Transmission and emission studies of the Exo-atmosphere of HD 189733b

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carmenes

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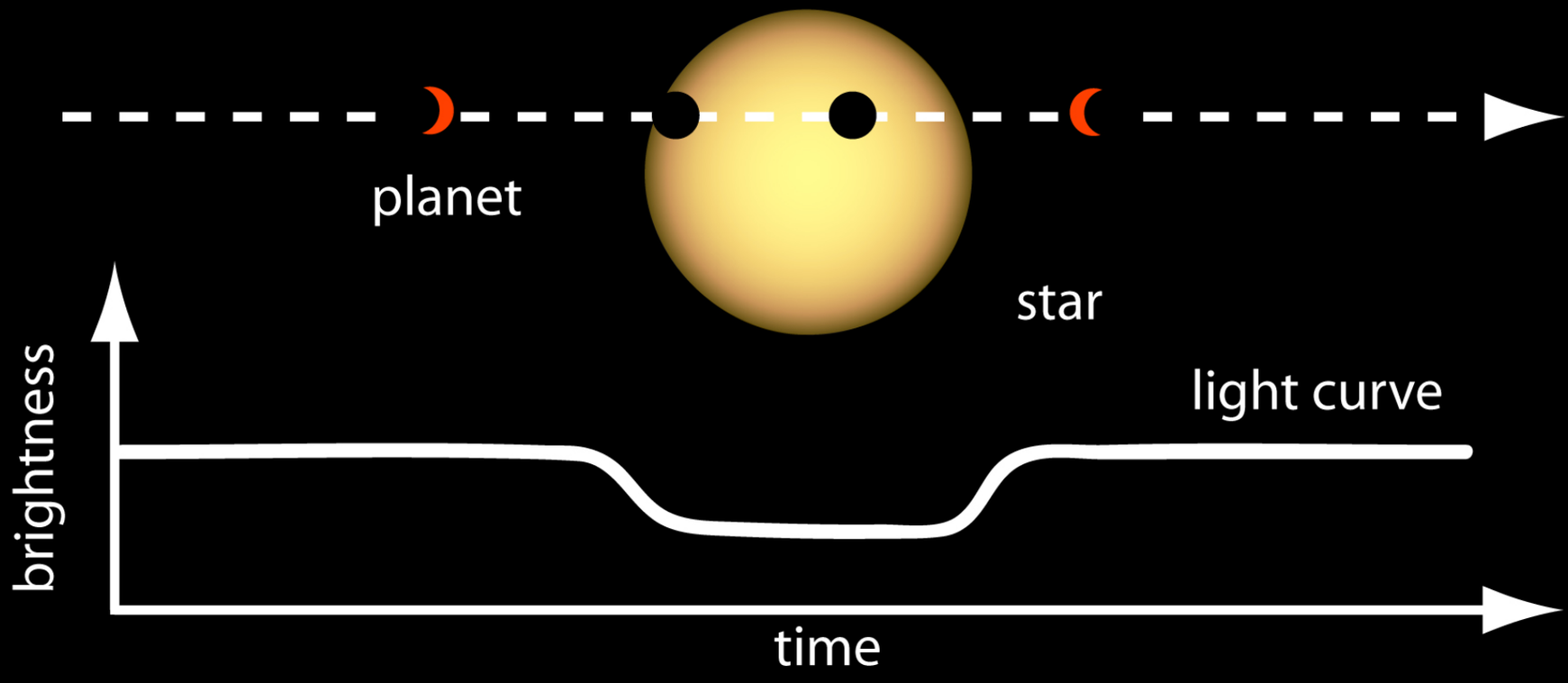
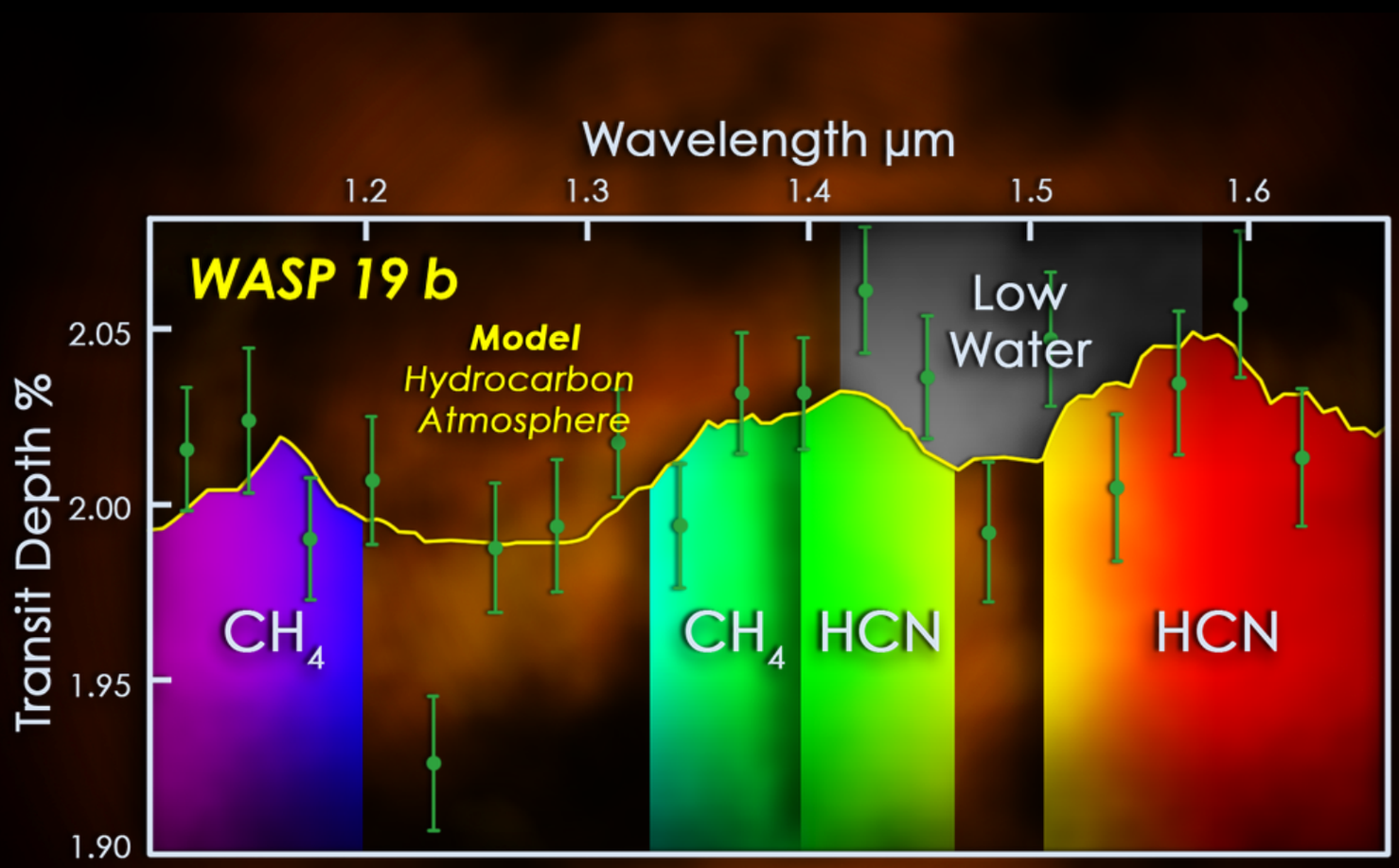
1. Transmission spectroscopy in the primary transit

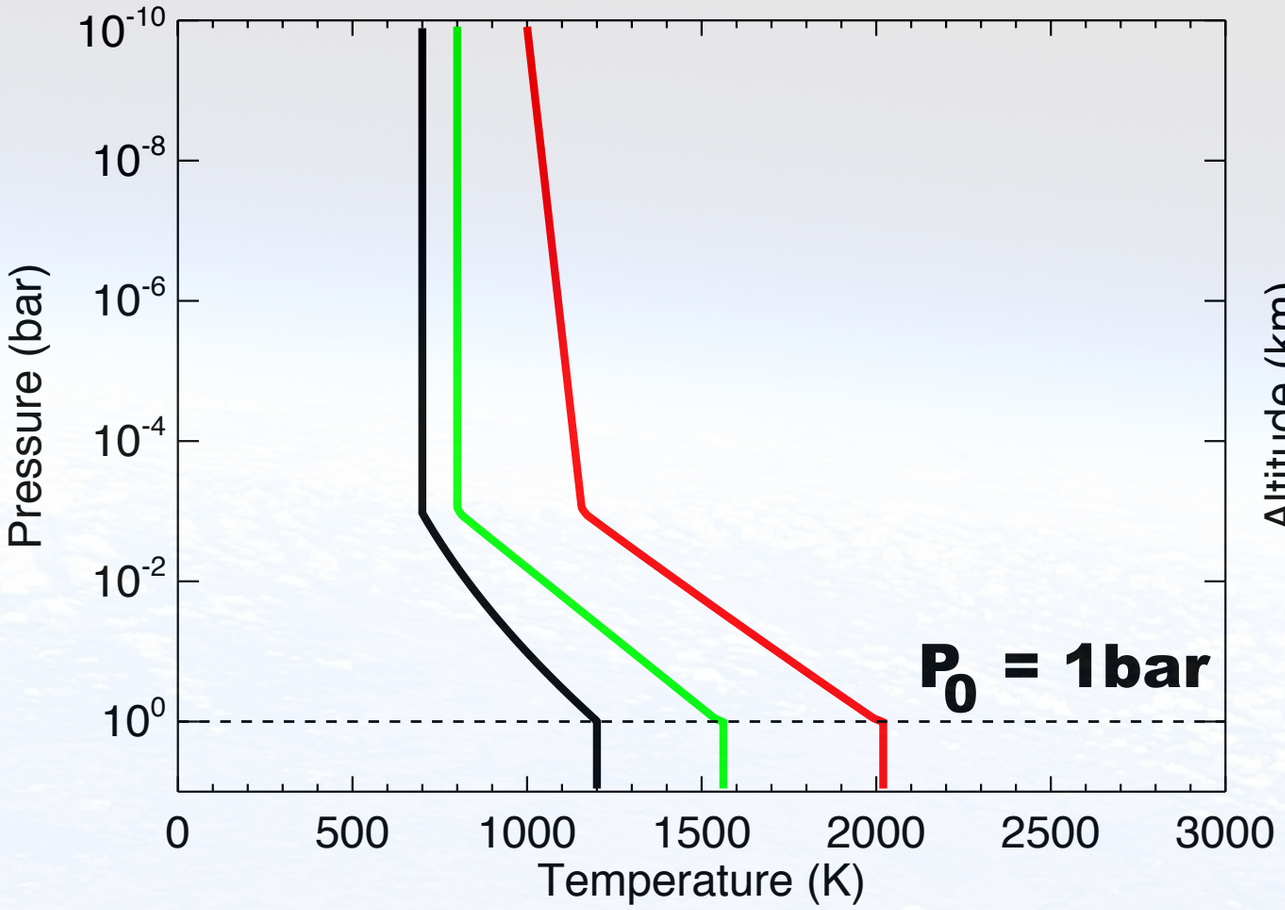


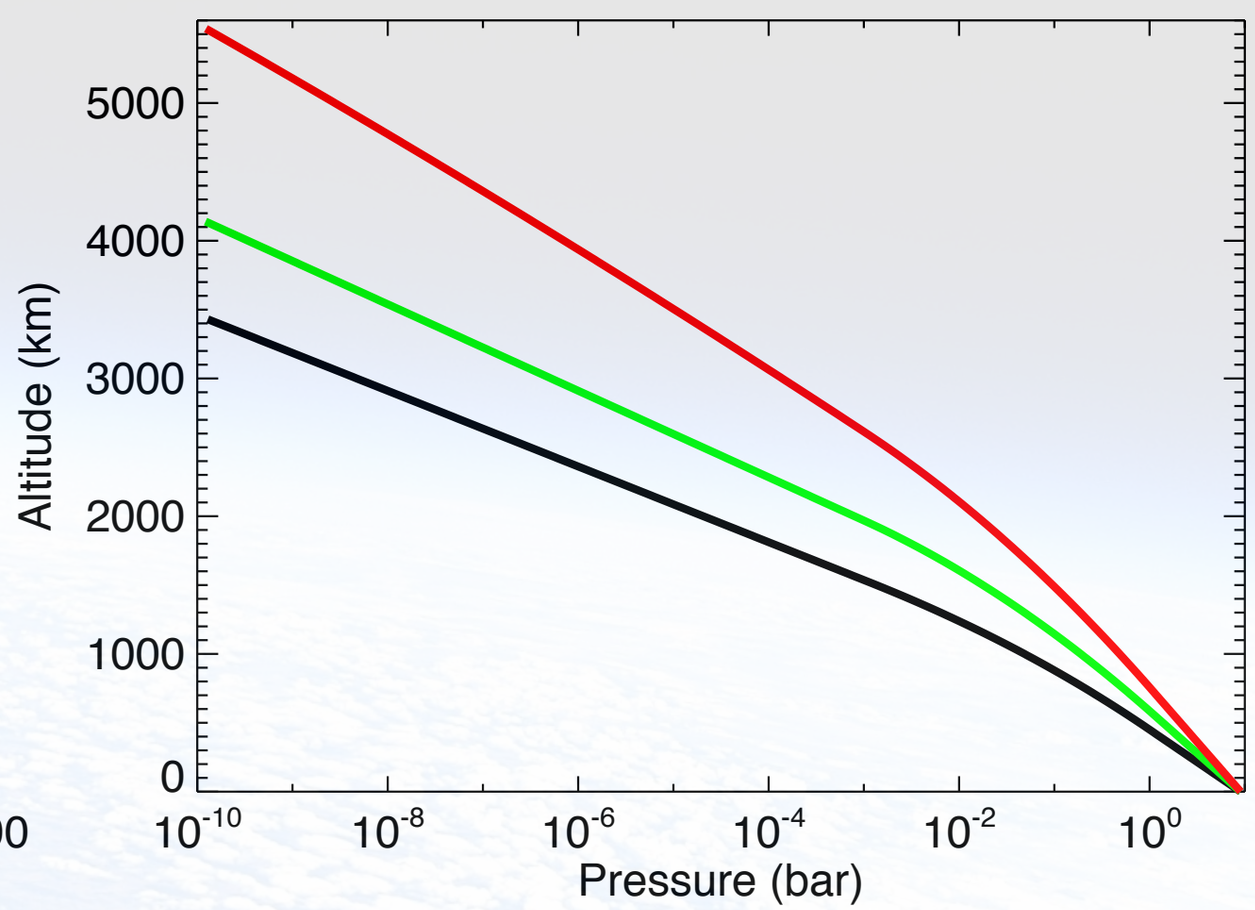


Our recent work: Simulate and analyze synthetic spectra for **HD 189733b** in order to:

(a) Validate it with HST/WFC3 data; **(b)** Extract information about the atmosphere; **(c)** Export the p-T & volume mixing ratio (vmr) profiles for the CARMENES studies.

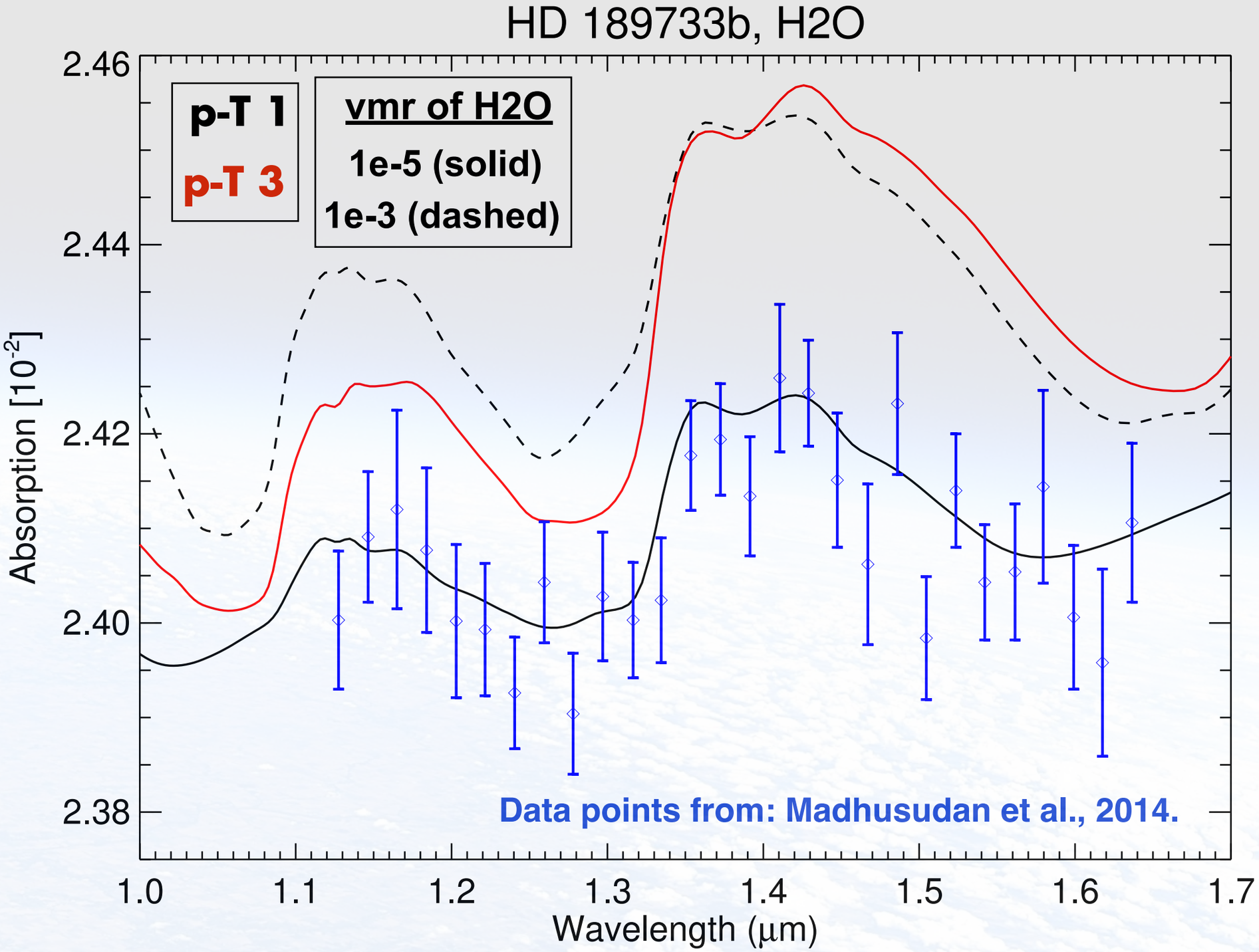
p-T 1 **p-T 2** **p-T 3**





- **p-T 2** and **p-T 3** bibliographic profiles from Madhusudhan & Seager (2009) and Sing *et al*. (2015).
- **p-T 1** is a colder perturbation of **p-T 2** .

1.1 HST/WFC3: H2O simulations & data analysis



- **Good fit to the data -> Good starting point and validation of tools.**

1.2 CARMENES high-res NIR spectra of HD 189733b

CARMENES Parameters	
Wavelength coverage (Δλ)	VIS: 0.52-0.96 μm; **NIR: 0.96–1.7 μm**
Spectral Resolution (R)	VIS: 94,600; **NIR: 80,400**
Working Temperature (T_{work})	VIS: 285.00 ± 0.05 K; **NIR: 140.00 ± 0.05 K**

Several observations of Hot Jupiter (including HD 189733b) atmospheres have been completed with CARMENES (more granted).

Data analysis

- **High-resolution cross-correlation of spectra**

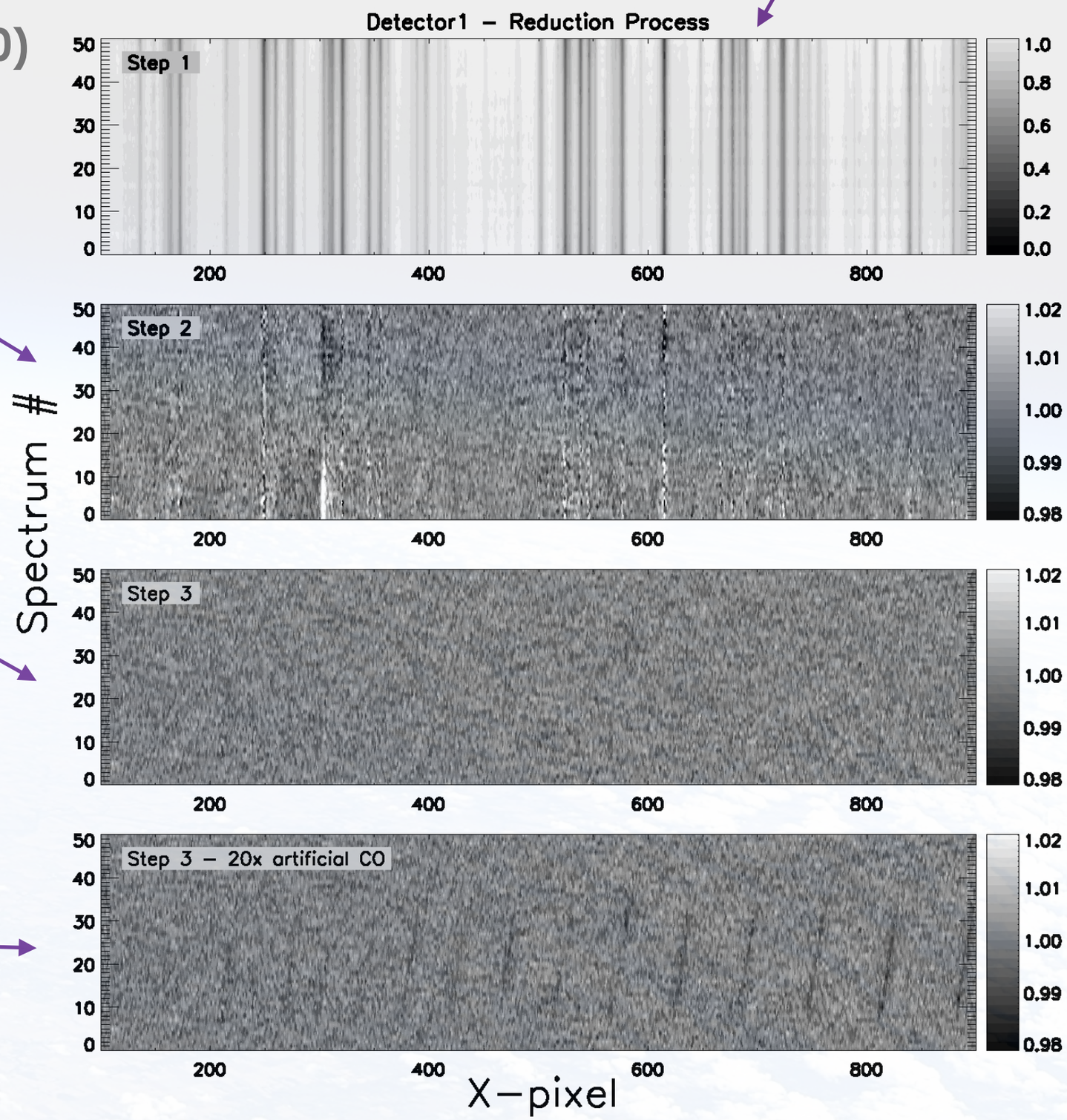
(Snellen et al. 2010)

spectra aligned and normalized

Correction for airmass variations over time

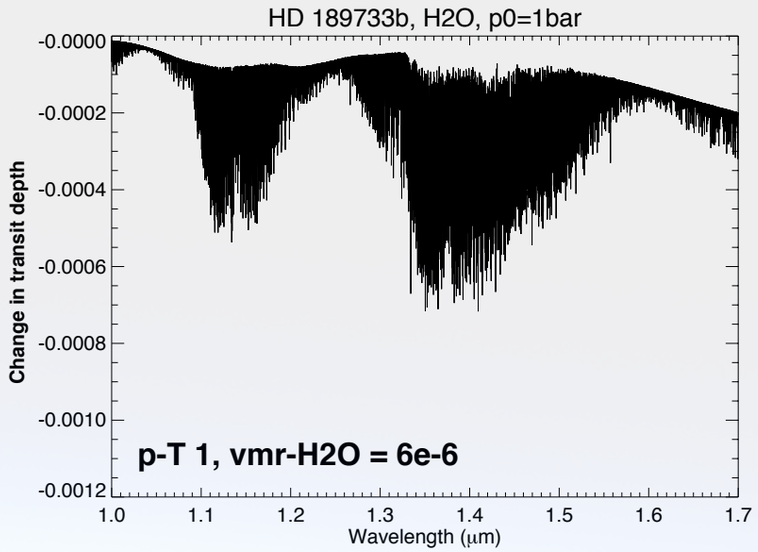
Telluric residuals corrected.
(We are starting to use Molecfit)

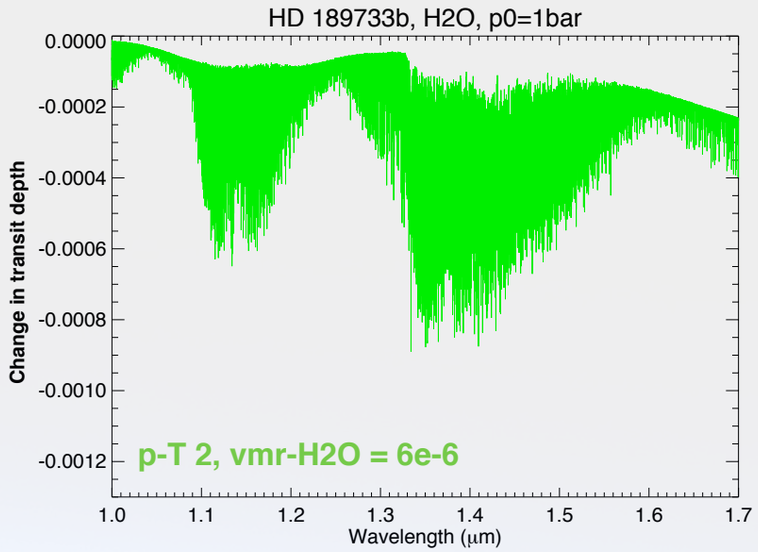
Injection of an artificial signal
(model spectra are needed)

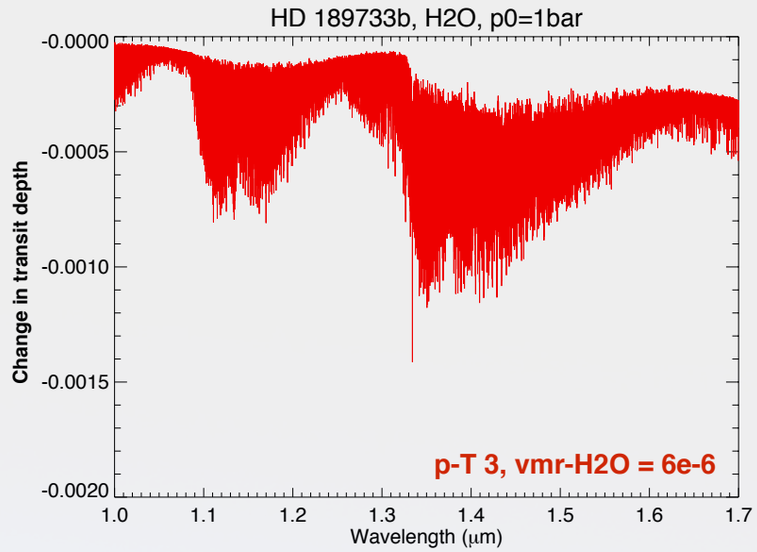


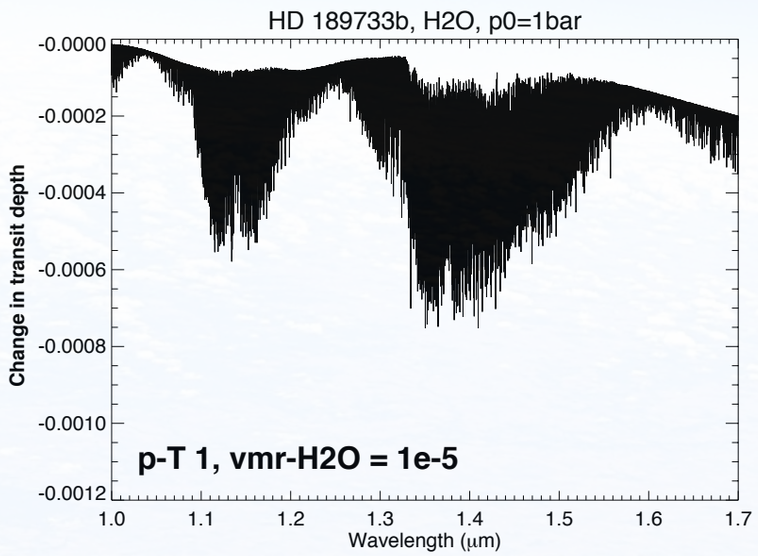
CARMENES H2O simulations

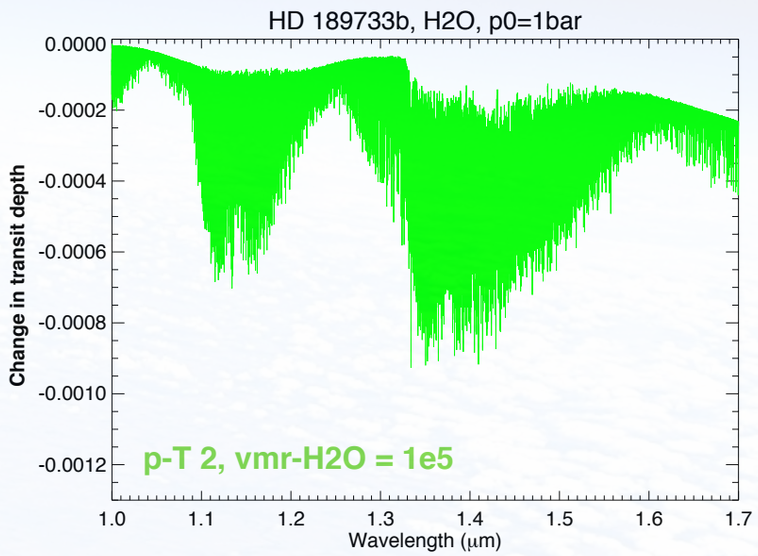
- **All p-T profiles (pT1, pT2, pT3) profiles and 3 bibliographic vmr's (6e-6, 1e-5, 5e-4).**

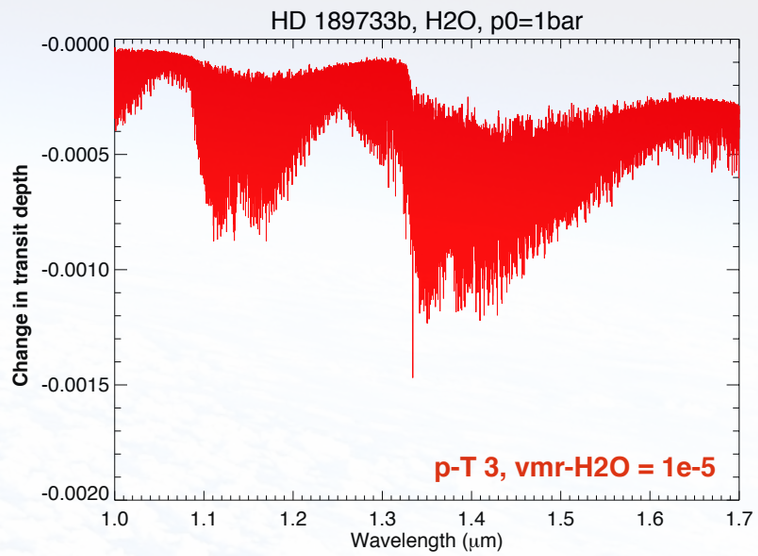


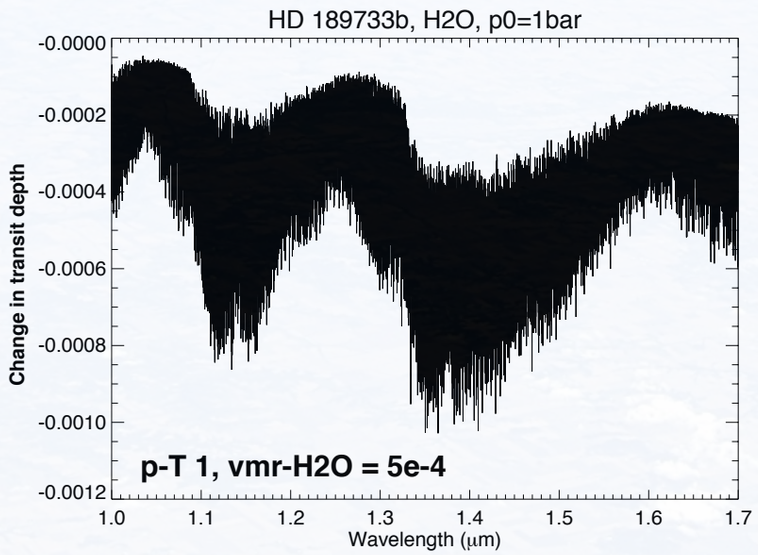


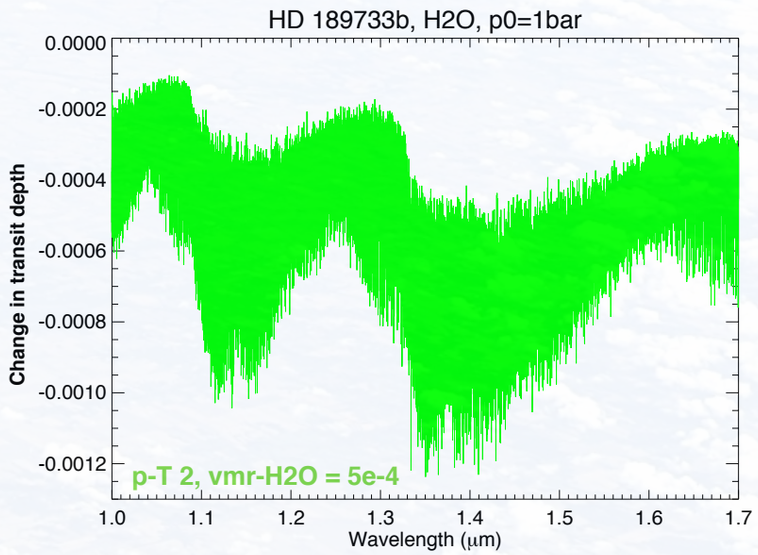


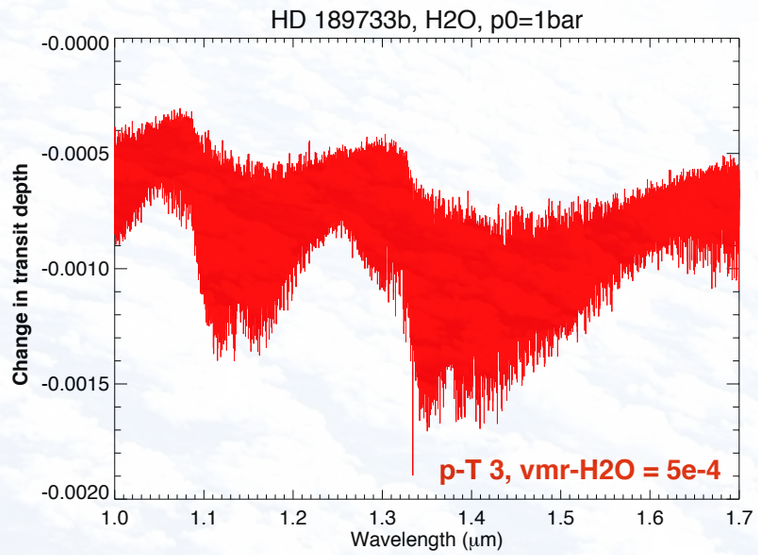












2. Secondary eclipse. LTE emission spectra

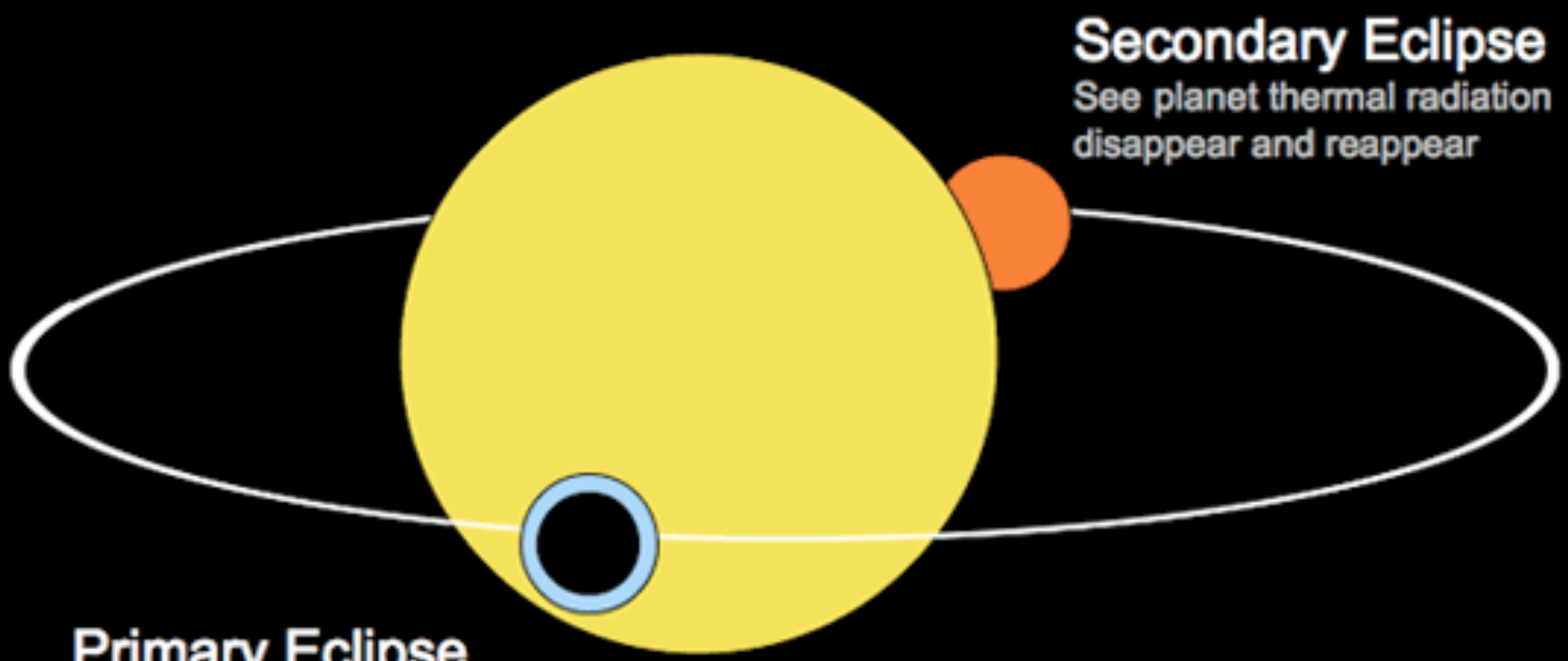


Figure by S. Seager

2.1 Exploratory results of LTE emission spectra of HD 189733b

- **Spectra computed with KOPRA at comparable JWST spectral resolution using p-T 2, and including:**

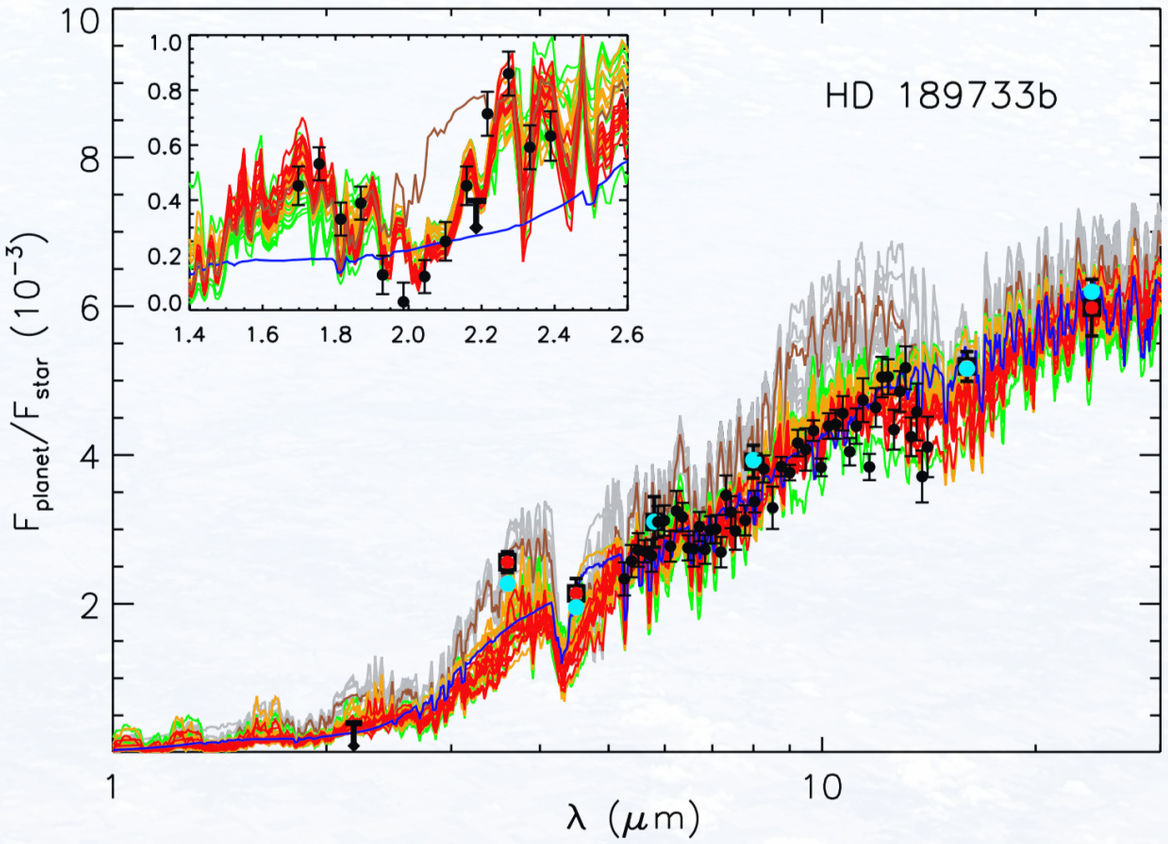
  H2O: 1e-4 CO: 1e-2 CH4: 1e-6 CO2: 1e-5 and 1e-3

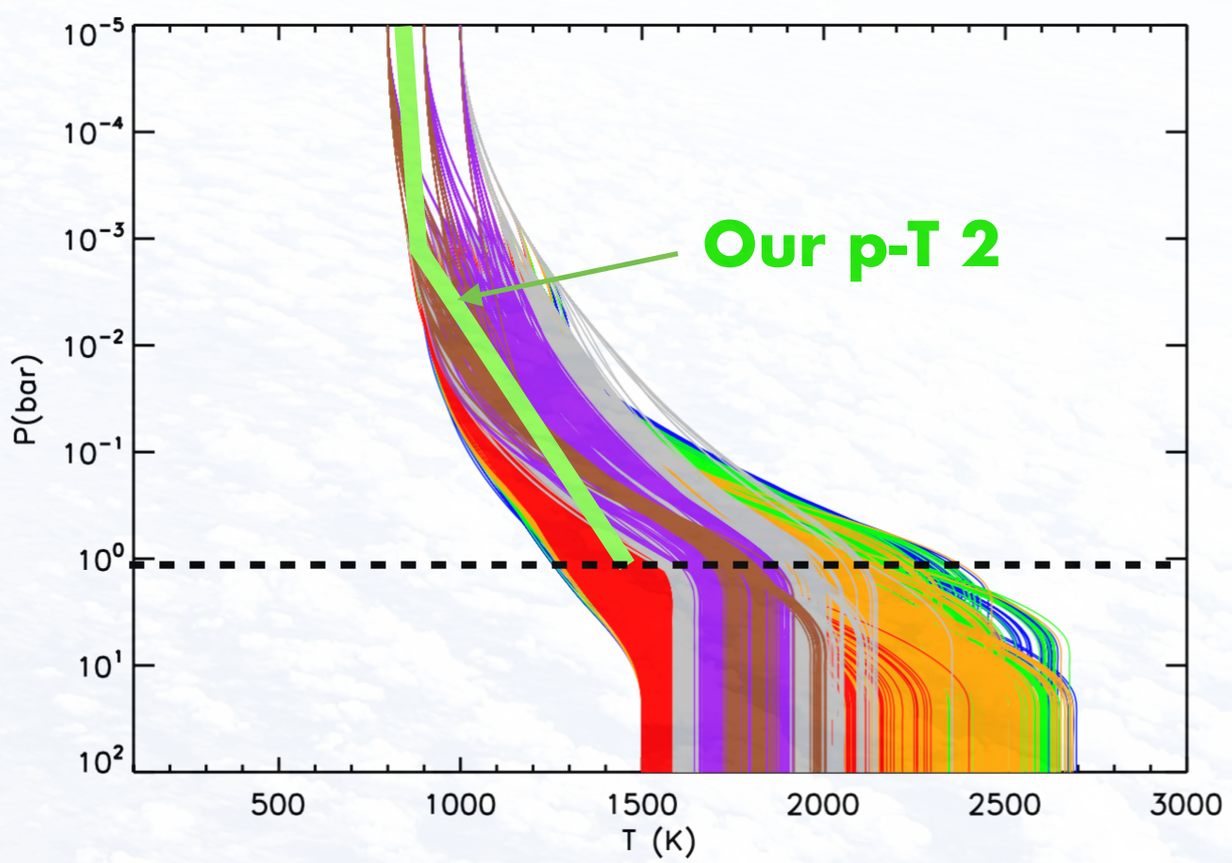
- **Not exact calculations, average nadir emission observing at a phase angle of 45º. NIR albedo set to 0.**

- **Spectroscopy: Hitemp 2010 for H2O, CO, CO2. Hitran 2012 for CH4 (to be improved).**

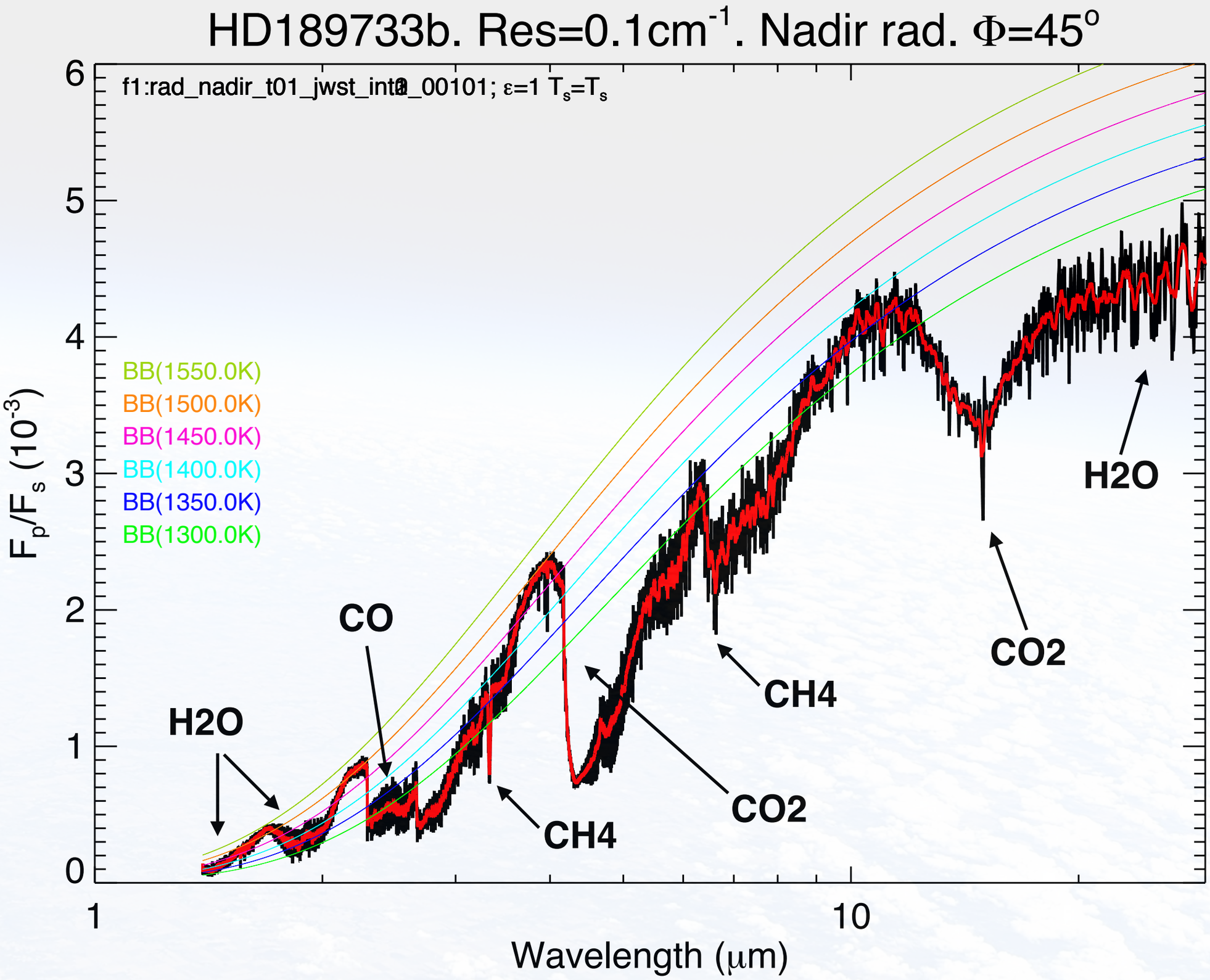
- **Stellar flux: BB at 4875K (we will include a realistic one).**

(Madhusudhan & Seager, 2009)

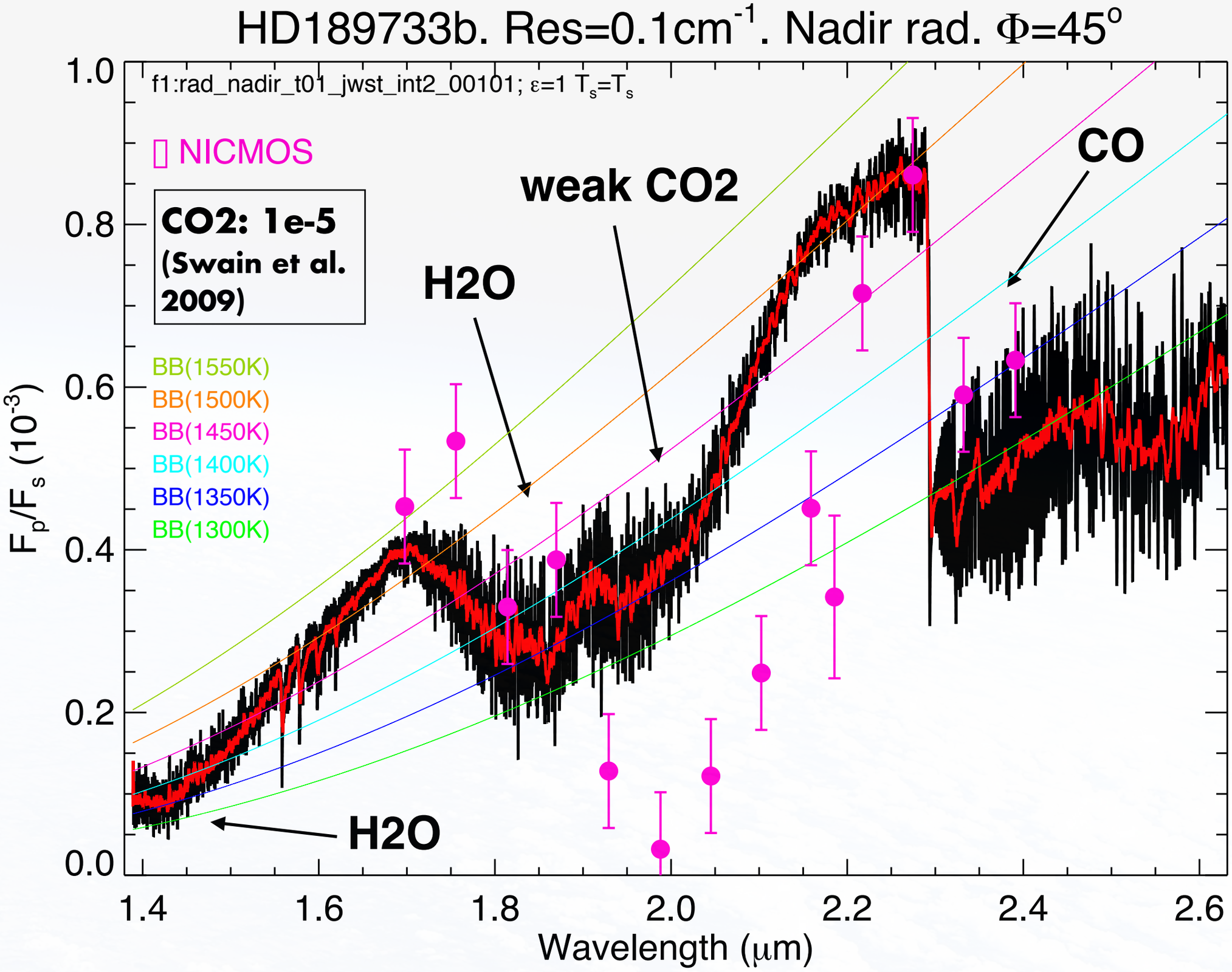




LTE emission spectra of HD 189733b (1-30 μm)

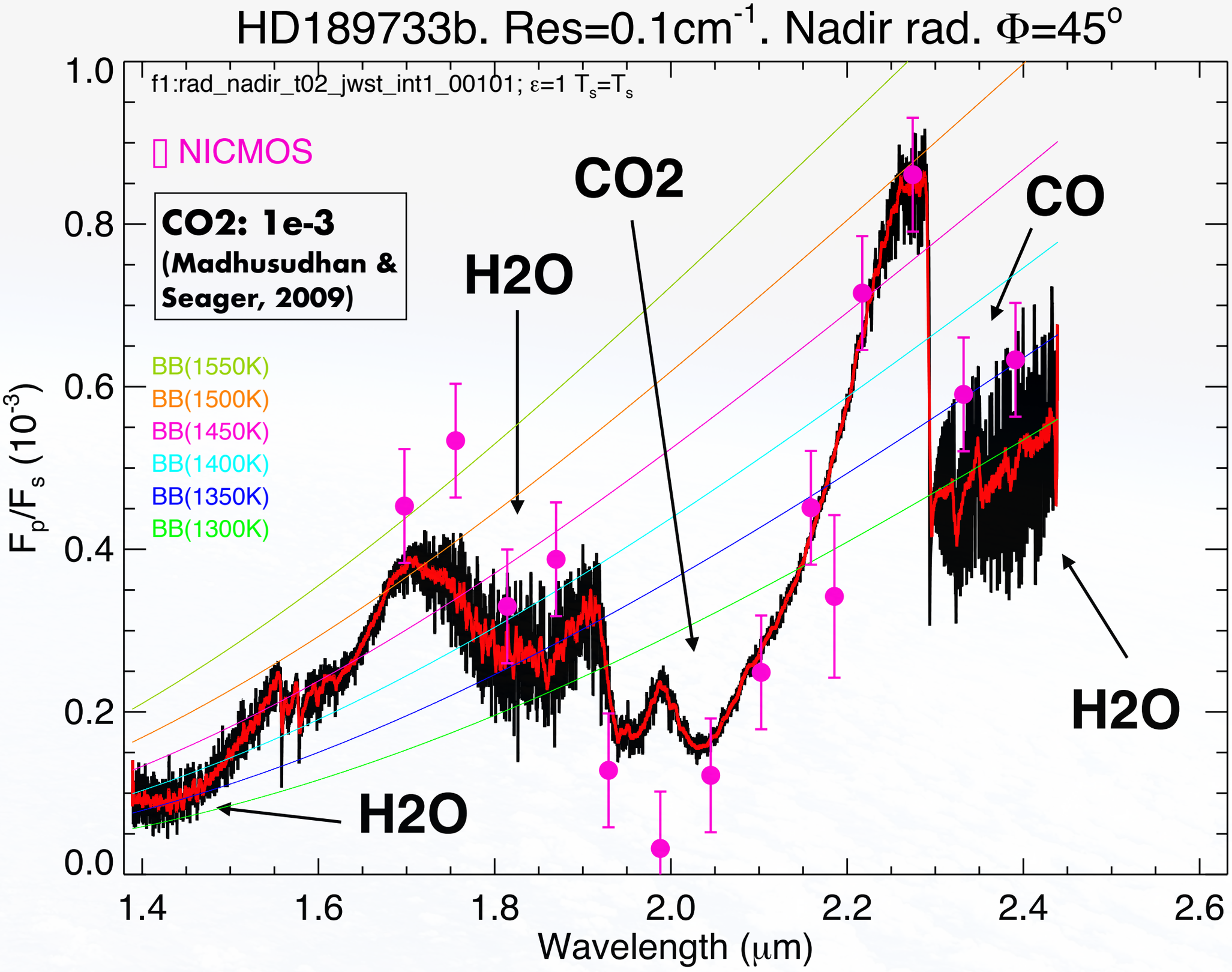


2.2 HST/NICMOS: Simulations and data analysis



HST/NICMOS data points from: Madhusudan & Seager, 2009

2.2 HST/NICMOS: Simulations and data analysis



HST/NICMOS data points from: Madhusudan & Seager, 2009

Conclusions

- We have started in the field of exoplanetary atmospheres very recently.
- Transmission spectroscopy in the NIR (primary transit):
  - Analysis of HST/WFC3 spectra in the NIR of HD189733b: Validation of p-T profile and H2O abundance.
  - Starting data analysis of CARMENES spectra in the NIR (Grid of synthetic spectra, telluric correction, etc.).
- Emission spectroscopy (2nd transit):
  - LTE emission spectra (1-30 μm): Preliminary analysis of NICMOS data suggests a larger CO2 concentration than derived in previous studies (Swain et al. 2009; Madhusudhan & Seager, 2009).
- Future:
  - Continue the analysis of CARMENES NIR spectra (implement CCF (Snellen's) technique).
  - Preparation for JWST observations: Continue emission spectra & extention to Non-LTE.