

Observing planetary cradles: uncovering the kinematics of young Class I disks with JWST MIRI

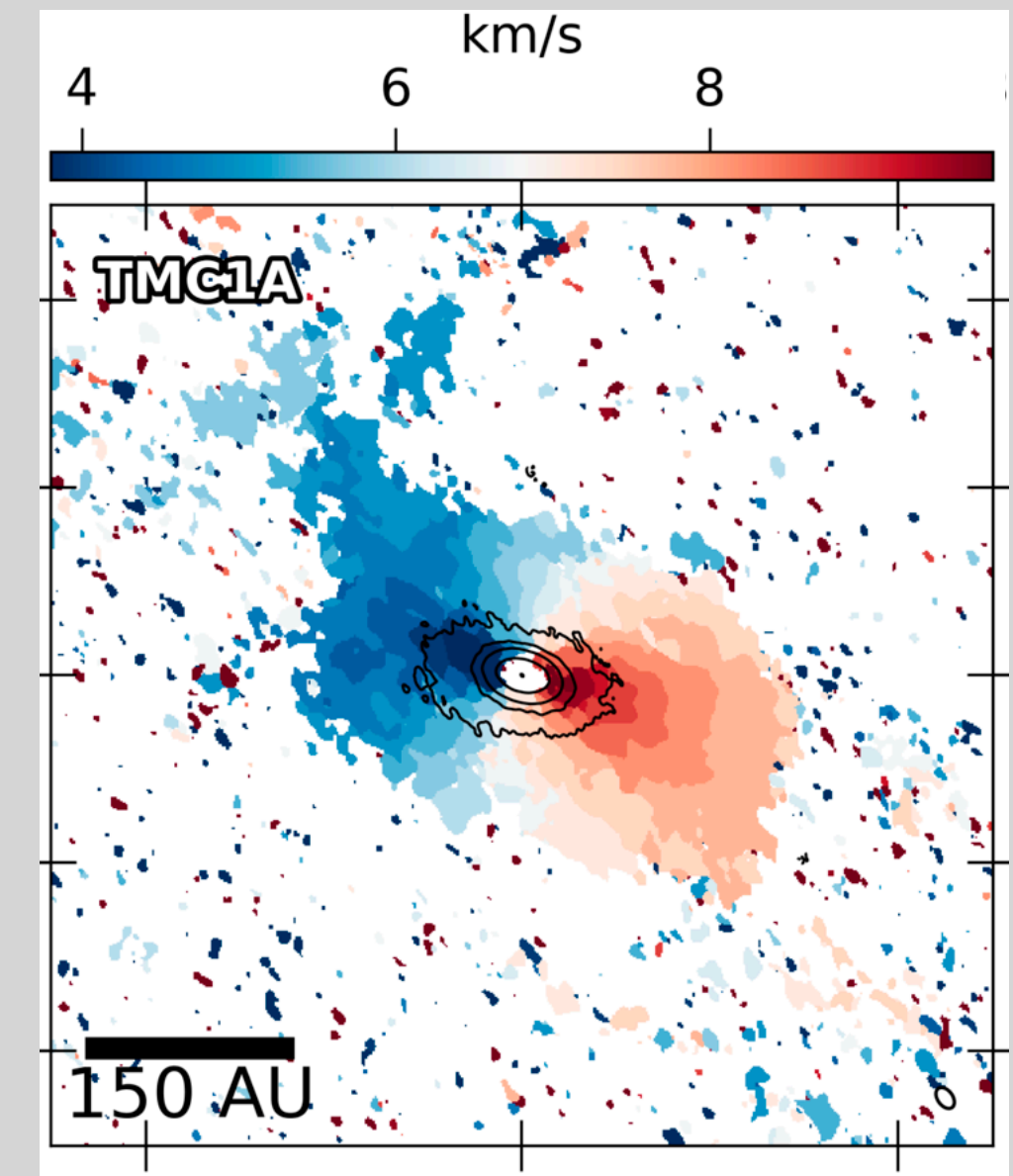
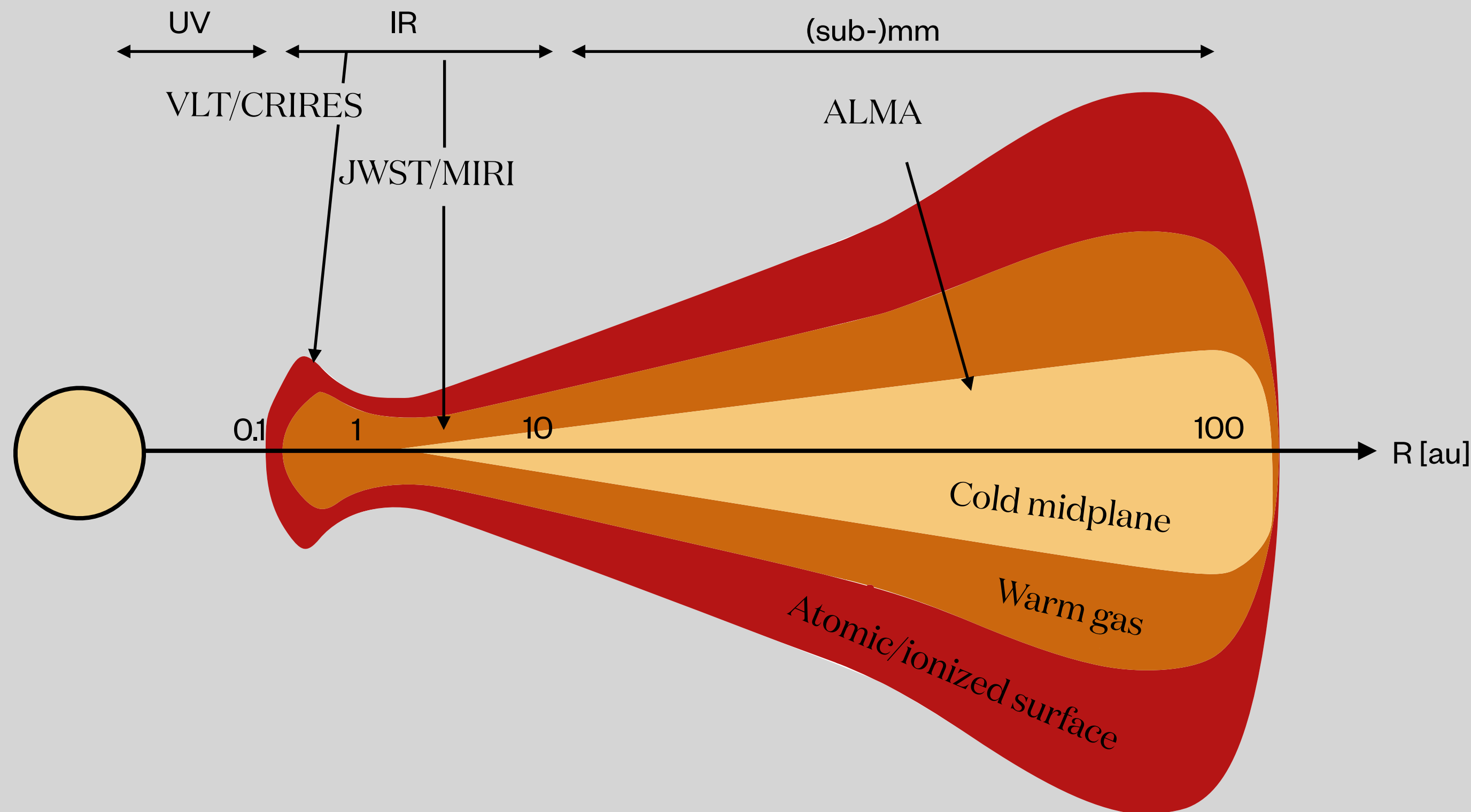
Job Callenbach, MSc-student

Collaborators: Łukasz Tychoniec, Andrew Sellek,
Logan Francis, Ewine van Dishoeck



Universiteit
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Sterrewacht Leiden

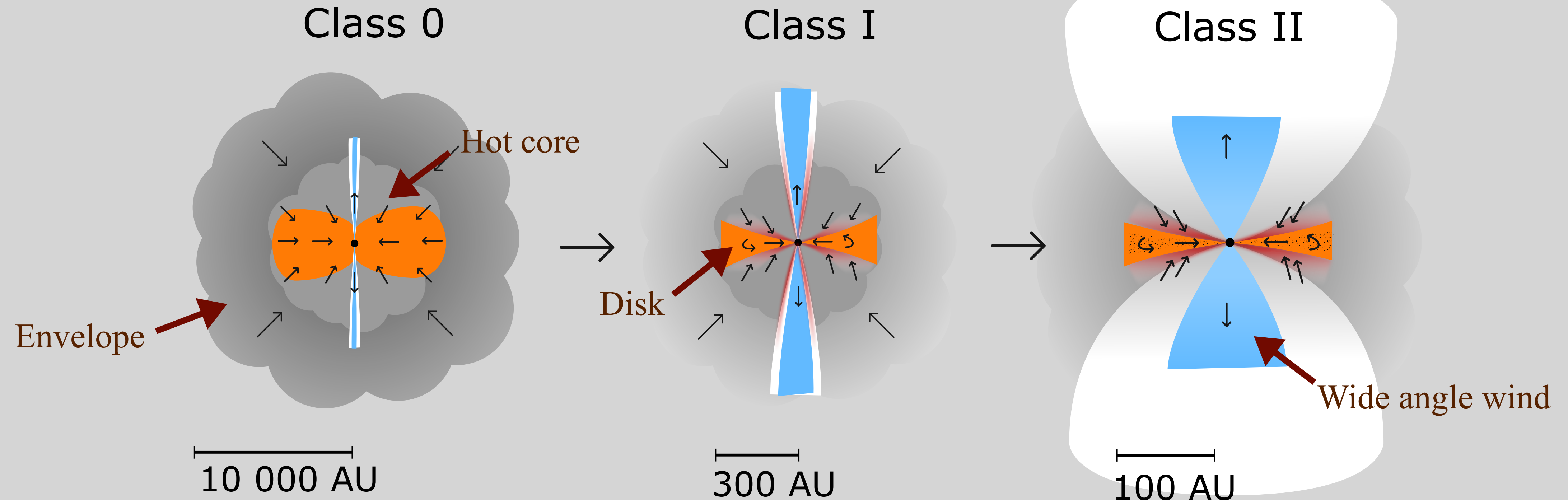
Tracing the inner disk



Disk-structure around young protostars (Sharma et al., 2025 eDisks)

What is the physical and chemical structure of young disks at start of planet formation?

Protostar & disk formation with JWST



JOYS

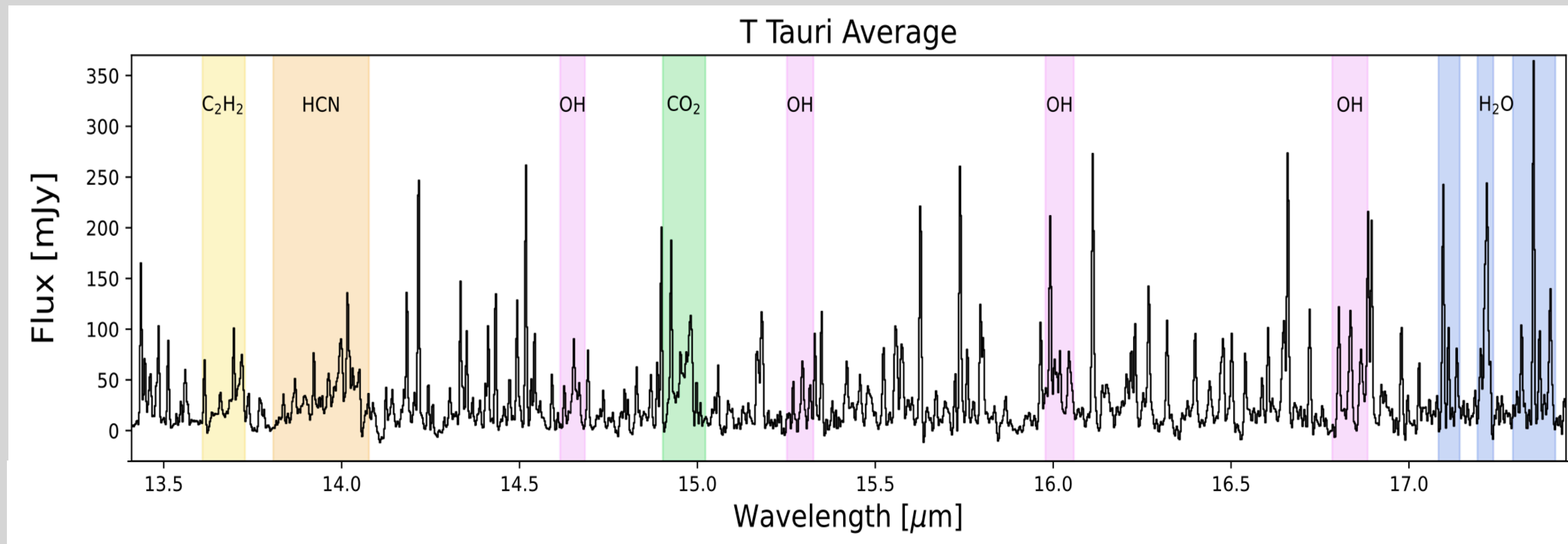
(JWST/MIRI GTO program,
PI E. Van Dishoeck)

MINDS

(JWST/MIRI GTO program,
PI T. Henning & I. Kamp)

Class II - MINDS

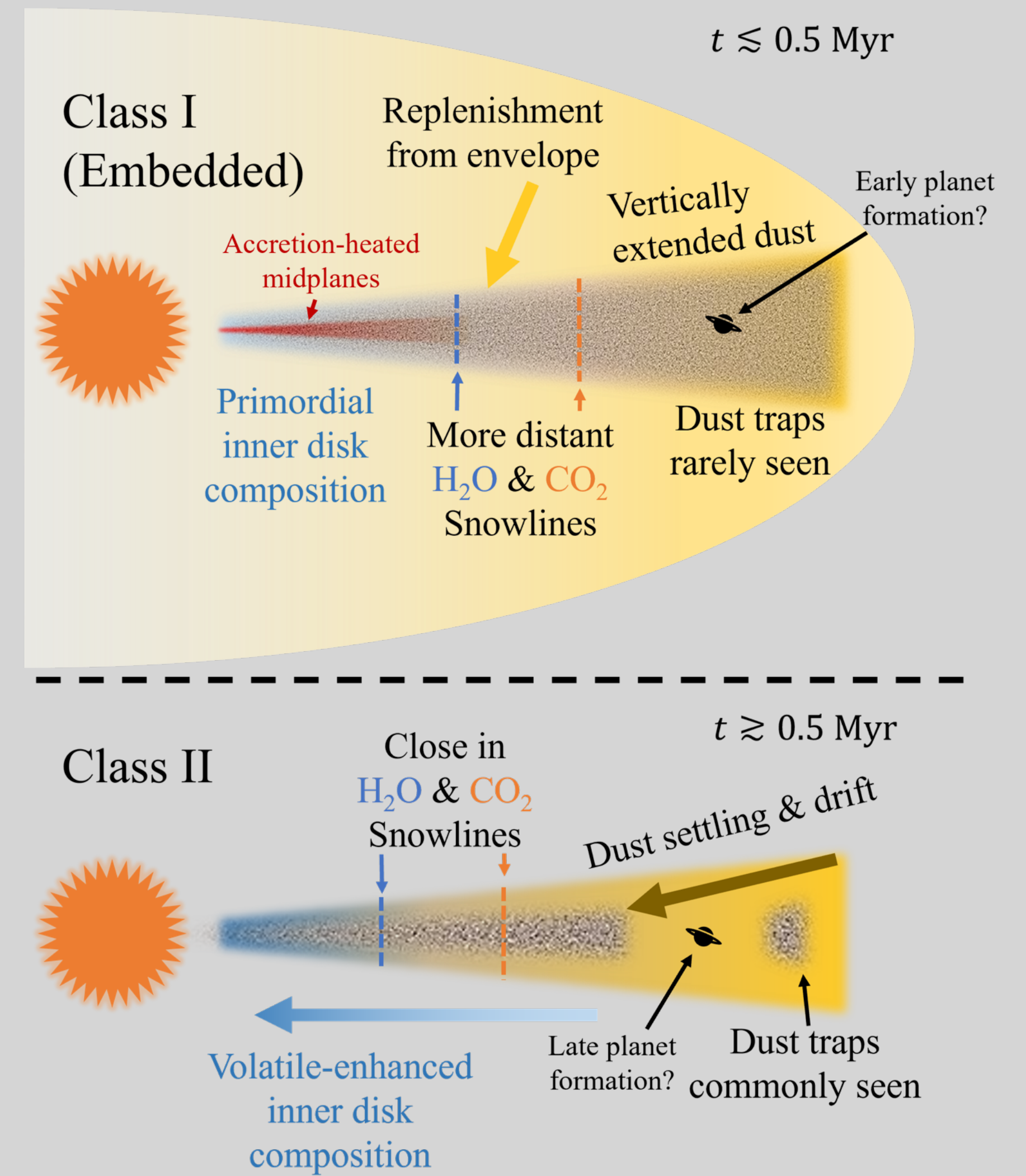
Grant et al., 2025



Spectra of T Tauri stars are rich in emission

Young Disks

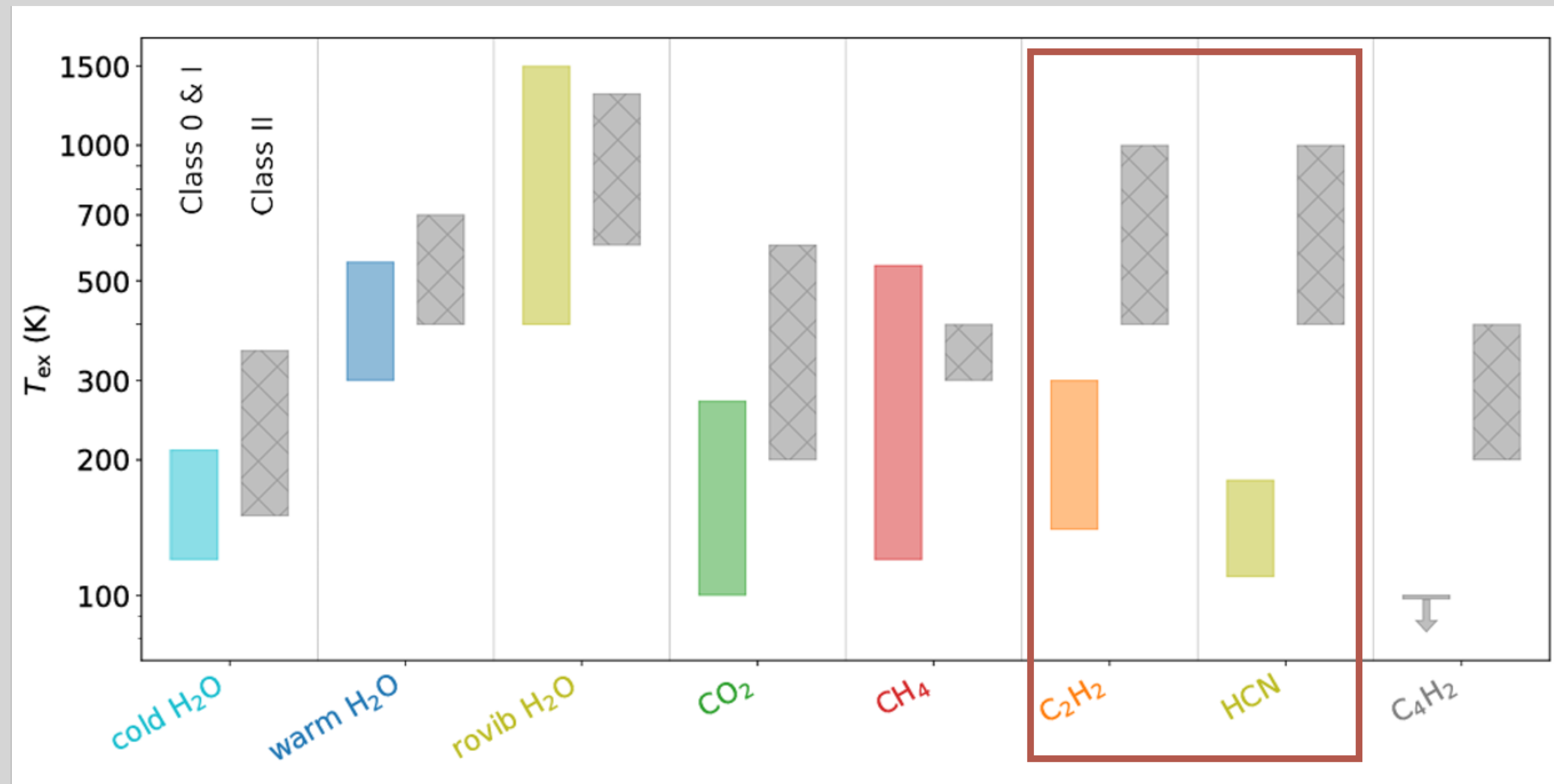
1. More massive
2. Warmer
3. Less structure formed
4. Composition should be less evolved
 - Less settling
 - Less drift



(Van Dishoeck et al, 2025)

Class 0 - JOYS

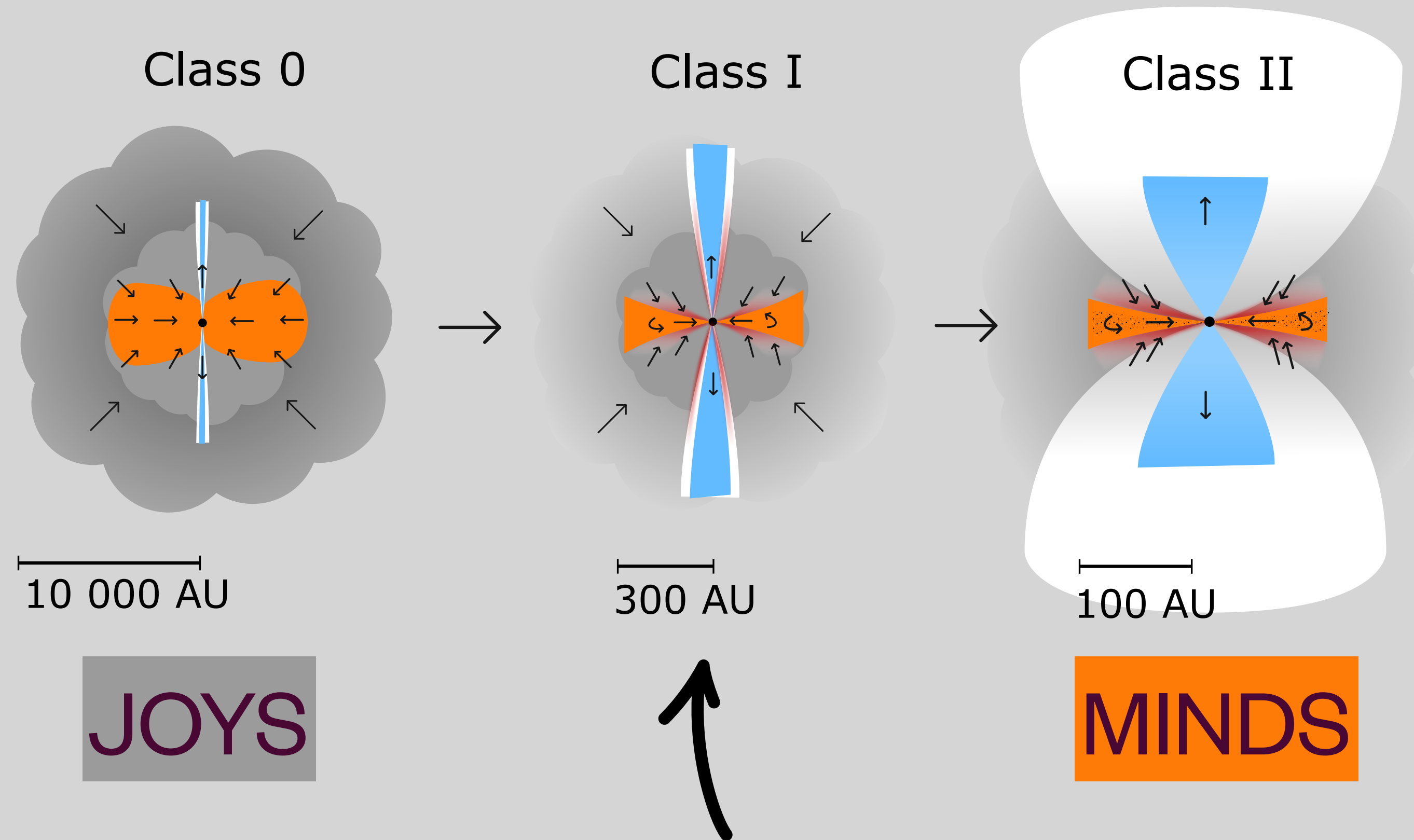
Van Gelder et al., 2024



Molecules are "colder" in Class 0 than in Class II

-> Unlikely to originate in (embedded) disks

Protostar & disk formation with JWST



What is the physical and chemical structure of young disks at start of planet formation?

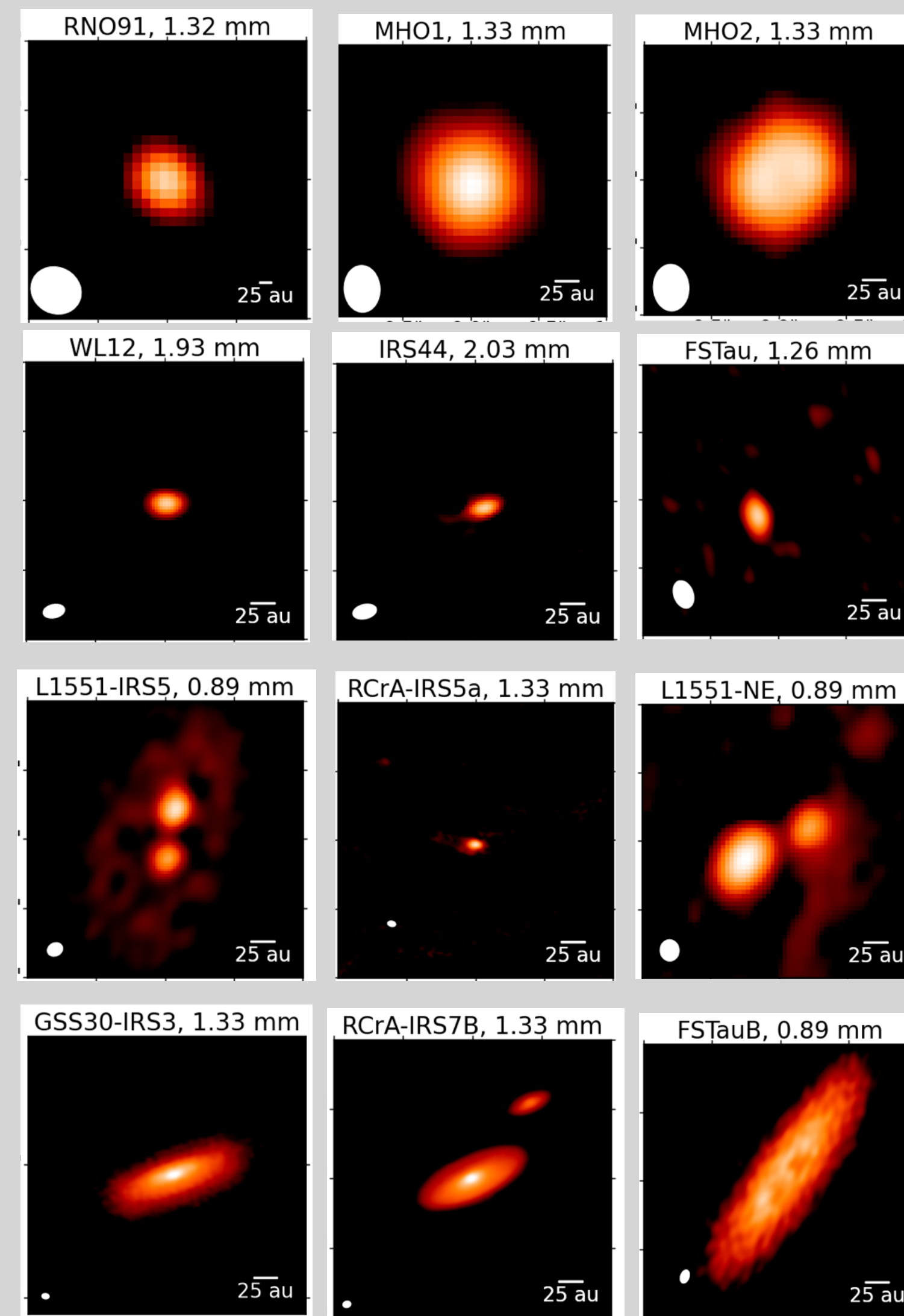
JWST 7890

(PI: Ł. Tychoniec)

(i) Measure the warm gas composition of 21 Class I disks.

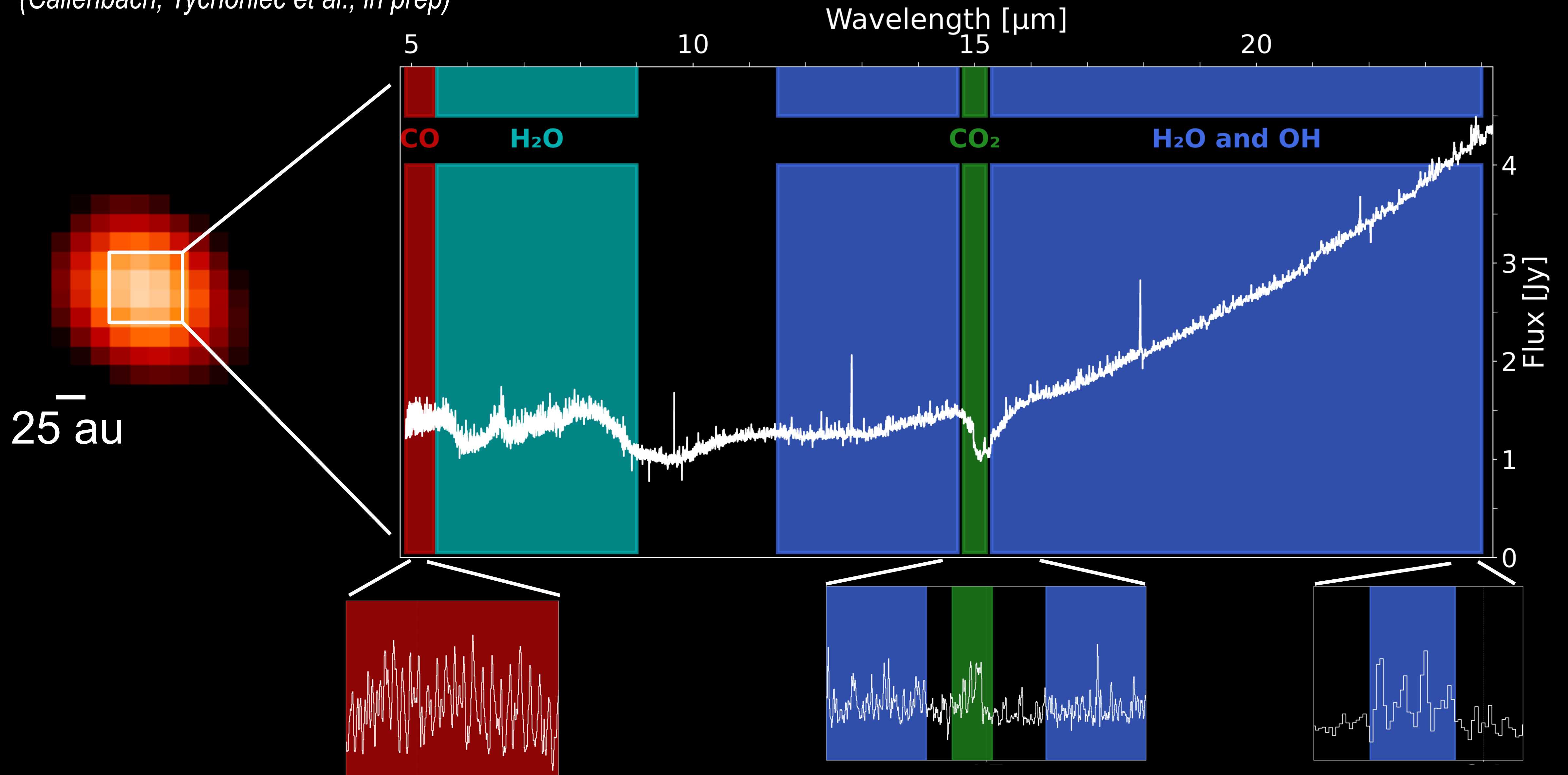
(ii) Trace this composition as a function of time.

(iii) link to radial drift timescales and dust traps.



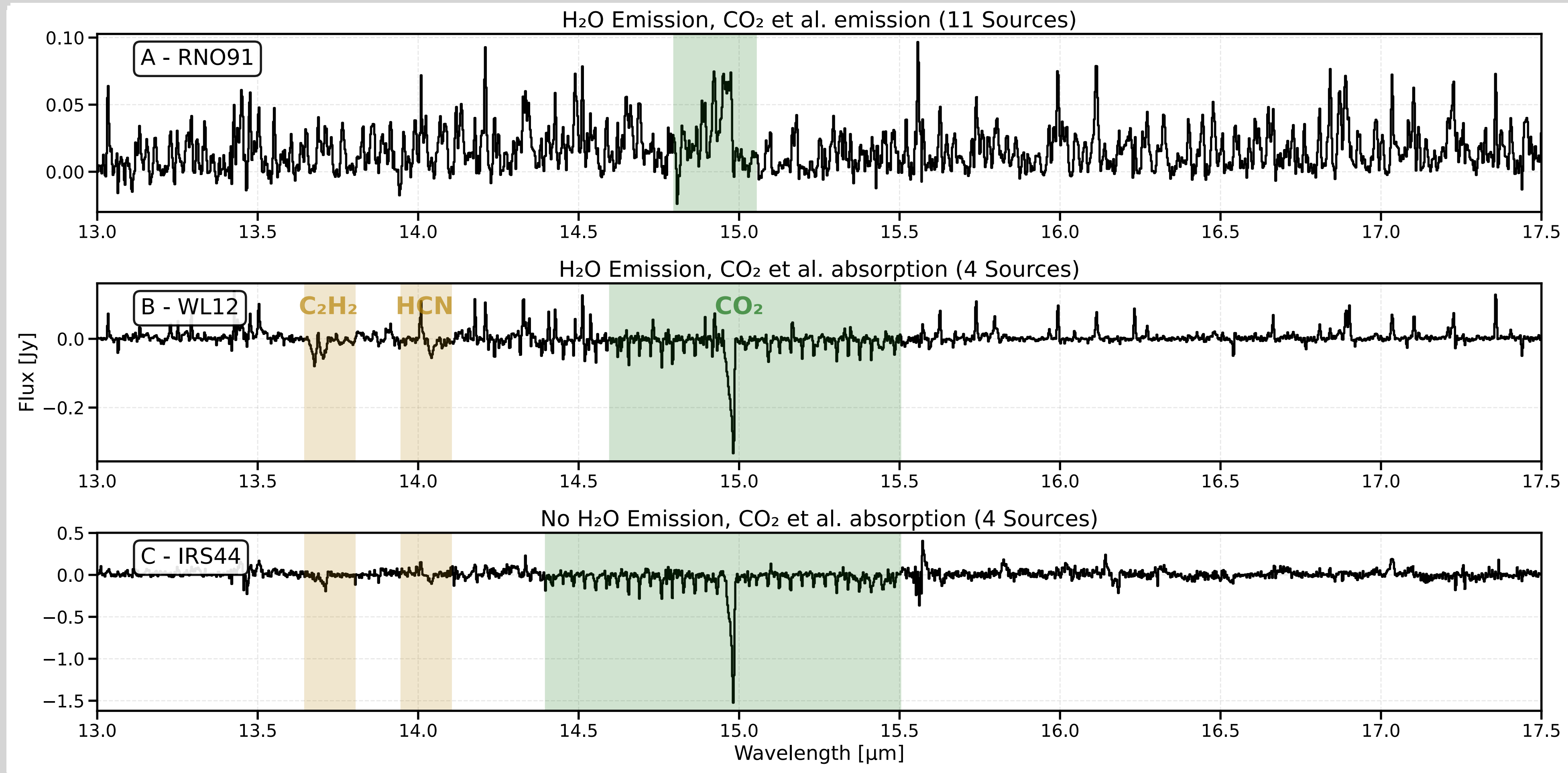
H₂O-rich gas in the planet-forming regions of a young embedded disk

(Callenbach, Tychoniec et al., in prep)



Overview of spectra

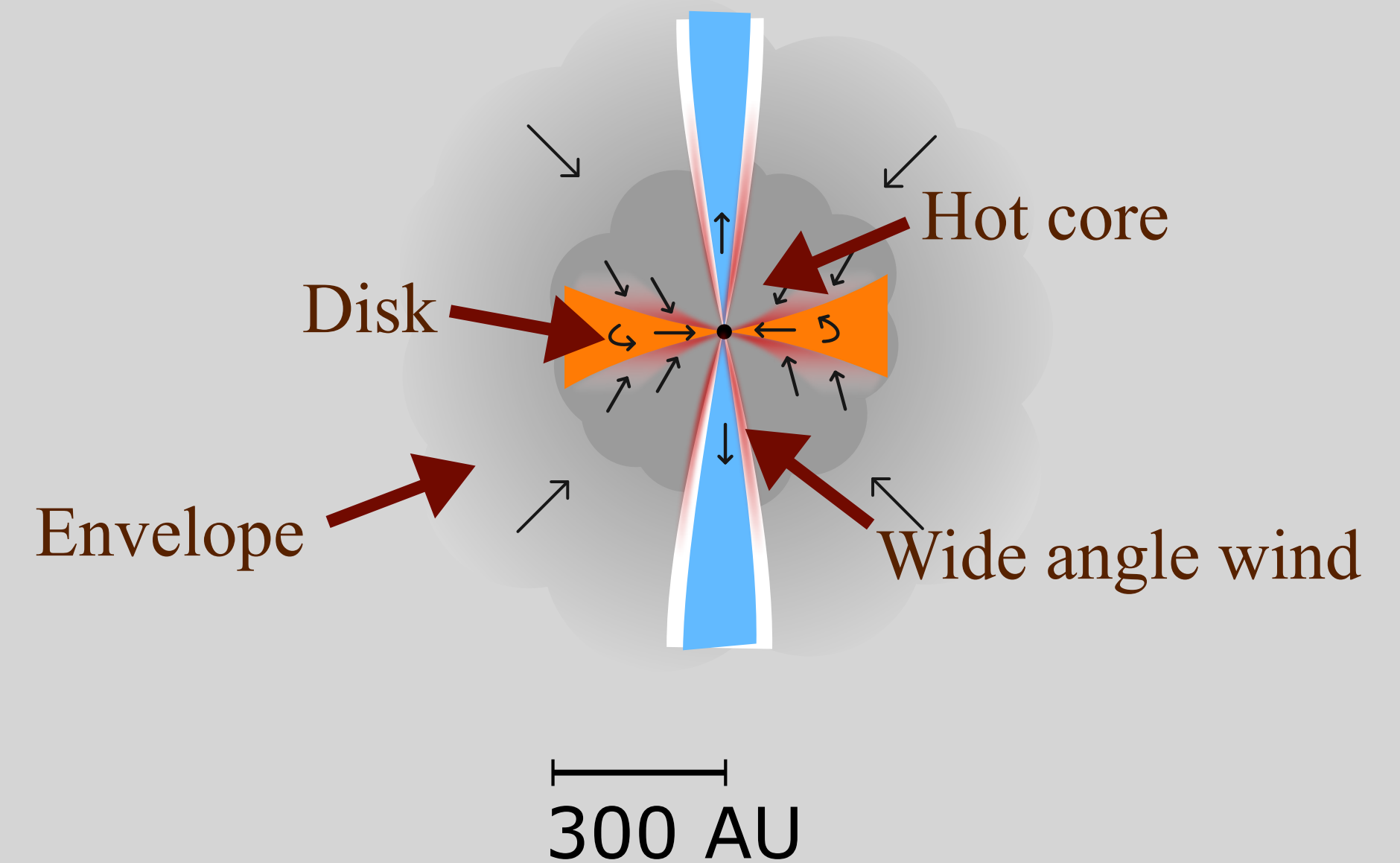
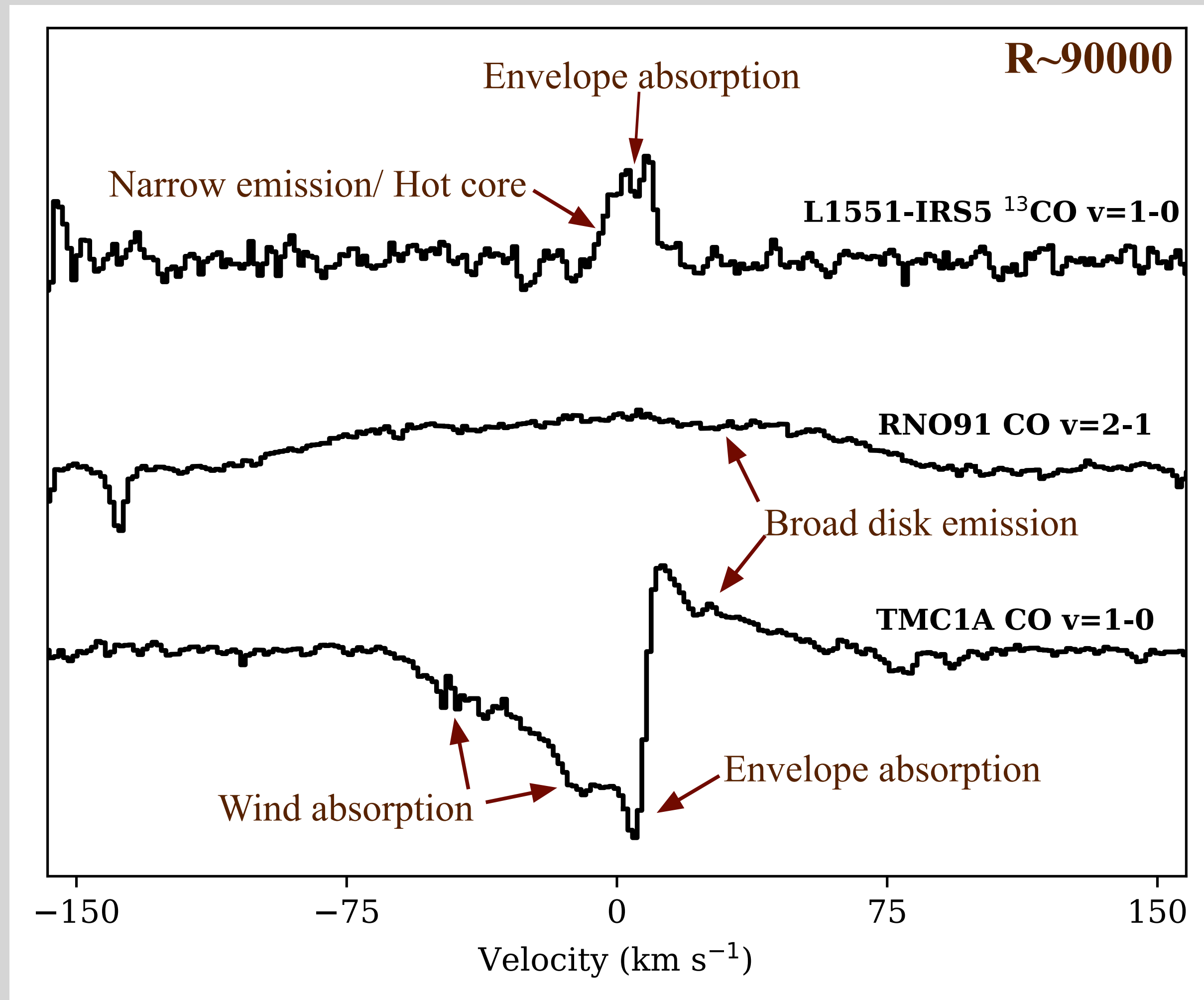
Spectra can be divided in three groups, based on emission vs absorption



Targets with emission-only are disk candidates

But what component do the other features trace?

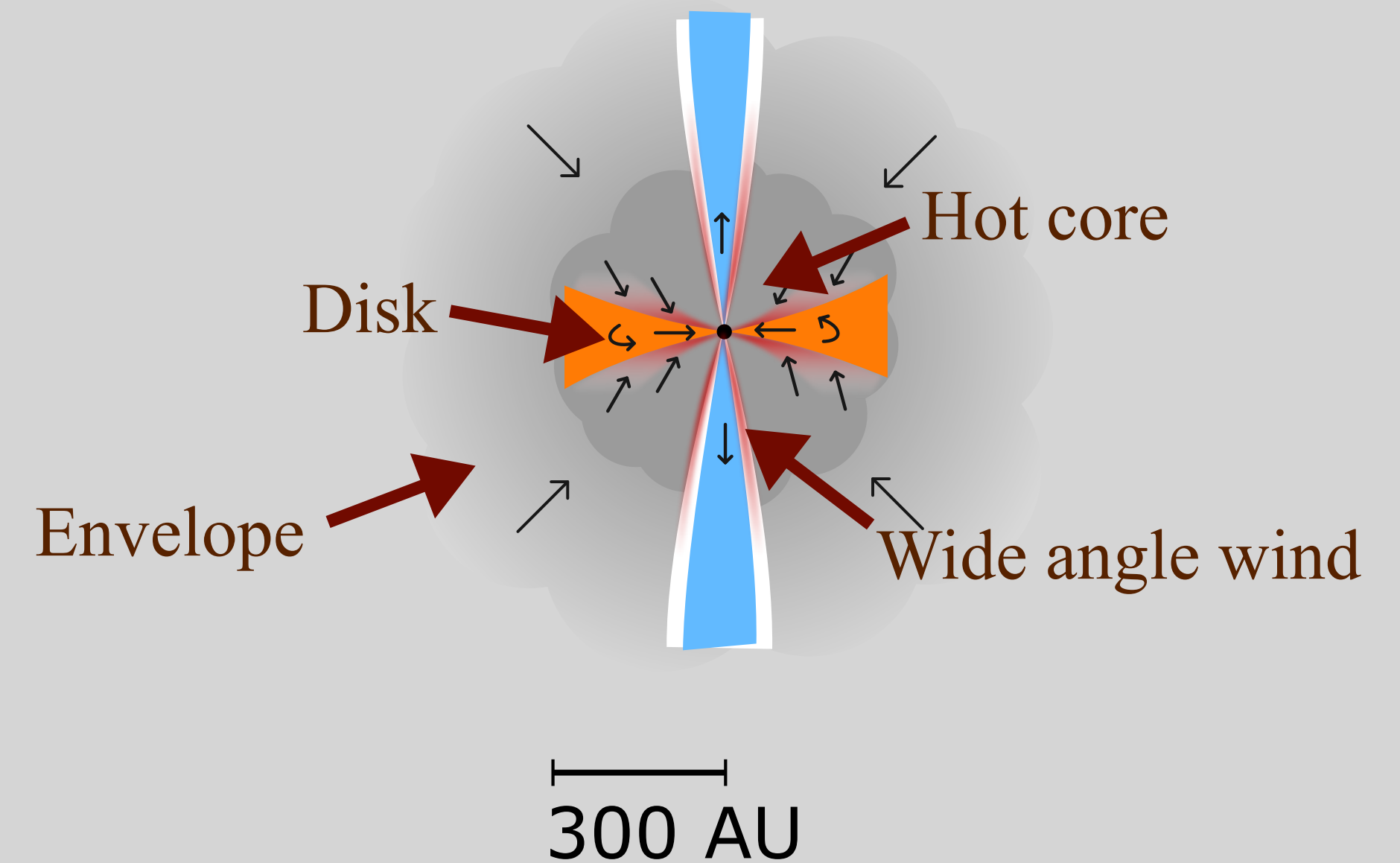
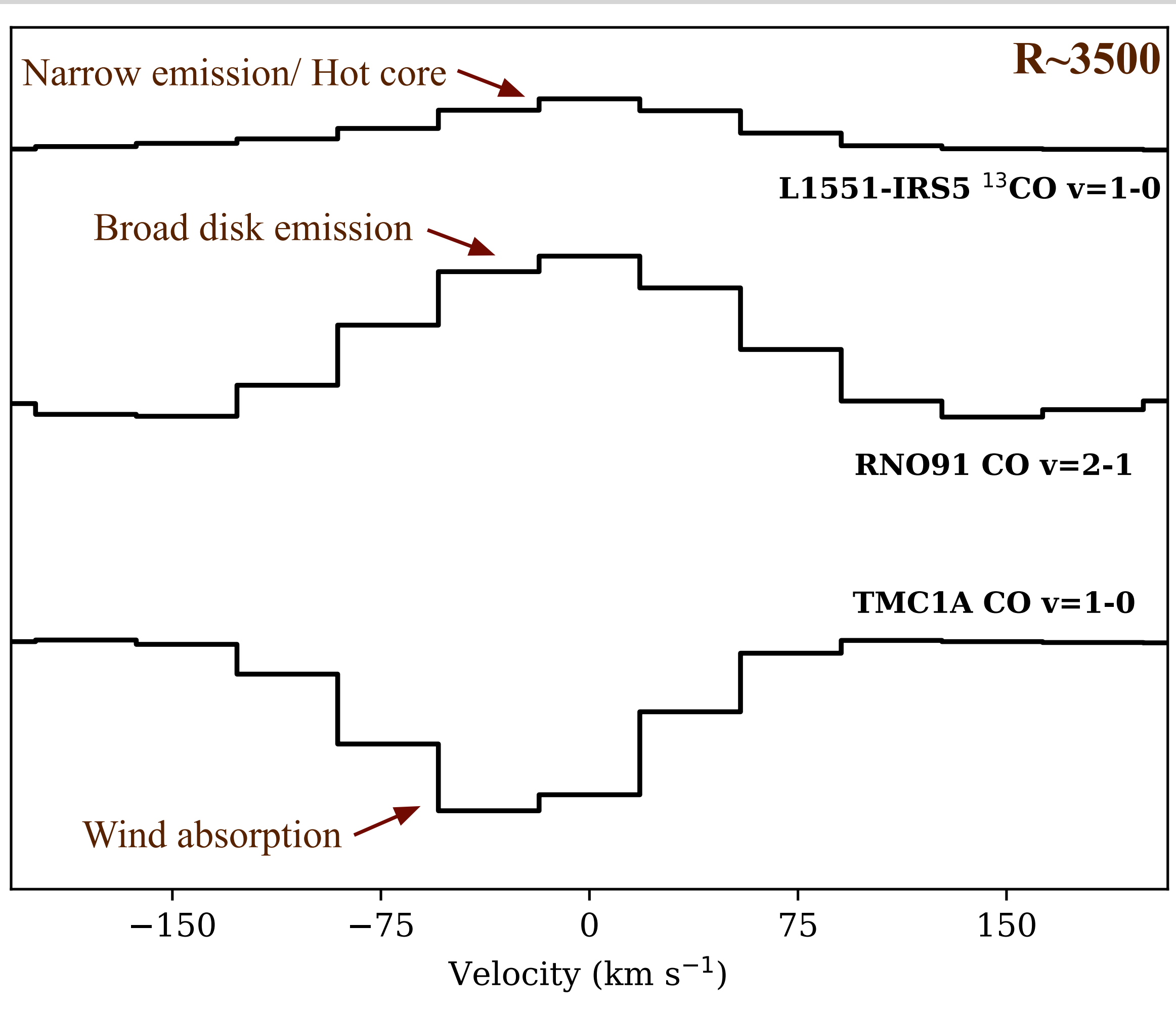
Kinematics from line Profiles



Origin of emission can be derived from line profiles of high spectral resolution observations (E.g. VLT/CRIRES; Herczeg et al., 2011)

Kinematics from line Profiles

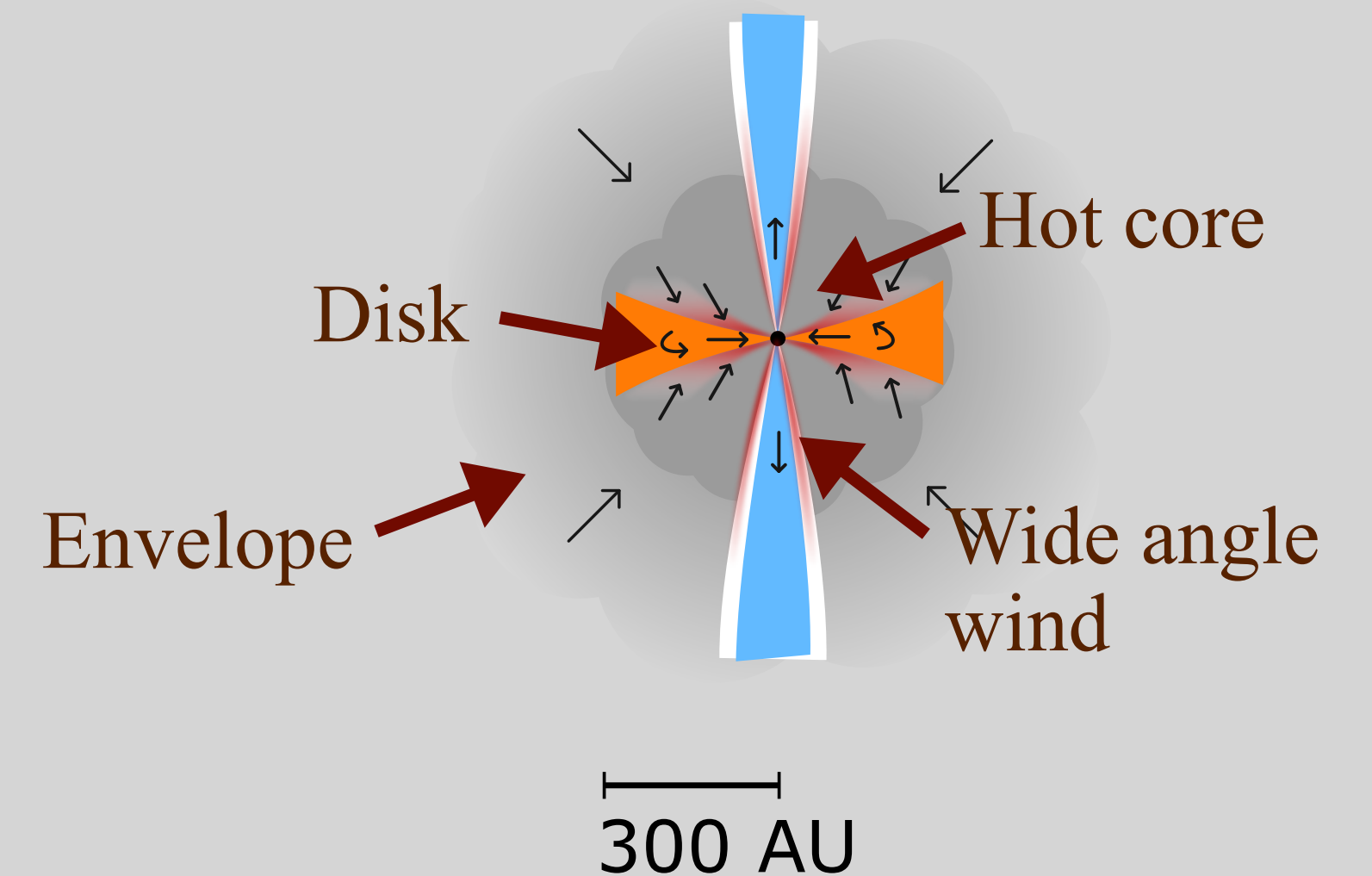
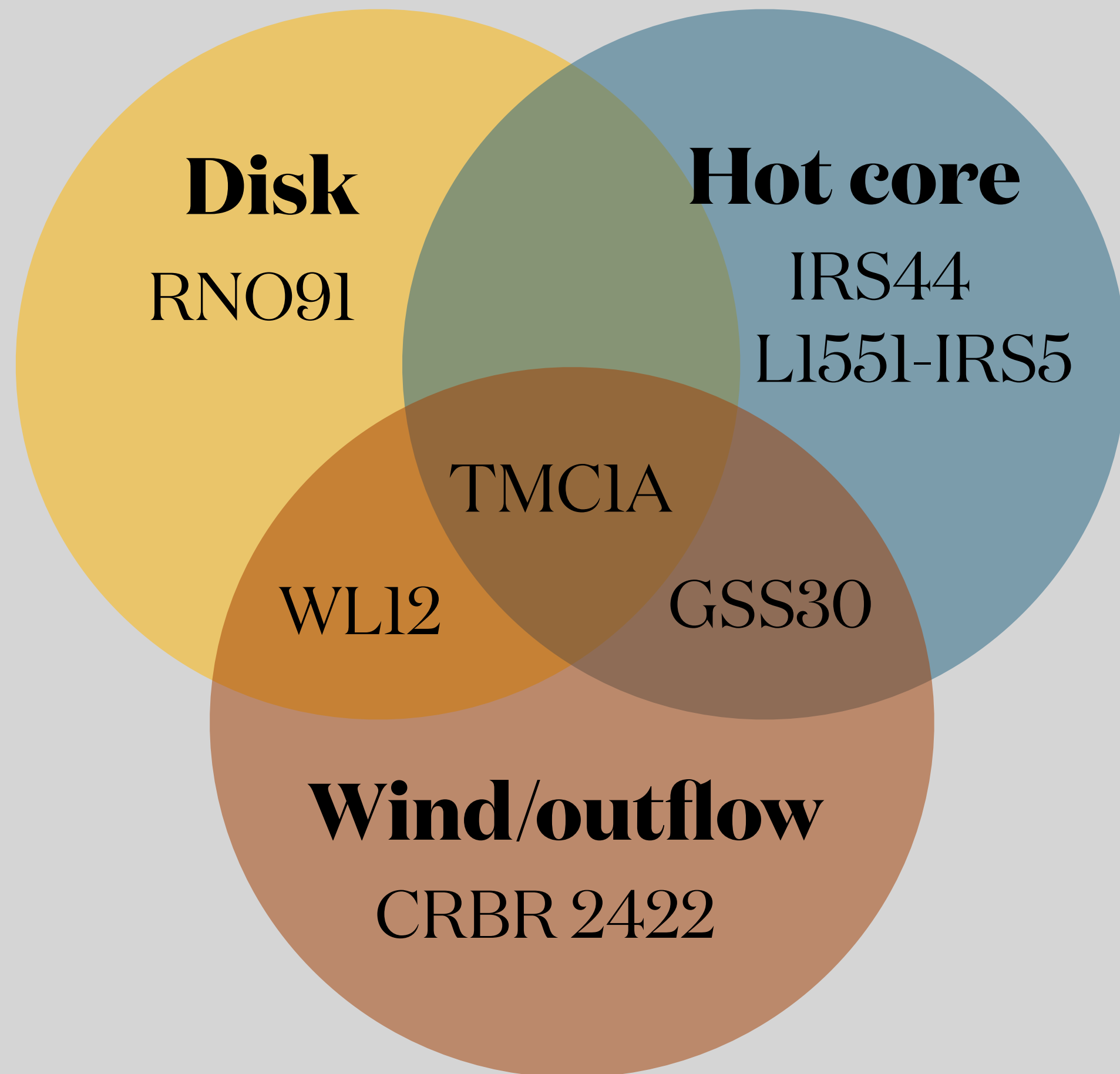
Same line profiles convolved and regridded to MIRI resolution...



Can we derive the same information from lower spectral-resolution JWST-MIRI/MRS data?

Seven test subjects!

Origin of CO (CRIRES)



Compare JWST observations with available VLT/CRIRES CO observations

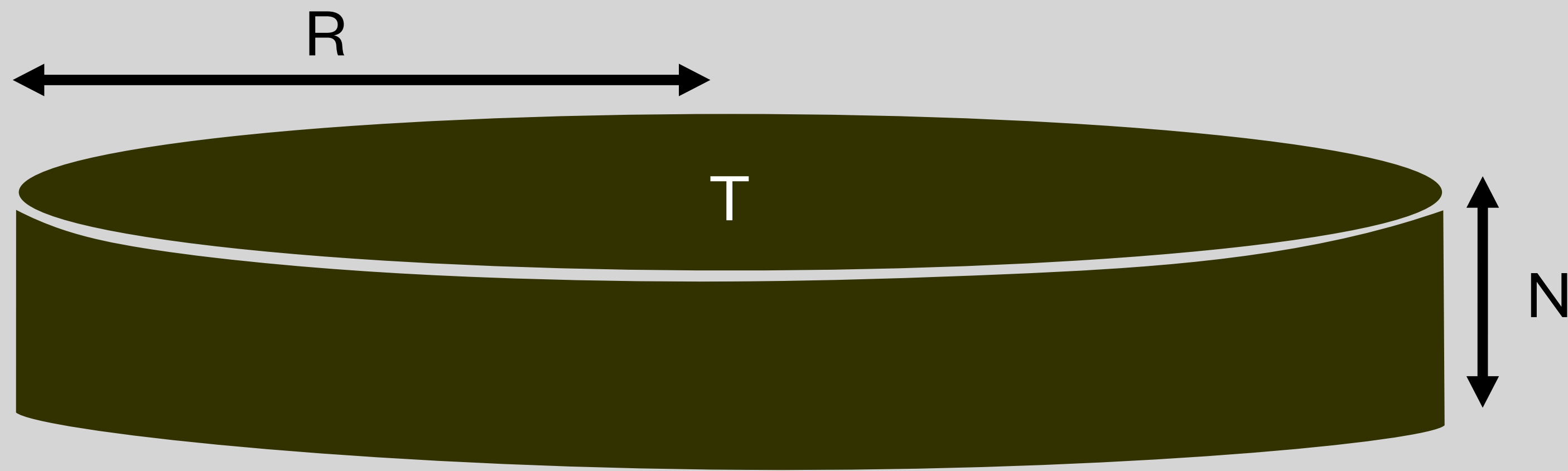
JWST Program

7890: RNO91, WL12, IRS 44, L1551-IRS5

1290: TMC1A

1959: GSS30-IRS1, CRBR 2422

Methods - LTE slab models

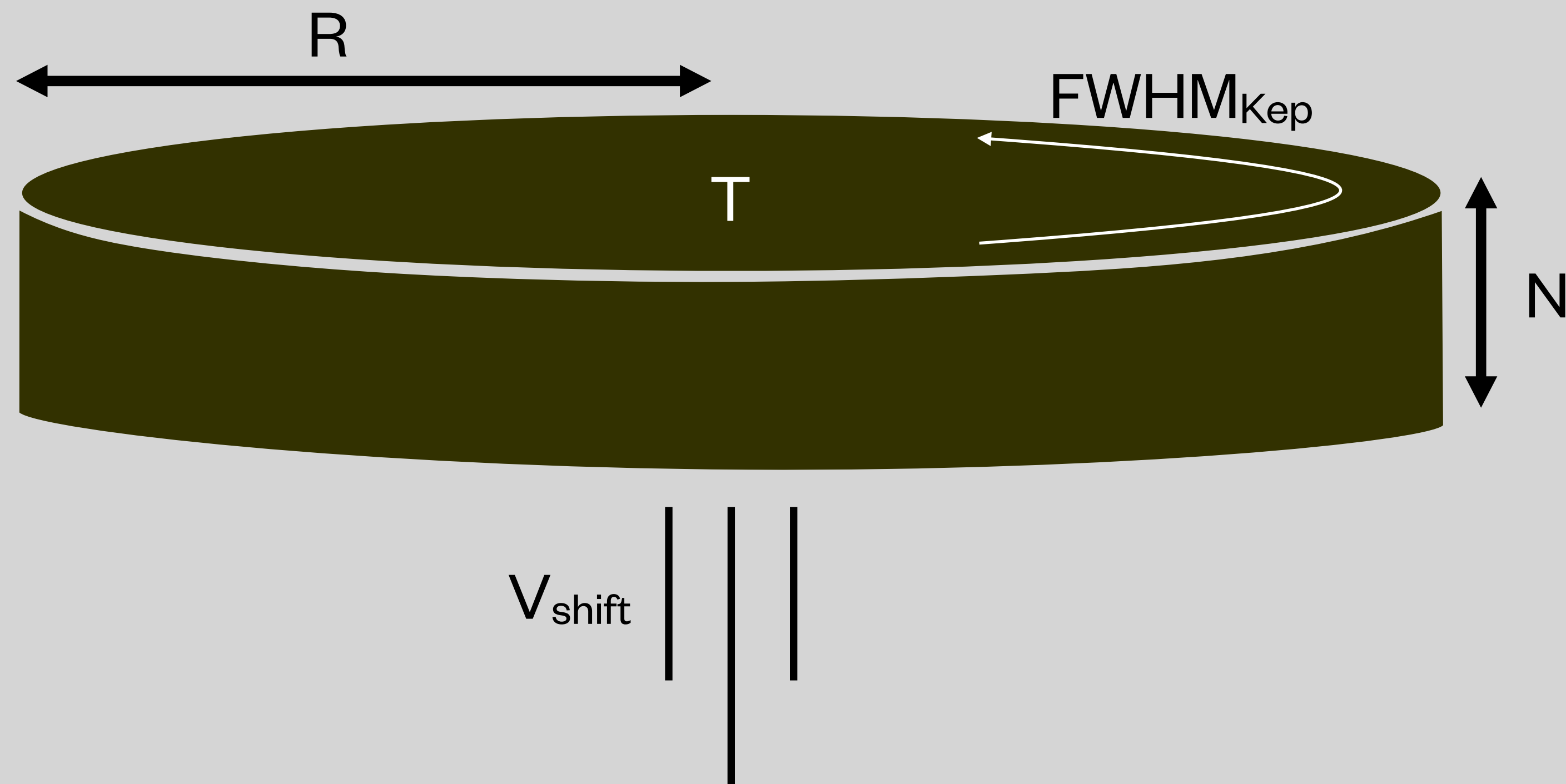


Combine multiple lines to model

- Temperature (T)
- Column density (N)
- Emitting area (πR^2)

And make a model of the emission!

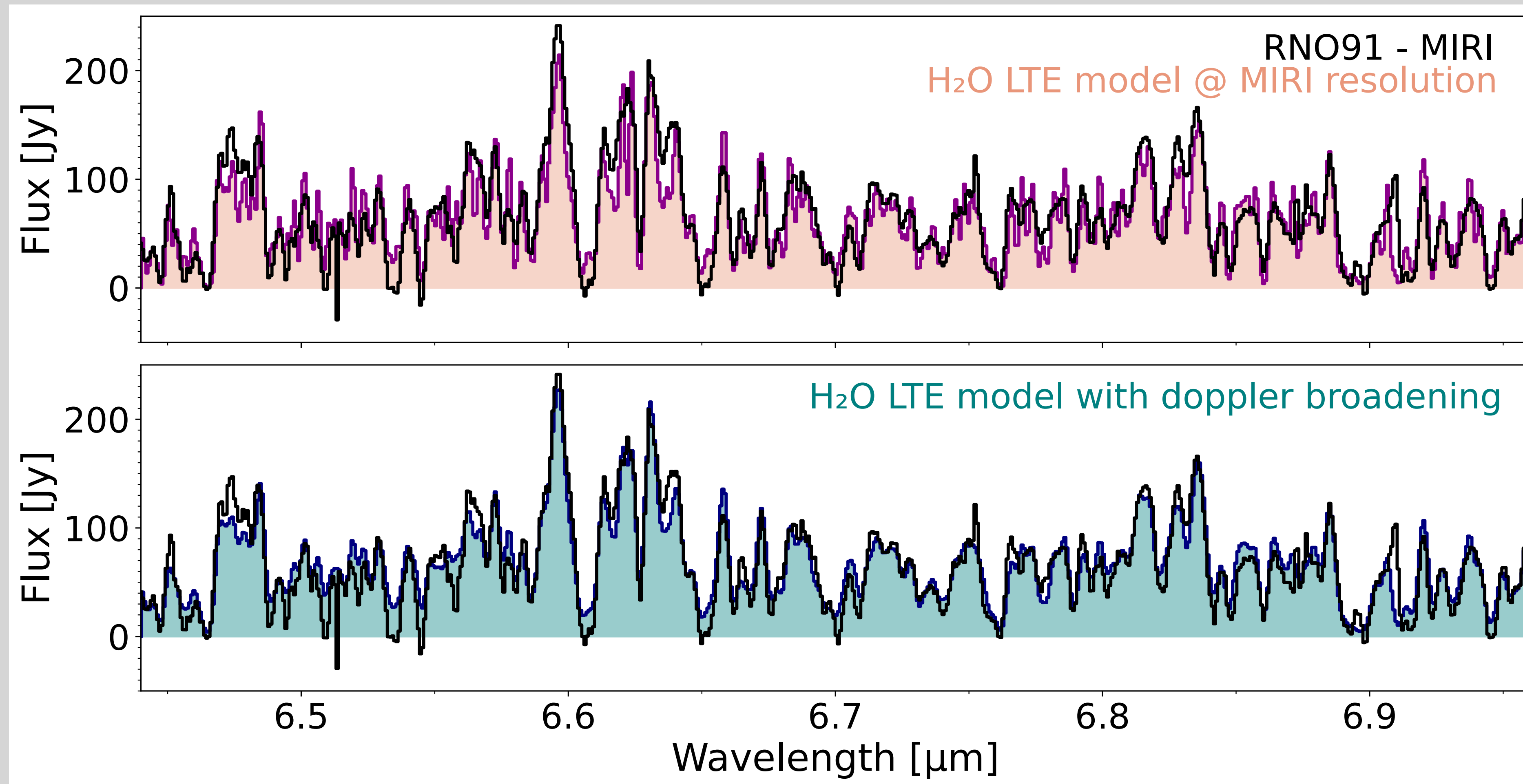
Methods - LTE slab models



Add Keplerian line broadening and velocity shift to determine if we are looking at disks

Line broadening in LTE model

Broad lines in RNO91 indicate disk emission!

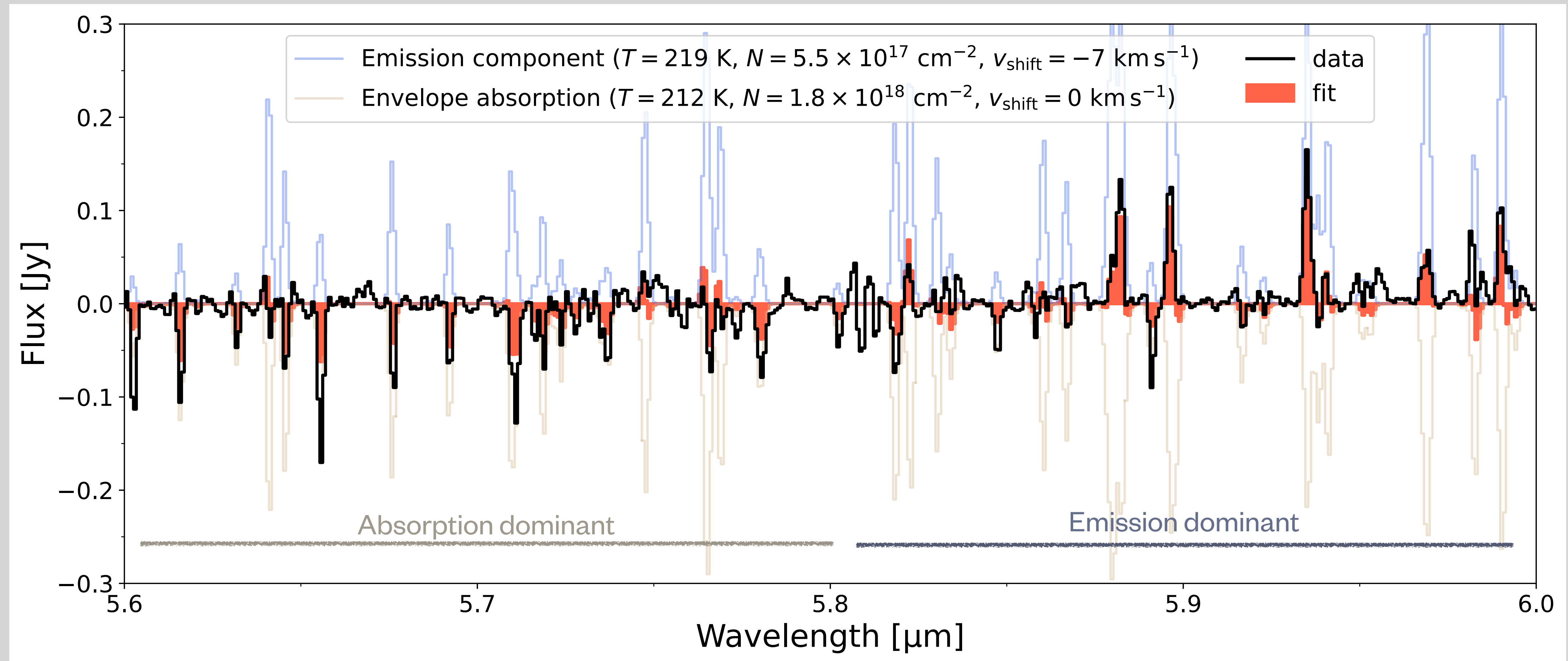


T = 780 K
N = $6 \times 10^{20} \text{ cm}^{-2}$
R = 0.3 AU
FWHM = 5 km s^{-1}

T = 780 K
N = $3 \times 10^{20} \text{ cm}^{-2}$
R = 0.2 AU
FWHM = 120 km s^{-1}

Mixed emission/absorption modelling

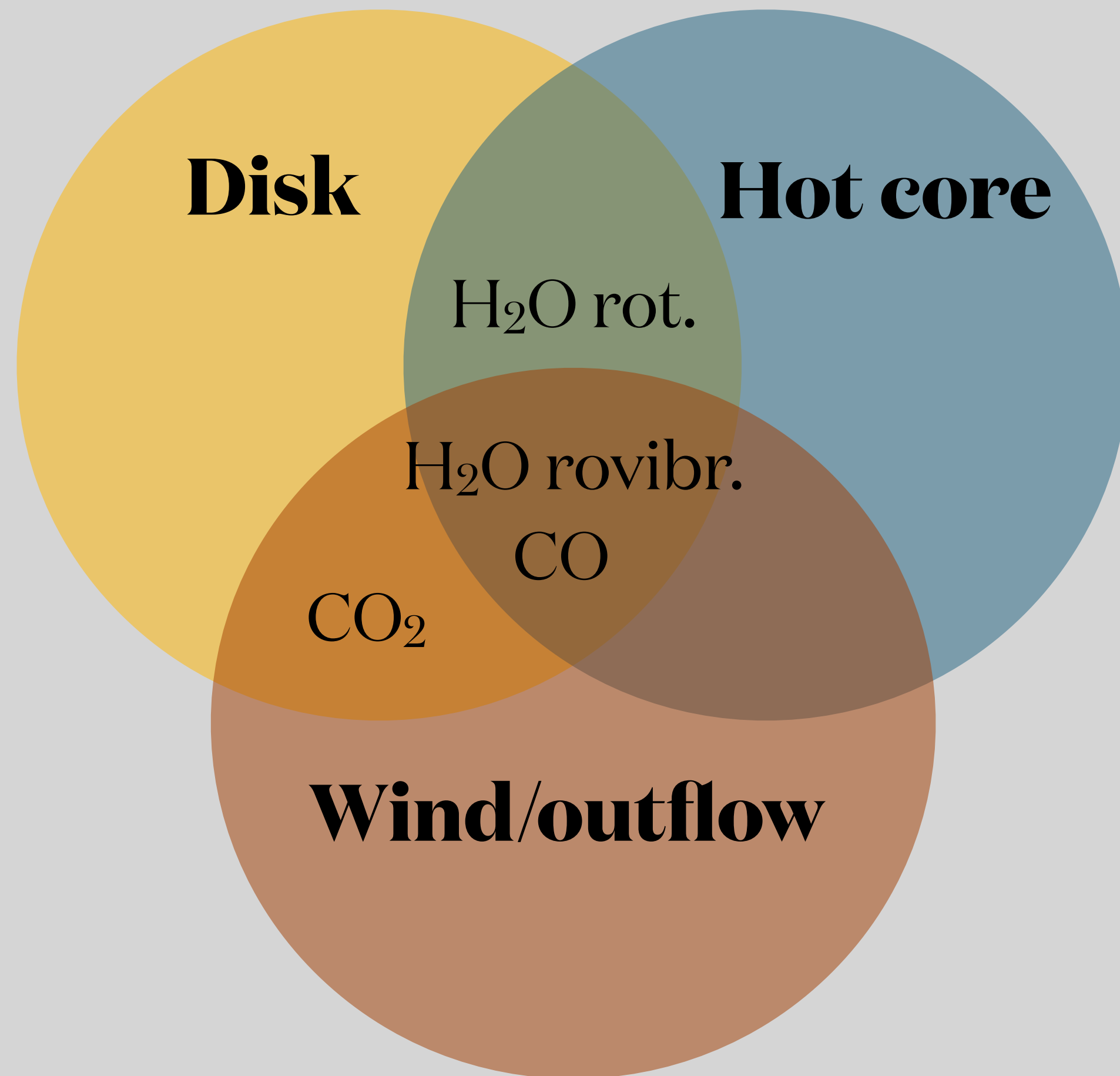
Rovibrational H₂O in IRS44 has an absorption and emission component



Which molecule traces what?

Evidence for multiple origins

Common molecules

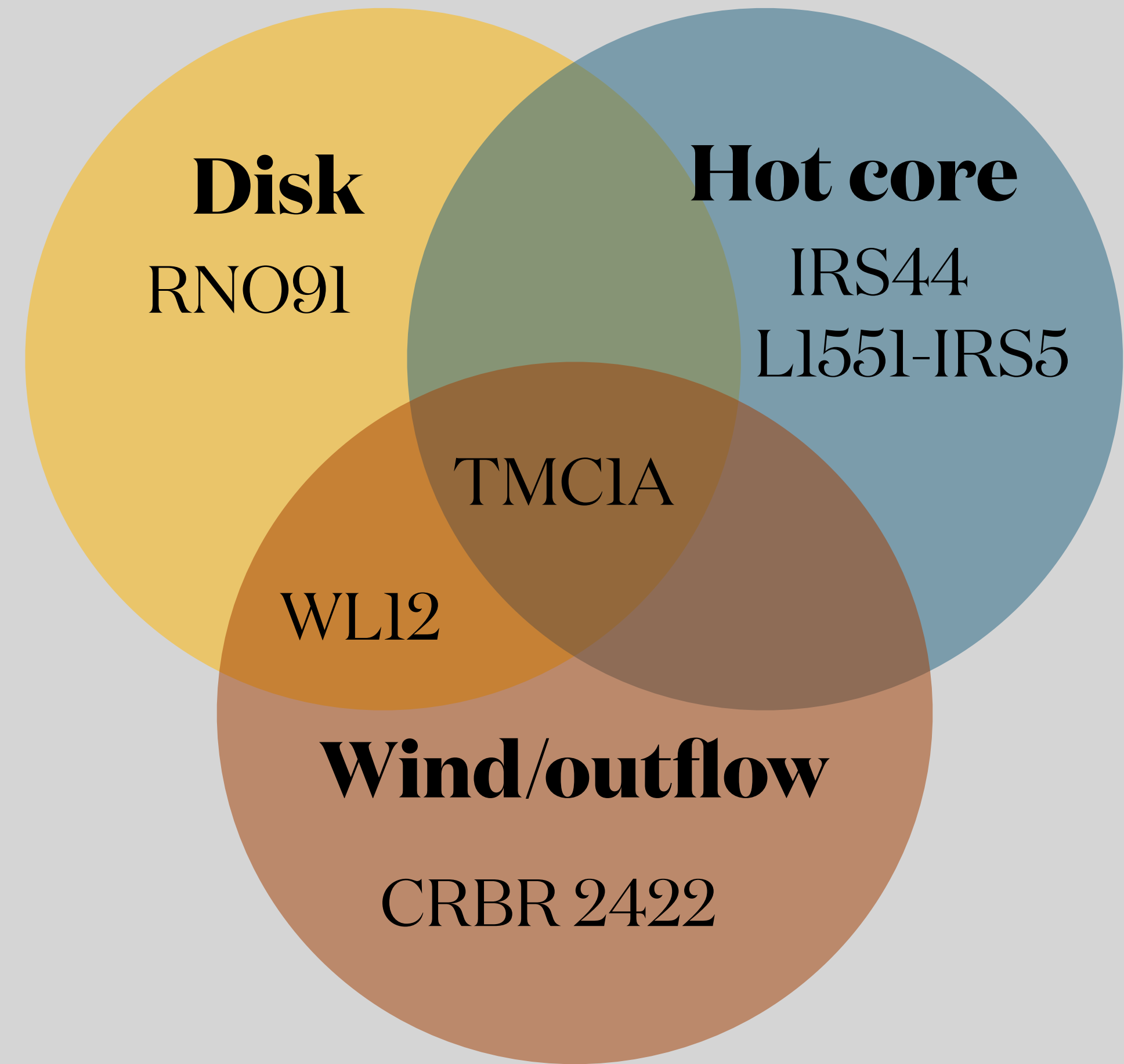


Envelope absorption



JWST detections similar to CO observations

Origin of CO (CRIRES)

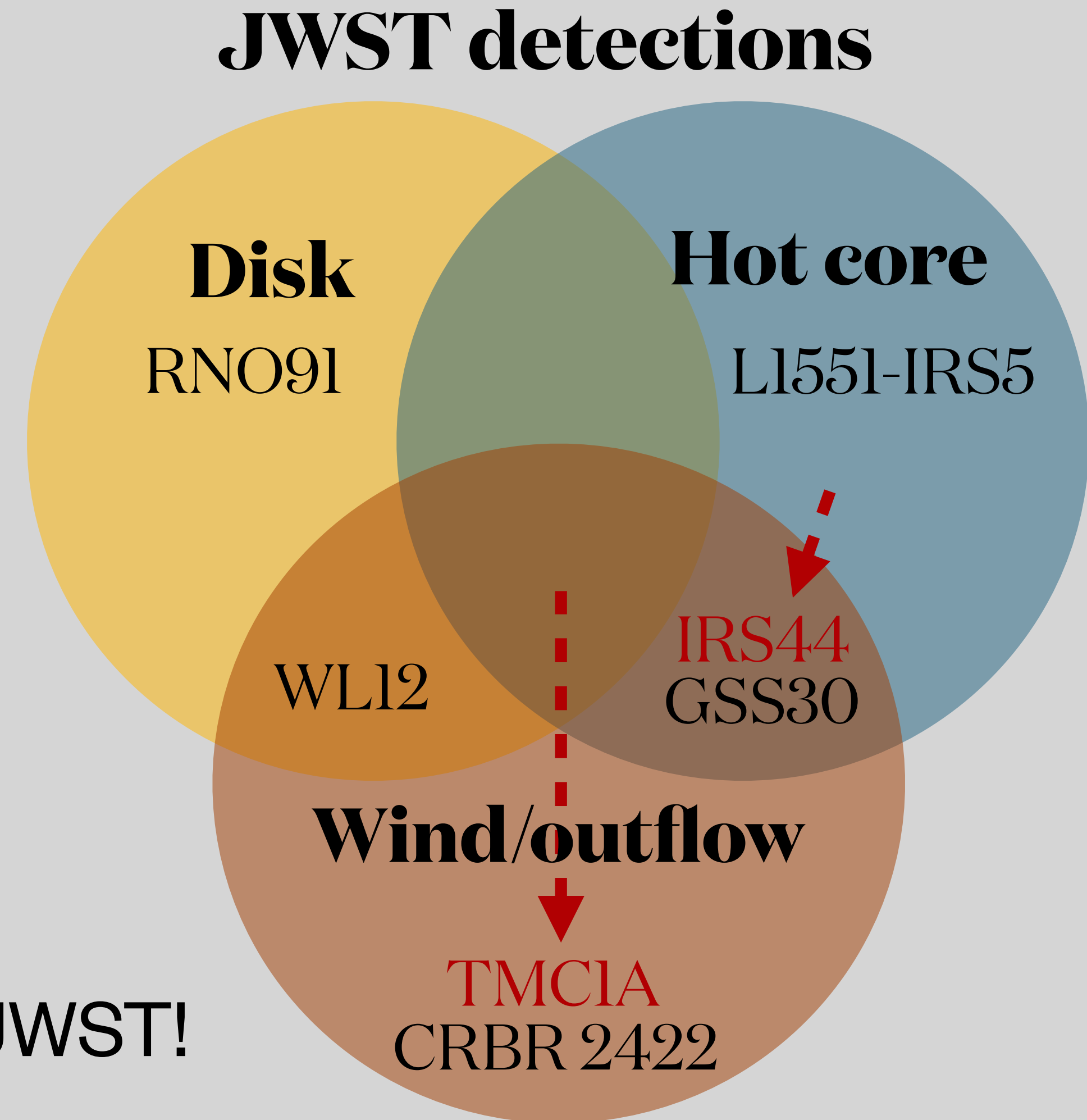


JWST detections similar to CO observations

Matches VLT/CRIFRES classification

Different classification compared to VLT/CRIFRES

Ground based observatories compliment JWST!



Conclusions

- ✦ **Evidence for disks in half of the targets!**
- ✦ Class I protostars and disks categorised in three distinct groups
 - ✦ Not every Class I observation traces a disk
- ✦ Able to distinguish in origin of emission
 - ✦ Doppler broadening useful tracer for disk emission
- ✦ High spectral resolution observations compliments JWST!
- ✦ H₂O-rich gas in the planet-forming regions of a young embedded disk

Series of papers in progress!