

Towards the Nature and Origin of Super-Earths

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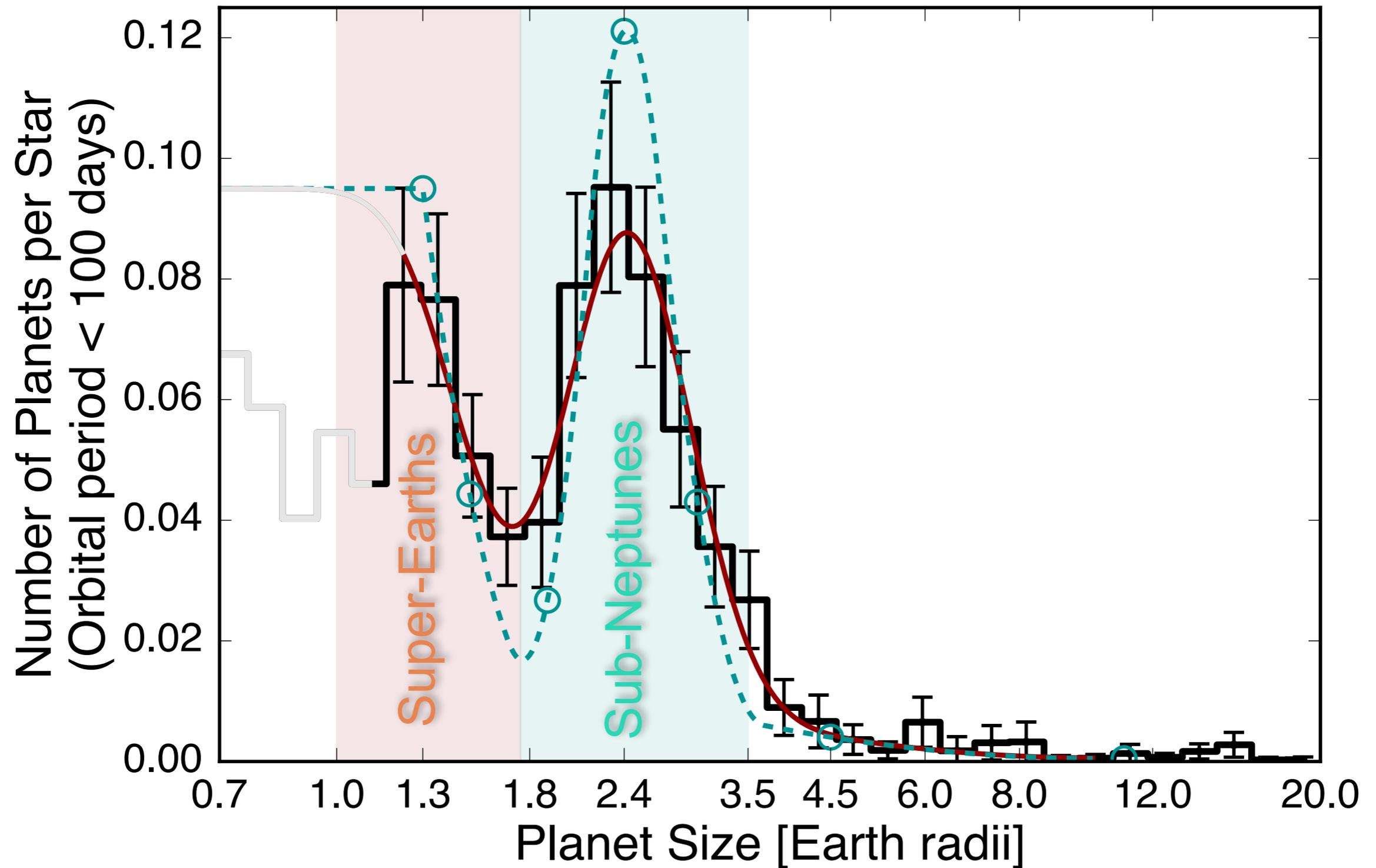
**Hubble Fellow
MIT Kavli Institute**

UNSOLVED PROBLEMS

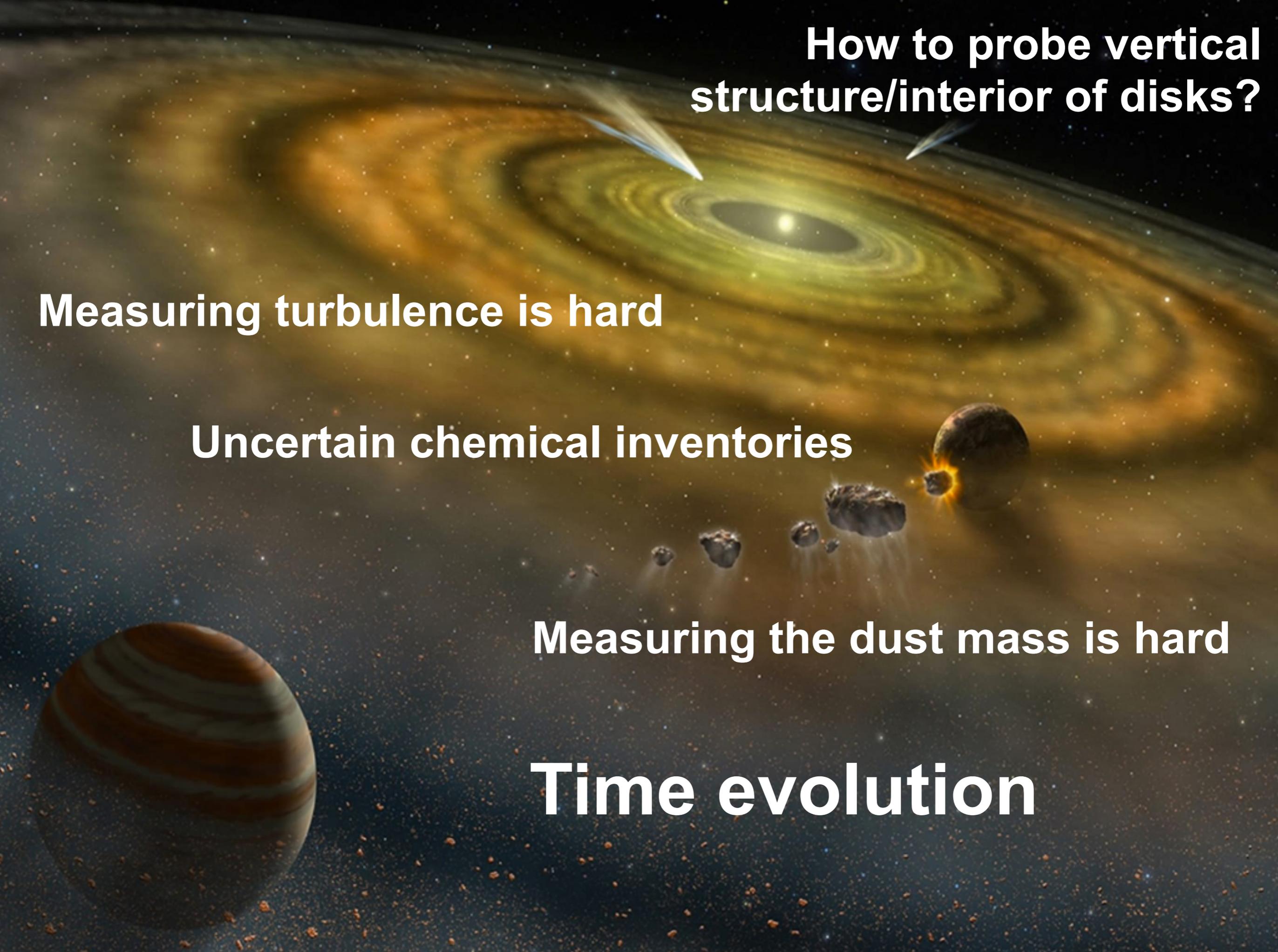
Budapest, Hungary

July 2, 2018

Small Exoplanets Are Common



Fulton et al. (2017)



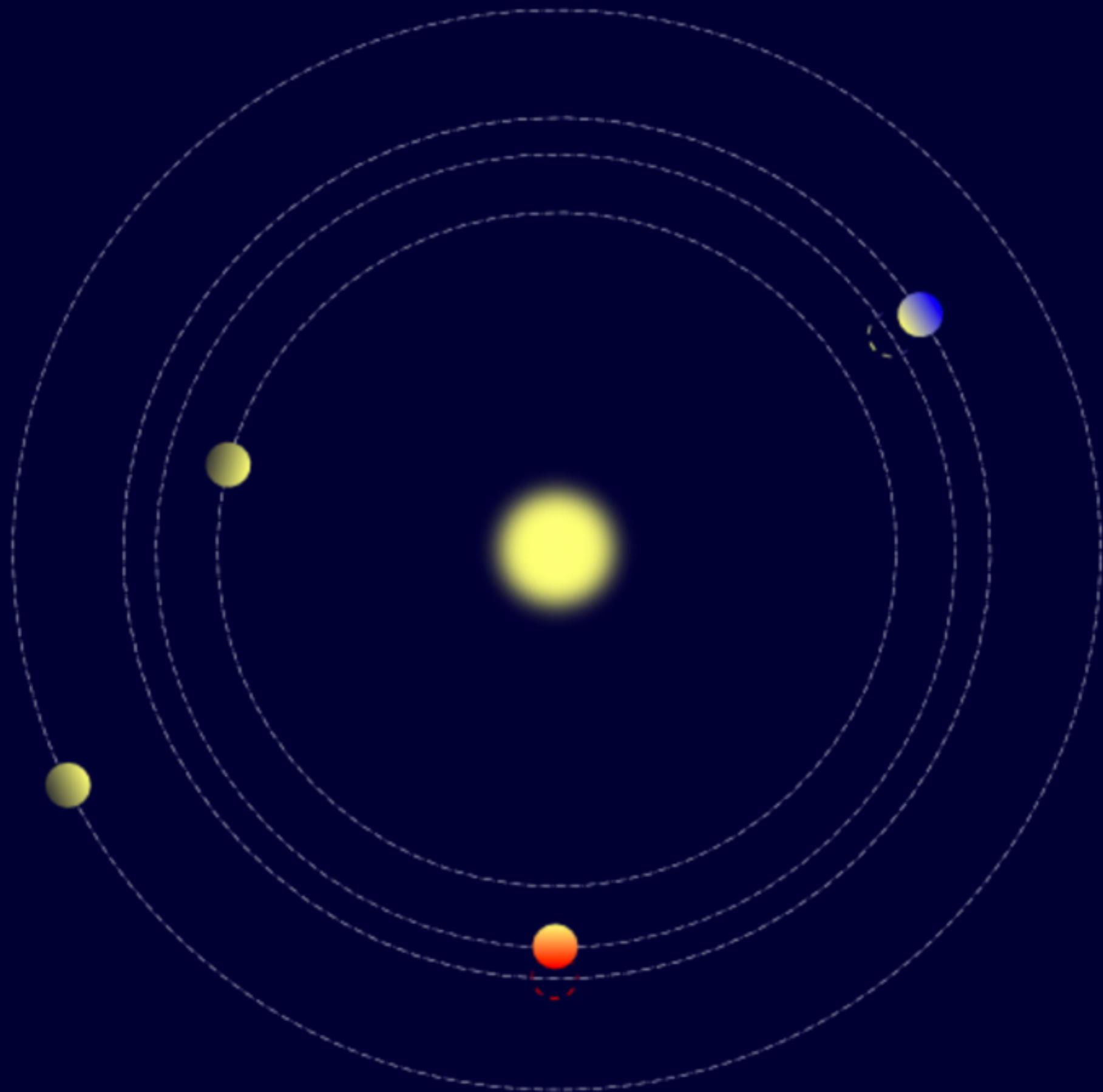
How to probe vertical structure/interior of disks?

Measuring turbulence is hard

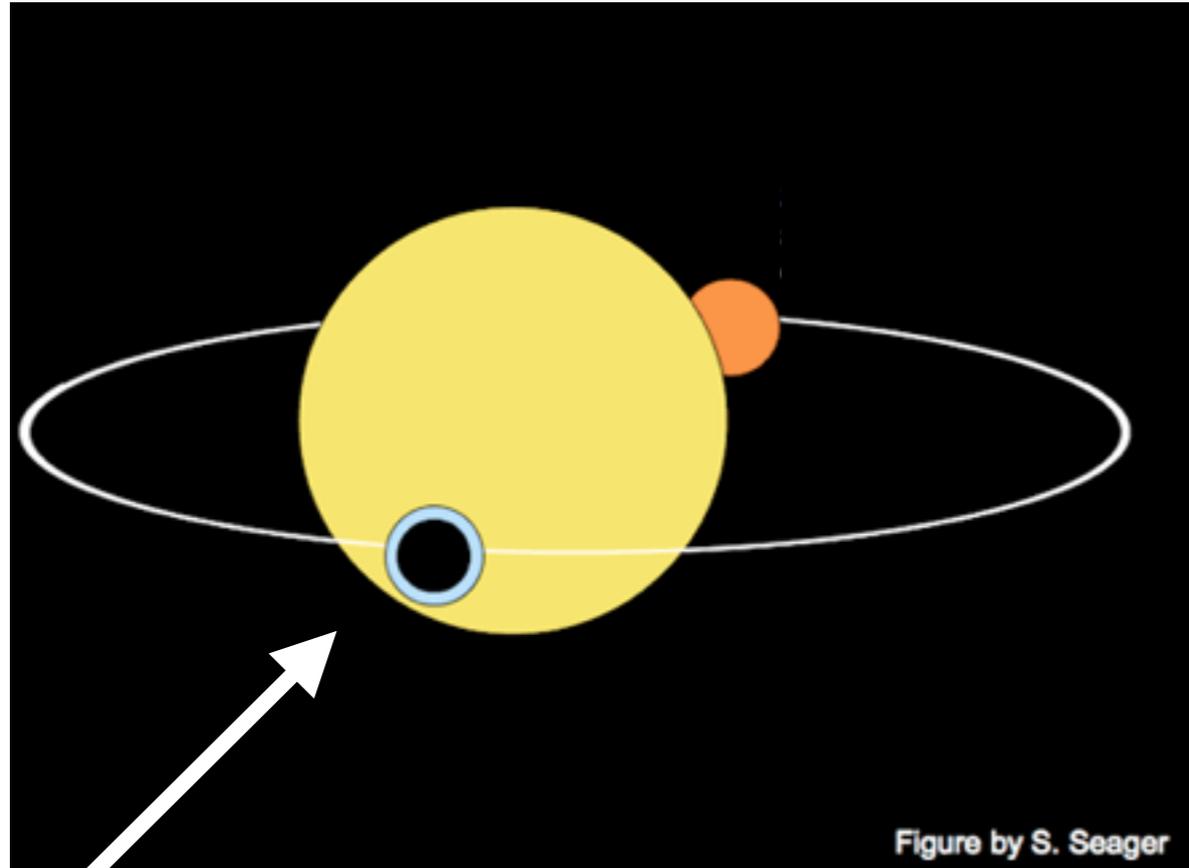
Uncertain chemical inventories

Measuring the dust mass is hard

Time evolution

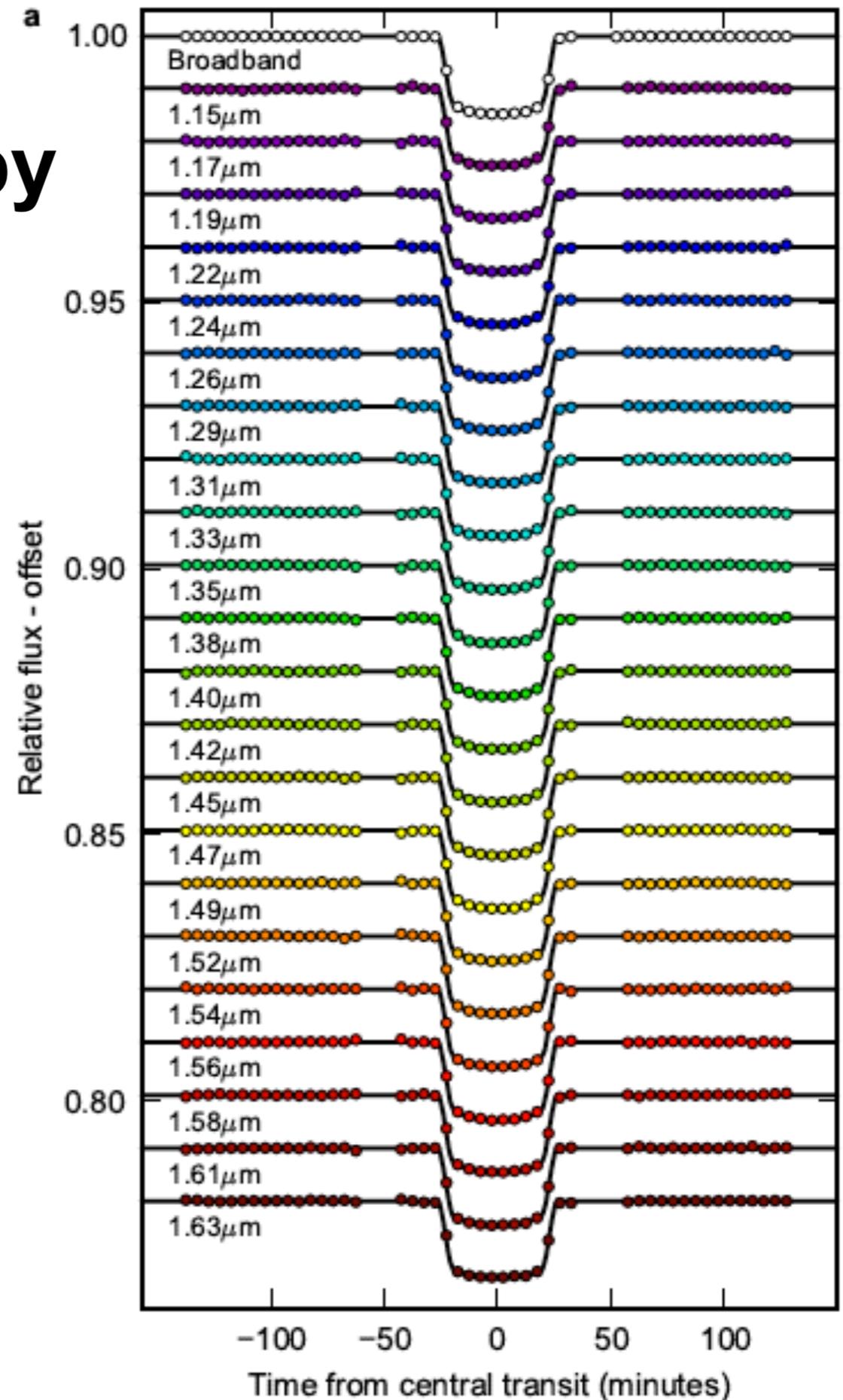


Exoplanet Atmospheres: Transmission spectroscopy



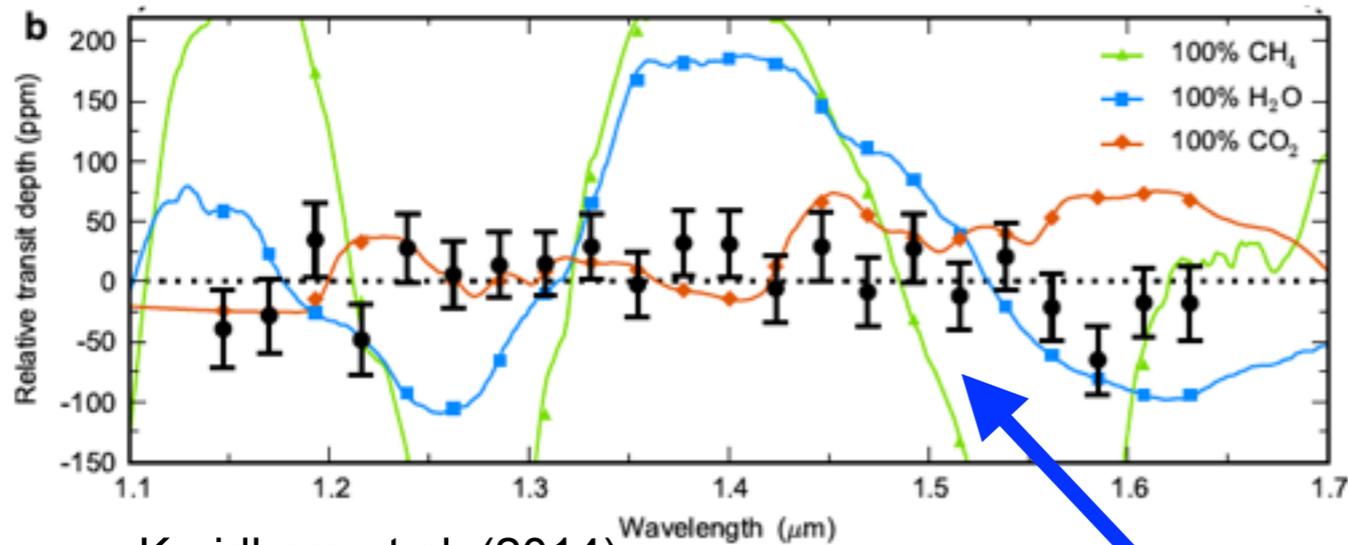
Can constrain:

- scale height (how puffy the atmosphere is)
- atmospheric composition
- molecular abundances



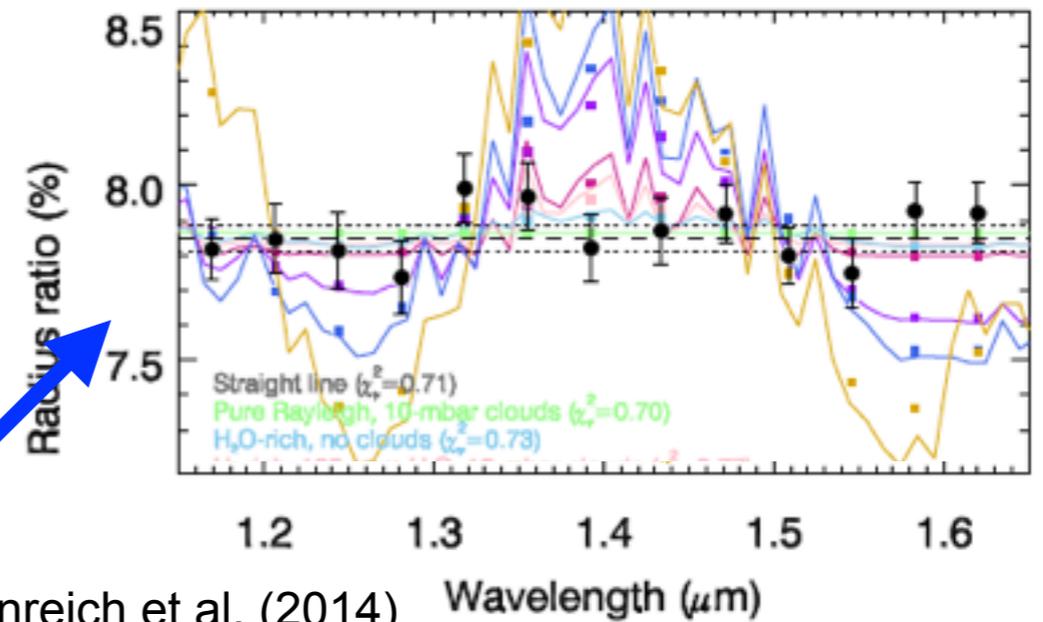
First Challenge: Small Exoplanet Atmospheres Are Often Cloudy...

GJ 1214b



Kreidberg et al. (2014)

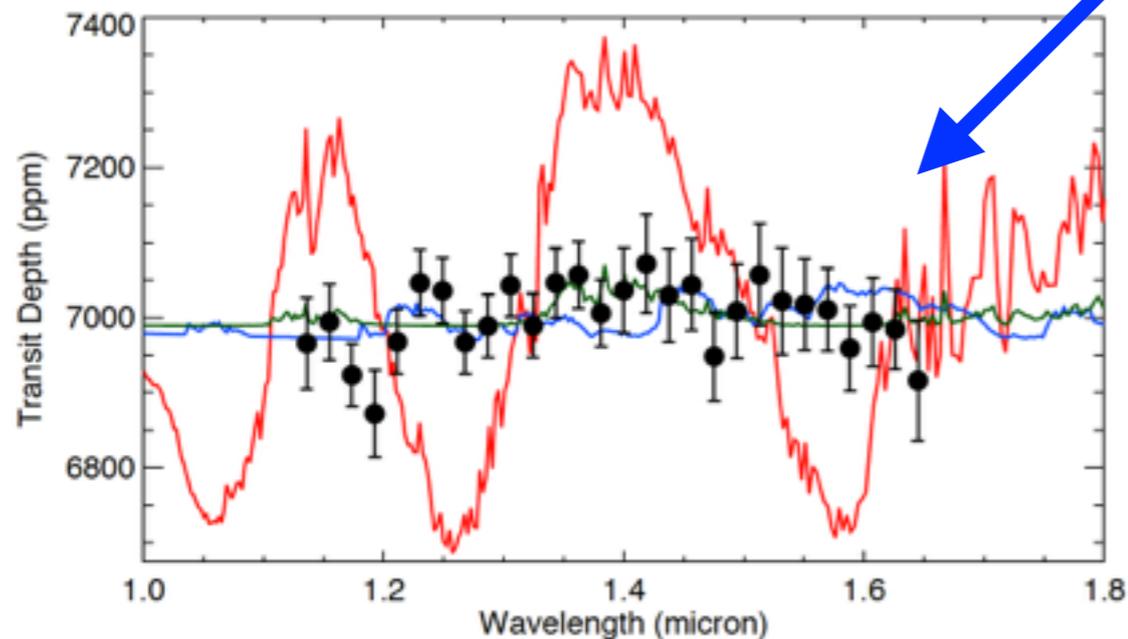
GJ 3470b



Ehrenreich et al. (2014)

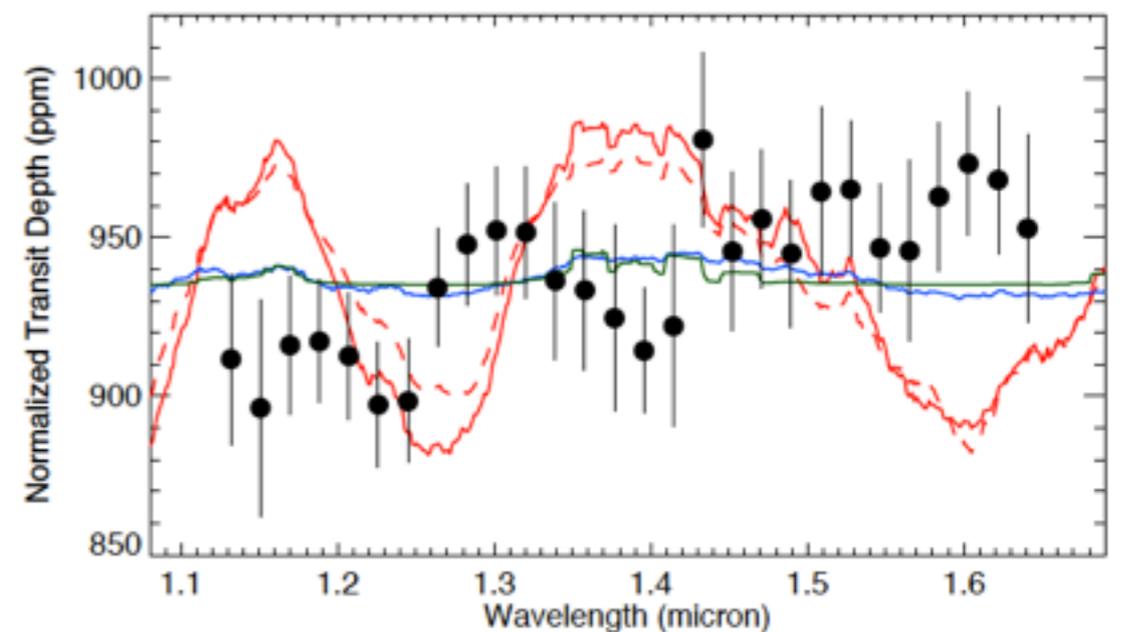
M dwarf host stars

GJ 436b



Knutson et al. (2014)

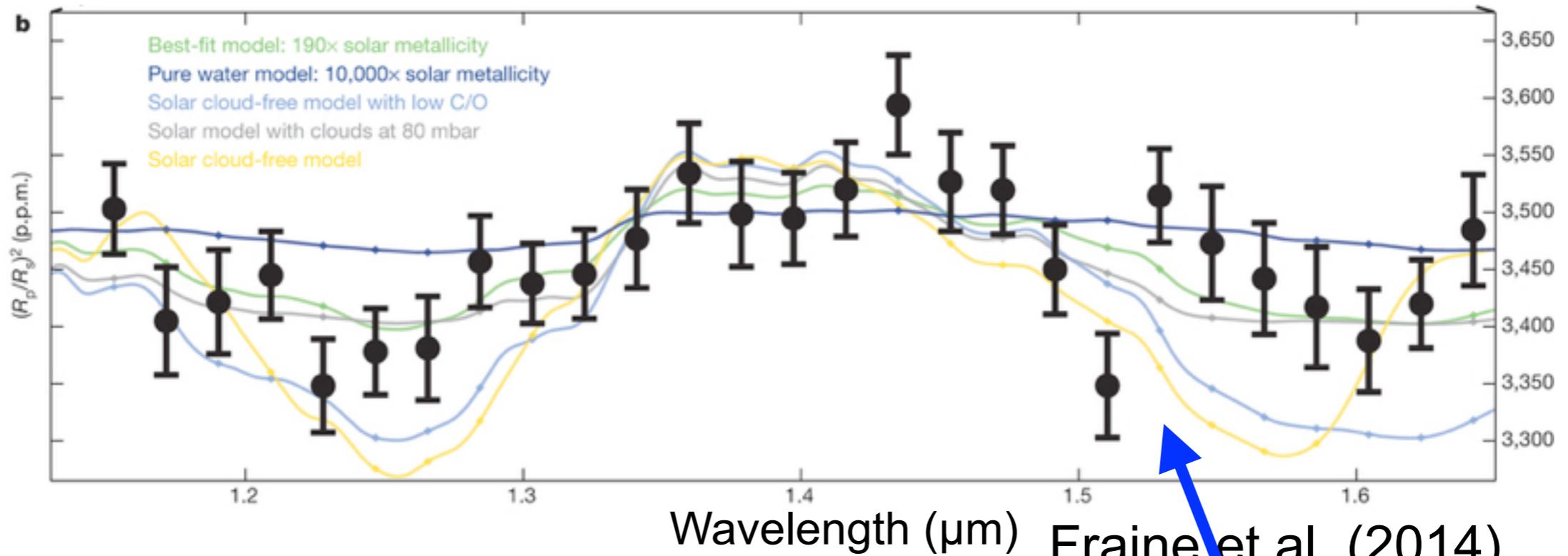
HD 97658b



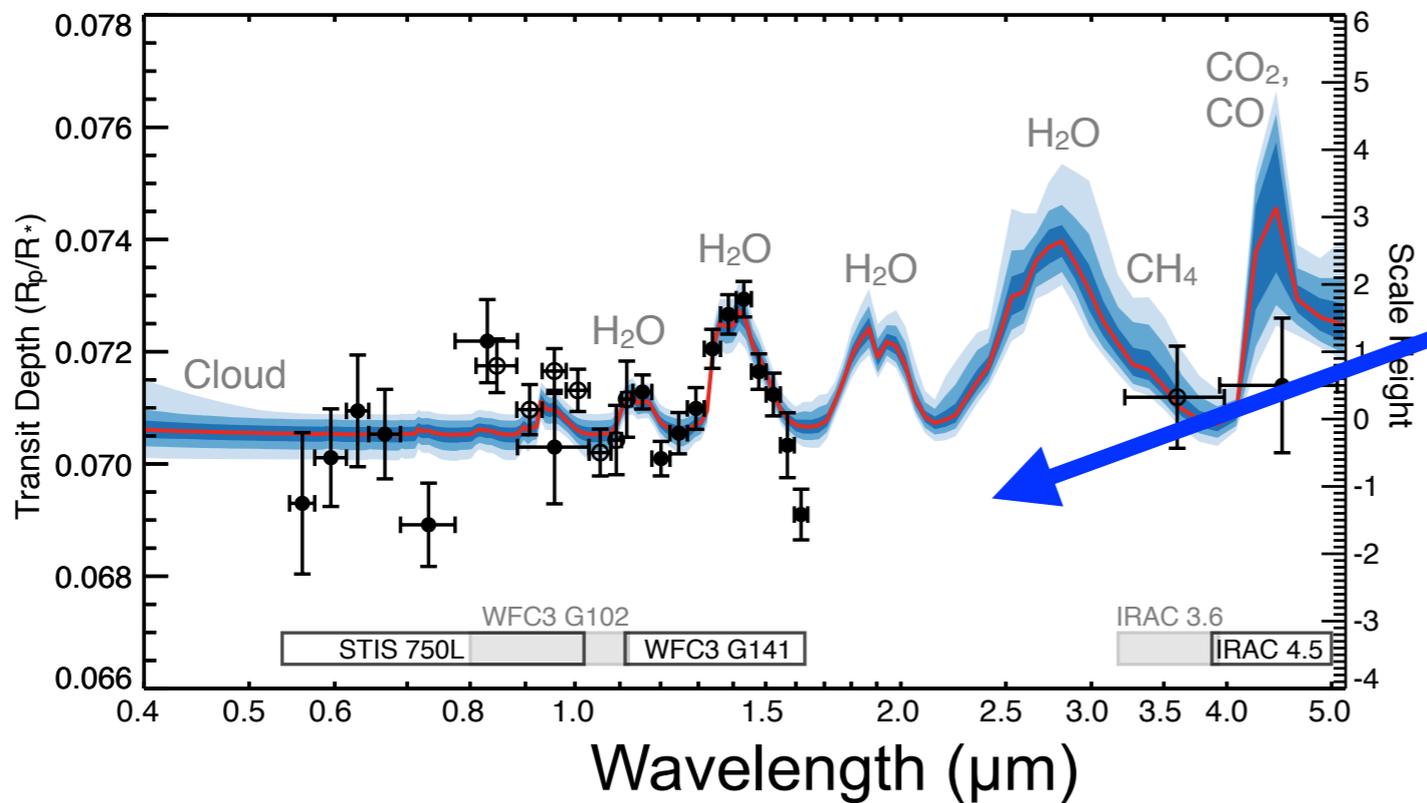
Knutson, Dragomir et al. (2014)

... But Not Always

HAT-P-11b

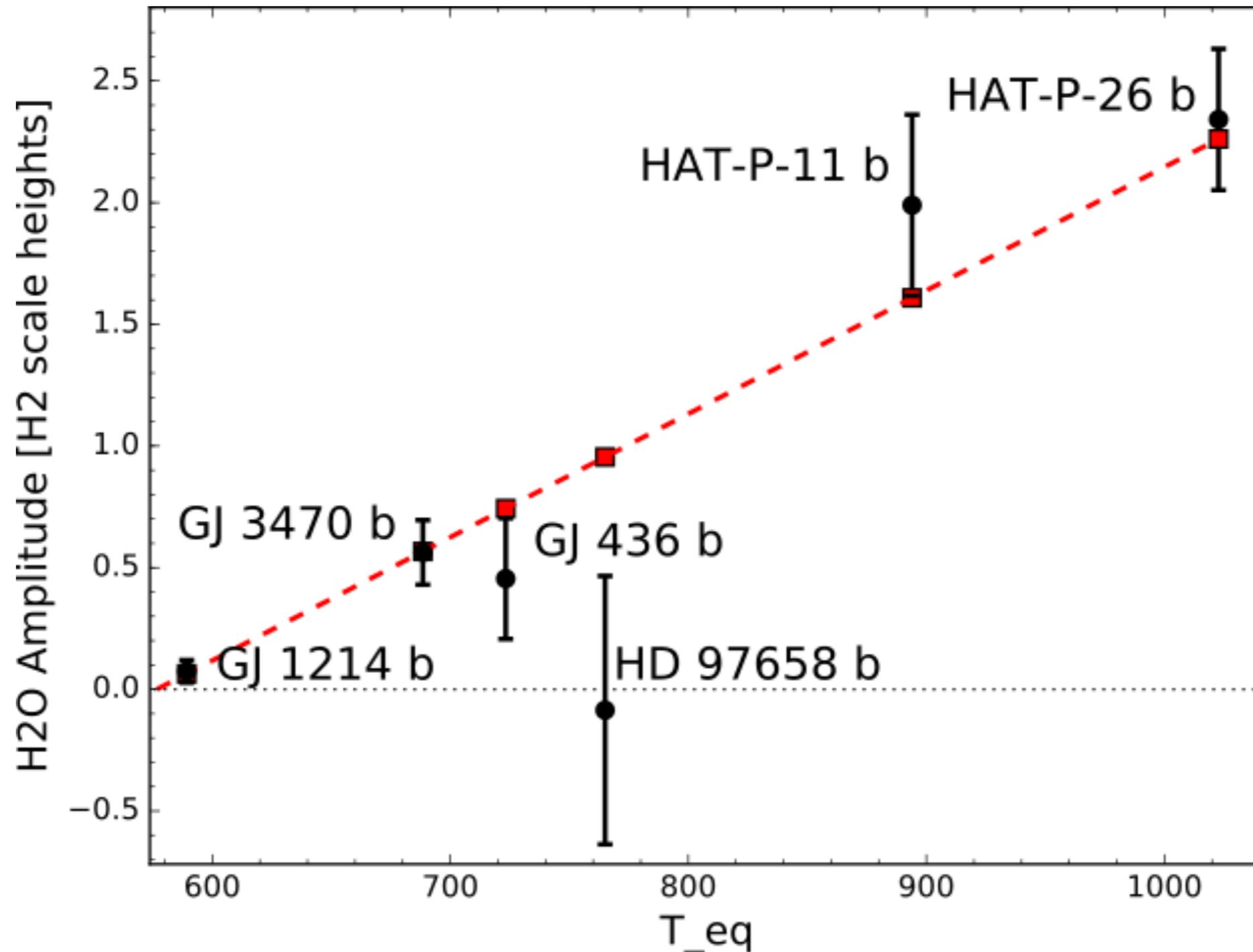


K dwarf host stars



HAT-P-26b
Wakeford et al. (2017)

Do Clouds/Hazes Correlate With Planet Temperatures?

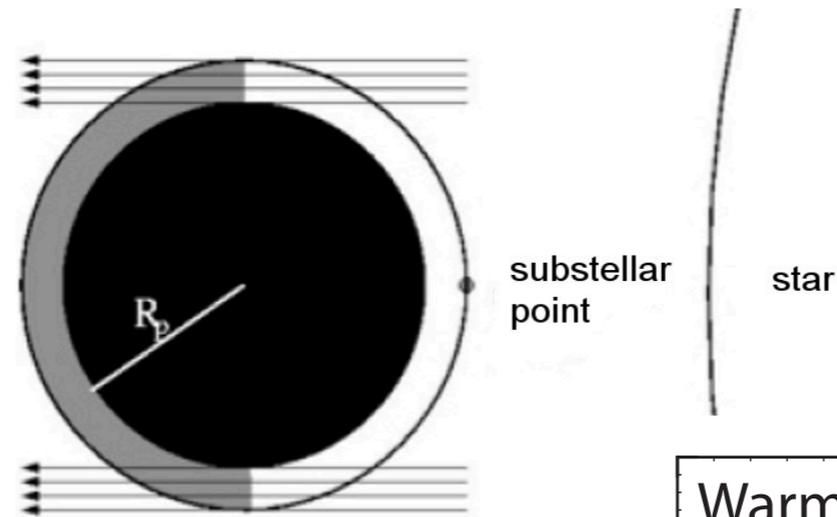


Crossfield & Kreidberg (2017)

see also Stevenson (2016)

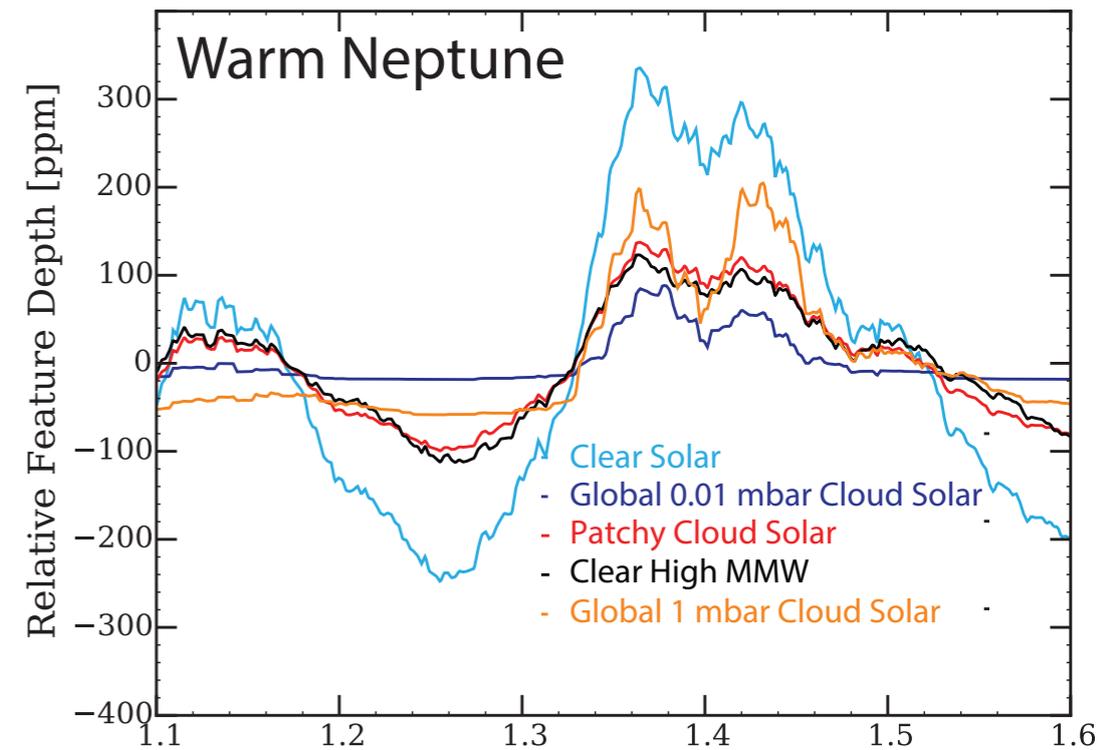
Other Challenges for Transmission Spectroscopy

Only probes day-night terminator



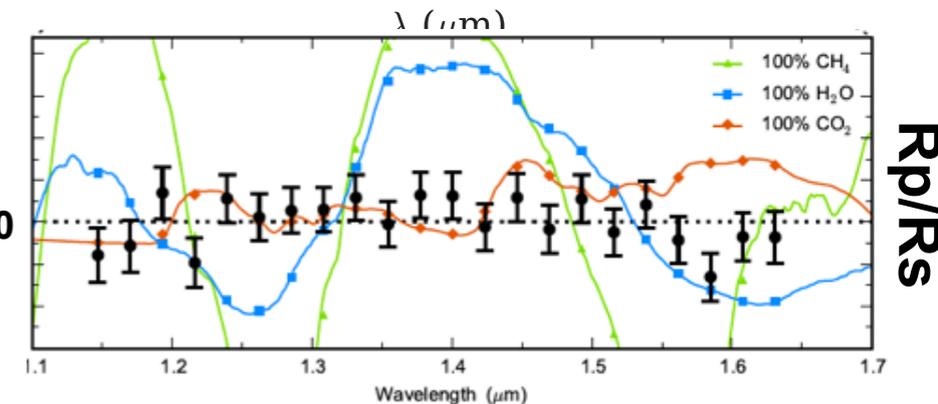
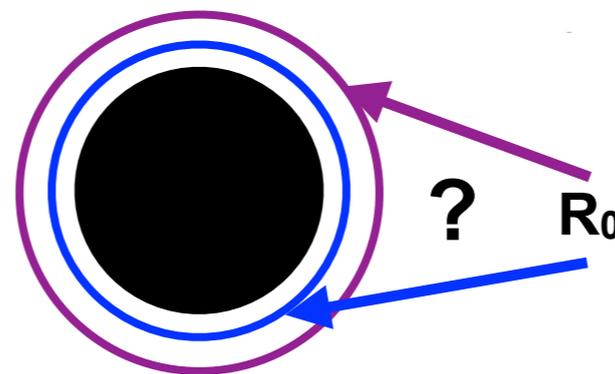
Partial Clouds vs. Mean Molecular Weight

Line & Parmentier (2015)

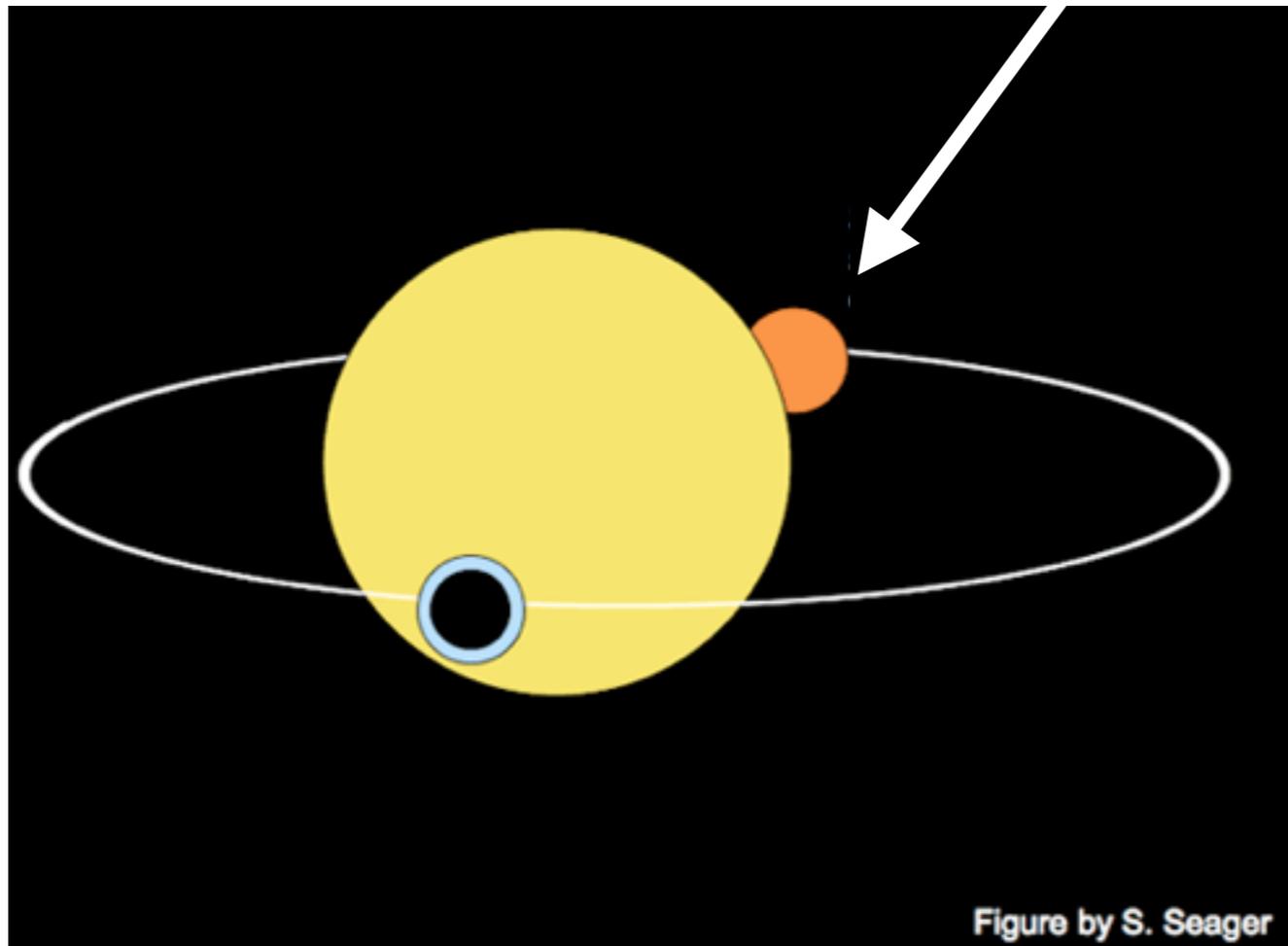


Degeneracy between molecular abundances and reference pressure

Heng & Kitzmann (2017)



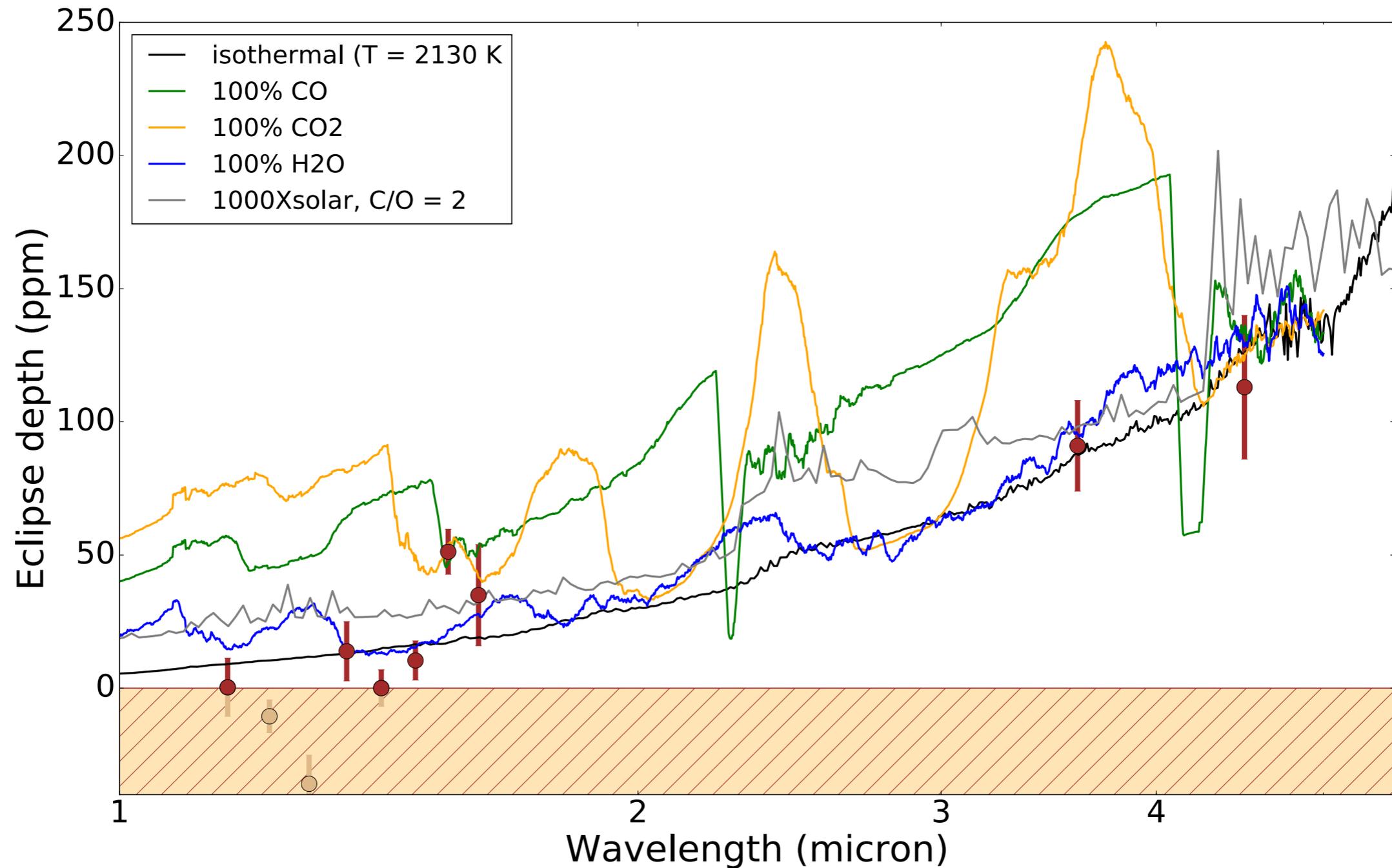
Other Paths: Emission Spectroscopy



Can constrain:

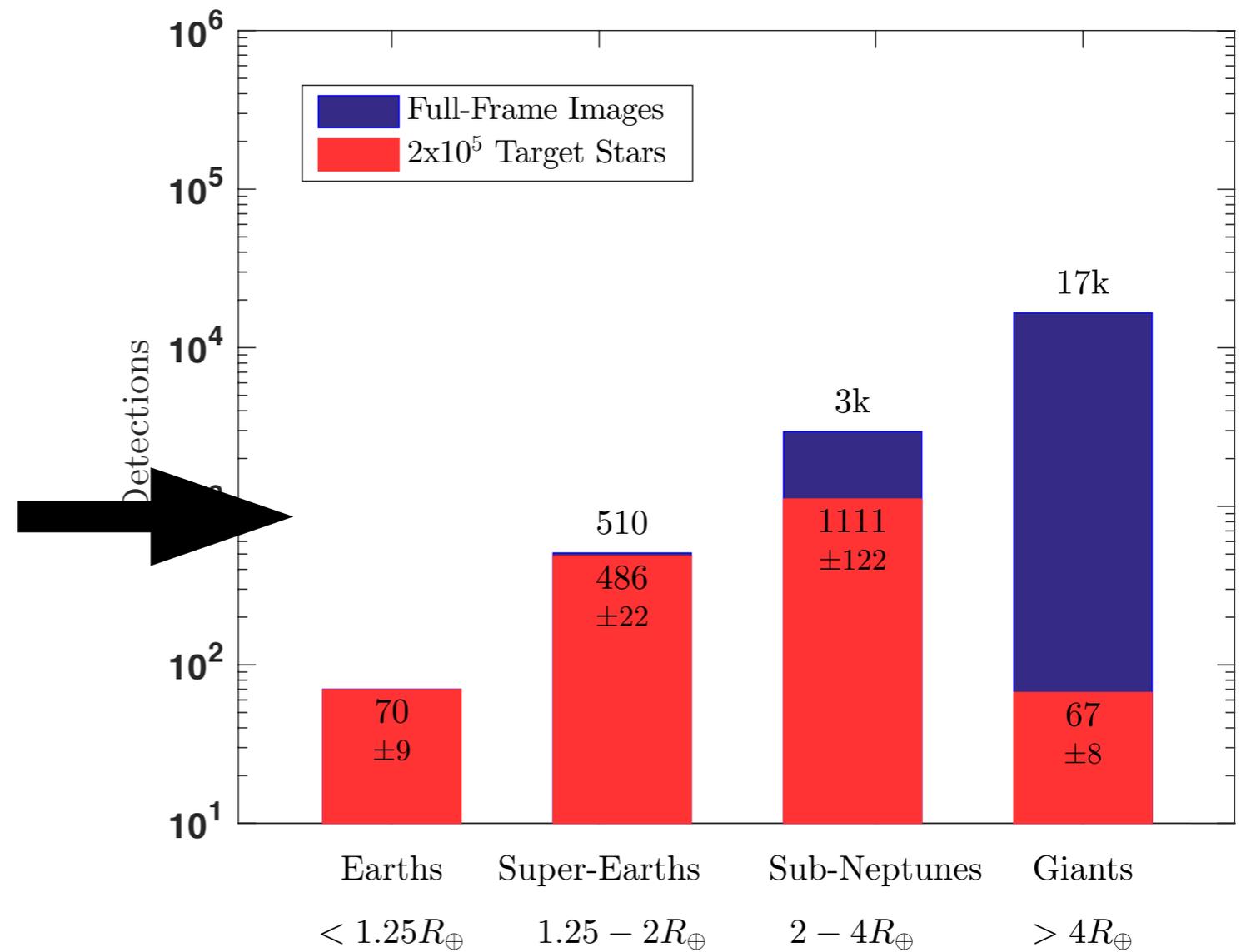
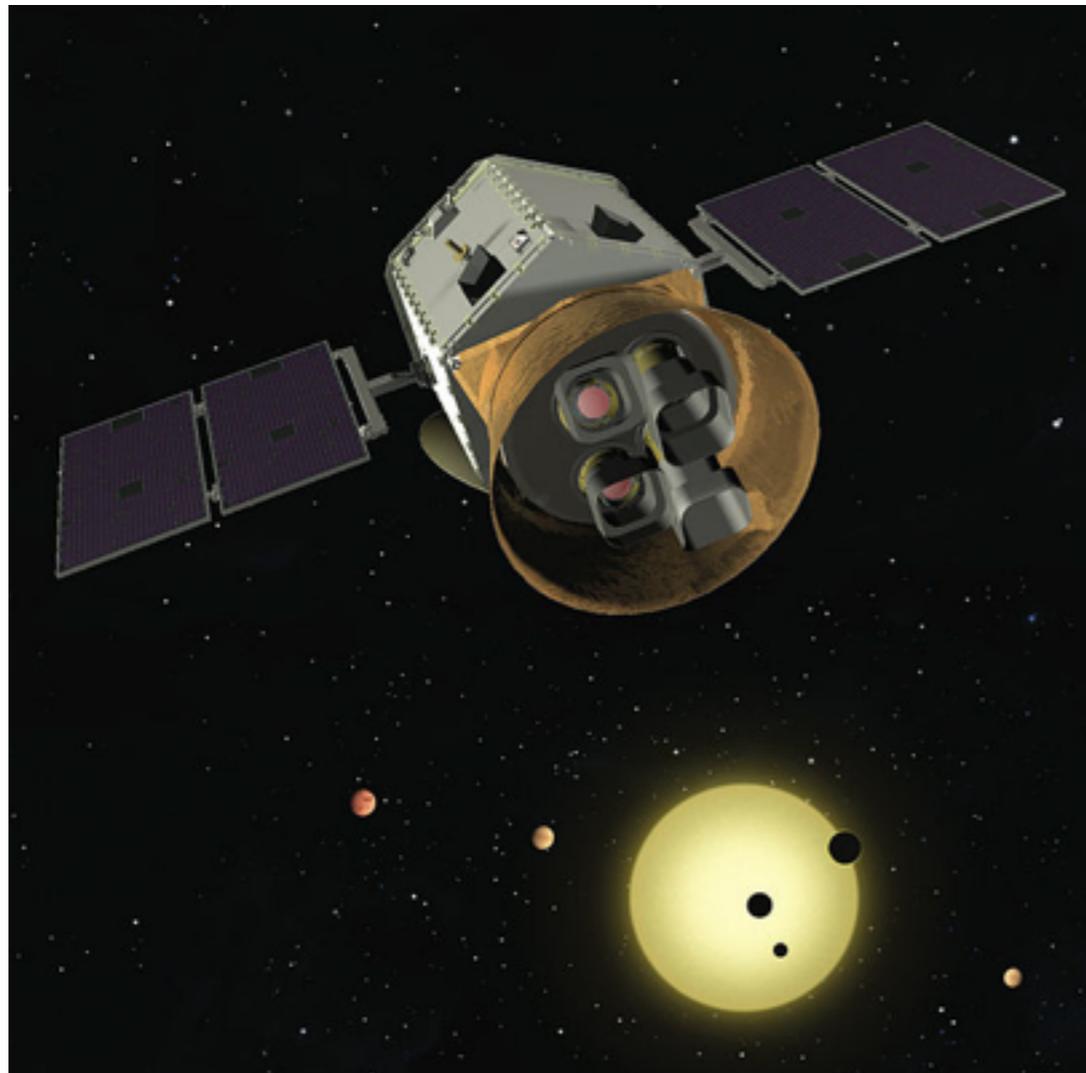
- the temperature - pressure profile, and thus the atmospheric structure
- heat redistribution efficiency
- atmospheric composition

The first emission spectrum of a super-Earth (55 Cnc e)



Dragomir et al. (2018)

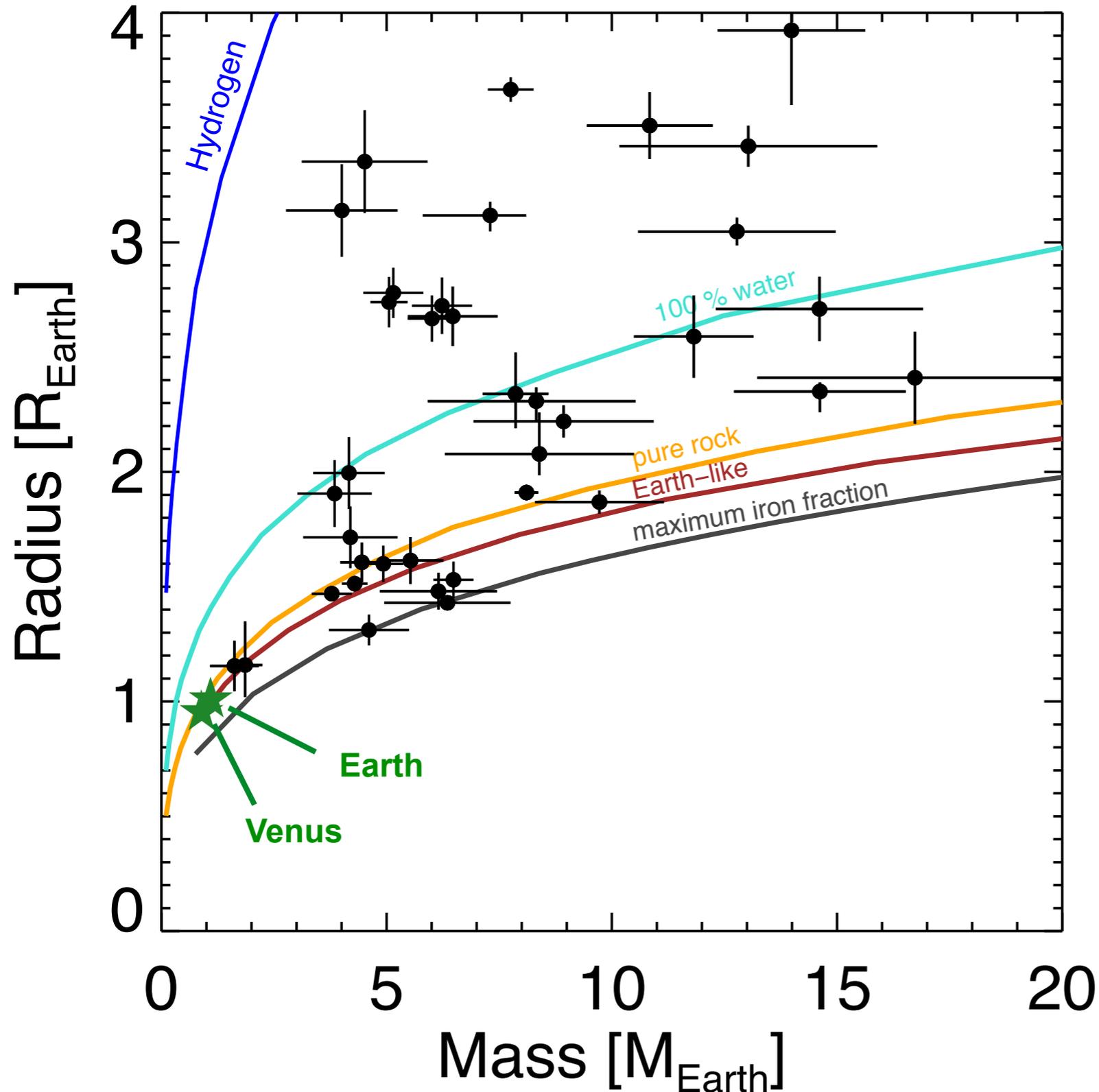
Transiting Exoplanet Survey Satellite (TESS)



Sullivan et al. (2015)

Launched April 18, 2018

Other Paths: Small Planet Mass-Radius Diagram



Search for trends as a function of:

- distance from the host star (orbital period)
- stellar mass
- stellar metallicity and abundances

Takeaways

- Connecting super-Earth composition to their formation is a multi-nuanced challenge
- Transmission spectroscopy is prone to degeneracies
 - ➔ but for now it is the only way to probe the atmospheres of most (transiting) super-Earths
- Use complementary approaches to enhance the efficiency of super-Earth characterization
 - ➔ emission spectroscopy and bulk density statistics