OPENING A NEW WINDOW ON OUR ORIGINS WITH SOFIA-HIRMES

Klaus Pontoppidan
Space Telescope Science Institute
On behalf of the HIRMES team

SOFIA teletalk 2019

11 December 2019

The HIRMES team

HIRMES Science Working Group			
Investigator	Institution	Investigator	Institution
Arendt, Richard*	UMBC	Pontoppidan, Klaus	STScI
Bergin, Edwin	U. Michigan	Richards, Samuel*	USRA
Bjoraker, Gordon	GSFC	Roberge, Aki	GSFC
Chen, Christine*	STScI	Rostem, Karwan*	UMBC
Kutyrev, Alexander	U. Maryland	Stacey, Gordon	Cornell U.
Melnick, Gary	Harvard U.	Tolls, Volker*	Harvard U.
Milam, Stefanie	GSFC	Su, Kate*	U. Arizona
Moseley, Harvey	GSFC Emeritus	Watson, Dan	U. Rochester
Neufeld, David	Johns Hopkins U.	Wollack, Edward	GSFC
Nikola, Thomas*	Cornell U.		

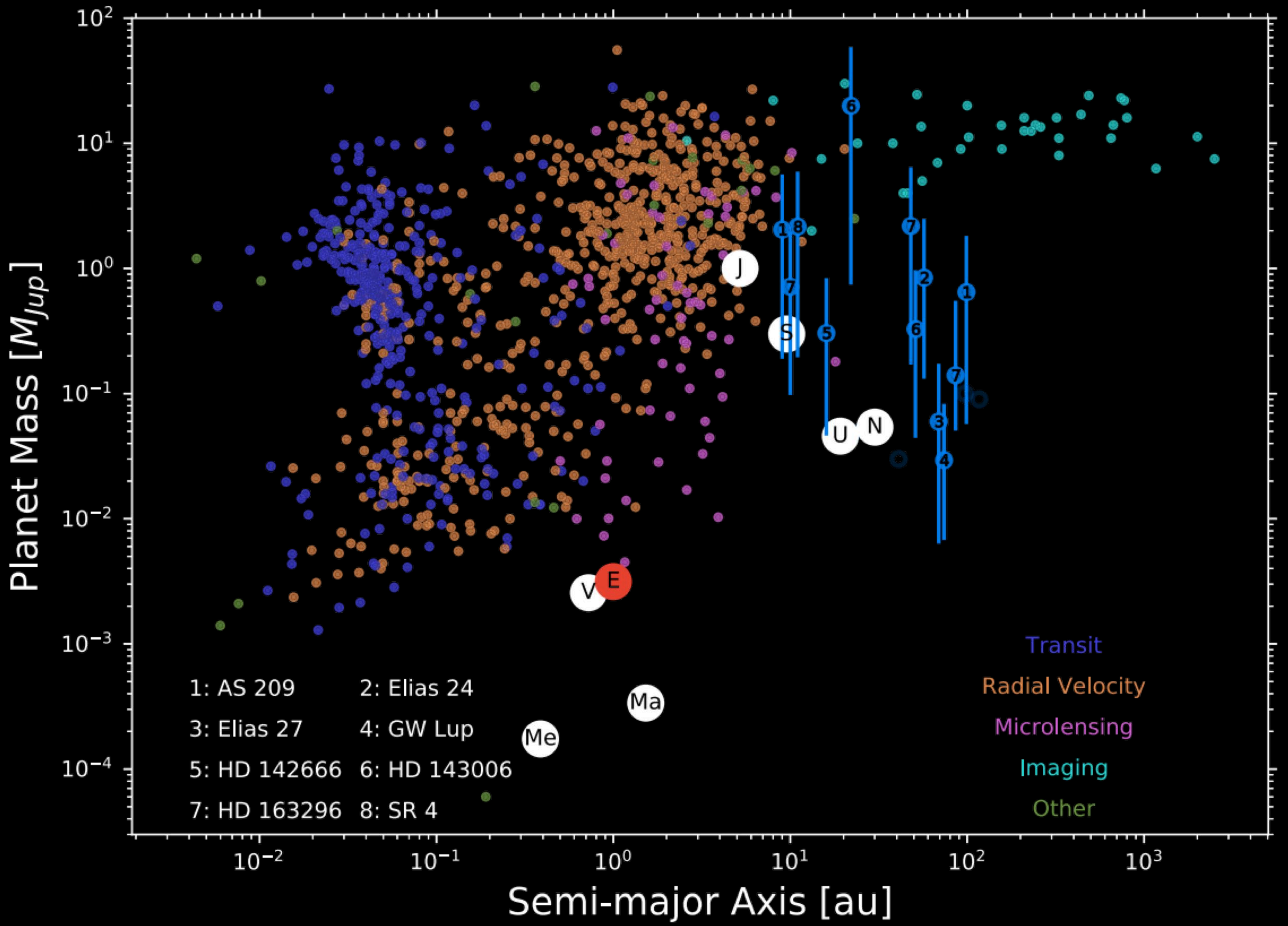
* Investigator added via Legacy Science Investigation proposal

HIRMES talk schedule

FY20 HIRMES Tele-Talks		
Instrument Overview	4 December	Matt Greenhouse
Protoplanetary Disks	11 December	Klaus Pontoppidan
Comets	15 January	Stefanie Milam
Deuterium in Giant Planets	29 January	Gordon Bjoraker
Debris Disks	5 February	Christine H. Chen

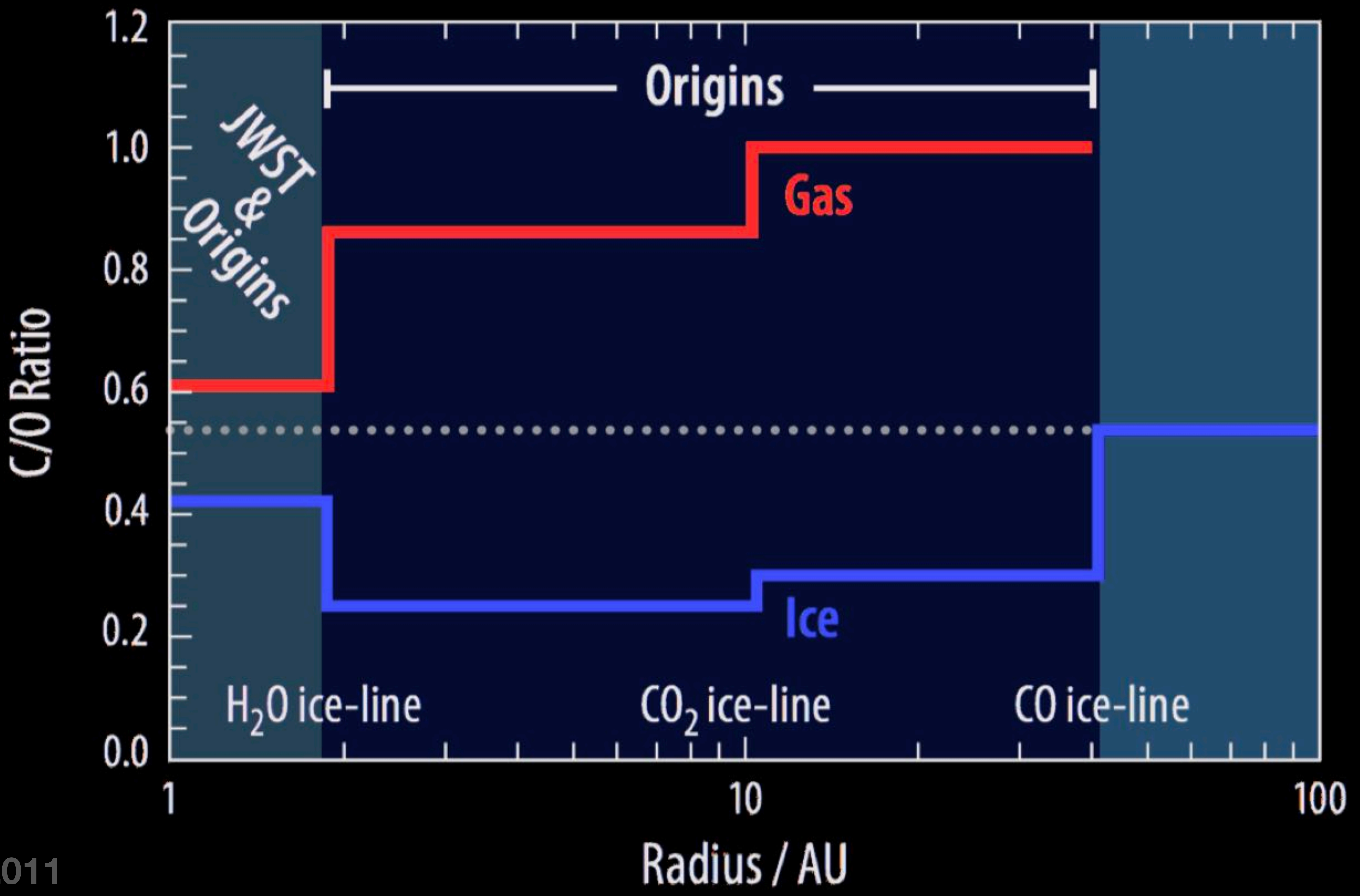
DSHARP collaboration

Most planets likely form within 10-20 AU



Zhang et al. 2018

The compositions of planets depend on their birth location

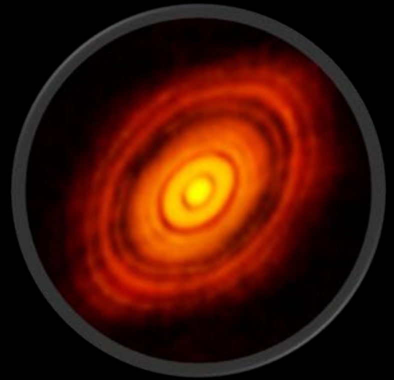


Oberg et al. 2011

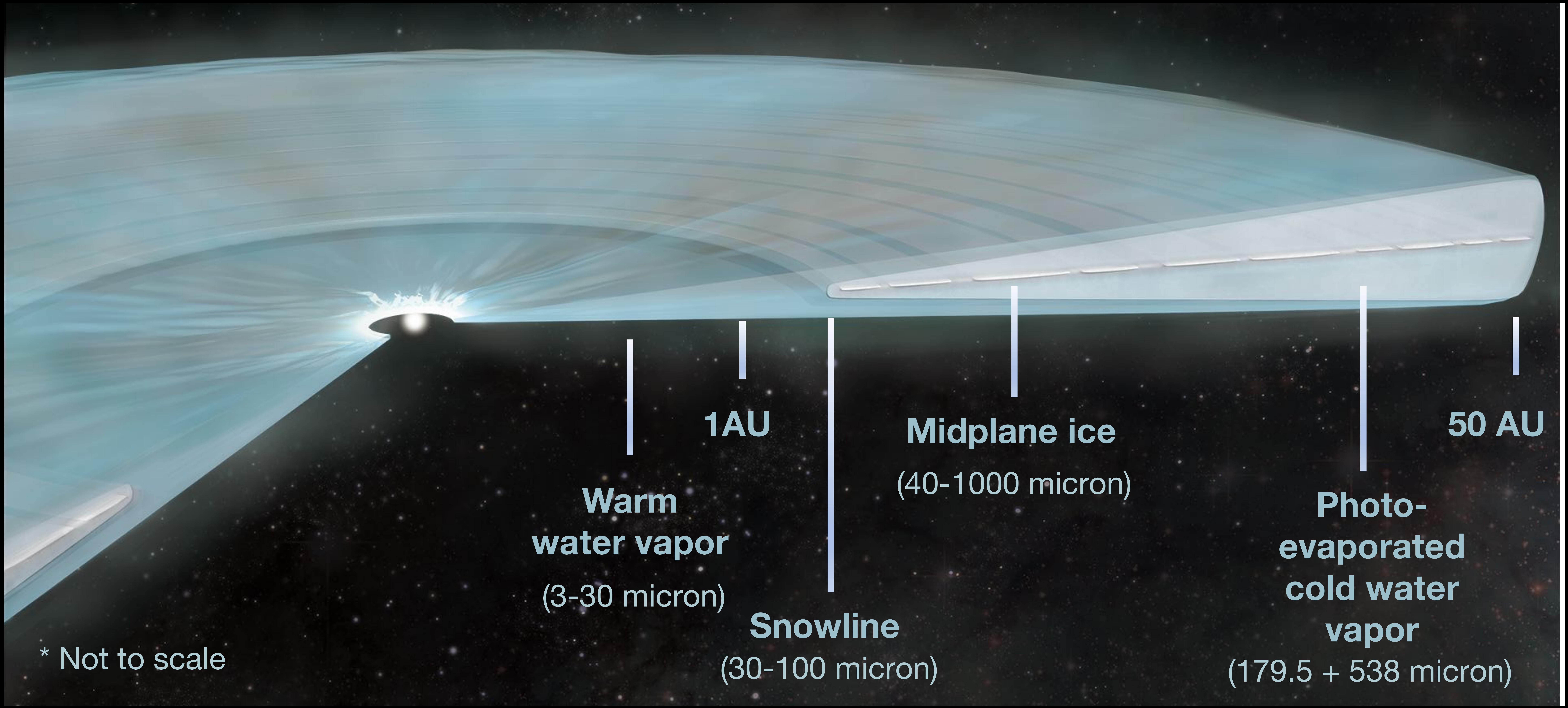
The transport of volatiles can also change composition

VLT SPHERE – micron dust/gas

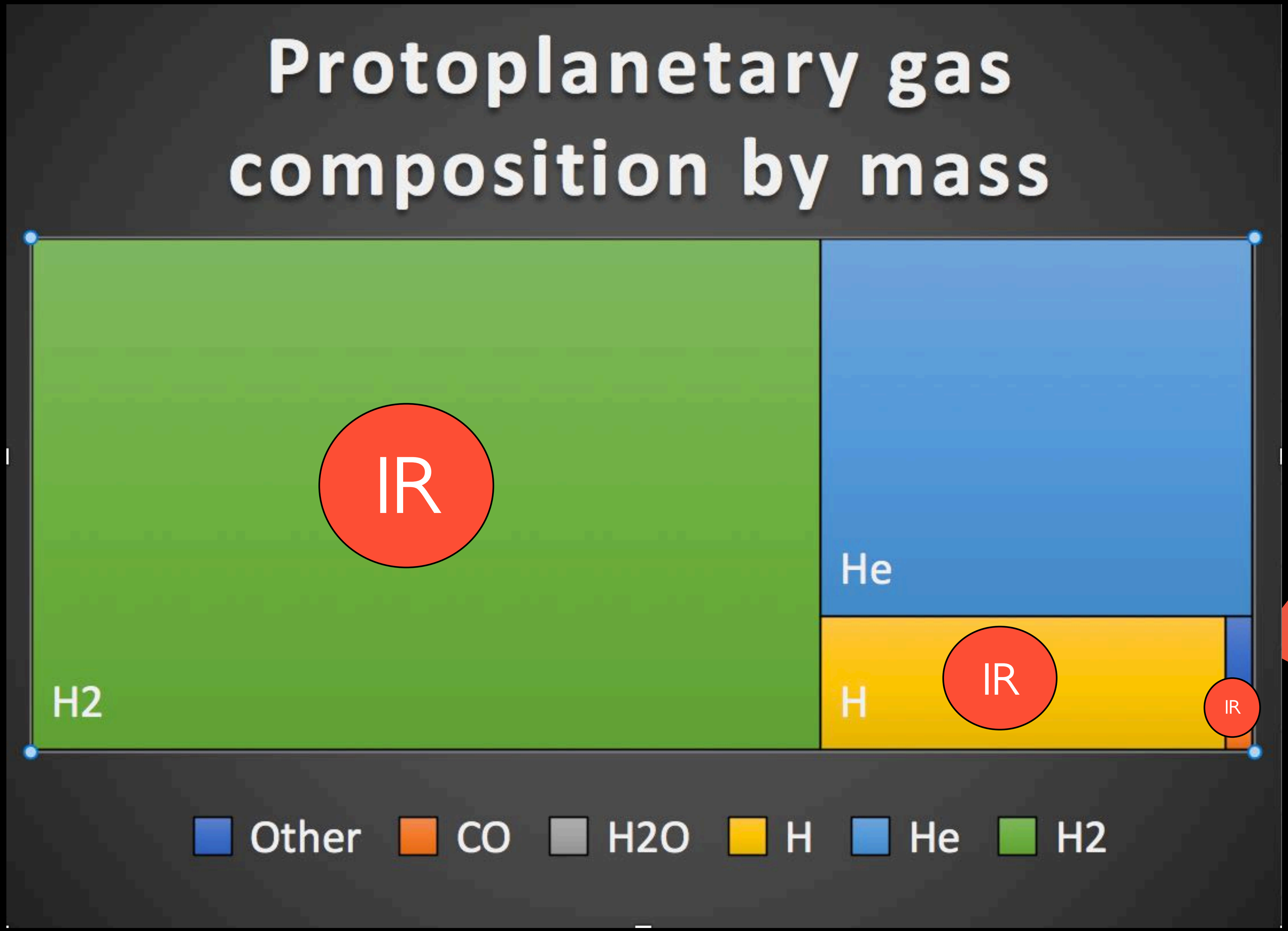
ALMA/DSHARP – mm dust

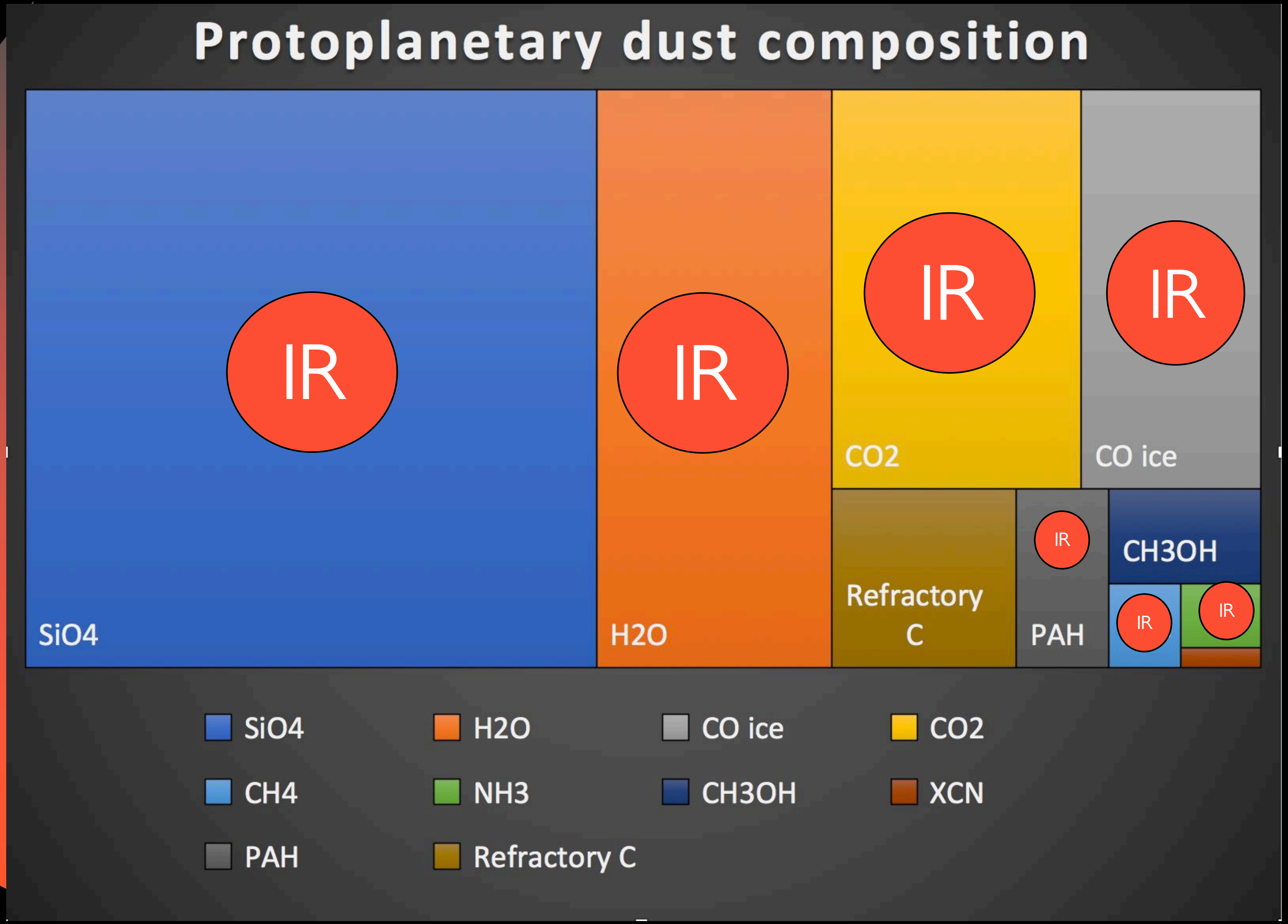


Planet-forming disks have different regimes of volatiles



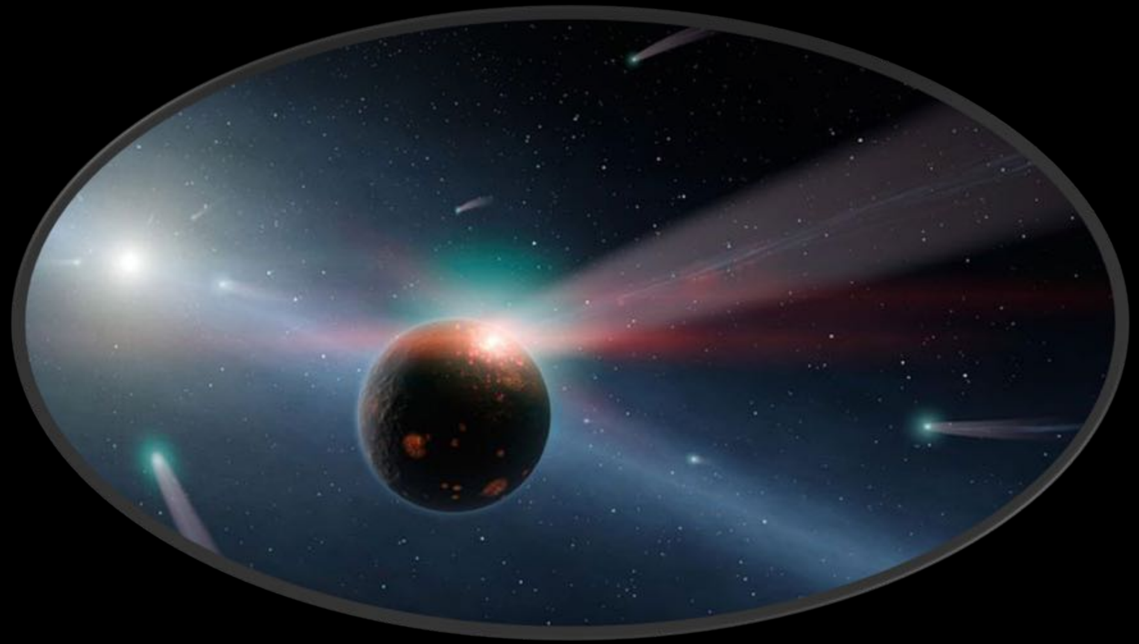
Bulk composition of gas and dust tends to be traced in IR





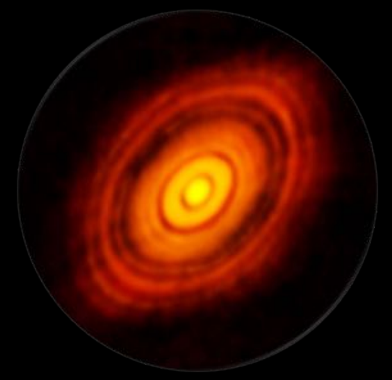
Based on the standard TT ProDimo Model (Woitke et al. 2009)

The mass of planet-forming matter

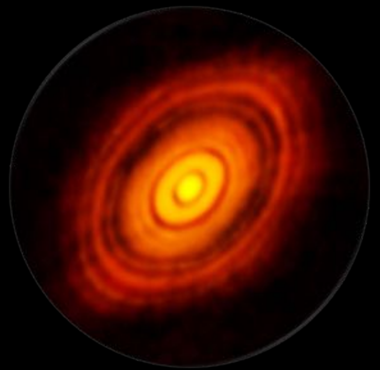


The trail of water

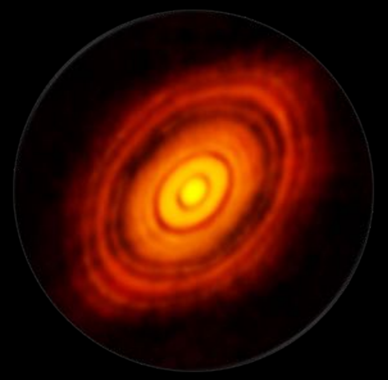
The origins of life’s elements



[X/CO]

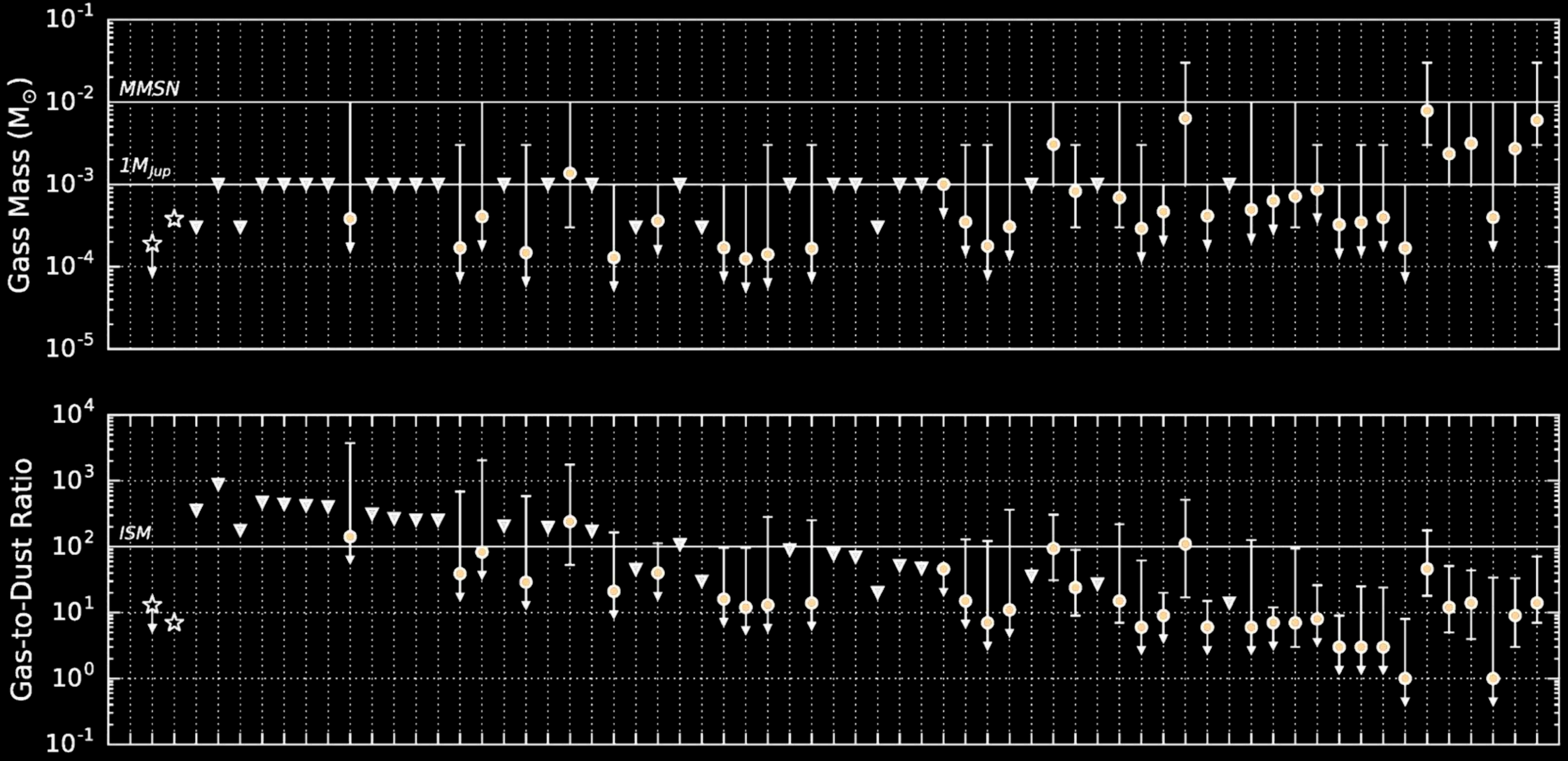


[X/dust]



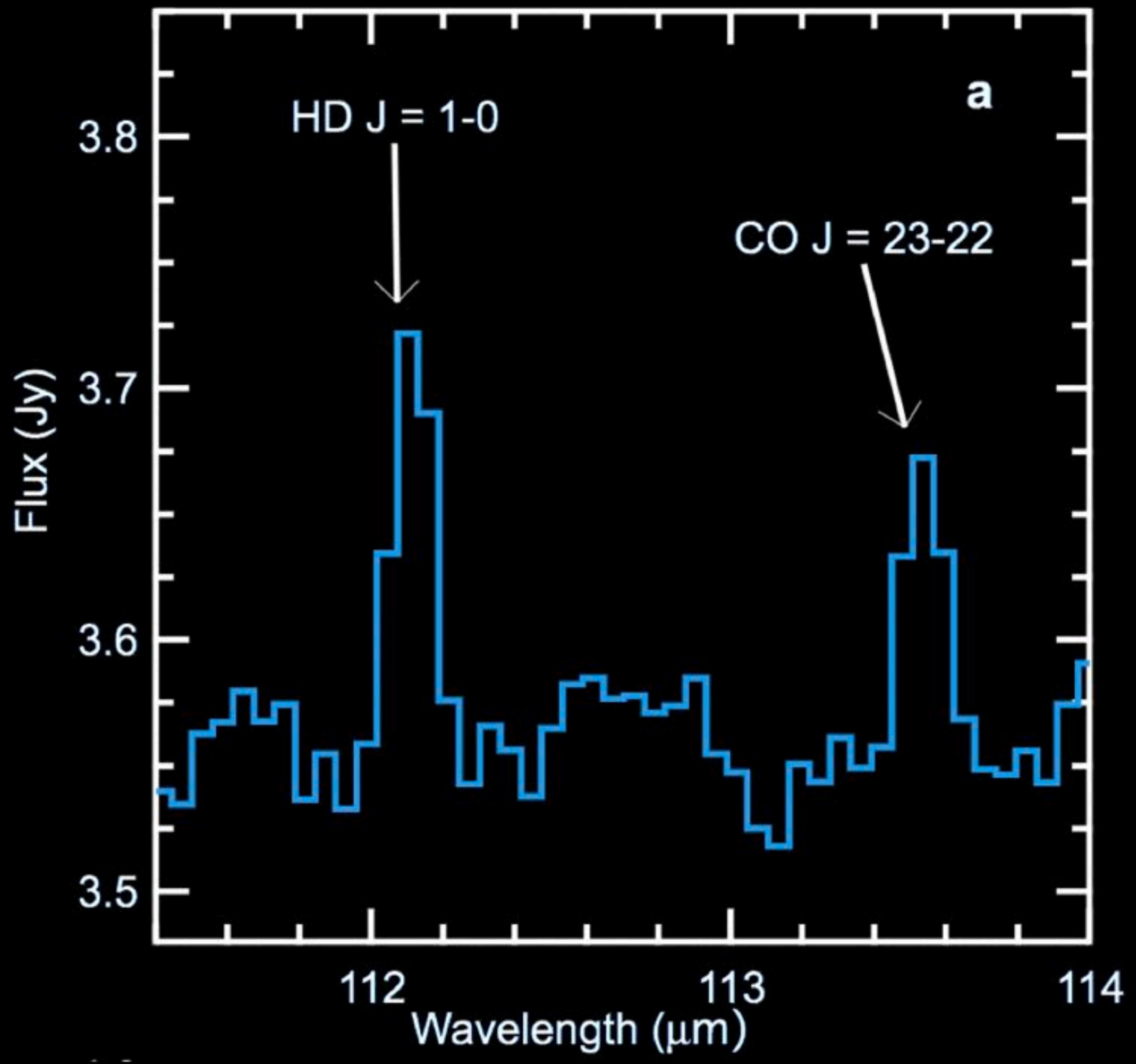
$$[X/(H_2+H)]?$$

Classical mass tracers, CO and dust, underestimate mass

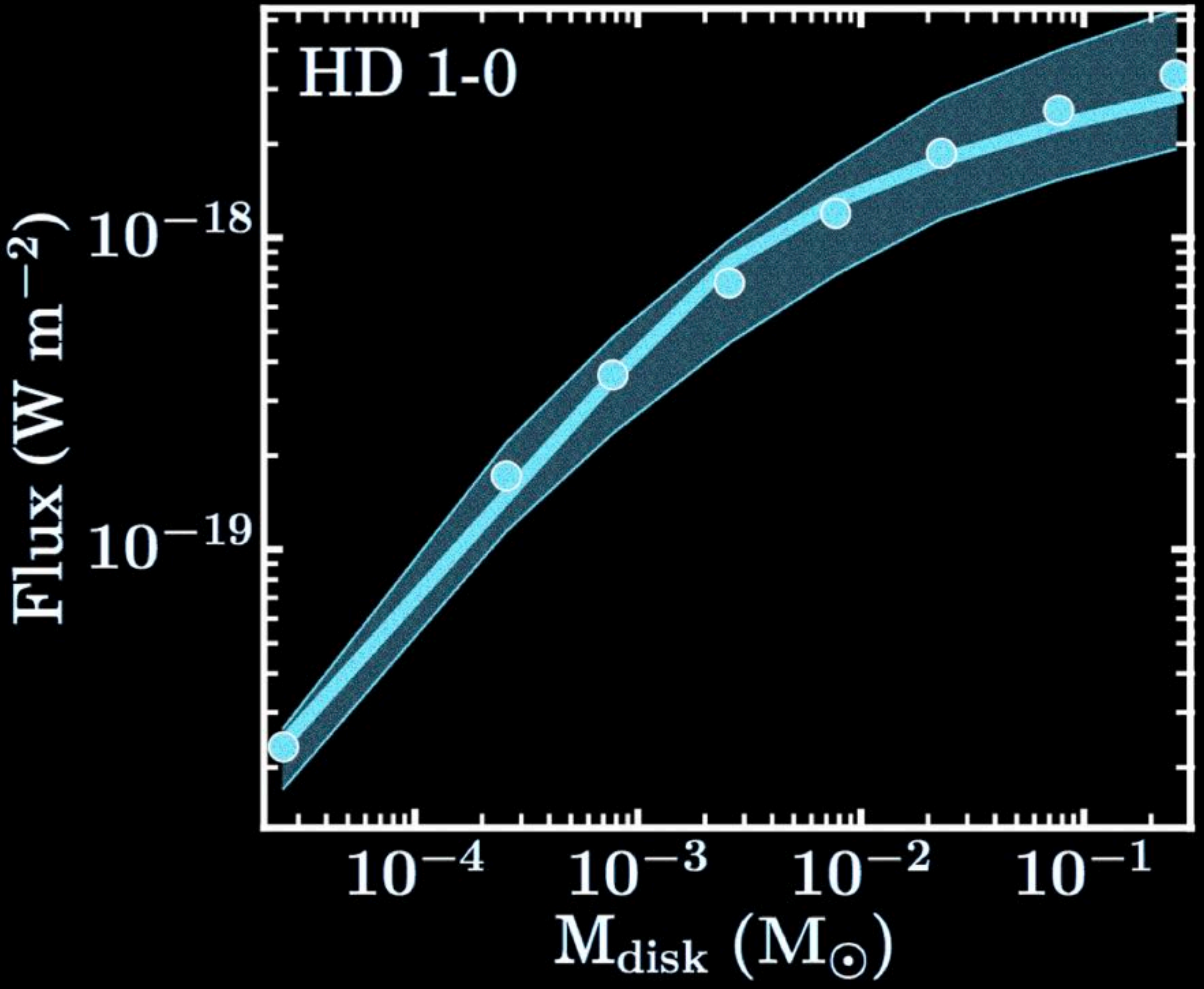


Ansdell et al. 2016

Hydrogen deuteride as a better mass tracer



Bergin et al. 2013; McClure et al. 2016

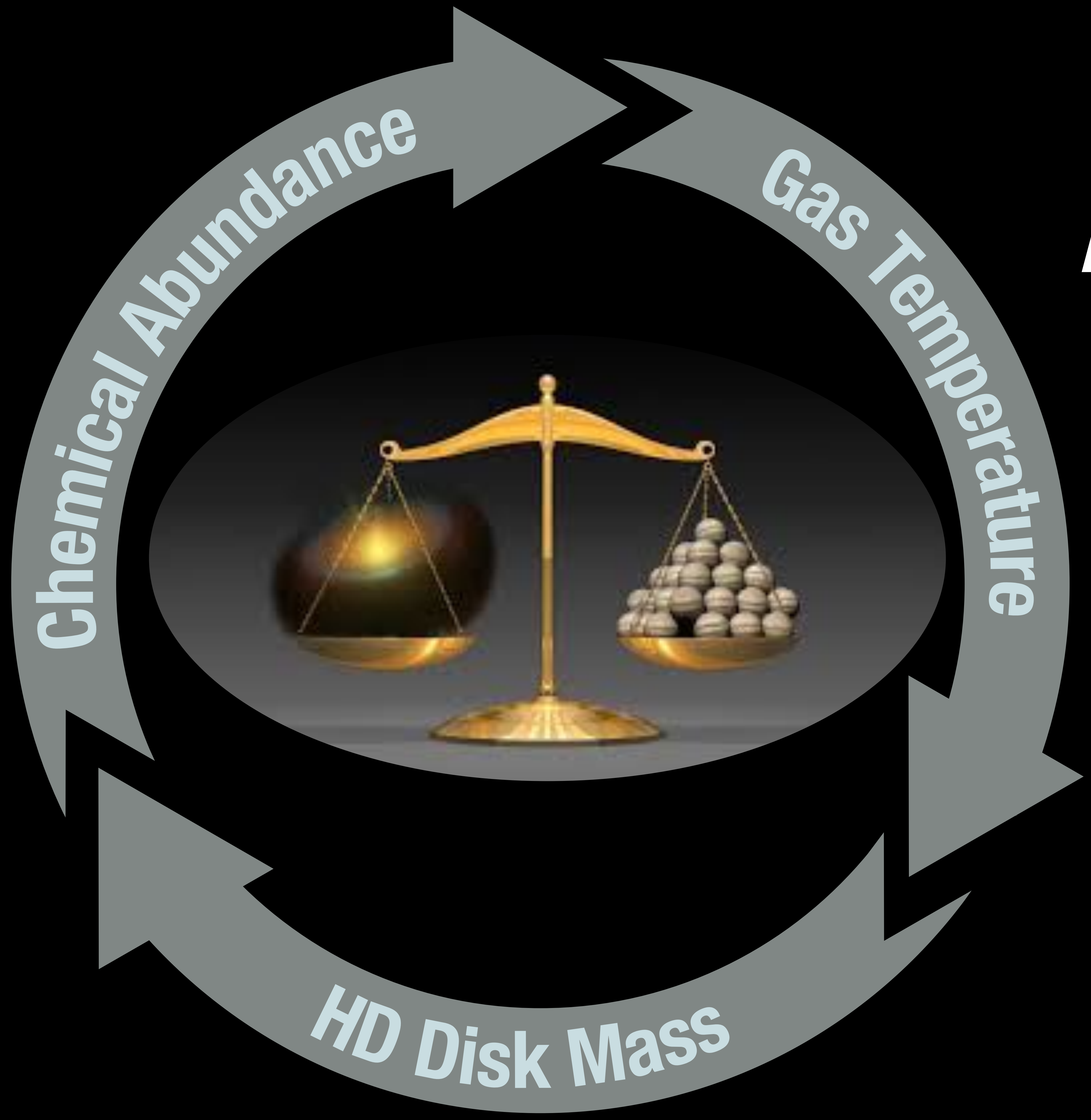


Trapman et al. 2017

HD disk mass is a synergy between ALMA and a FIR facility

Any molecule from ALMA/JWST

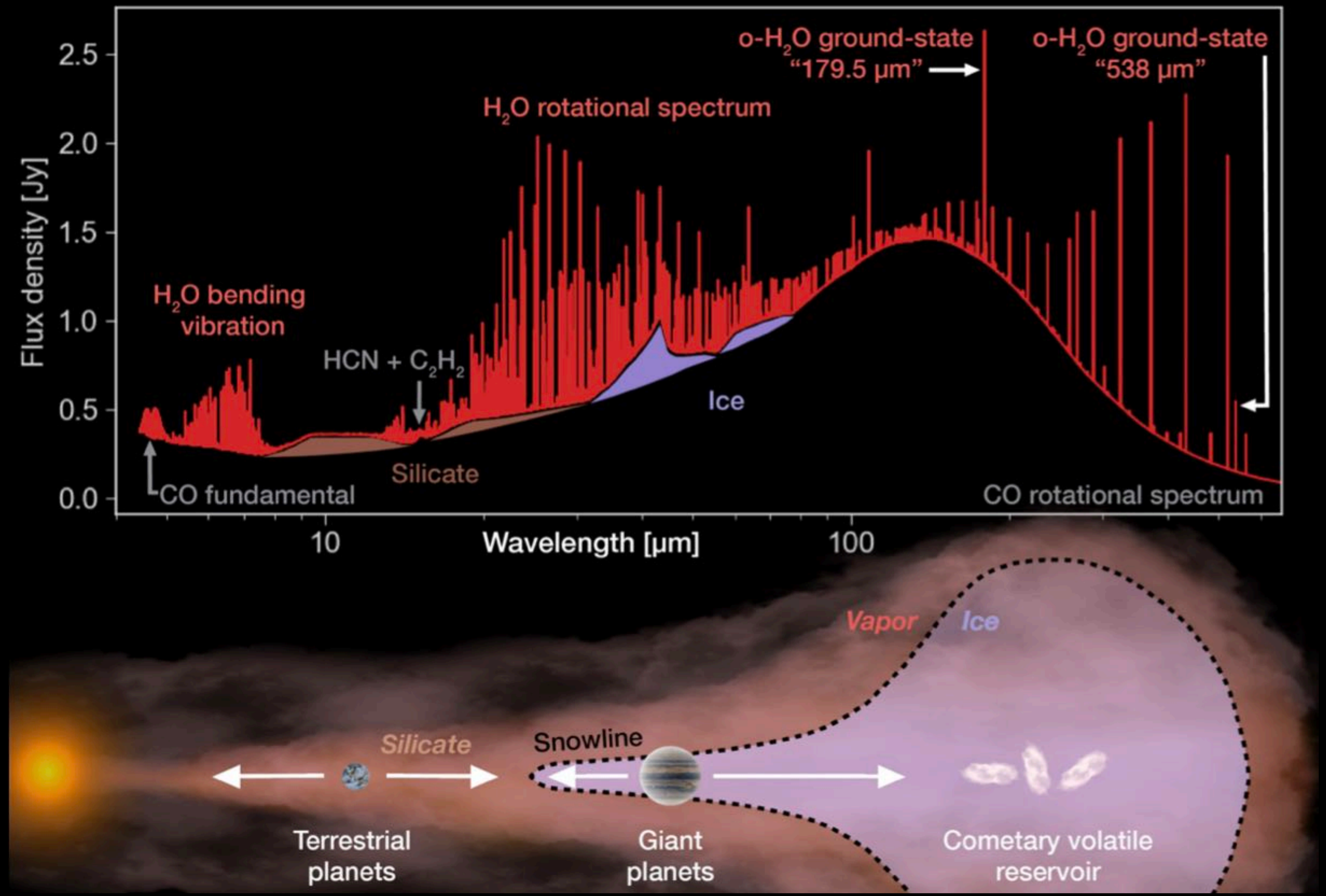
ALMA

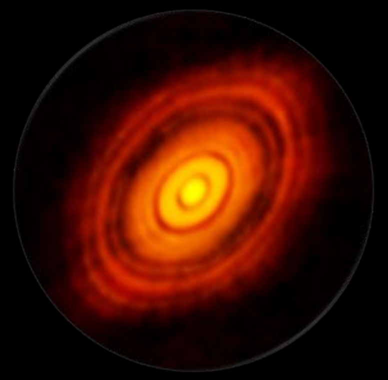


112 micron spectroscopy

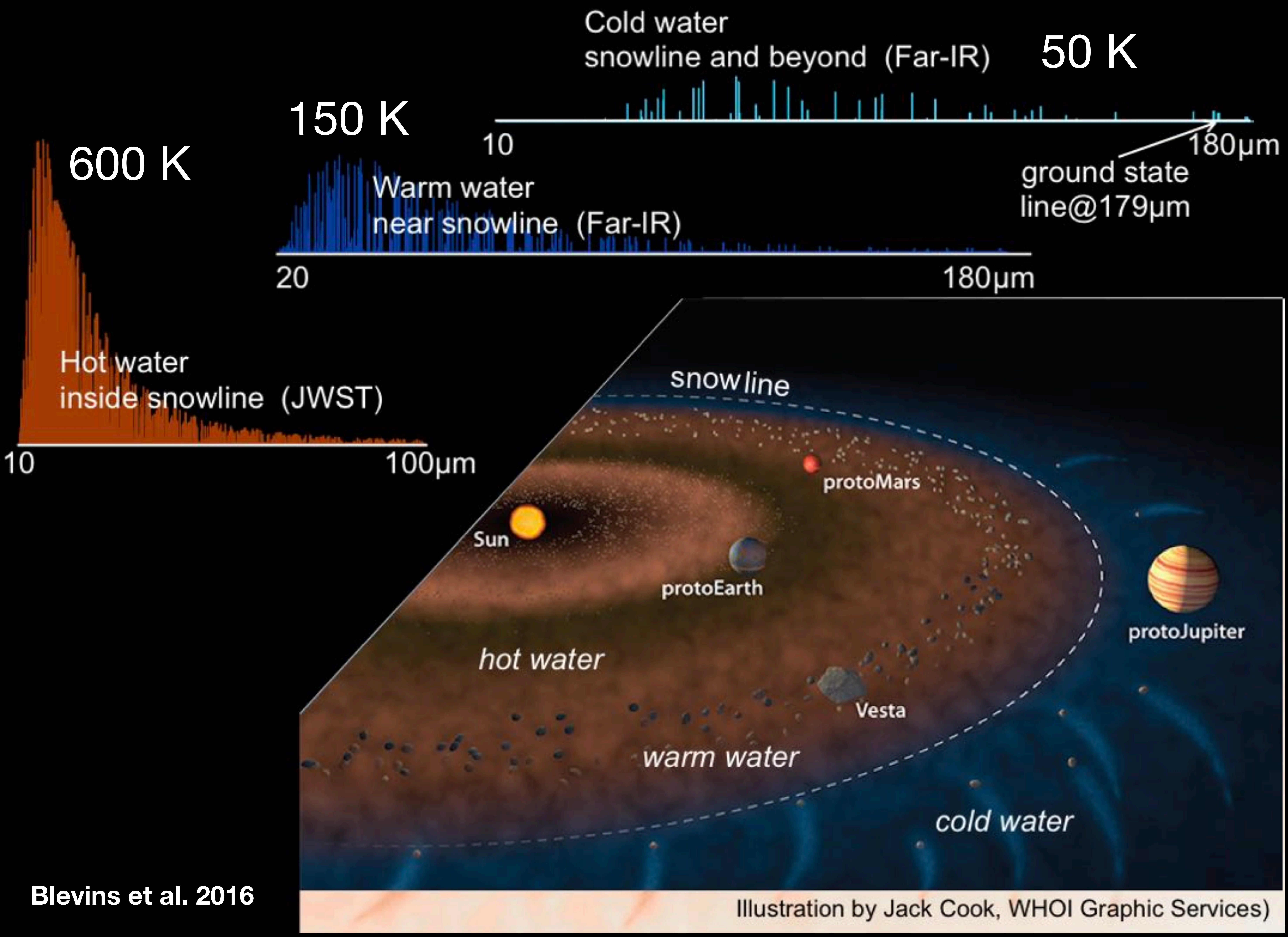
- HD → robust tracer of H_2
- J=1-0 at 112 micron
- We detected HD in 3 disks with Herschel-PACS

- The HD line is temperature dependent
- Requires good models of disk temperature



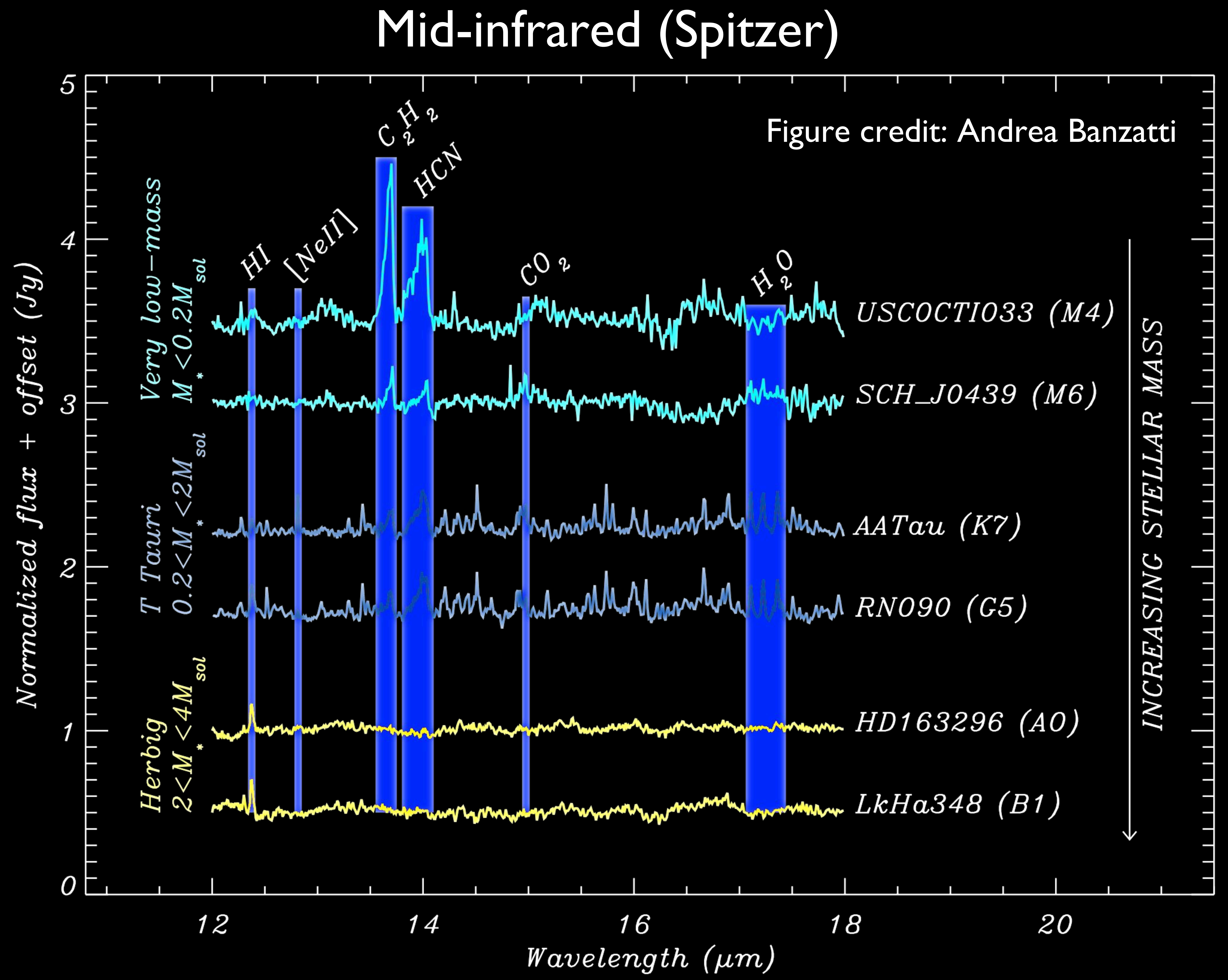


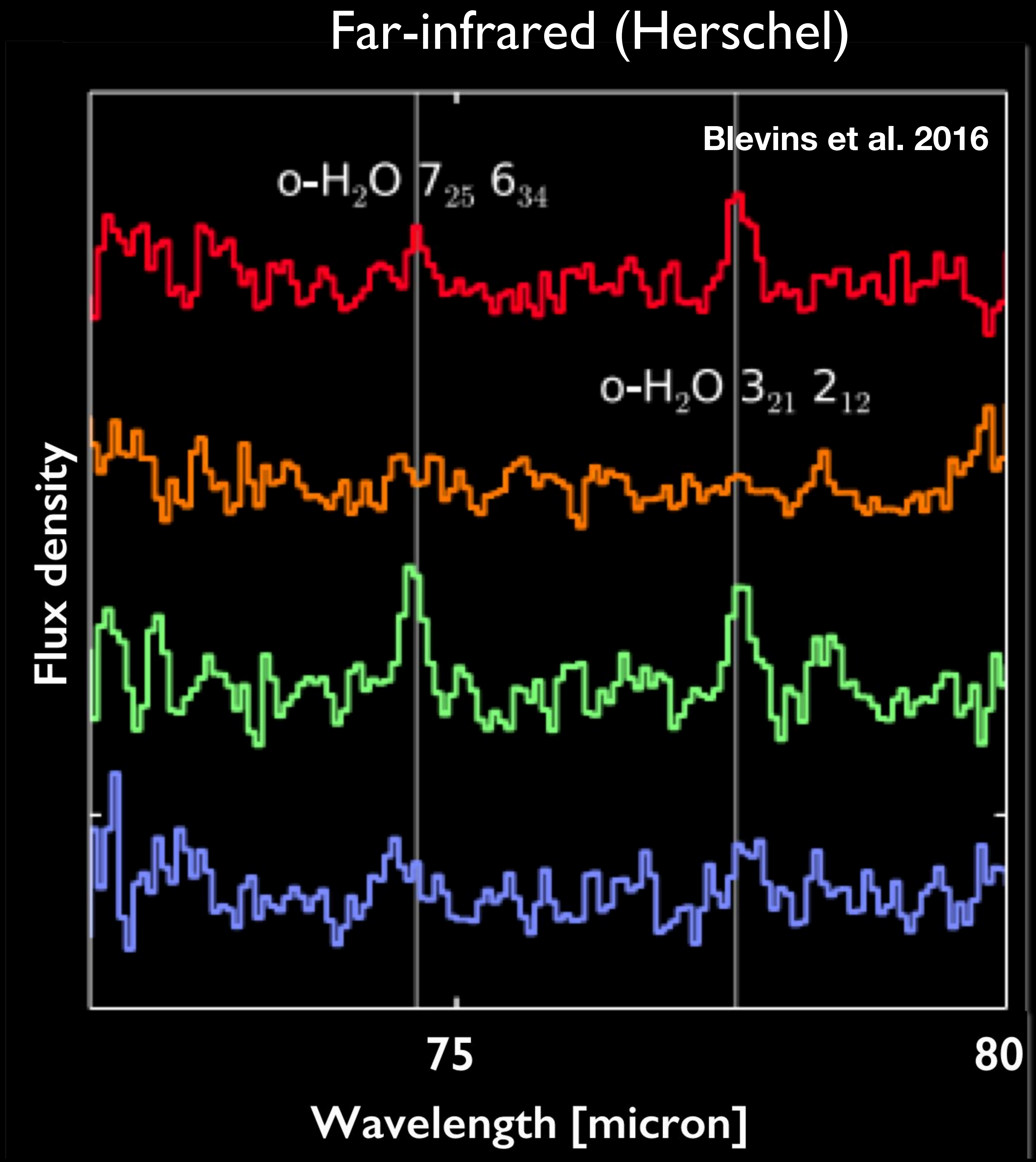
Pontoppidan et al. 2019



Blevins et al. 2016

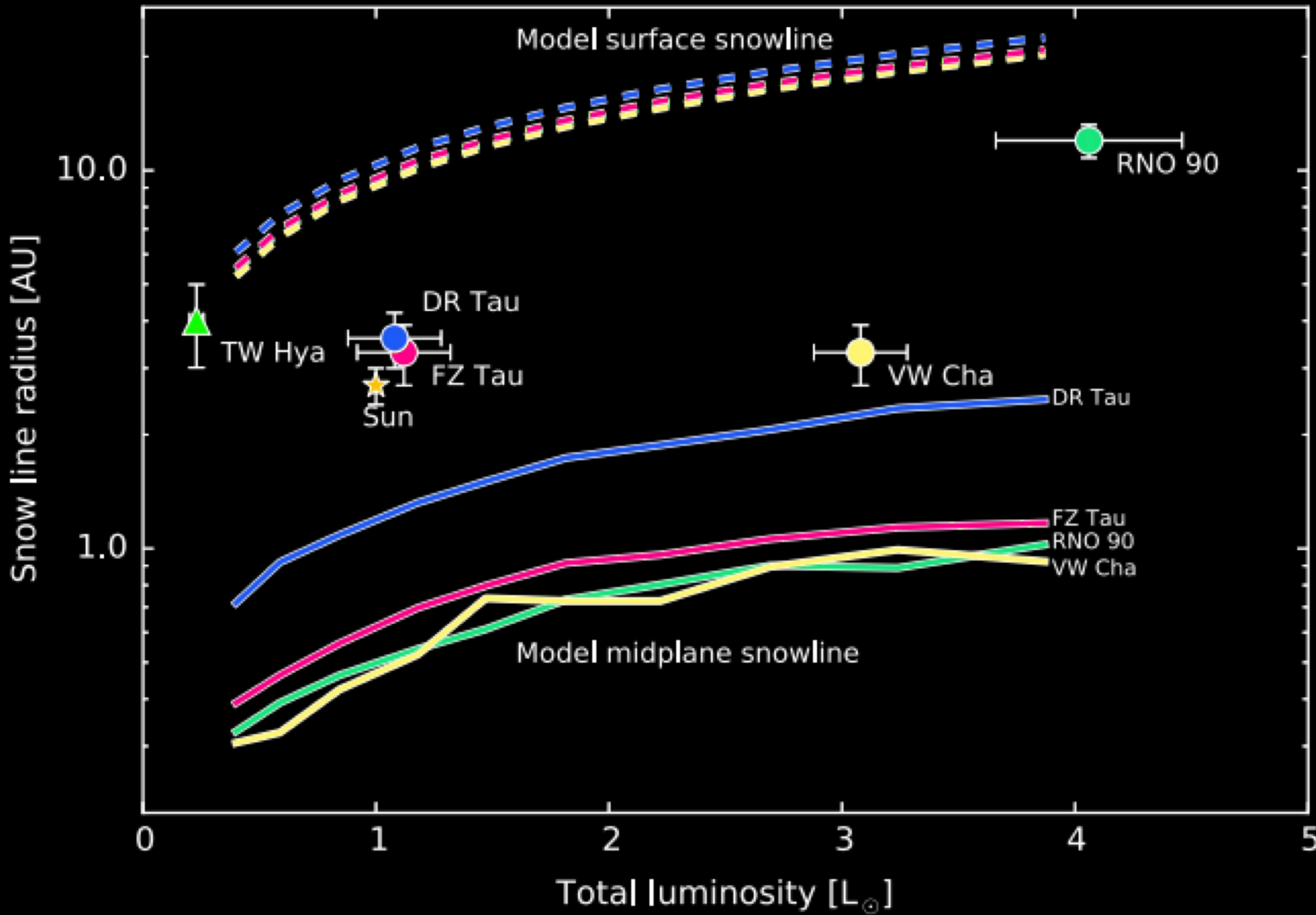
The trail of water





Also Carr & Najita, 2008, 2011; Salyk et al. 2008, Pontoppidan et al. 2011

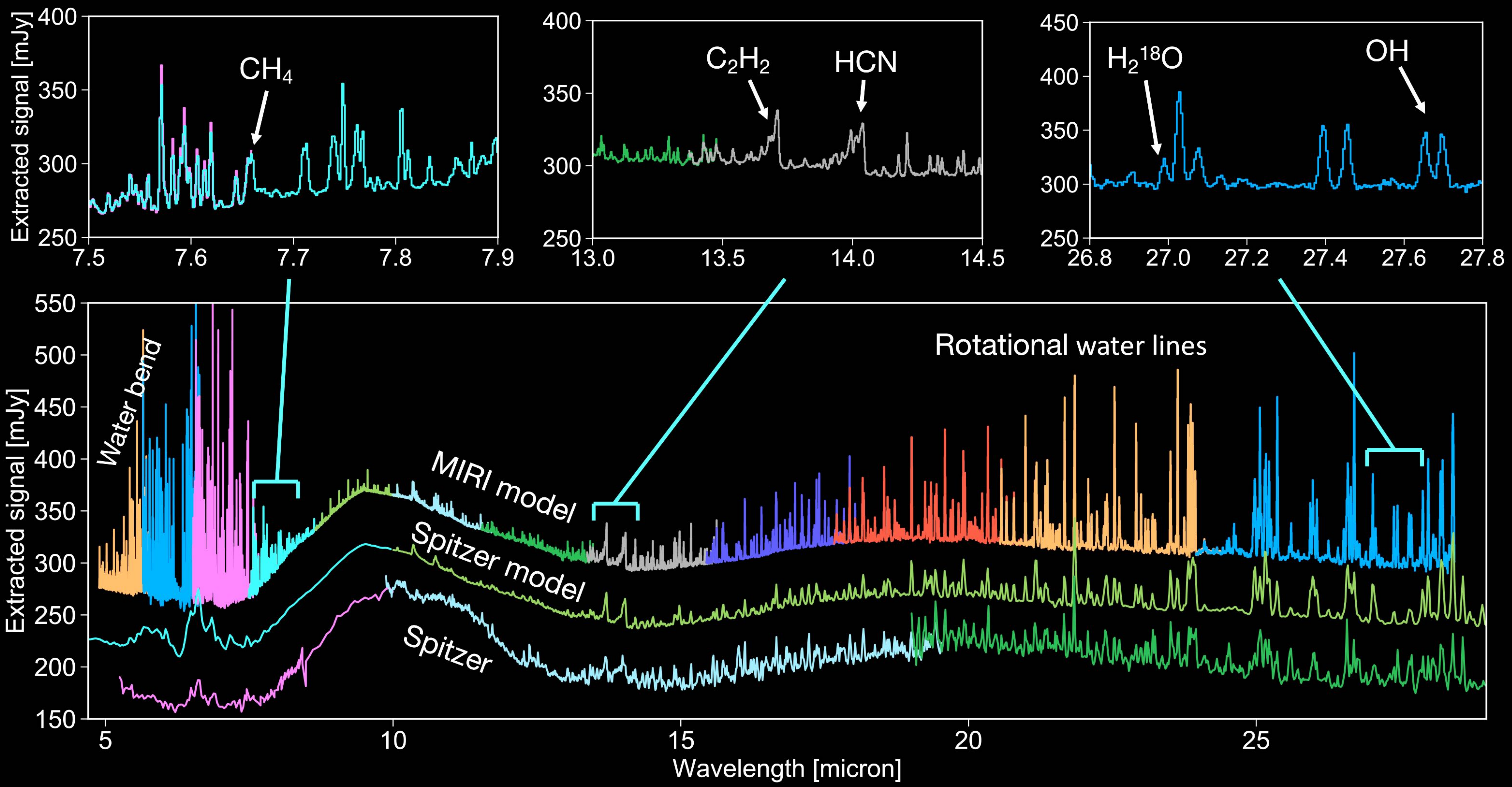
Combining Spitzer and Herschel-PACS detected surface snow lines



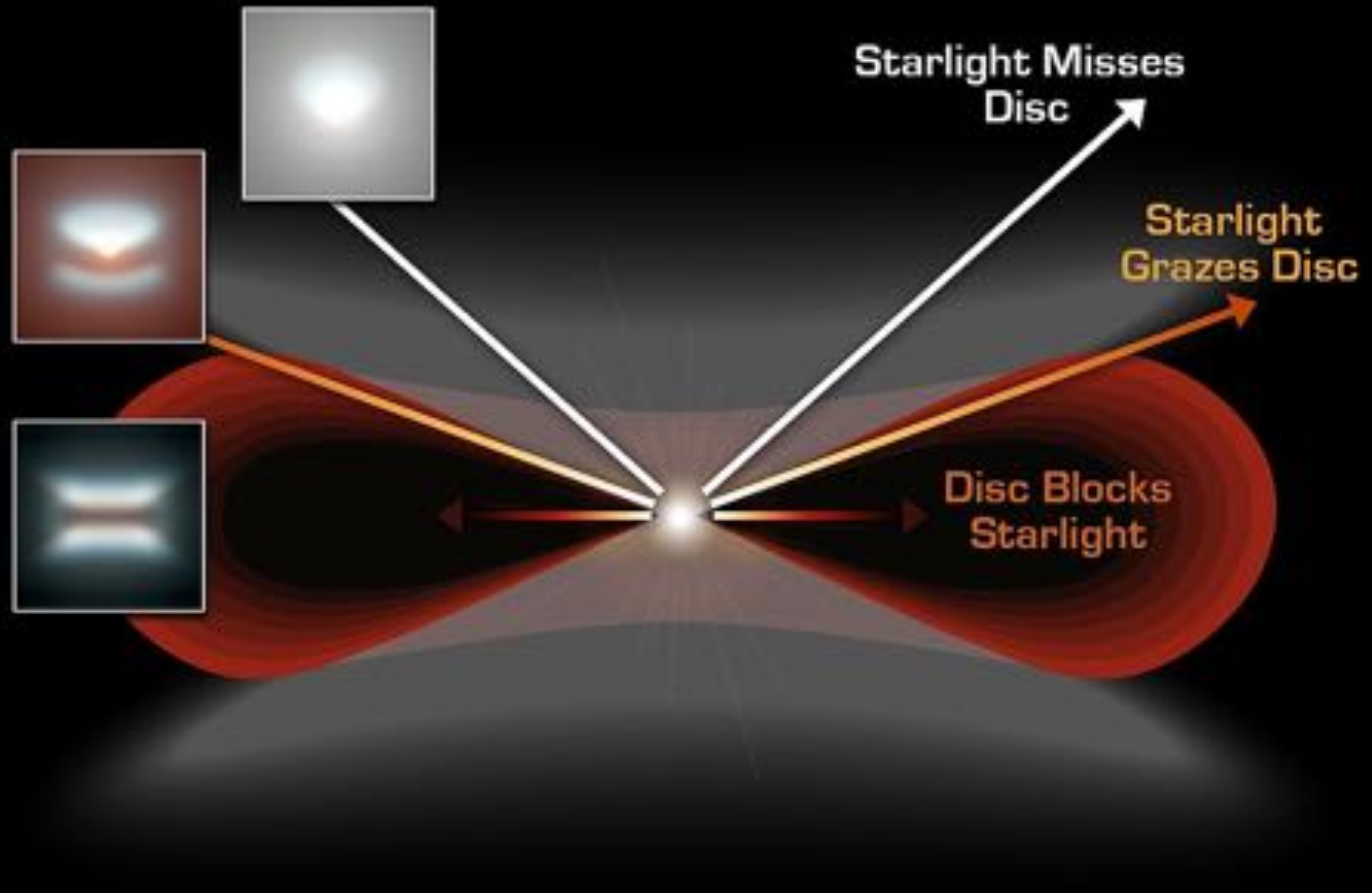
Zhang+, 2013
Blevins+ 2016

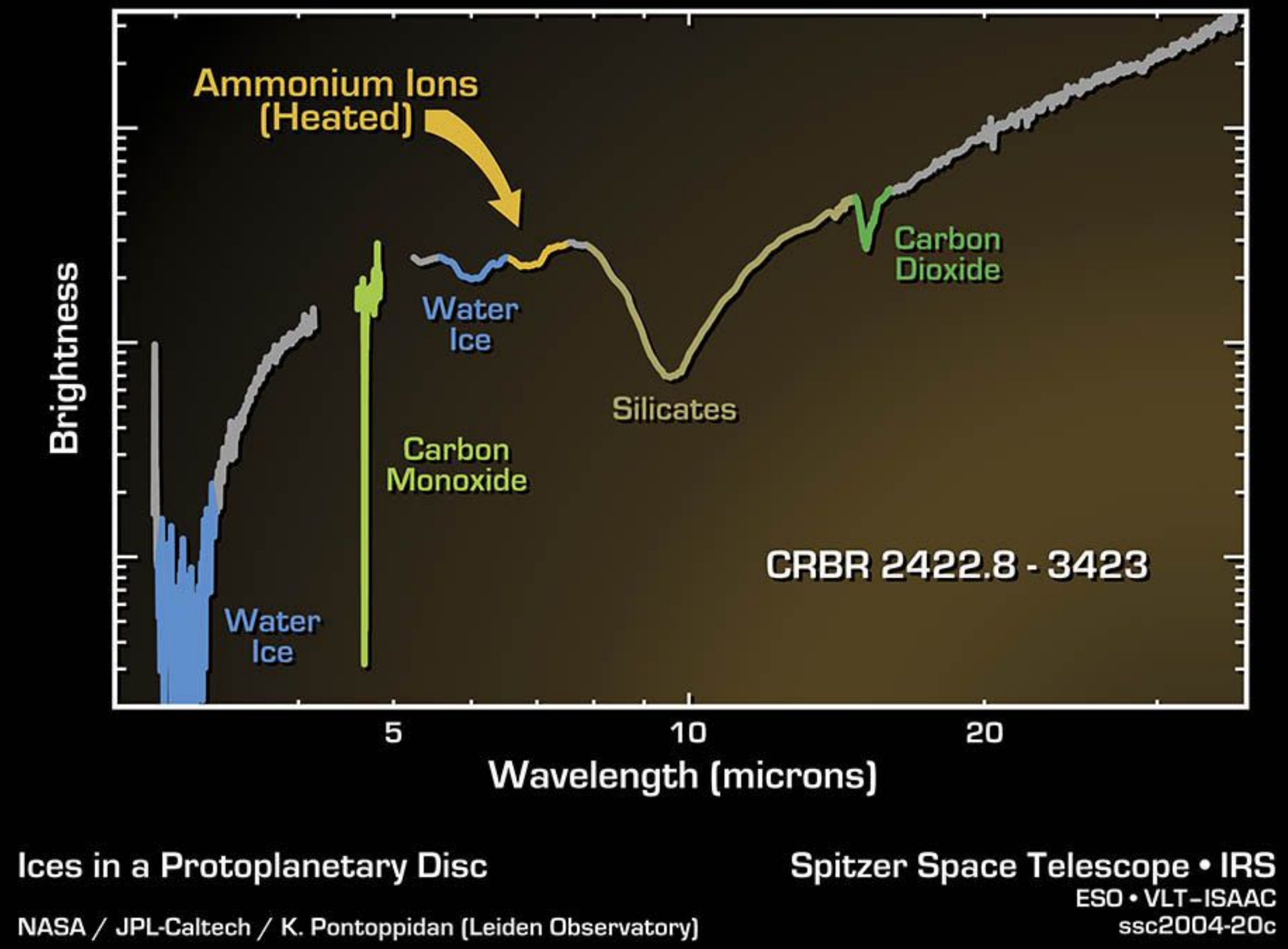
JWST will create a census of terrestrial planet-forming chemistry

Lowest H_2O energy available to JWST: ~800 K

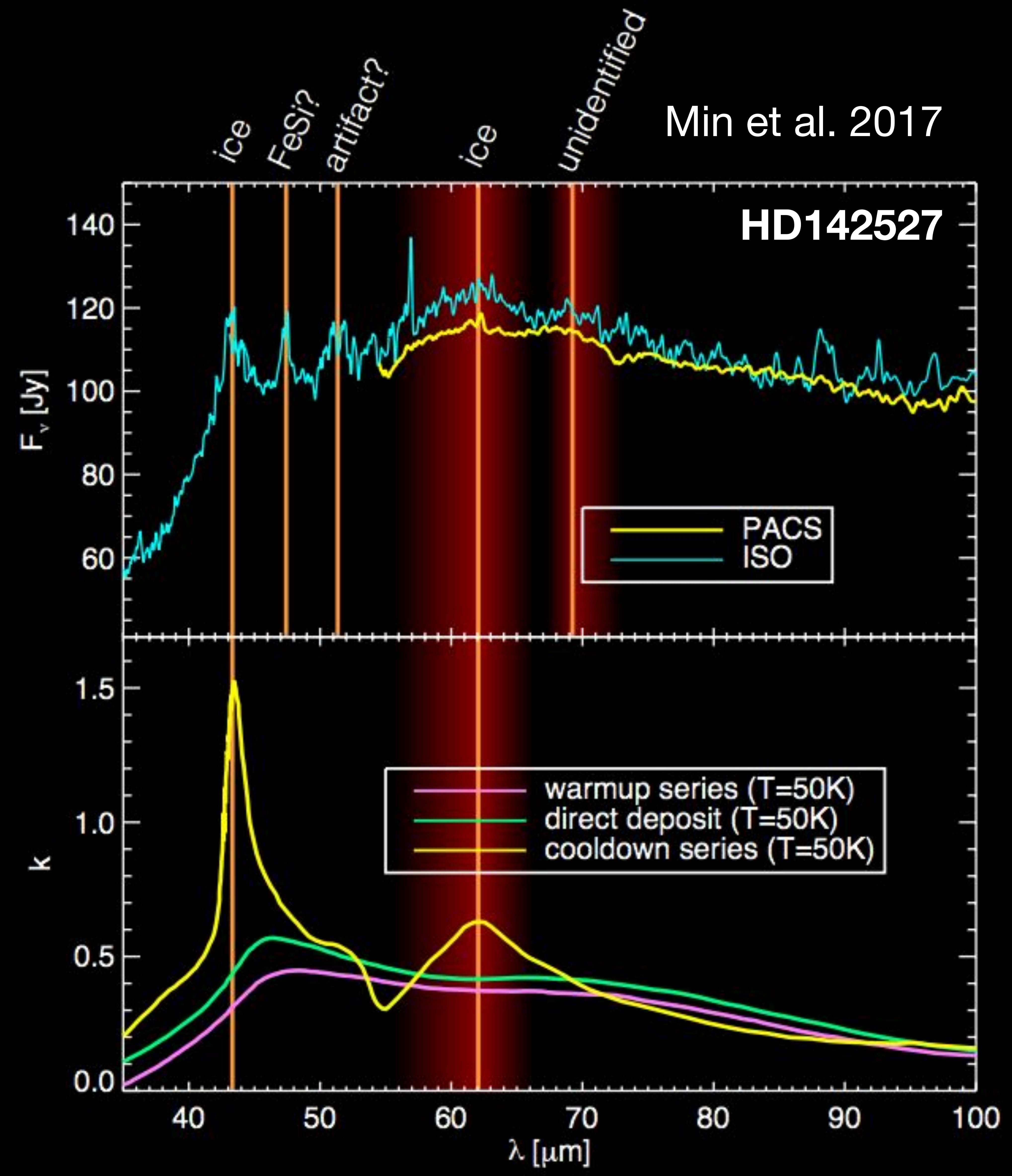


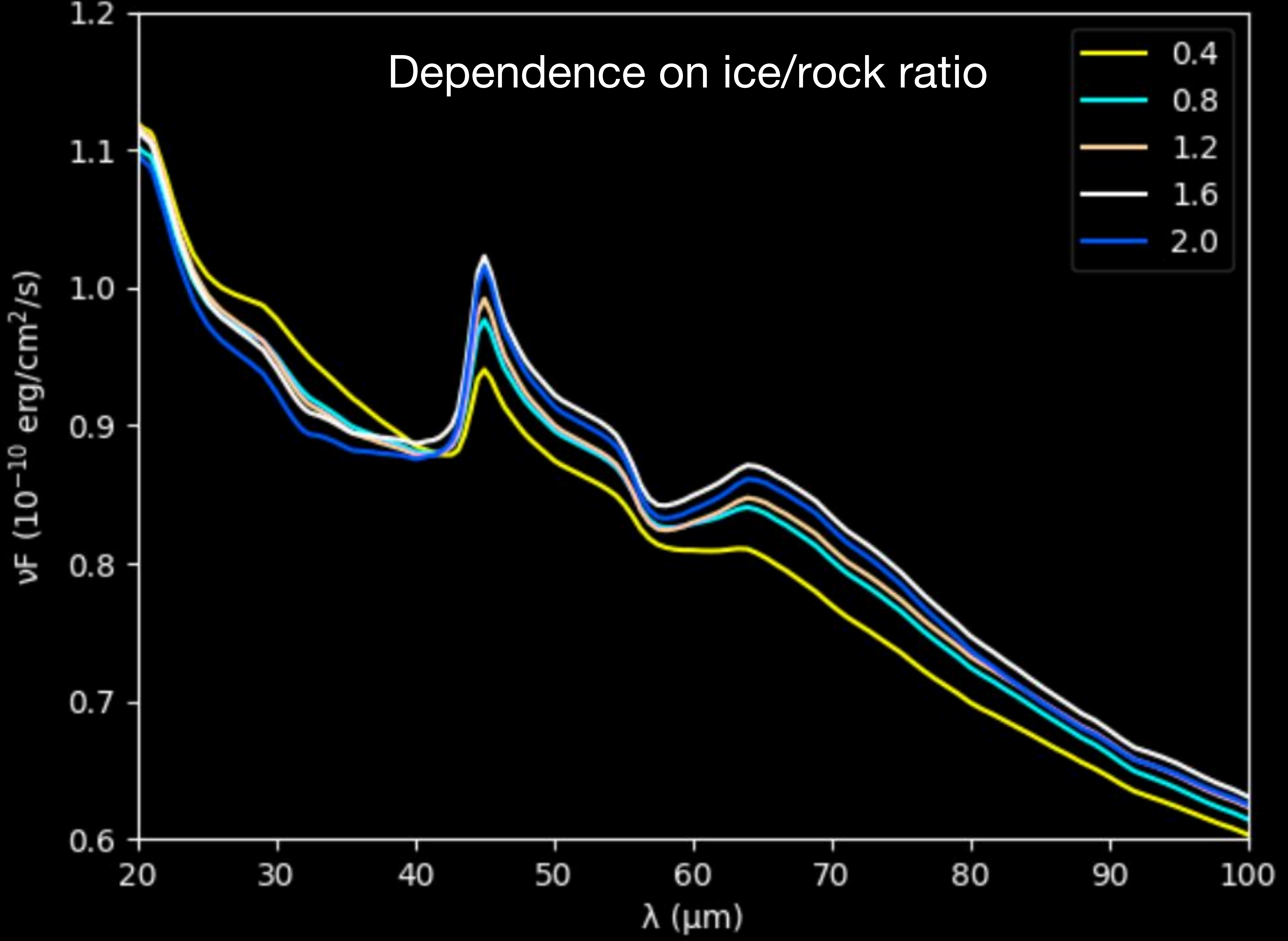
Classical methods to detect ice in disks





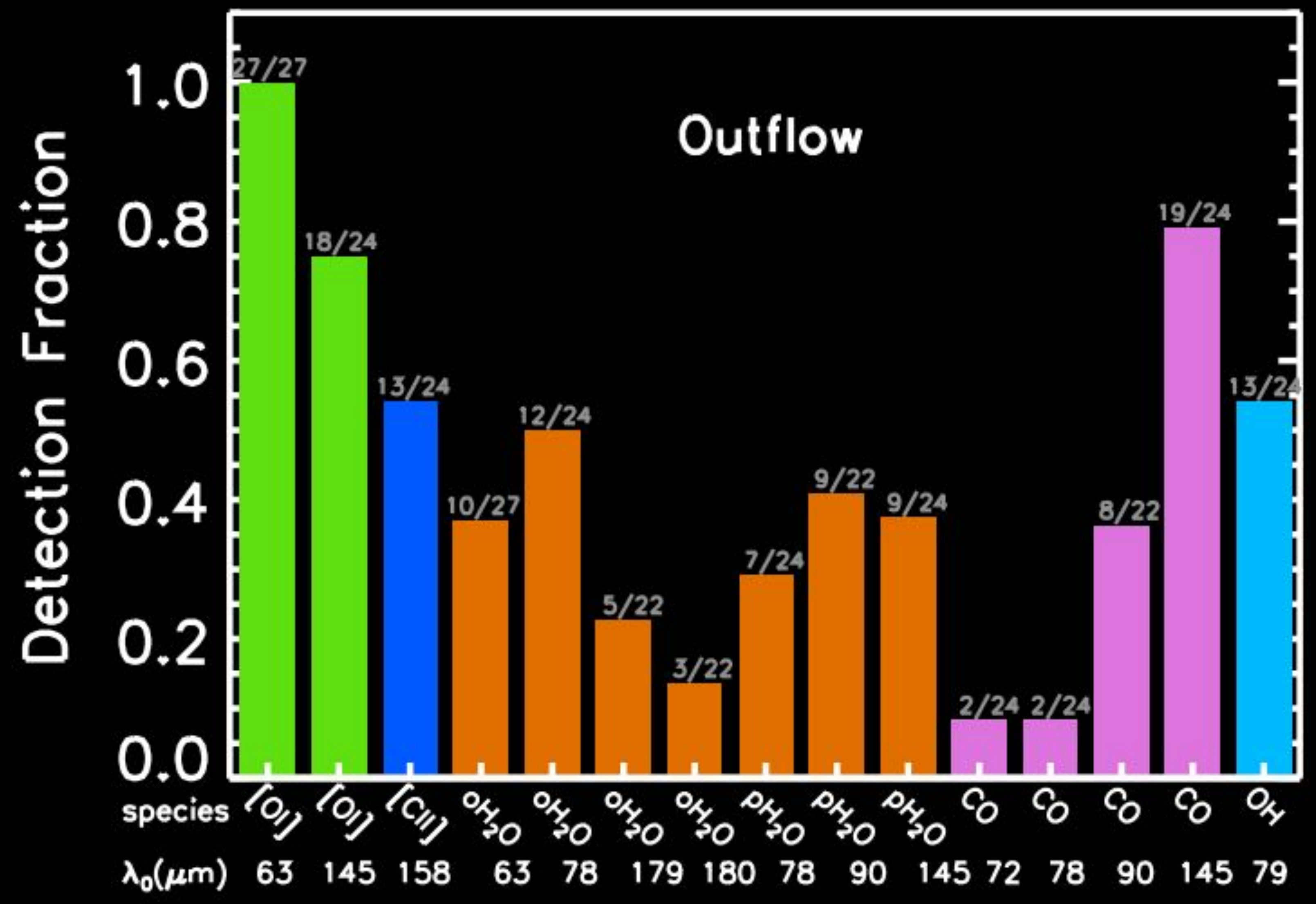
Water ice emission using FIR phonon modes



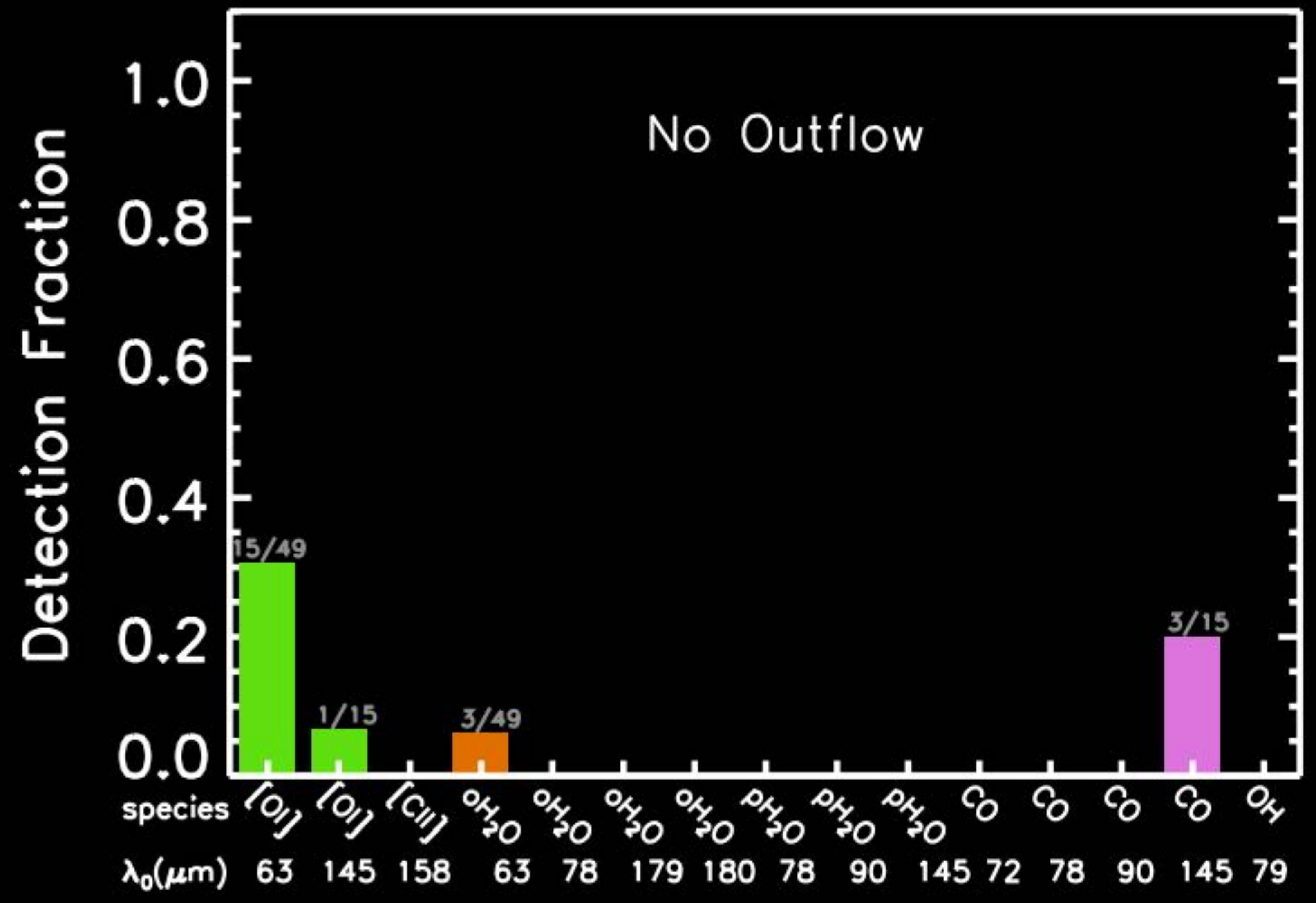


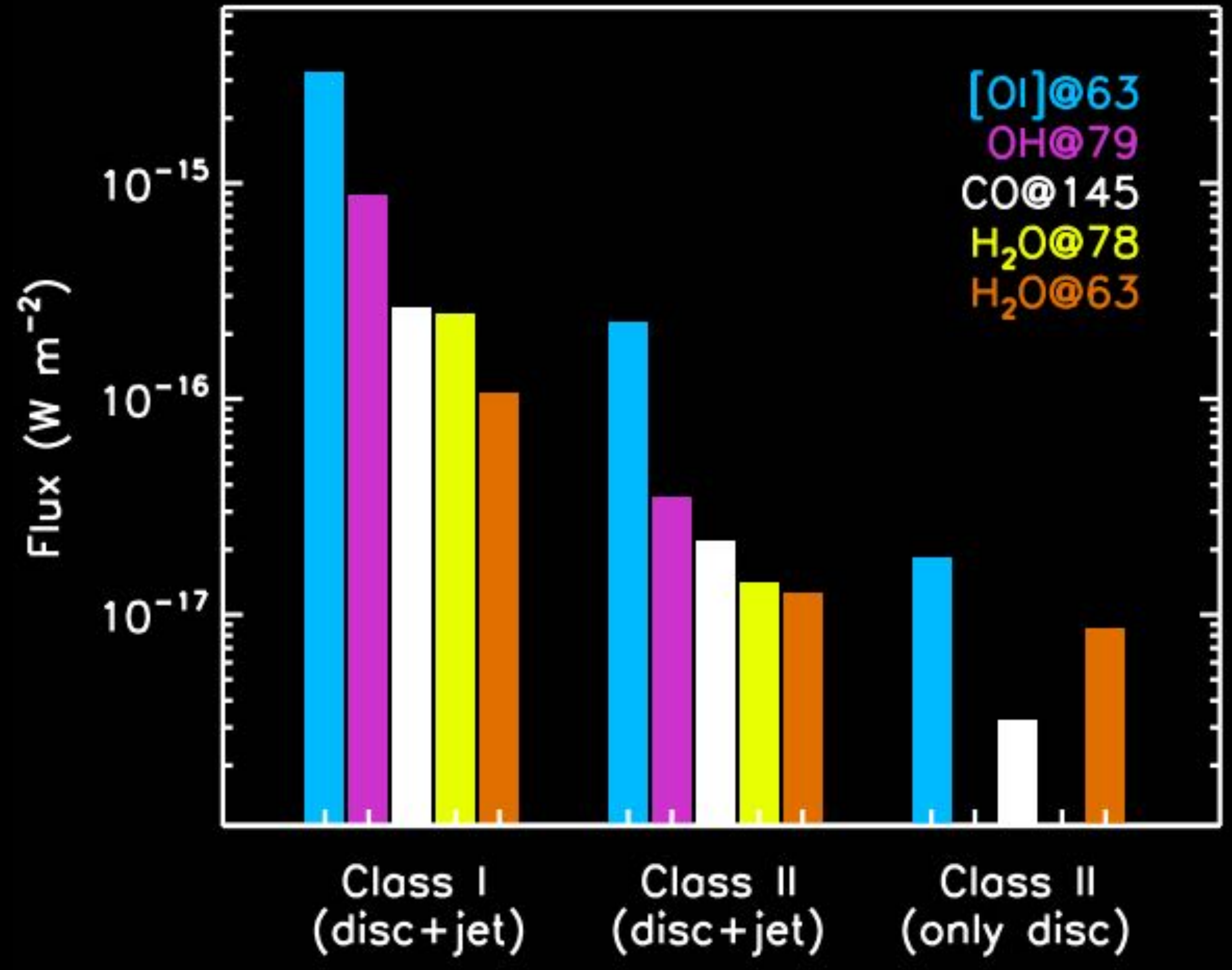
Kamp et al. 2017

63 micron [OI] as a tracer of disk gas thermal balance



Alonzo-Martinez et al. 2017





High-resolution Mid-InfraRed Spectrometer

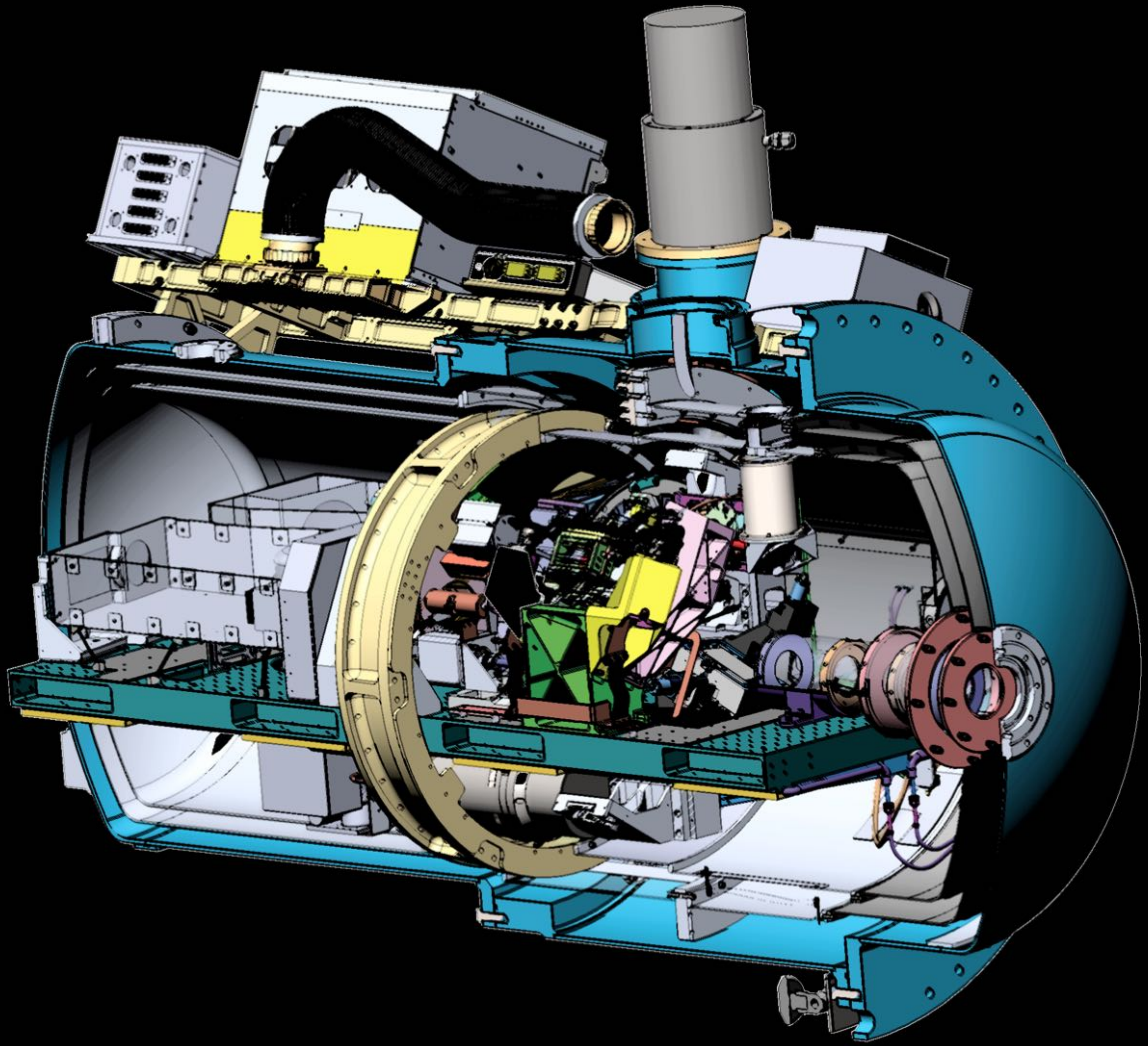
HIRMES

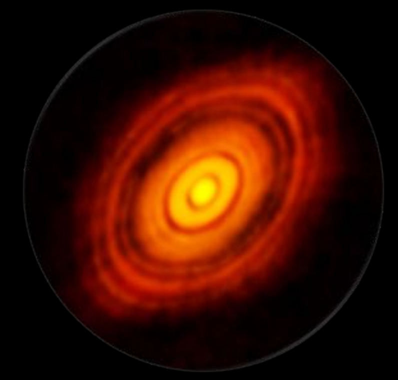
GSFC
SDL
PCS
Cornell
USRA

CfA
STScI
Umich
JHU
Rochester
UofA

Matt Greenhouse (PI) -- Science WG: Ted Bergin, Christine Chen, Gary Melnick, Klaus Pontoppidan, Aki Roberge, Kate Su, Dan Watson, David Neufeld, Gordon Stacey, Gordon Bjoraker, Stefanie Milam

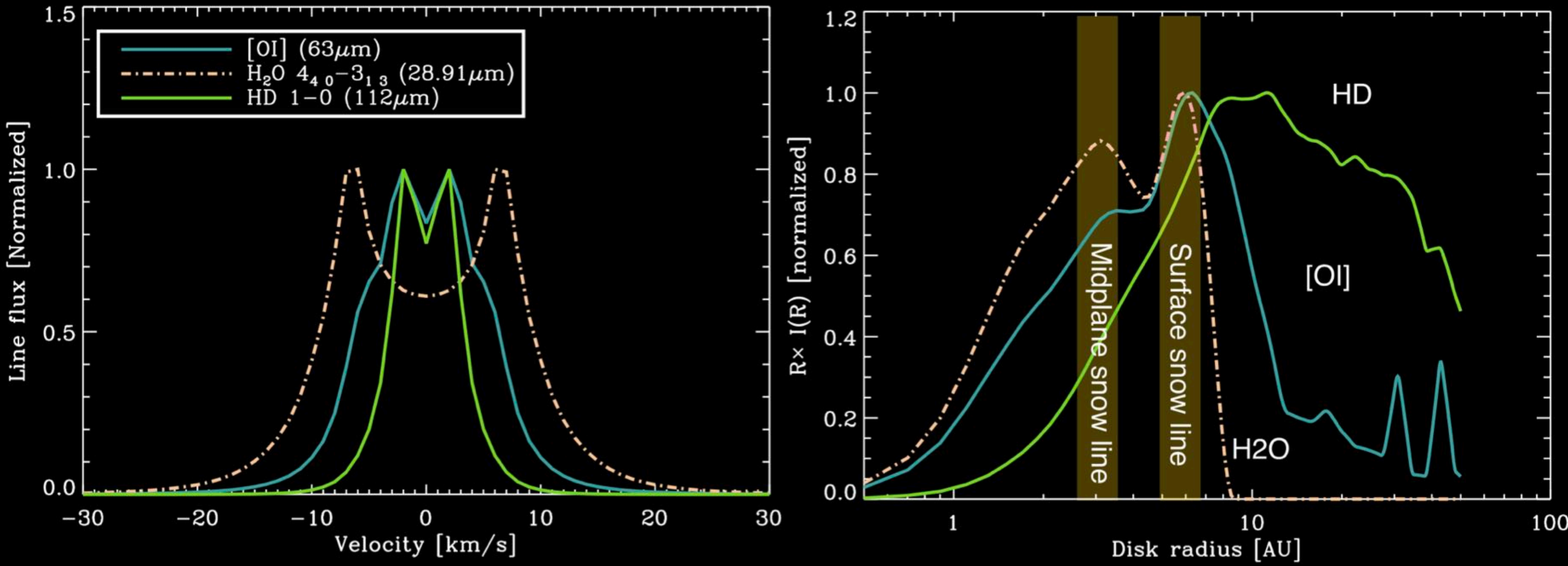
Richards et al. 2018, JAI



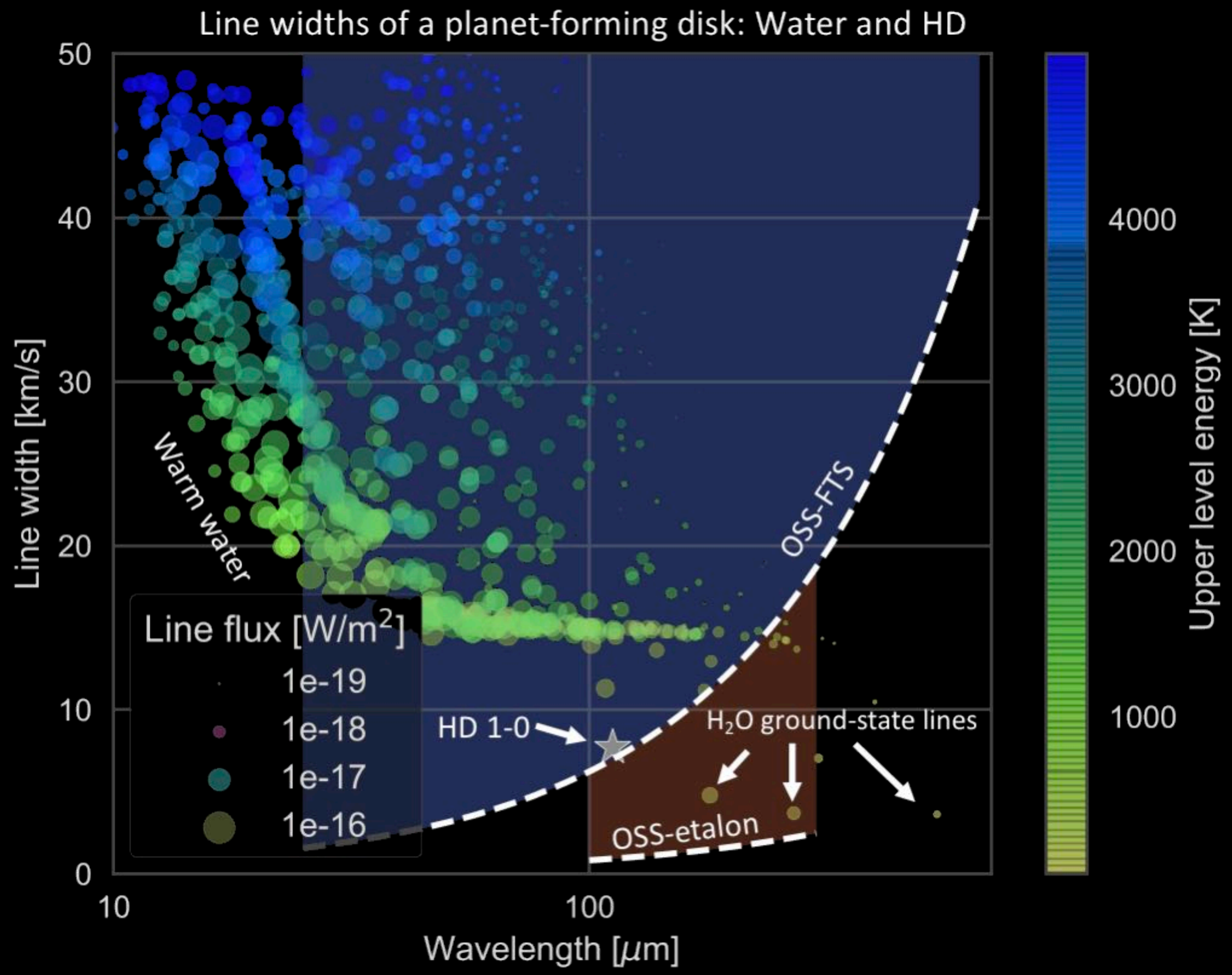


- **Provide Herschel-PACS line sensitivity**
- **at high spectral resolving power**
- **(R=50,000-100,000)**
- **cover unexplored region between Spitzer and Herschel**
- **increase spectral mapping speeds**

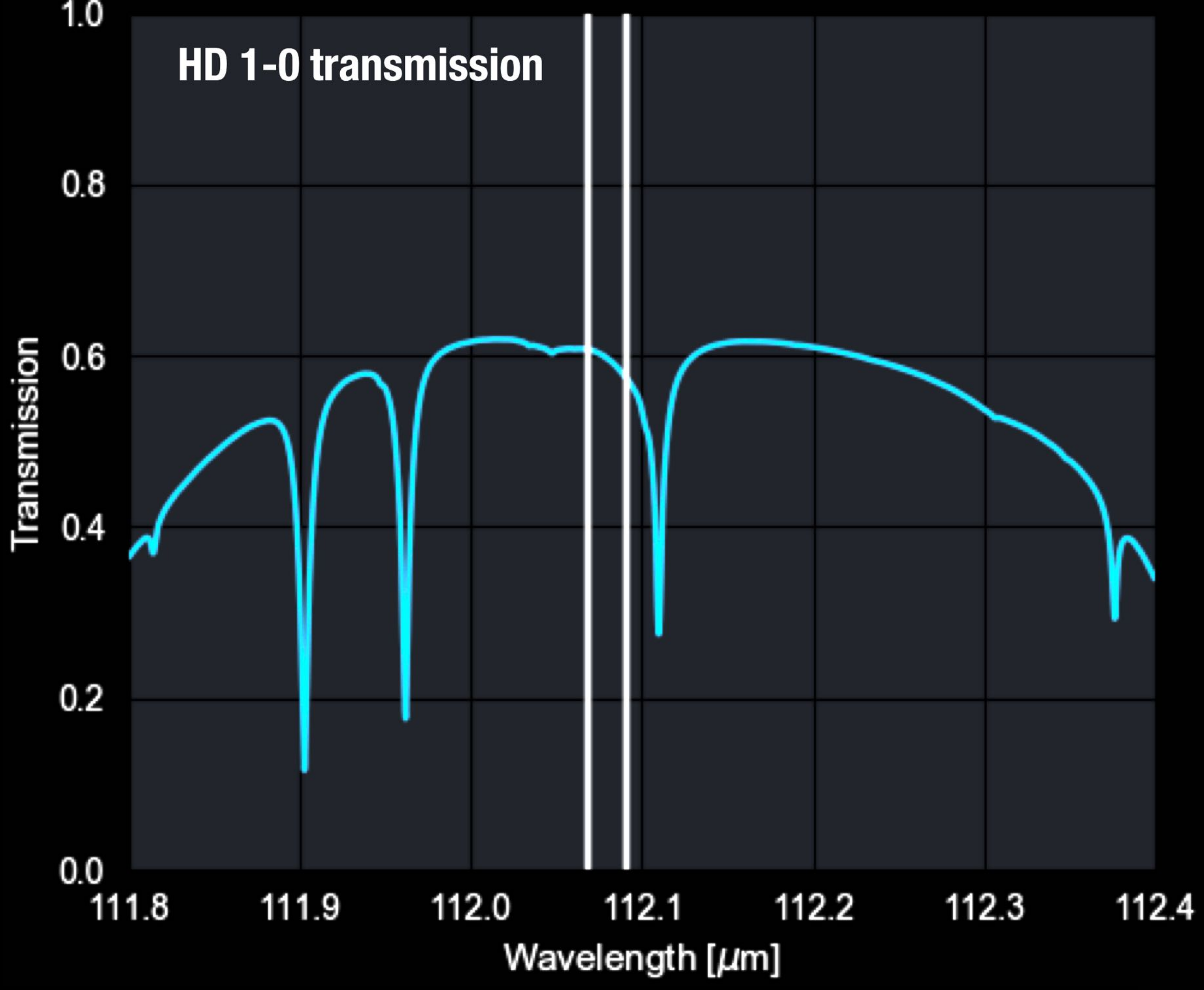
Line tomography as an independent measure of abundance distributions

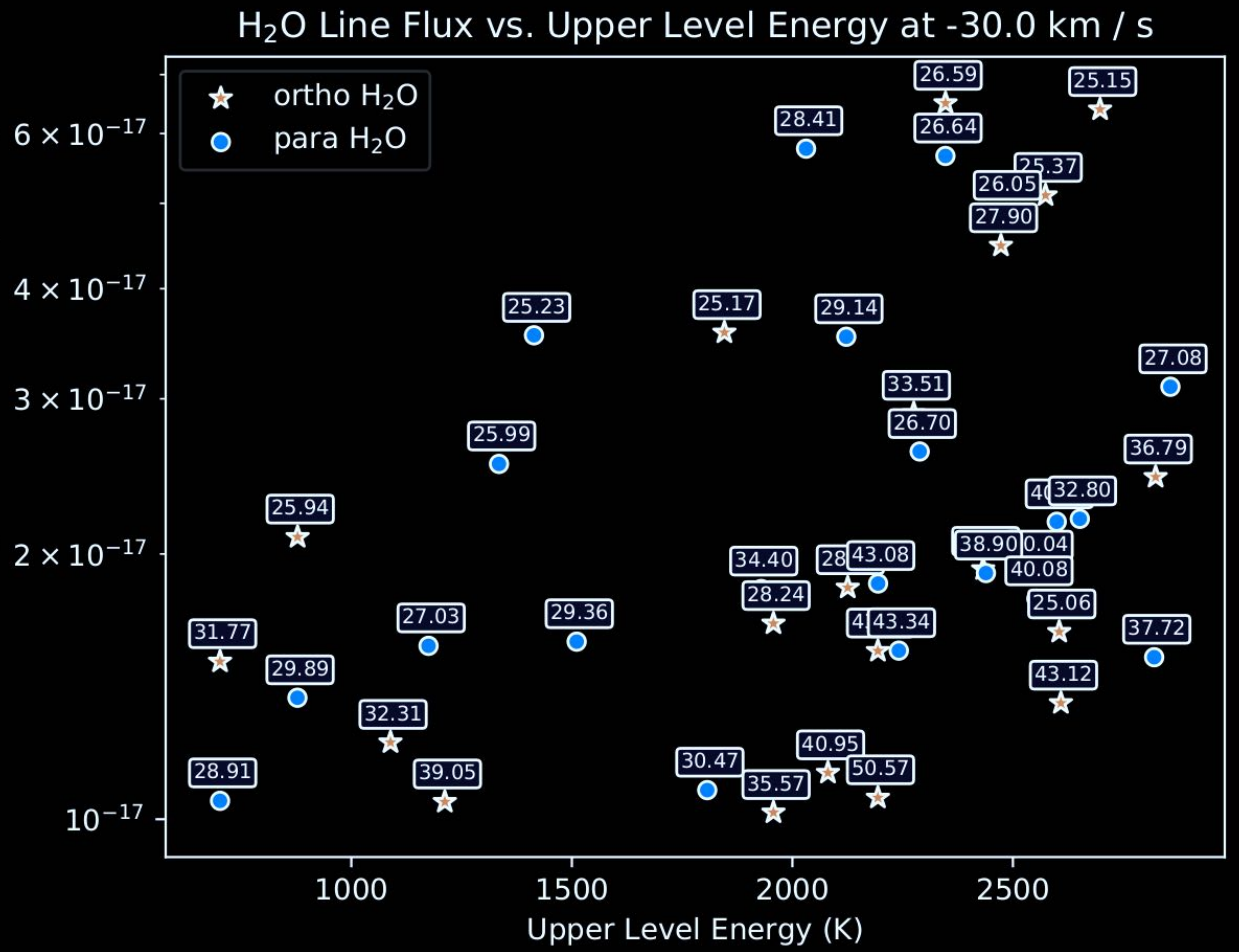


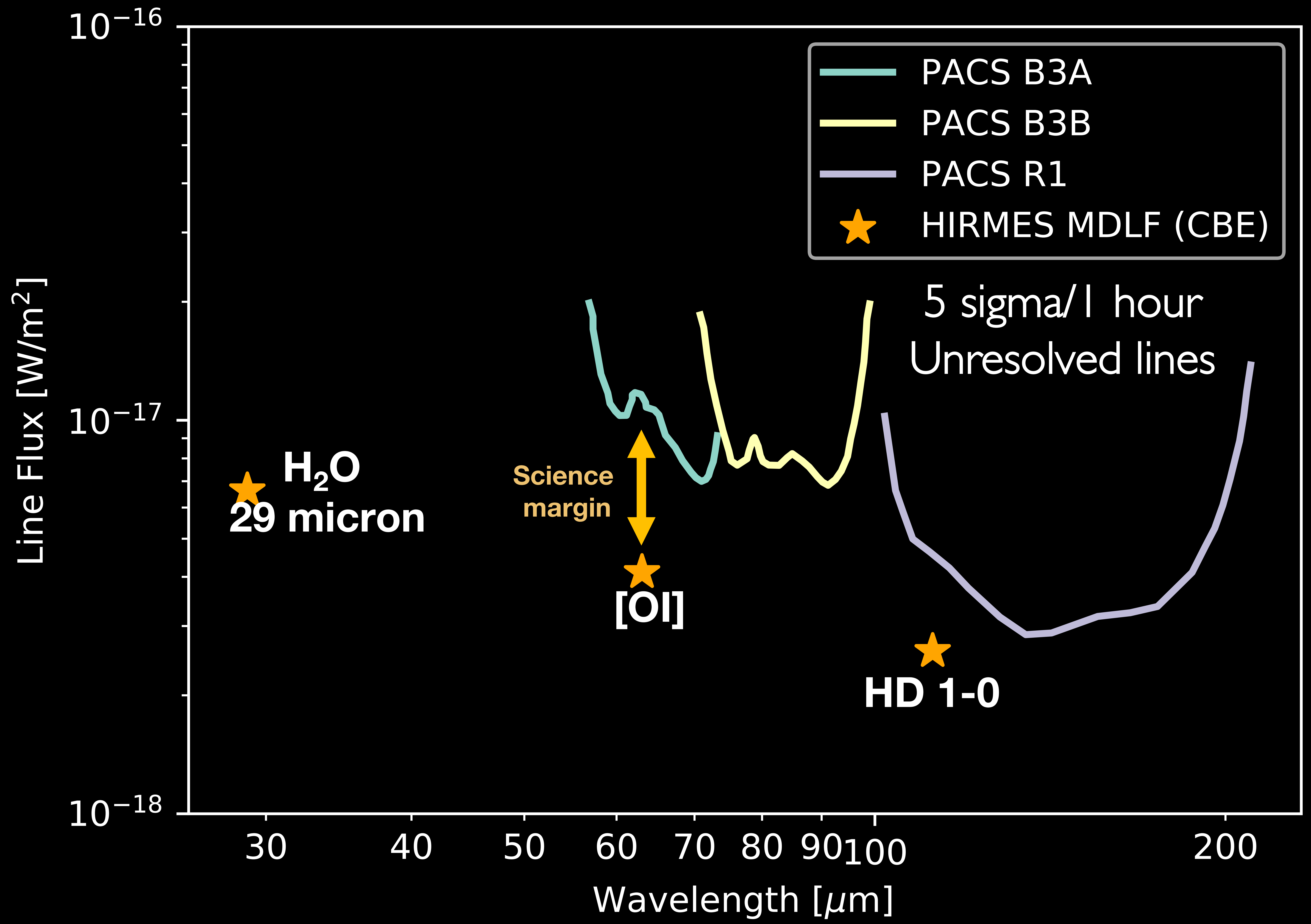
Value of resolving power



Transmission from the stratosphere

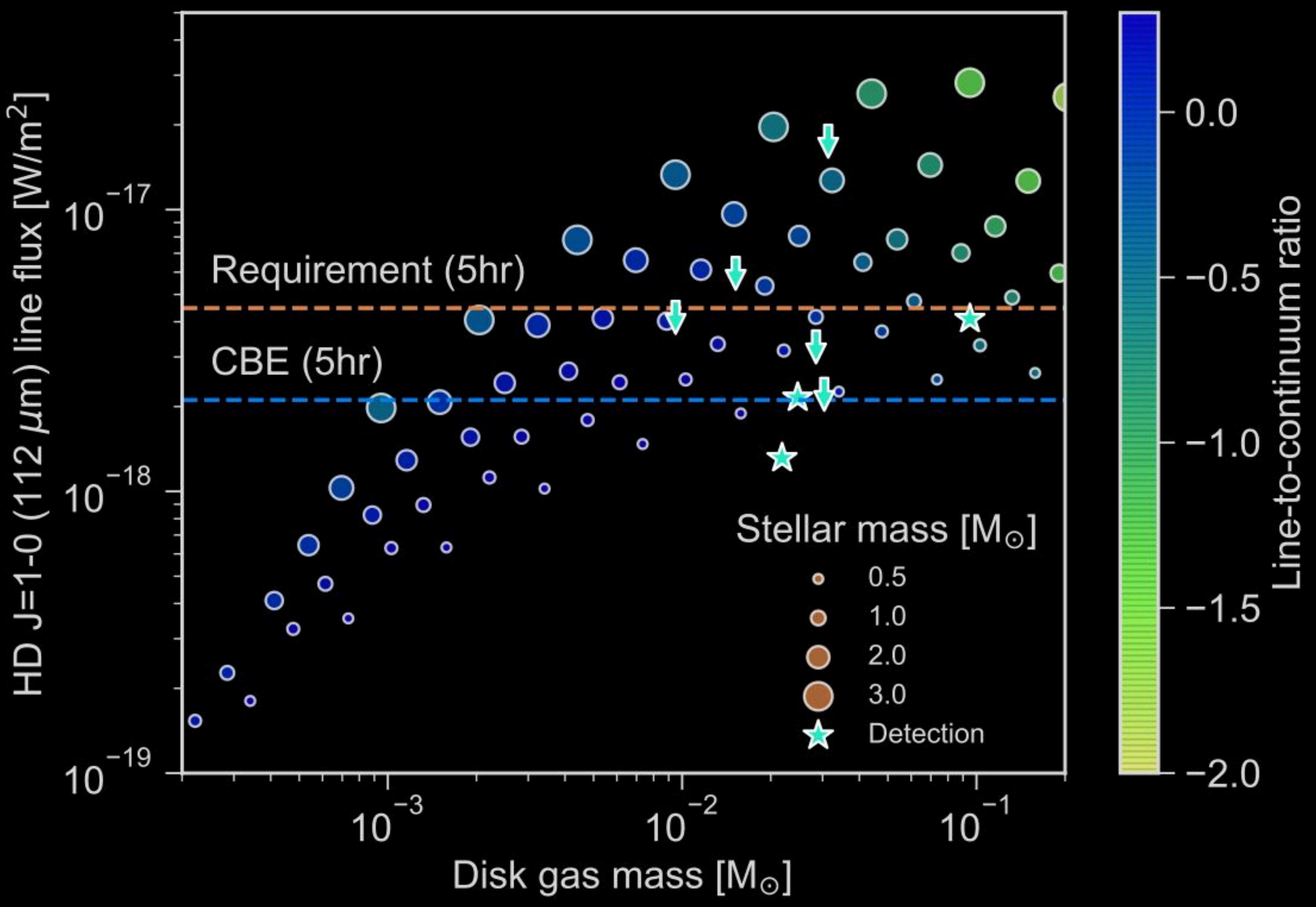






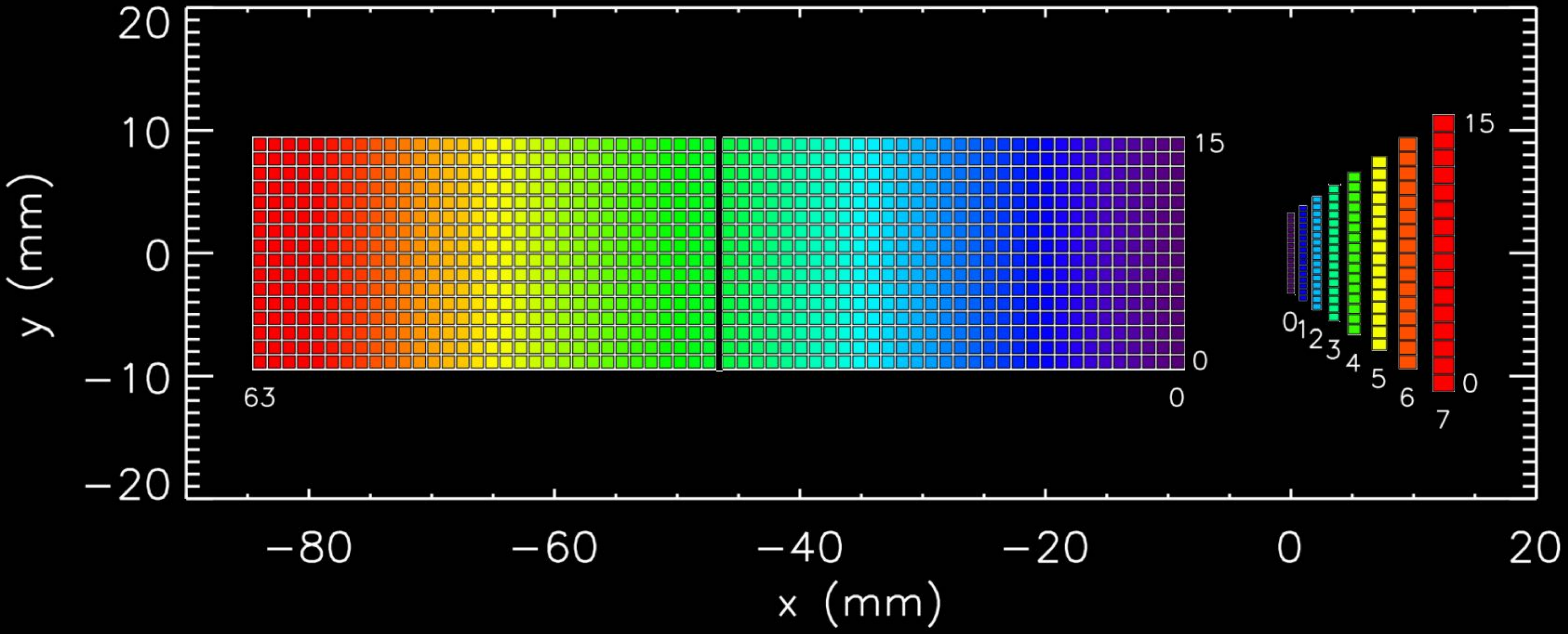
PACS B3A
PACS B3B
PACS R1
HIRMES MDLF (CBE)
5 sigma/1 hour
Unresolved lines
H_2O
29 micron
Science margin
[OI]
HD 1-0
Line Flux [W/m^2]
10^{-16}
10^{-17}
10^{-18}
30
40
50
60
70
80
90
100
200
Wavelength [μm]

Comparison with existing HD detections

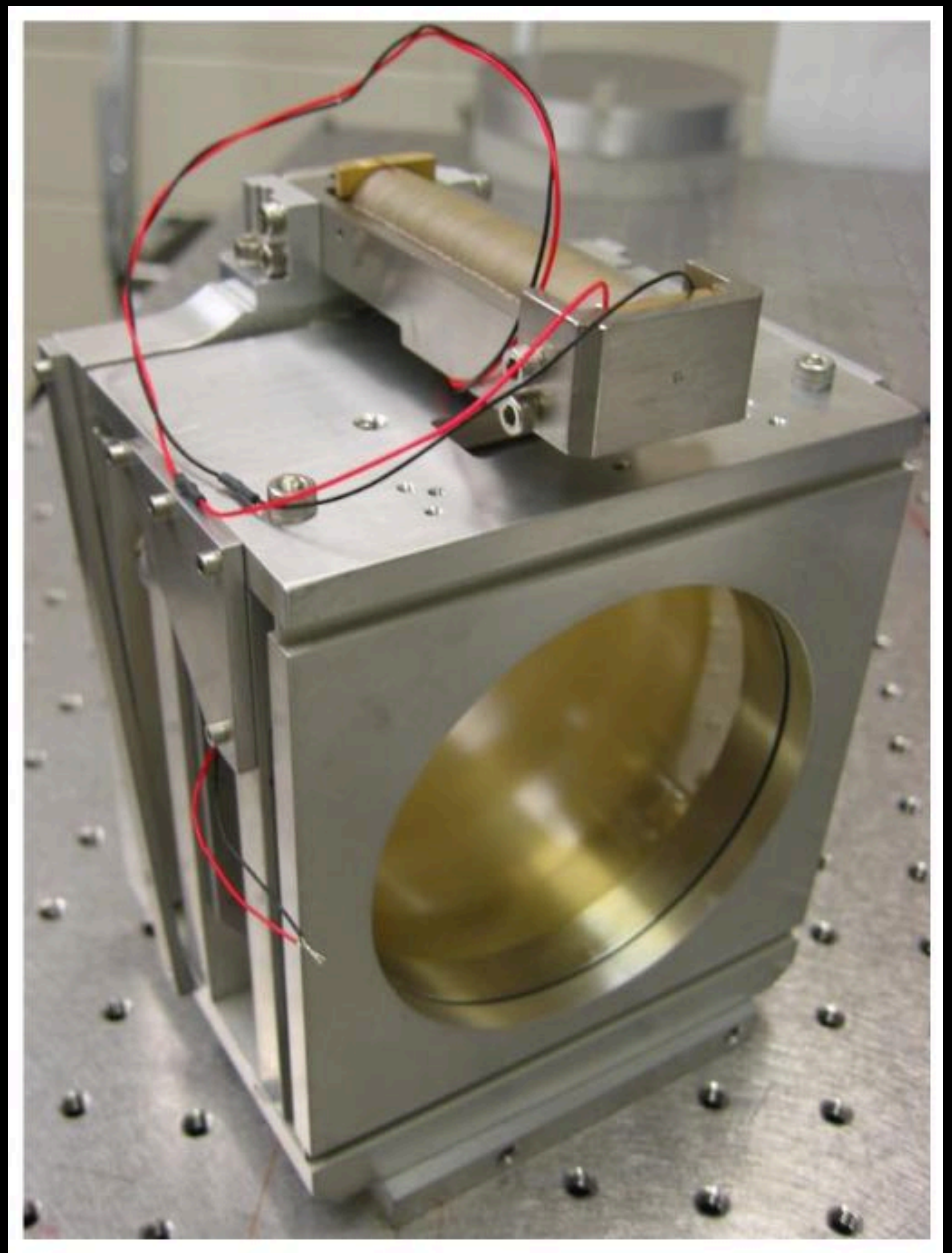


The HIRMES sensitivity is achieved by…

HIRMES TES detectors



Fabry-Perot spectroscopy

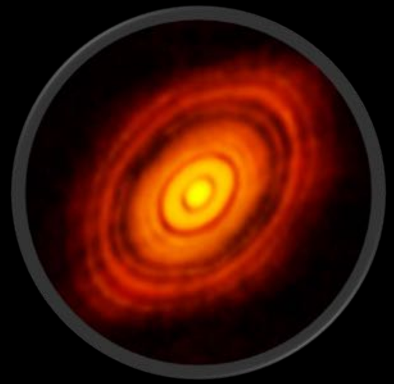


Richards et al. 2018
Barrentine et al. 2018
Brown et al. 2018
Miller et al. 2018
Douthit et al. 2018

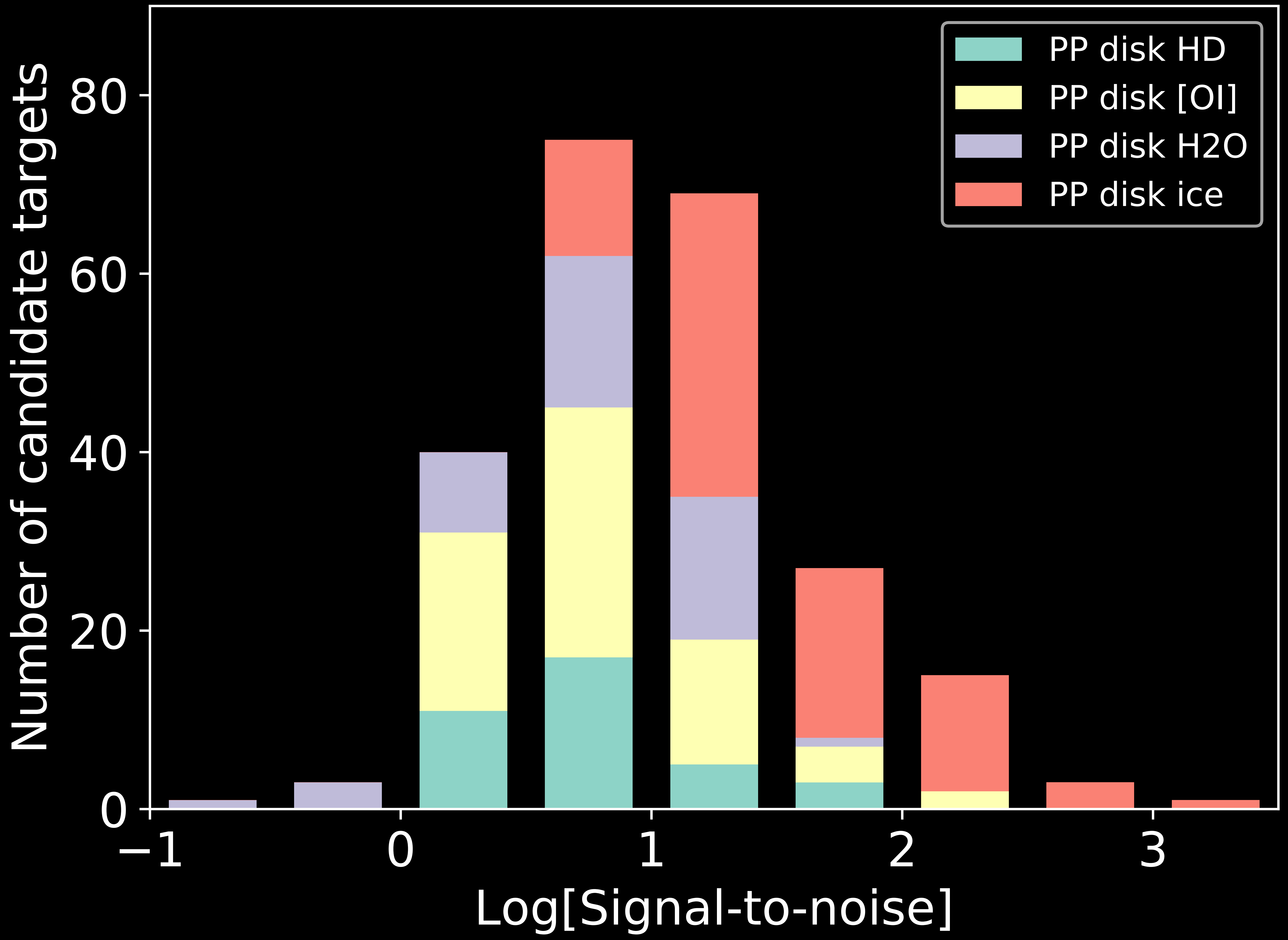
Planned legacy science investigation

- **For the community**
- **No proprietary time**
- **Lots of remaining potential for GO programs**

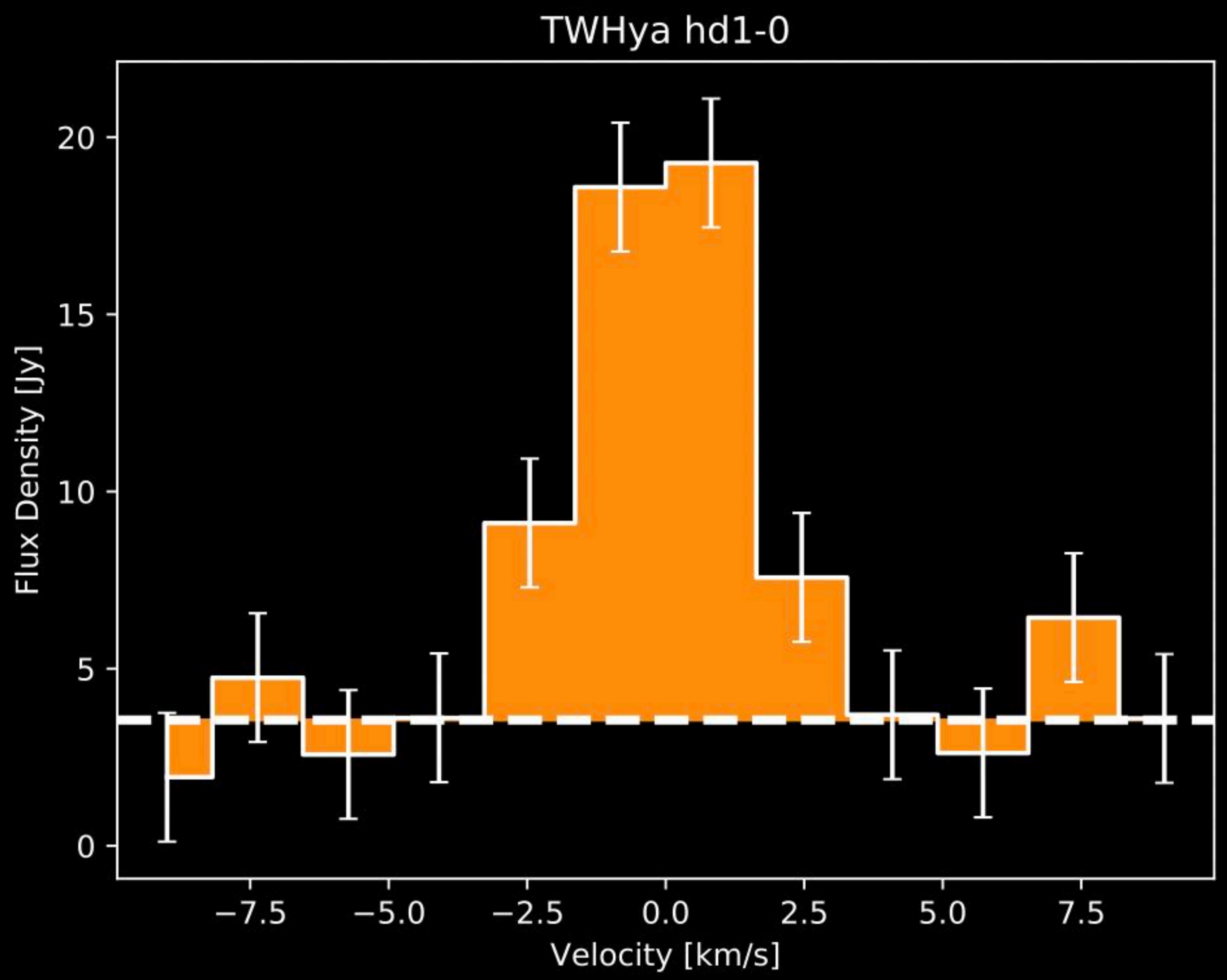
1. **HD:** measure disk masses, needed by ALMA+JWST studies of the same disks
2. **Water vapor:** locate inner disk molecular gas observed by JWST
3. **Water ice:** measure ice/rock ratio in ALMA+JWST selected disks
4. **Oxygen:** measure energy balance/critical input to thermochemical models



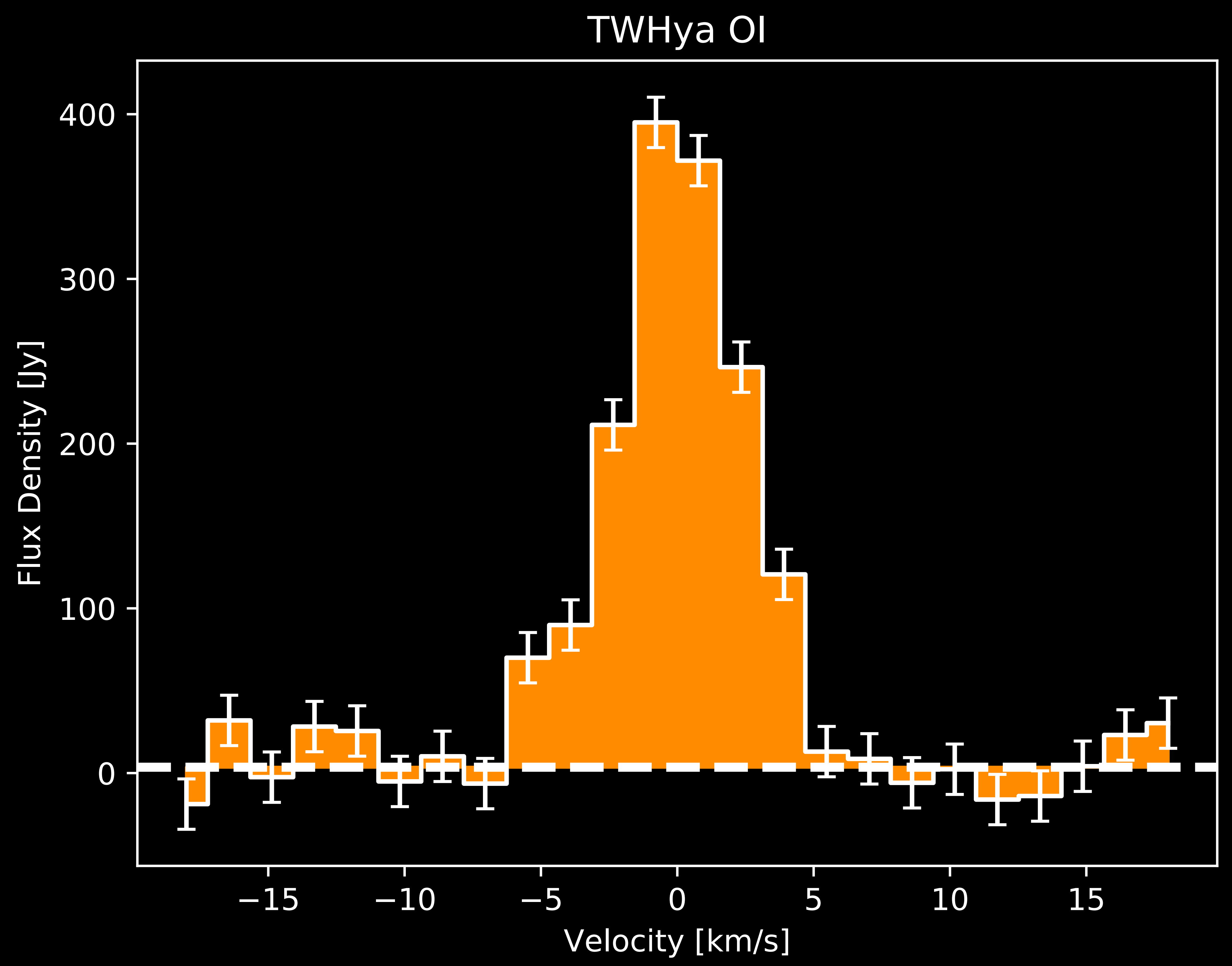
Available protoplanetary disk targets



High-resolution of HIRMES observations of TW Hya

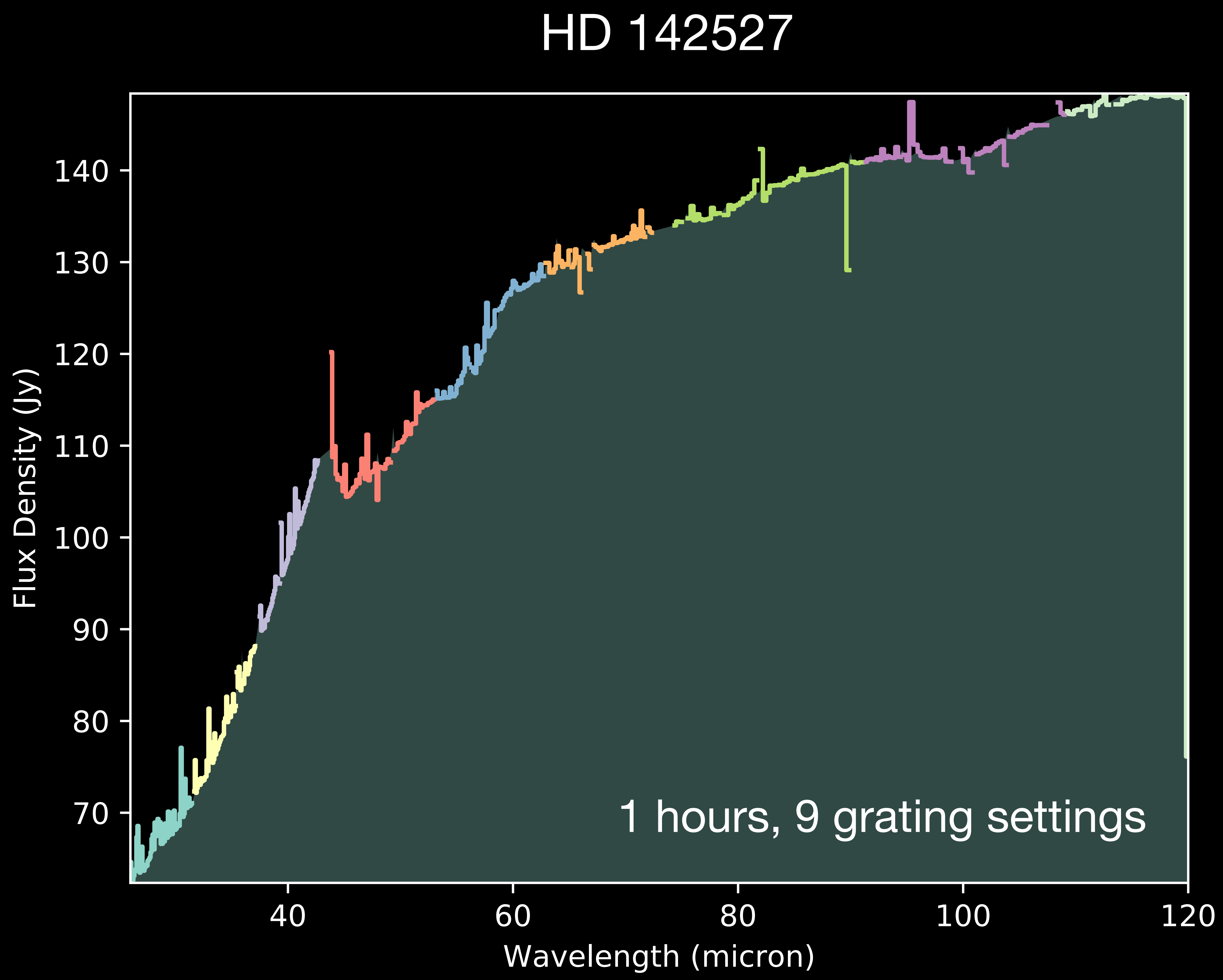


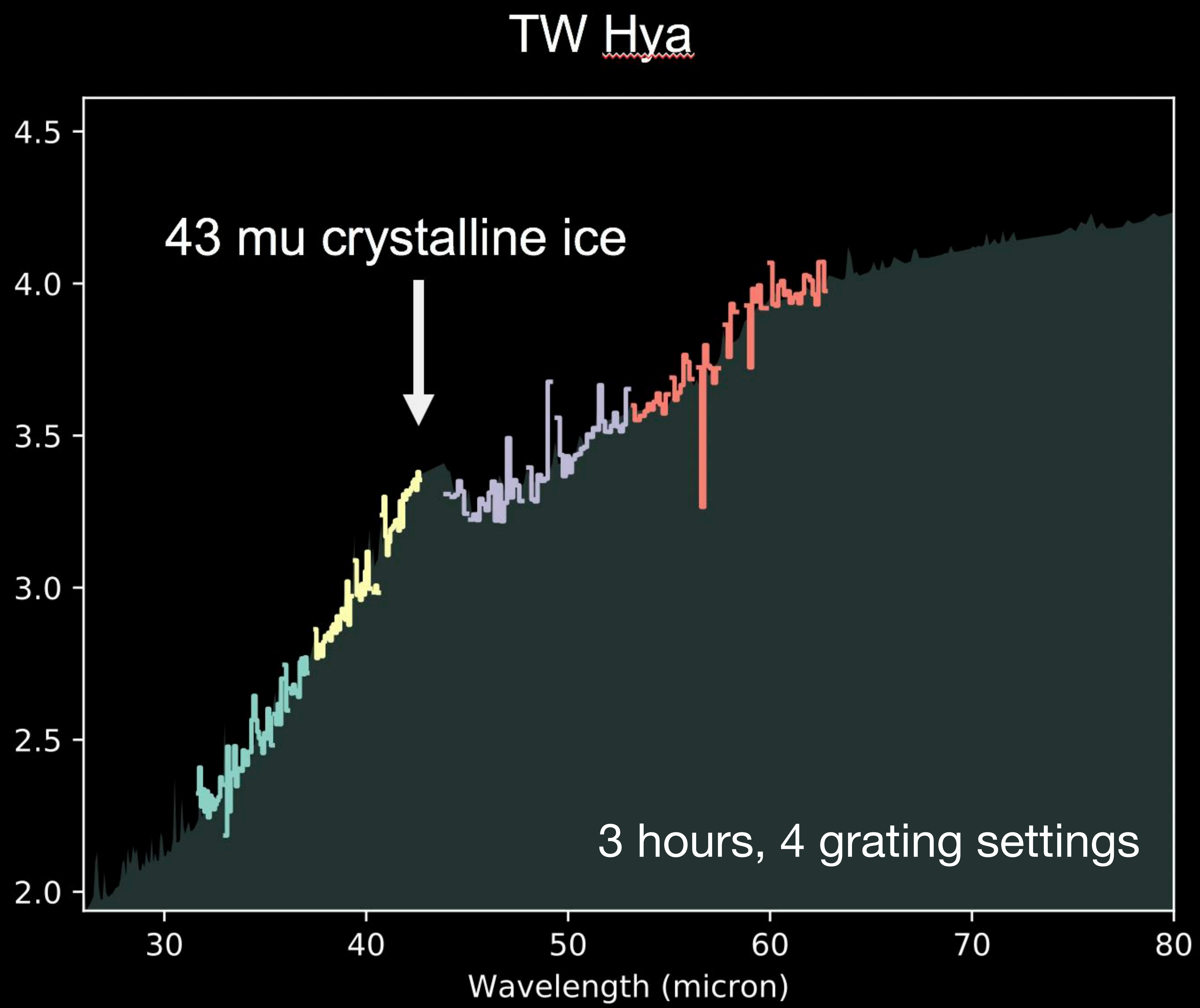
18 km/s scan, 4 hours



36 km/s scan, 6 minutes

Low-resolution simulations of ice





Summary of future infrared disk spectroscopy