Exoplanet Host Stars:
from Stellar to Planet Parameters

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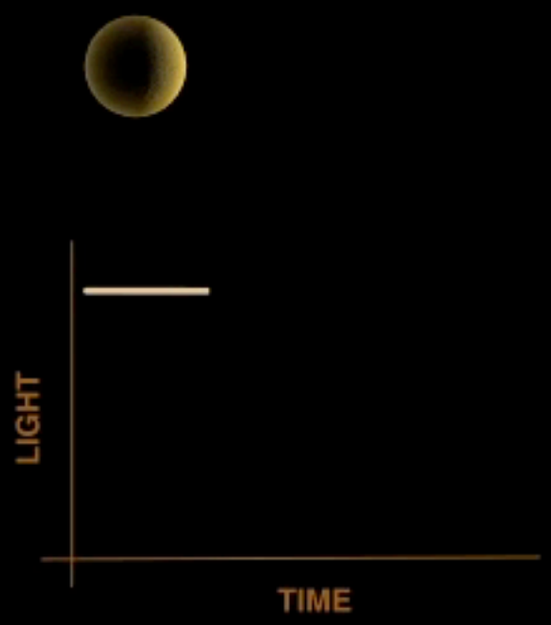
Asteroseismology and Optical Interferometry
October, 2017

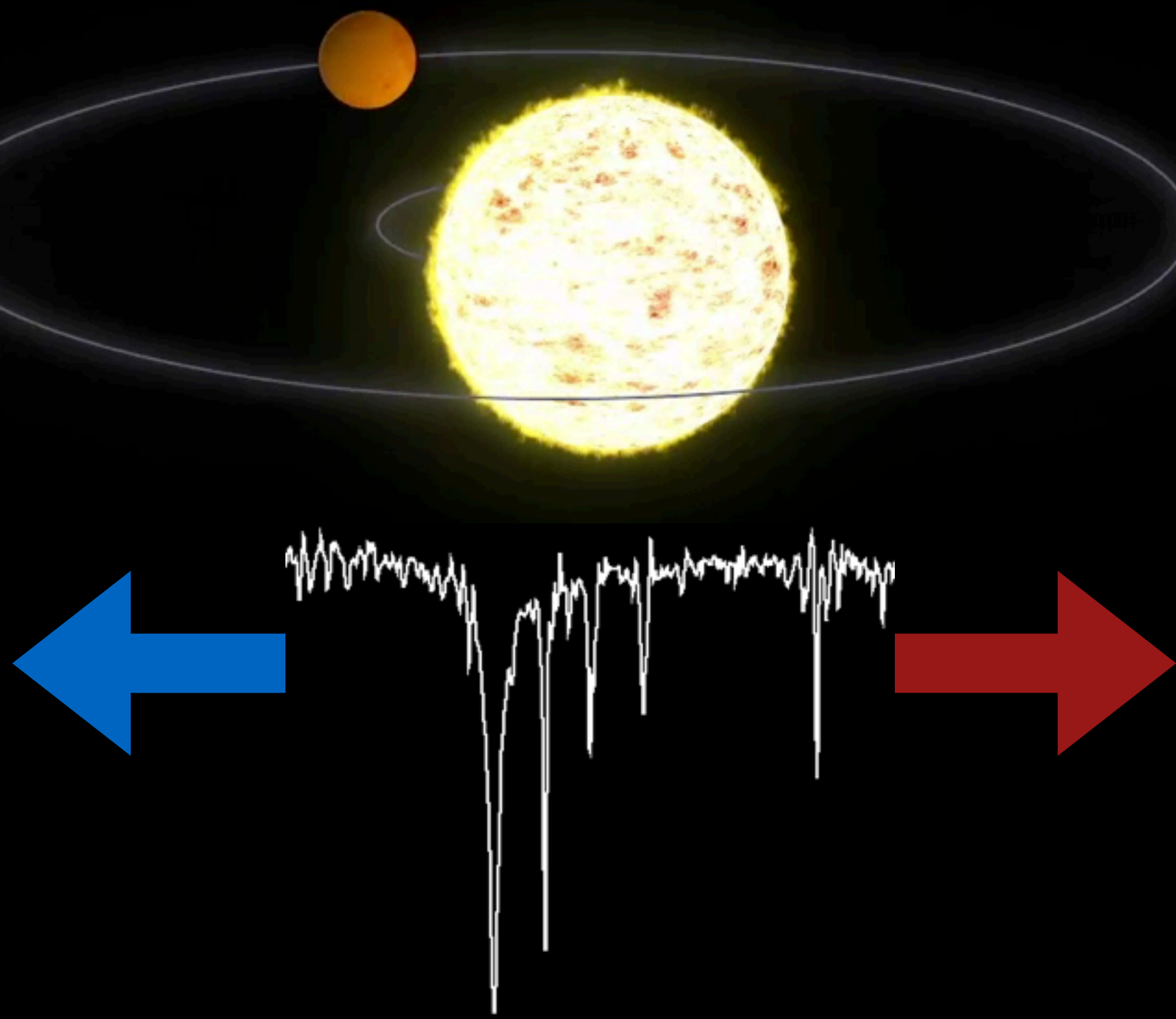
We only know the planet
as well as we know its host star

Stellar Radii for Transits



Credit: NASA

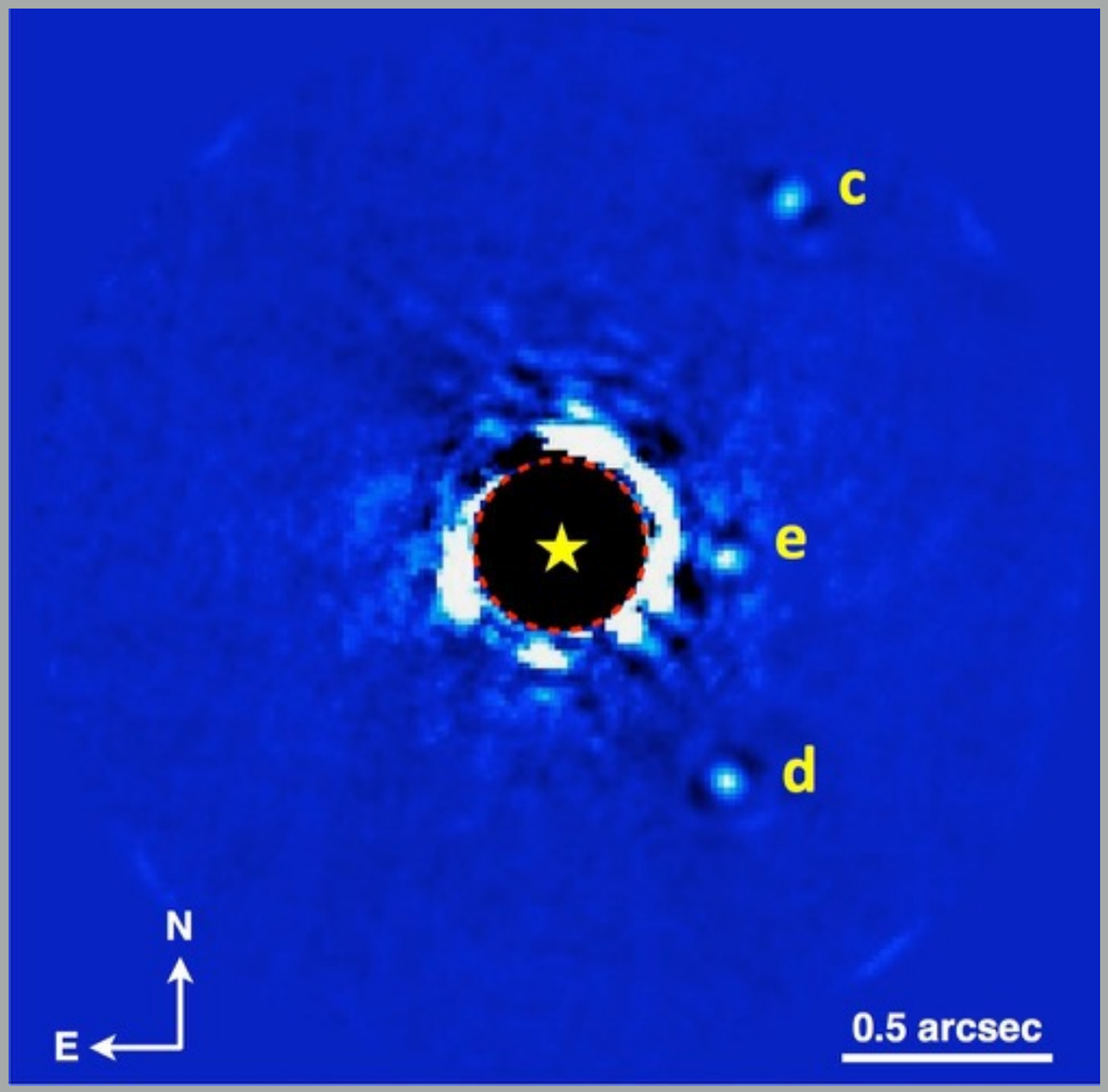
Stellar Masses for Radial Velocities

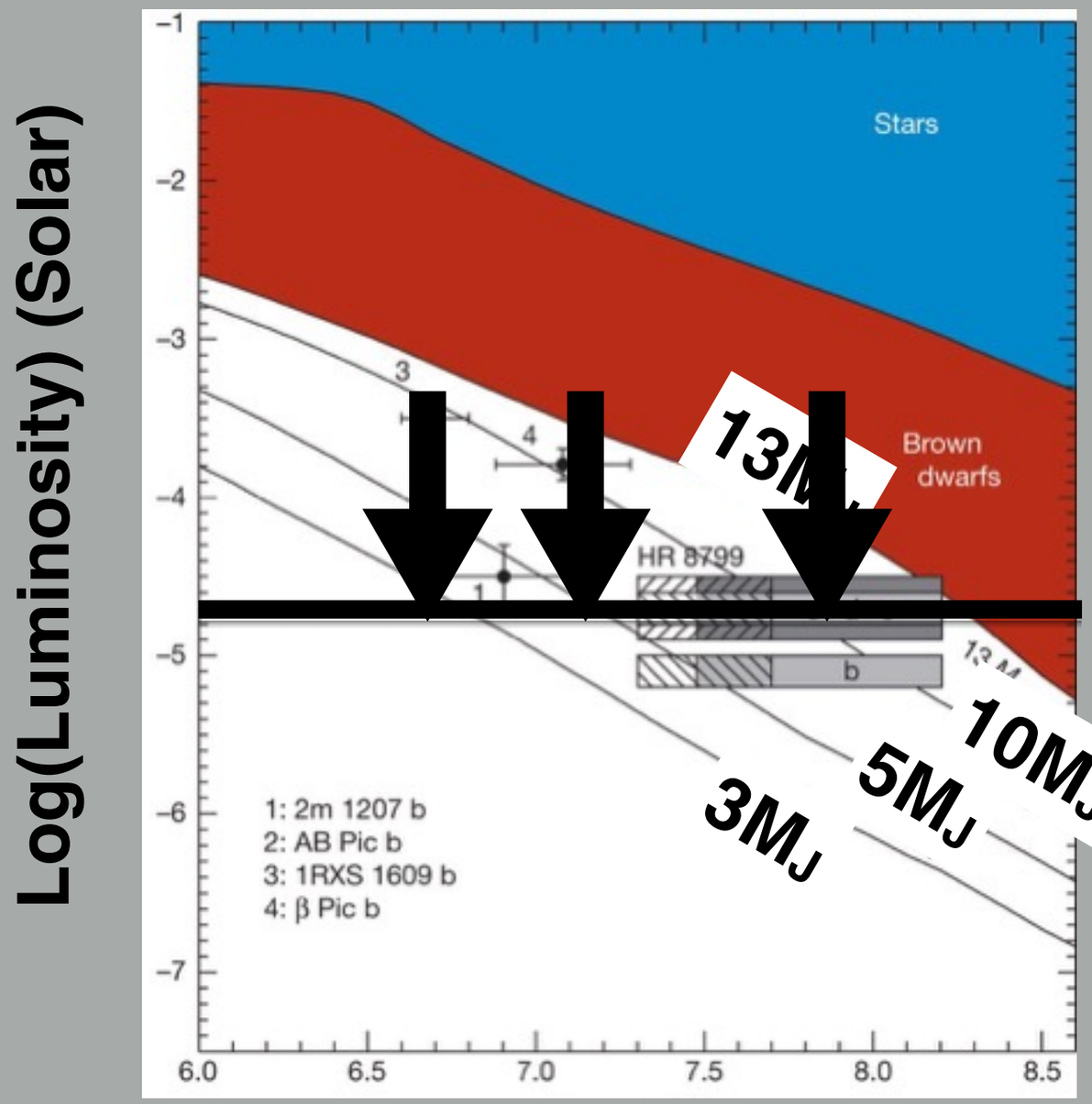


Exaggerated for clarity

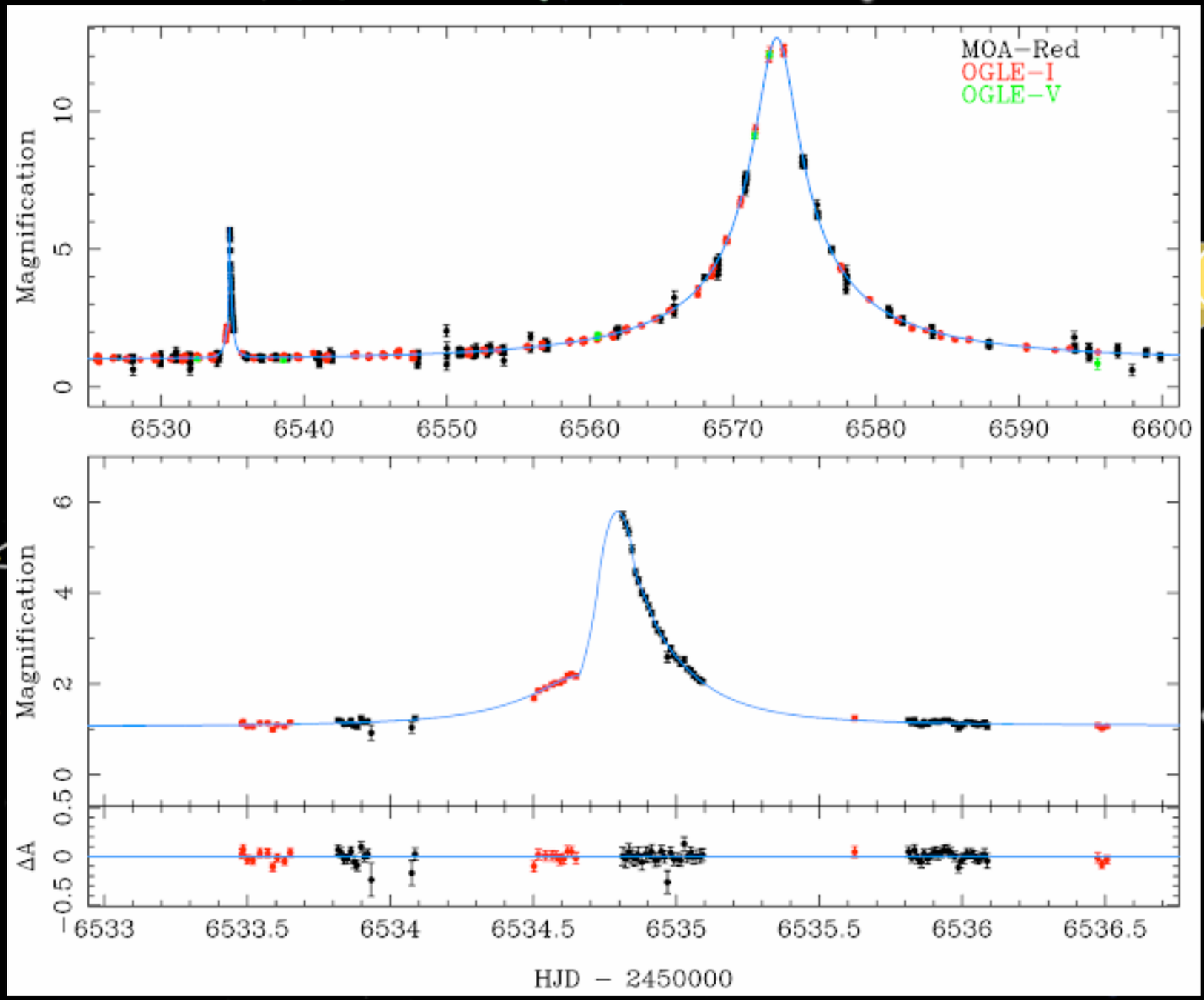
Credit: NASA

Stellar Ages for Direct Imaging

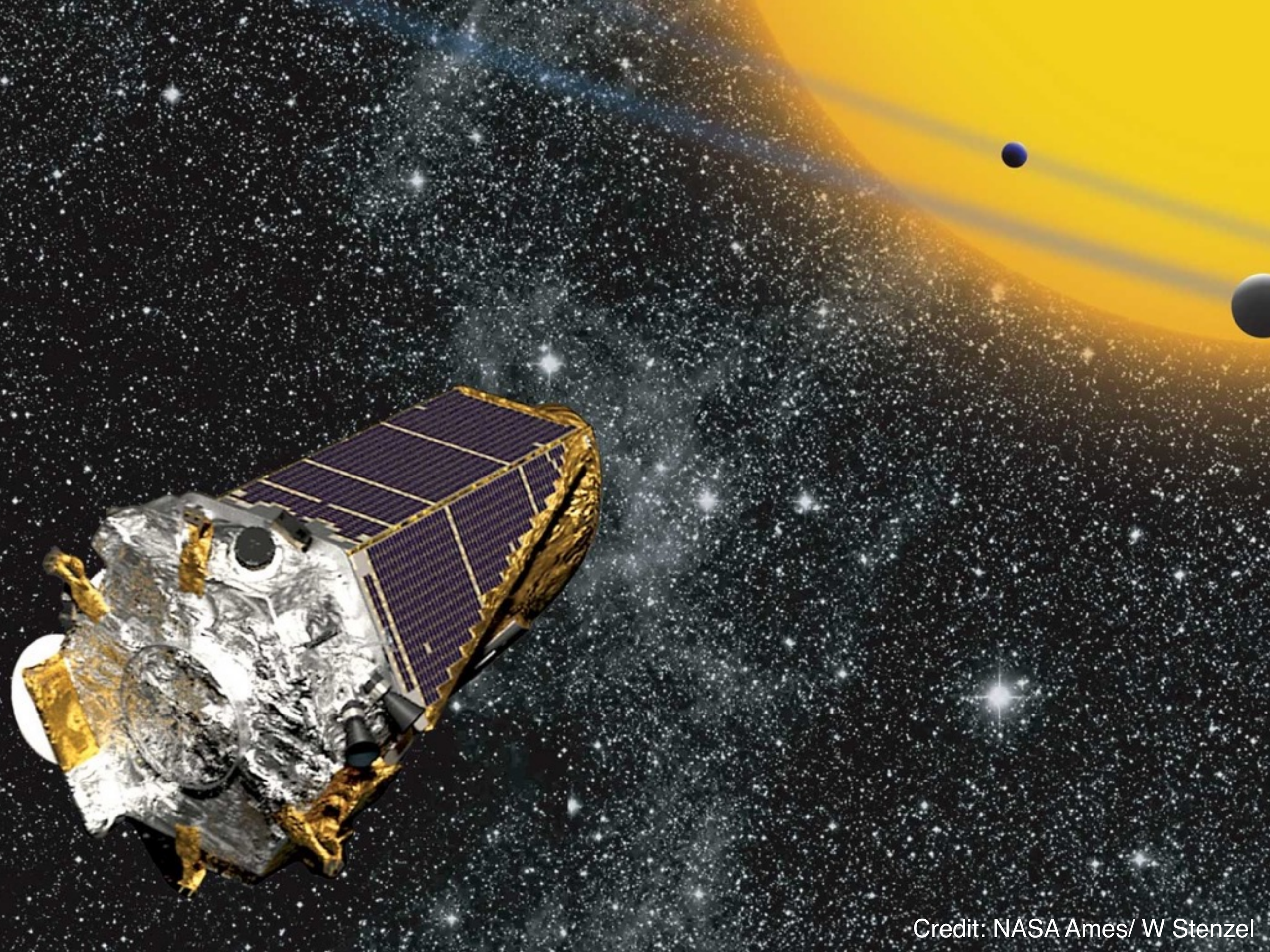




Lens Mass for Microlensing

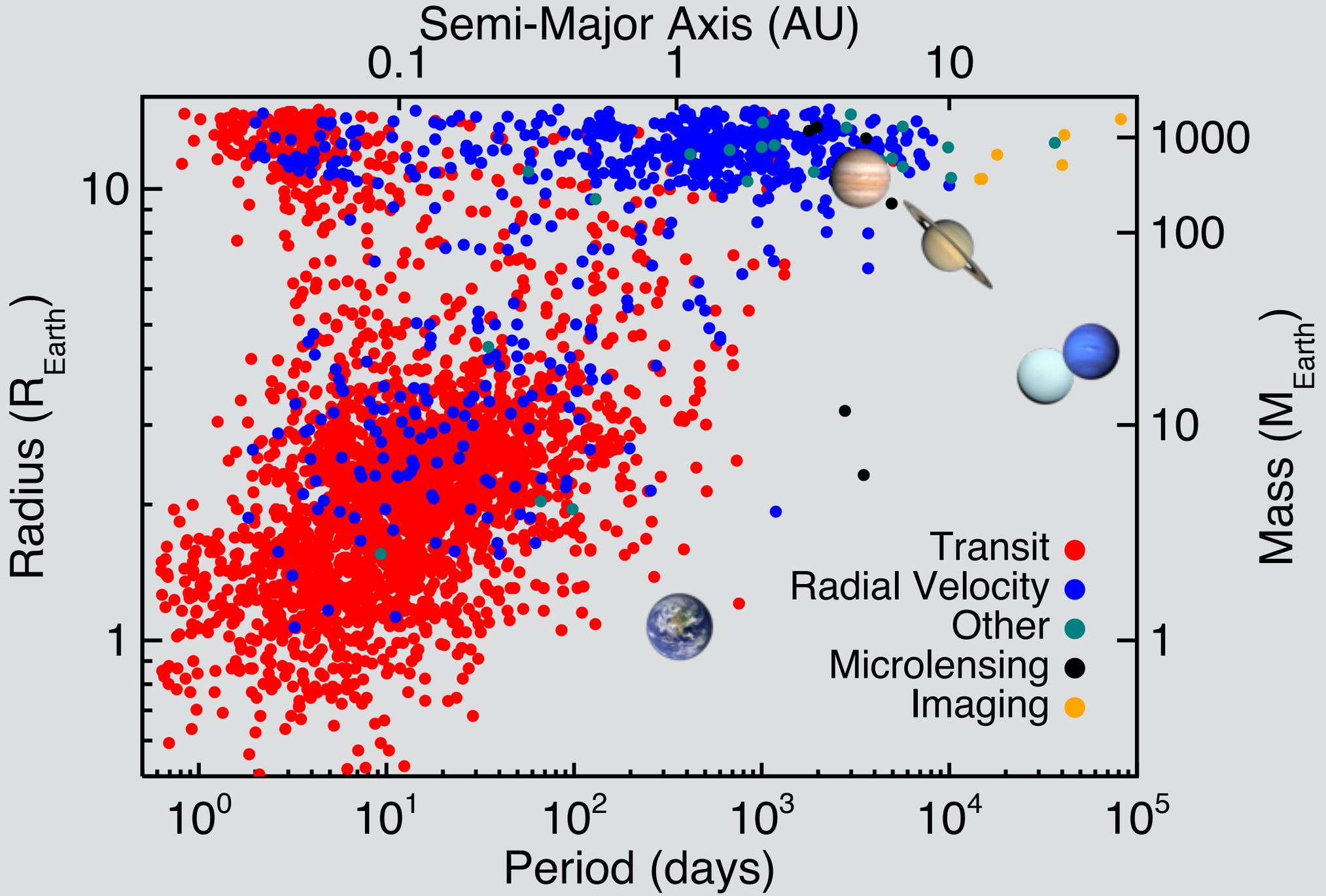


Sumi et al. (2015)



Credit: NASA Ames/ W Stenzel

The Exoplanet Census

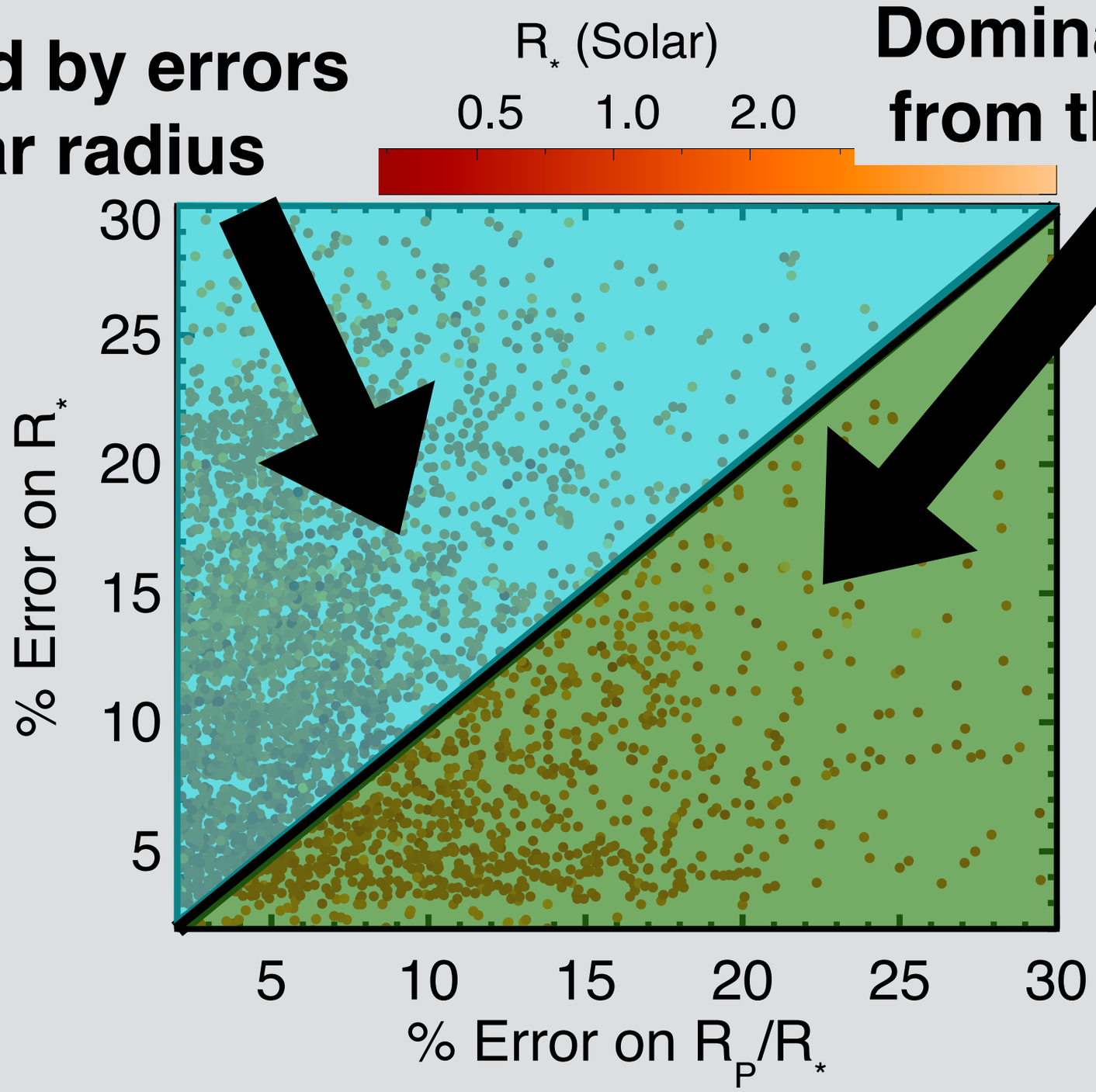


source: exoplanets.eu

Errors on Kepler Planet Radii

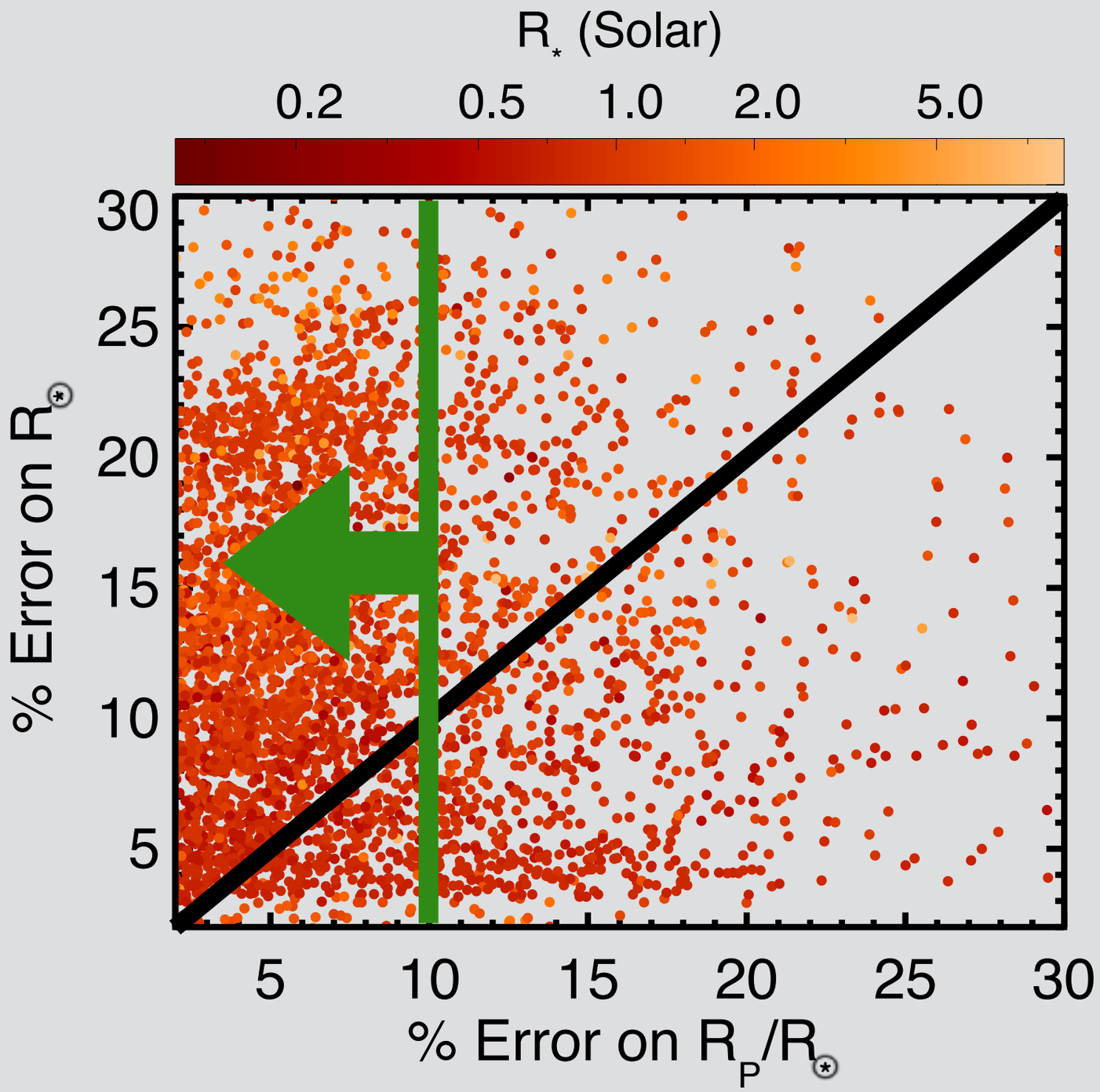
Dominated by errors in stellar radius

Dominated by errors from the light curve



Sources:
NASA exoplanet archive
CFOP
CKS, Huber et al. (2014)

Kepler light curves are very precise



The Stellar Parameter Ladder for exoplanet hosts

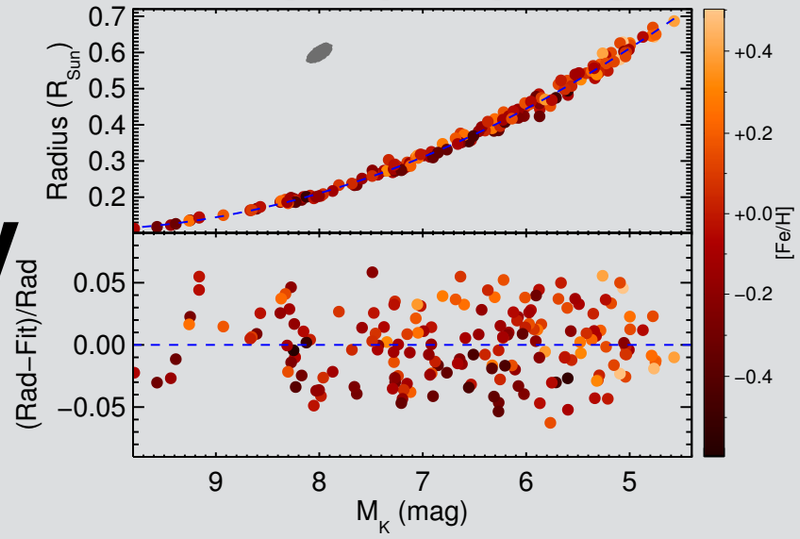
More precise, less applicable

Broadly applicable, imprecise

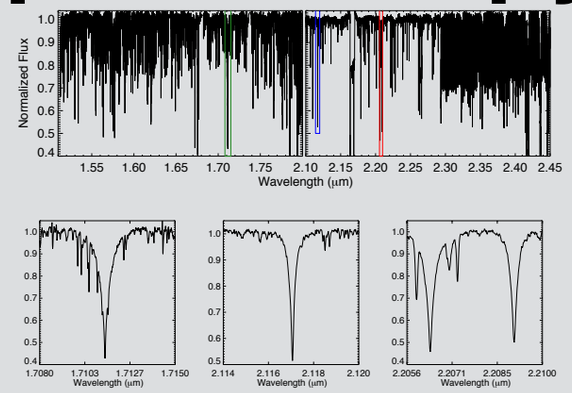
Asteroseismology

Interferometry

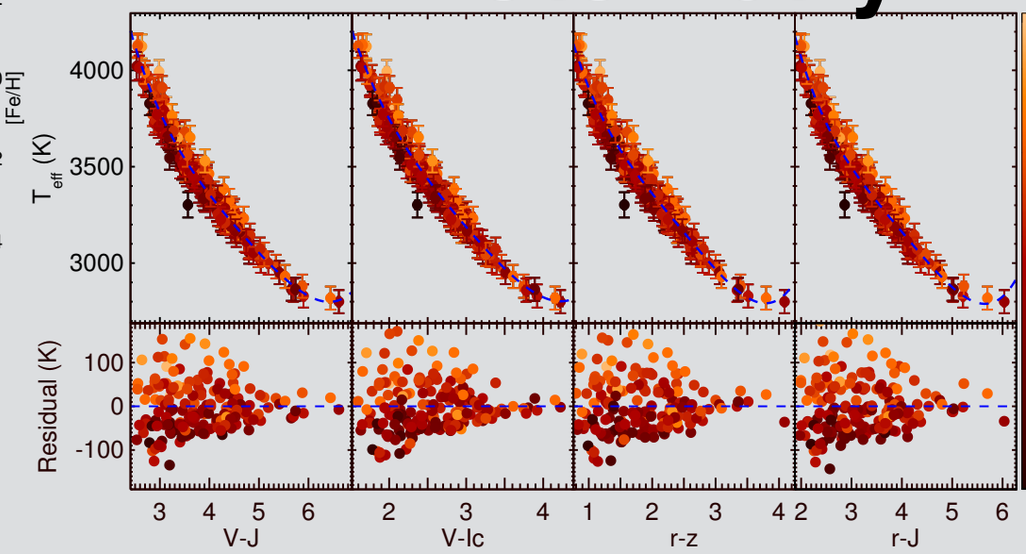
Parallaxes



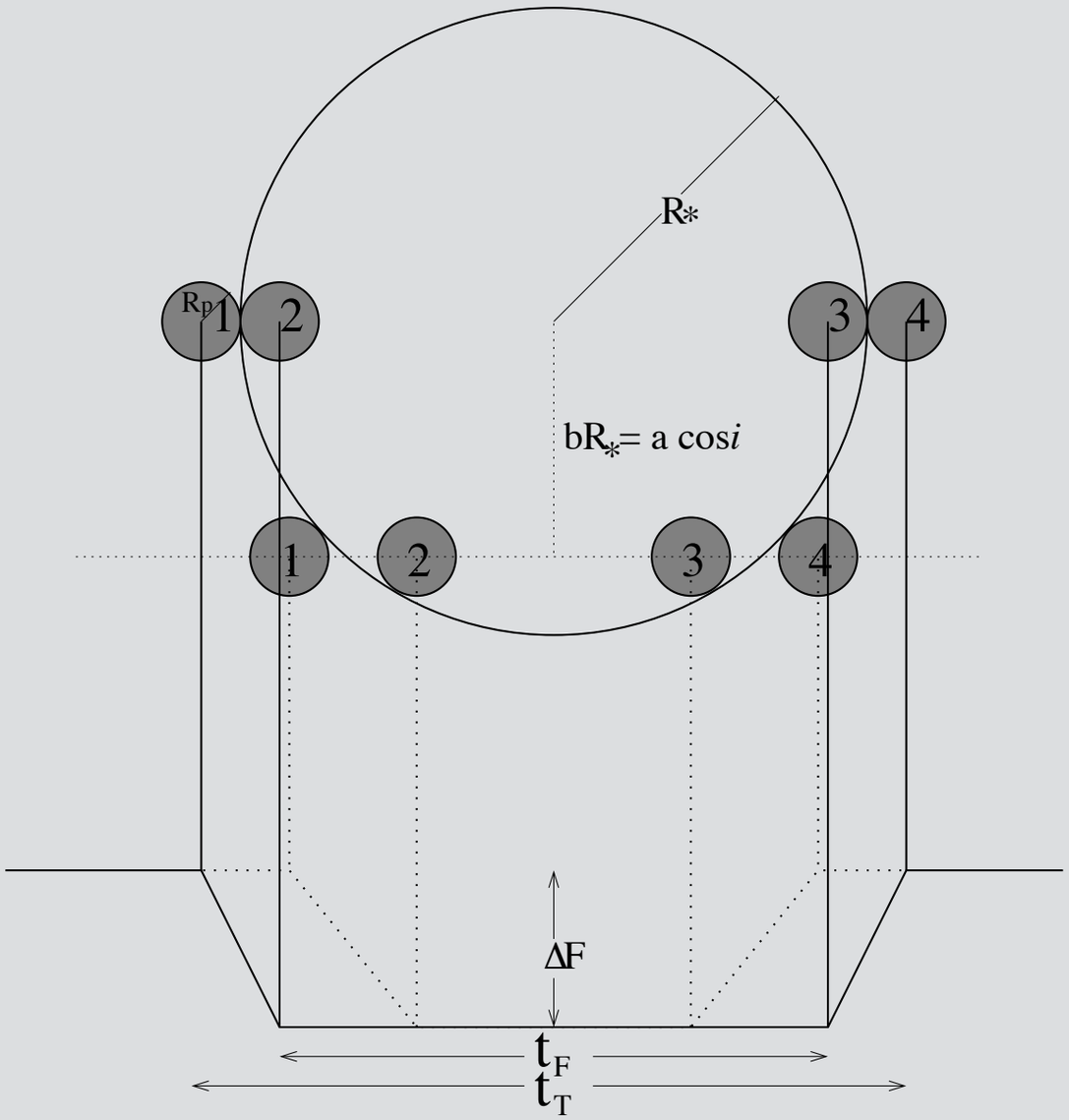
Spectroscopy



Photometry

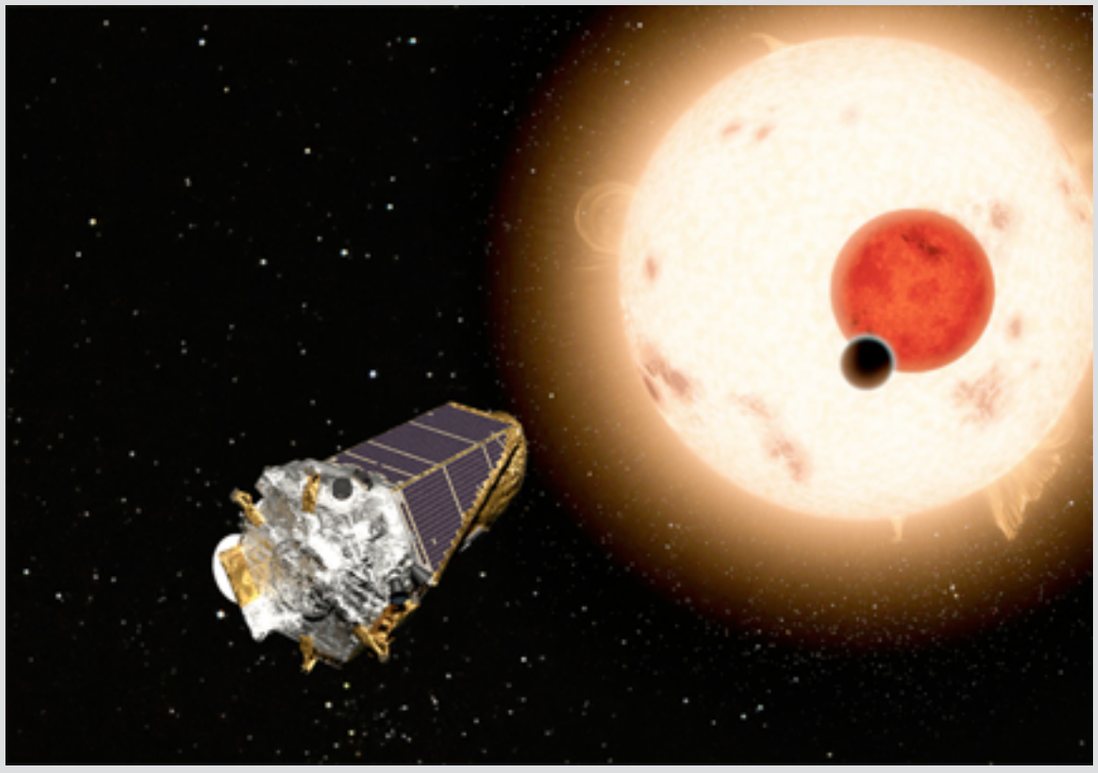


Density from Transits



e.g.,
Beatty et al. 2017
Eastman et al. 2016
Plavchan et al. 2014
Anglada-Escudé et al. 2013

Circumbinary Planets



e.g.,
Orosz et al. 2012
Welsh et al. 2012
Doyle et al. 2011

e.g.,
Mann et al. (2016a,b)
Meibom et al. (2013)
Quinn et al. (2013)

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Broadly applicable, imprecise

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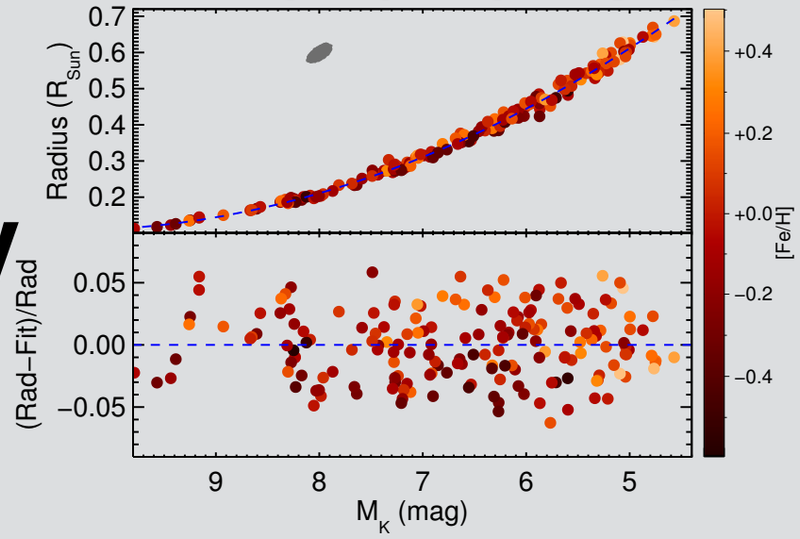
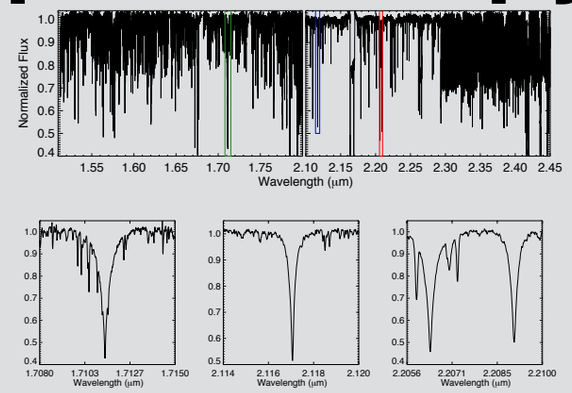
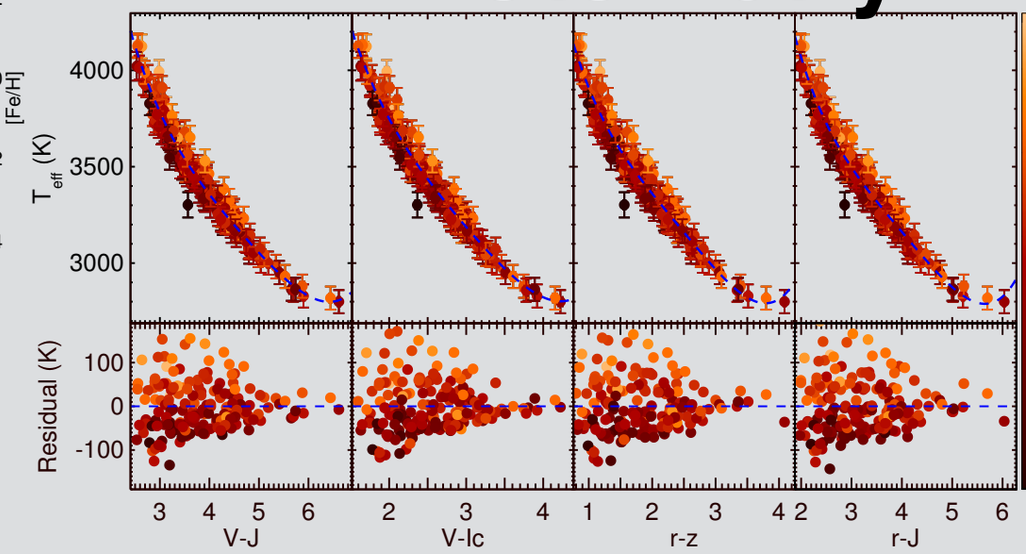
Parallaxes



Spectroscopy



Photometry

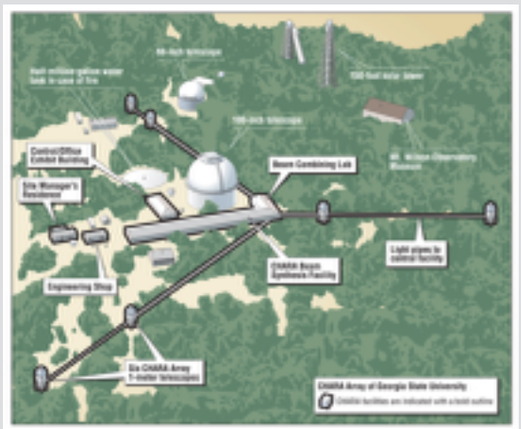


The Stellar Parameter Ladder for exoplanet hosts

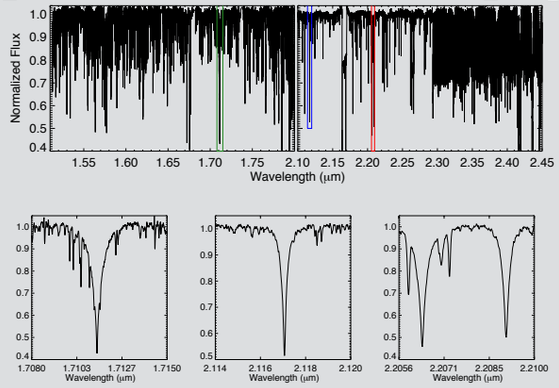
Direction of Calibration

Asteroseismology

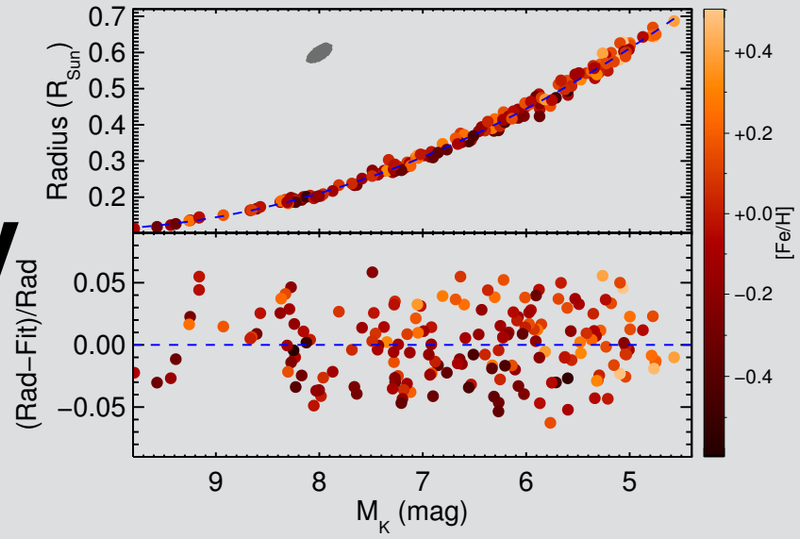
Interferometry



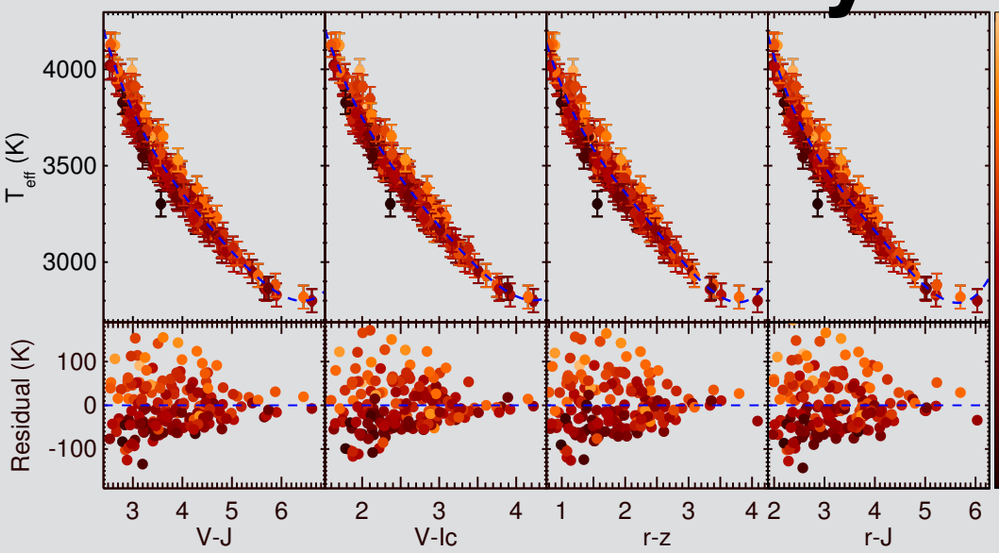
Spectroscopy



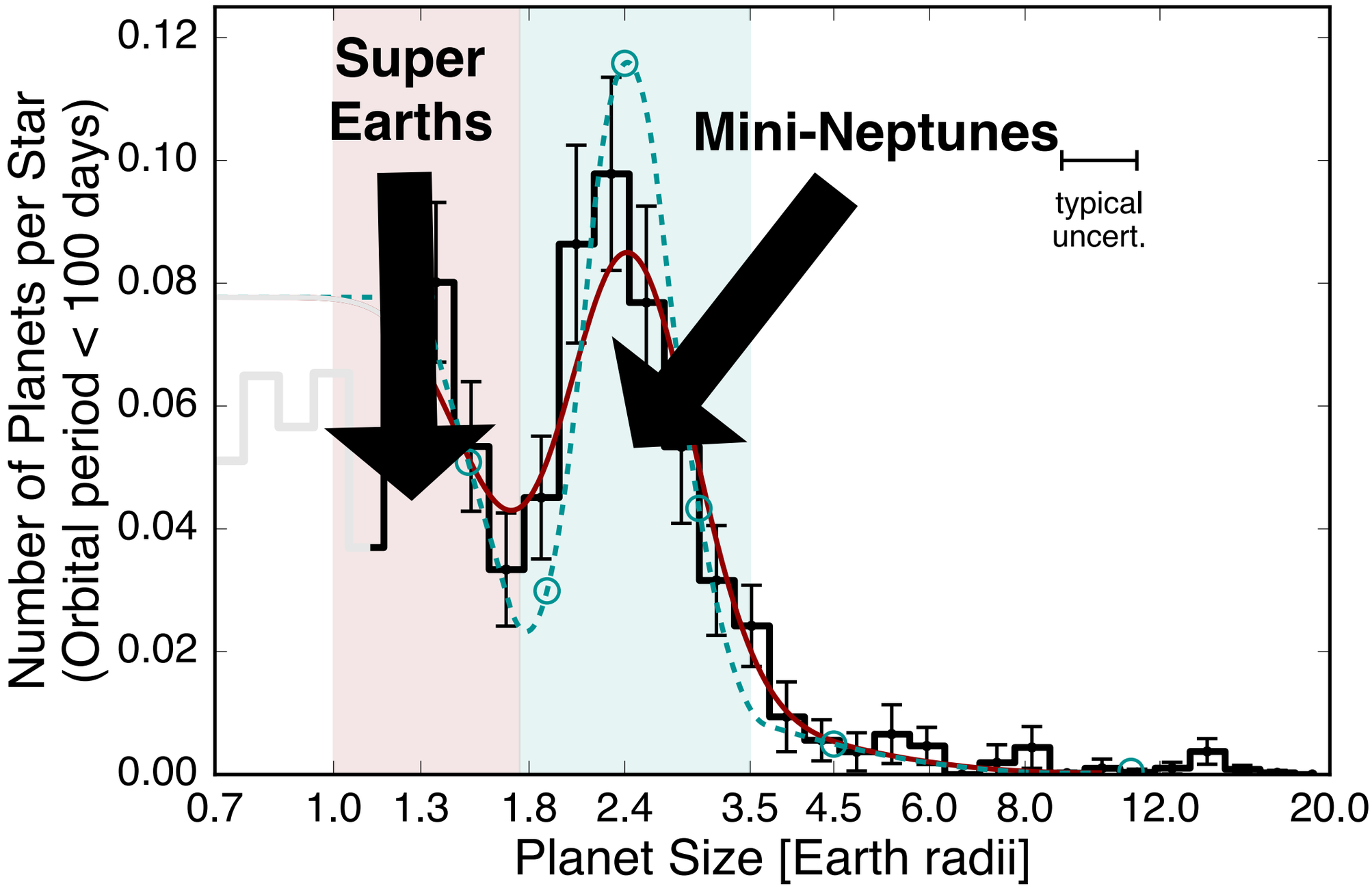
Parallaxes



Photometry



The California Kepler Survey (CKS)

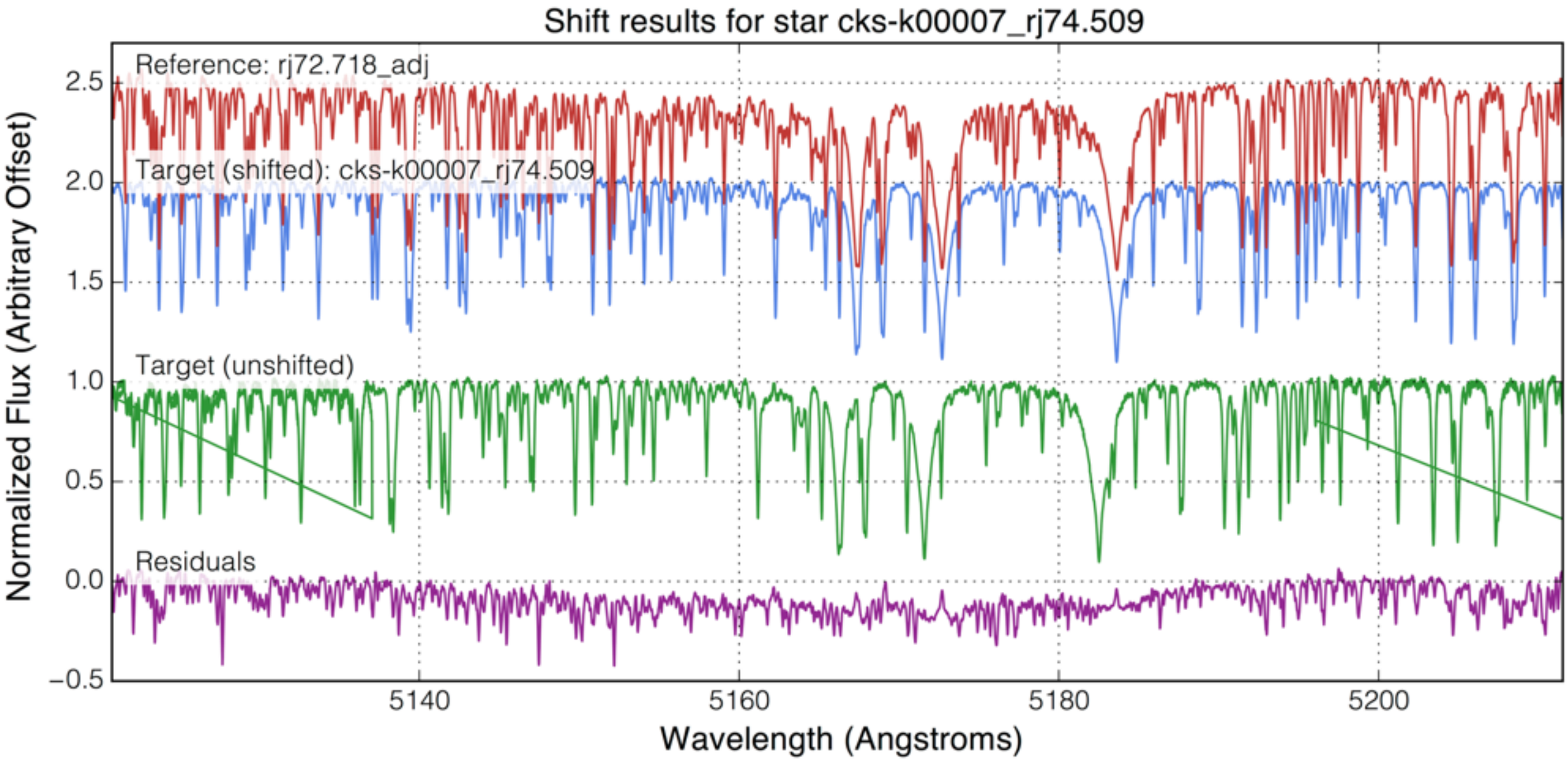


Fulton et al. 2017

Assembly Line of Planets

Image credit: NASA

The California Kepler Survey

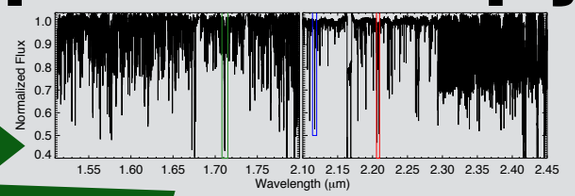


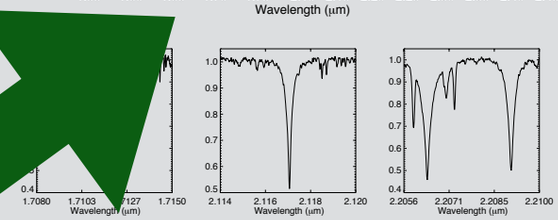
Petigura et al. 2017

The Stellar Parameter Ladder for exoplanet hosts

Asteroseismology

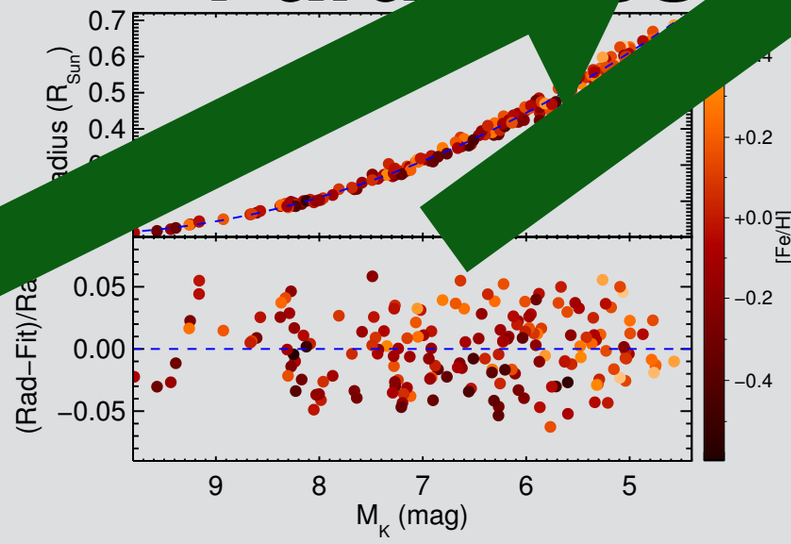
Spectroscopy



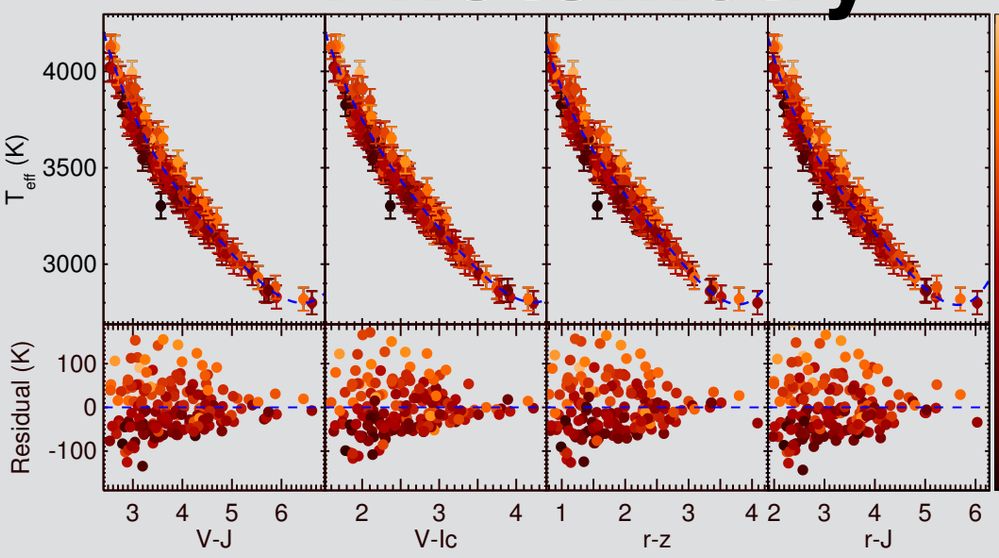


Interferometry

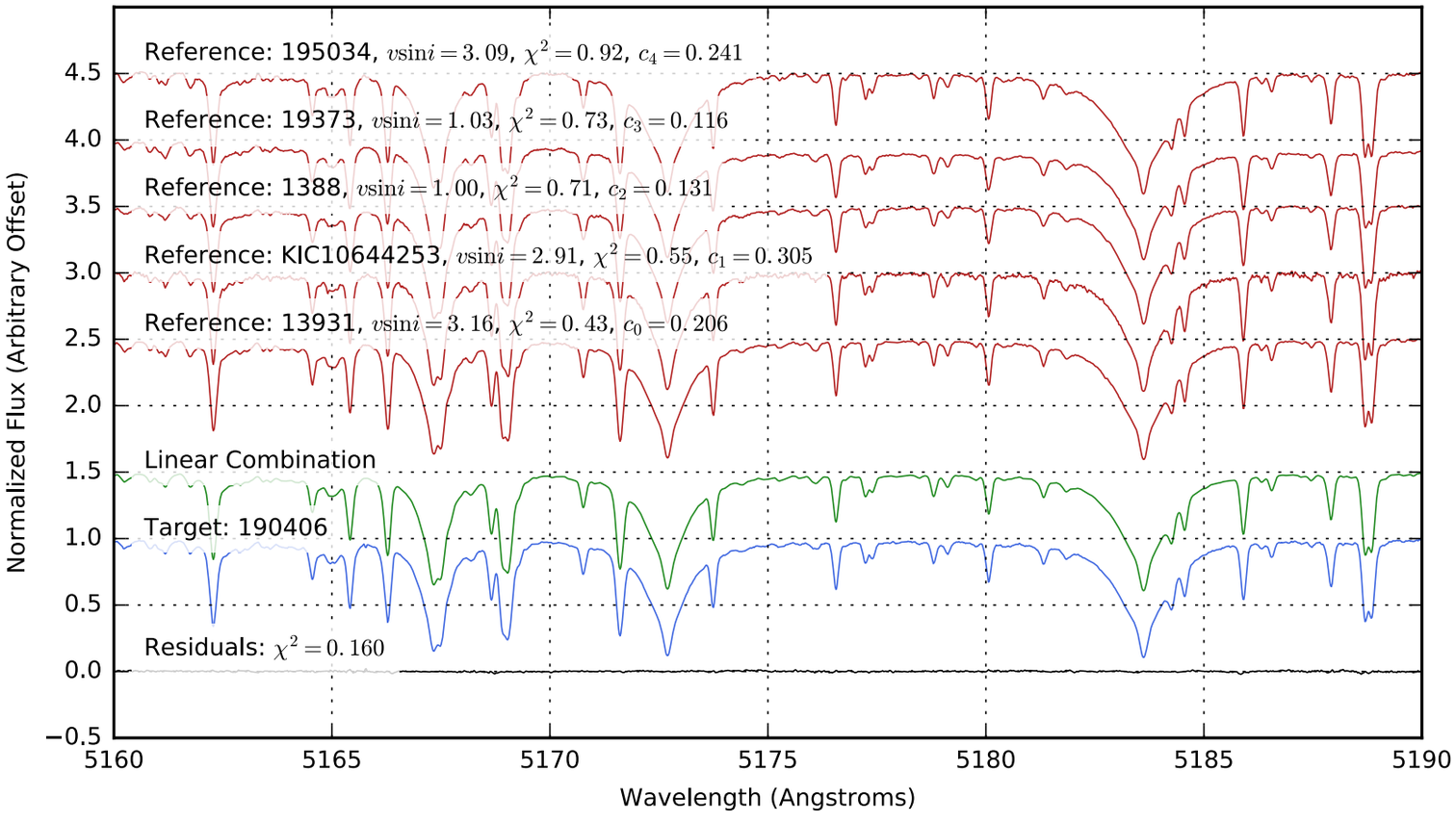
Parallaxes

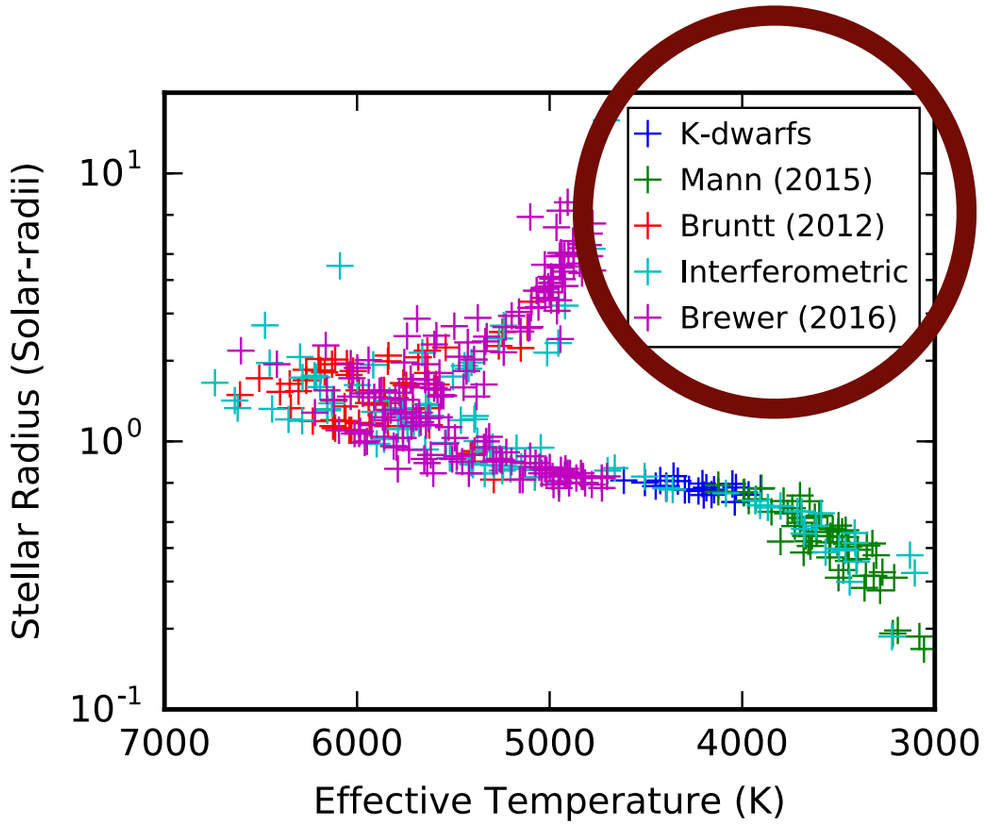


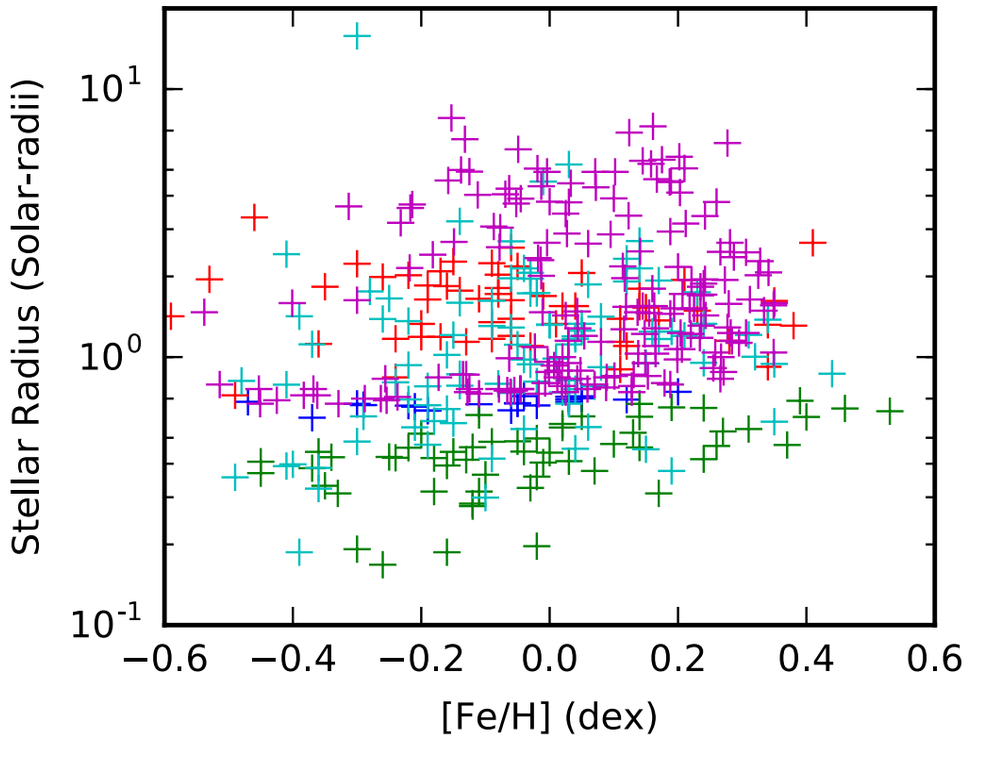
Photometry



Empirical SpecMatch

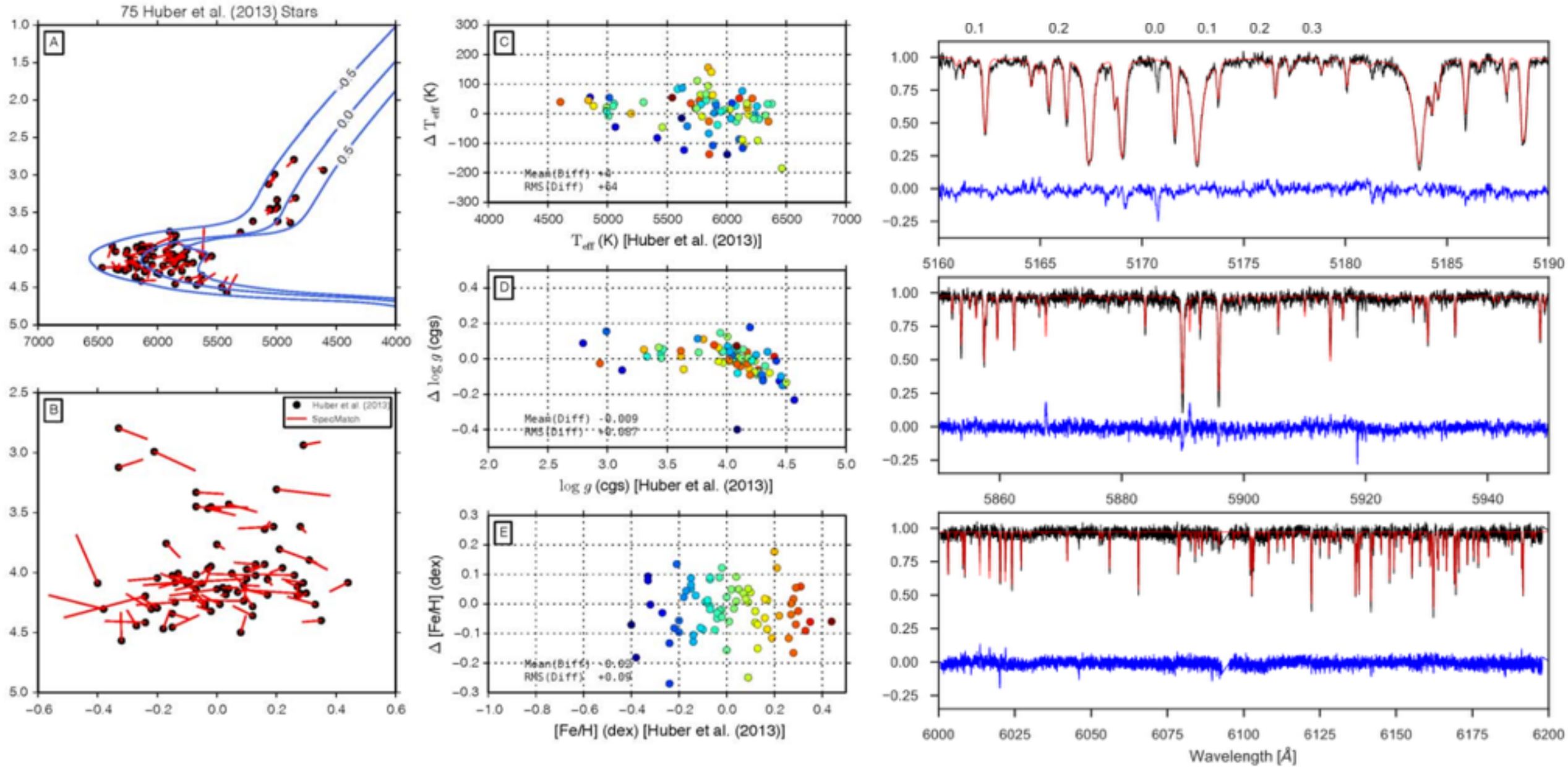






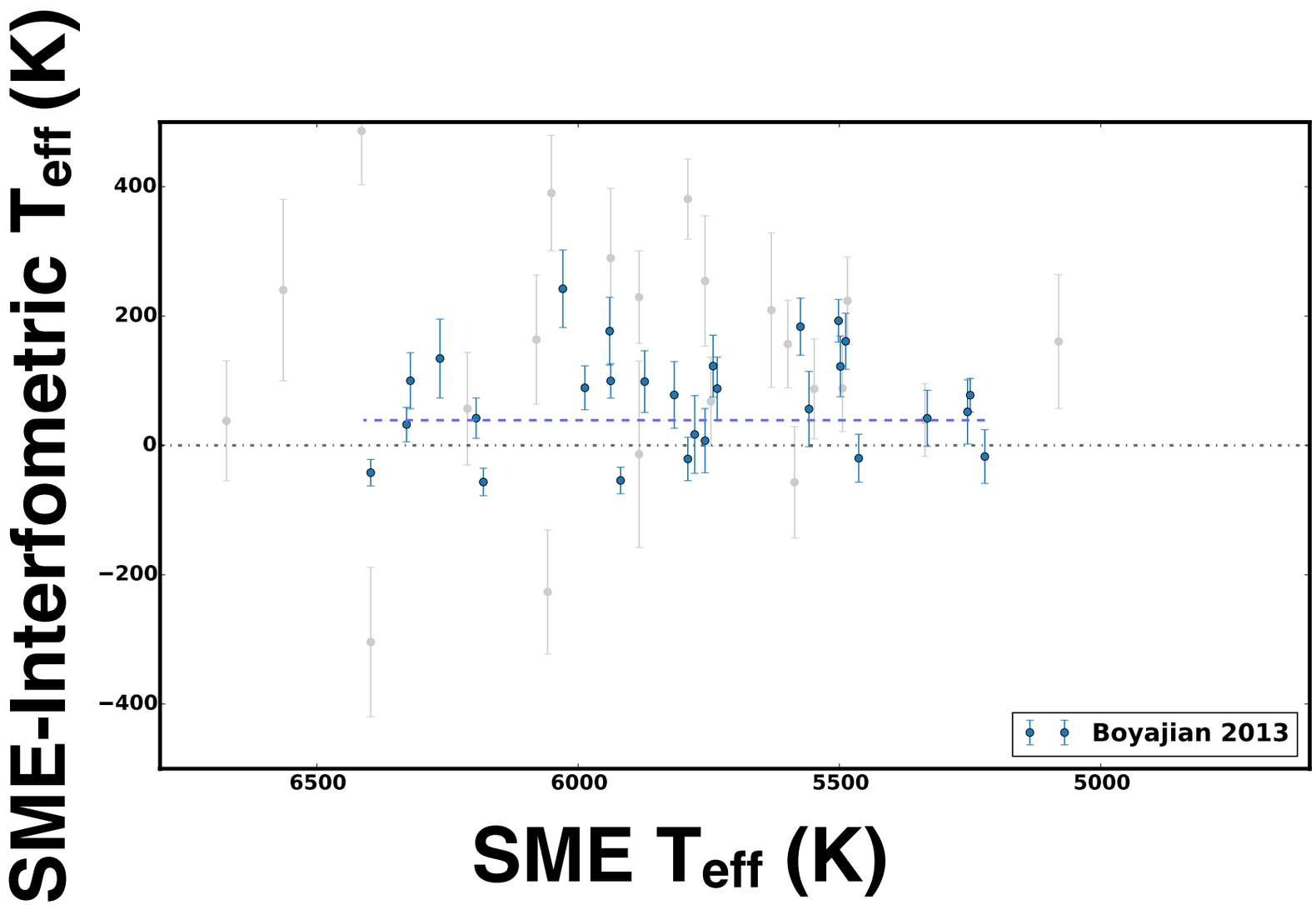
Yee et al. 2017

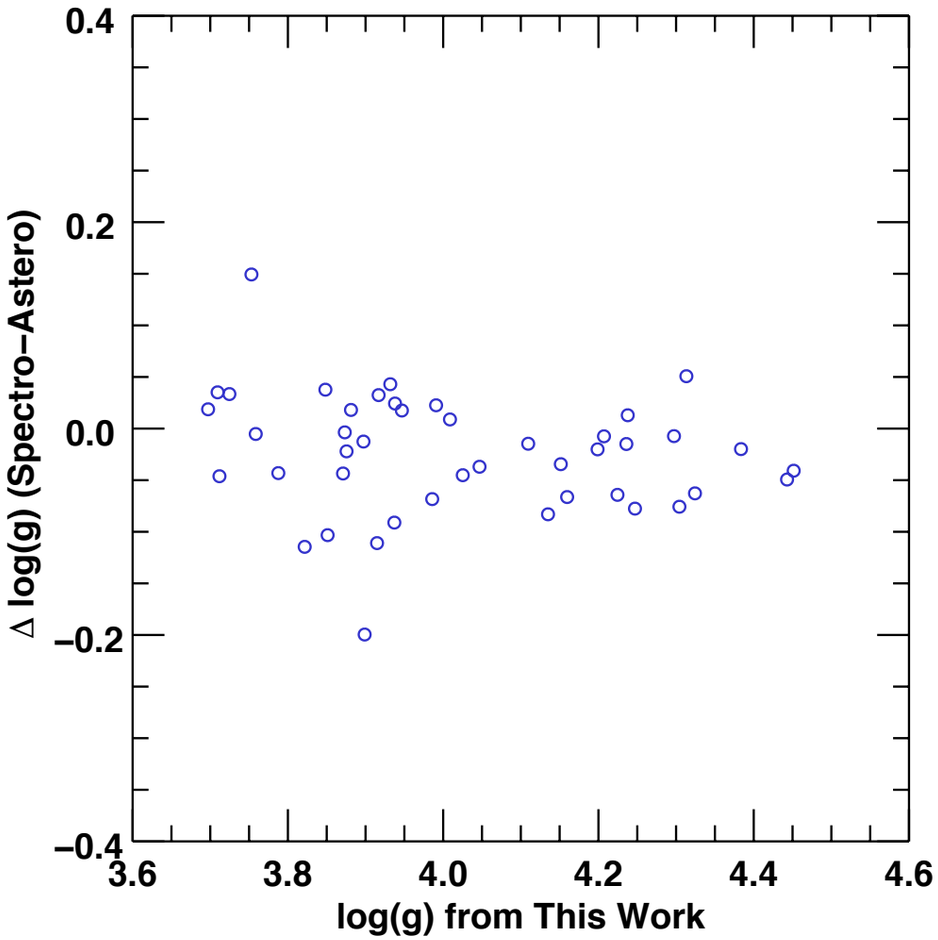
Library SpecMatch & SME@XSEDE



Petigura et al. (2015)

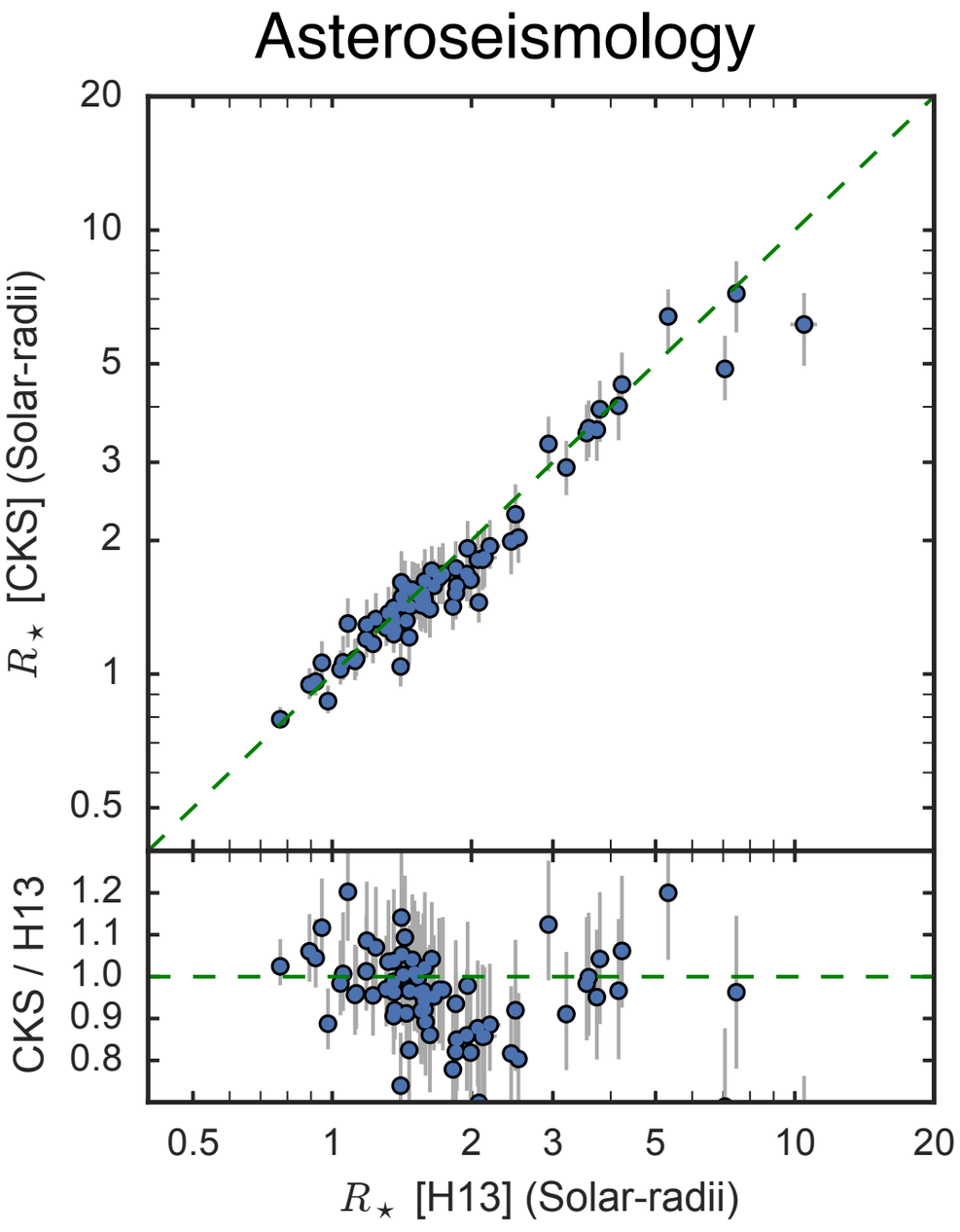
Calibration of SME

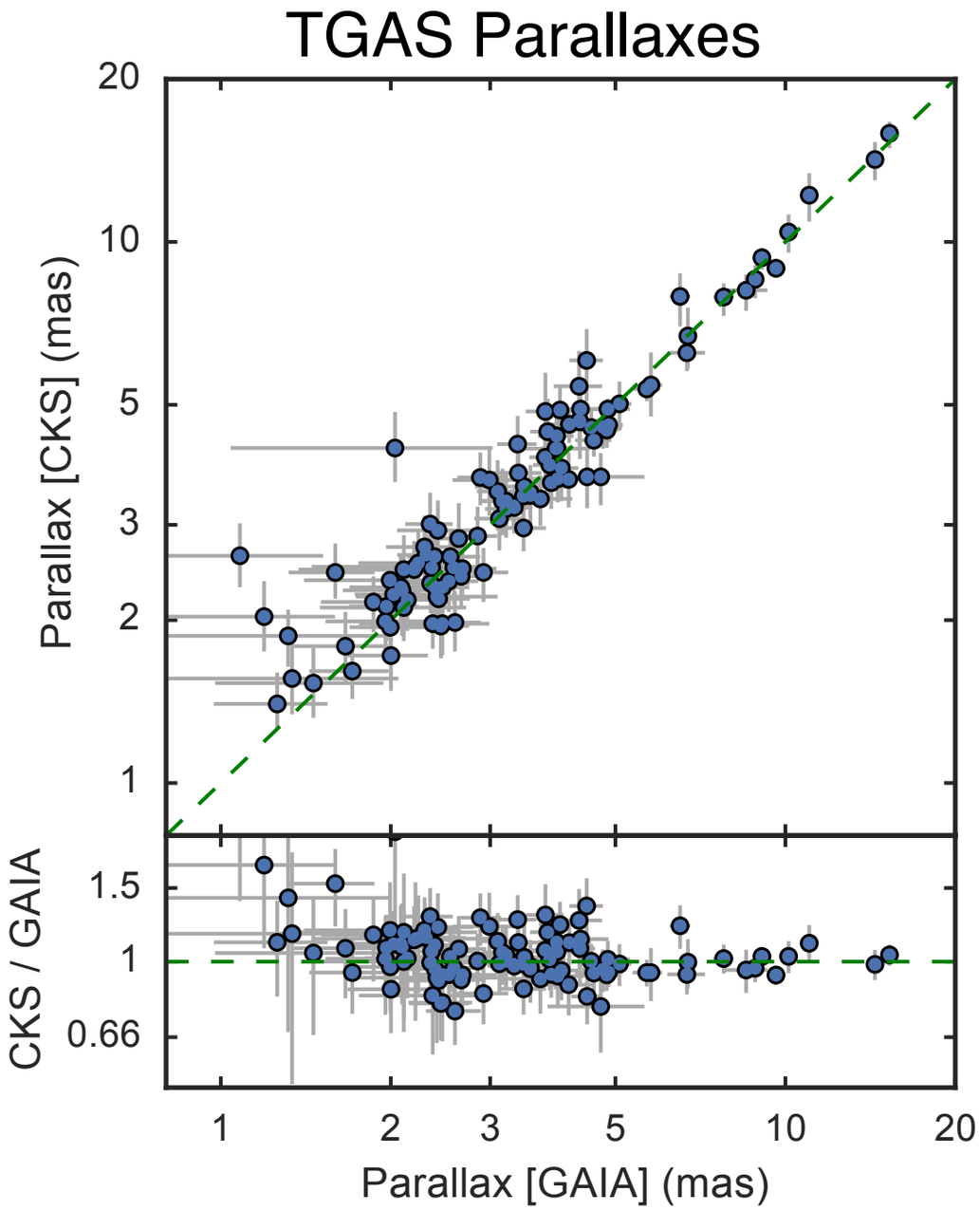




Brewer et al. (2015, 2016)

Testing the CKS Results



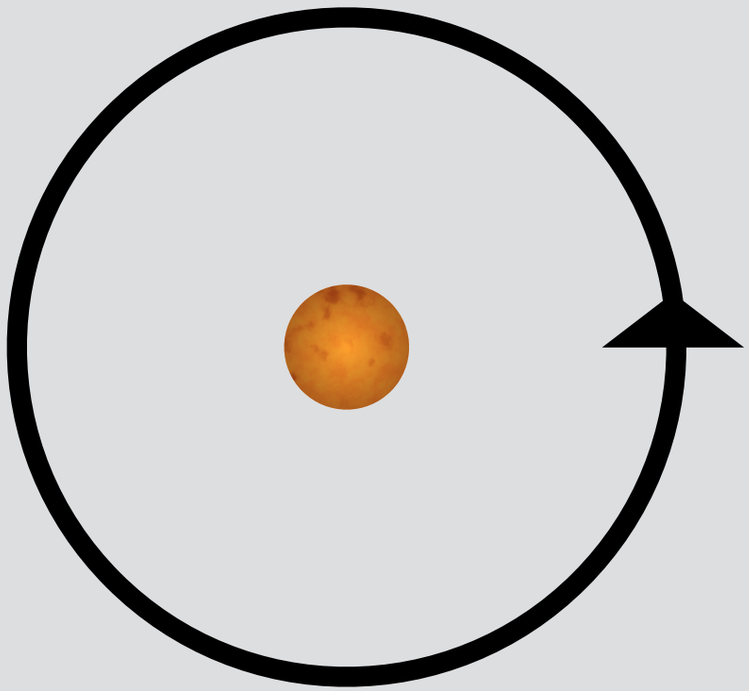


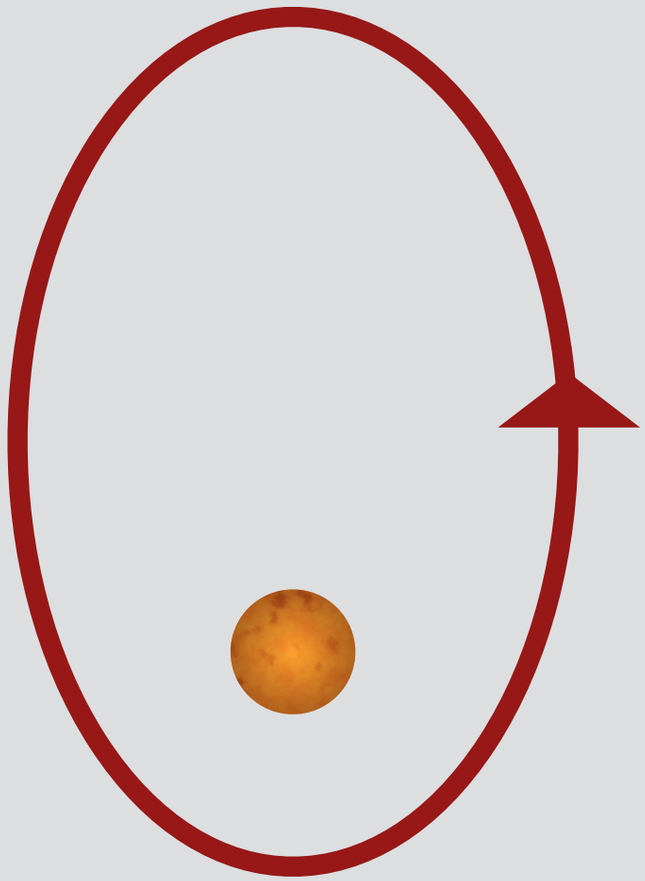
Johnson et al. 2017

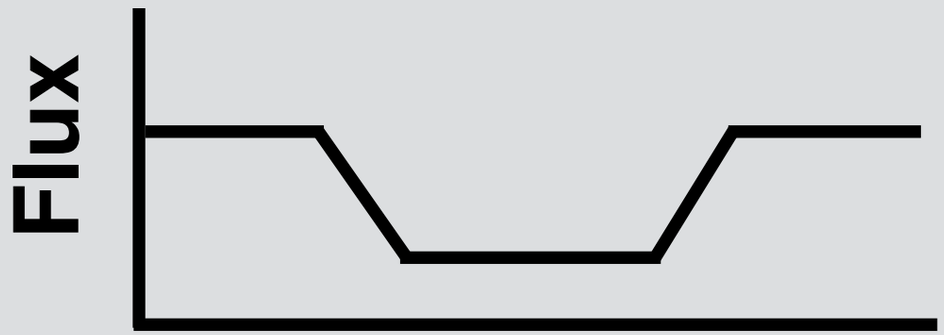
Stellar radii are an obvious example

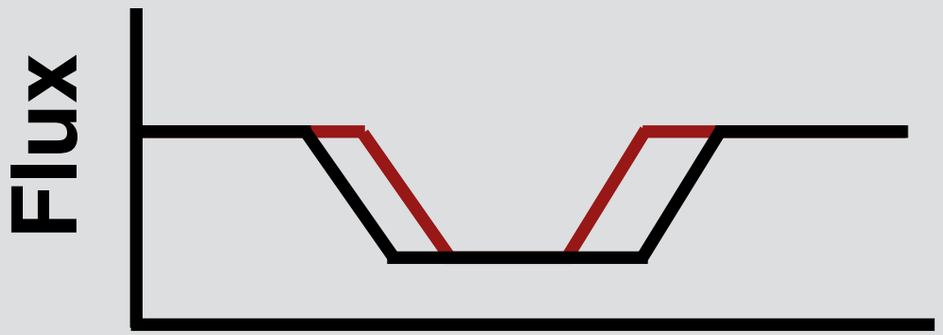
Stellar parameters matter
in more nuanced ways

Eccentricities

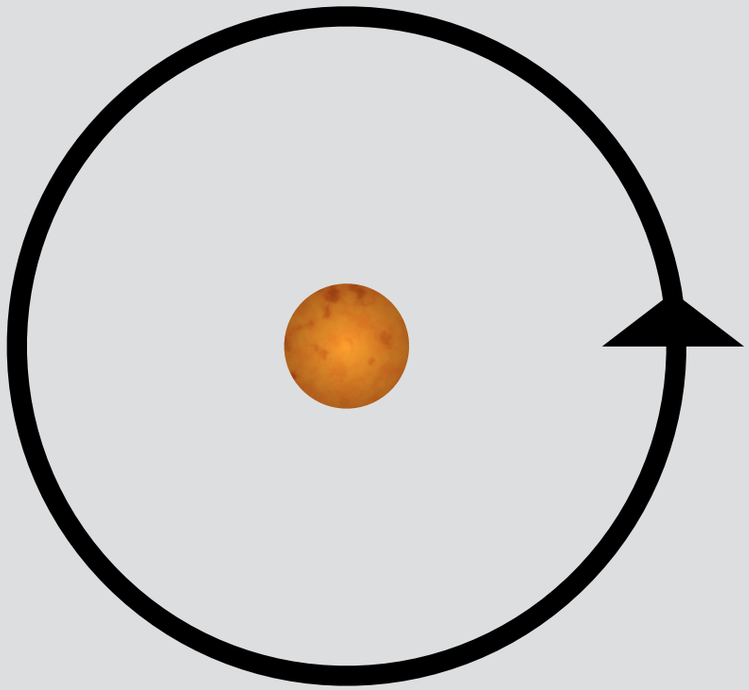


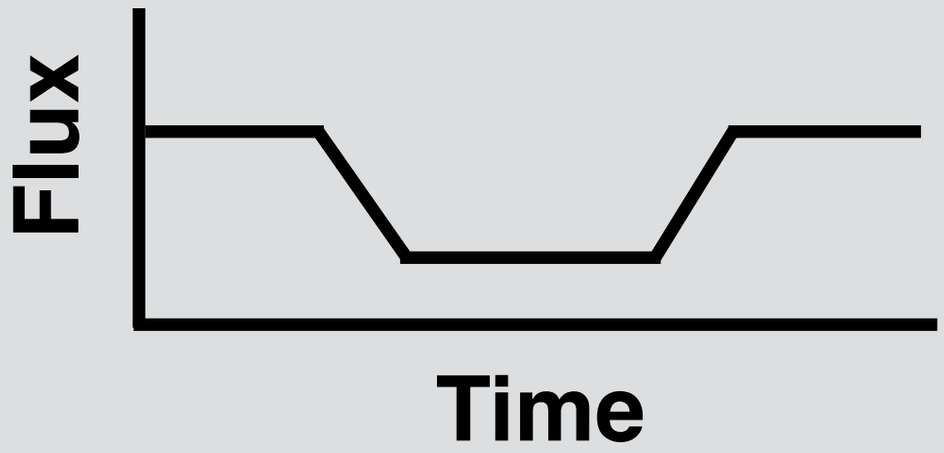


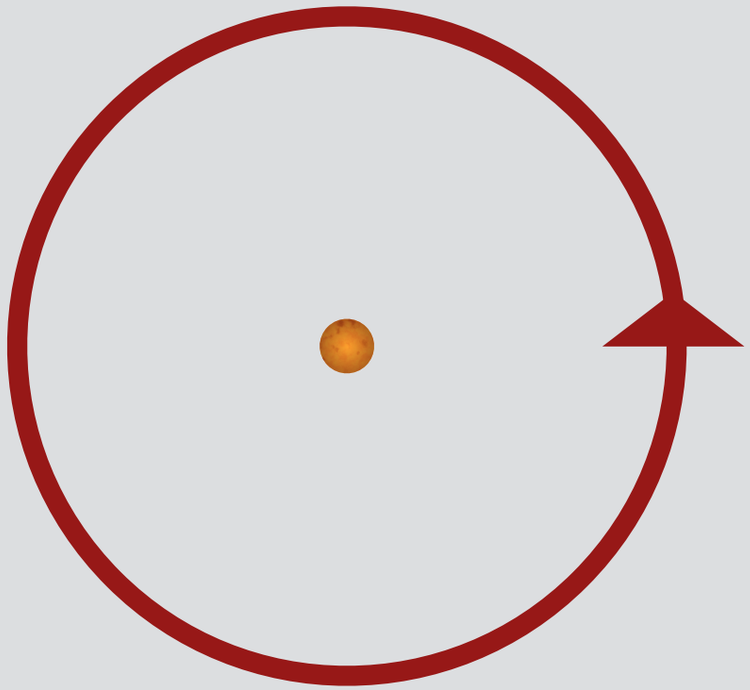


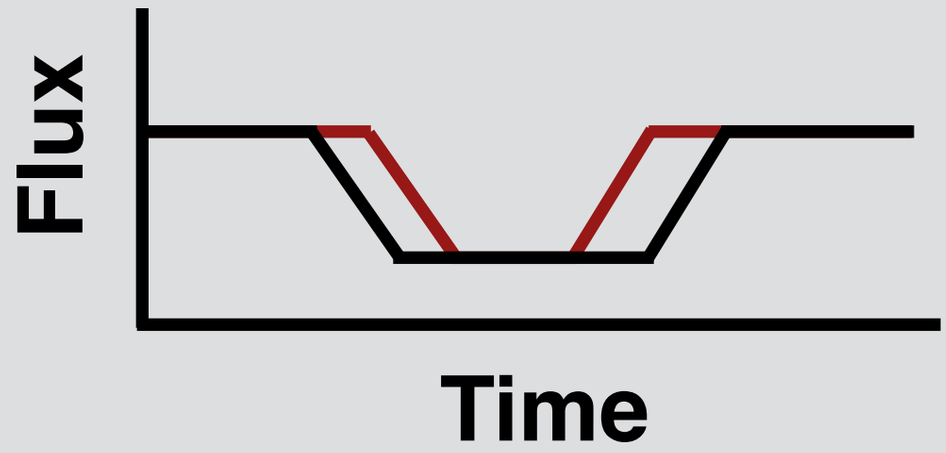


Eccentricities

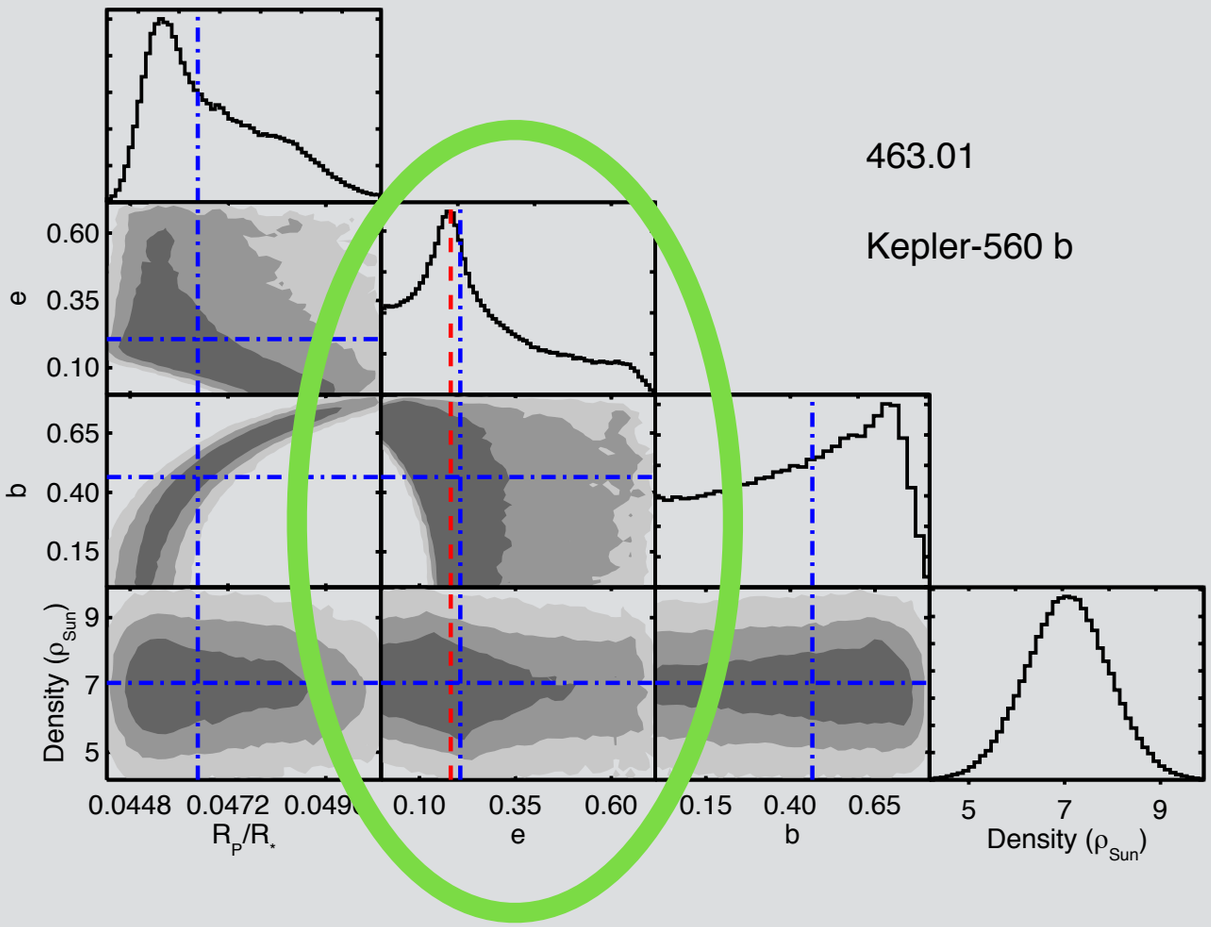


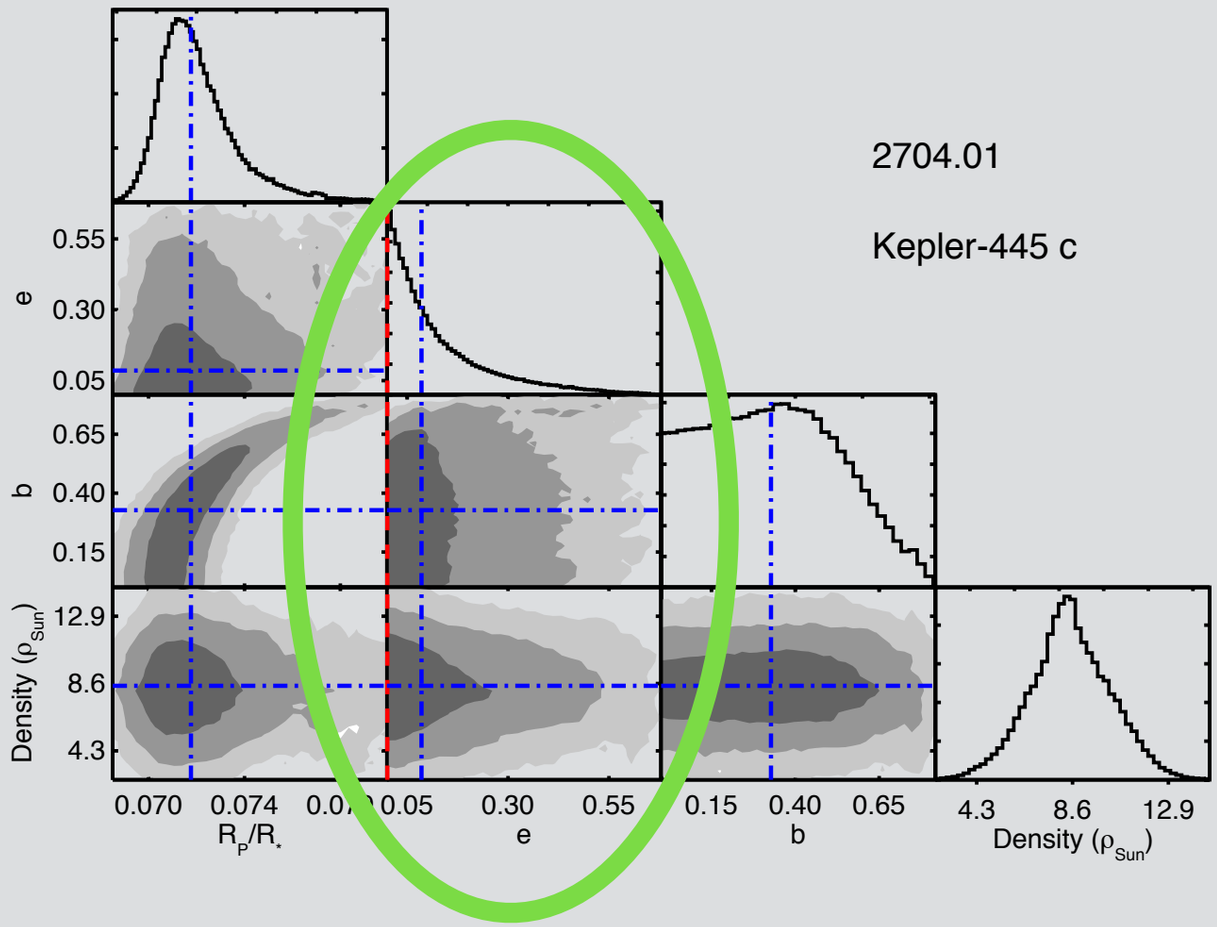






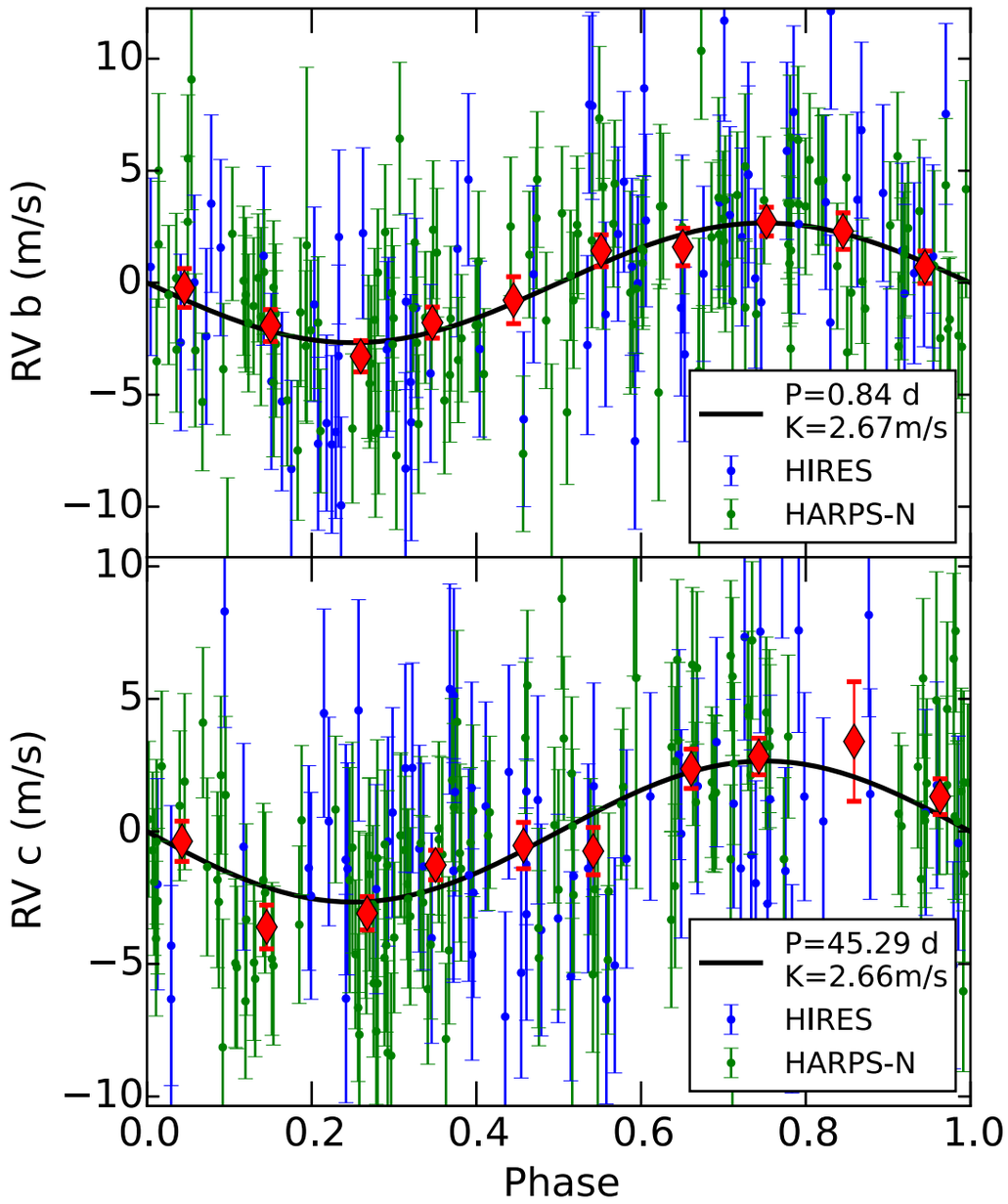
Stellar Density ->
Dynamics of Small Planets



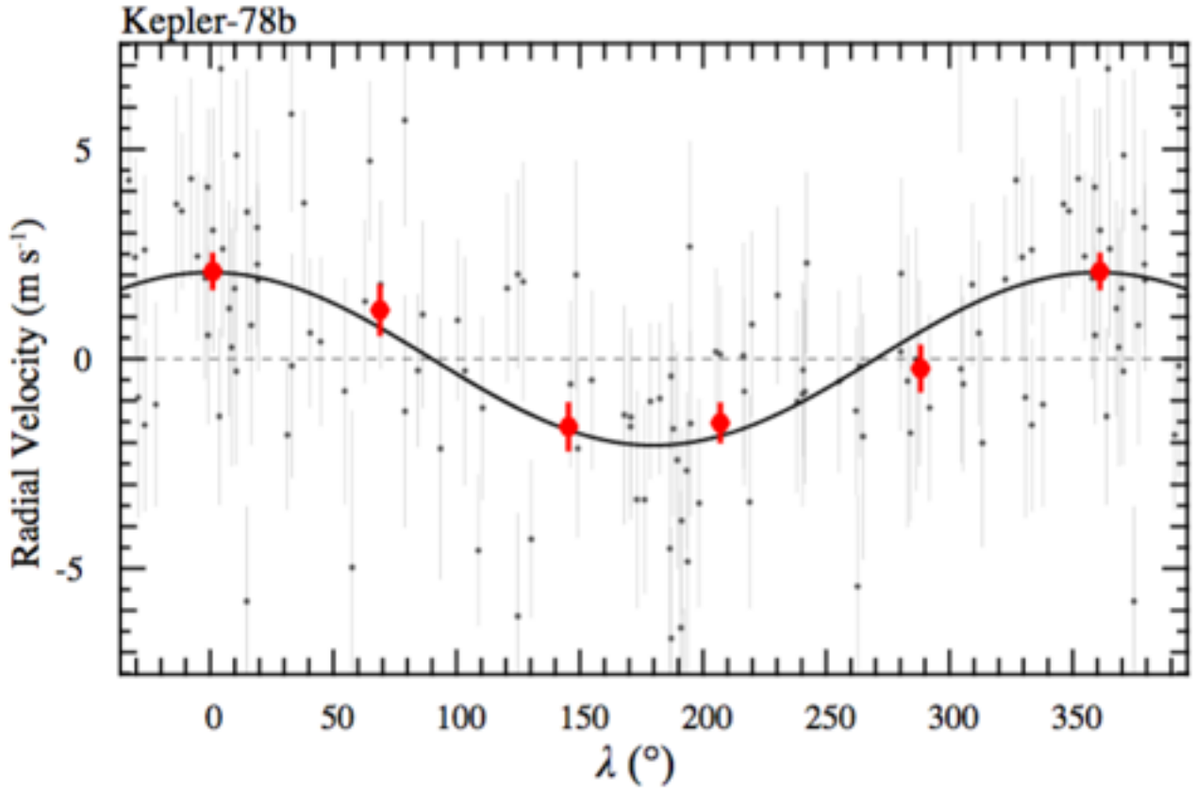


Mann et al. 2017b

This is too difficult with radial velocities

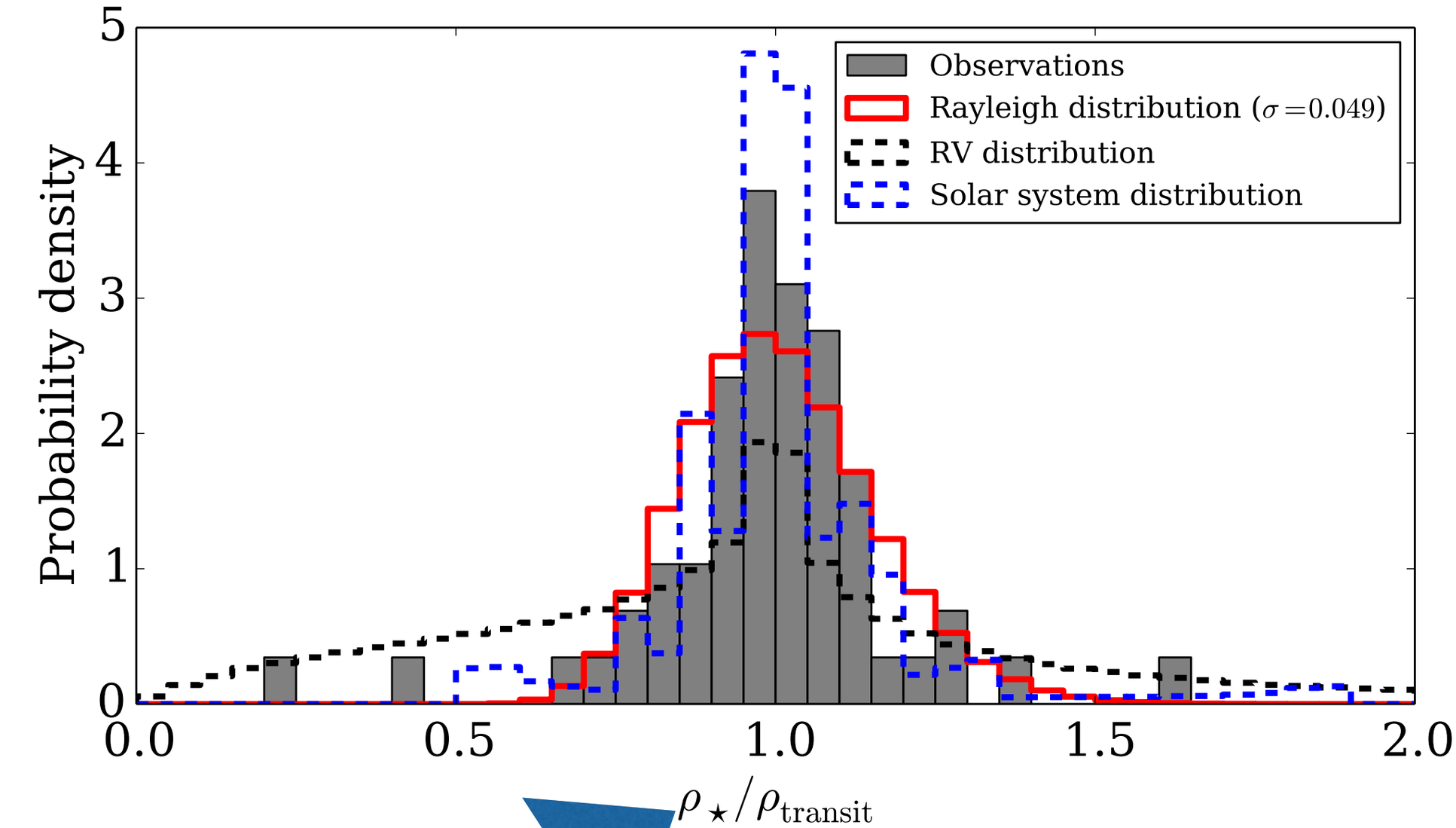


Weiss et al. (2016)



Pepe et al. (2013)

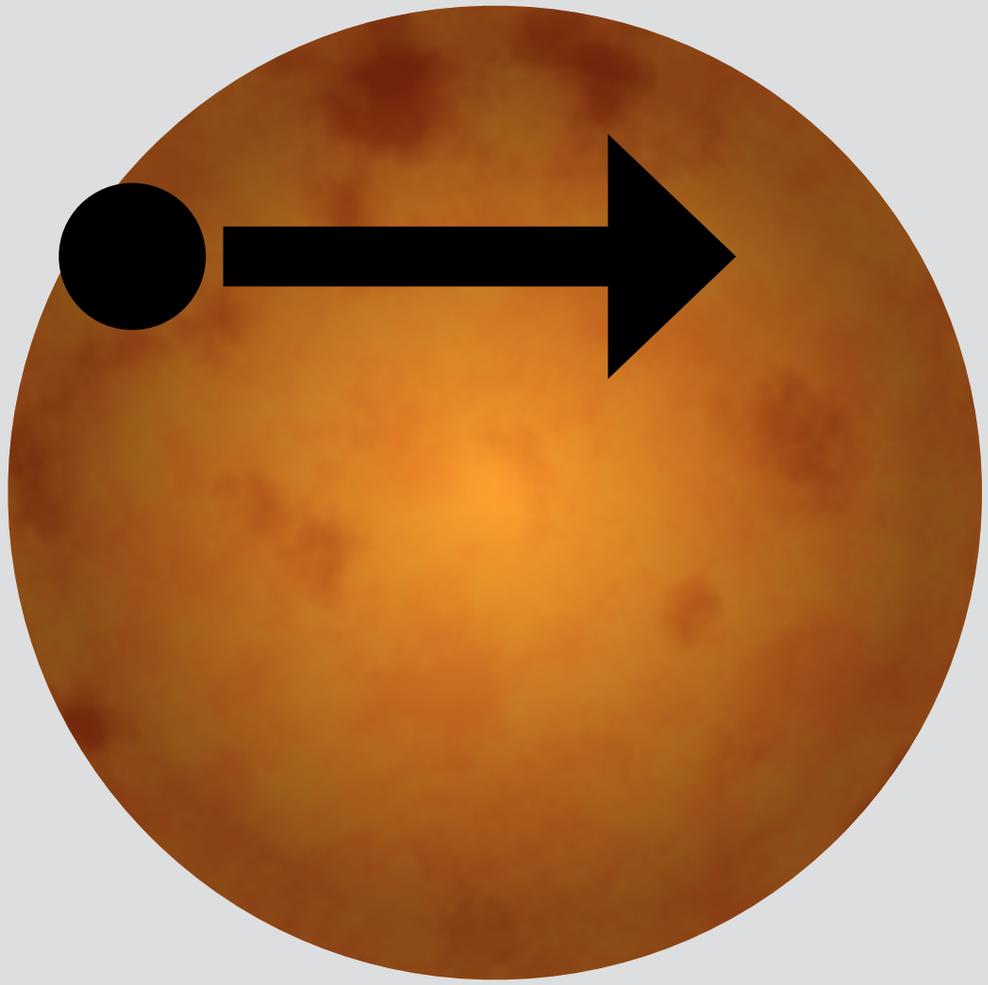
Eccentricity distribution of small planets

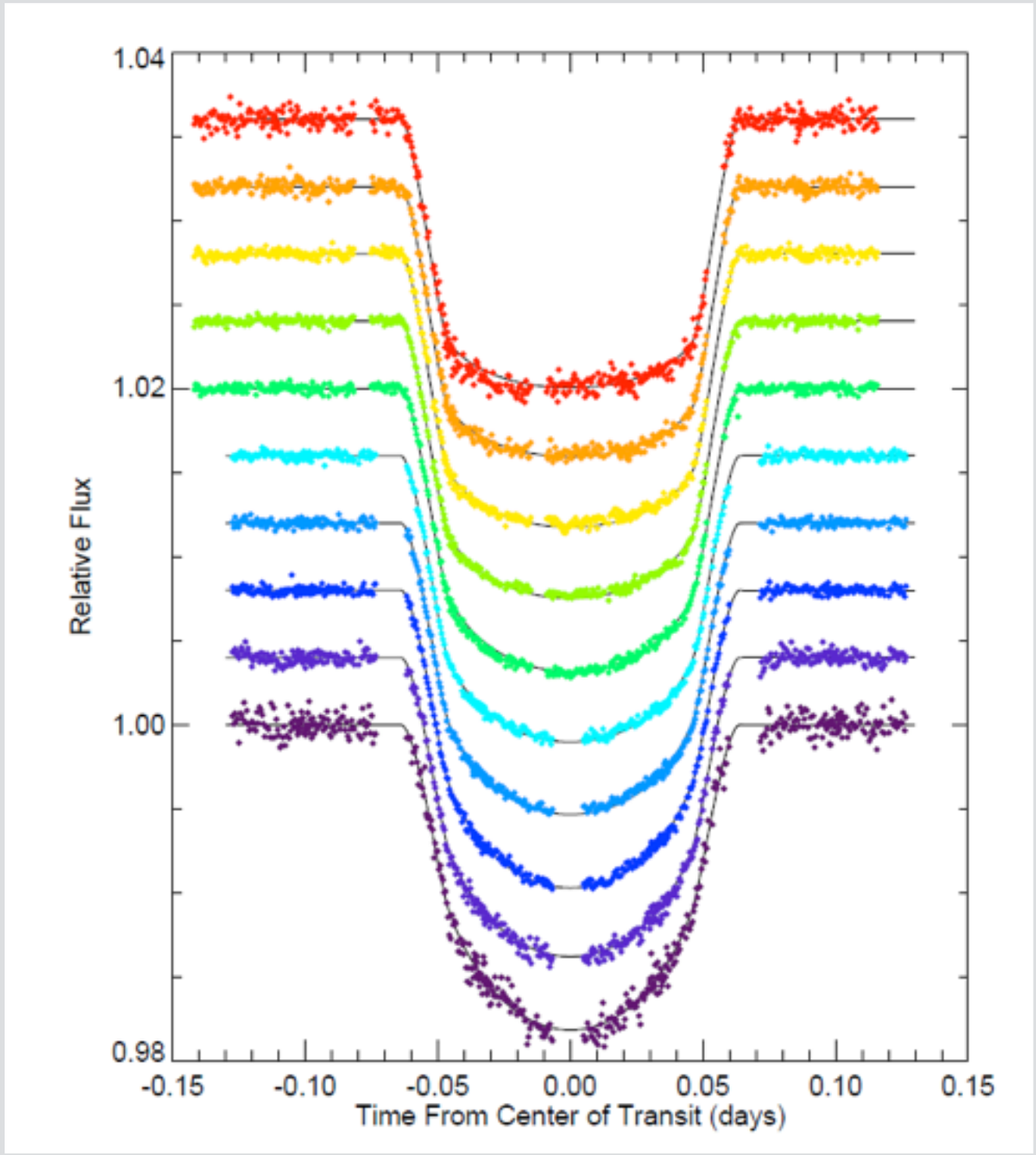


Asteroseismic Density

Van Eylen & Albrecht 2015

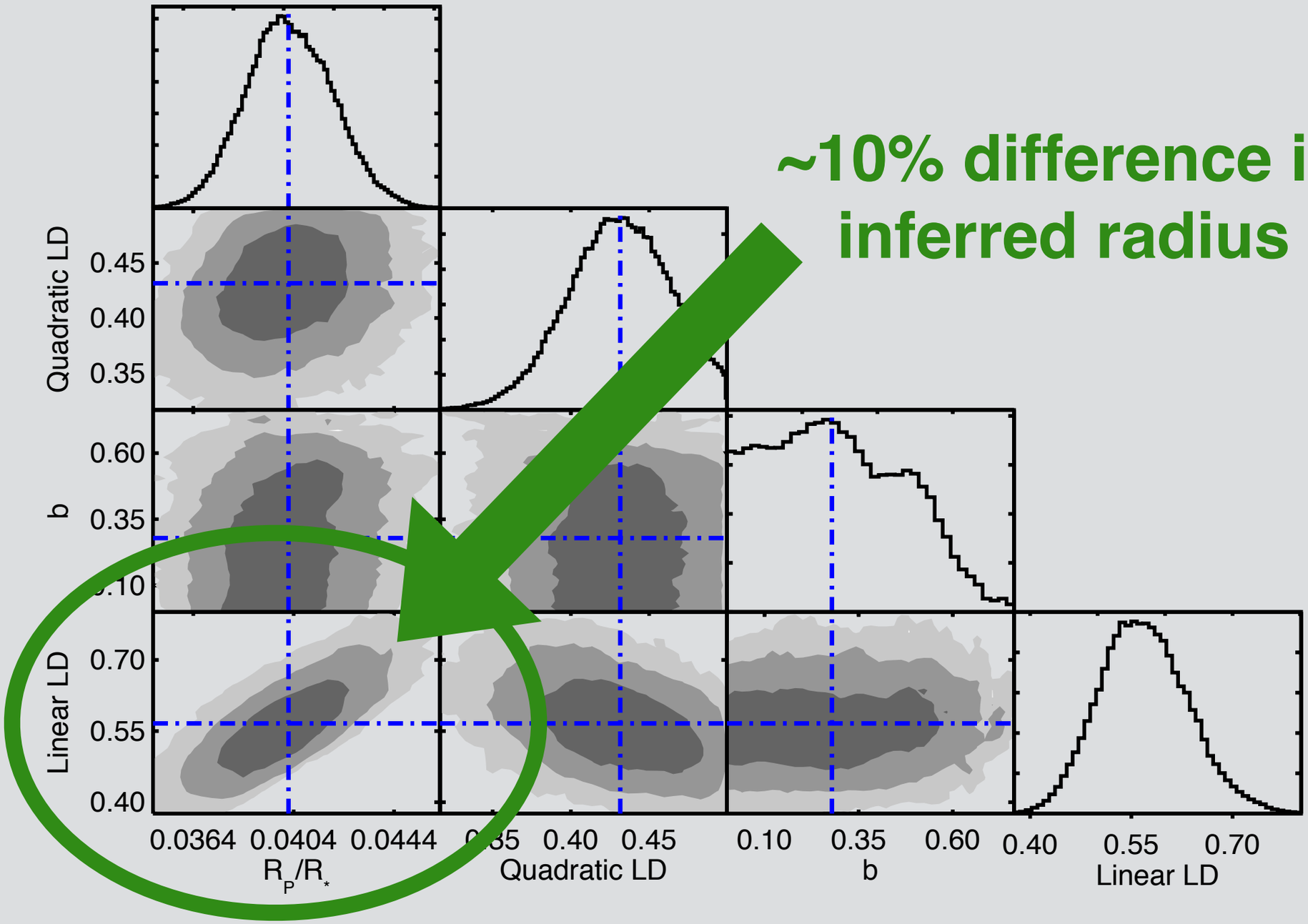
Limb-Darkening





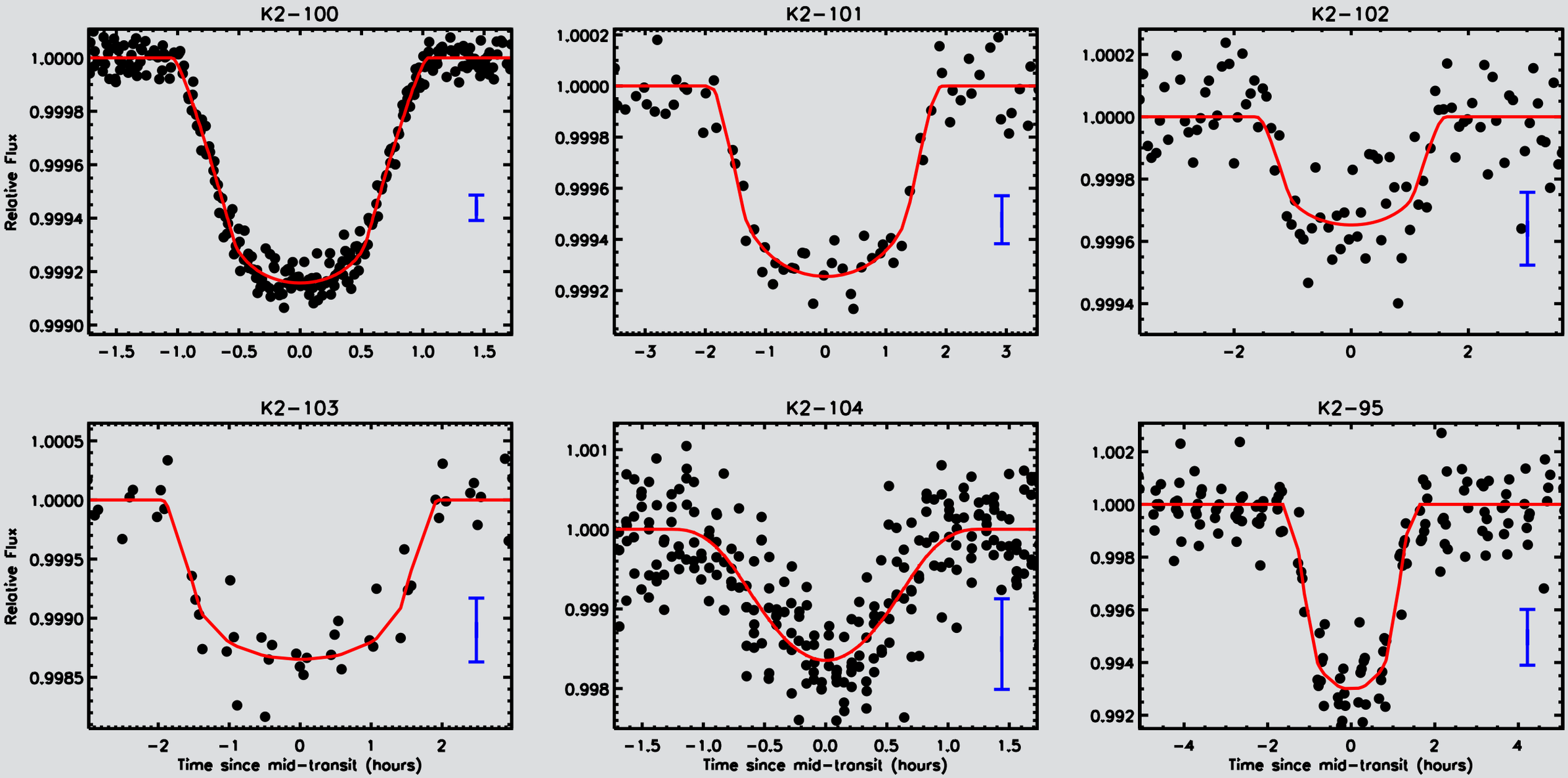
Knutson et al. 2007

Limb-Darkening

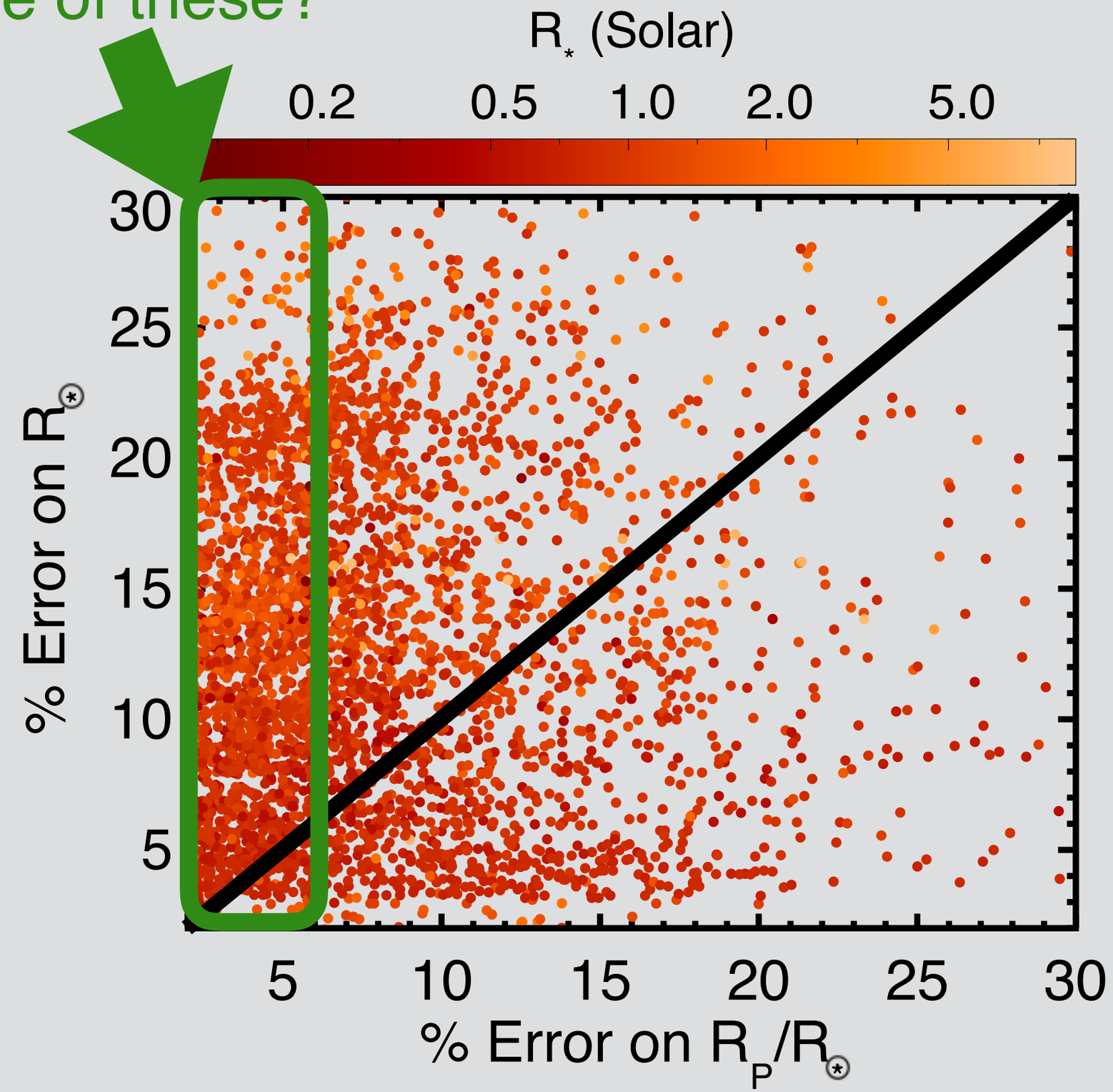


Mann et al. 2016b
Espinoza & Jordán 2015

Poorly Resolved Ingress/Egress



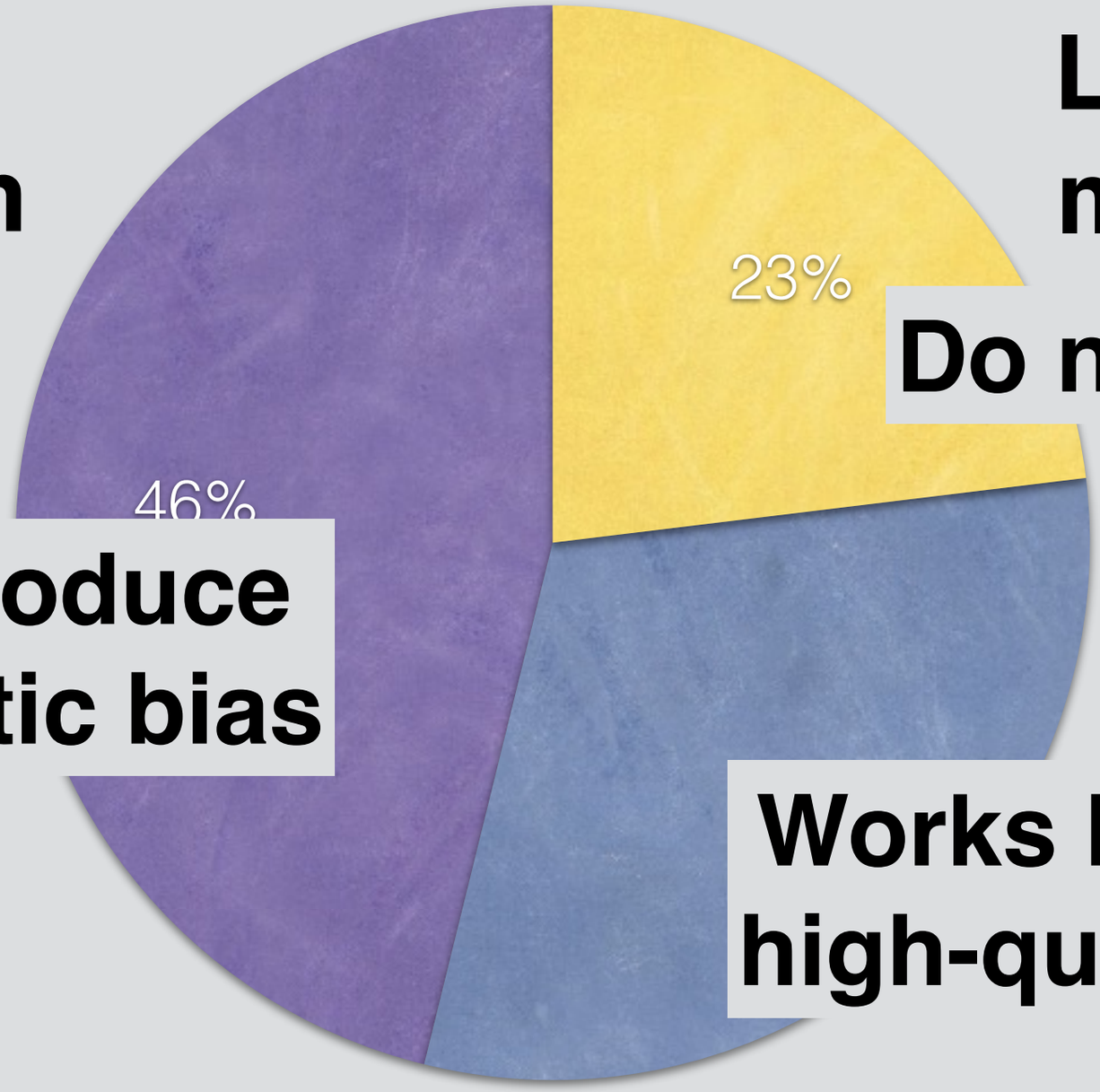
Should we be skeptical of some of these?



How do exoplaneteers handle limb-darkening?

Prior from models

May introduce systematic bias

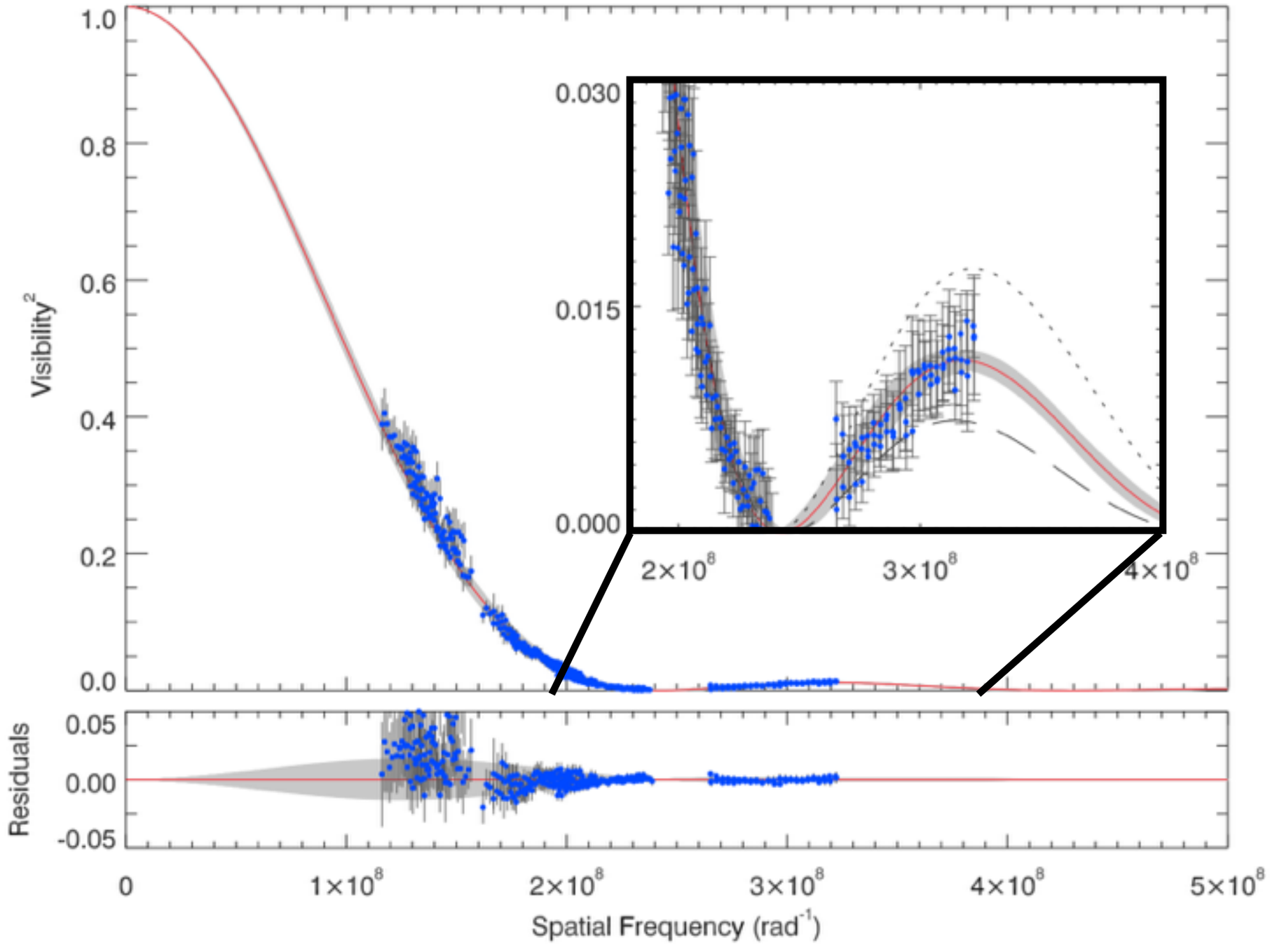


Lock to models

Do not do this!

Works best with high-quality data

Limb-Darkening



White et al. in prep

The Future of Exoplanet Host Characterization

- *Gaia* will make this dramatically easier, but will not solve everything.

- Even with parallaxes, we need to calibrate T_{eff} scale, mass-luminosity, and mass-radius relations.

- We need to know if model limb-darkening values are reasonable.

- Exoplanet surveys are pushing to cooler (e.g., Trappist-1) and younger (e.g., K2-33, V830Tau) targets, which are more complicated.

- We will need to devote more time to understading systematics instead of random errors.

Begin bonus slides