

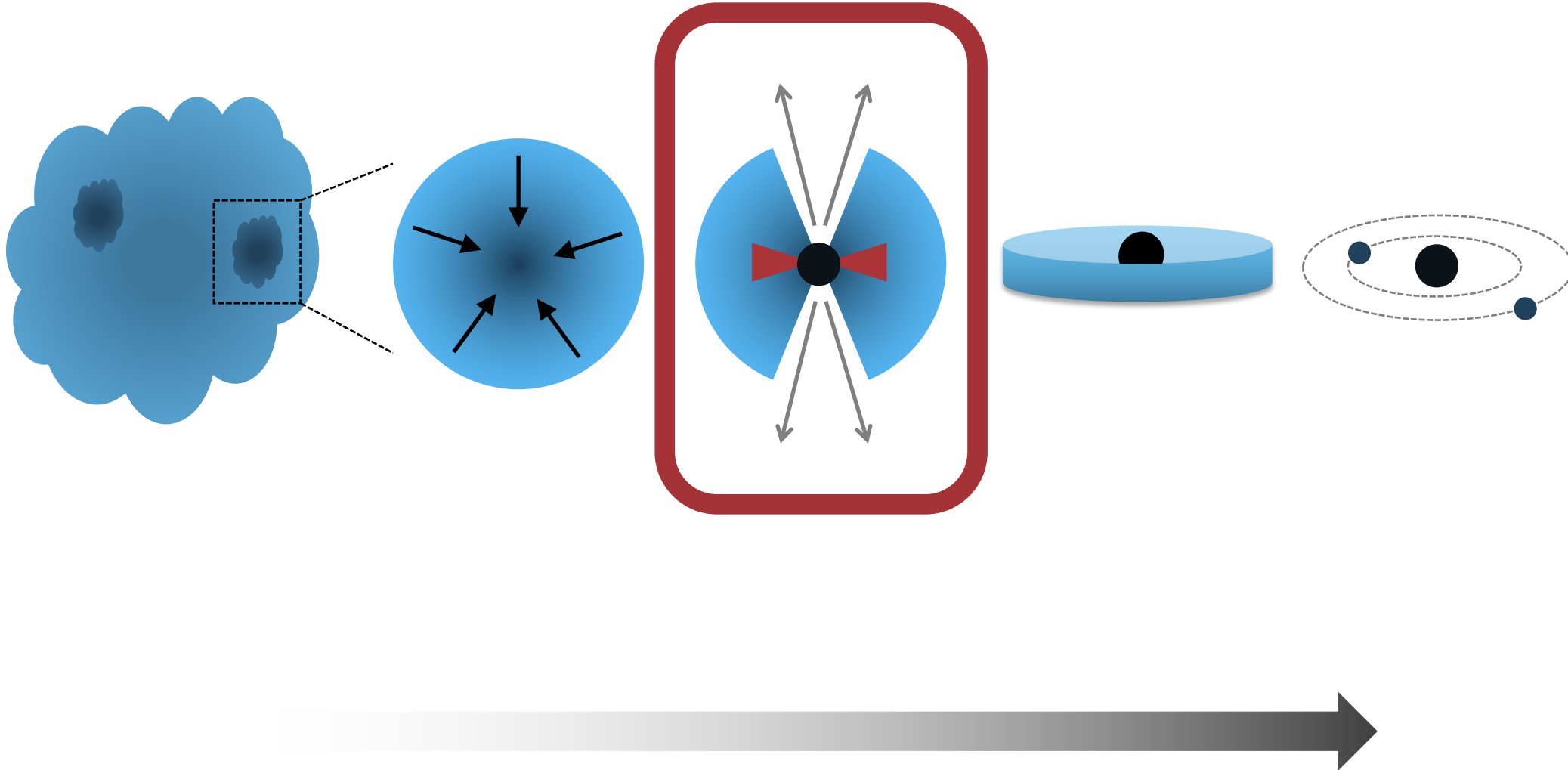
# YOUNG EMBEDDED DISKS:

*The ALMA (WSU) and JWST era*

**MEREL VAN 'T HOFF**

*Purdue University*

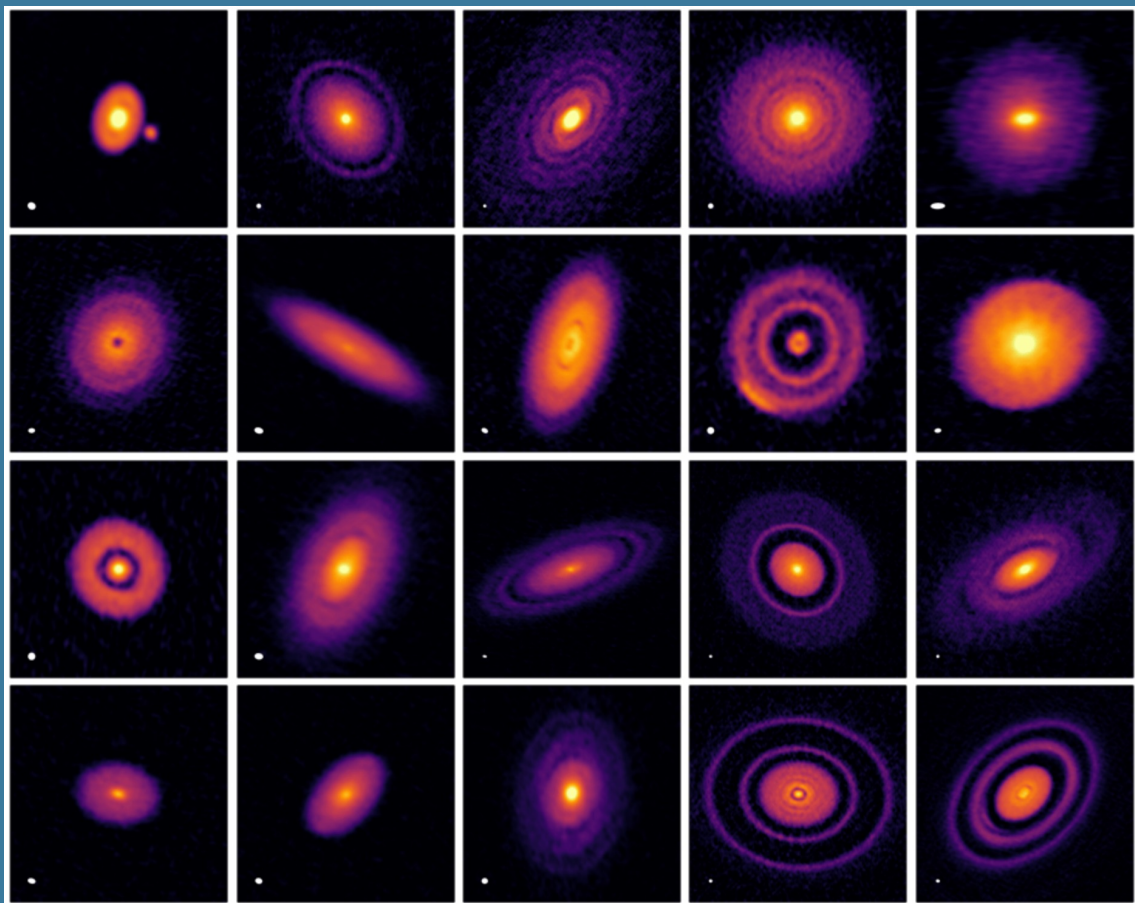
# YOUNG EMBEDDED DISKS





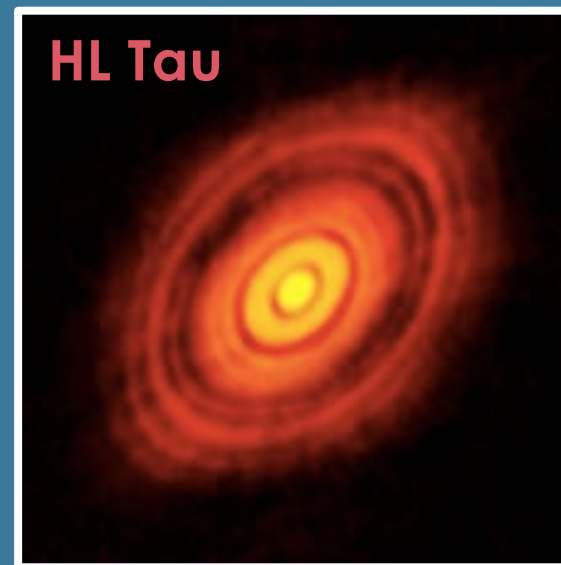
# CONTINUUM

*Are dust substructures common in young disks?*

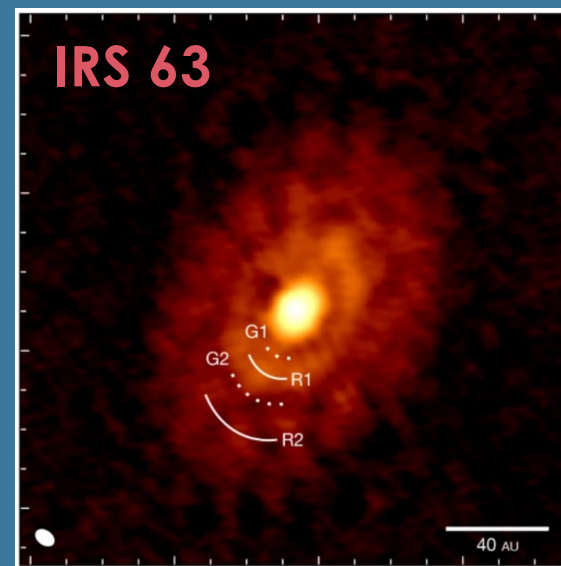


Mature protoplanetary disks (DSHARP)

Andrews et al. 2020



ALMA Partnership 2015



Segura-Cox et al. 2020

Young embedded disks

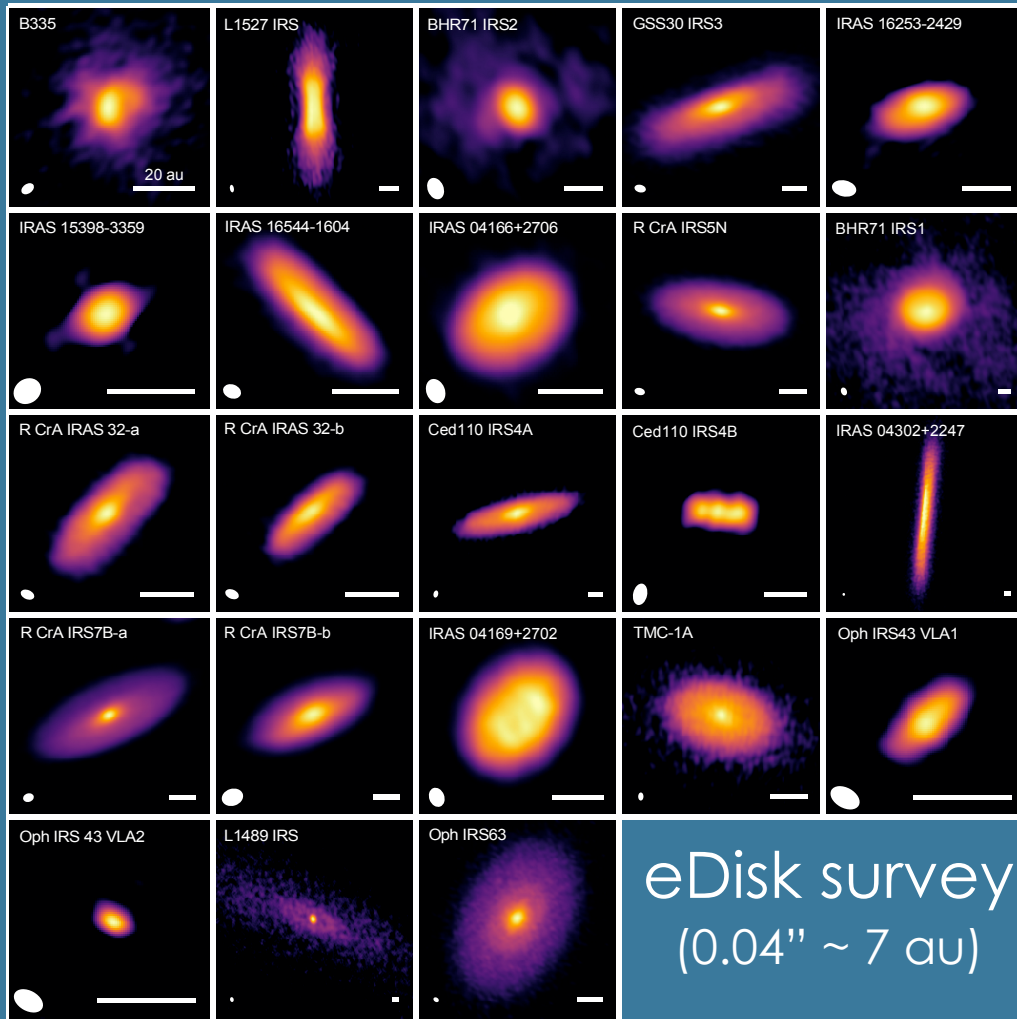
# CONTINUUM

*Are dust substructures common in young disks?*

ALMA

ALMA WSU

JWST



eDisk survey  
(0.04" ~ 7 au)

Maybe not...

... but dust may be optically thick

... but eDisk is biased toward edge-on disks

If not, substructures may form quickly once Class 0 and I protostars evolve into Class II.  
(see also Nazari et al. 2024)

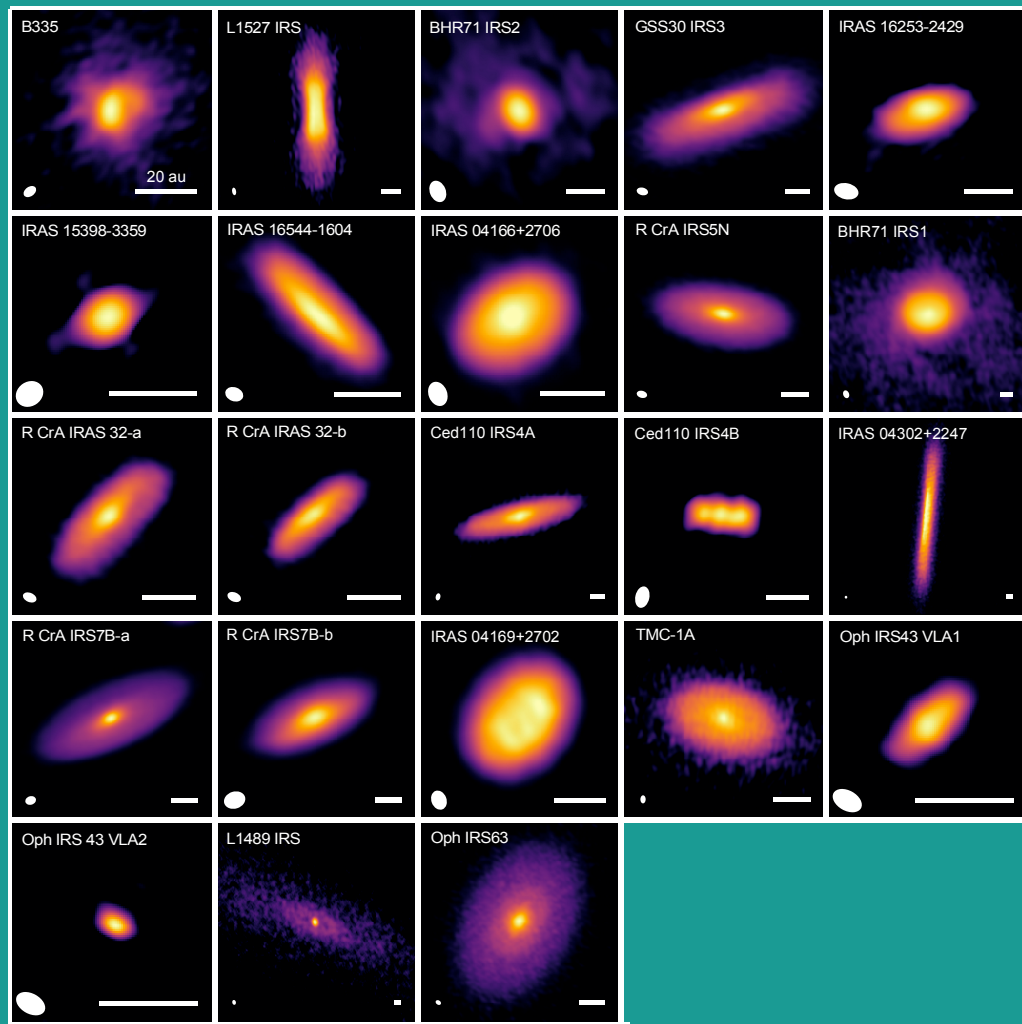
## Most common structure:

Asymmetry along the disk minor axis,  
Suggest optically thick vertically extended disk, so dust not settled toward midplane.



# CONTINUUM

*Are dust substructures common?*

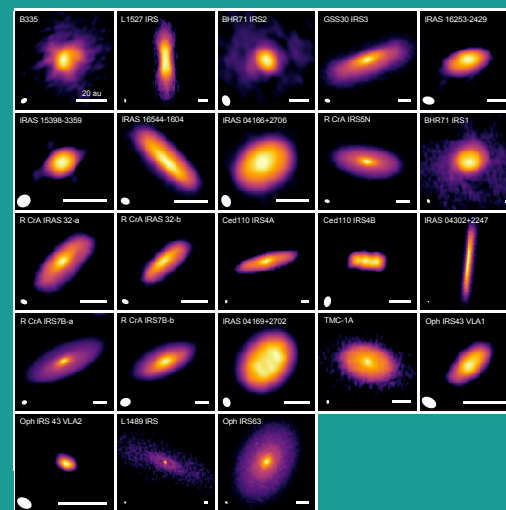
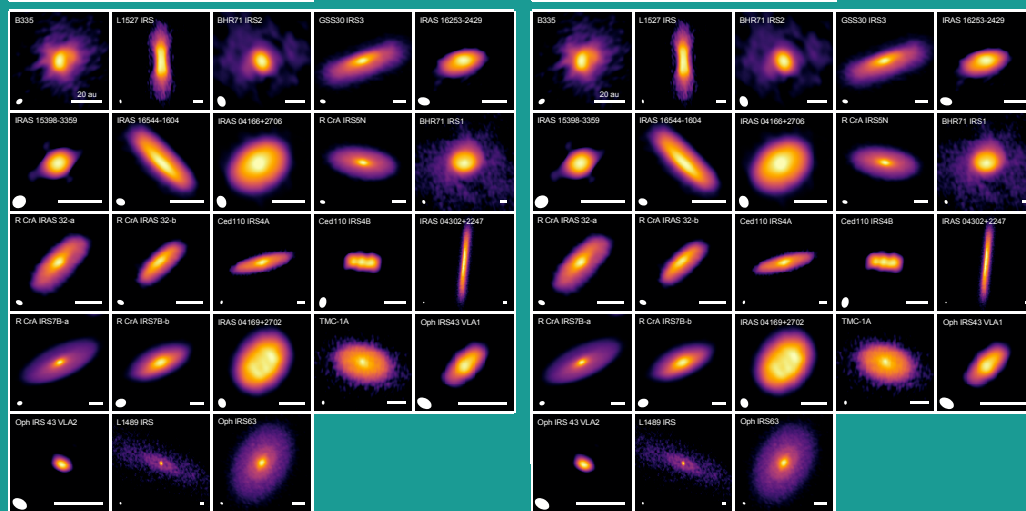
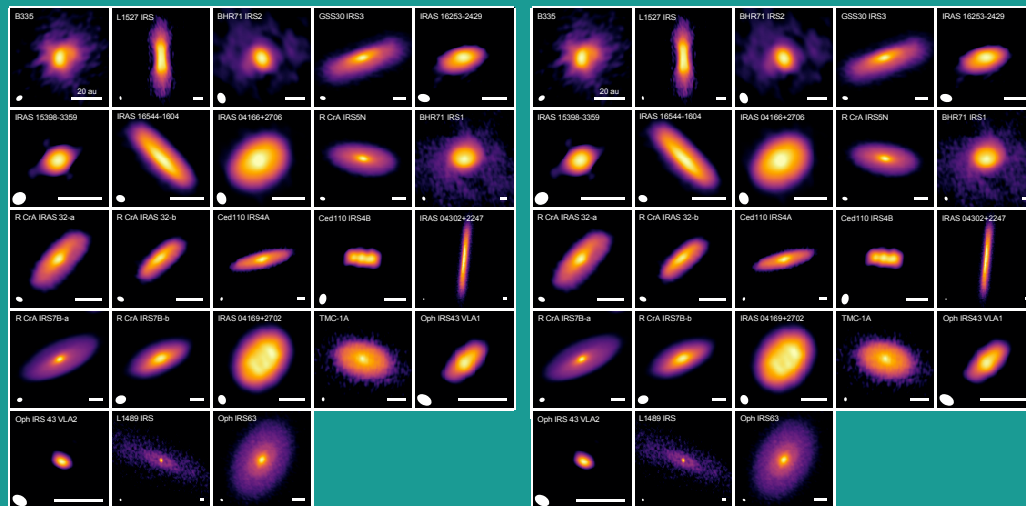


$\geq 4.8x$  (for 2x BW correlation)  
increase in continuum imaging  
speed

# CONTINUUM

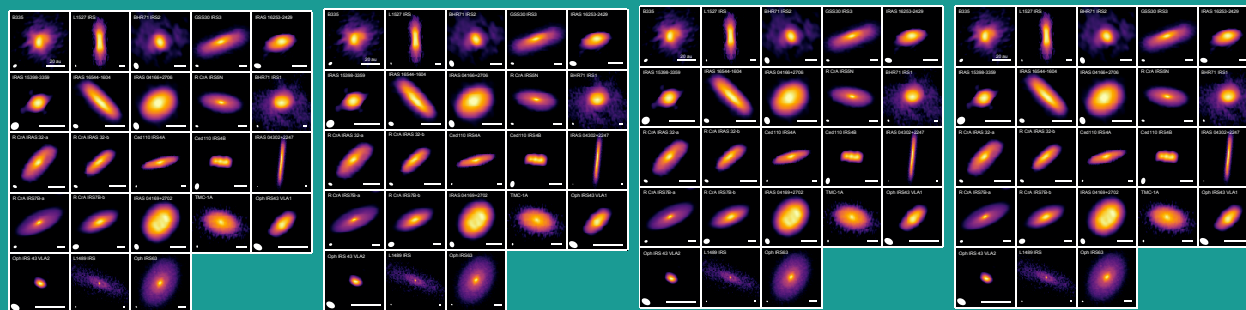
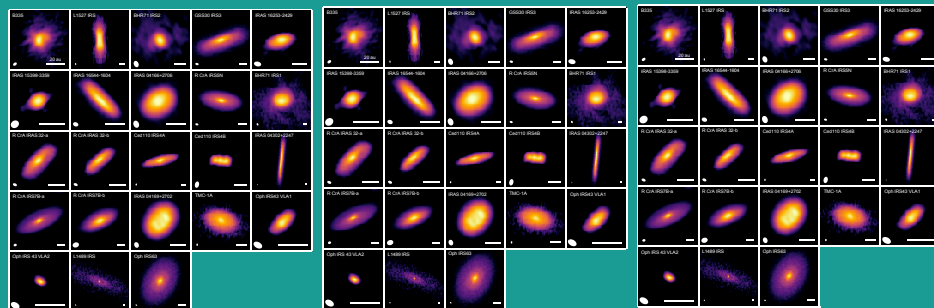
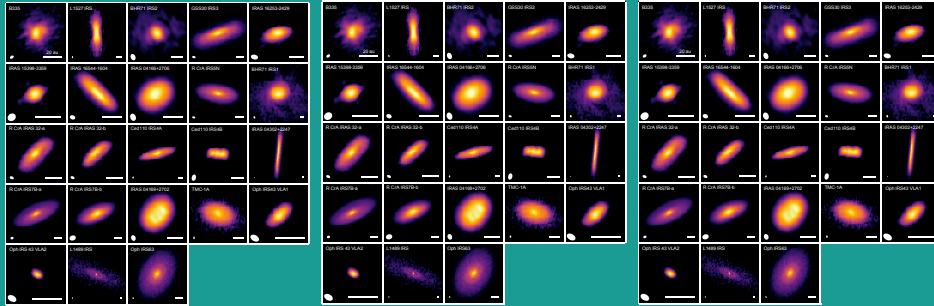
*Are dust substructures common?*

$\geq 4.8\times$  (for 2x BW correlation)  
increase in continuum imaging  
speed



# CONTINUUM

*Are dust substructures common?*



$\geq 4.8x$  (for 2x BW correlation)  
increase in continuum imaging  
speed

Another 2x increase for 4x BW  
correlation

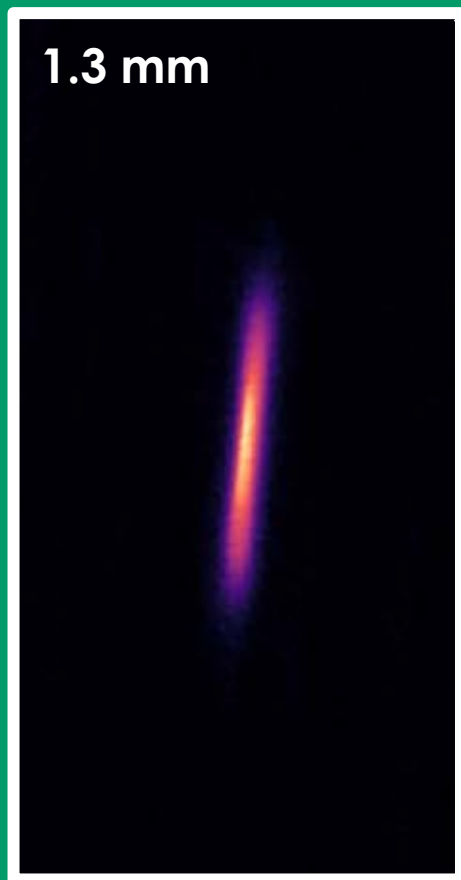


# CONTINUUM

*Disk structure*

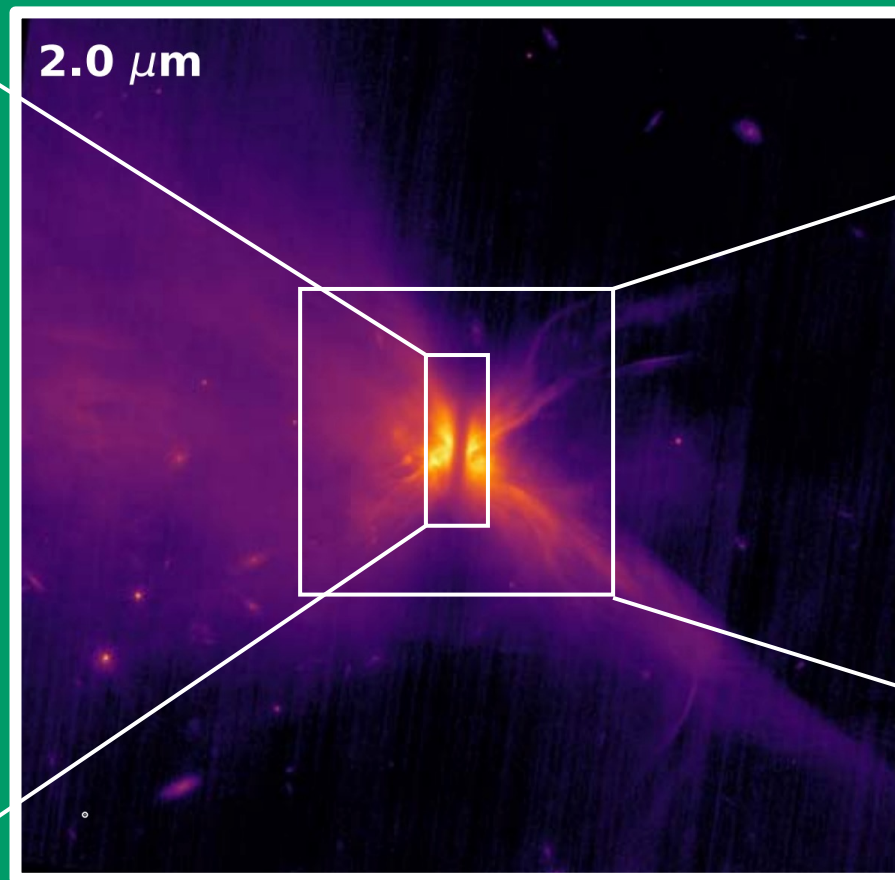
Asymmetry in scattered light  
suggest tilted inner disk

**ALMA:** thermal emission

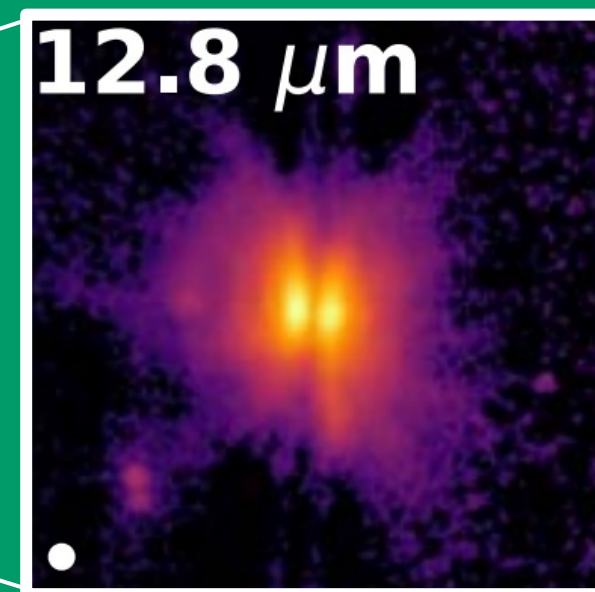


eDisk: Lin et al. 2023

**JWST:** scattered light



Villenave et al. 2024



# CONTINUUM

*Dust composition*

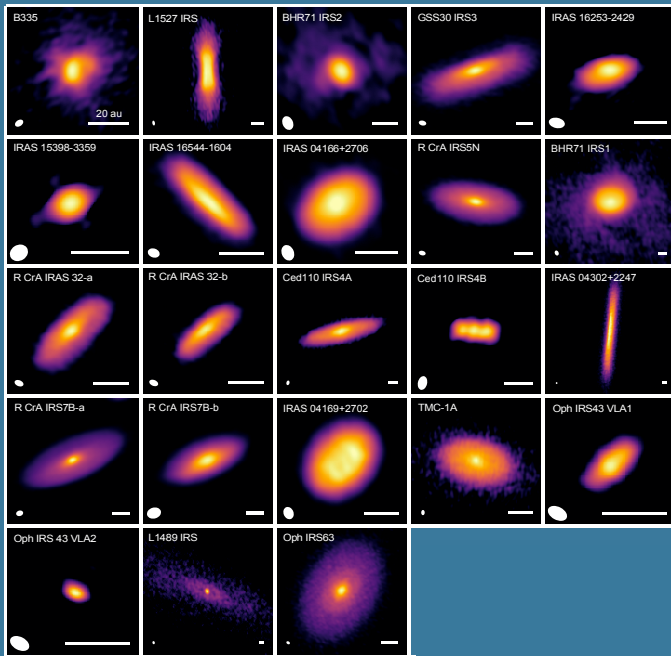
JWST MIRI spectrum can be decomposed into contributions from different minerals

# CONTINUUM

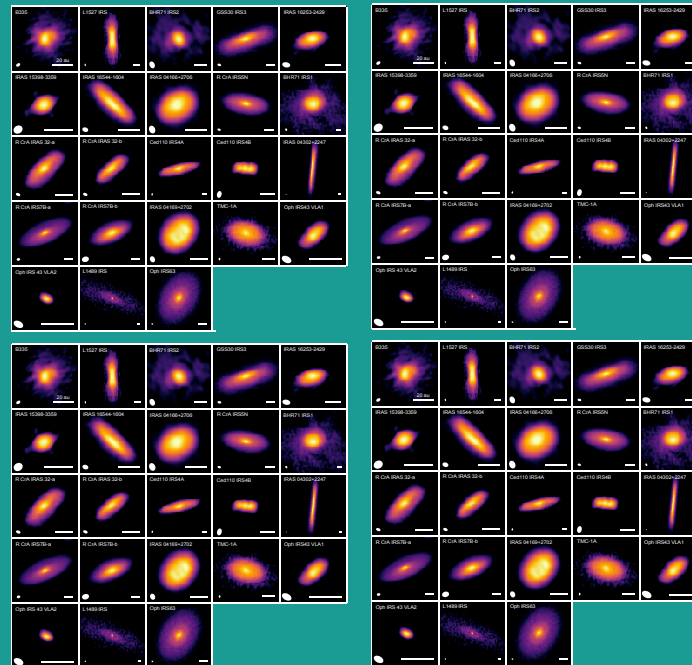
Dust in young disks

ALMA

Substructures not common  
in young disks



Study much larger disk  
sample



ALMA WSU

Complementary info on  
structure and composition

JWST

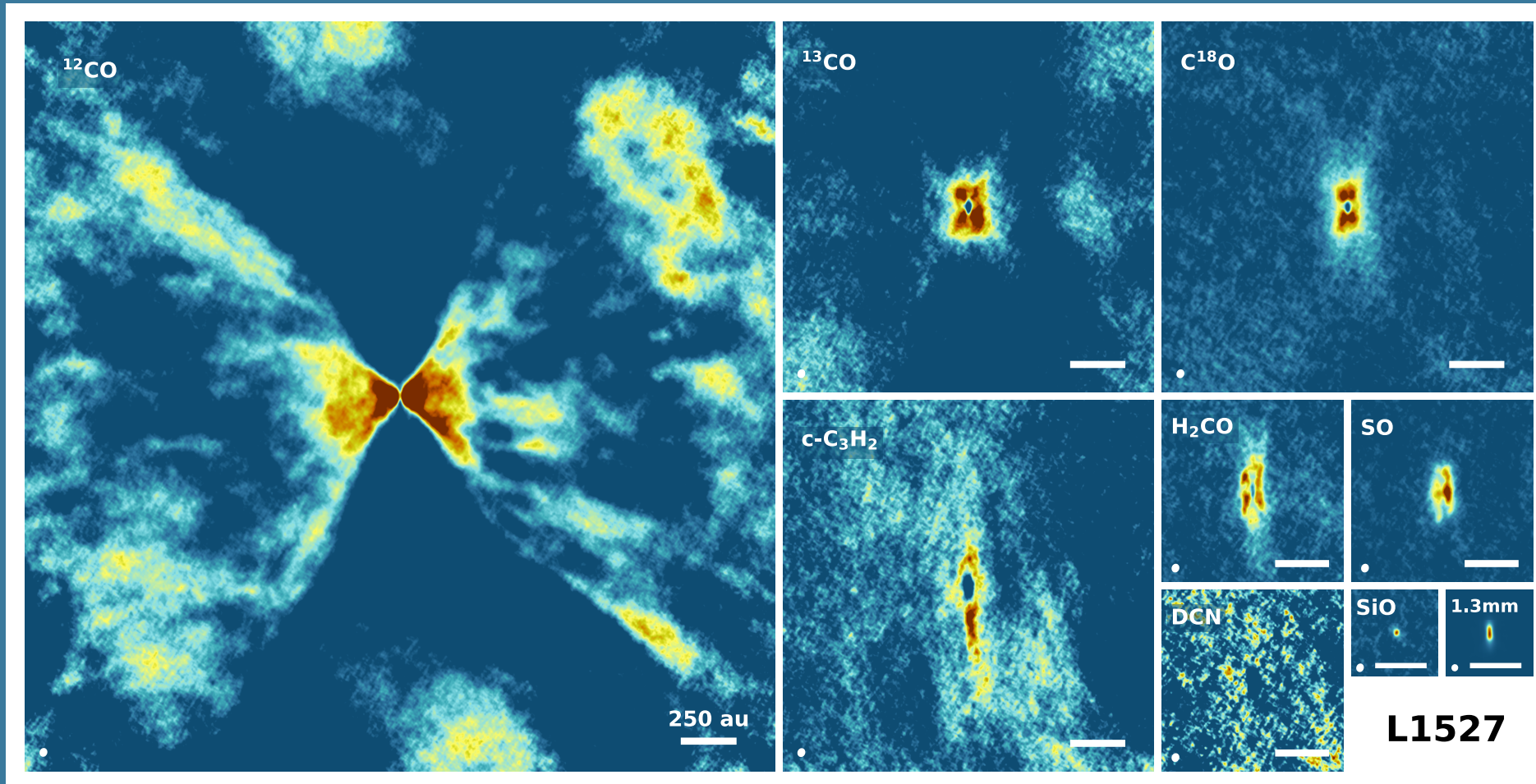
# MOLECULAR LINES

Physical and chemical structure of young disks

ALMA

ALMA WSU

JWST



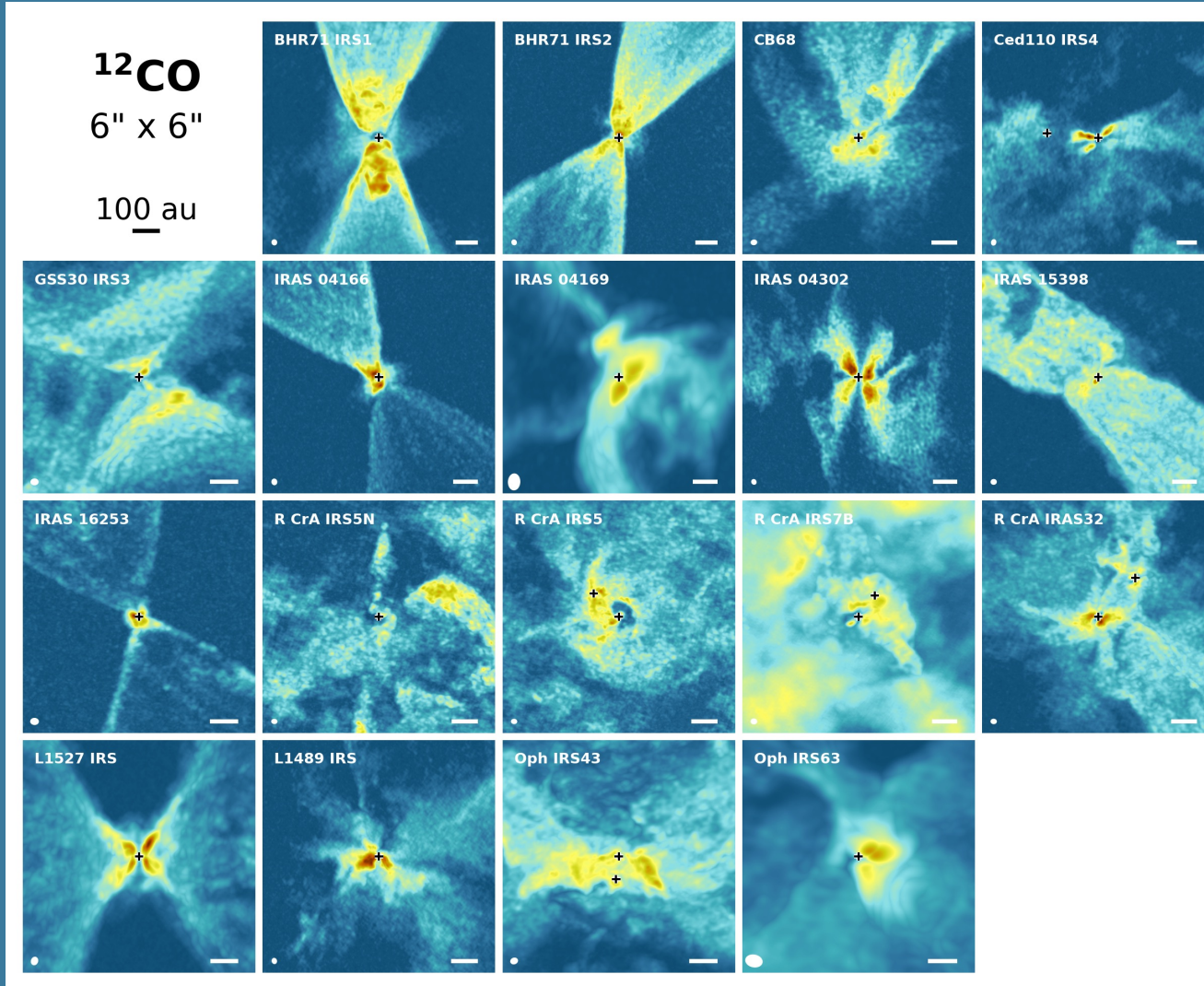
eDisk: van 't Hoff et al. 2023



# MOLECULAR LINES

Physical and chemical structure of young disks

$^{12}\text{CO}$  mainly traces outflows

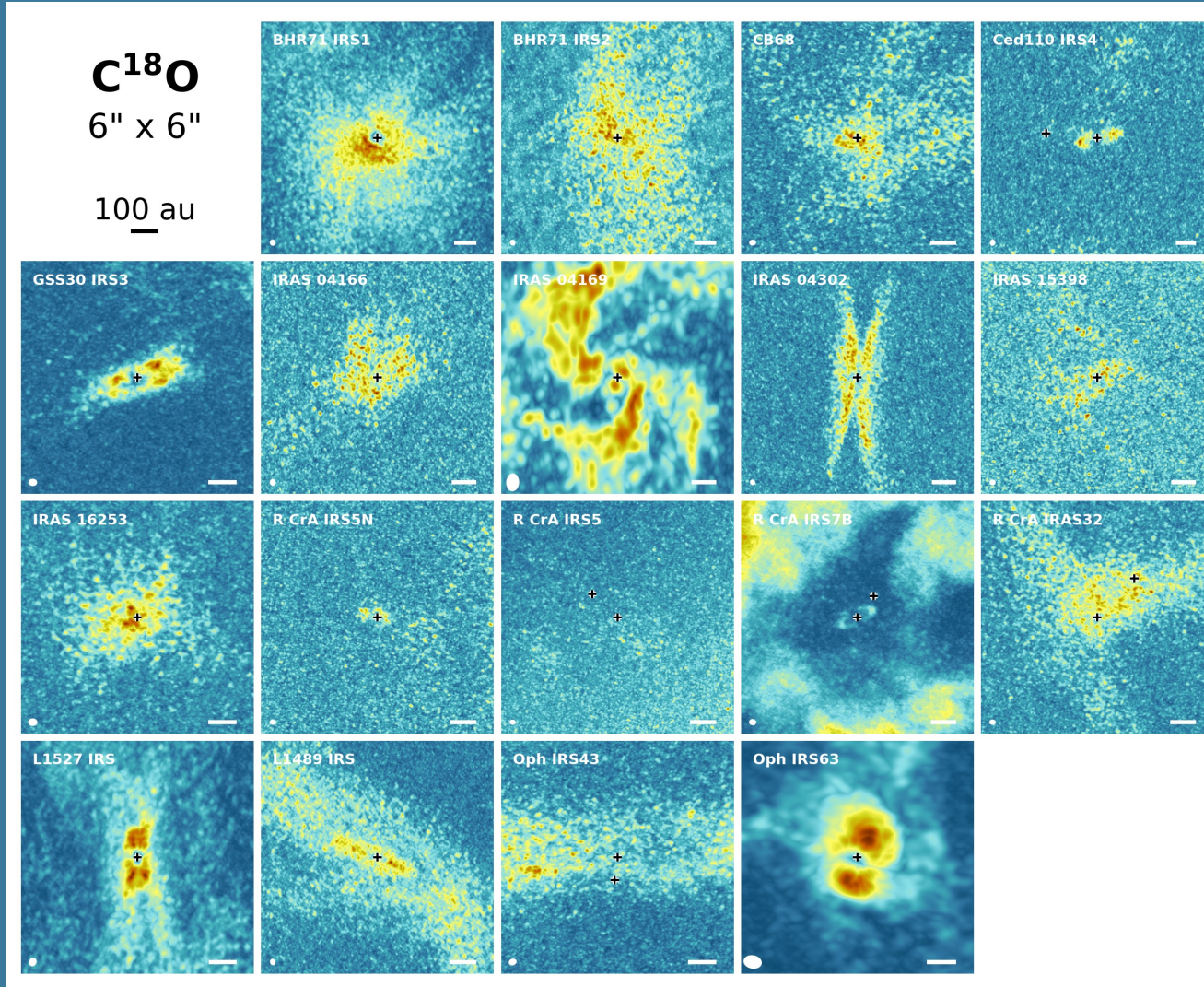


eDisk: Sharma et al. subm



# MOLECULAR LINES

Physical and chemical structure of young disks



C<sup>18</sup>O mainly traces disk  
(and some envelope)

eDisk: Sharma et al. subm

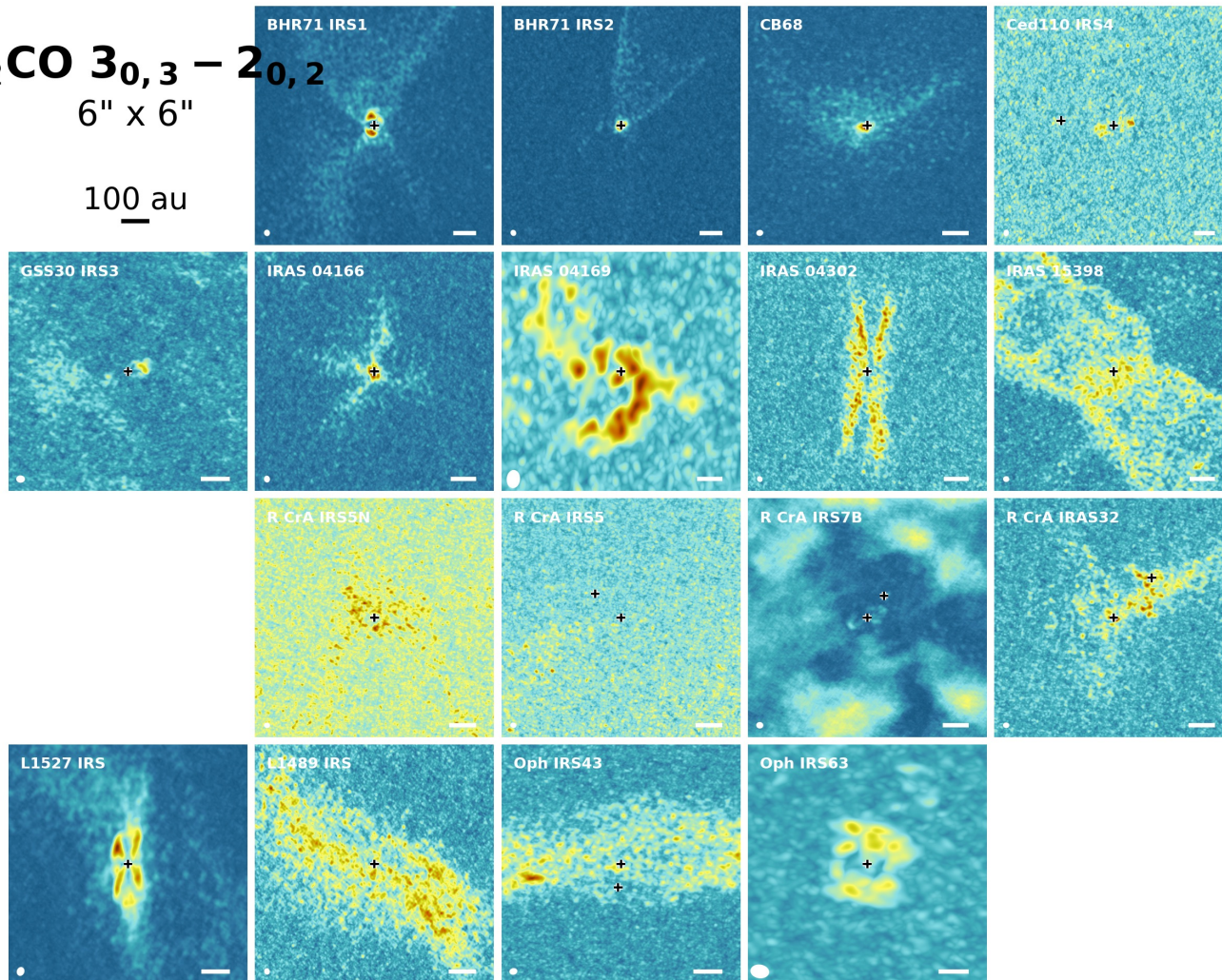


# MOLECULAR LINES

Physical and chemical structure of young disks

$\text{H}_2\text{CO } 3_{0,3} - 2_{0,2}$   
6" x 6"

100 au



$\text{H}_2\text{CO}$  can trace different components

eDisk: Sharma et al. subm



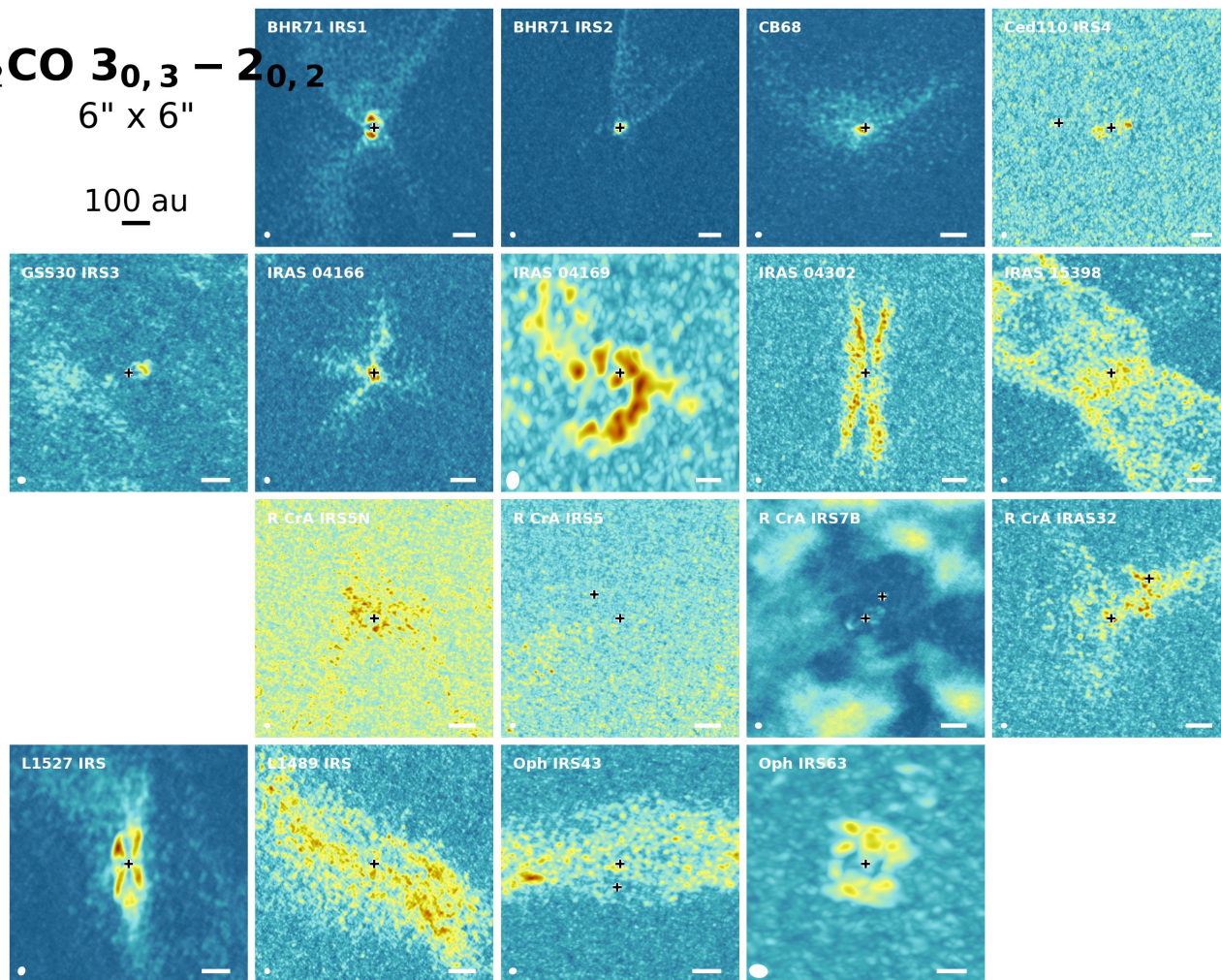
# MOLECULAR LINES

Physical and chemical structure of young disks

**$\text{H}_2\text{CO } 3_{0,3} - 2_{0,2}$**

6" x 6"

100 au



Up to a factor  $\sim\sqrt{2}$  to  $\sim\sqrt{3}$  deeper

eDisk: Sharma et al. subm



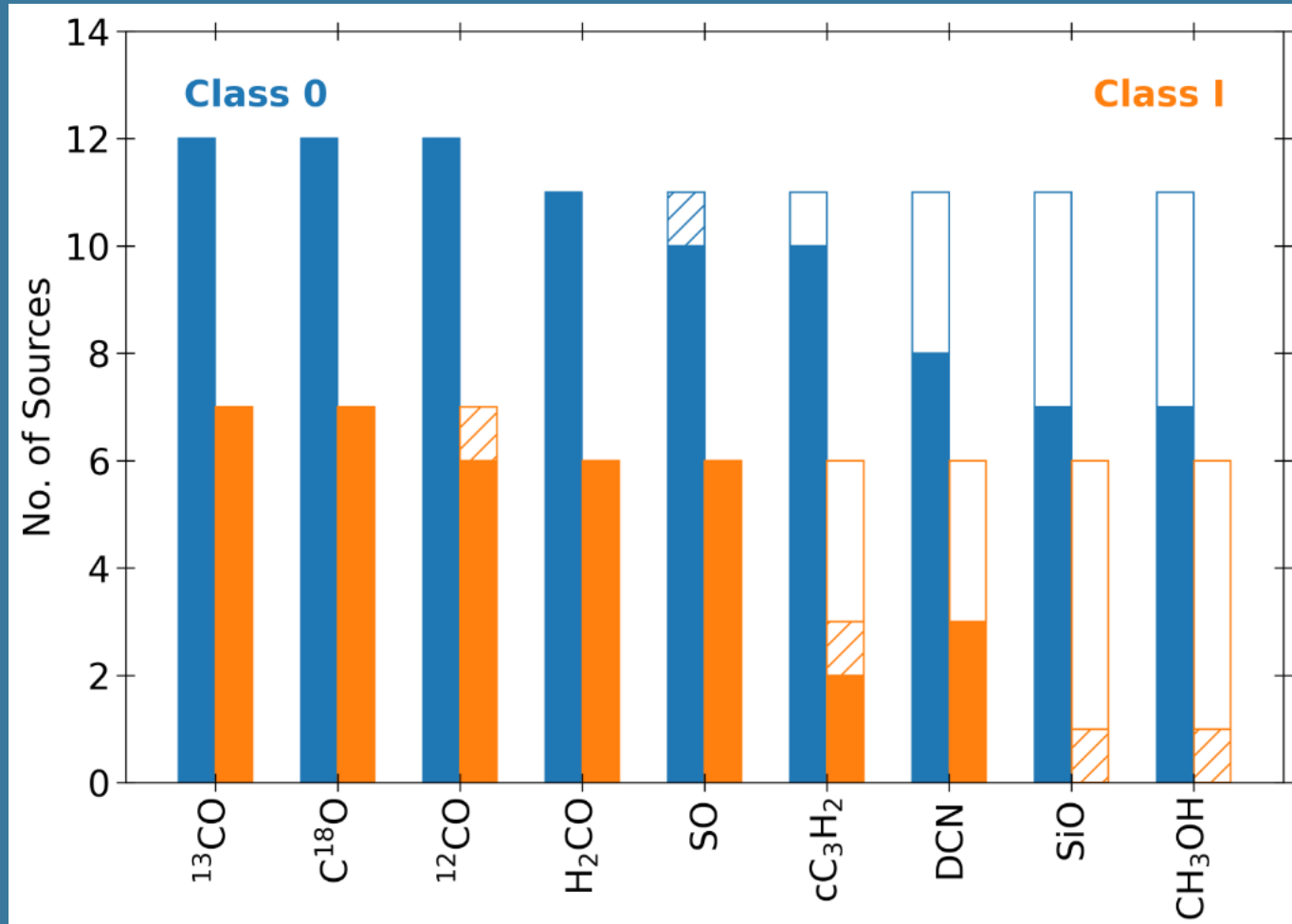
# MOLECULAR LINES

Physical and chemical structure of young disks

ALMA

ALMA WSU

JWST



eDisk: Sharma et al. subm

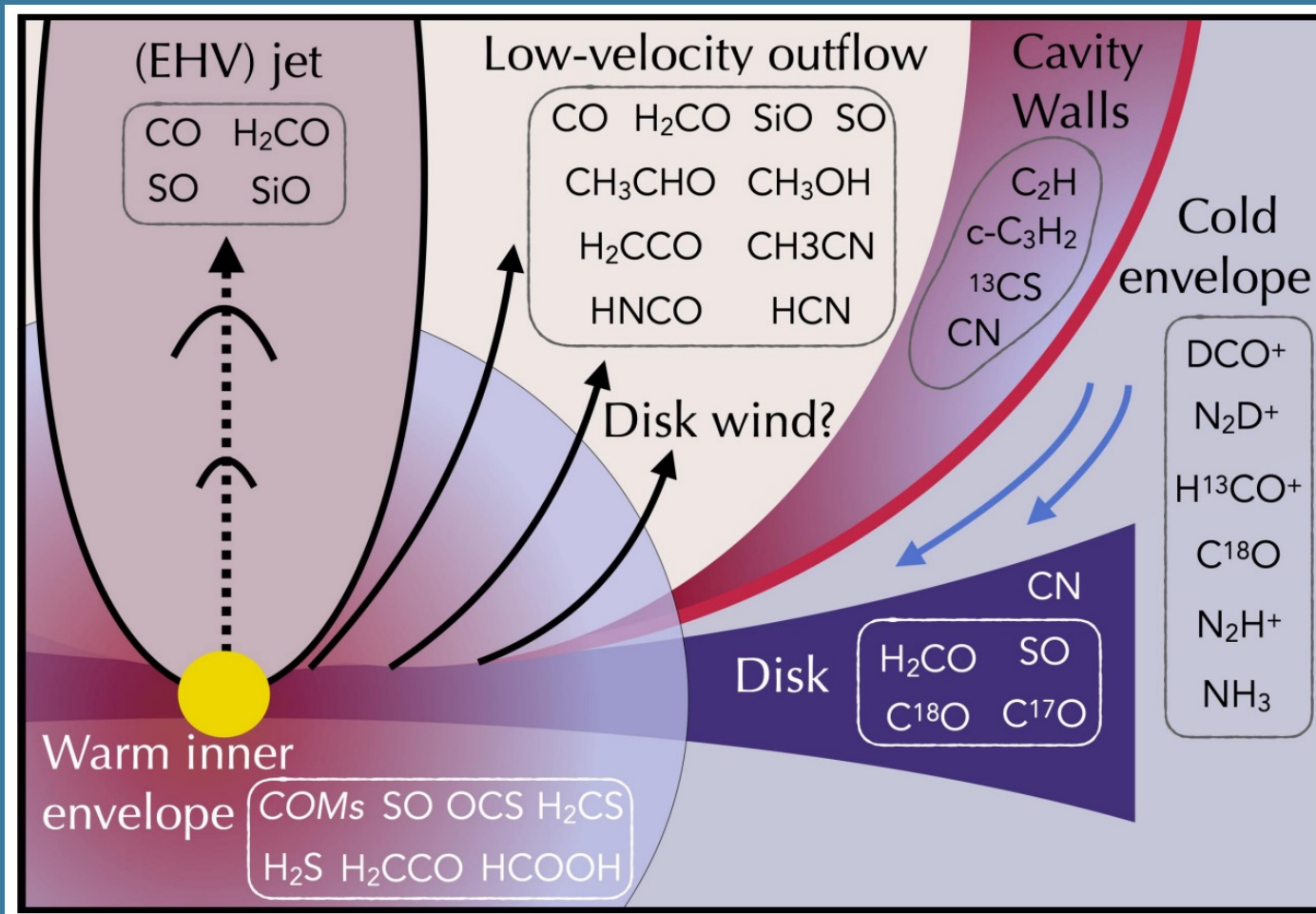
# MOLECULAR LINES

Physical and chemical structure of young disks

ALMA

ALMA WSU

JWST

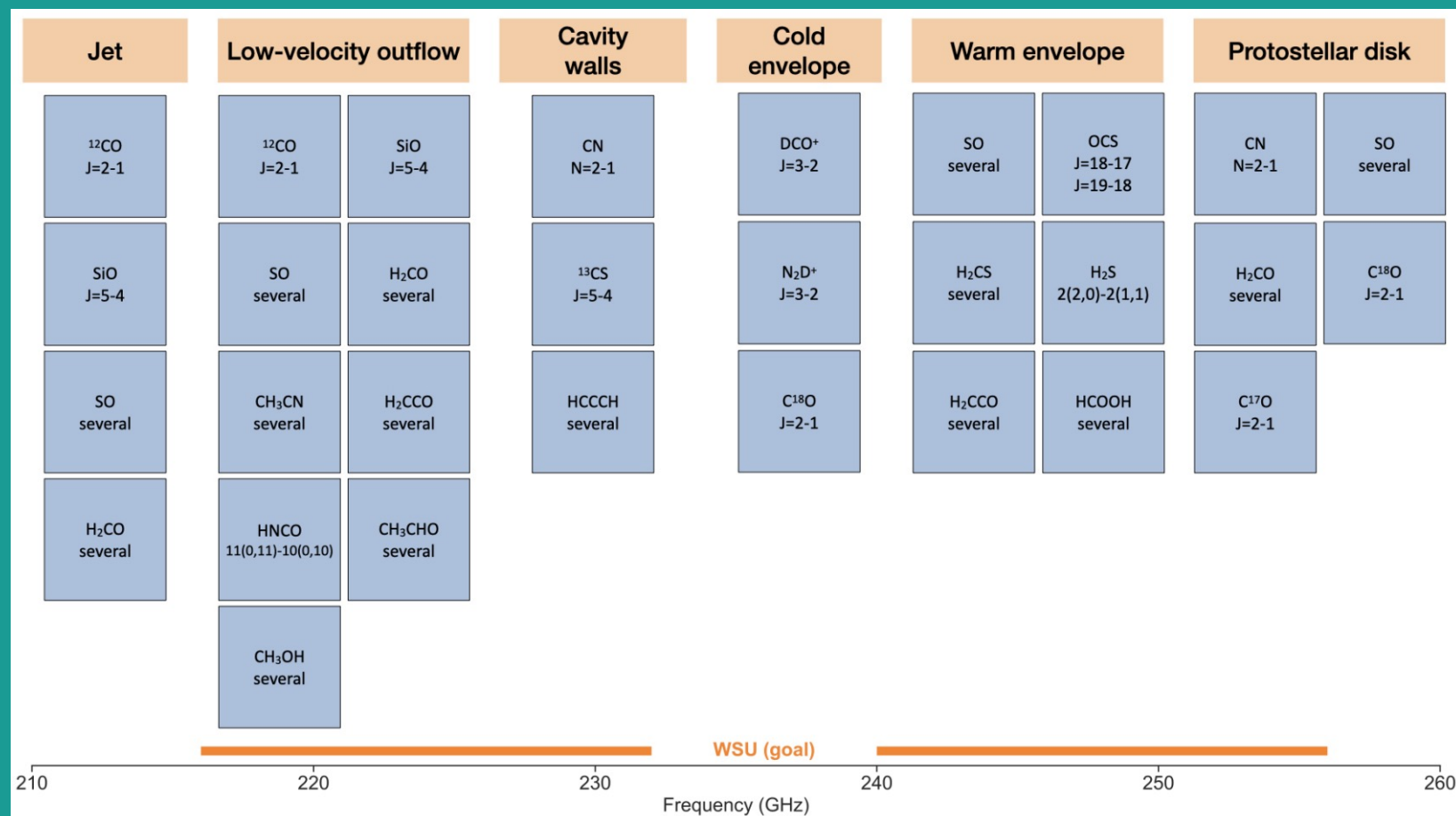


6 different programs:  
27 species  
(incl. isotopologues)

Tychoniec et al. 2021

# MOLECULAR LINES

Physical and chemical structure of young disks



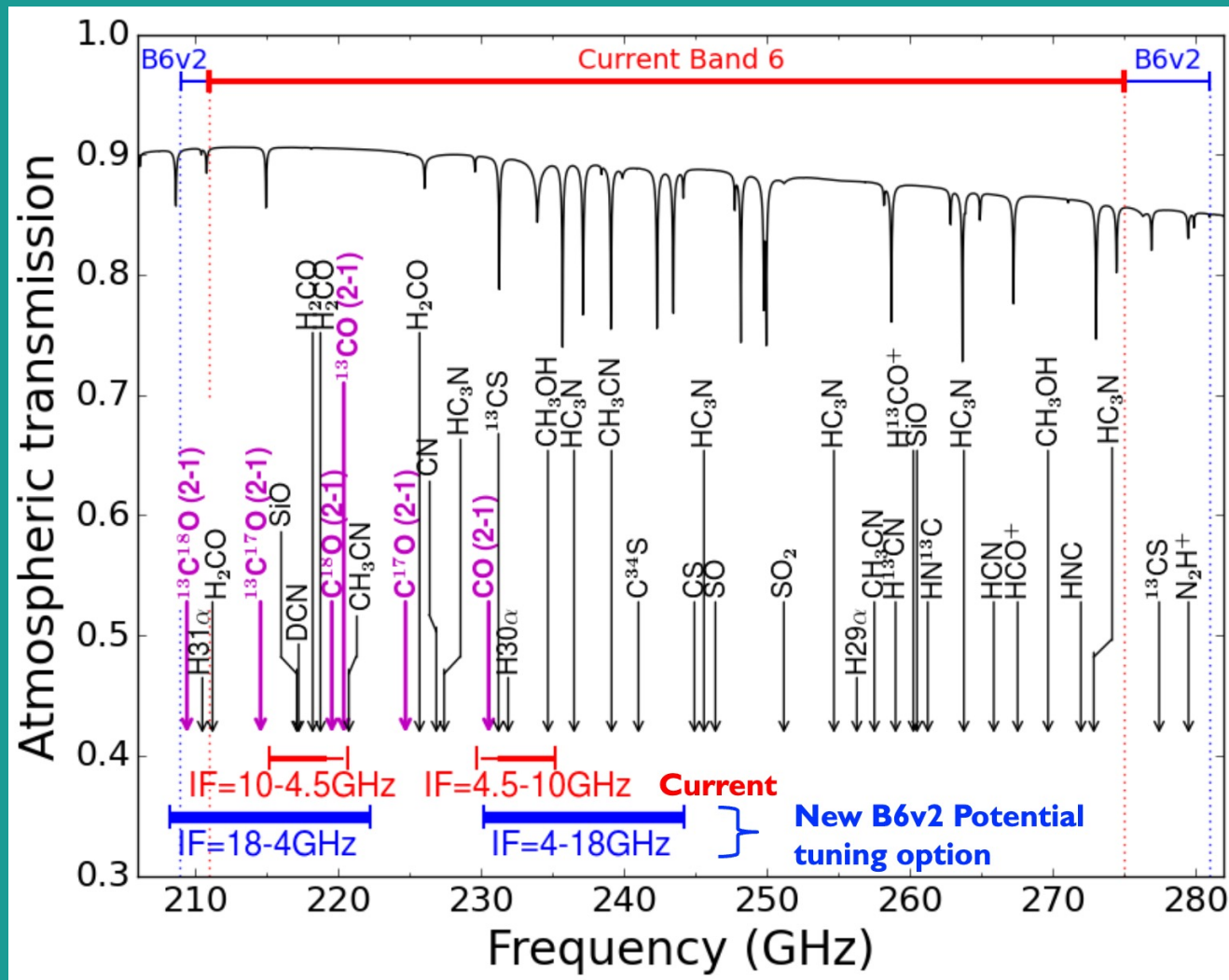
All these species  
(and more) in one  
tuning

Carpenter et al. 2022



# MOLECULAR LINES

## Physical and chemical structure of young disks



New Band 6 will cover  $^{13}\text{C}^{18}\text{O}$  and  $\text{N}_2\text{H}^+$

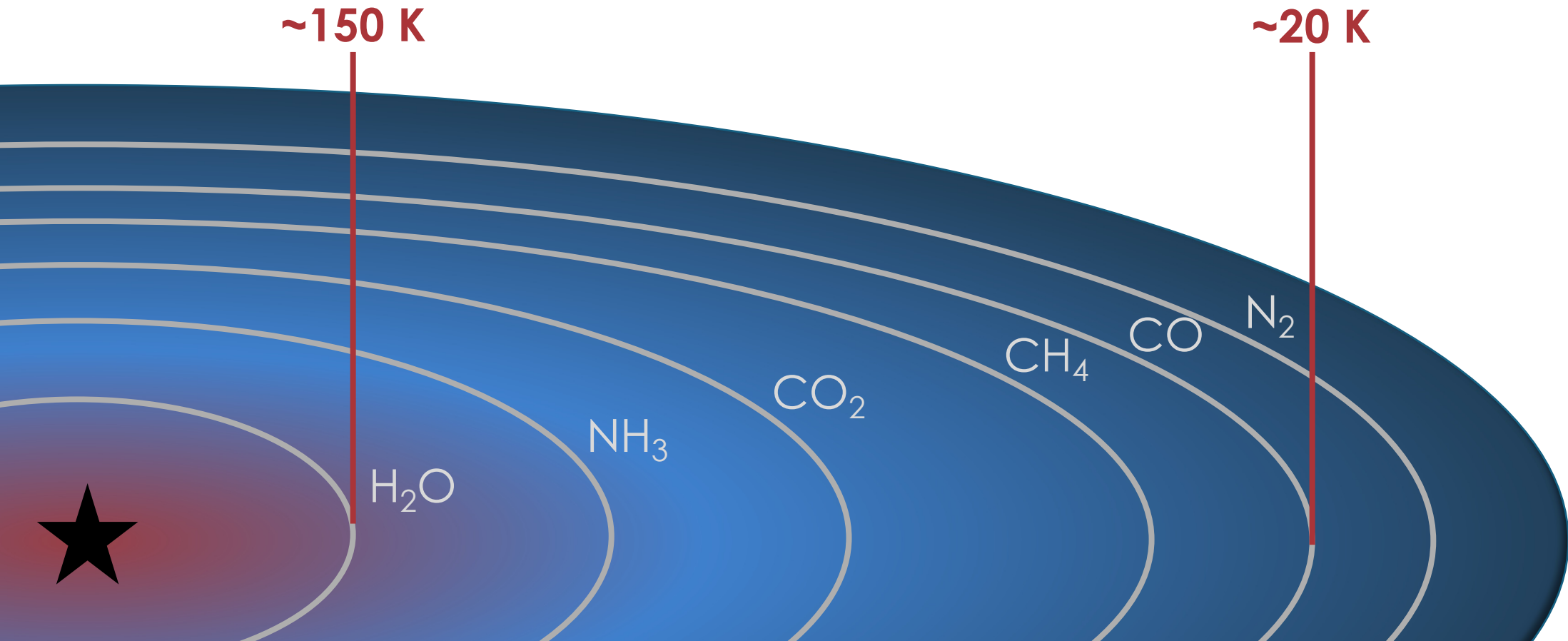
# MOLECULAR LINES

Temperature structure

ALMA

ALMA WSU

JWST



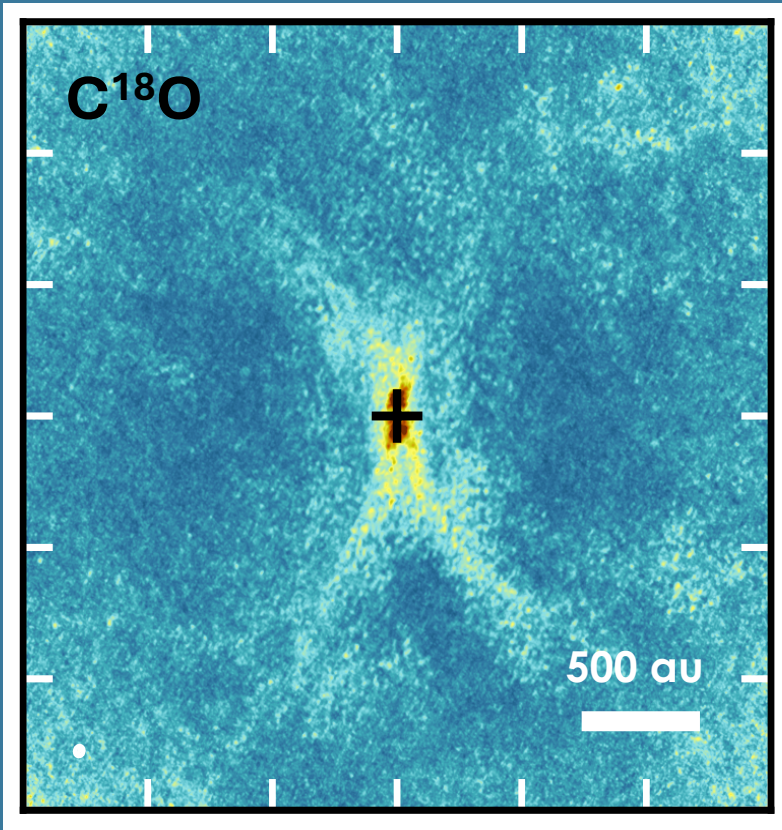
# MOLECULAR LINES

*Temperature structure*

ALMA

ALMA WSU

JWST



eDisk: van 't Hoff et al. 2023



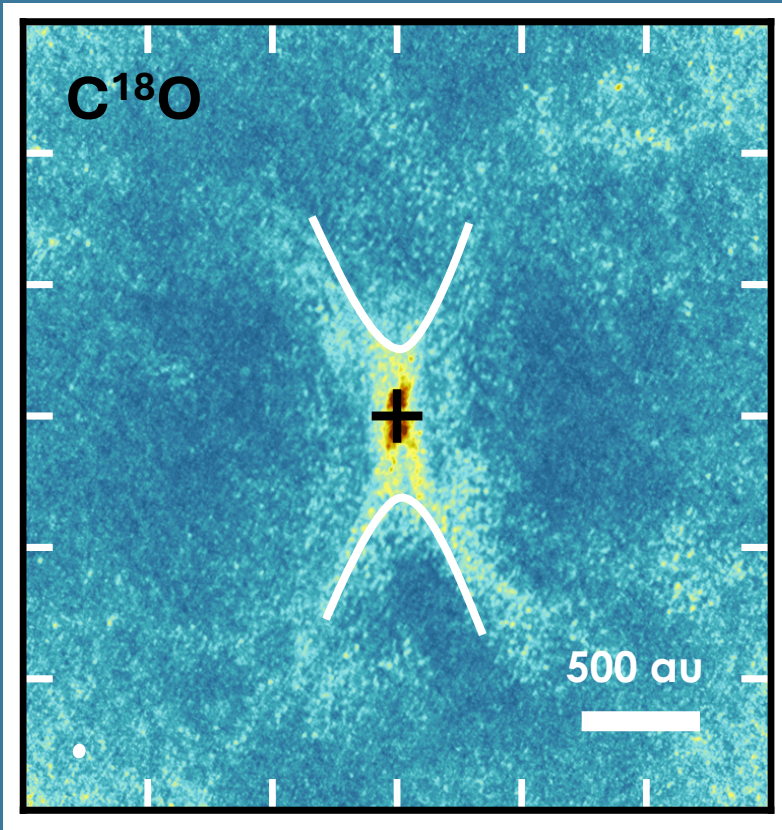
# MOLECULAR LINES

*Temperature structure*

ALMA

ALMA WSU

JWST



eDisk: van 't Hoff et al. 2023

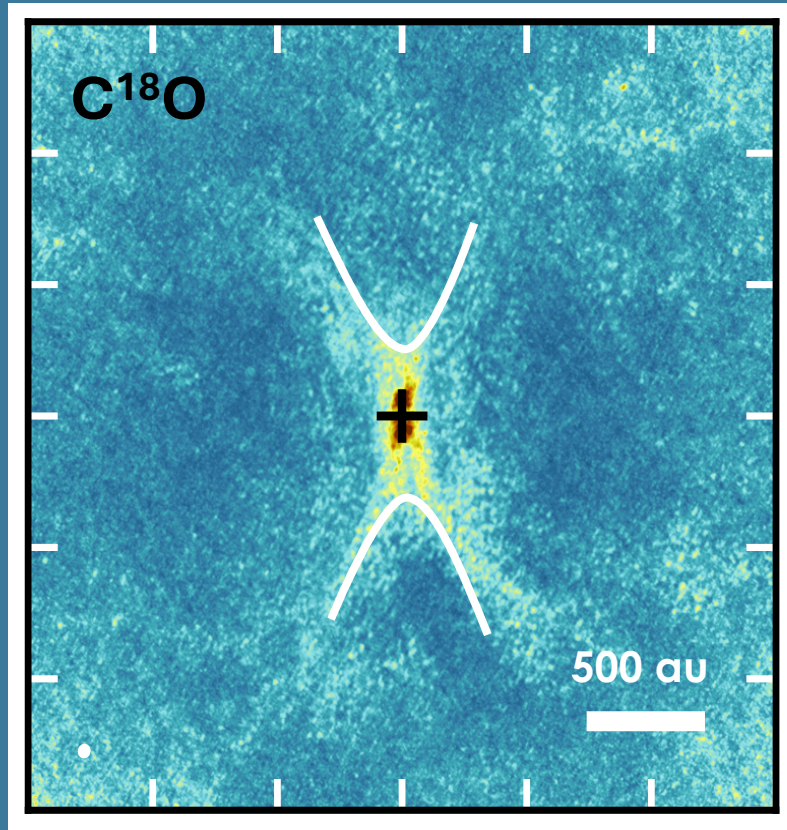
# MOLECULAR LINES

Temperature structure

ALMA

ALMA WSU

JWST



CO snowline outside the disk:  
Disk warmer than  $\sim 20$  K

See also van 't Hoff et al. 2018, 2020

eDisk: van 't Hoff et al. 2023

# MOLECULAR LINES

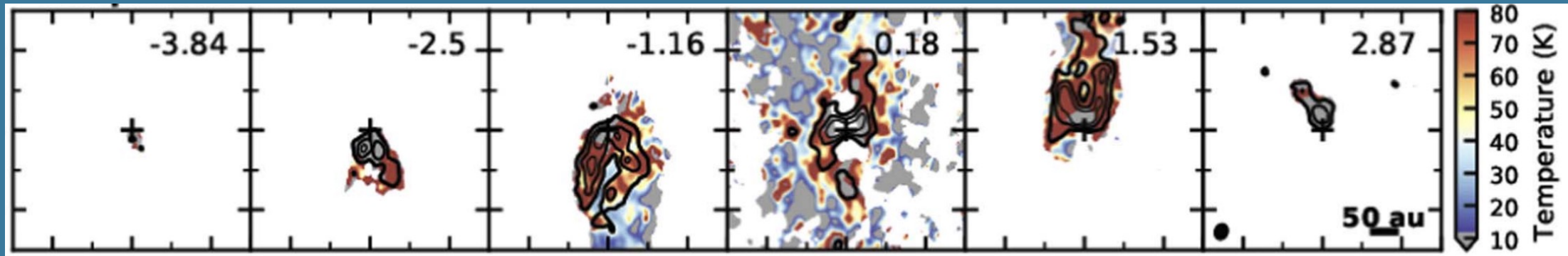
*Temperature structure*

ALMA

ALMA WSU

JWST

Temperature in velocity channels from the ratio of two  $\text{H}_2\text{CO}$  transitions



eDisk: van 't Hoff et al. 2023



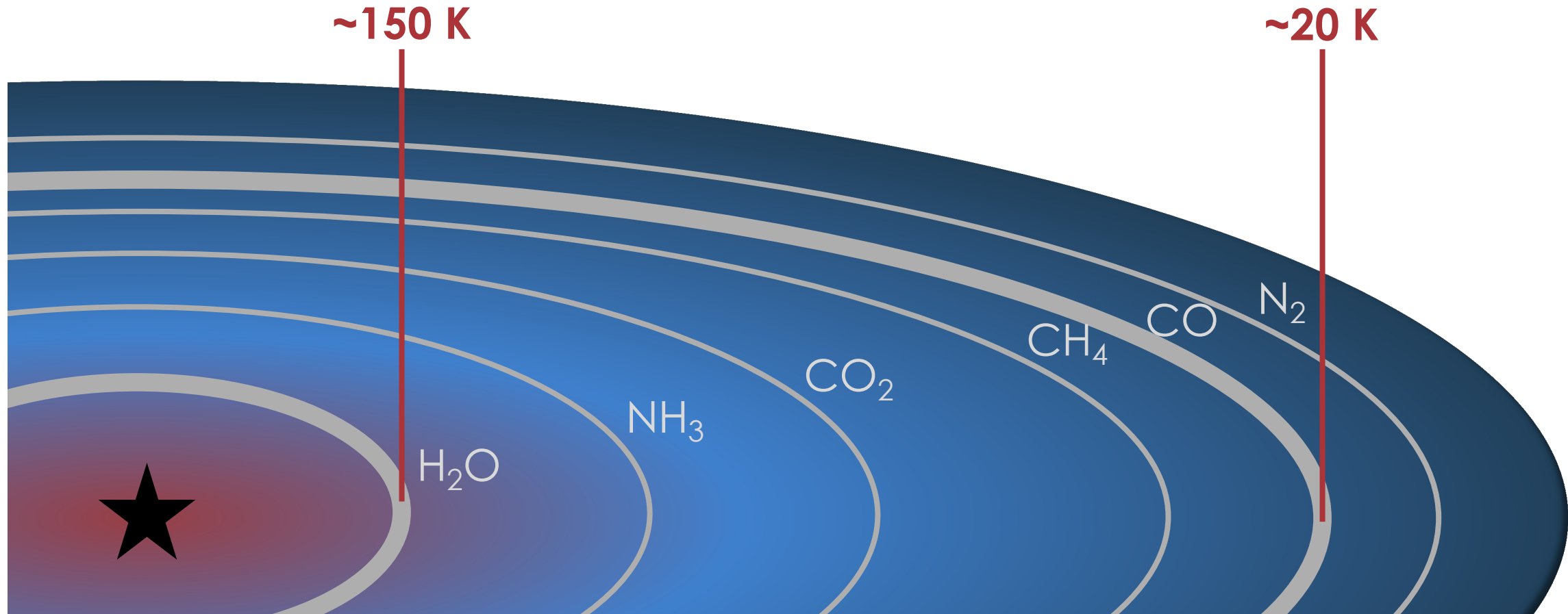
# MOLECULAR LINES

*Temperature structure*

- Increased imaging speed ( $\sim 2.2\times$ ) will make it easier to do
  - Deeper observations
  - Higher resolution observations
  - Larger samples
  - Observations of different transitions from a molecule in different Bands
- Increased bandwidth will allow more temperature probes to be observed simultaneously

# MOLECULAR LINES

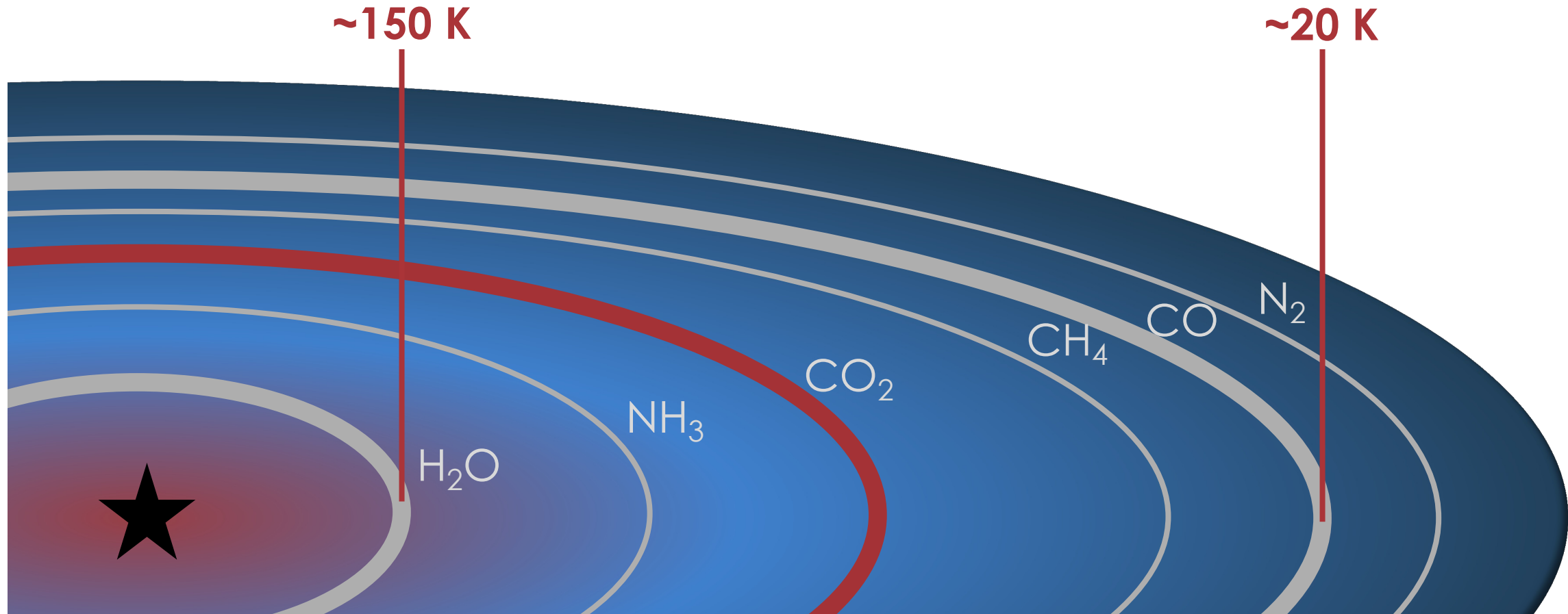
Temperature structure



# MOLECULAR LINES

Temperature structure

Kaçan et al. in prep.

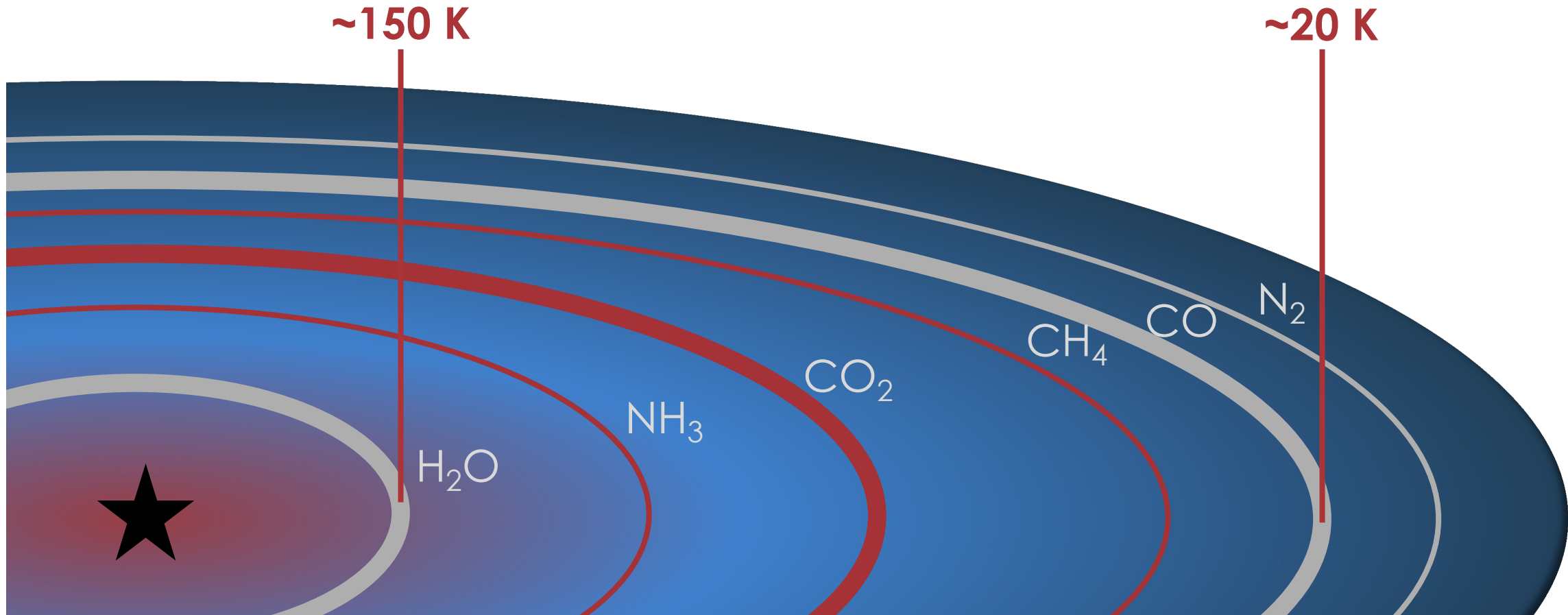




# MOLECULAR LINES

Temperature structure

Kaçan et al. in prep.

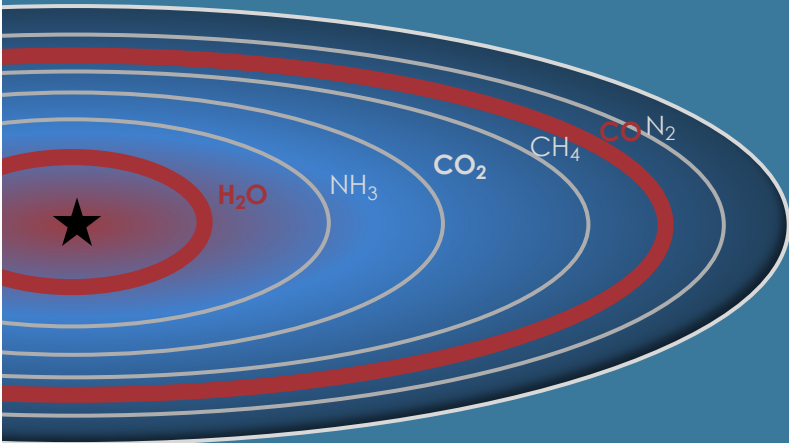


# MOLECULAR LINES

Physical and chemical structure of young disks

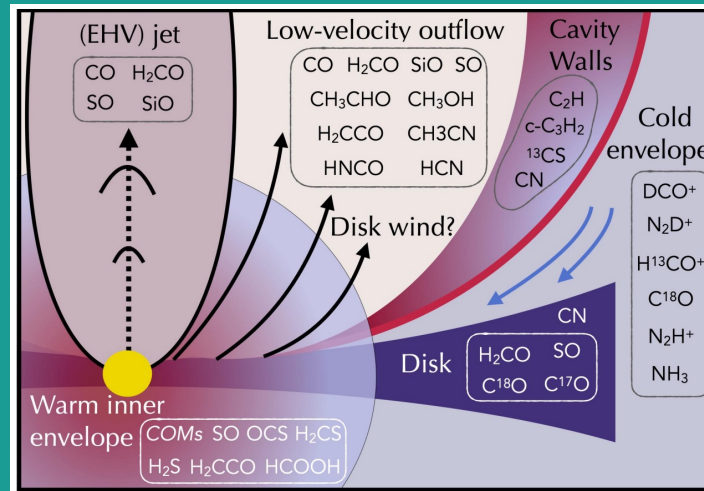
ALMA

Young disks traced by  $\text{C}^{18}\text{O}$ ;  
Too warm for CO ice



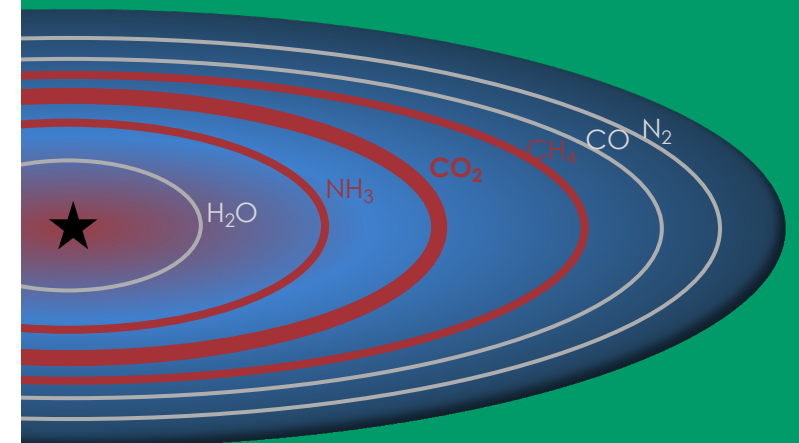
ALMA WSU

Study many tracers  
simultaneously



JWST

Complementary info on  
molecules without rotational  
transitions



# MOLECULAR LINES

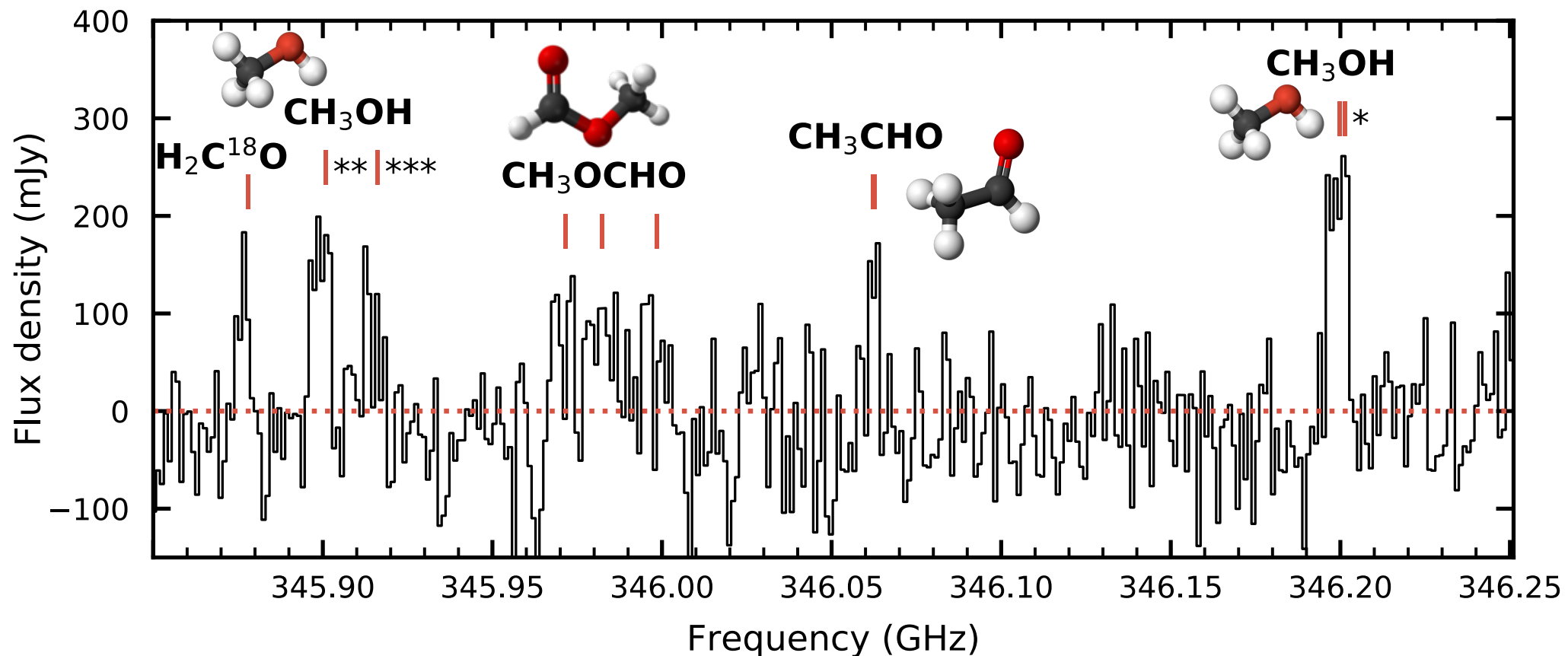
*Chemical complexity*

ALMA

ALMA WSU

JWST

V883 Ori (1 minute with ALMA)

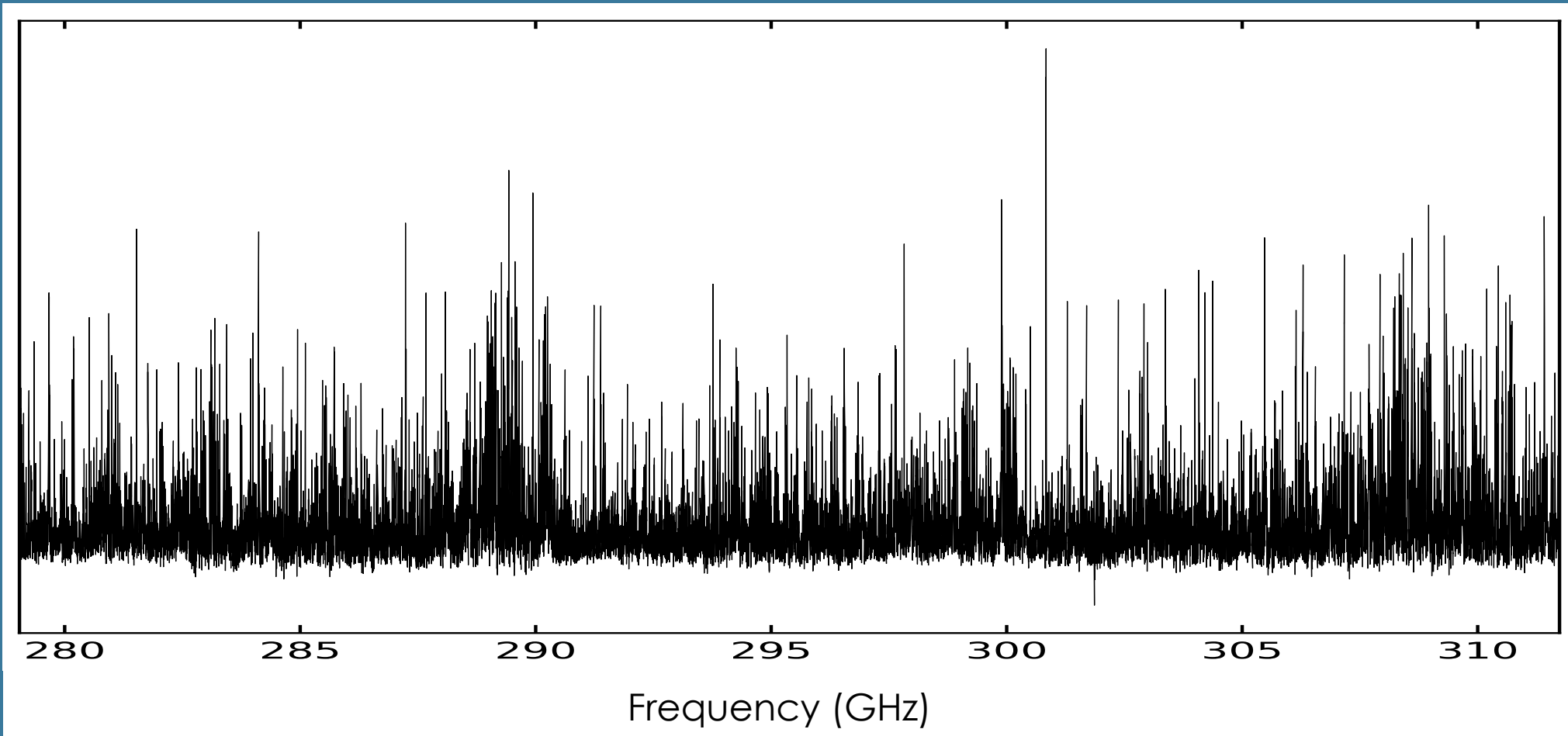


van 't Hoff et al. 2018 (see also Lee et al. 2019; Yamato et al. 2024; Jeong et al. 2024)

# MOLECULAR LINES

*Chemical complexity*

V883 Ori with COMPASS Large Program (PI: Jes Jørgensen)

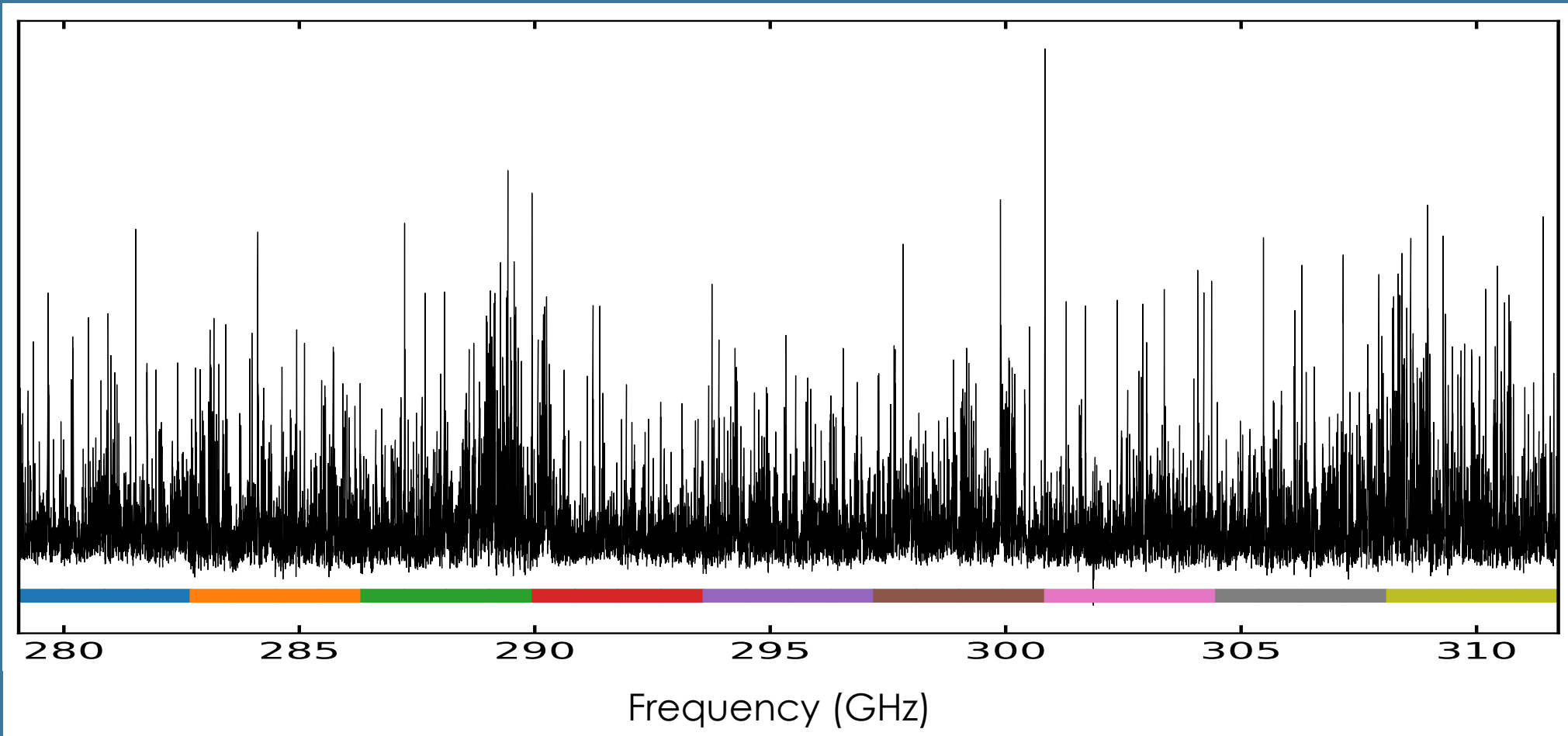




# MOLECULAR LINES

*Chemical complexity*

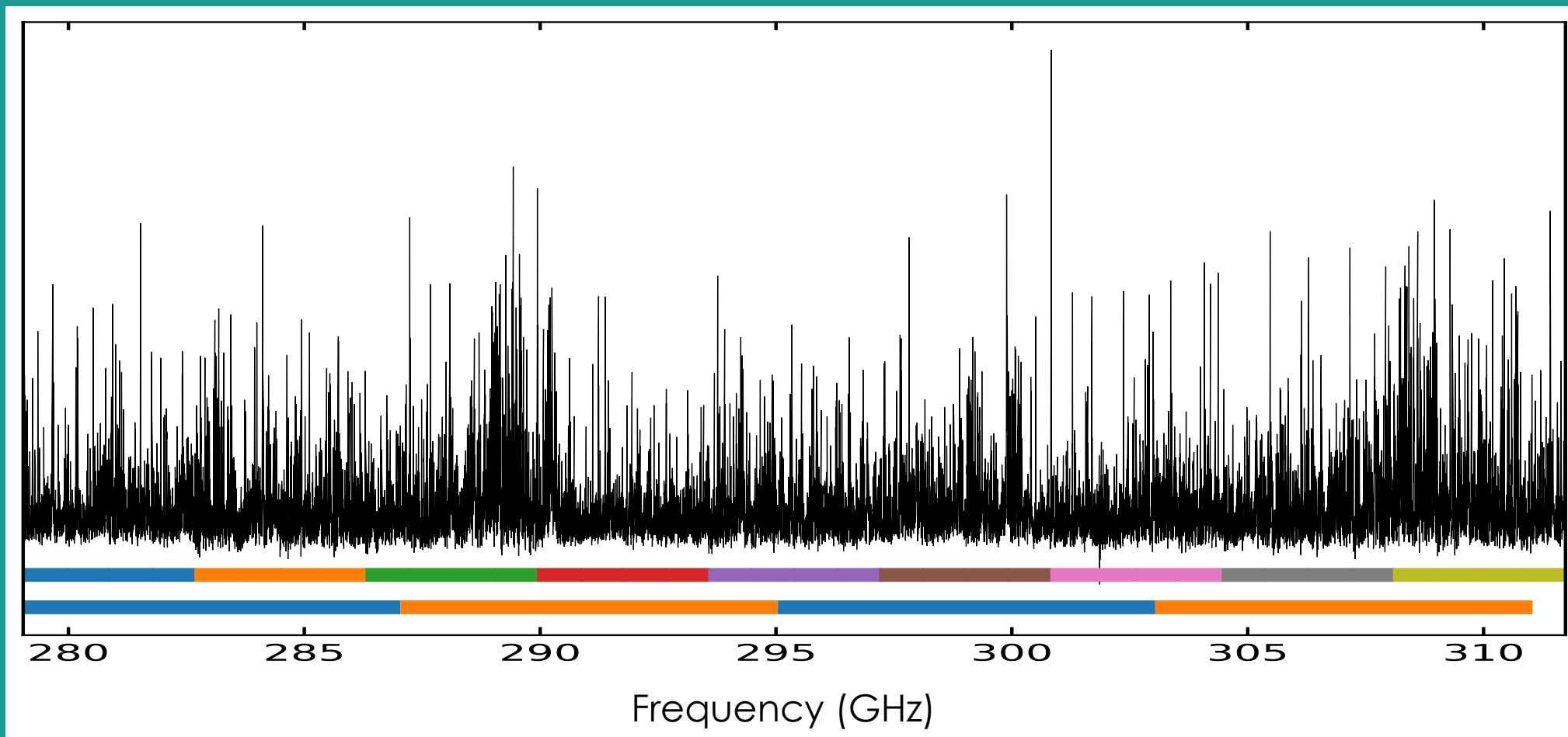
V883 Ori with COMPASS Large Program (PI: Jes Jørgensen)



# MOLECULAR LINES

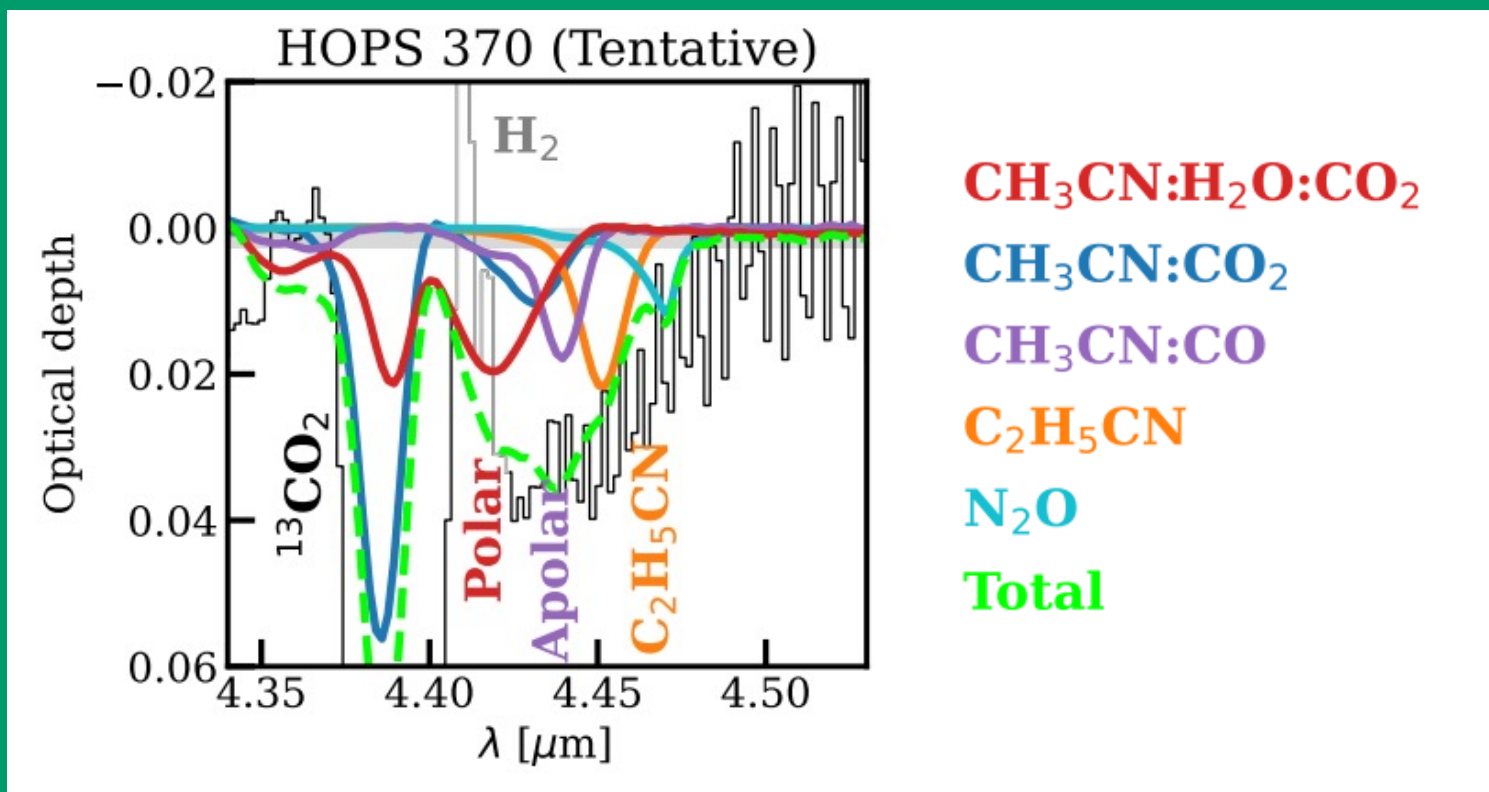
*Chemical complexity*

V883 Ori with COMPASS Large Program (PI: Jes Jørgensen)



# MOLECULAR LINES

*Chemical complexity*



Complementary  
COMPASS JWST  
program to  
study ice  
composition in  
the envelope

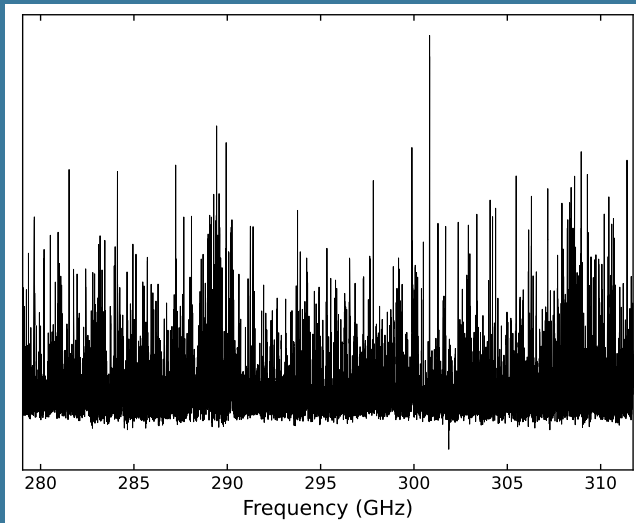
Nazari et al. 2024

# MOLECULAR LINES

*Chemical complexity in young disks*

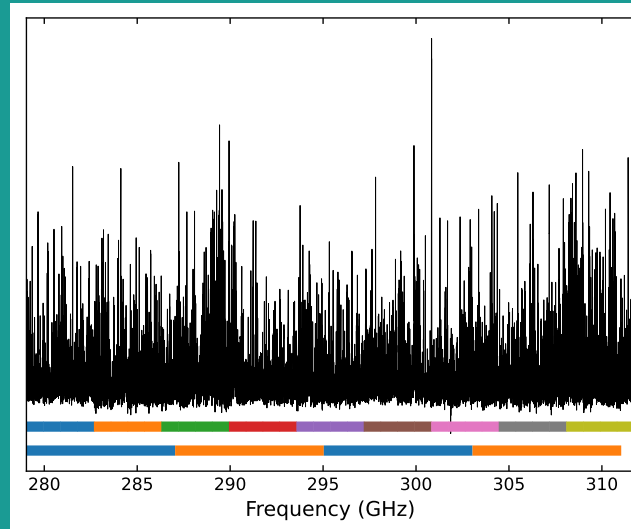
ALMA

High level of chemical complexity in young disks, but mostly frozen out



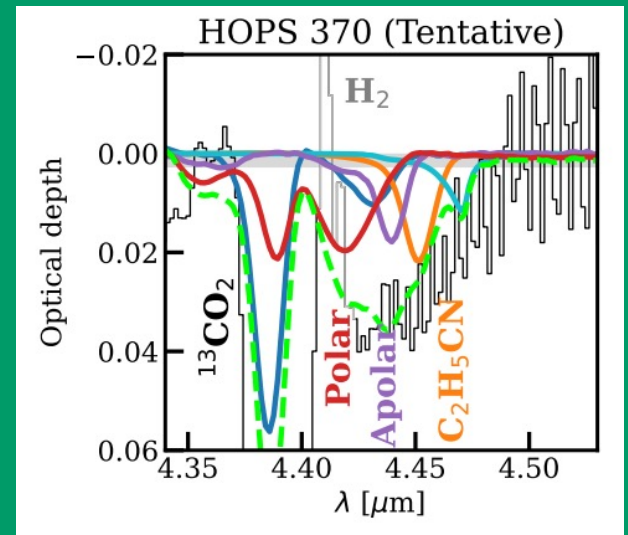
ALMA WSU

Much more efficient to study



JWST

Complementary info on chemical complexity in ice





# YOUNG EMBEDDED DISKS:

*The ALMA (WSU) and JWST era*

# WE HAVE ONLY SCRATCHED THE SURFACE!