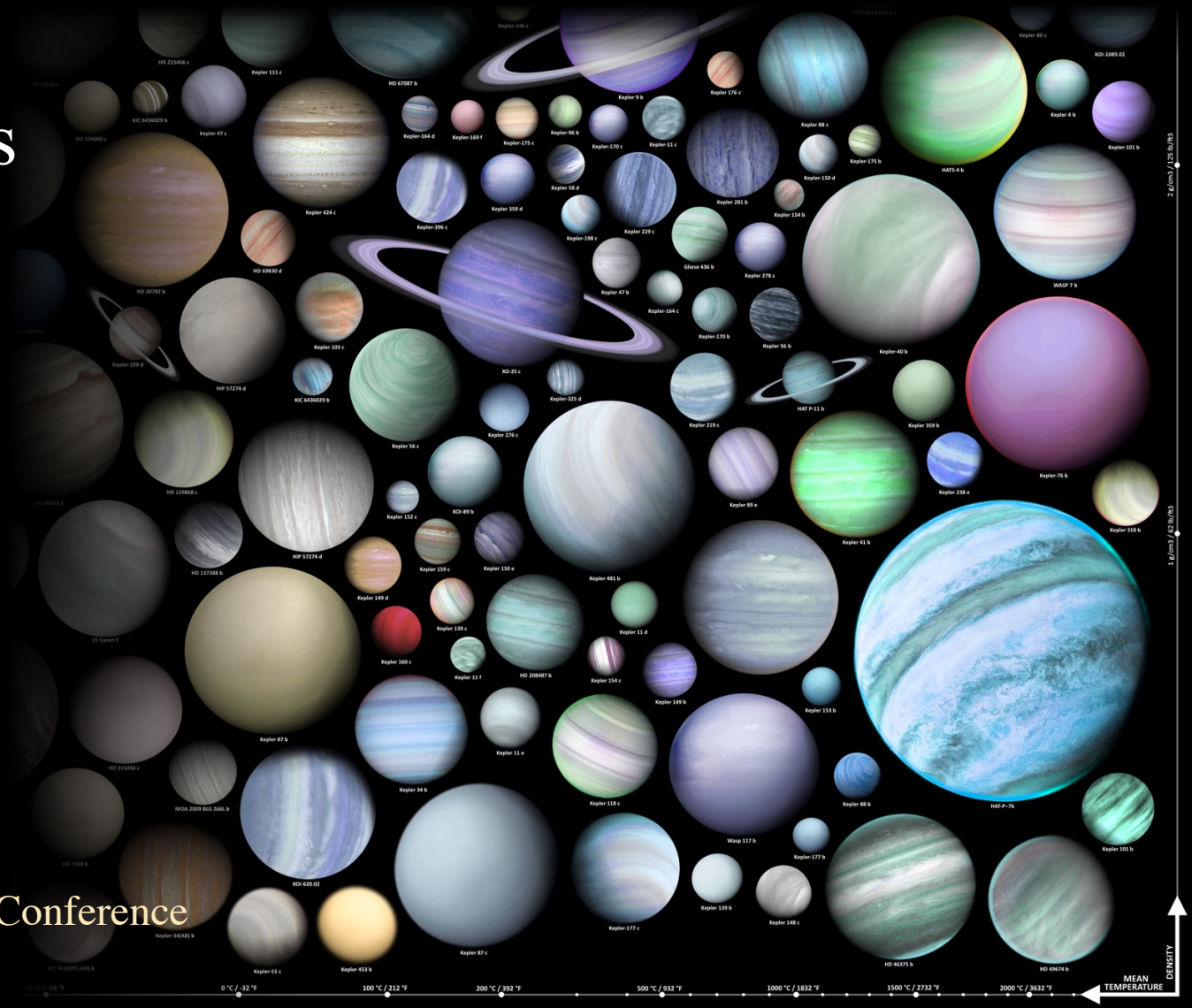
A population study of hot Jupiter atmospheres

Angelos Tsiaras

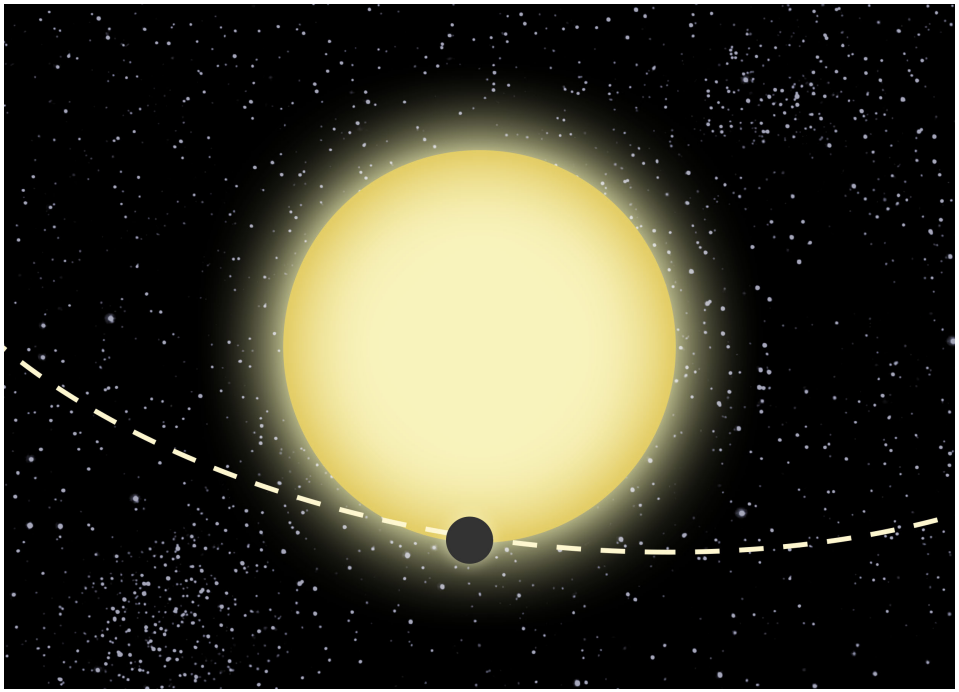
UCL

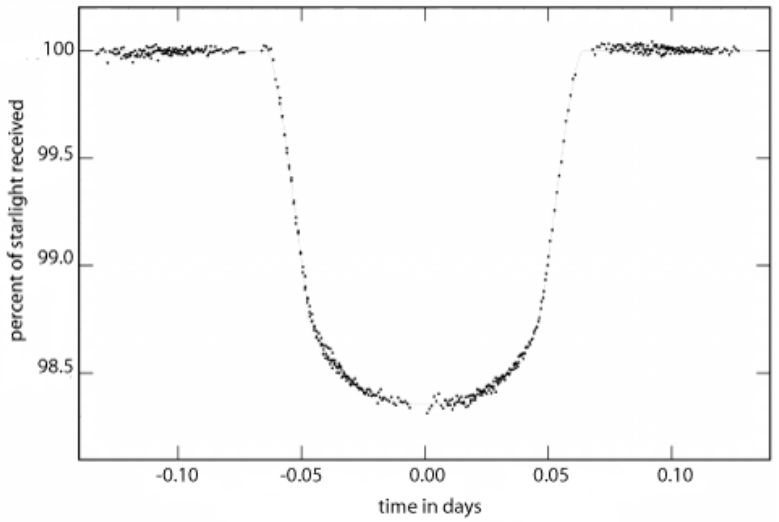


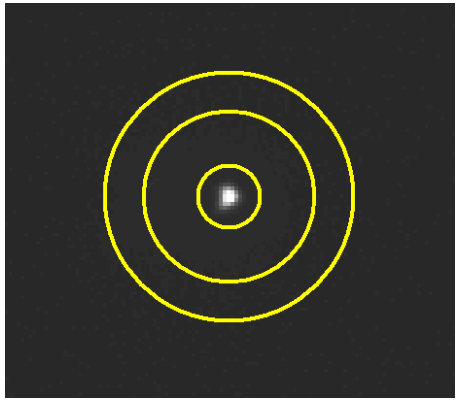
erc

13th Hellenic Astronomical Conference
Herakleion, 5th July 2015

Transits – photometry

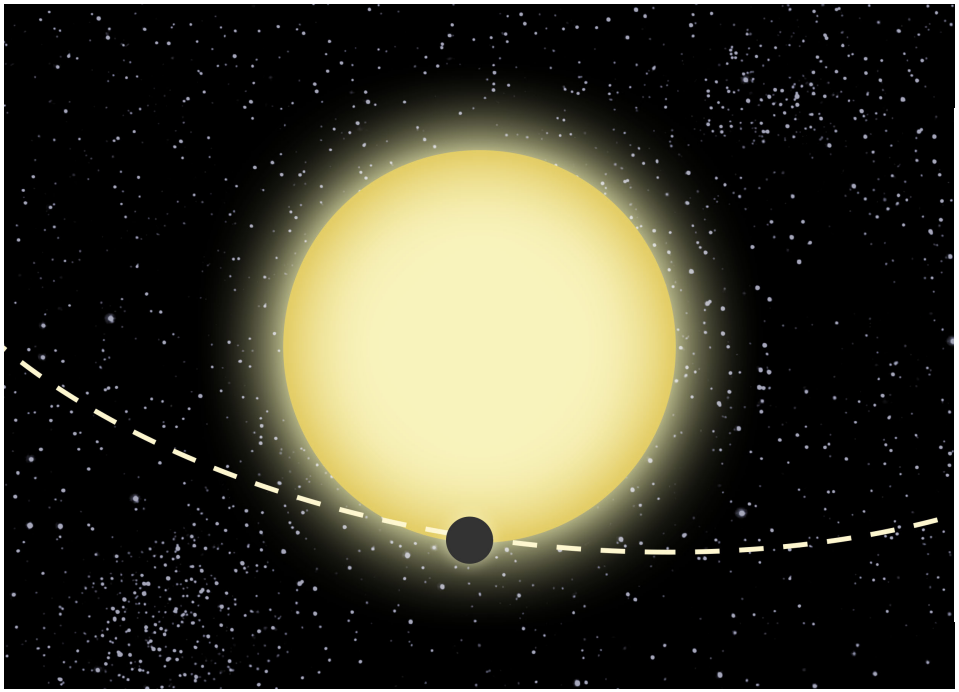


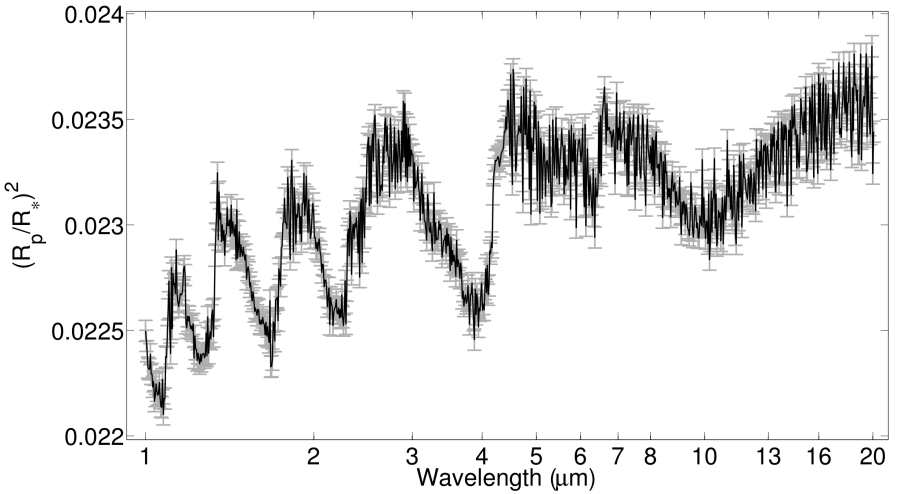




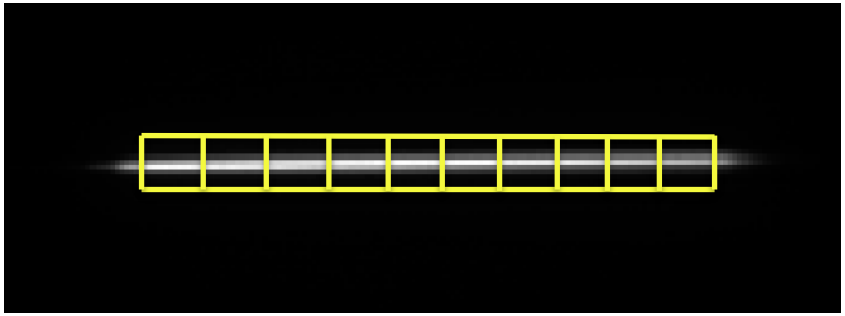
- ✓ Detection
- ✓ Orbital parameters
- ✓ Size

Transits – spectro-photometry

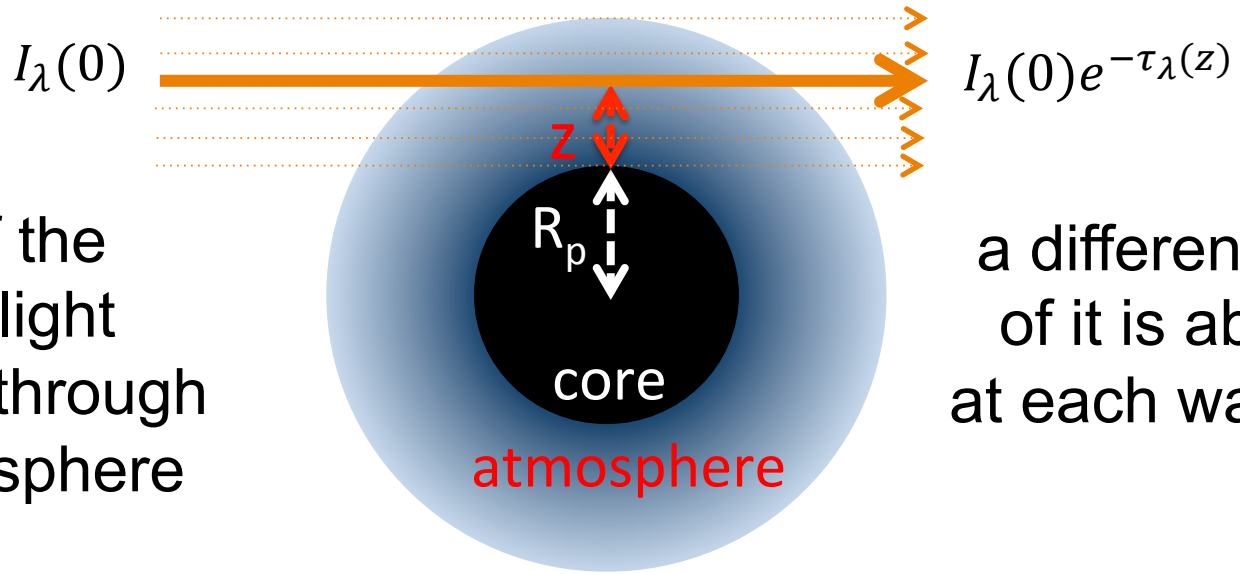




Waldmann et al. 2015



Transmission – fundamentals



part of the stellar light is filtered through the atmosphere

a different portion of it is absorbed at each wavelength

$$\tau_{\lambda,m}(z) = 2\int_0^{l(z)} \varsigma_m(\lambda)\chi_m(z)\rho_N(z)dl$$

$$\tau_\lambda(z) = \sum_{m=1}^{N_m} \tau_{\lambda,m}(z)$$

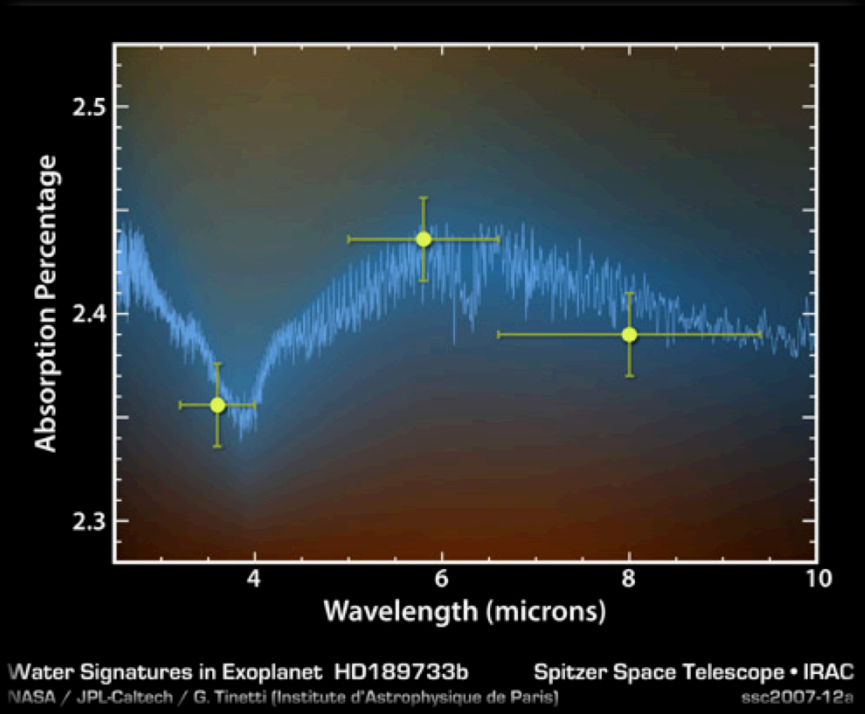
$$\alpha_\lambda = 2\int_0^{z_{max}} (R_p + z)\left(1 - e^{-\tau_\lambda(z)}\right)dz$$

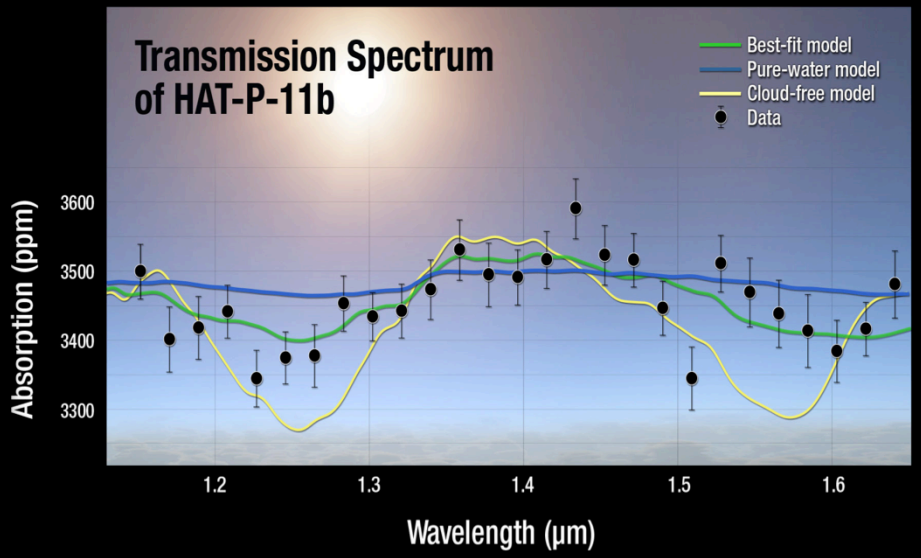
$$\delta_\lambda = \frac{R_p^2 + \alpha_\lambda}{R_*^2} \equiv p^2(\lambda)$$

Waldmann et al. 2015

Why is the atmosphere important?

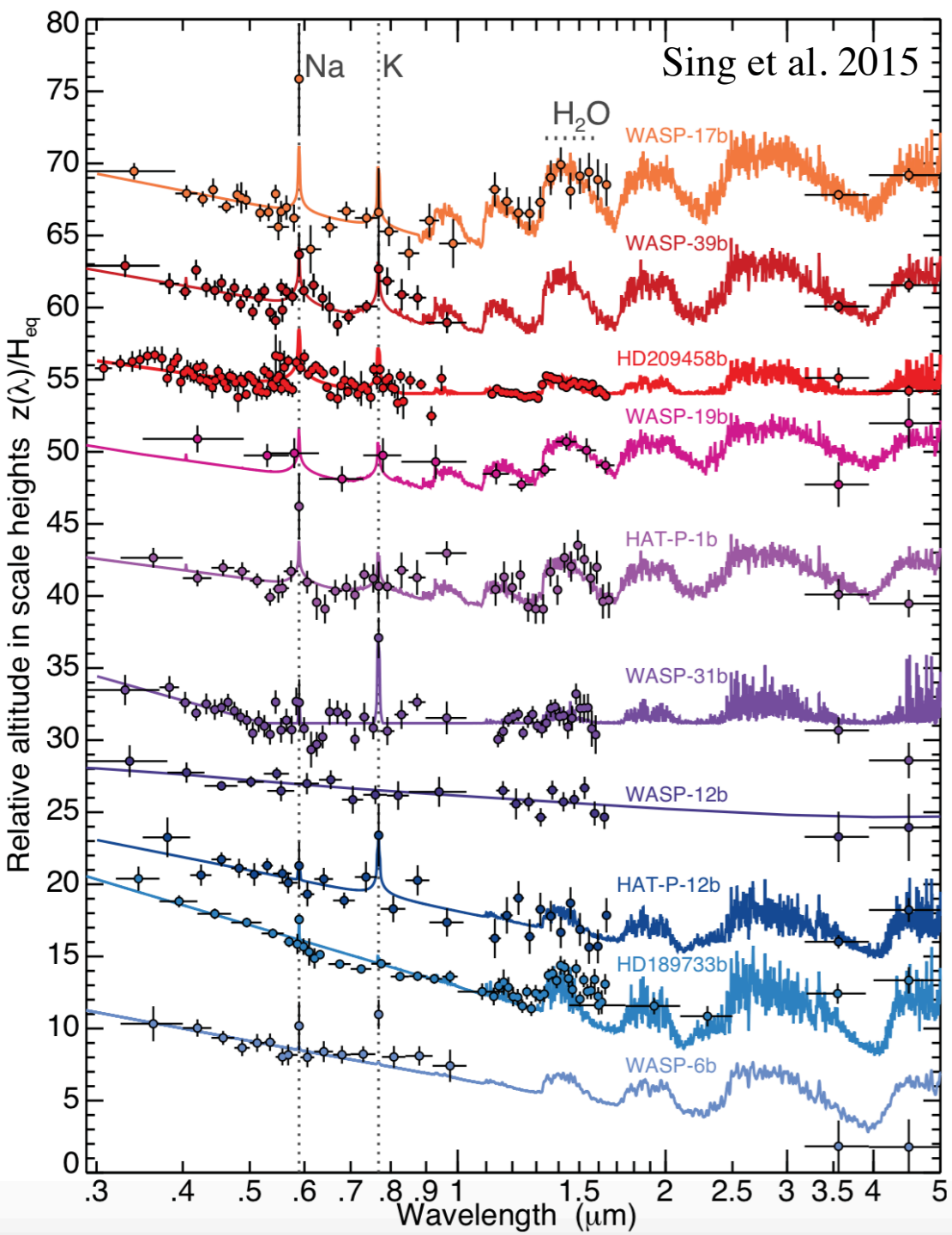
HST – Improving observations





Hot Jupiters

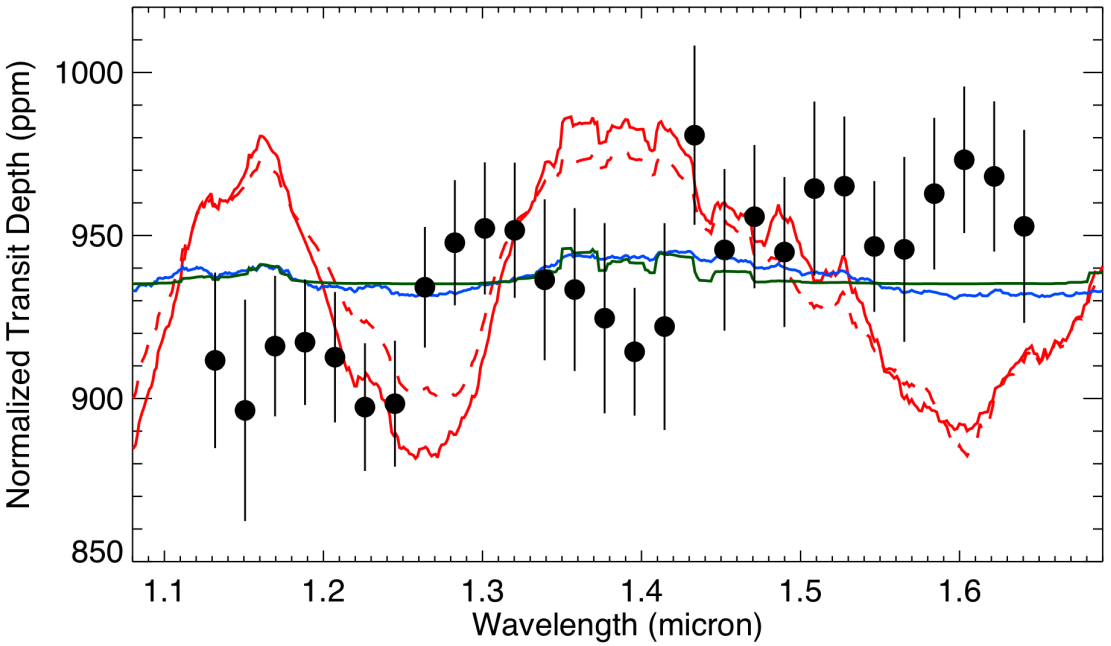
H_2O + clouds



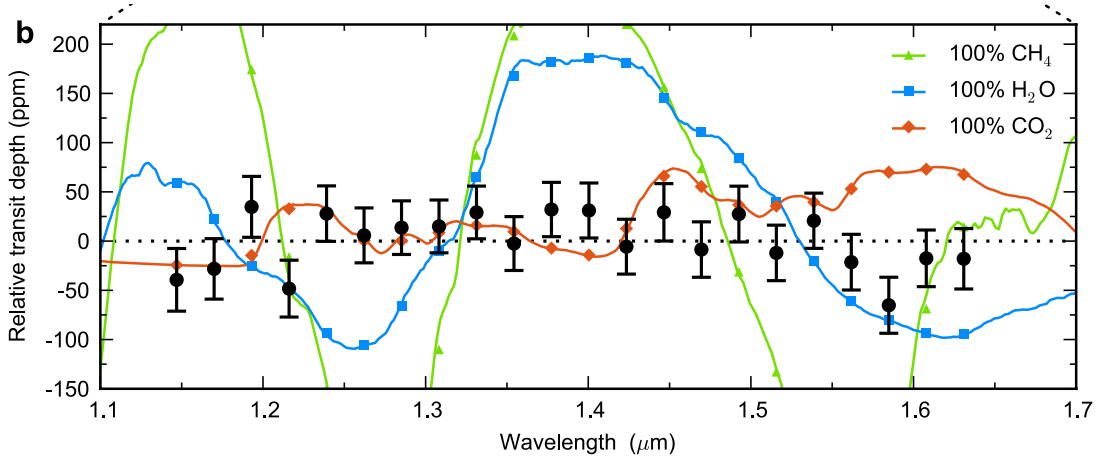
Super Earths

no atmosphere ?

clouds ?

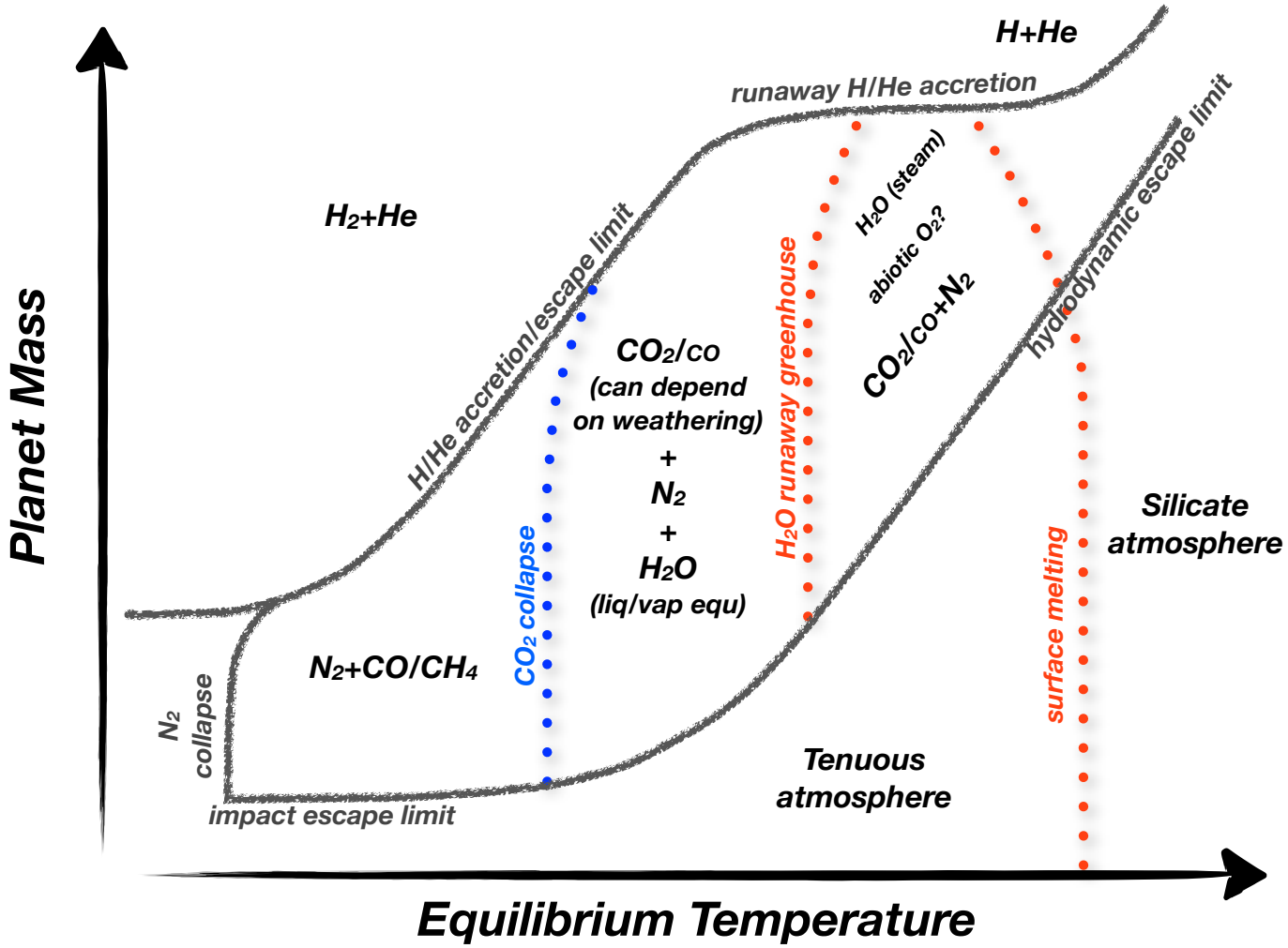


HD97658 b - Knutson et al. 2014



GJ1214 b - Kreidberg et al. 2014

Main scope - Planetary “H-R”



Forget & Leconte 2013

Iraclis - data analysis

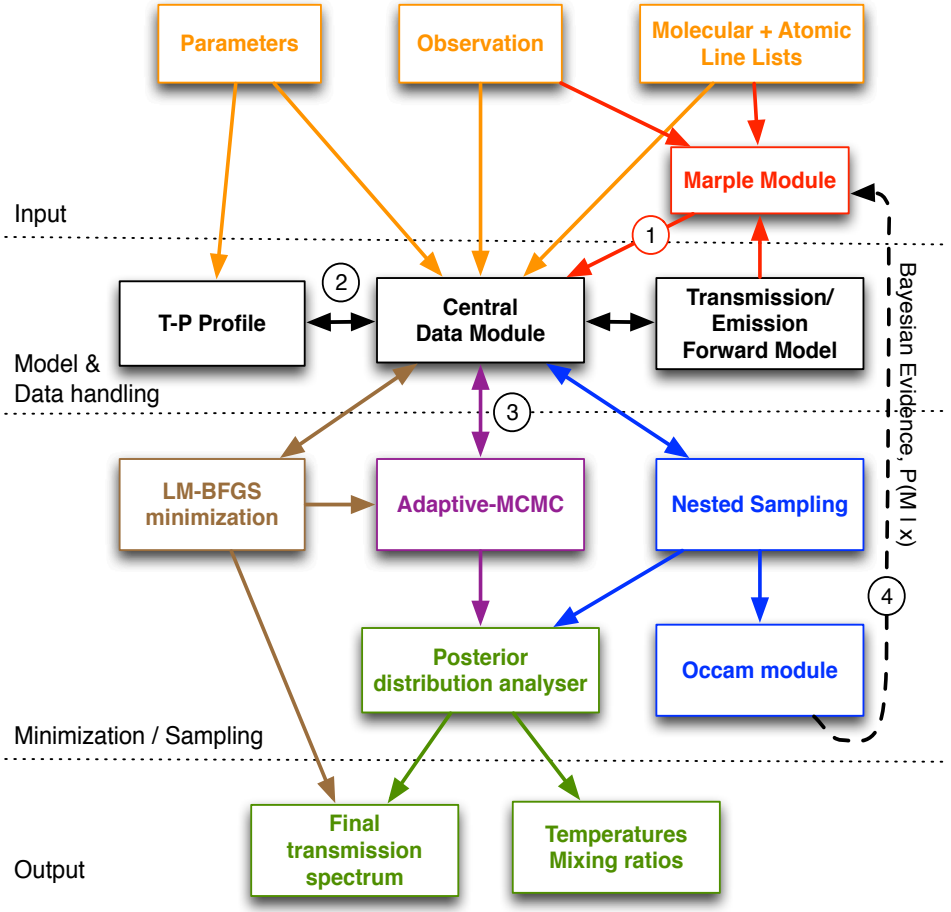
- **Data reduction**
  - Non-linearity, dark current, gain
- **Background correction**
  - Sky background and cosmic rays
- **Position**
  - Horizontal and vertical shifts
- **Calibration**
  - Wavelength and flux (flat-field) calibration
- **Extraction**
  - Aperture calculation and fractional pixels estimation
- **Fitting**
  - MCMC fit for the transit, systematics and planetary spectrum

Tsiaras et al. 2016

Tau-REx – spectral retrieval

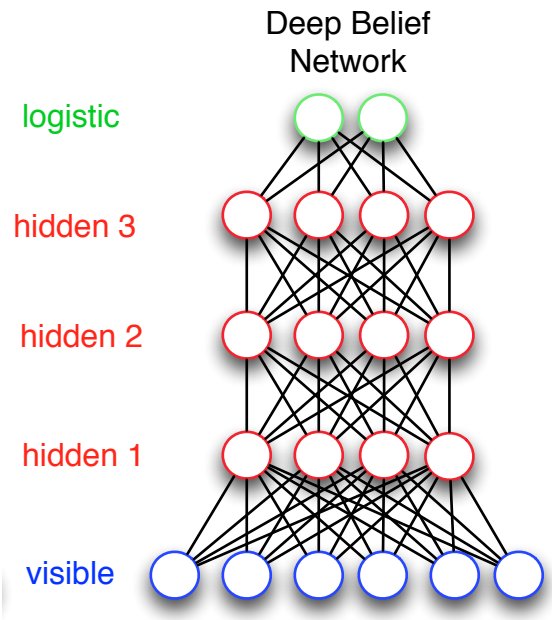
- **Fully Bayesian Retrieval**
  - MCMC
  - Nested Sampling
  - Maximum Likelihood
- **Cross-sections**
  - ExoMol project
- **Pattern recognition**
  - Prior composition selection
- **Full parallelisation for cluster computing**

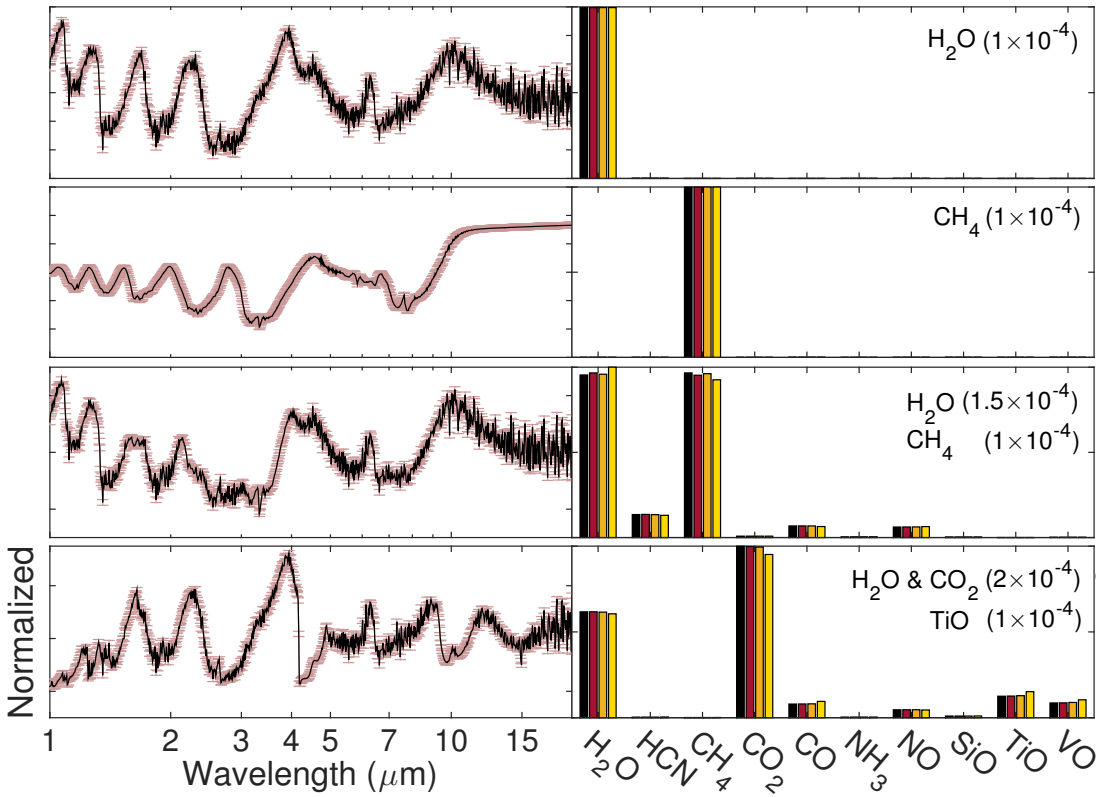
> 25k lines of code



Waldmann et al. 2015a,b

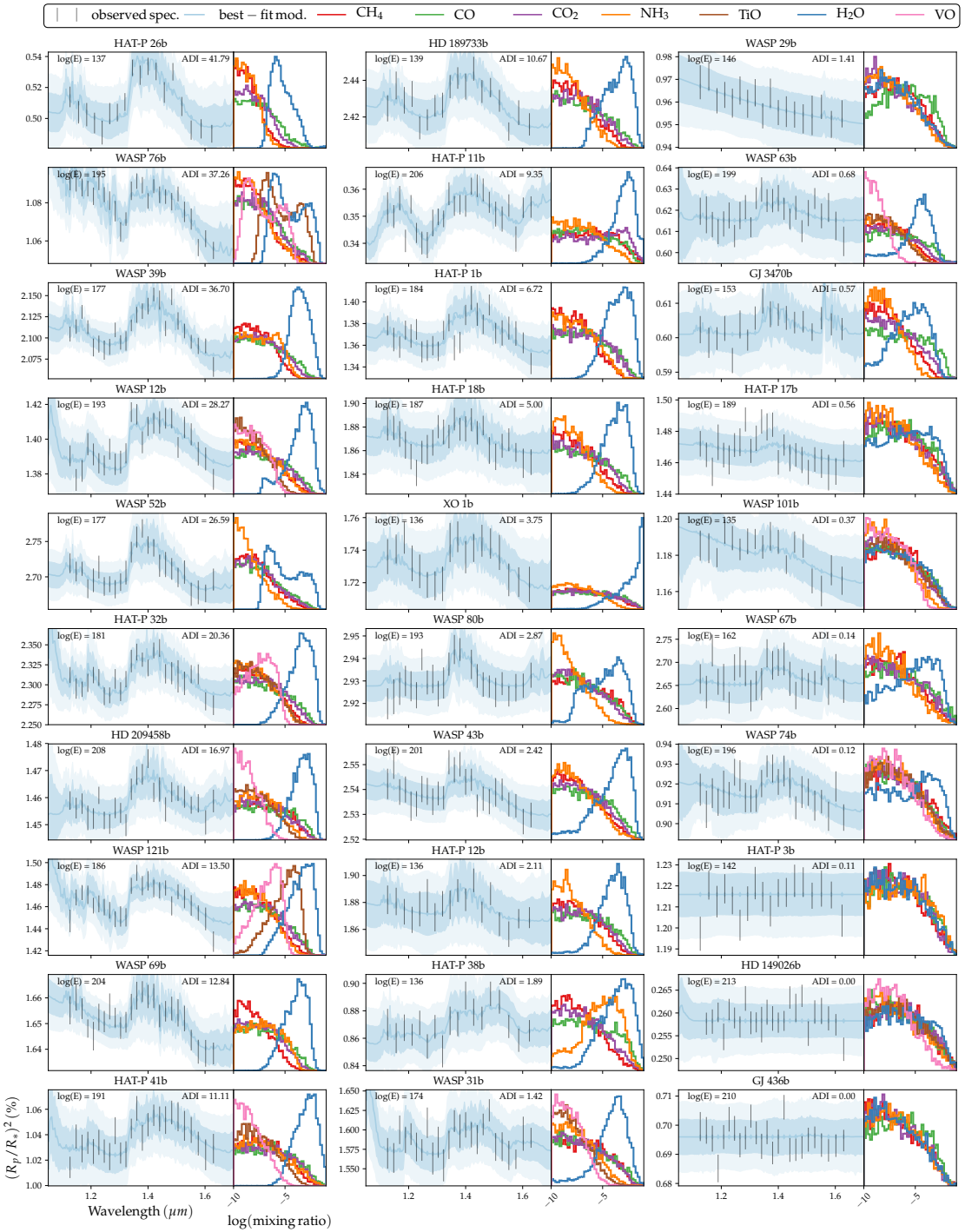
RobERt – spectral recognition AI



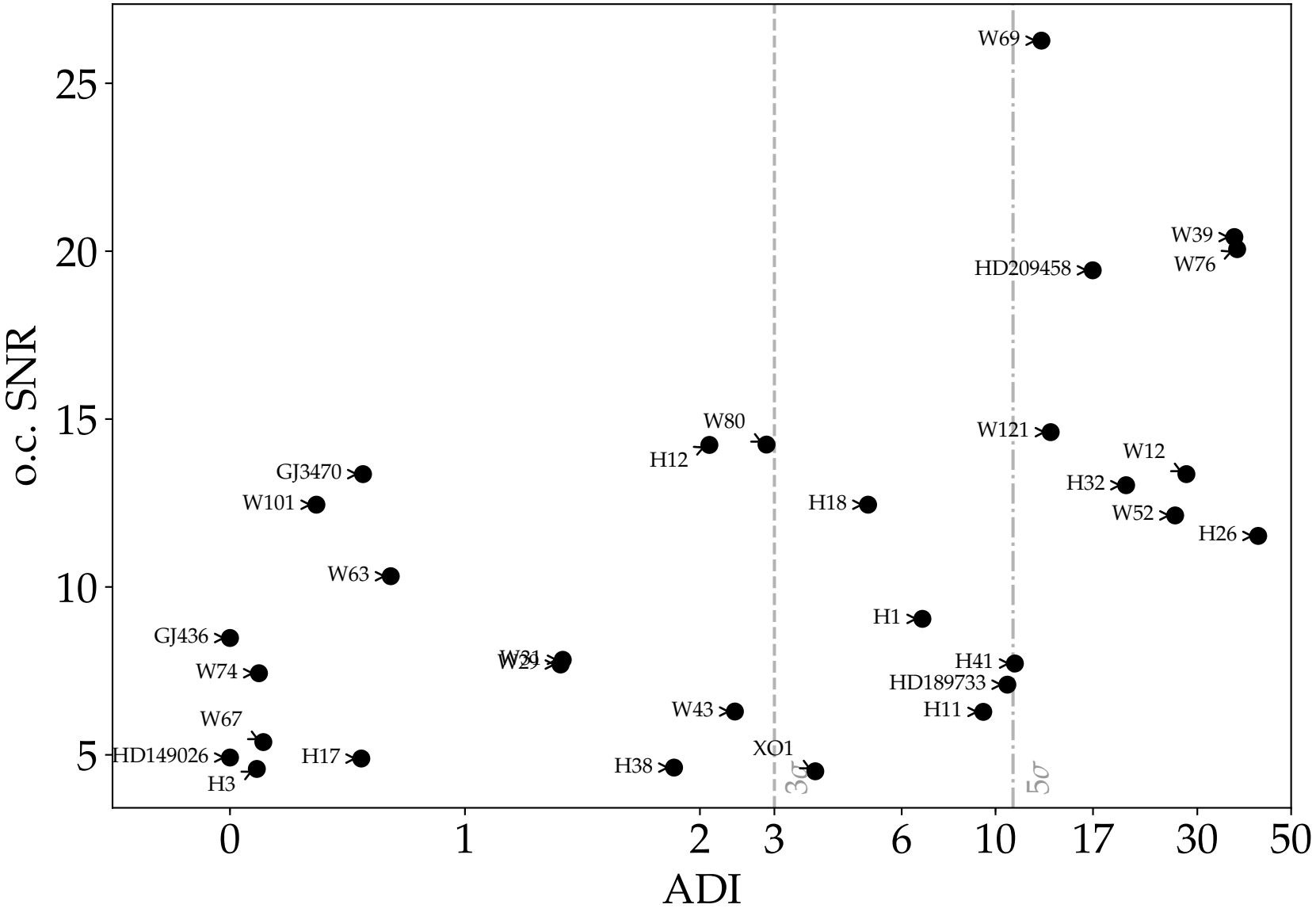


Waldmann et al. 2016

A population of 30 planets



Population study – results



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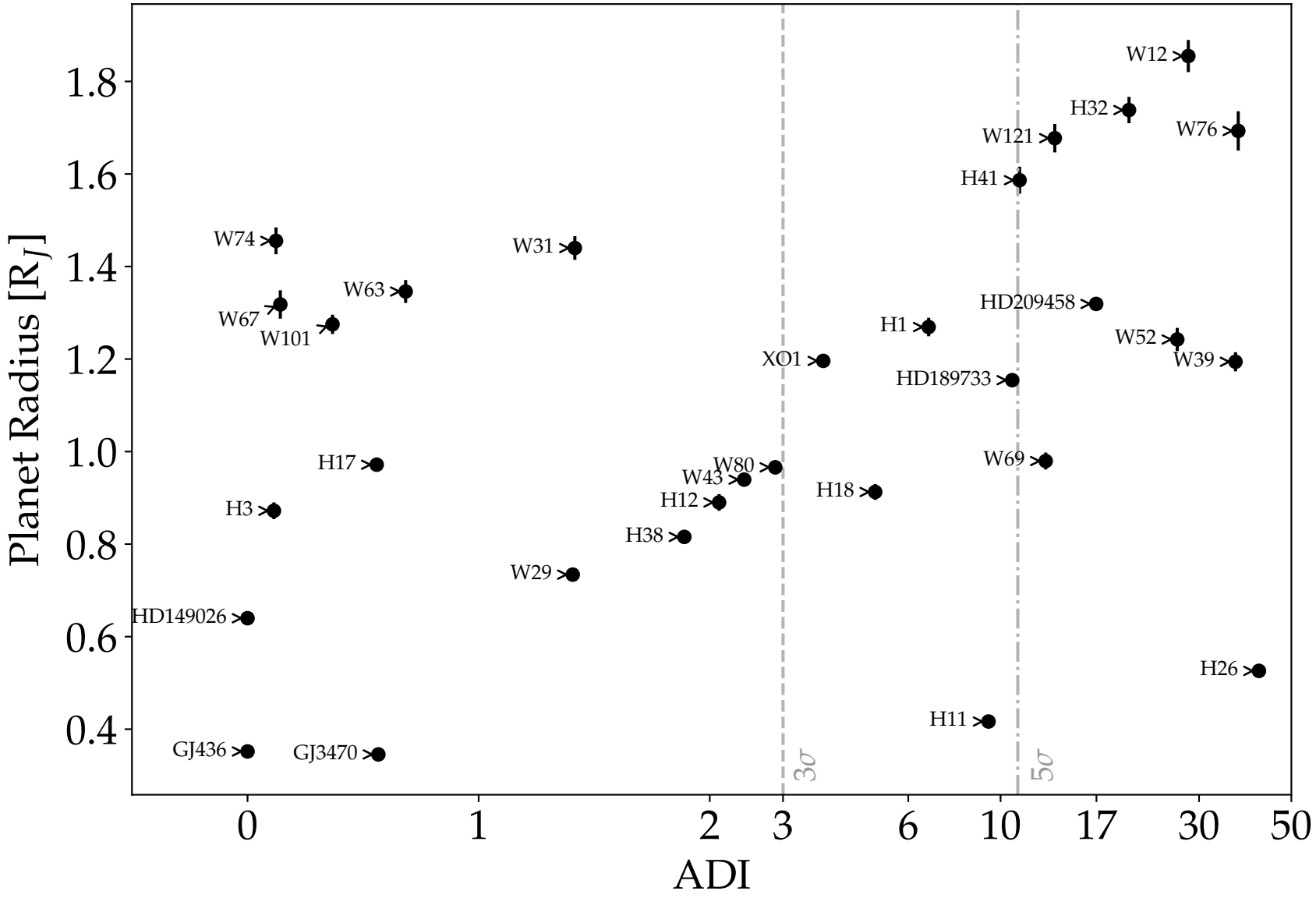

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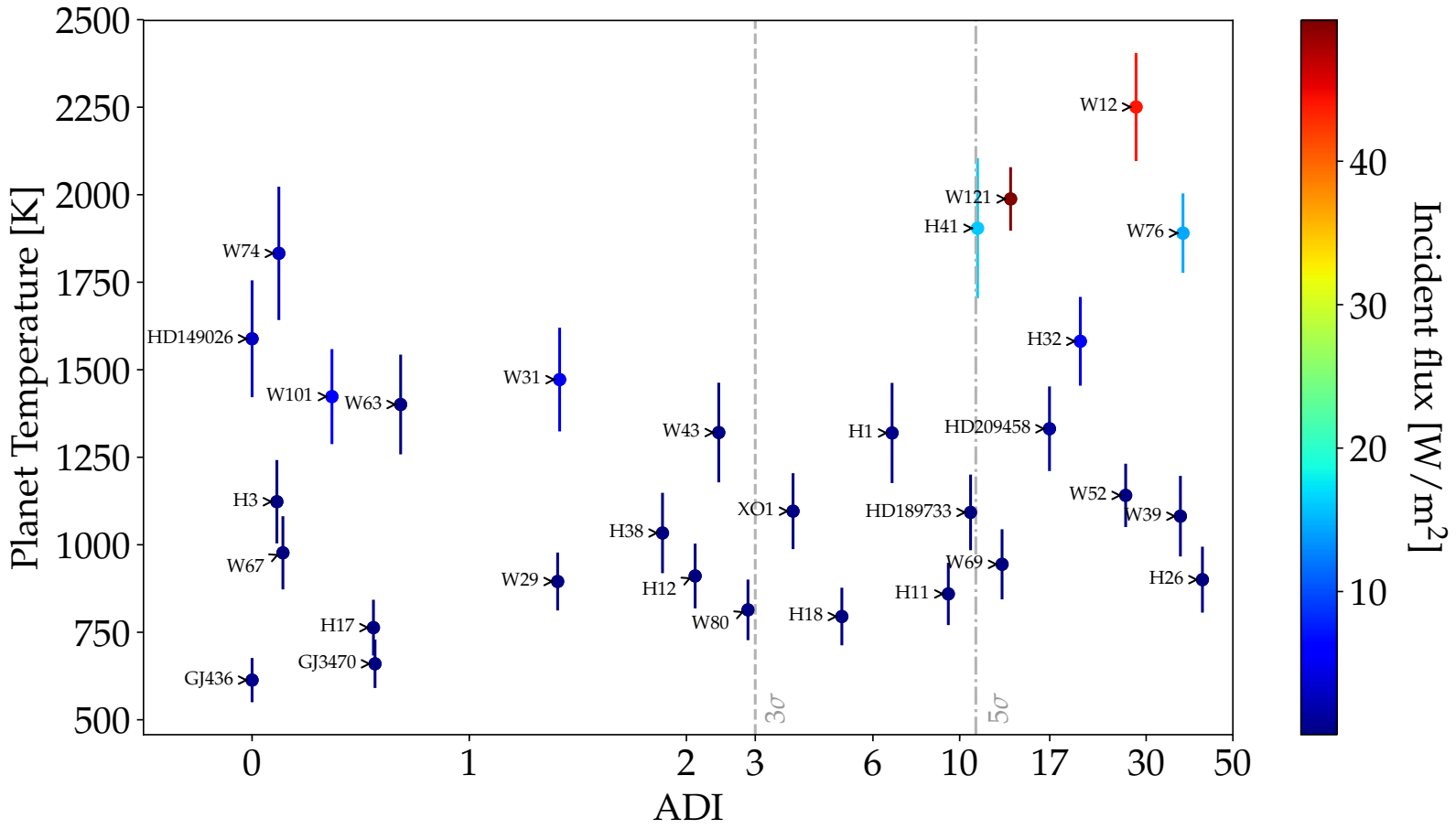
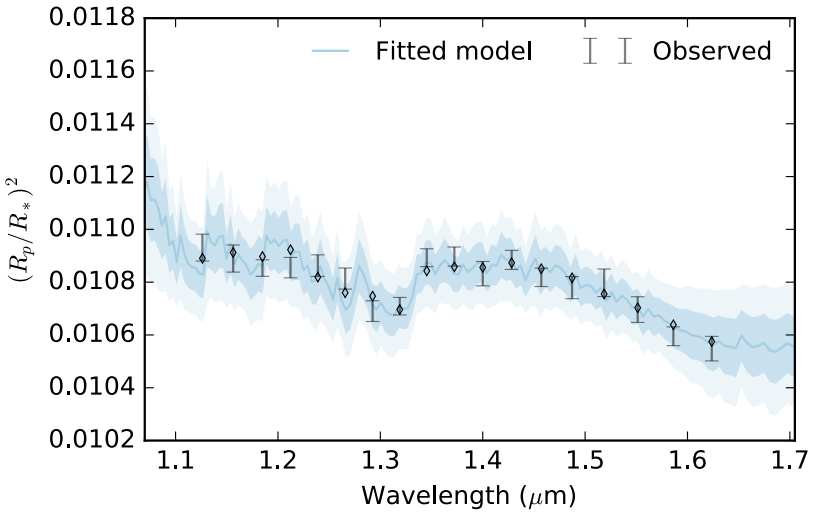
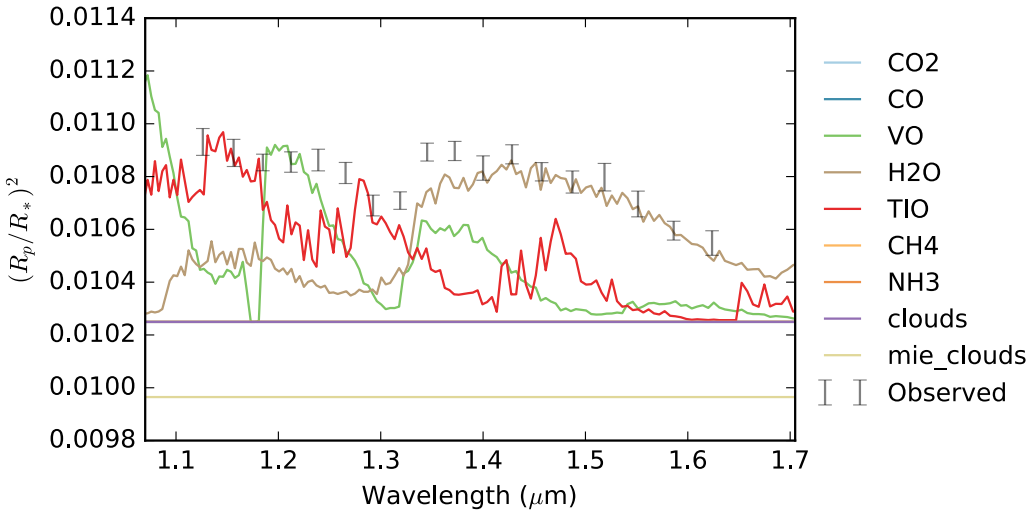


Population study – TiO/VO



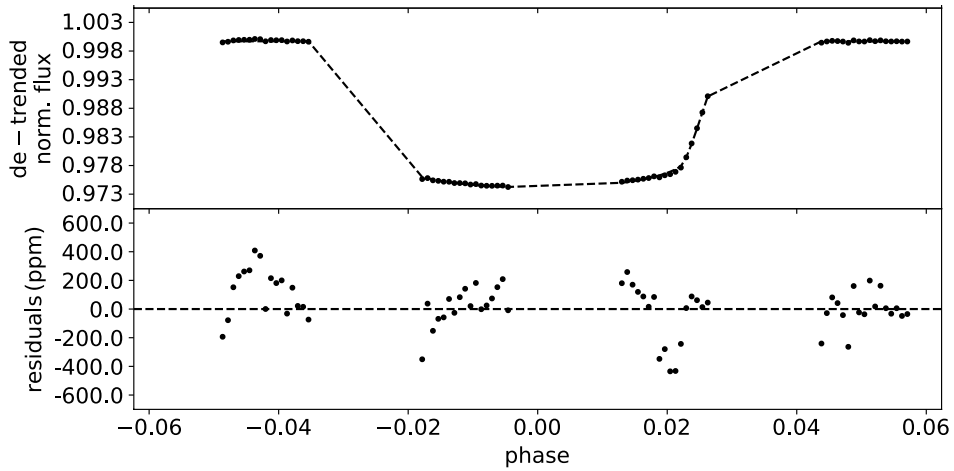


WASP-74 b

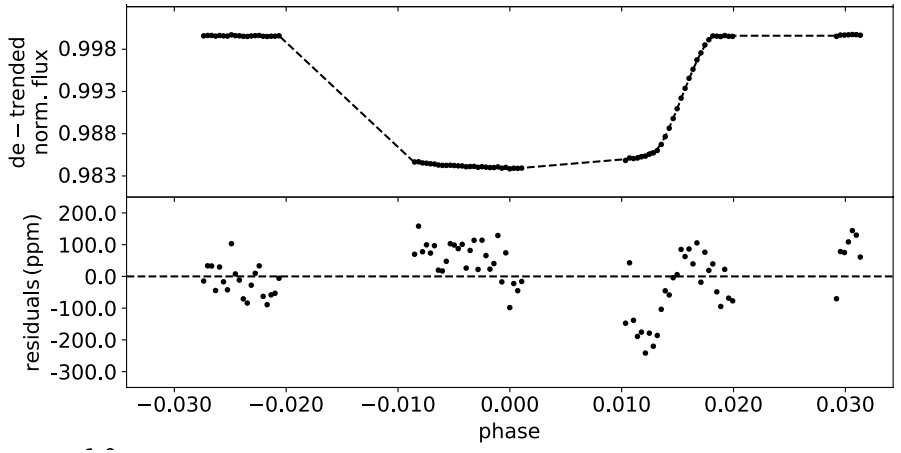
First confident detection (>5σ) of TiO and VO in an exoplnaet

Population study – Limb darkening

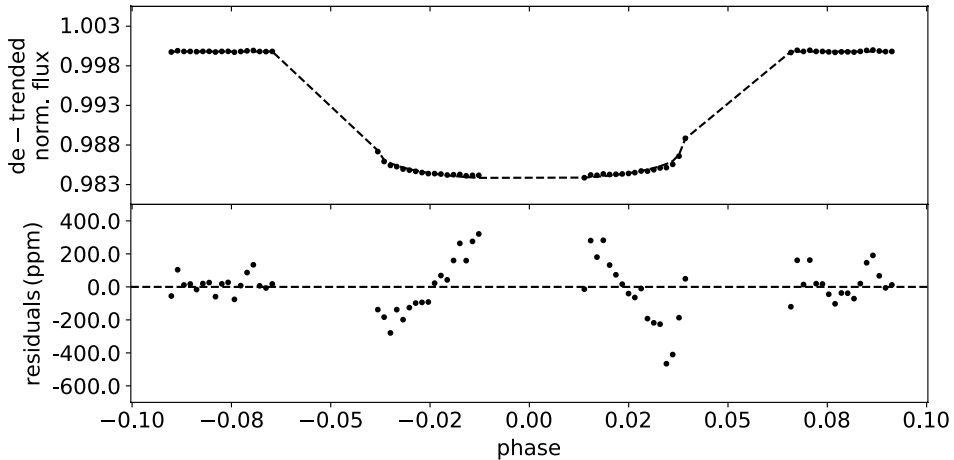
HAT-P-32 b



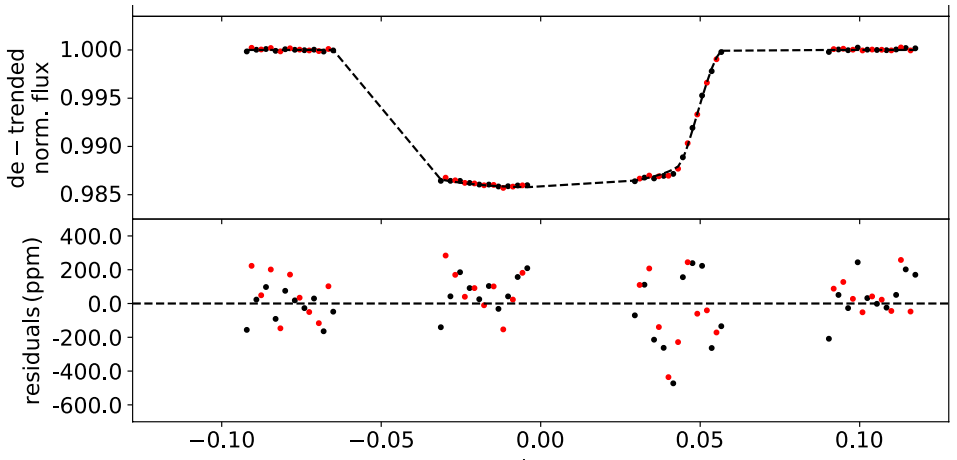
HD 209458 b



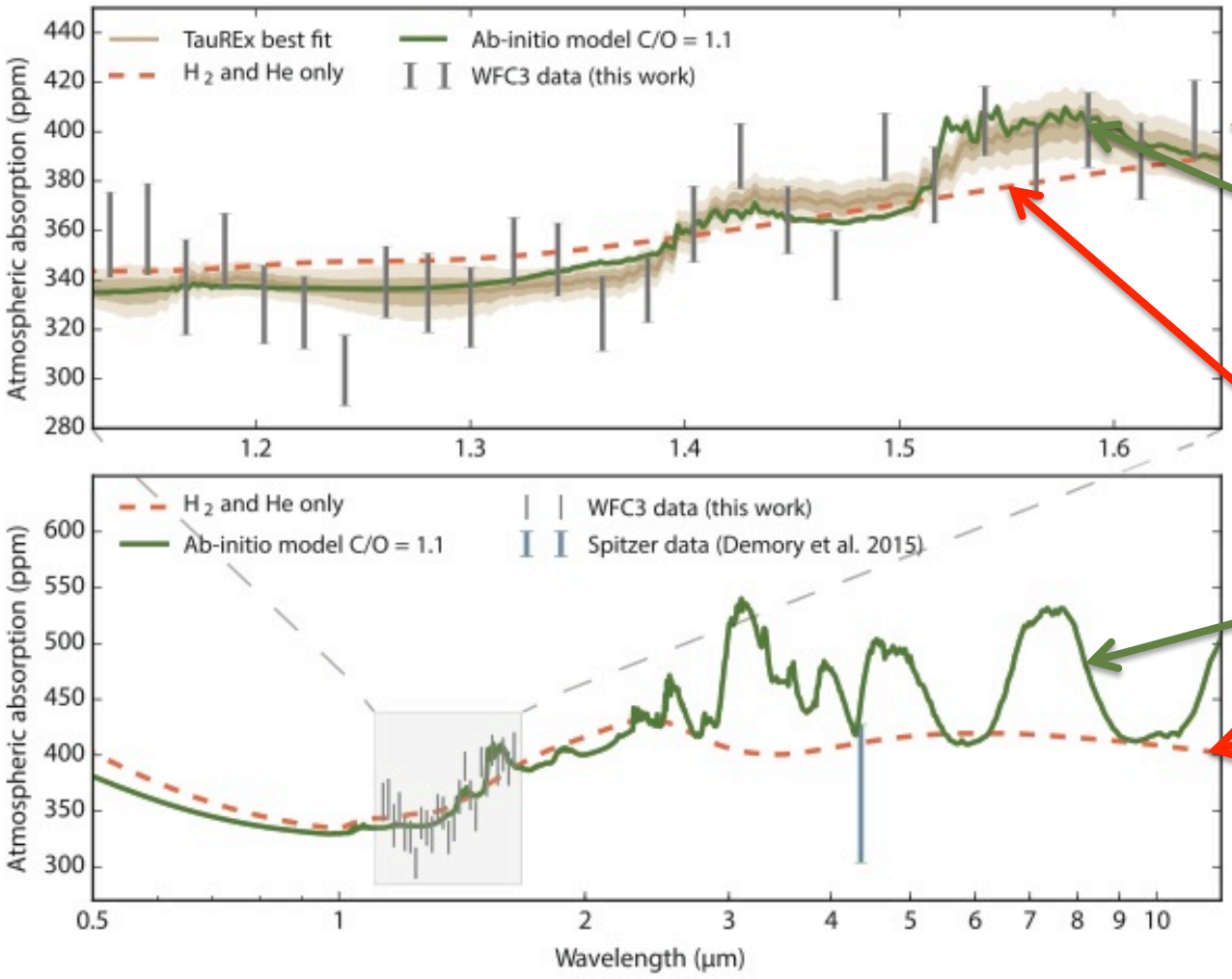
WASP-121 b



WASP-12 b



55 Cnc e – H/He and HCN (?)



H/He + HCN
Tau-REx fit

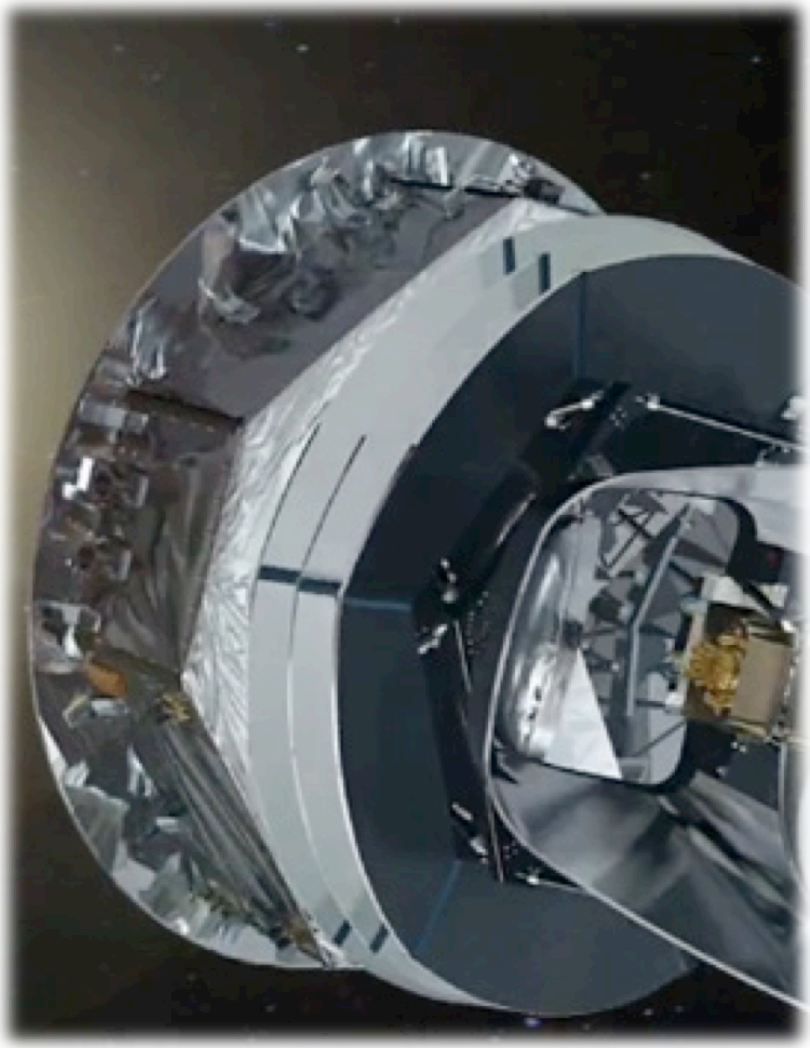
chemical model
not fitted

H/He

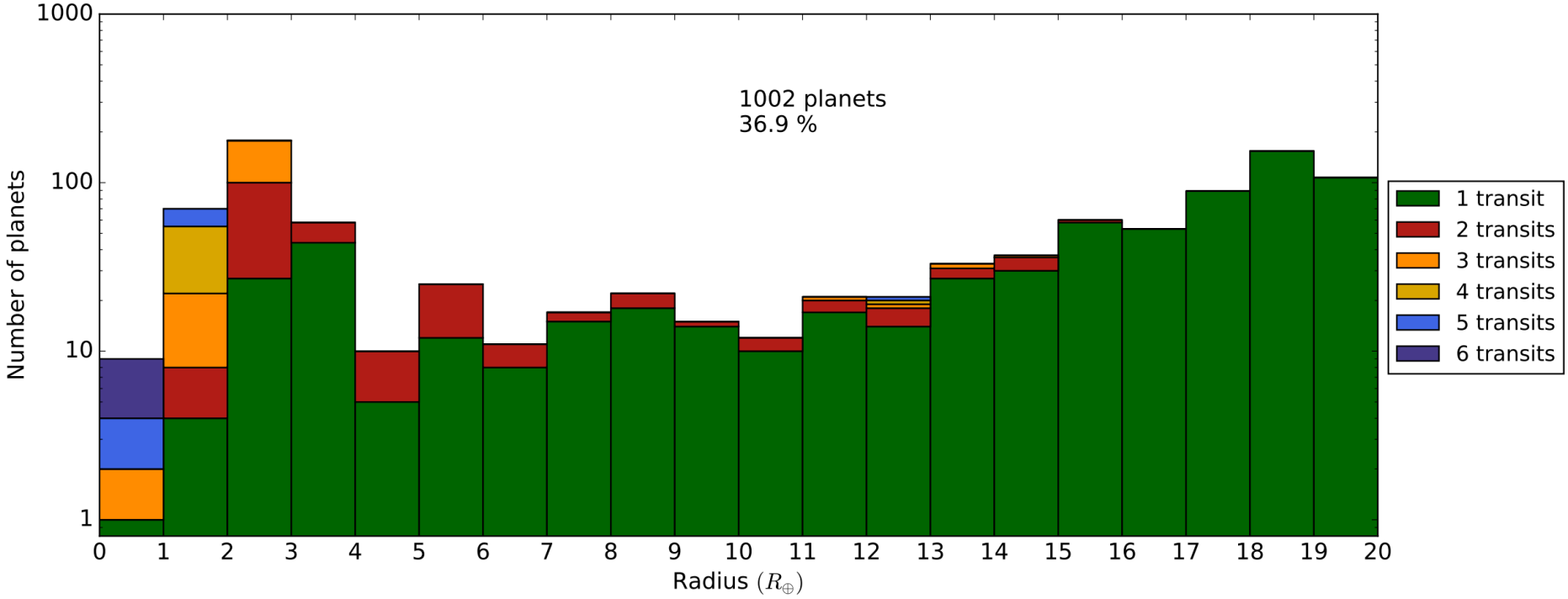
Tsiaras et al. 2016

Next generation – ARIEL

- European Space Agency M4 mission candidate
- Competing for launch 2026
- UK-led consortium of 12 EU countries
- Satellite 1.5 million kilometers away from Earth
- Hundreds of exoplanets observed



Next generation – ARIEL



Zingales et al. 2017