Silicate clouds and a circumplanetary disk in the YSES-1 exoplanet system

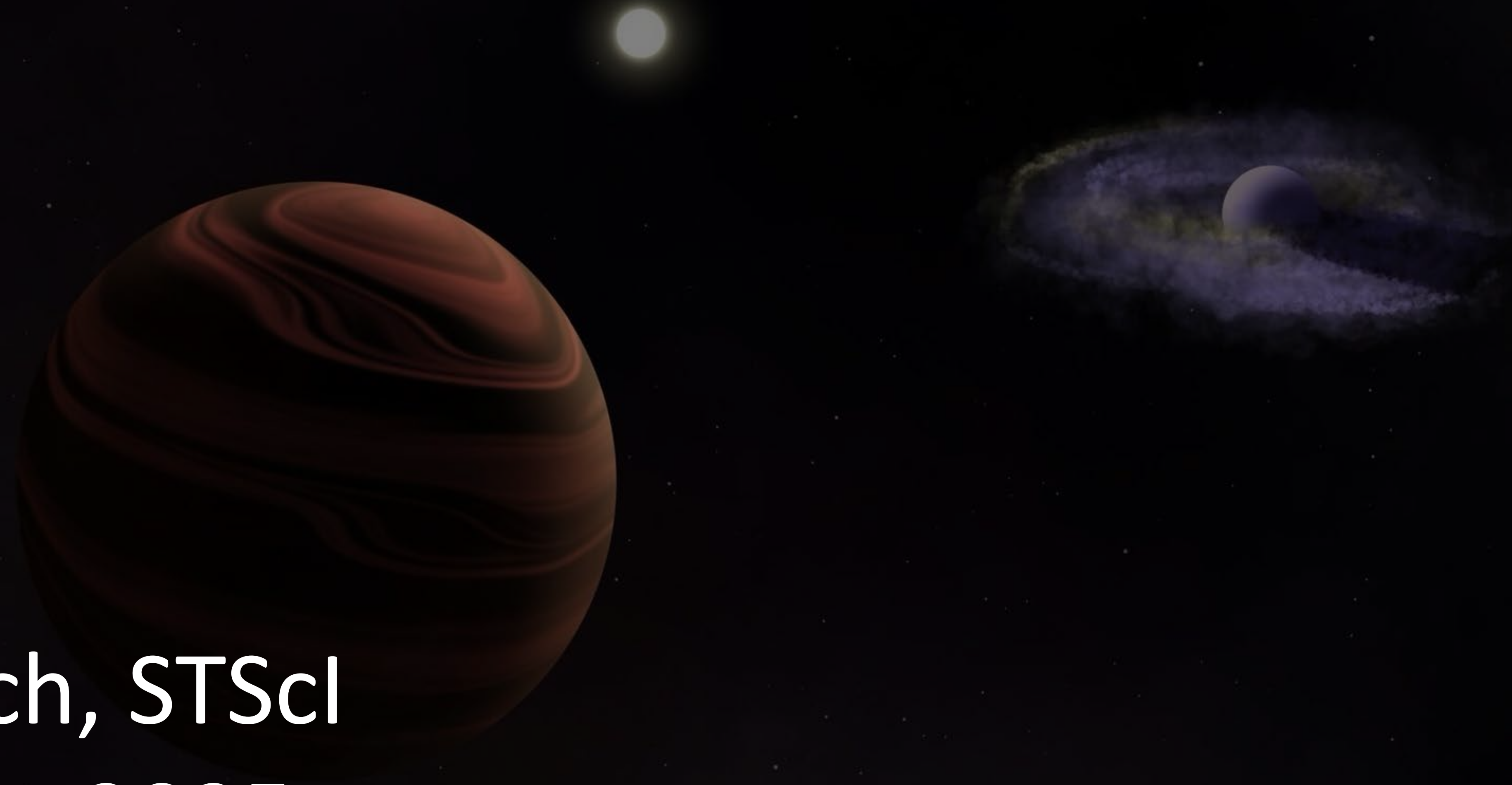


Image Credit: Ellis Bogat

Dr. Kielan Hoch, STScI

AAS 246, June, 2025

The team:

Melanie Rowland, Simon Petrus, Carl Ingebretsen, Evert Nasedkin, Marshall Perrin, Alex Madurowicz, Jens Kammerer, Eileen Gonzales, Sarah Moran, Christopher Theissen, William Balmer, Caroline Morely, Christine Chen, Laurent Pueyo, Emily Rickman, J.-B. Ruffio, Valentina D'Orazi, Yapeng Zhang, Kim Ward-Duong, Quinn Konopacky, Travis Barman, Bruce Macintosh, Mickael Bonnefoy, Gael Chauvin, Matt Kenworthy, Bin Ren, Julien Girard, Rob De Rosa, Gabriele Cugno, Sierra Grant

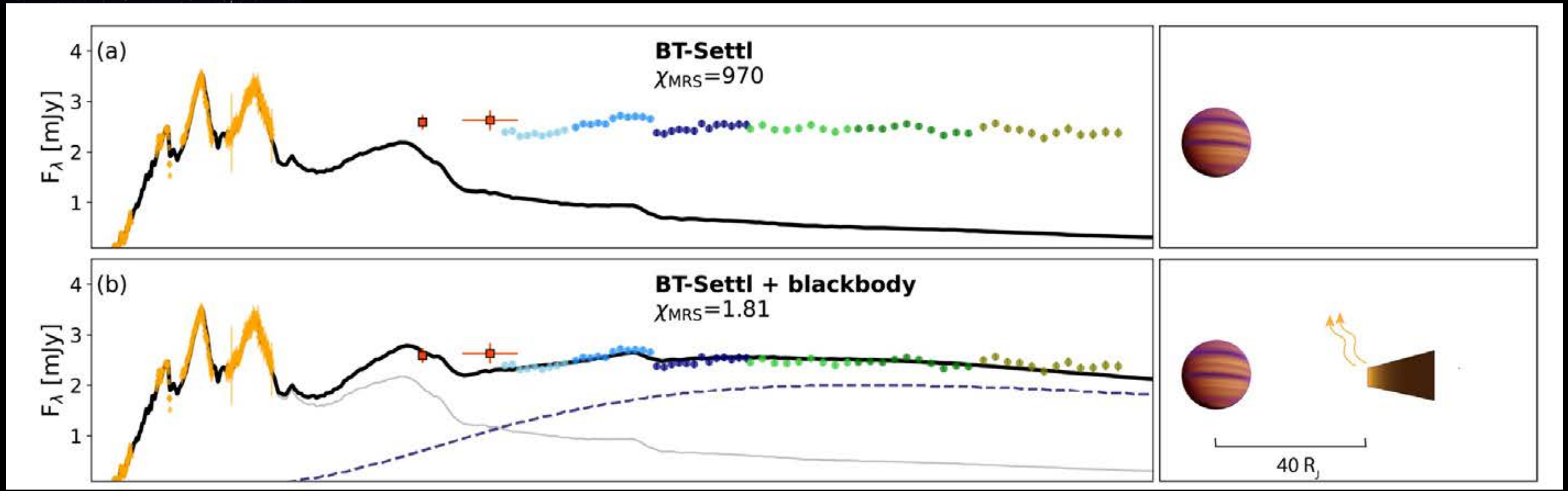
JWST was not made for exoplanet observations, but has made incredible discoveries in the field

Image credit: NASA/ESA/CSA and Joseph Olmsted (STScI)

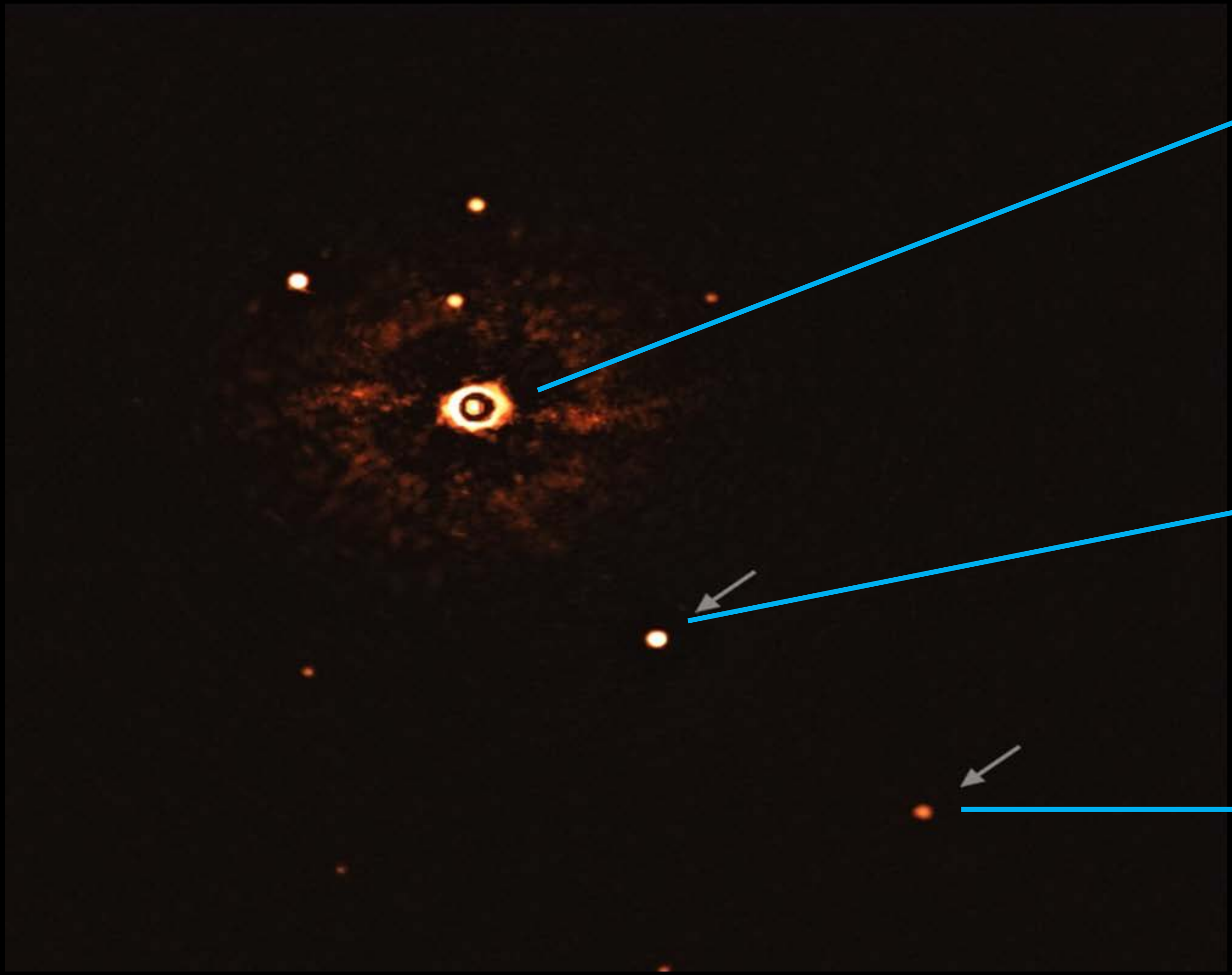
- Silicate clouds in a *planetary mass companion* to an M dwarf binary system
- Led by early career researcher Brittany Miles

- Circumplanetary disk around *brown dwarf companion*
- Led by early career researcher Gabriele Cugno

Cugno et al. 2024



The YSES-1 exoplanetary system



Host Star: Solar-type

- Sun mass
- ~16 millions years old
- 100 parsecs away (~326 light years)

YSES-1 b:

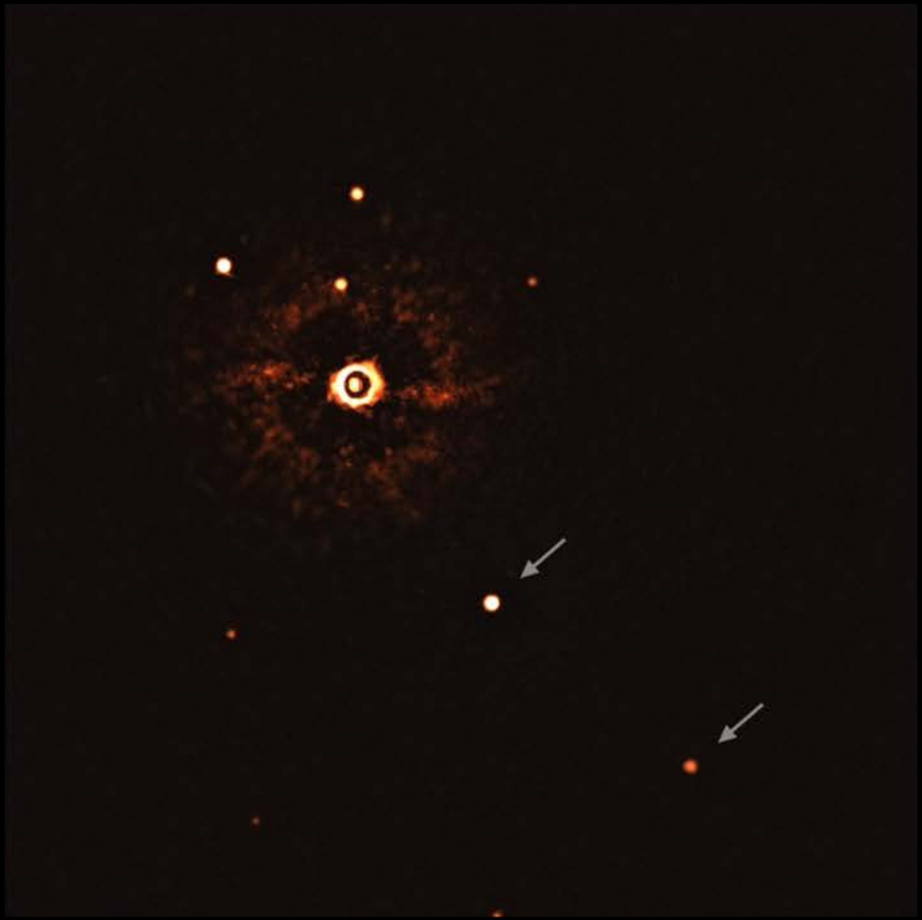
- 160 au away from its star
- 14 times the mass of Jupiter

YSES-1 c:

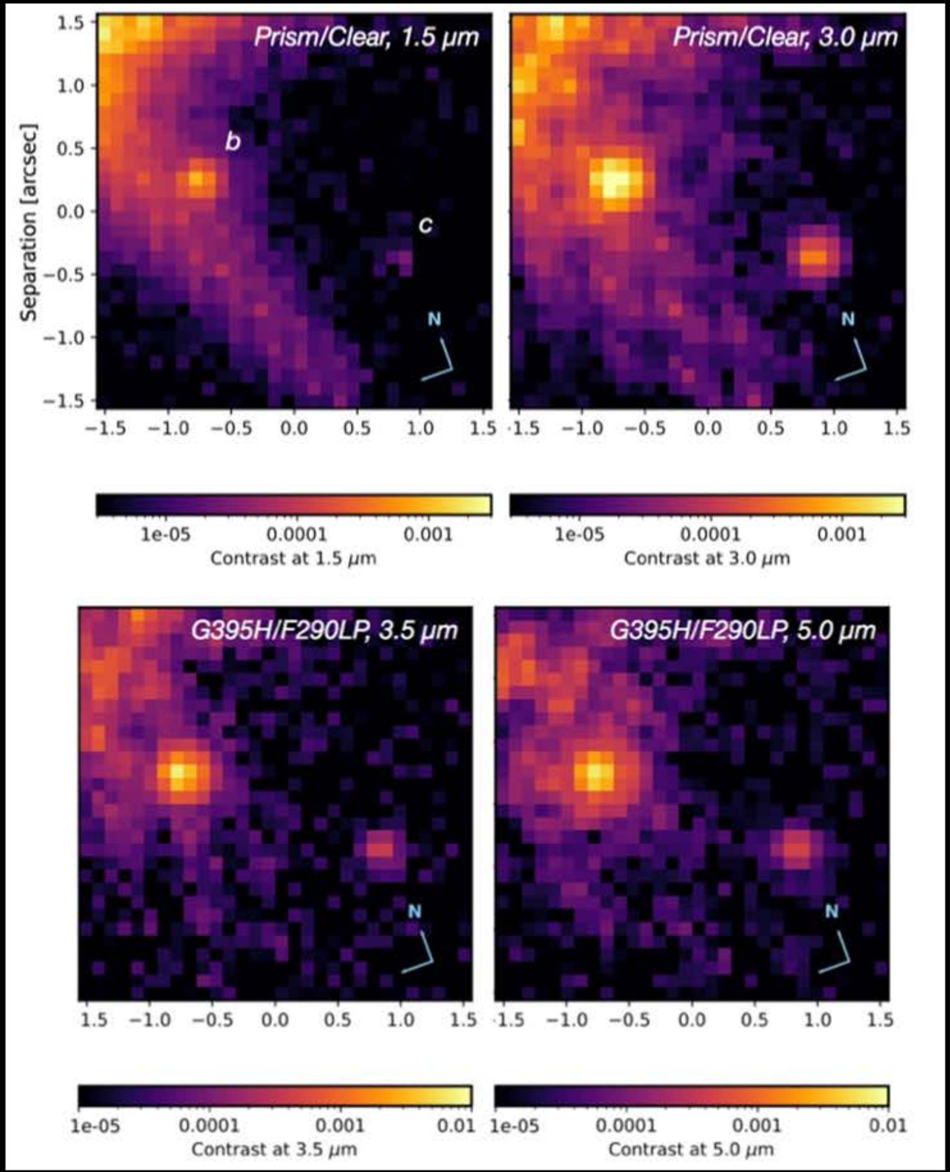
- 320 au away from its star
- 6 times the mass of Jupiter

Bohn et al. 2020

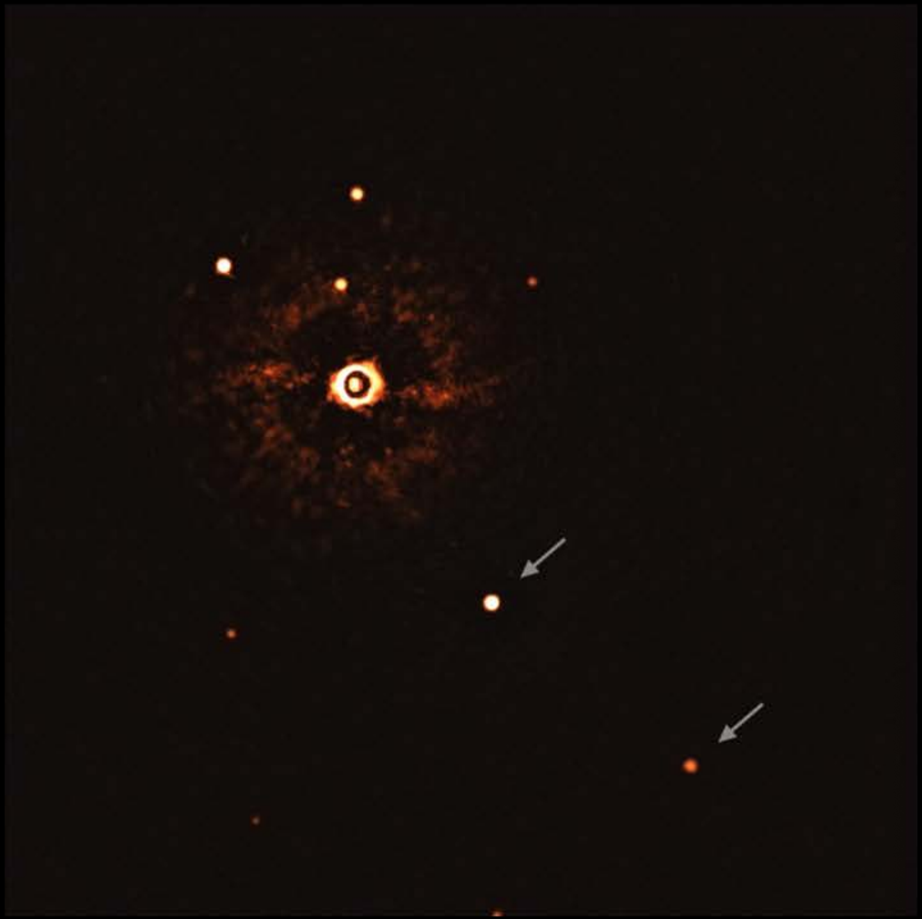
JWST Cycle 1 Program: Spectroscopy of the multi-planet system YSES-1



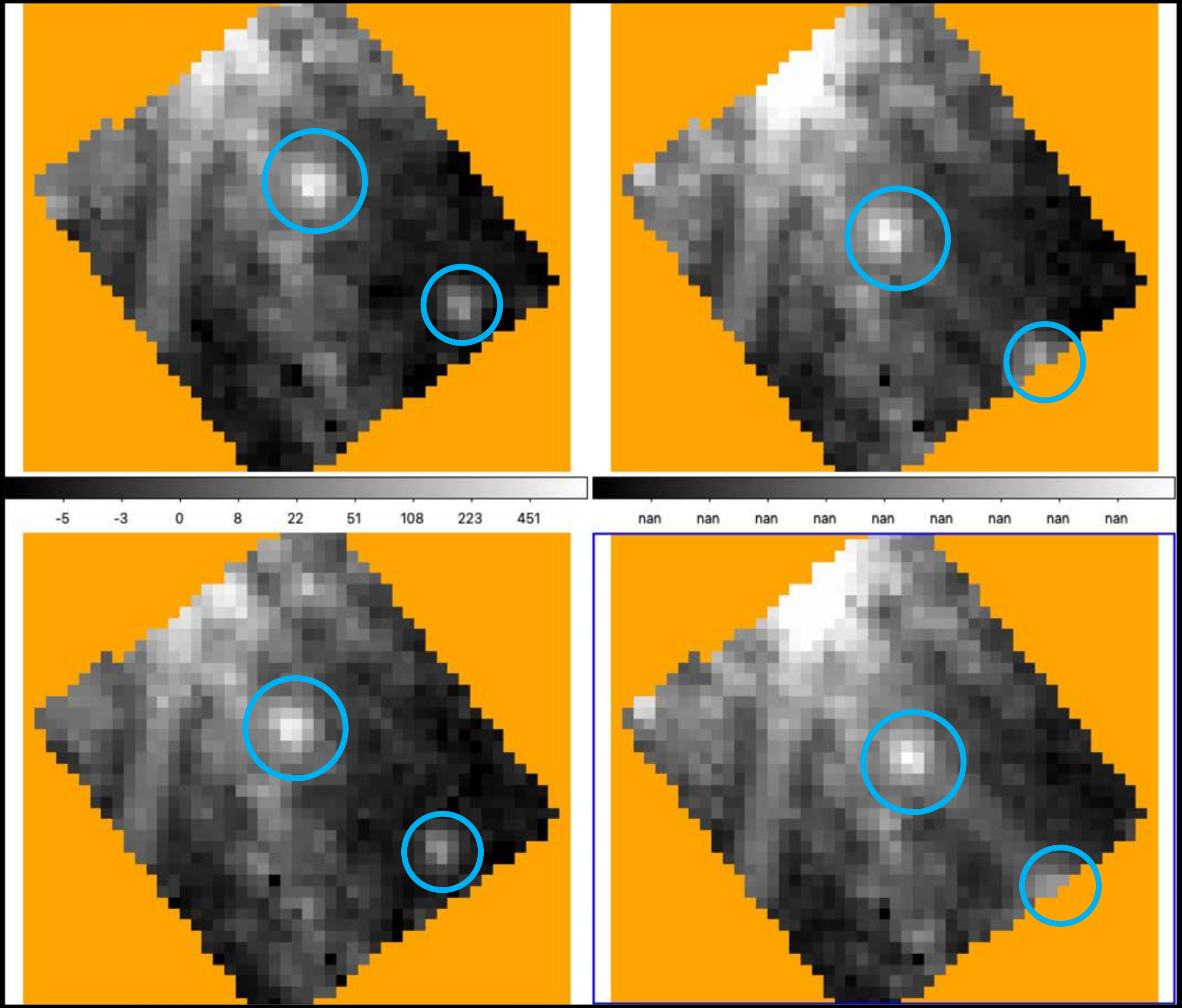
Bohn et al. 2020



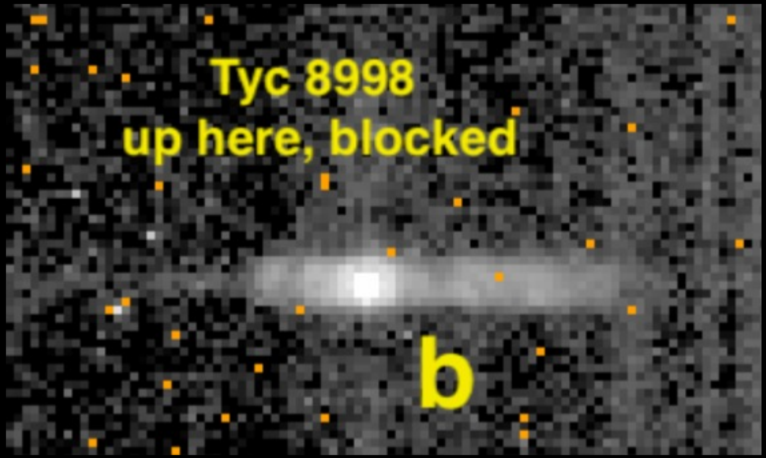
Spectroscopy of the multi-planet system YSES-1

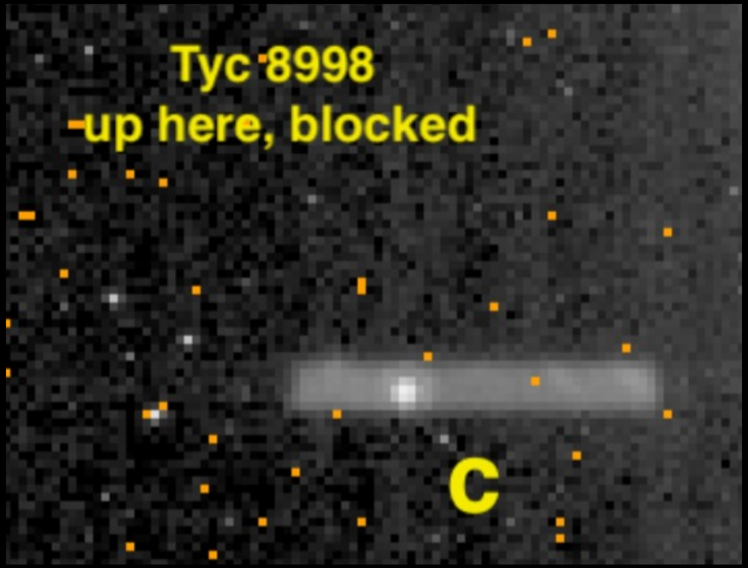


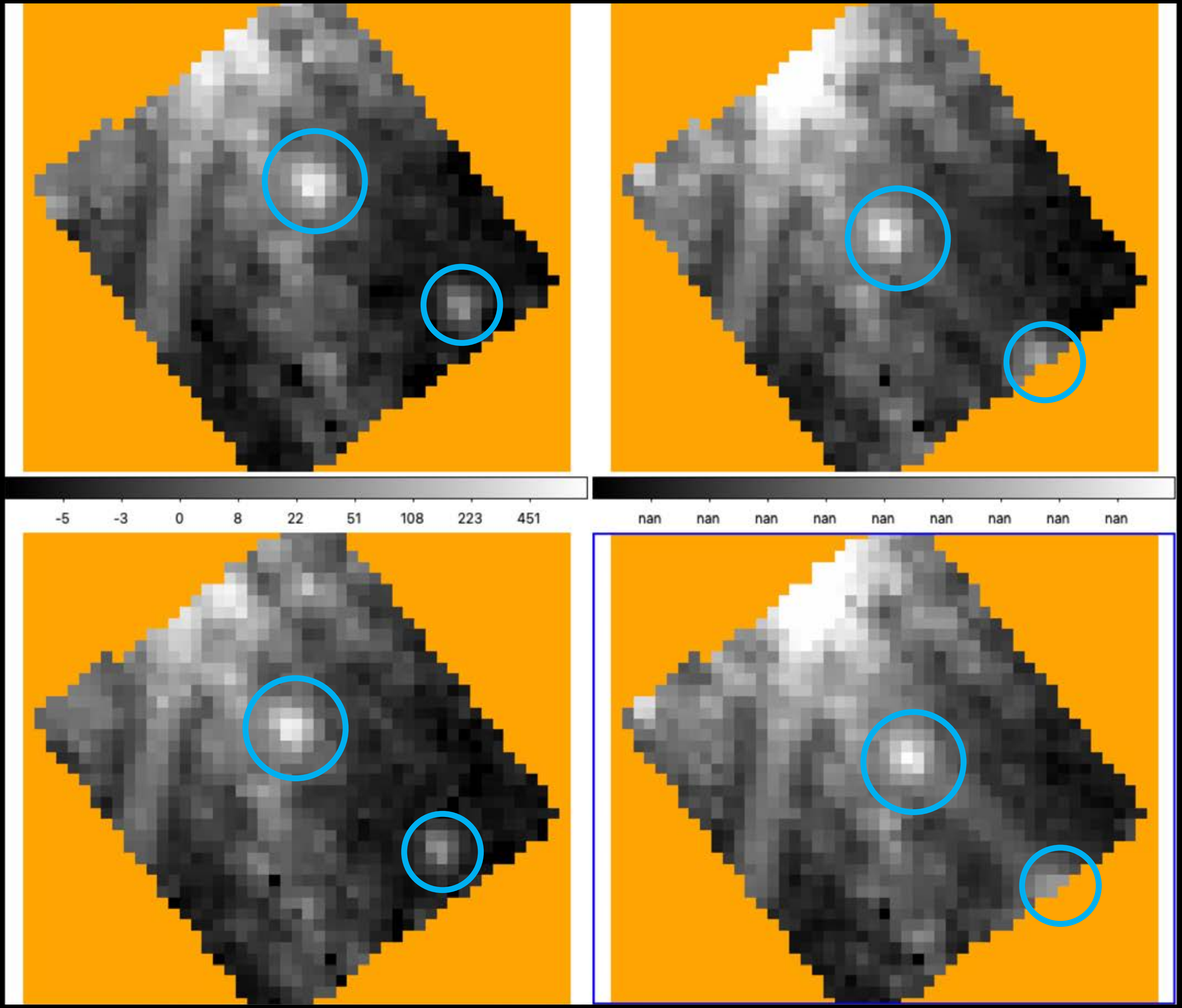
Bohn et al. 2020



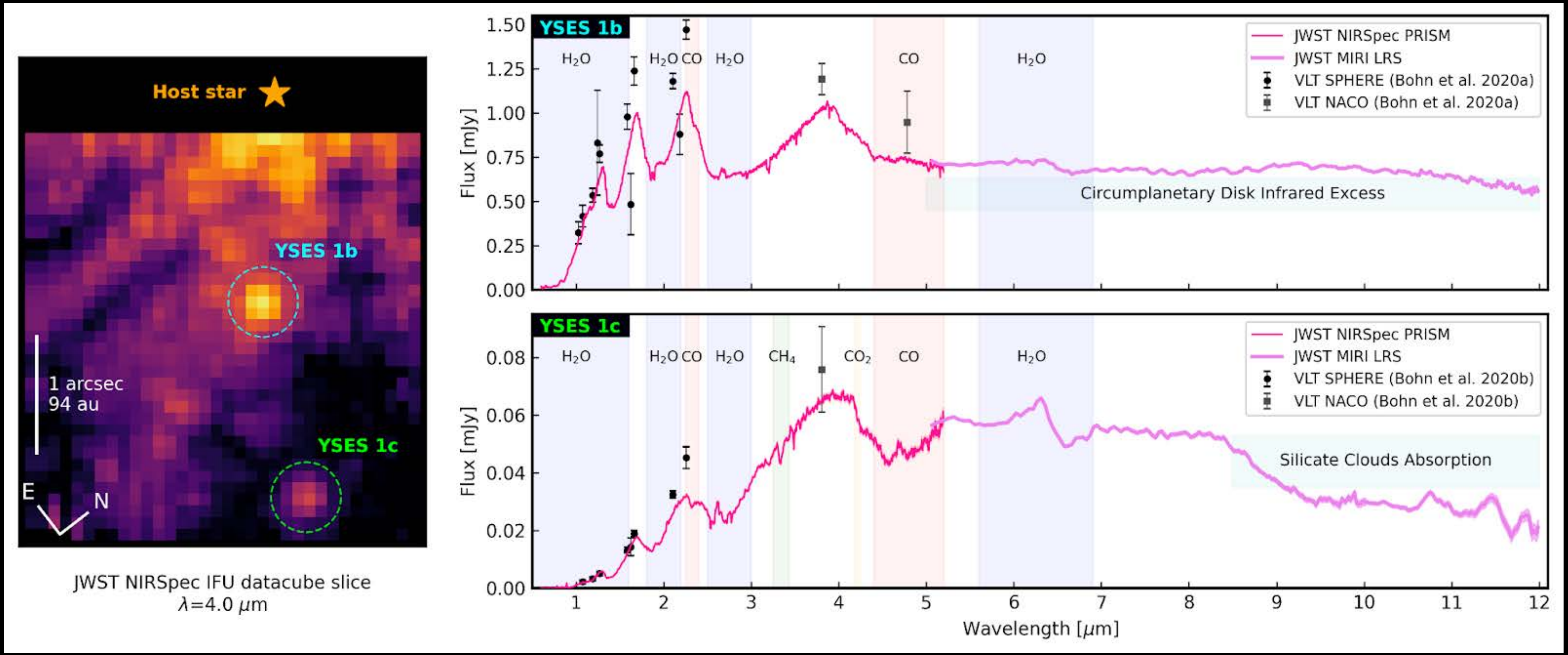
Spectroscopy of the multi-planet system YSES-1





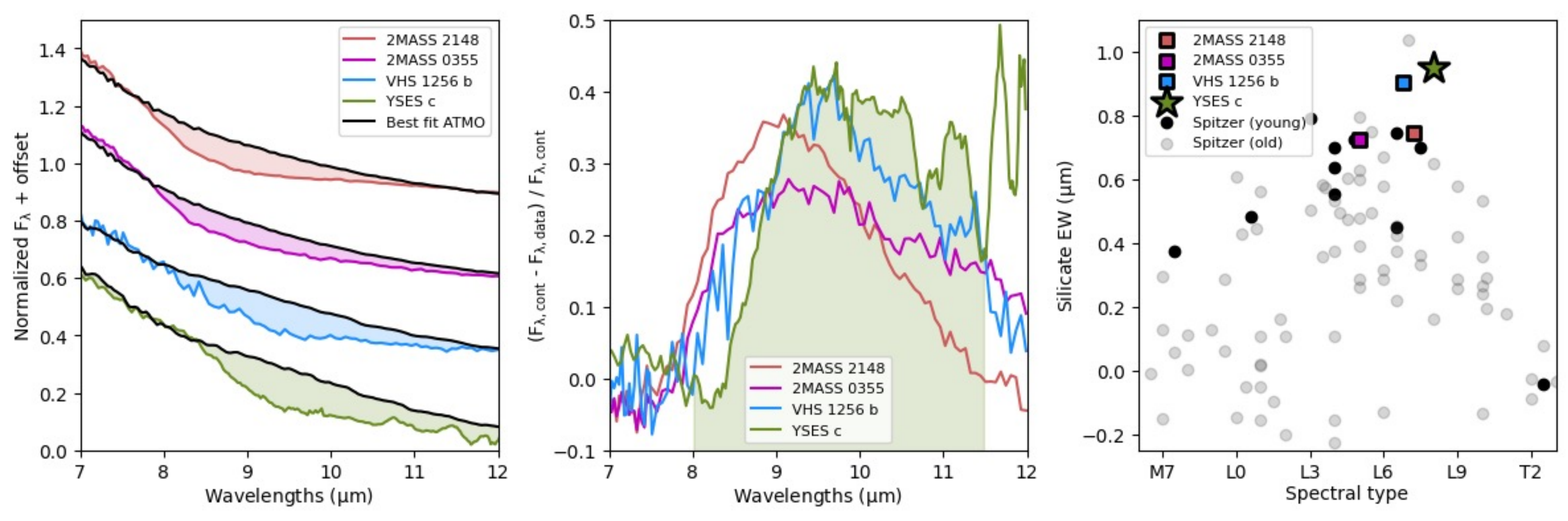


YSES-1 system total spectral coverage with JWST



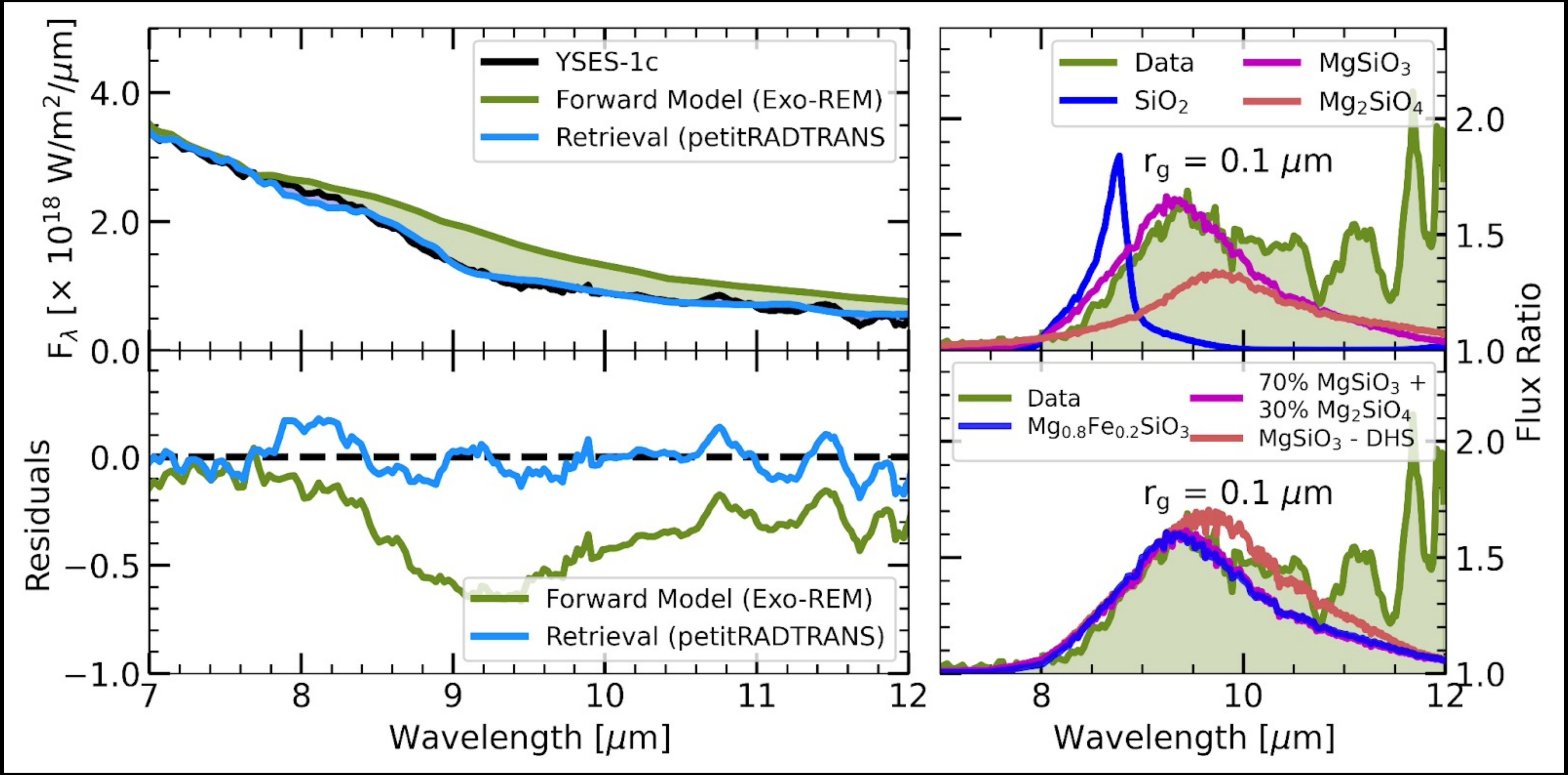
Hoch et al. 2025

Not only do models not fit the feature, but the feature is distinct from field brown dwarfs and from VHS 1256 b



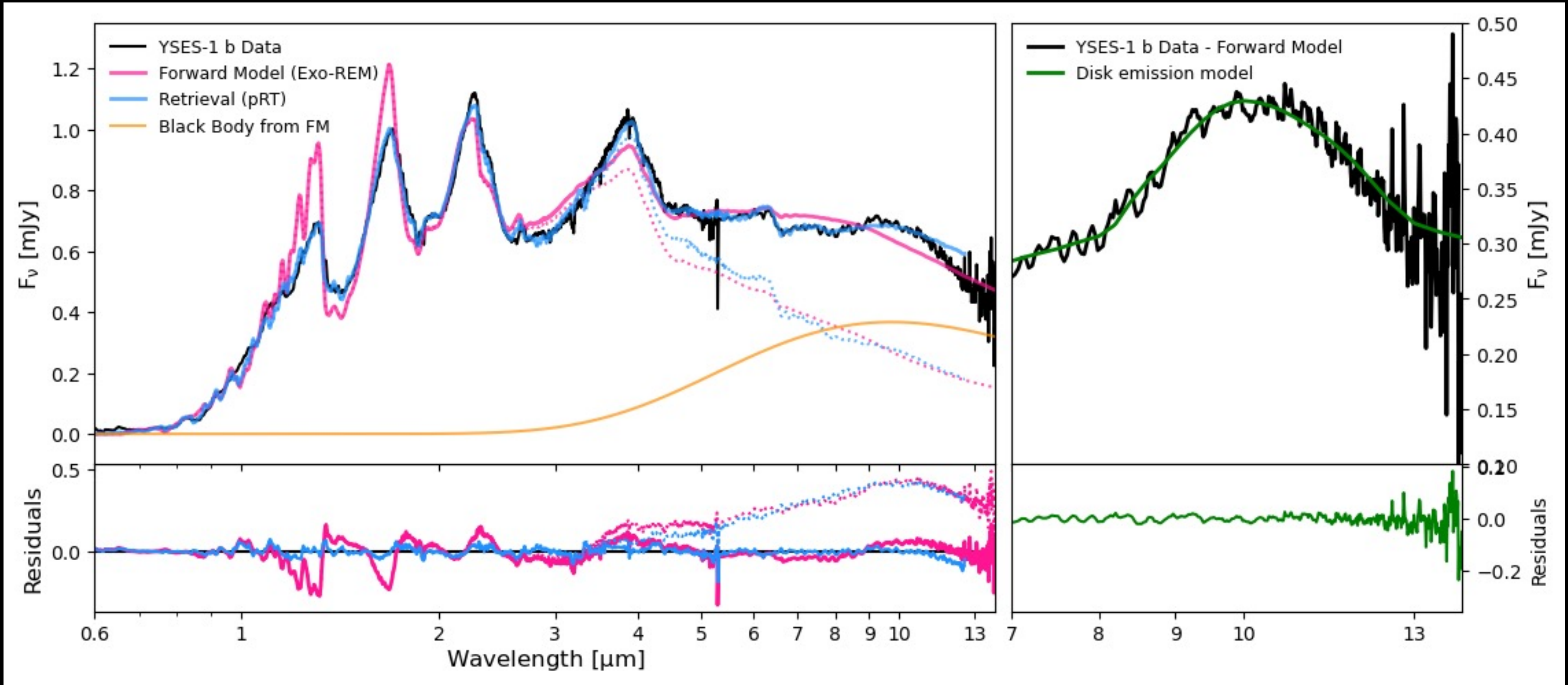
Hoch et al. 2025

The clouds are most likely made of amorphous enstatite with a small amount of iron OR a combination of enstatite and forsterite



Hoch et al. 2025

YSES-1 b: Models could not account for the *first direct detection* of silicate (olivine) emission in a cpd



Hoch et al. 2025

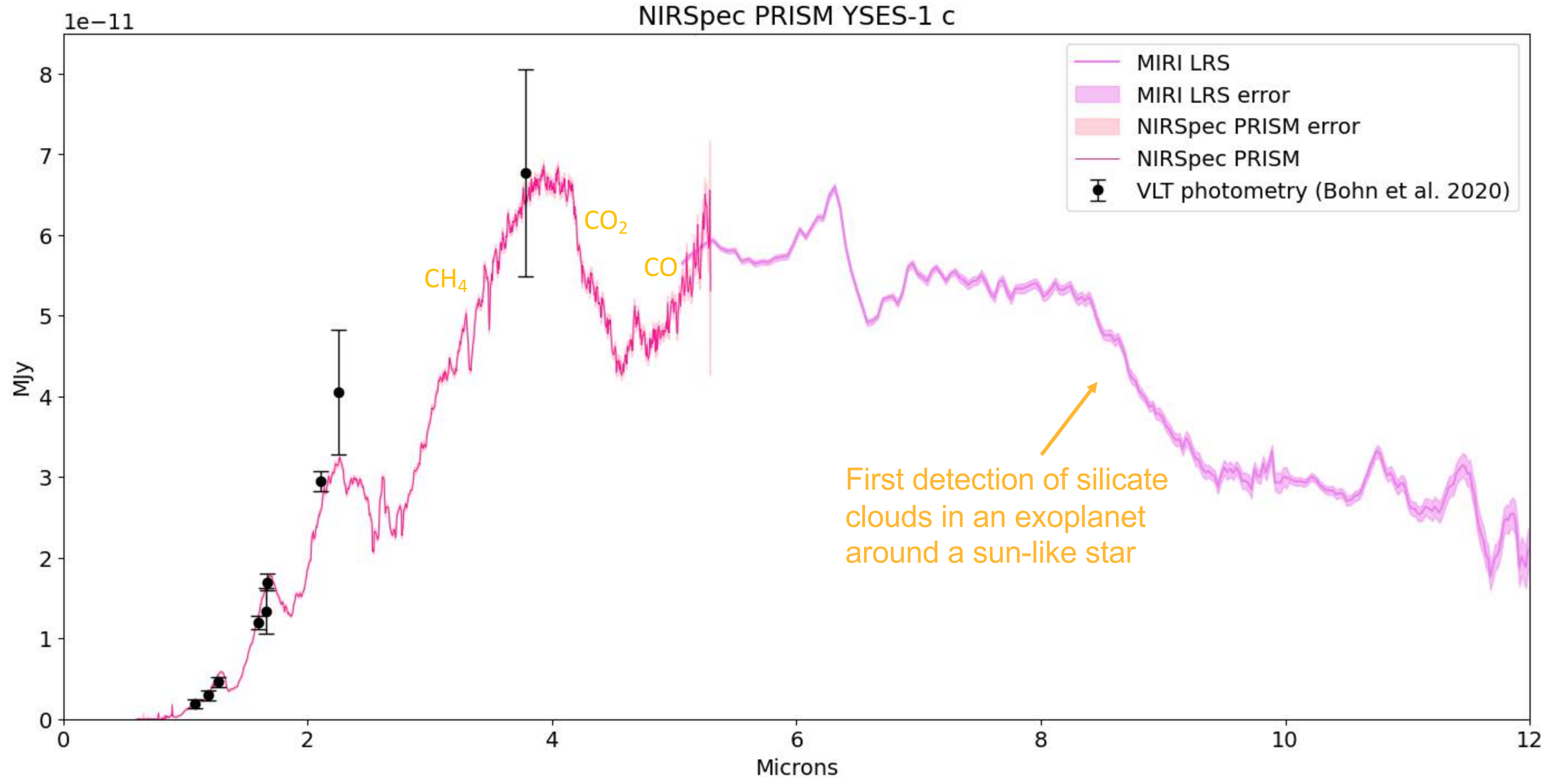
What does this mean for planet formation?

- Theories say that directly imaged planets may have distinct clouds from their brown dwarf counterparts, and we could be seeing the first evidence of this in YSES-1 c!
- Wil this trend hold and can it be linked to how planets form versus brown dwarfs?
- Models tell us that CPD material should be short lived but that may not be the case…
- YSES-1 b is not only old to host a disk, but the olivine emission challenges disk and planet formation models unless we are seeing evidence for collisions or exomoon formation

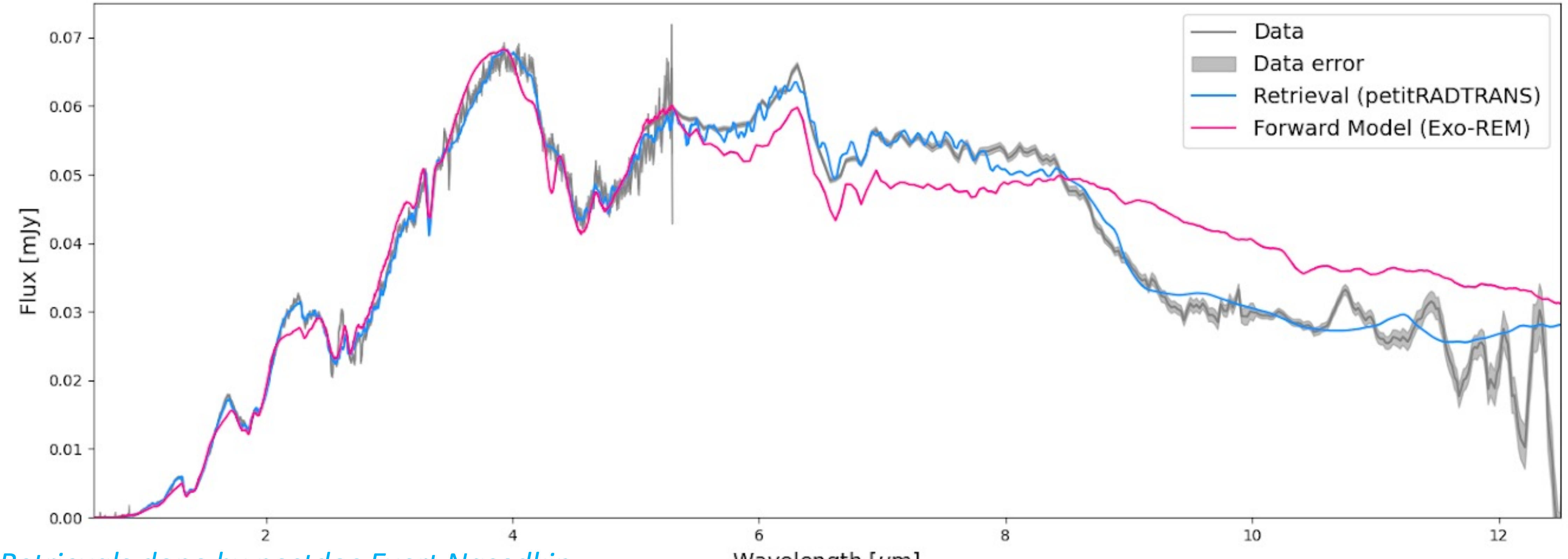
Credit: Ellis Bogat

BACK UP SLIDES

First NIR–>Mid IR Spectra of YSES 1c



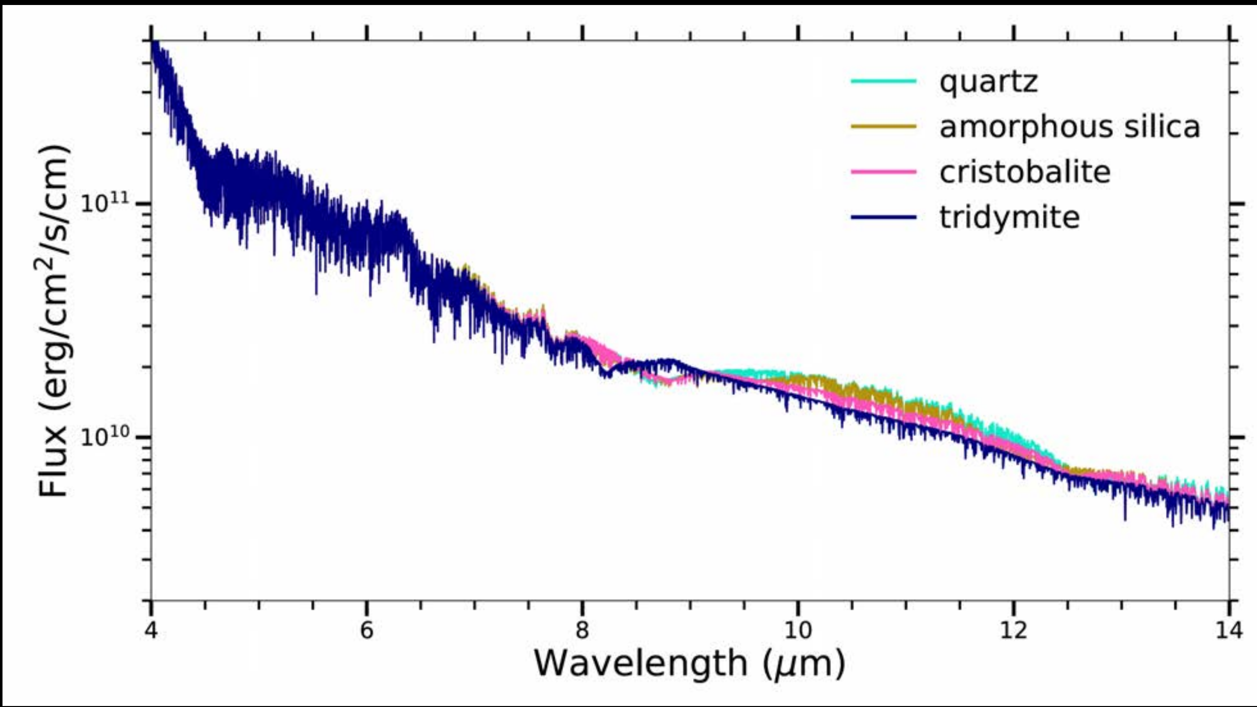
YSES-1 c: Even when using a multidisciplinary approach with retrievals and forward models, the silicate cloud absorption is not well reproduced



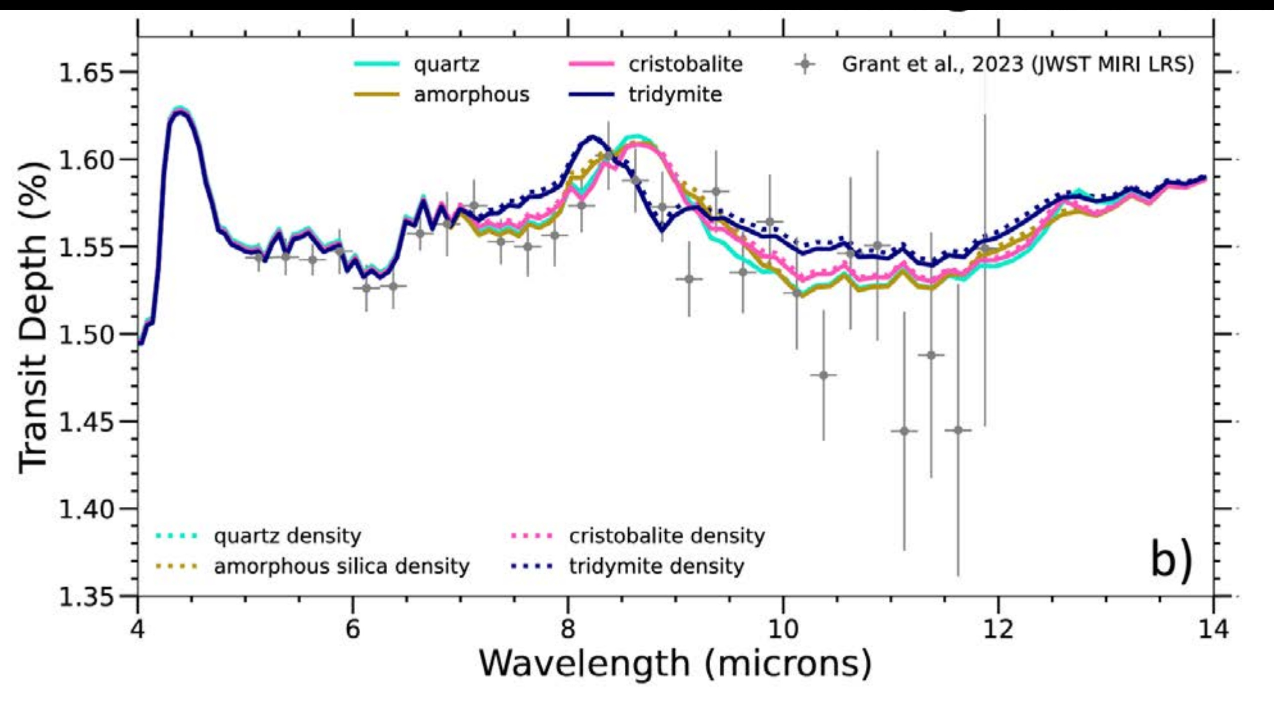
Retrievals done by postdoc Evert Nasedkin

JWST MIRI wavelengths will also test other silicate crystalline structures that may form more easily in atmospheric conditions

Directly imaged L-dwarf models



Transiting WASP-17 b data and models

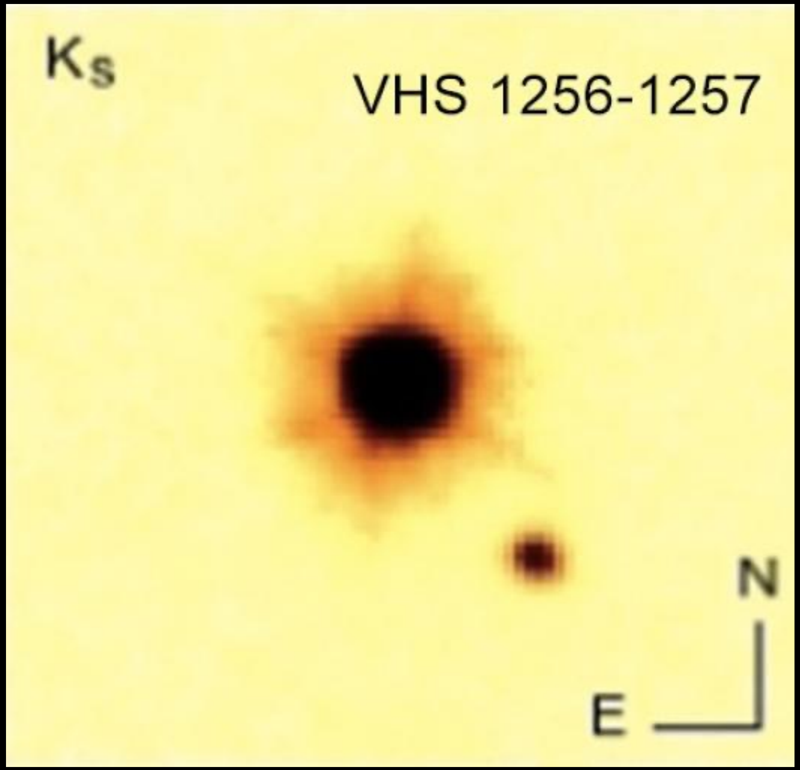


Moran et al. 2024

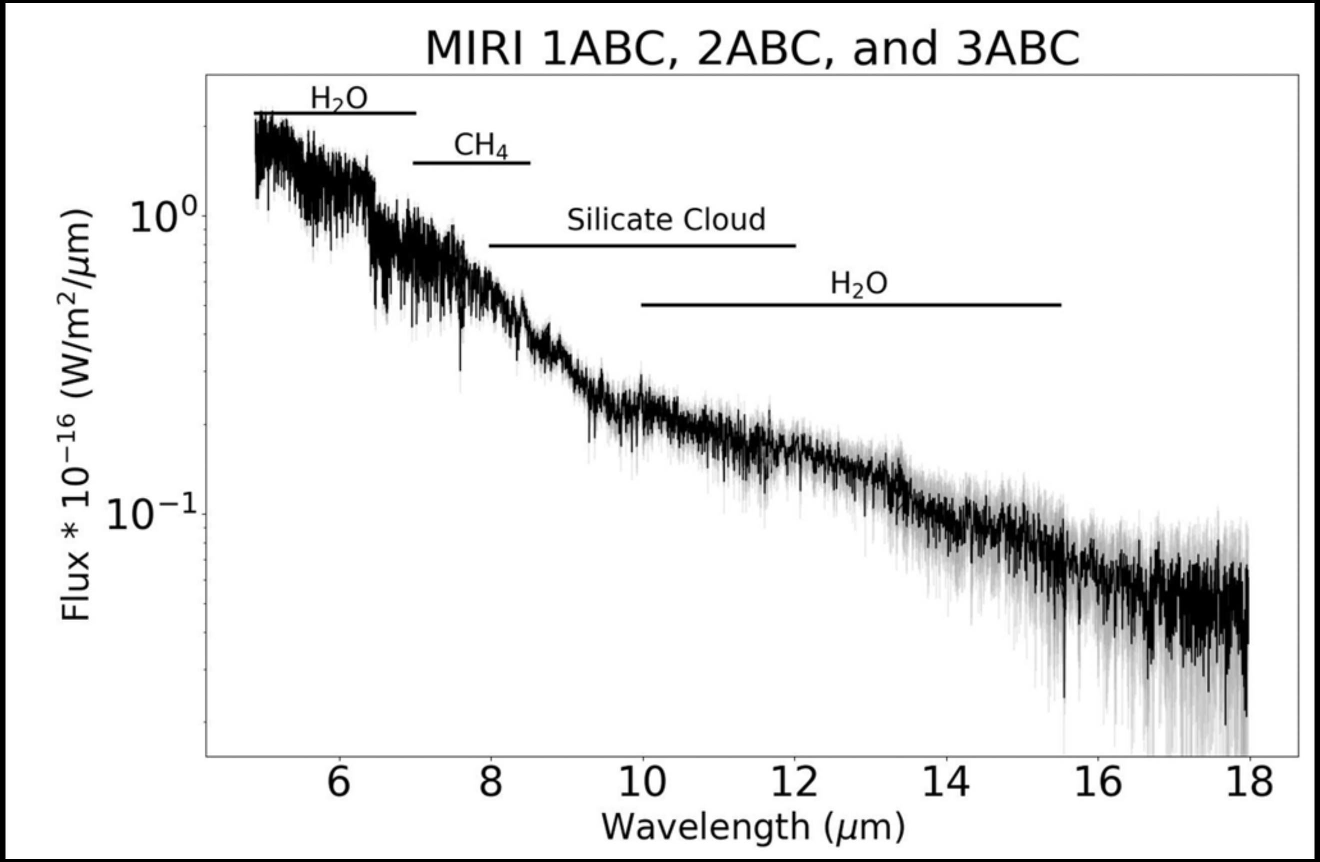
Work done by Sarah Moran (Sagan Fellow)

JWST spectra reveal silicate clouds in a planetary mass companion

- Mass: ~ 13 Mjup, Age: 140 Myrs, Host: M-dwarf binary

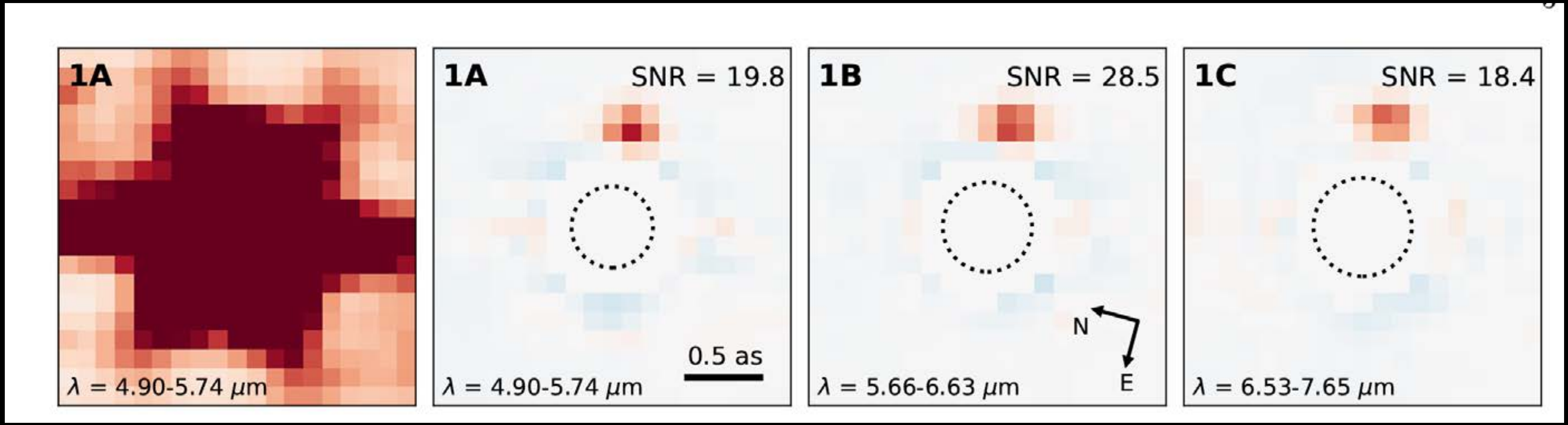


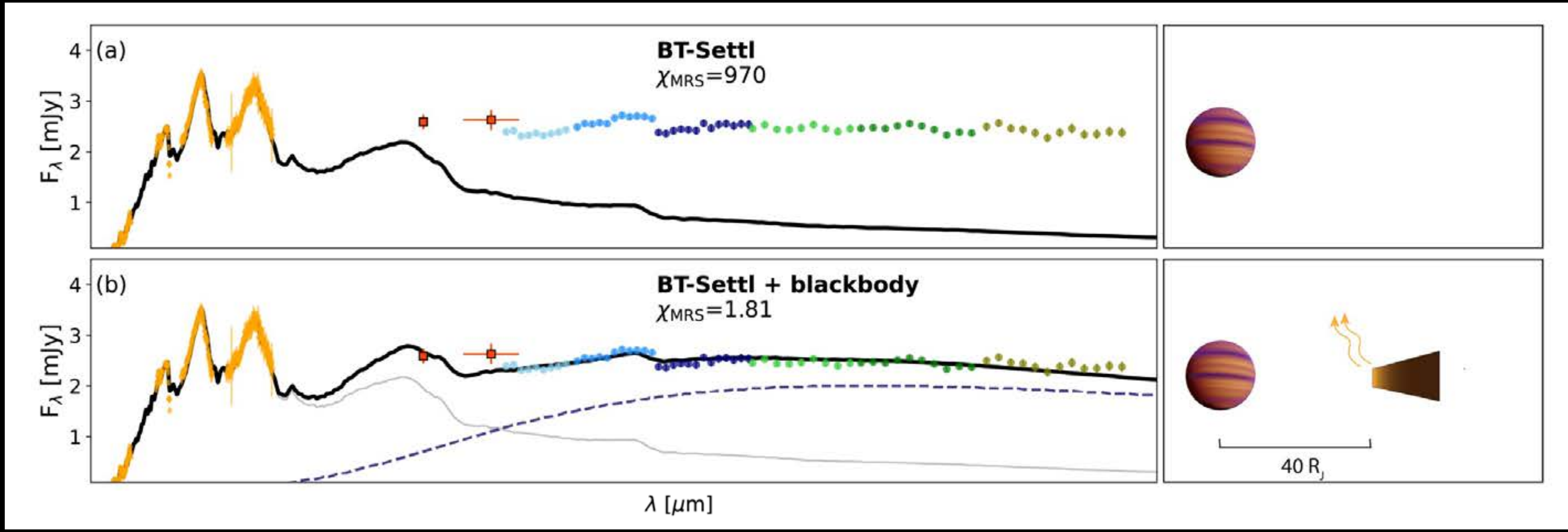
Gauza et al. 2015



Miles et al. 2023

JWST data reveal a circumplanetary disk around brown dwarf companion

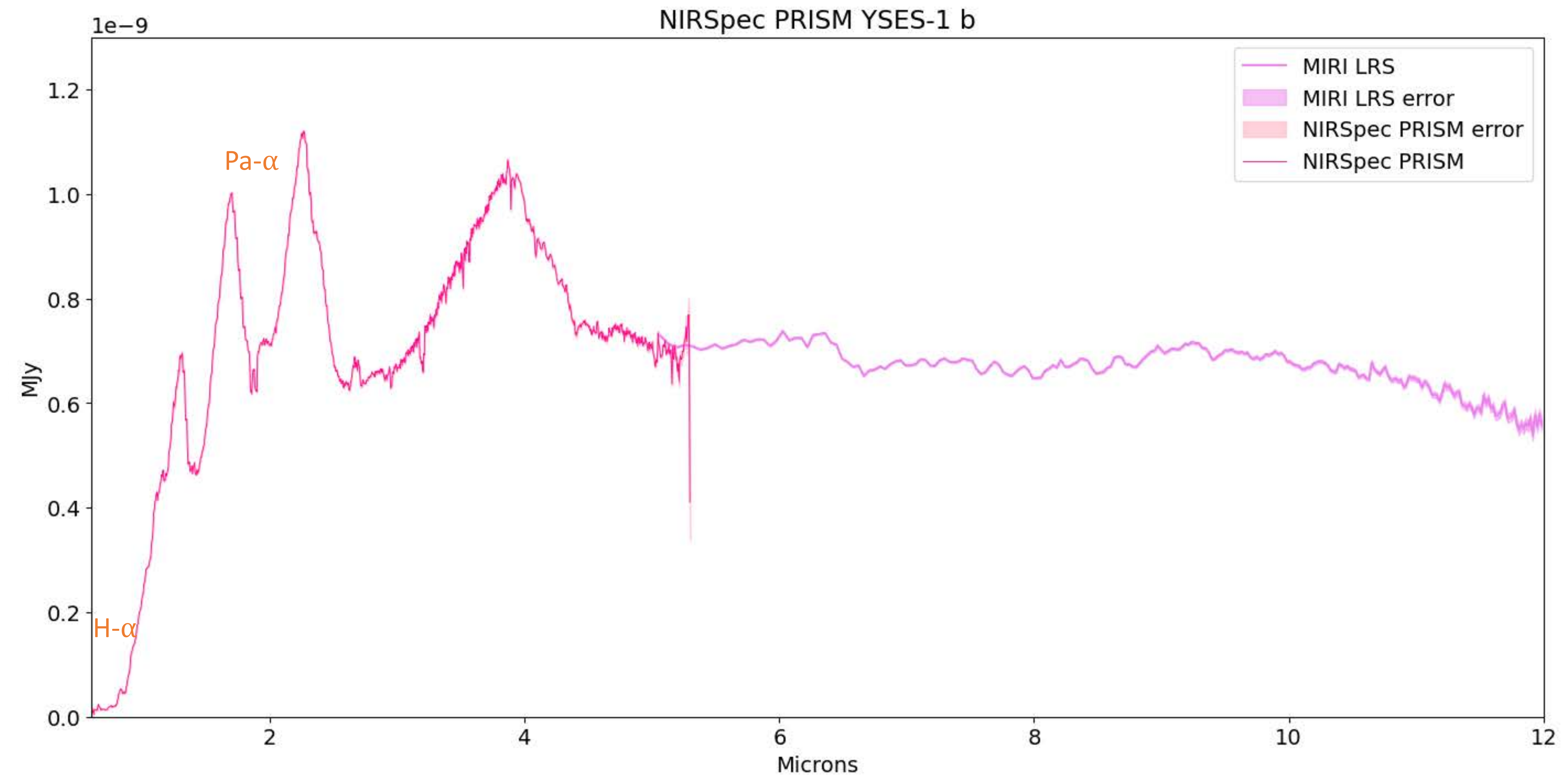




- Age: 2-5 Myr
- Mass: 30 Mjup
- Host: T. Tauri
- No silicate emission
- Actively accreting

Cugno et al. 2024

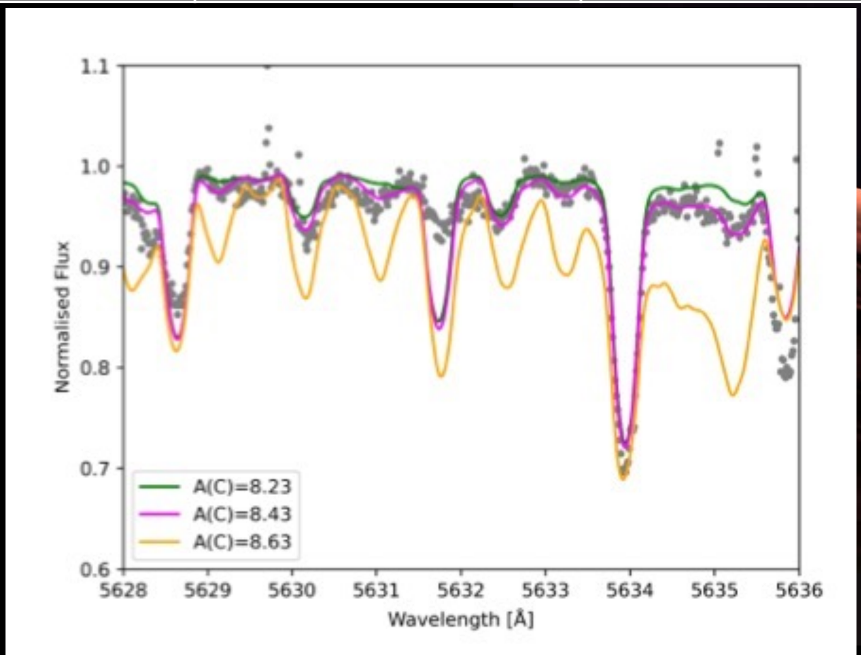
First NIR–>Mid IR Spectra of YSES 1b

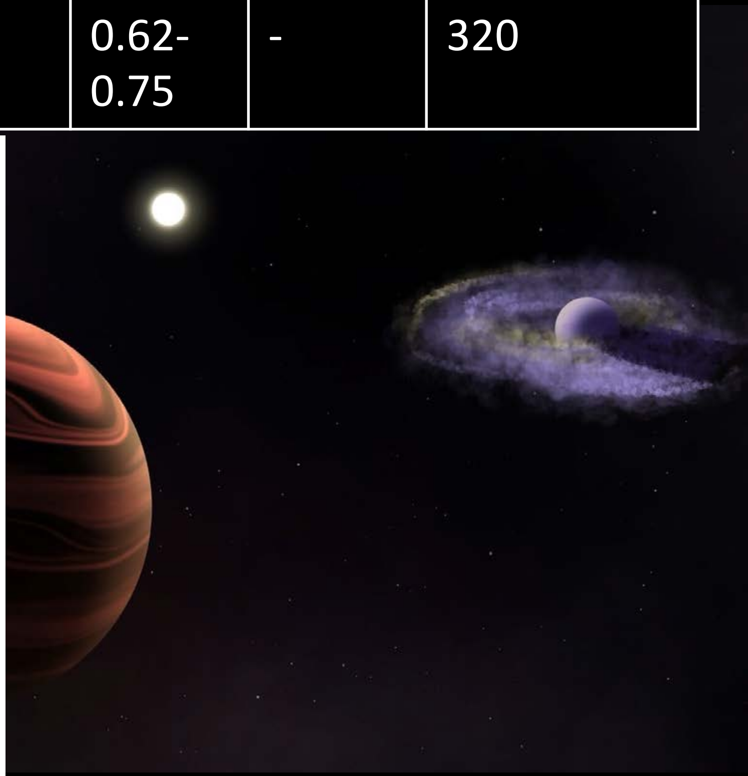


YSES-1 system questions and formation

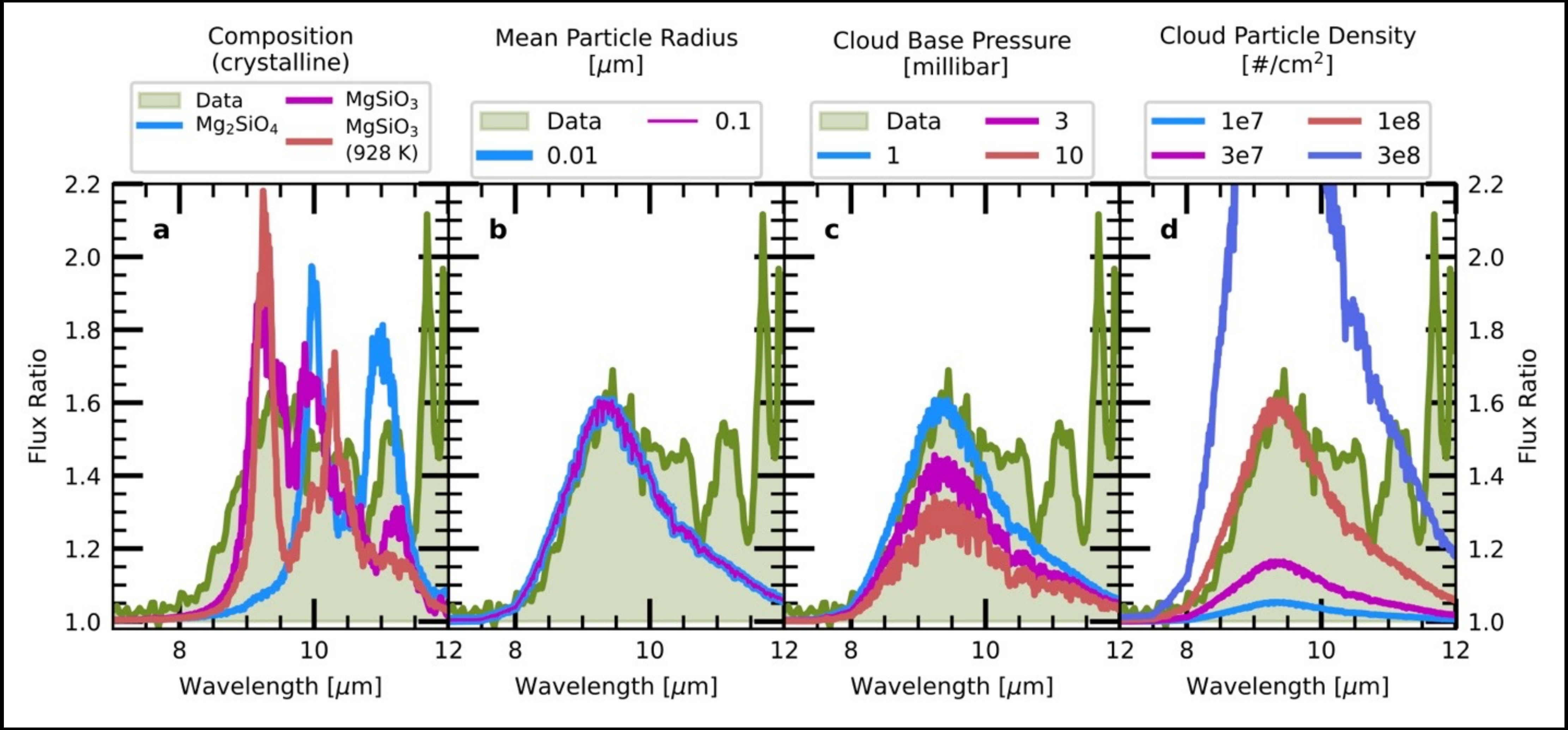
- *Inclination of the host star is ~ 81 +/- 9 degrees*
- Is the YSES-1 b cpd edge-on as well?
- Is the inclination of YSES-1 c showing the maximum cloud depth absorption?
- Zhang et al. 2024 suggested formation in a disk—how did these planets become so widely separated?

YSES-1	Temperature (K)	Surface Gravity (log(g))	C/O	Age (Myr)	Separation (au)
Host	4680 +/- 53	4.62 +/- 0.05	Solar	~16	-
b	~1700 K	~4.5	0.60-0.72	-	160
c	~1000 K	~3.5	0.62-0.75	-	320



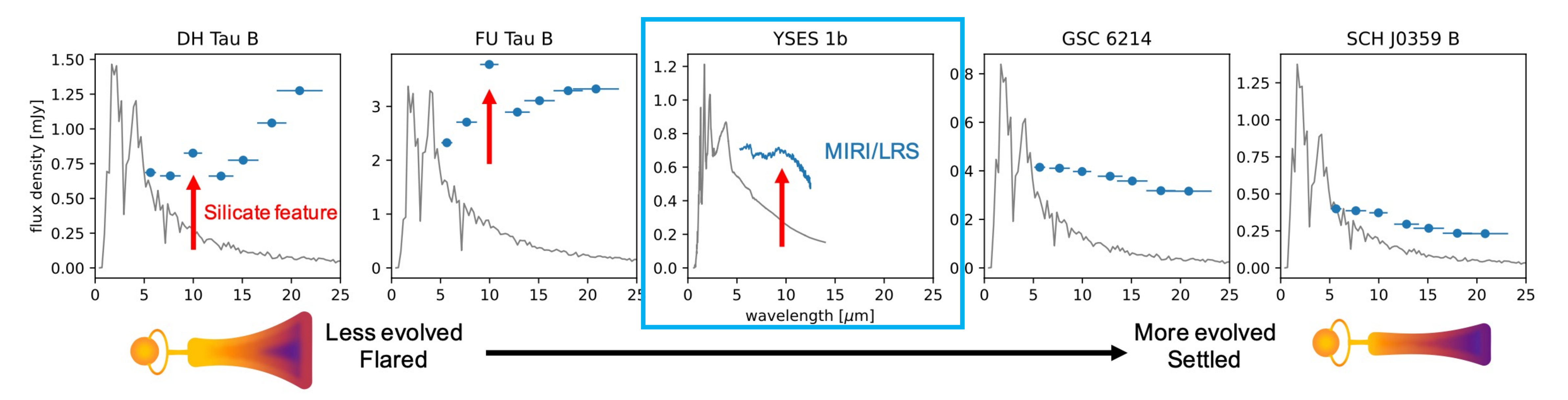


Cloud model comparisons



Hoch et al. 2025

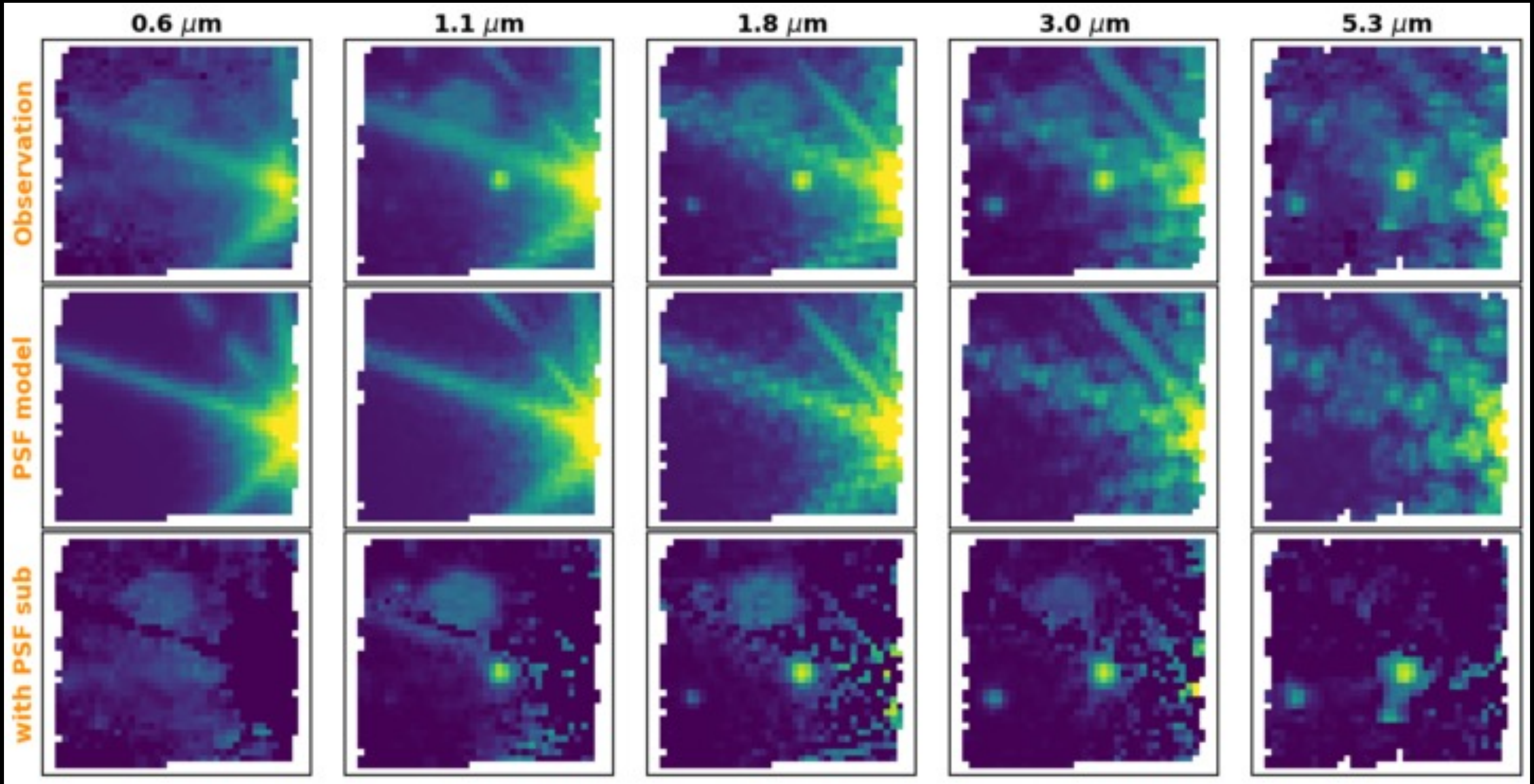
JWST GO-07538 (PI's: Gabriele Cugno & Sierra Grant) CPDs with MIRI MRS!



Second generation grains
sub micron sized??

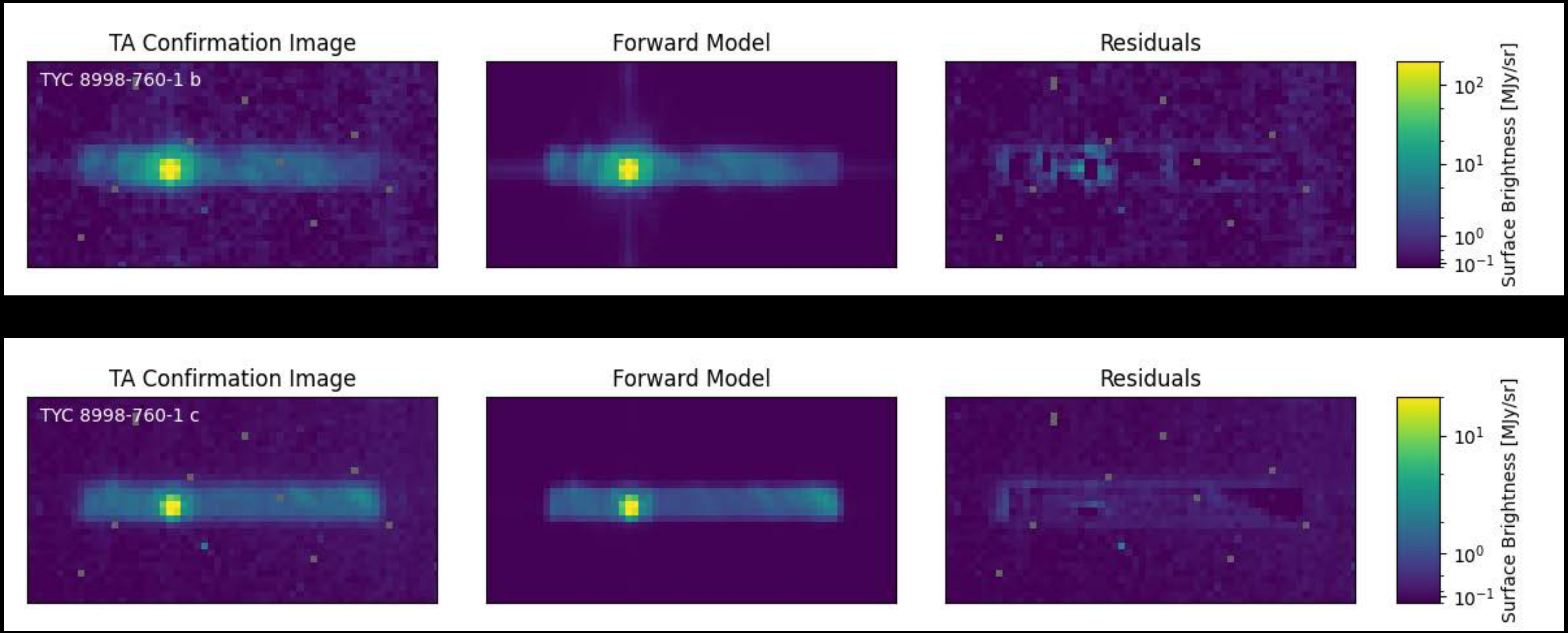
Small grains, younger objects → Larger grains → Smaller dust grains/settled dust

To remove the host starlight we used WebbPSF to model the host star and the speckles (NIRSpec PRISM)



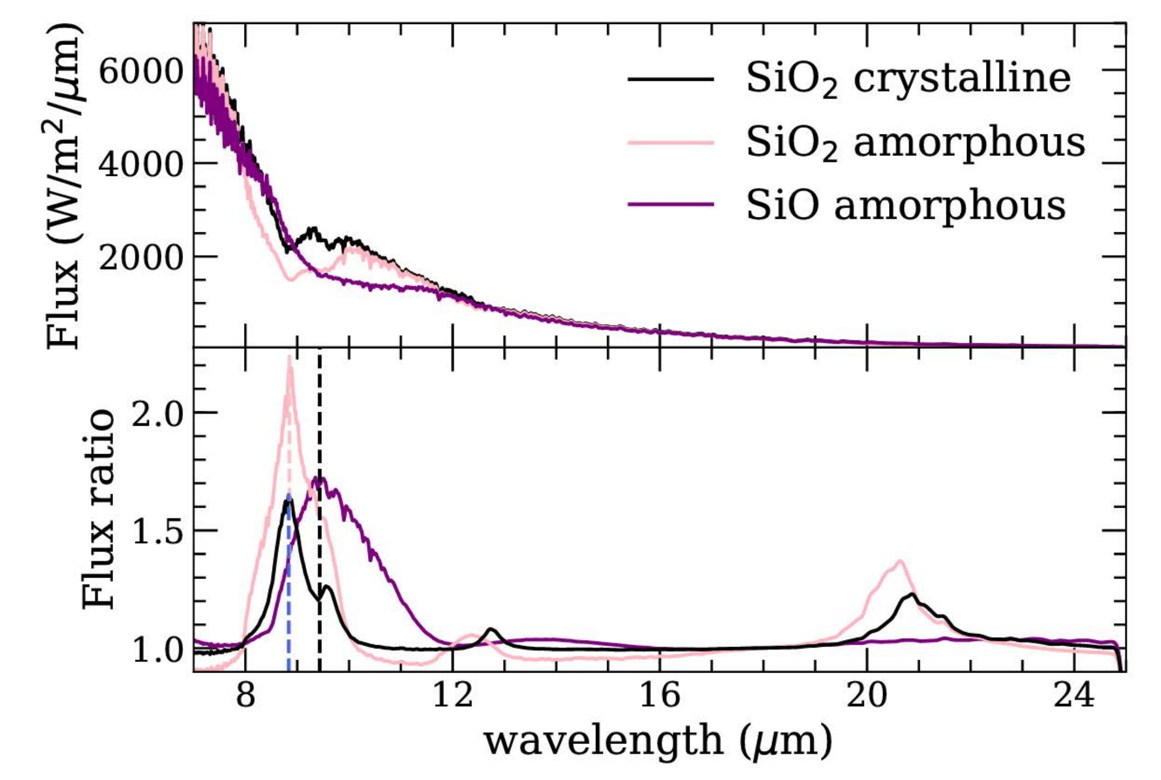
Hoch et al. in review

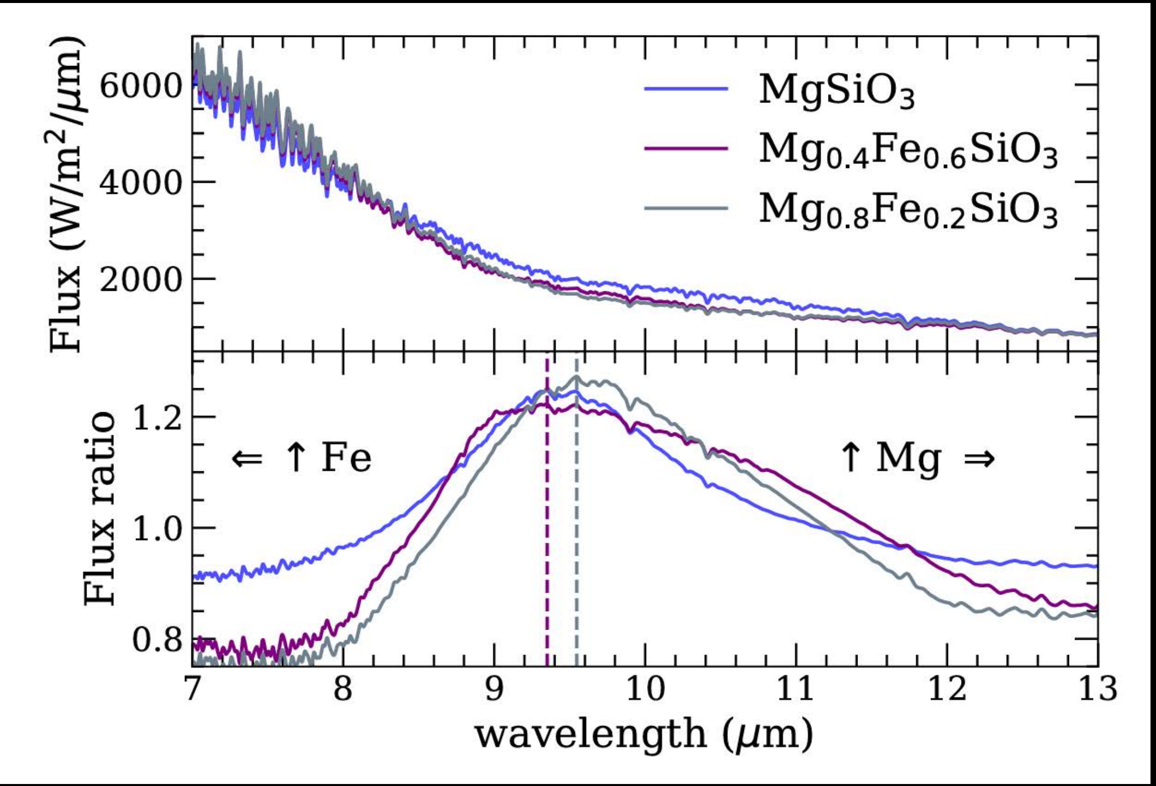
To remove the host starlight we used WebbPSF to model the host star and the speckles (MIRI LRS)



Hoch et al. in review

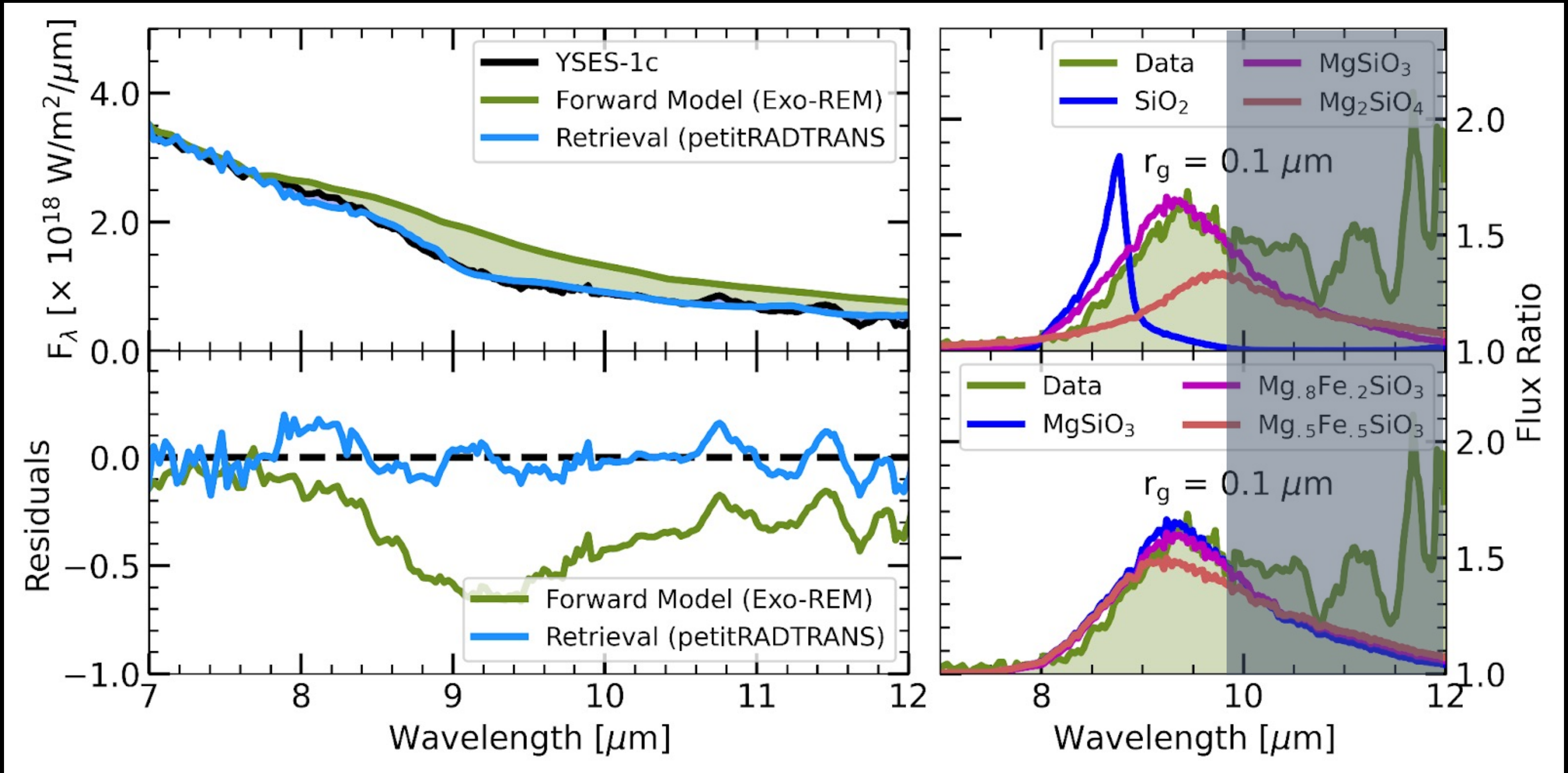
To shift the silicate feature you can vary silicates and vary the Mg and Fe content





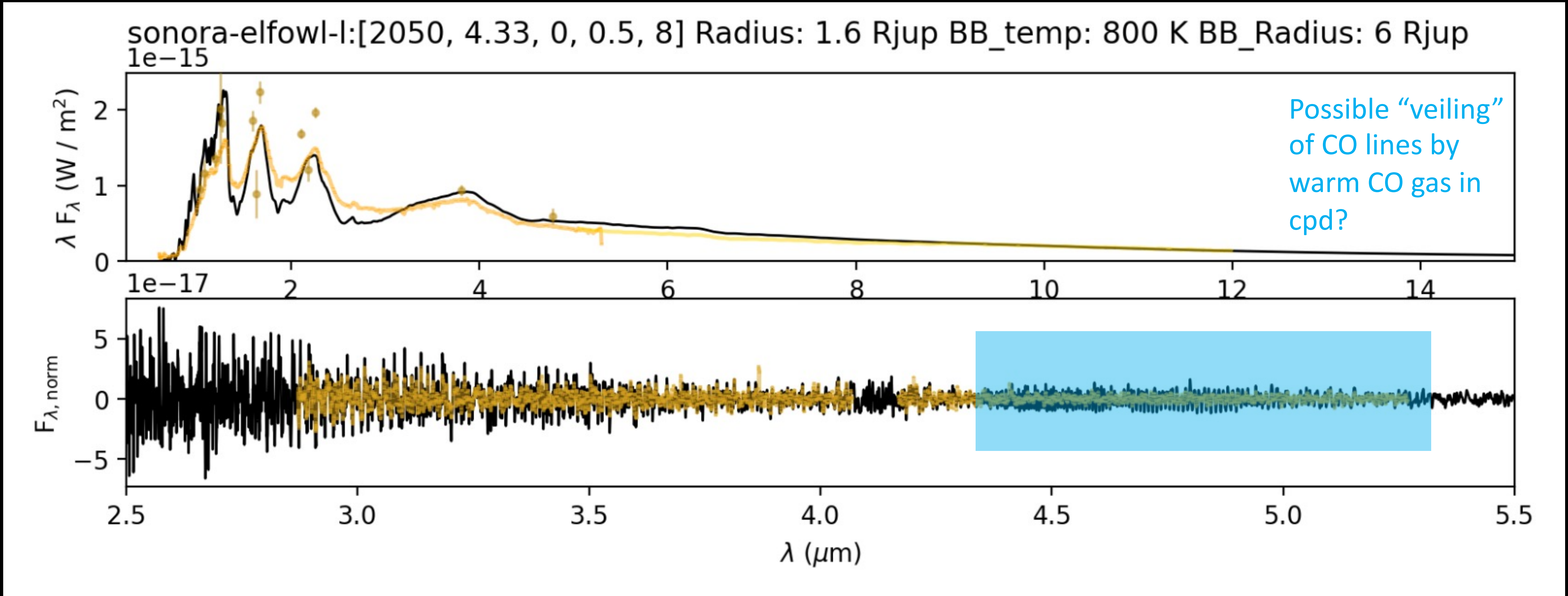
Luna et al. 2021

However, the quality of the MIRI LRS data decreases beyond 11 microns, so we are missing the full feature (out to ~14 microns)



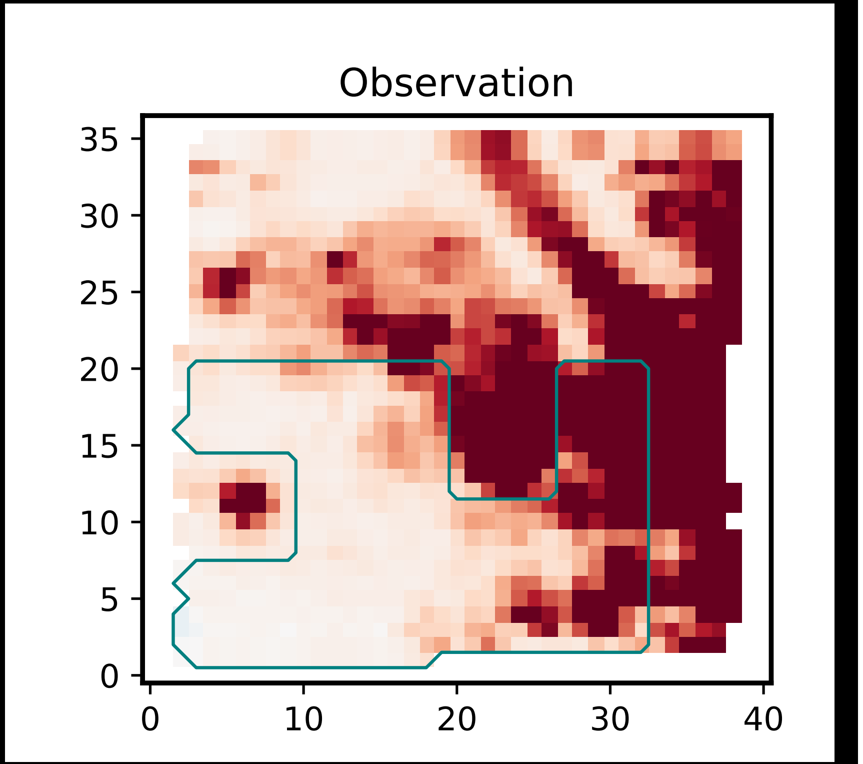
Hoch et al. in review

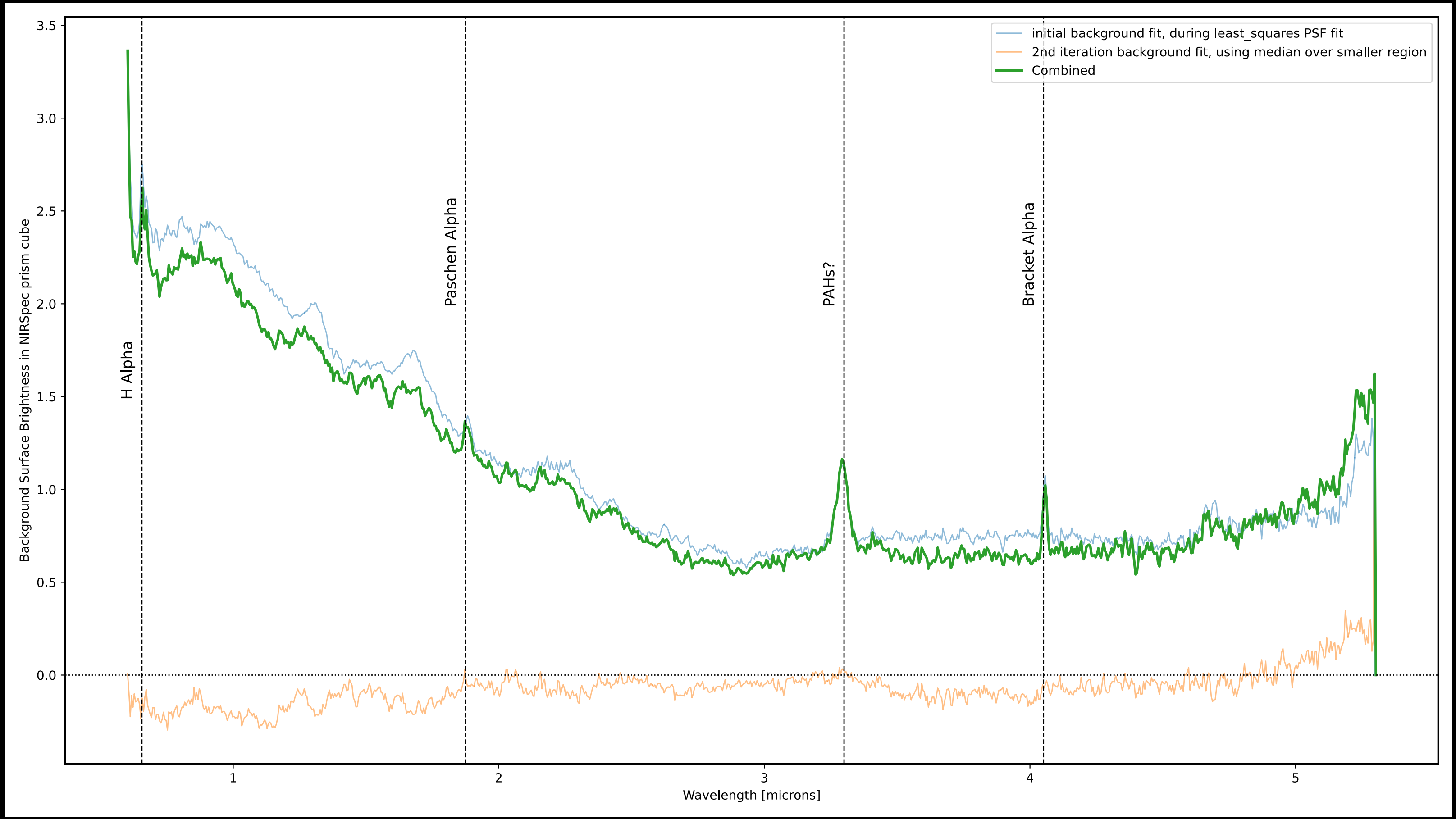
First look at G395H data of YSES-1 b



Work done by postdoc Alex Madurowicz (STScI)

But there are more mysteries…. Like emission lines in the background

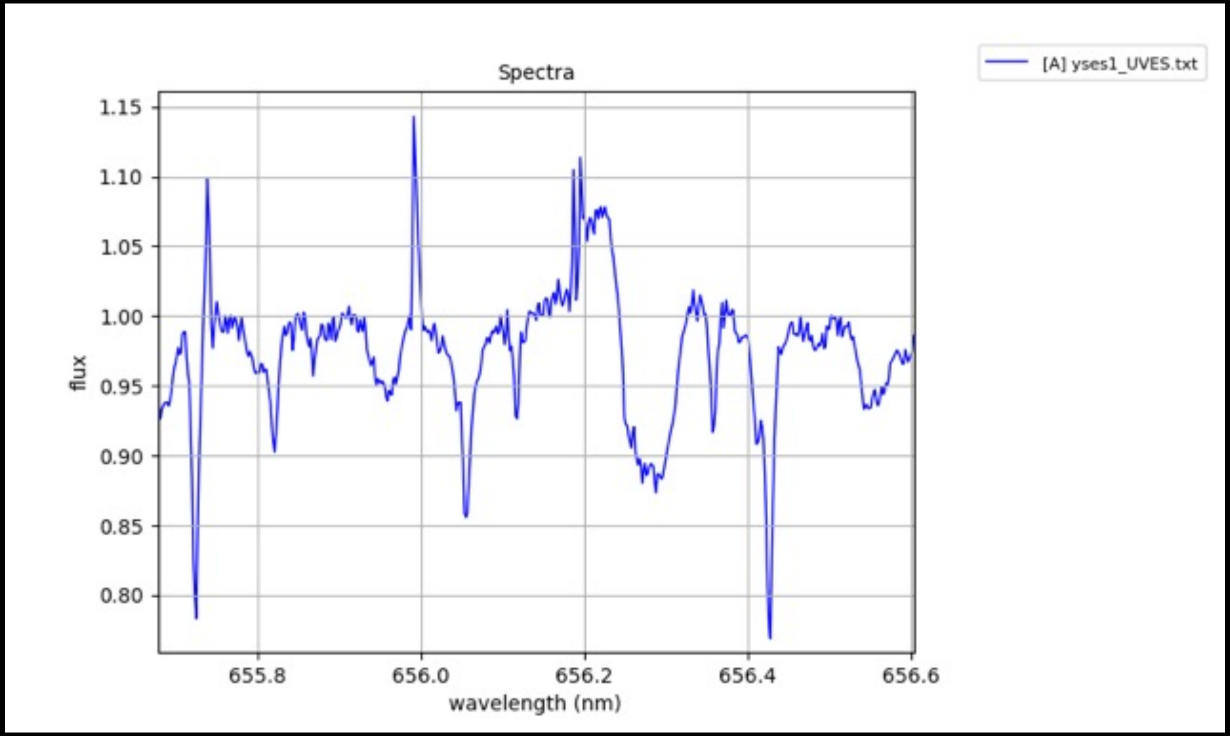




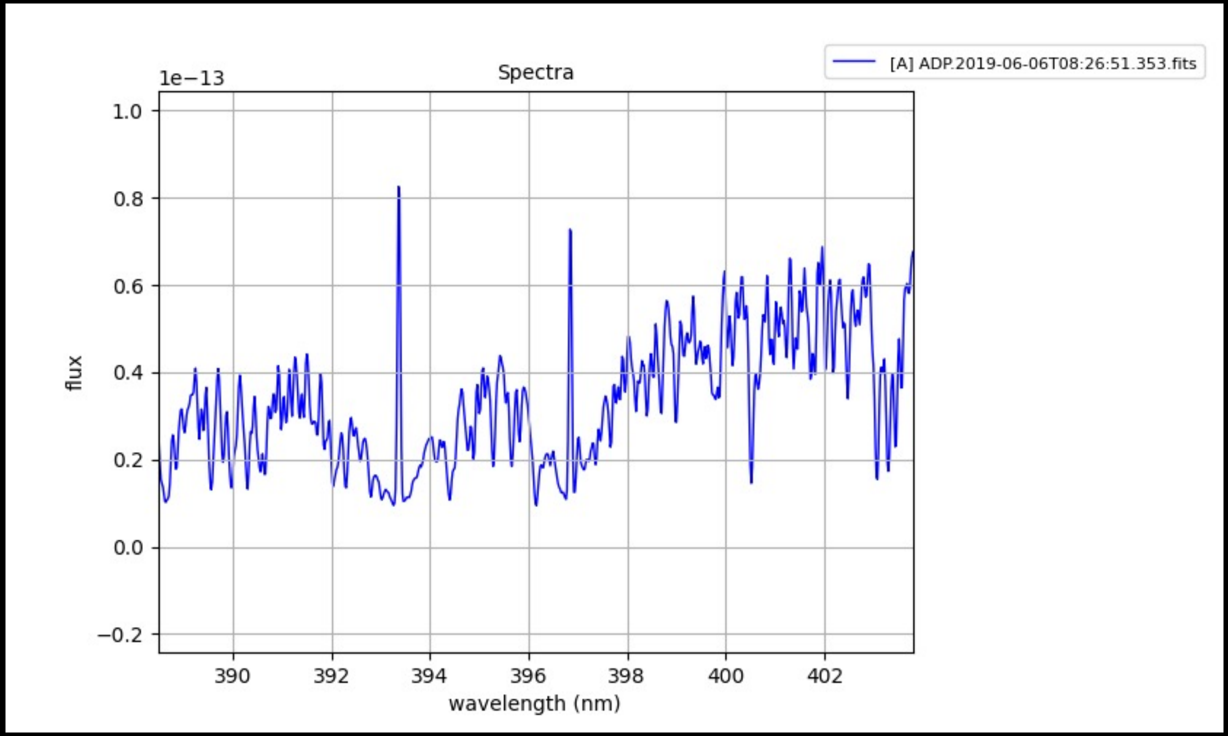
Hoch et al. in prep

Is the host star accreting?

H alpha



Ca III



Hoch et al. in prep

Is this surprising due to Sco Cen having so much star formation?