HOW PLANETARY PROPERTIES AND STELLAR IRRADIATION SET ATMOSPHERIC STRUCTURE

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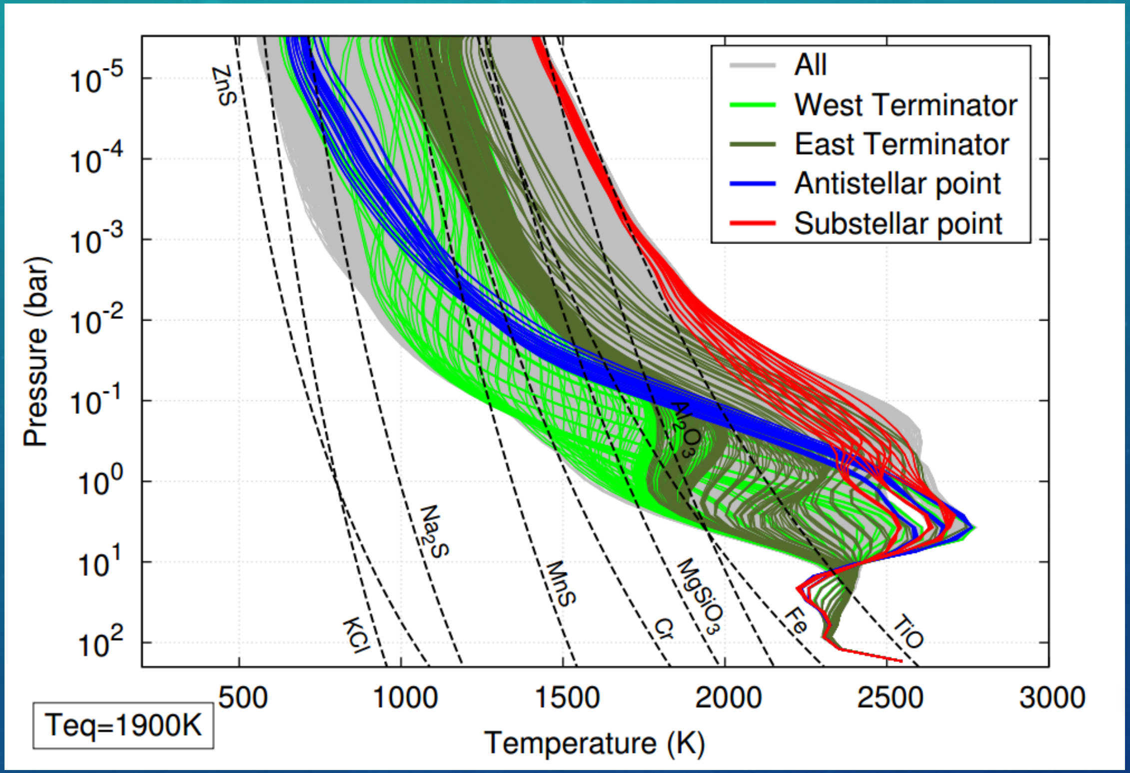
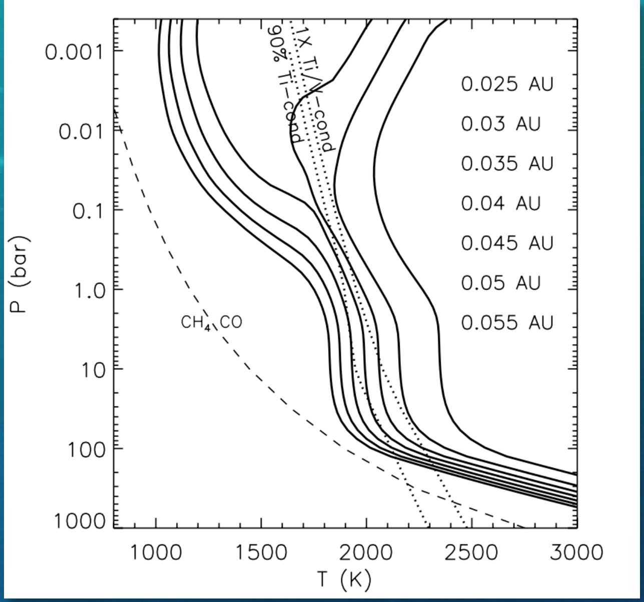
Hot Jupiter atmospheres are complicated, multi-parameter, systems.



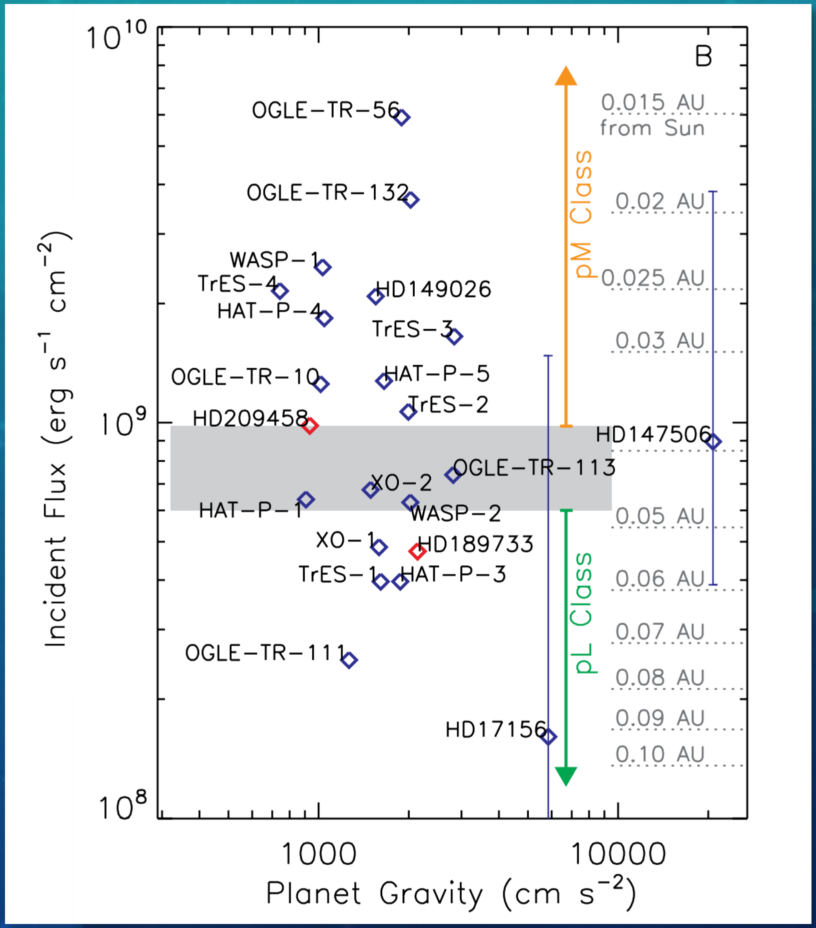
Parmentier et al. (2016)

Inversions are believed to be caused by either TiO or VO gas in the upper atmosphere



Fortney et al. (2008)

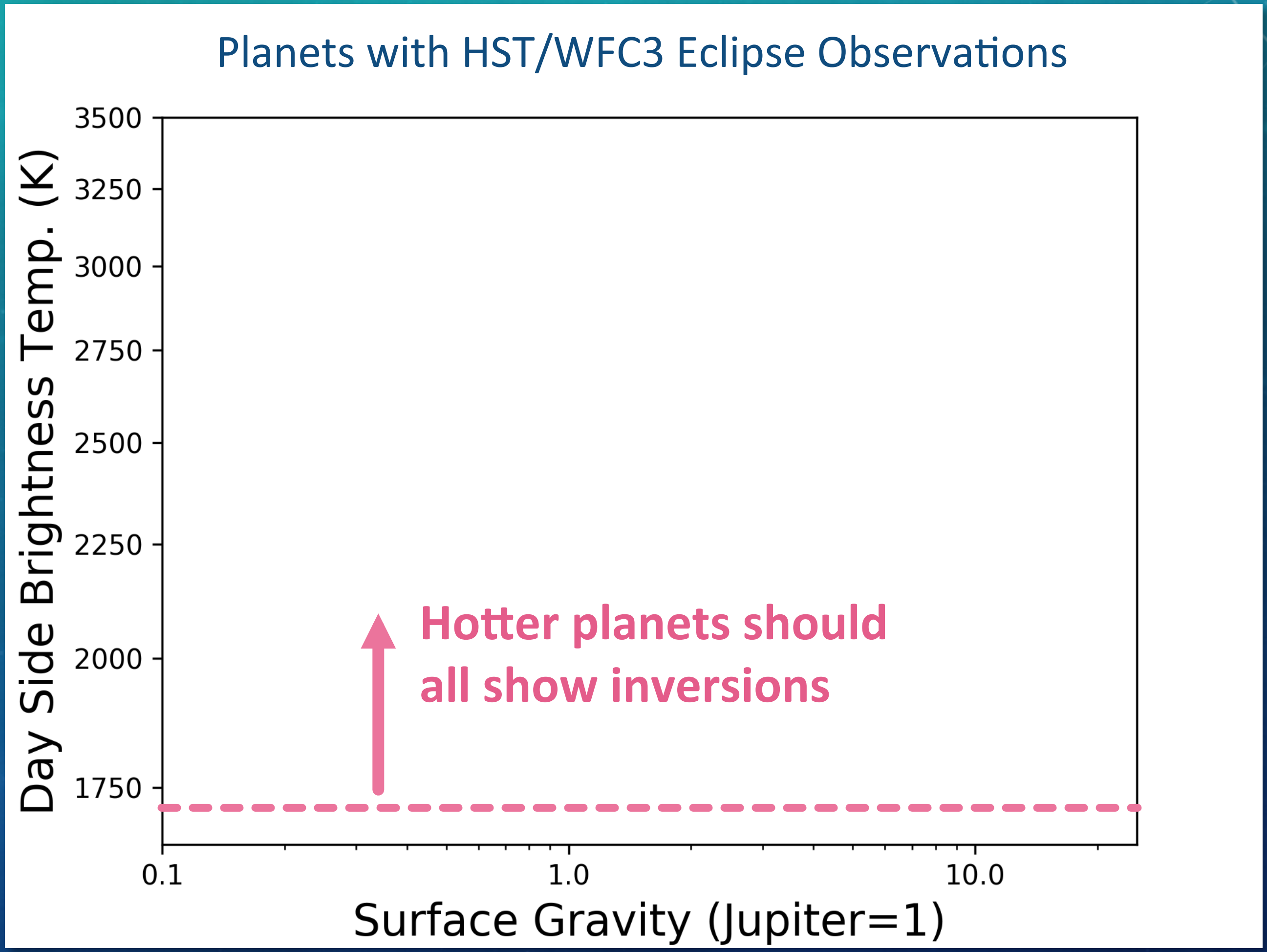
Gaseous TiO should be in the upper atmosphere of giant planets hotter than about 1700K



Fortney et al. (2008)

Know Thy Star – Know Thy Planet

We have planets expected to show an inversion, but do not have a clear signature of one



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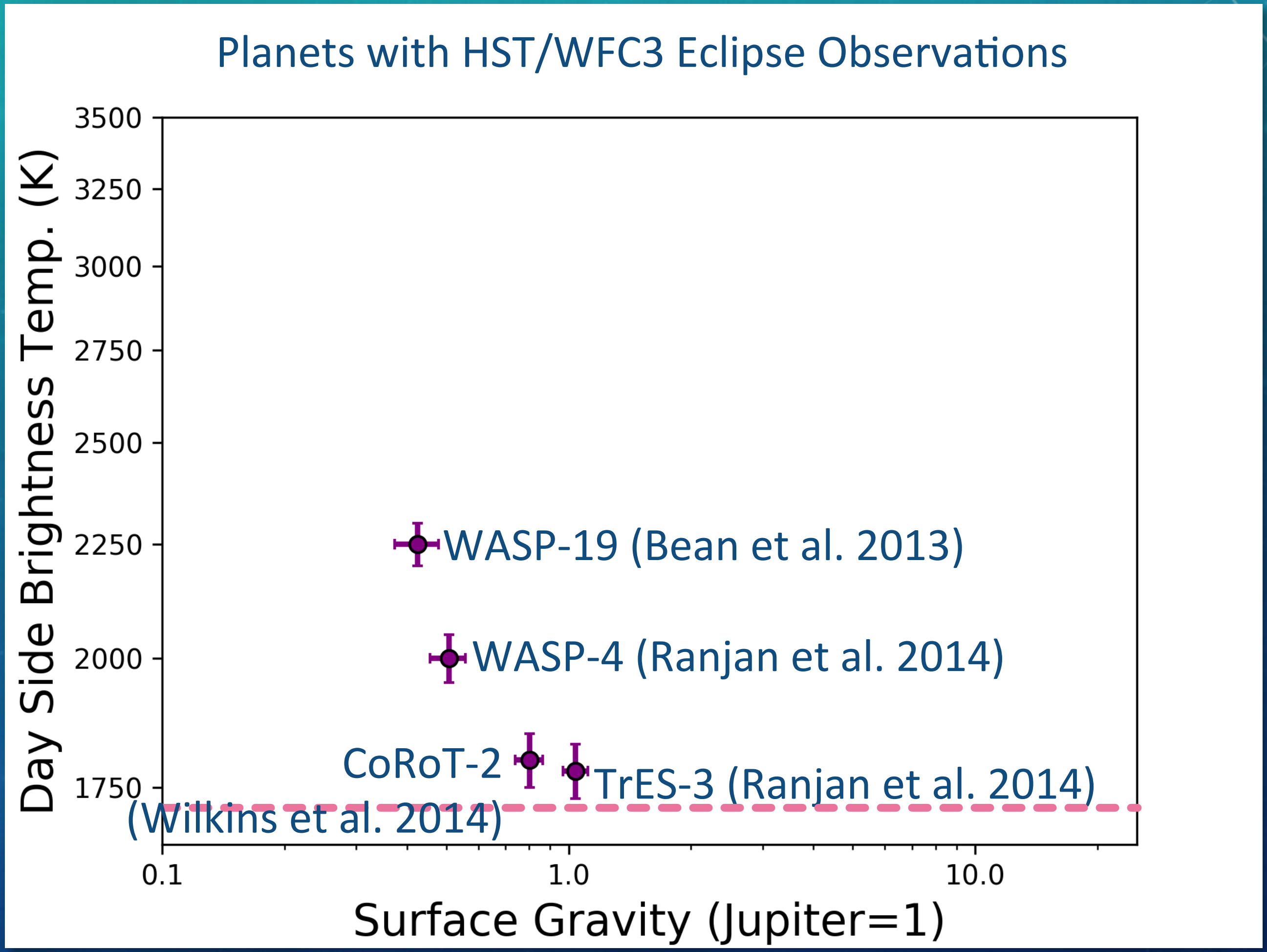
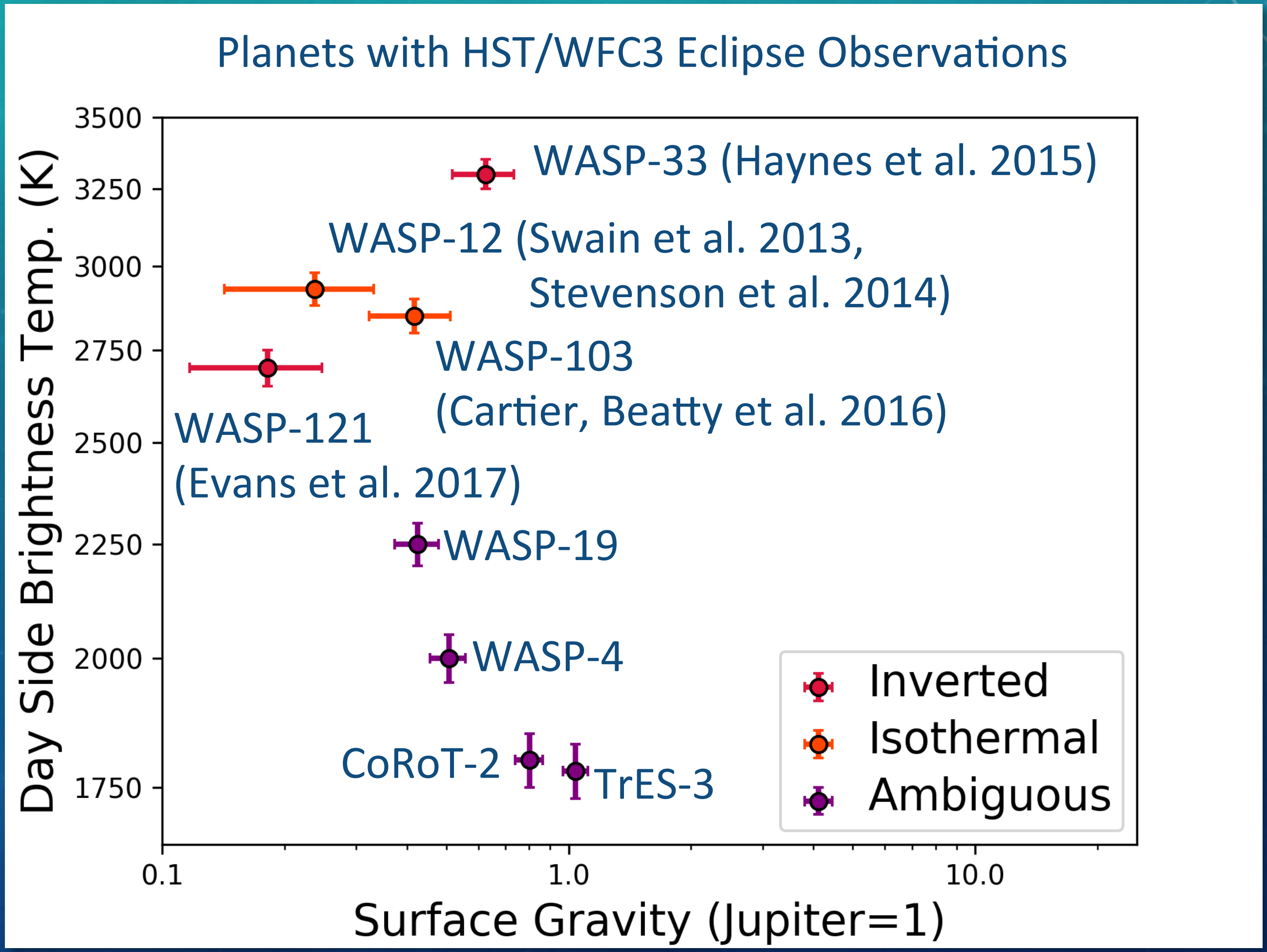
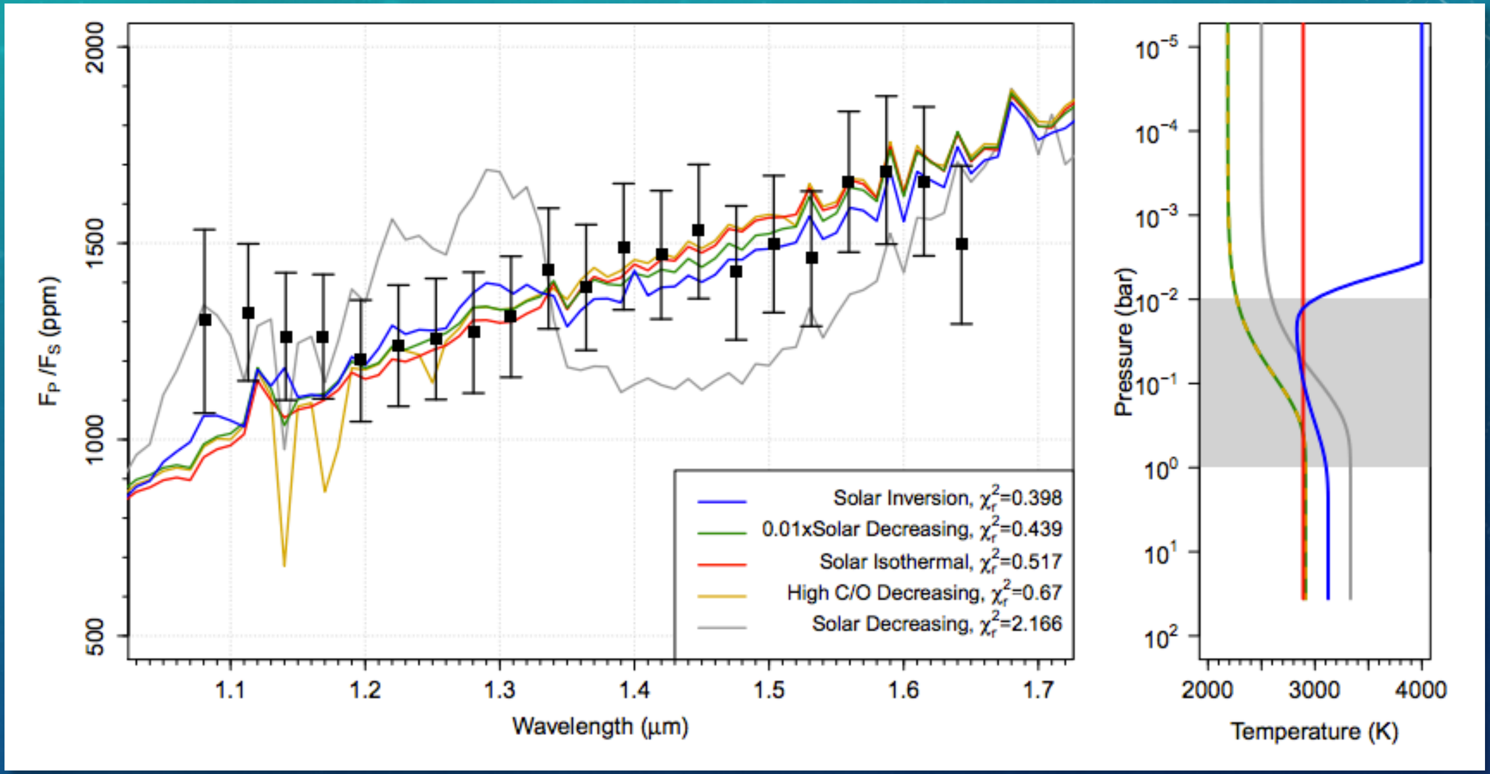


While very hot planets do show inversions

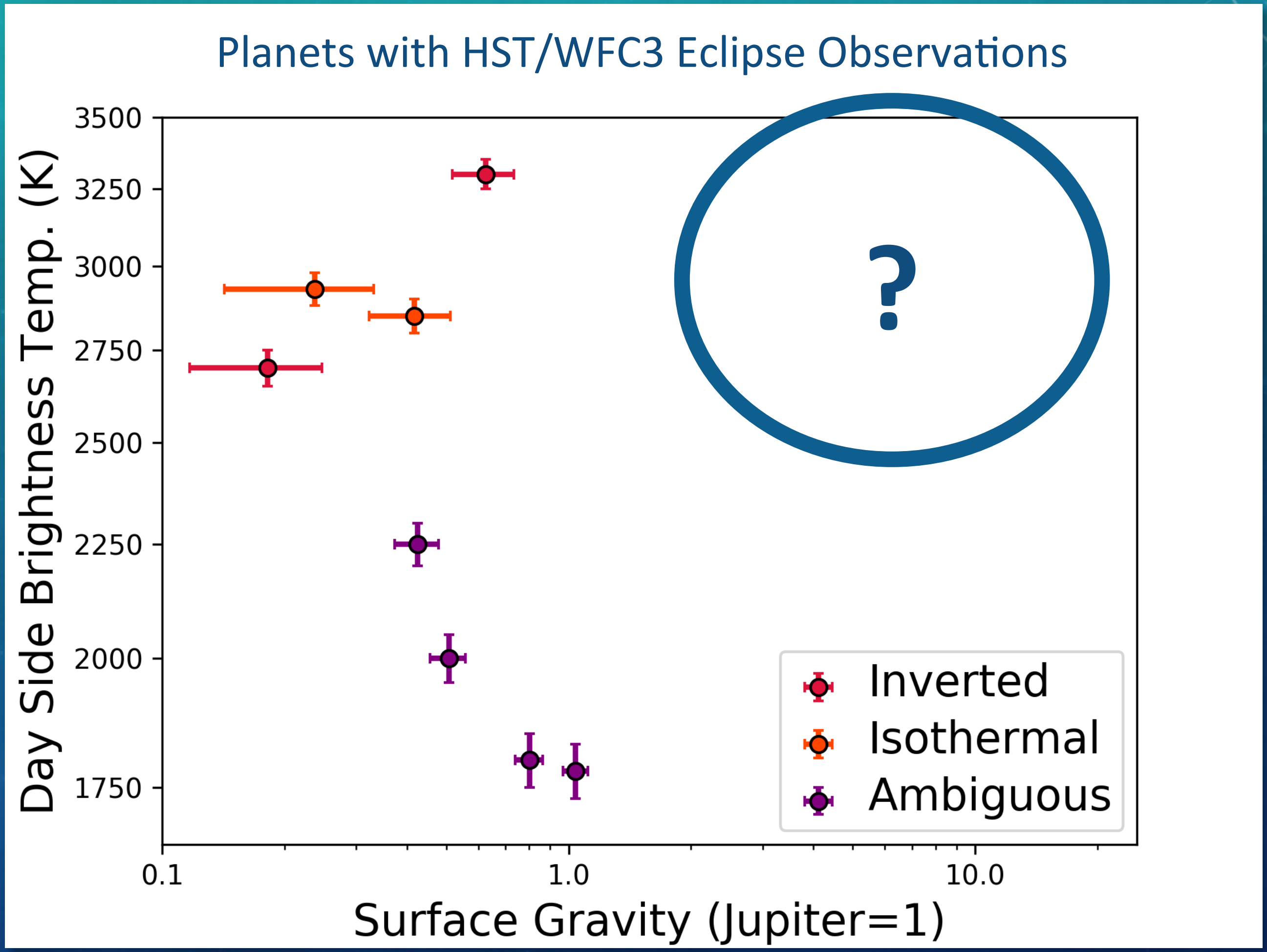


HST/WFC3 observations of WASP-103b (2900K) appear isothermal

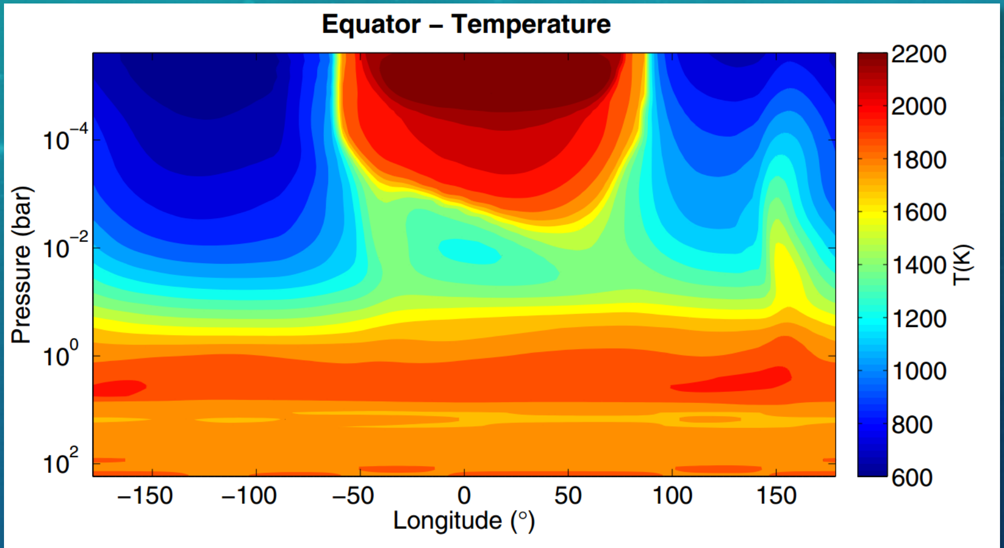


Cartier, Beatty, et al. (2016)

What happens at high surface gravity?



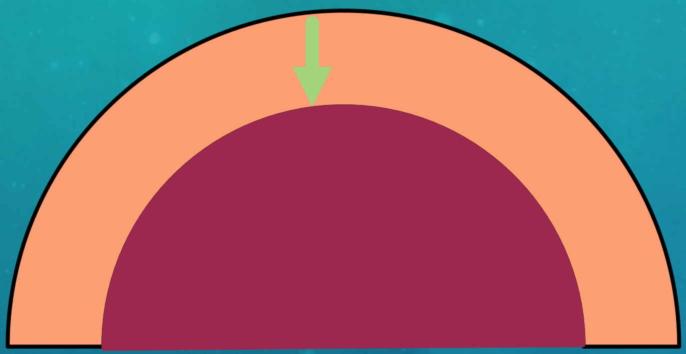
In high surface gravity atmospheres, a cold-trap can clear out the material causing an inversion



- Day-night cold trap: condensation occurs on the cold night side, and condensates fall deep enough to not revaporize during the day (Parmentier et al. 2013).

Parmentier et al. (2013)

To first order, the efficiency of a cold-trap will scale as the free-fall timescale, which goes as:

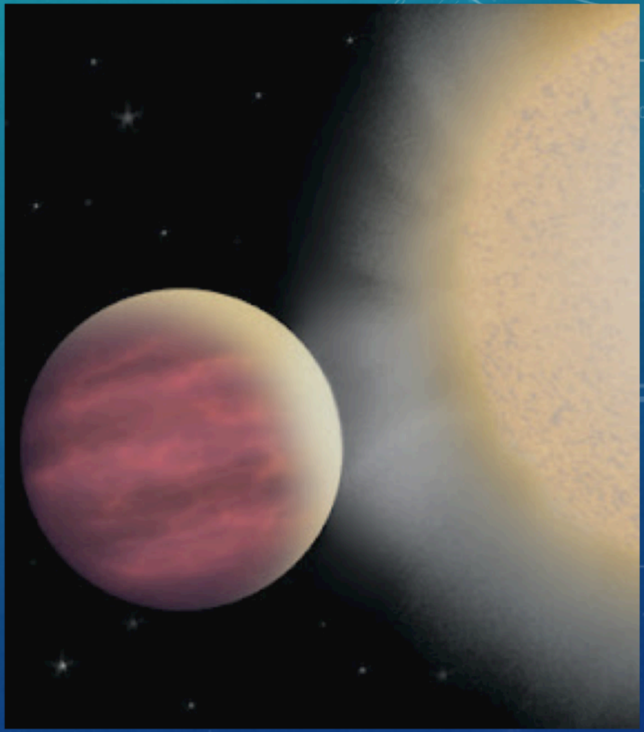


$$\textit{scale height}\,(H)/\textit{terminal velocity}\,(V_T) \propto T/$$

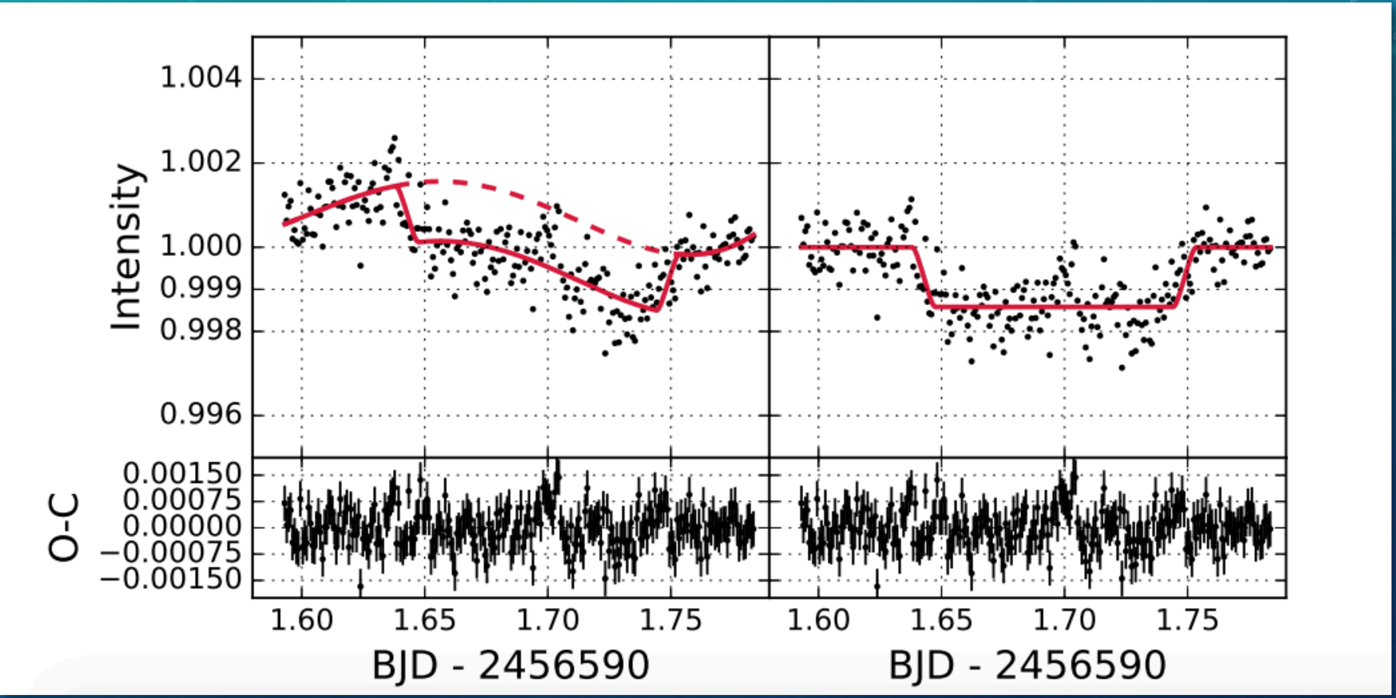
$$H = k_b T/\mu_m g \qquad V_T = 2a^2 g(\rho_p - \rho)/9\eta$$

- T – temperature
- g – surface gravity
- a – particle size

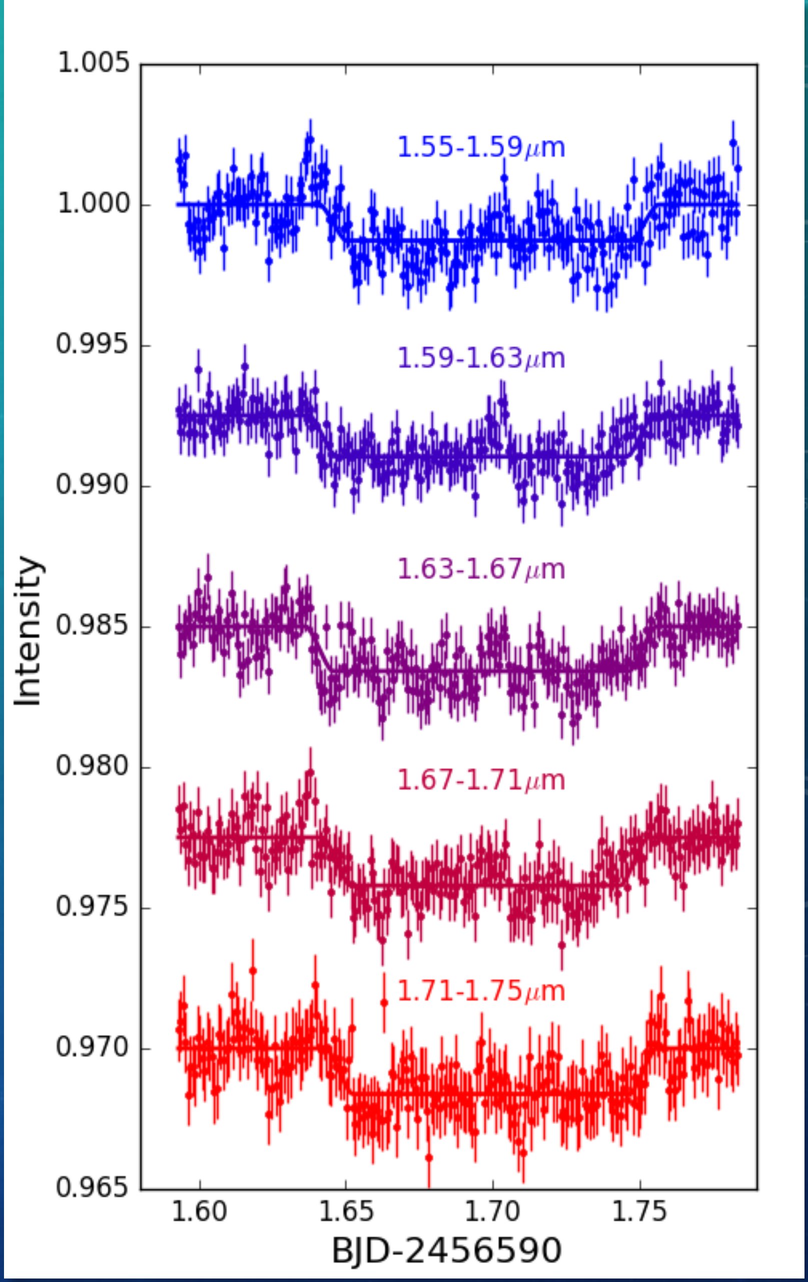
We observed an eclipse of the transiting 30 Jupiter-mass brown dwarf KELT-1, using LBT



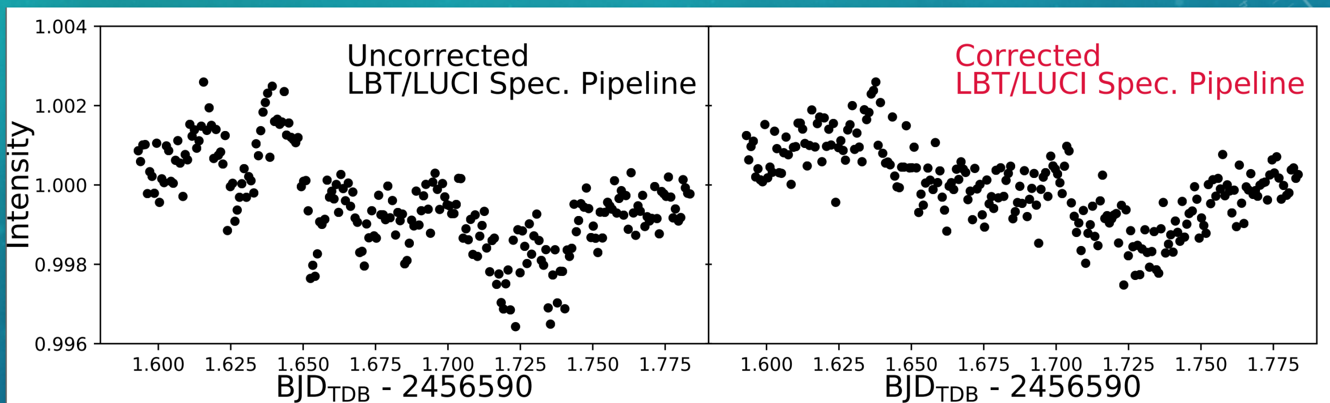
A GP regression gives a +/-94 ppm broadband eclipse measurement

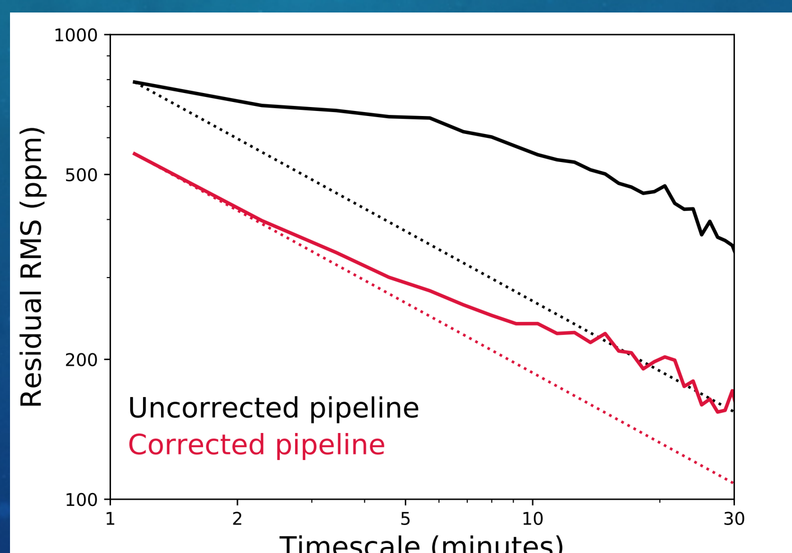


We measure the eclipse spectrum at R~50 and a precision of 135 ppm

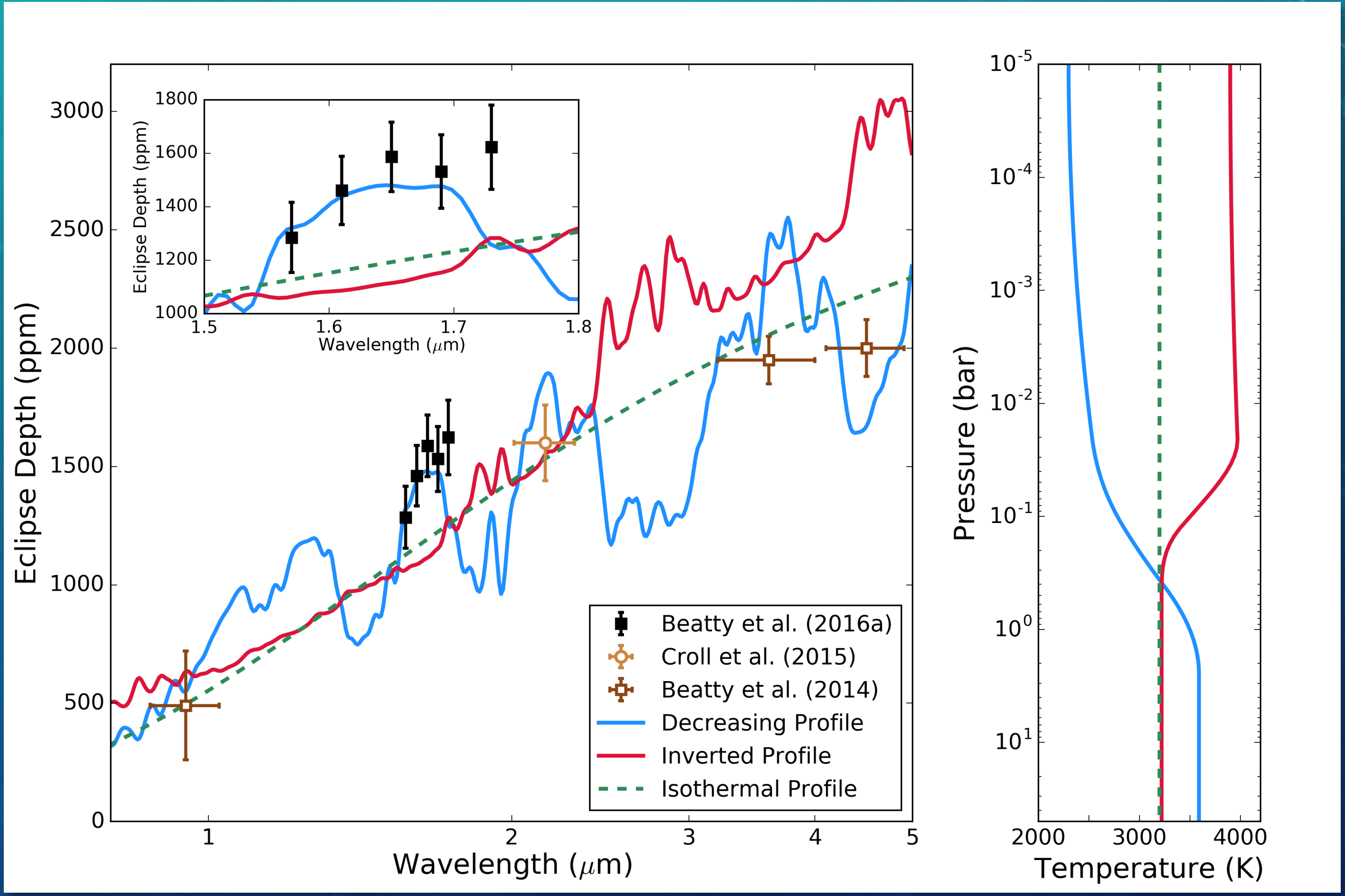


Both measurements rely on a detailed spectrophotometric pipeline we've developed to work with LUCI's H2RG detectors



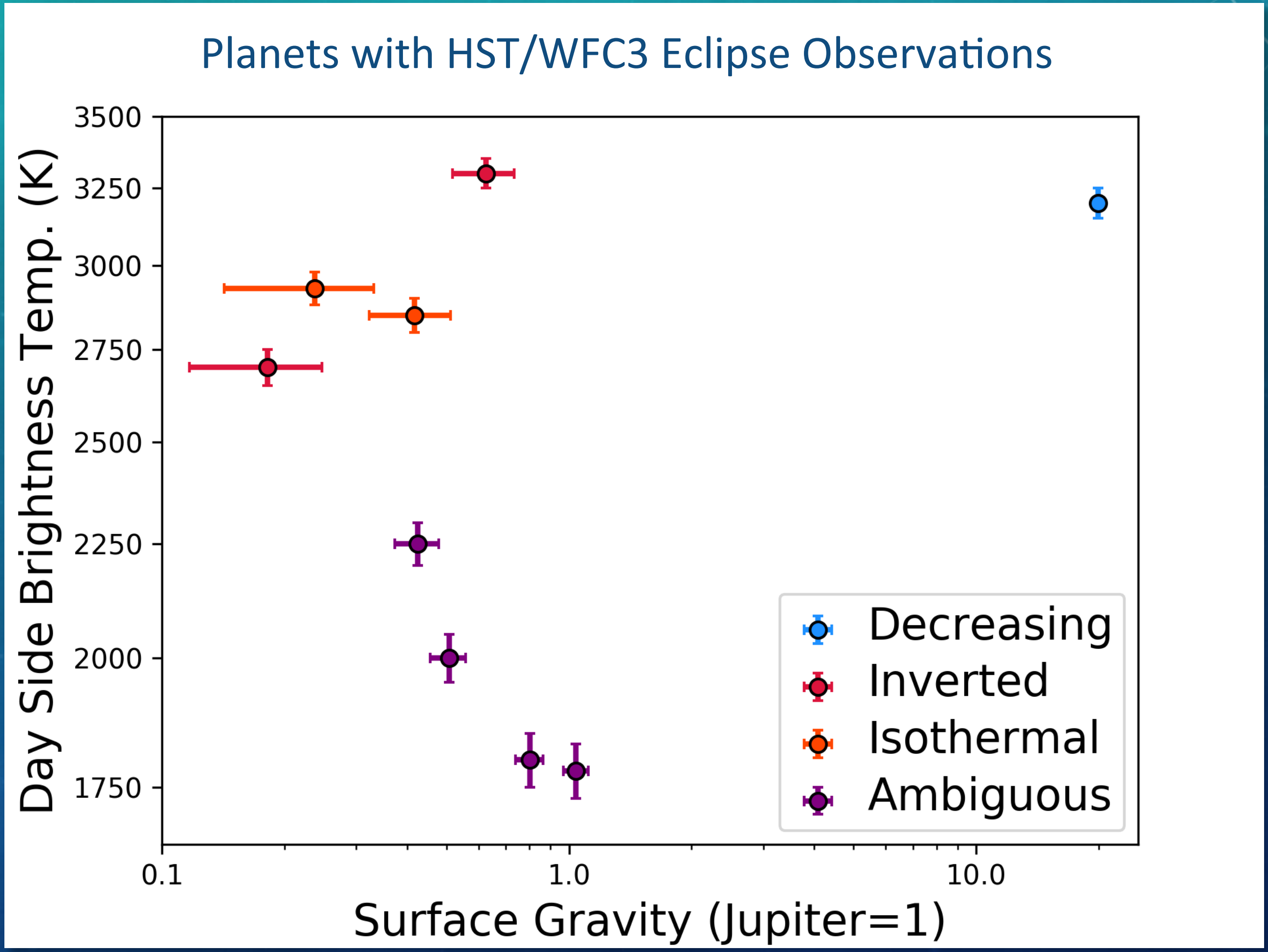


The dayside temperature profile of KELT-1b is monotonically decreasing

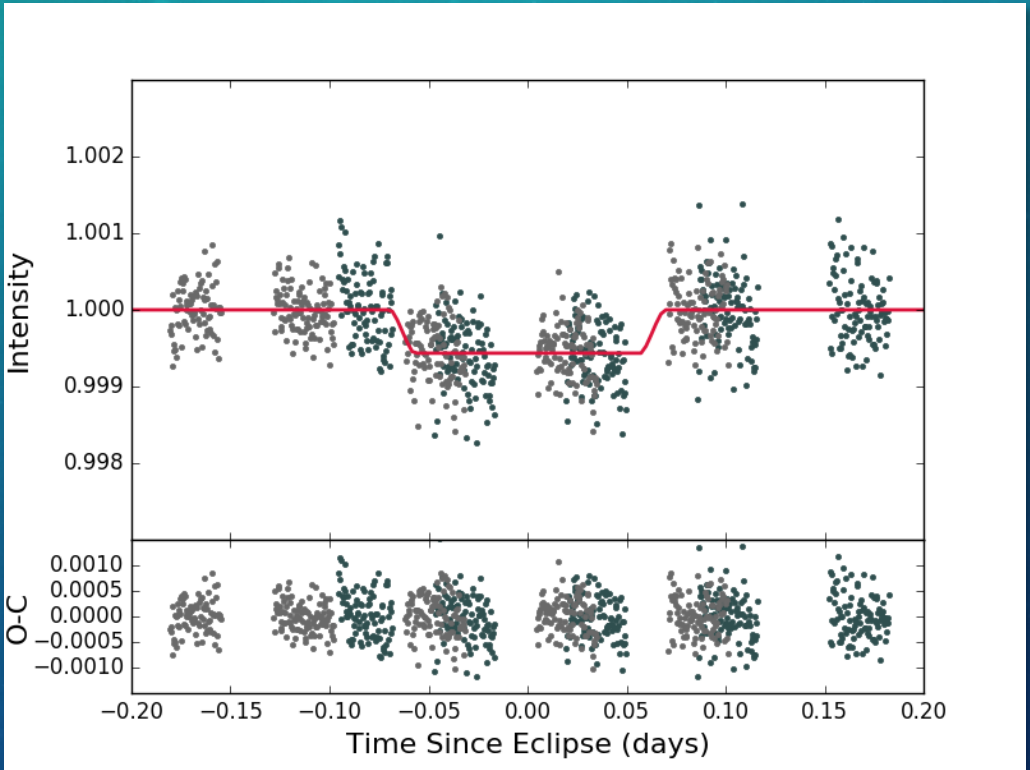


Beatty et al. (2016a)

The high surface-gravity of KELT-1b plays a significant role in its atmospheric properties

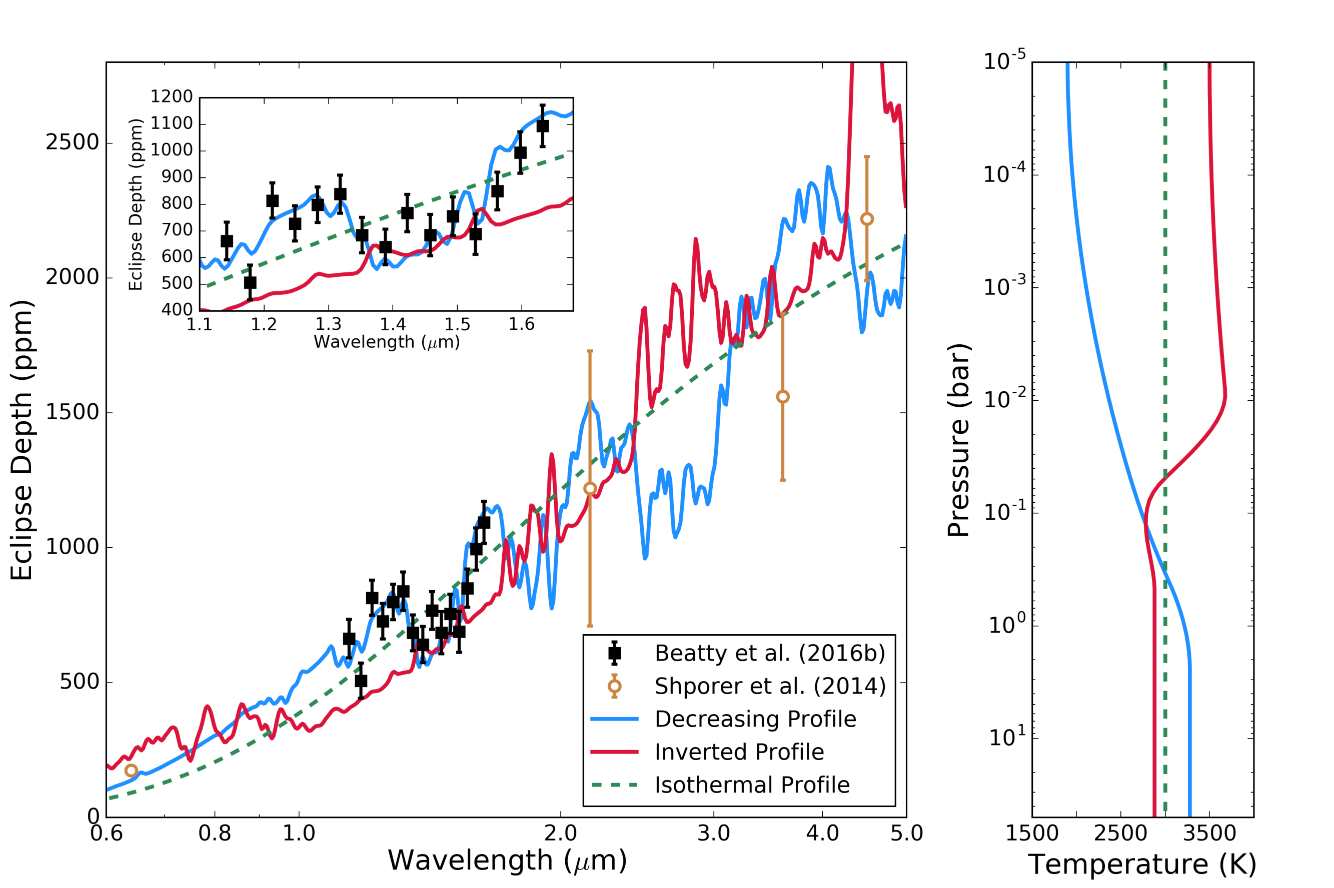


We also observed an HST/WFC3 eclipse of the 6.5 Jupiter-mass planet Kepler-13Ab



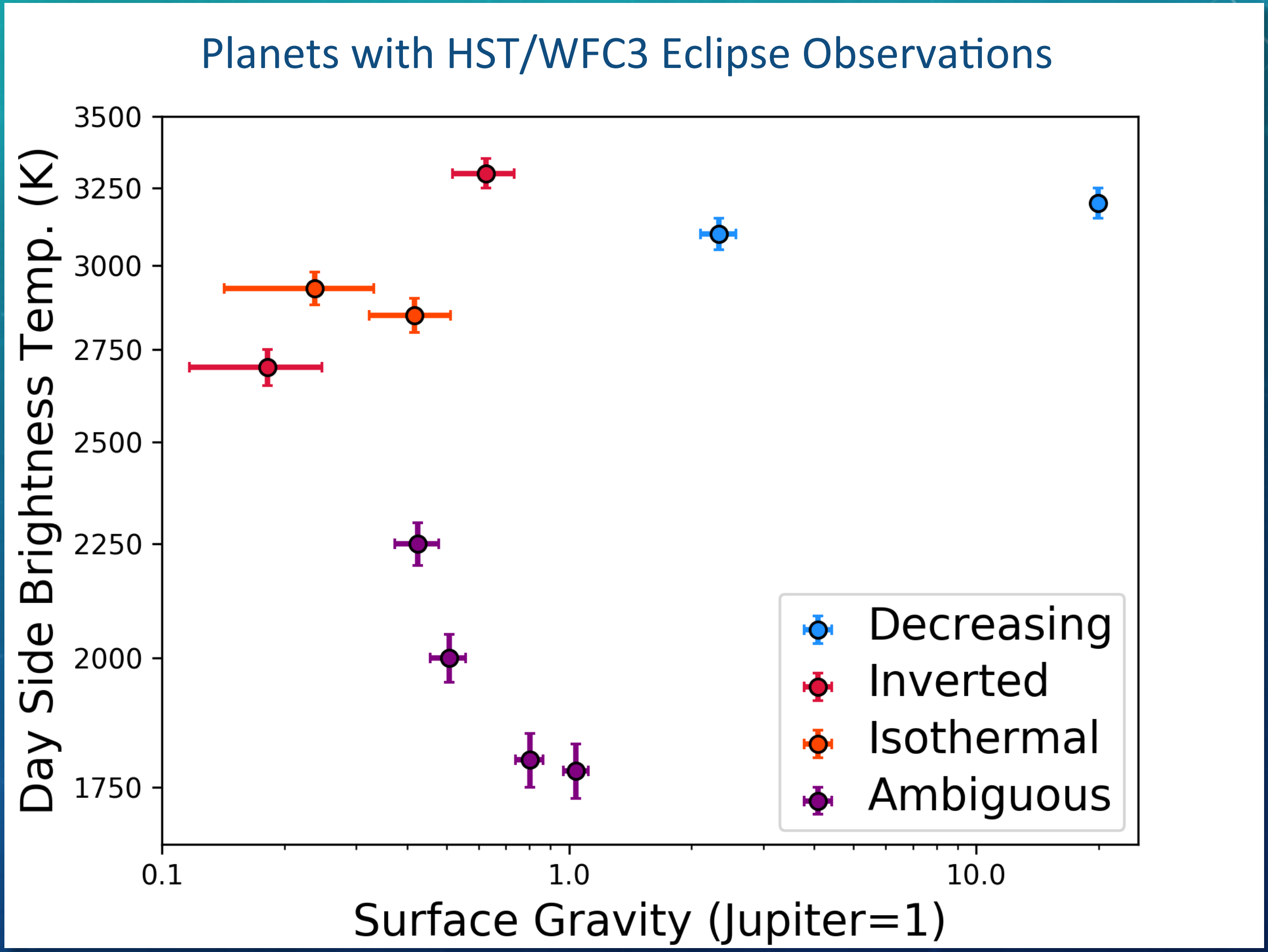
Beatty et al. (2016b)

The eclipse spectrum we measure also indicates a monotonically decreasing temperature

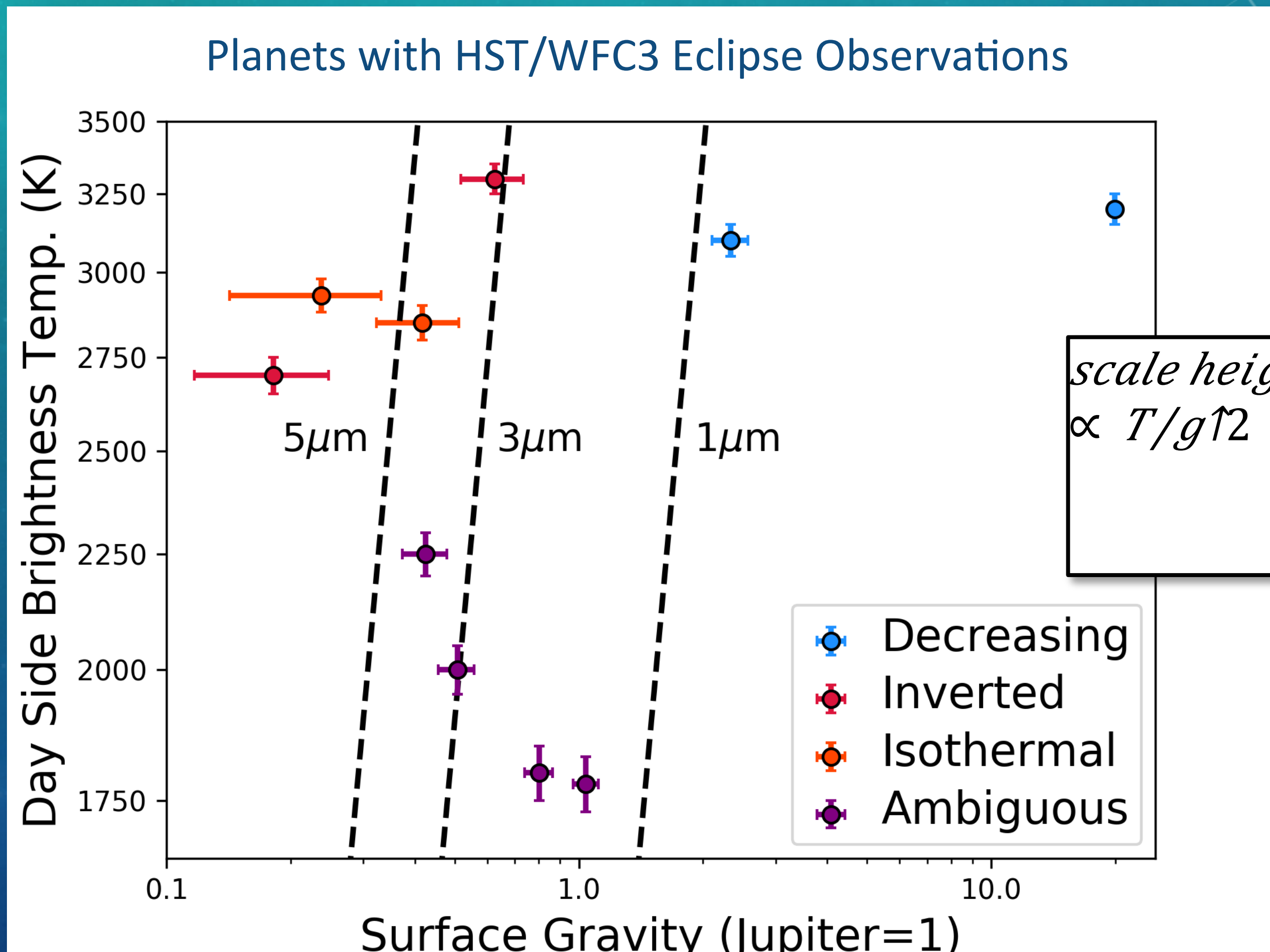


Beatty et al. (2016b)

In planets, high surface gravity also plays a clear role in setting the atmospheric properties

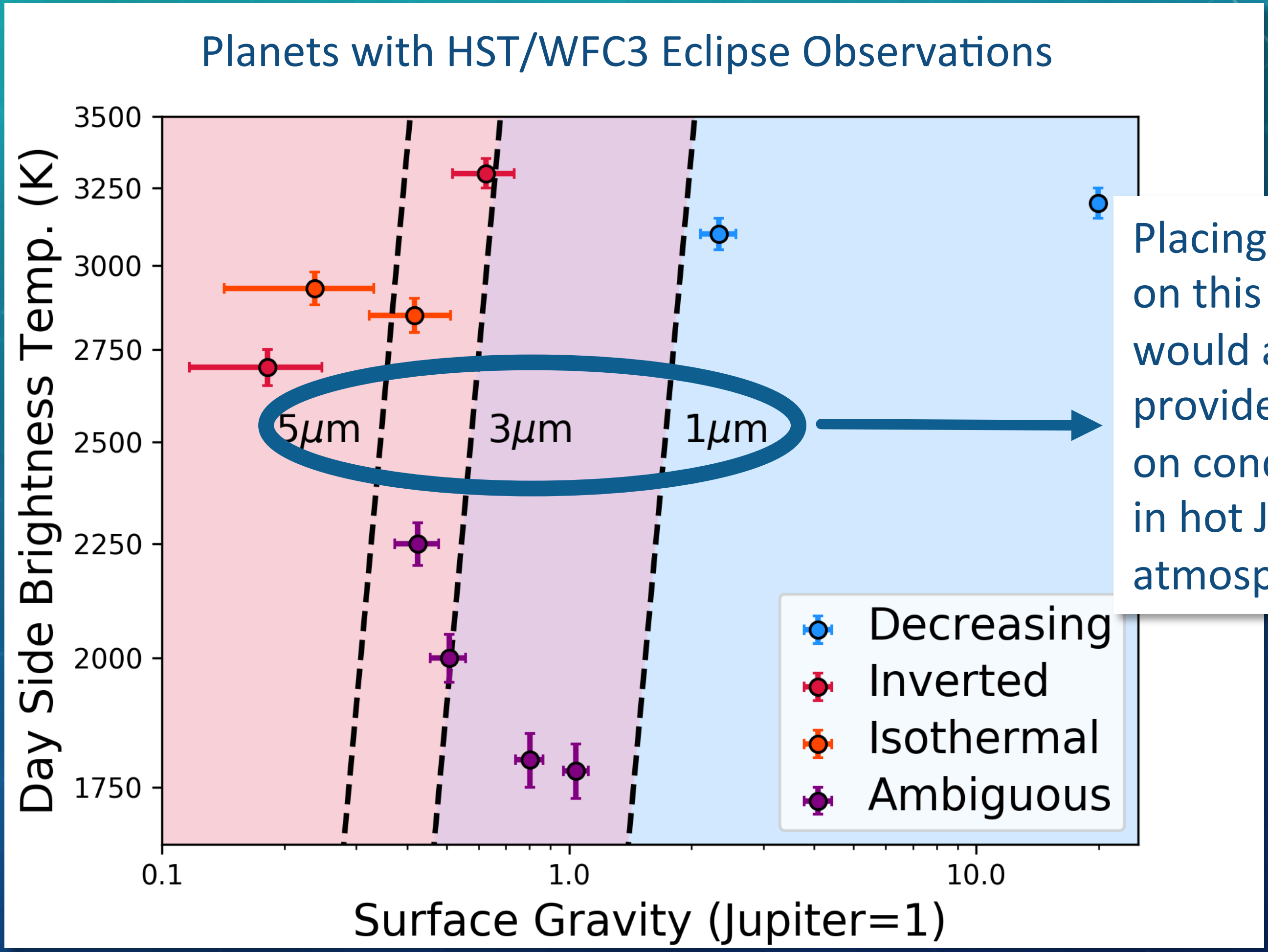


A toy model based on Parmentier et al. (2013), shows where the atmospheres will clear



scale height (H)/termin
∝ *T/g*↑2 *a*↑2

The transition in atmospheric structure could be explained as the signature of cold-traps



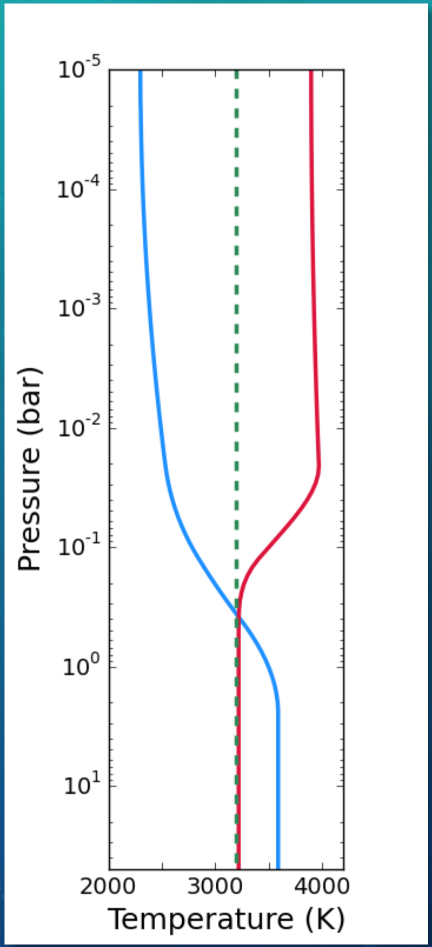
Placing more planets on this diagram would allow us to provide a constraint on condensate sizes in hot Jupiters' atmospheres

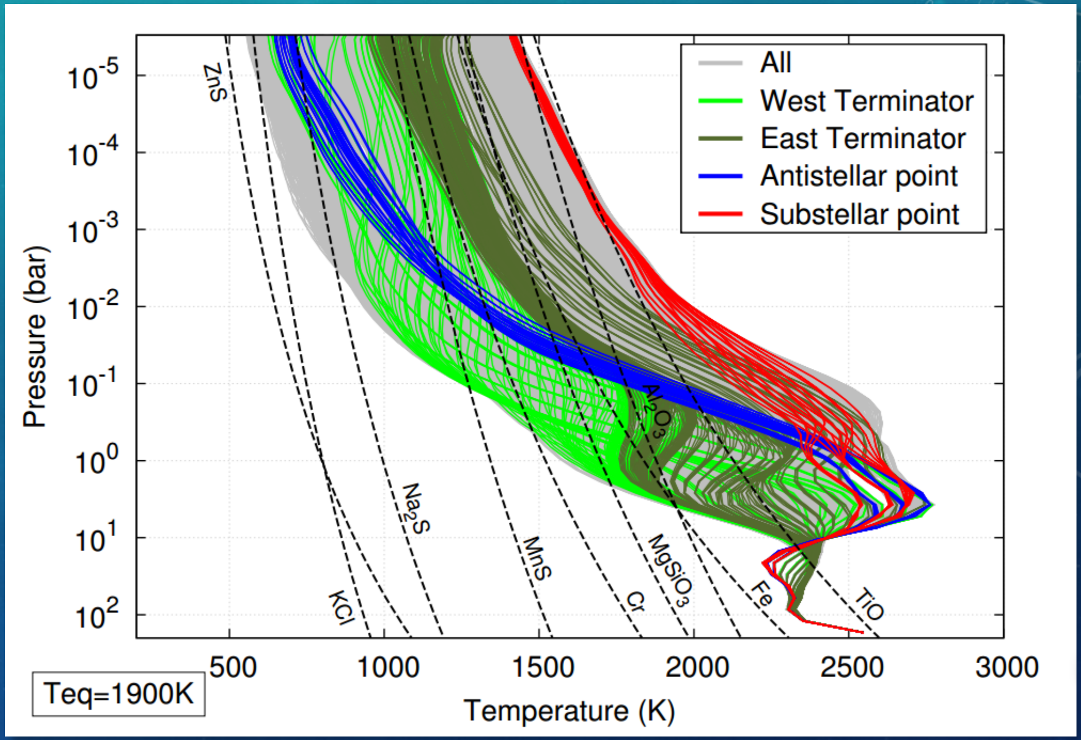
Beatty et al. (2016b)

Know Thy Star, and Know Thy Planet

This year we're on track to observe six more systems with LBT/LUCI

The other aspect is how the temperature structure changes from the day to night

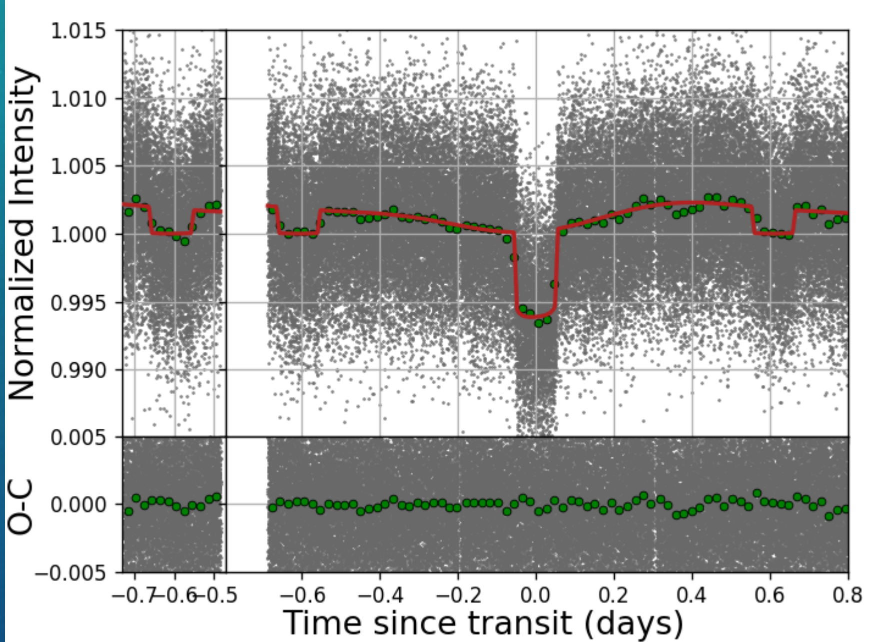


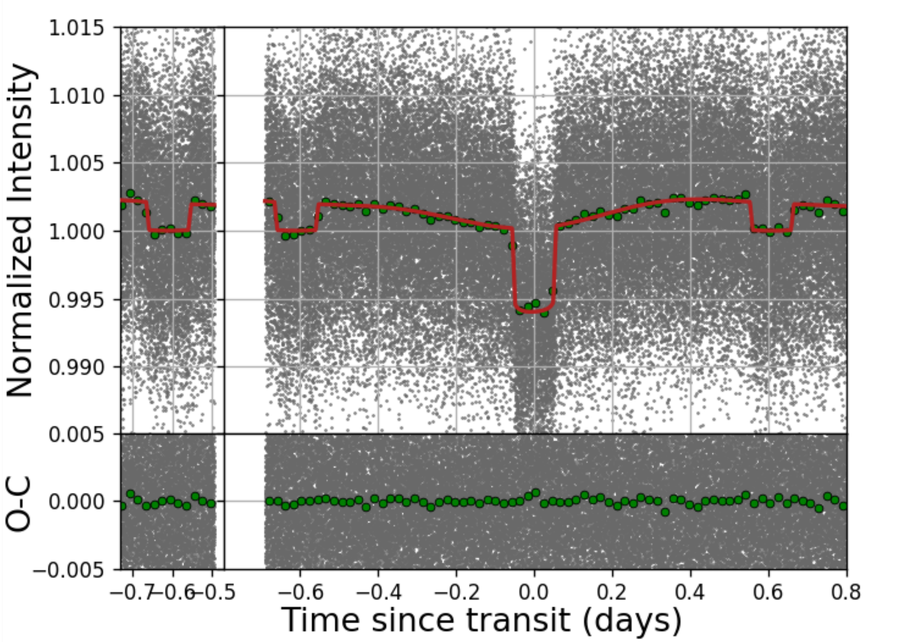


Spitzer phase curves of KELT-1b

3.6 µm

4.5 µm





Summary:

- Know thy star: very hot Jupiters around 3000K show atmospheric temperature inversions. The high amount of stellar irradiation helps set the temperature structure.
- We can observe precise exoplanet eclipse spectra from the ground in the NIR.
  - 135ppm and R~50; effectively HST-quality results.
- Eclipse spectra show a transition in temperature structure going from low to high surface gravity, which match the predicted observational signatures of “cold-trap” processes.
  - Since cold-trap efficiency depends upon condensate size, this could allow us to map out the condensate sizes in these atmospheres for the first time.
- **For atmospheres, we need to know thy star, and thy planet.**