Space-based characterisation of super-Earth exoplanets

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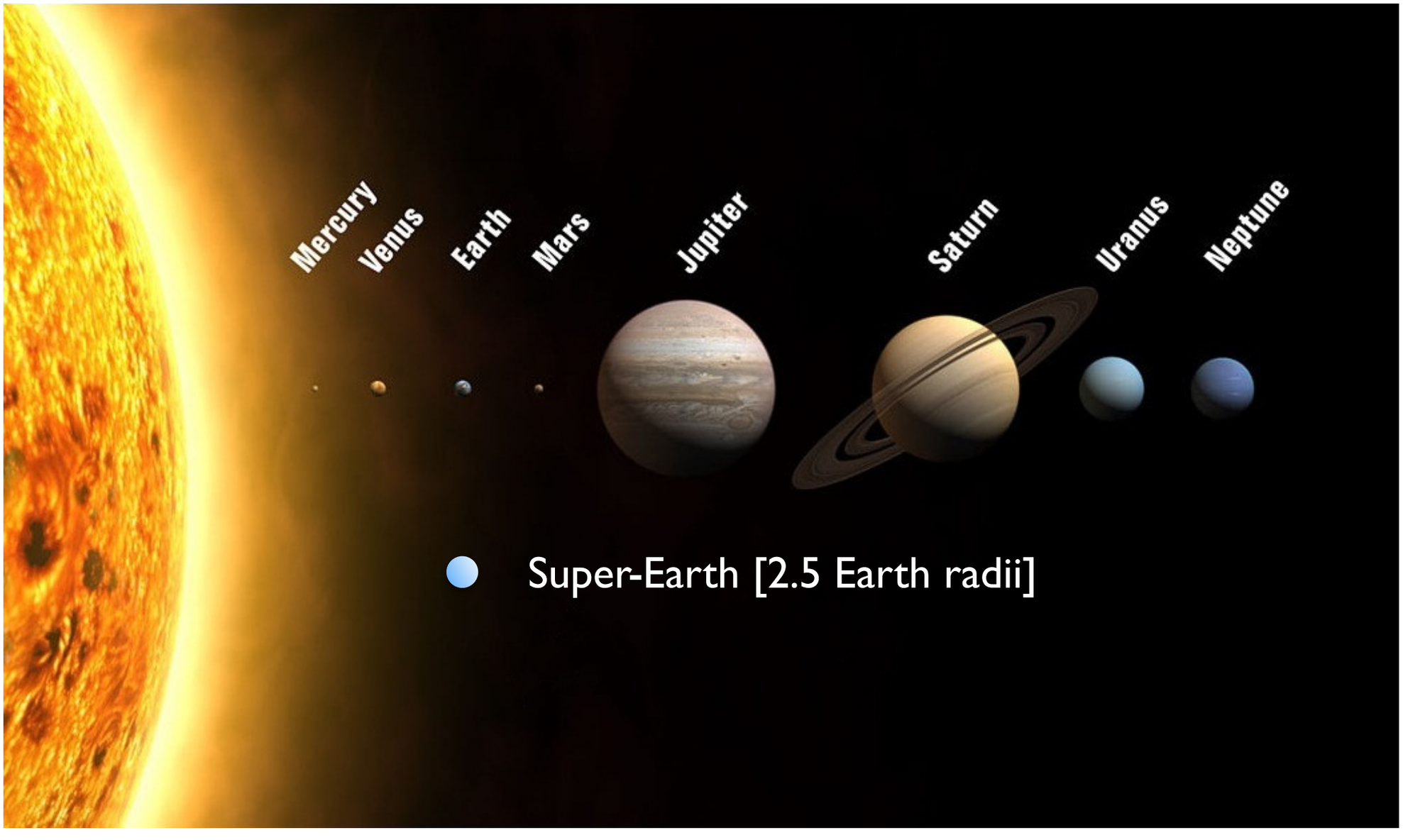
Super-Earths are unknown to our Solar System…



… but ubiquitous in exoplanetary systems (e.g. Mayor+2011, Dressing+2013, Fressin+ 2013…)

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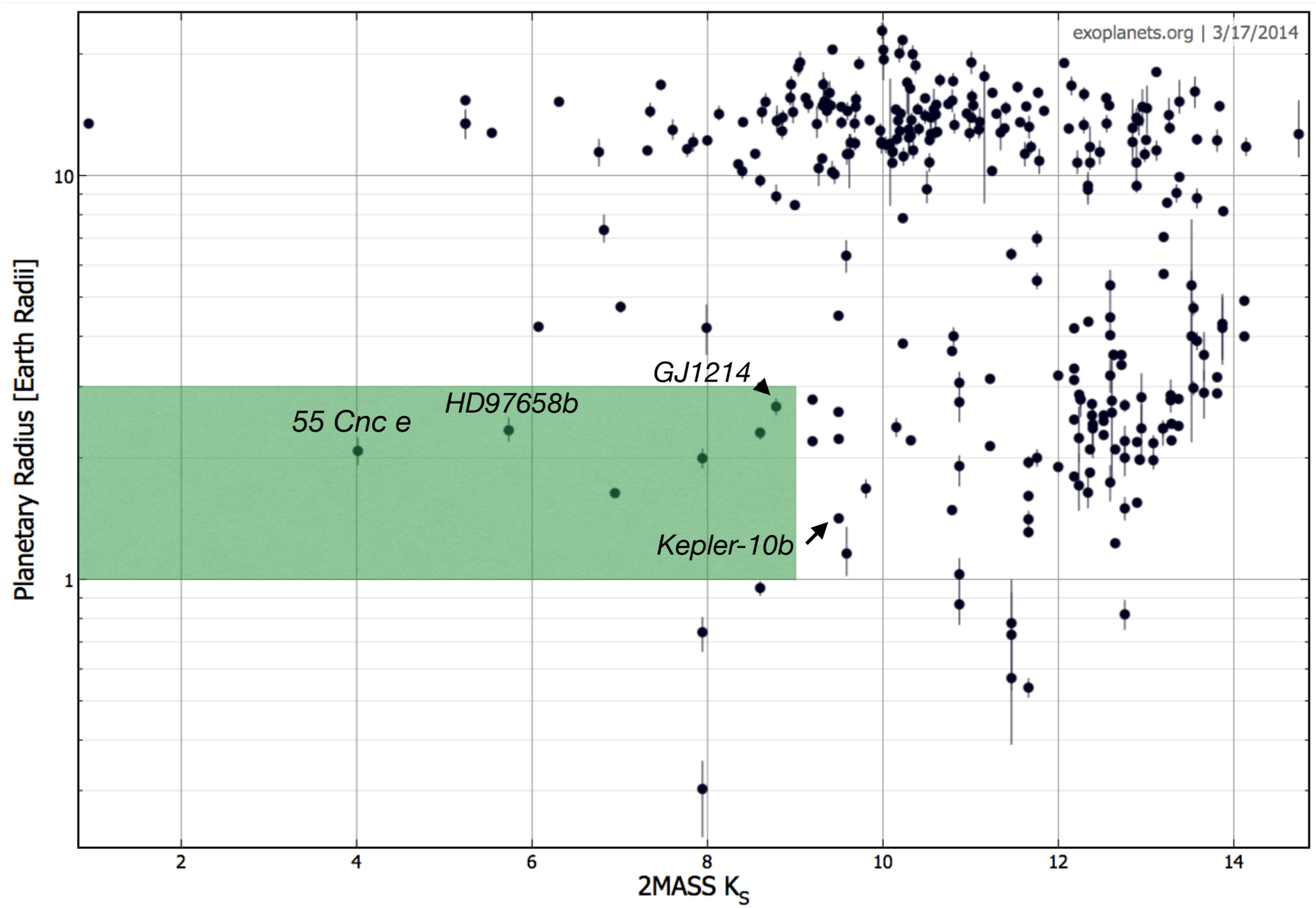
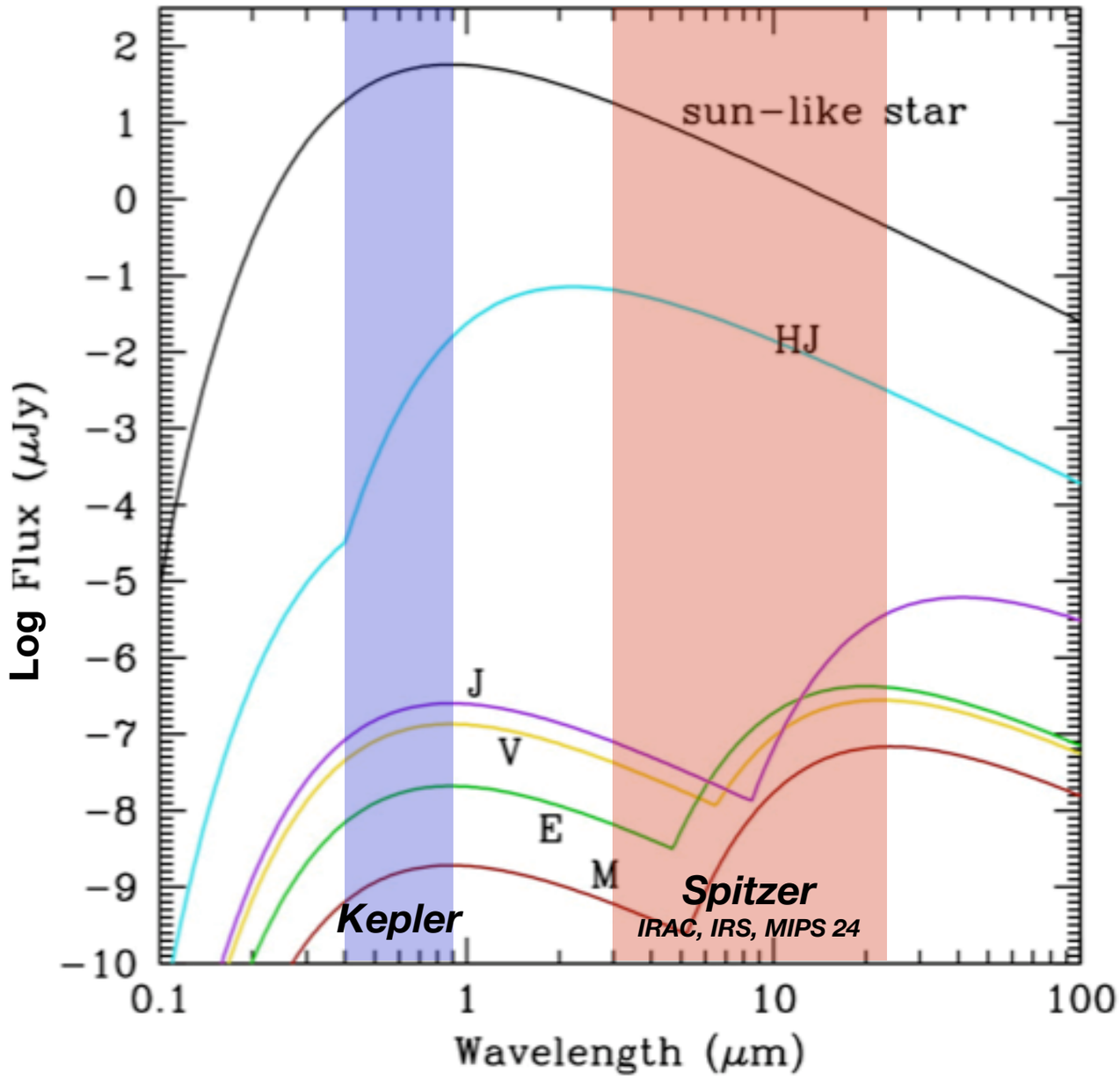
- Density-based definition: only rocky objects, or include water-rich planets?

Bright stars enable small planet studies

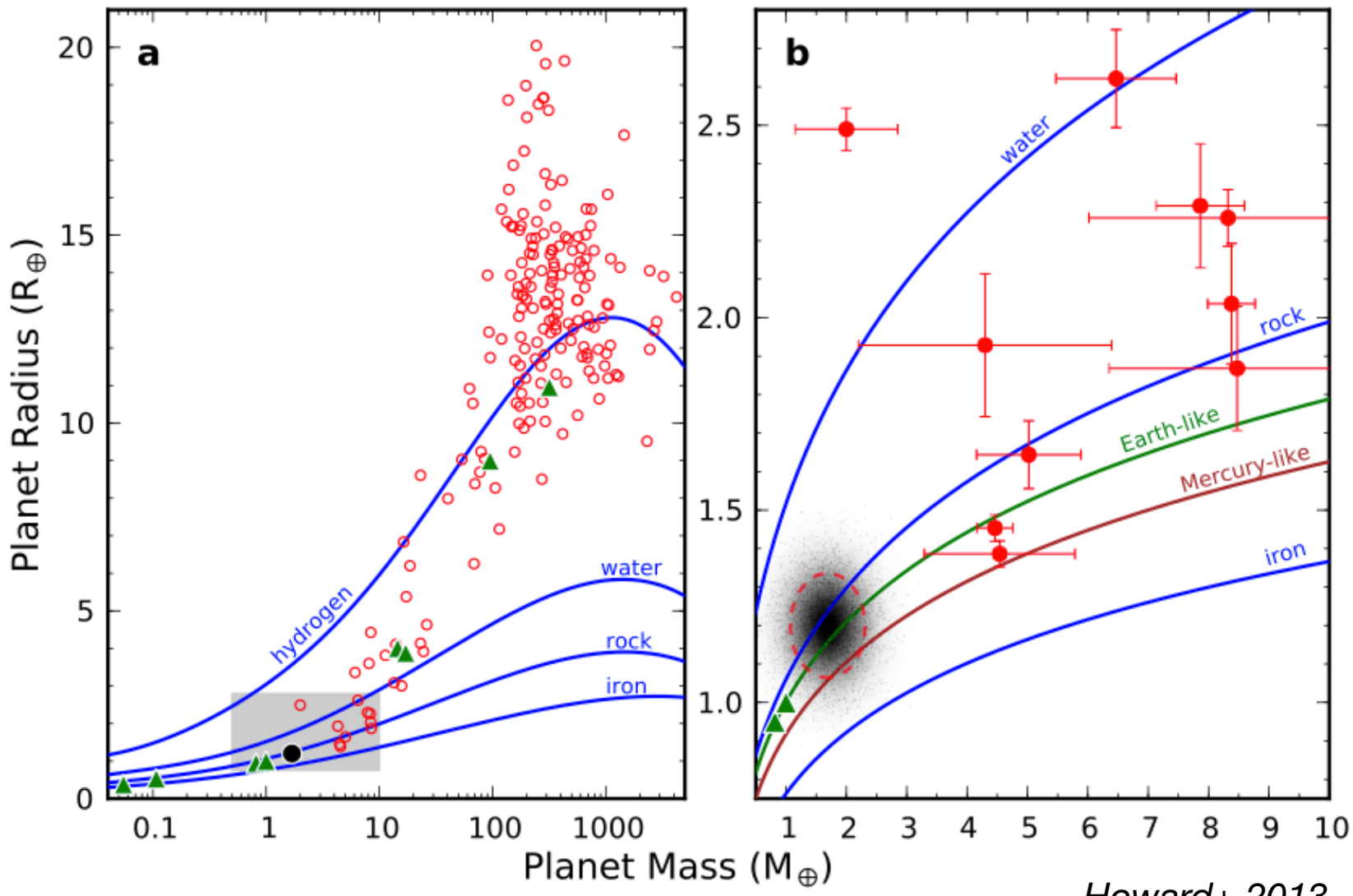


The Solar System at 10 pc



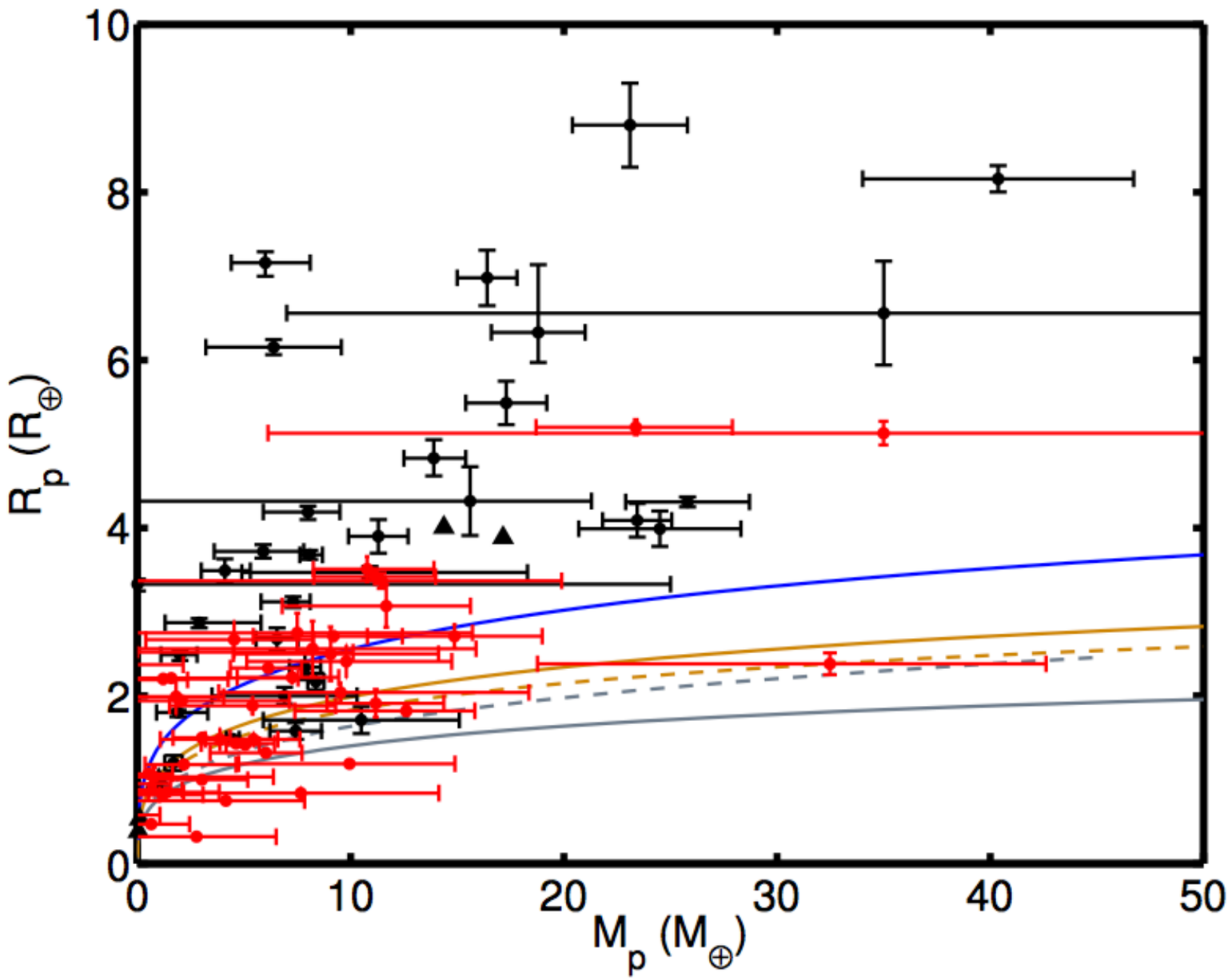
Seager et al., 2003

The challenging diversity of super-Earths



Howard+ 2013

A rocky-volatile rich boundary?



Rogers 2014
see also Lopez & Fortney 2013
and Angie Wolfgang's talk.

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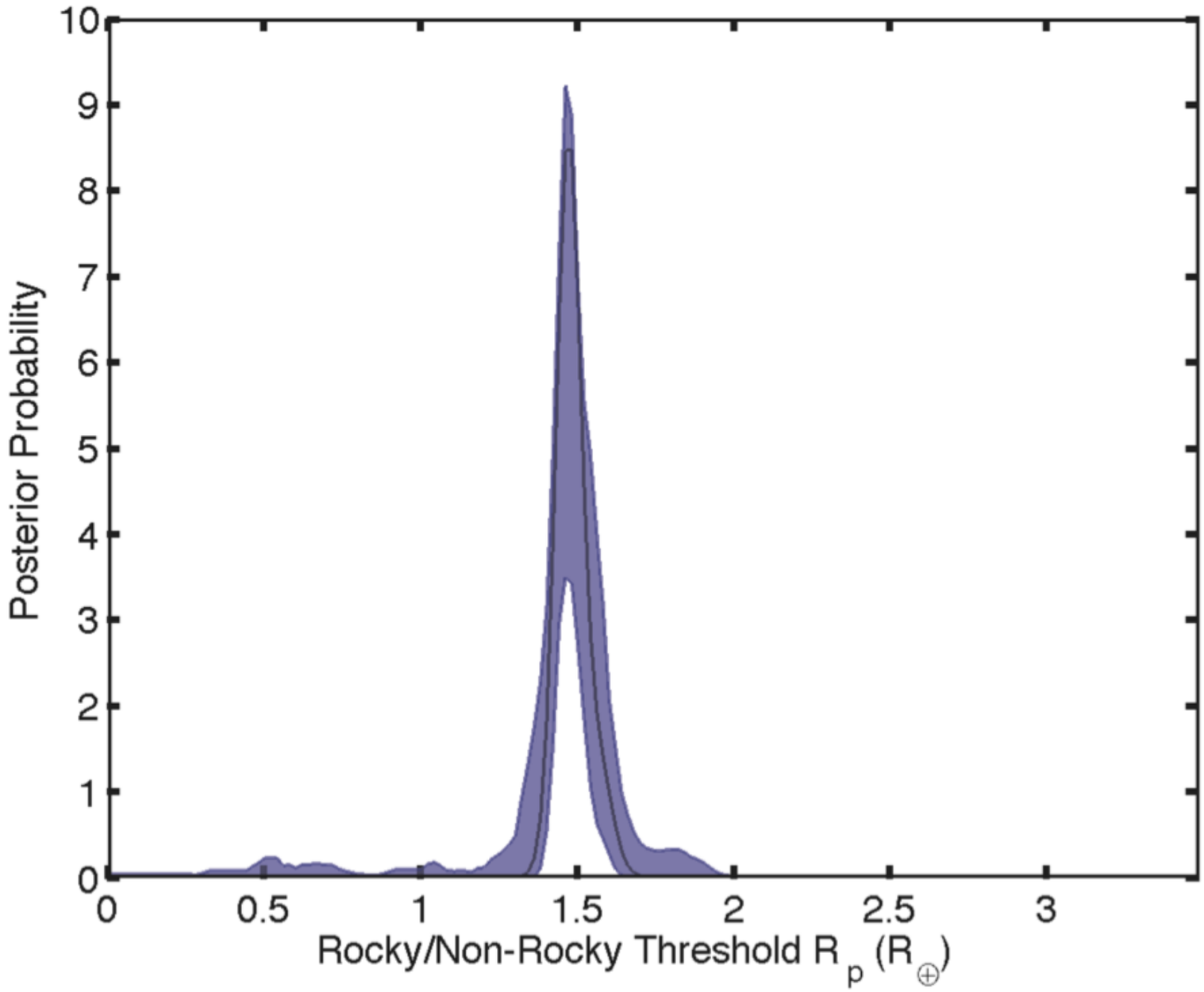

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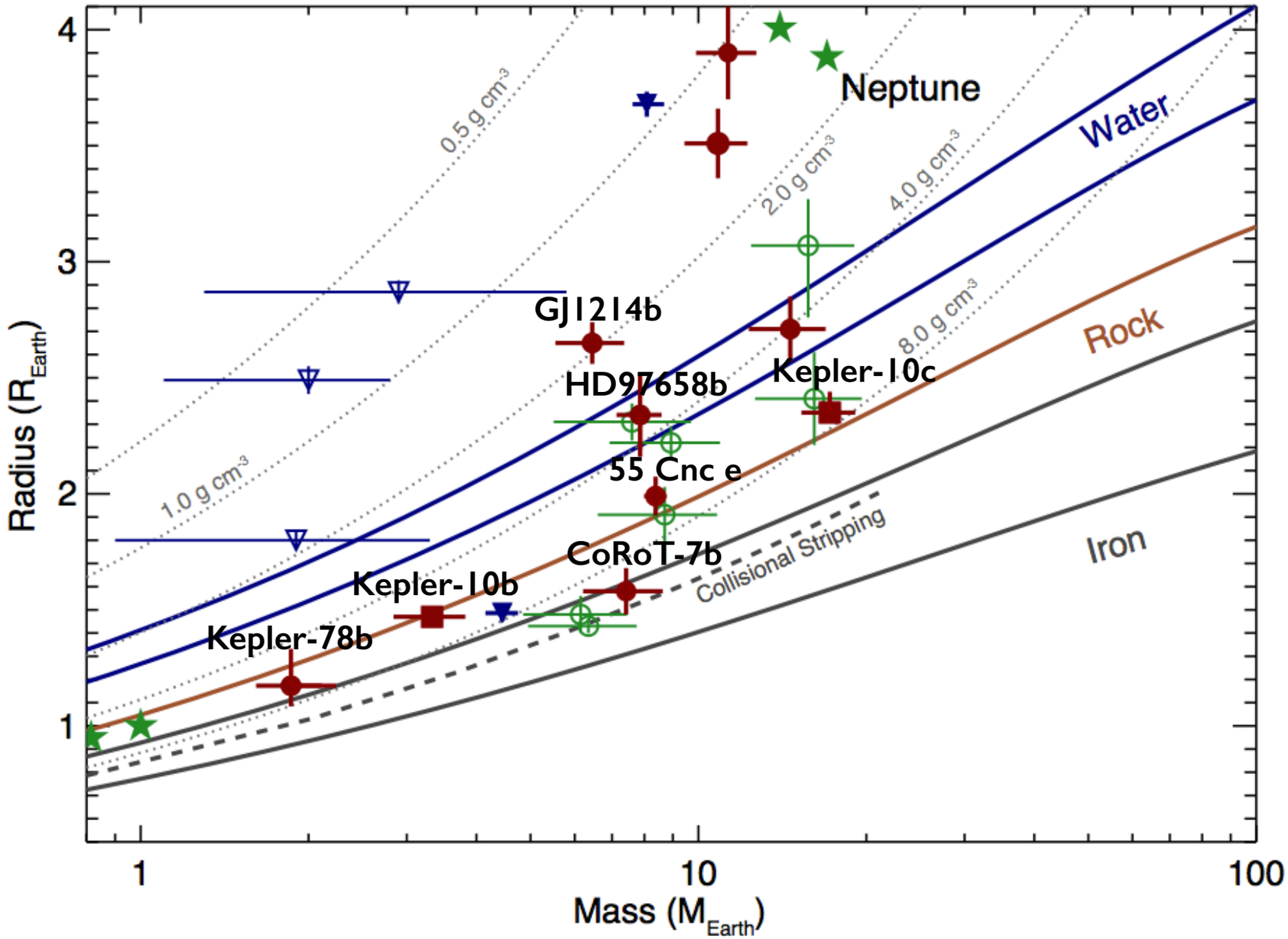

Dumusque+ 2014

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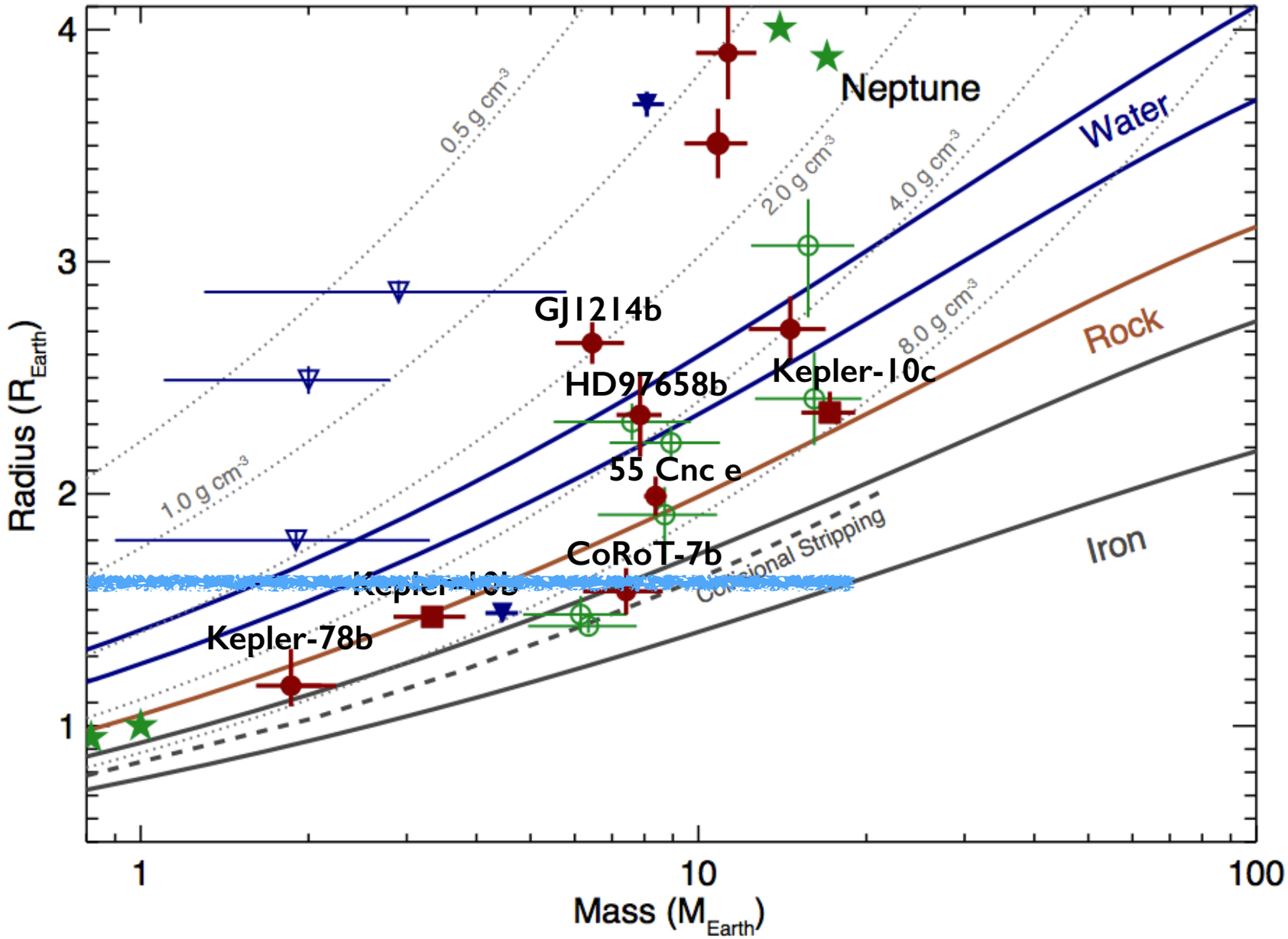
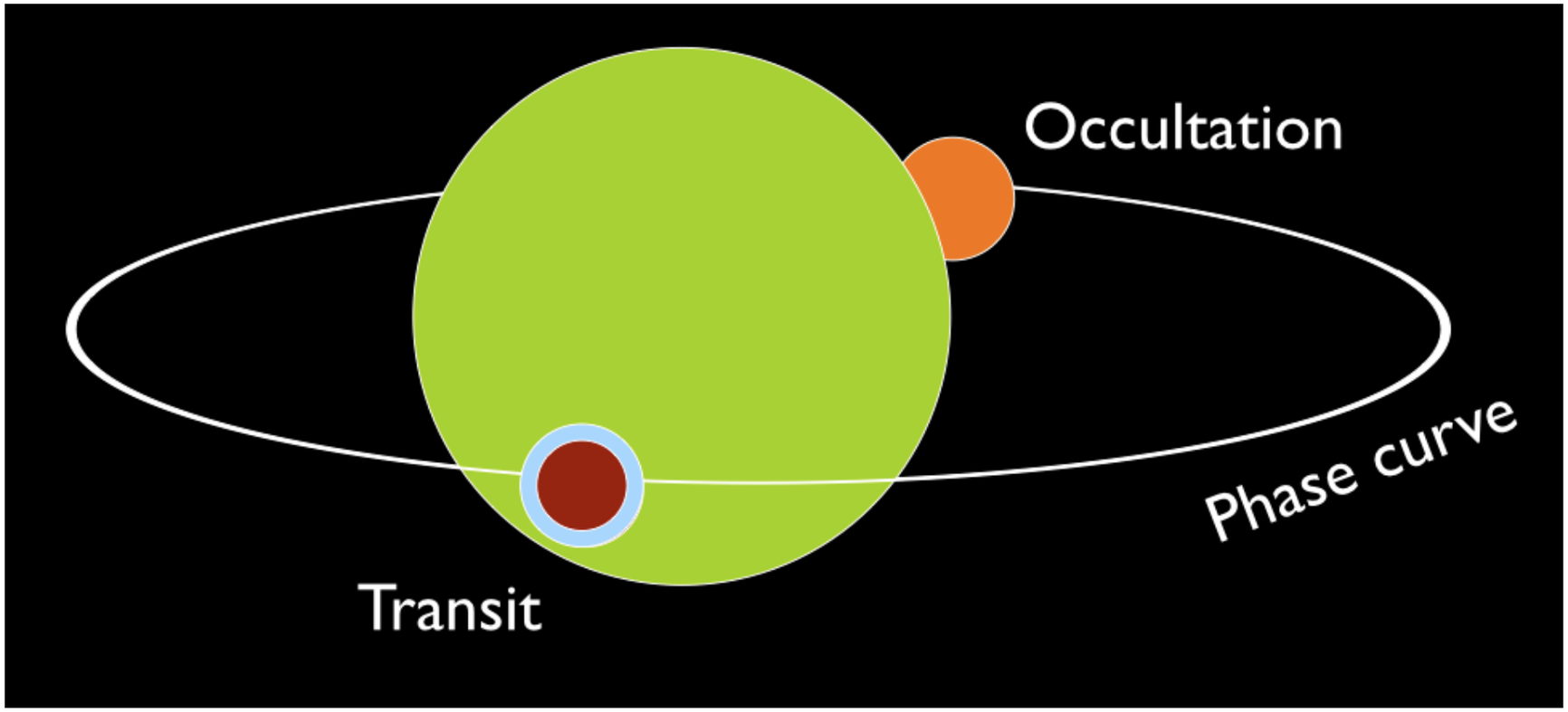


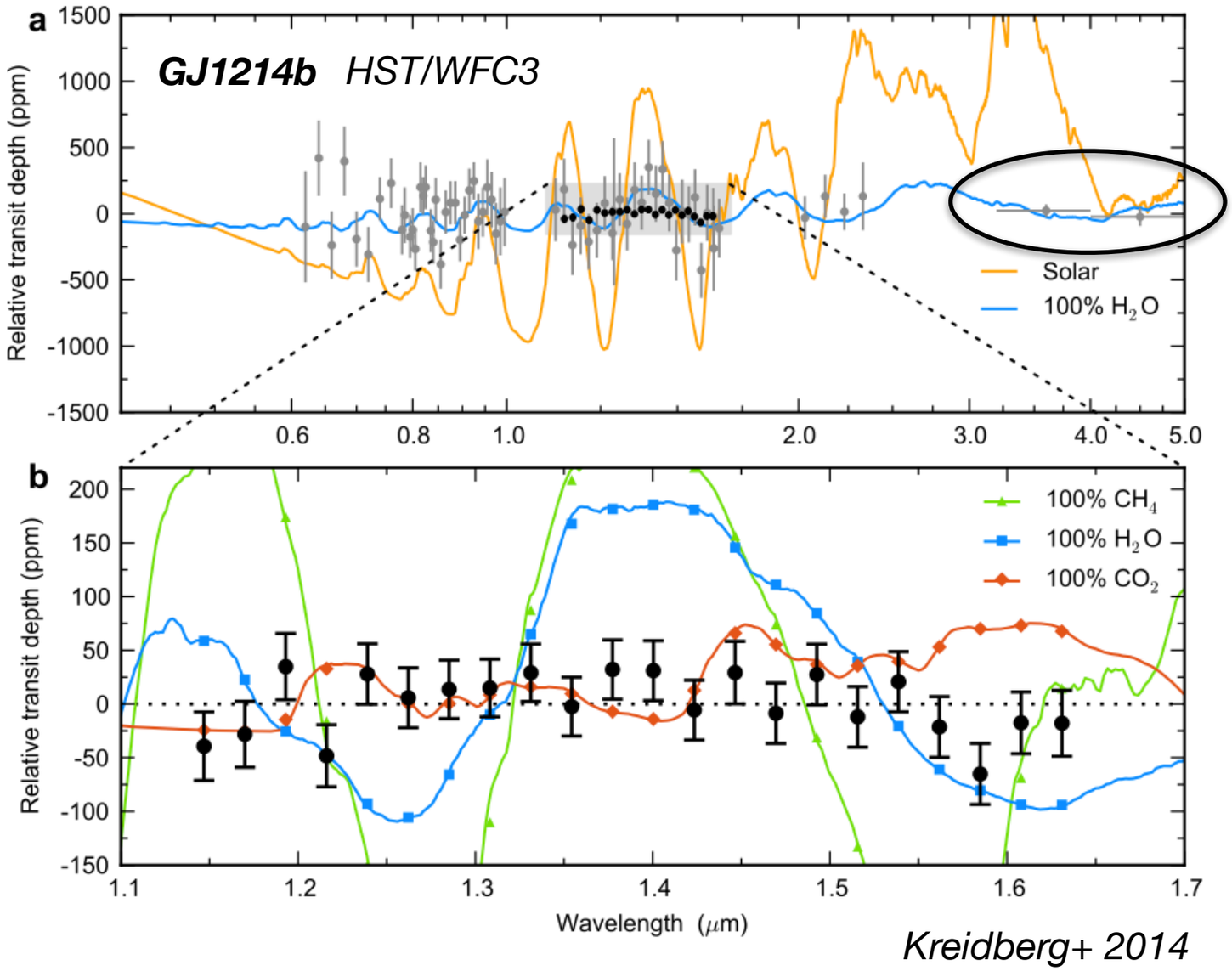
Dumusque+ 2014

Probing atmospheric properties of super-Earths



- Transmission spectroscopy (probes the atmospheric limb)
- Emission spectroscopy (probes the averaged dayside emission)
- Phase-curve photometry (probes longitudinal variations of the emergent spectrum)

GJ1214b: flat transmission spectrum



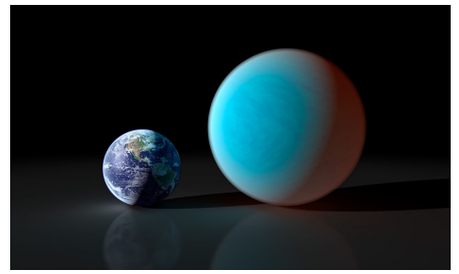
Kreidberg+ 2014

Spitzer 3.6 and 4.5 microns *(Fraine+ 2013)*

15 transits and **60** HST orbits.

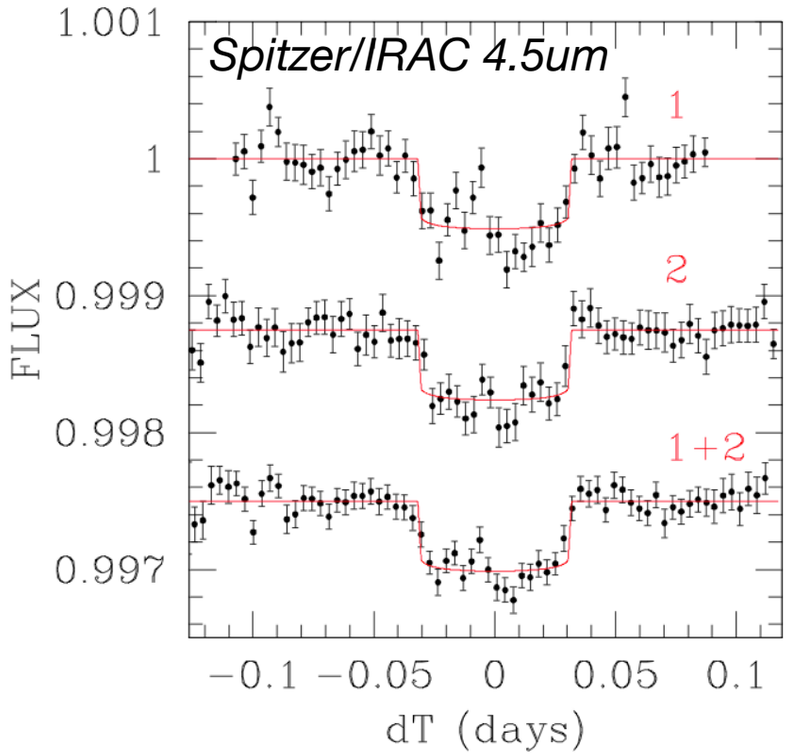
Transmission spectrum **flat from 0.6 to 5 microns**.

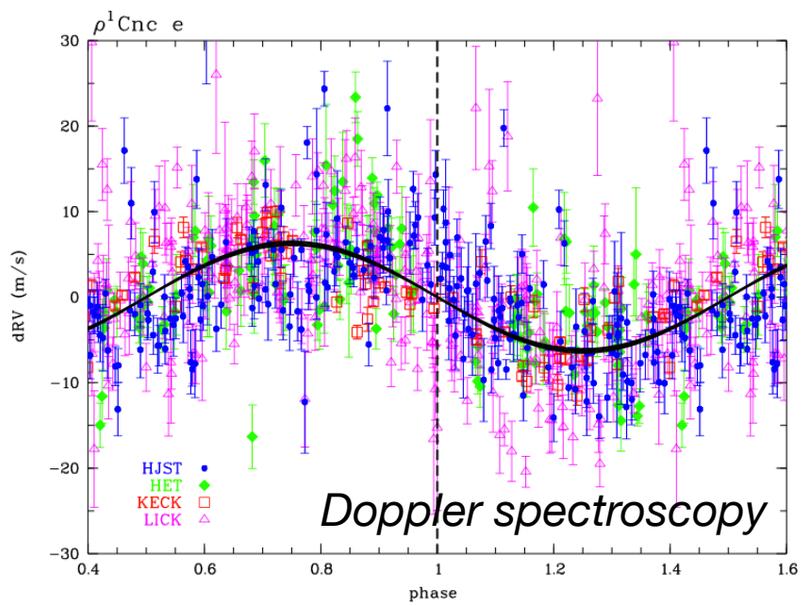
The super-Earth 55 Cnc e



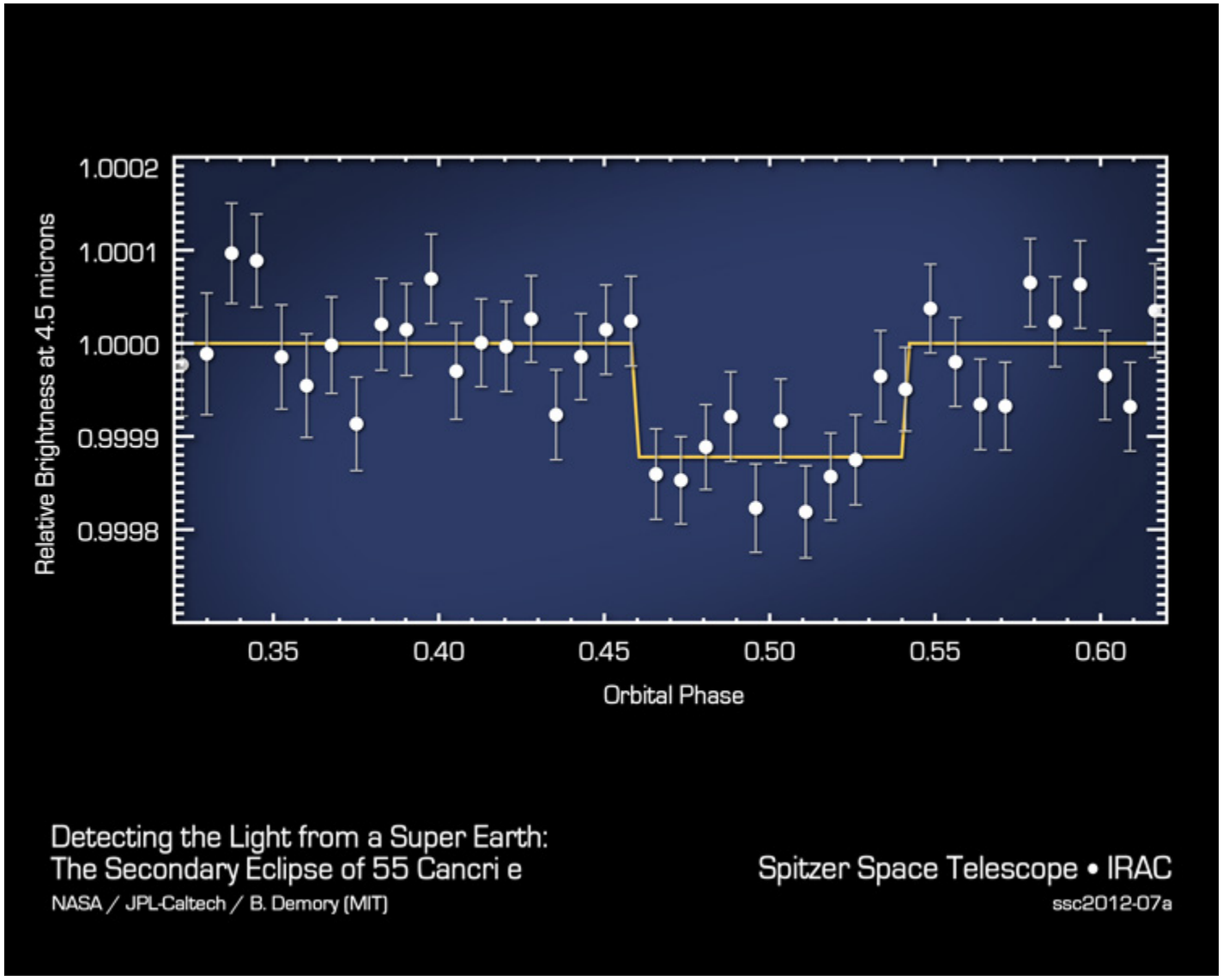
- Discovered (transit) in 2011
- Host star: **V=6**, 0.90 M_{Sun}, 0.94 R_{Sun}
- Period : 0.74 days
- Radius : 2.17 ± 0.10 $R_{\oplus}$
- Mass : 8.37 ± 0.38 $M_{\oplus}$
- Density : 4500 ± 200 kg/m^3
- Eq. Temp. : 2380 K (Ab=0)

Dawson et al., 2010
Demory et al. 2011
Winn et al. 2011
von Braun et al., 2011
Gillon et al. 2012
Endl et al. 2012





Thermal Emission from 55 Cnc e



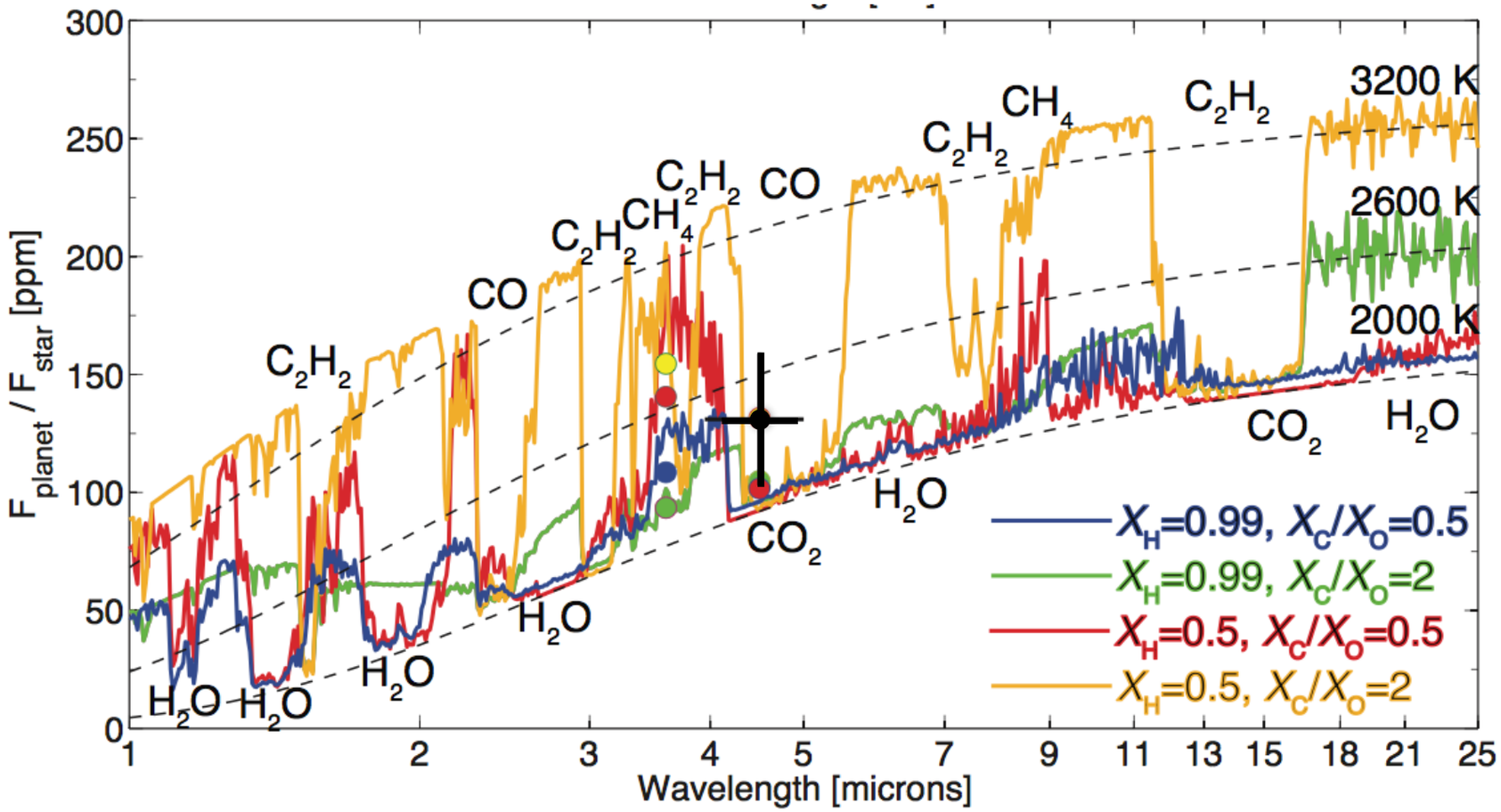
Four Spitzer 4.5-micron occultations, **three** independent analyses

Occultation depth:
128 +/- 30 ppm

Translates to
T_B = 2000 +/- 300K

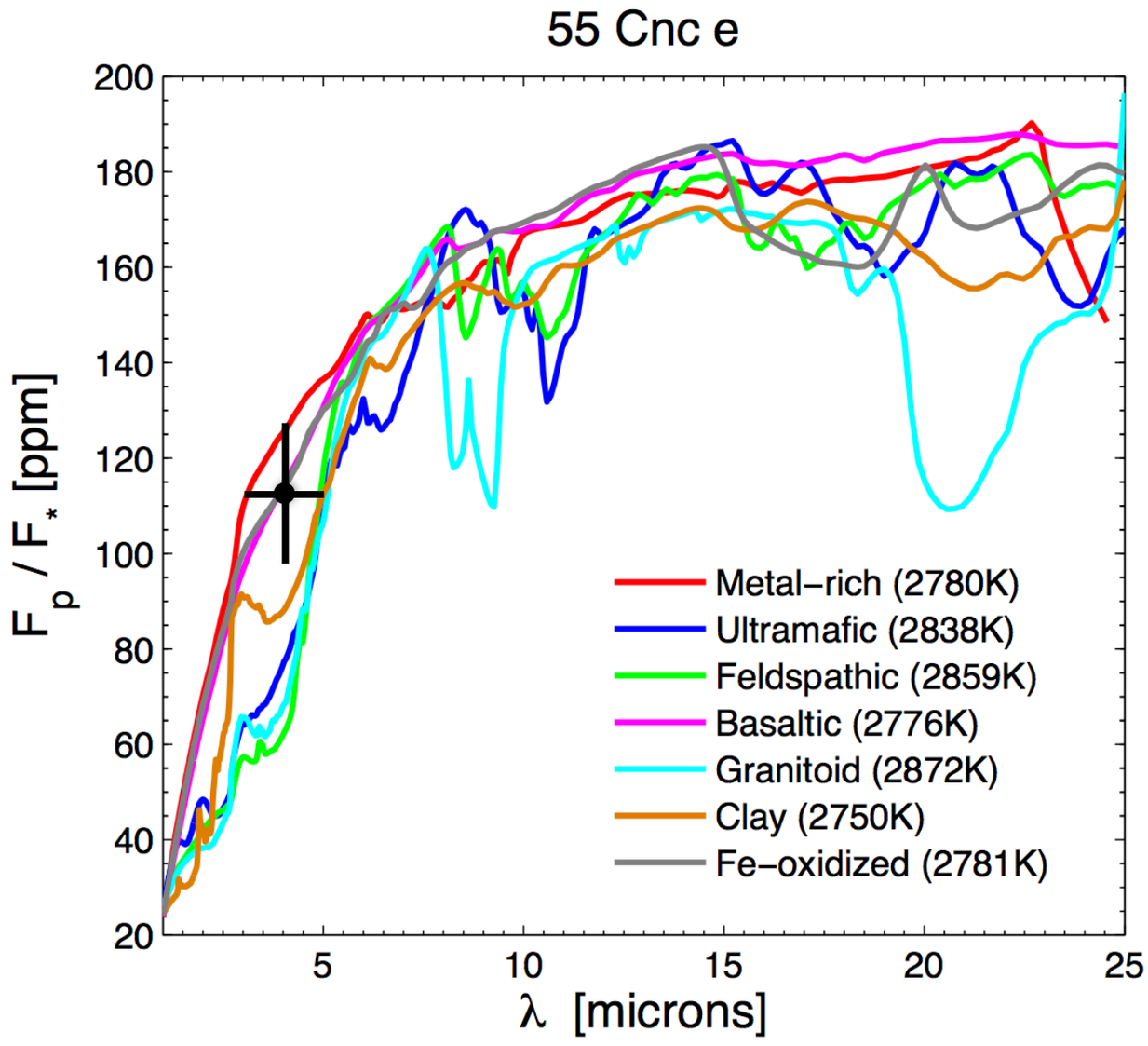
Demory+ 2012

55 Cnc e: atmosphere-dominated?



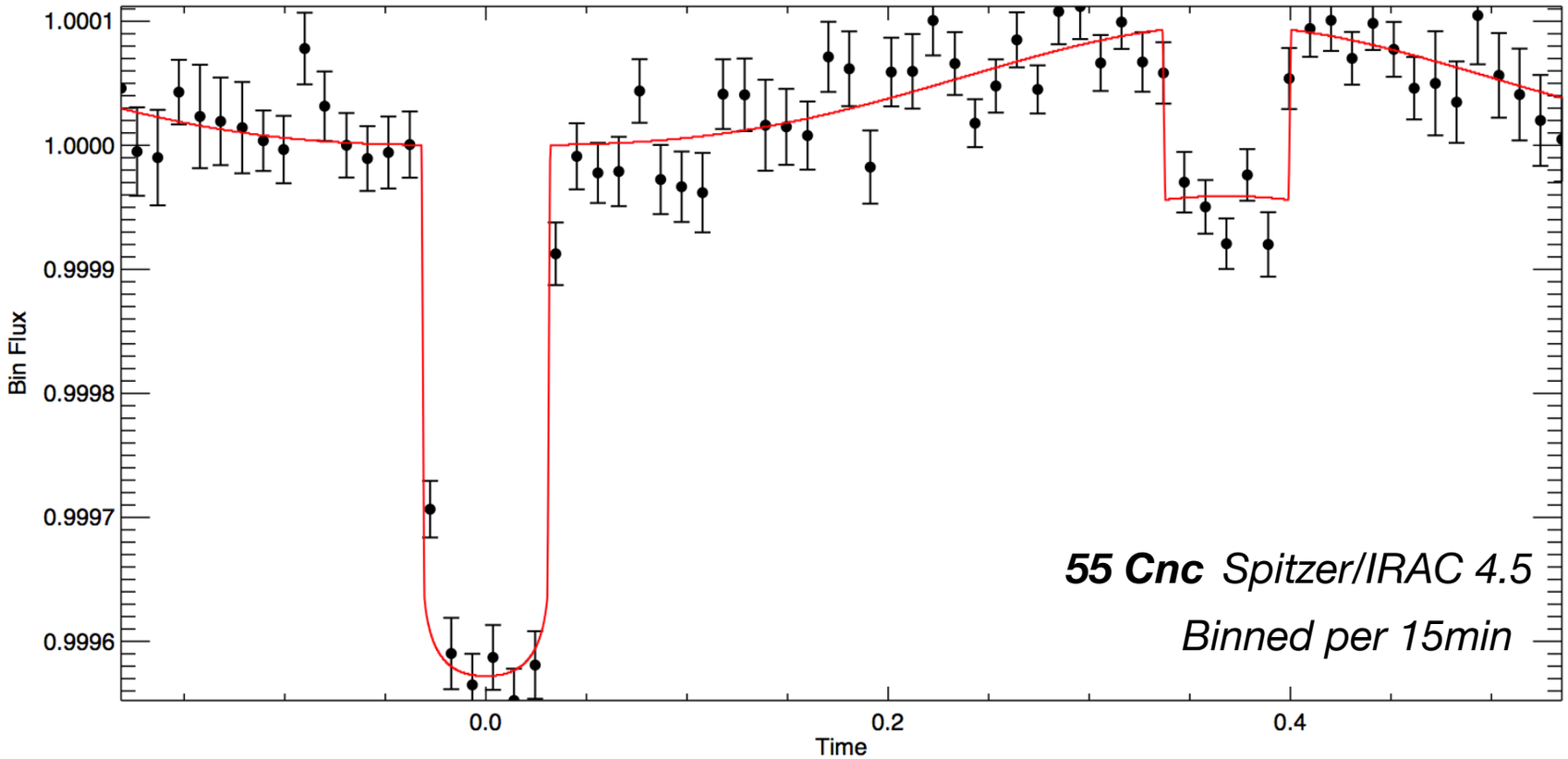
Hu+ 2014

55 Cnc e: atmosphere-less?



Hu+ 2012

Infrared phase-curve of 55 Cnc e



80-hr *Spitzer* program (PI Demory)

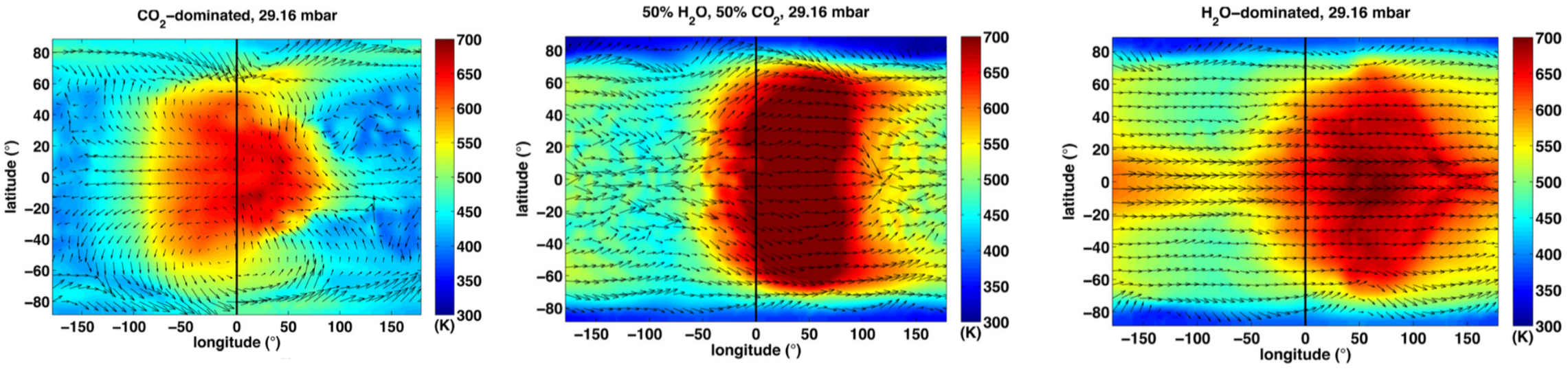
Phase amplitude:
85 +/- 35 ppm

No offset detected:
17 +/- 40 deg

Demory+ in prep.

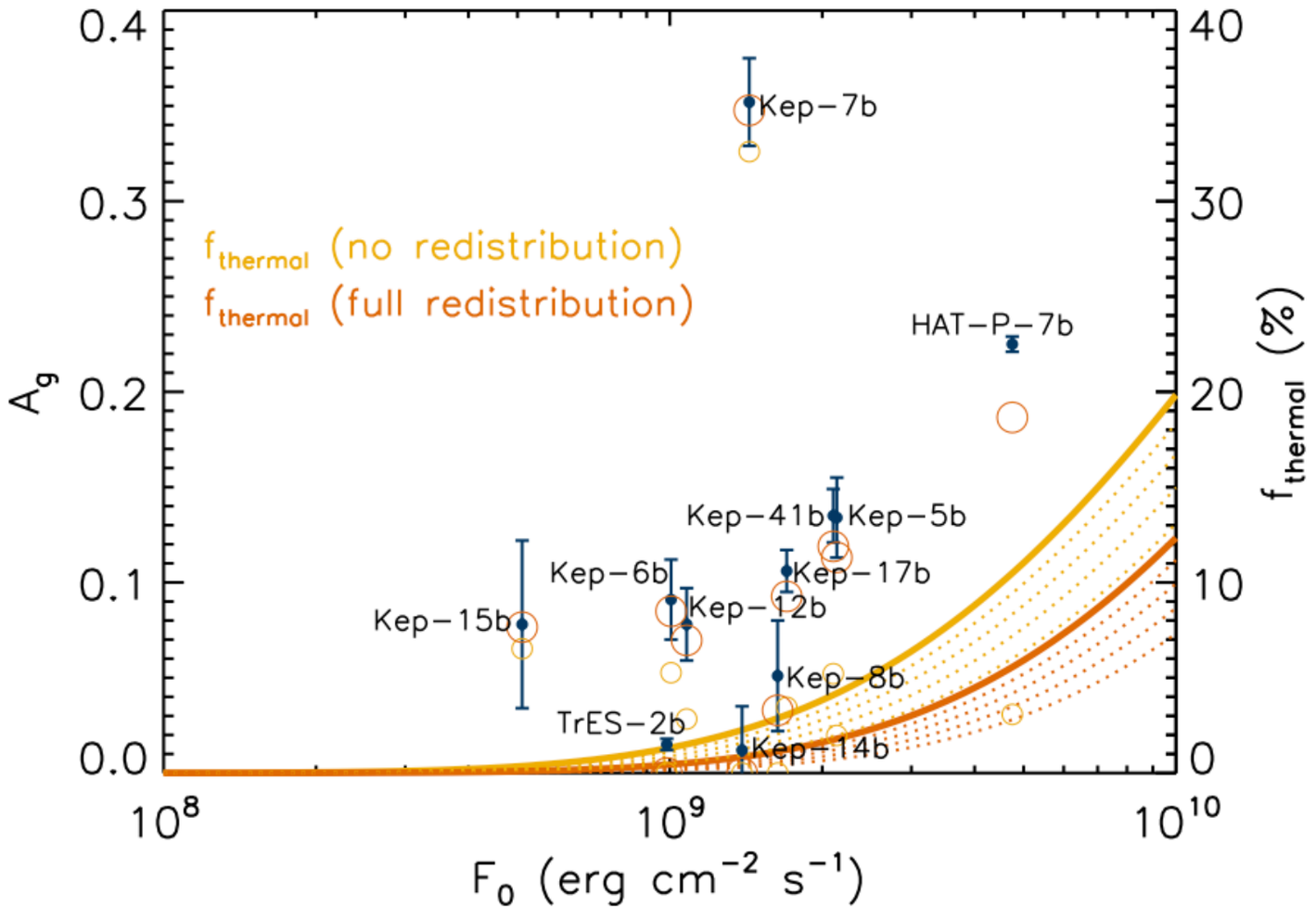
Super-Earth circulation patterns

GJ1214
GCM simulations



Kataria+ 2014

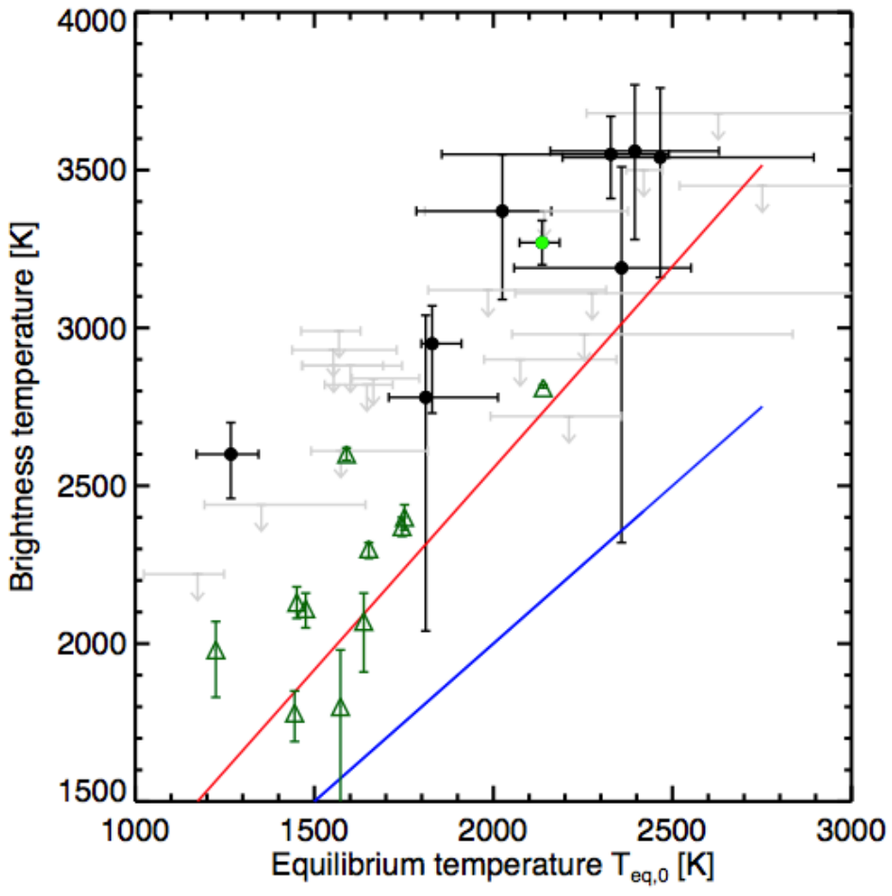
The albedos of *Kepler* hot Jupiters

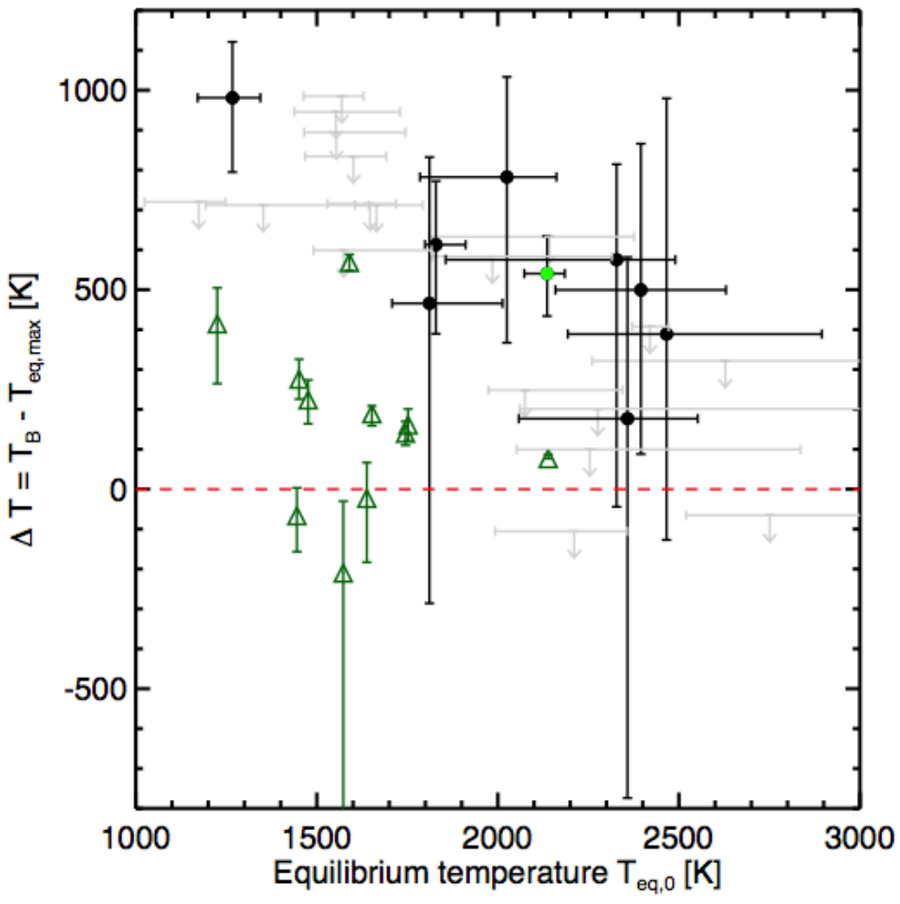


***Kepler* A_g (hot Jupiters) : 0.06 - 0.11**

Heng & Demory 2013

The albedos of *Kepler* close-in super-Earths





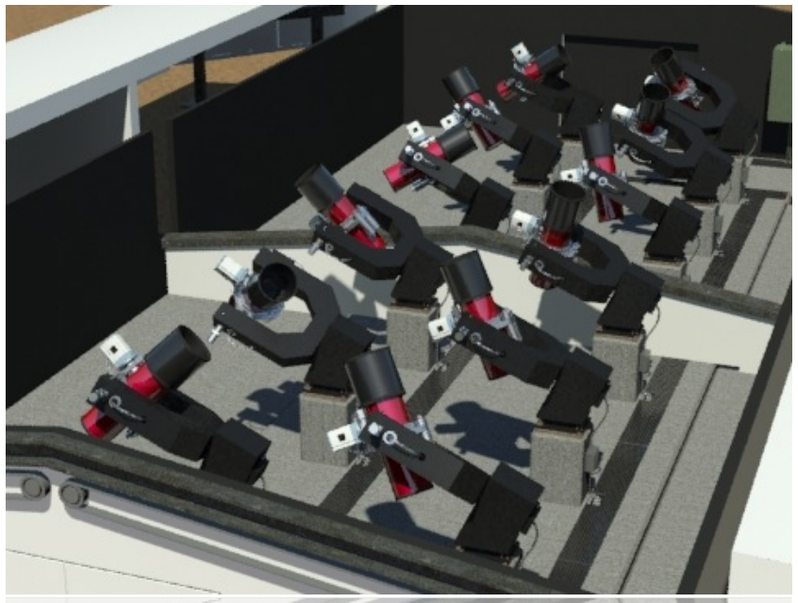
Kepler A_g (close-in super-Earths) : 0.16 - 0.30

(Hierarchical Bayesian modeling analysis)

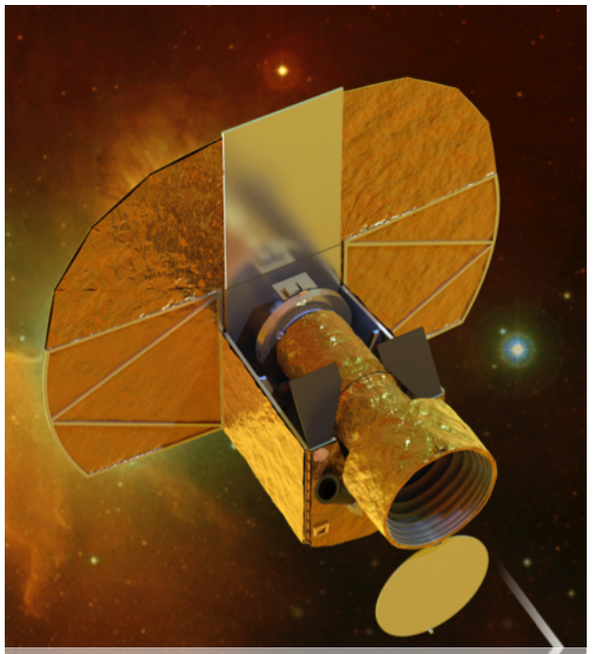
Demory 2014

see also Sheets & Deming 2014

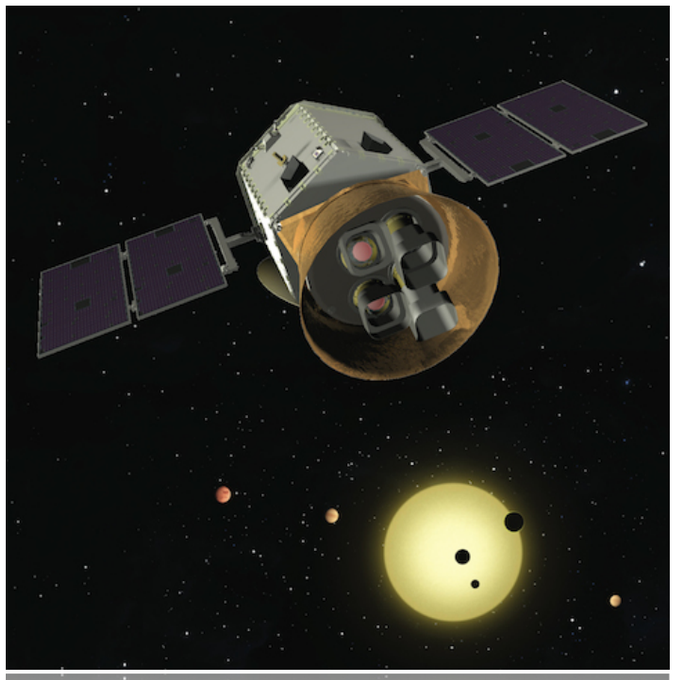
Prospects in the next 3-4 years



NGTS
Next Generation Transit Survey



CHEOPS
CHaracterising ExOplanet Satellite



TESS
Transiting Exoplanet Survey Satellite

K2
until 2016

Summary and prospects

- **Super-Earth characterisation is challenging**. Atmospheric scale heights for Earth-size objects is **~5-10 times smaller** than for hot Jupiters.

- **Population-level analyses** are key to understand patterns in reflectivity and dependence with size/irradiation/stellar type, etc. Clues about surface/atmosphere properties **at a statistical scale.**

- Most super-Earths will need expensive follow-up to **distinguish whether those are rocky or gaseous** in the 1.6-2.5 Earth radii range.