

Atmospheres of ultra-hot exoplanets: Metals and chemistry on WASP-121 b

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Lund Observatory



LUND UNIVERSITY

Overview

Introduction / background

Theory

Methodology

WASP-121 b

HST transmission/day-side spectra

High-resolution results w. HARPS/ESPRESSO

Conclusion/outlook

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Ultra-hot Jupiters:

Early-type stars

Short orbital periods (1-2 days)

$T > 2000$ K

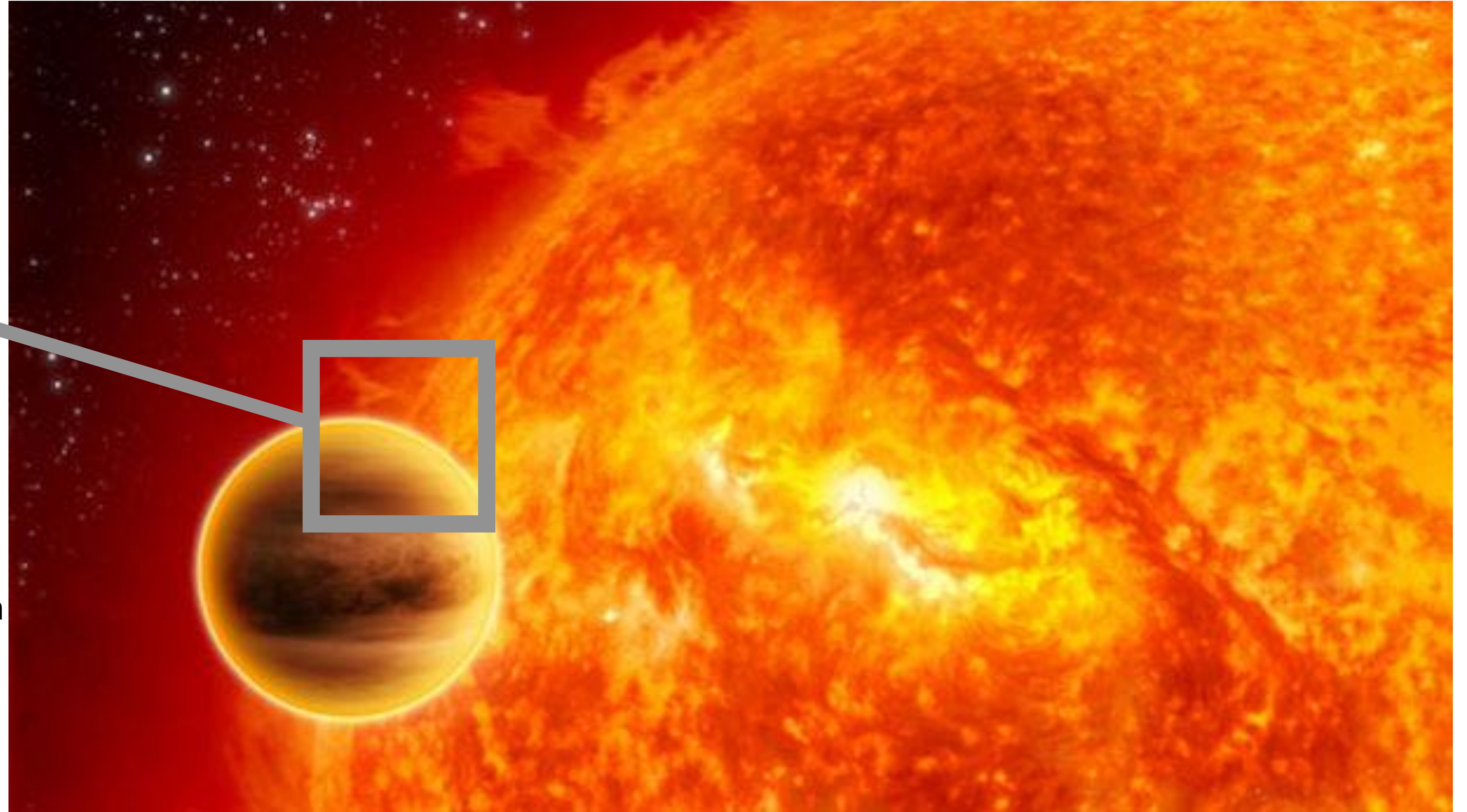
Metals in the gas phase

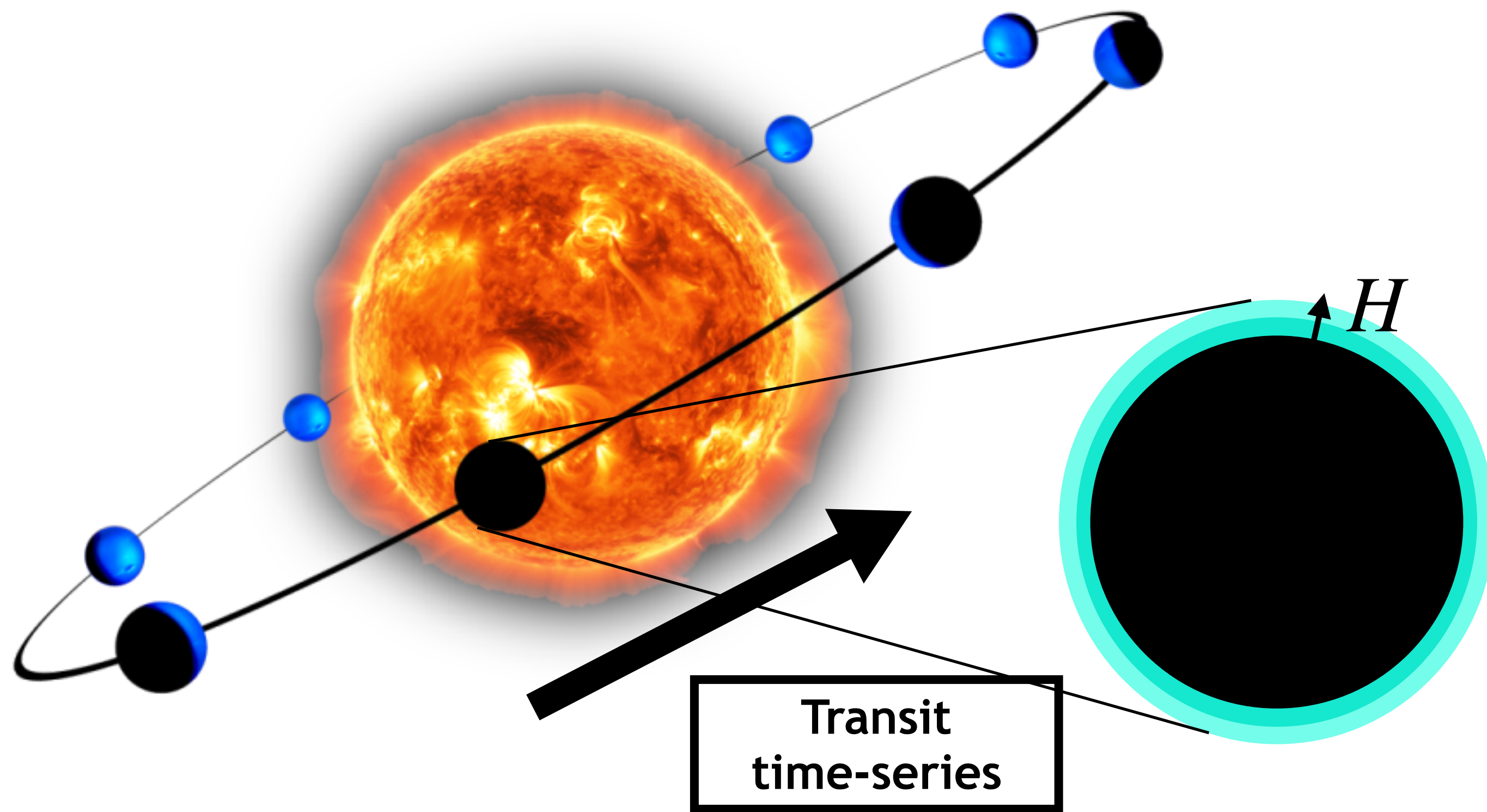
Spectroscopy of ultra-hot Jupiter atmospheres

Atmosphere
Composition
Structure
Dynamics

Planet
formation/evolution

Future characterisation
of small planets





Time-series spectroscopy:

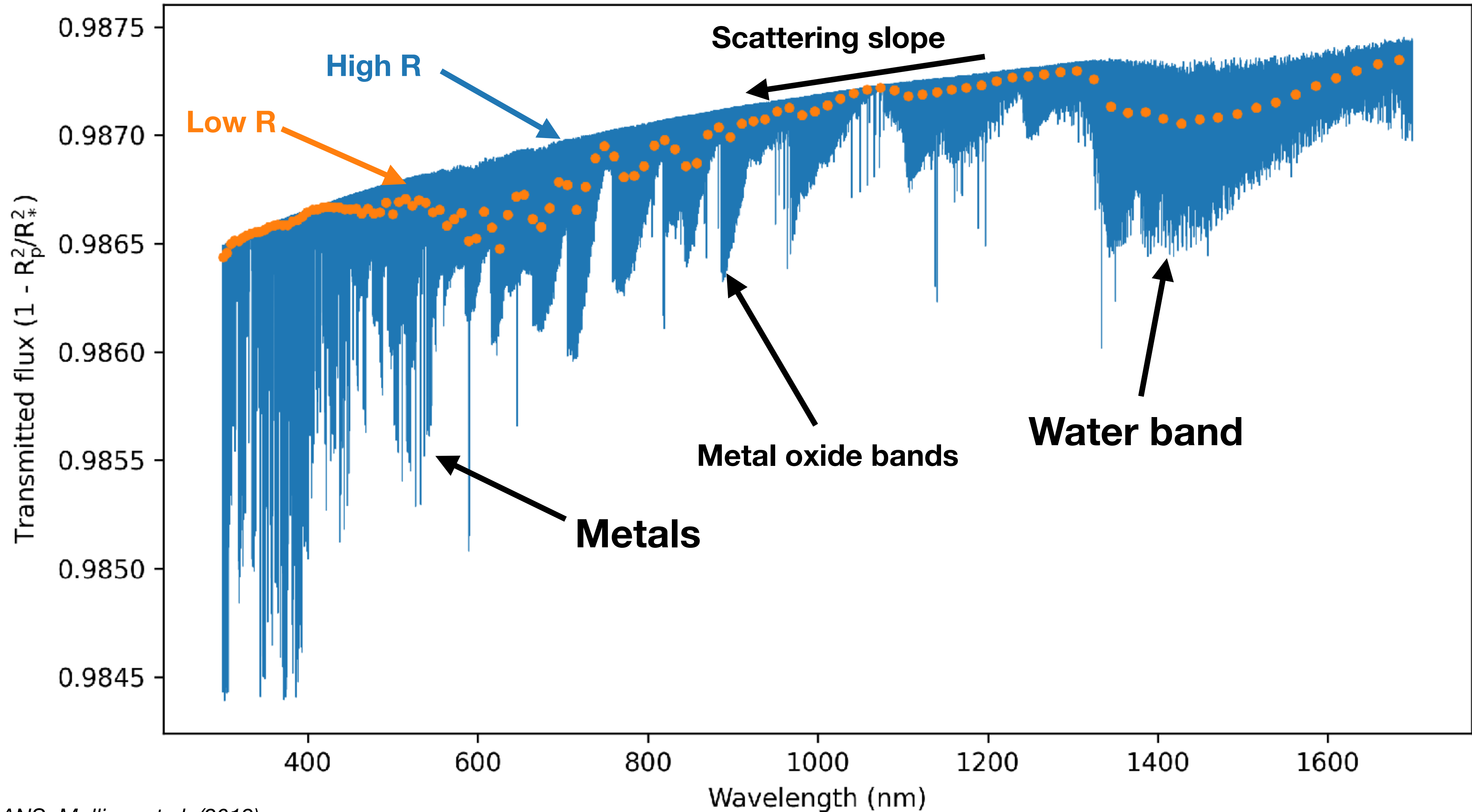
Compare spectrum in/out of transit or secondary eclipse to isolate planet contribution

Transit geometry:

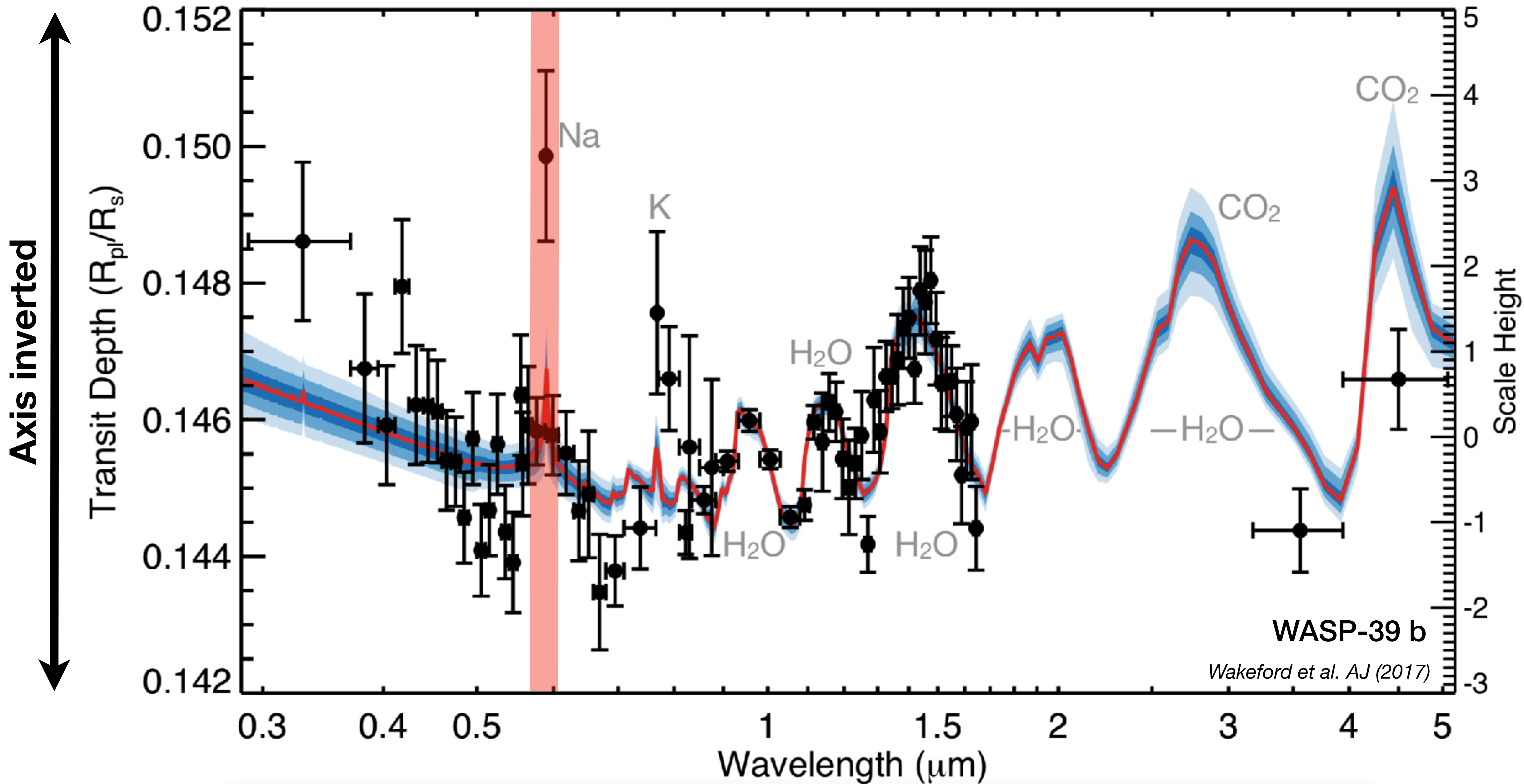
Apparent radius is proportional to the scale-height H :

- Strong dependence on T, g, m
- Degeneracy** between abundances and pressure of continuum

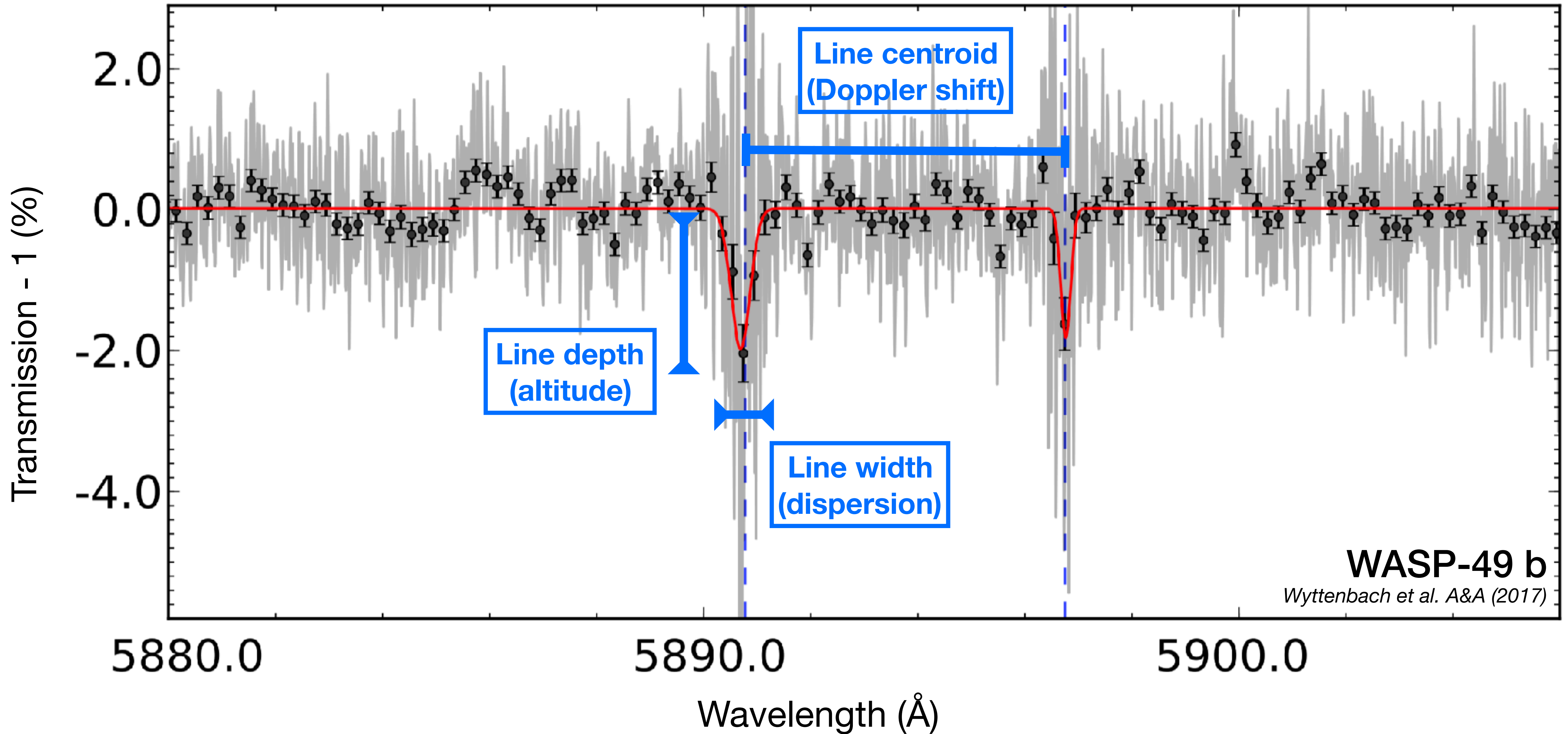
Transmission spectroscopy



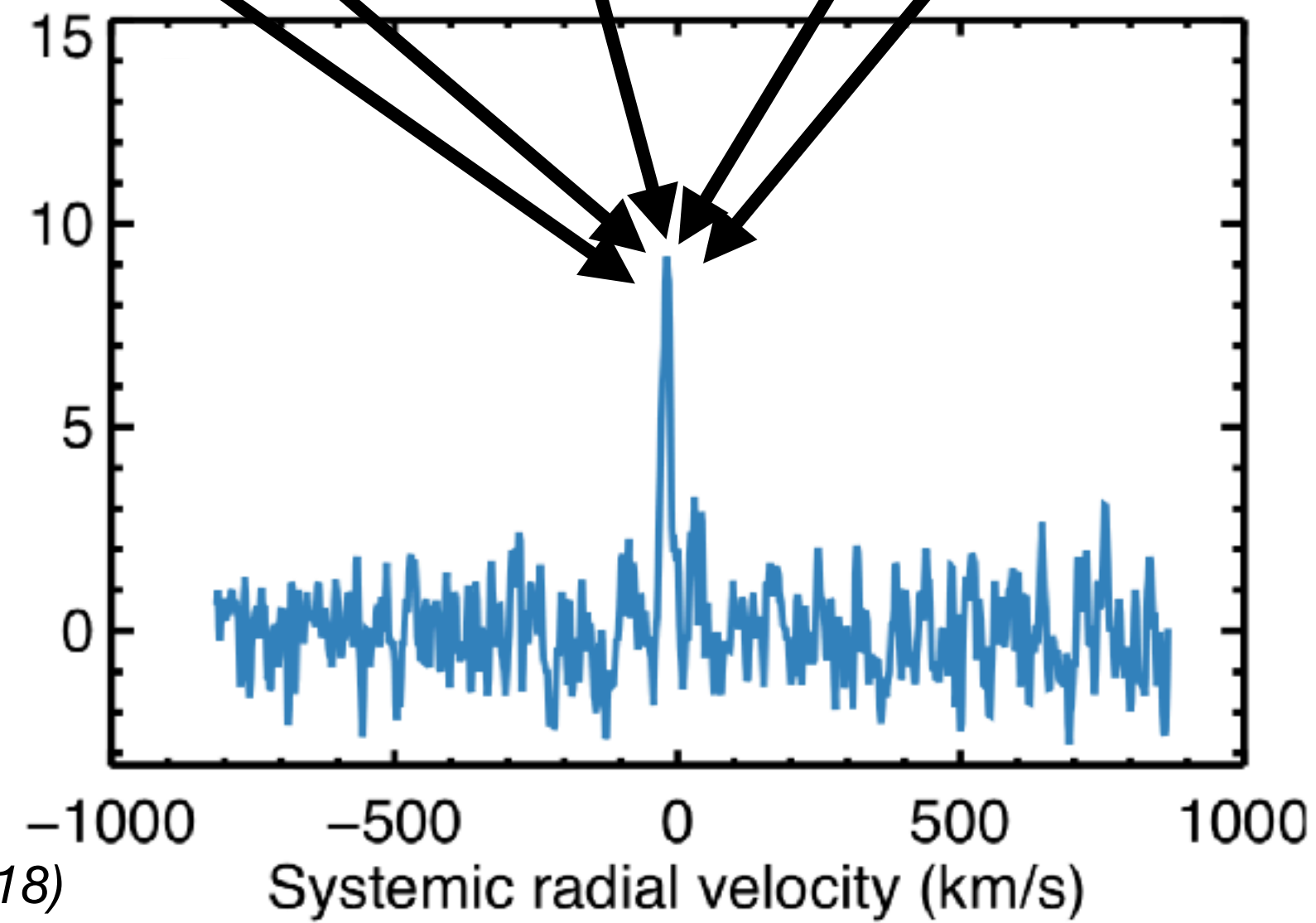
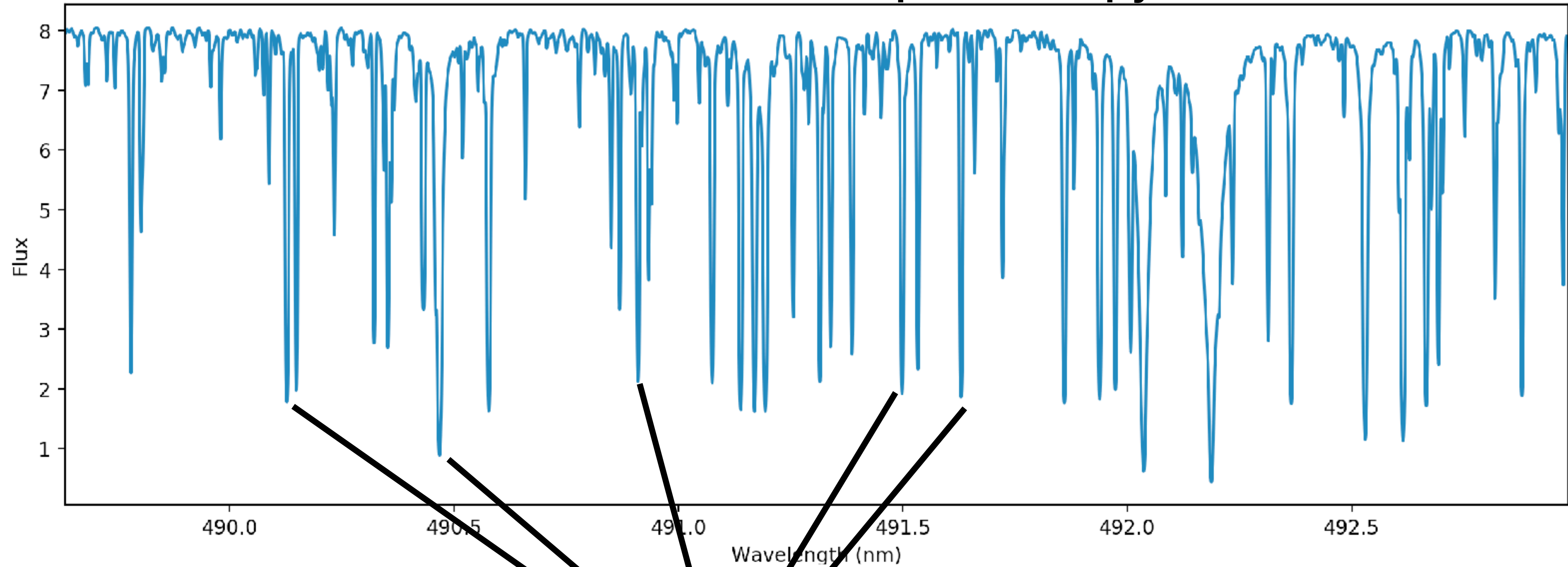
Low-resolution spectroscopy



High-resolution spectroscopy



Cross-correlation spectroscopy



- Stack lines using cross-correlation**
- Boost SNR
 - Resolve km/s velocities
 - Unique fingerprint

Why study odd-ball ultra-hot Jupiters?

Observationally favourable:

Bright stars

Large scale heights, inflated atmospheres

Many absorbers in NUV/VIS/NIR

Strong thermal flux with good NIR contrast

Thermal inversions (line emission)

Reduced chemical complexity:

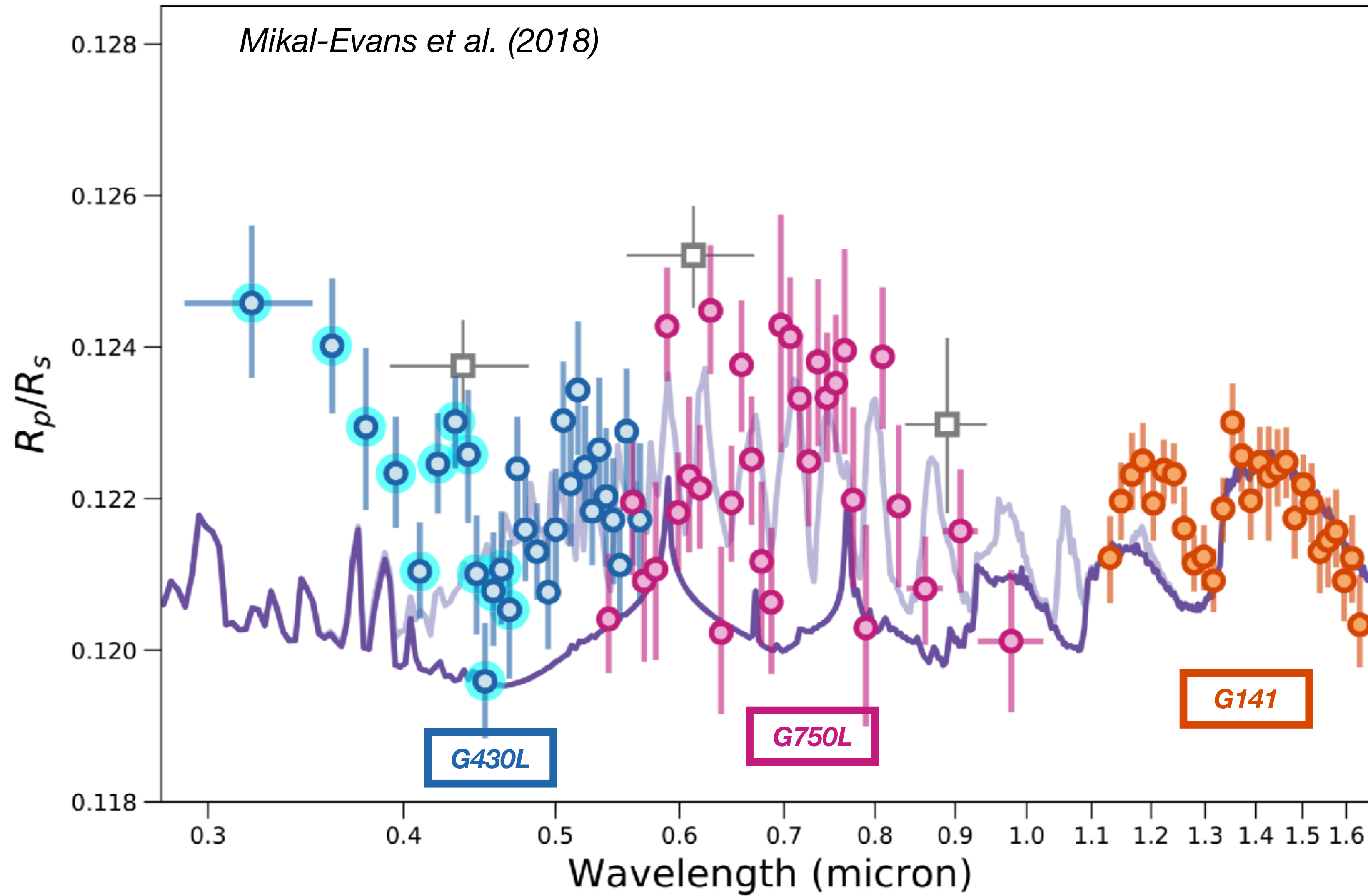
Short chemical time-scale -> Equilibrium chemistry

No clouds

Few molecules

WASP-121 b

Transmission spectrum HST WFC3+STIS



WASP-121 b

Transmission spectrum HST WFC3+STIS

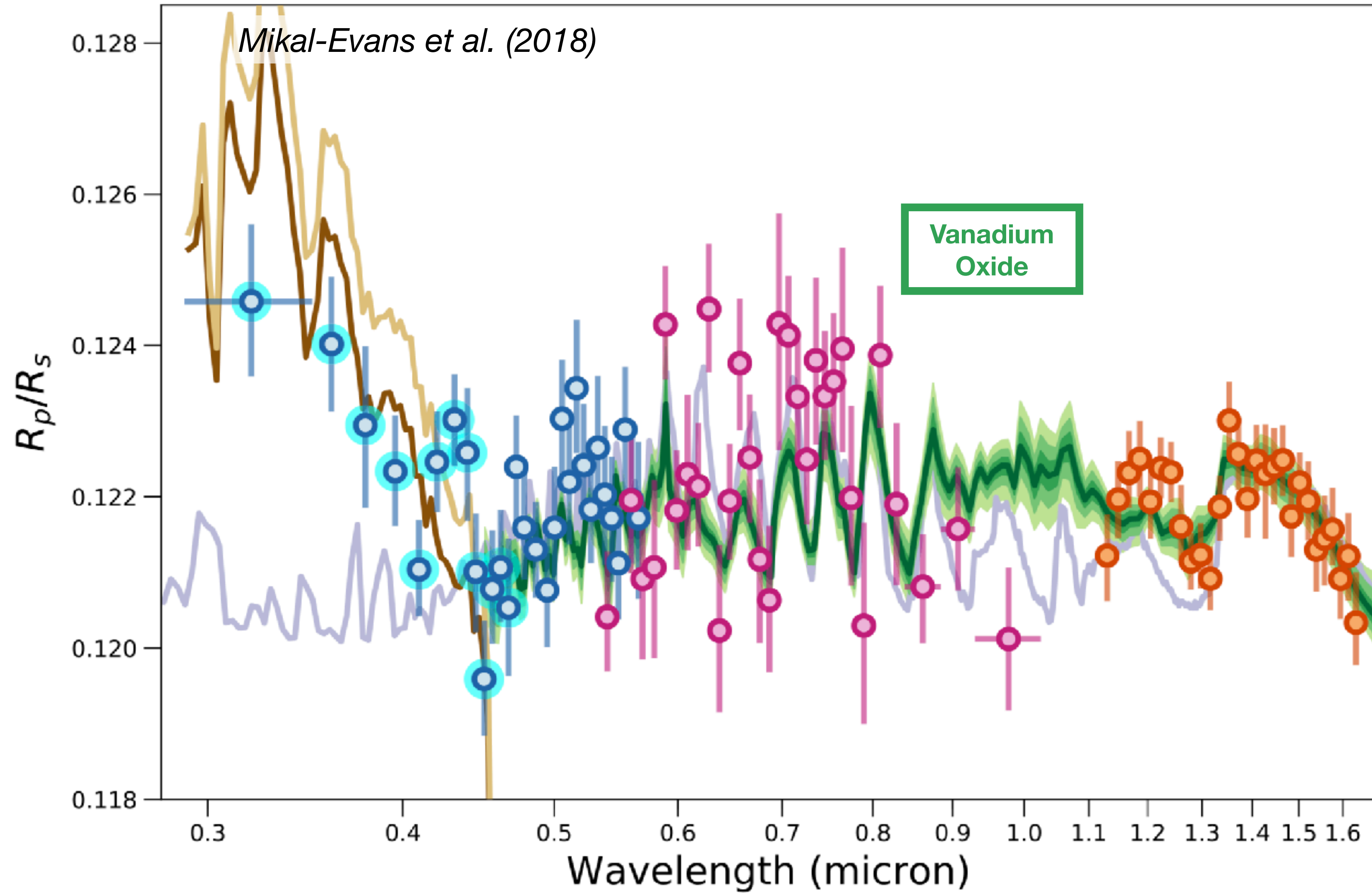


Image credit: Evans et al. (2018)

WASP-121 b

Transmission spectrum HST WFC3+STIS

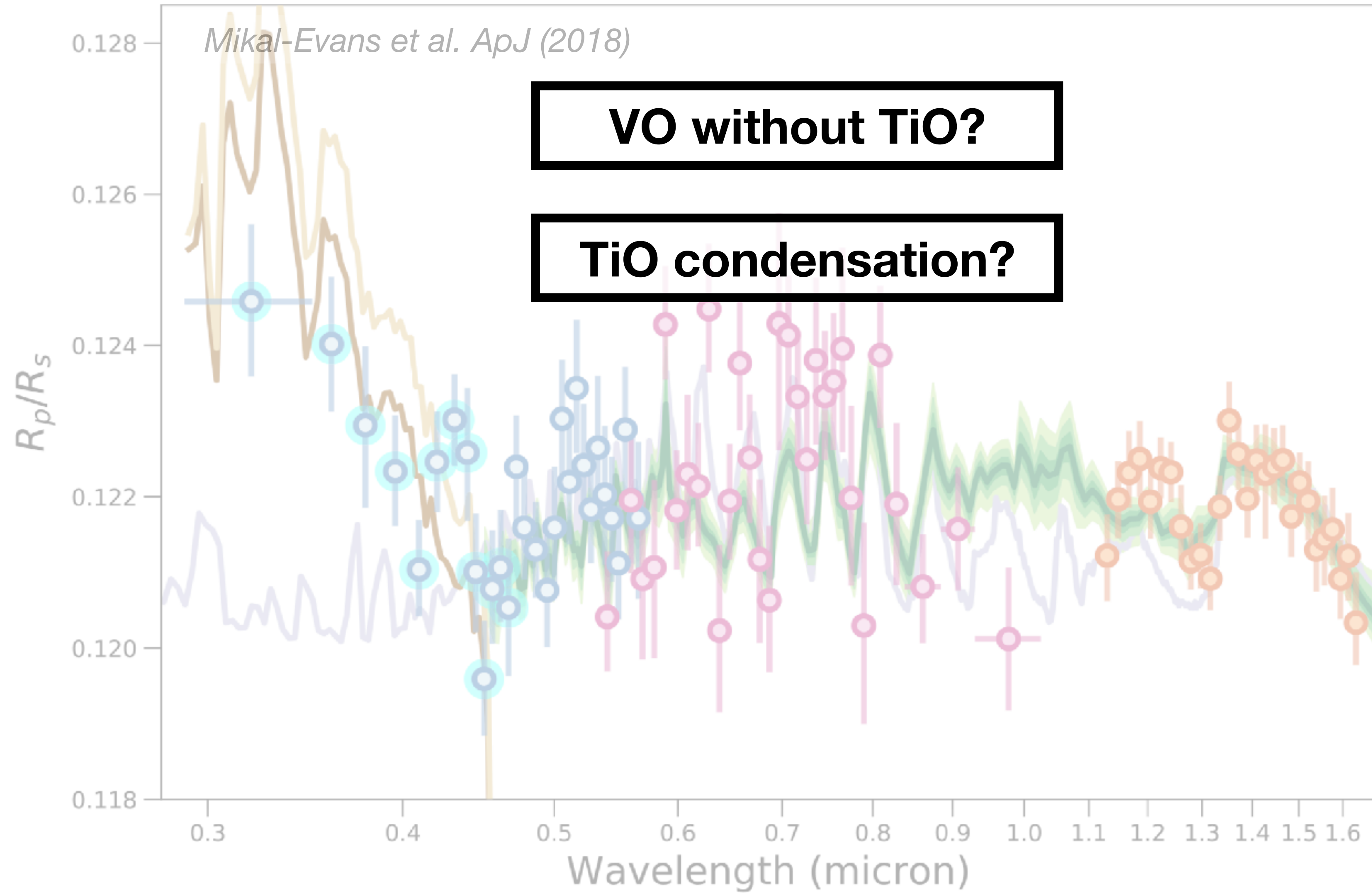
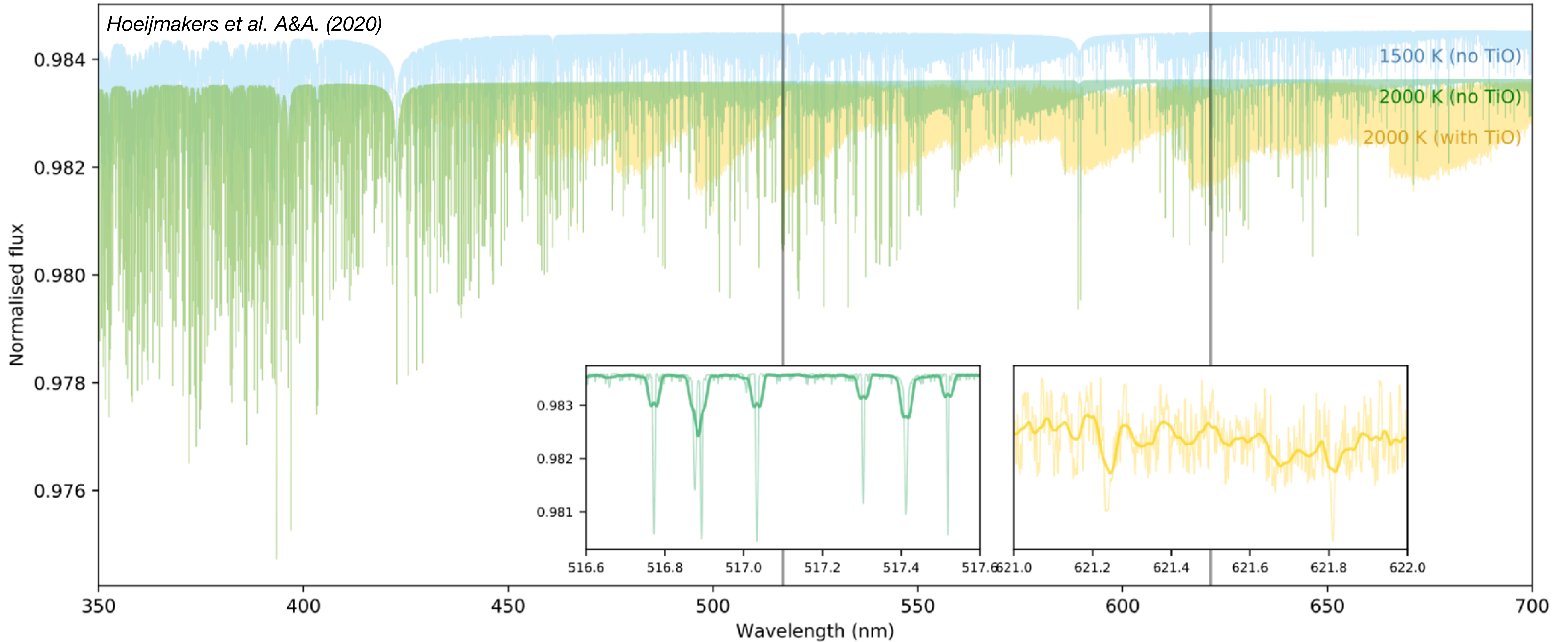
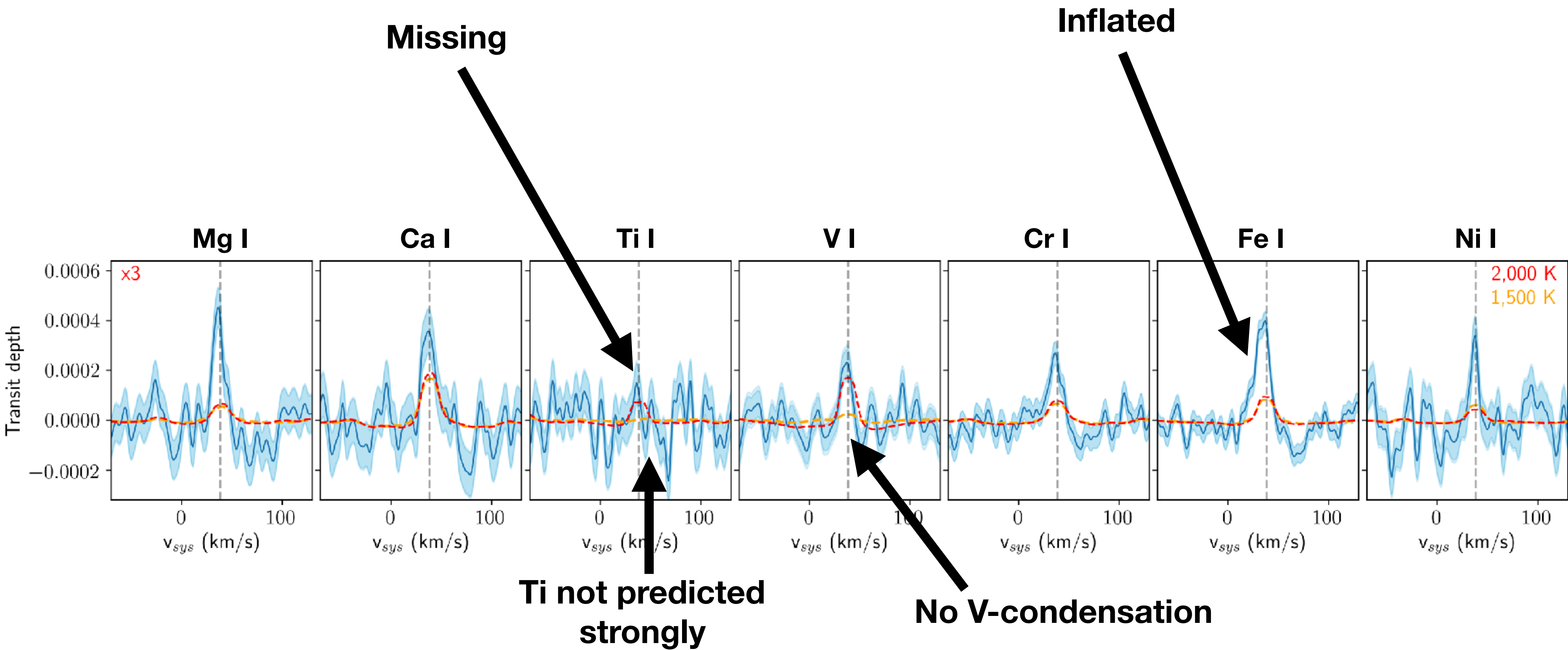


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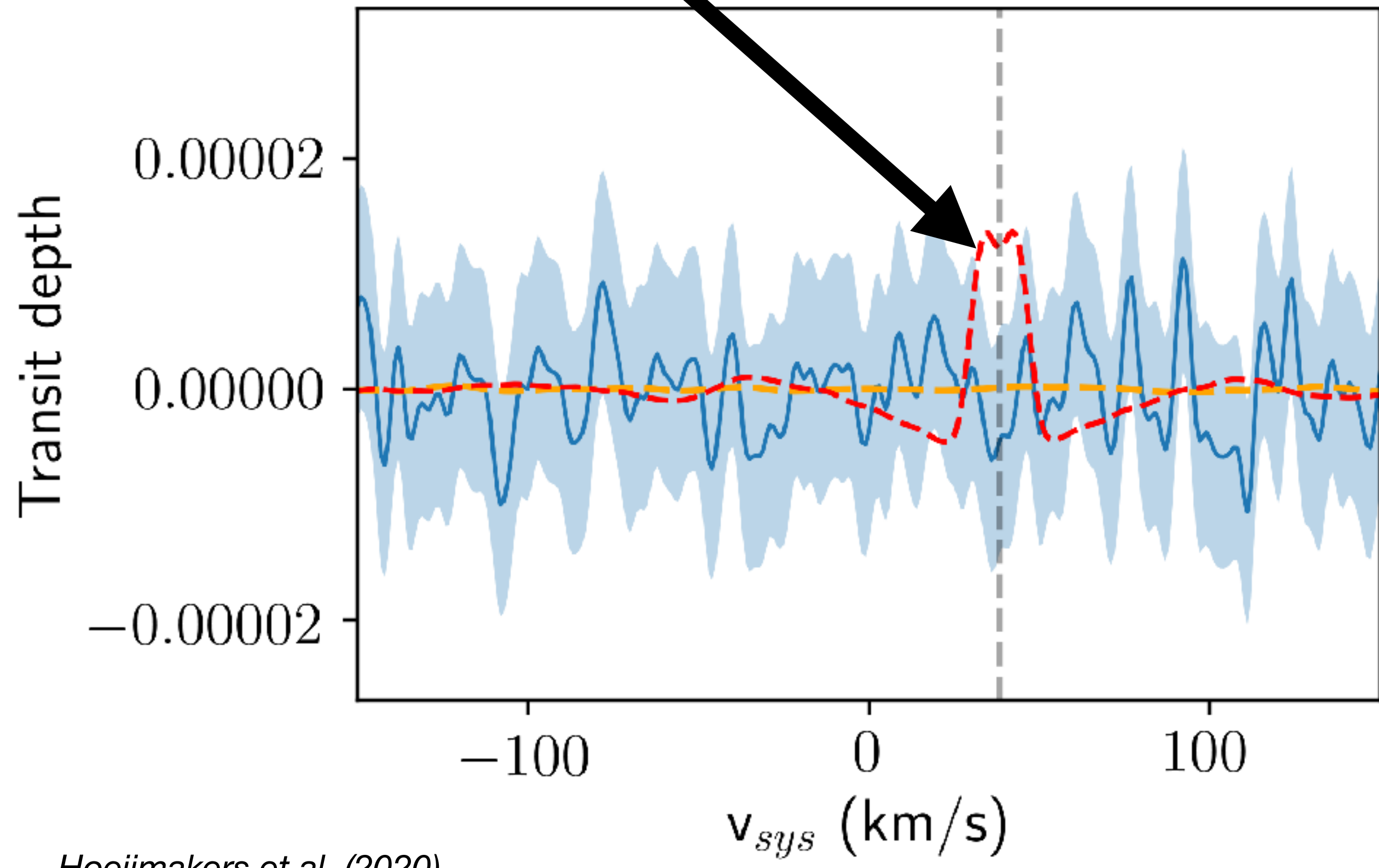
High resolution cross-correlation spectroscopy





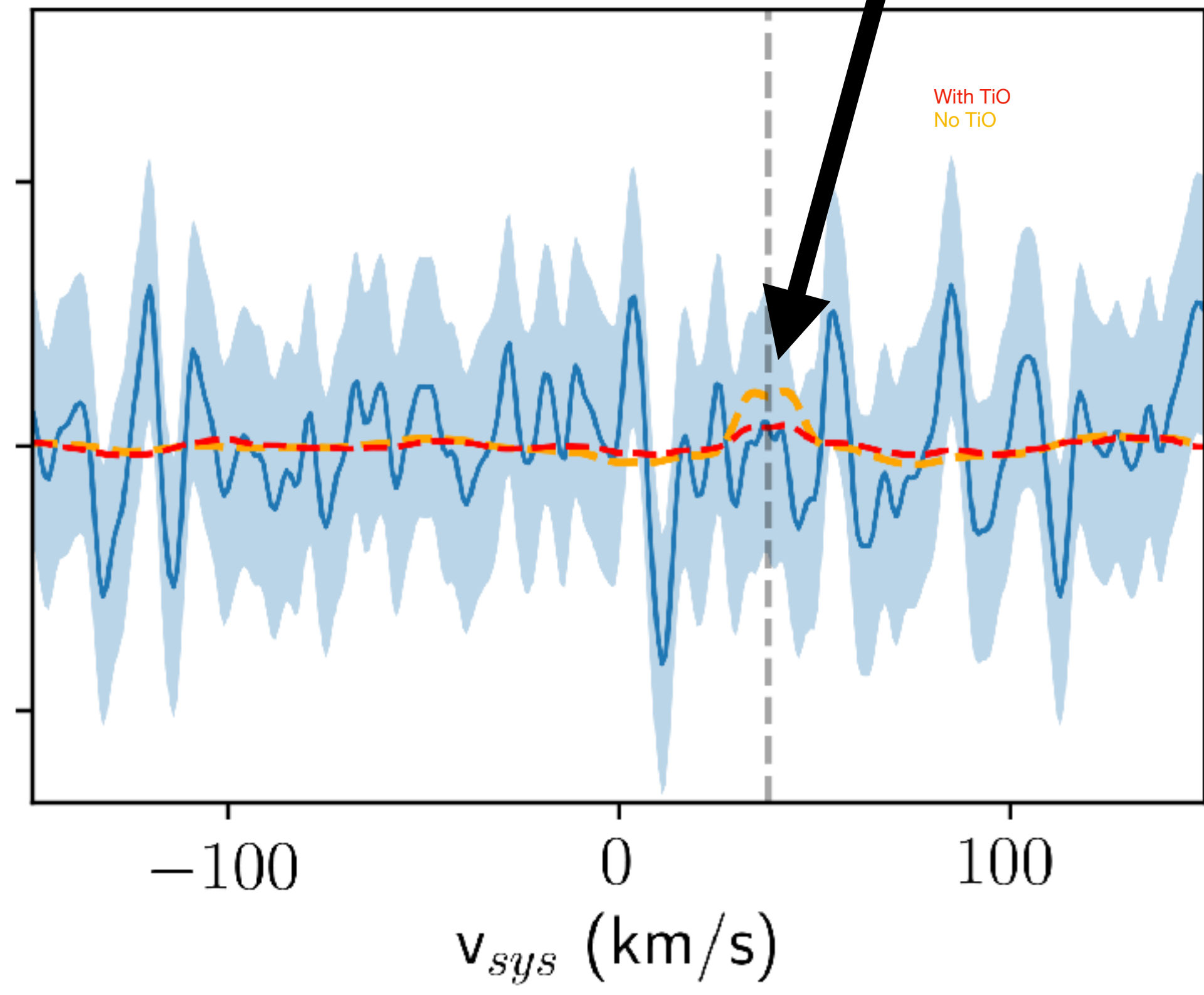
Non-detection

TiO

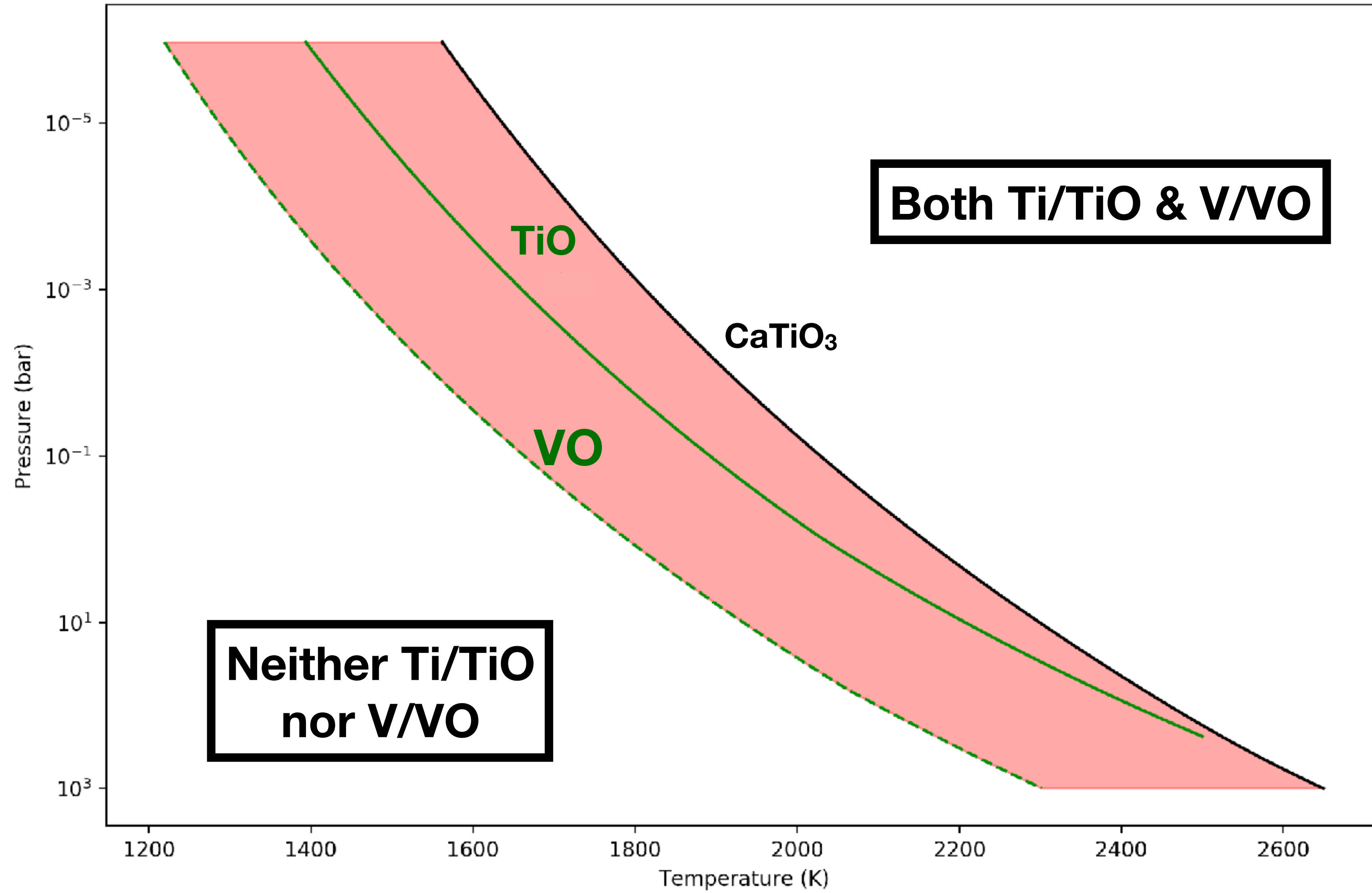


Poor sensitivity to VO

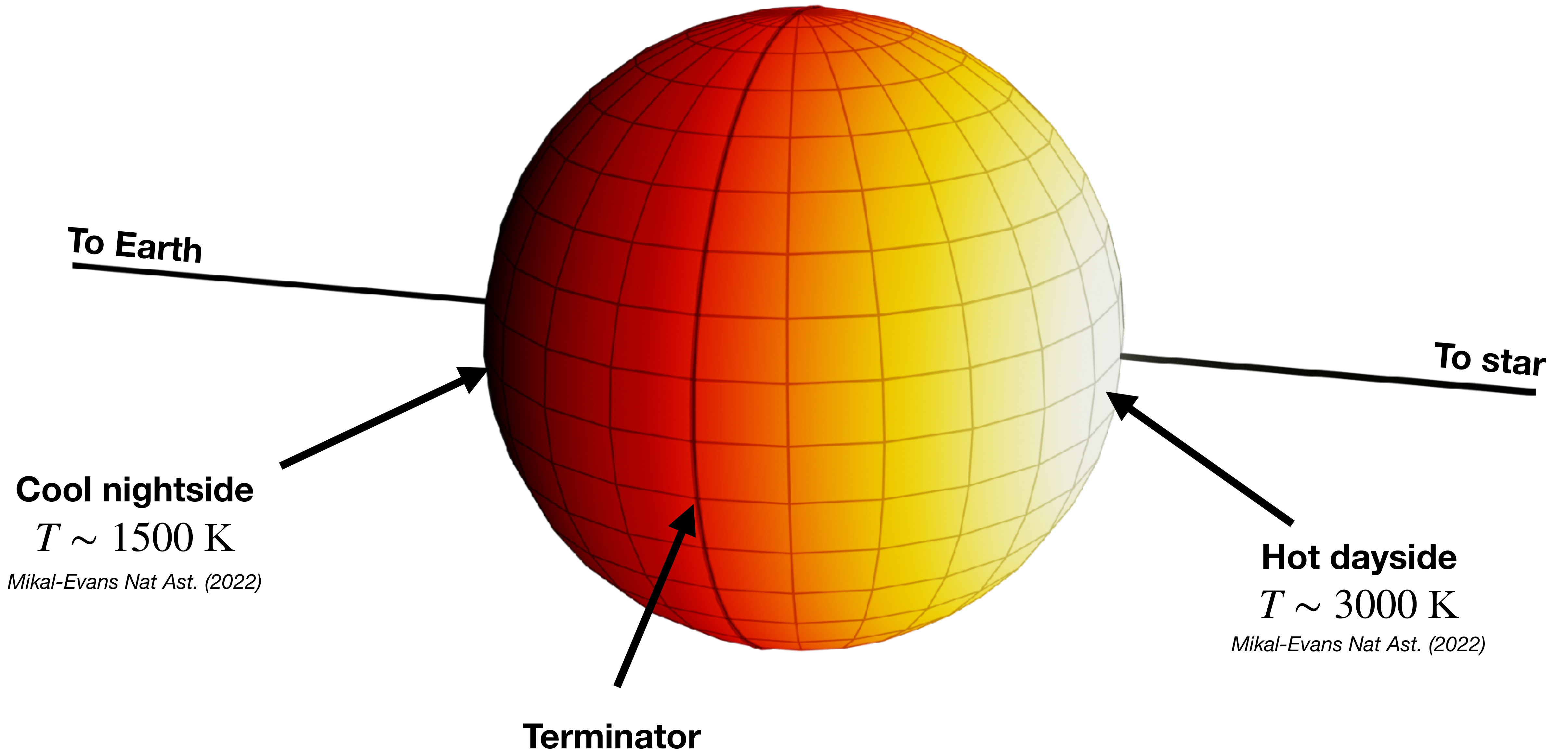
VO

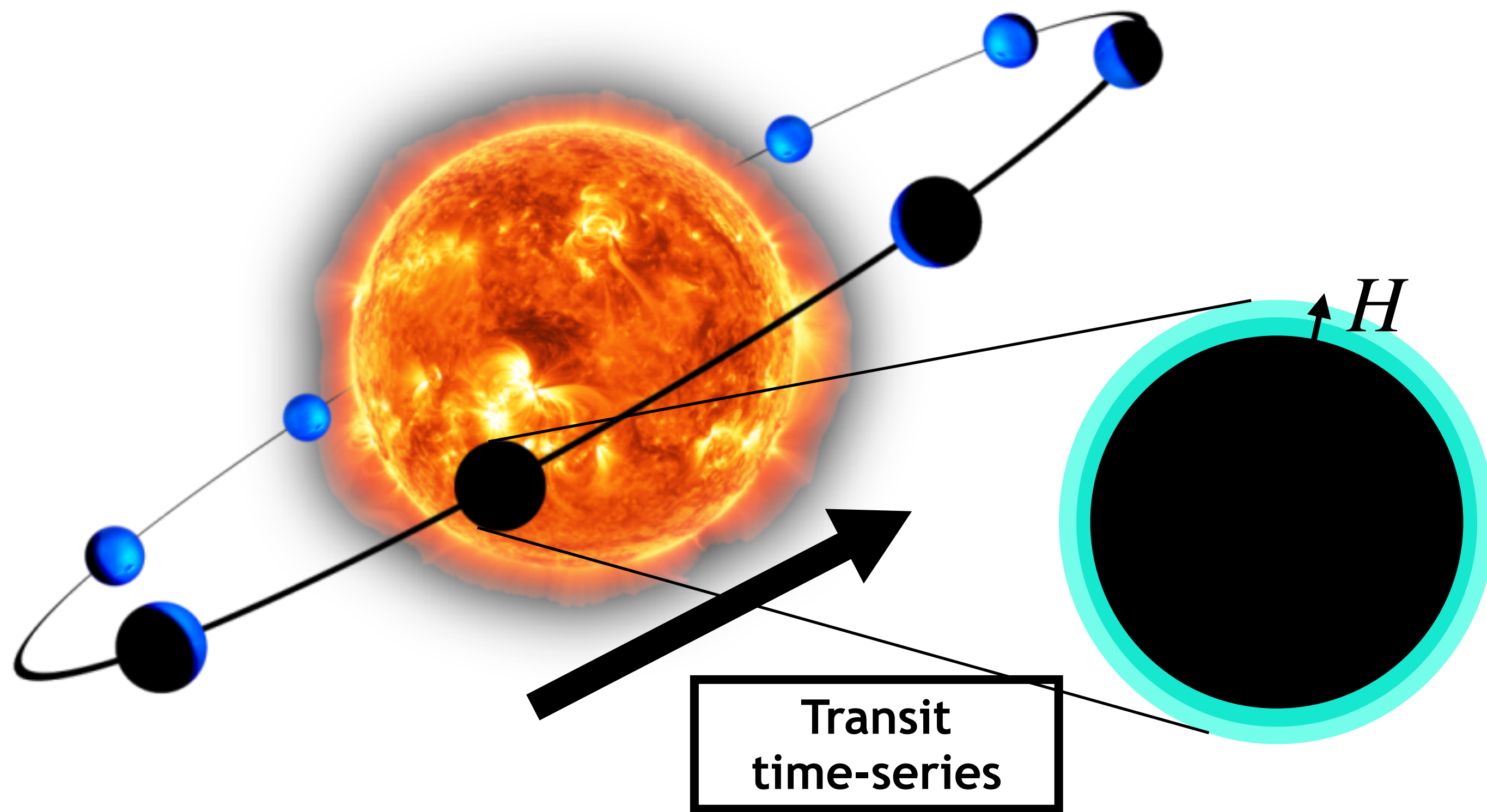


TiO-condensation?



Where is this happening? Terminator or hemispheric?





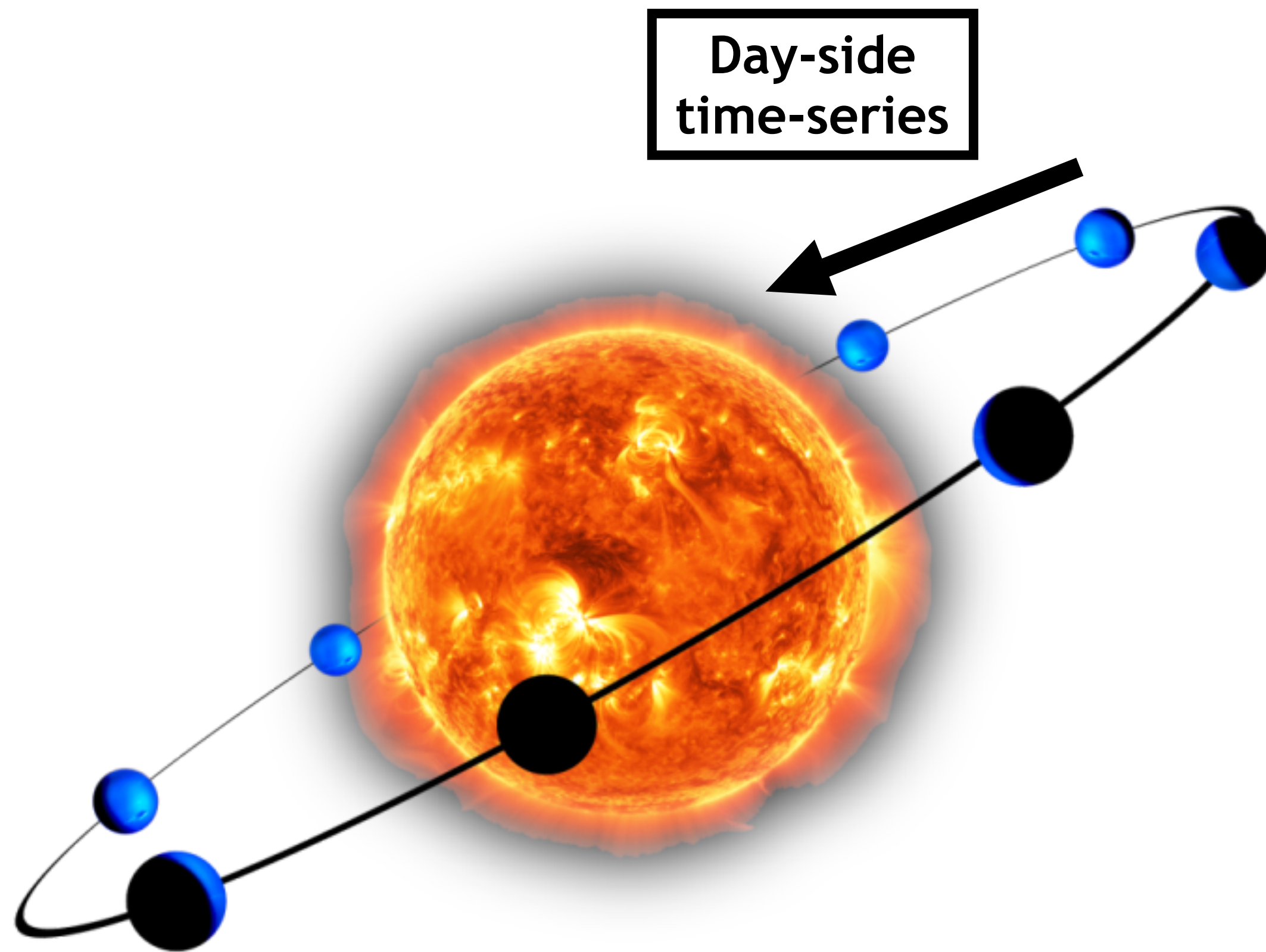
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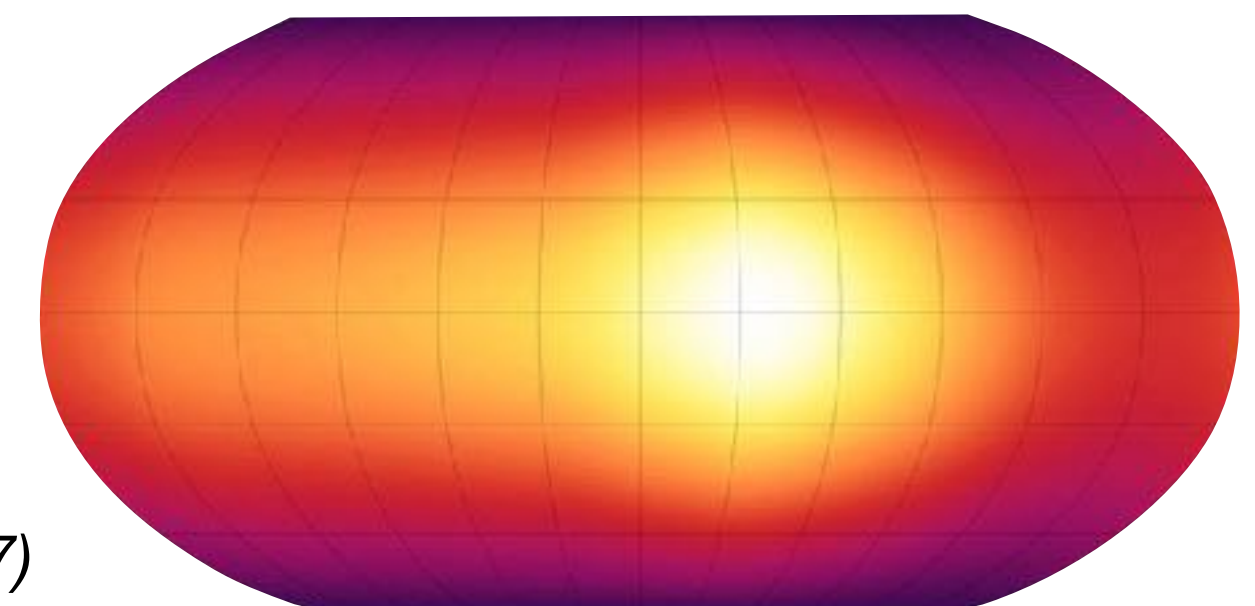
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Thermal emission:

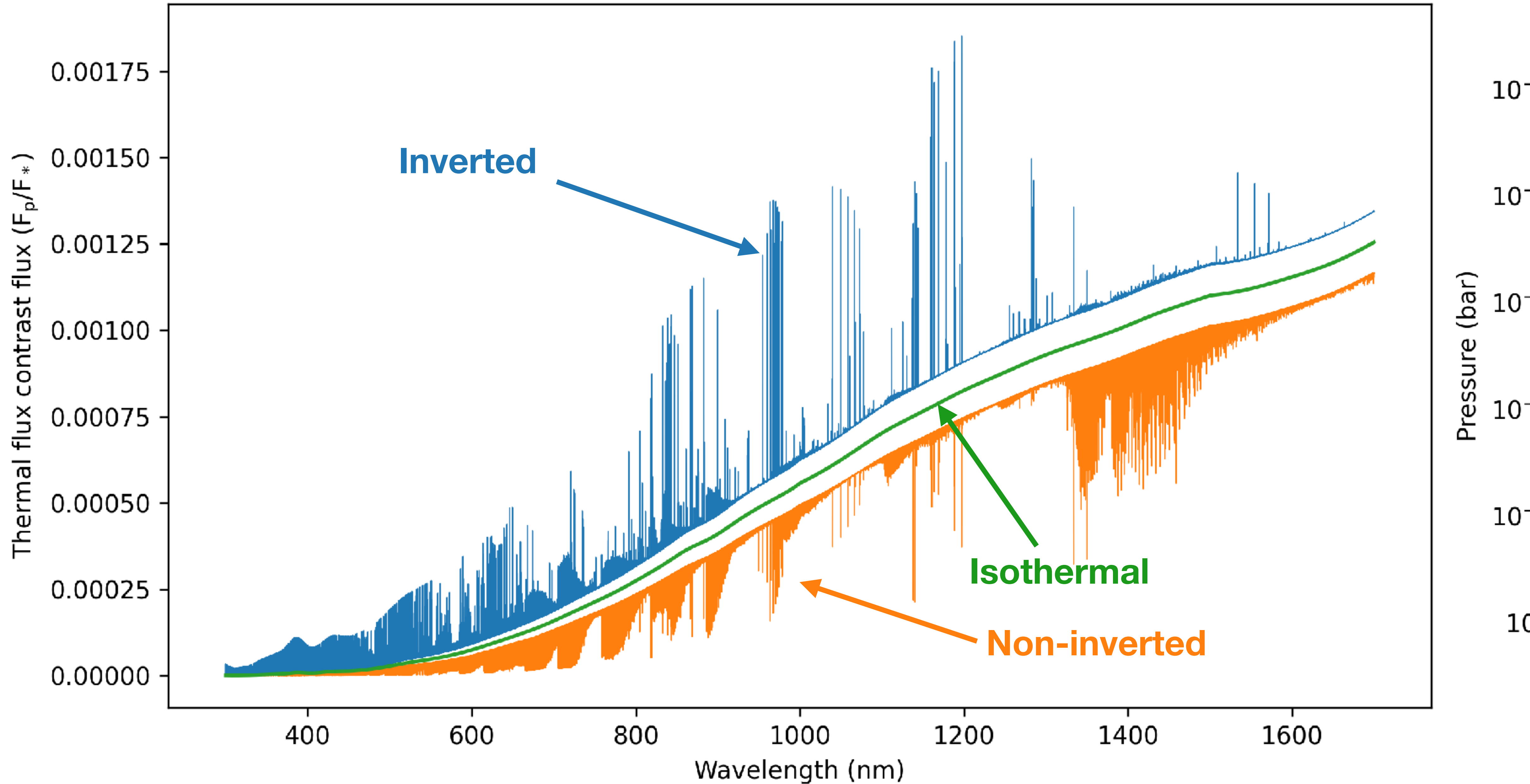
Spectral lines due to temperature differences in emitting gas.

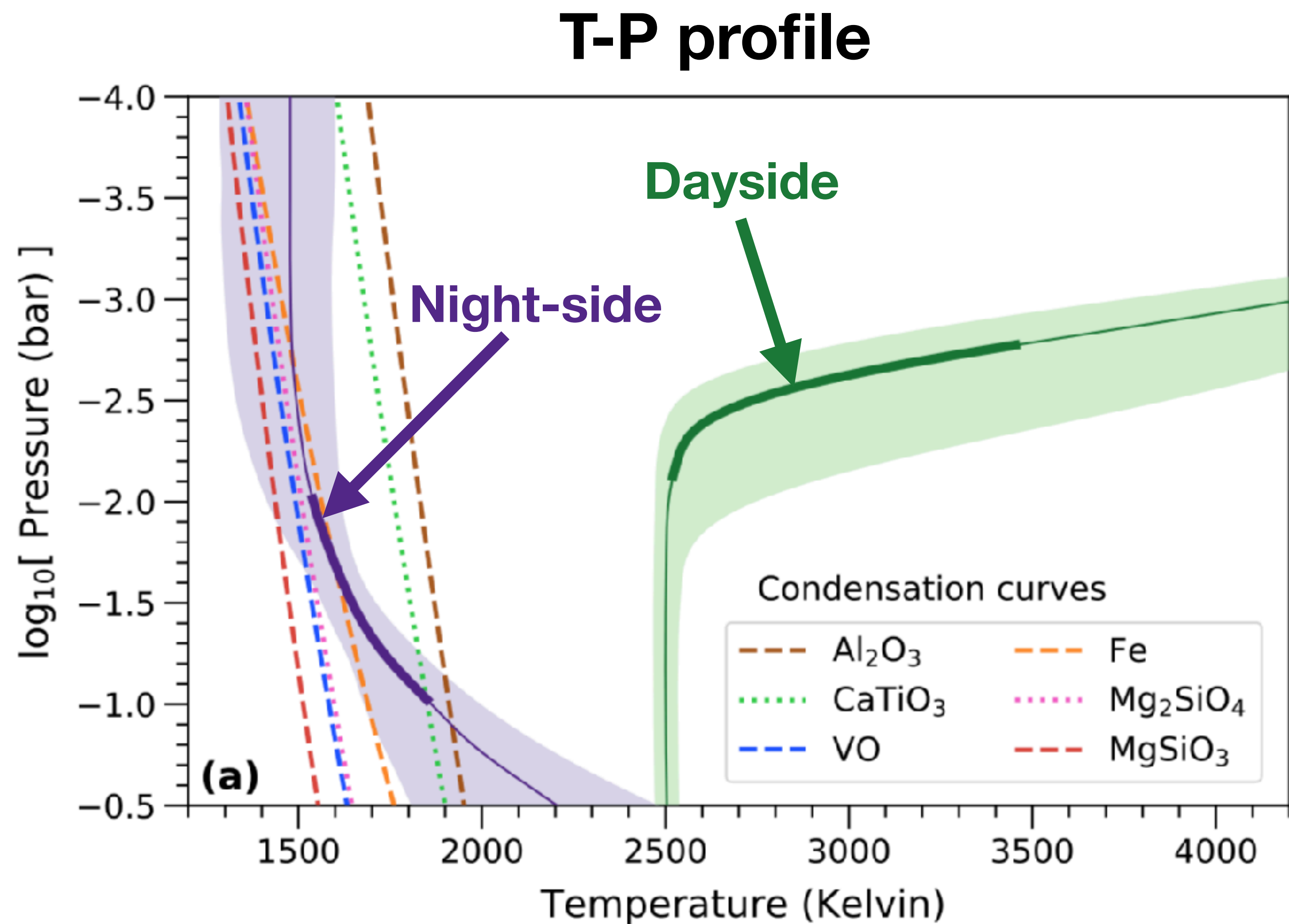
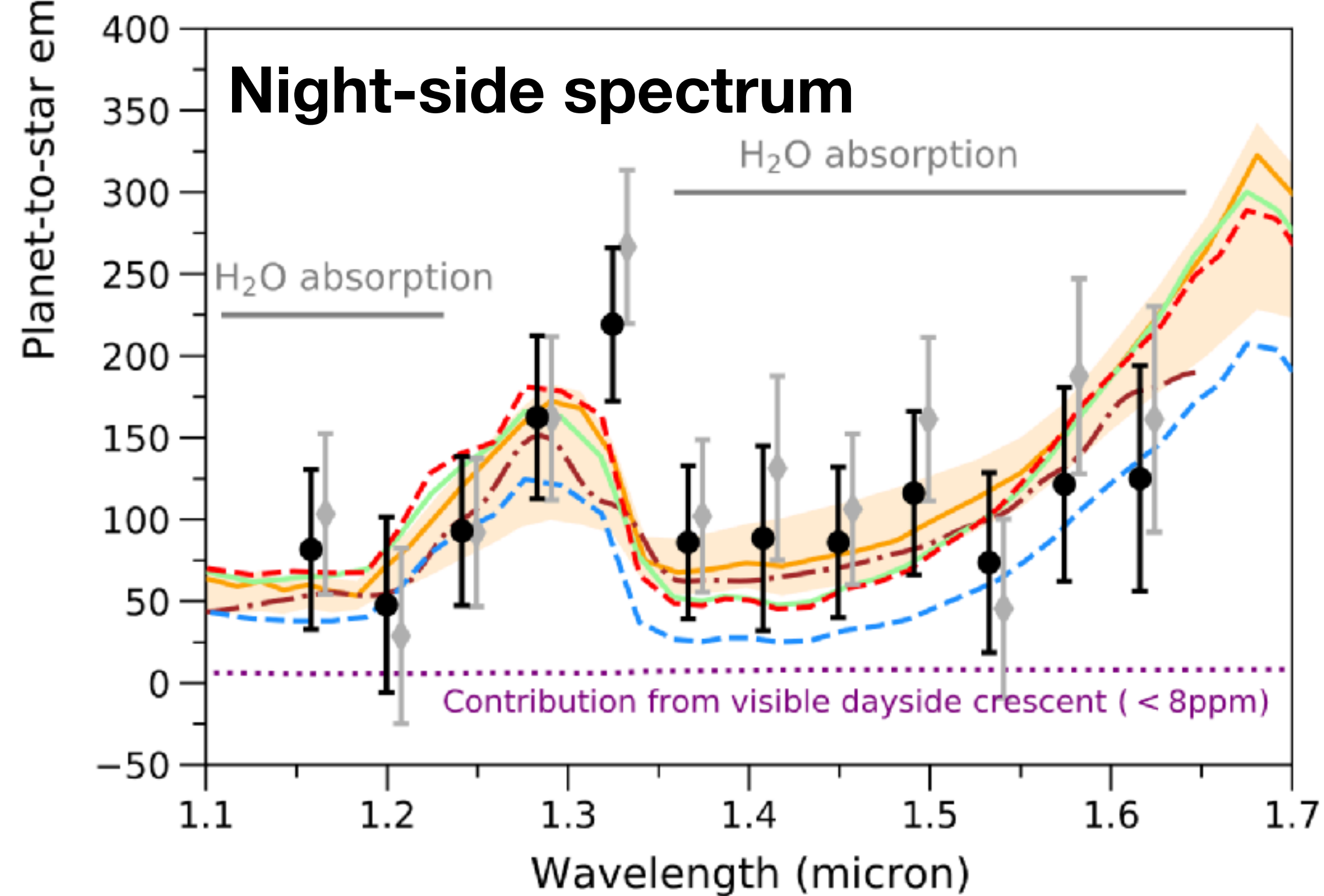
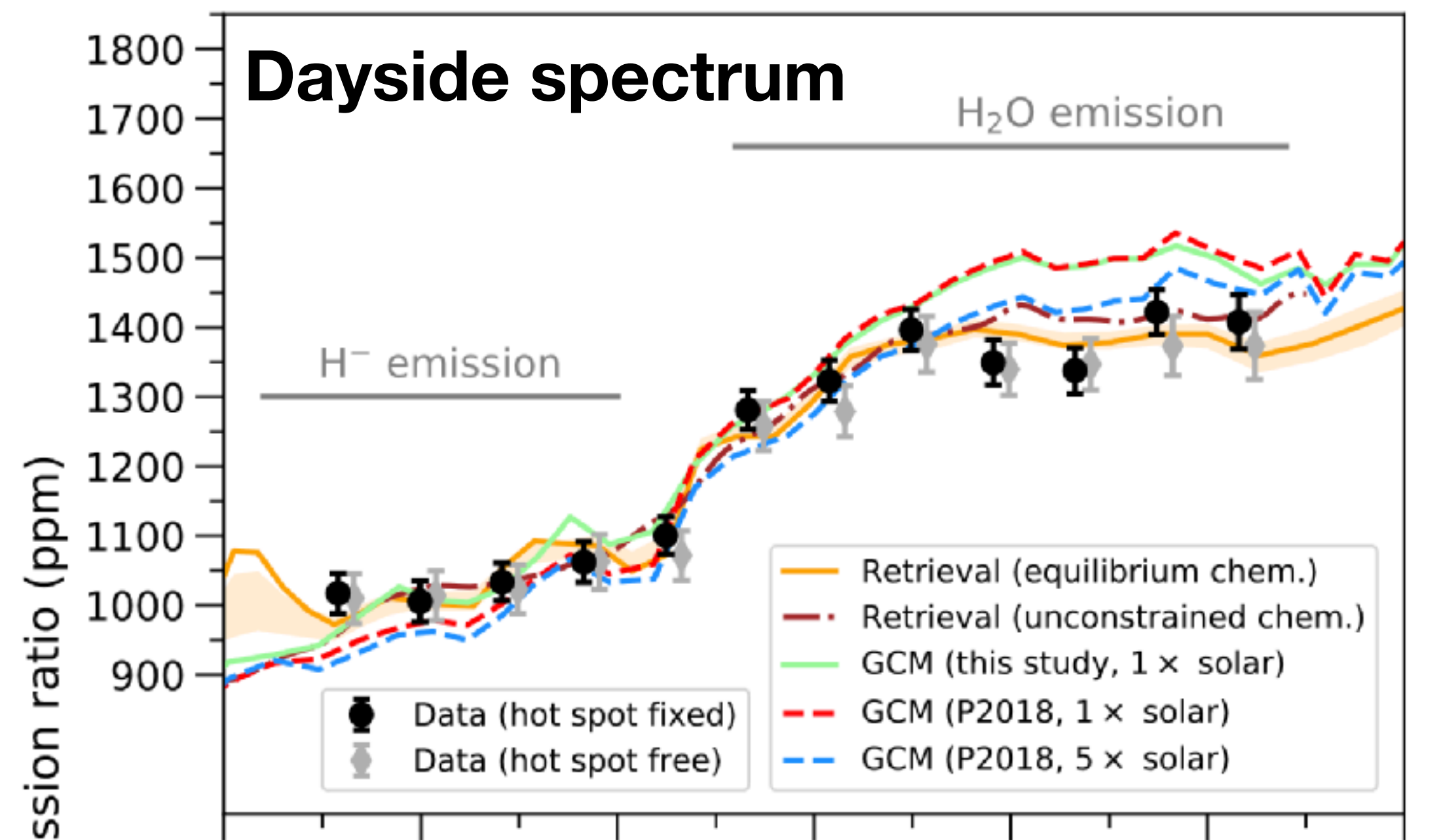
-Function of $T, \frac{dT}{dz}, \chi_{(P)}$

-3D distributions may be (more) important



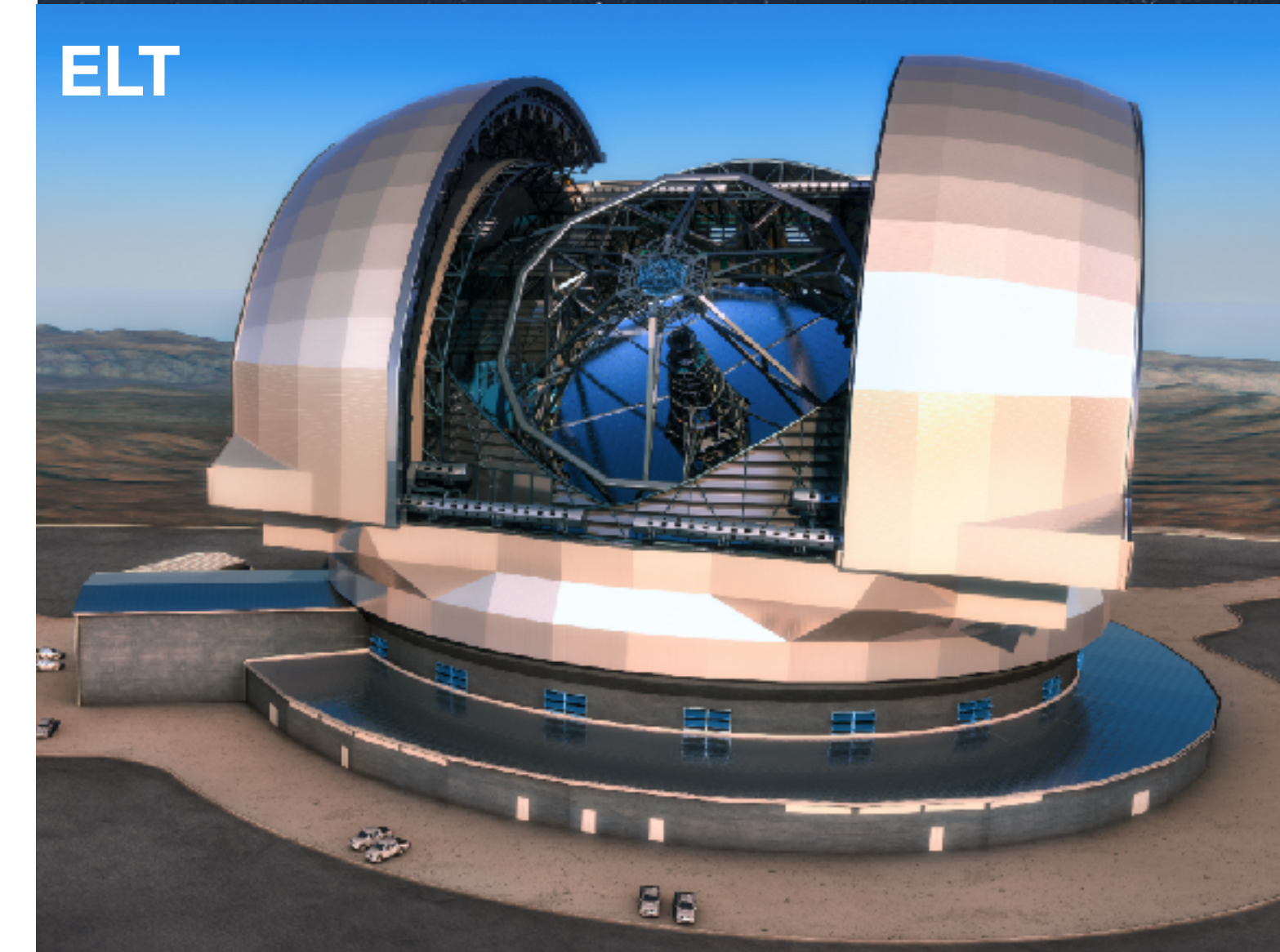
Thermal emission spectroscopy





Implications

- 1) Concepts like 'metallicity' or 'abundance'**
Atmosphere may not be representative of bulk
No single value (global distributions)
- 2) No 'continuum of planets':**
Sharp chemical transitions
GCMs & condensation physics needed
- 3) Ground and space are complementary**
Prepare for JWST-era and ELT
Translate to small planets?



Acknowledgements

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ESO



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