Warm super-Earths:
HD 97658b as a case study

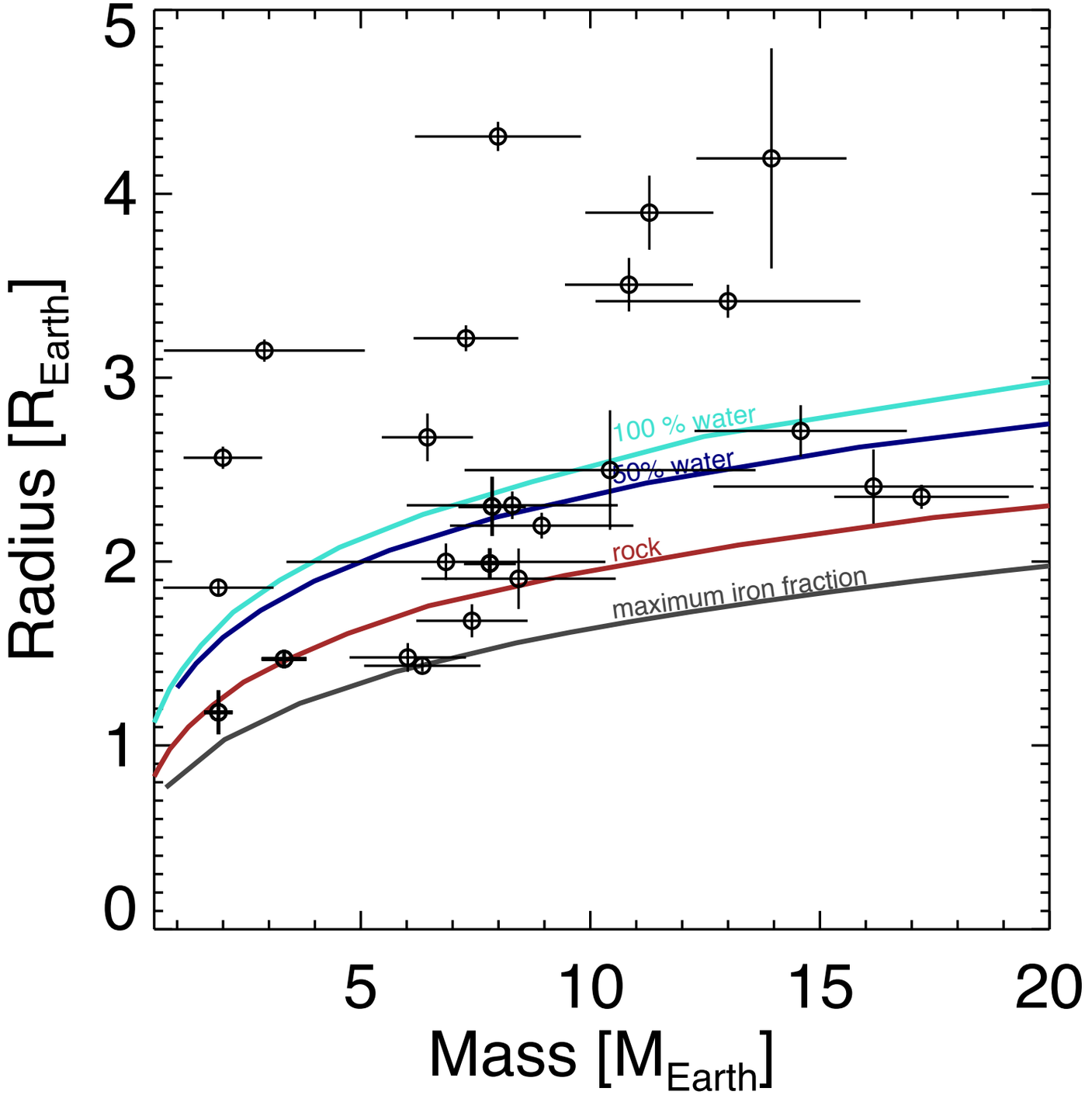
Diana Dragomir[1], B. Benneke, I. Crossfield,
J. Fortney, M. Gillon, A. Howard, E. Kempton,
H. Knutson, J. Matthews, V. van Grootel, ...

[1]**UCSB/Las Cumbres Observatory Global Telescope (LCOGT)**

Towards Other Earths II (The Star-Planet Connection)
Porto, Portugal

September 15, 2014

Known small transiting exoplanets



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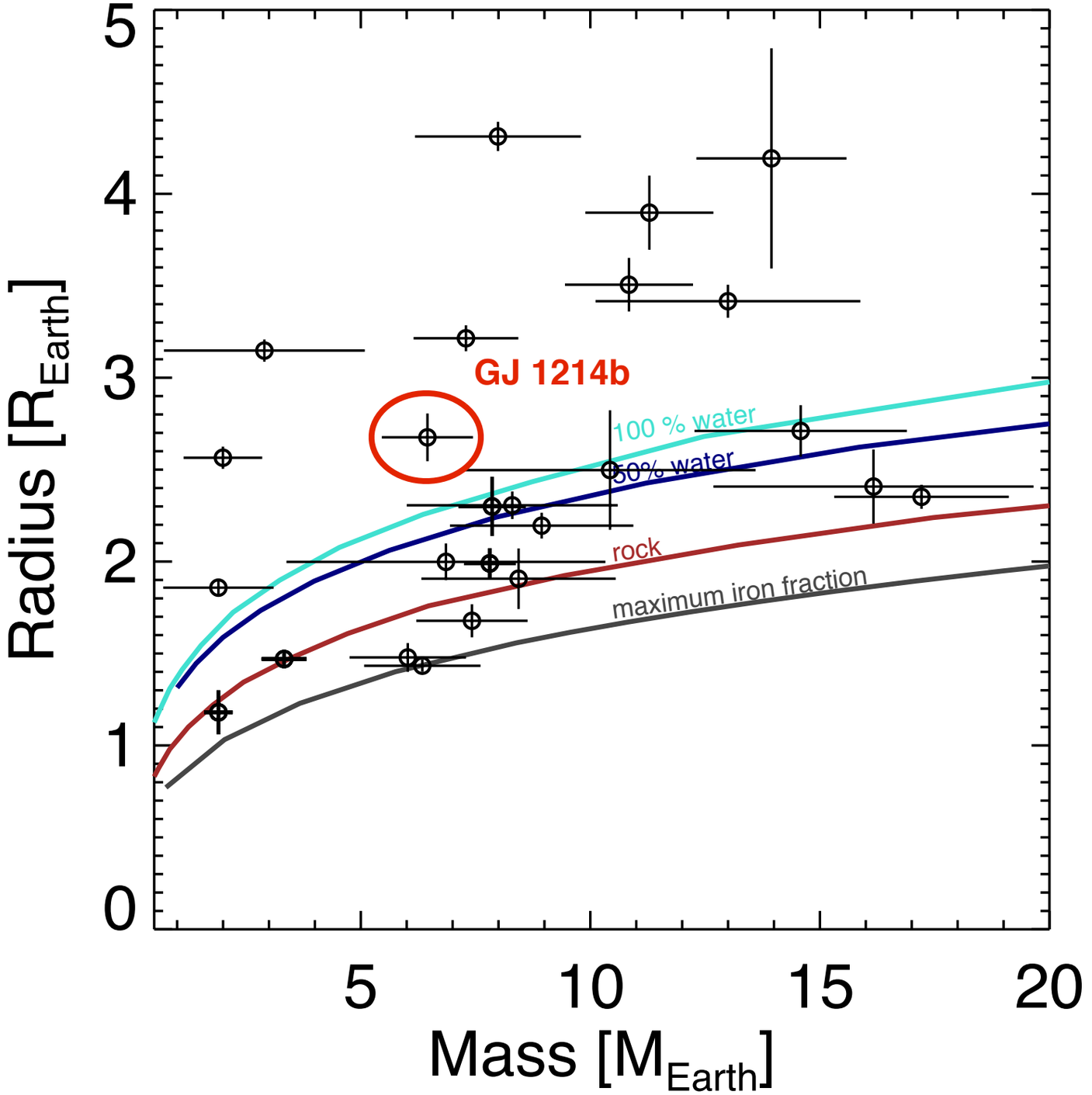

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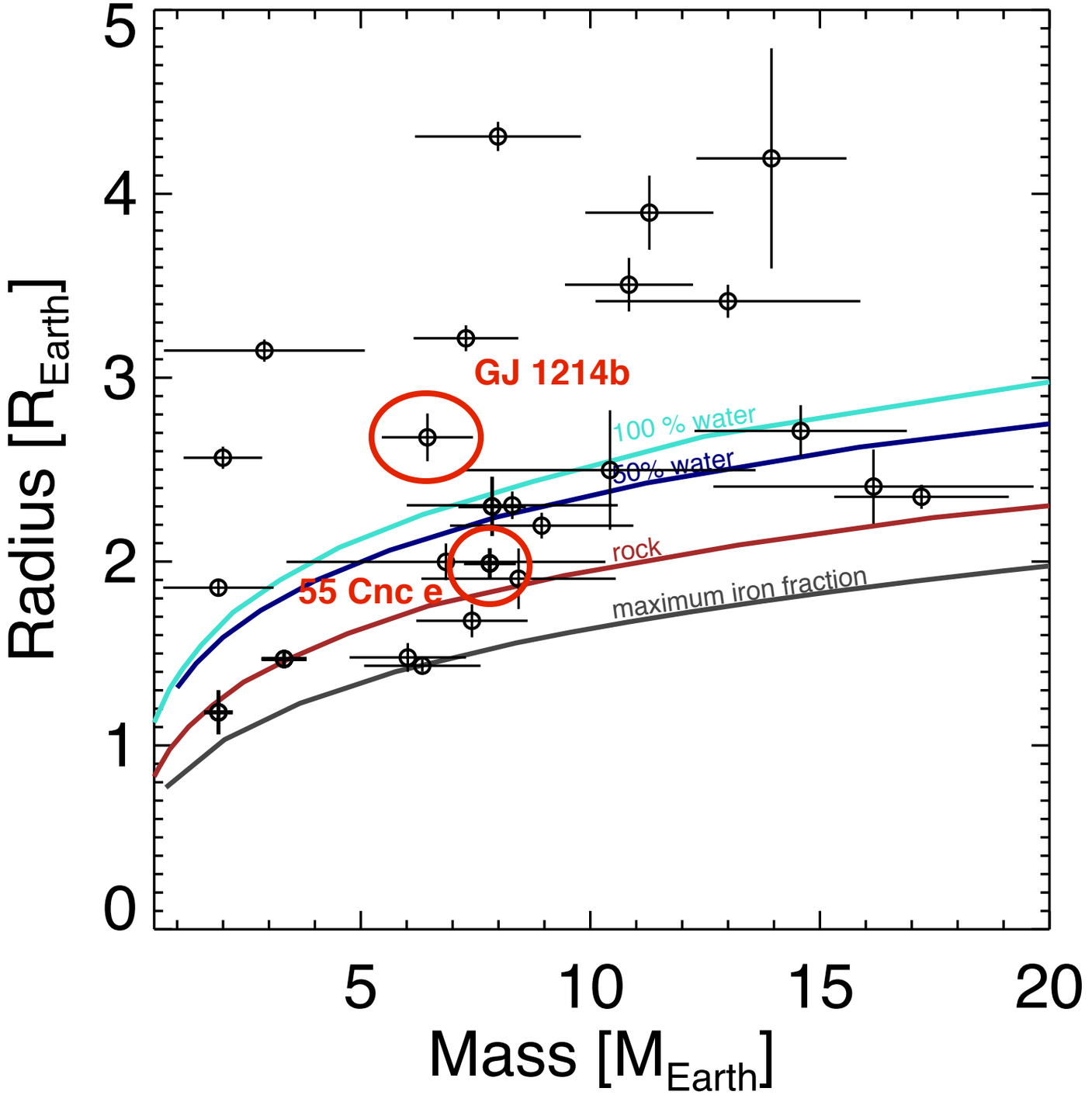
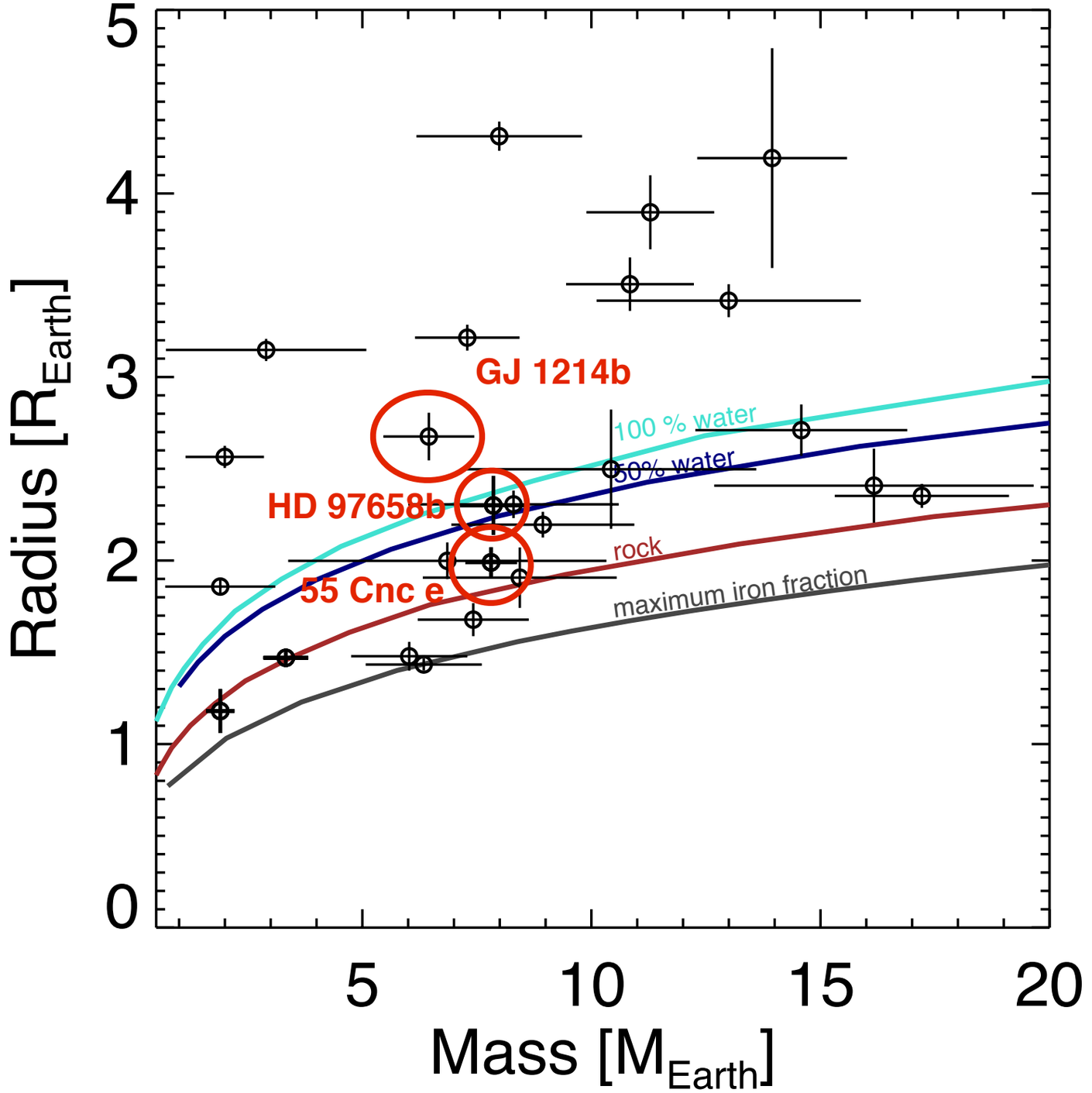
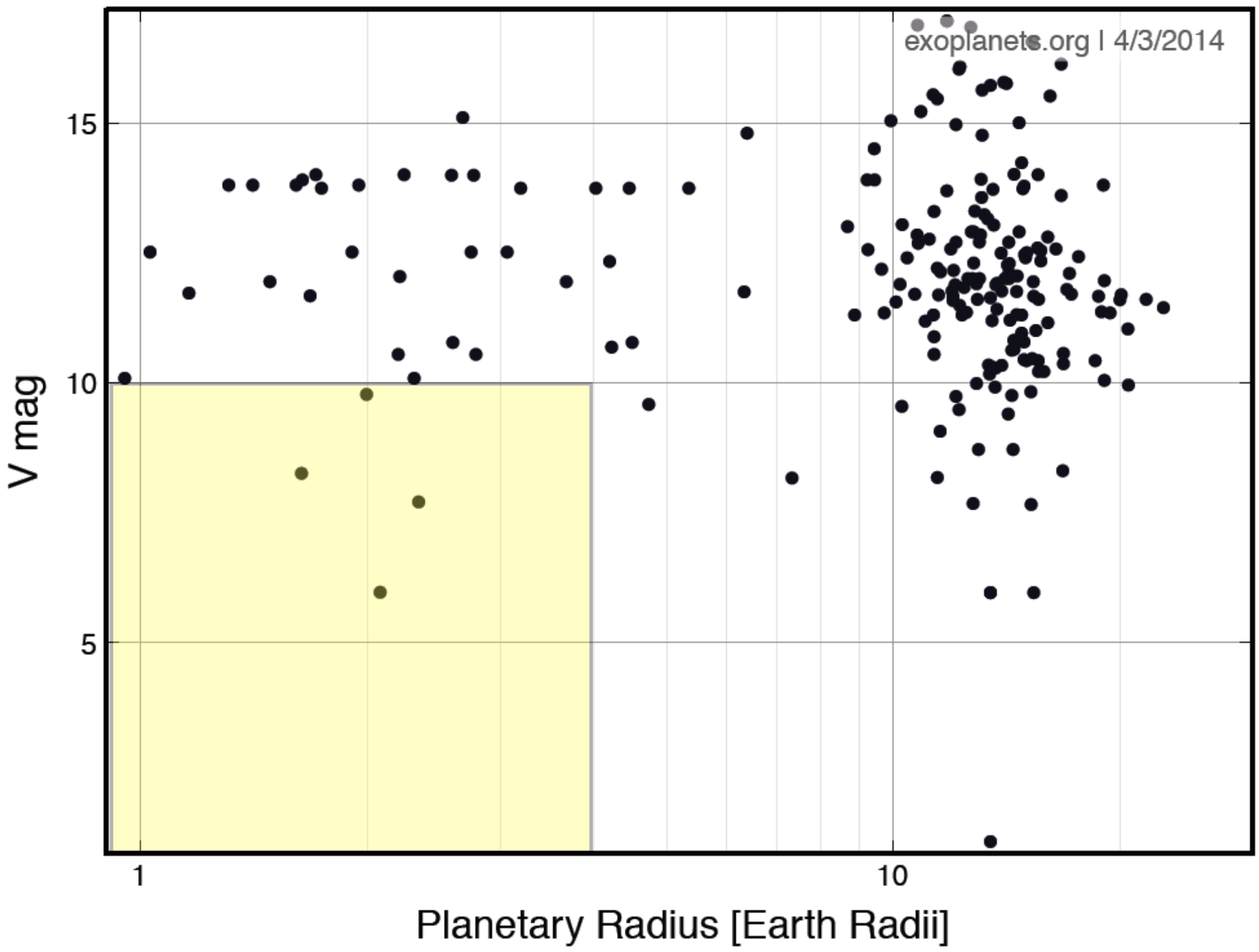


Known small transiting exoplanets



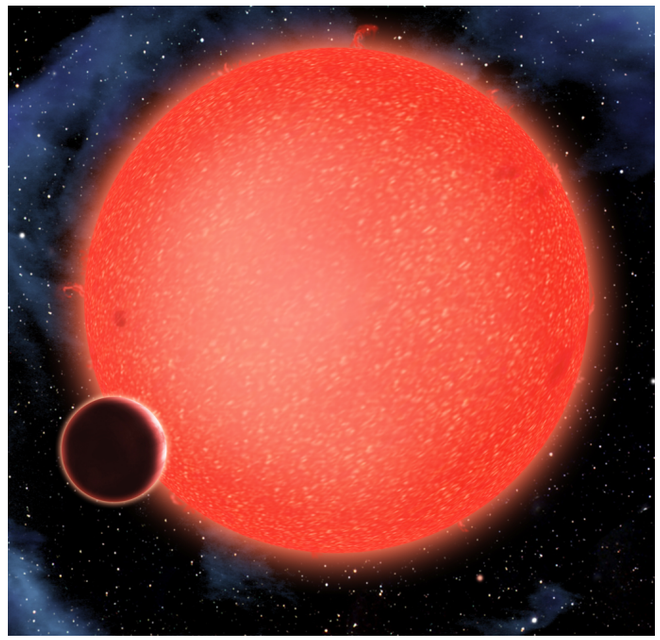
Known transiting exoplanets

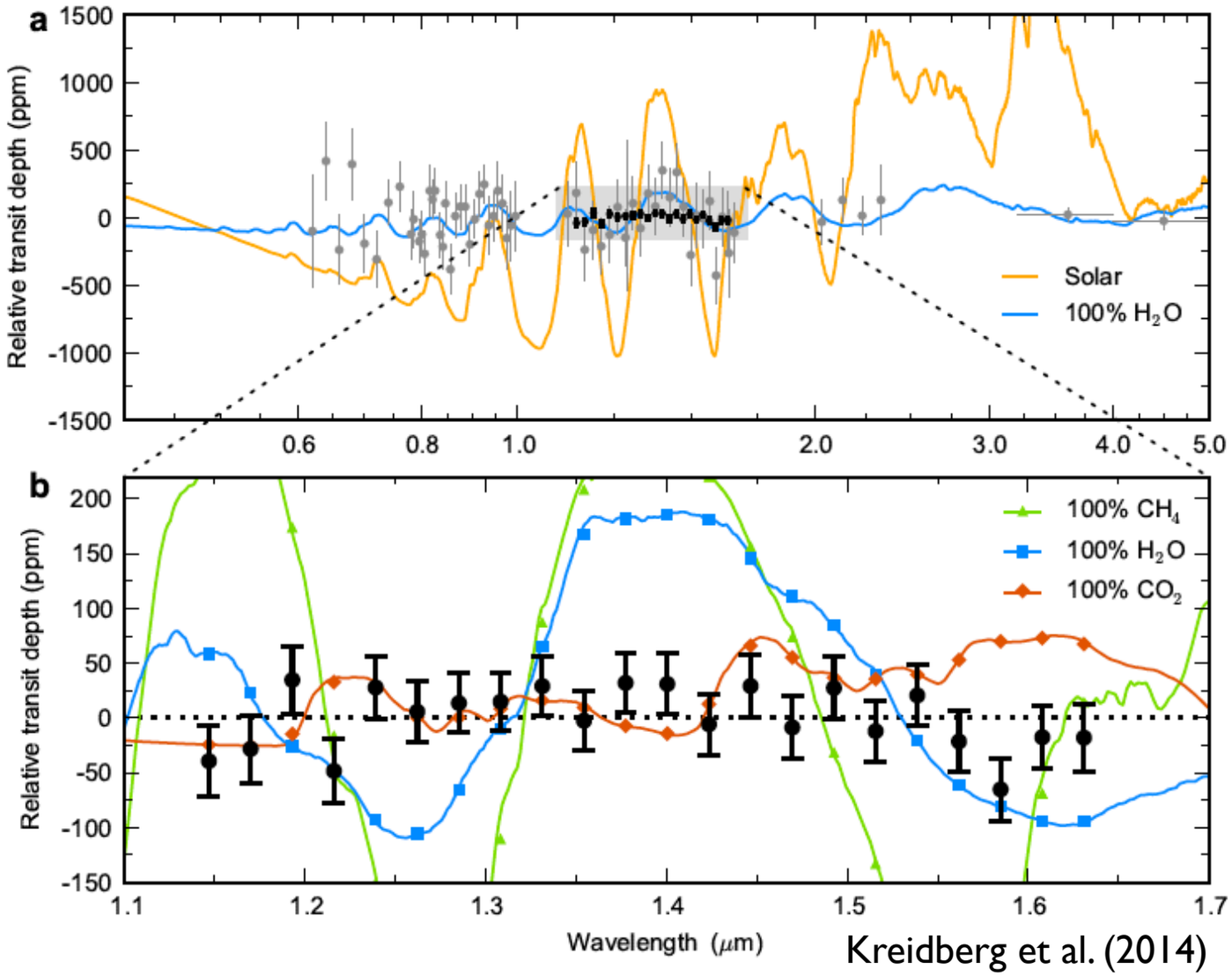
(with measured masses and radii)



Deep super-Earth transits
(small host stars)

GJ 1214b is a super-Earth orbiting a M5 dwarf, discovered from the ground by the MEarths survey thanks to its deep (~1.5 %) transits.



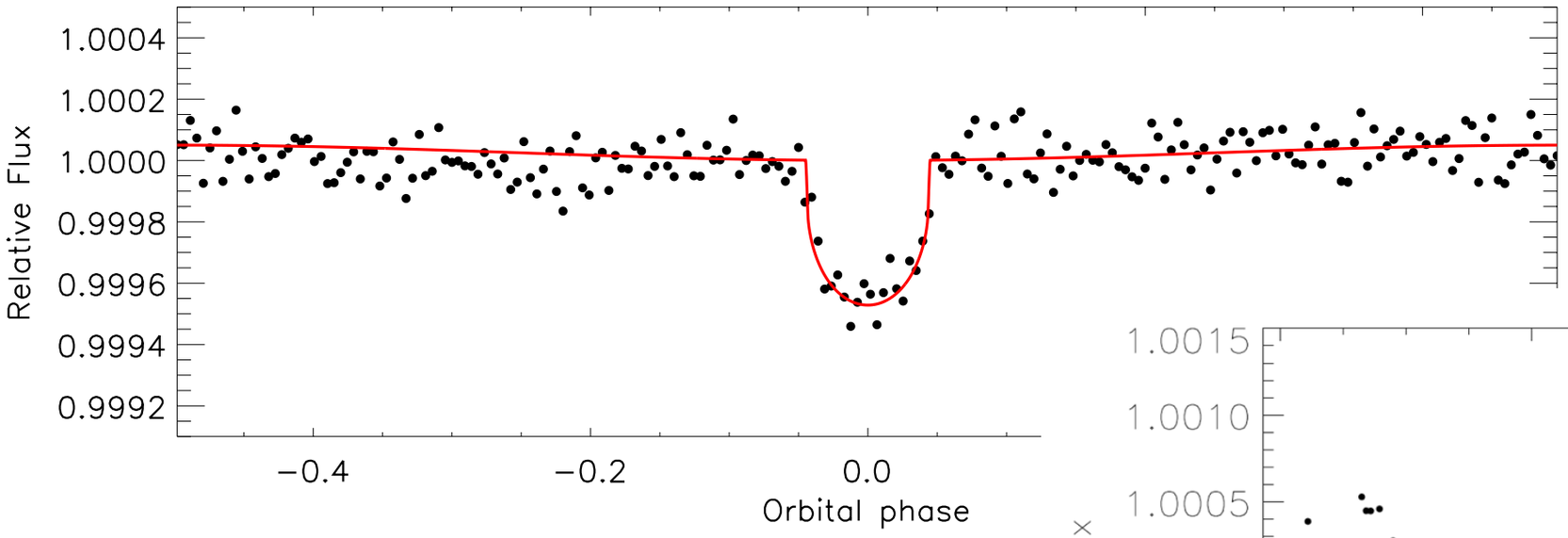


Kreidberg et al. (2014)

A significant disadvantage is that, at the same distance from the star, the geometric transit probability is smaller.

Super-Earths Transiting Bright Stars

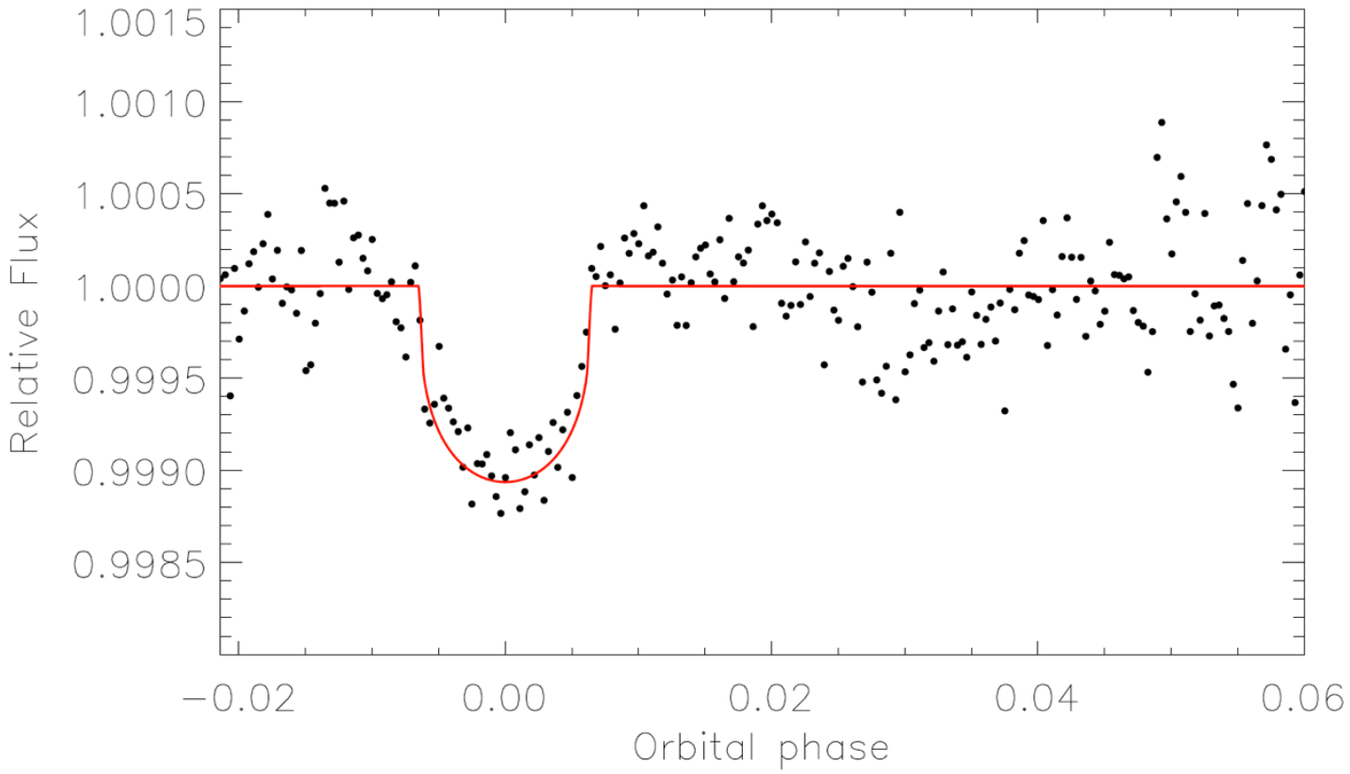
55 Cancri e



planetary radius = **1.990 ± 0.082 R_{Earth}**
planetary mass = **7.81 ± 0.56 M_{Earth}**
planetary mean density = **5.49 ± 0.79 g/cm^3**

period=0.7365417 ± 0.0000027 days

HD 97658b

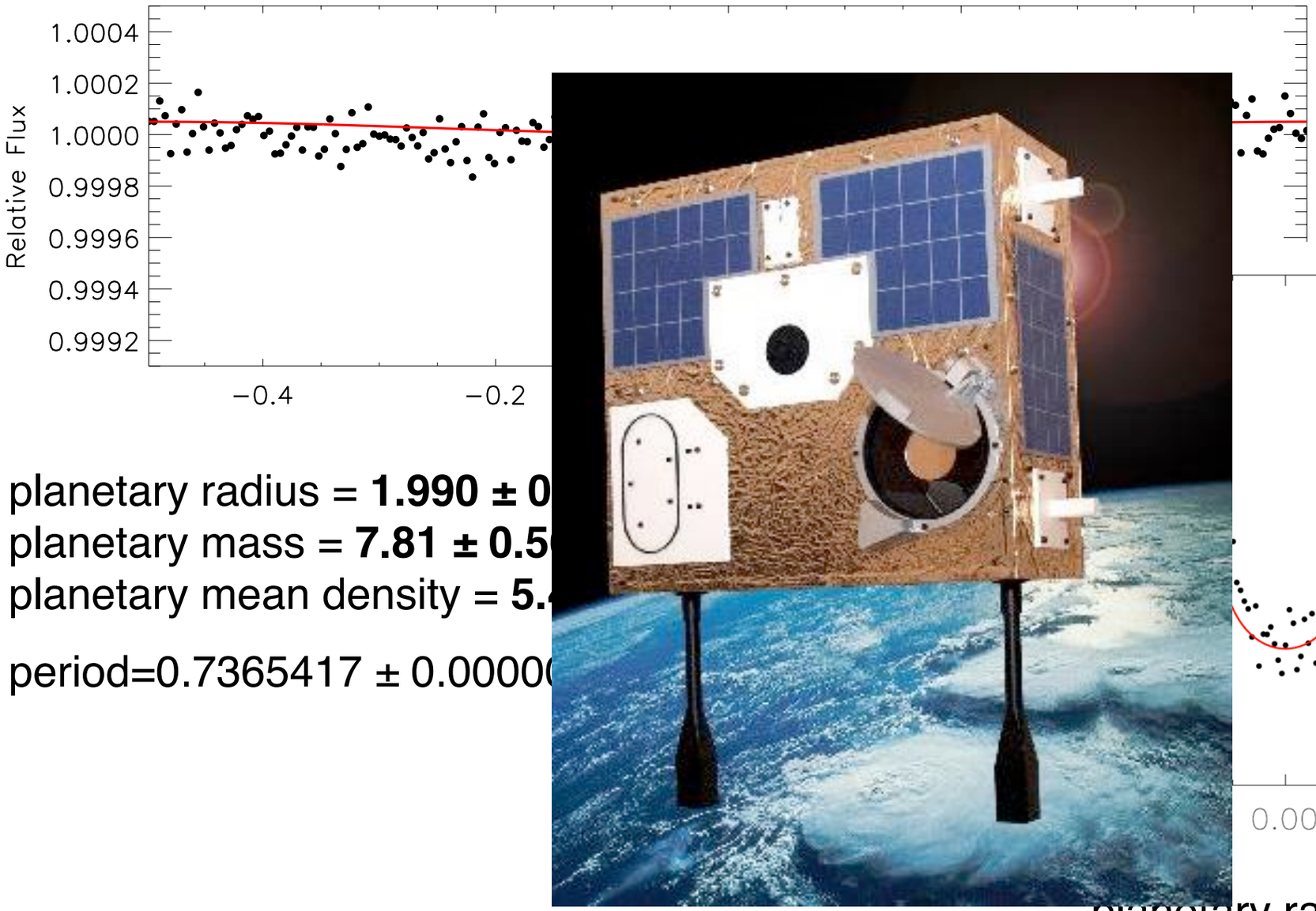


planetary radius = **2.34 ± 0.16 R_{Earth}**
planetary mass = **7.86 ± 0.73 M_{Earth}**
planetary mean density = **3.4 ± 0.7 g/cm^3**

period=9.4894 ± 0.0002 days

Super-Earths Transiting Bright Stars

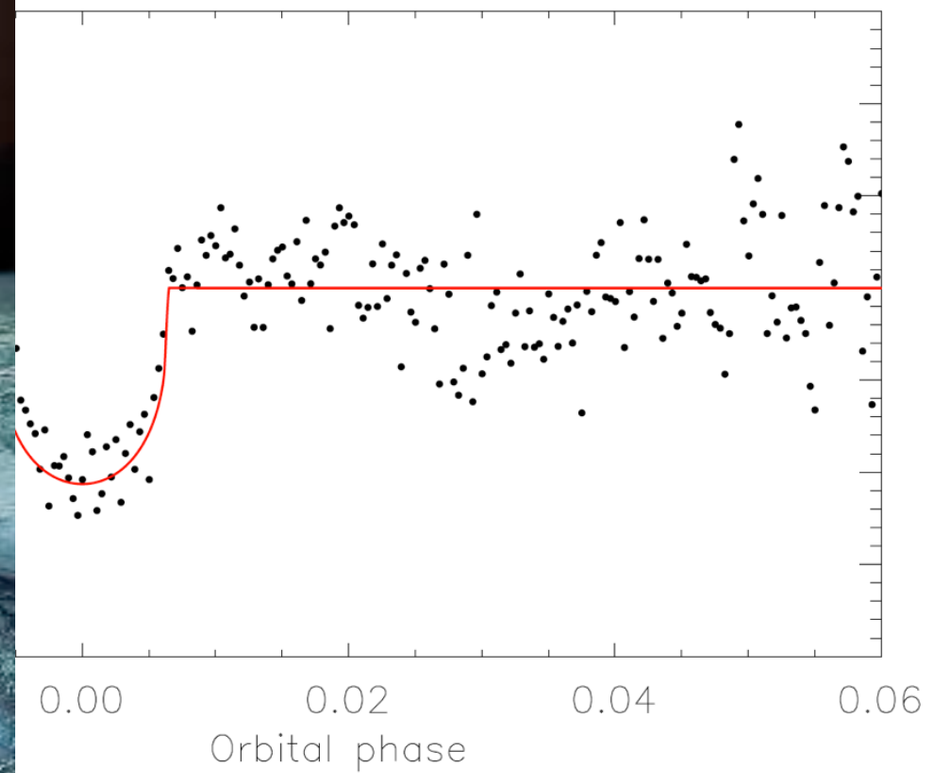
55 Cancri e



planetary radius = **1.990 ± 0**
planetary mass = **7.81 ± 0.5**
planetary mean density = **5.**

period=0.7365417 ± 0.0000

HD 97658b



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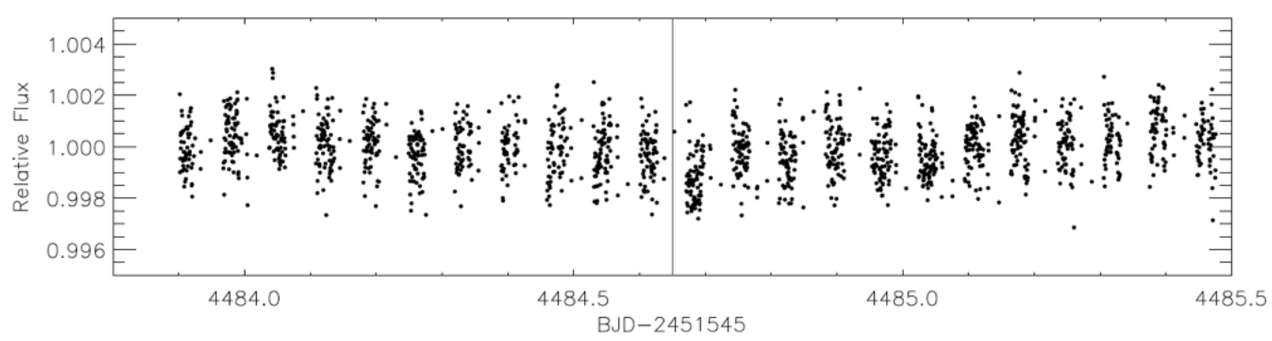
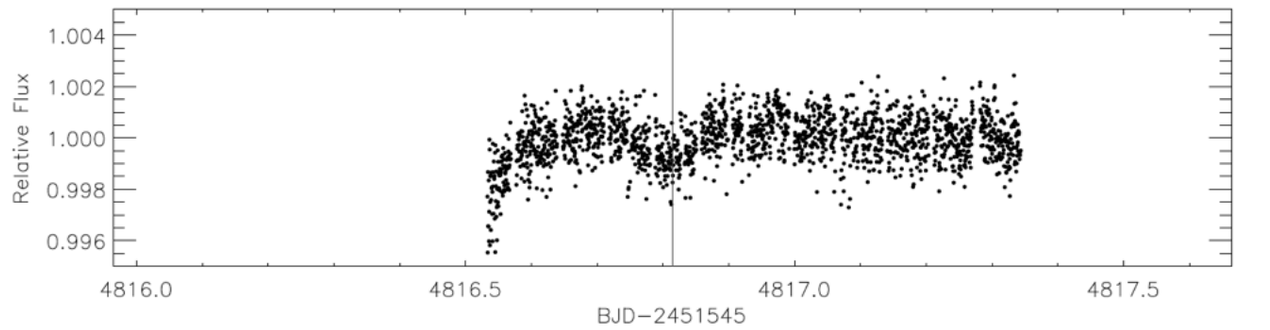
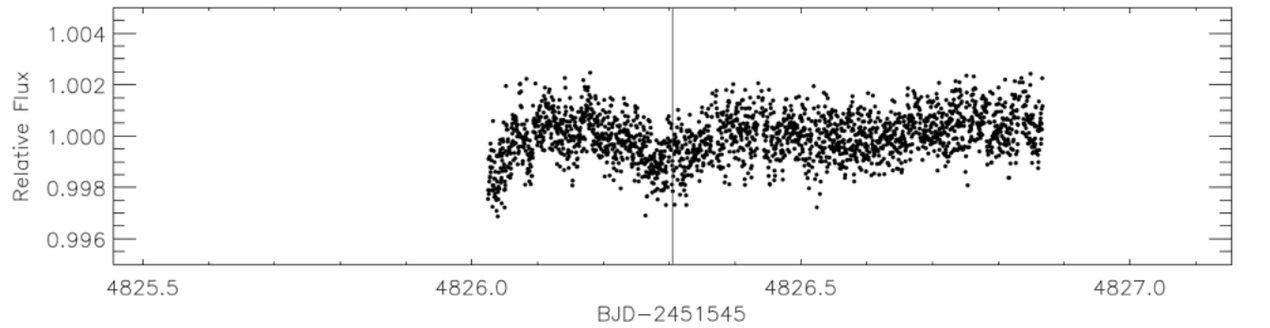
HD 97658b: MOST transits

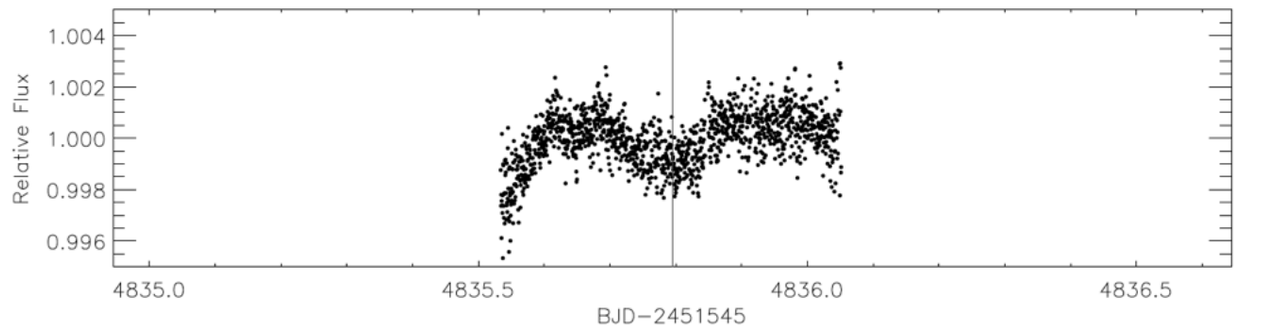
2012

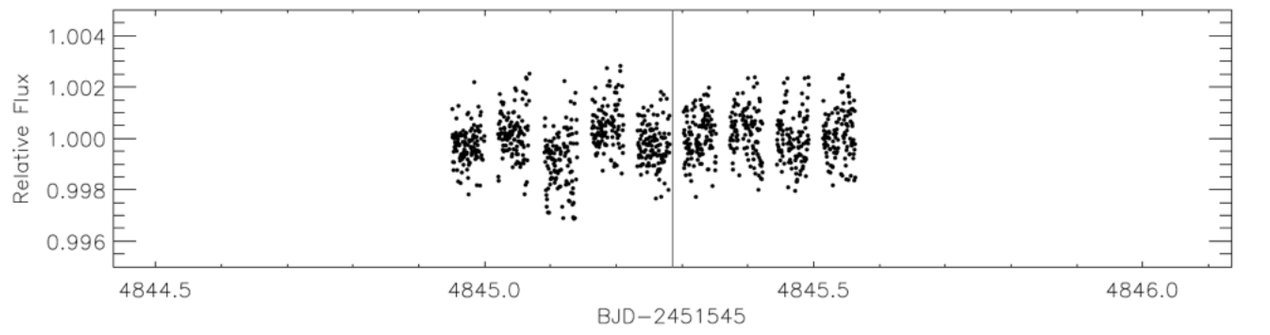
2013





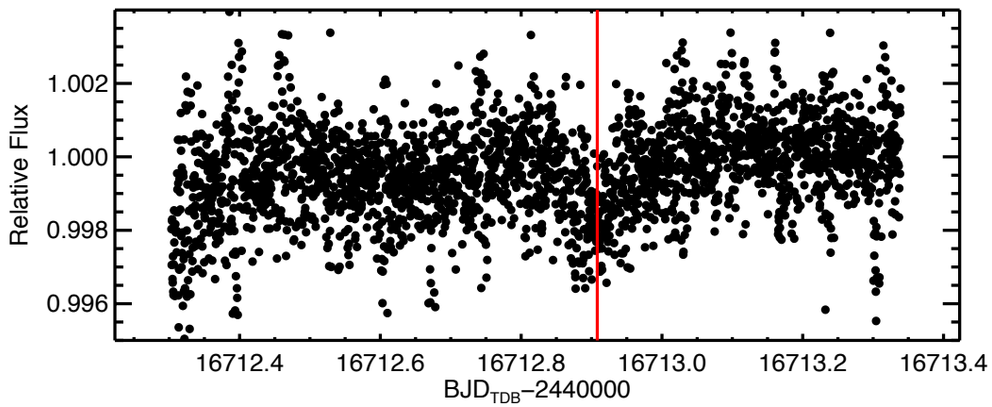


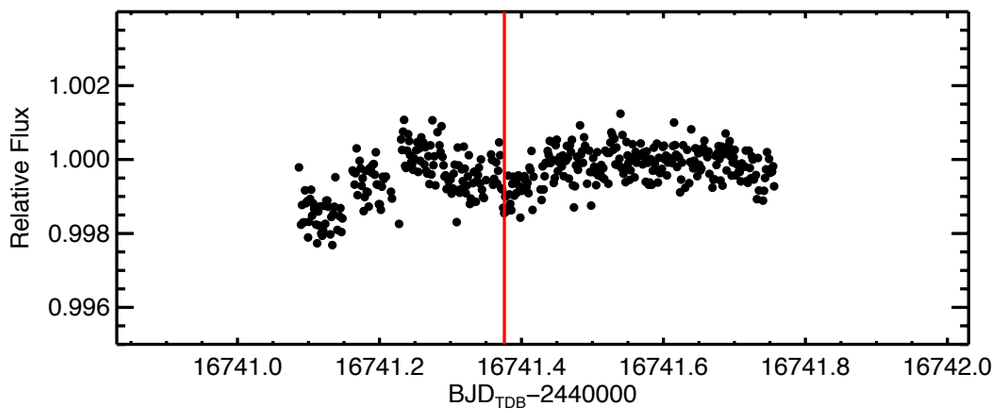


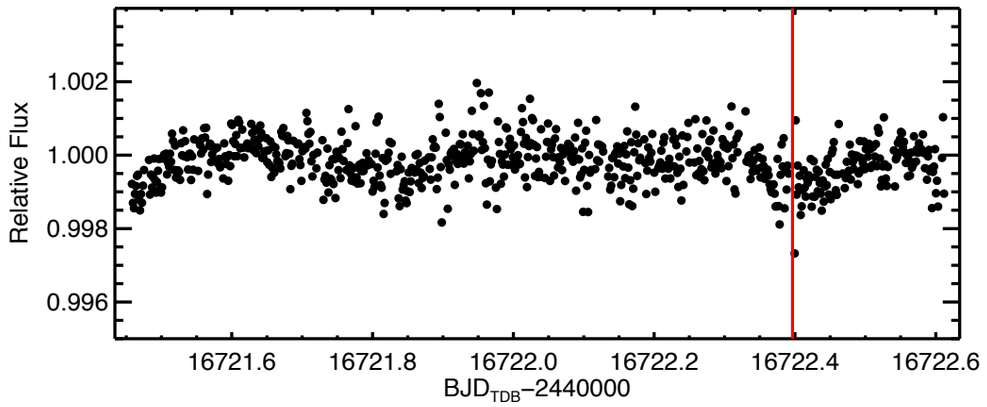


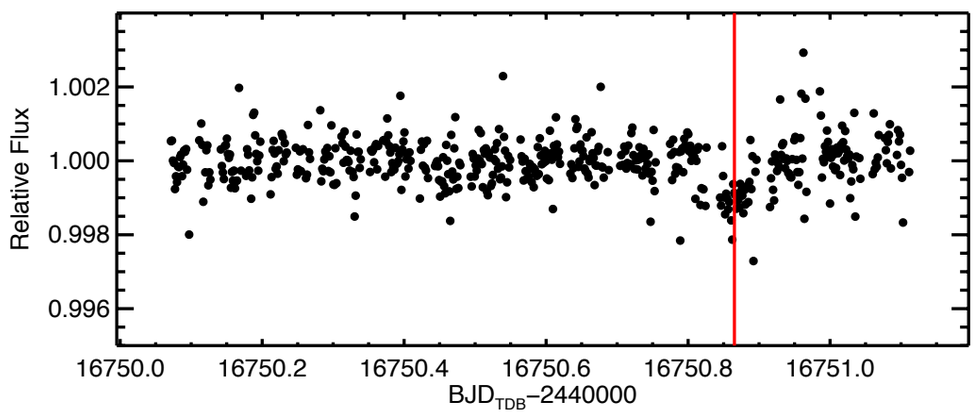
Dragomir et al. (2013)

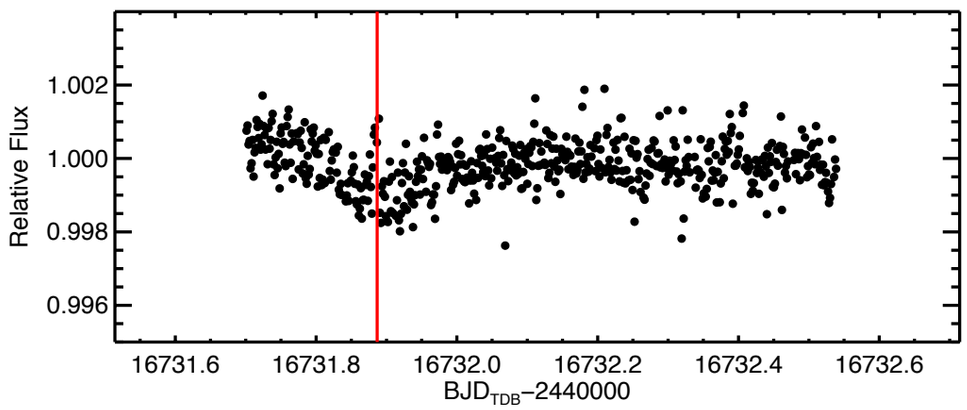
HD 97658b: MOST transits





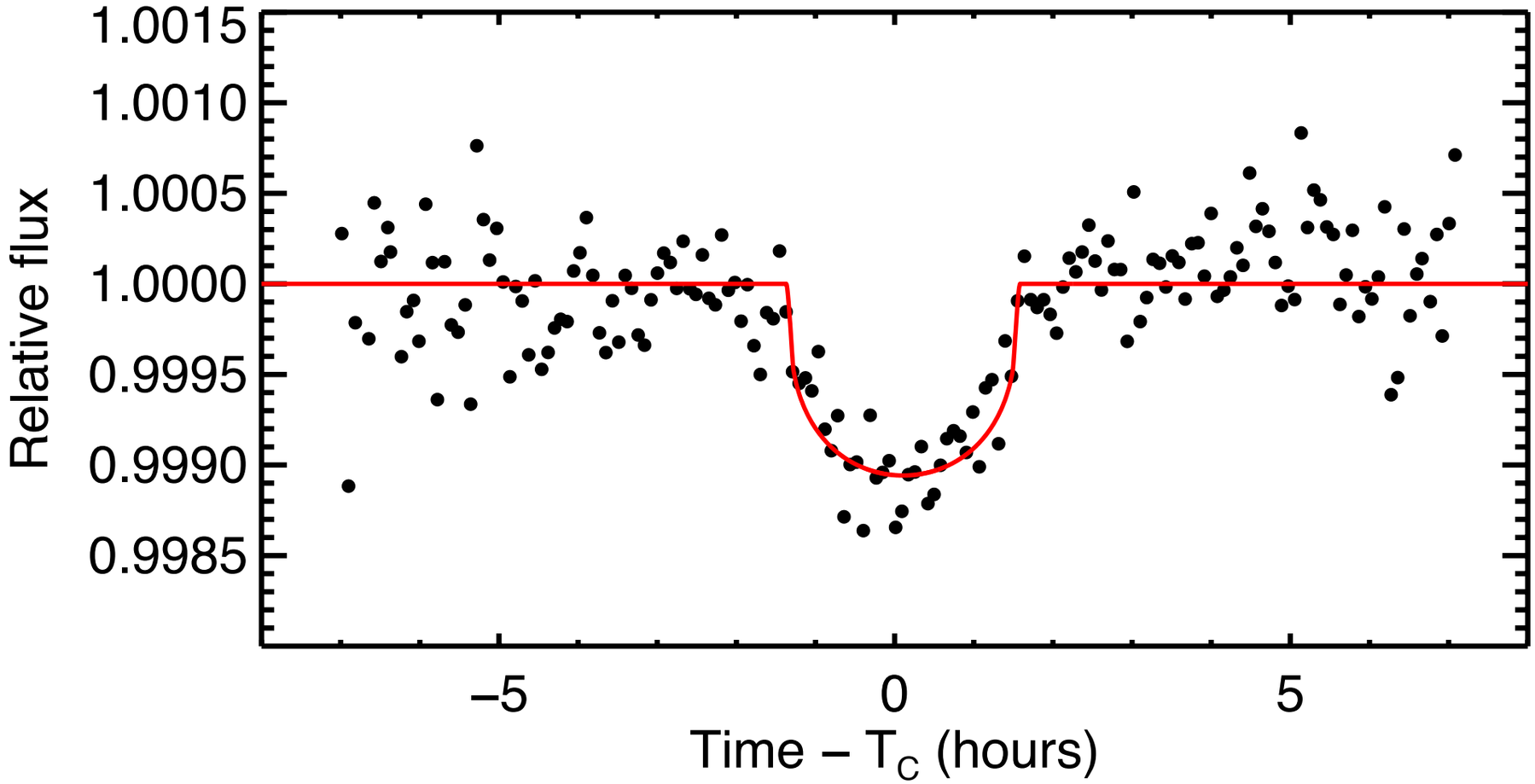






2014

Properties of the HD 97658 System



Star:

K1V

V mag = 7.7

R_{star} = 0.74 ± 0.024 R_{Sun}

M_{star} = 0.77 ± 0.050 M_{Sun}

Age = 7.7 ± 4.4 Gyr

Planet:

Period = 9.4909 ± 0.0016 days

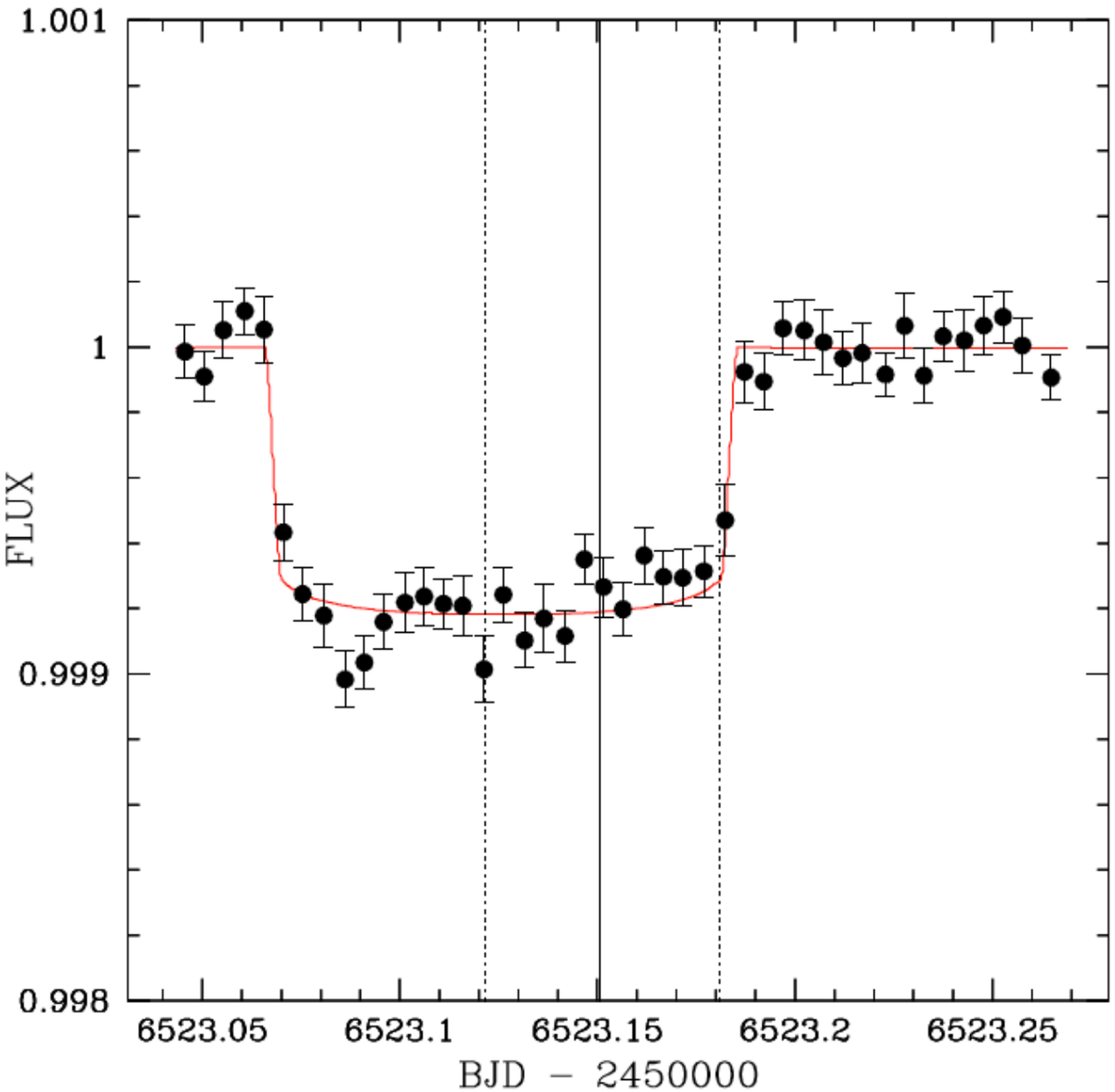
M_P = 7.55 ± 0.8 M_{Earth}

Orbital inclination = 89.29 ± 0.4 deg

R_P = 2.38 ± 0.12 R_{Earth}

ρ_p = 3.0 ± 0.5 g cm^{-3}

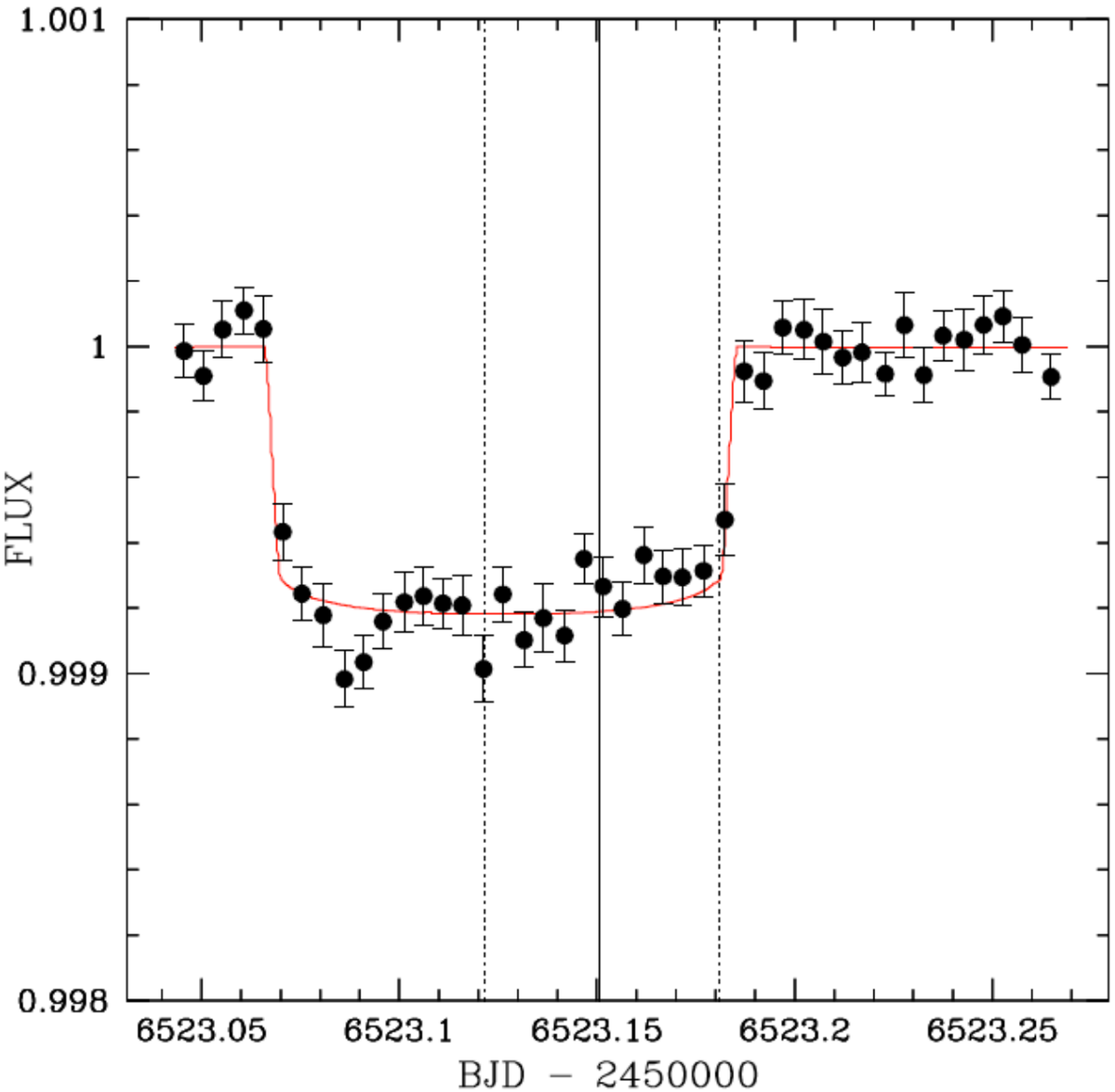
Spitzer Transit



Planetary radius and mid-transit time consistent with MOST results.

van Grootel et al. (2014)

Spitzer Transit



van Grootel et al. (2014)

Planetary radius and mid-transit time consistent with MOST results.

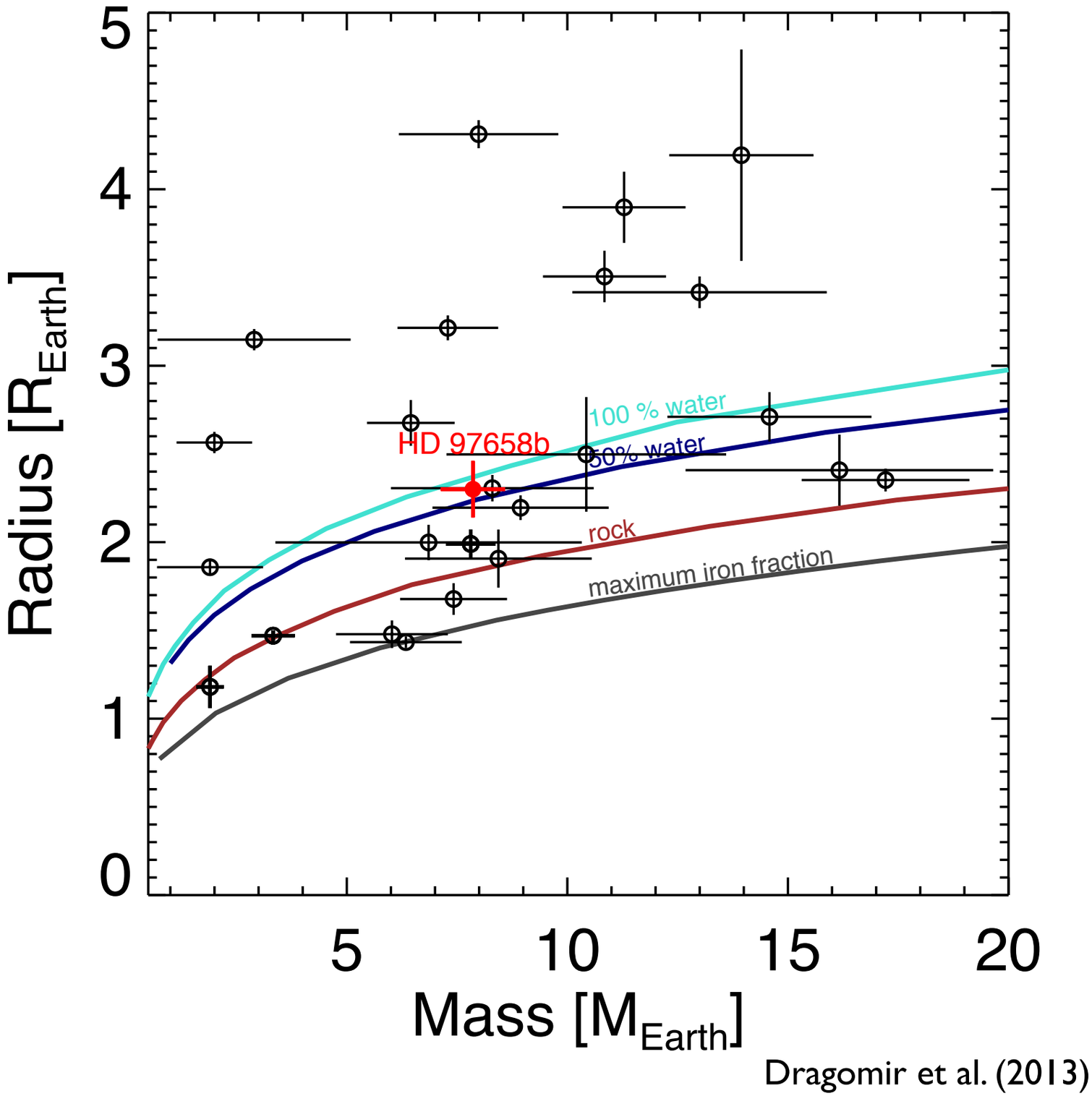
Period = 9.4909 ± 0.0016 days

$M_P = 7.55 \pm 0.8\ M_{Earth}$

$R_P = 2.25 \pm 0.097\ R_{Earth}$

$\rho_p = 3.9 \pm 0.7\ g\ cm^{-3}$

The composition of HD 97658b



Dragomir et al. (2013)

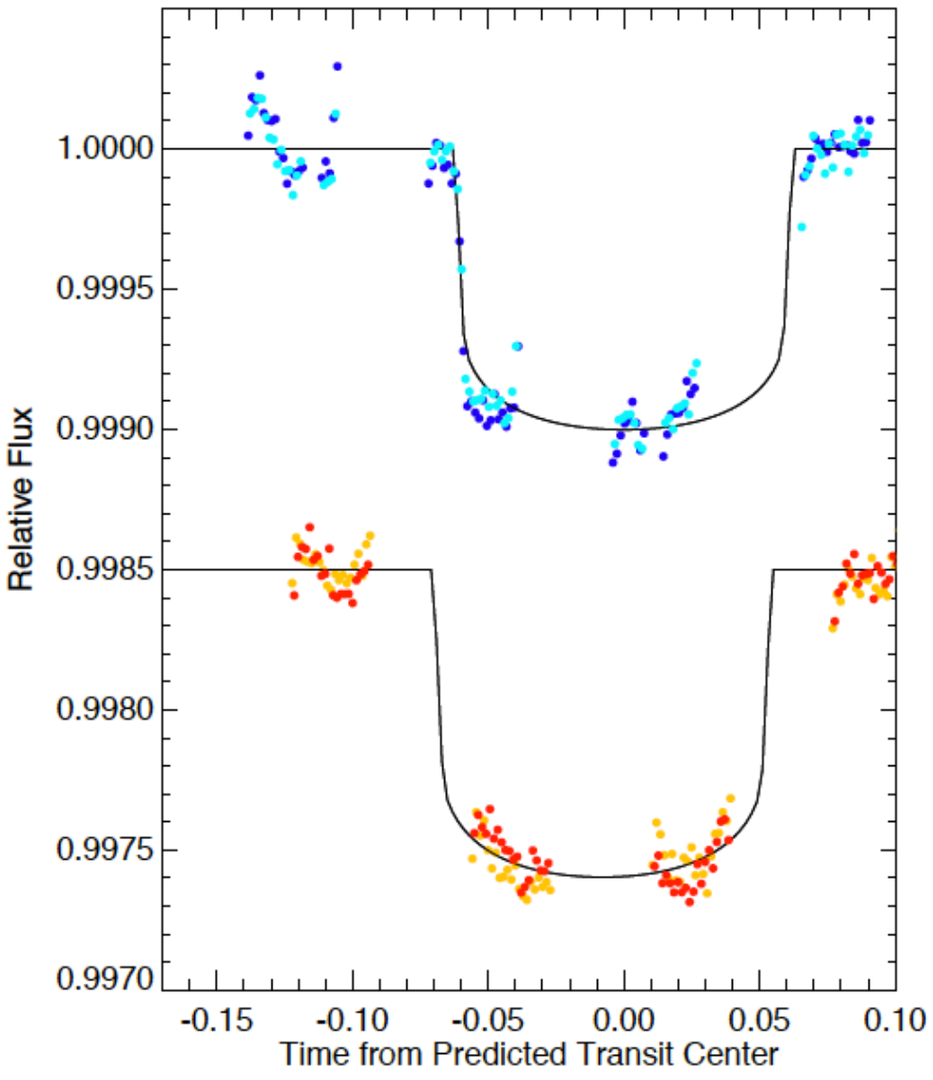
HD 97658b

A low mean molecular weight (hydrogen/helium) atmosphere fits the planetary density;

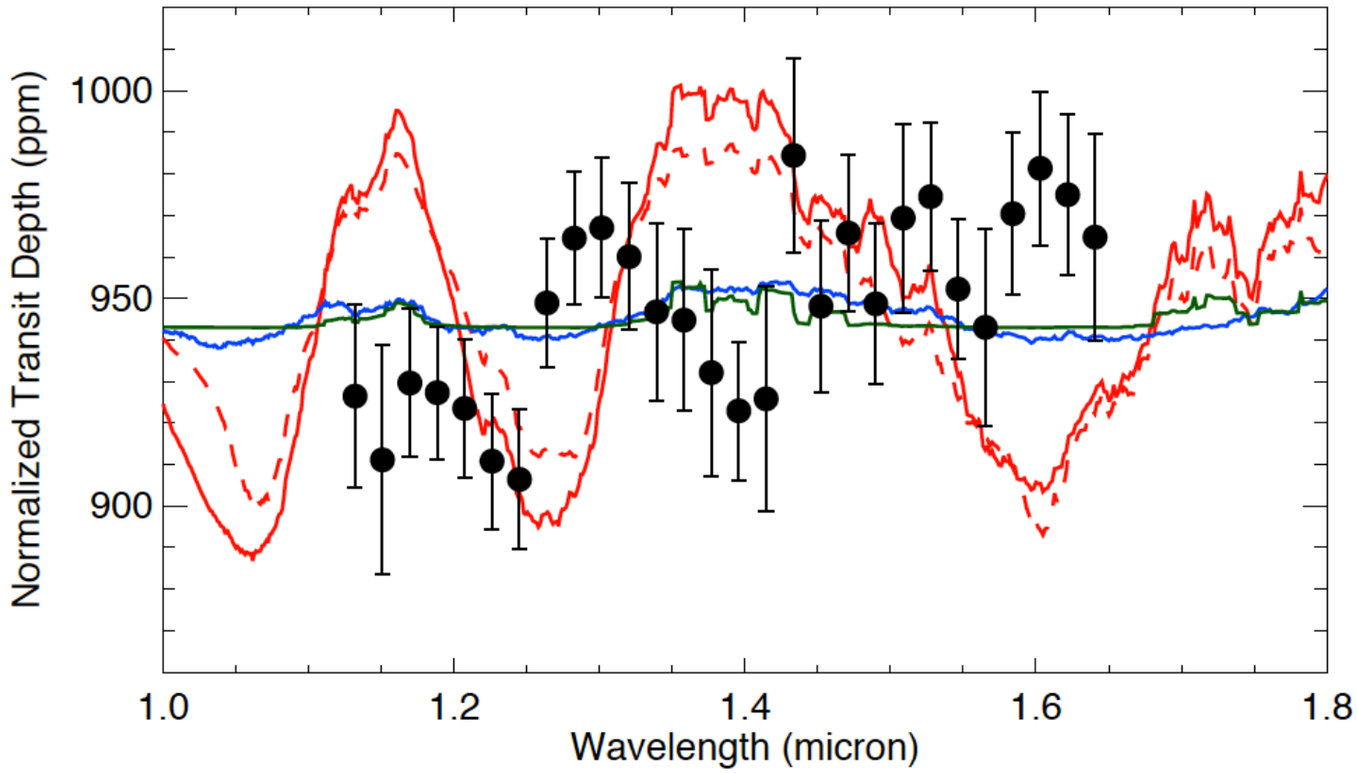
but a water vapor atmosphere cannot be ruled out

HST WFC3 observations

White light curves



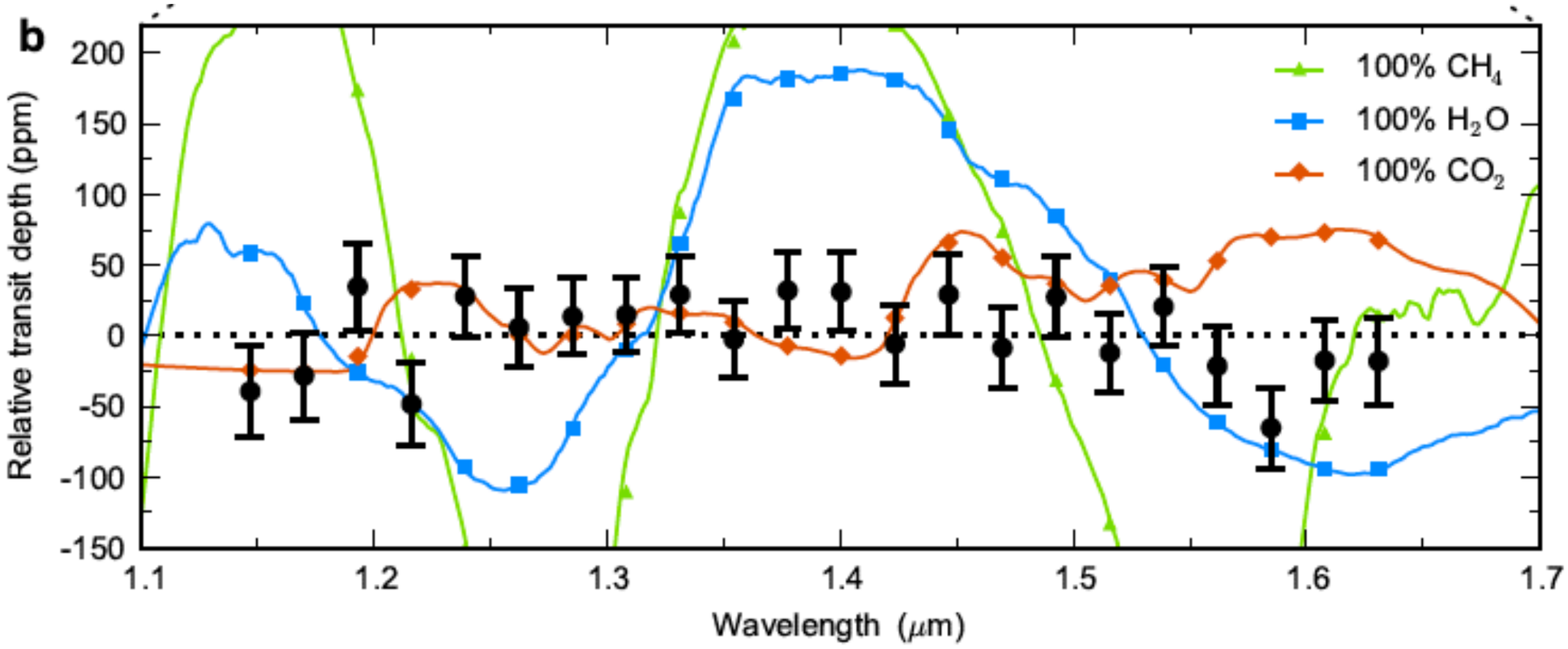
Knutson et al., in press



Knutson et al., in press

The HD 97658b WFC3 transmission spectrum is inconsistent with the solar cloud-free model at the 17σ level.

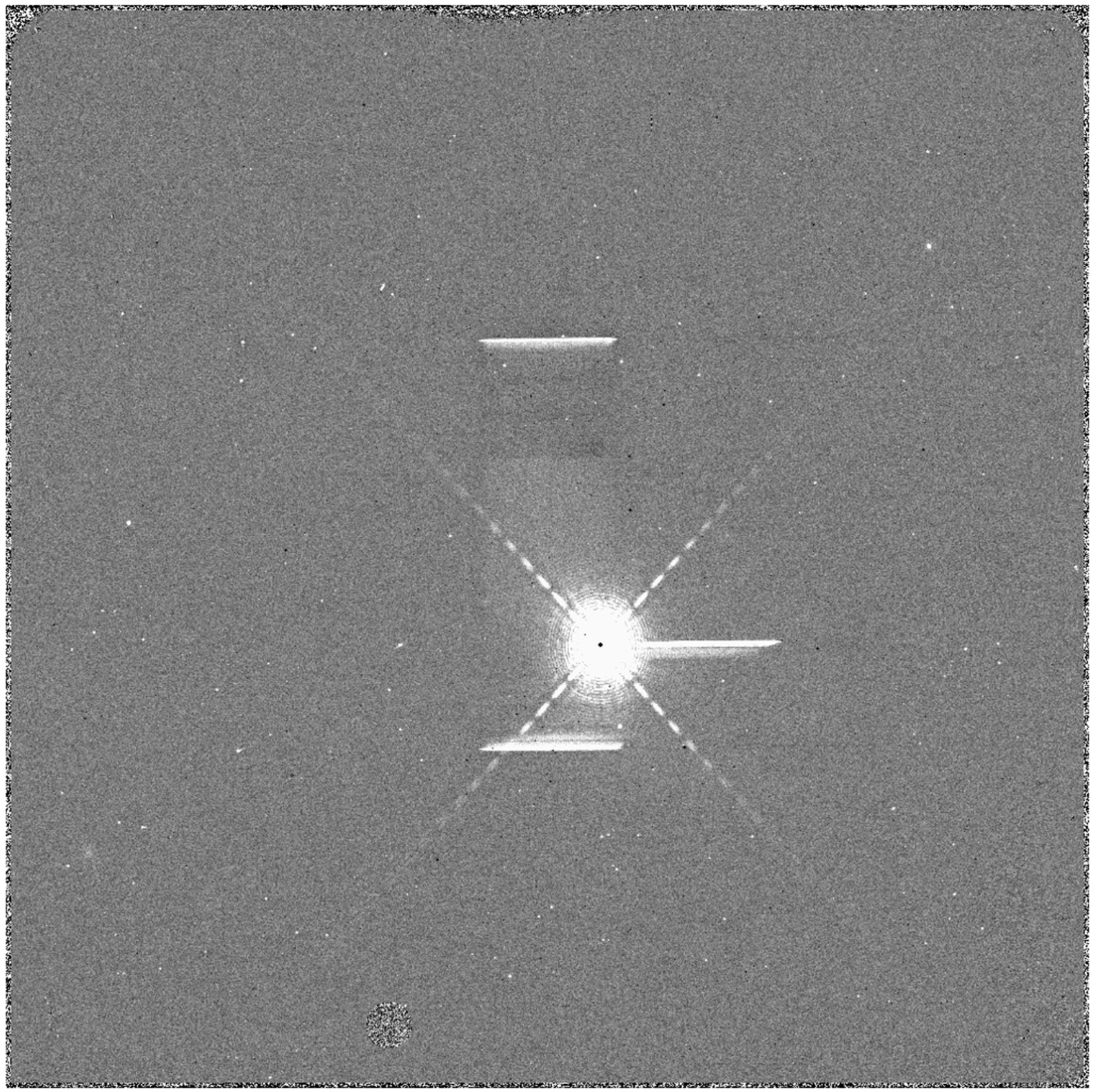
Compare with the NIR spectrum of GJ 1214b...



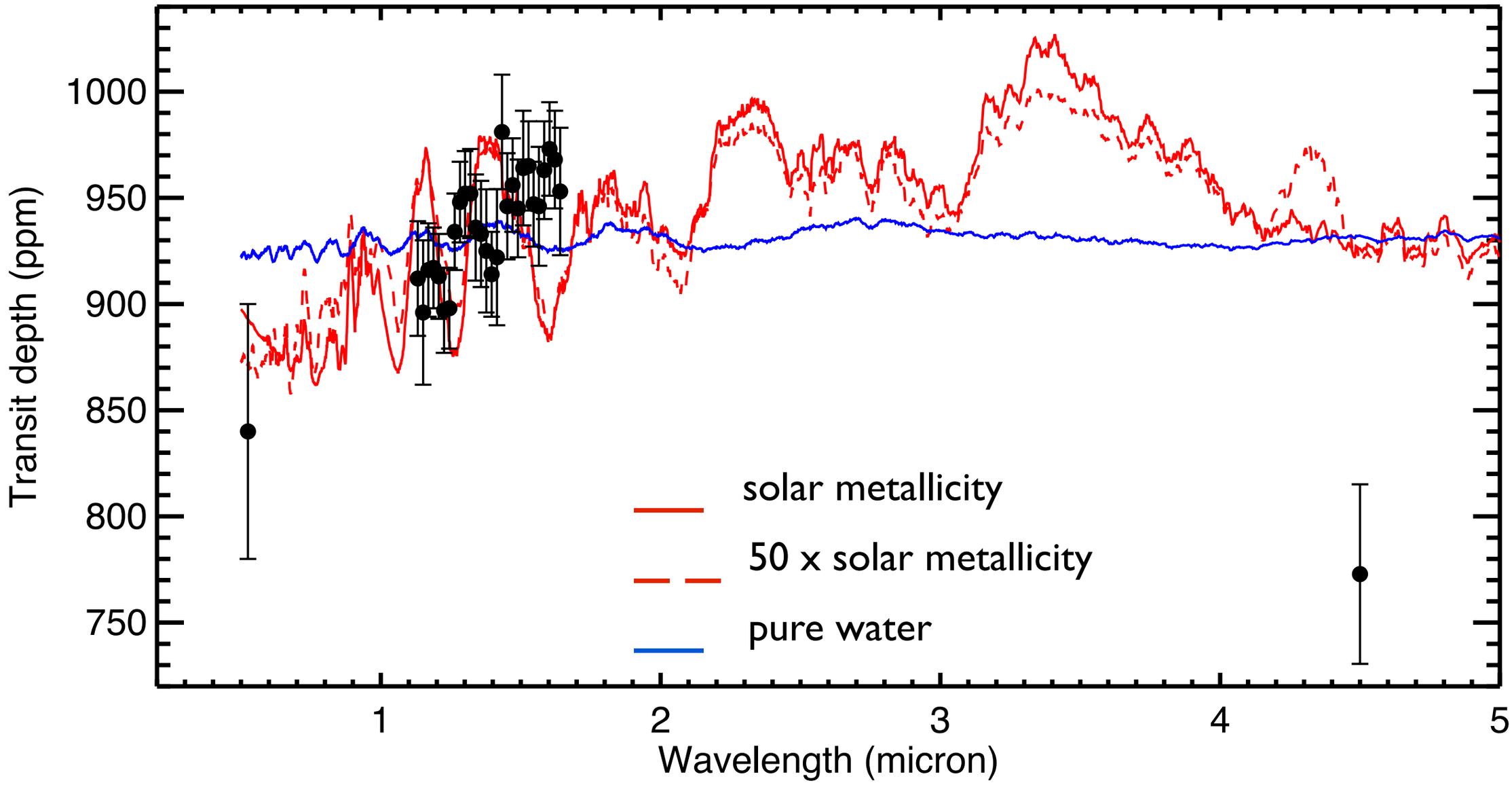
Kreidberg et al. (2014)

...which strongly suggests the presence of clouds in the planet's atmosphere

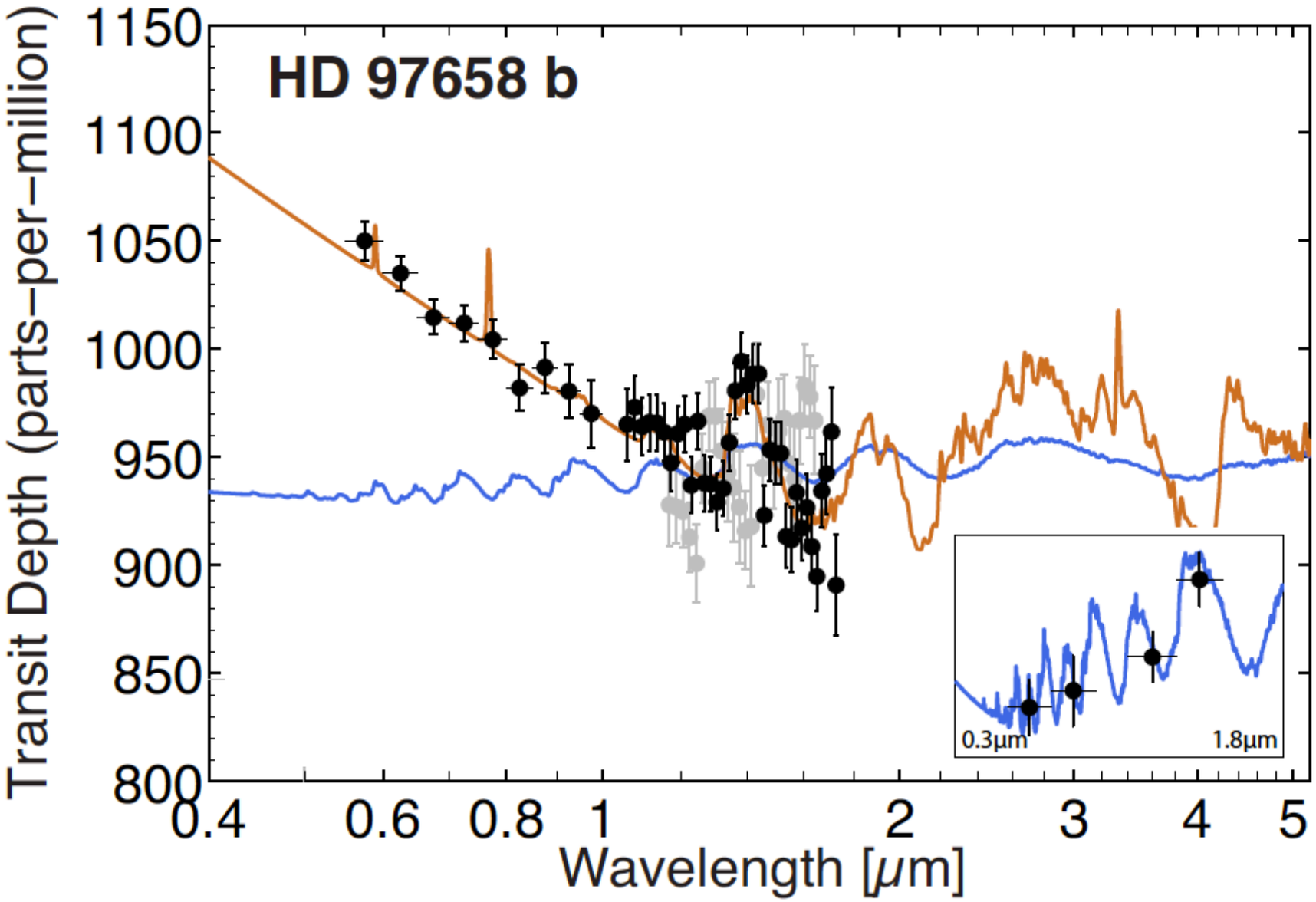
How (not) to make friends with the Extra-Galactic People



Transmission Spectrum to Date



Rayleigh Scattering?

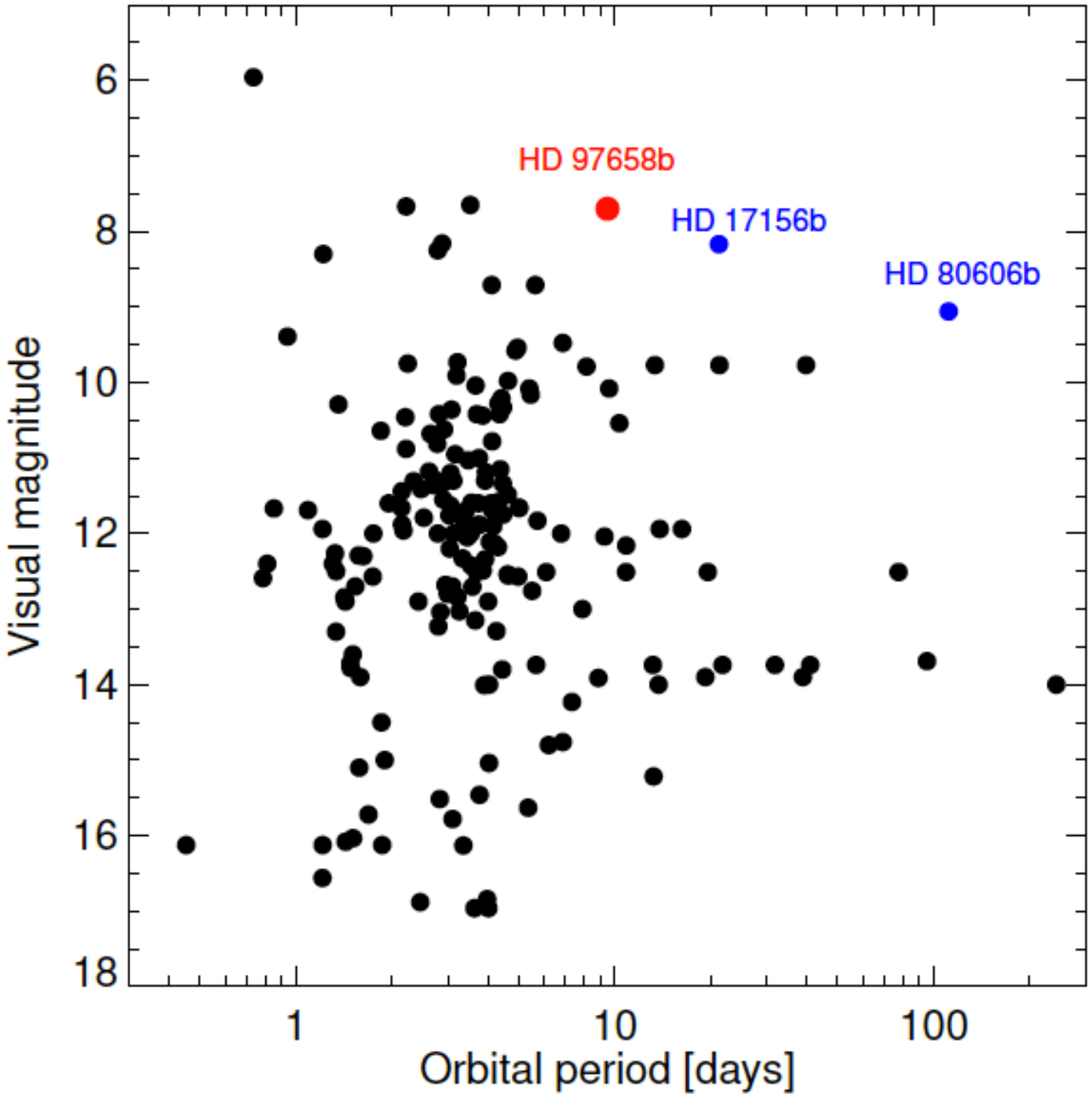


Simulated observations!

Figure credit: B. Benneke

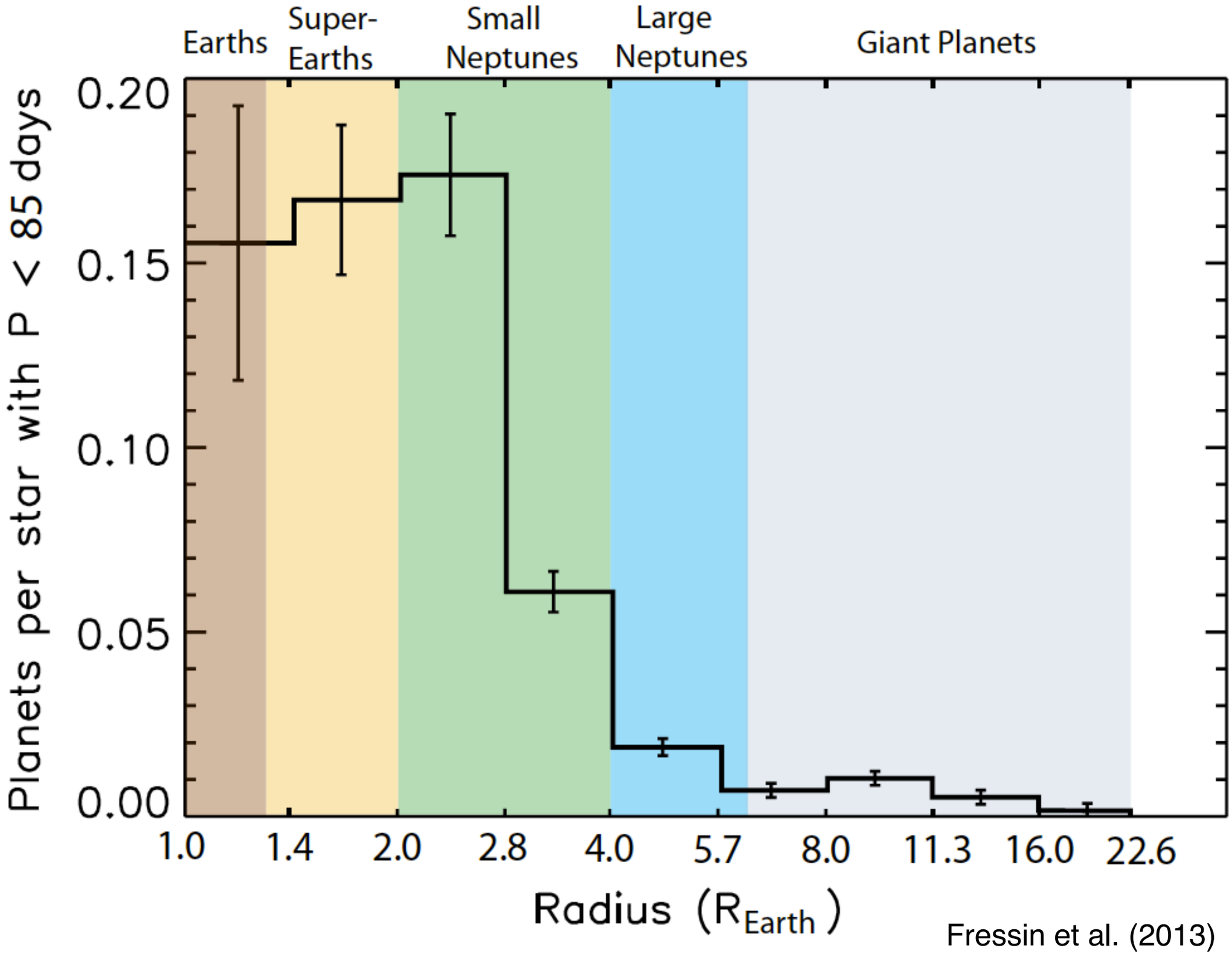
Rayleigh scattering may be key to determining scale height.

A Warm Super-Earth around a Very Bright Star



Dragomir et al. (2013)

HD 97658b in context

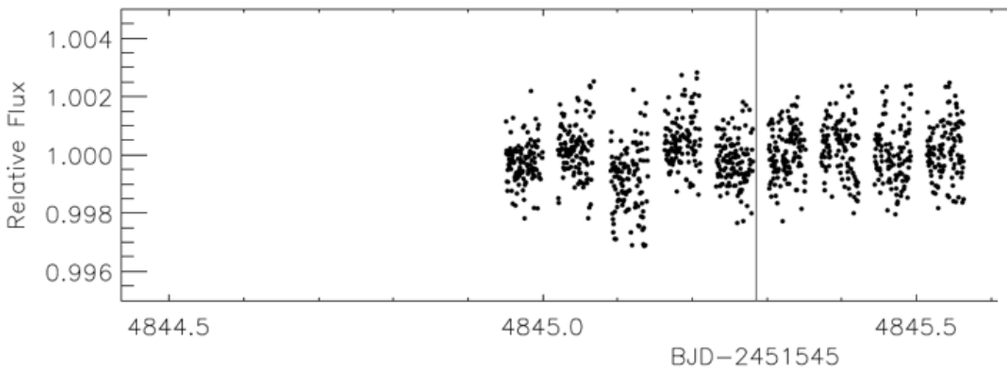


Fressin et al. (2013)

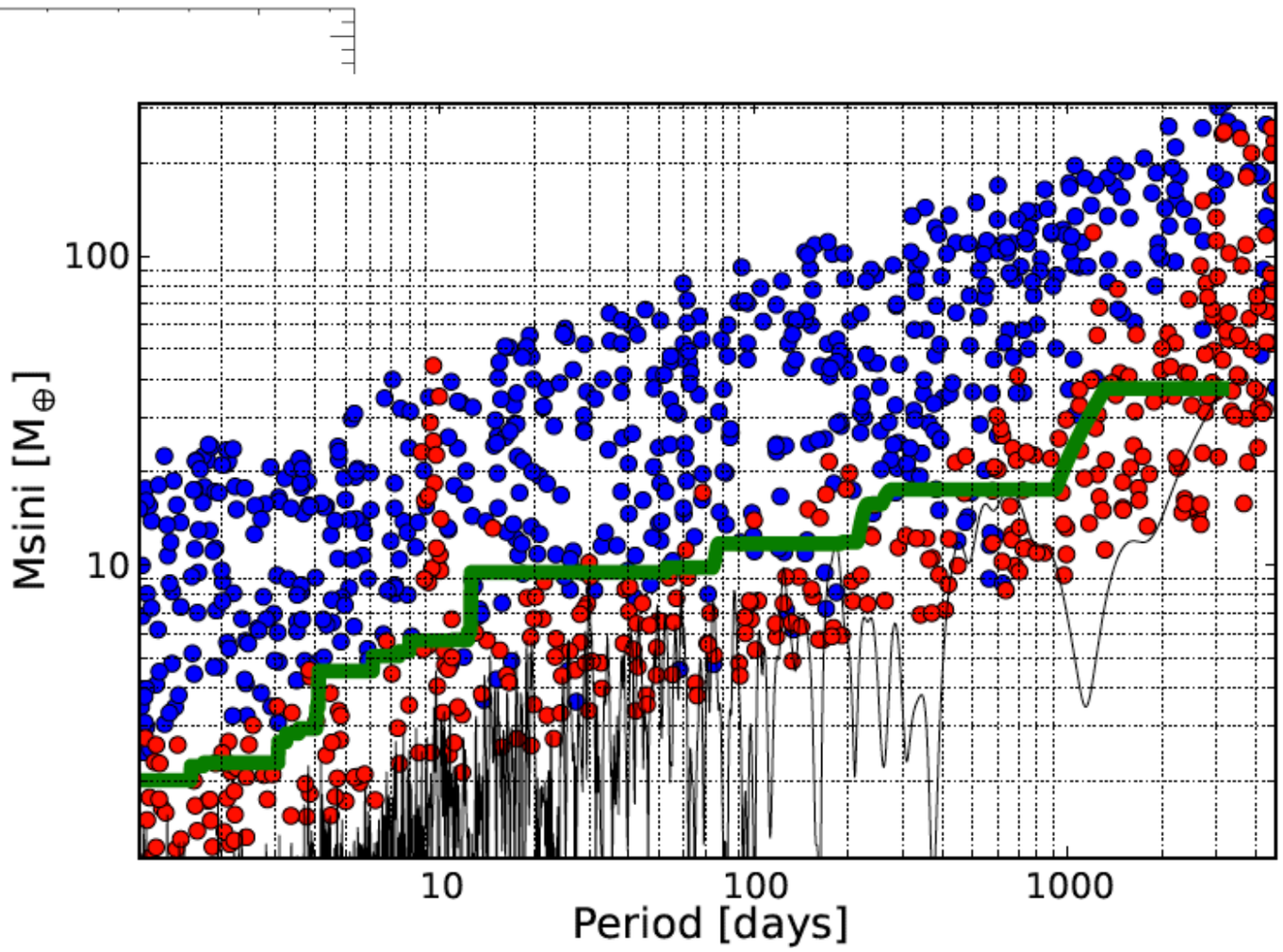
Ongoing Follow-up

- *Spitzer* observations at 3.6 μm (PI: D. Dragomir)
- upcoming *HST STIS* and *WFC3* observations (PIs: B. Benneke and I. Crossfield)
- Possible *CHARA* observations to directly measure the stellar radius.

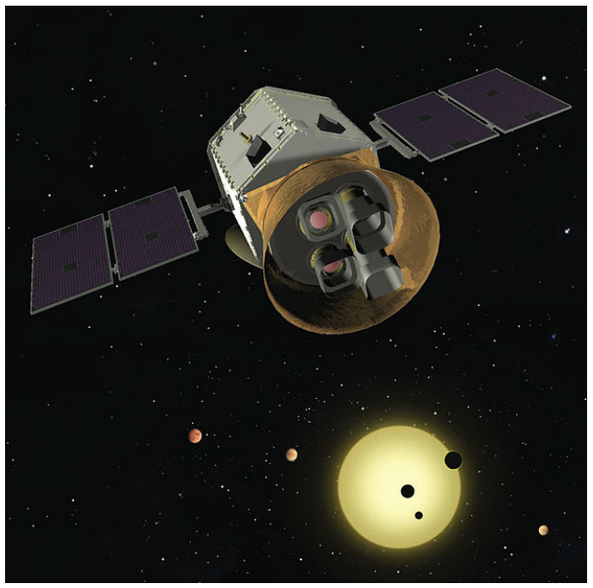
Search for additional planets



If orbits are co-planar, then the transit probability of a planet with an orbit inner to that of HD 97658b is close to 100%.

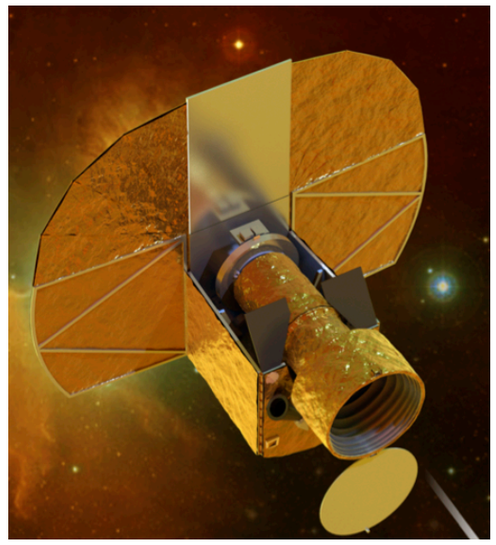


Future



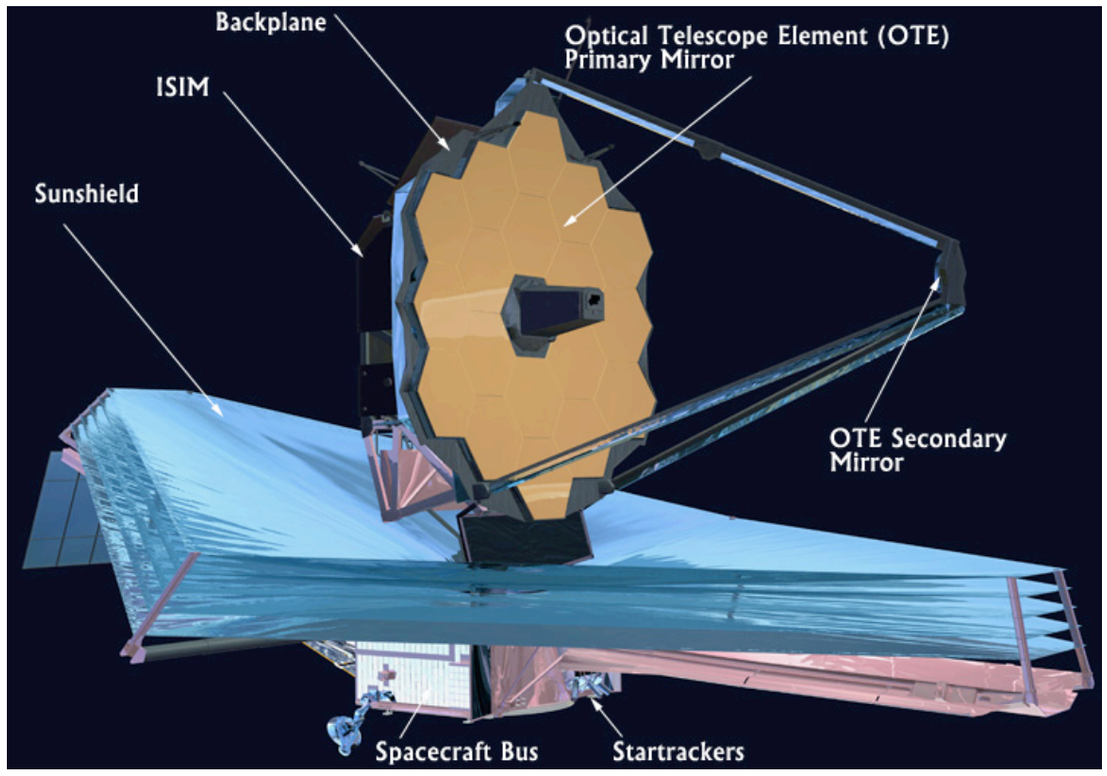
TESS (launch 2017)

Credit: TESS team



CHEOPS (launch 2017)

Credit: University of Bern



JWST (launch 2018)

Credit: STScI

Summary

- Super-Earths transiting bright stars are our main hope for understanding these objects.

- HD 97658b is a 2.3 R_{Earth} exoplanet orbiting a K dwarf with a period of 9.5 days.

- It has a very low density, encouraging studies of its atmosphere.

- Current data rules out a substantial H/He atmosphere.

- Upcoming measurements will determine whether the atmosphere of HD 97658 has a high mean molecular weight, or whether it is hydrogen-rich and covered by clouds;

    - if clouds, a measurement of the Rayleigh scattering slope may help constrain its scale height.