

# The Effect of Exotic Clouds on the Emission and Transmission Spectra of Planets and Brown Dwarfs

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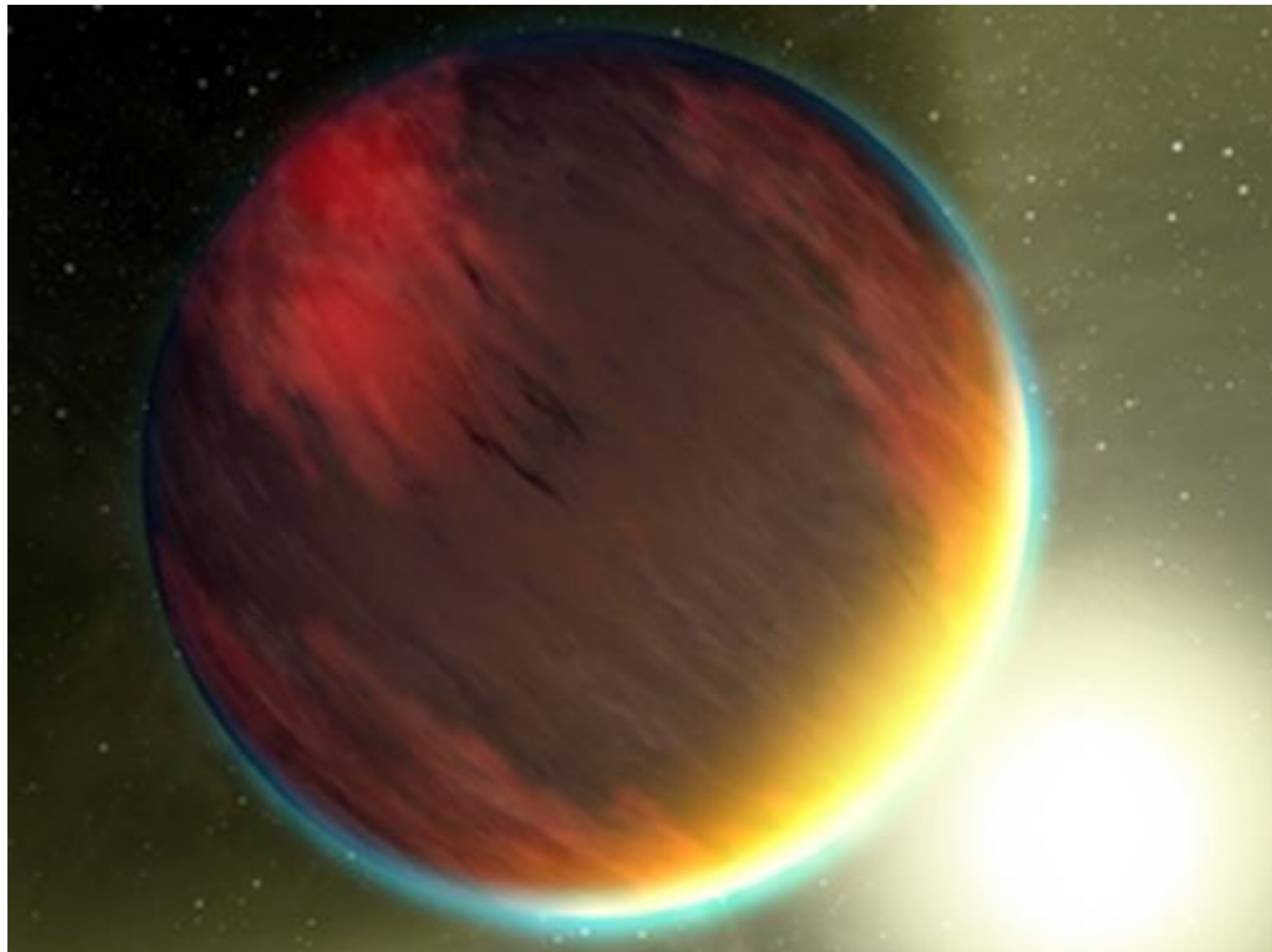
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Didier Saumon

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Exoclimes 2012

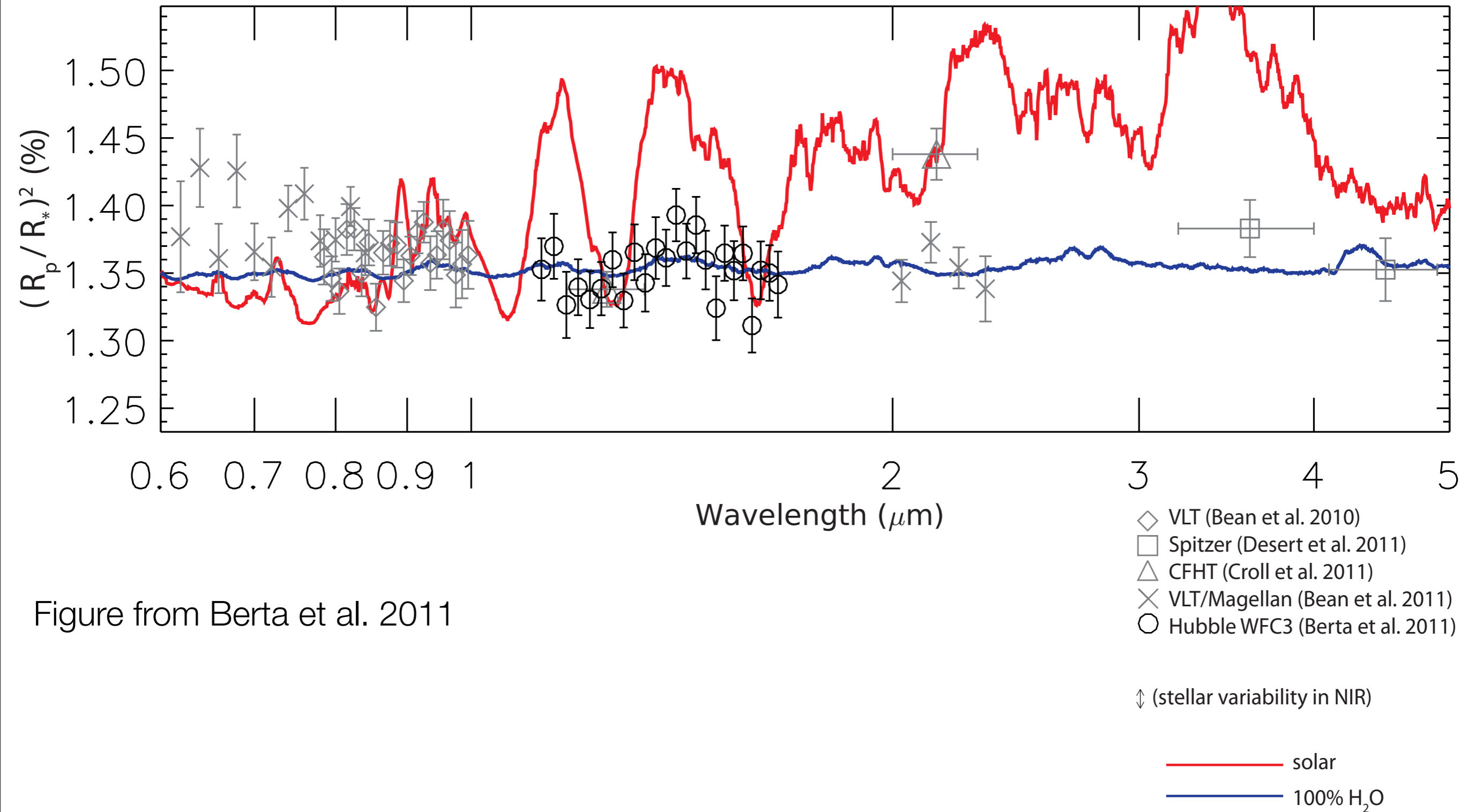
1/19/2012

# Overview of Talk

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- ✦ Motivation for considering new cloud species:  
GJ 1214b and T-dwarfs
- ✦ Adding new clouds to the Ackerman & Marley  
cloud model
- ✦ Preliminary results for transiting super-Earths  
and brown dwarfs

Clouds/hazes have been invoked to explain the flat transmission spectrum of GJ 1214b.



Cool T-dwarfs seem to be redder than cloud-free models.

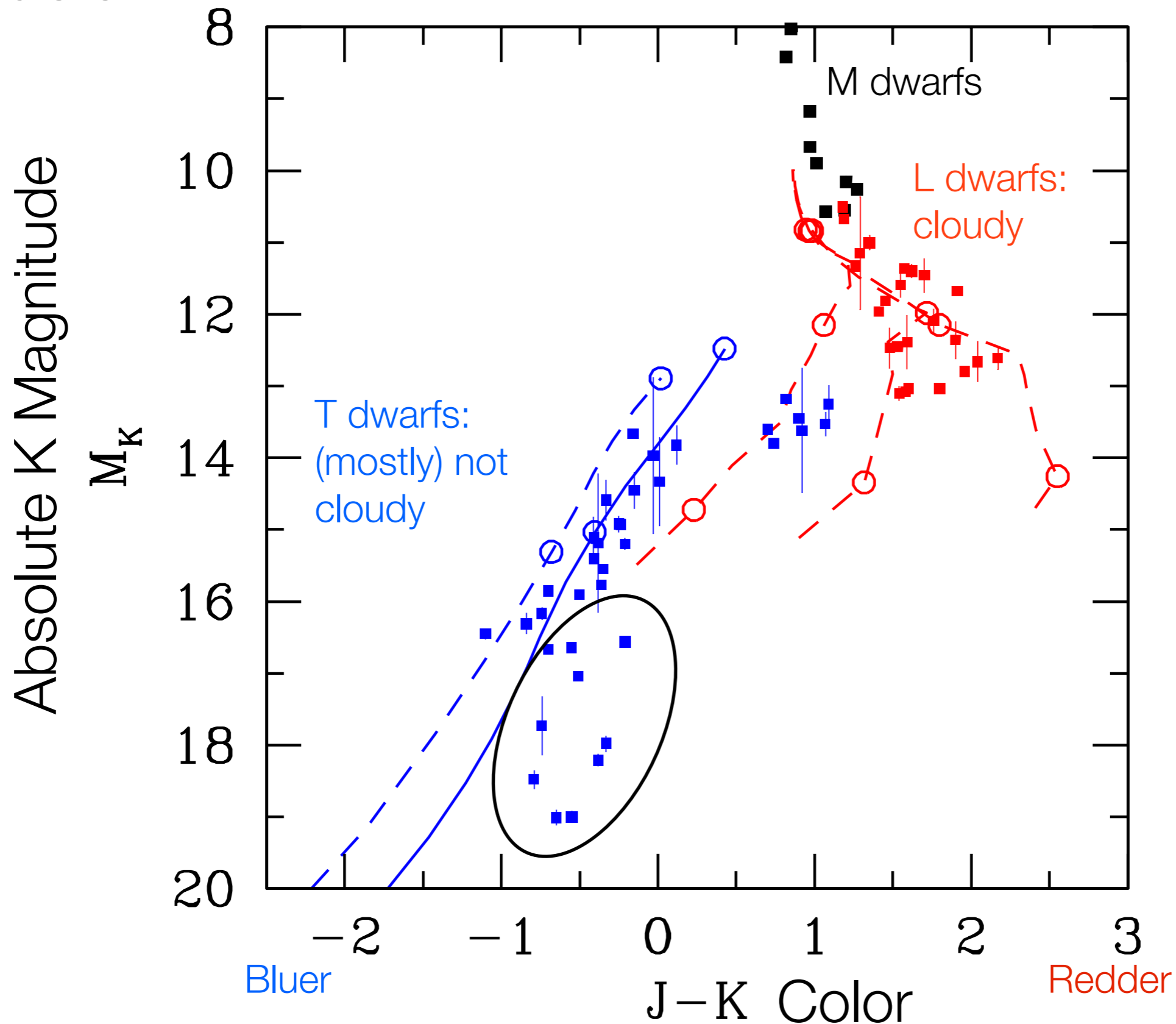
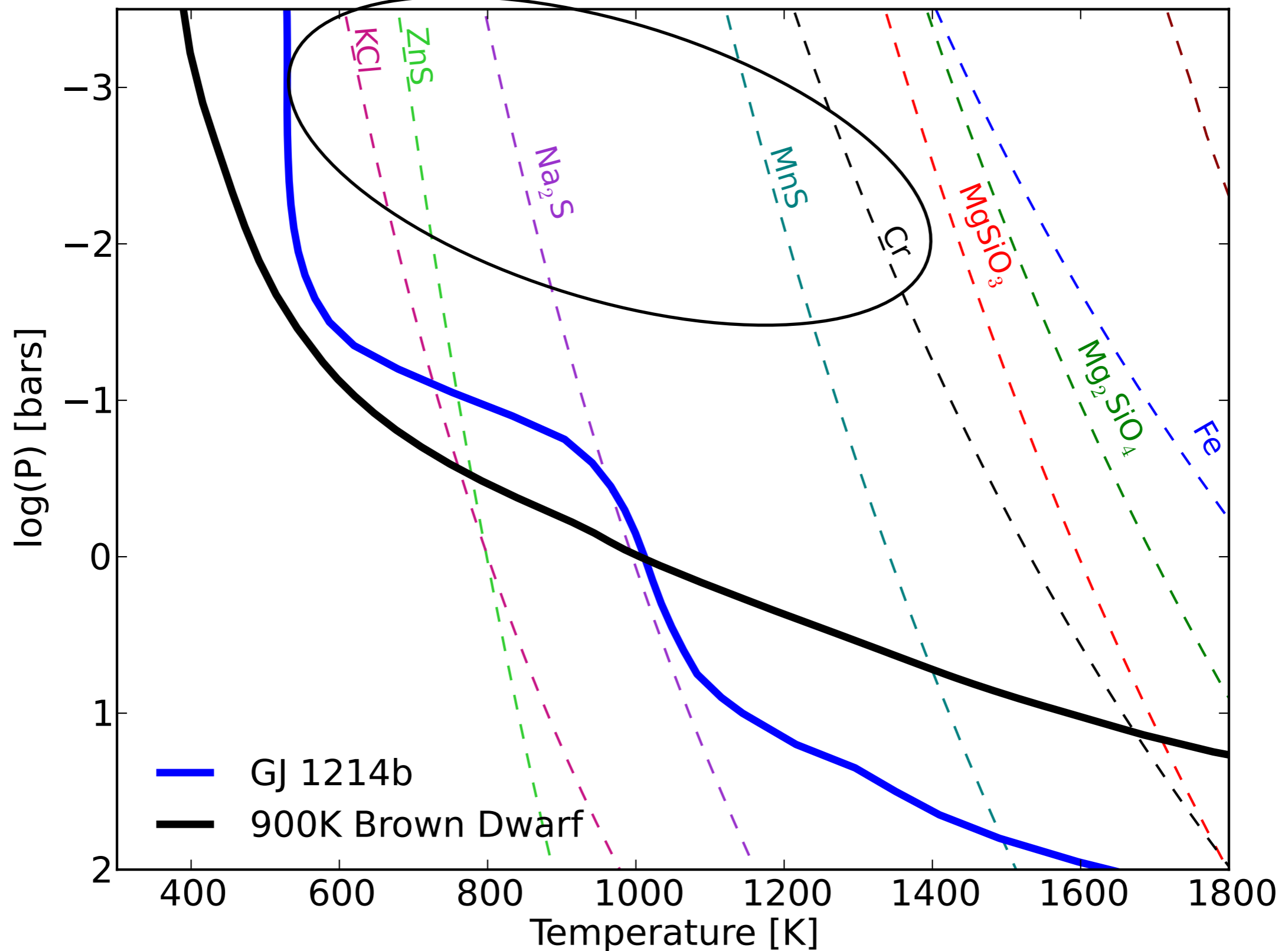


Figure from Saumon et al. 2011

The clouds expected to form in these atmospheres had **never been included** in models.



# Quick reminder: Ackerman & Marley 2001 cloud code balances the

↑ Upward turbulent mixing of particles

↓ Downward transport by sedimentation

$$-K \frac{\partial q_t}{\partial z} - f_{sed} w_* q_c = 0$$

$q_c$  : mole fraction of condensate

$w_*$  : convective velocity

$f_{sed}$  : sedimentation efficiency parameter

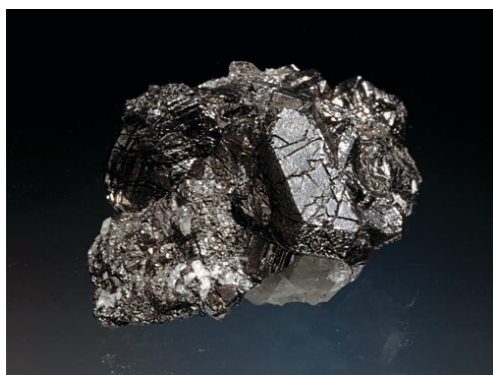
$K$  : Eddy diffusion coefficient

$q_t$  : mole fraction of condensate + vapor

We use equilibrium chemistry models of the atmosphere to determine **where clouds form** and **how much material forms them**.

Chemistry calculations for new clouds are from collaborator Channon Visscher

## Condensates studied:



*Manganese Sulfide*



*Sodium Sulfide*



*Potassium Chloride*



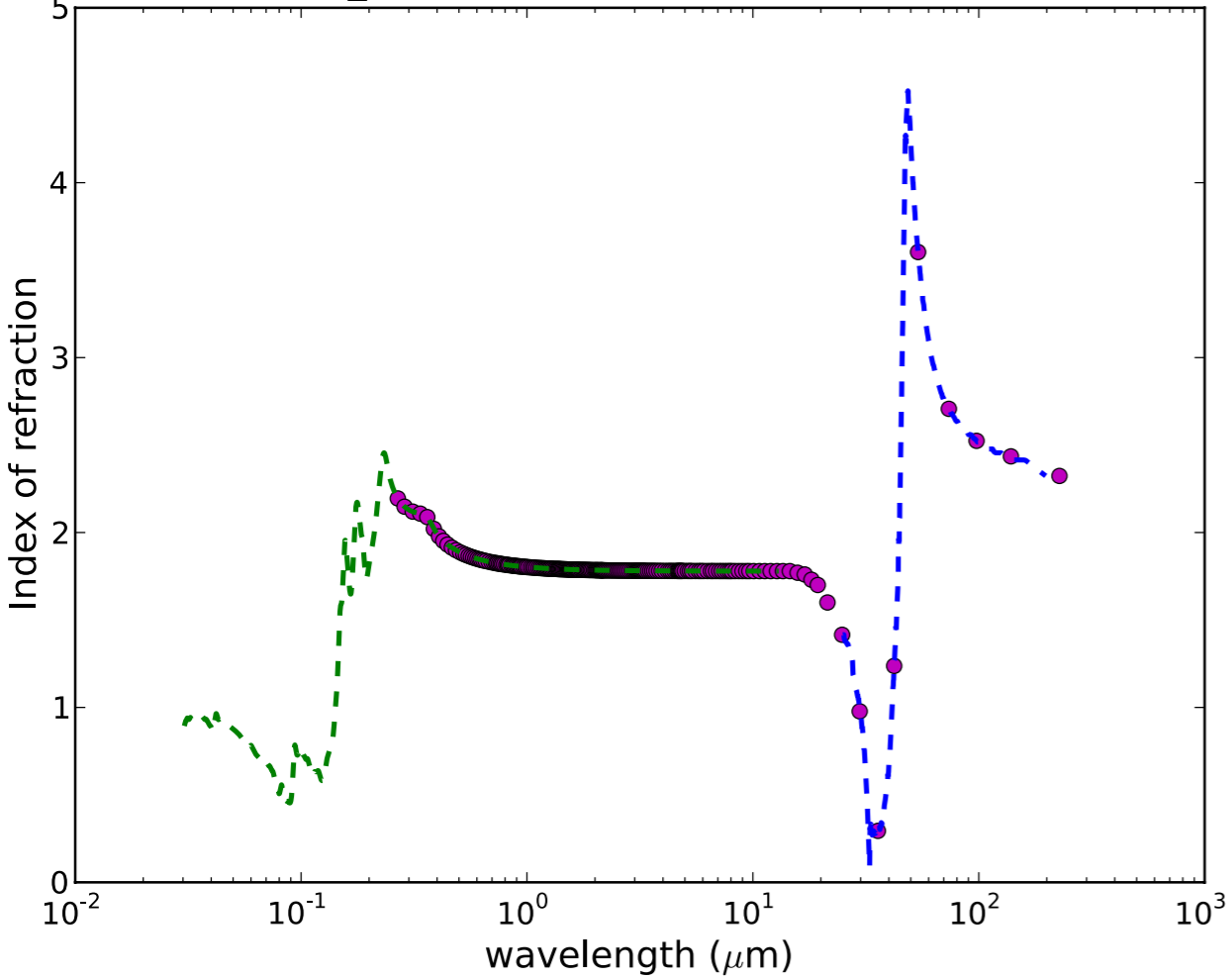
*Zinc Sulfide*



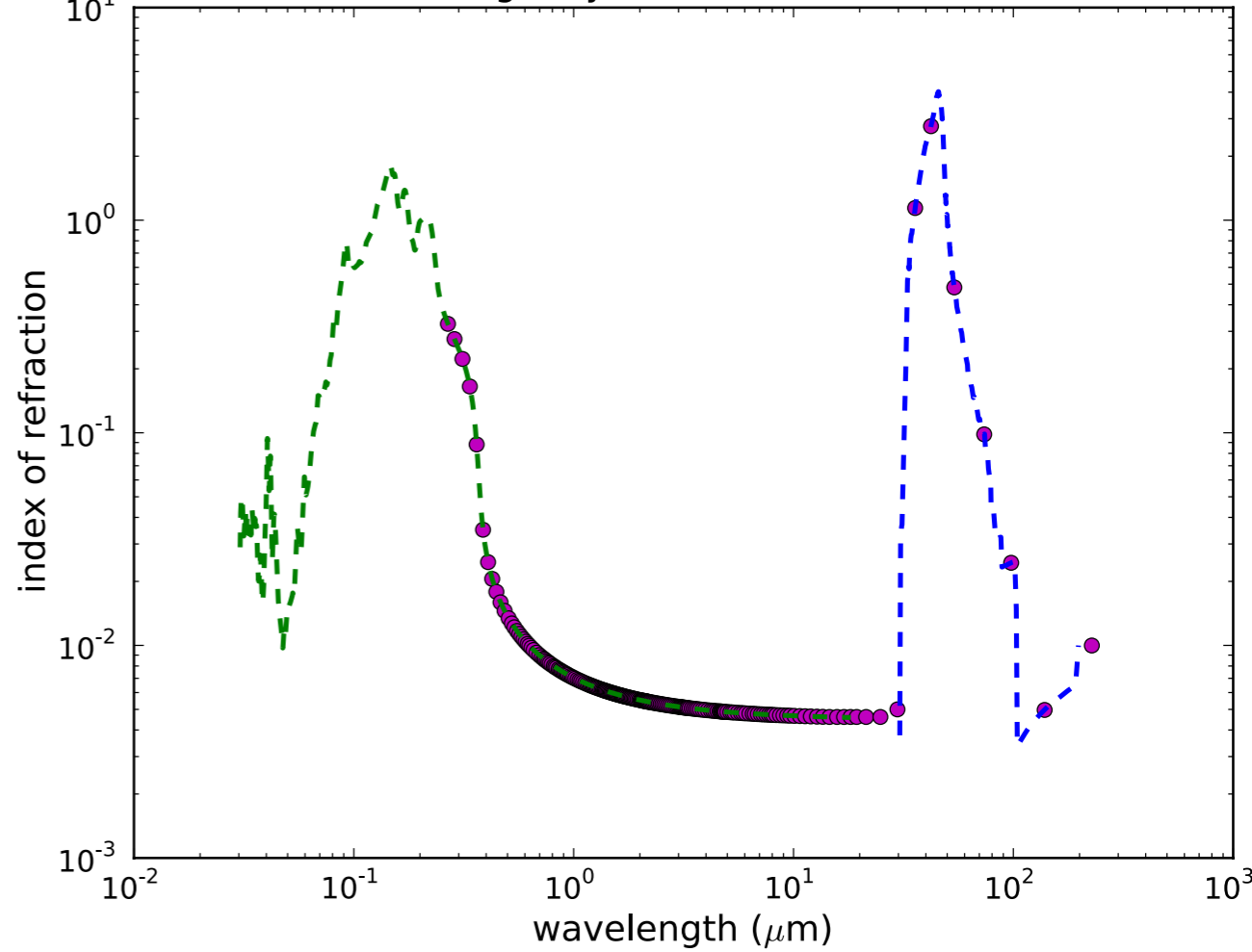
*Chromium*

To add a new condensate, we need to know the optical properties of the material (indexes of refraction)

Na<sub>2</sub>S Real index of refraction



Na<sub>2</sub>S Imaginary index of refraction



## Condensates studied:



*Manganese Sulfide*



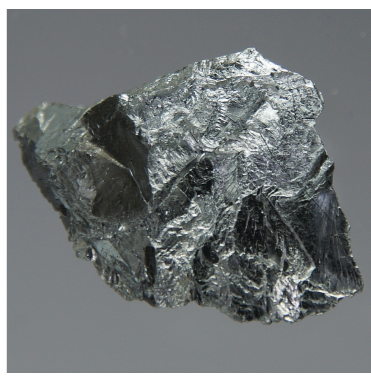
*Sodium Sulfide*



*Potassium Chloride*



*Zinc Sulfide*



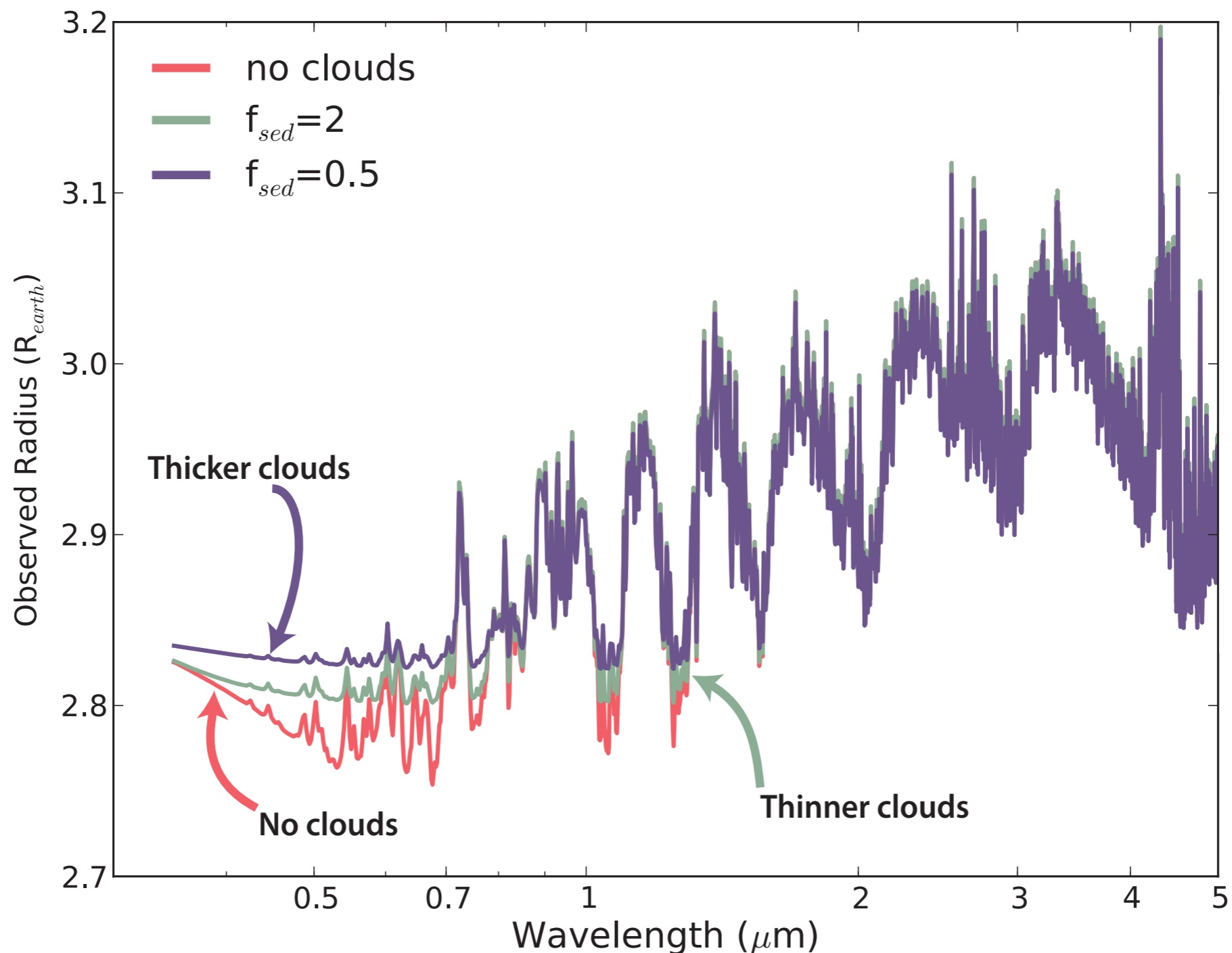
*Chromium*



# Preliminary results

These clouds flatten the **transmission spectrum** of GJ 1214b at optical wavelengths, but not IR wavelengths.

## GJ 1214b



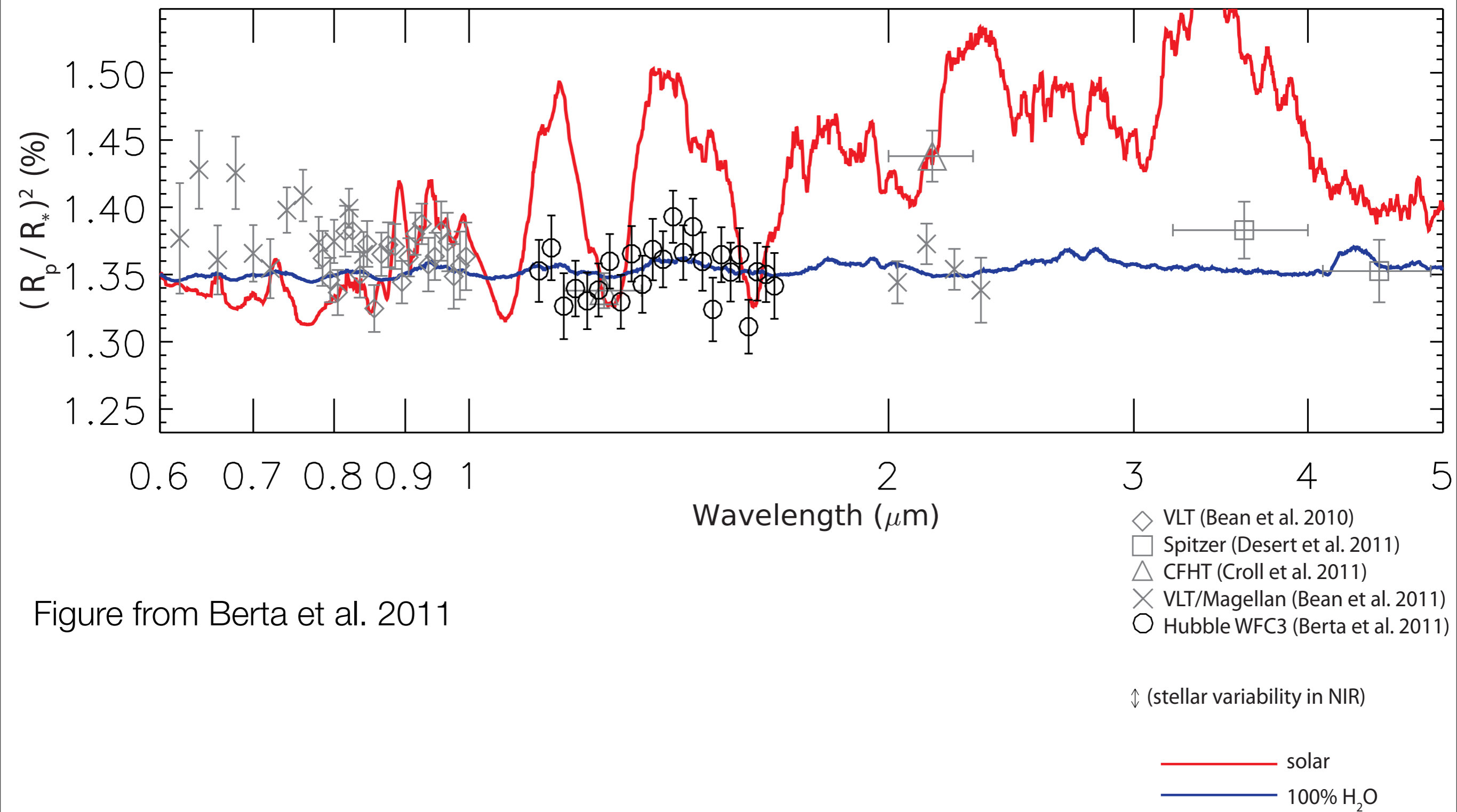
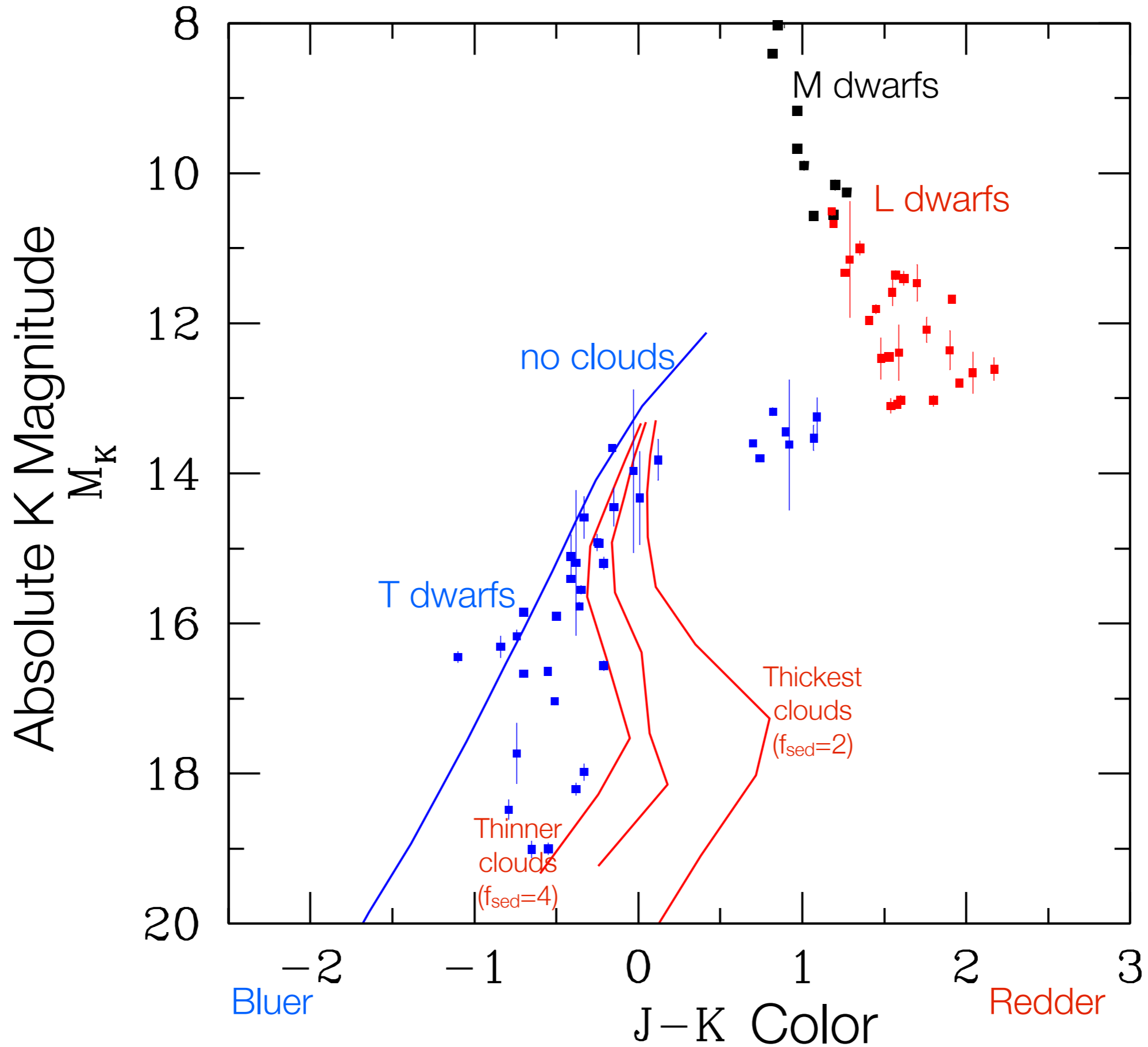


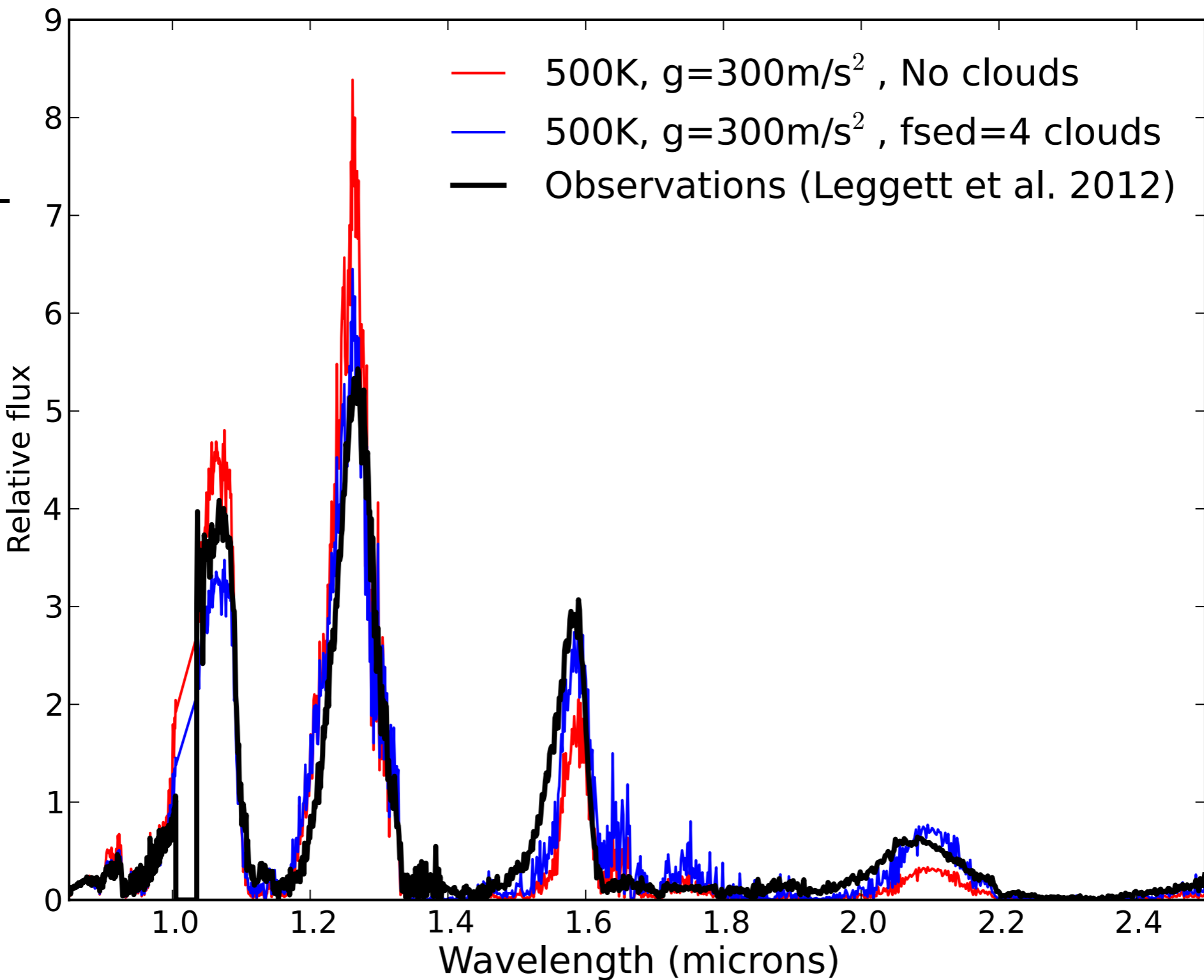
Figure from Berta et al. 2011

# Brown dwarf color-magnitude plot with new clouds.



We're also beginning to compare model spectra to observations of cool T-dwarfs.

UGPS  
J072227.51-  
054031.2



# Conclusions

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- ✘ We've added **5 new clouds** to the Ackerman & Marley cloud code, which condense at temperatures between the silicate/iron and water clouds.
- ✘ Determined that these clouds alone CANNOT fully explain GJ 1214b observations.  
...but there could still be photochemical hazes, etc.
- ✘ Offered a preliminary explanation for T-dwarf observations.