

# Asteroseismology as an exoplanet tool

TASC2 & KASC9 Workshop – July 2016

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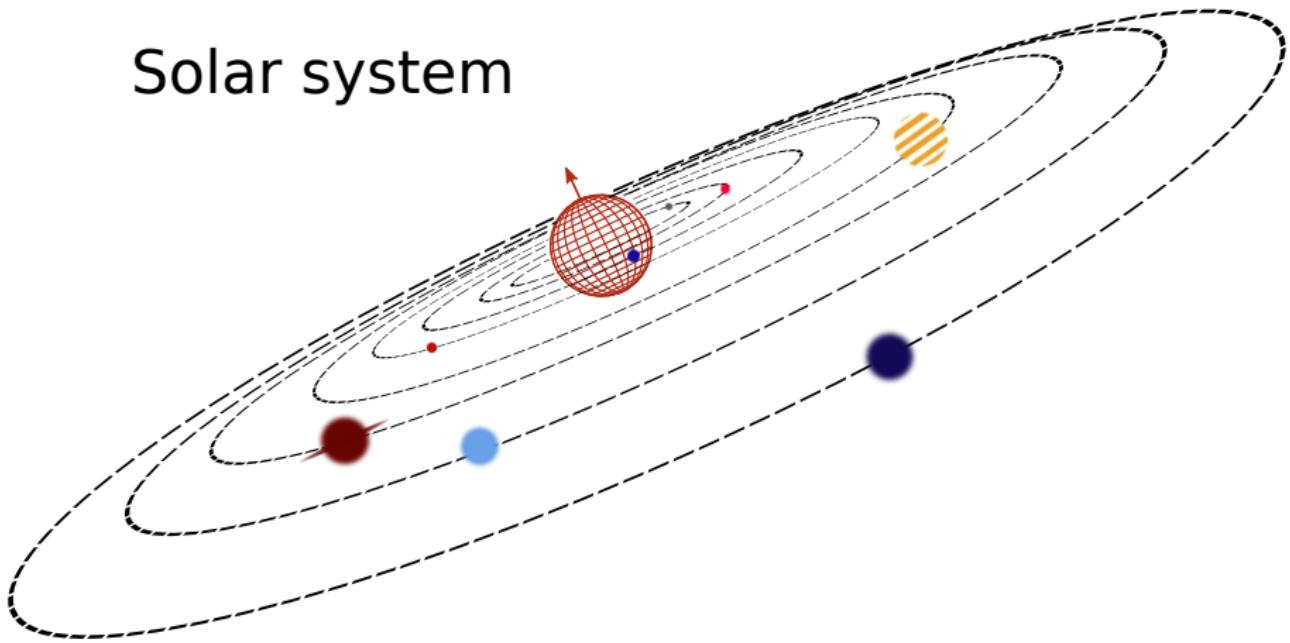
Vincent Van Eylen

Oort Fellow  
Leiden University

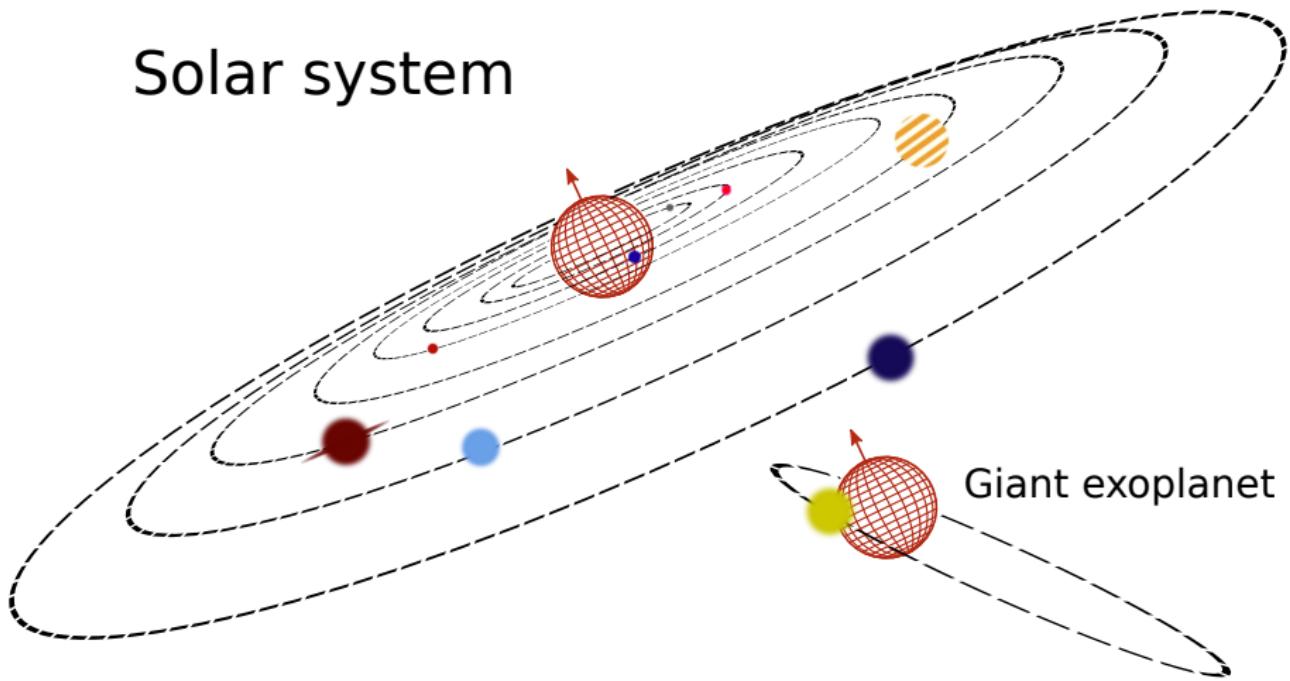
# Solar system



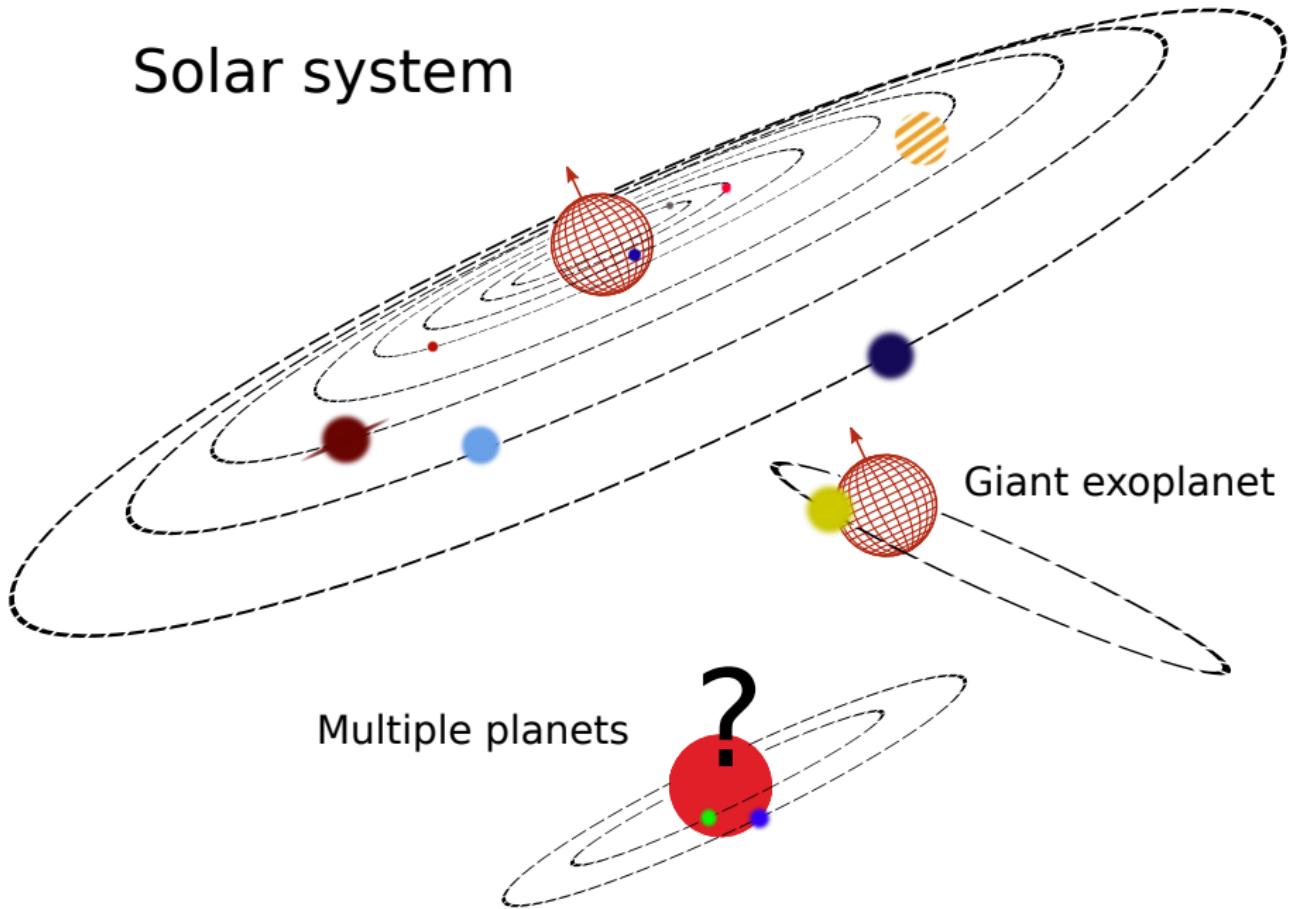
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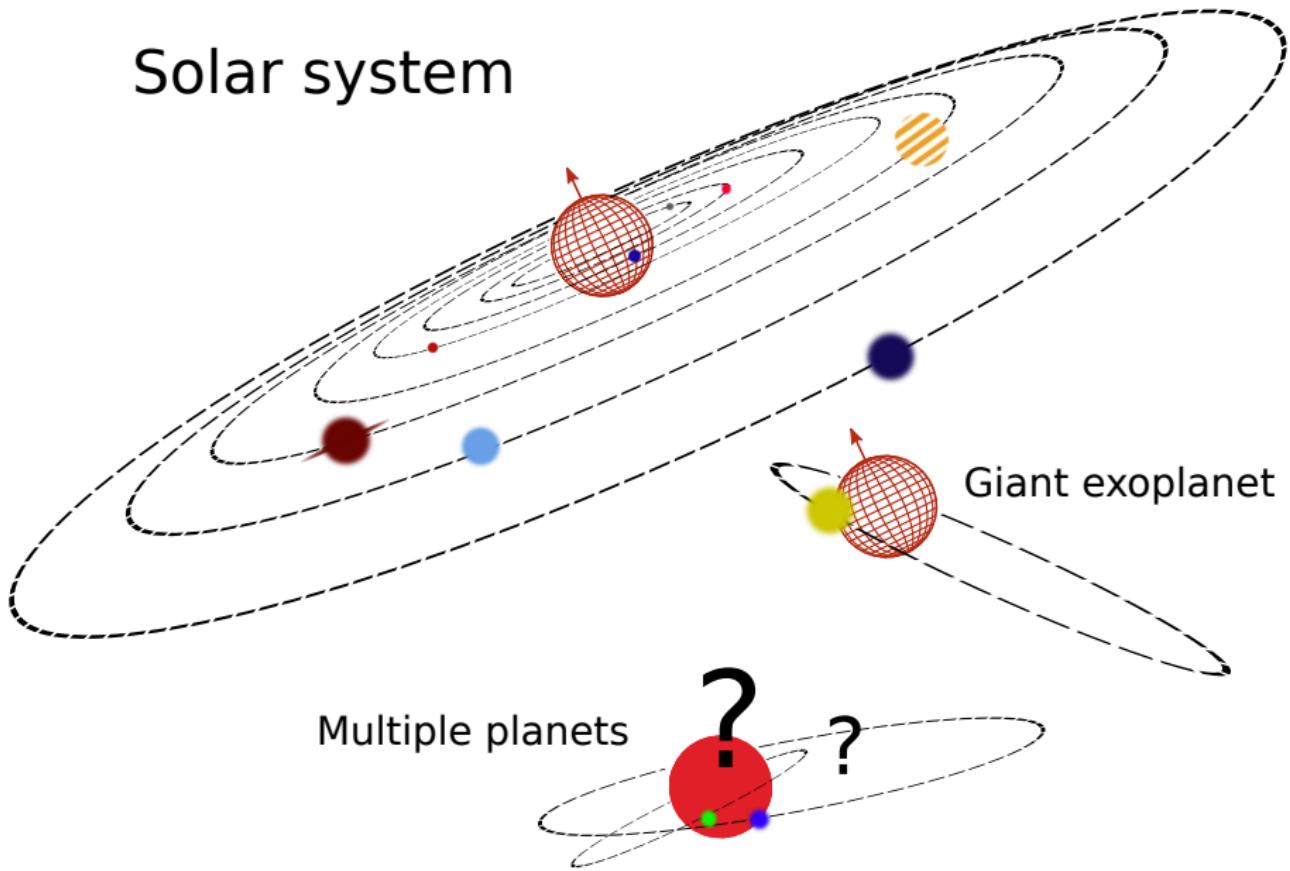
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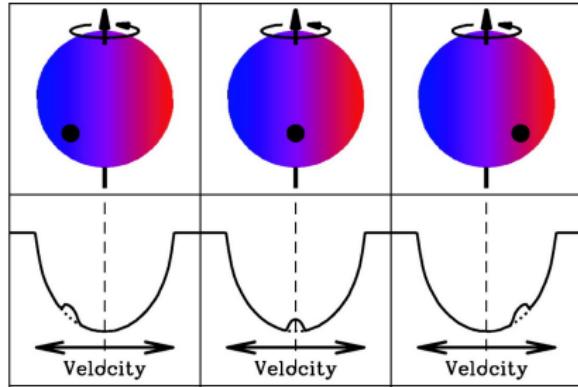


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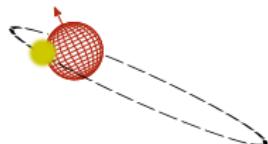


# How to observe obliquities?

## Rossiter-McLaughlin effect

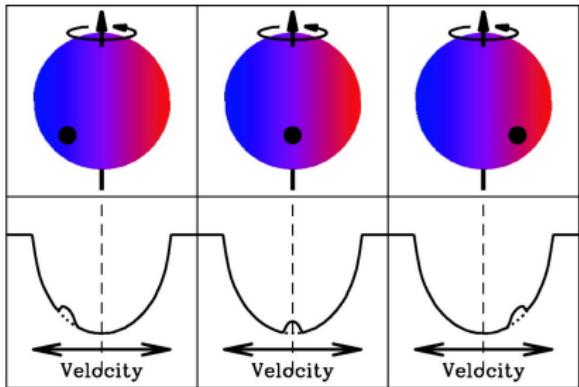


## Large planets

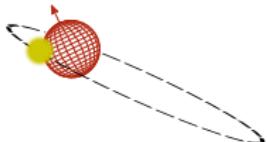


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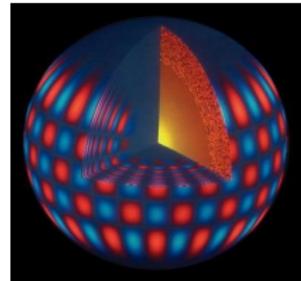


**Large planets**



## Asteroseismology

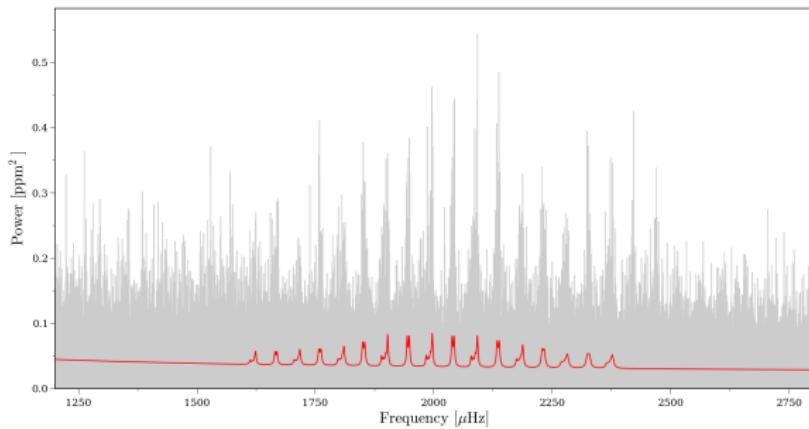
Accurate mass, radius, age, ...



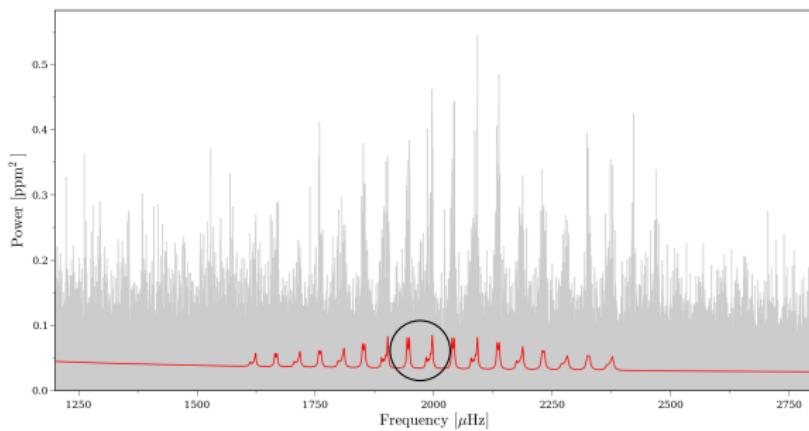
... and stellar inclination!  
**Independent of planet**



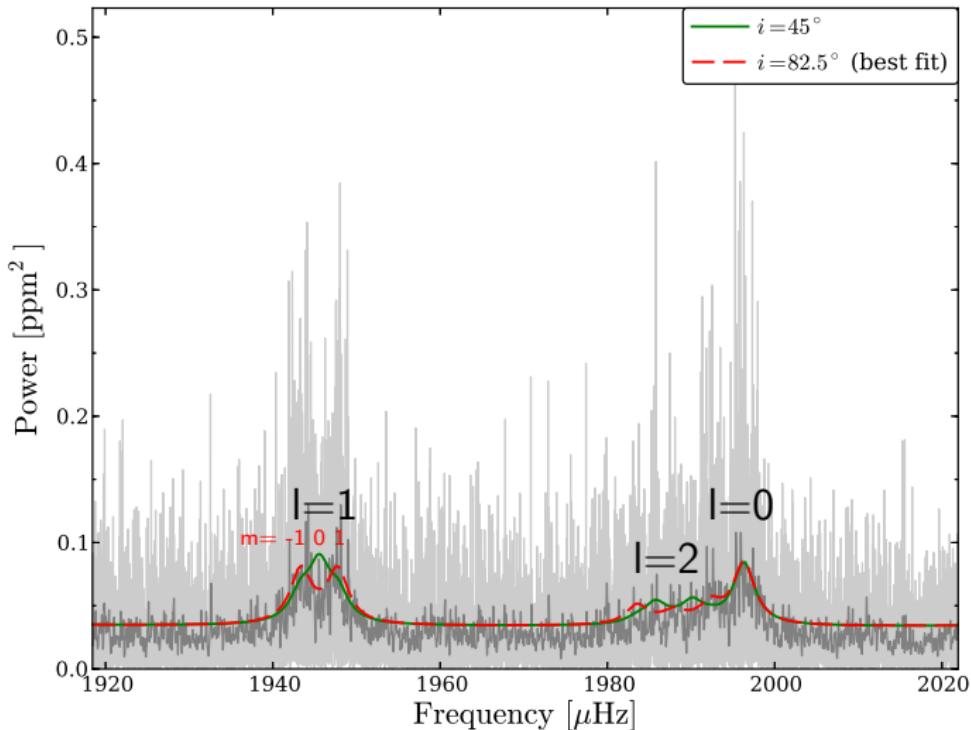
Rotational splitting provides info on stellar rotation and inclination



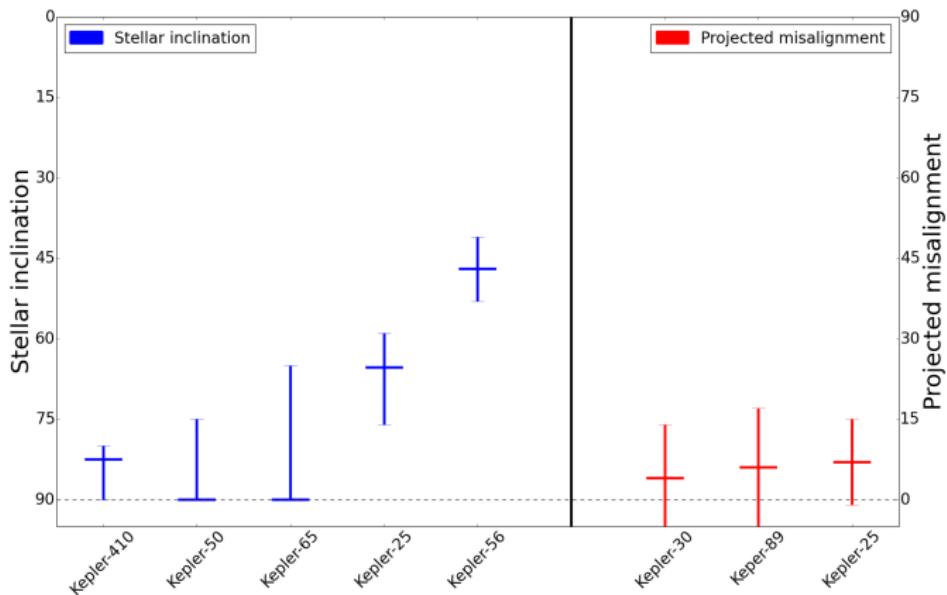
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# Rotational splitting provides info on stellar rotation and inclination

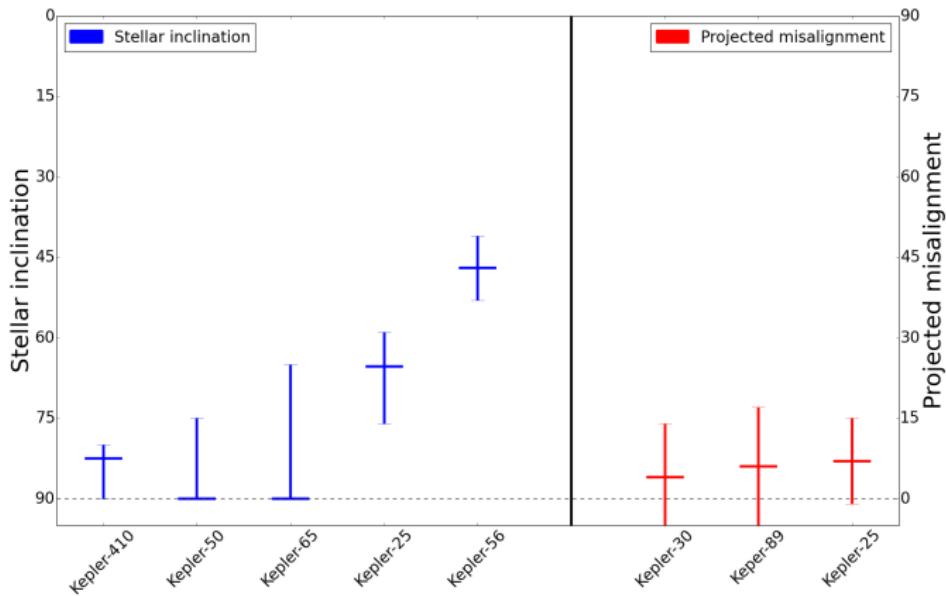


# 1 Obliquity of multi-planet systems?



Values from: Sanchis-Ojeda et al. 2012, Hirano et al. 2012, Albrecht et al. 2013, Chaplin et al. 2013, Huber et al. 2013, Van Eylen et al. 2014, Benomar et al. 2014

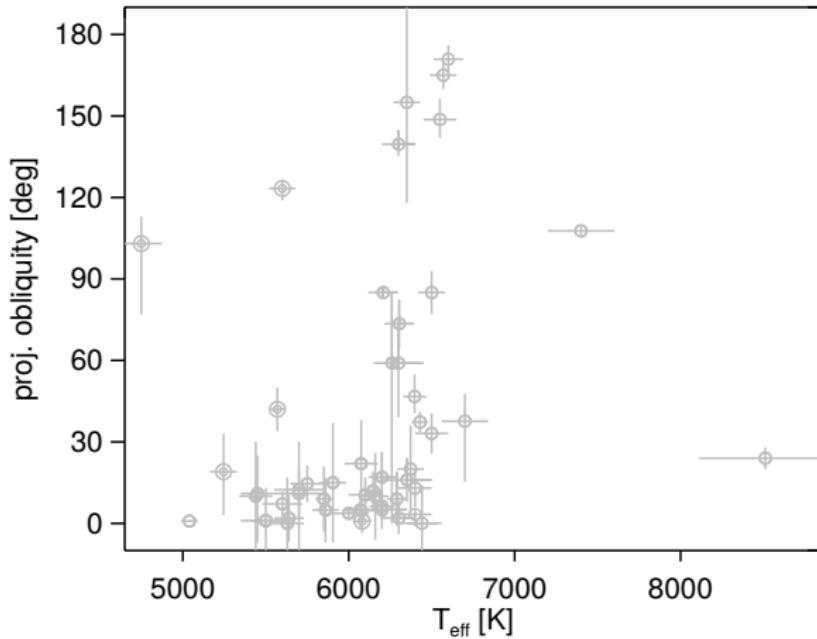
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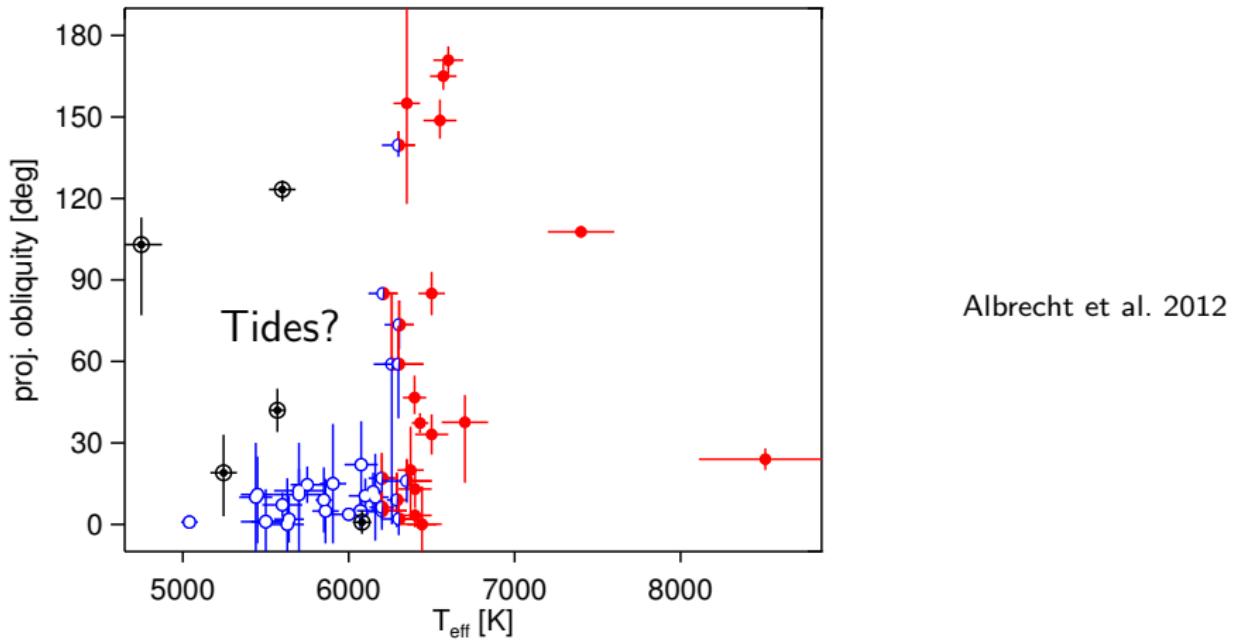
**Ensemble study:** Campante et al. 2016

- ➊ Obliquity of multi-planet systems: low
- ➋ Obliquity of single-planet systems: a wide range

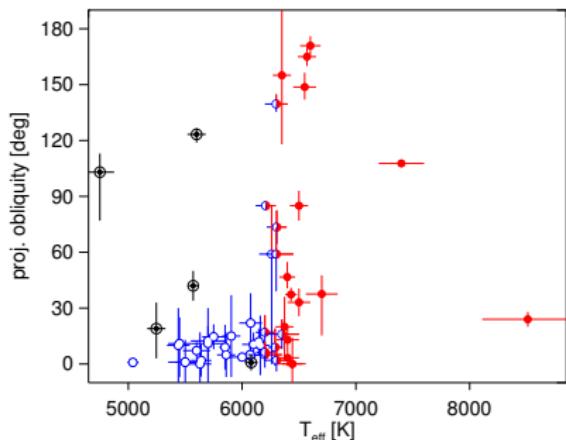


Albrecht et al. 2012

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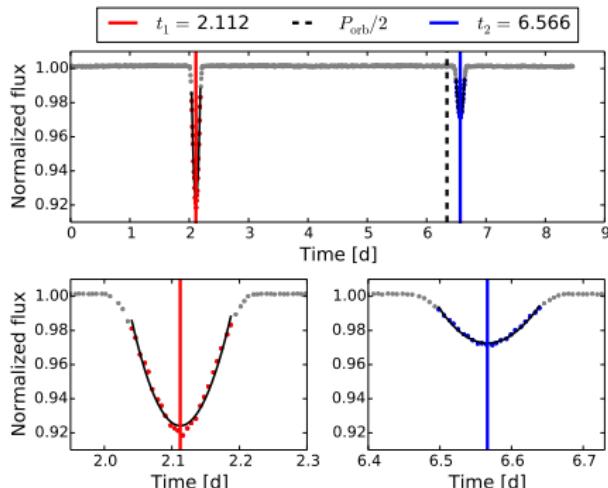


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Obliquity

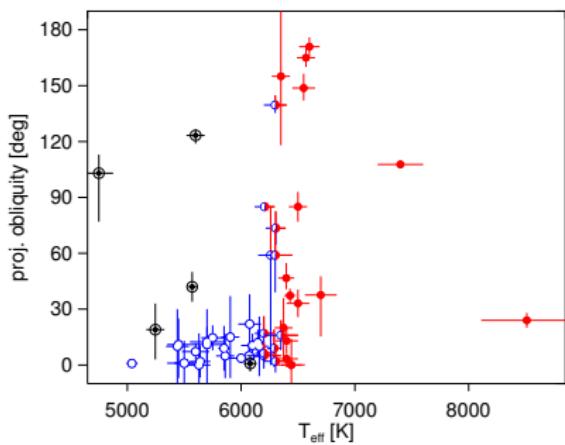
Winn et al. 2010, Albrecht et al. 2012



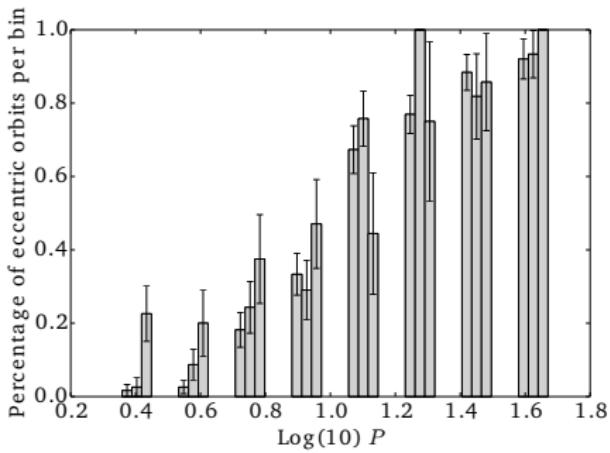
Binary star eccentricity

Van Eylen, Winn & Albrecht 2016

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Obliquity

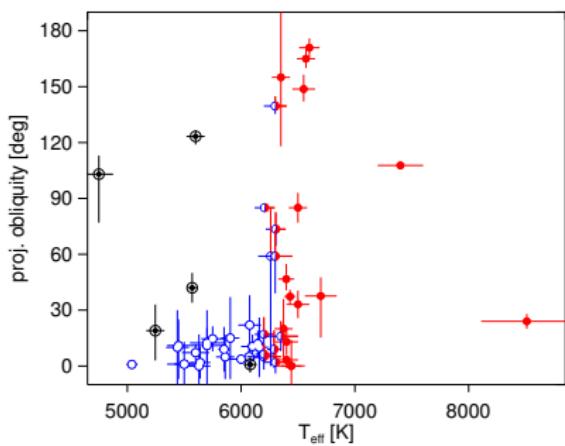


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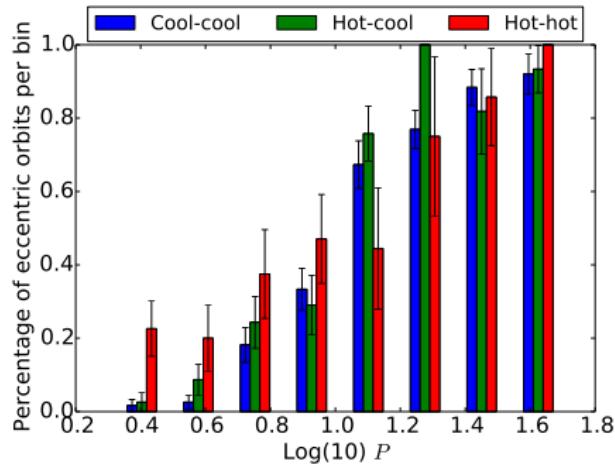
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Obliquity

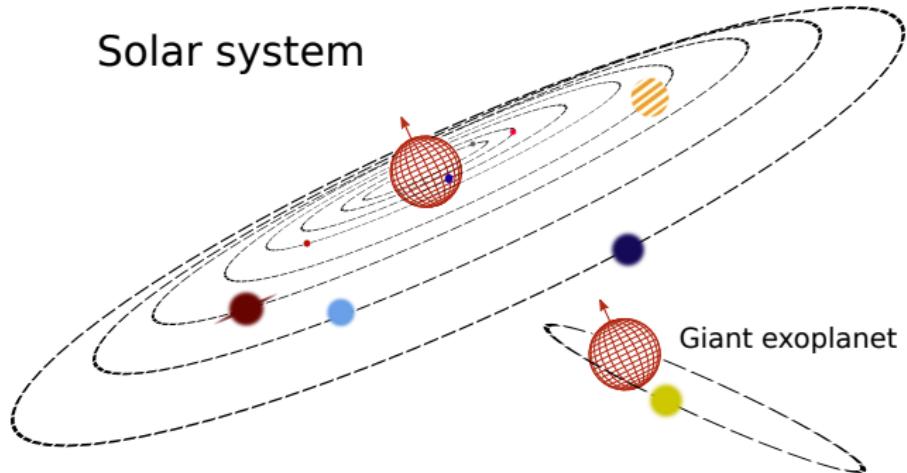


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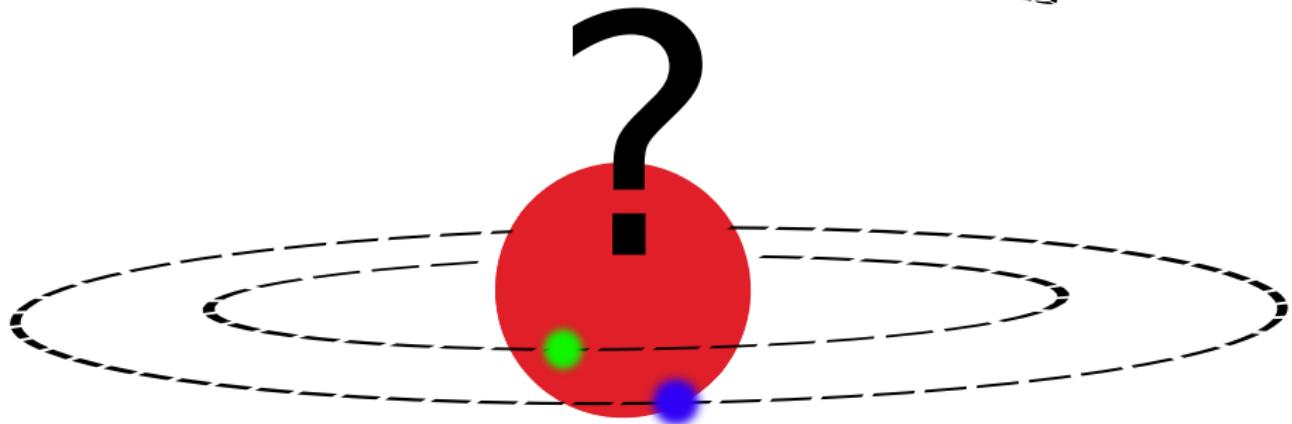
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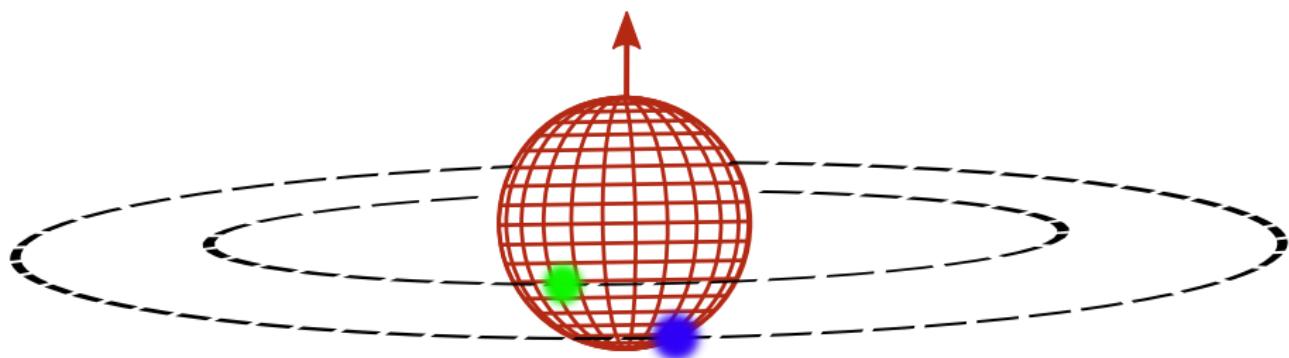
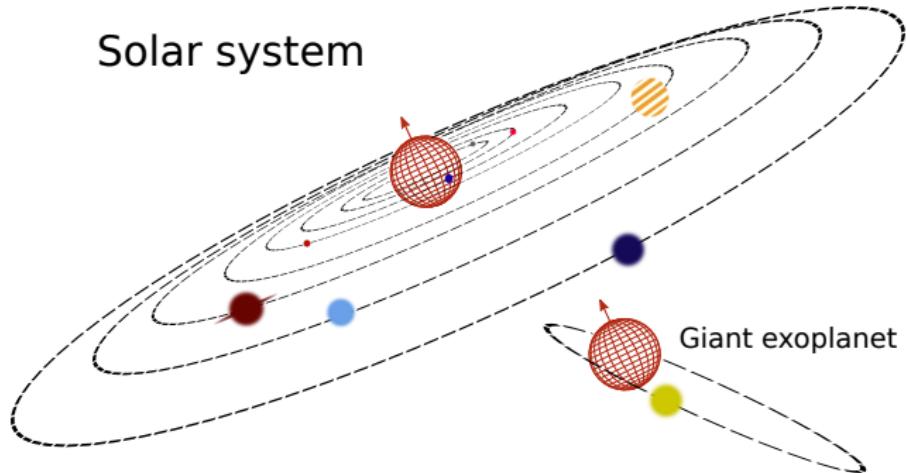
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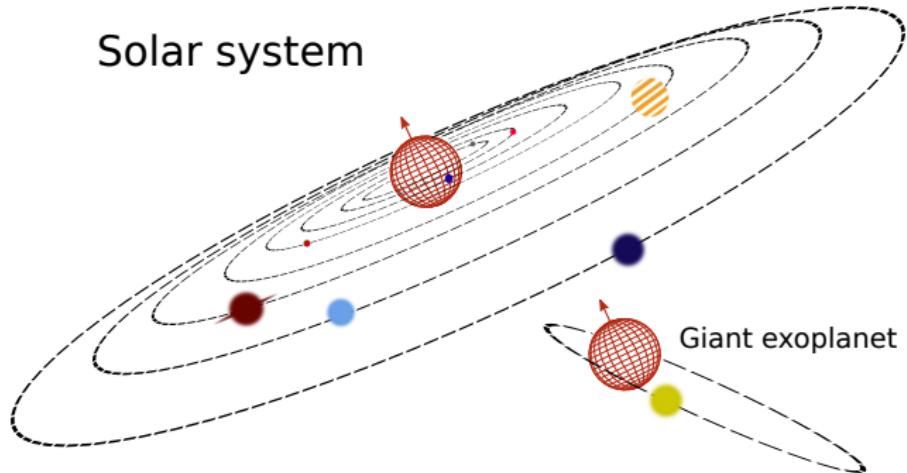
?



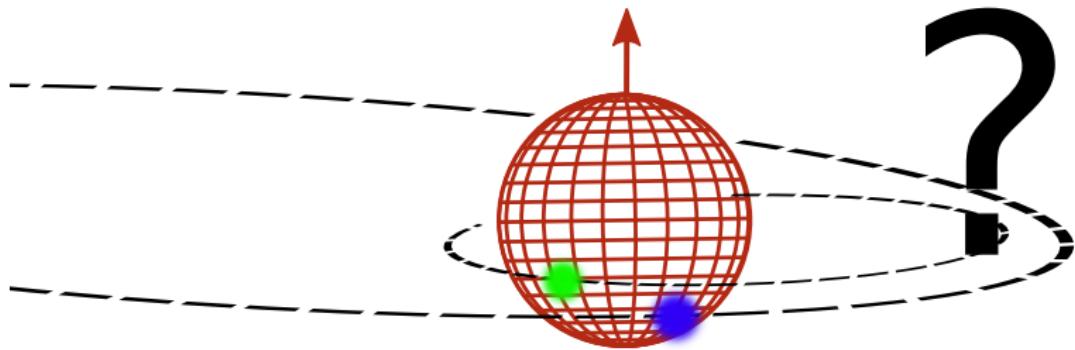
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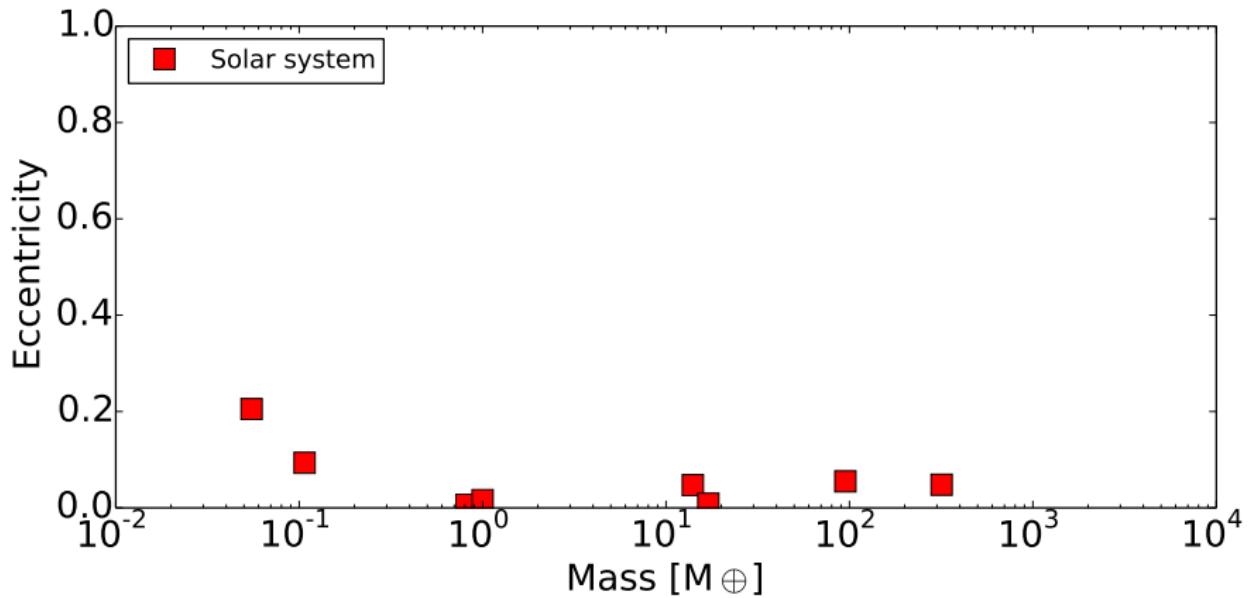


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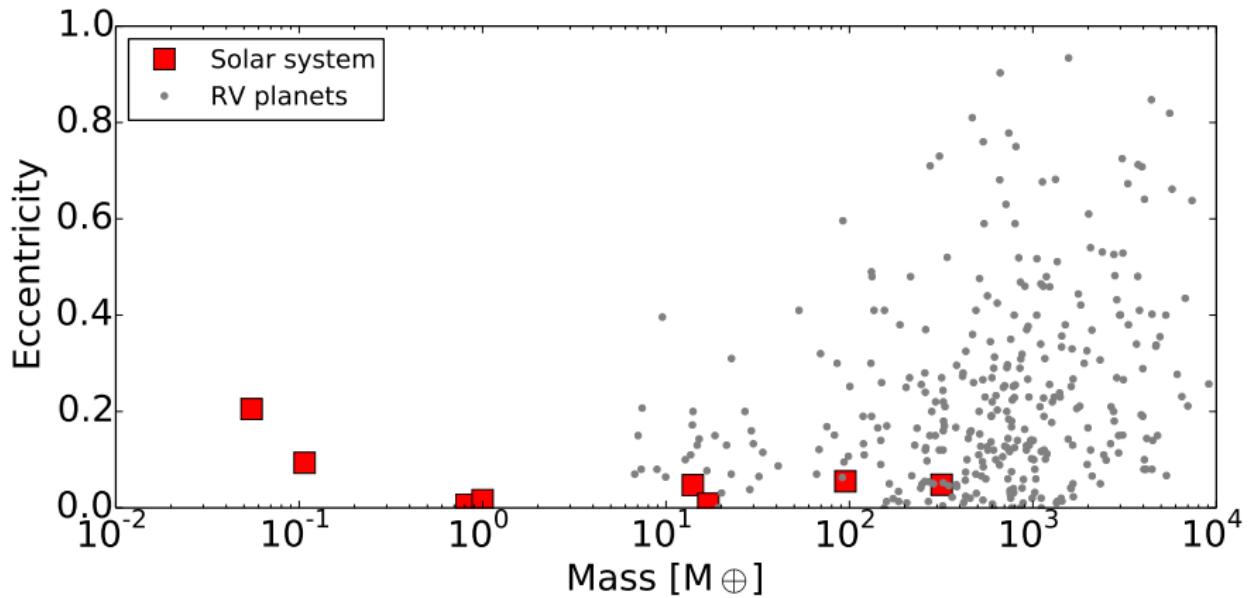


Giant exoplanet

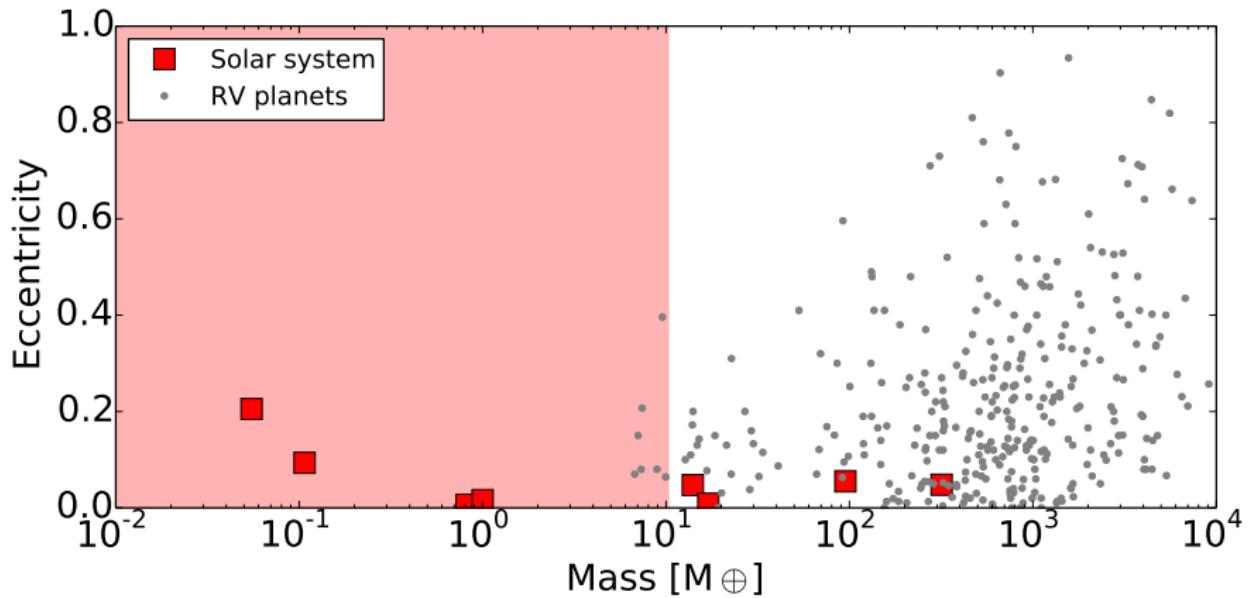




Eccentricities from RV detections from [exoplanets.org](http://exoplanets.org) (27 April '15).

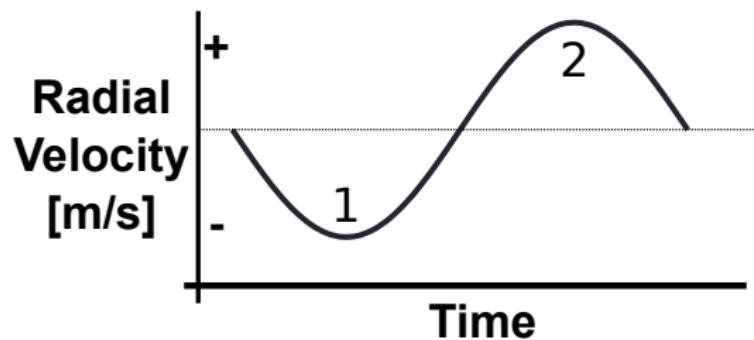
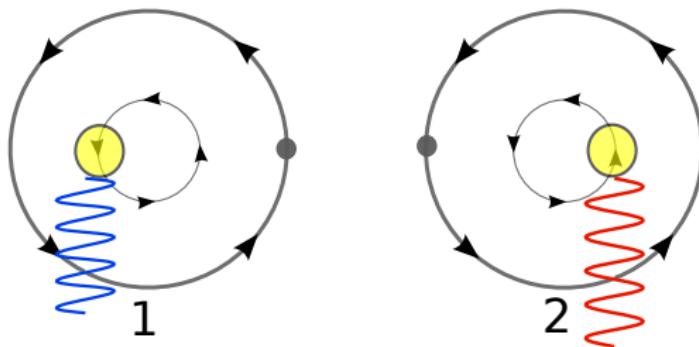


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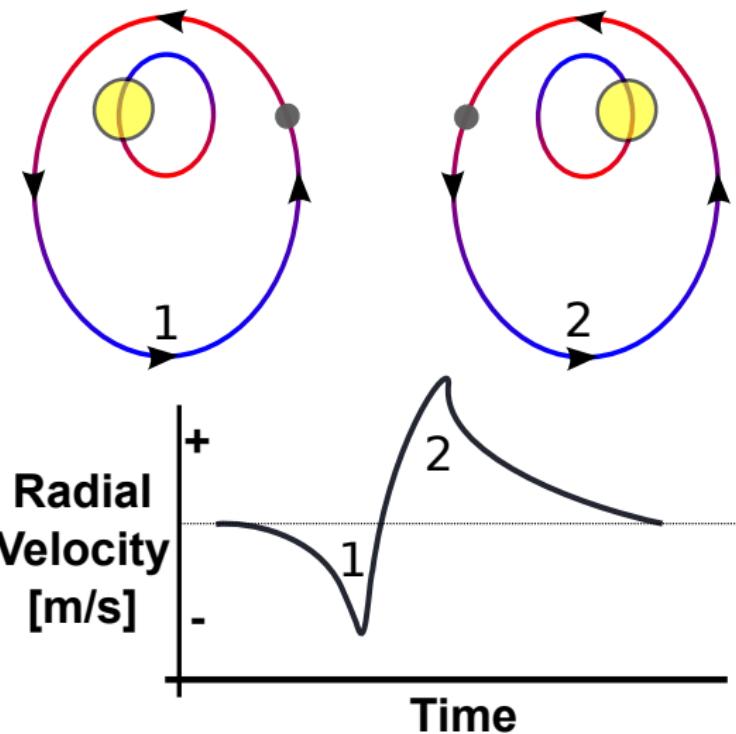


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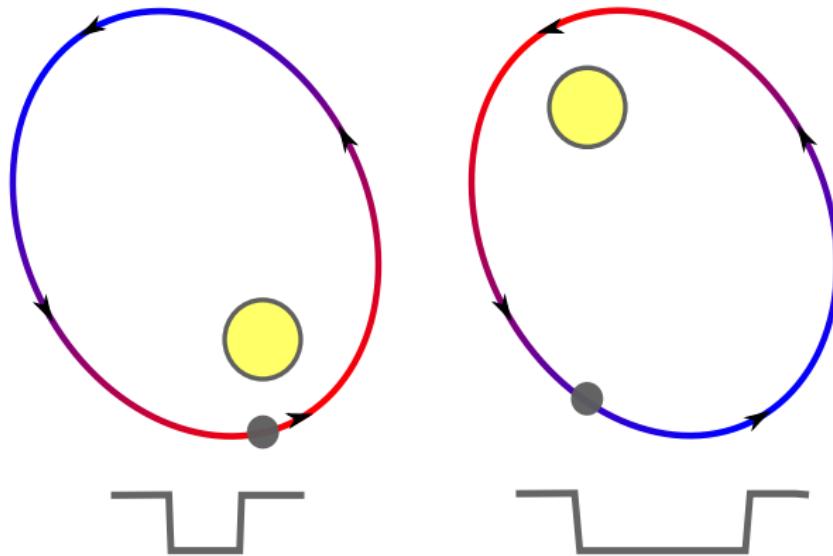
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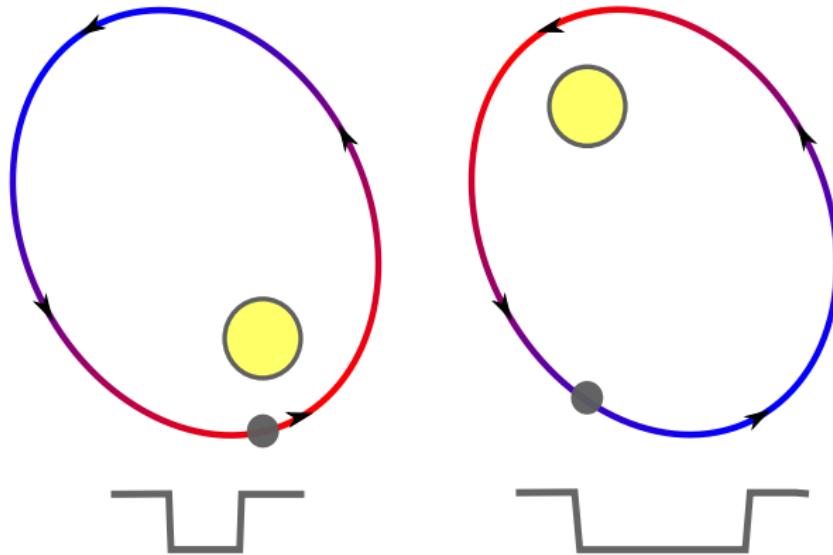
## How to observe eccentricity?



Small planets: no RV possible. Eccentricity? **Transit durations!**

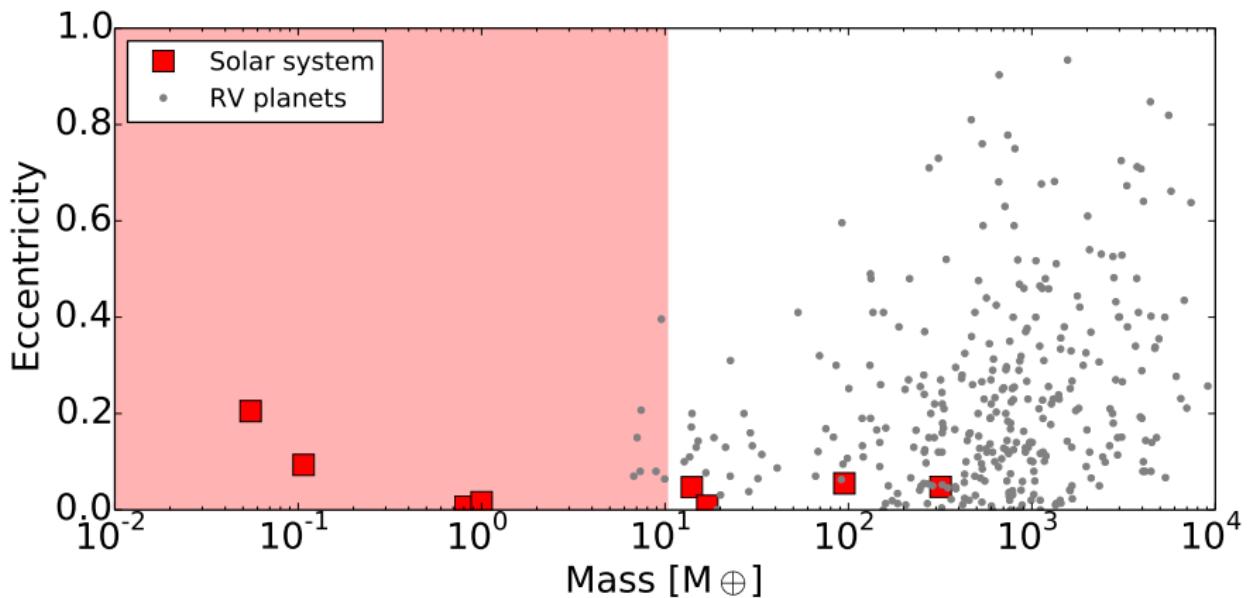
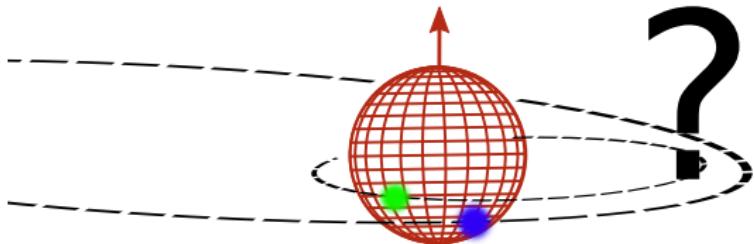


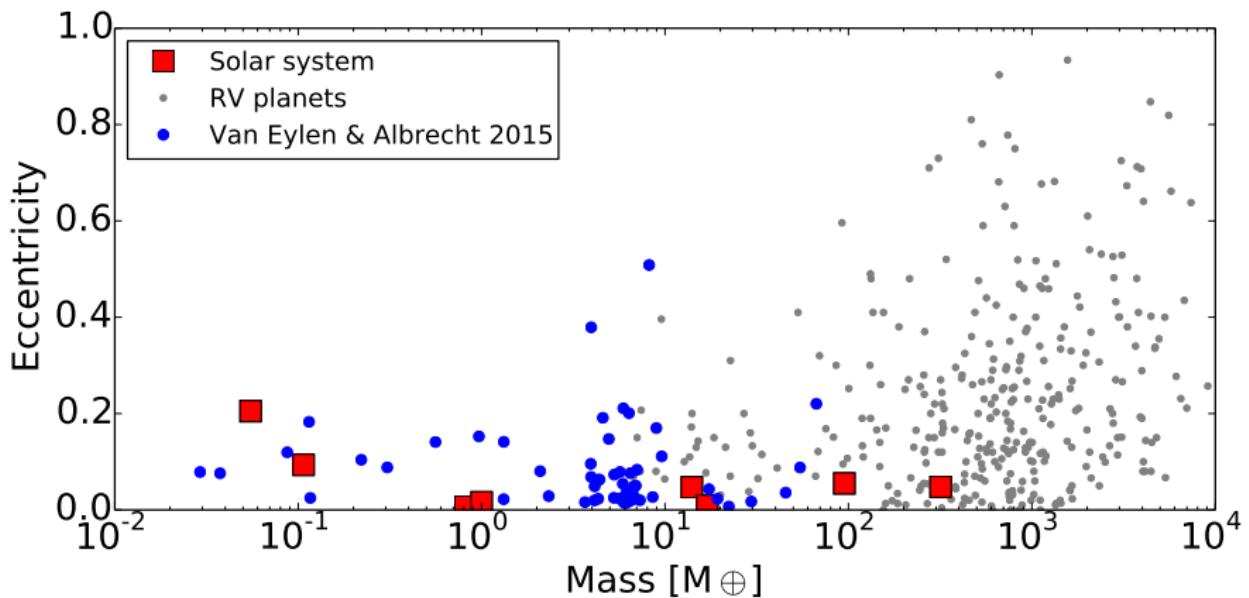
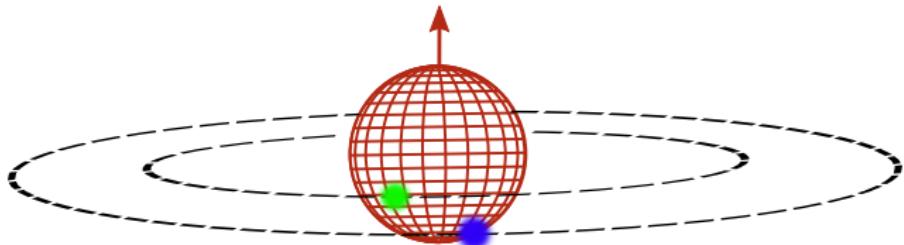
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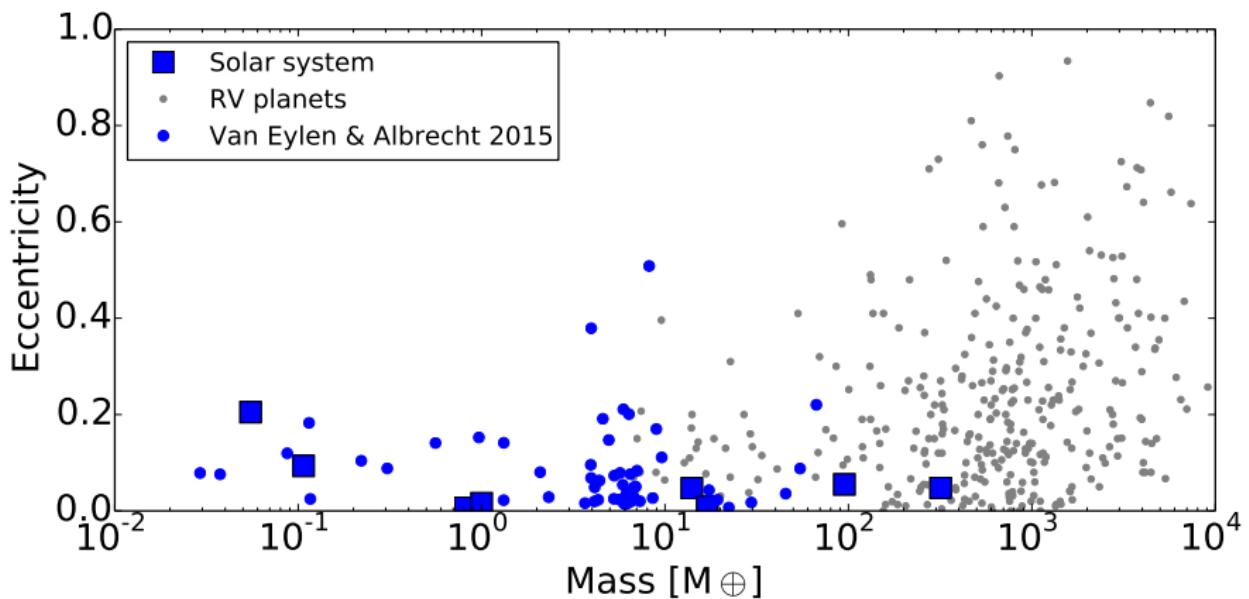
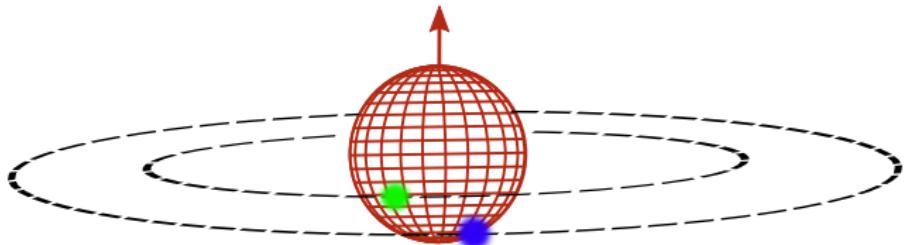
$$\text{Transit duration} \propto \rho_* \frac{(1+e \sin \omega)^3}{(1-e^2)^{3/2}}$$

- ⇒ measure the stellar density  $\rho_*$  (asteroseismology)
- ⇒ marginalize over unknown orientation  $\omega$

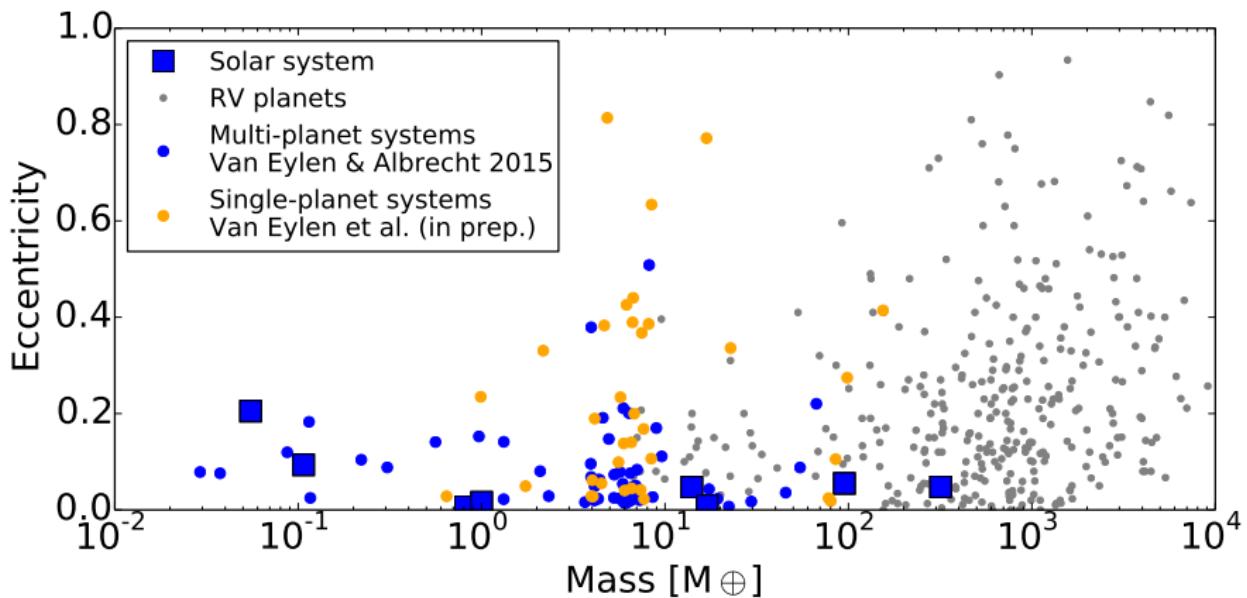
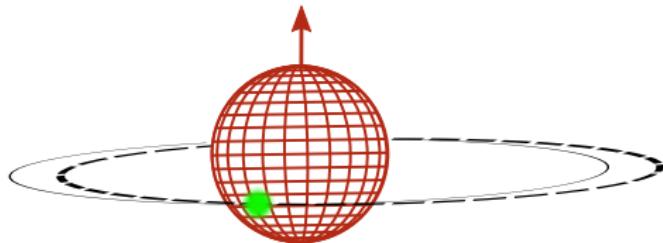




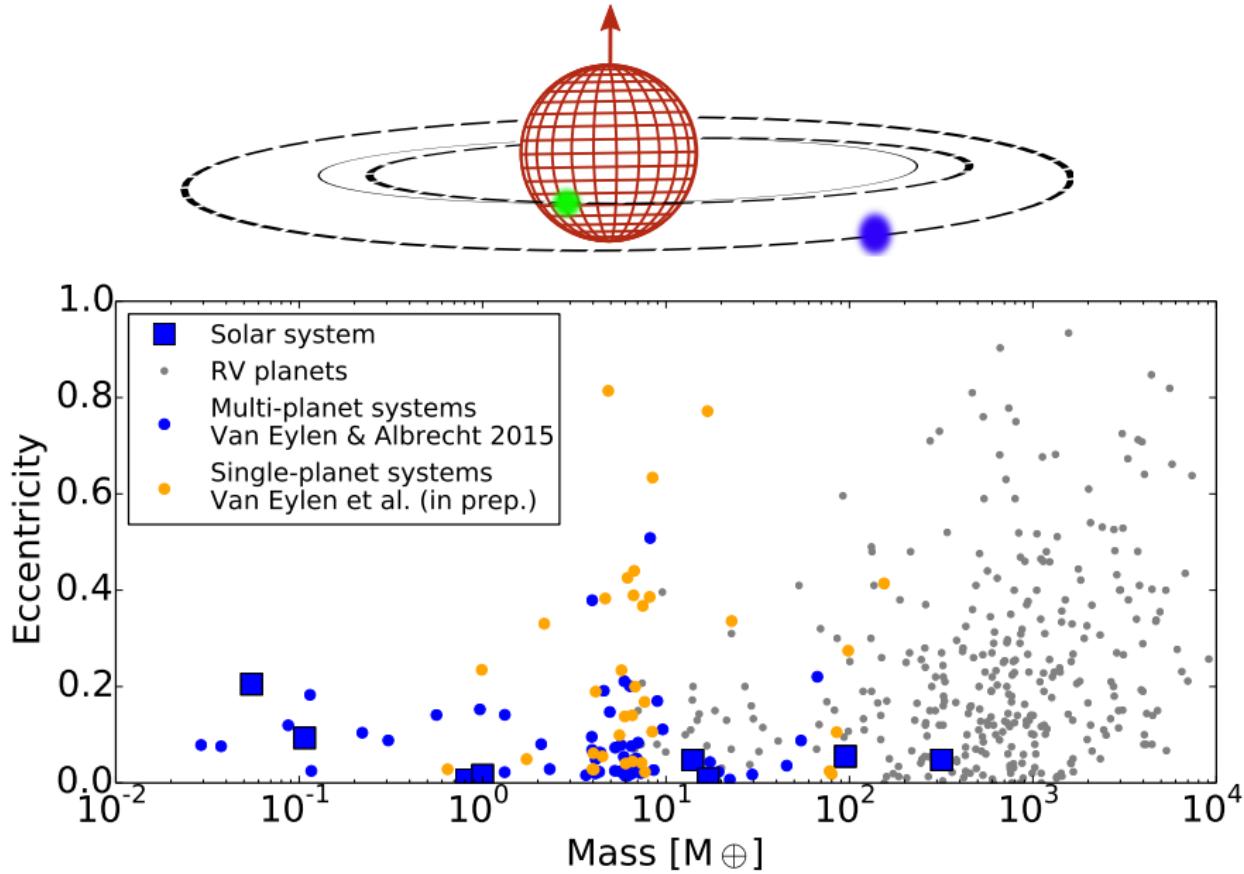
Asteroseismic  $\rho_*$  from Silva Aguirre et al. 2015 and Lundkvist et al. 2015



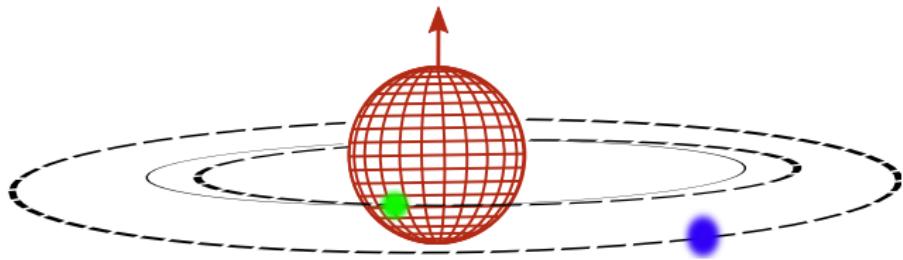
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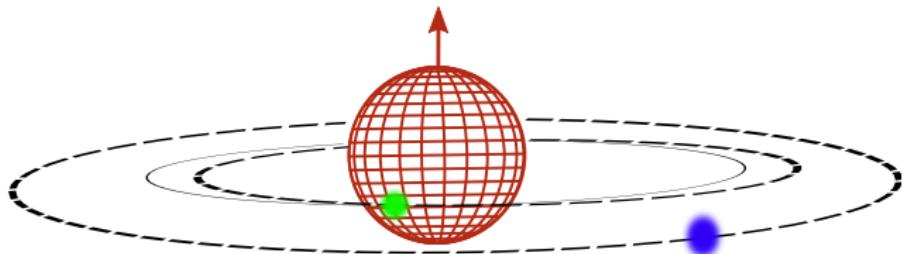


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“Two types” of planetary systems?

- ① flat, circular systems
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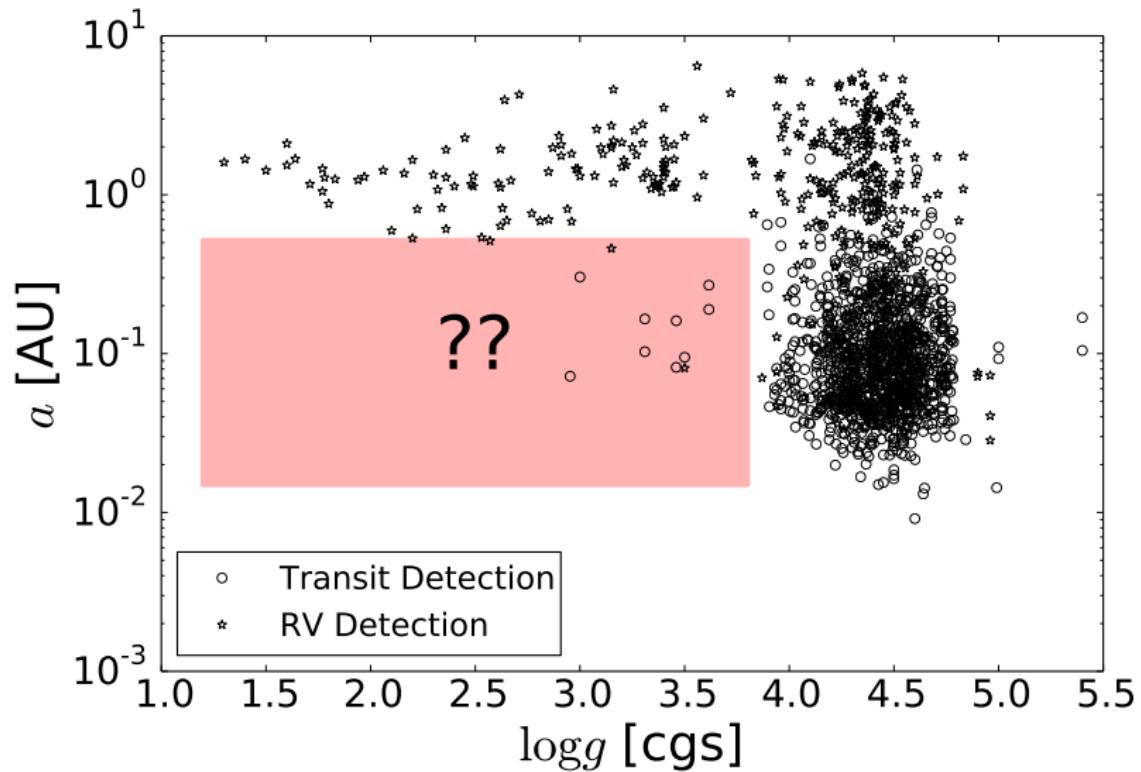
Consistent with simulations by e.g. Dawson, Lee & Chiang 2016:

- gravitational scattering increase inclination/eccentricity
- mergers dampen, depending on gas density

# Asteroseismology of planet host stars with K2? TESS?

Cadence and/or amplitude issues ⇒ Giants!

# Giants orbiting (sub)giants



There are very few short-period (giant) planets orbiting evolved stars.

e.g. Bowler et al. 2010, Johnson et al. 2010, Reffert et al. 2015

Why is this?

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### **Explanation 1:**

The observed evolved stars have a systematically higher mass, this make the lifetime of the protoplanetary disk shorter.

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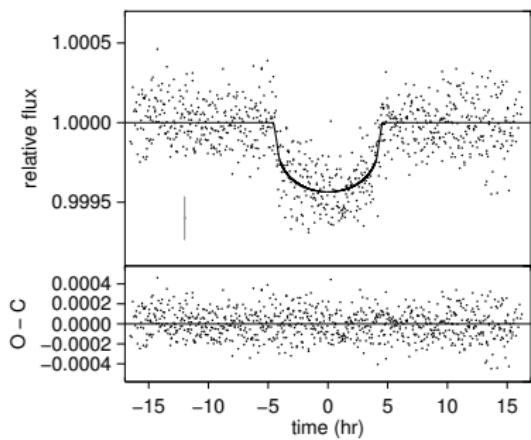
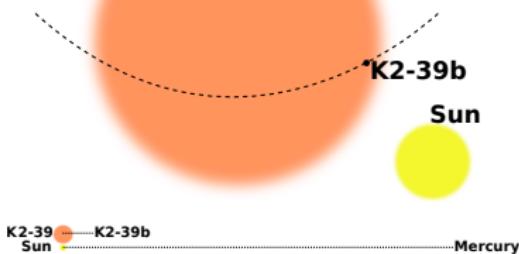
### **Explanation 2:**

As stars evolve, short-period planets are destroyed.

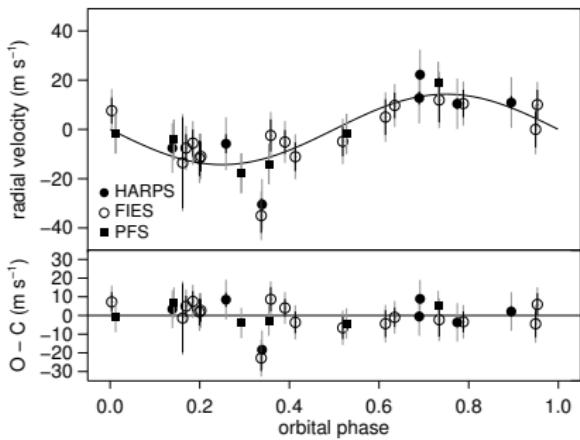
e.g. Rasio et al. 1996, Villaver & Livio 2009, Schlaufman & Winn 2013

To make progress, new short-period planets are needed.

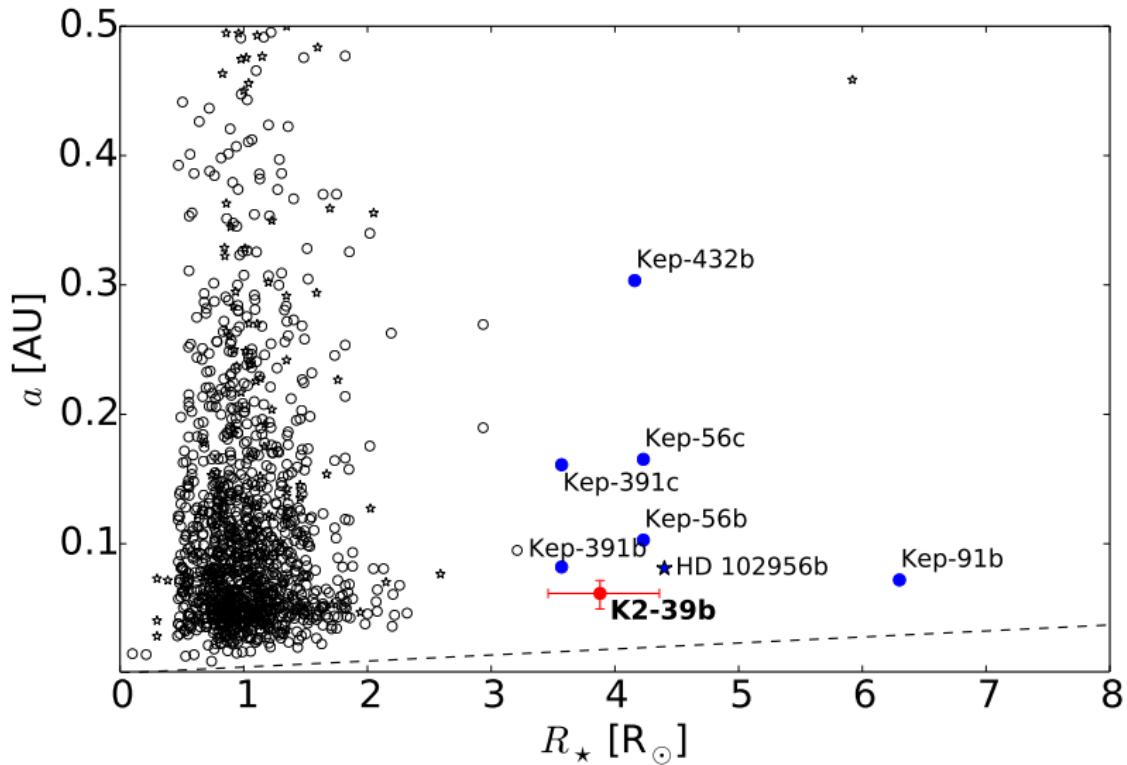
# K2-39



$$\hookrightarrow R = 8.2_{-1.1}^{+1.1} R_{\oplus}$$



$$\hookrightarrow M = 50.3_{-9.4}^{+9.7} M_{\oplus}$$



Van Eylen et al. 2016c

See also poster S13.81 by Grunblatt et al.!

# Conclusions

## Asteroseismology as/is an exoplanet tool!

**Kepler era:** progress on dynamics of exoplanet systems

- Obliquity measurements (for multi-planet systems)
- Eccentricity measurements of planet orbits

**Future:** asteroseismology of giant planet host stars

- Planet occurrence? (Re)inflation of hot Jupiters?
- Data ideally suited for progress