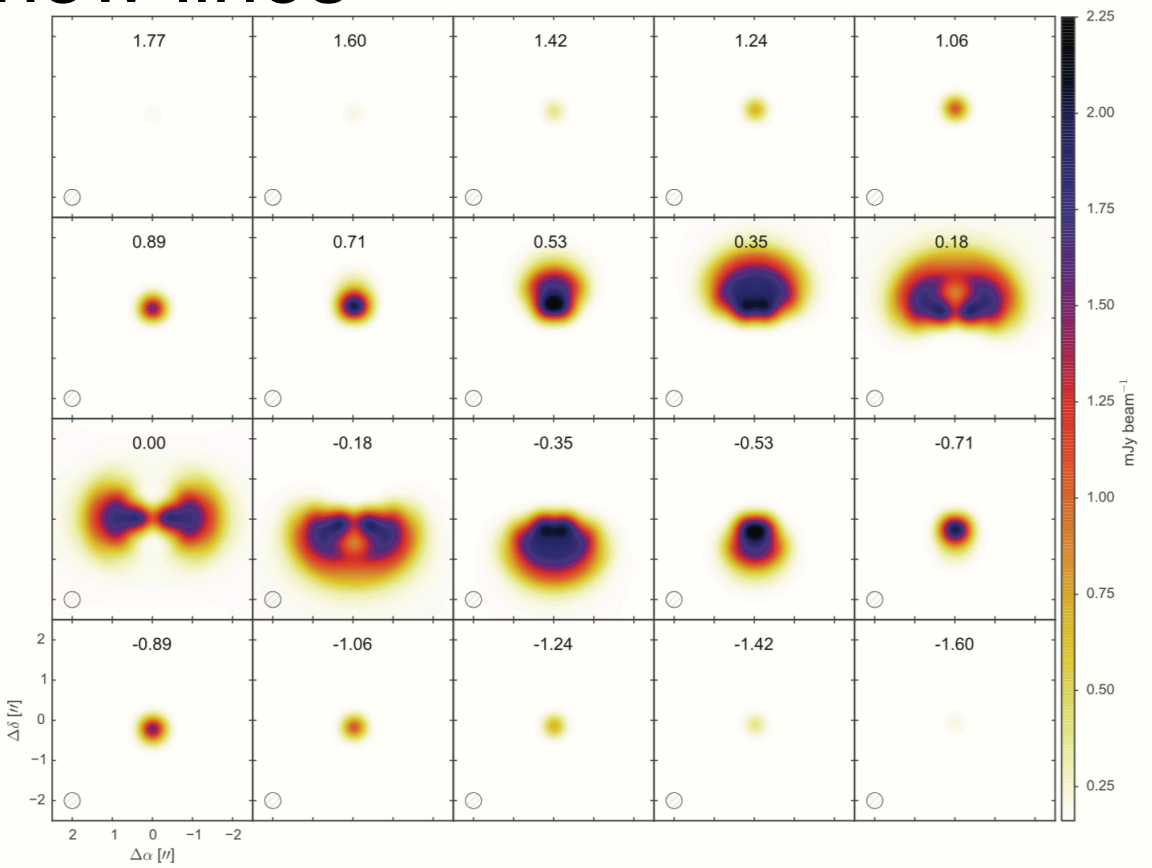
Mixed ices desorb together!



4) Seeking snow lines

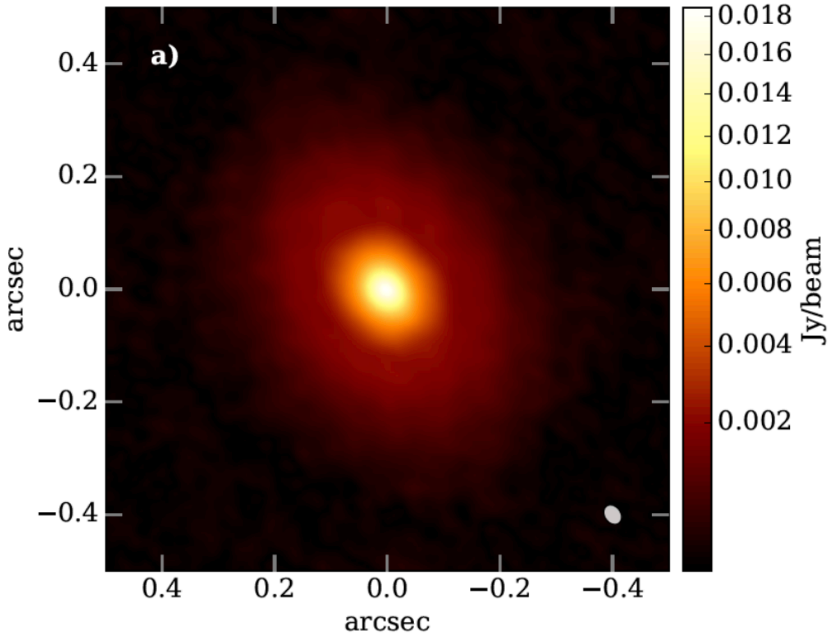
Zhang+2018 ngVLA chapter, predictions for NH_3 detectability toward TW Hya.

Going to be challenging. Requires ~0.25 mJy/beam in 0.2 km/s channels for TW Hya

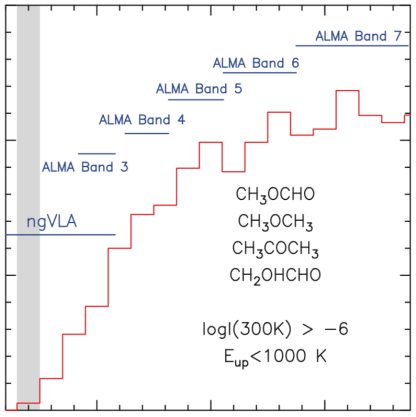


4) Seeking snow lines

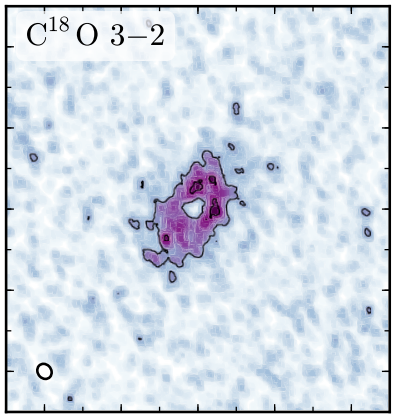
- However we'll get a first order 'proof of context' soon
- PI: Tobin A-ranked VLA proposal to detect NH3 toward outbursting V883 Ori
- ~1e-6 NH_3 / H abundance detectable in ~30h



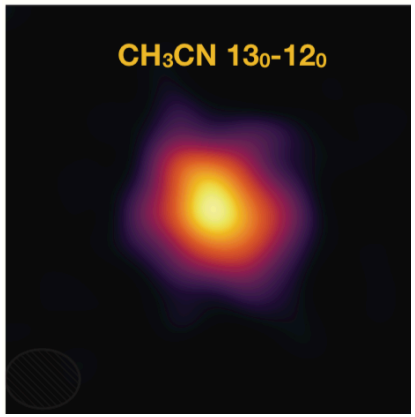
Summary



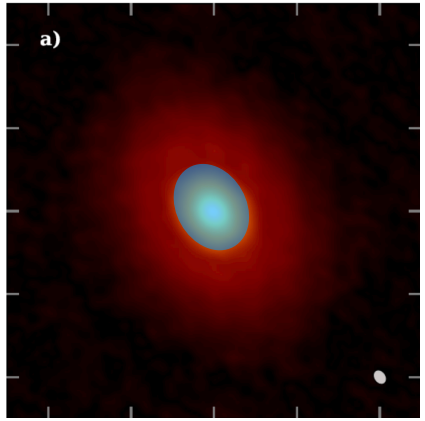
Chemistry of the cloud informs initial chemistry of the disk



Probing the chemistry of < 10 AU, C/O ratios through sulfur bearing species?



Testing out cold organic chemistry in disks, much work in lab + model + observations



Seeking water snow line using NH_3 (also possible with continuum)

+ much more!

Next Generation Very Large Array