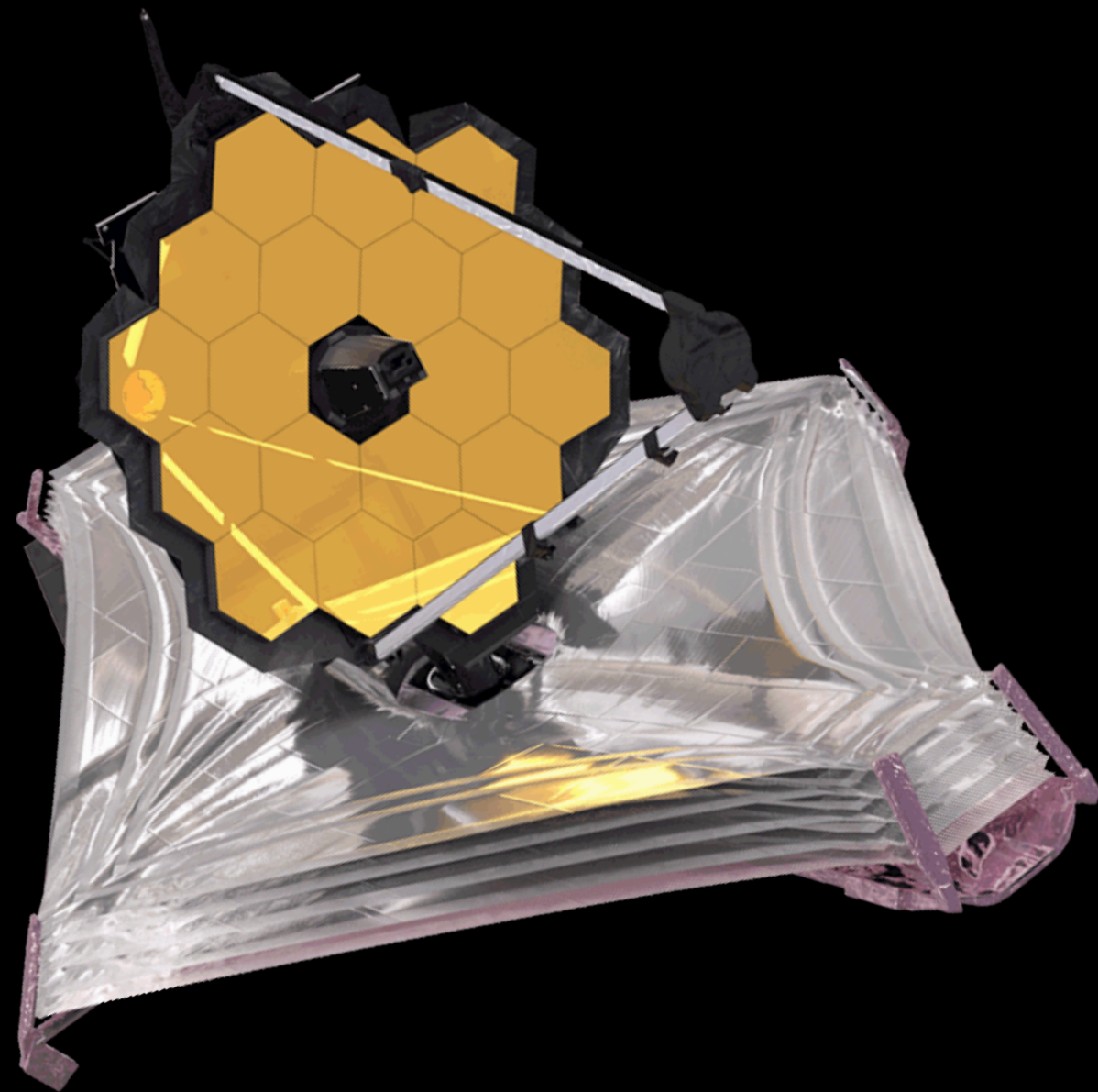


JWST reveals abundant methane and depleted carbon dioxide on the temperate sub-Neptune LP 791-18 c



2024 CRAQ annual meeting
May 8th, 2024

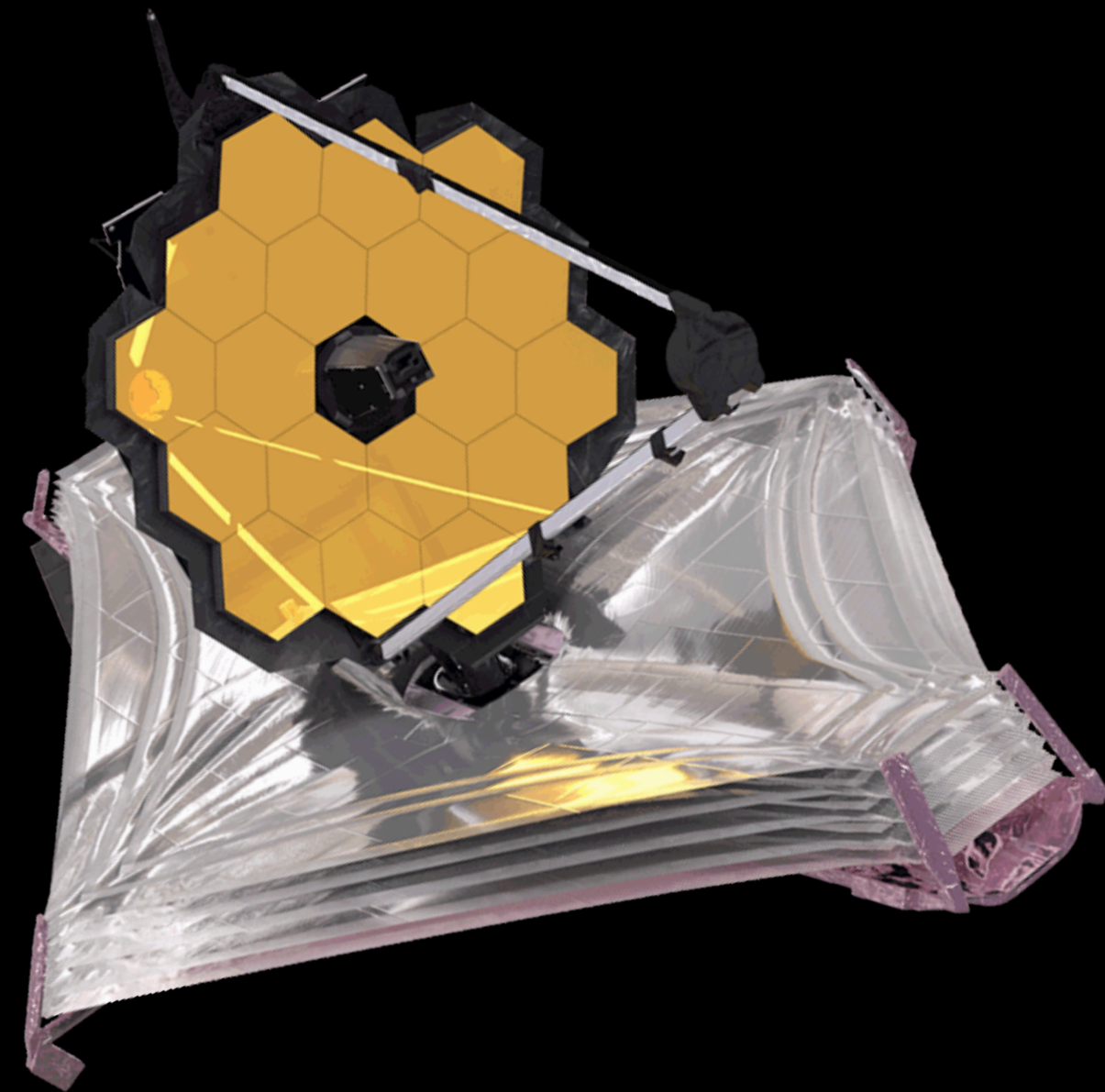
Pierre-Alexis Roy

with

B. Benneke, M. Fournier-Tondreau, C. Piaulet, L.-P. Coulombe,
D. Lafrenière and the **NEAT team**.



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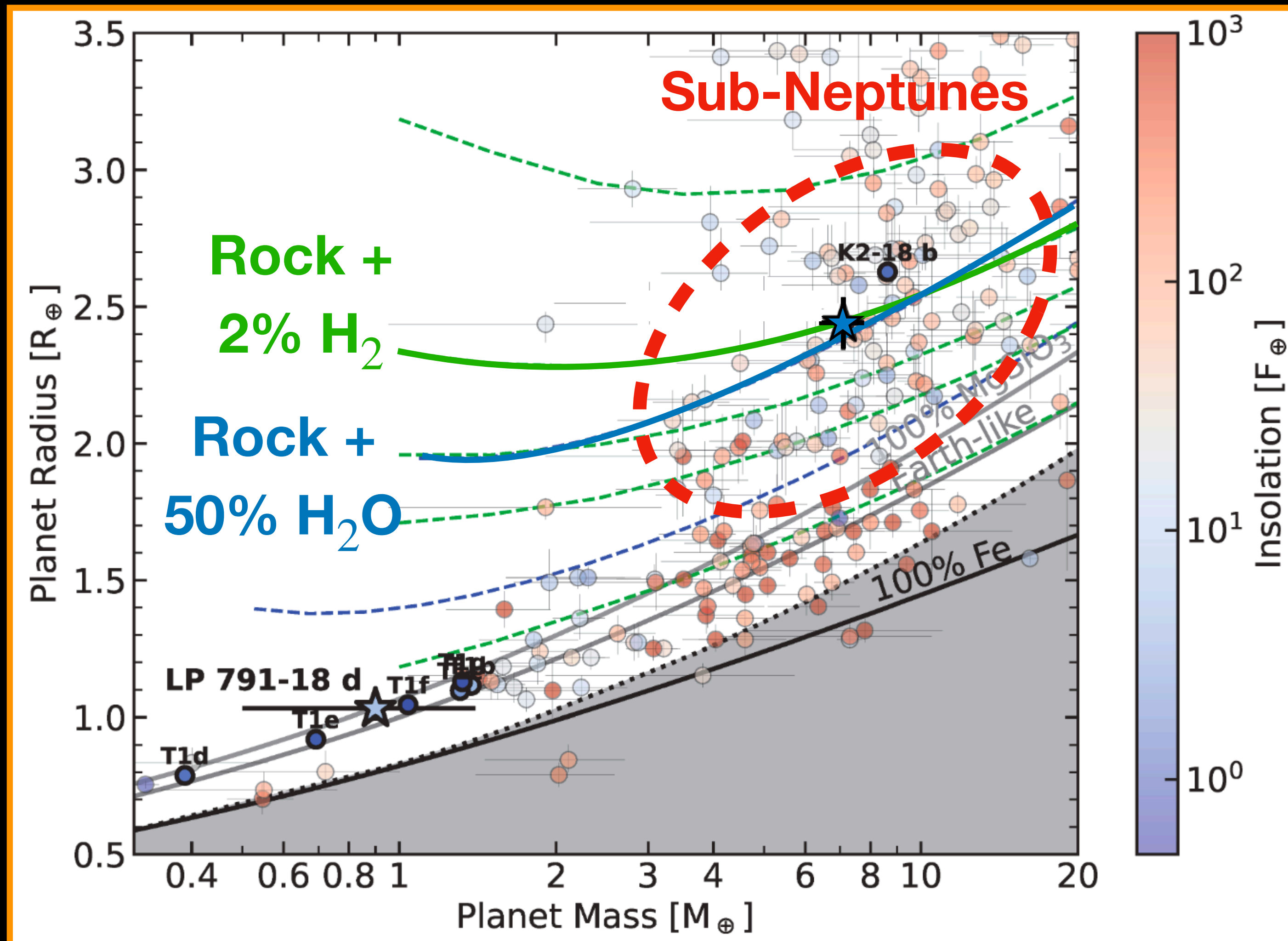
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with

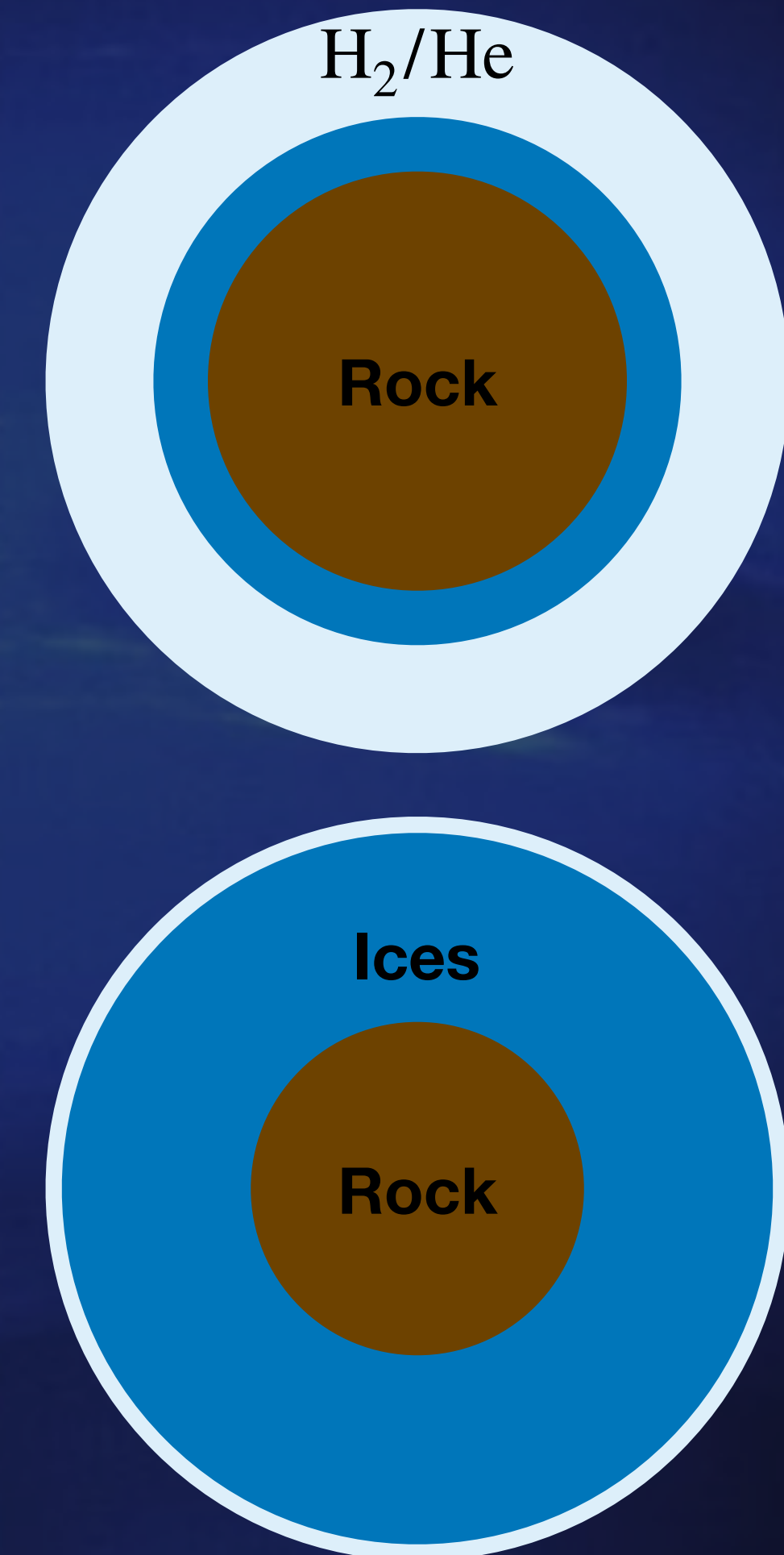
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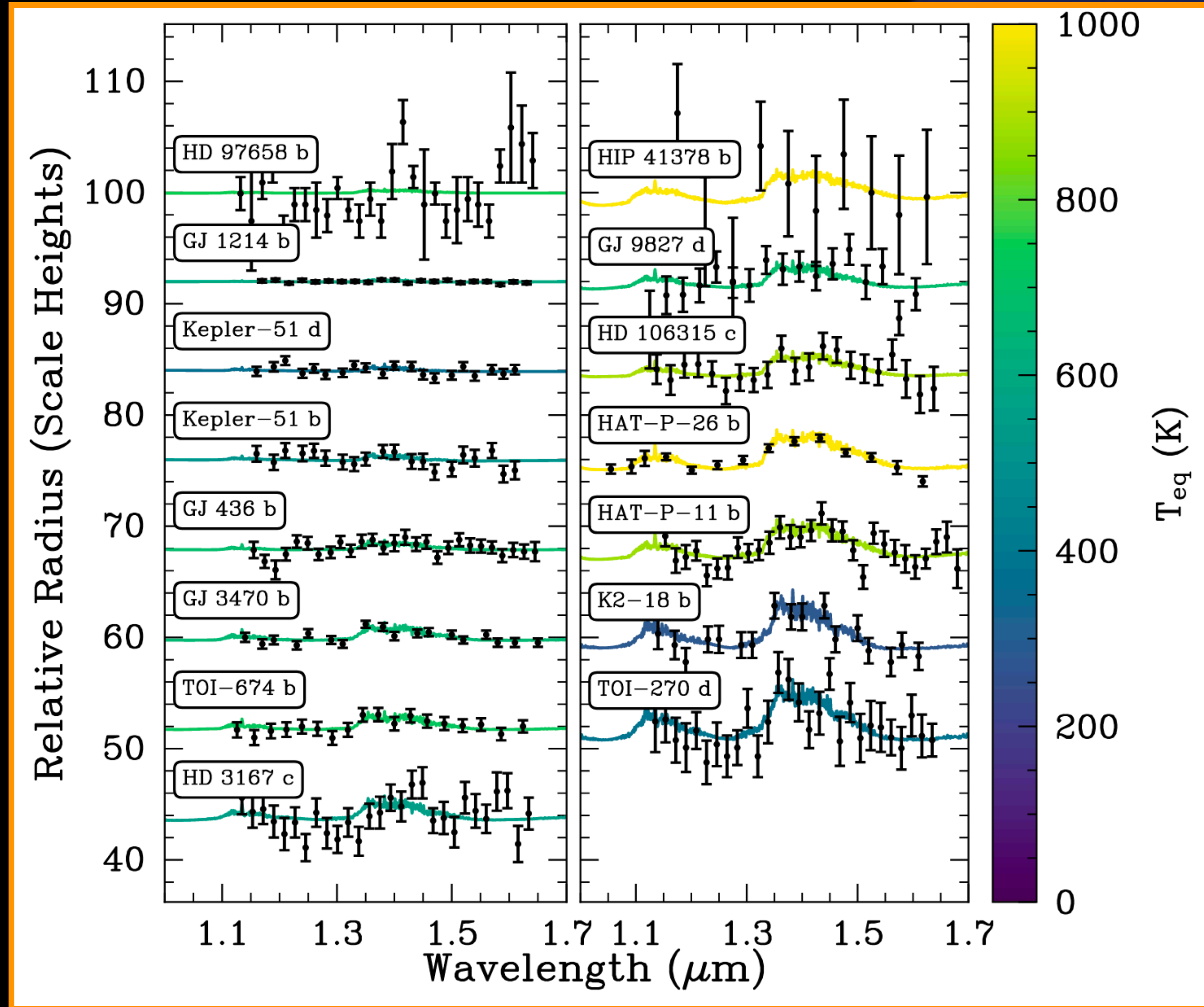
Sub-Neptunes are in a degenerate mass-radius and metallicity space



Peterson et al. 2023

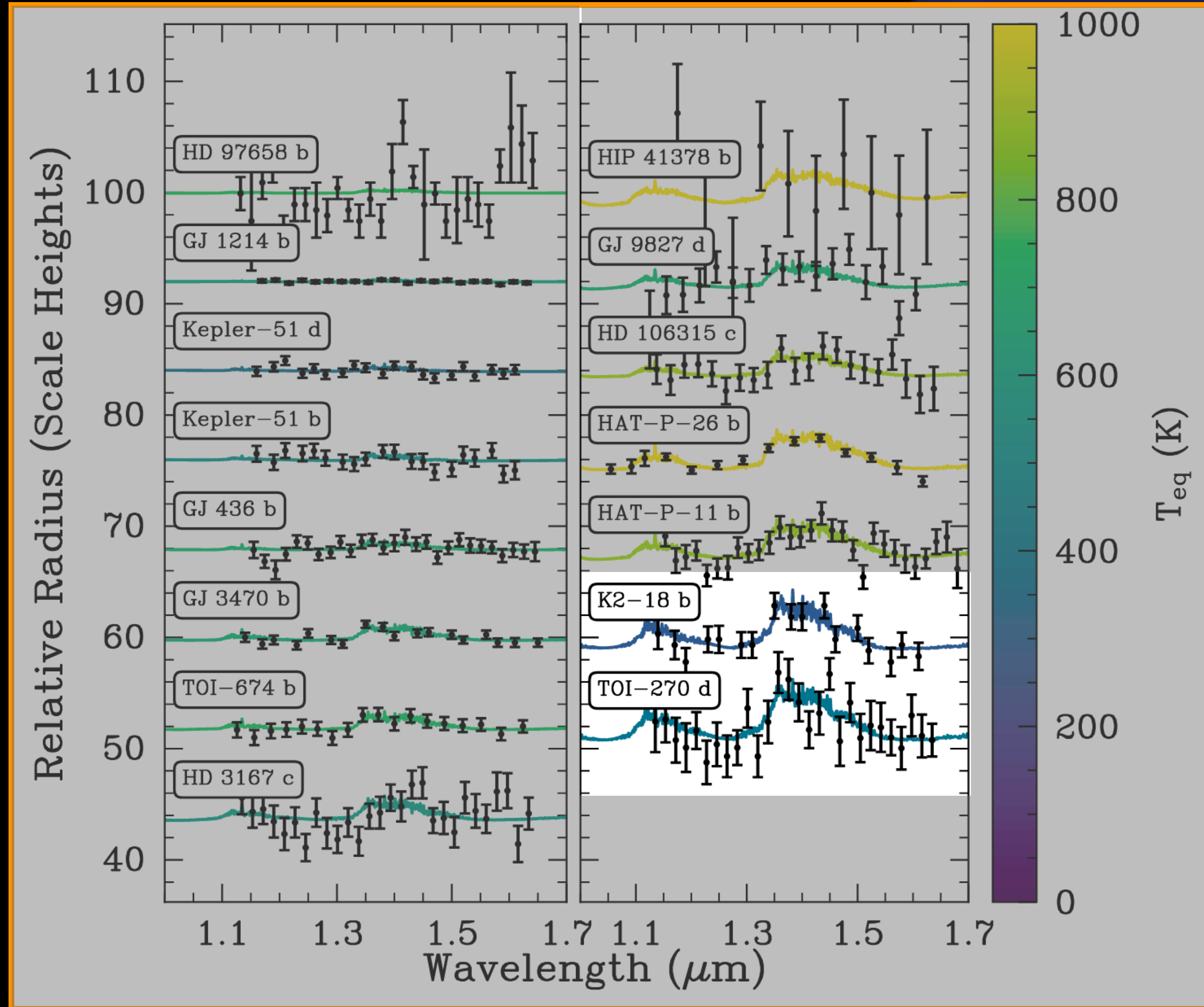


Trying to understand the composition of sub-Neptunes



Brande et al. 2023

Trying to understand the composition of sub-Neptunes

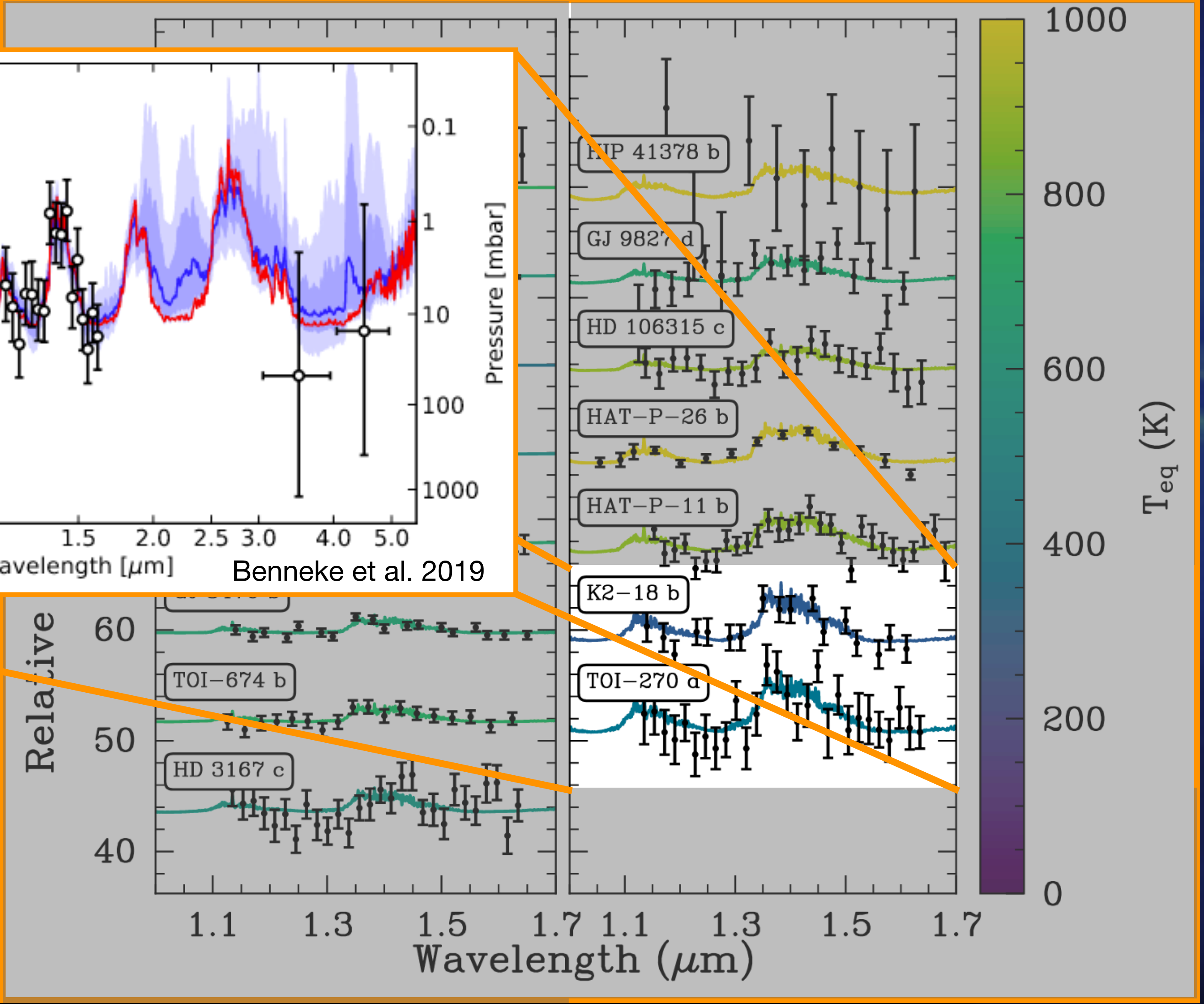
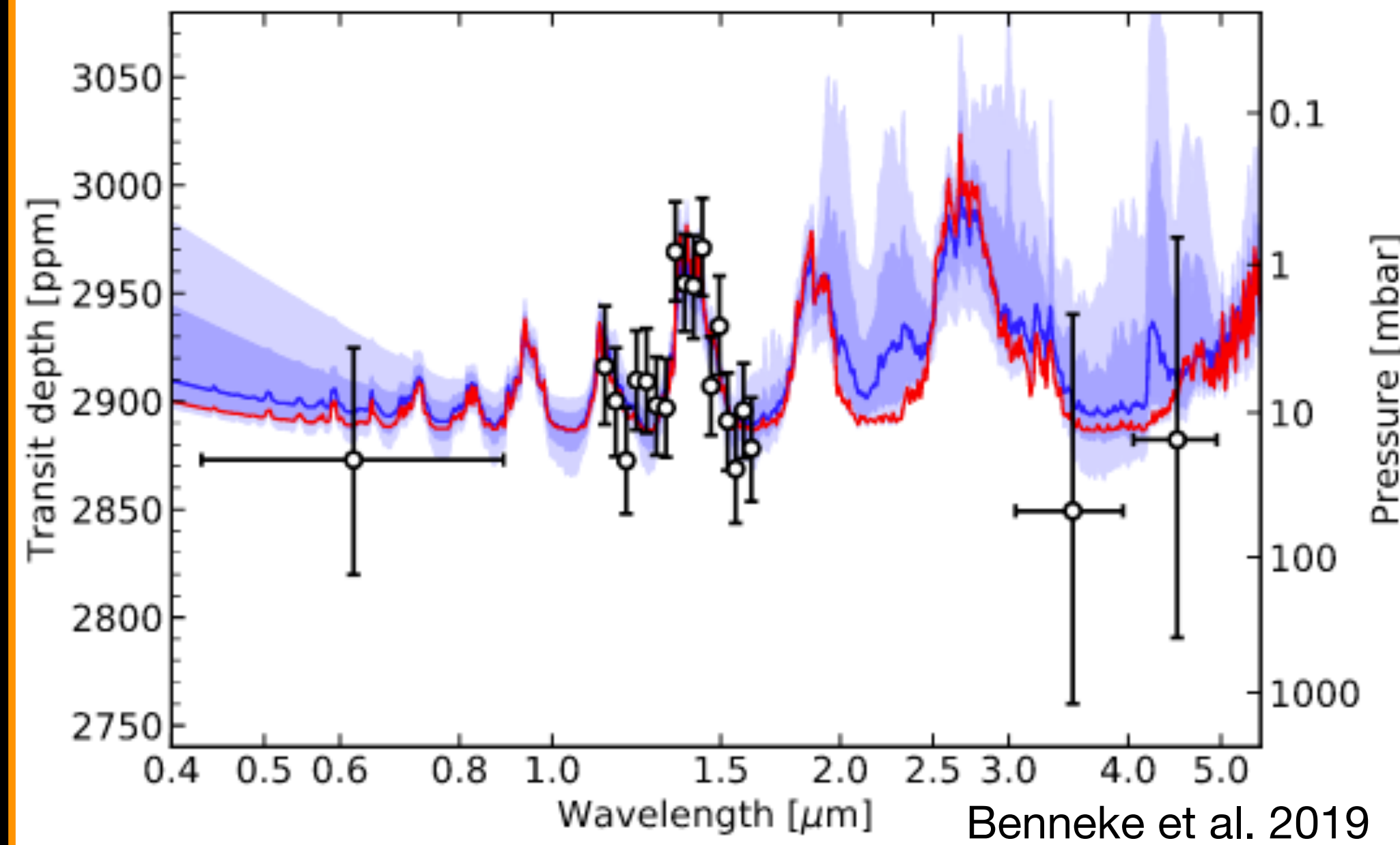


Low-temperature
sub-Neptunes opportunity

Less clouds at low
equilibrium temperatures

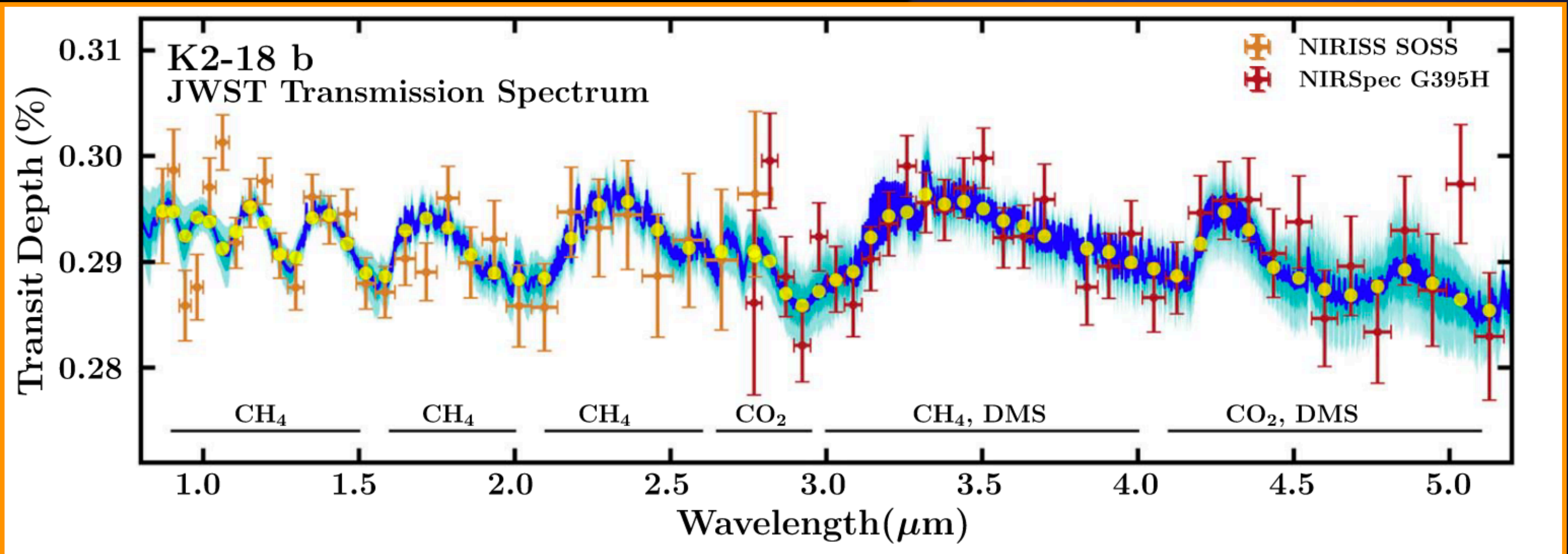
Brande et al. 2023

Trying to understand the composition of sub-Neptunes



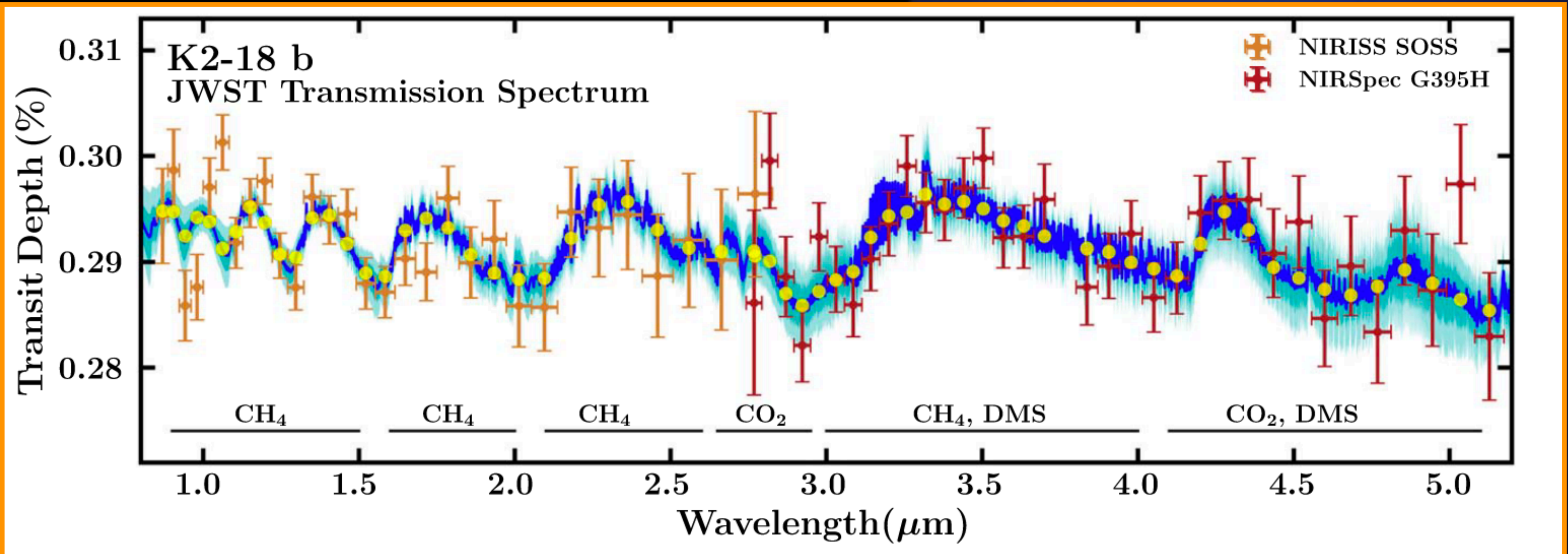
Low-temperature sub-Neptunes opportunity
Less clouds at low equilibrium temperatures

JWST confirms H₂-dominated atmosphere and detects CH₄ and CO₂ on K2-18b



Madhusudhan et al. 2023

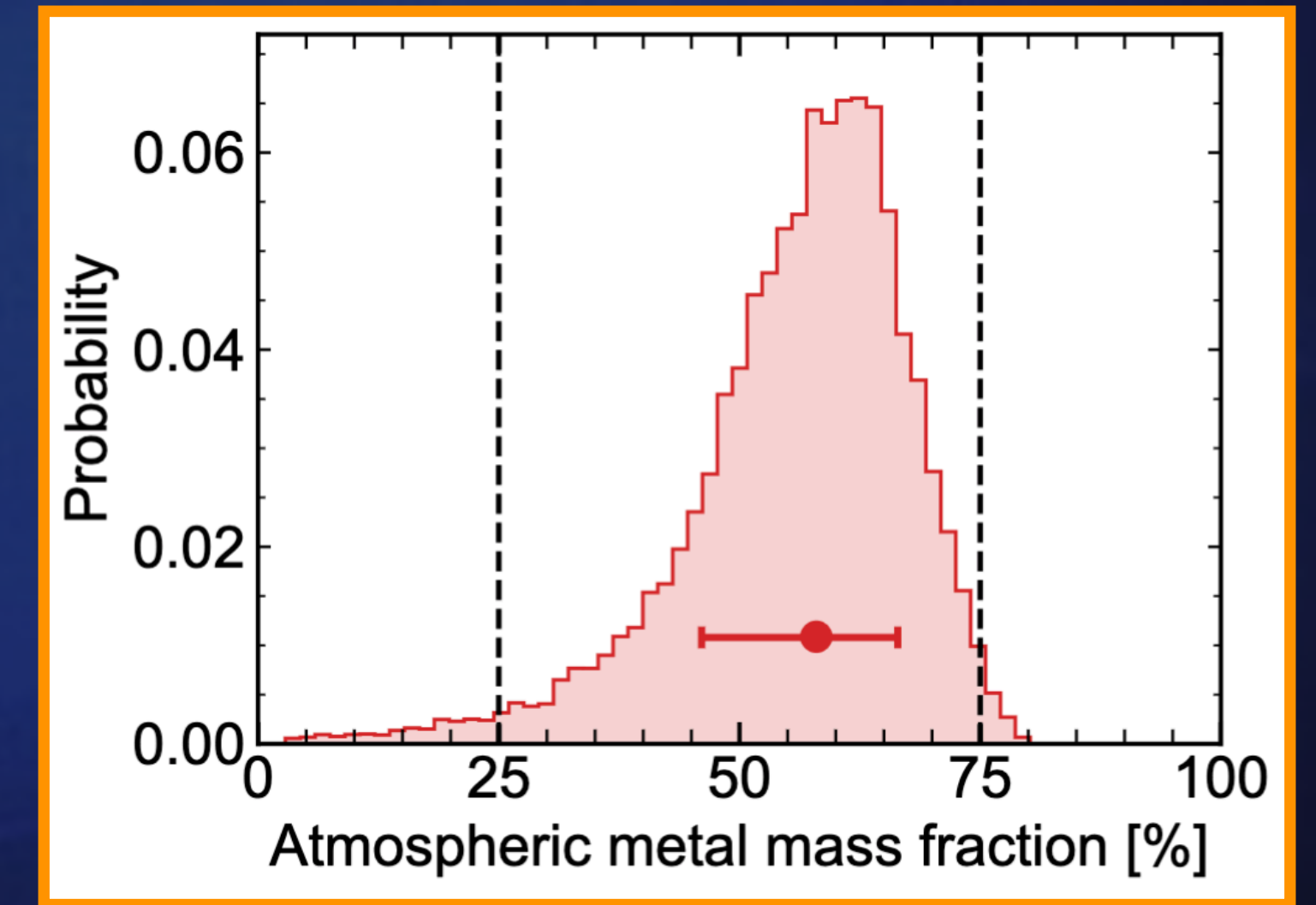
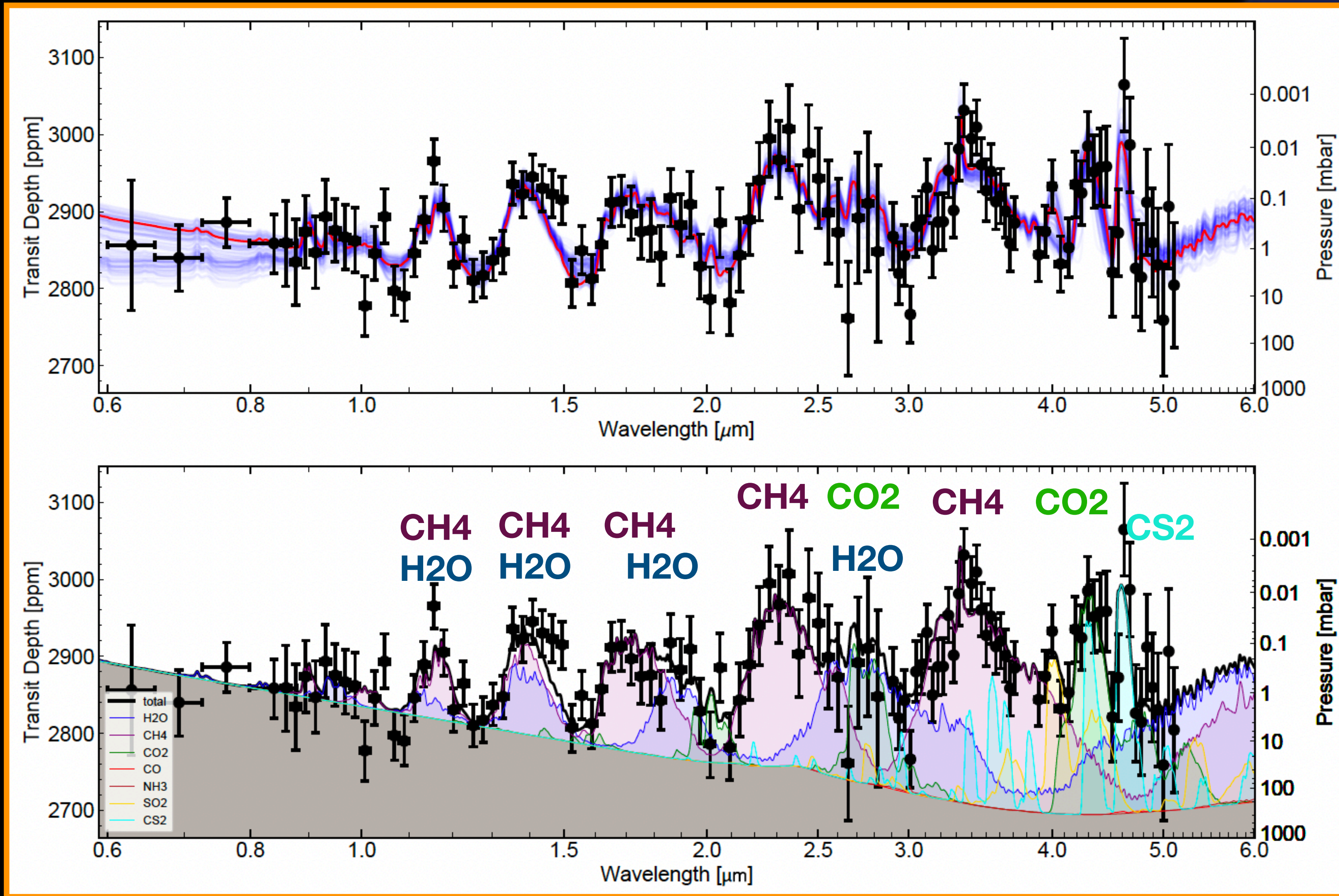
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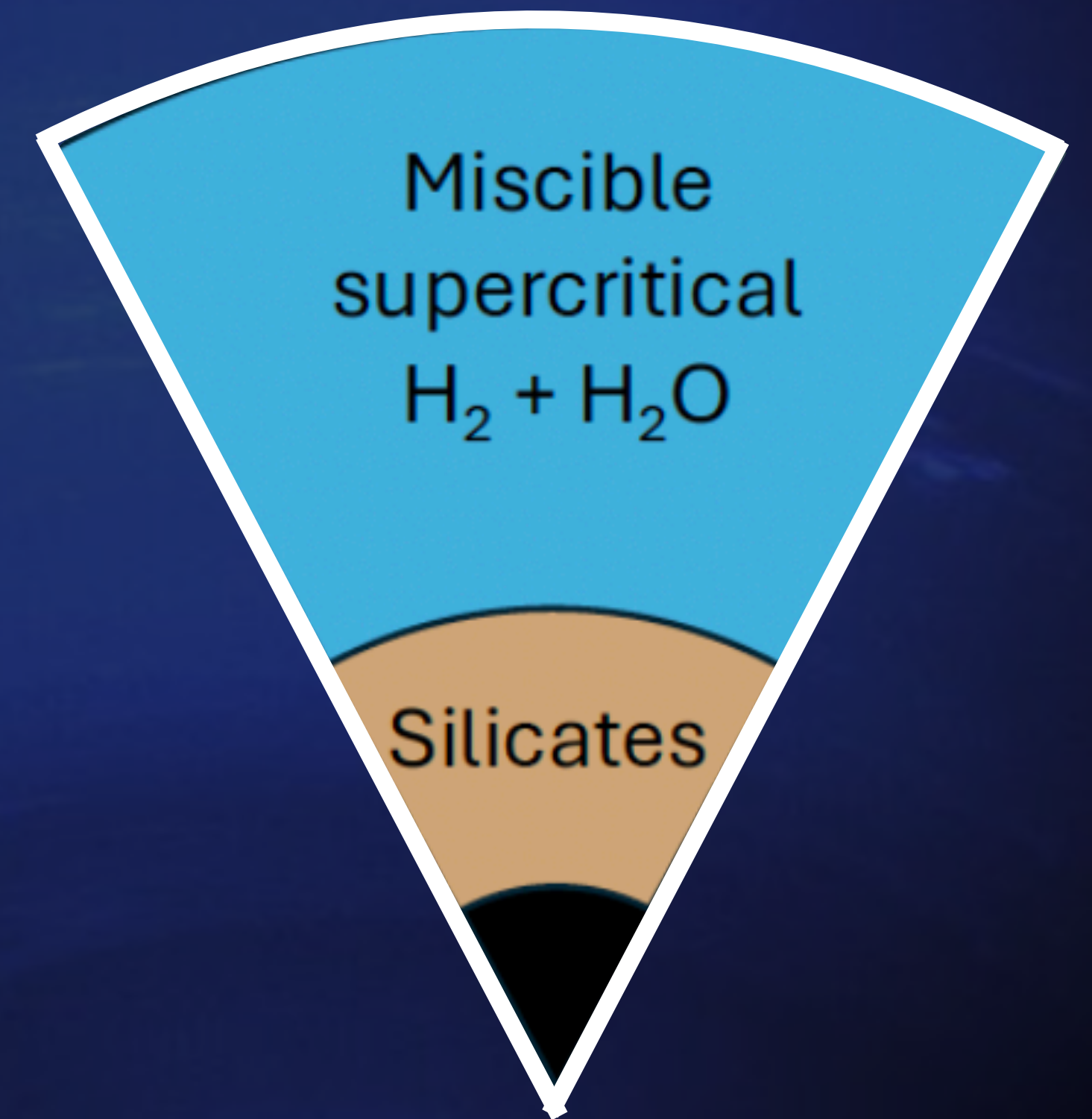
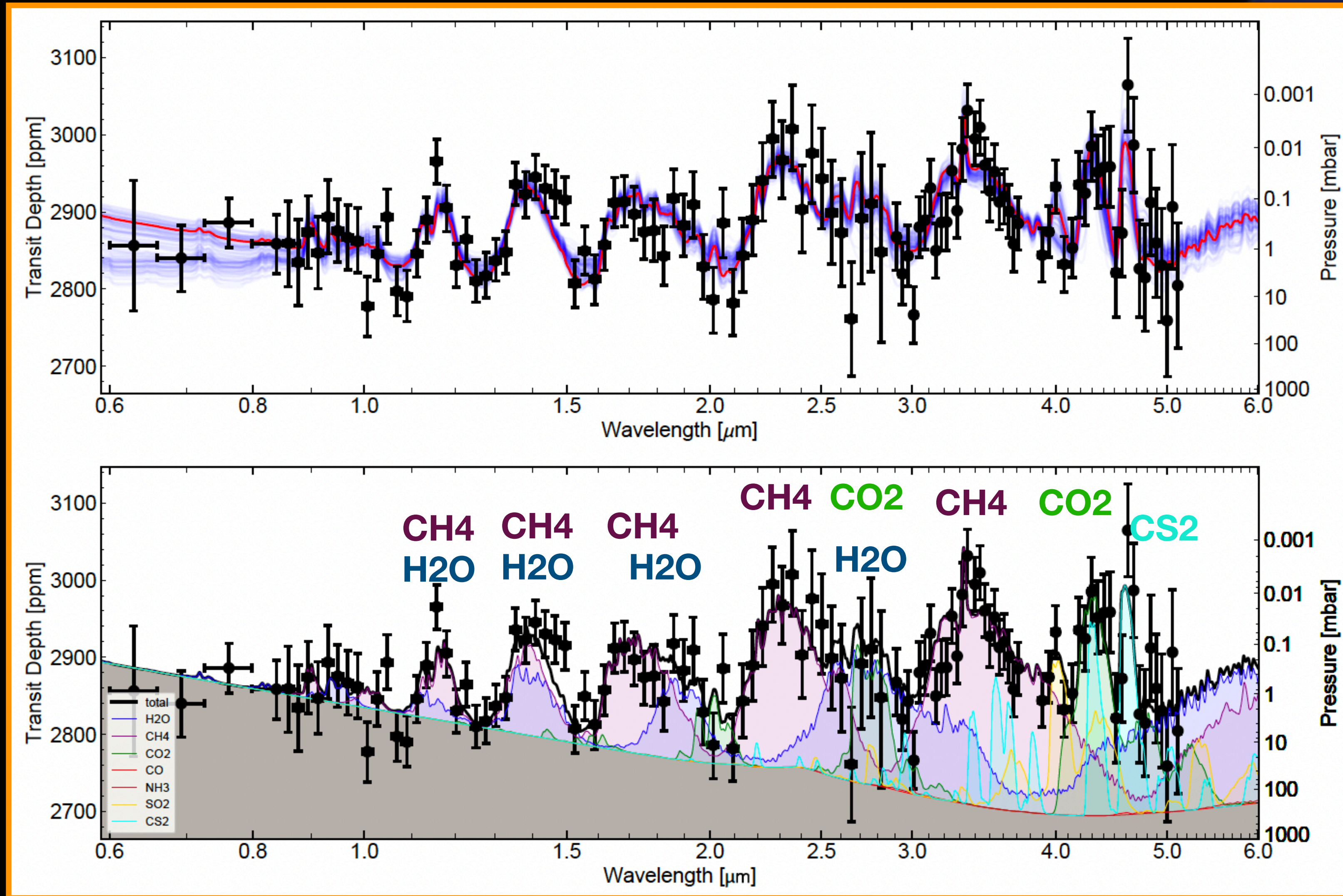
More SNR is needed to measure the H₂O/CH₄ and the mean molecular weight of the atmosphere

JWST reveals that sub-Neptunes have mixed envelopes with TOI-270d



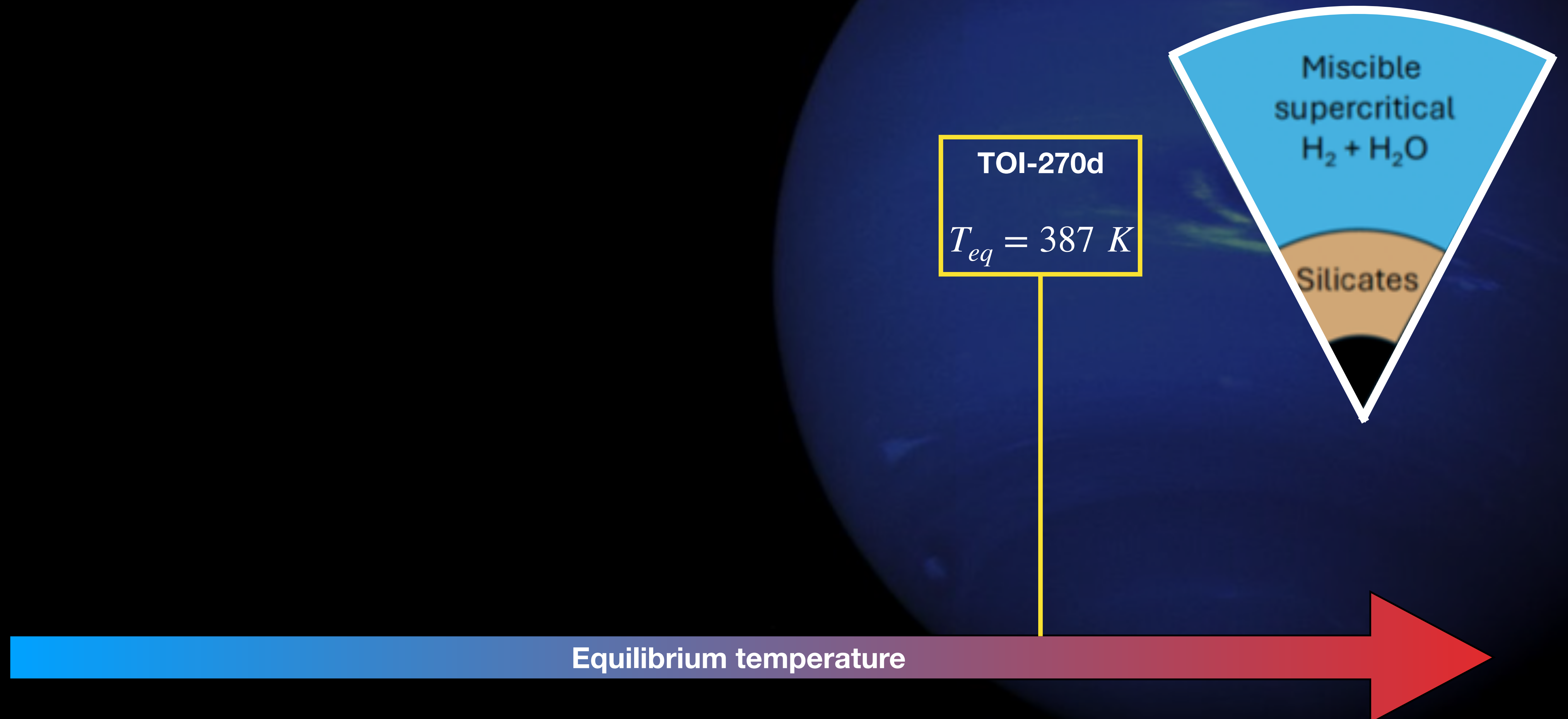
Benneke, Roy, et al. (submitted)

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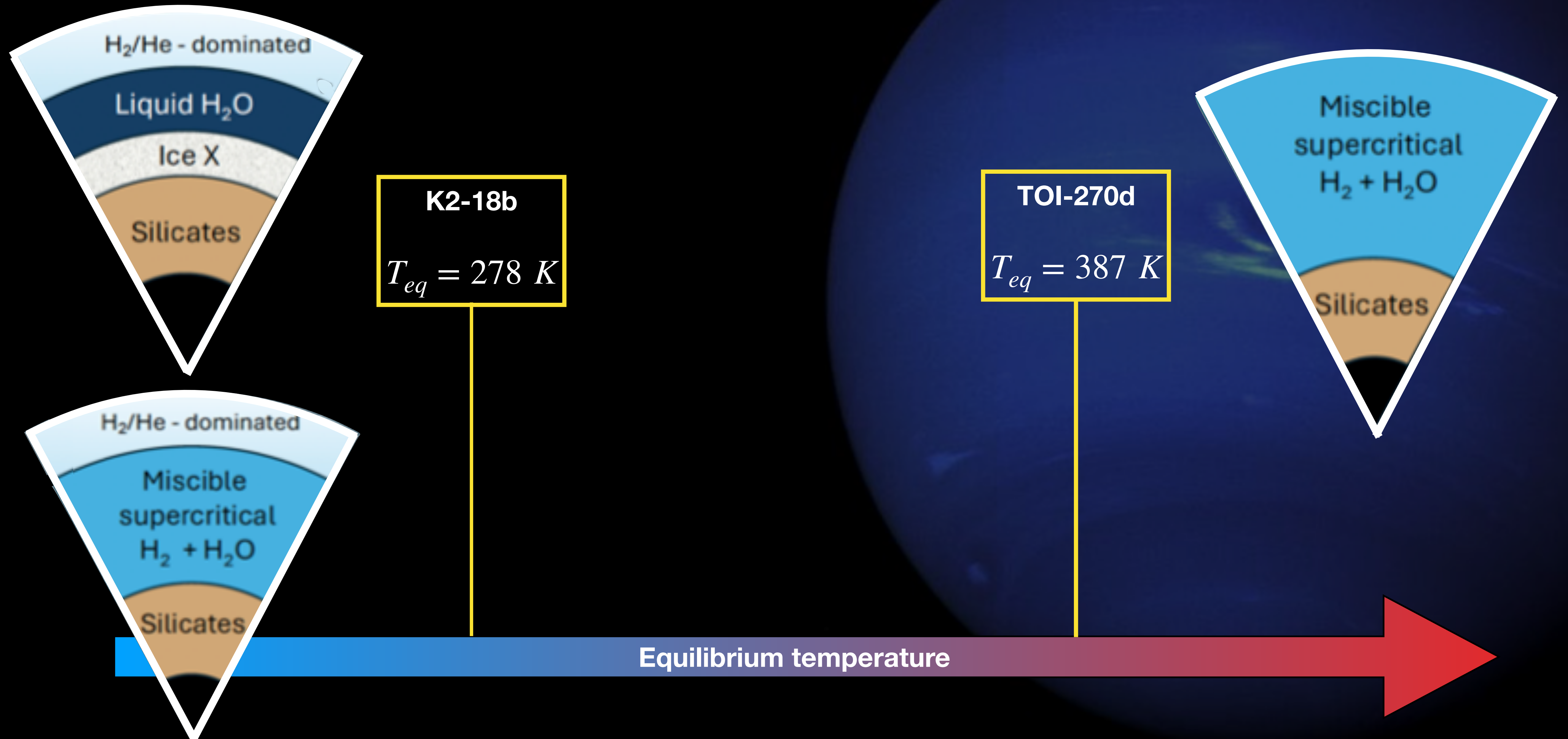


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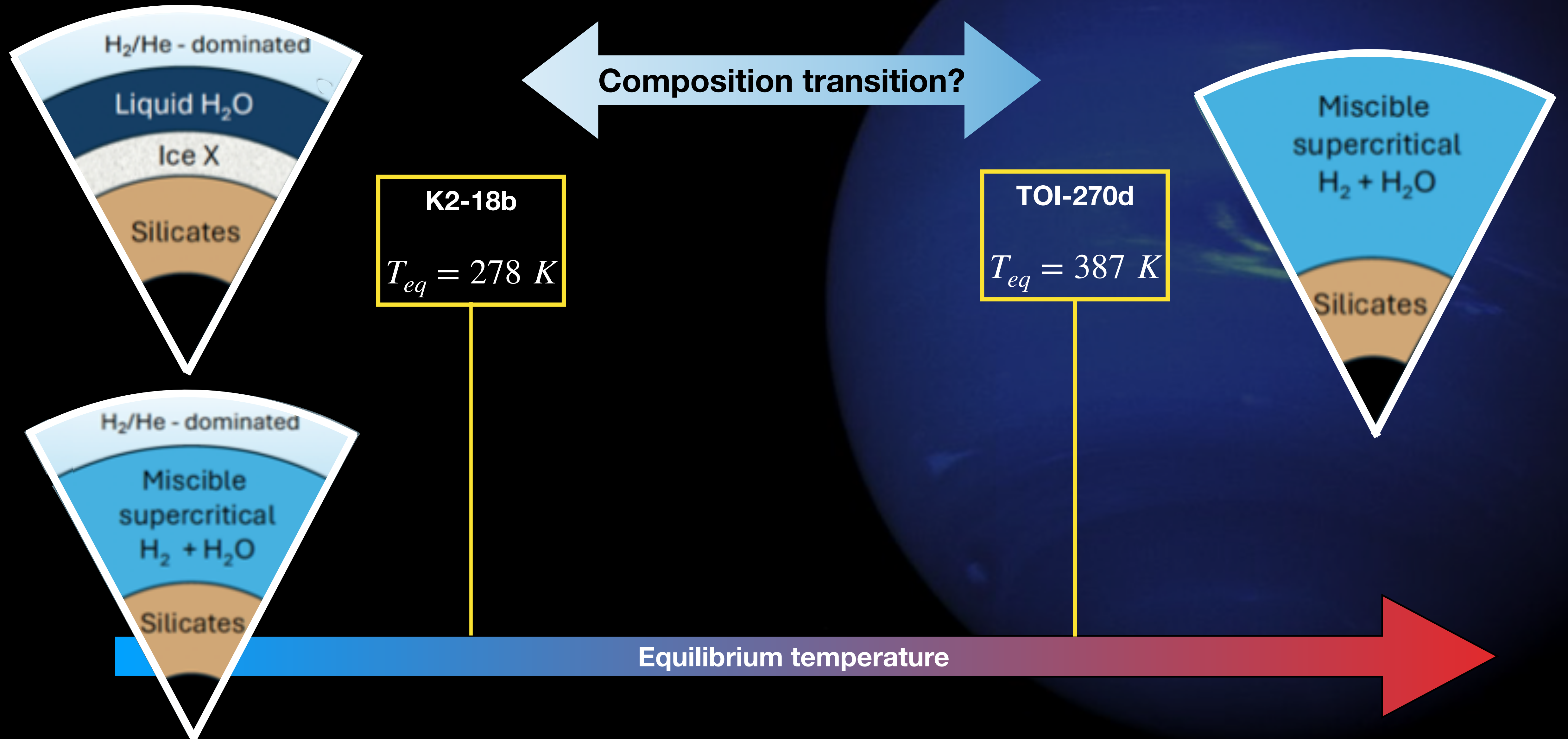
TOI-270d re-writes the rules:
only the coldest sub-Neptunes can have stratified/Hycean compositions



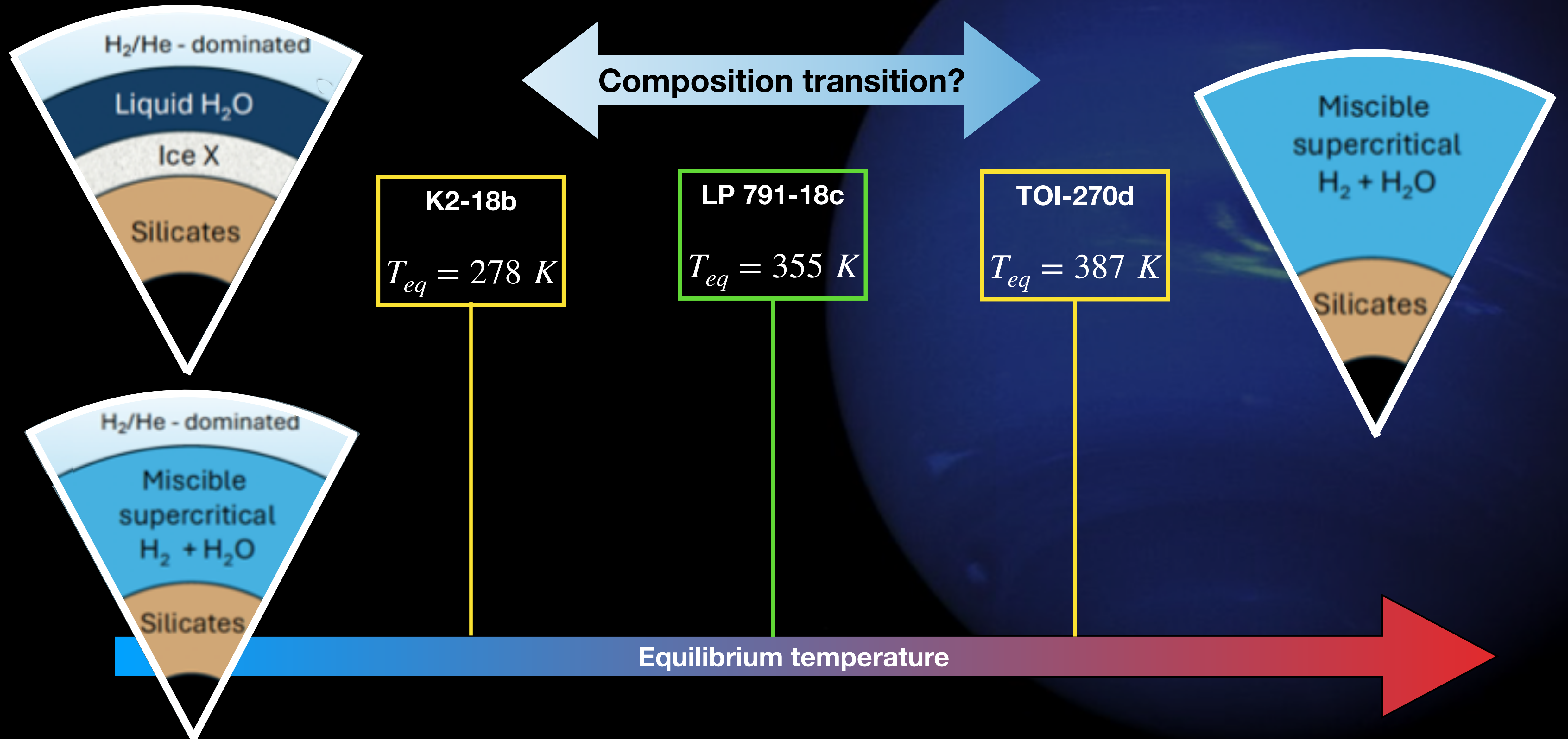
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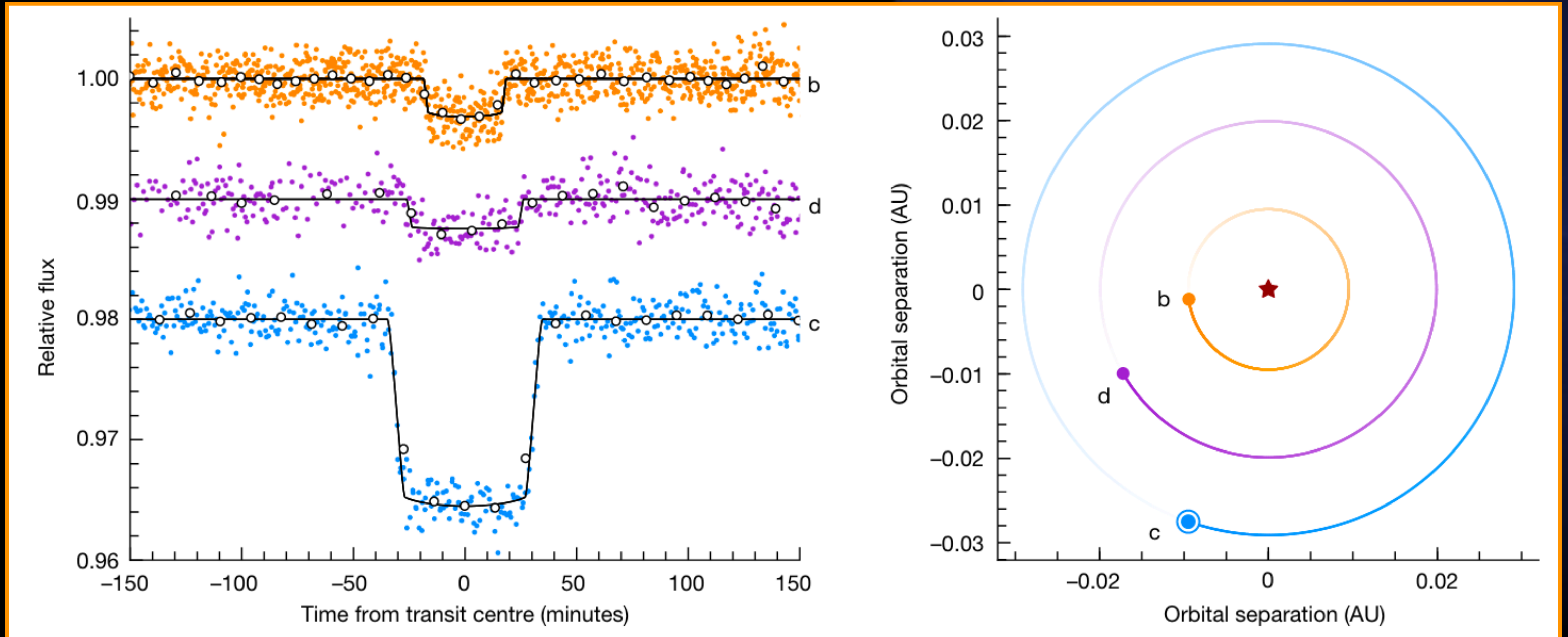
The next step: Study new sub-Neptunes that probe the transition between mixed and stratified compositions



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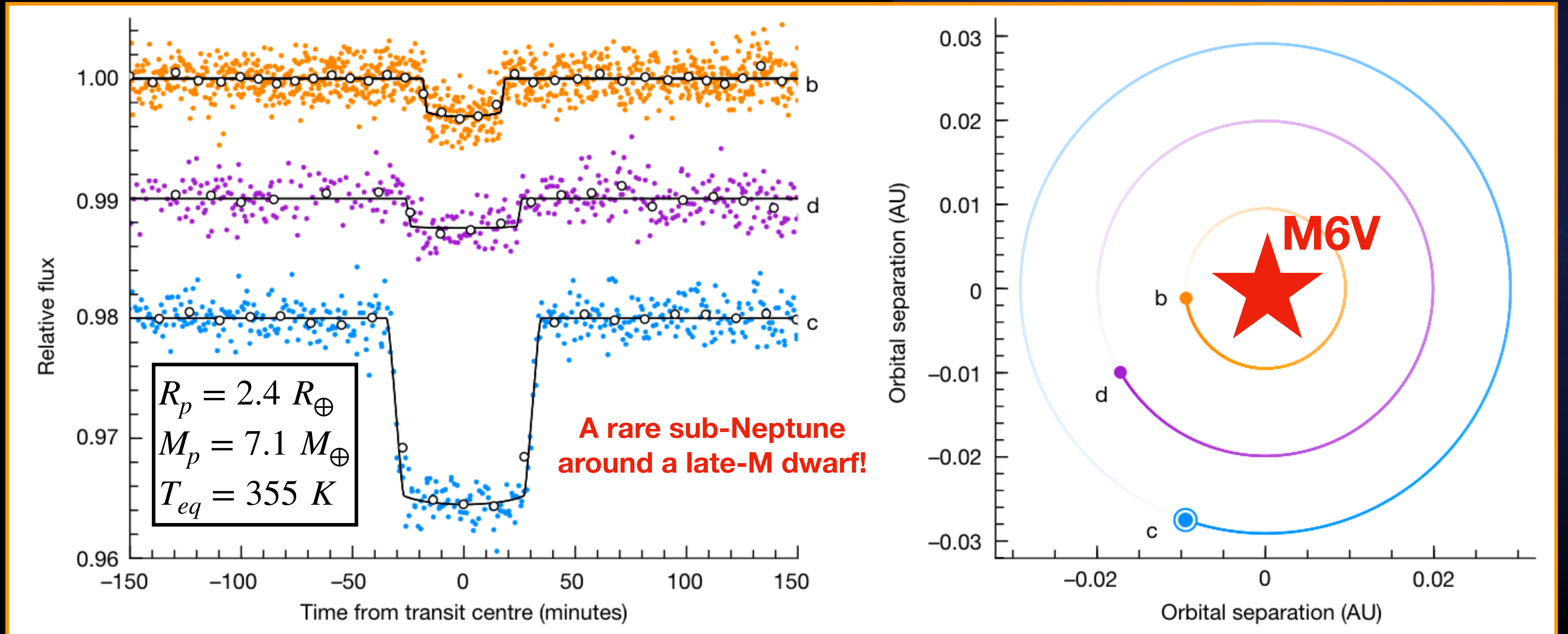


The LP 791-18 system: Three planets around a late M dwarf



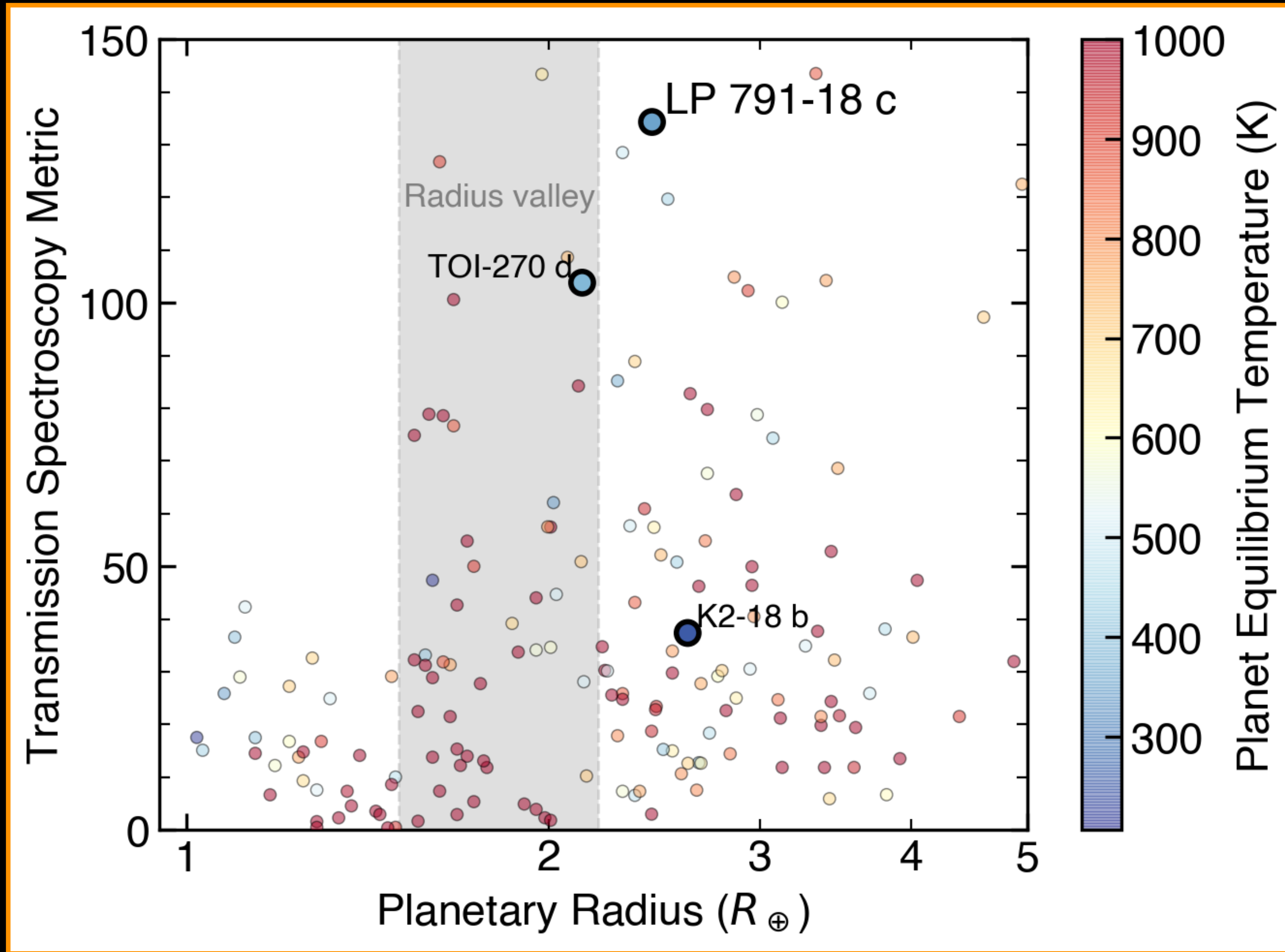
Peterson et al. 2023

The LP 791-18 system: Three planets around a late M dwarf



Peterson et al. 2023

LP 791-18 c: An ideal sub-Neptune for transit spectroscopy



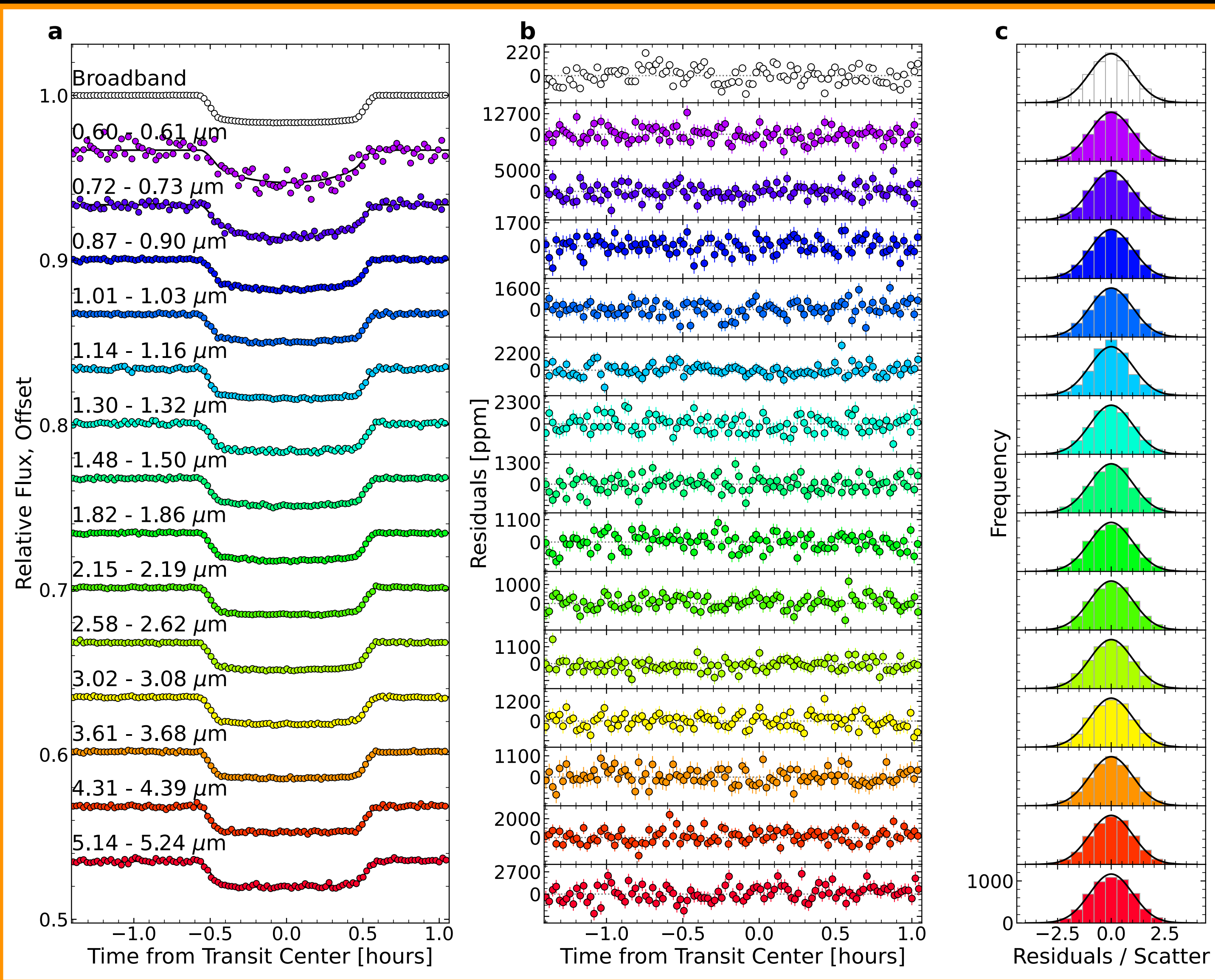
Roy et al. in prep.

Orbits a **small M6V dwarf**,
one of the smallest known
exoplanet hosts



**Very high SNR for
transit spectroscopy!**
TSM is 3 times that of K2-18b

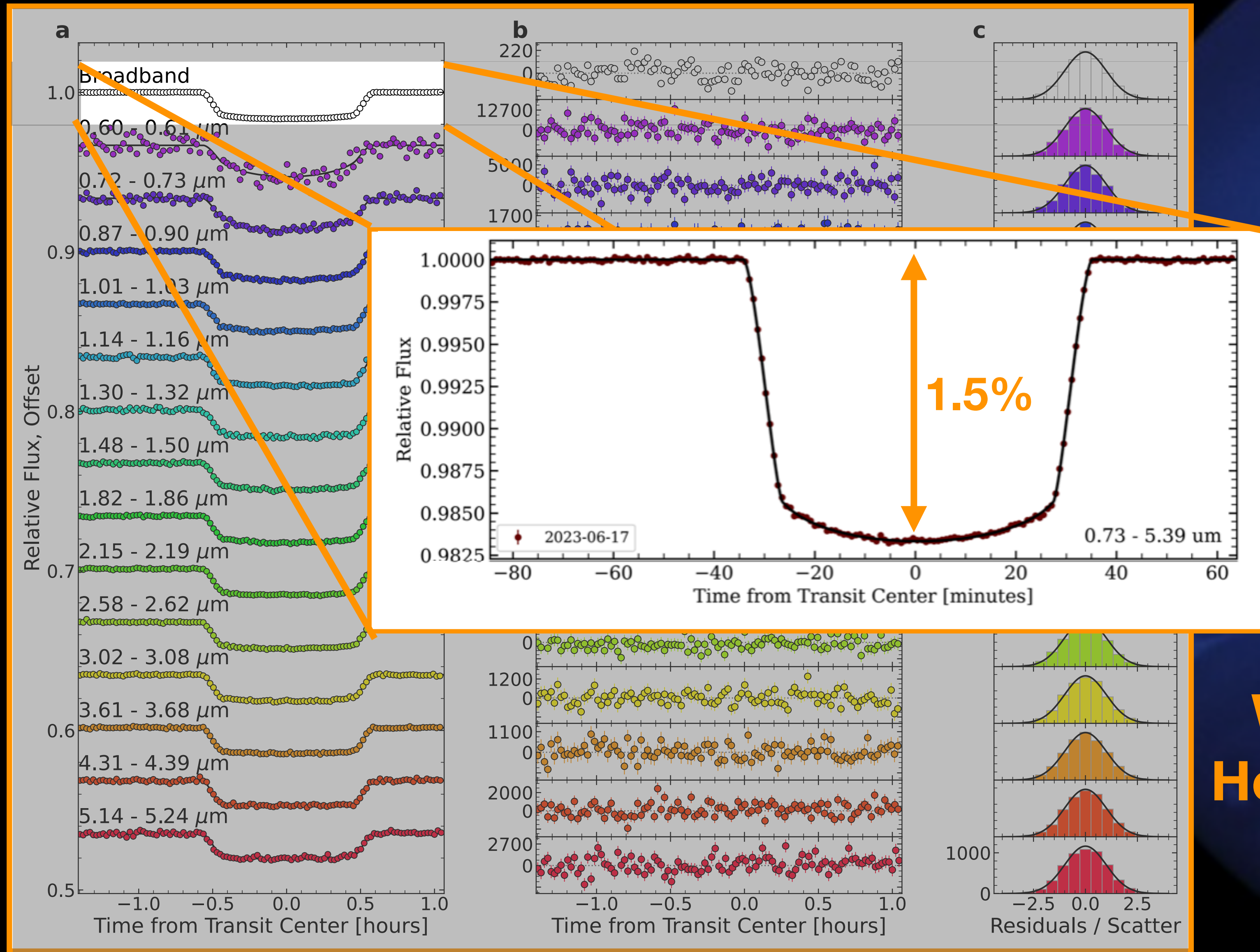
JWST look at the temperate sub-Neptune LP 791-18 c



**NIRSpec/PRISM transit
GTO 1201, PI Lafrenière**

Roy et al. in prep.

JWST look at the temperate sub-Neptune LP 791-18 c



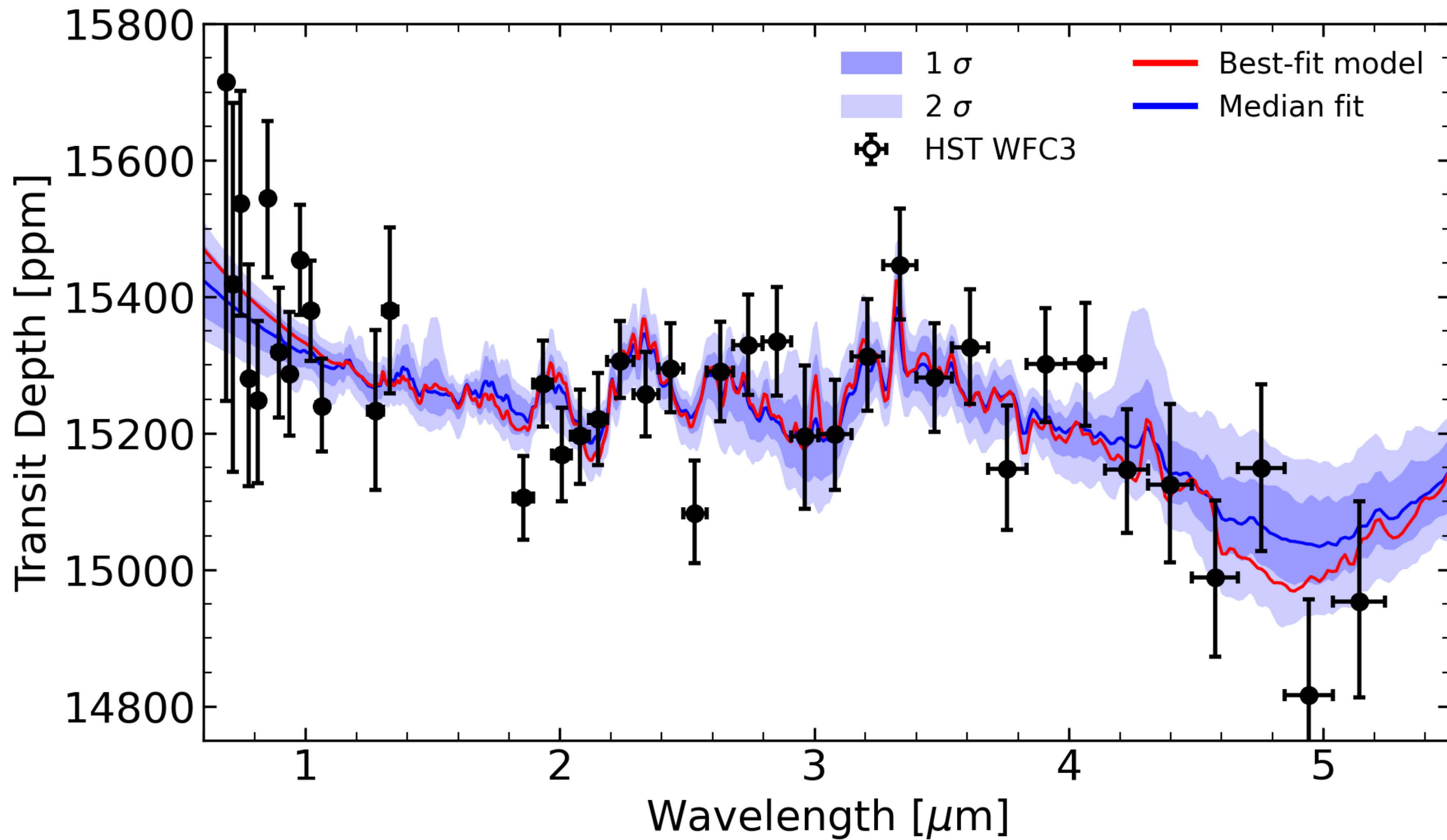
**NIRSpec/PRISM transit
GTO 1201, PI Lafrenière**

**The host star is small and bright
(Wasp-39-like magnitude)**

**We get a 1.5% transit depth:
Hot Jupiter-quality light curves!**

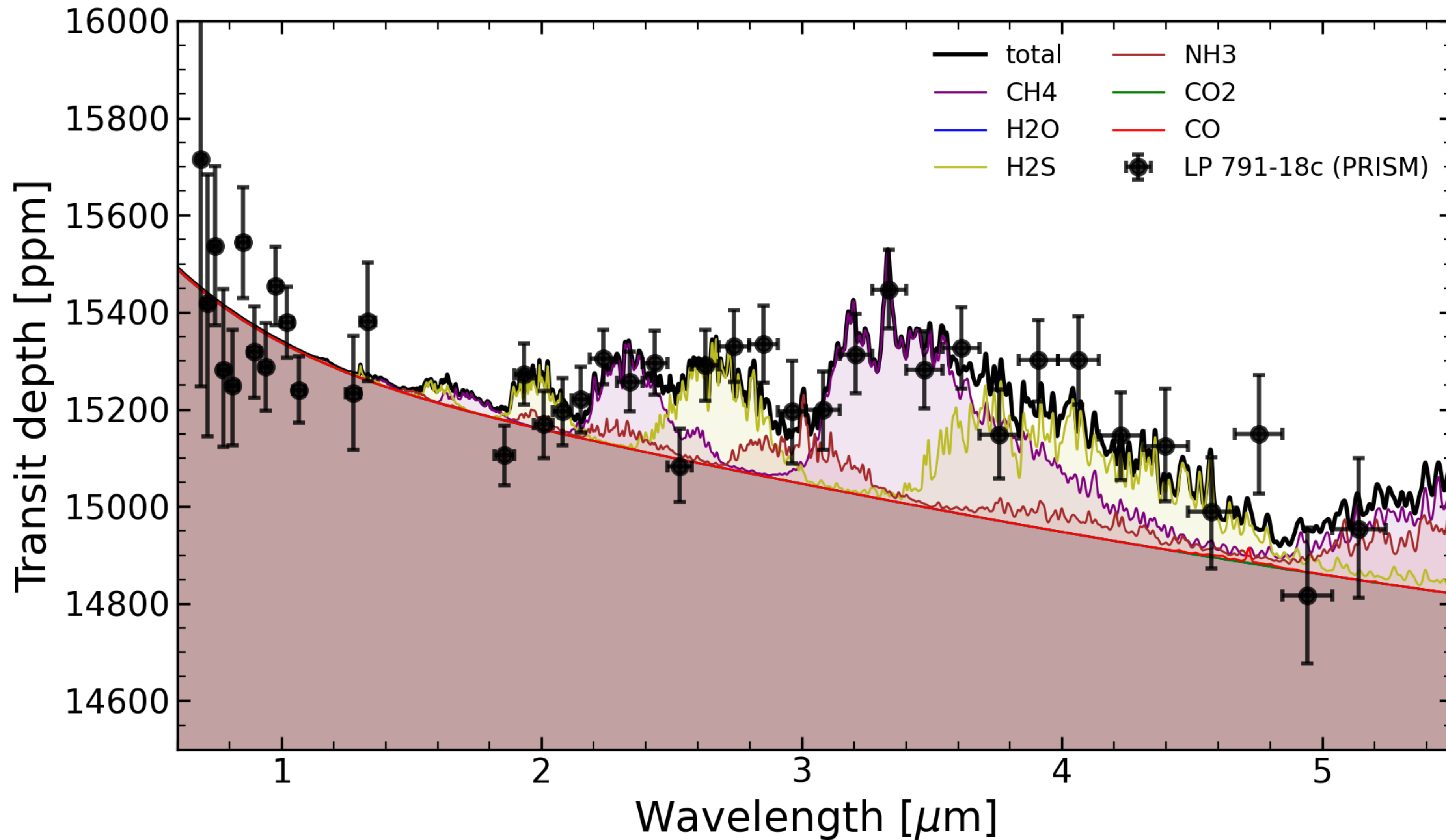
Roy et al. in prep.

NIRSpec/PRISM transit spectrum of LP791-18c

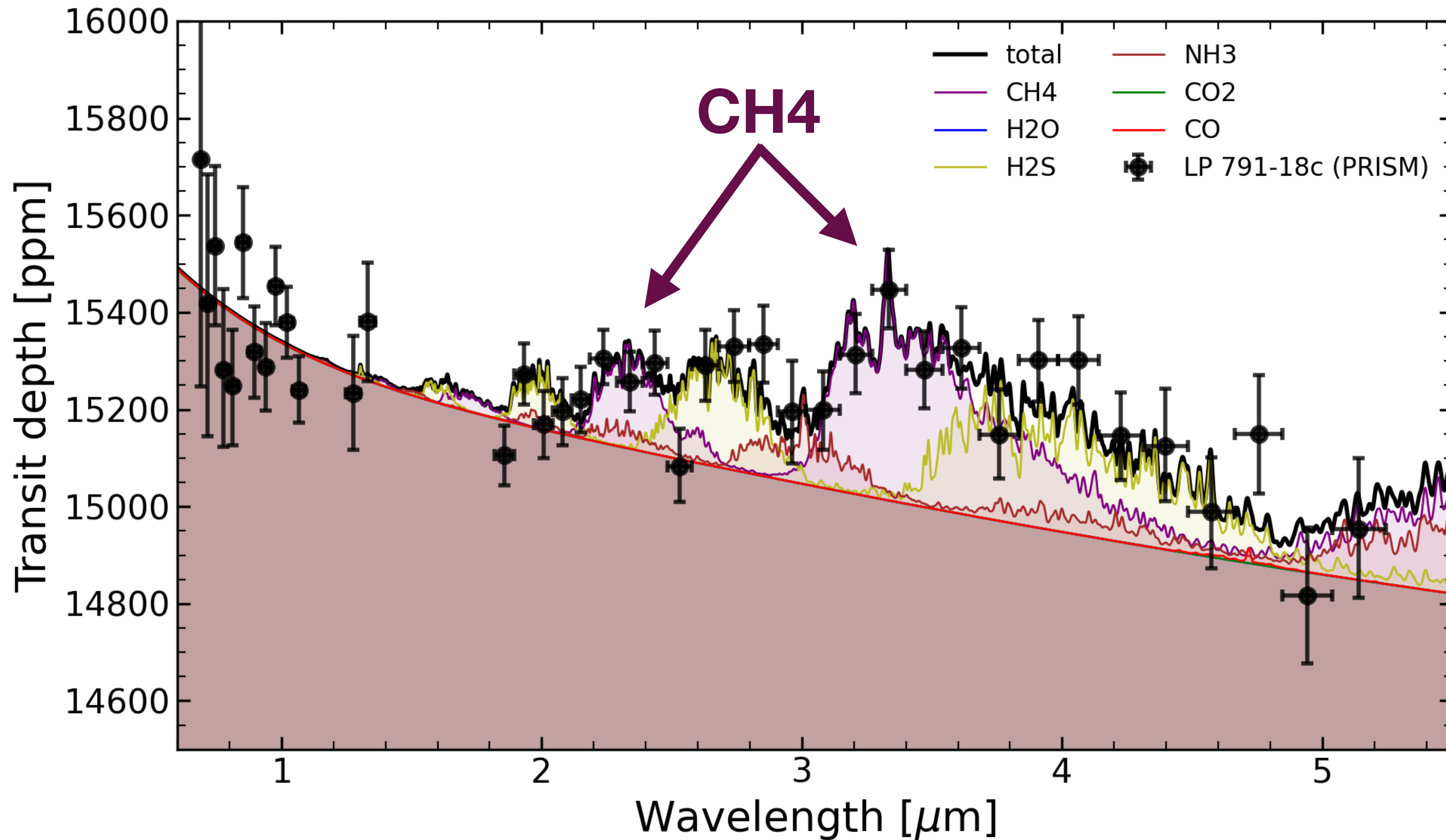


Roy et al. in prep.

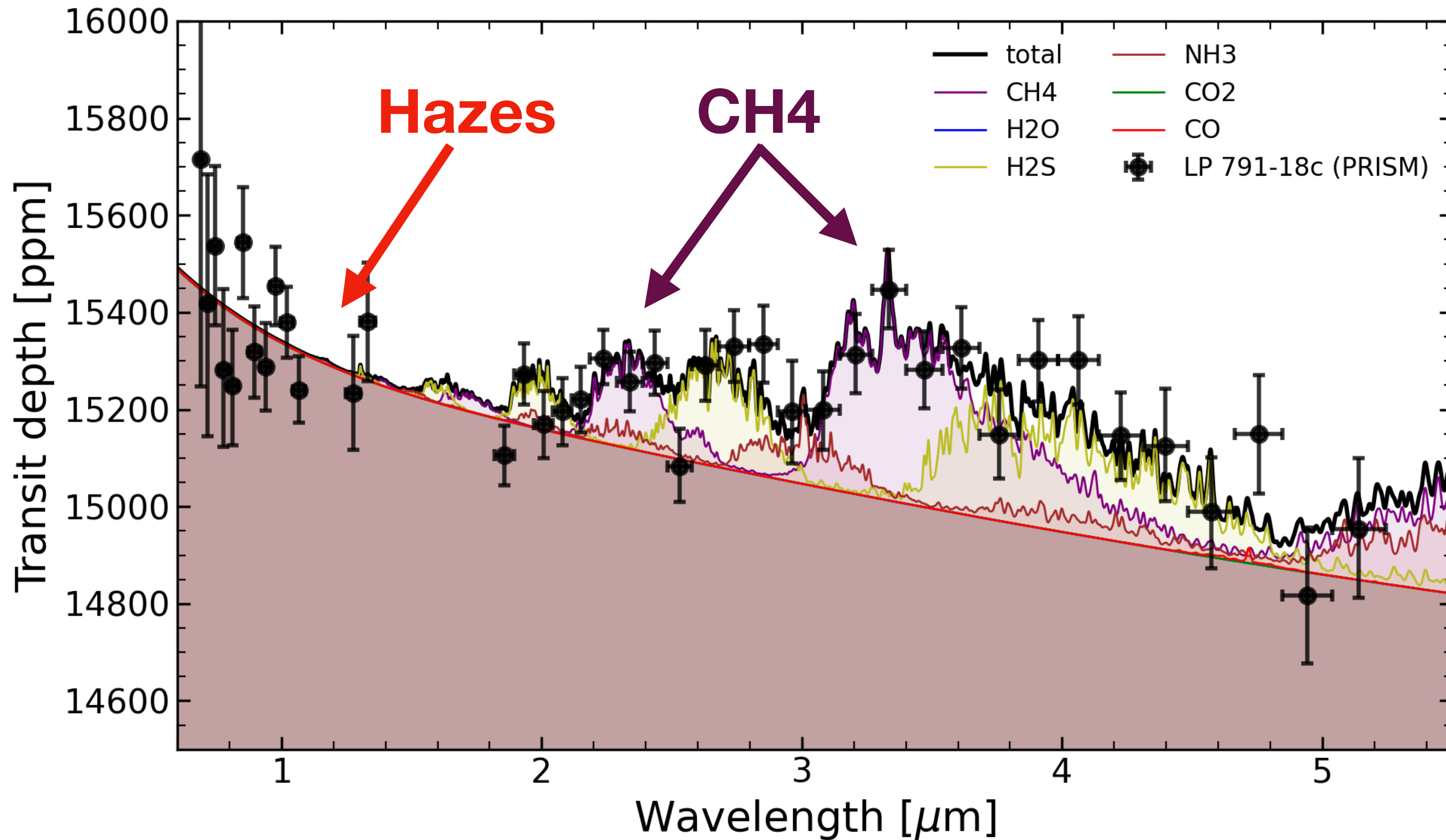
A methane-rich, hazy atmosphere



A methane-rich, hazy atmosphere

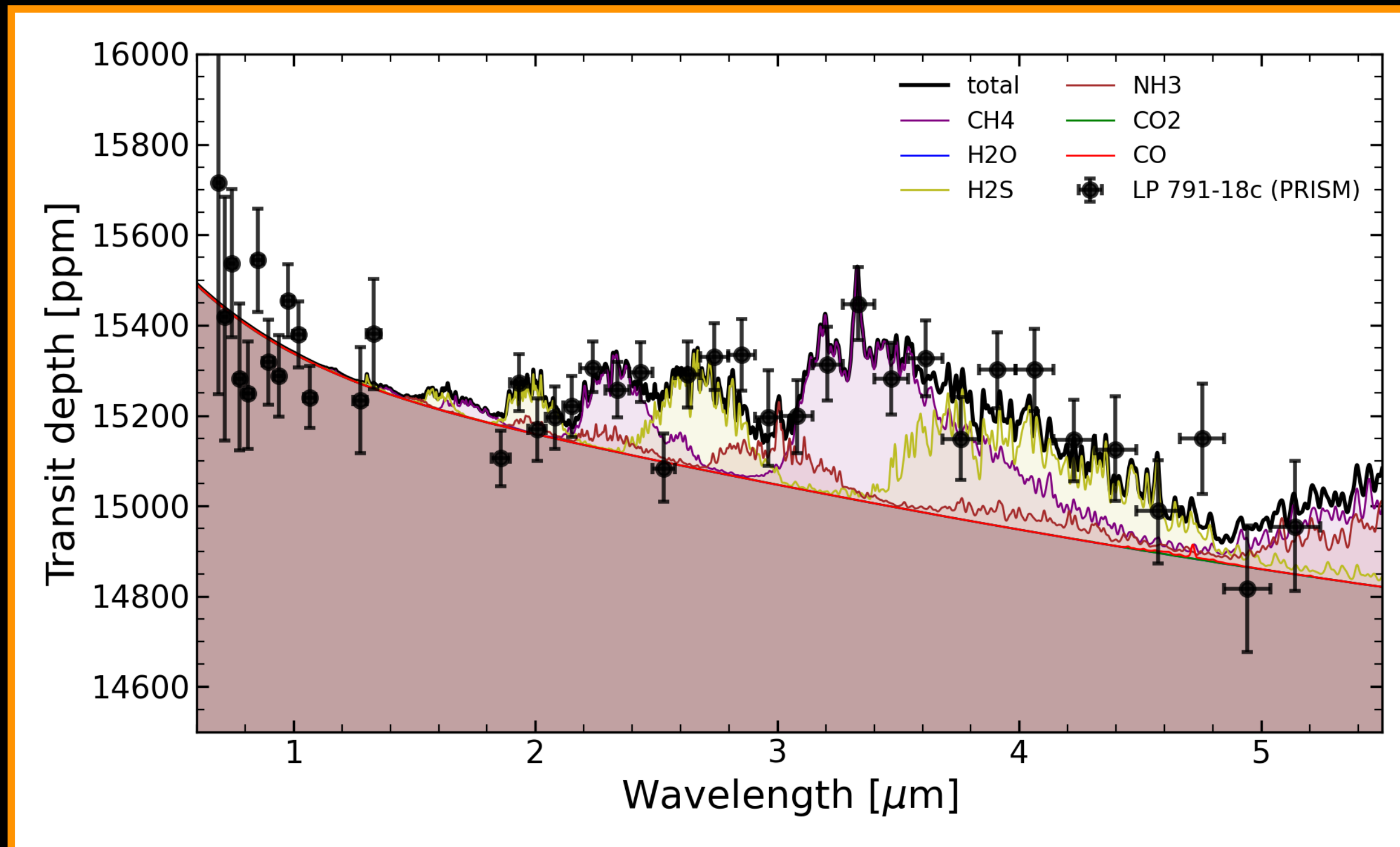


A methane-rich, hazy atmosphere

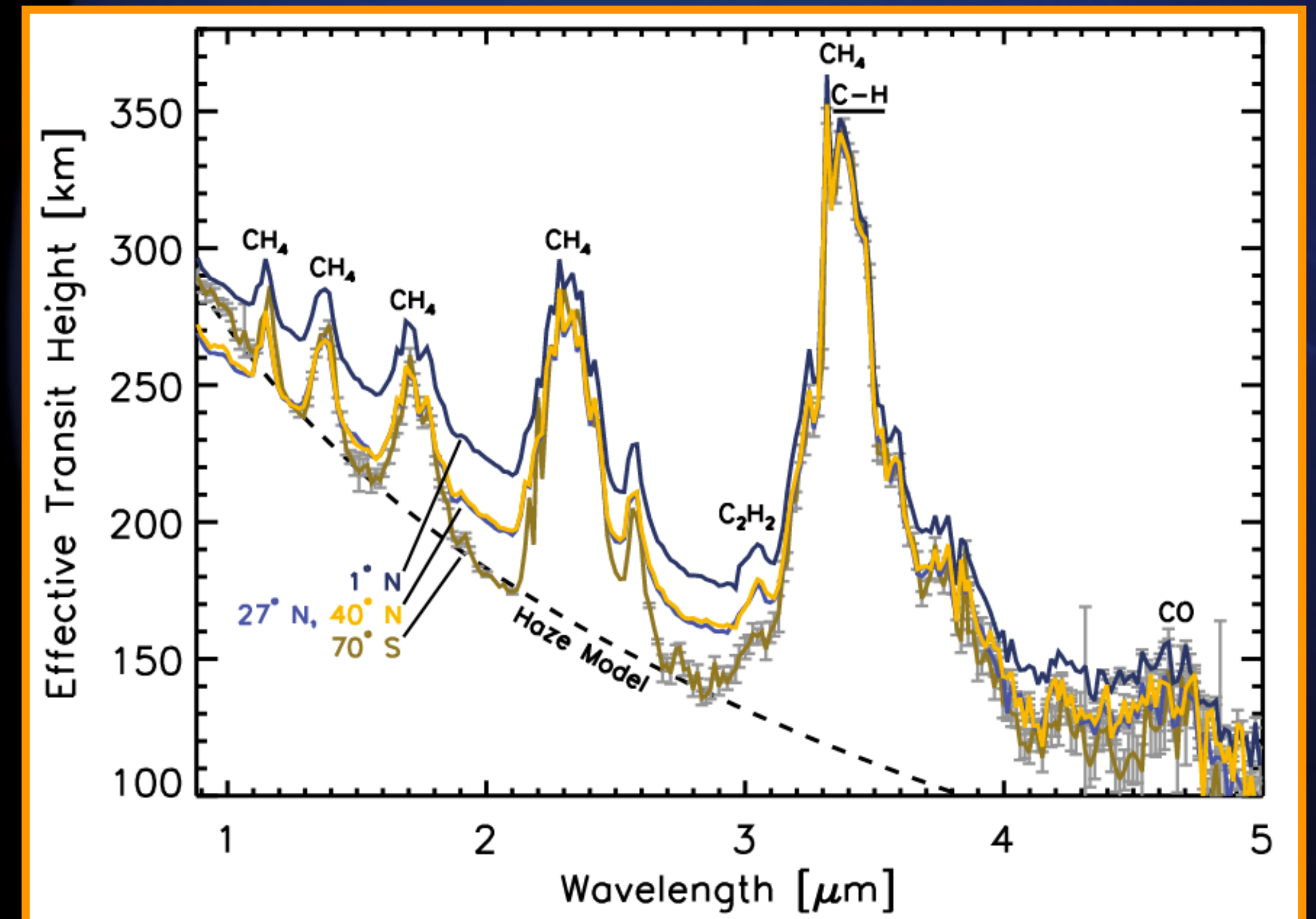


A methane-rich, hazy atmosphere

Reminiscent of Titan's occultations with the spectrum dominated by methane and hazes

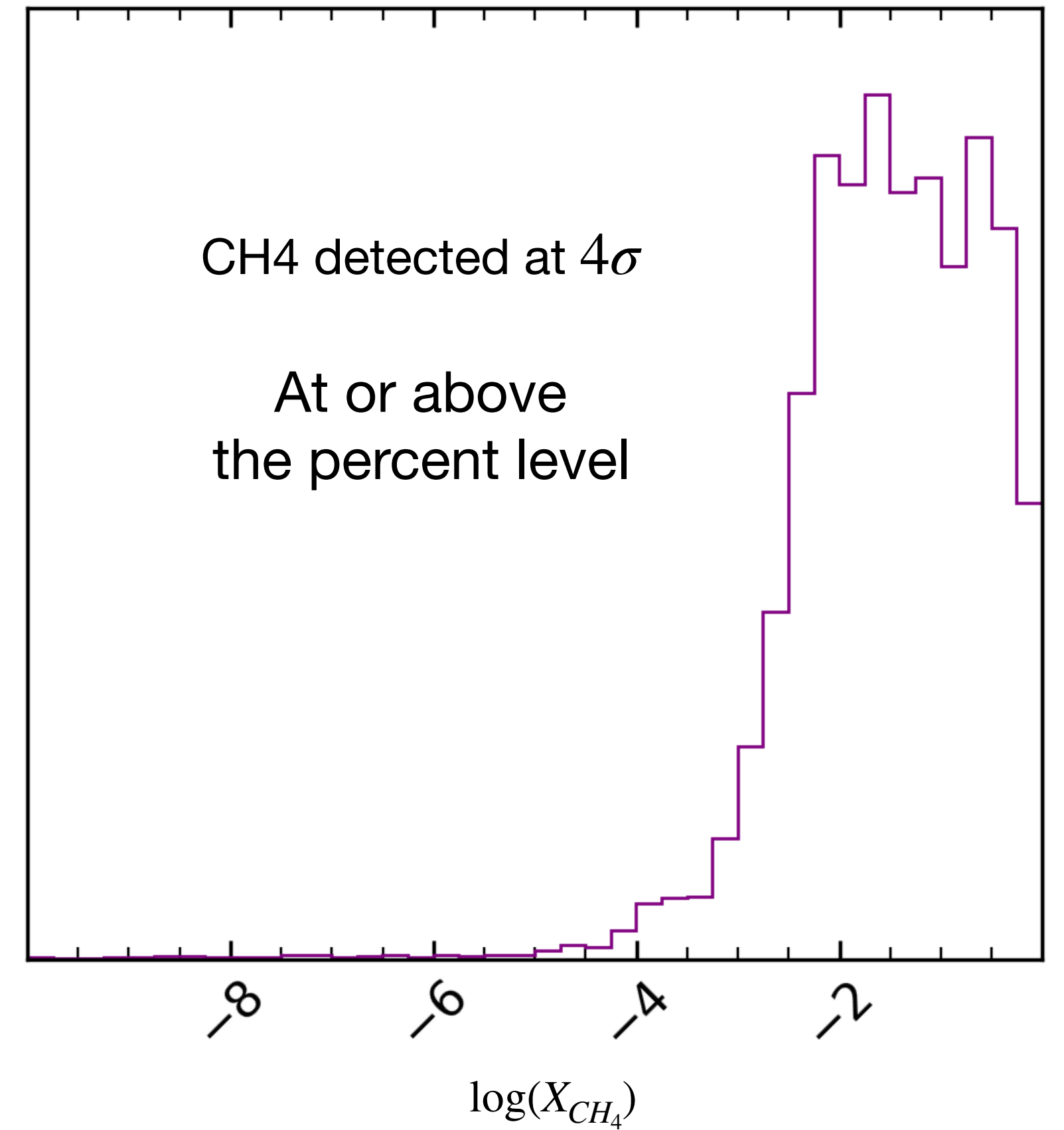
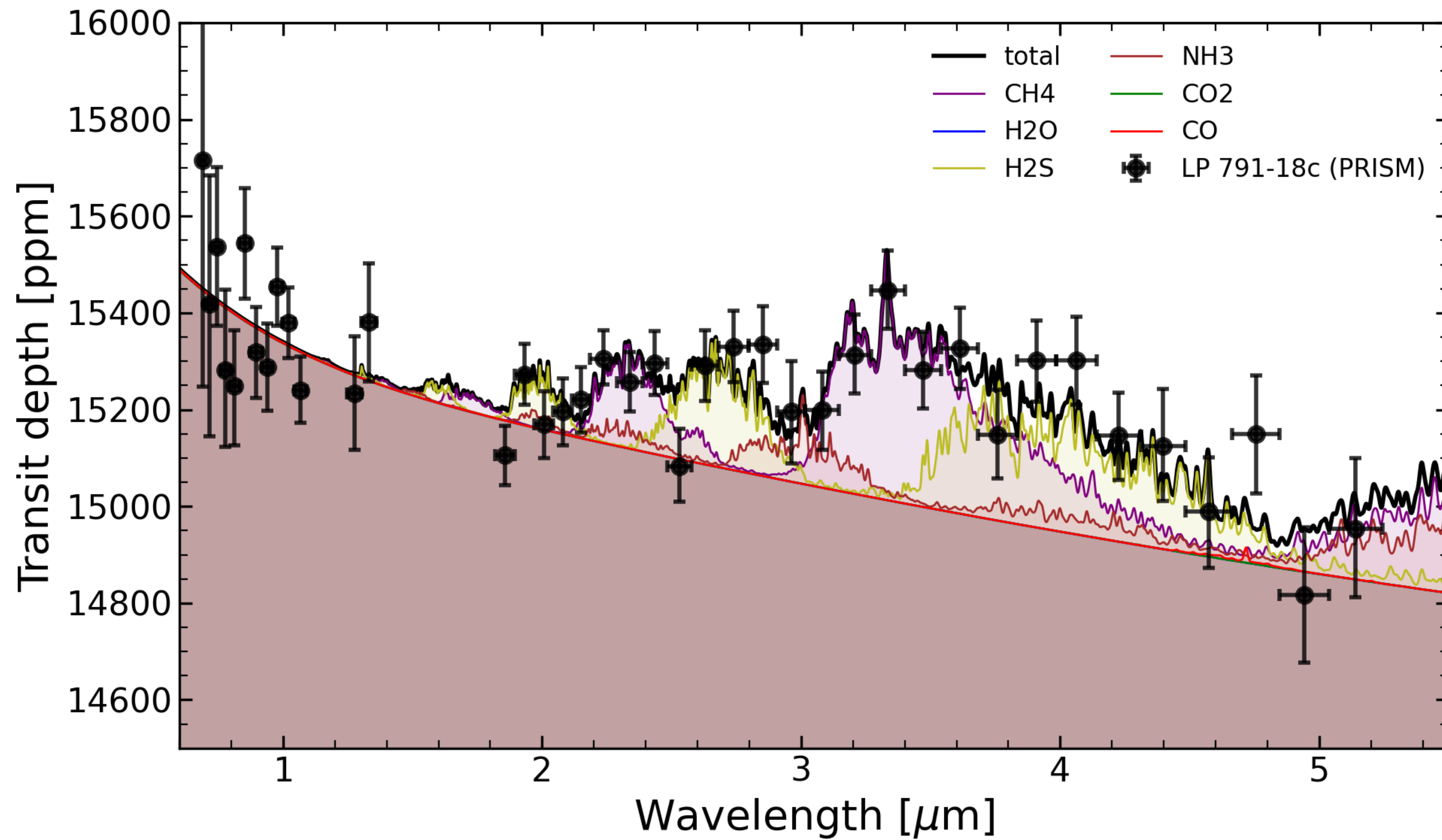


Roy et al. in prep.



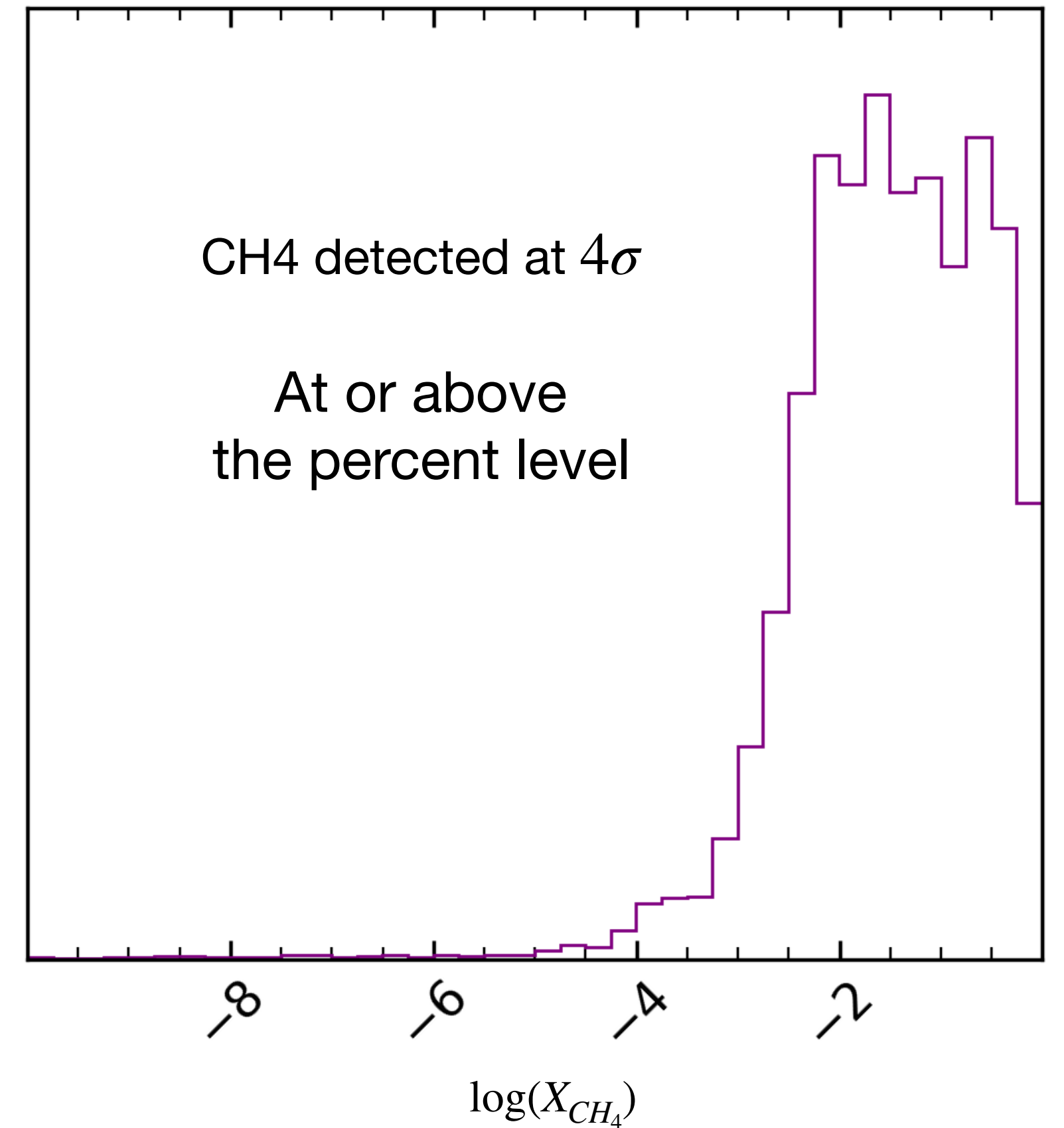
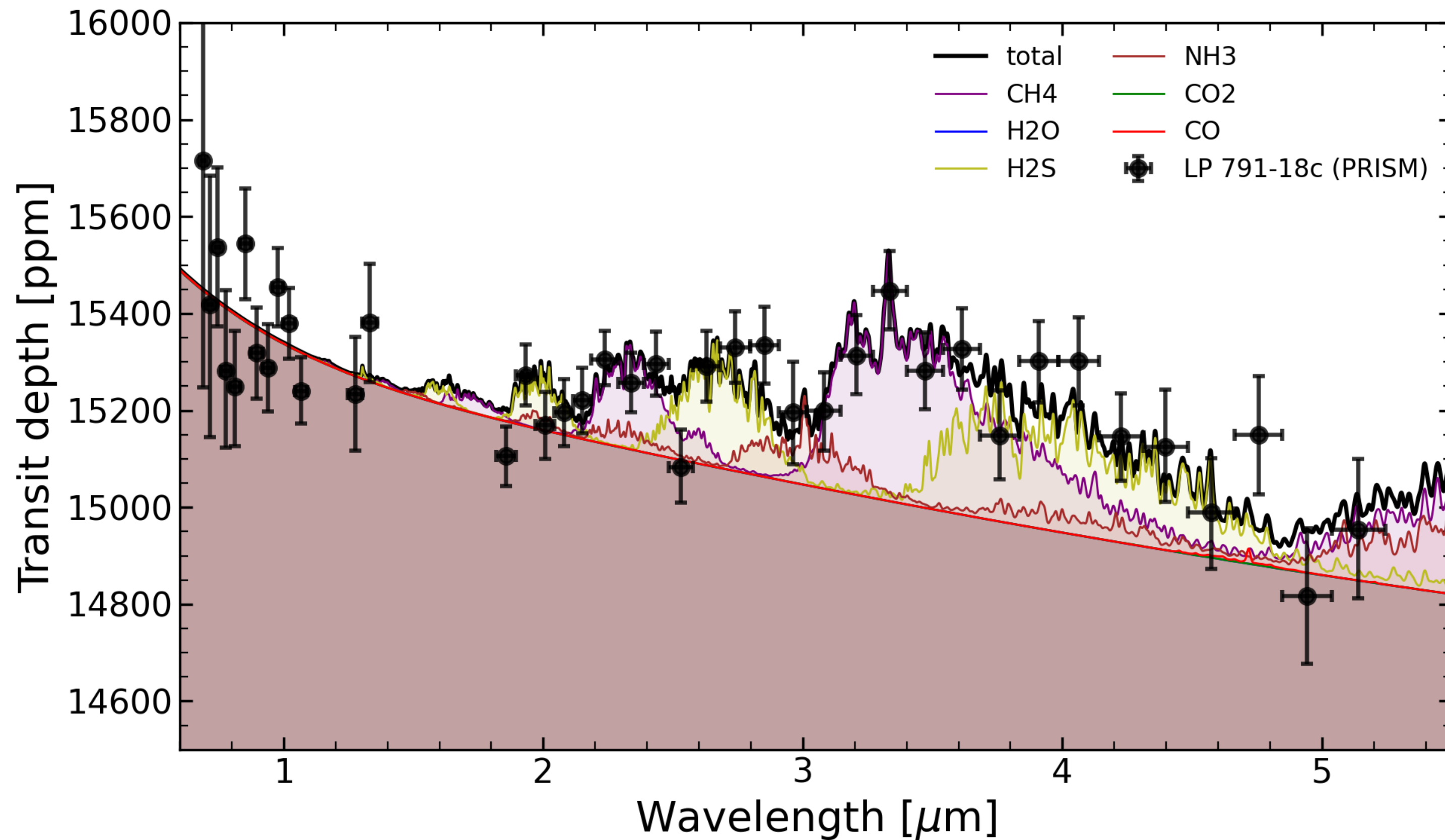
Robinson et al. 2014

A methane-rich, hazy atmosphere



Roy et al. in prep.

A methane-rich, hazy atmosphere

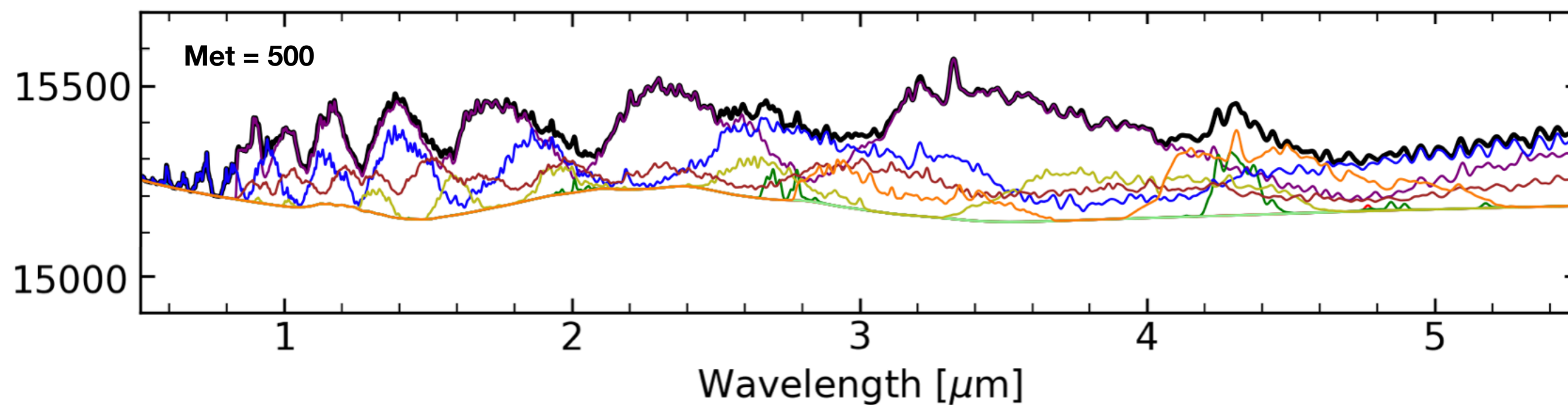
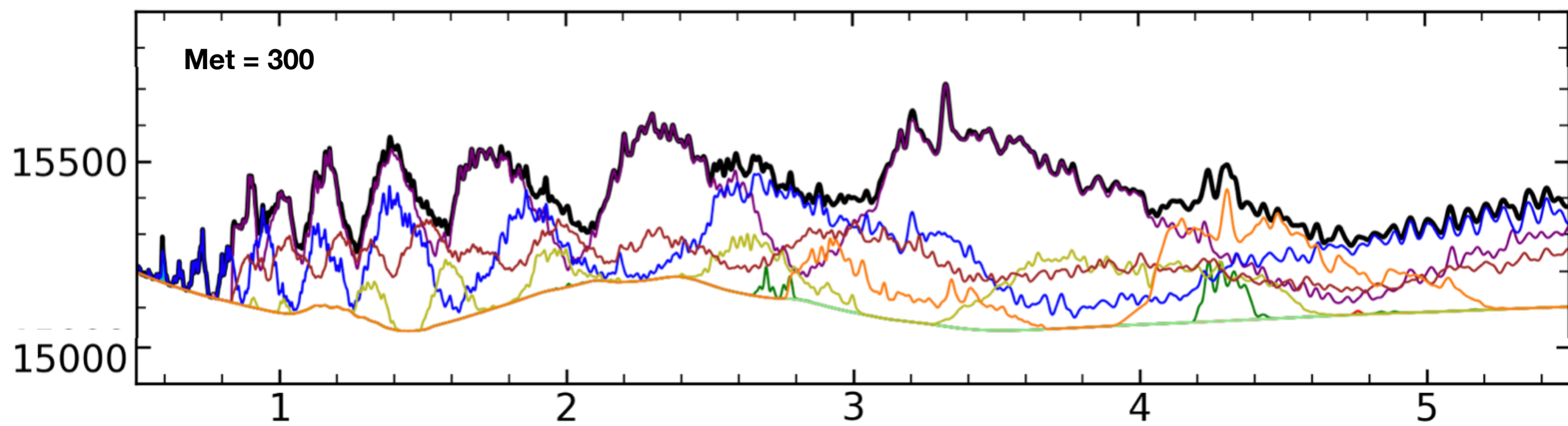
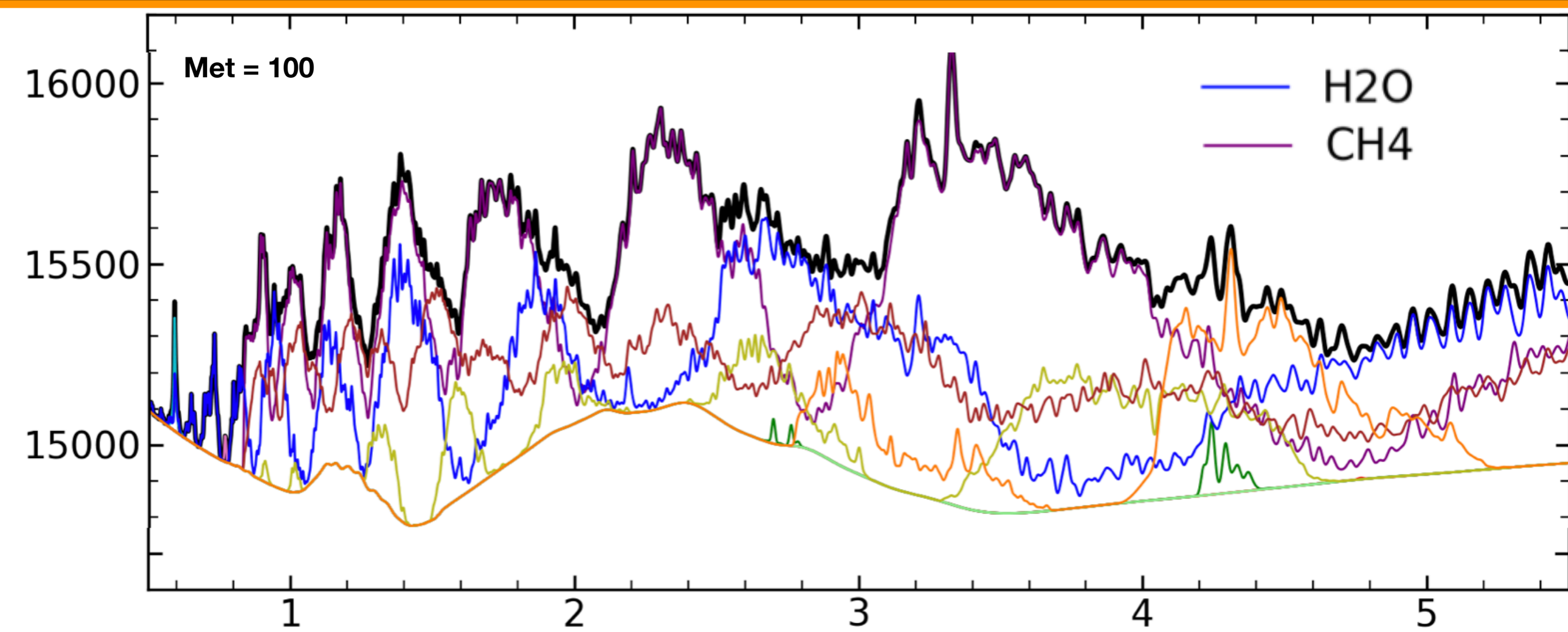


Roy et al. in prep.

No detection of O-bearing species...

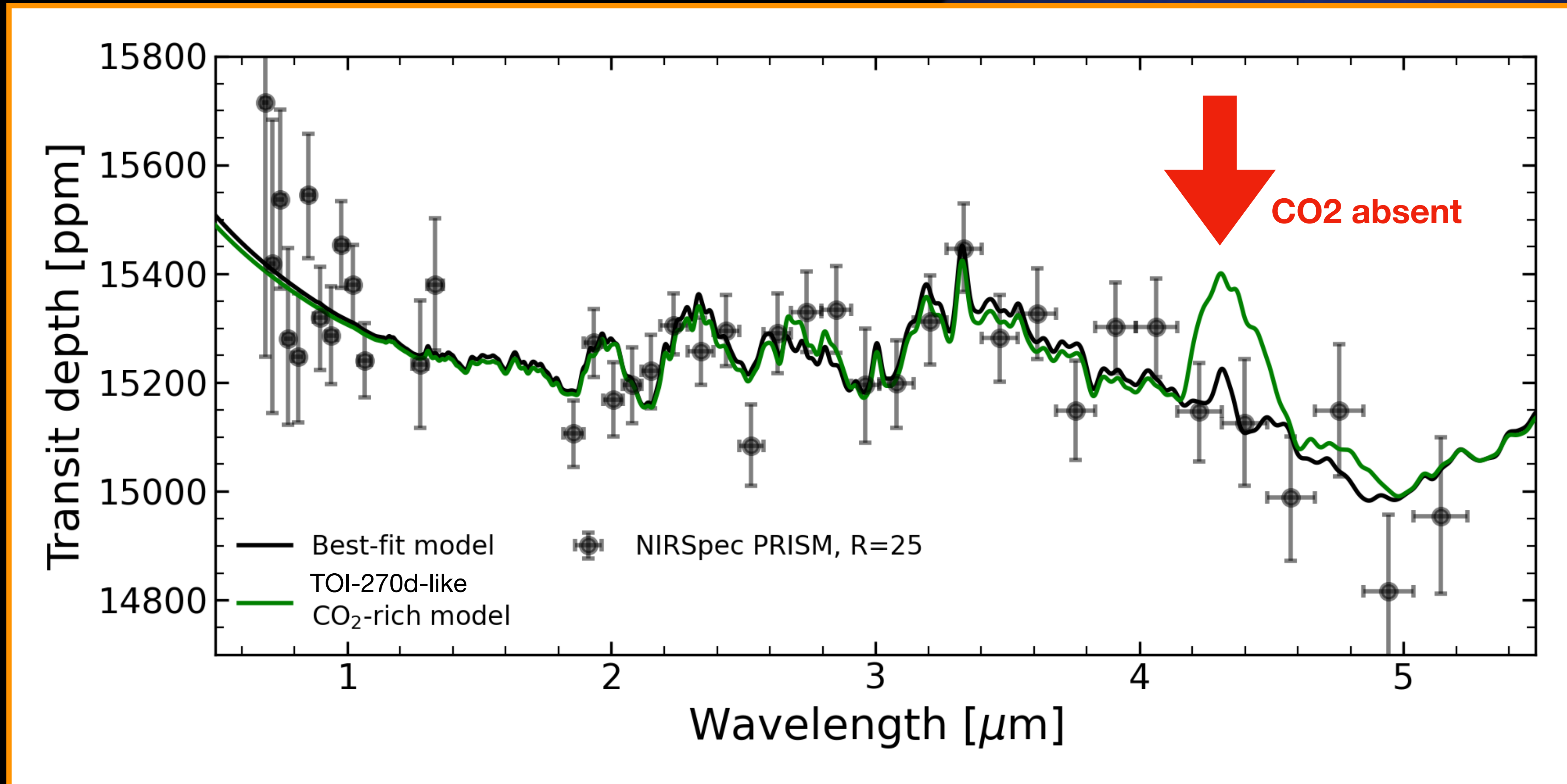
Water is hard to see in the presence of methane

Transit depth [ppm]



Even if water is abundant, the large abundance of methane and the hazes make it very hard to measure it

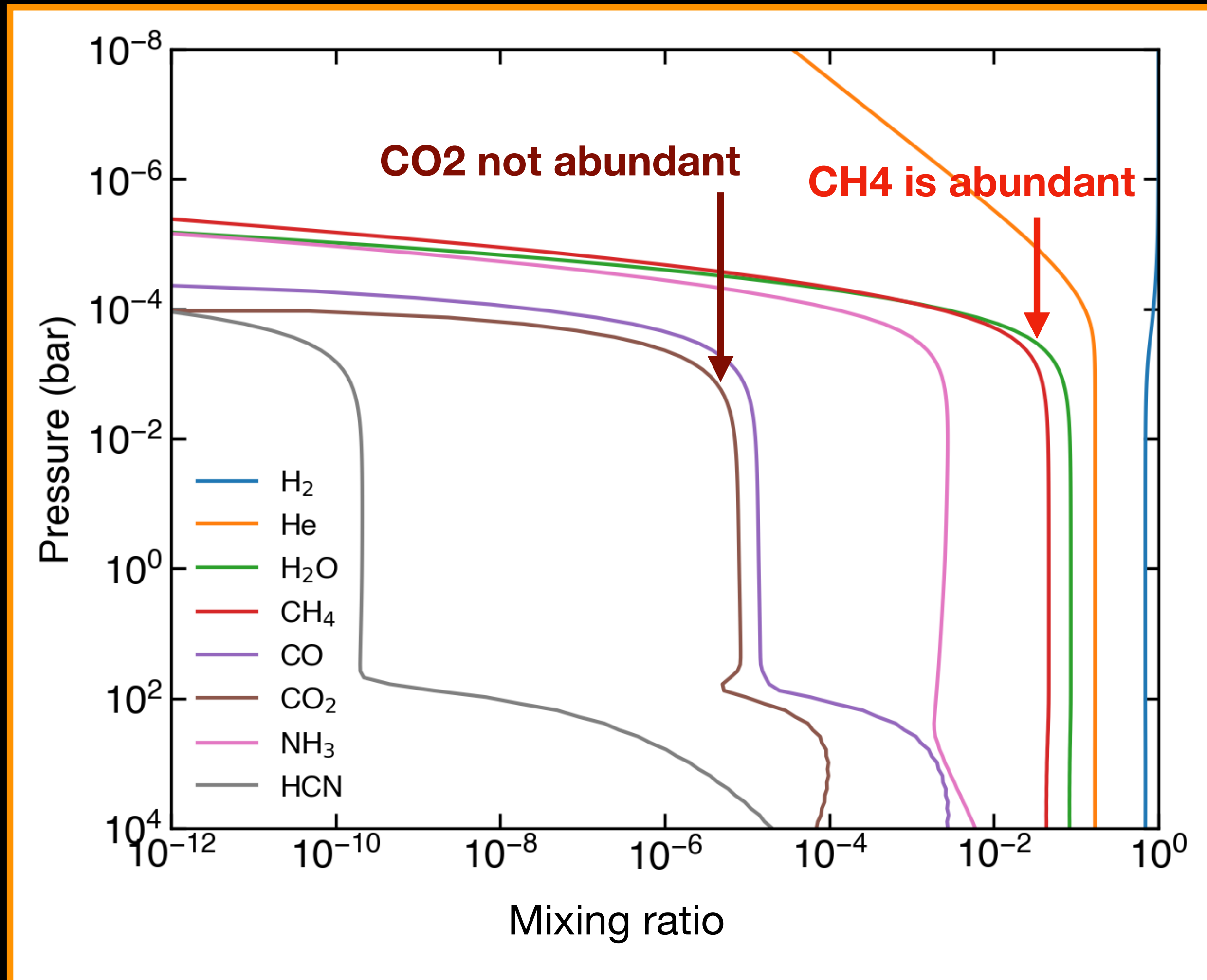
If CO₂ was similarly abundant to K2-18b and TOI-270d, we should see it.



Roy et al. in prep.

Where is the CO2?

A) The metallicity is low



Chemical Kinetics model

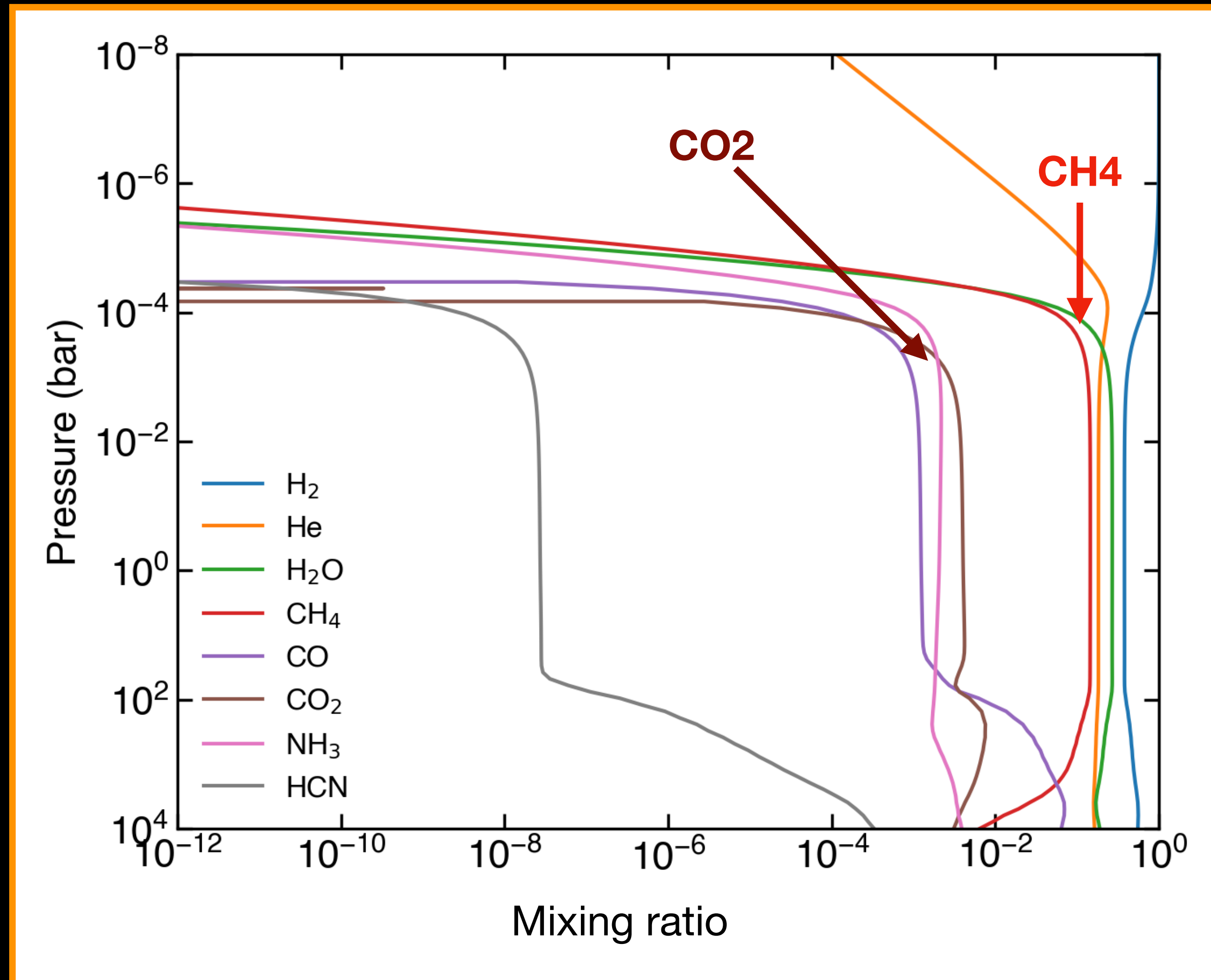
Met = 100 x solar

C/O = 0.54 (solar)

Methane and water are already very abundant, but the CO_2 is not, even with mixing.

Where is the CO₂?

B) The metallicity and C/O are high



Chemical Kinetics model

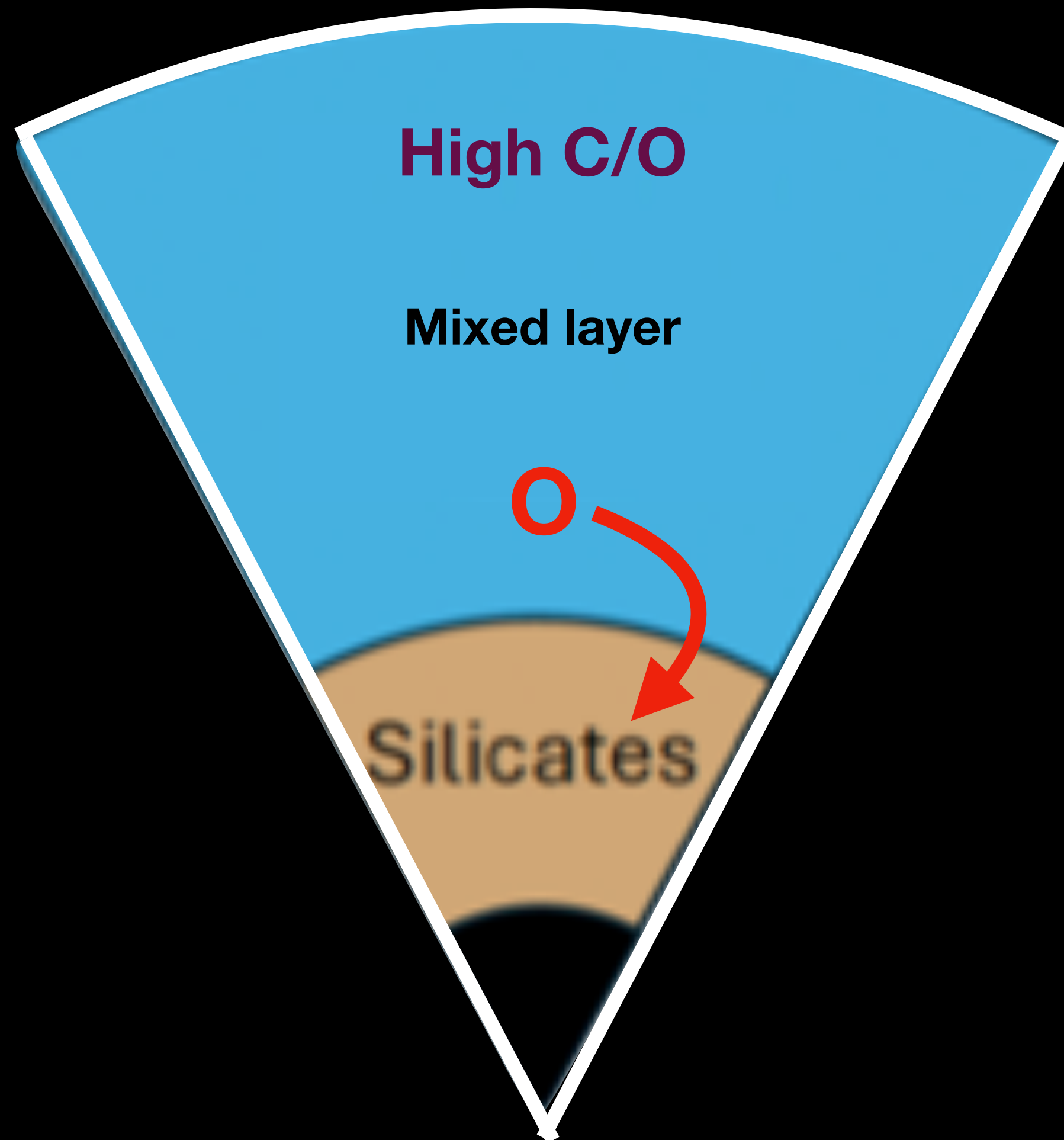
Met = 300 x solar

C/O = 0.54 (solar)

For higher metallicities, the CO₂ is abundant unless C/O is high

Where is the CO₂?

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Chemical Kinetics model

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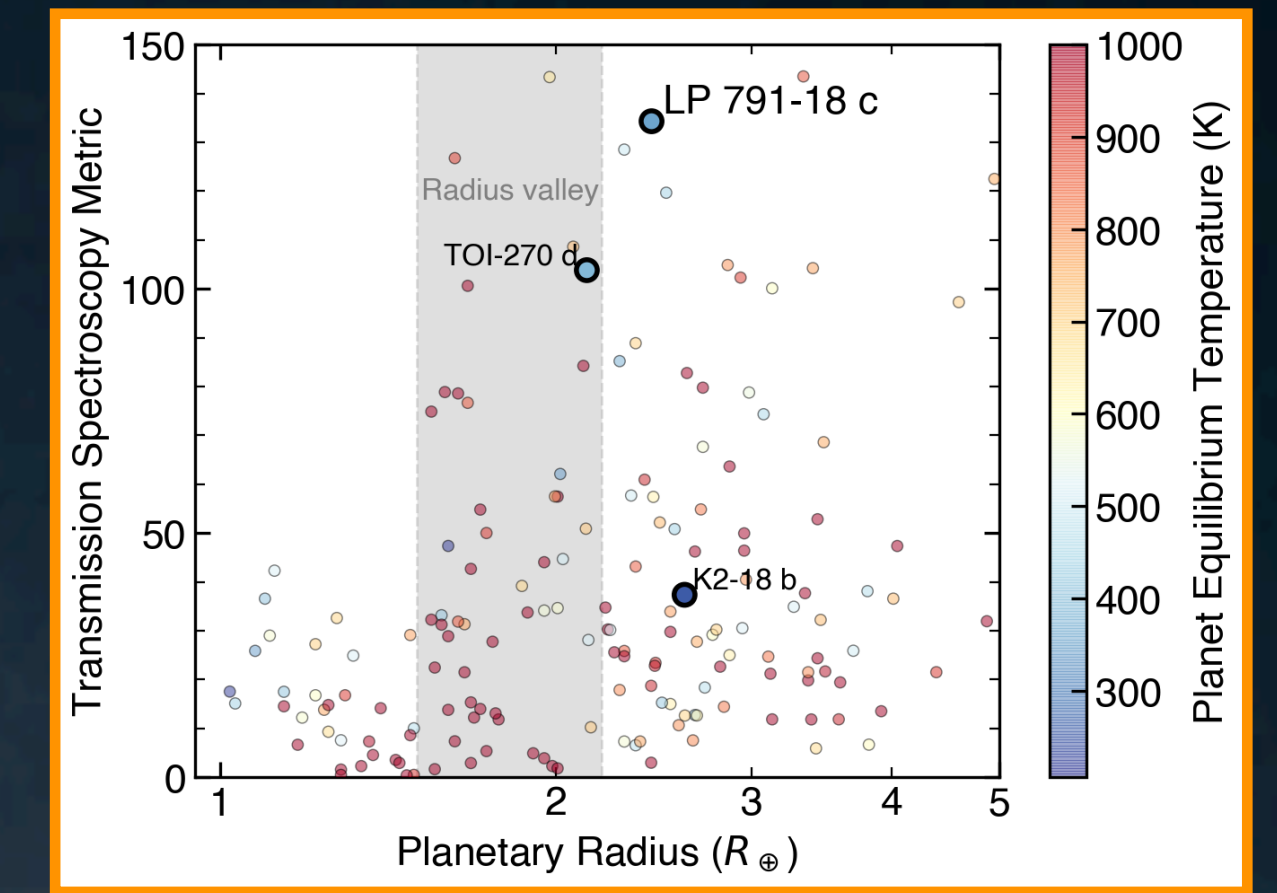
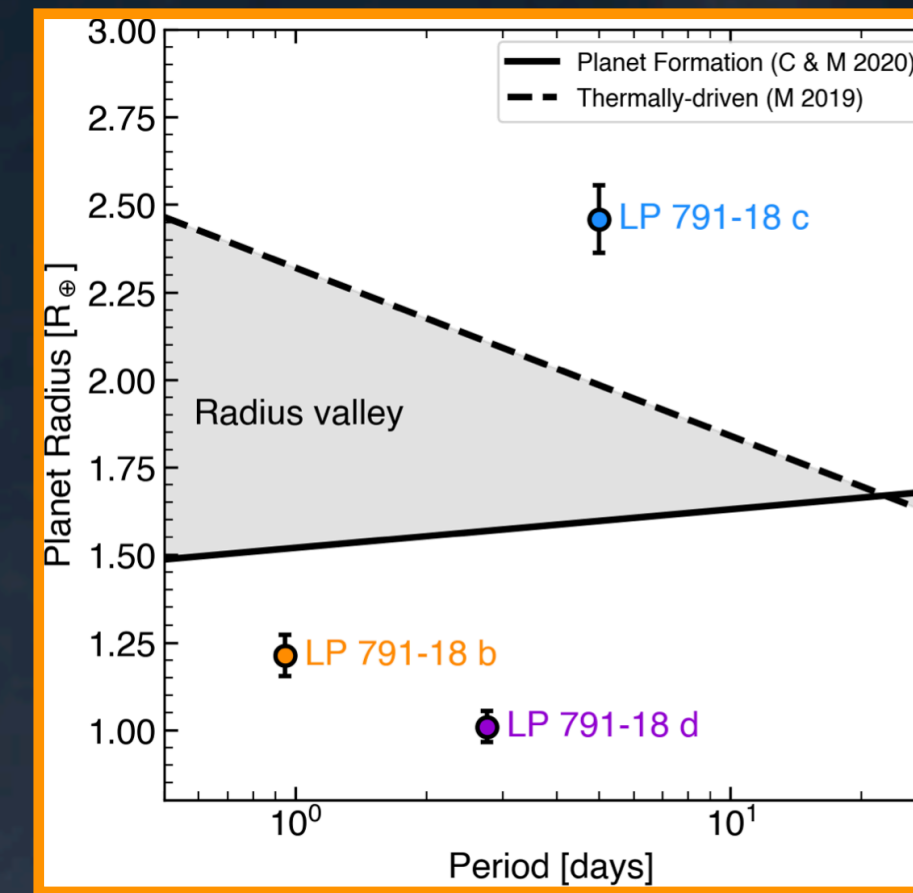
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Conclusions:

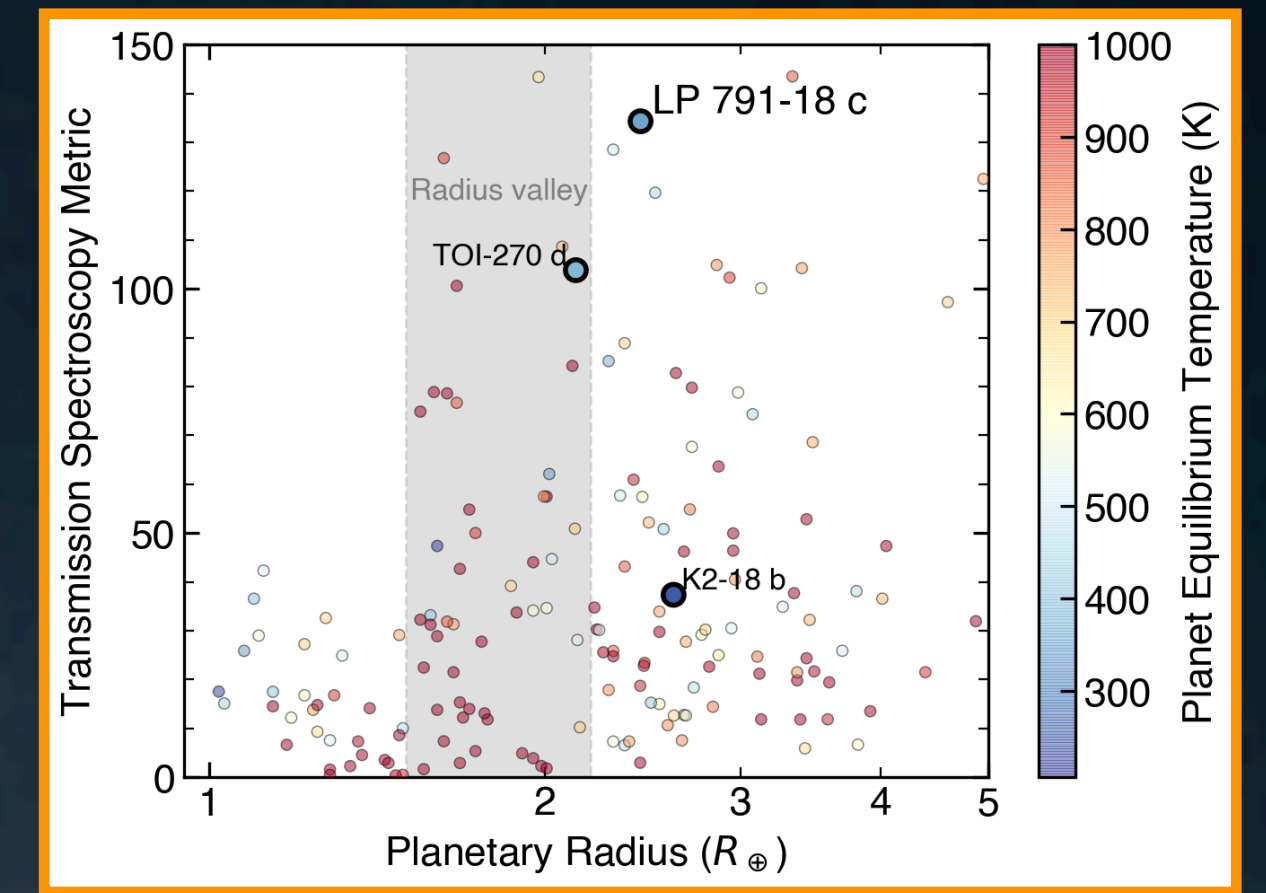
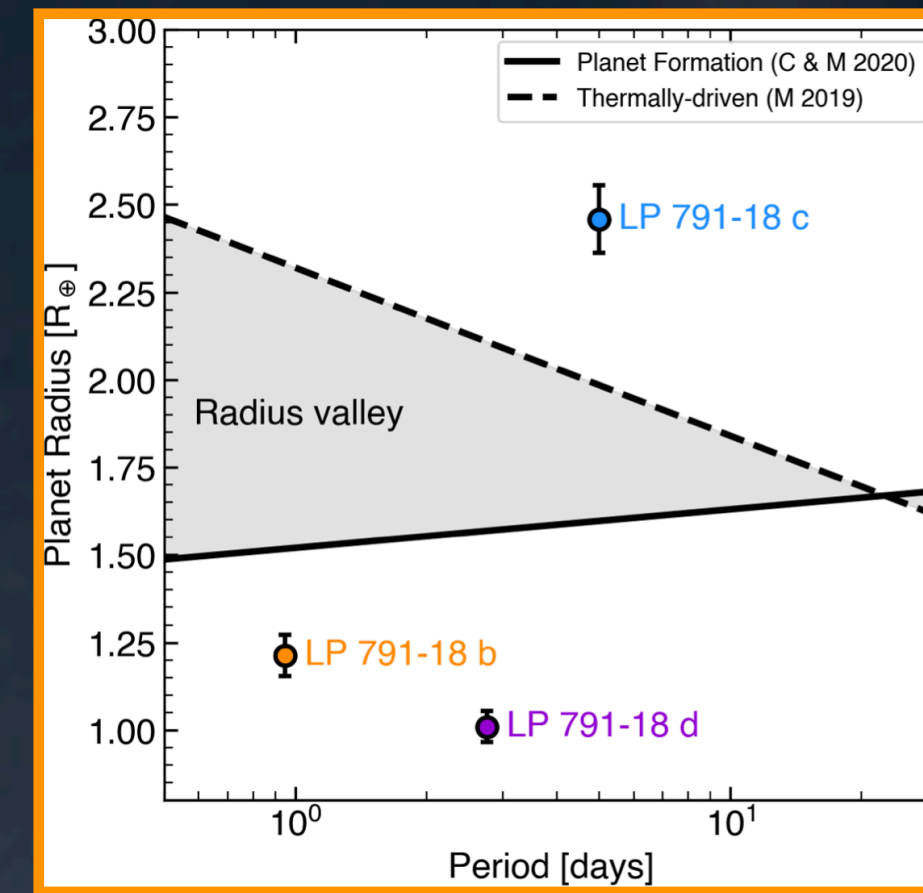
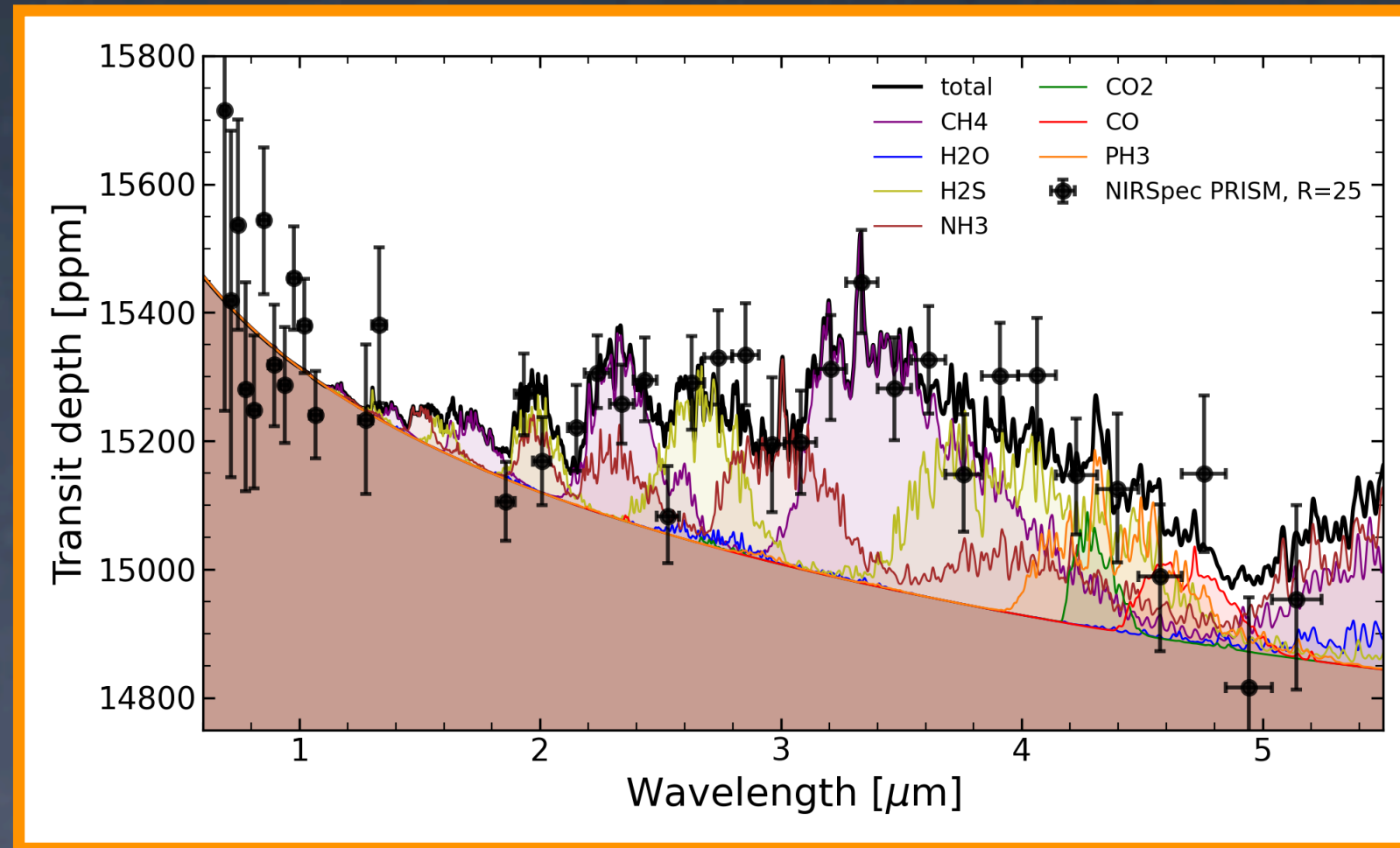
Conclusions:

LP 719-18 is an ideal and unique system to study close-in small planets



Conclusions:

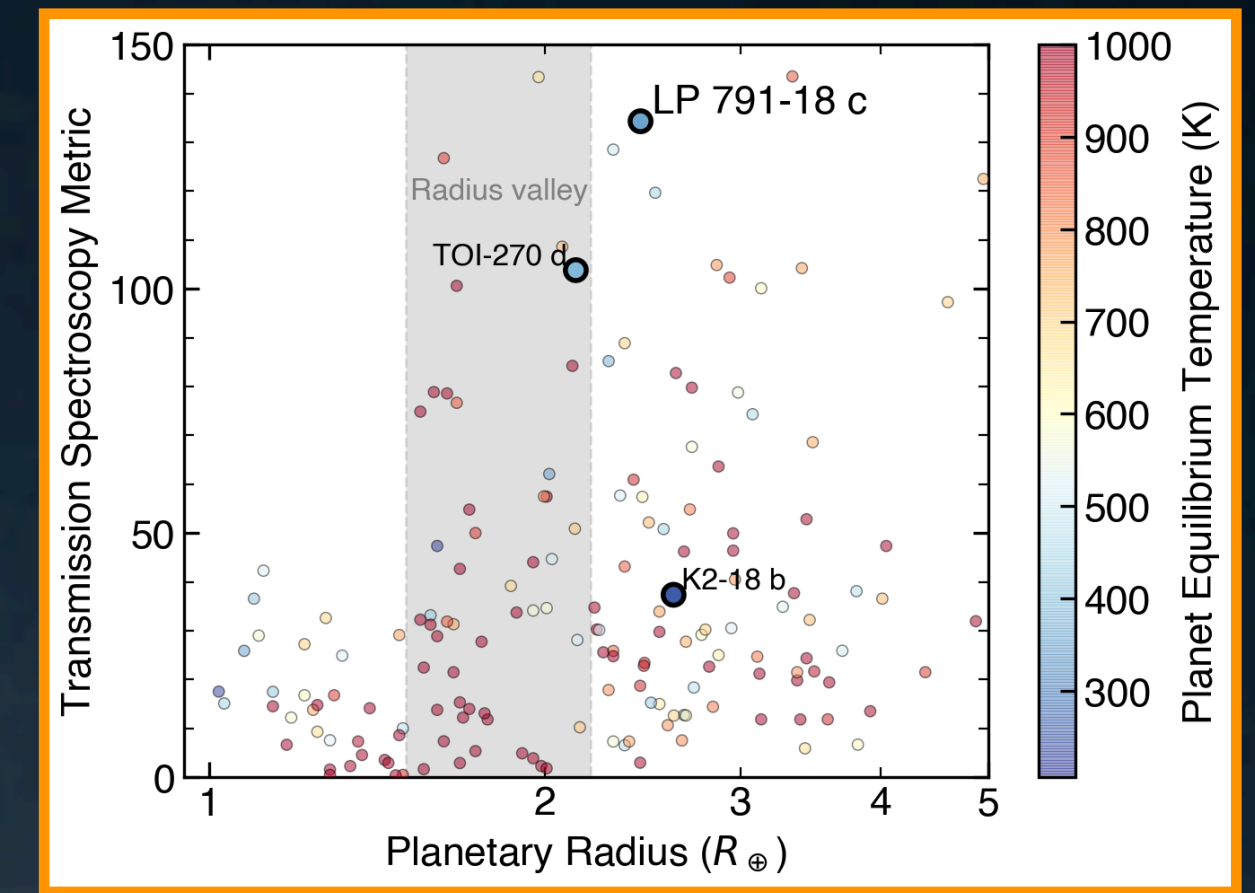
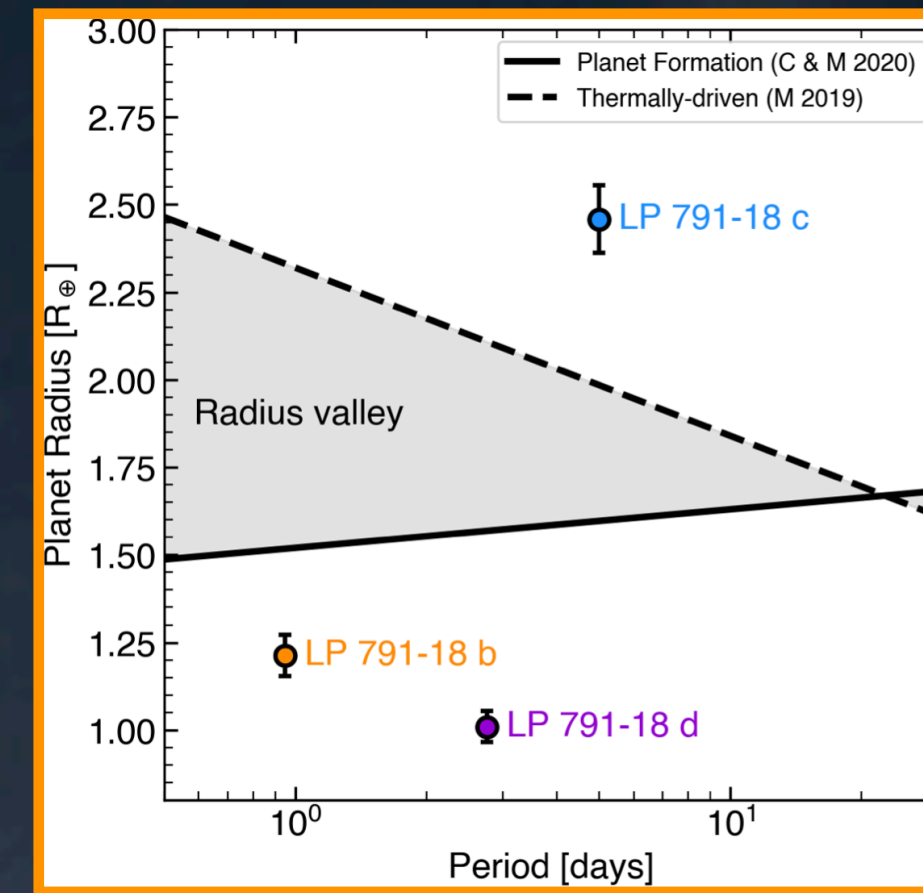
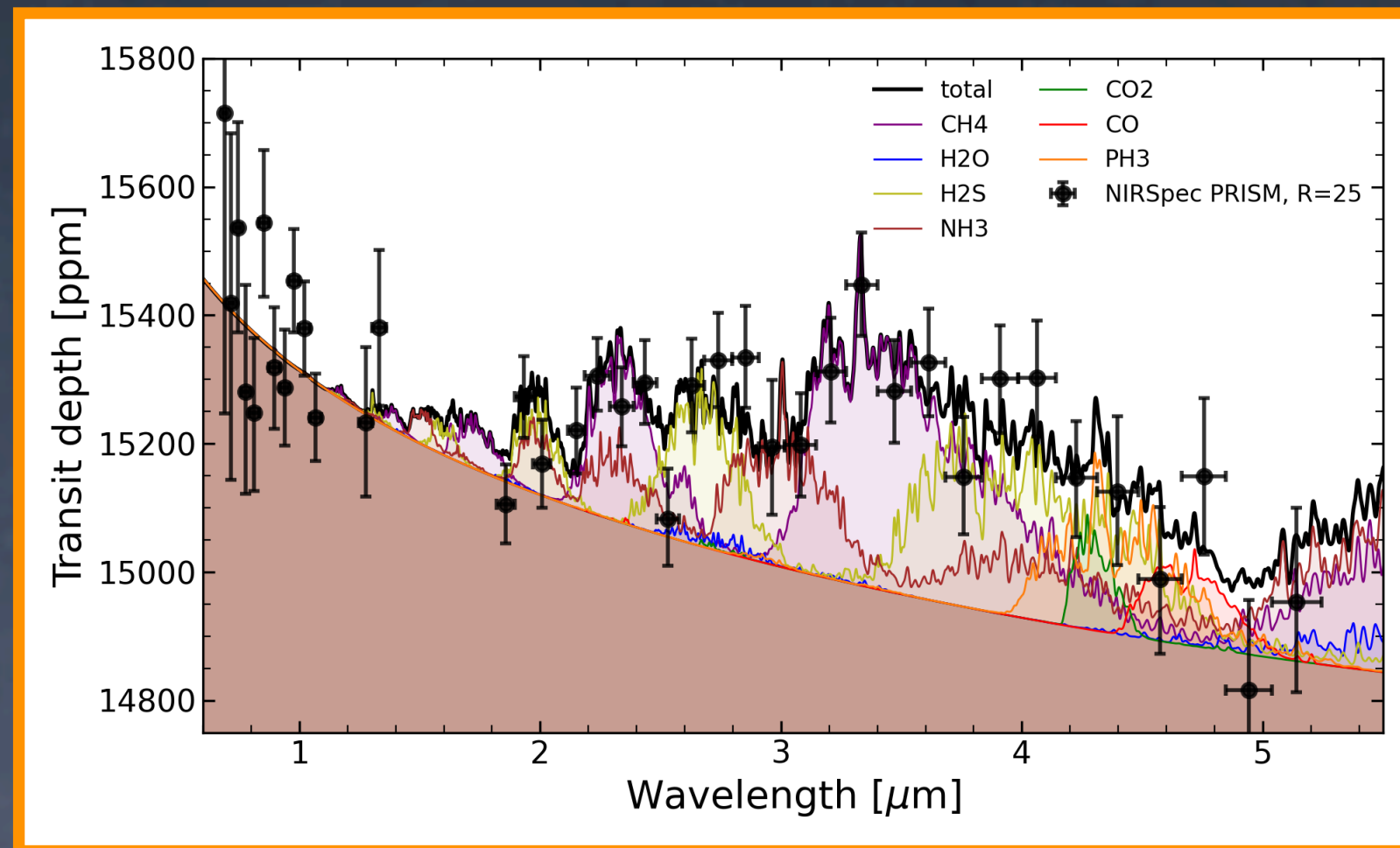
LP 719-18 is an ideal and unique system to study close-in small planets



JWST revealed a CH₄-rich, hazy atmosphere on the temperate sub-Neptune LP 791-18c.

Conclusions:

LP 719-18 is an ideal and unique system to study close-in small planets

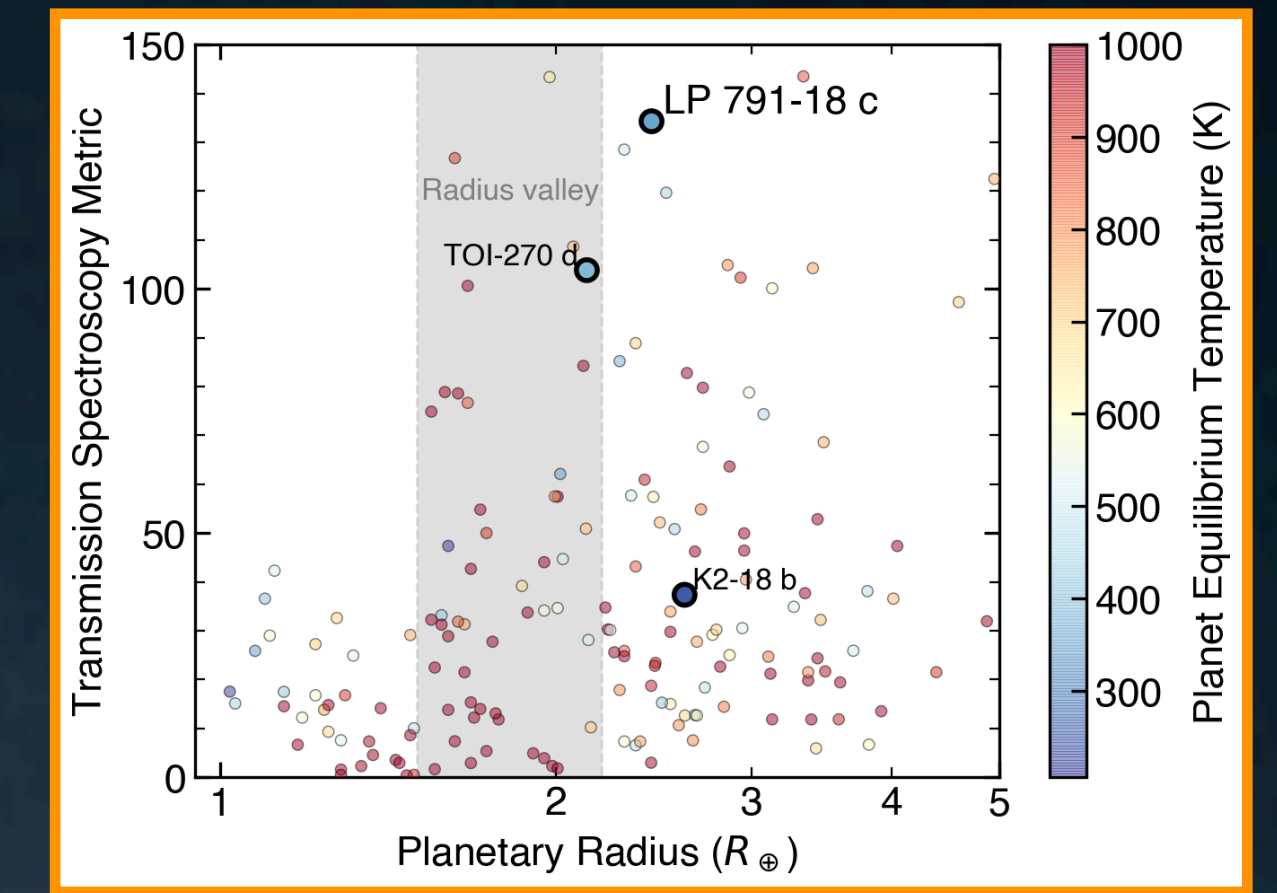
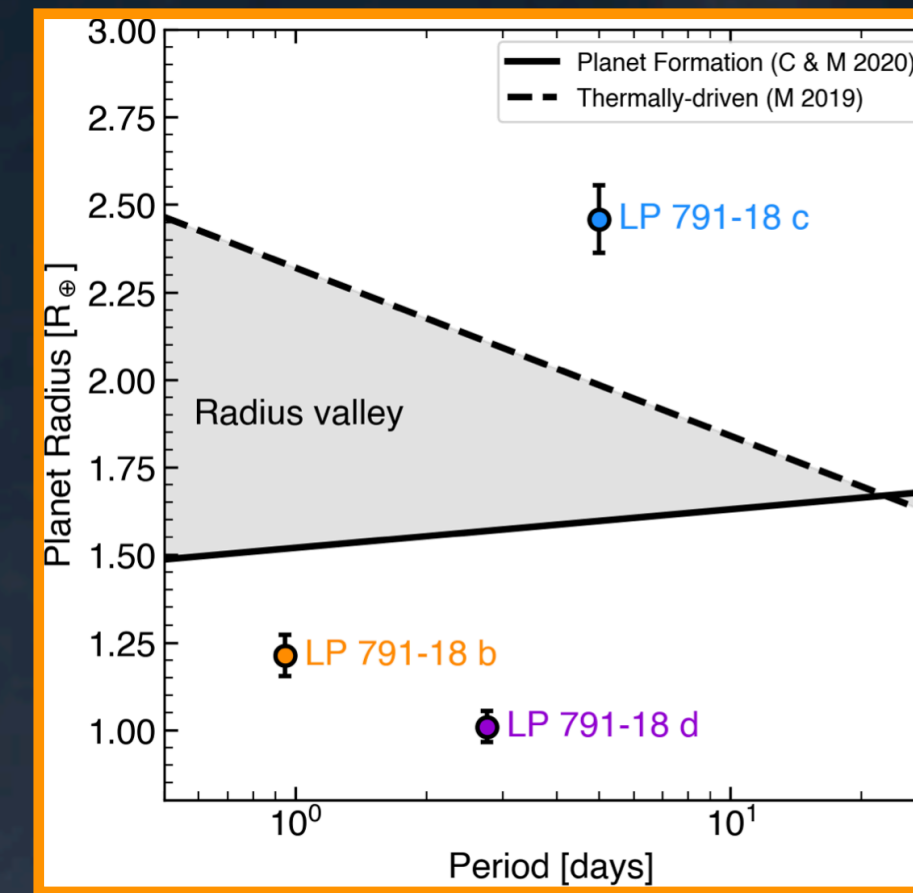
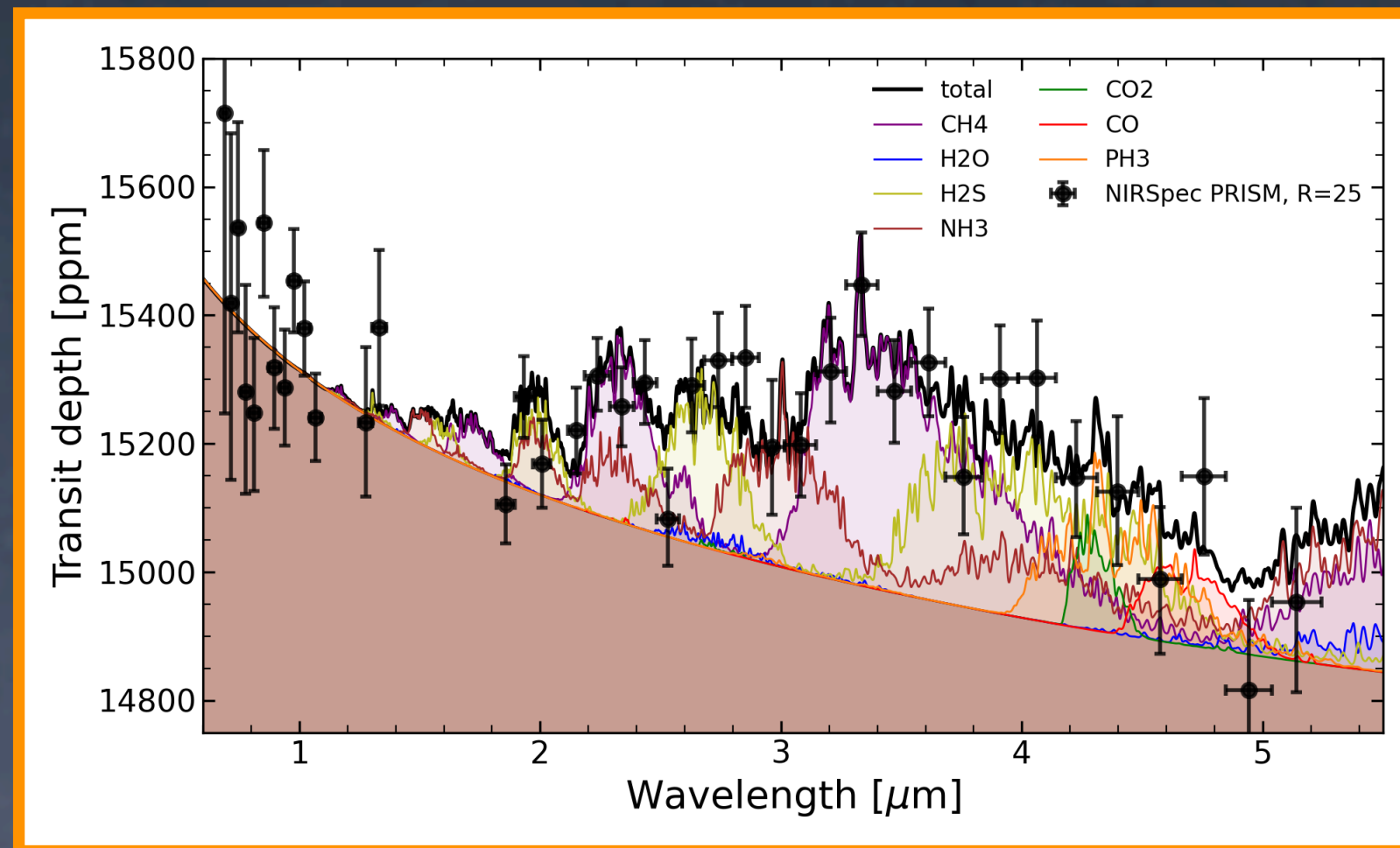


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An important example of the diversity in sub-Neptune compositions, and of the need for high-SNR transmission spectra in the endeavor to characterize these metal-rich atmospheres.

Conclusions:

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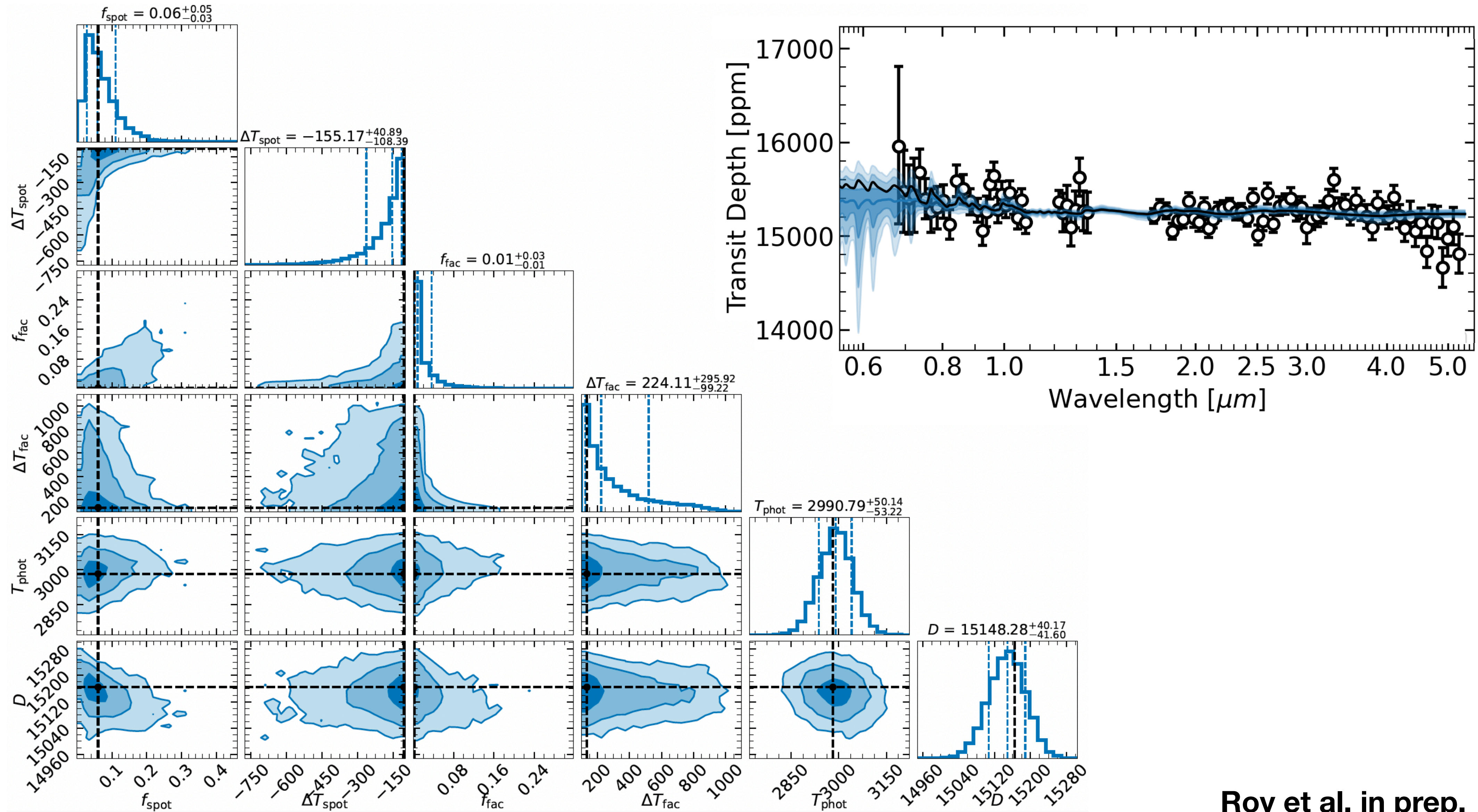
An important example of the diversity in sub-Neptune compositions, and of the need for high-SNR transmission spectra in the endeavor to characterize these metal-rich atmospheres.



Thank you!



Backup: No apparent stellar contamination



Roy et al. in prep.

Backup: Could it be a Hycean world?

LP 791-18c

