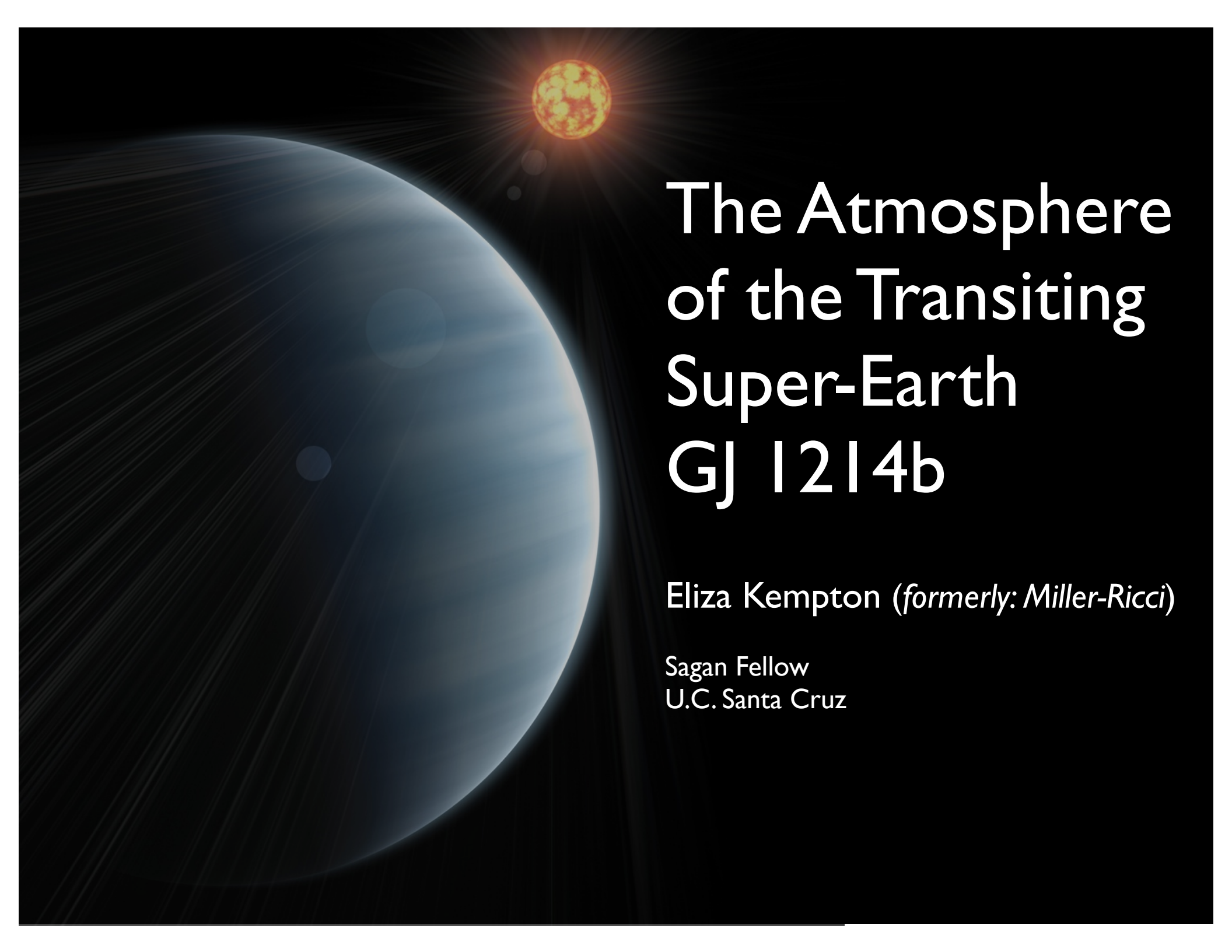


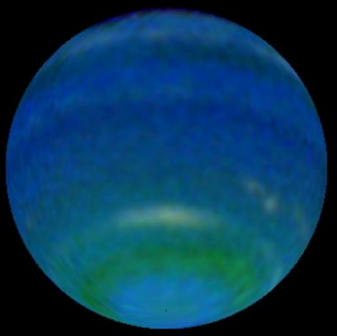
The background of the slide is a black space. On the left, a large, blue, hazy planet (GJ 1214b) is shown in a crescent phase, with a bright orange star (the host star) visible in the upper left. The planet's surface is depicted with a blue gradient and some darker, swirling patterns. The star is a bright orange-yellow sphere with a textured surface and a prominent lens flare effect. The title text is positioned on the right side of the slide.

The Atmosphere of the Transiting Super-Earth GJ 1214b

Eliza Kempton (*formerly: Miller-Ricci*)

Sagan Fellow
U.C. Santa Cruz

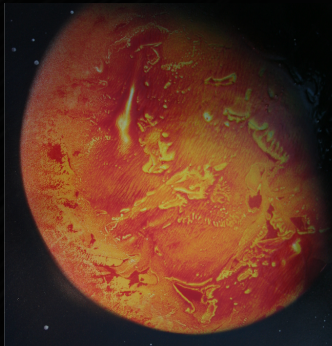
3 Possible Compositions of GJ 1214b



1) Accretion Scenario:

Rock / Ice + Accreted gas (mostly H_2)

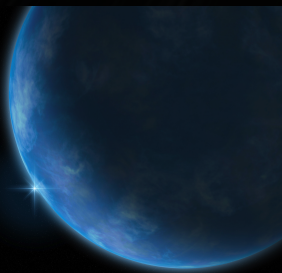
→ H_2 and He atmosphere + trace gasses



2) Outgassing Scenario:

Rock / Ice + Outgassed material (mostly H_2 but with no He)

→ H_2 atmosphere + trace gasses



3) Water World Scenario:

Mostly H_2O

→ H_2O (steam) atmosphere

Transmission Spectroscopy - What We Expect

----- No atmosphere

☉☉ Solar

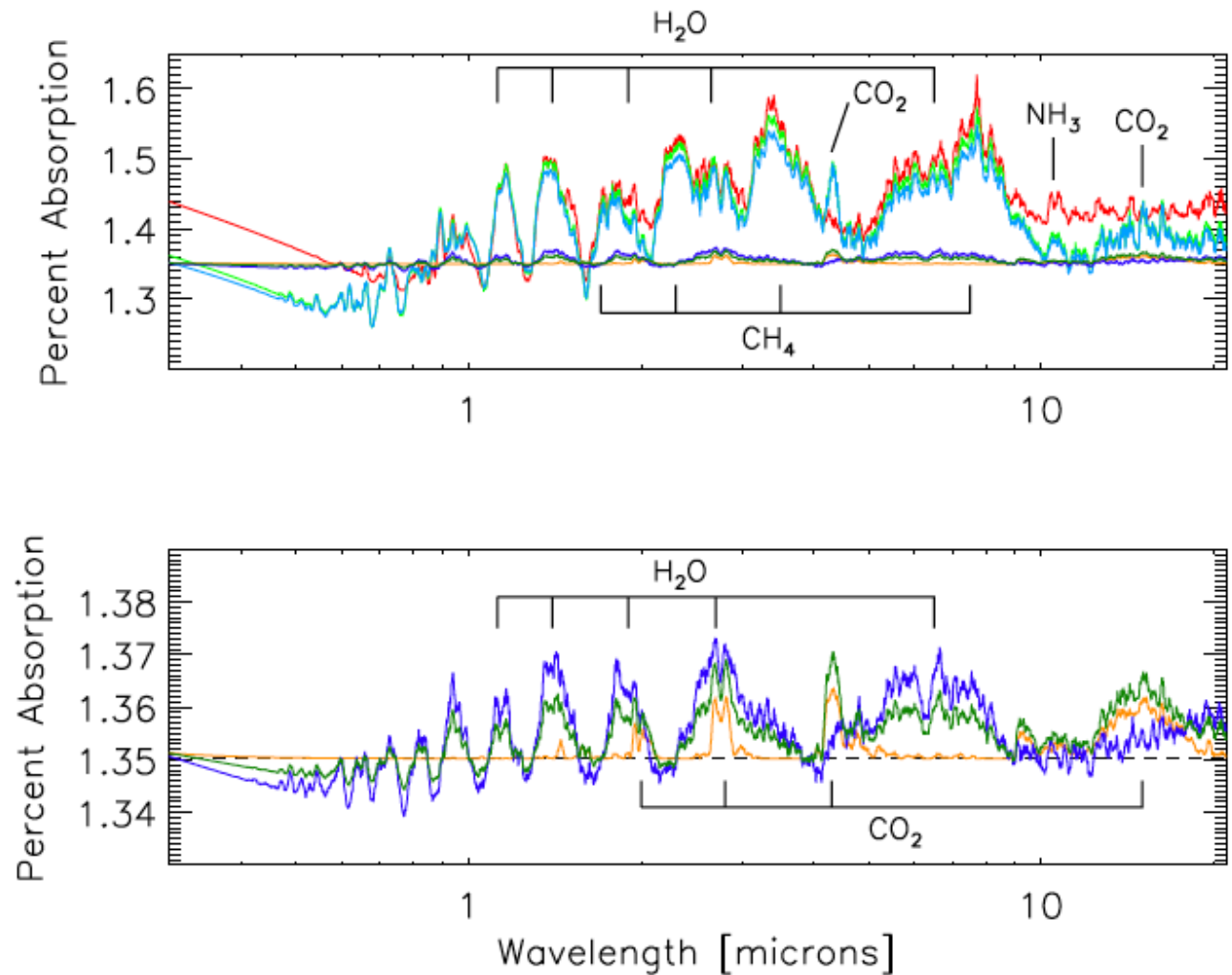
☉☉ 30 x Solar

☉☉ 50 x Solar

☉☉ H₂O

☉☉ H₂O - CO₂

☉☉ CO₂



$$\Delta_{\text{depth}} \sim 20H R_{\text{pl}} / R_{*}^2$$

Transmission Spectroscopy - What We Expect

----- No atmosphere

☉☉ Solar

☉☉ 30 x Solar

☉☉ 50 x Solar

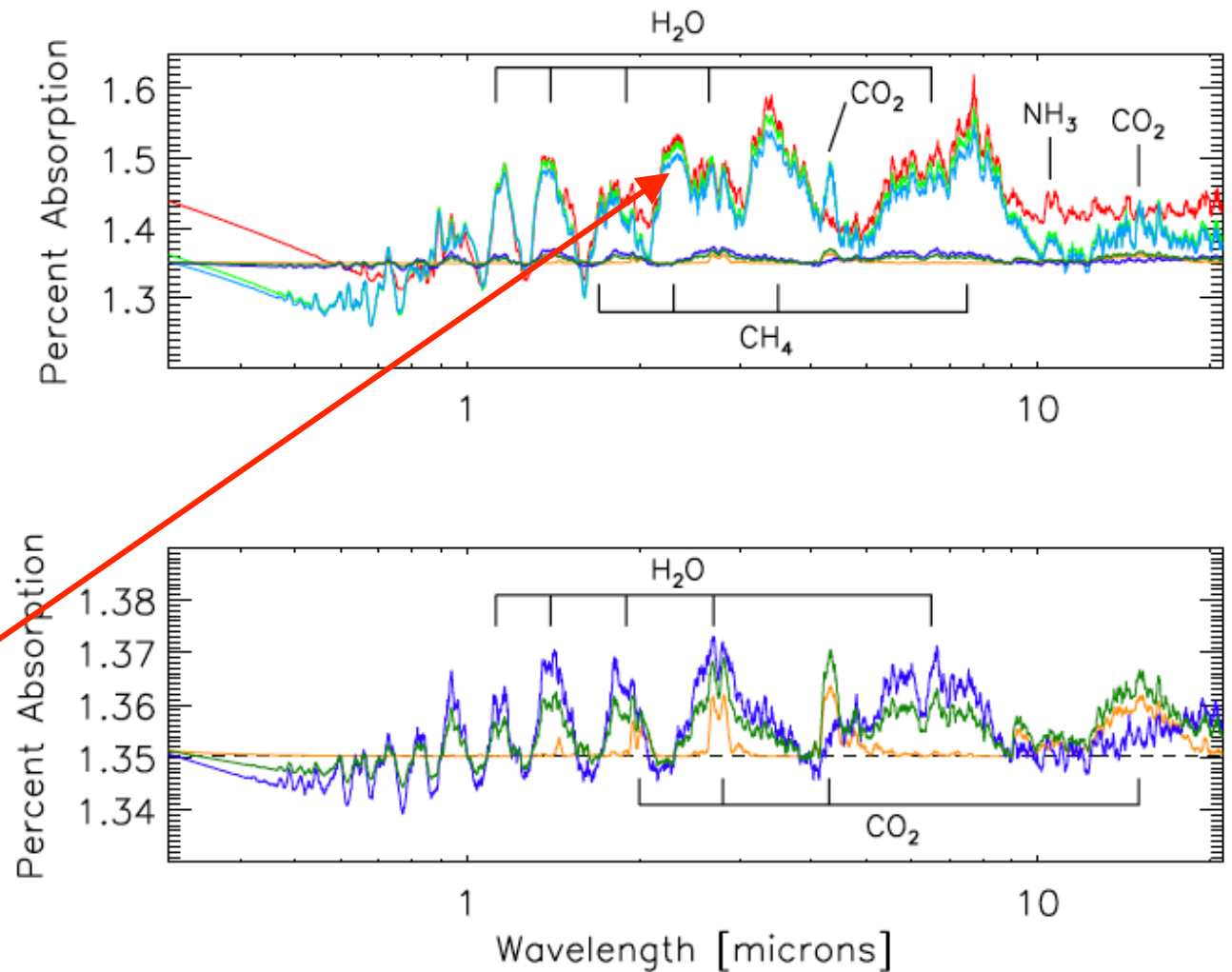
☉☉ H₂O

☉☉ H₂O - CO₂

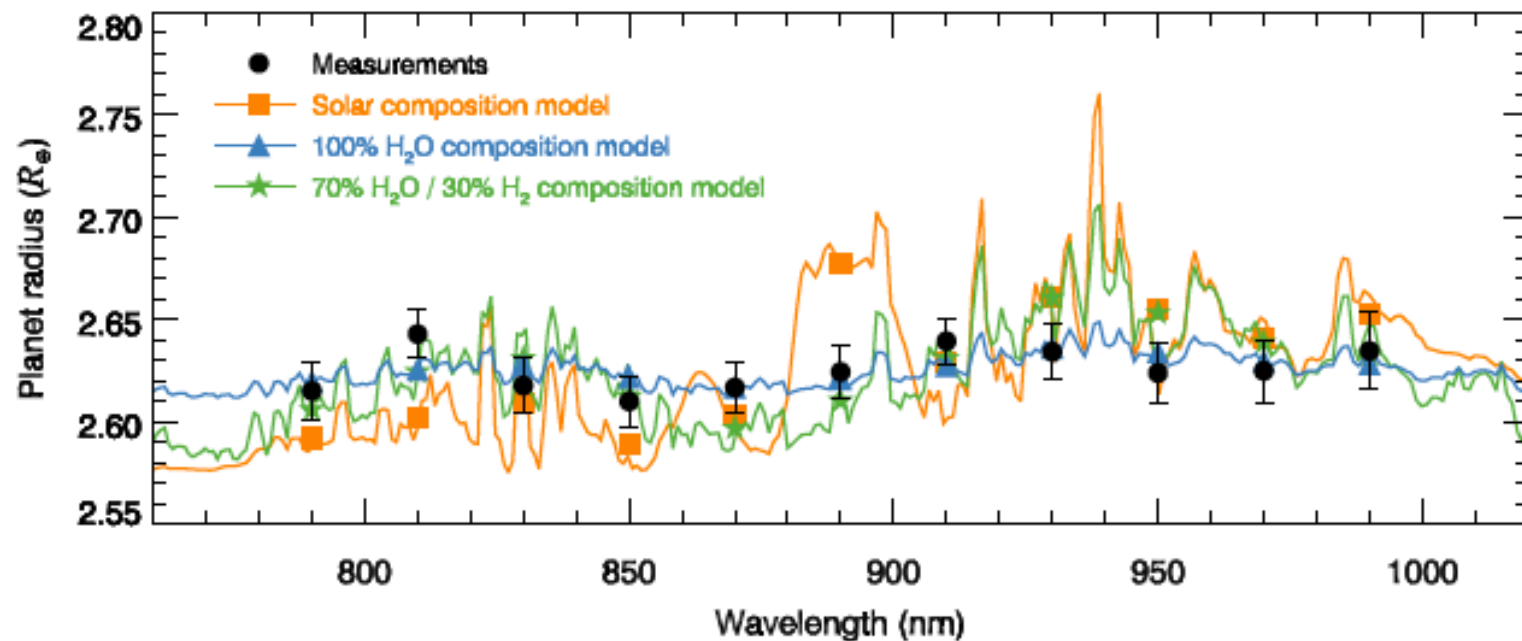
☉☉ CO₂

Signatures of 0.1 - 0.3%
for H-rich atmospheres!

$$\Delta_{\text{depth}} \sim 20H R_{\text{pl}} / R_{*}^2$$



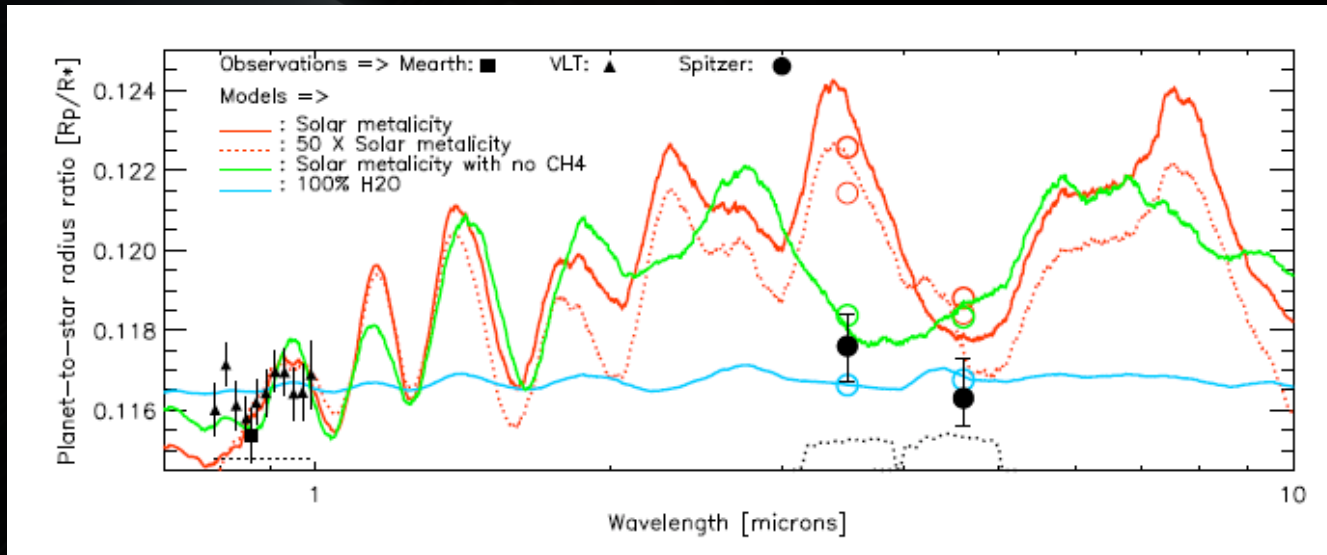
Transmission Spectroscopy - What We See



Bean, Miller-Ricci Kempton, Homeier, *Nature*, 2010

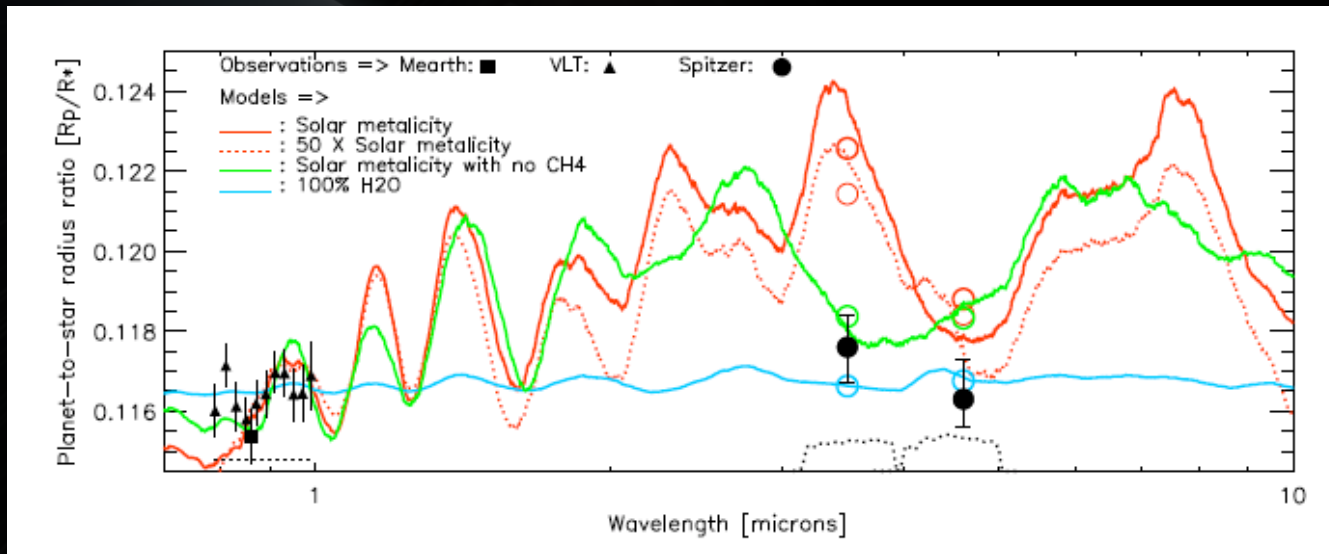
- H-rich composition ruled out at 4.9σ confidence
- 20% water by volume (70% by mass) required to be within 1σ
- Alternative is high-altitude clouds or hazes...

Other Data

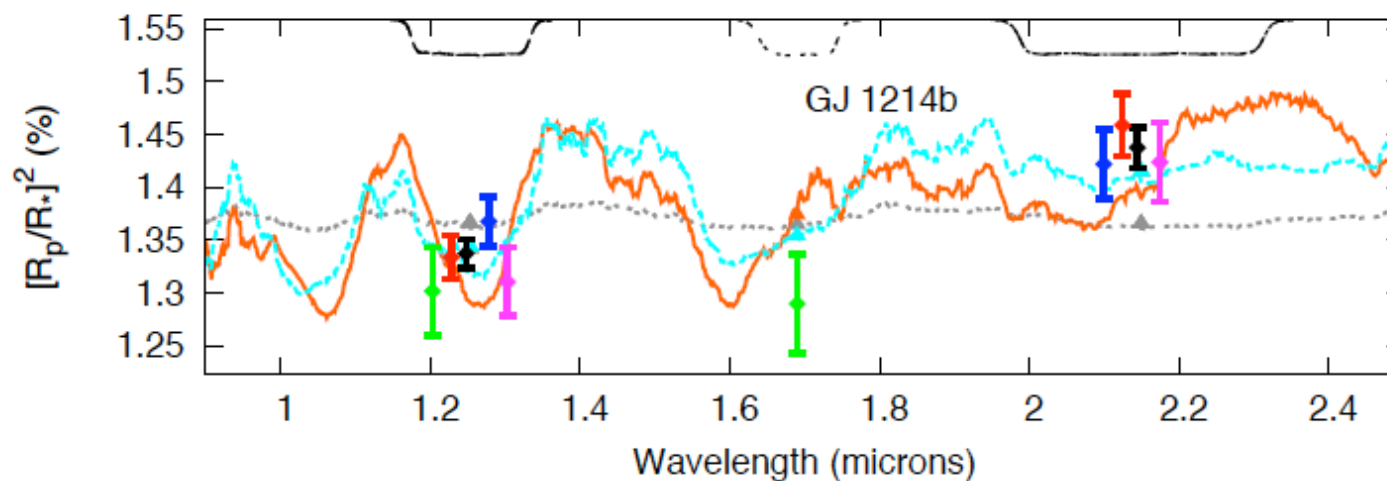


Désert, Bean, Miller-Ricci Kempton, et al., *ApJ*, 2011
(Poster Characterization.08)

Other Data

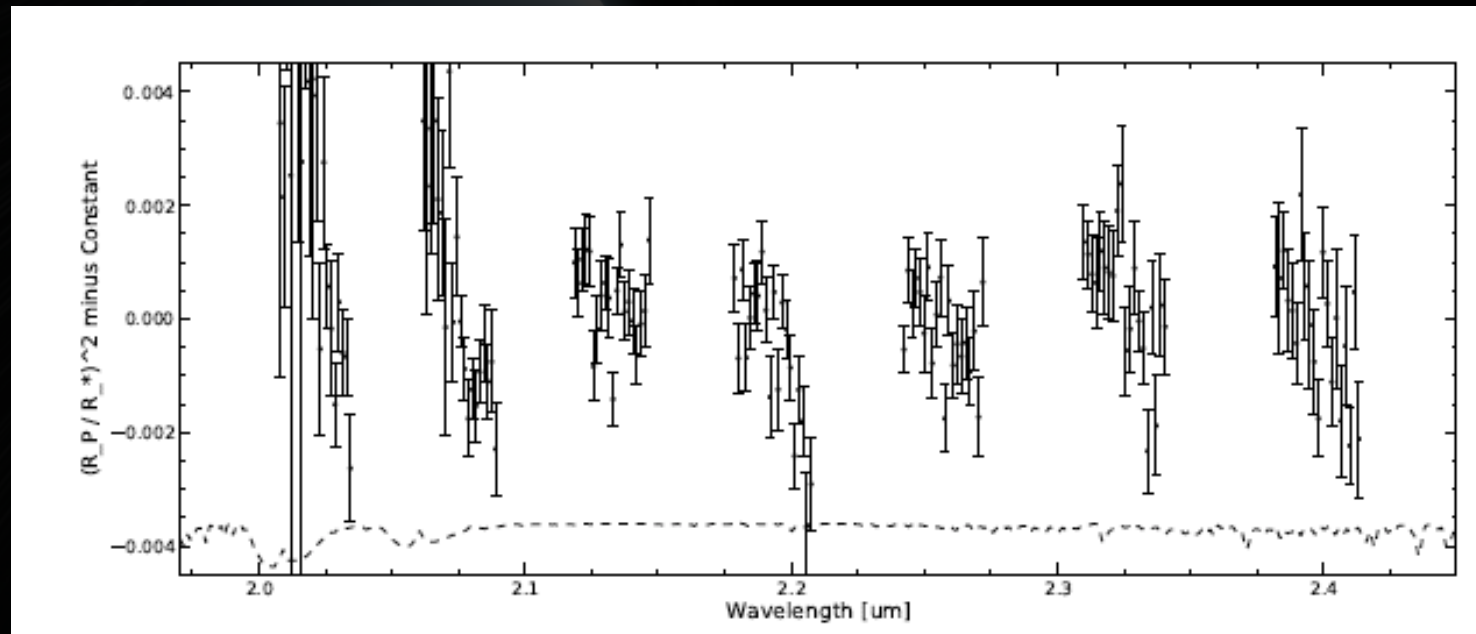


Désert, Bean, Miller-Ricci Kempton, et al., *ApJ*, 2011
(Poster Characterization.08)



Croll, Albert, Jayawardhana, Miller-Ricci Kempton, et al., *ApJ*, submitted

Other Data

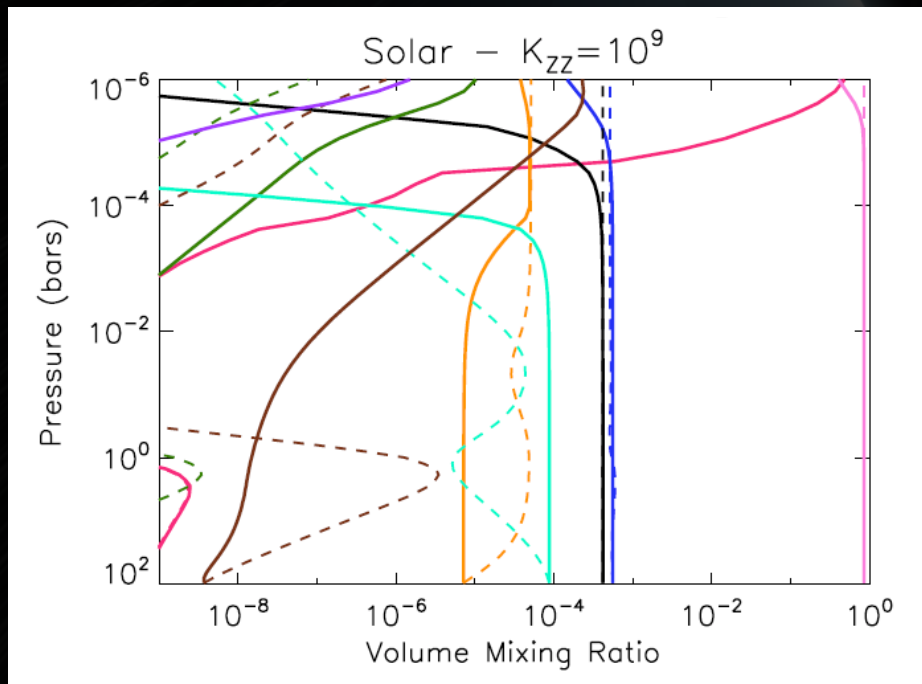


Crossfield, Barman, Hansen, *ApJ*, submitted
(Poster Characterization.05)

- Also Kundurthy et al., Berta et al., Sada et al.

Non-equilibrium Chemistry

'Major' Species



Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

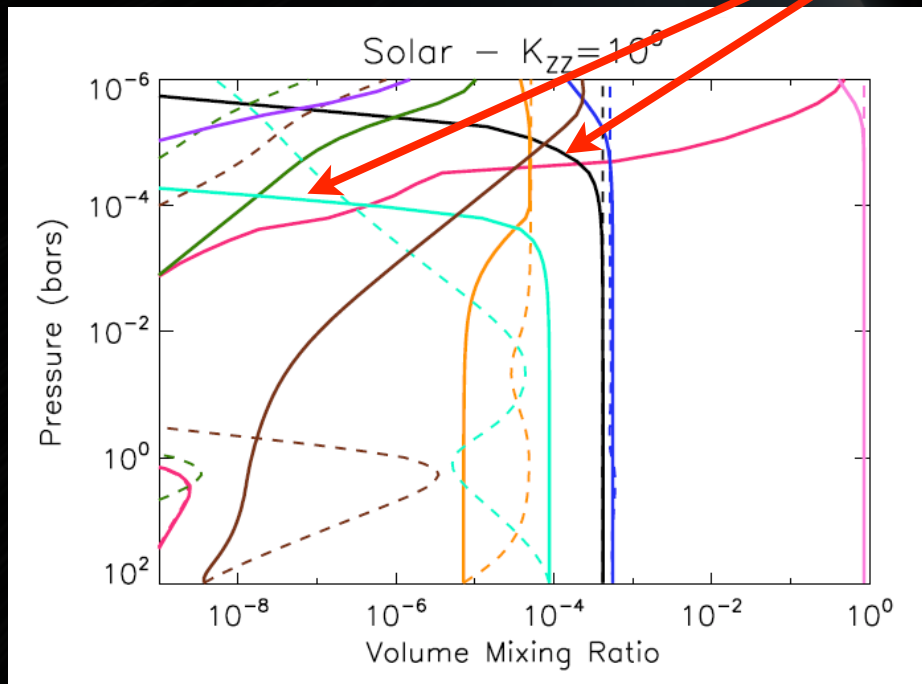
H_2	H_2O	CH_4	NH_3	N_2
CO	CO_2	H	OH	

- - - - Equilibrium Abundances — Photochemical Abundances

Non-equilibrium Chemistry

'Major' Species

Depletion of methane + ammonia via photodissociation



Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

H_2	H_2O	CH_4	NH_3	N_2
CO	CO_2	H	OH	

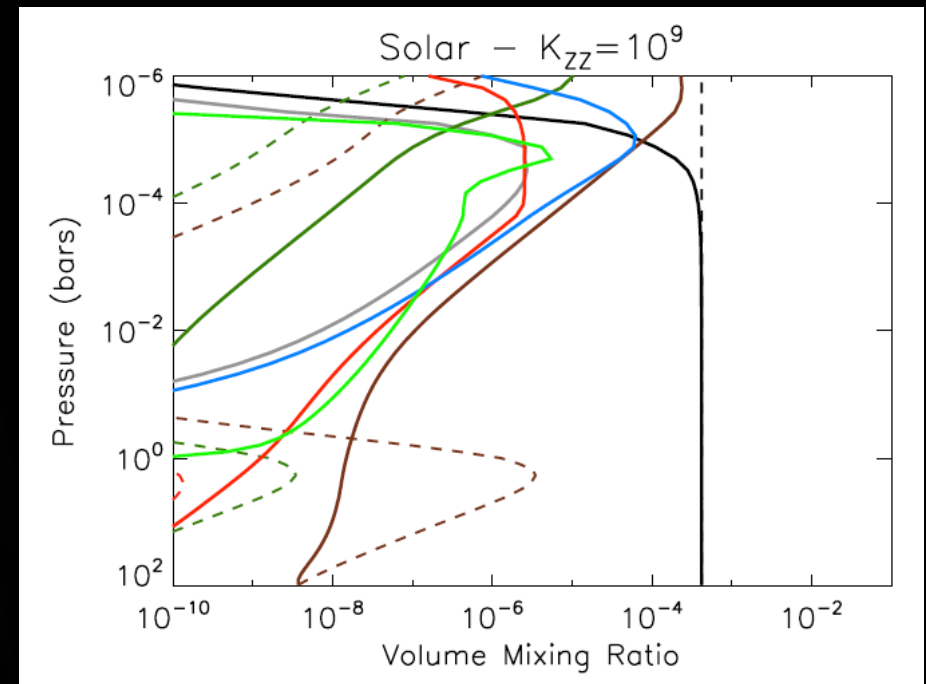
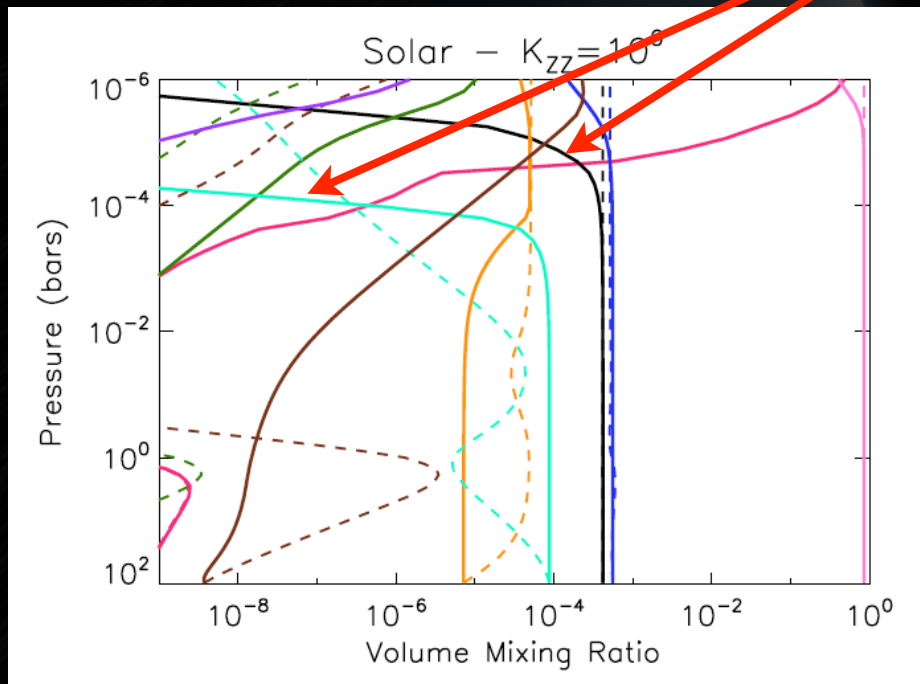
- - - Equilibrium Abundances — Photochemical Abundances

Non-equilibrium Chemistry

'Major' Species

Depletion of methane + ammonia via photodissociation

Carbon-Bearing Species



Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

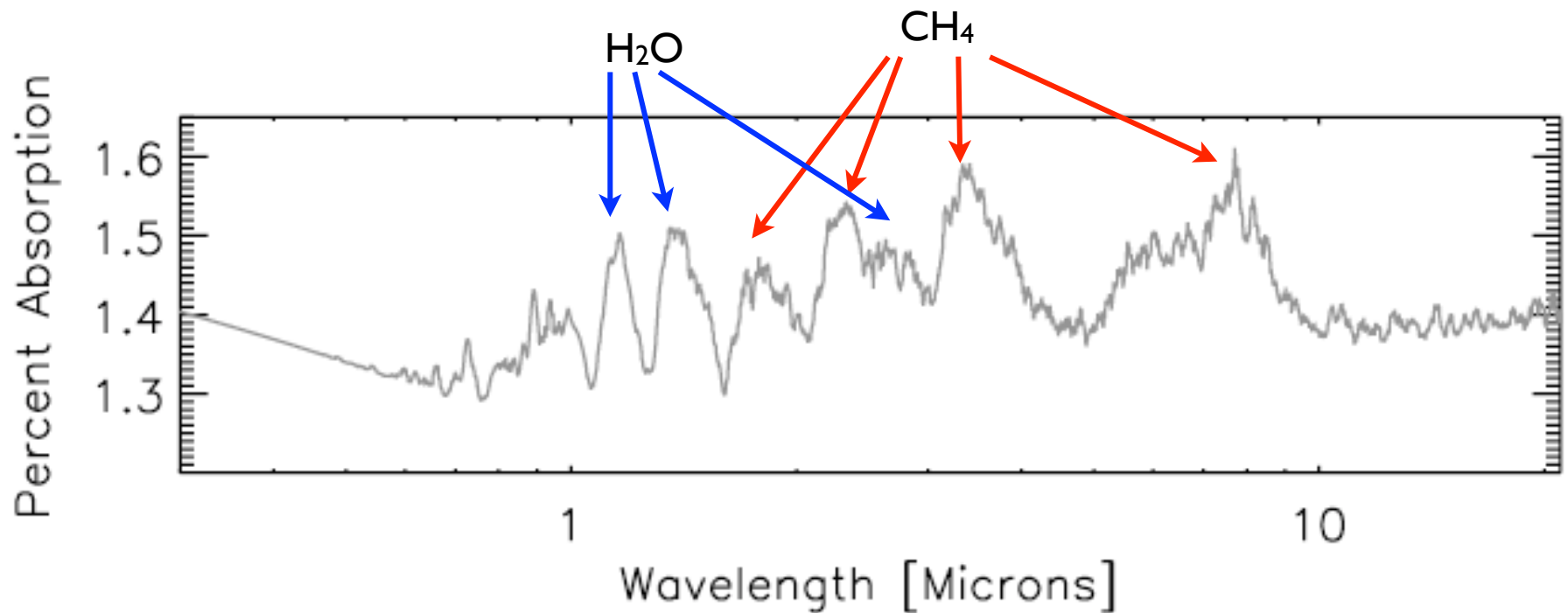
H_2 — H_2O — CH_4 — NH_3 — N_2 —
 CO — CO_2 — H — OH —

CH_4 — C_2H_2 — C_2H_4 — C_2H_6 —
 HCN — CO — CO_2 —

- - - - Equilibrium Abundances — Photochemical Abundances

Transmission Spectra

5 x Solar

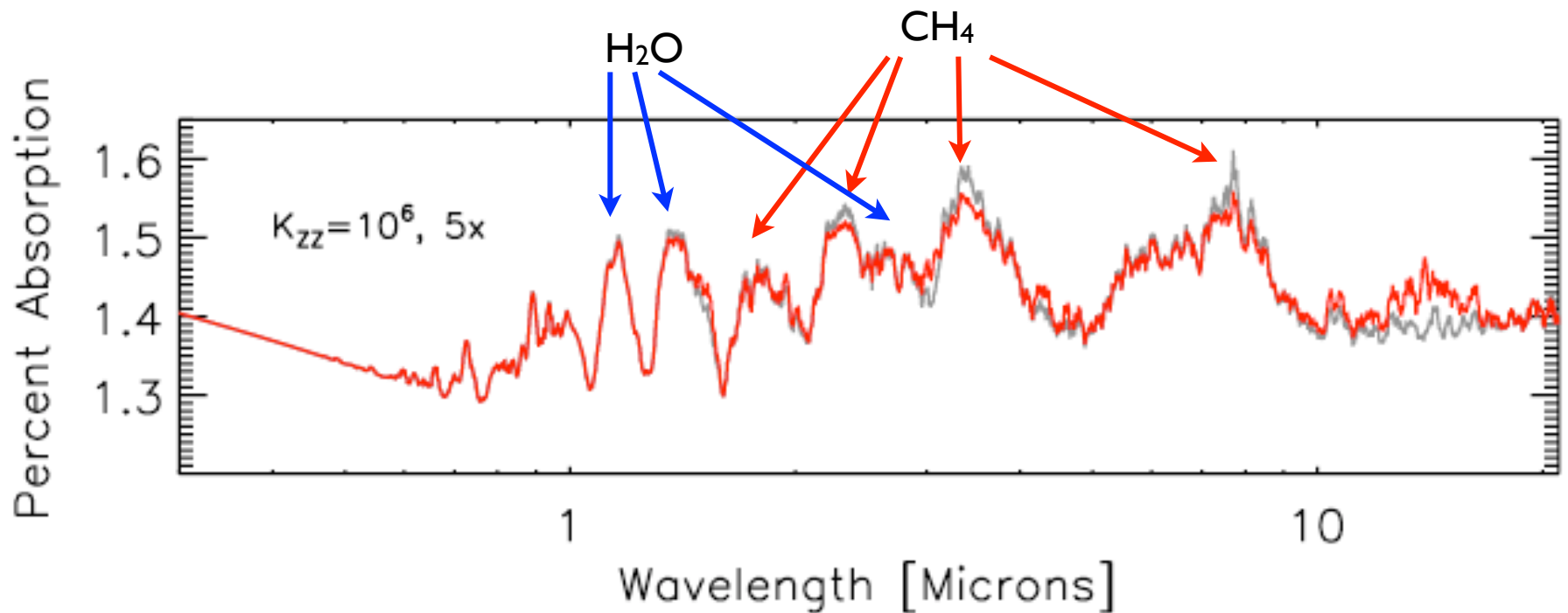


— Equilibrium Abundances
— Photochemical Abundances

Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

Transmission Spectra

5 x Solar

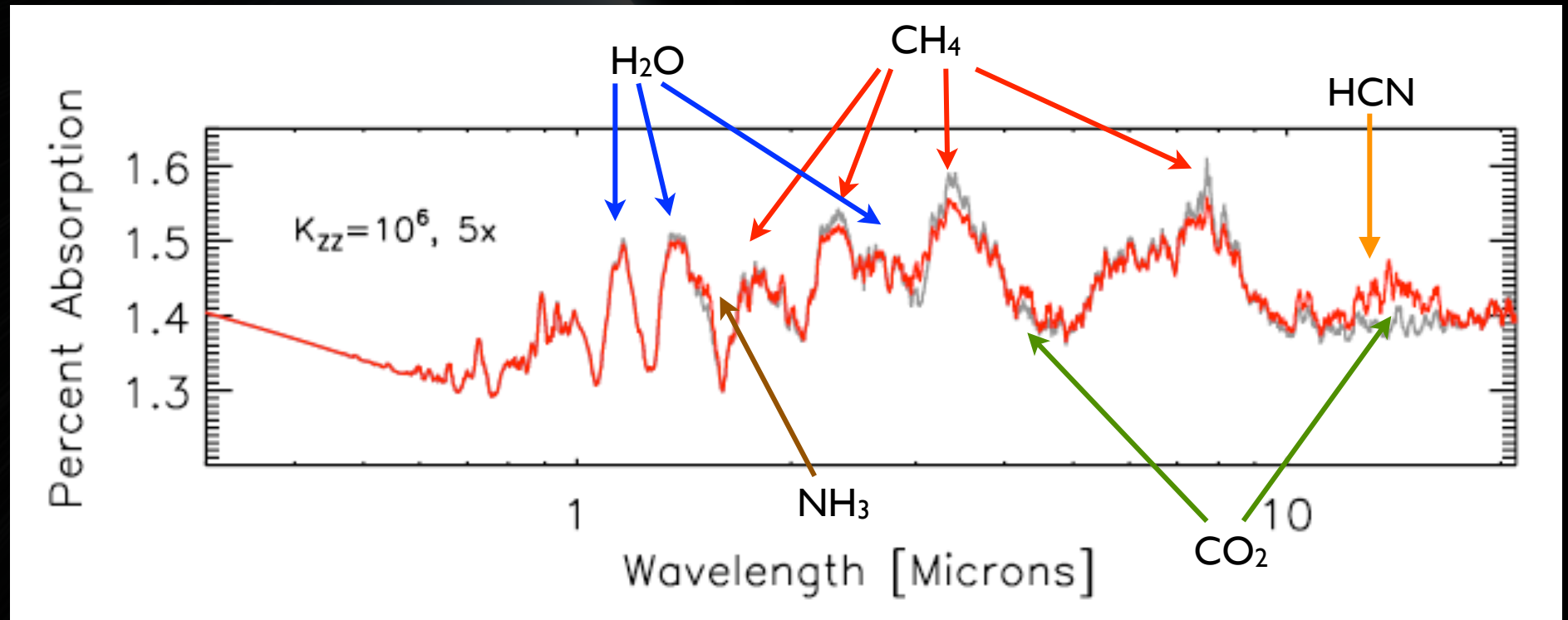


— Equilibrium Abundances
— Photochemical Abundances

Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

Transmission Spectra

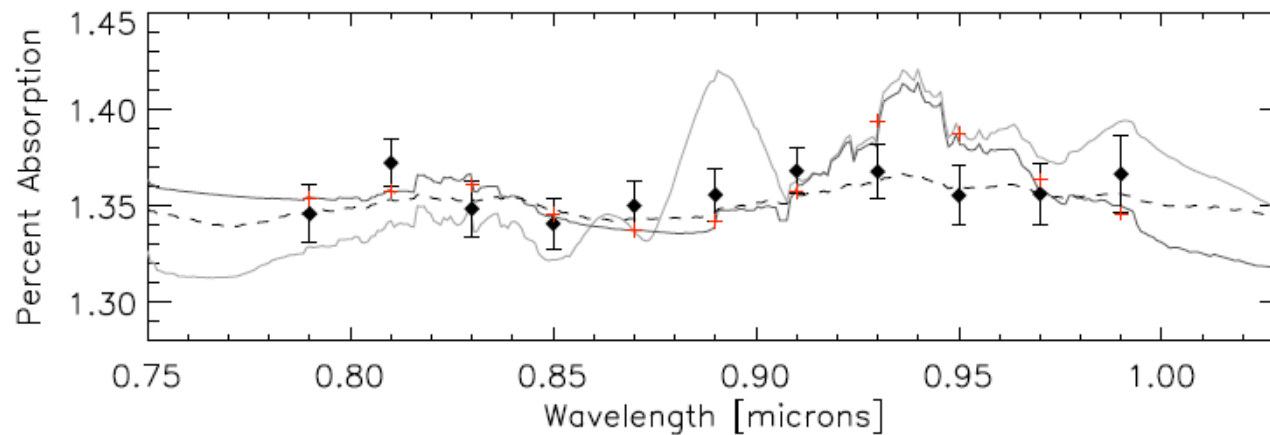
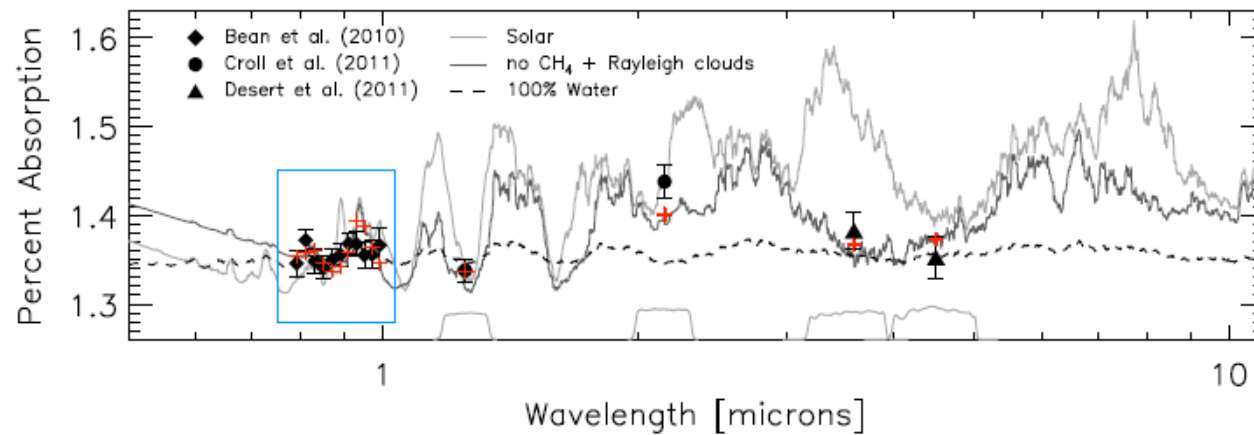
5 x Solar



— Equilibrium Abundances
— Photochemical Abundances

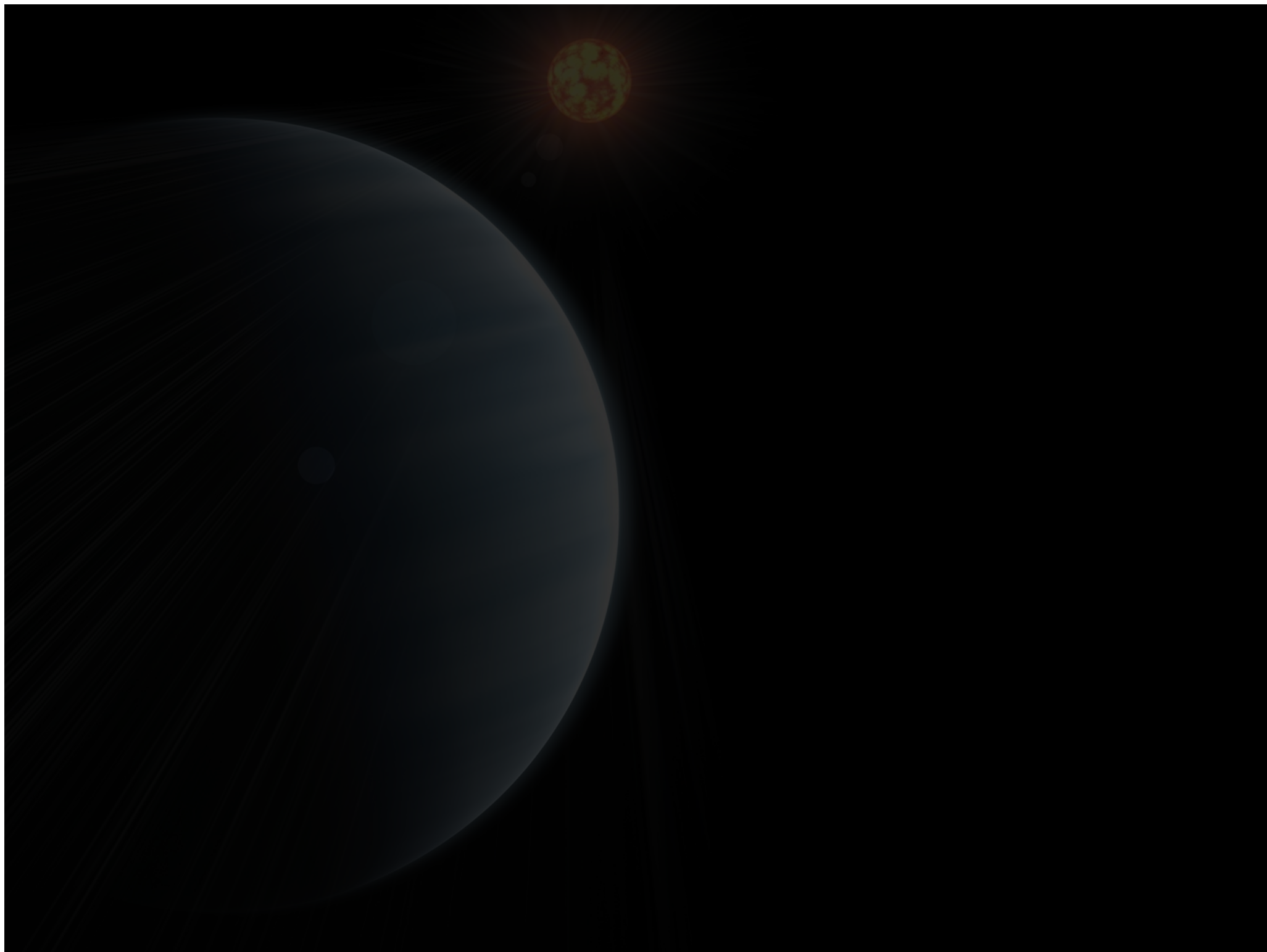
Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

Comparison of Models and Data

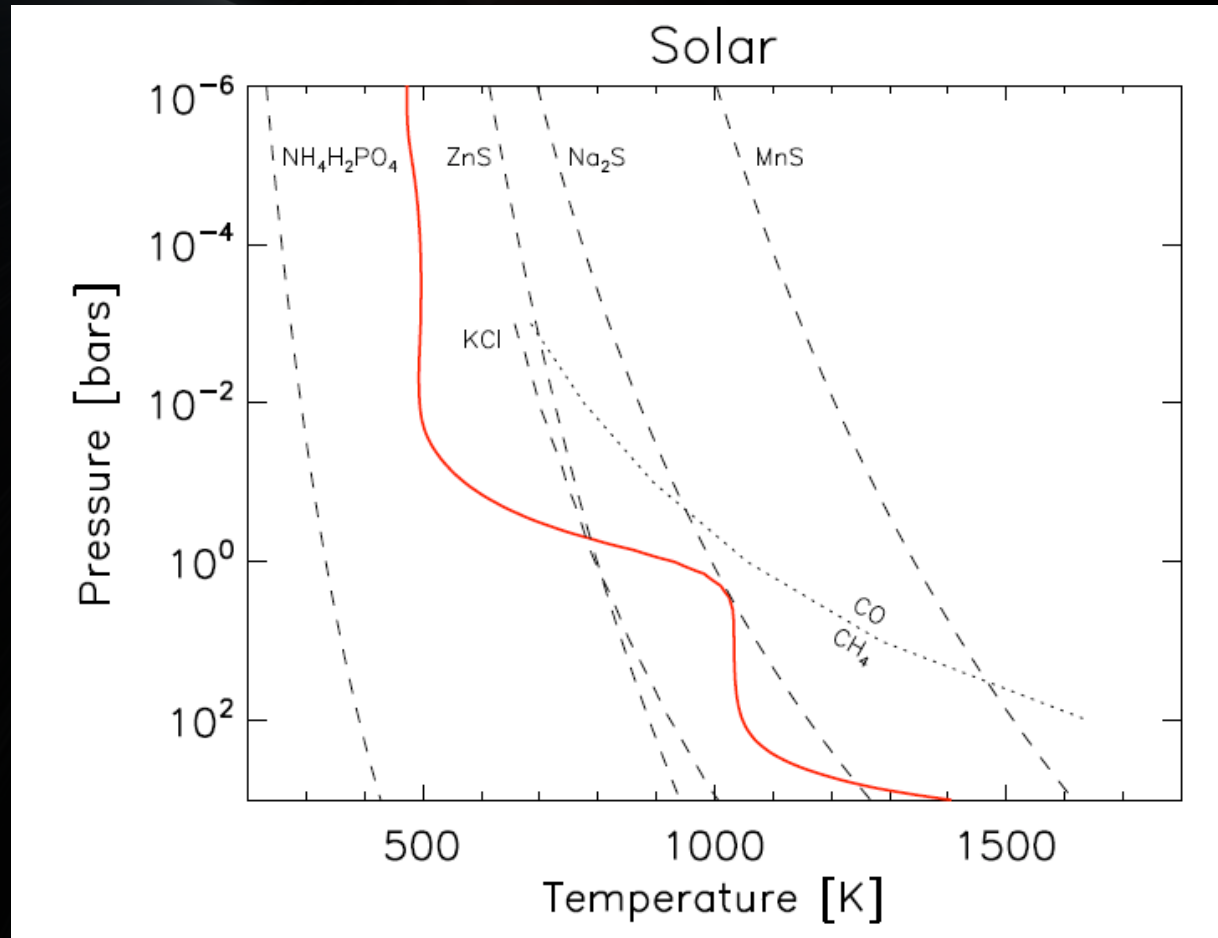


Conclusions

- GJ 1214b's atmosphere is not well-described by a hydrogen-dominated atmosphere in chemical equilibrium
- Other possibilities include:
 - No methane / High clouds
 - High mean molecular weight atmosphere ($> 20\% \text{ H}_2\text{O}$)
- Additional observations will be necessary to break the degeneracy between the different possibilities



Clouds on GJ 1214b?



Miller-Ricci Kempton, Zahnle, Fortney, *ApJ*, submitted

- KCl and ZnS are possibilities for condensate clouds
- Also a possibility for photochemically induced haze of unknown composition