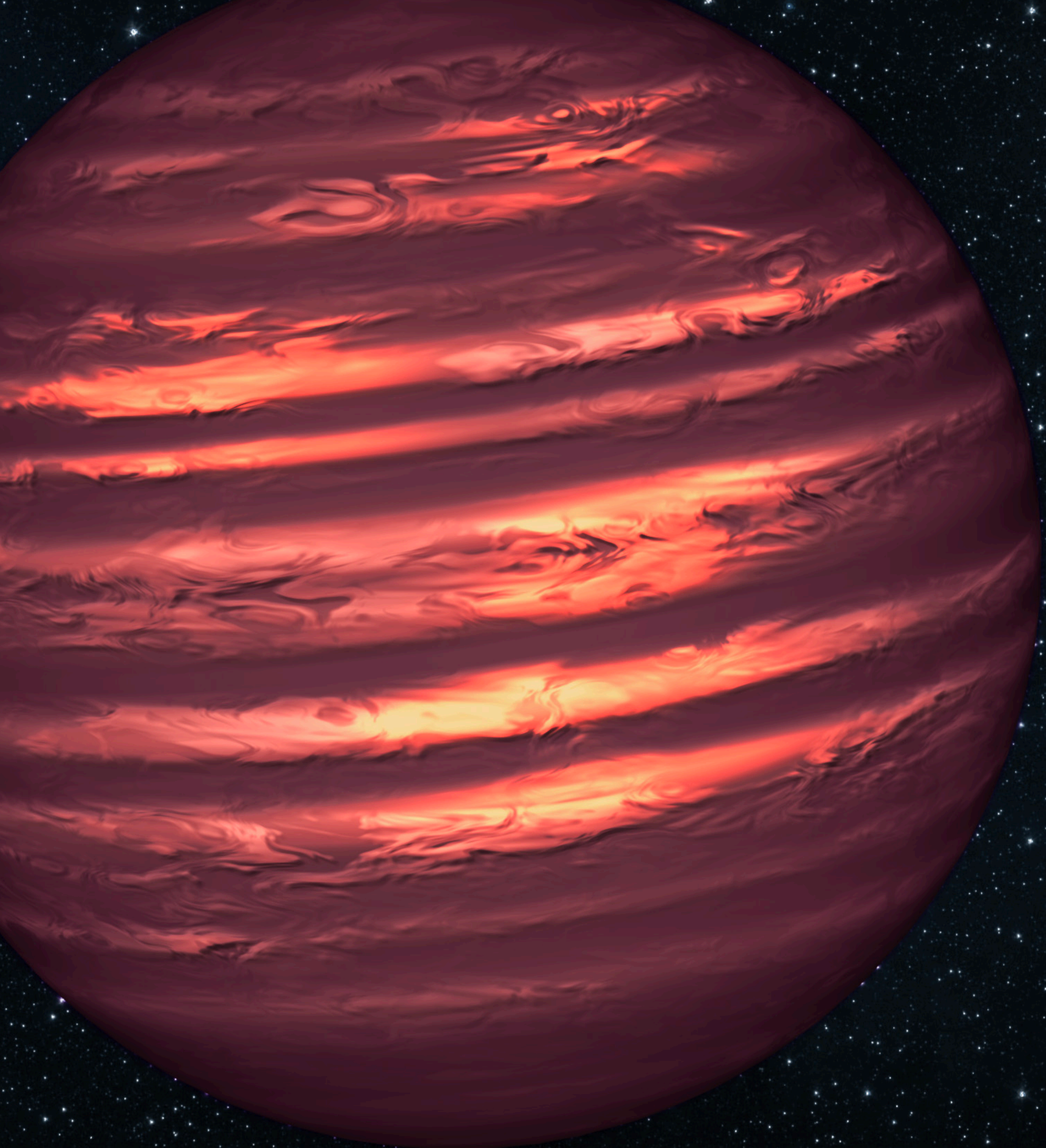


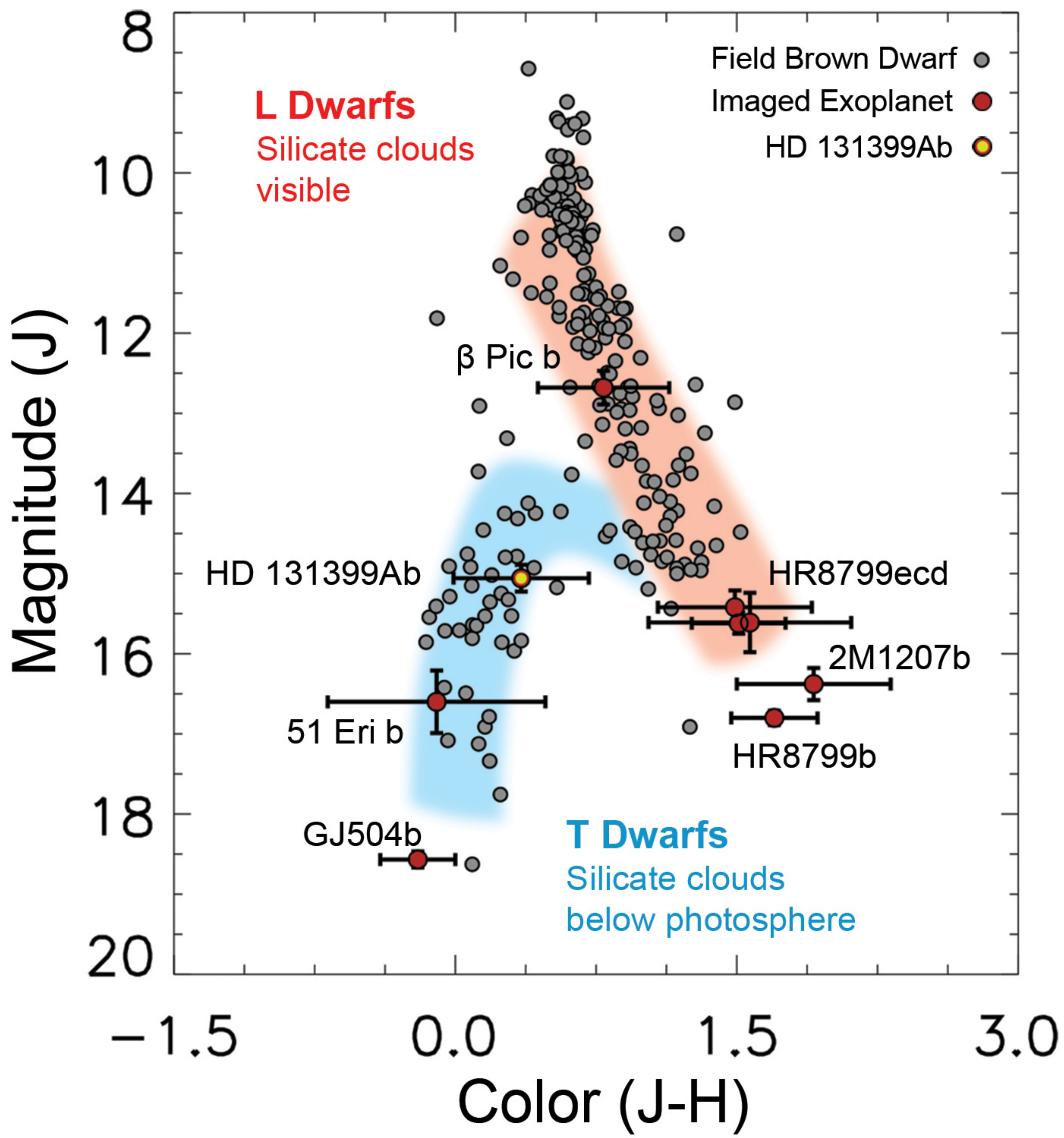
Brown Dwarf Retrievals on FIRE! Atmospheric Retrieval of a T9 Dwarf with Medium Resolution Spectroscopy

Callie Hood (UCSC)

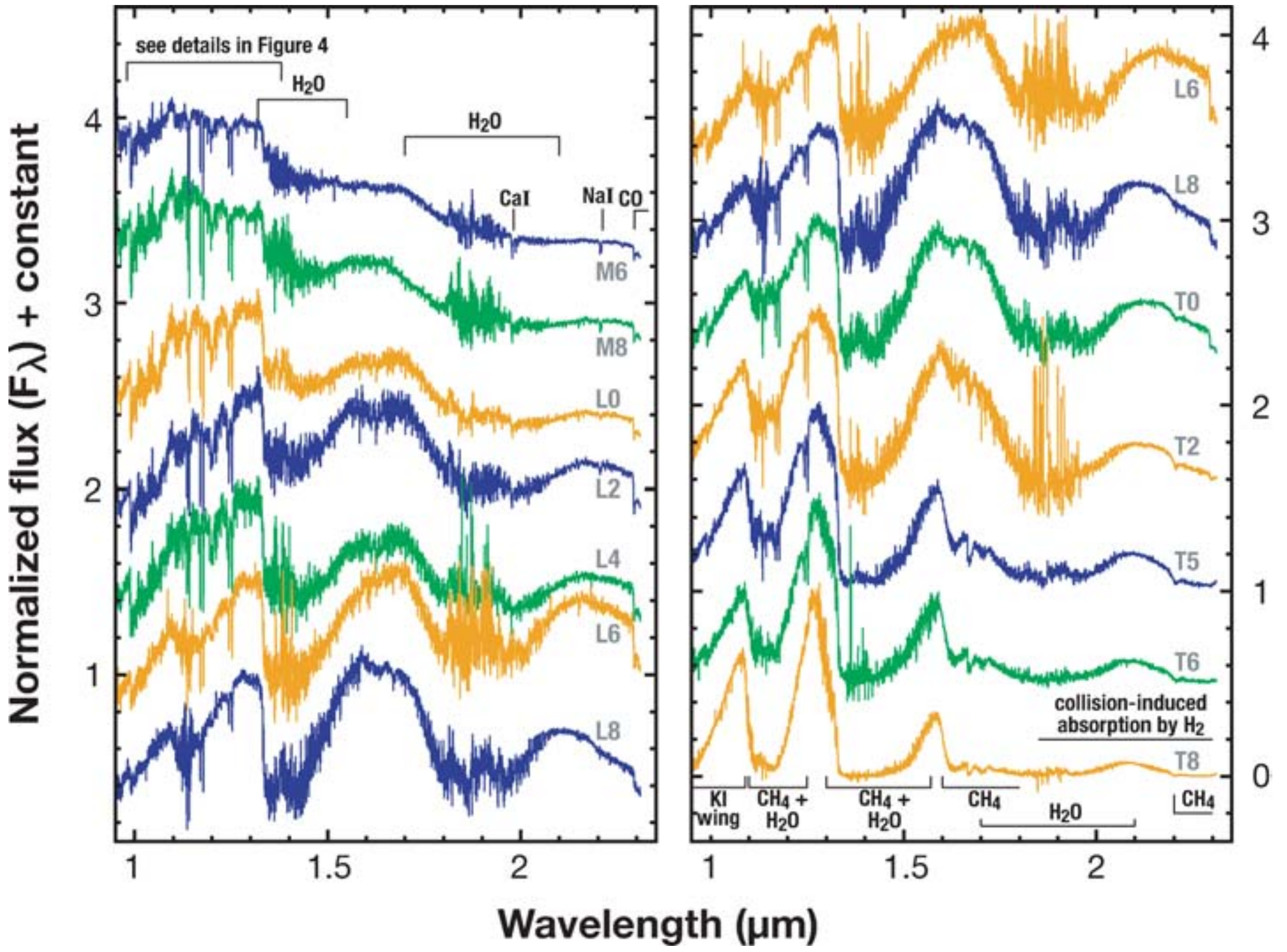
Jonathan Fortney (UCSC)

Mike Line (ASU)

Brown dwarfs are a testbed for our understanding of chemistry and physics in cool atmospheres



Wagner et al. 2016



Kirkpatrick 2005

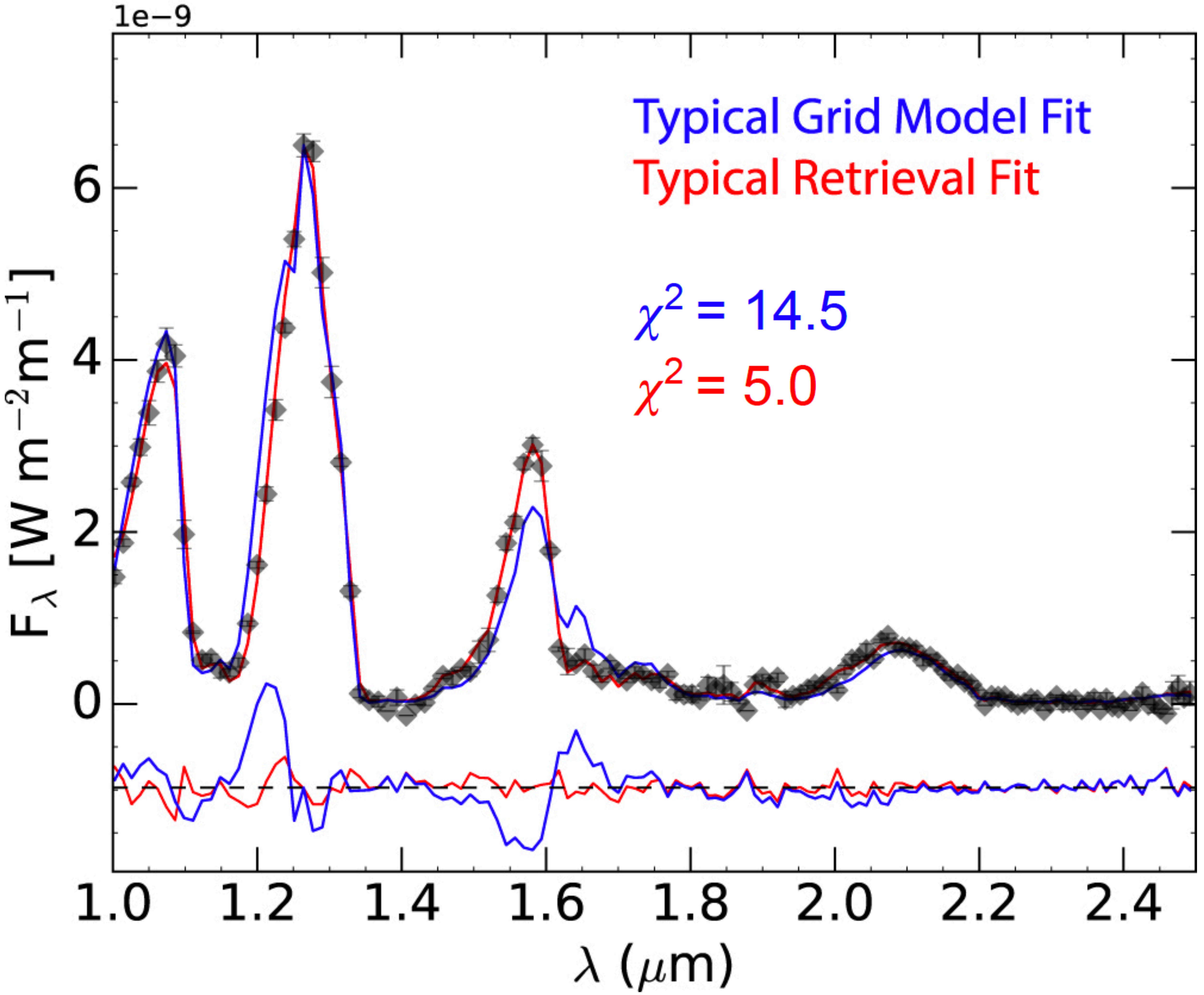
Retrievals can yield complementary insight to grid models on brown dwarf spectra

Grid Models

- Pro: Self-consistent, physical combination of (typically fewer) parameters
- Con: Many assumptions , i.e. radiative/convective equilibrium

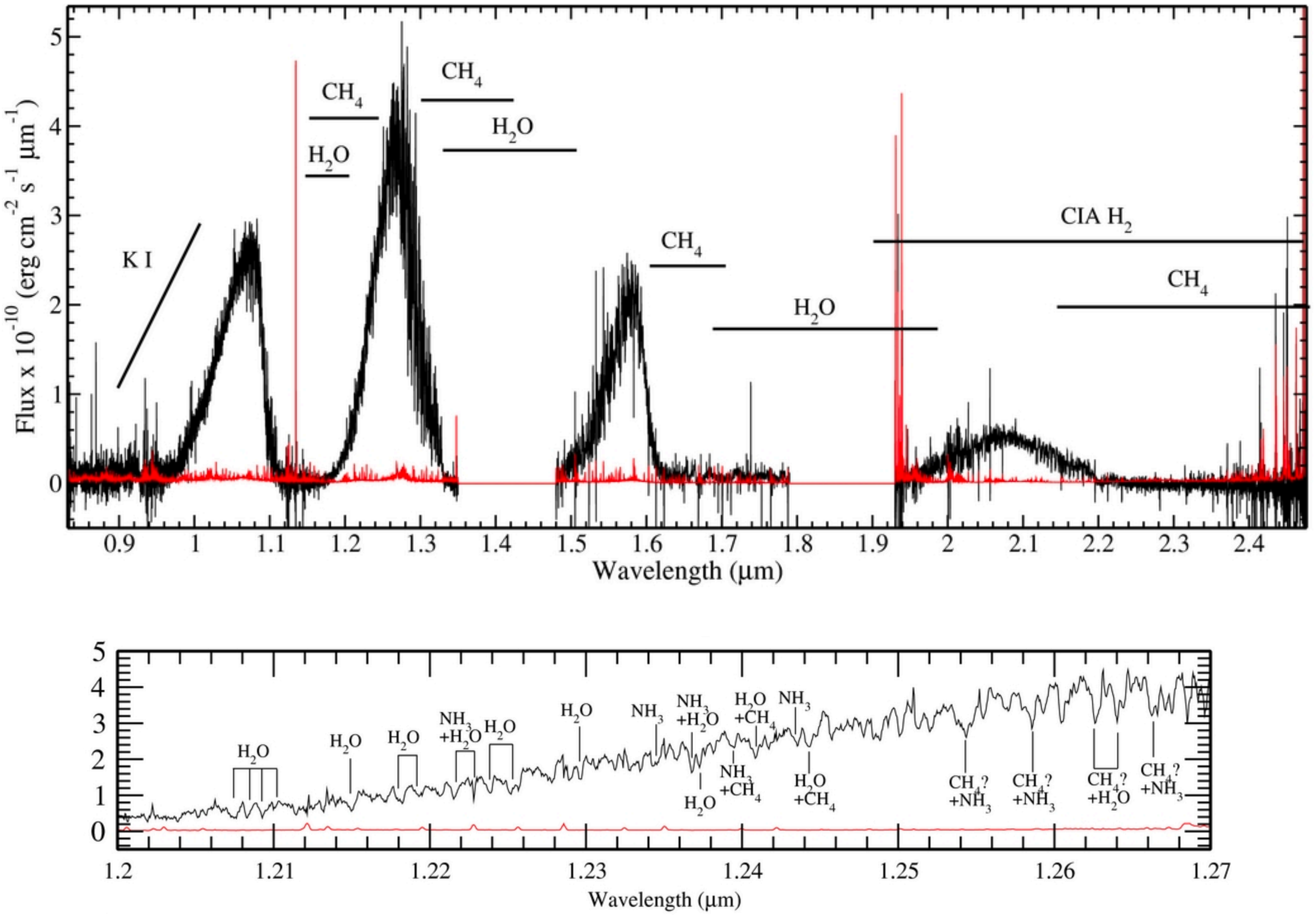
Retrievals

- Pro: Bayesian inverse models, less assumptions
- Con: More parameters, possibly unphysical solutions



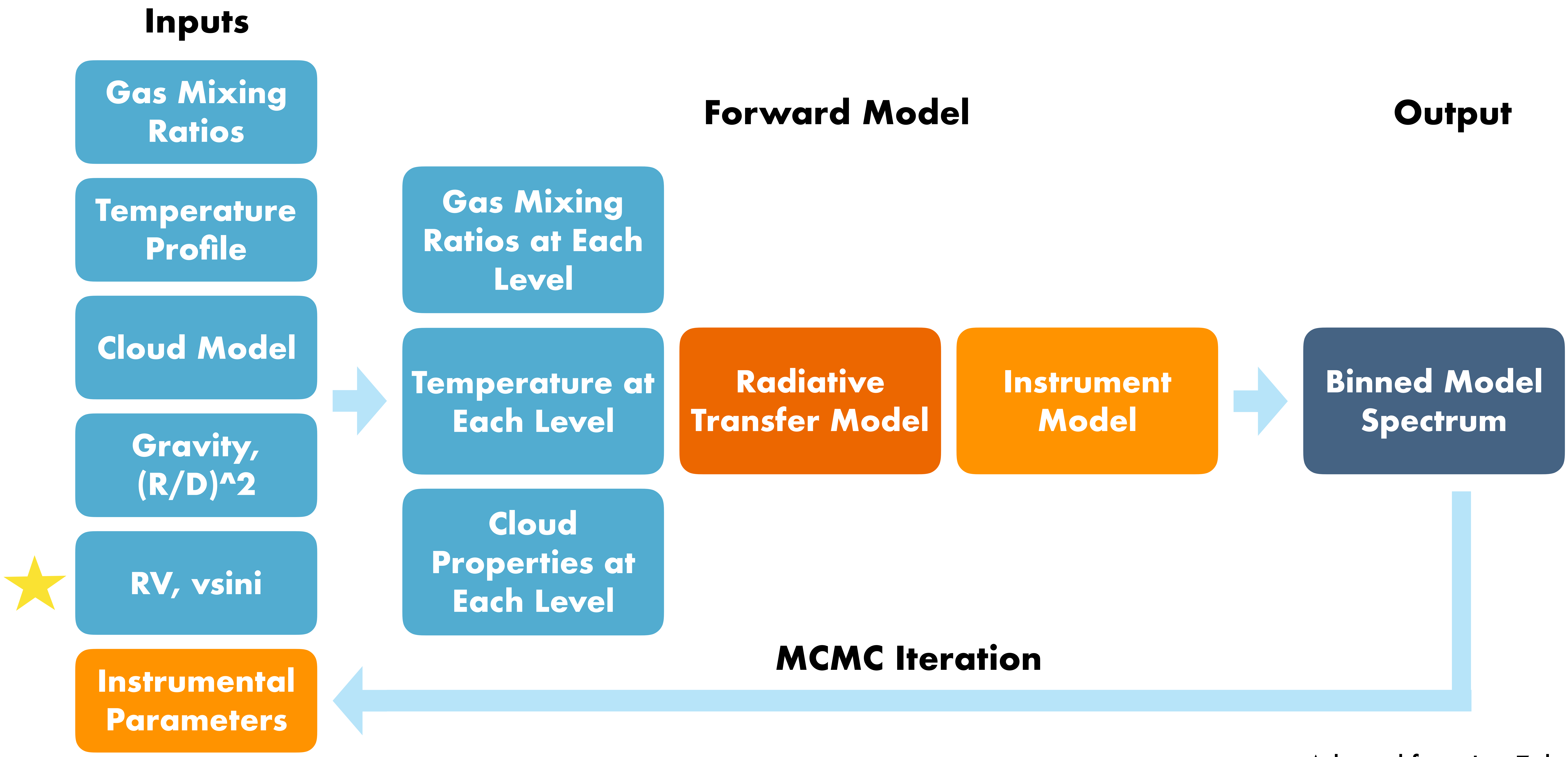
Line et al. 2017

What can we learn at higher spectral resolution?



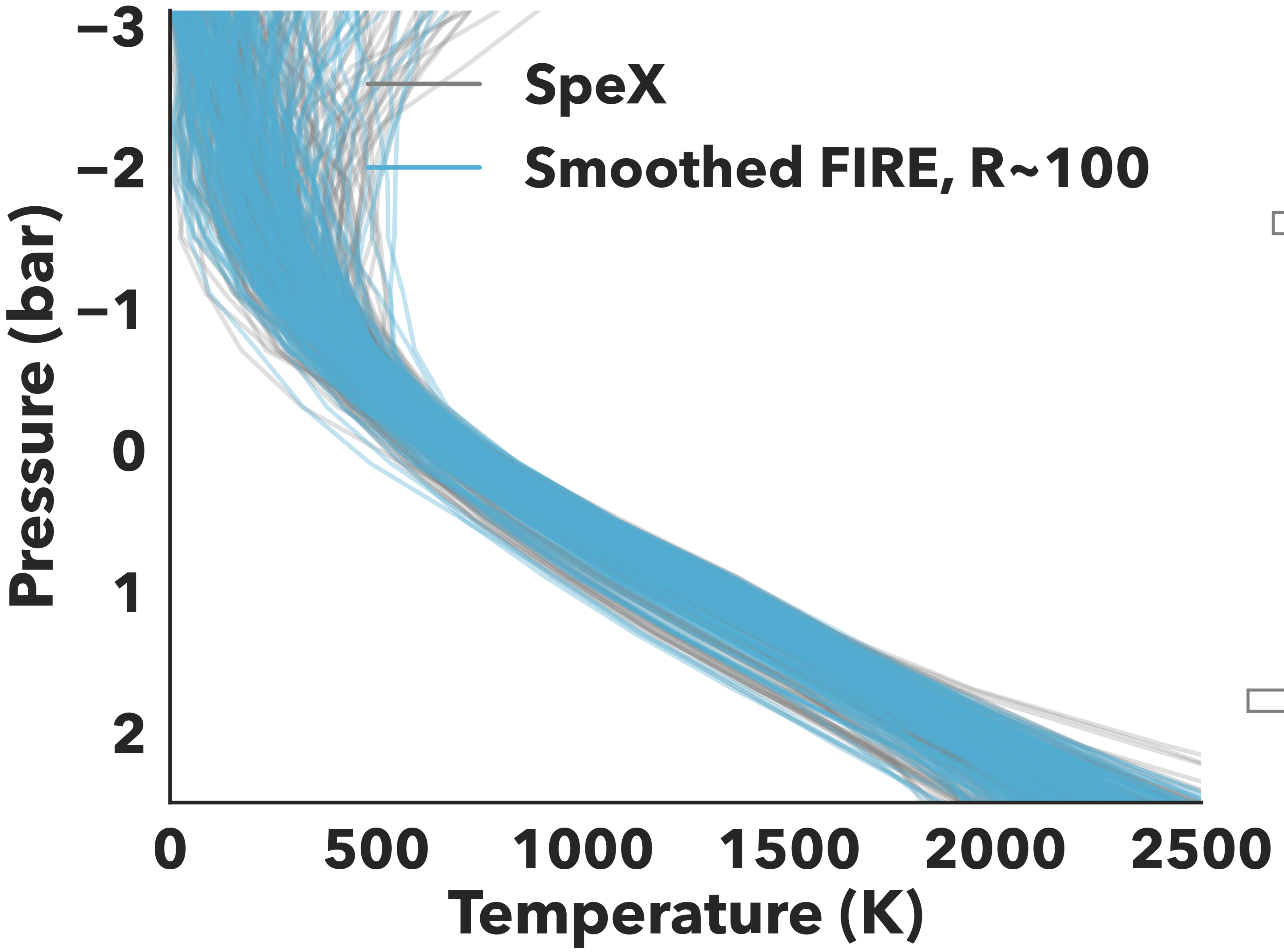
- JWST: 11 GTO programs on substellar objects with NIRSPec R ~ 1000 or 2700 spectra
- At higher spectral resolution:
  - Molecules can be resolved into distinct lines
  - The upper atmosphere is more readily probed
- The data: FIRE (R ~ 6,000) spectrum of the nearby T9 dwarf, UGPS J072227.51-054031.2
  - S/N ~ 200 over 0.9-2.5 microns
  - Bochanski et al. 2011 identified H2O, K, CH4, and NH3 features, as well as determined physical parameters by fitting to grid models

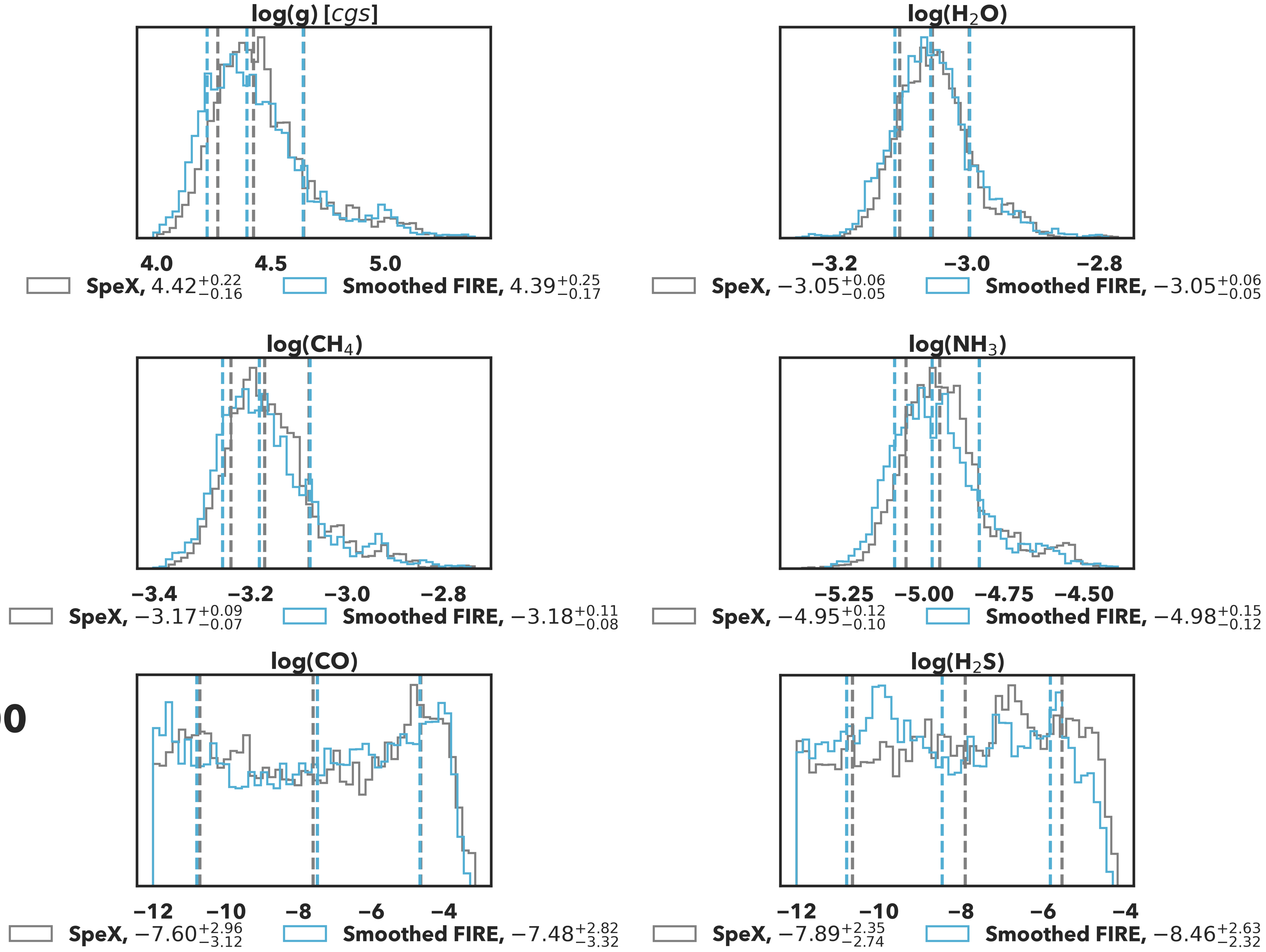
Overview of the CHIMERA retrieval framework



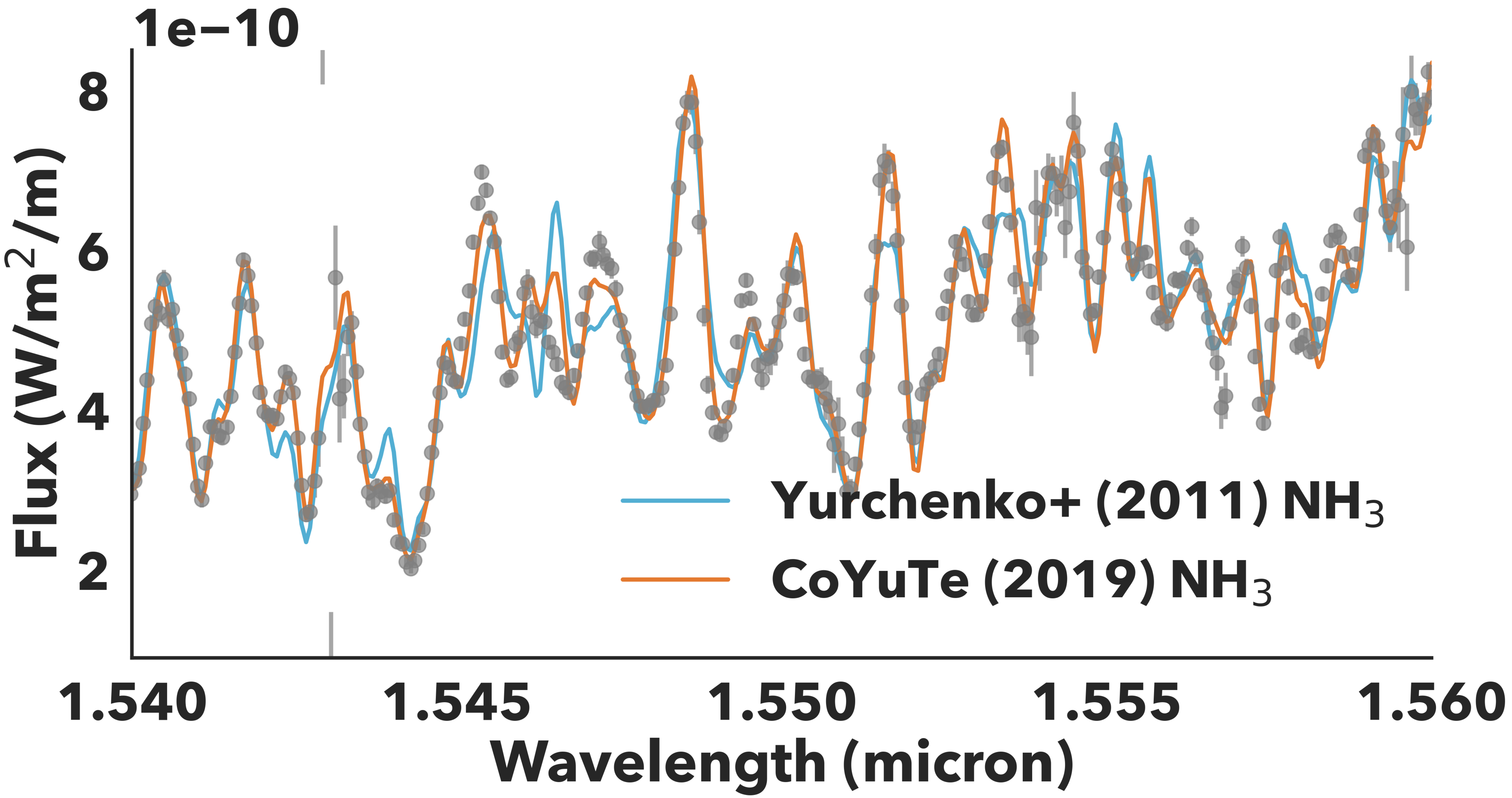
Adapted from Joe Zalesky

Results from the smoothed FIRE spectrum agree well with SpeX results





At FIRE resolution, new NH3 and CH4 line lists clearly a better match to the data



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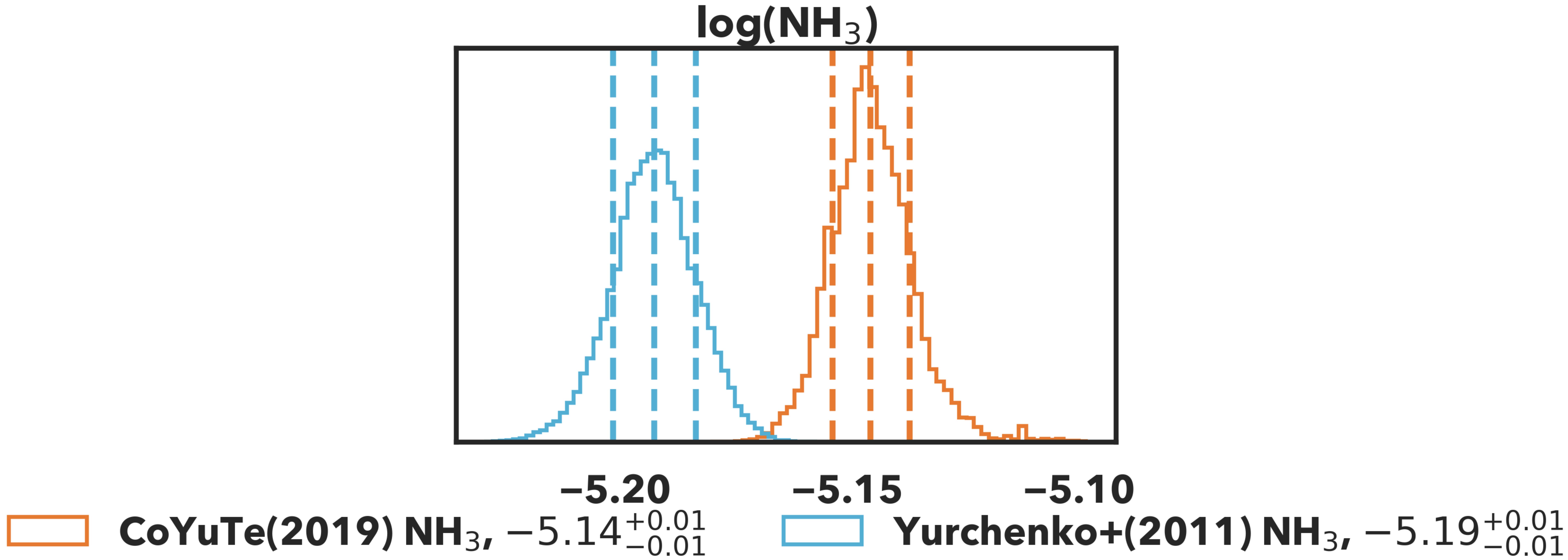
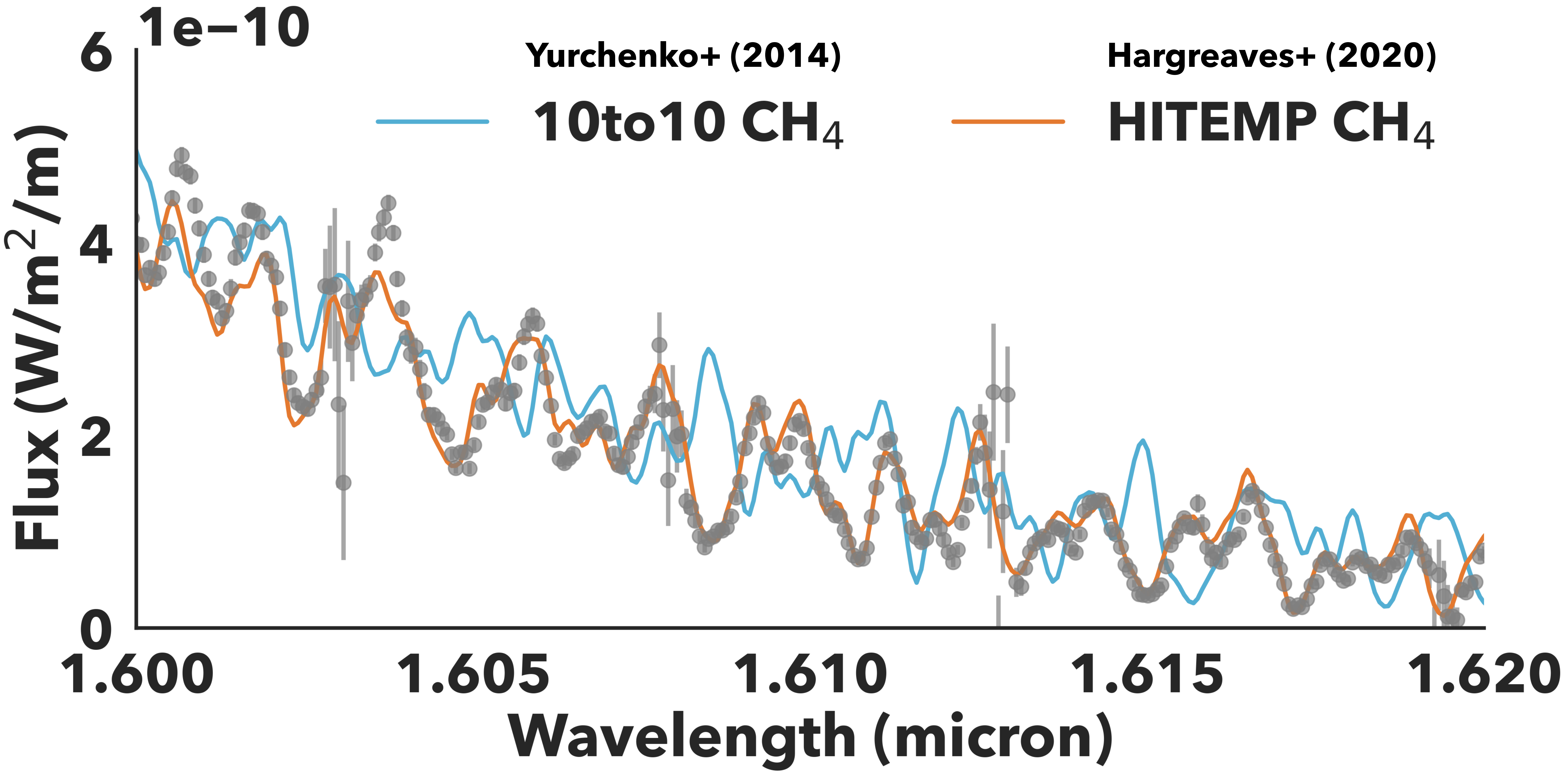
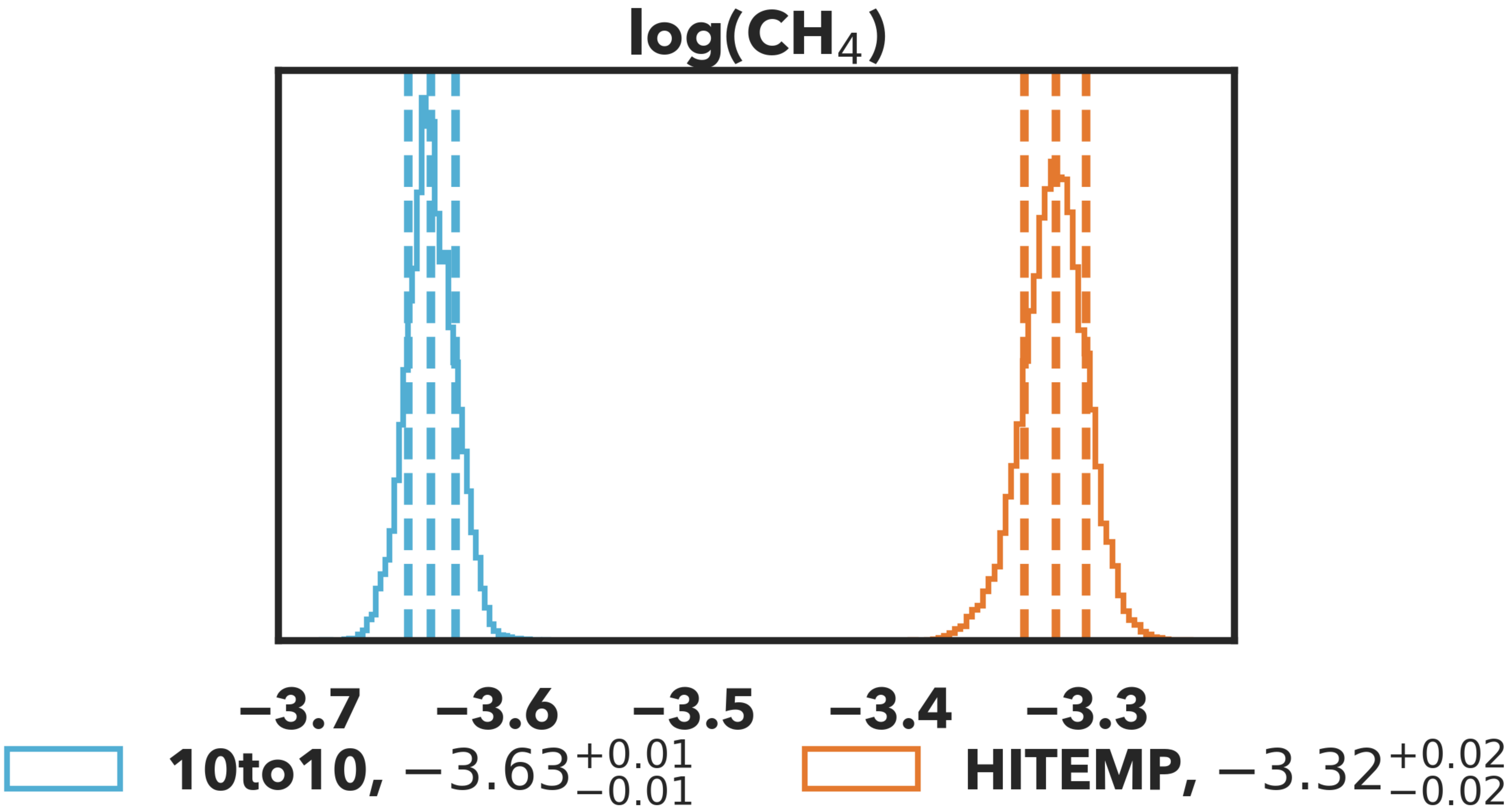


At FIRE resolution, new NH3 and CH4 line lists clearly a better match to the data

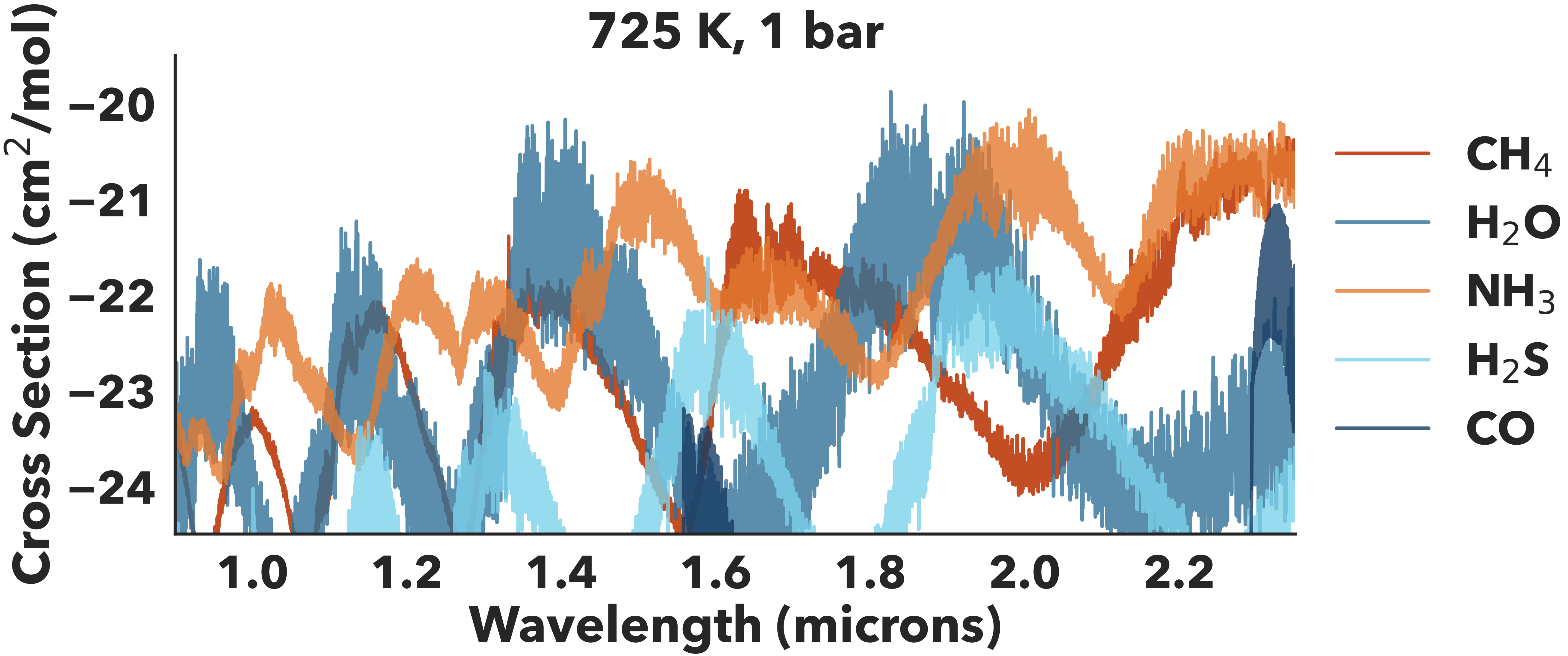


At FIRE resolution, new NH_3 and CH_4 line lists clearly a better match to the data

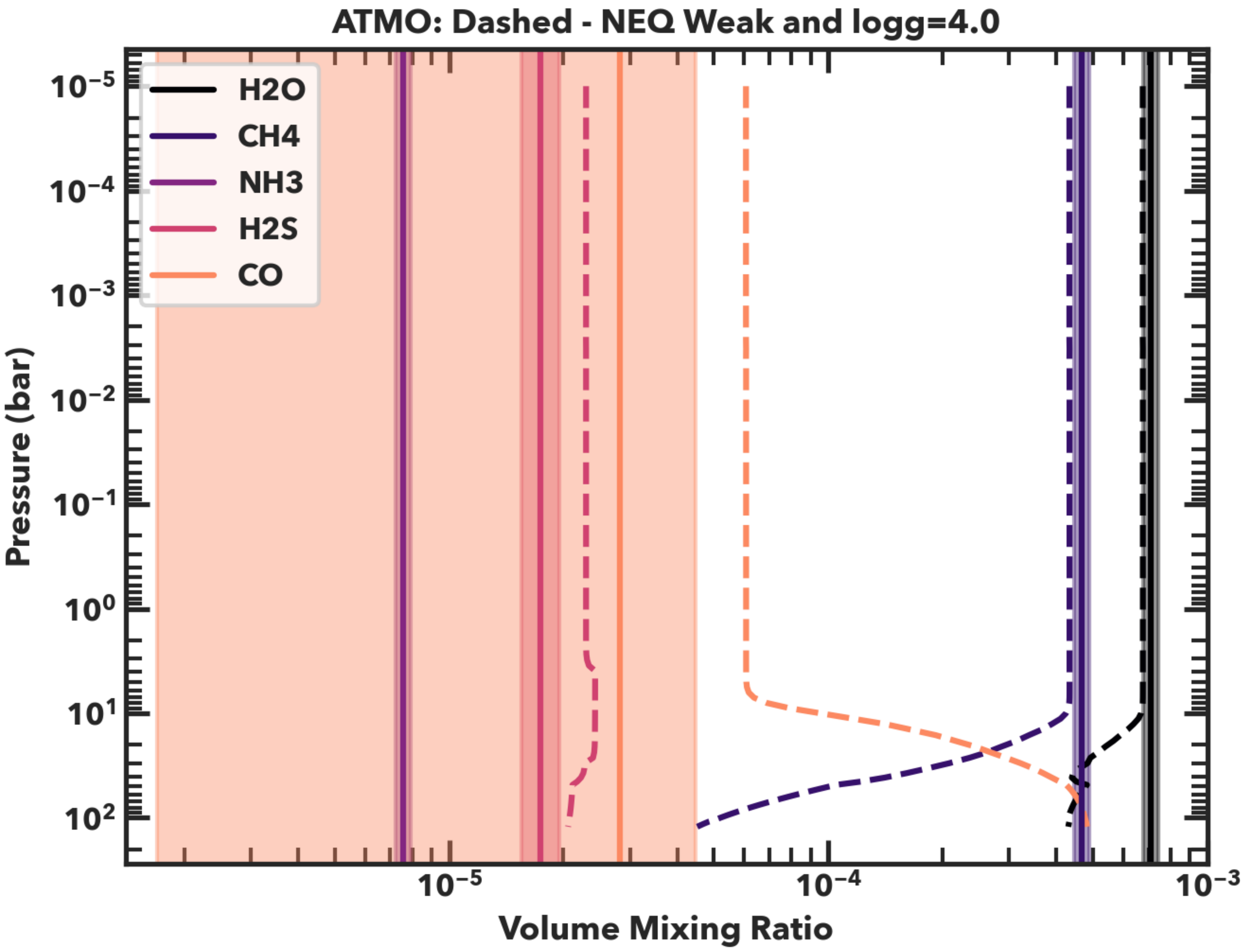


Comparison of preliminary FIRE and SpeX results:

Increased spectral resolution = greater precision on molecular abundances

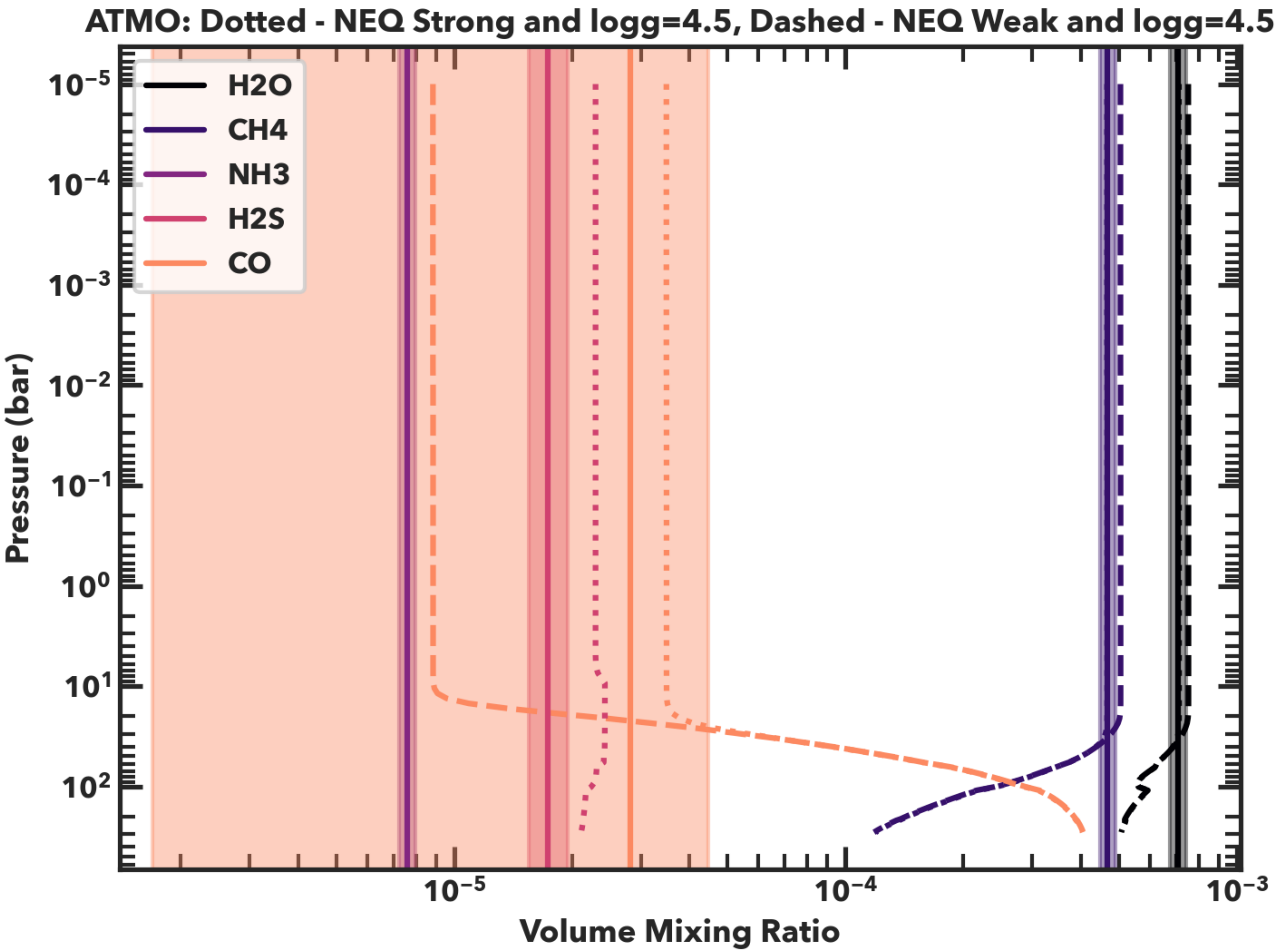


We can compare our results to the ATMO 2020 non-equilibrium chemistry models.

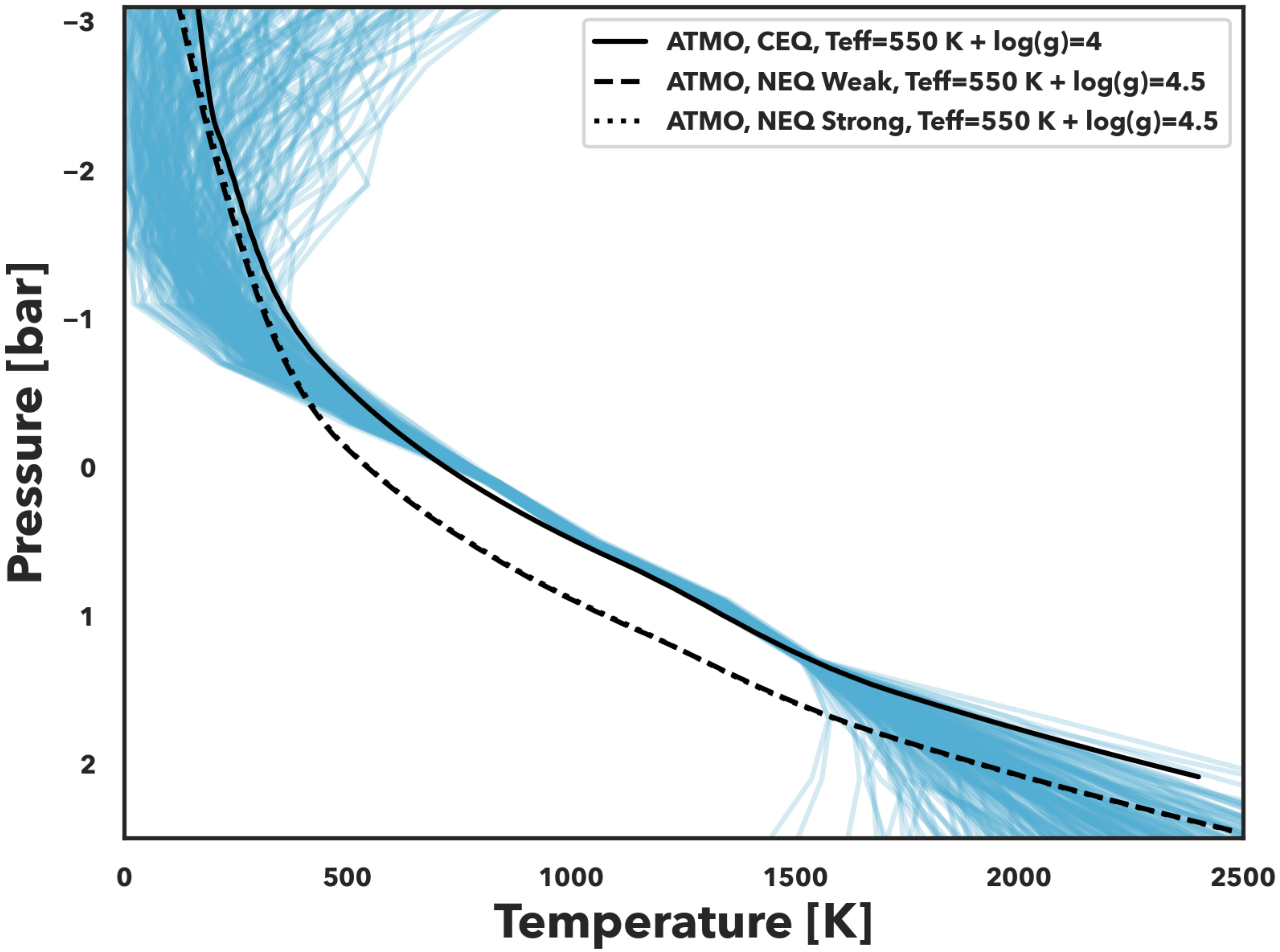


ATMO: Phillips+ 2020

FIRE retrieved abundances agree well with the ATMO strong mixing model… but at higher gravity



FIRE retrieved abundances agree well with the ATMO strong mixing model… but the T-P profiles don't quite match



Summary and Next Steps

1. In preparation for high signal-to-noise and medium resolution spectra with JWST, we need to assess how our current modeling tools and theory compare to these better quality observations. To that end, I am working on applying the CHIMERA framework to medium resolution spectroscopy of brown dwarfs - starting with one test object, then will move on to a population of late T dwarfs observed with FIRE.

2. The increased spectral resolution of FIRE (R ~ 6000) compared to SpeX (R ~ 100) gives much more precise constraints on the T-P profile and chemical abundances, particularly of CO and H_2S. Choice of line list matters greatly for these kinds of observations, with the potential to lead to very different retrieved abundances.

3. Our retrieved abundances are reasonable compared to ATMO non equilibrium chemistry models, but there are lingering questions around the surface gravity and T-P profile.