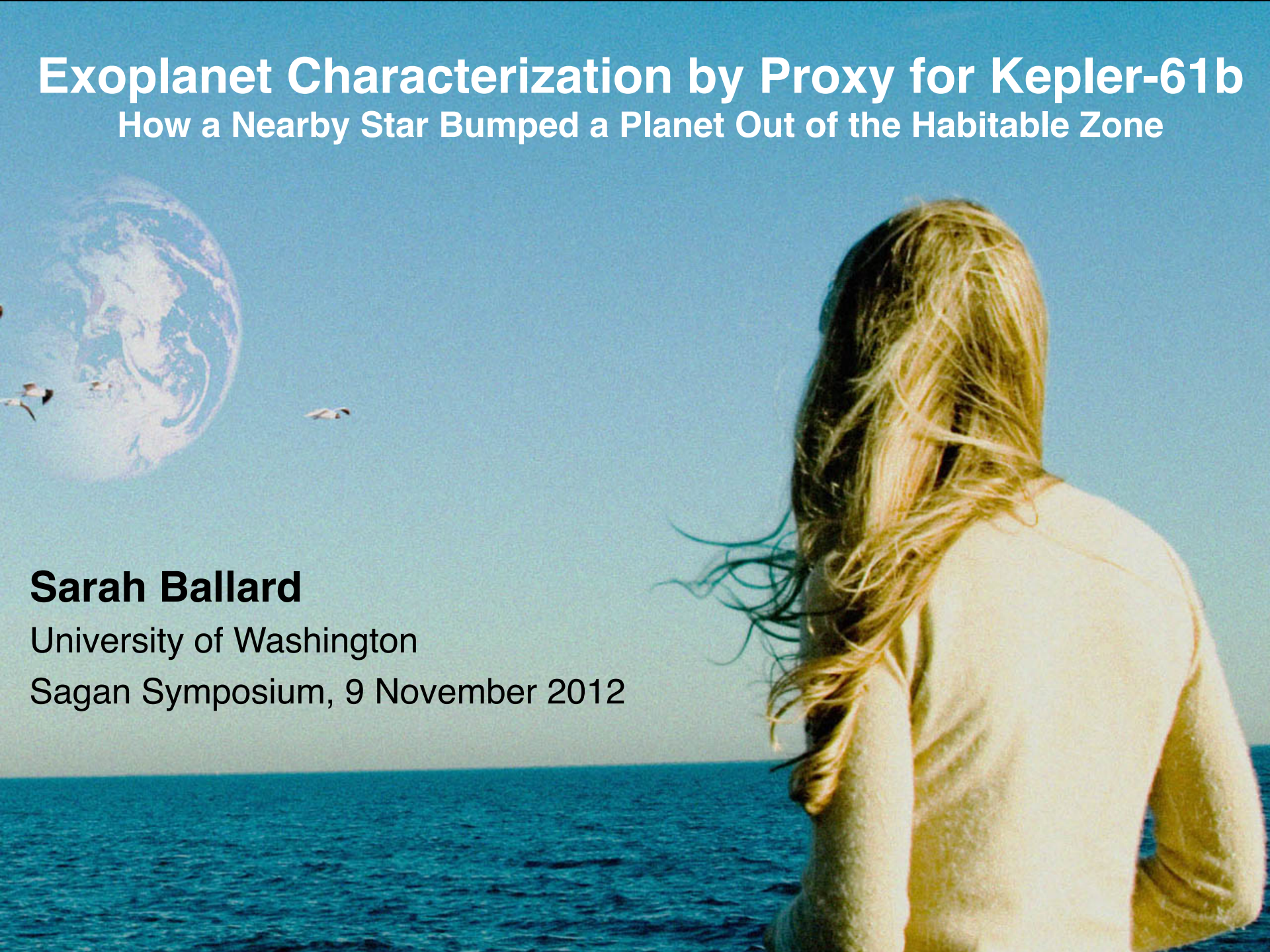
Exoplanet Characterization by Proxy for Kepler-61b

How a Nearby Star Bumped a Planet Out of the Habitable Zone



Sarah Ballard

University of Washington

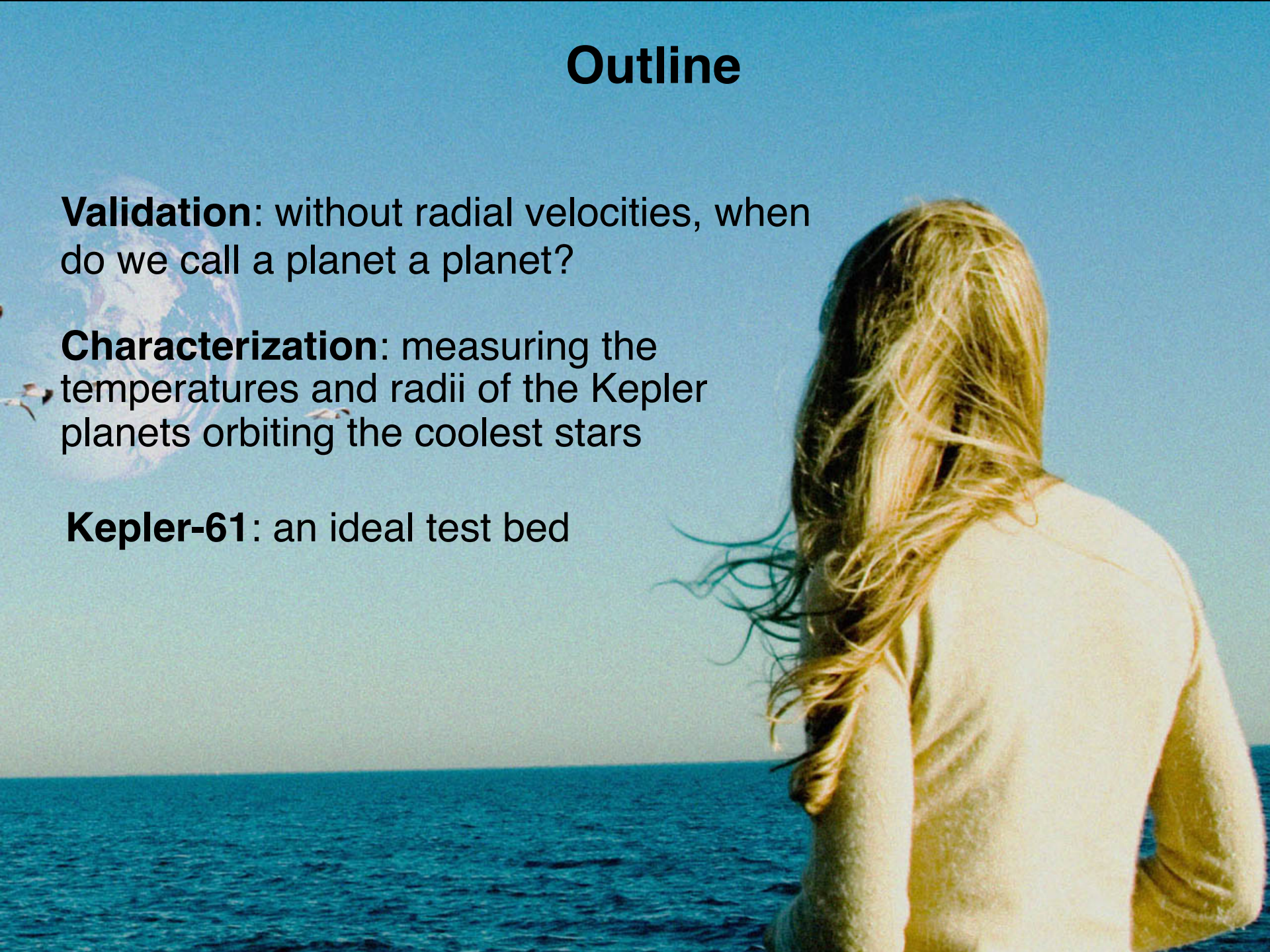
Sagan Symposium, 9 November 2012

Outline

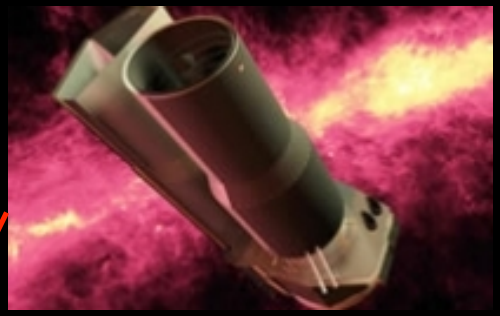
Validation: without radial velocities, when do we call a planet a planet?

Characterization: measuring the temperatures and radii of the Kepler planets orbiting the coolest stars

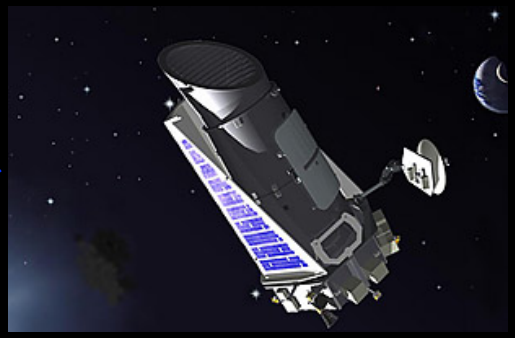
Kepler-61: an ideal test bed

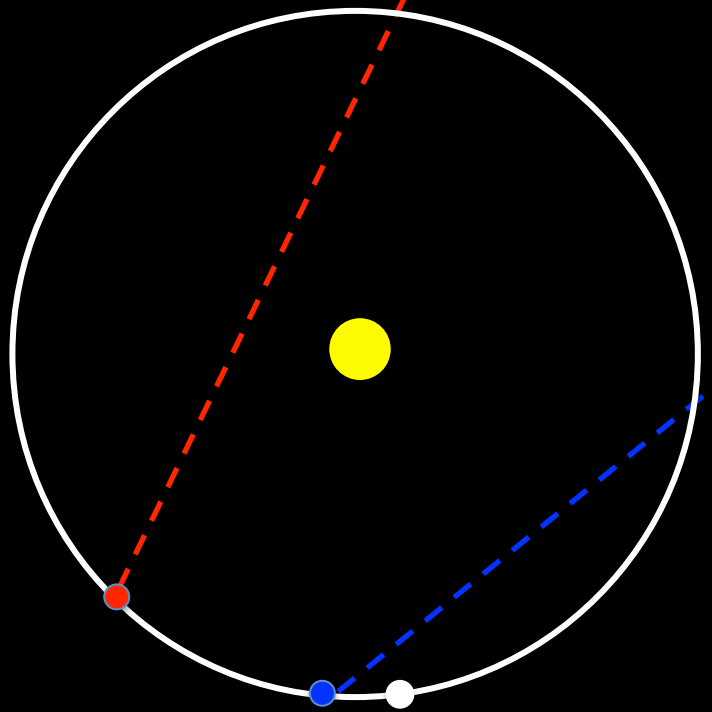


Spitzer

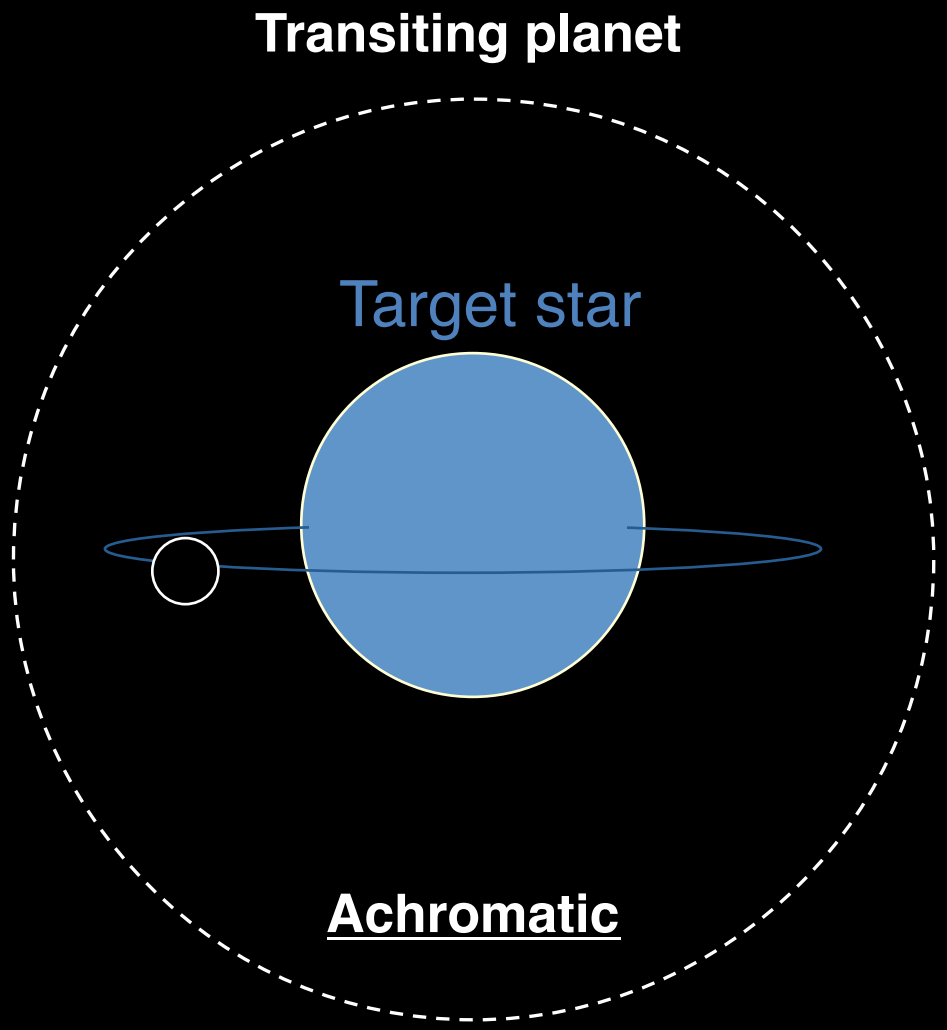


Kepler



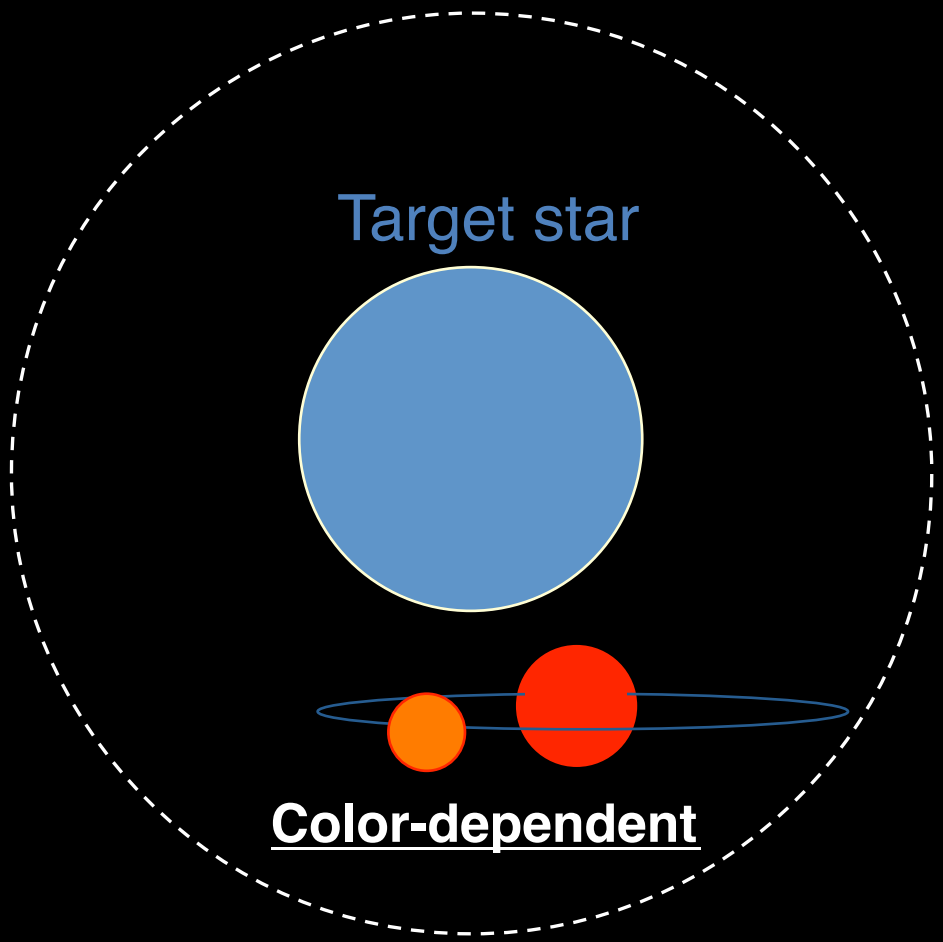


Ruling Out False Positives with Color Dependence



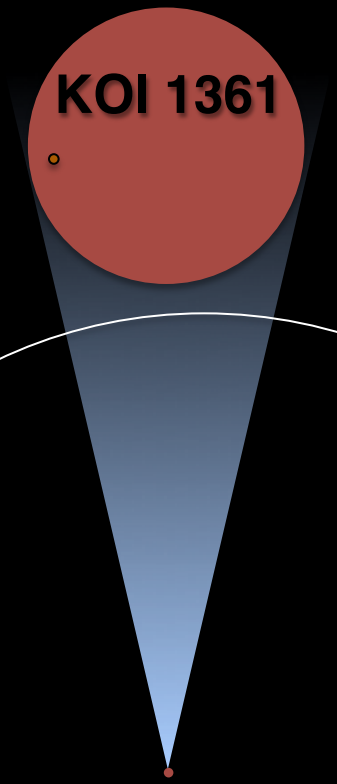
Ruling Out False Positives with Color Dependence

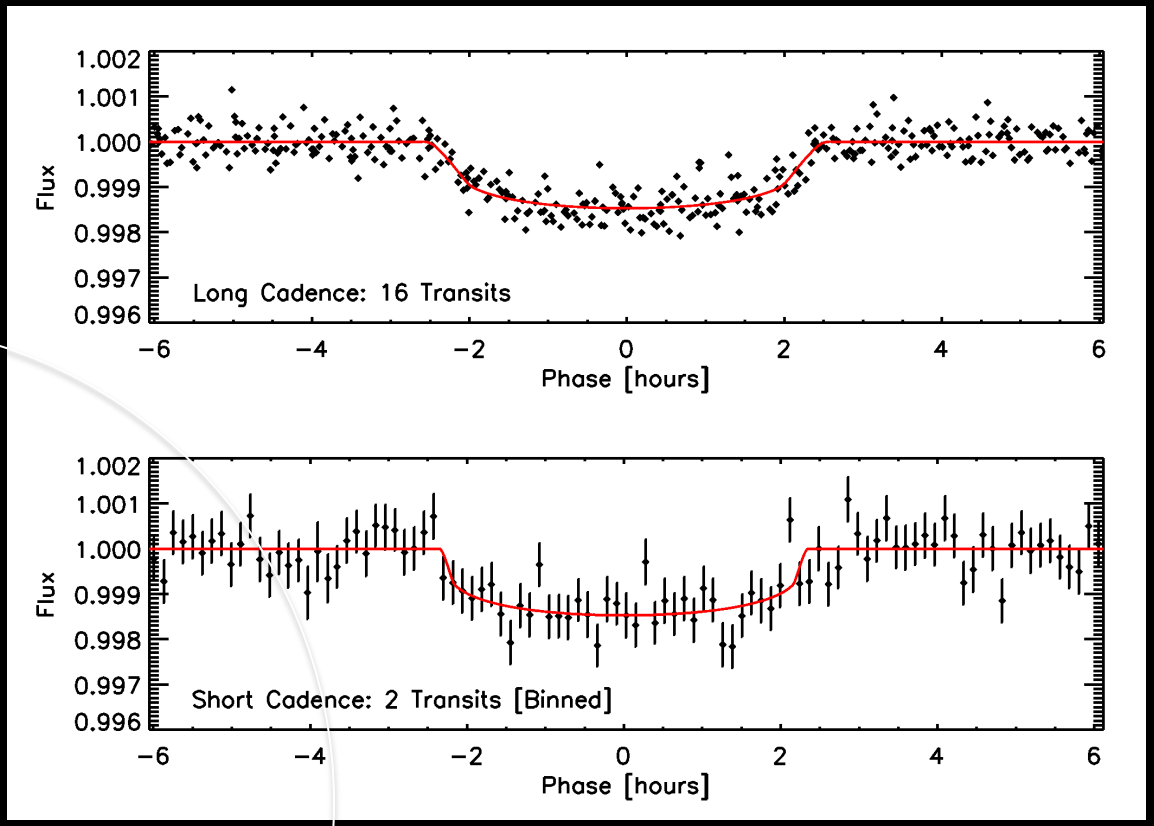
Eclipsing binary (Star + Star or Planet)



Color-dependent

Introduction to KOI 1361.01





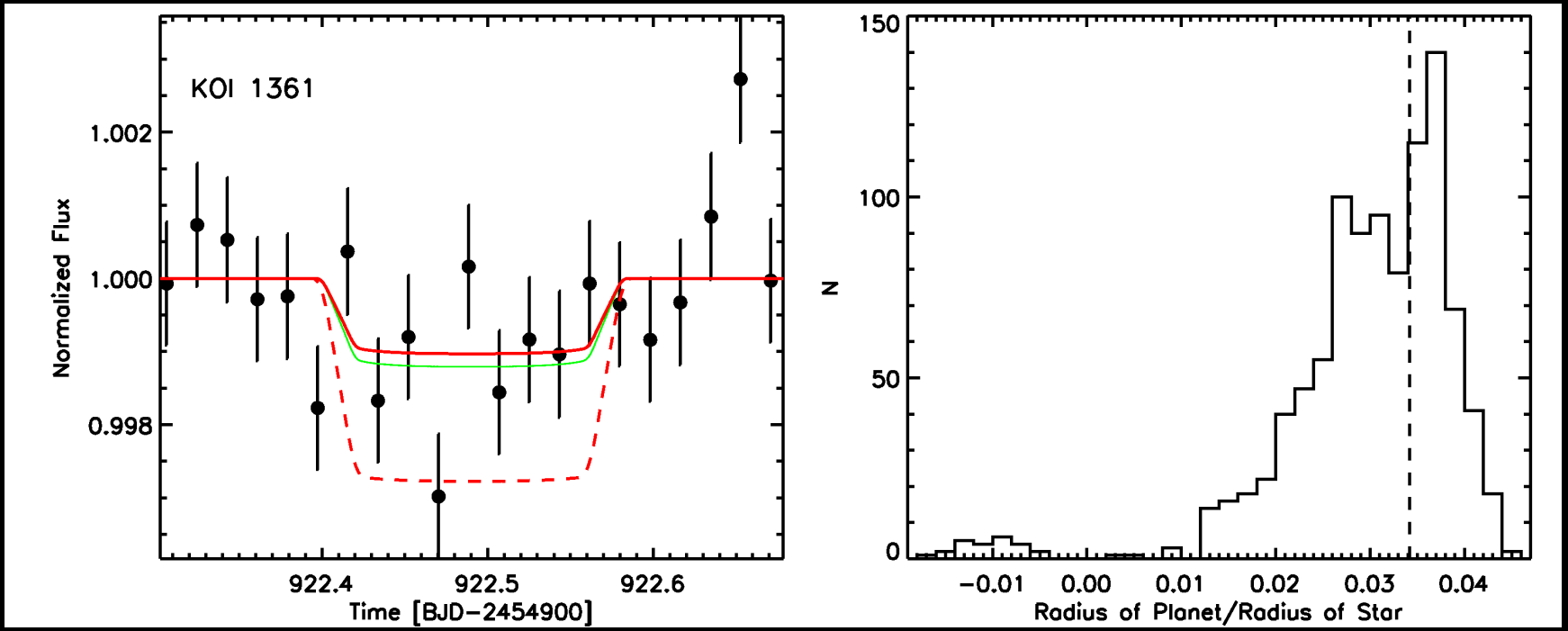
Ballard+ (2012, submitted)

KOI 1361.01: A super-Earth candidate (**2.0 R_{Earth}**) in a **59.8 day period** around a **15th Kepler magnitude** star

From published near-IR spectra (Muirhead et al. 2011):
$T_{eff}=3929^{+66}_{-135}$ K , [Fe/H]=-0.02+/-0.11 dex

Spitzer Observations of KOI 1361.01

Gathered on 17 September 2011
(Part of 600-hour Warm *Spitzer* Campaign)



Ballard+ (2012, submitted)

Spitzer depth $(R_p/R_\star)^2 = 990^{+482}_{-387}$ ppm

Kepler depth : 1403^{+73}_{-65} ppm

A cache of cool, potentially rocky planets transiting M dwarfs

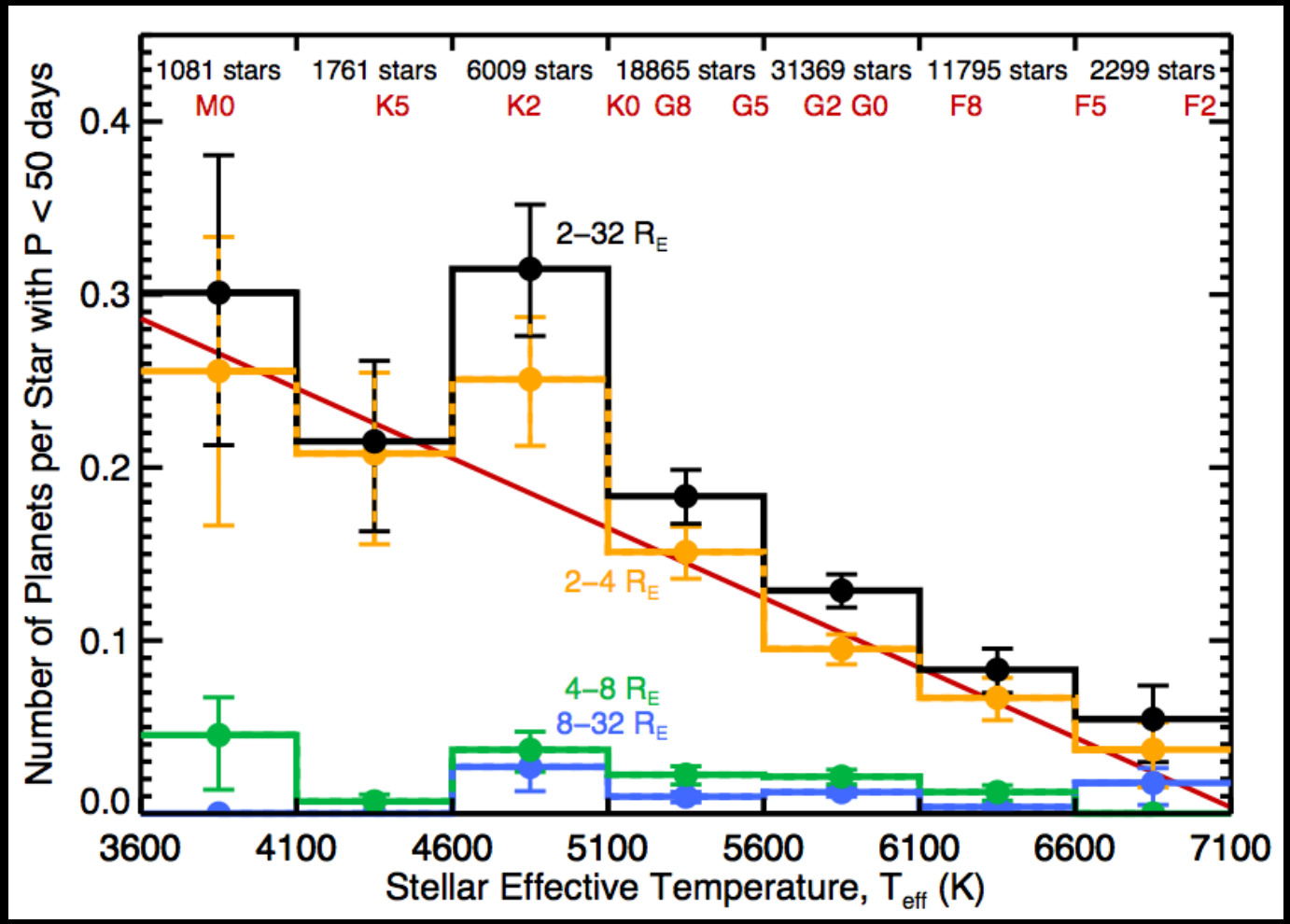
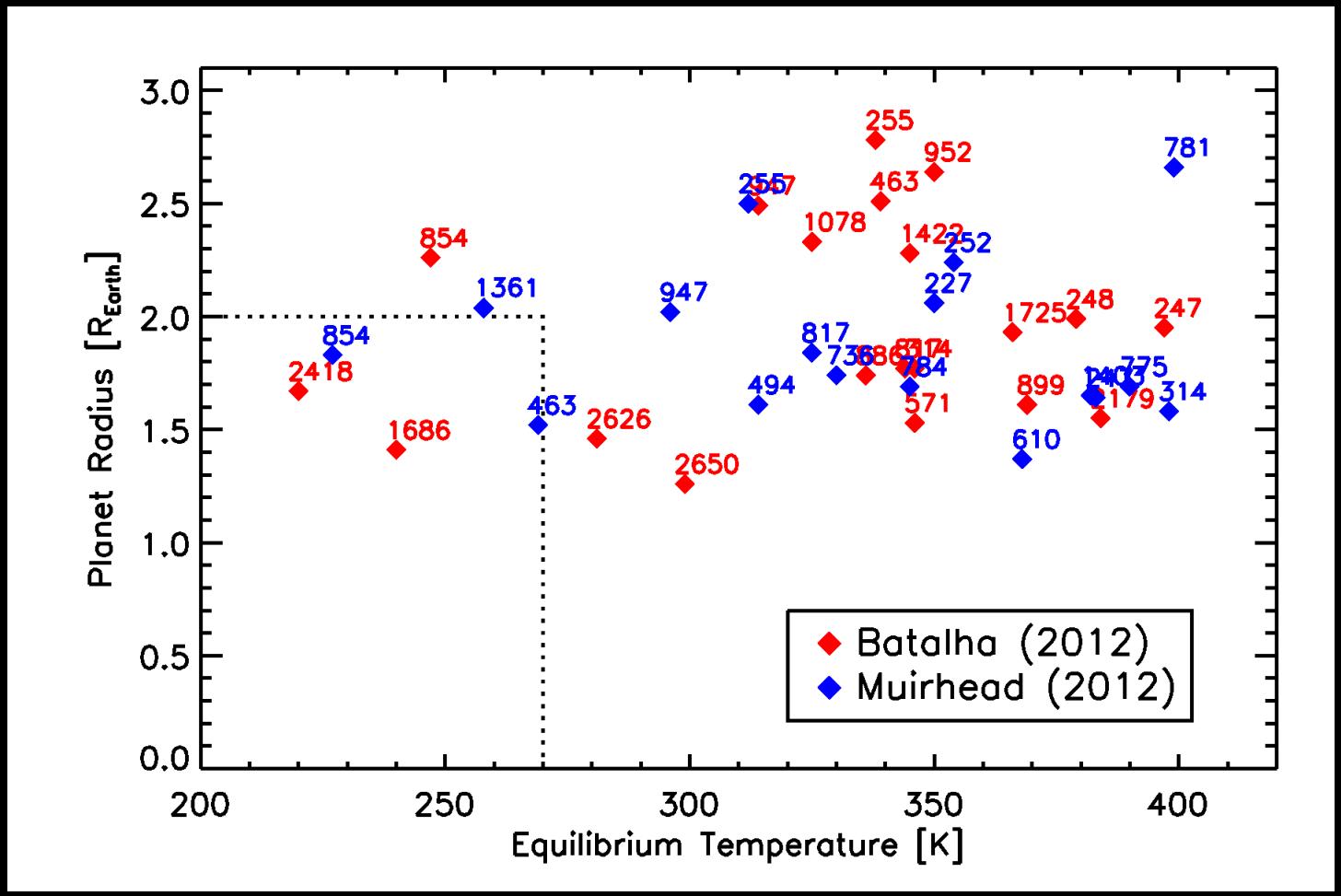


Figure from Howard+ (2012)

A cache of cool, potentially rocky planets transiting M dwarfs

All public KOIs (Borucki+ 2011, Batalha+ 2012) orbiting stars cooler than 4100 K



Stellar Characterization of M Dwarf KOIs

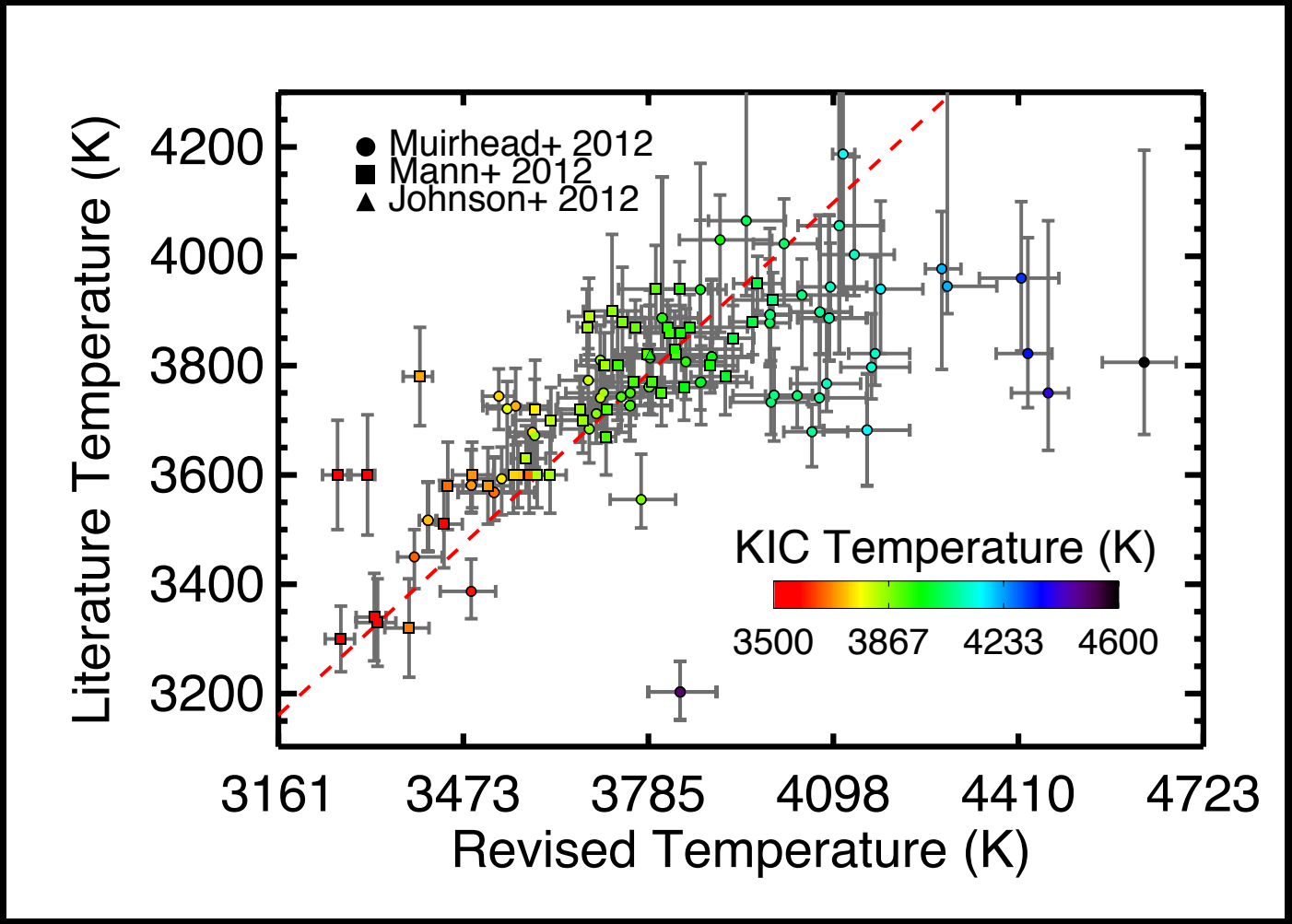
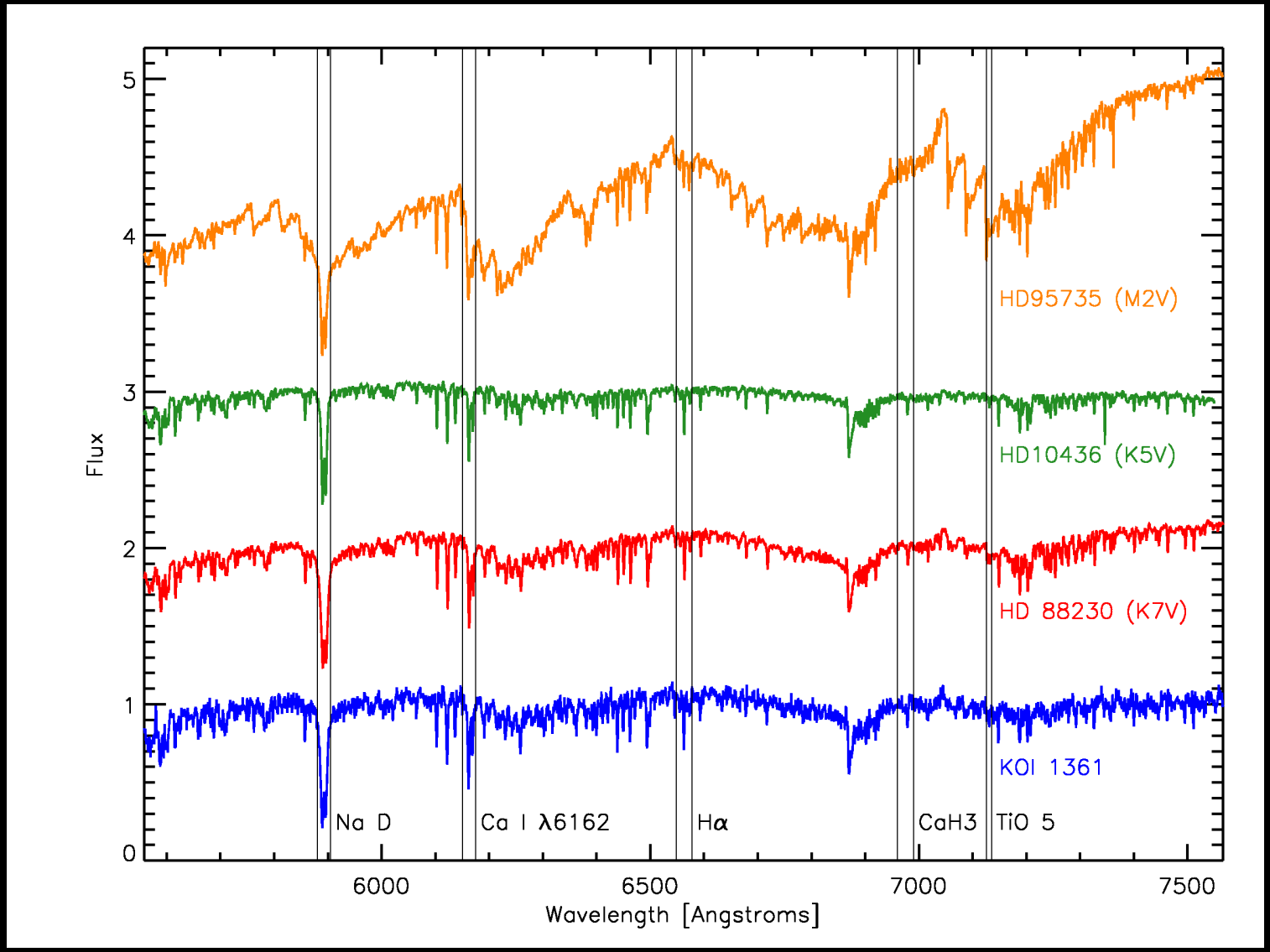


Figure from Dressing+ (in prep)

Stellar characterization: Bootstrapping from a nearby standard



Kepler Proxy Stars in Our Backyard?

As of a couple months ago, 75% of the stars in the solar neighborhood are M dwarfs

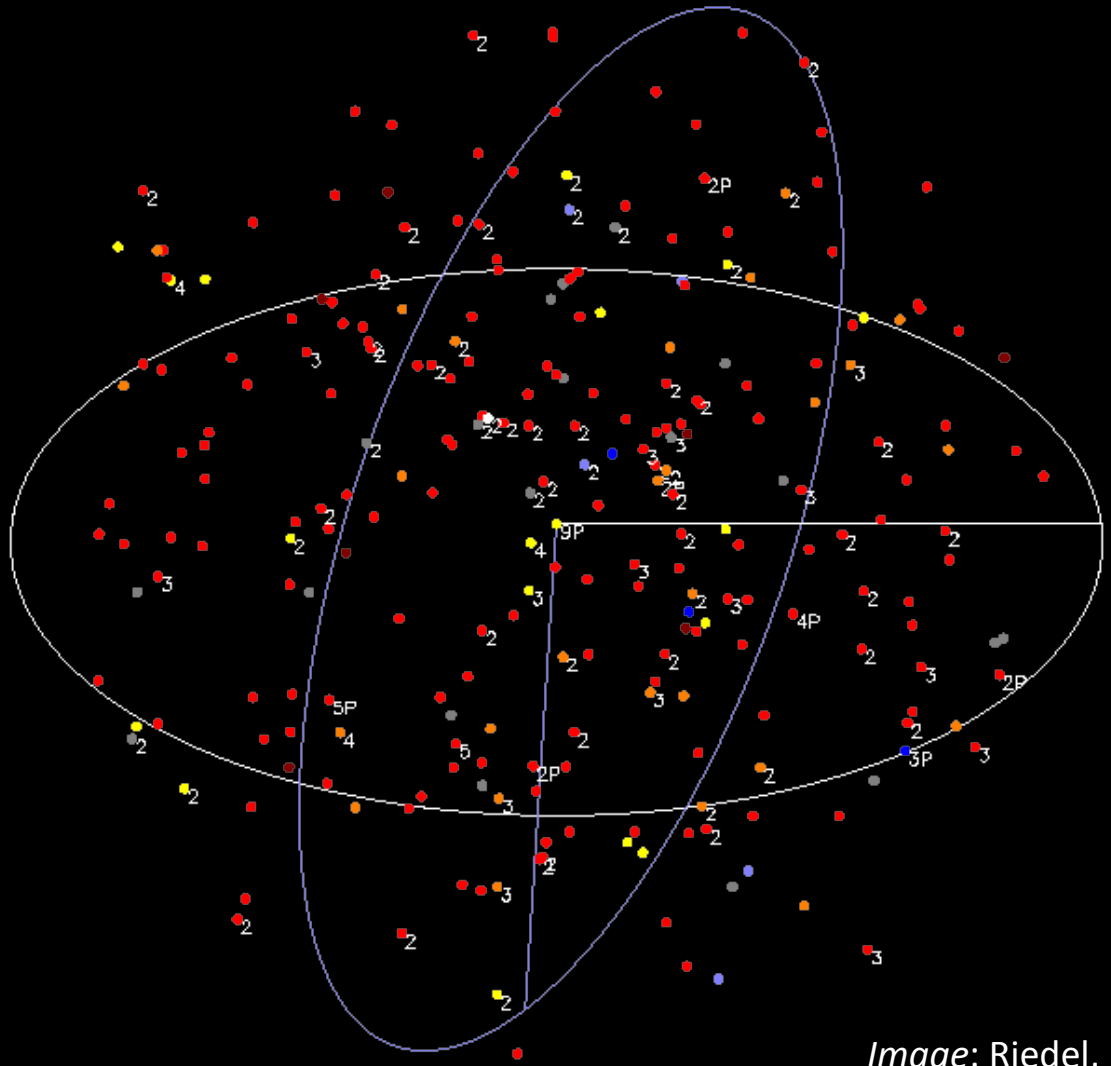
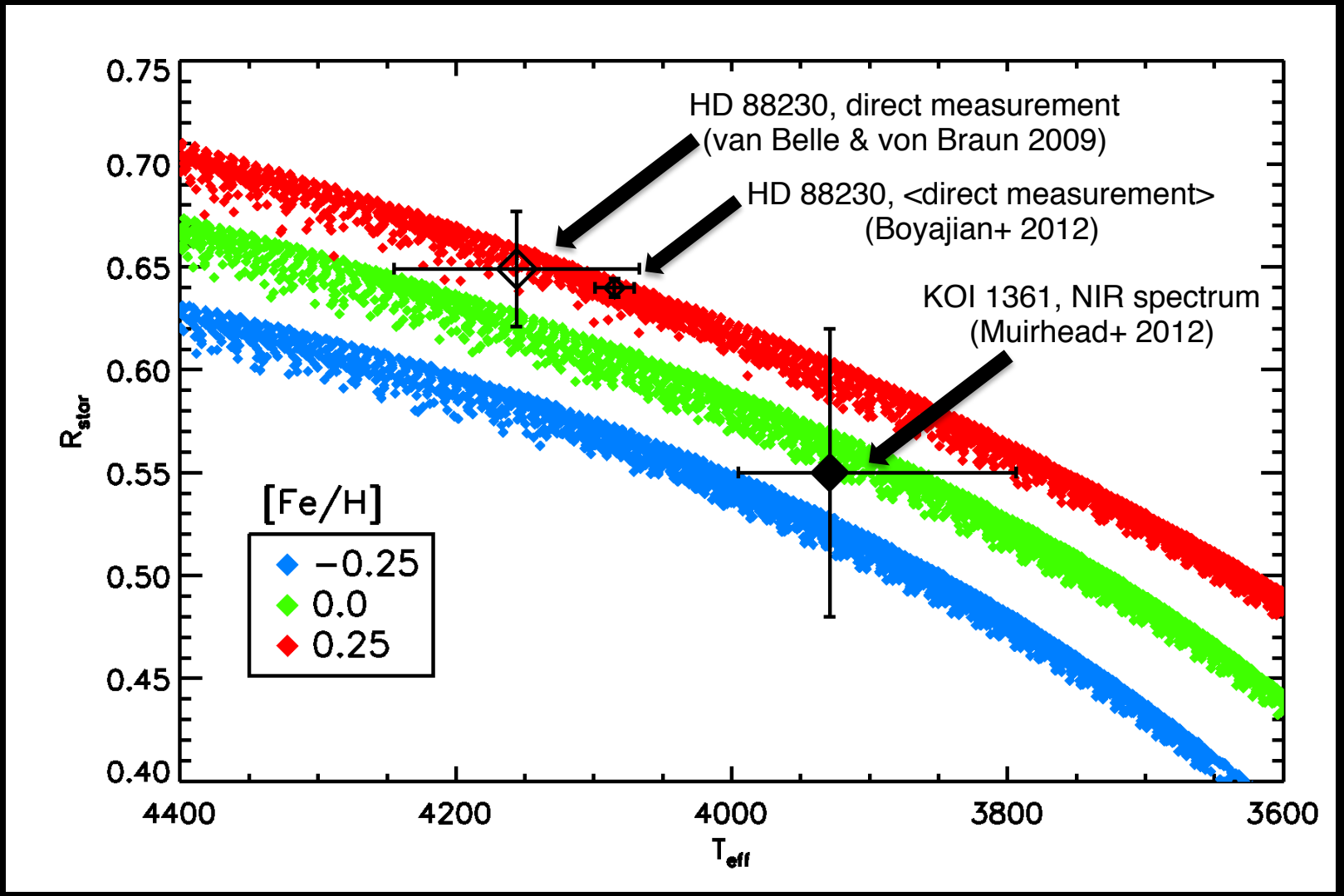


Image: Riedel, Henry, & RECONS group

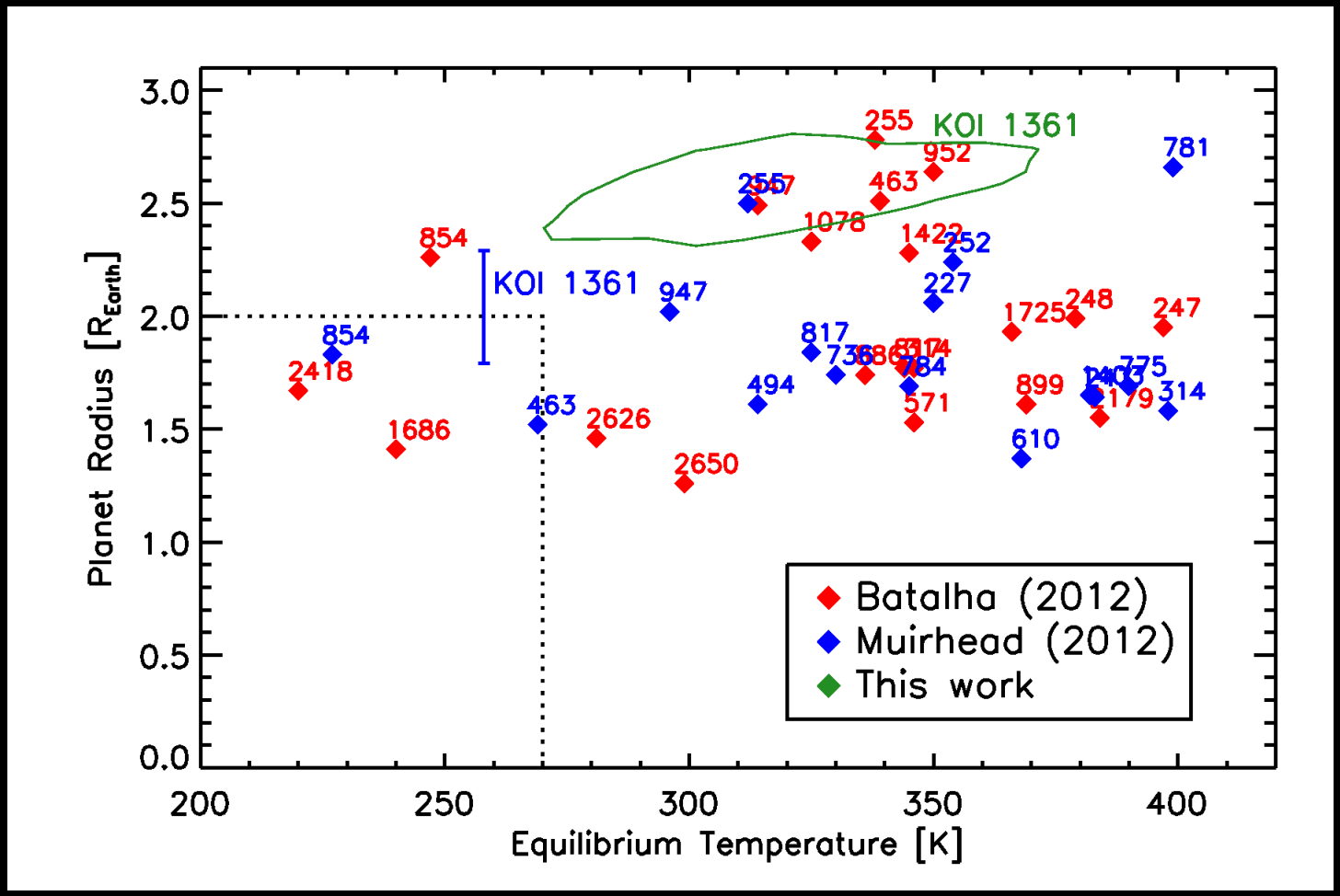
Stellar characterization: Bootstrapping from a nearby standard

Stellar models from Dartmouth group (Dotter et al. 2008)



Ballard+ (2012, submitted)

A cache of cool, potentially rocky planets transiting M dwarfs



Ballard+ (2012, submitted)

Composition of Kepler-61b?

Table 2. Properties of Transiting Planets from 1.4–3.0 $R_\oplus$ with Dynamically-Measured Masses

Name	Radius $[R_\oplus]$	Mass $[M_\oplus]$	Mean Density [g cm^{-3}]	Reference
Kepler-10b	$1.416^{+0.033}_{-0.036}$	$4.56^{+1.17}_{-1.29}$	$8.8^{+2.1}_{-2.9}$	Batalha et al. (2011)
CoRoT-7b	1.58±0.10	7.42±1.21	10.4±1.8[b]	Bruntt et al. (2010), Hatzes et al. (2011)
Kepler-20b	$1.91^{+0.12}_{-0.21}$	8.7±2.2	$6.9^{+5.3}_{-2.6}$[b]	Gautier et al. (2012)
Kepler-11b	1.97±0.19	$4.3^{+2.2}_{-2.0}$	$3.1^{+2.1}_{-1.5}$	Lissauer et al. (2011)
Kepler-18b	2.00±0.10	6.9±3.4	4.9±2.4	Cochran et al. (2011)
55 Cnc e	2.00±0.14	8.63±0.35	$5.9^{+1.5}_{-1.1}$	Winn et al. (2011)
Kepler-11f	2.61±0.25	$2.3^{+2.2}_{-1.2}$	$0.7^{+0.7}_{-0.4}$	Lissauer et al. (2011)
GJ 1214	2.678±0.13	6.55±0.98	1.87±0.4	Charbonneau et al. (2009)
HD 97658b	~~2.[illegible]~~	6.4±0.7	$1.40^{+0.53}_{-0.36}$	Henry et al. (2011), Howard et al. (2011b)

Doesn't transit after all!
(Dragomir+ 2012)

Looking ahead

- Extended *Spitzer* and *Kepler* missions
- Ongoing program with Apache Point Observatory 3.5 m telescope DIS and TripleSpec to observe KOIs + nearby standards