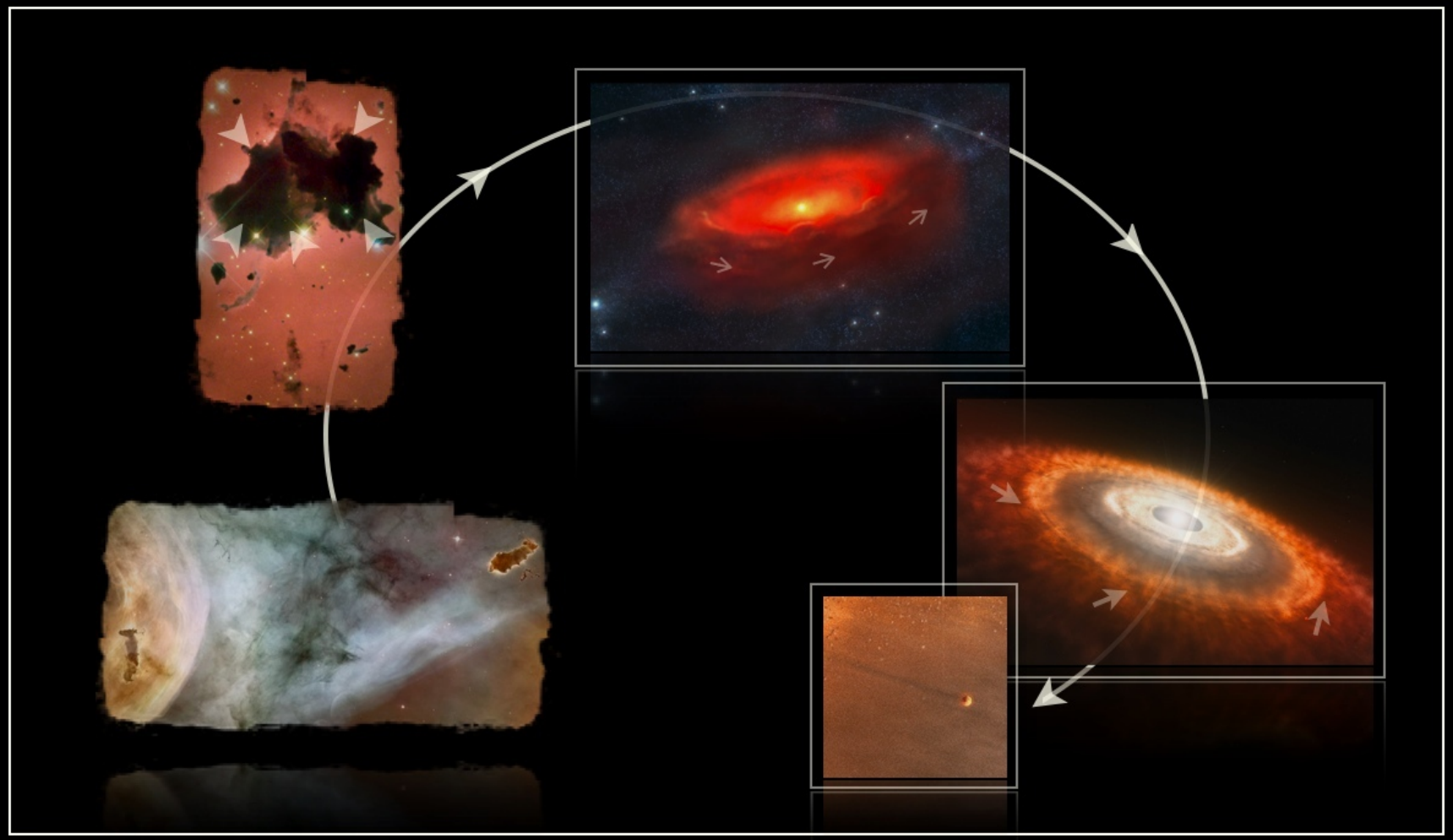
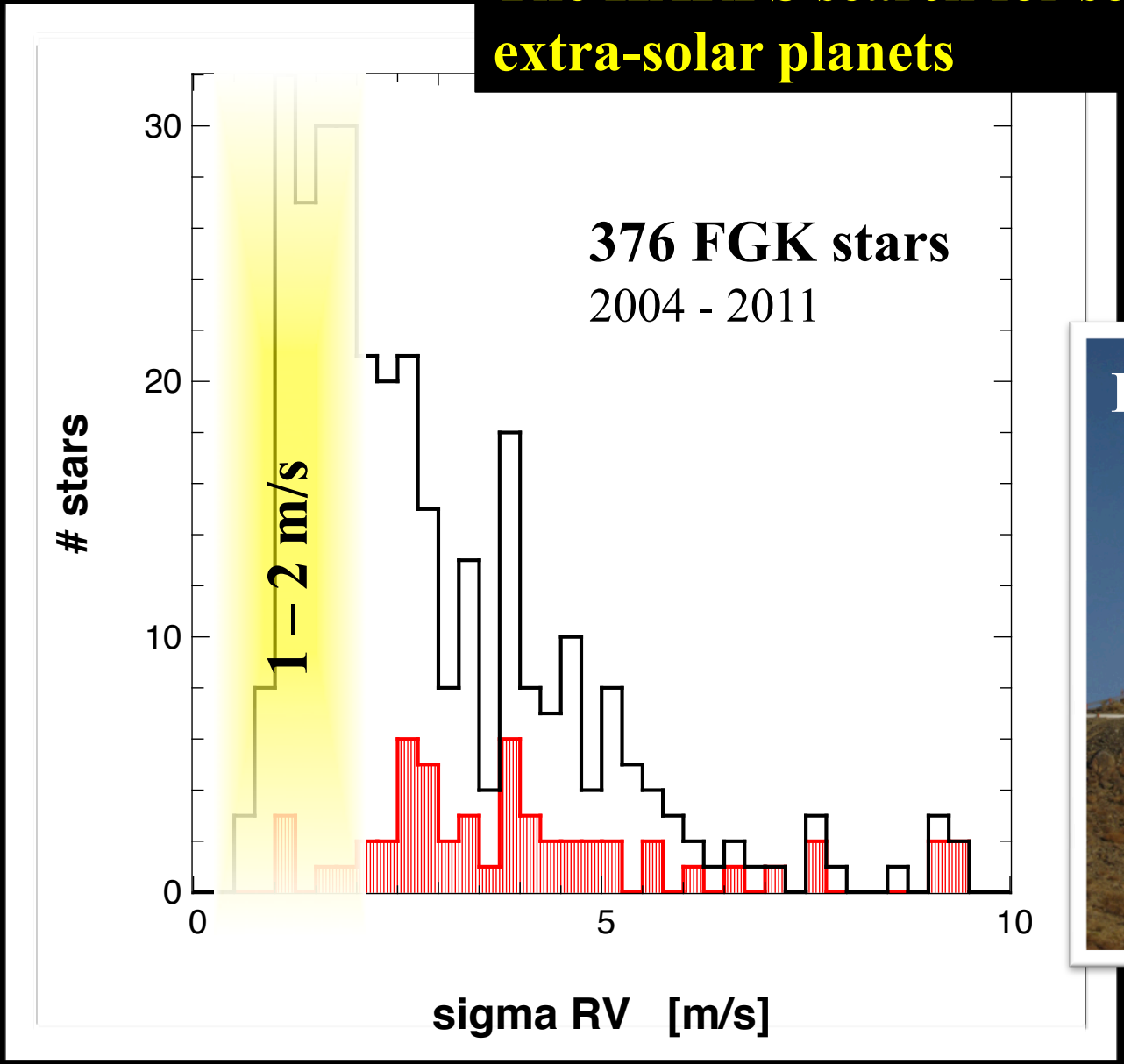
Observational constraints on the planet formation process

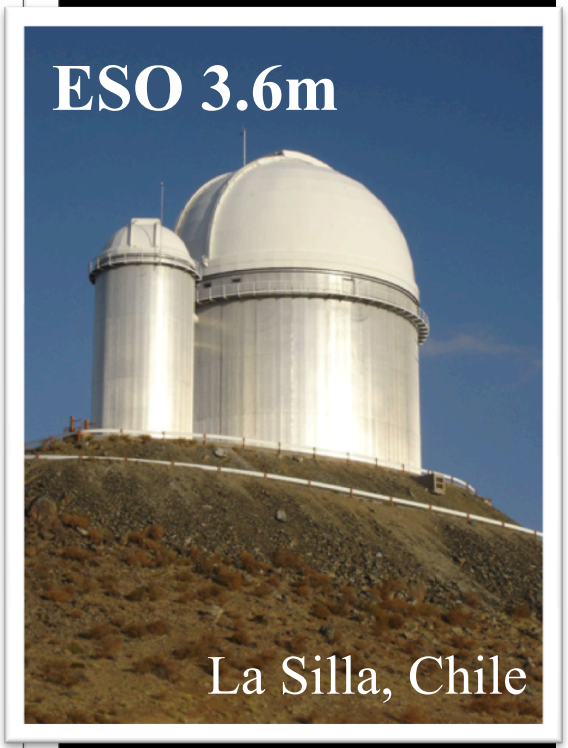
UNIVERSITÉ DE GENÈVE
FACULTÉ DES SCIENCES
Département d'astronomie

Didier Queloz



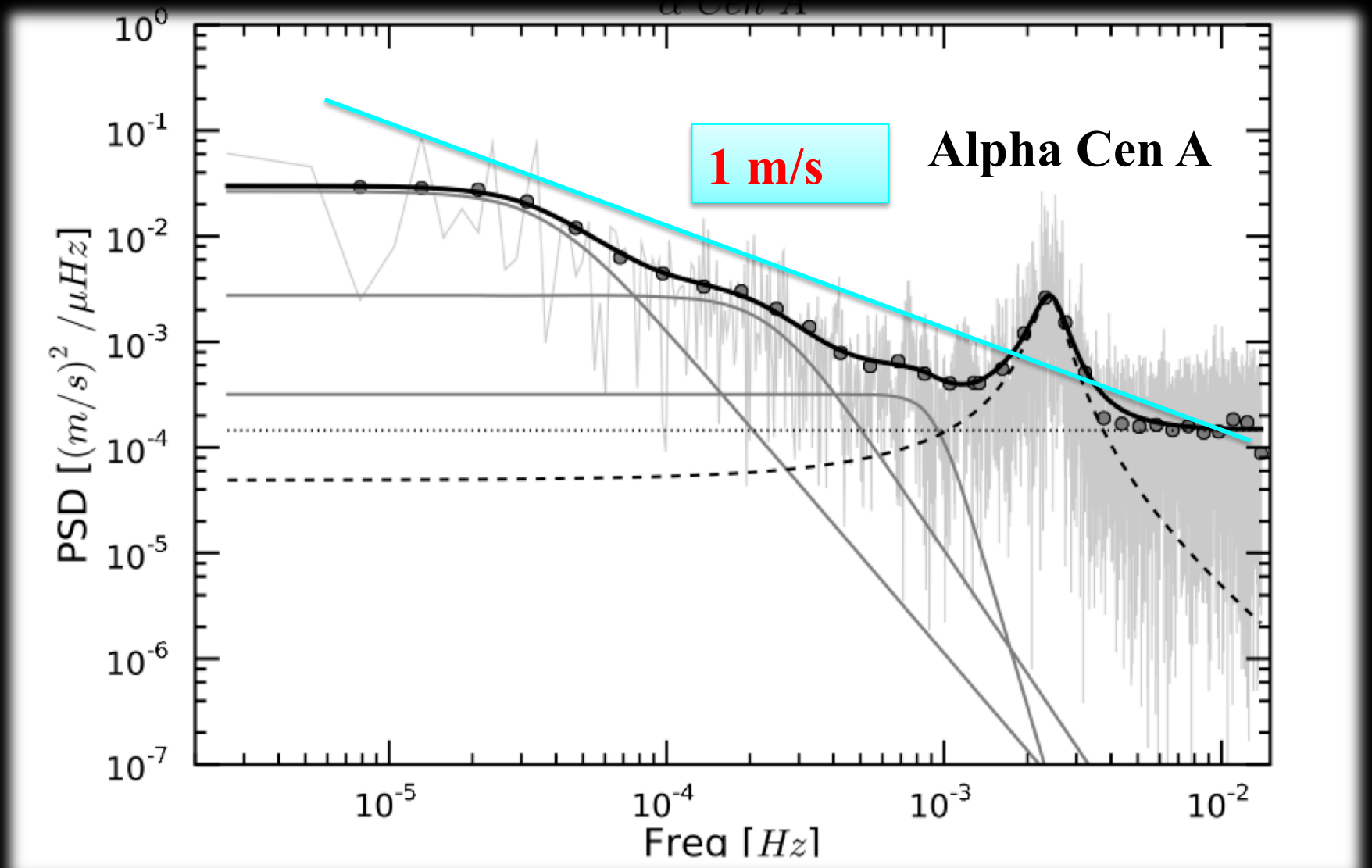
The HARPS search for southern extra-solar planets





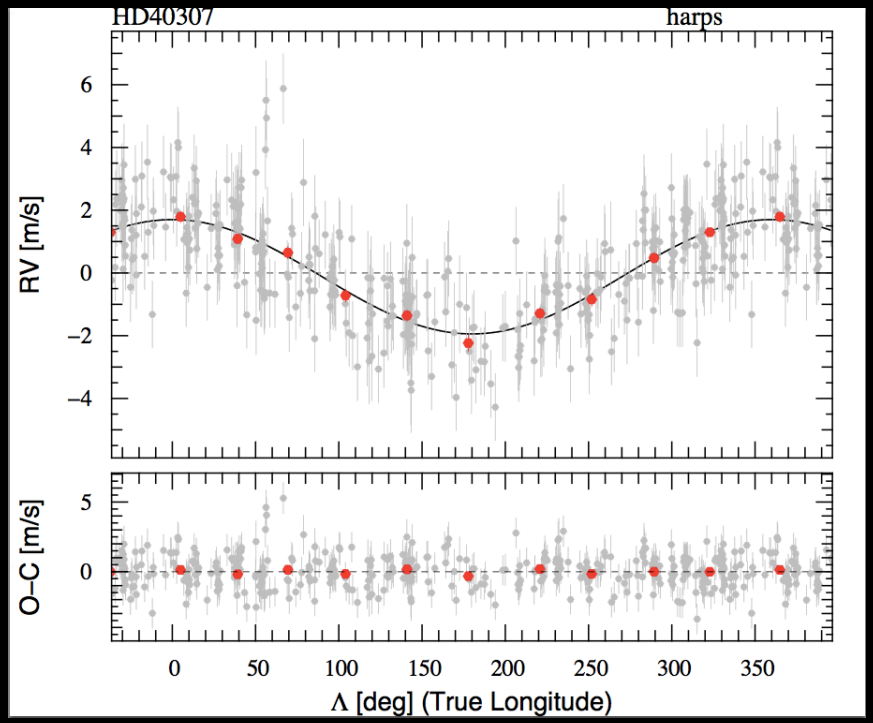
Mayor et al. 2011

Stellar « noise »



Dumusques et al. 2010

Pushing down the limits



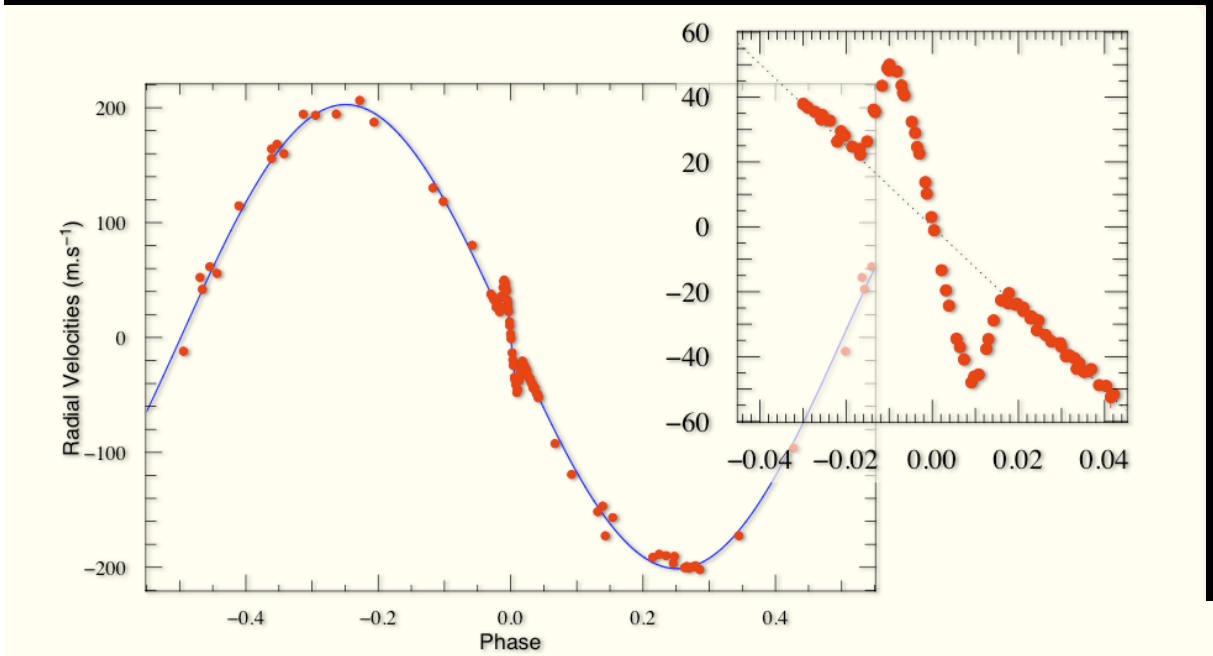
397 data points:
O-C=1.00 m/s

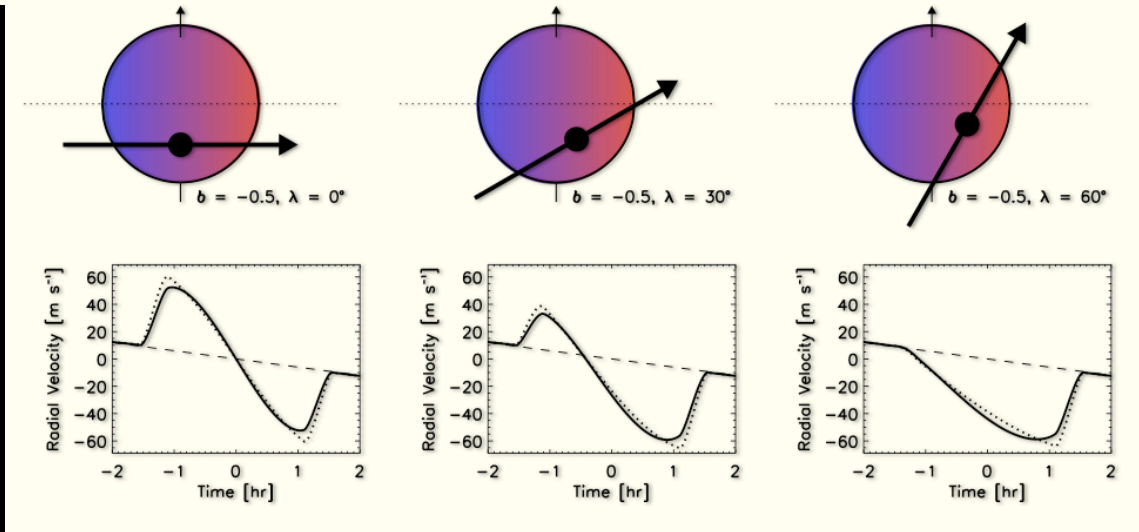
10 binned data points:
O-C = 18 cm/s

HD 40307
K2 V

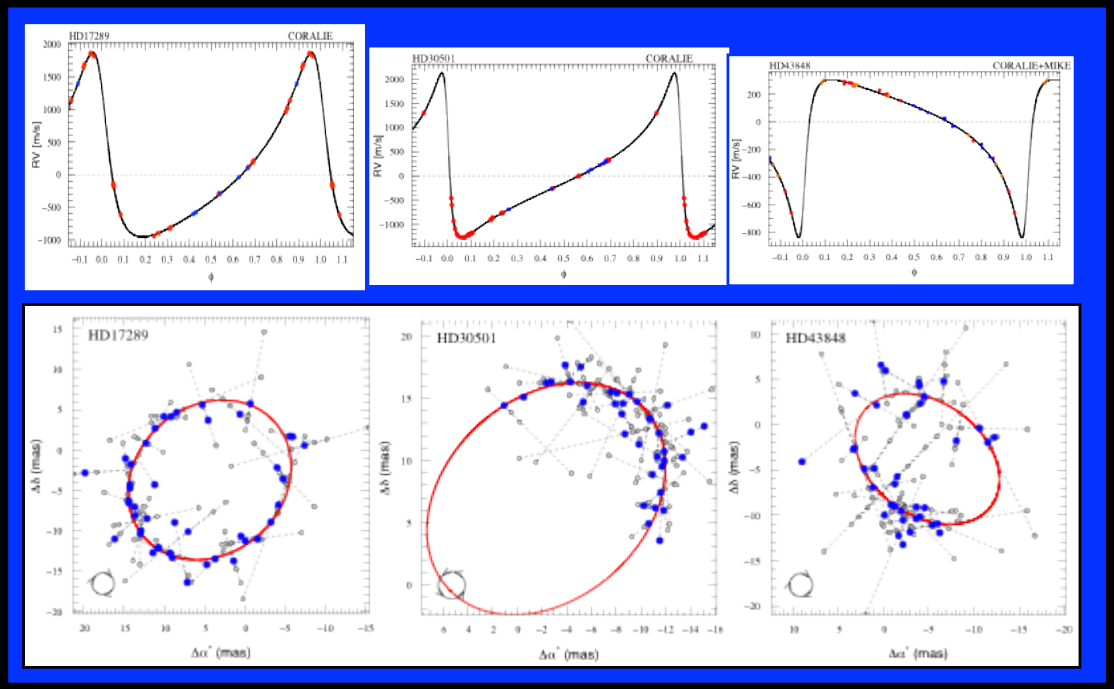
Parameter		HD 40307 b	HD 40307 c	HD 40307 d
P	[days]	4.3115 ± 0.0006	9.620 ± 0.002	20.46 ± 0.01
T	[JD-2 400 000]	54 562.77 ± 0.08	54 551.53 ± 0.15	54 532.42 ± 0.29
e		0.0	0.0	0.0
ω	[deg]	0.0	0.0	0.0
K	[m s^{-1}]	1.97 ± 0.11	2.47 ± 0.11	4.55 ± 0.12
V	[km s^{-1}]		31.332	
drift	[m s^{-1}/yr]		0.51 ± 0.10	
$f(m)$	[10^{-14} $M_\odot$]	0.35	1.53	3.59
$m_2 \sin i$	[$M_\oplus$]	4.2	6.9	9.2
a	[AU]	0.047	0.081	0.134

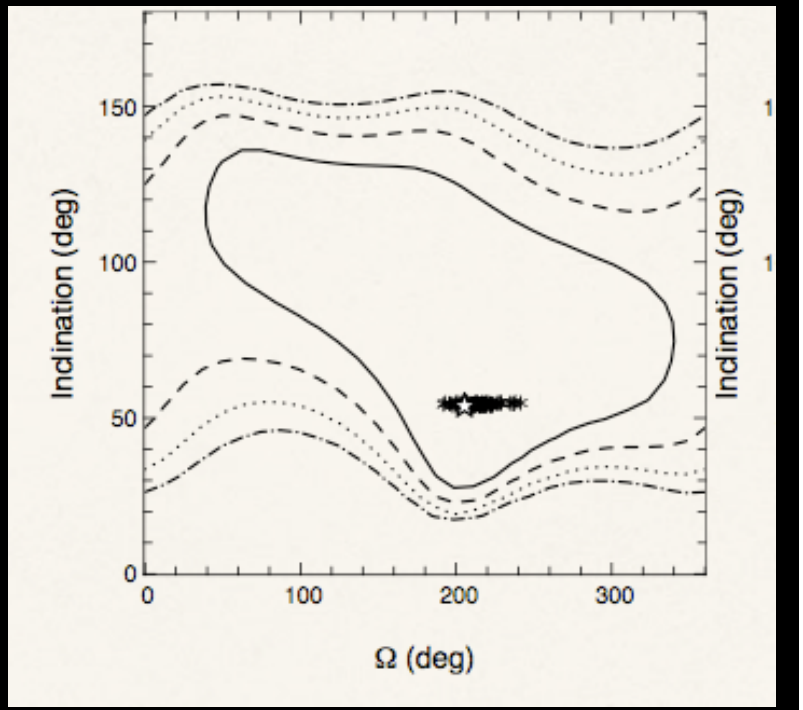
The Rossiter- Mac Laughlin effect

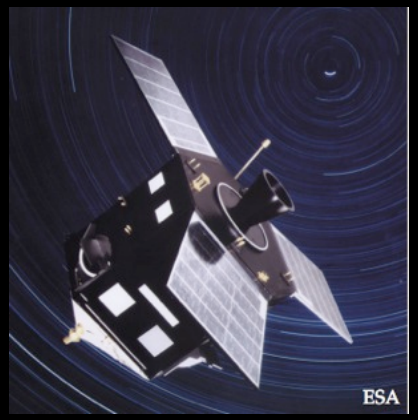




Combining astrometry and RV

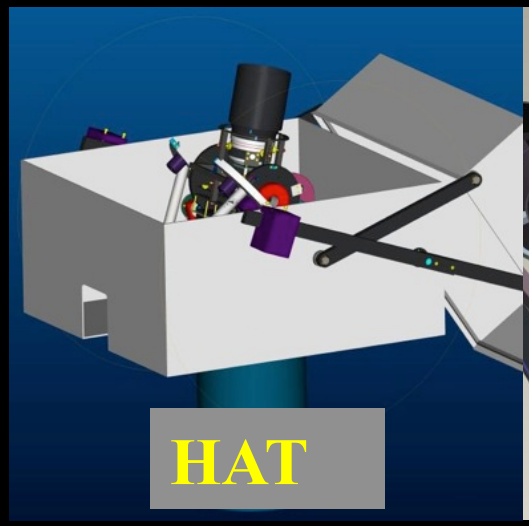


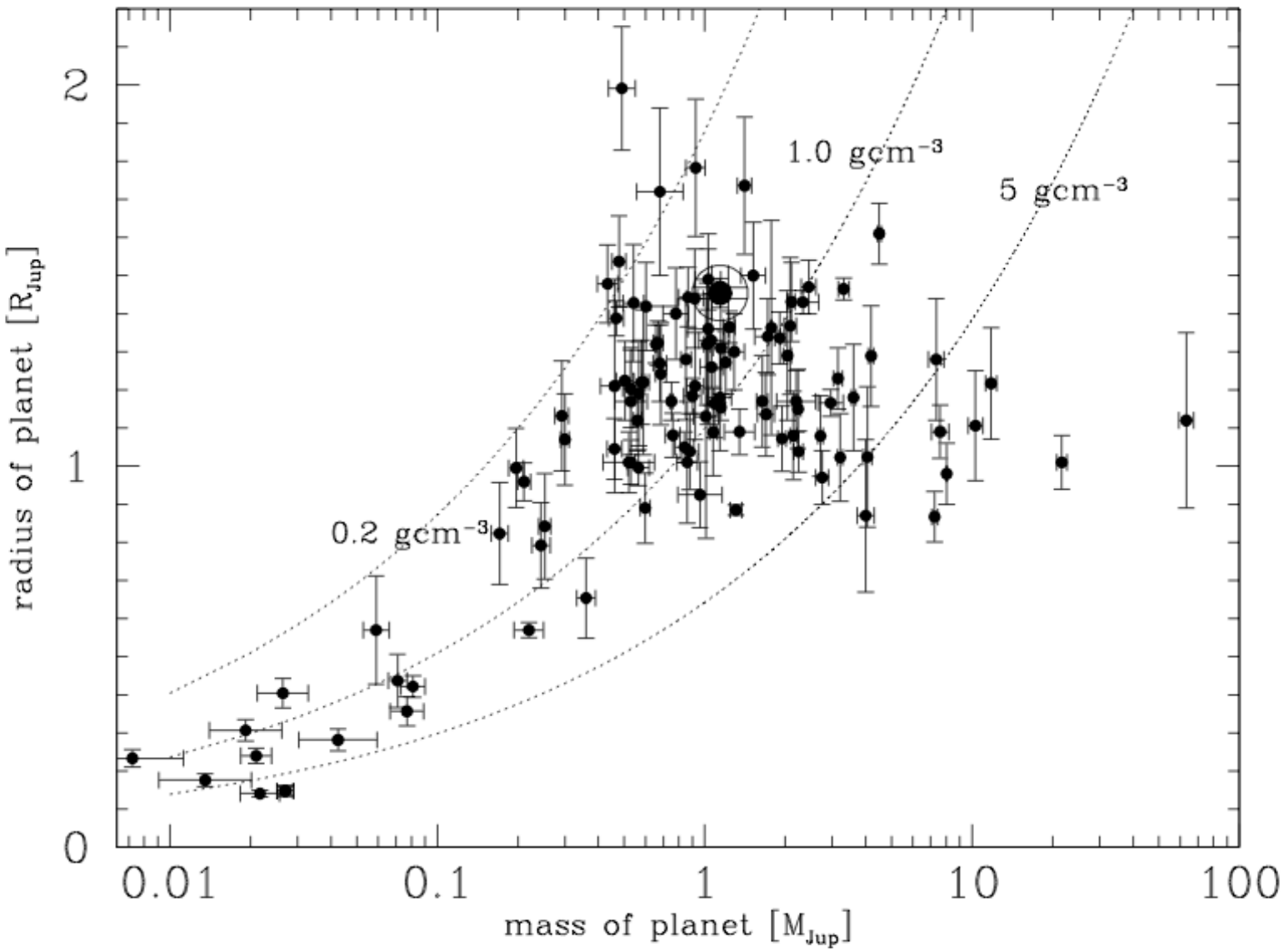


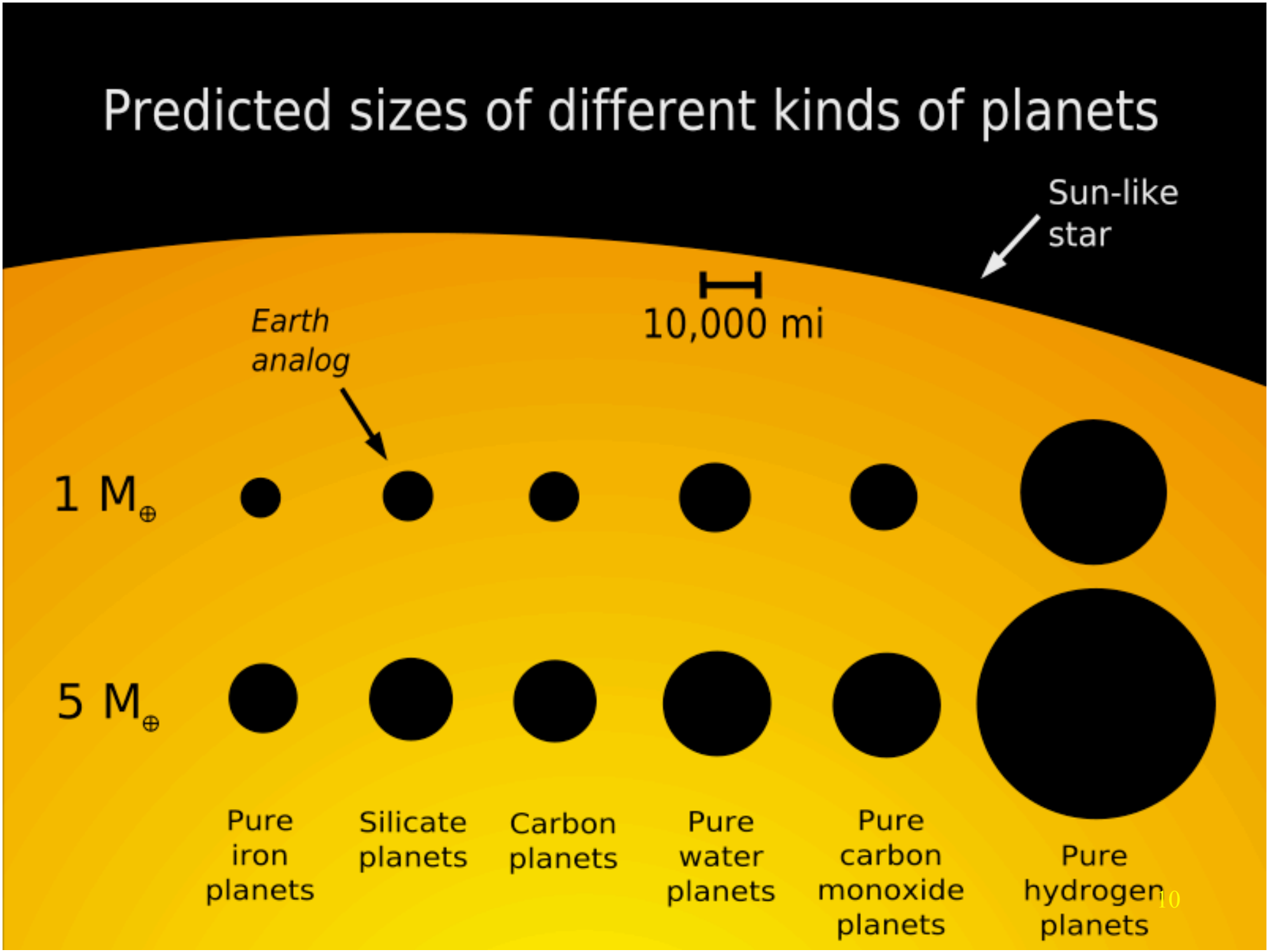


$(P, T_0, e, \omega, K_1$ from RV$)$

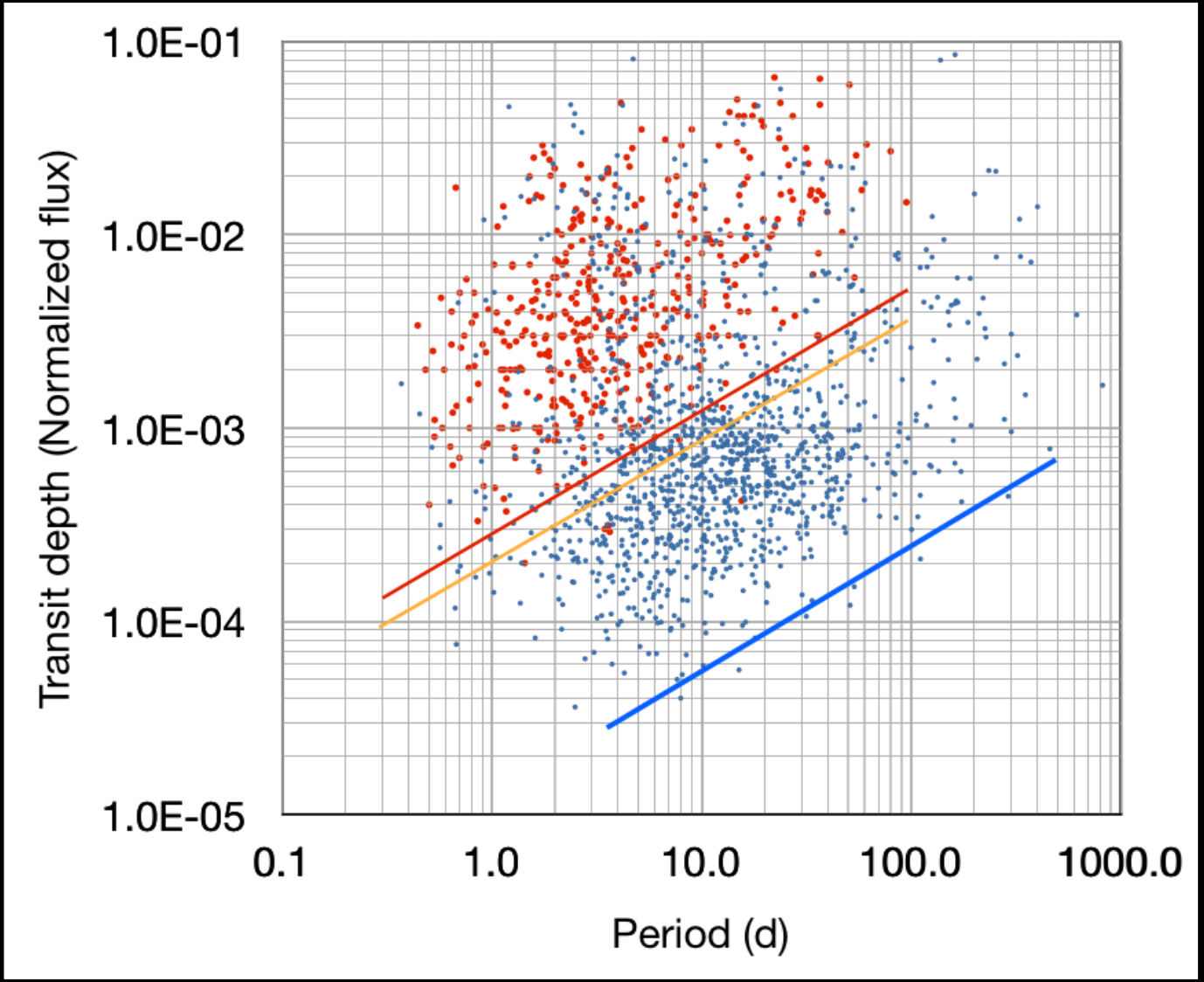
Transit search surveys




2
1
0
radius of planet [R_{Jup}]
0.01
0.1
1
10
100
mass of planet [M_{Jup}]
0.2 gcm^{-3}
1.0 gcm^{-3}
5 gcm^{-3}

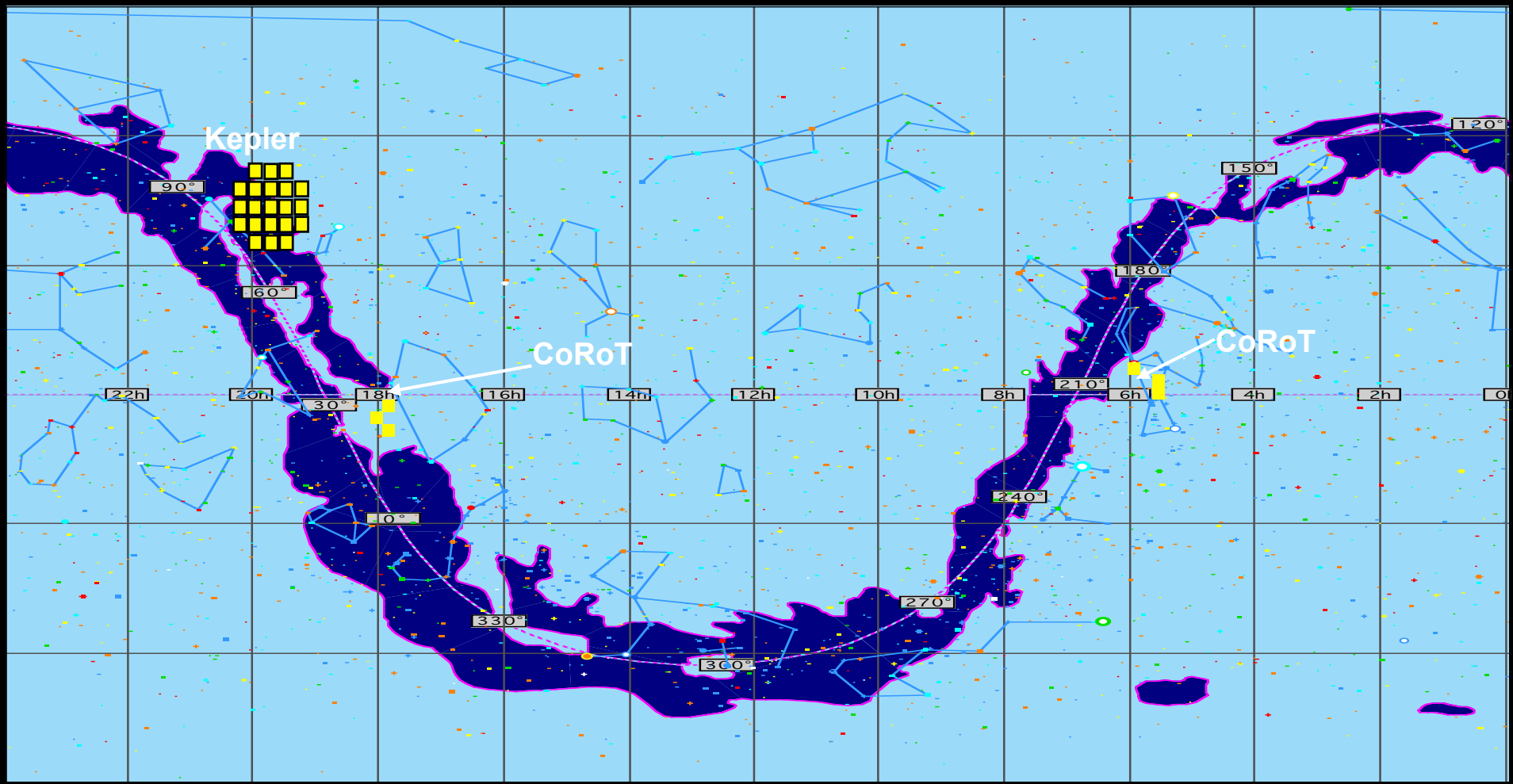

Predicted sizes of different kinds of planets
Sun-like star
10,000 mi
Earth analog
1 M⊕
5 M⊕
Pure iron planets
Silicate planets
Carbon planets
Pure water planets
Pure carbon monoxide planets
Pure hydrogen planets

Corot & Kepler candidats at a glance

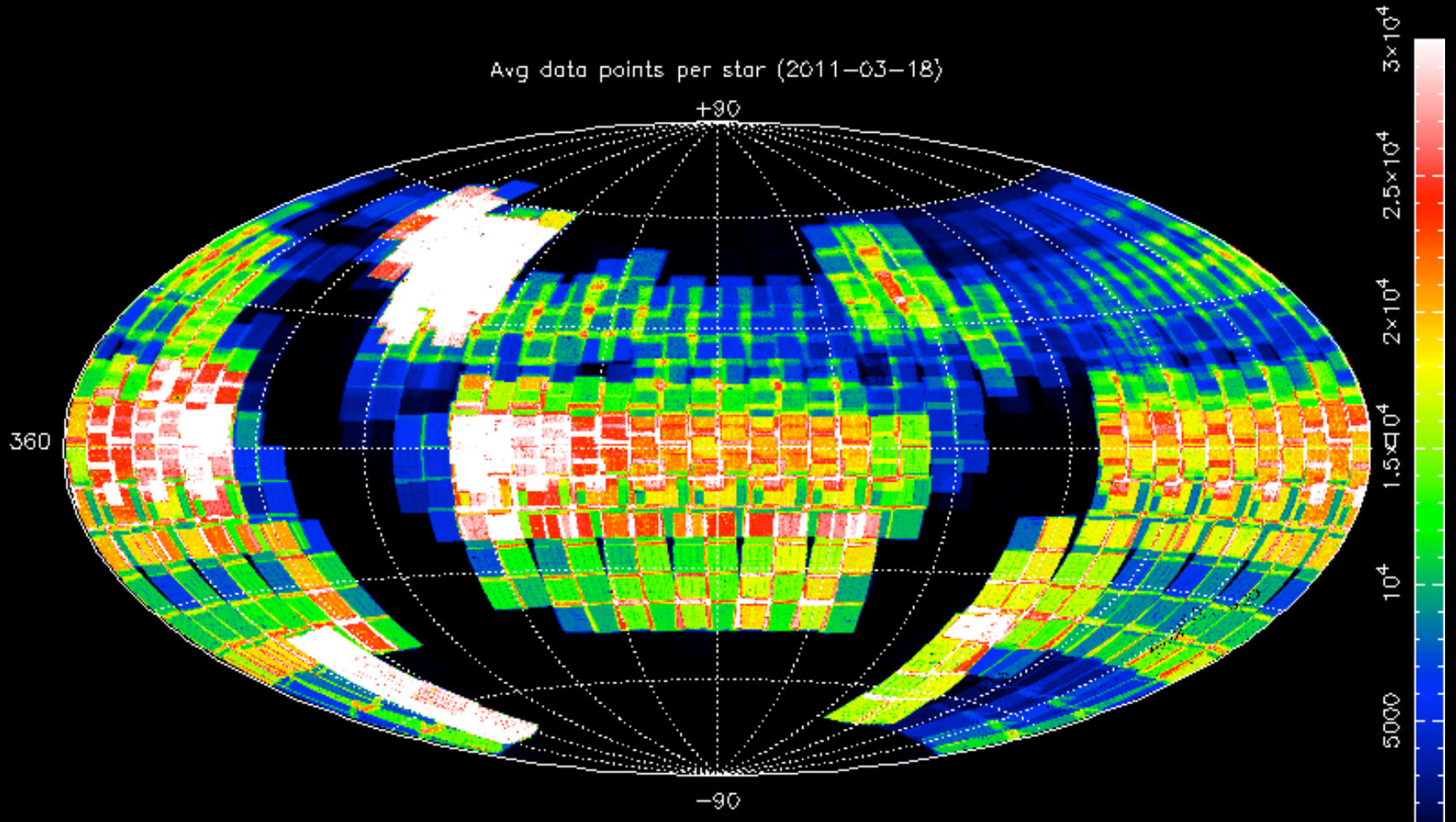


Alonso et al. 2011

Space missions

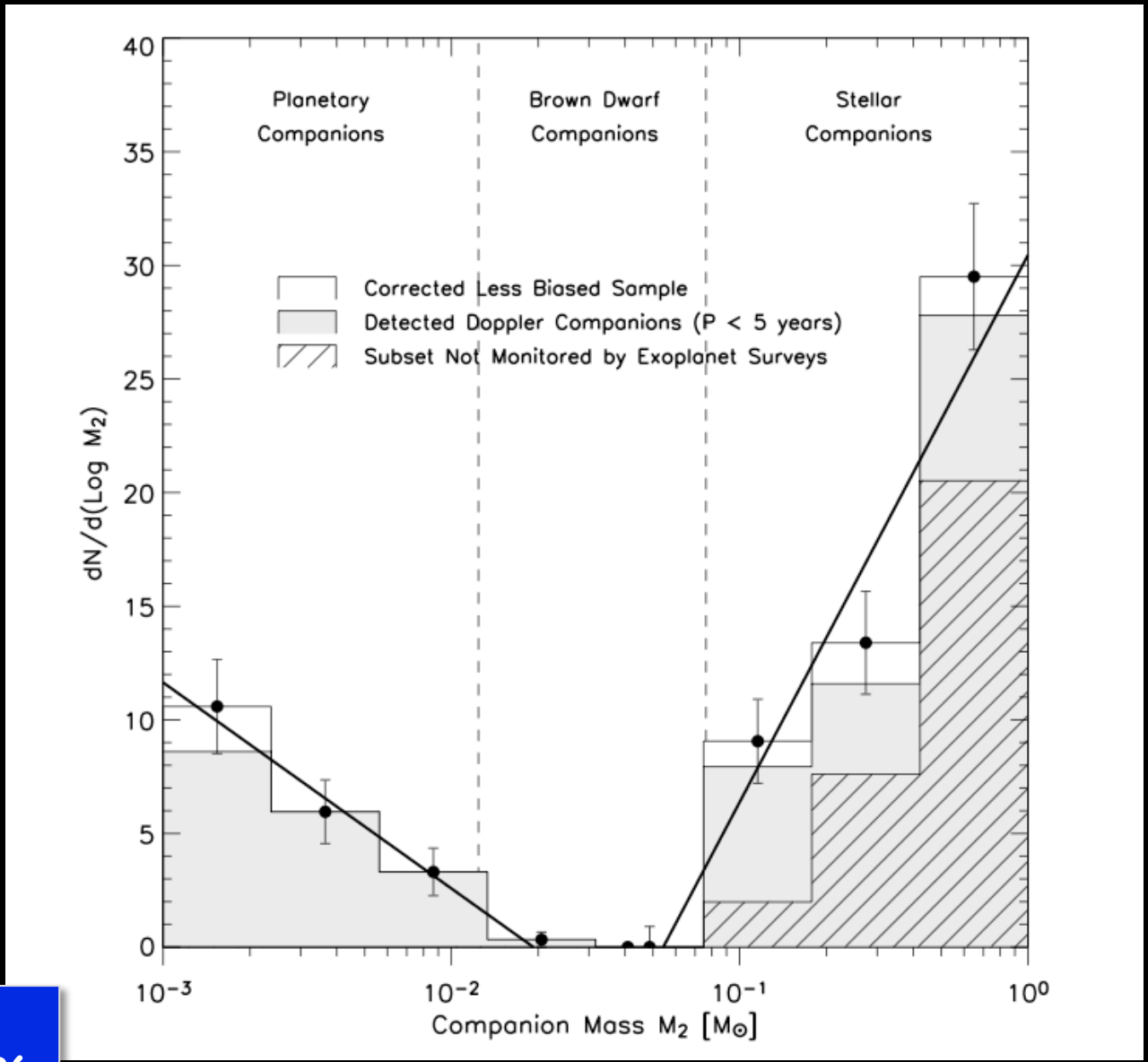


Ground based: WASP



Massive planets
or
Brown dwarfs

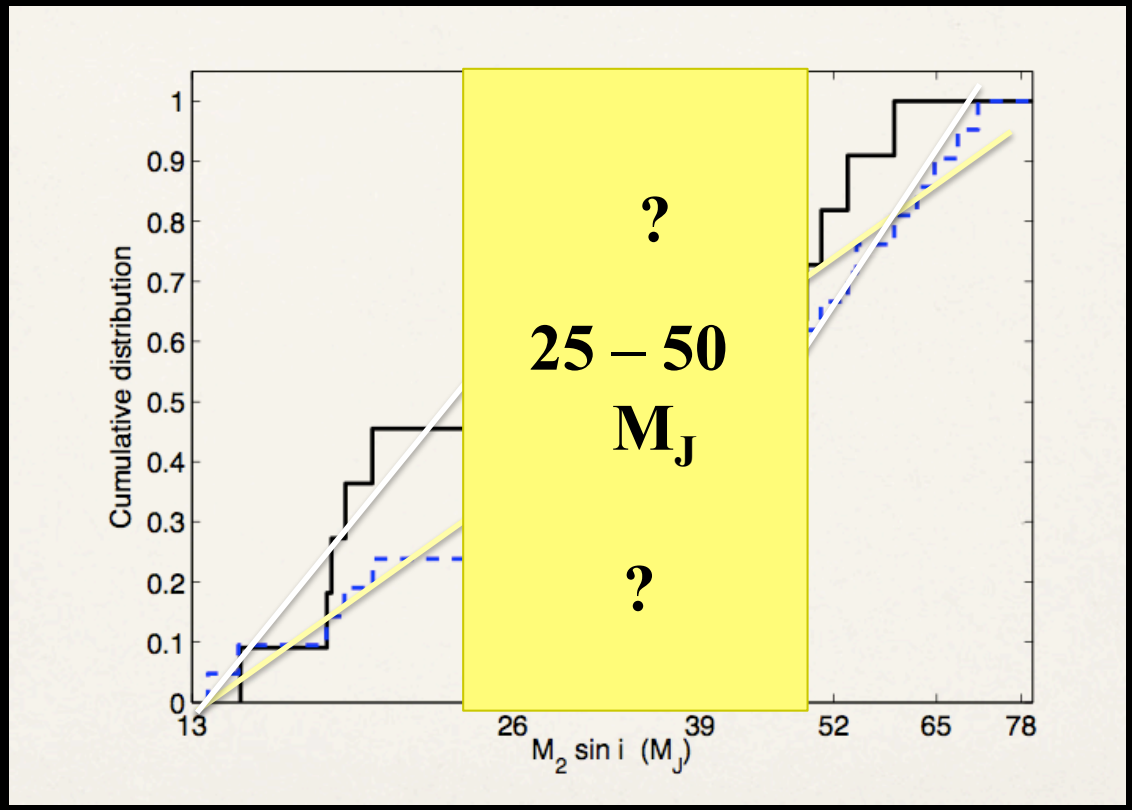
Planet- Brown-dwarfs -Stars

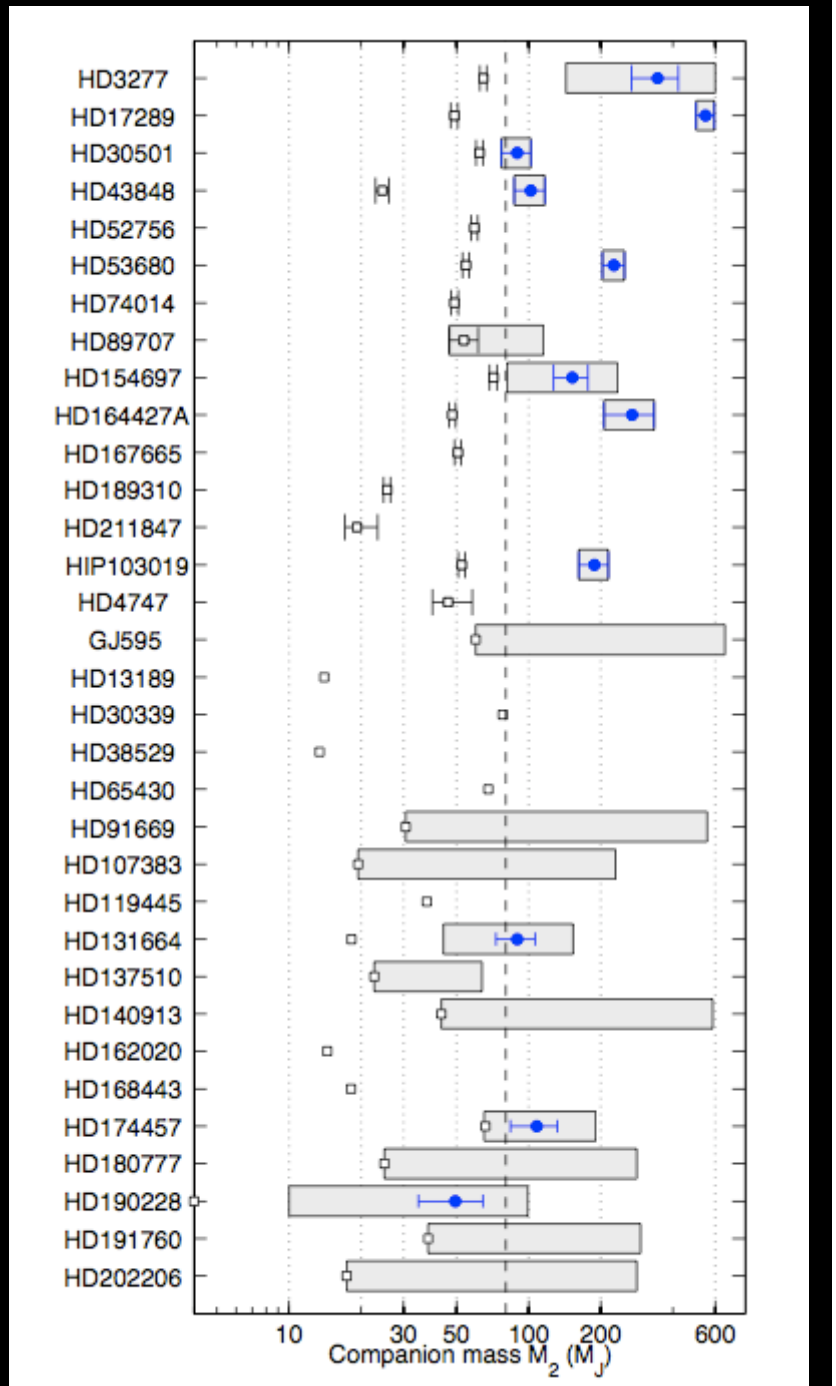


Grether & Lineweaver 2006

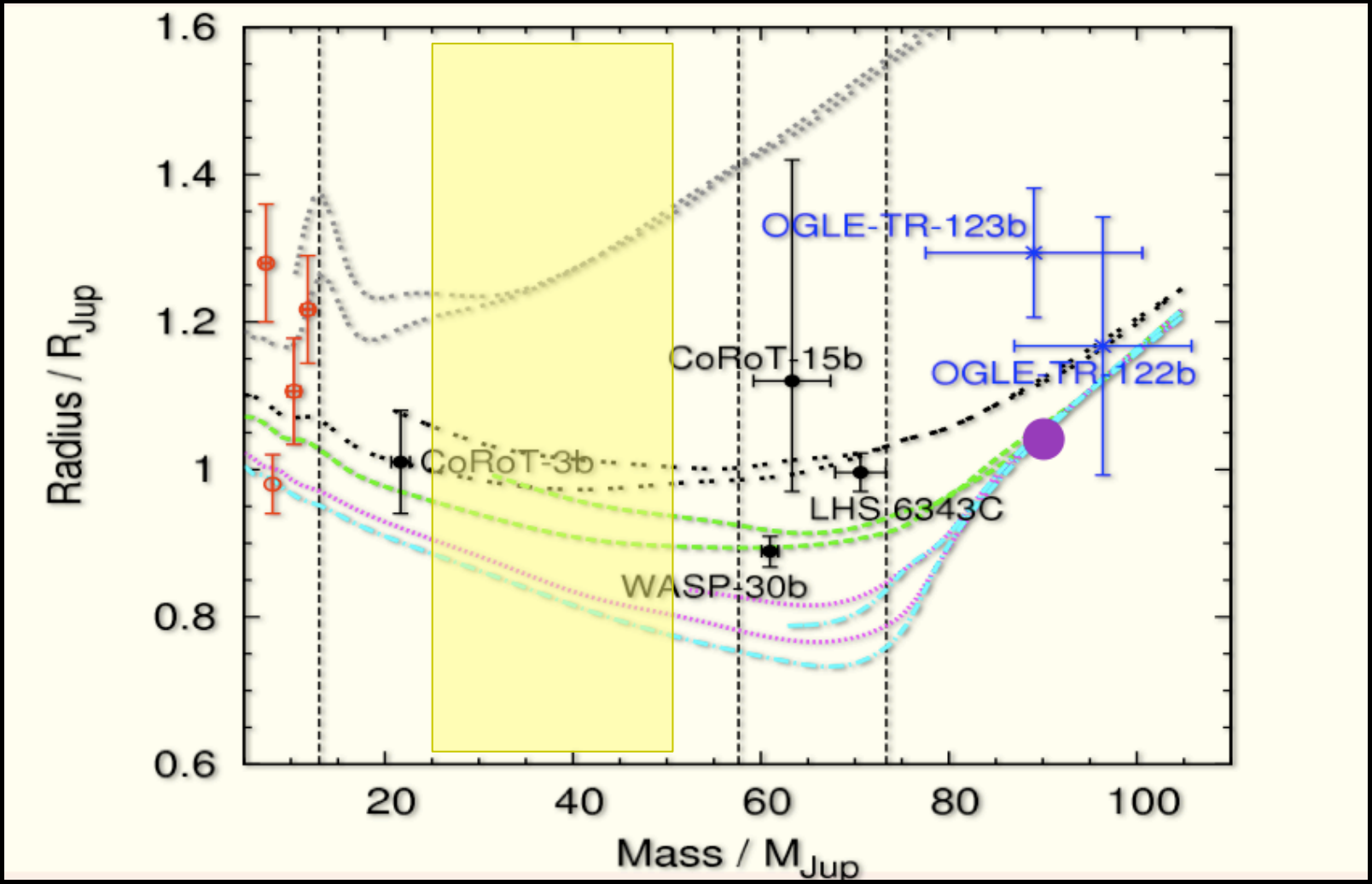
The upper mass of planets

Sahlmann et al. A&A 525, A95

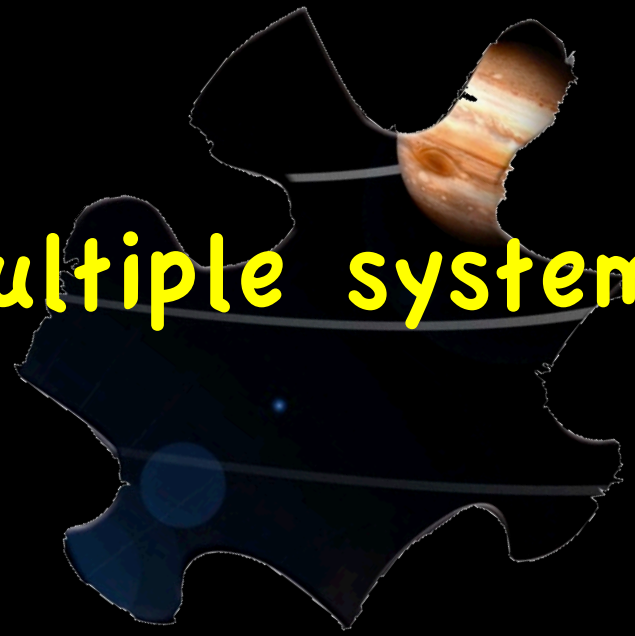


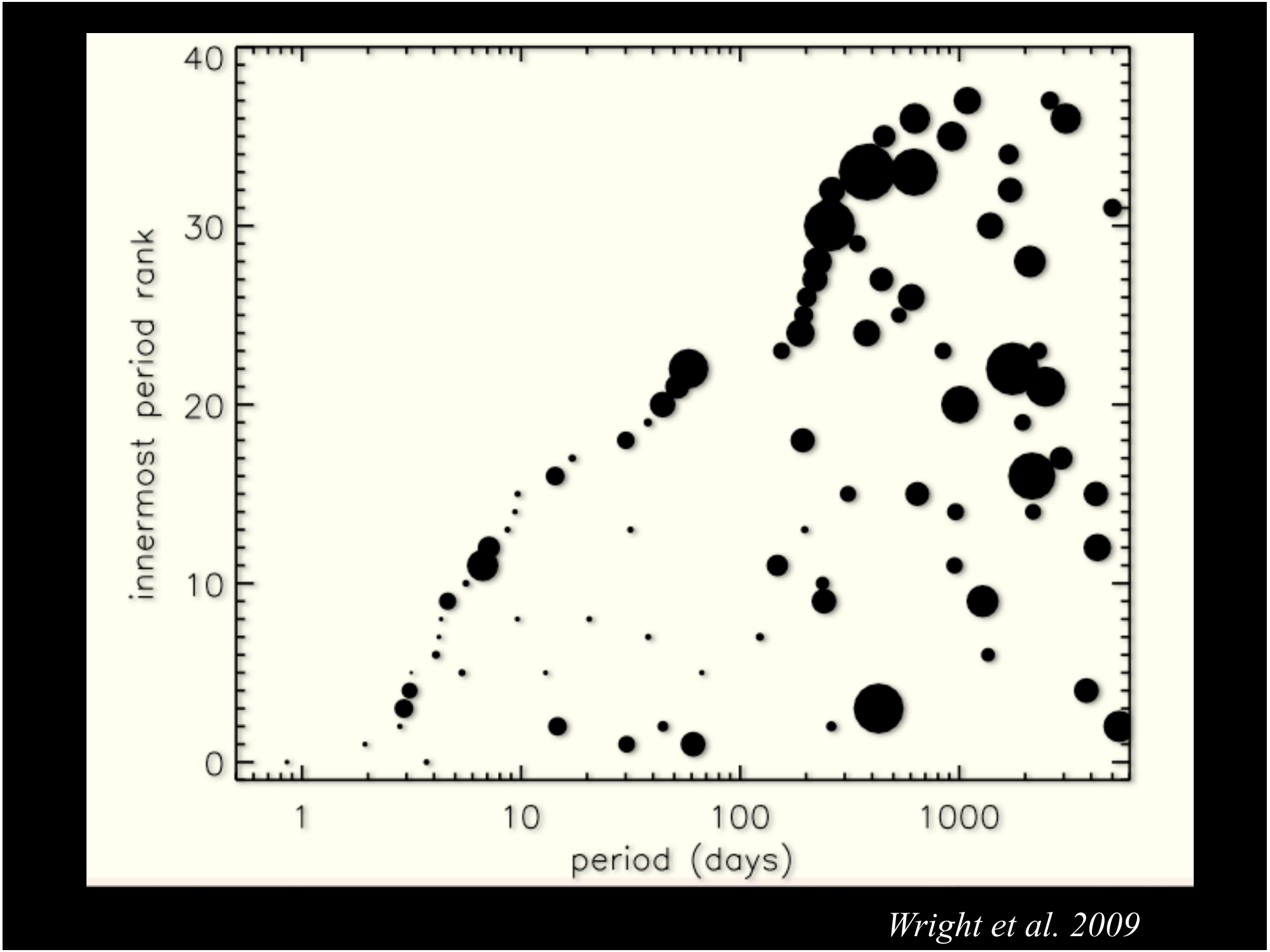


The upper mass of planets

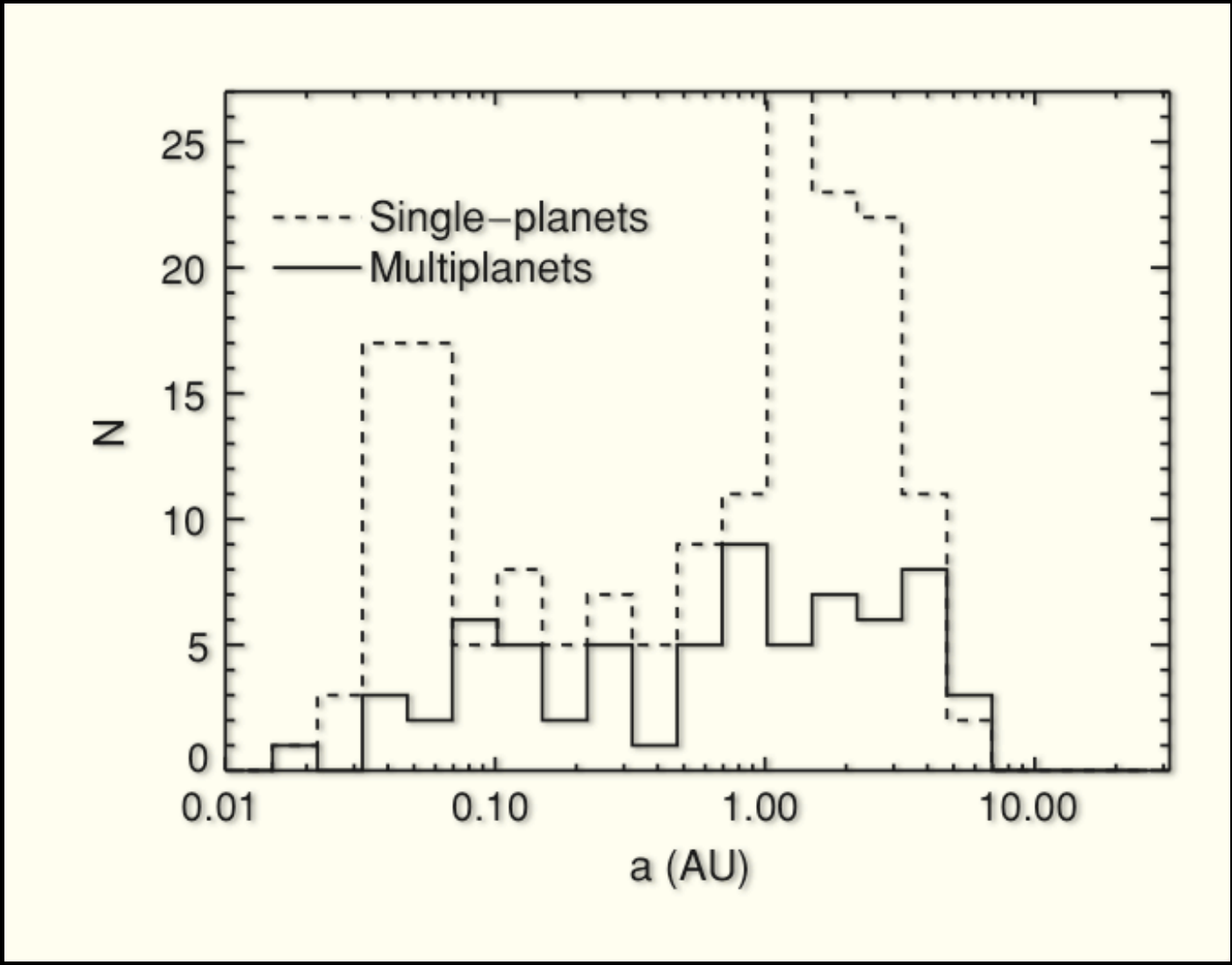


Multiple systems

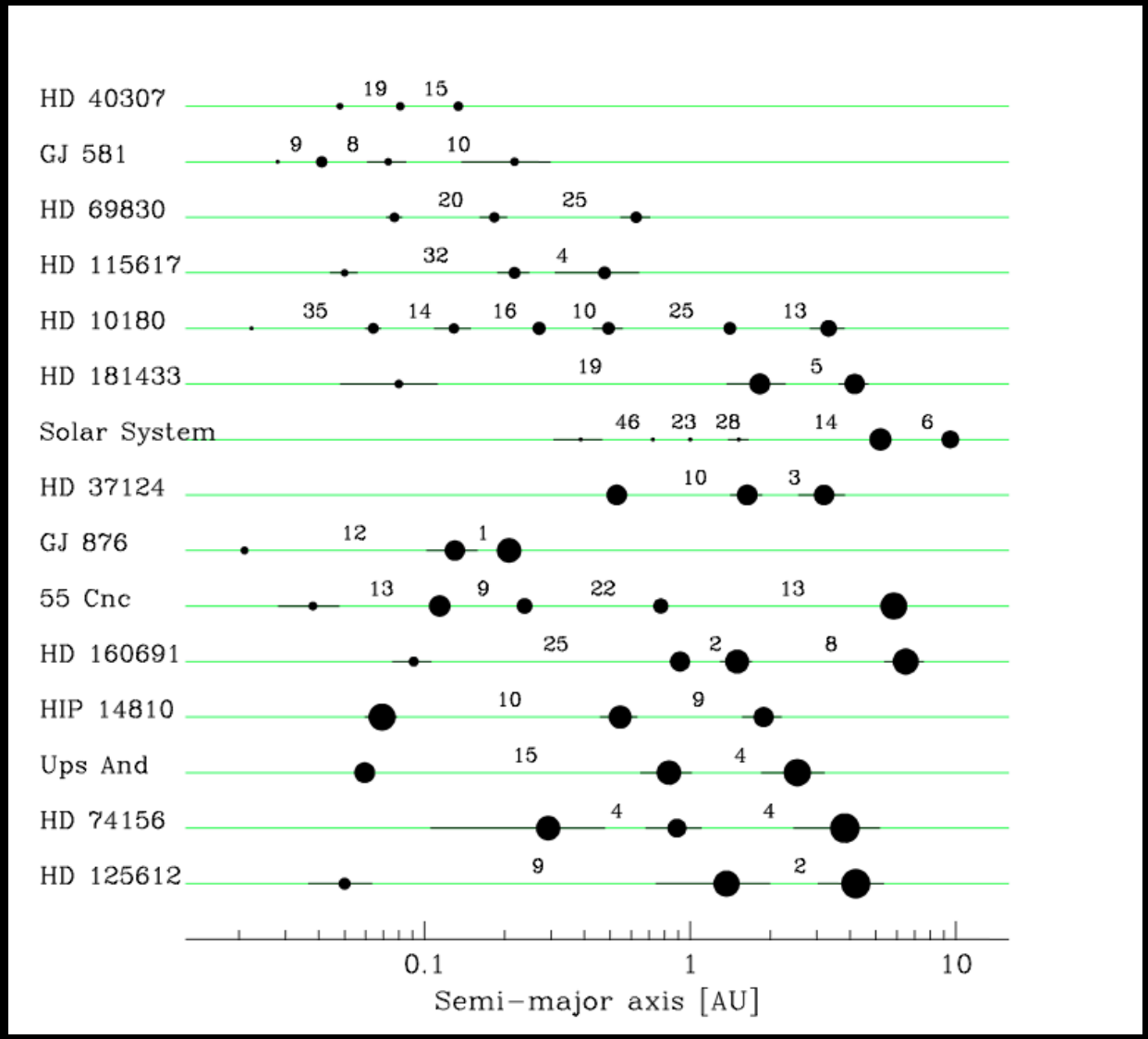




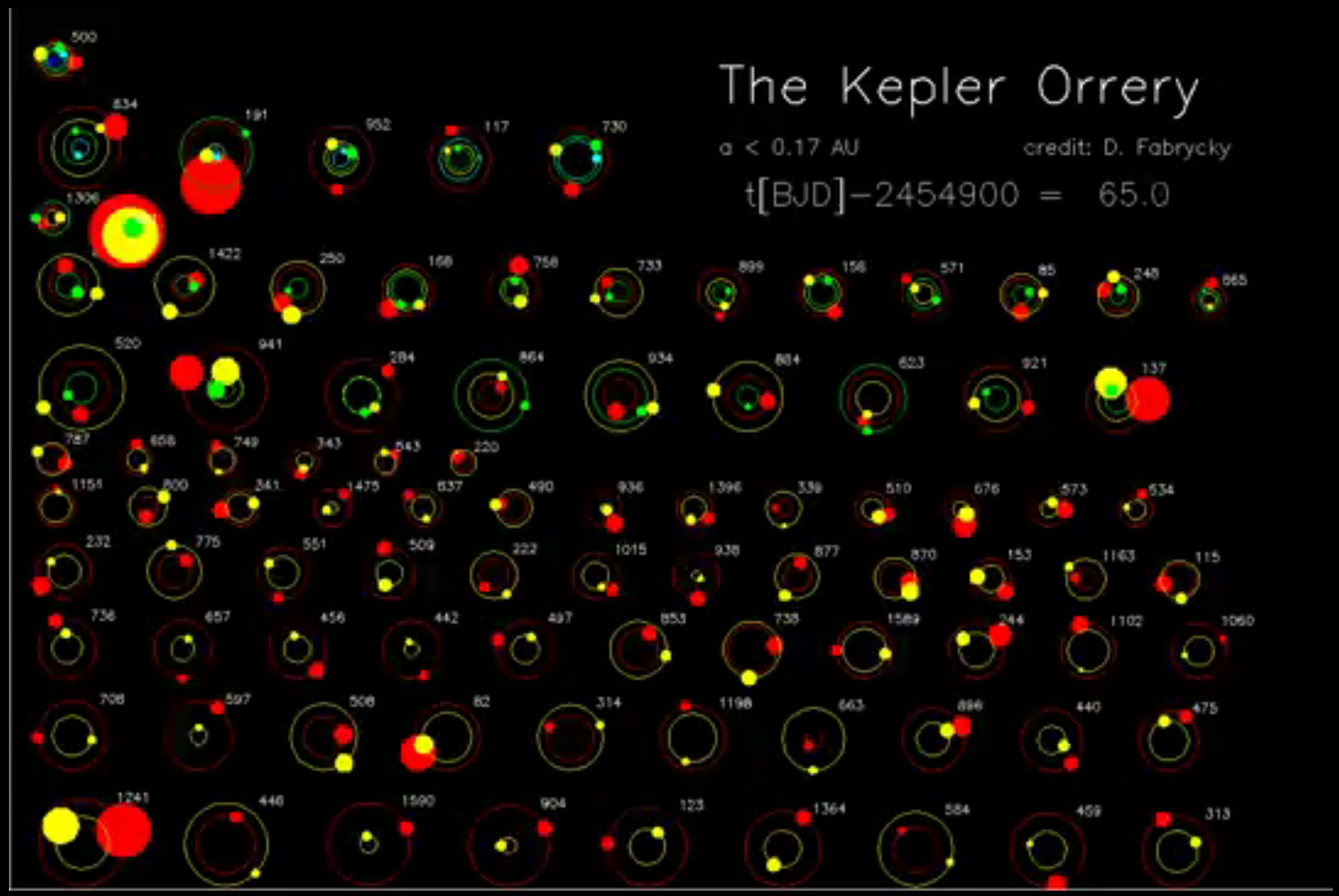
Wright et al. 2009

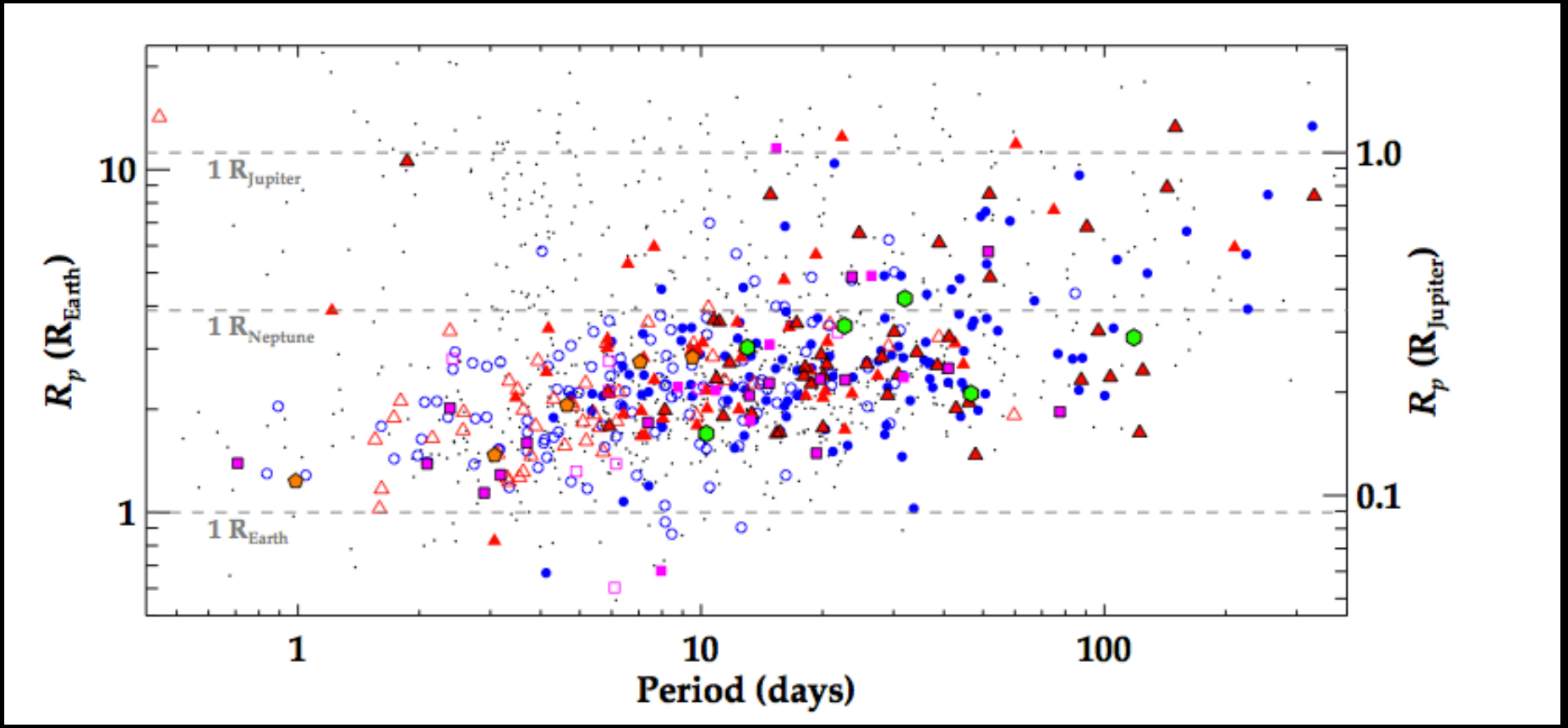


Wright et al. 2009



Lovis et al. 2011

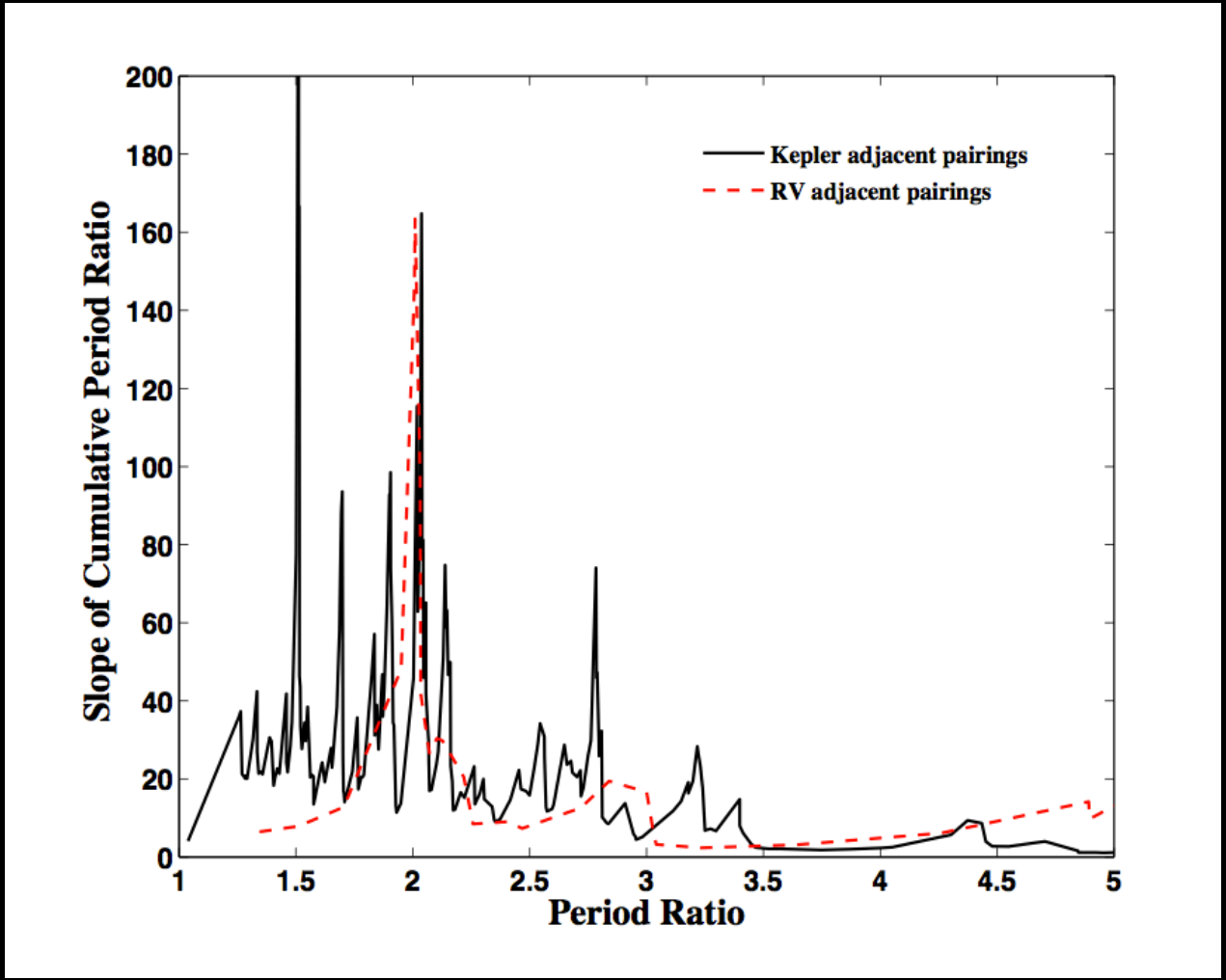

The Kepler Orrery
a < 0.17 AU
credit: D. Fabrycky
t[BJD]−2454900 = 65.0



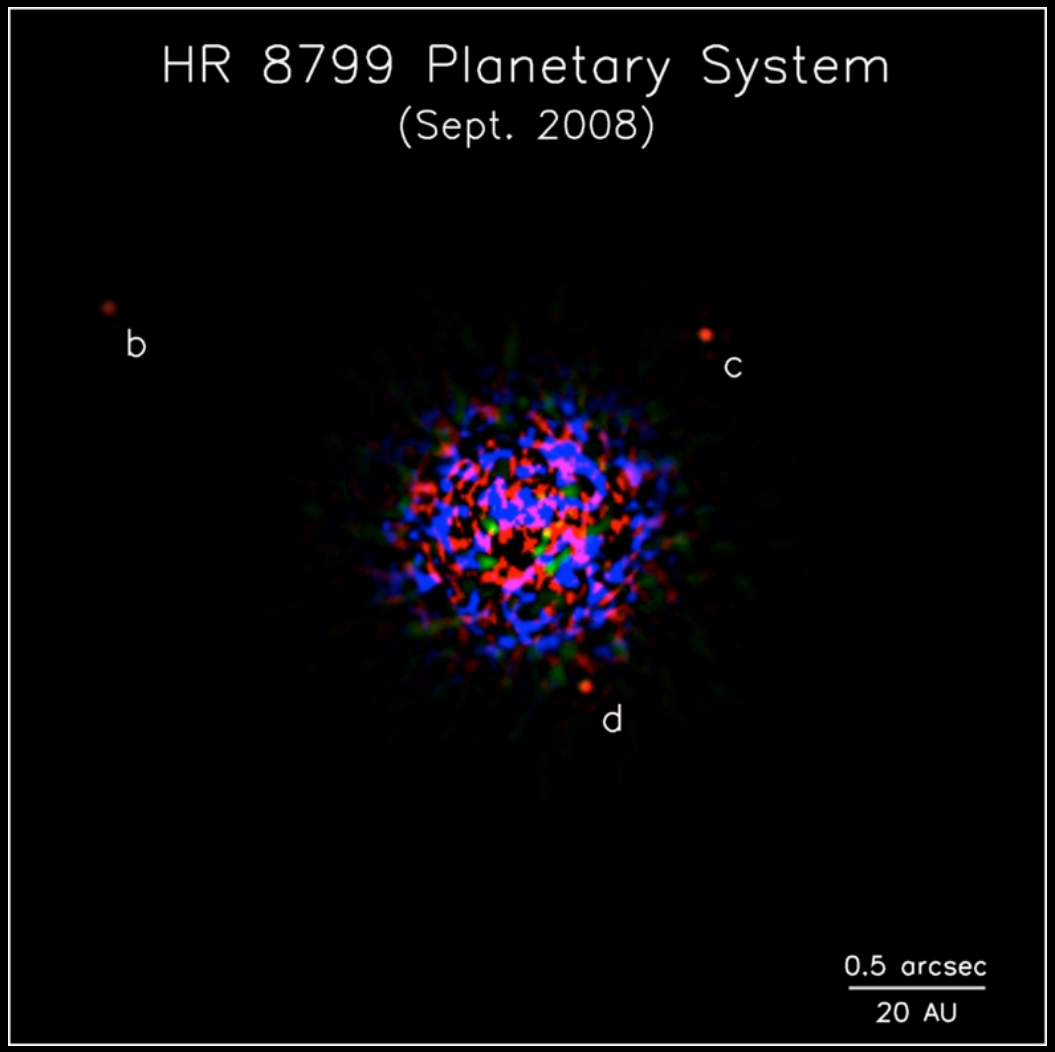
Lissauer et al. 2011

« It is immediately apparent that there is a paucity of giant planets in multi-planet systems »…

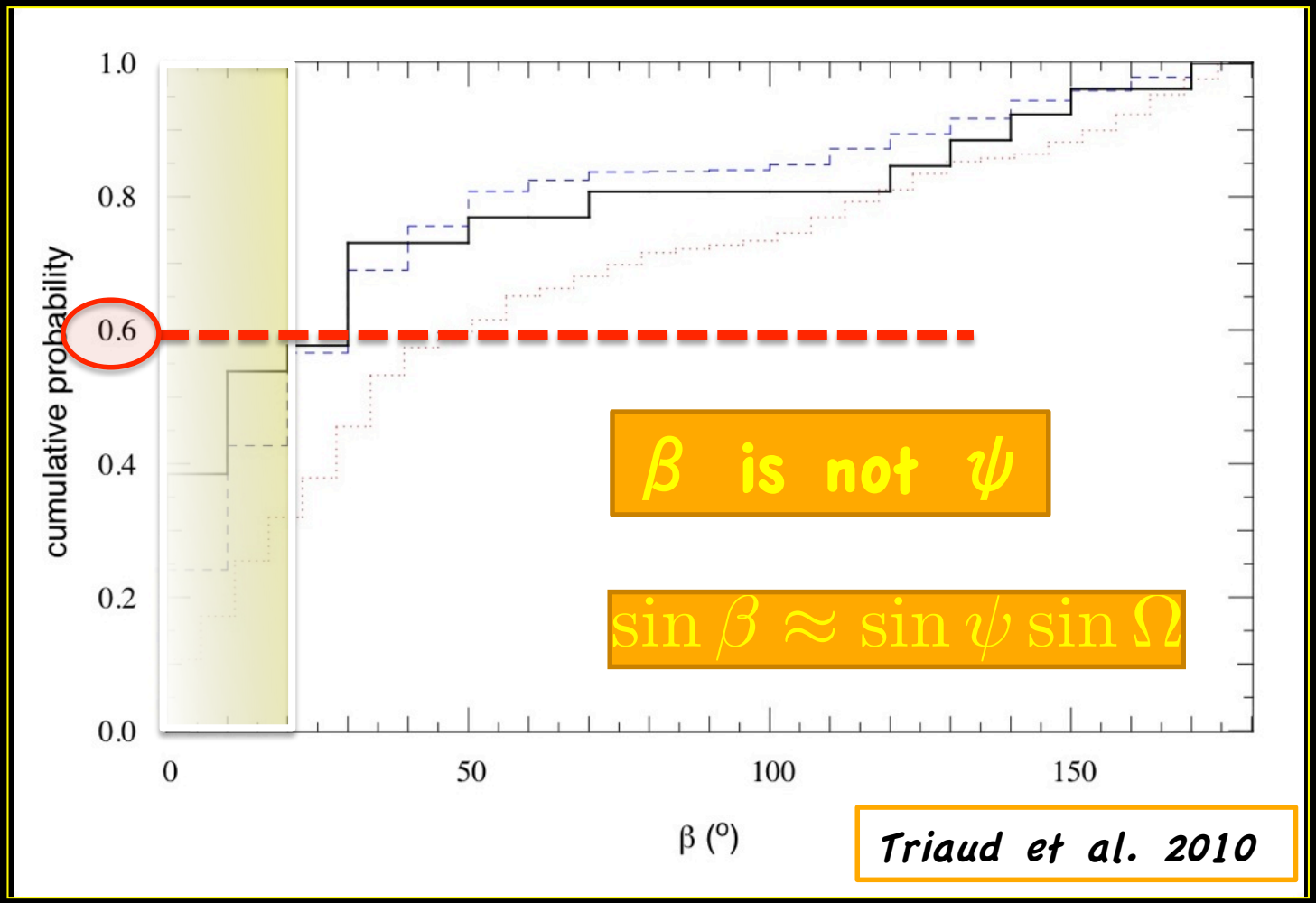
Resonant or not resonant?



Lissauer et al. 2011

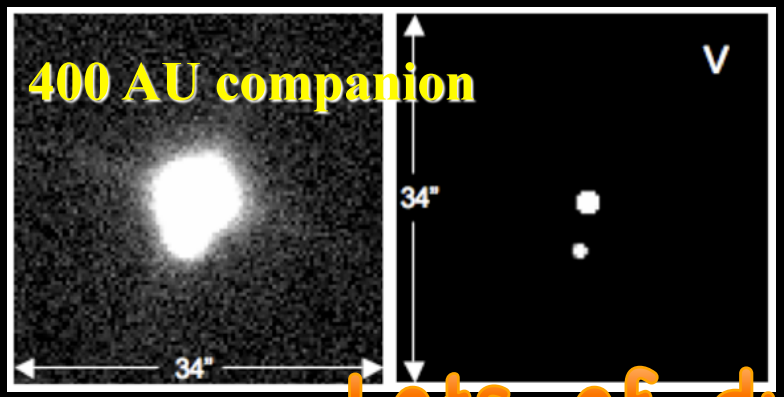

HR 8799 Planetary System
(Sept. 2008)
b
c
d
0.5 arcsec
20 AU

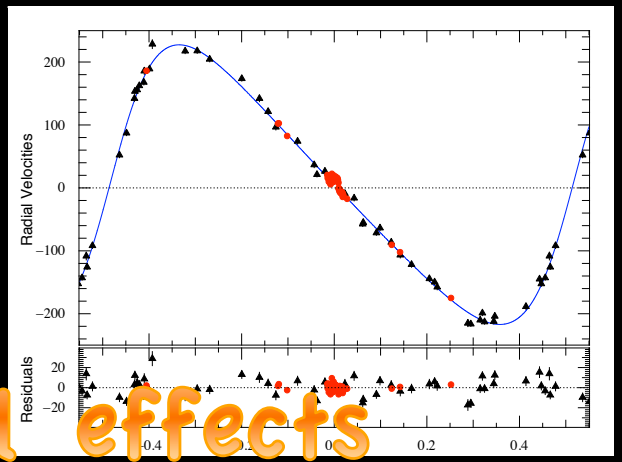
A majority of hot Jupiter are misaligned



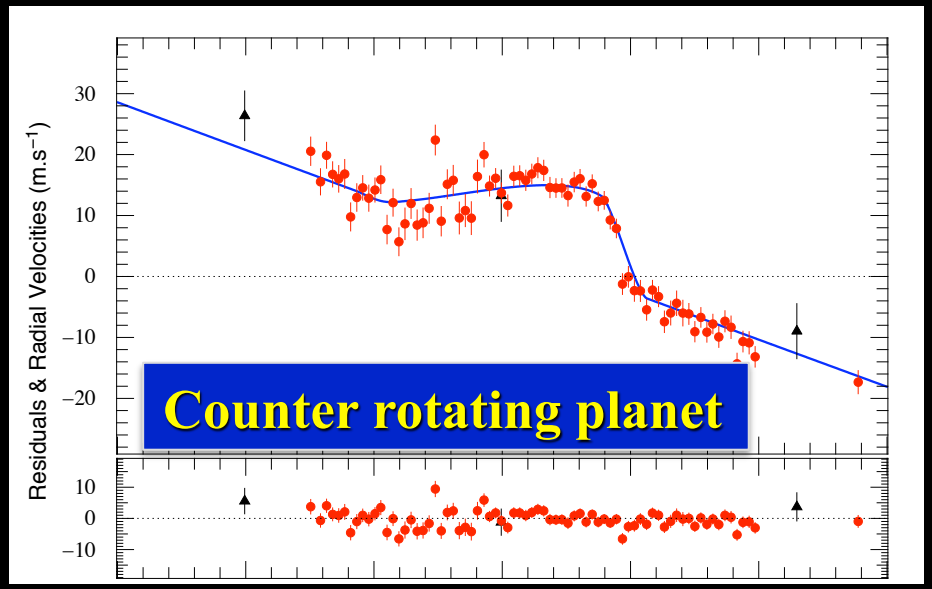
WASP-8 complex system

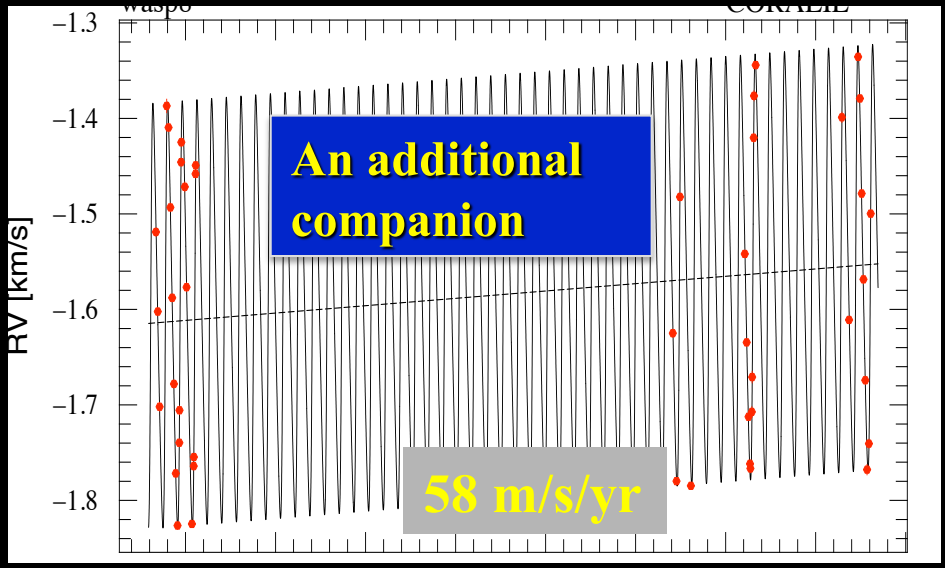
Eccentric P=8d orbit





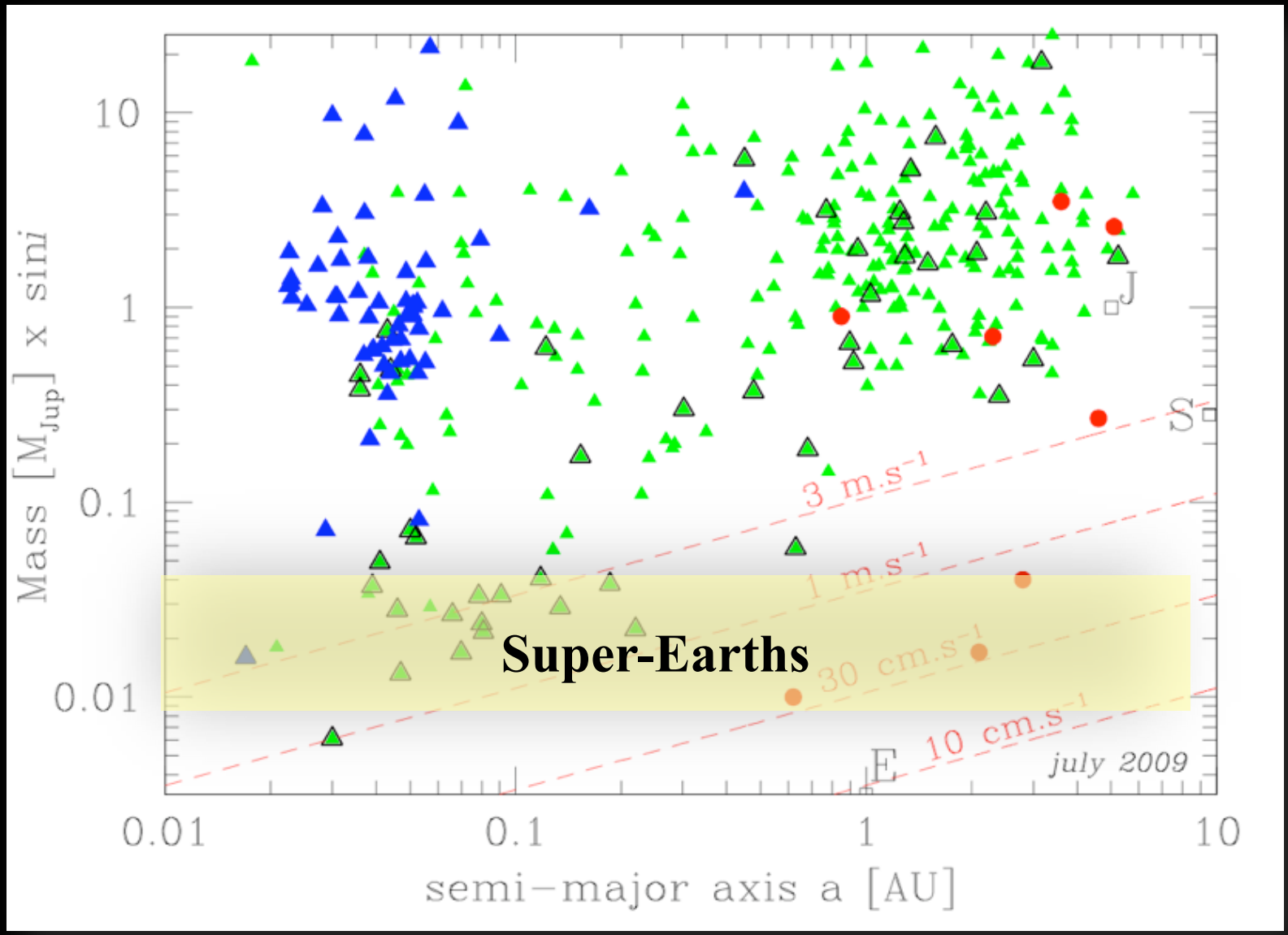
Lots of dynamical effects



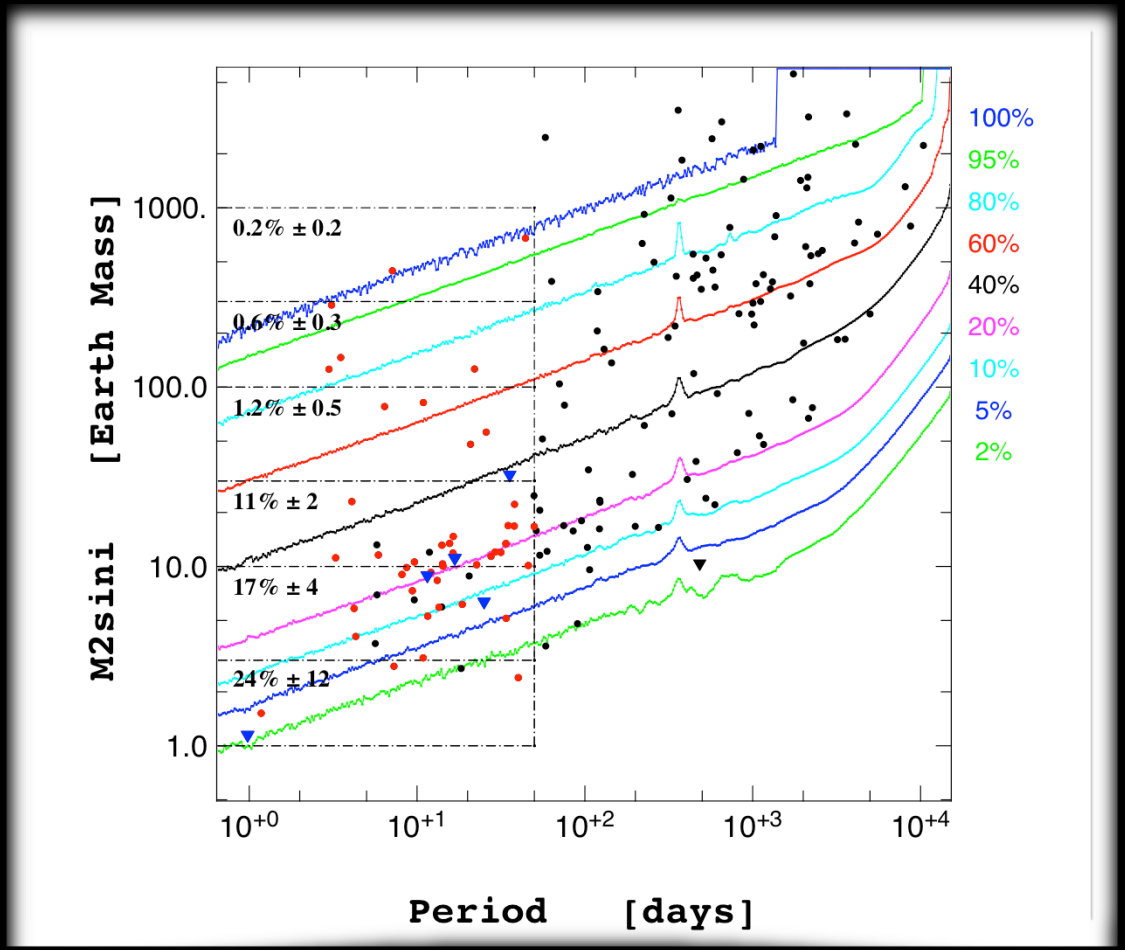


Super-Earth

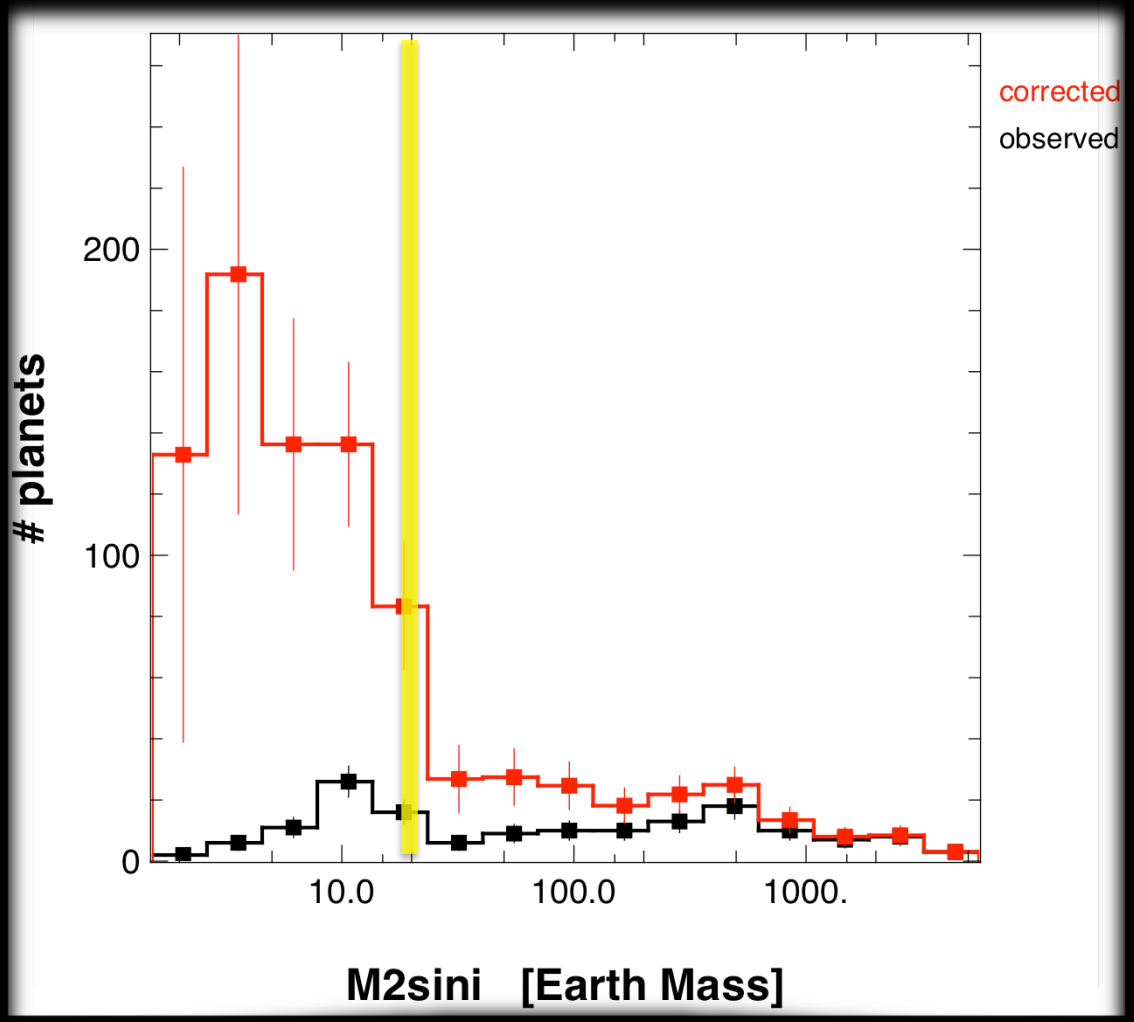
A zoo of semi-major axis



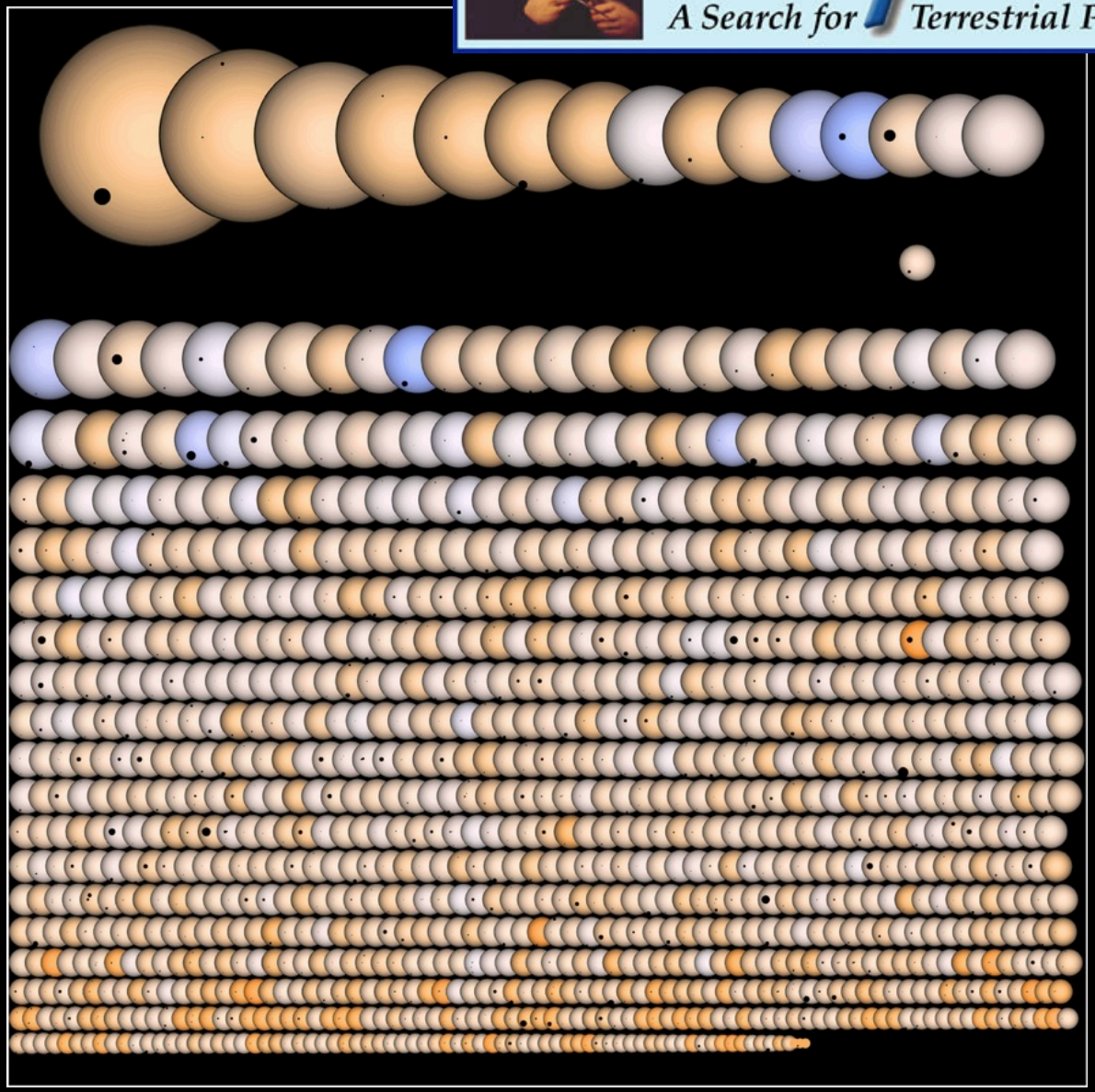
Super-Earths yield



Mayor et al. 2011



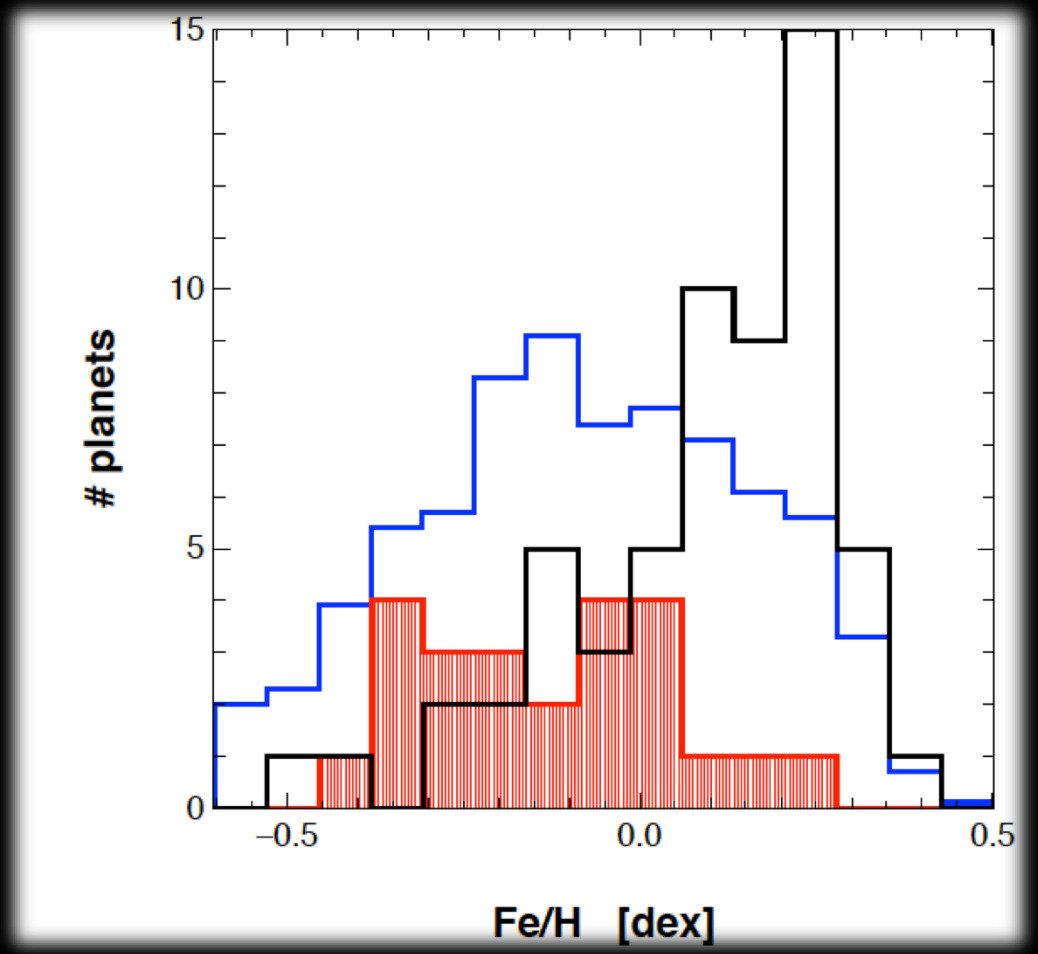
Mayor et al. 2011




Kepler
A Search for Terrestrial Planets

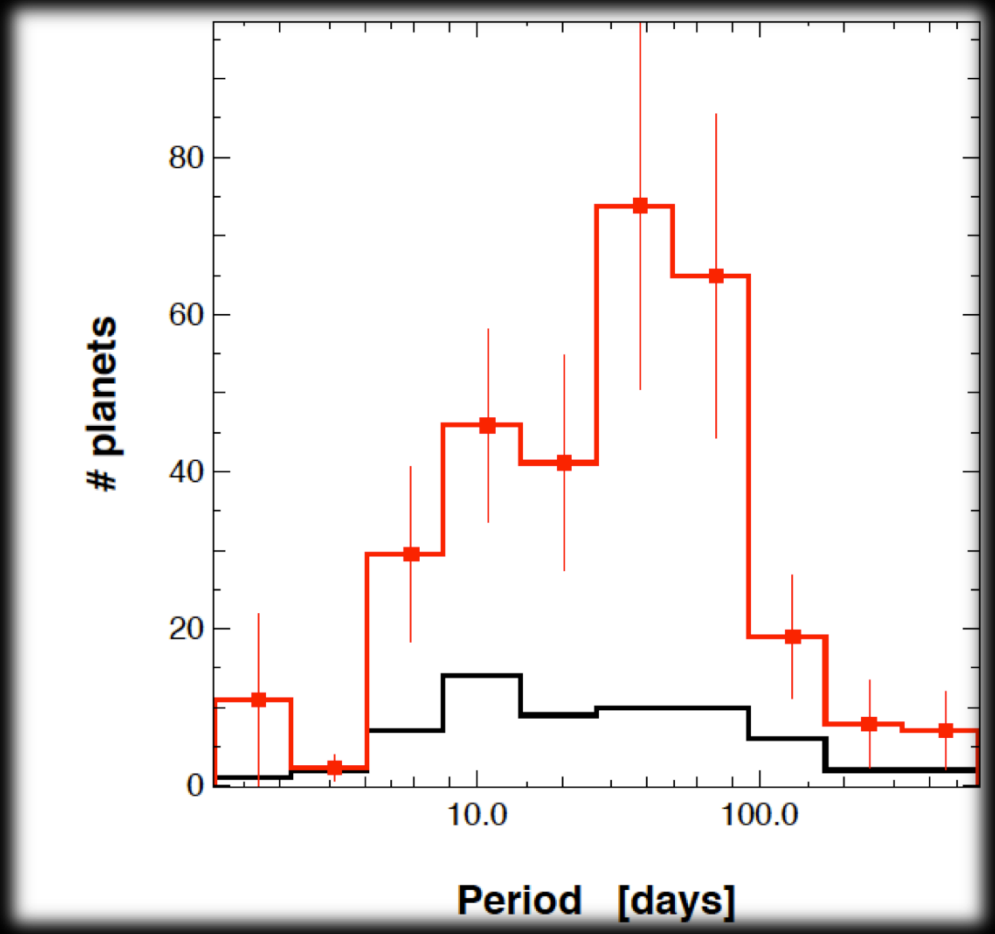
< 30Me

>150 Me



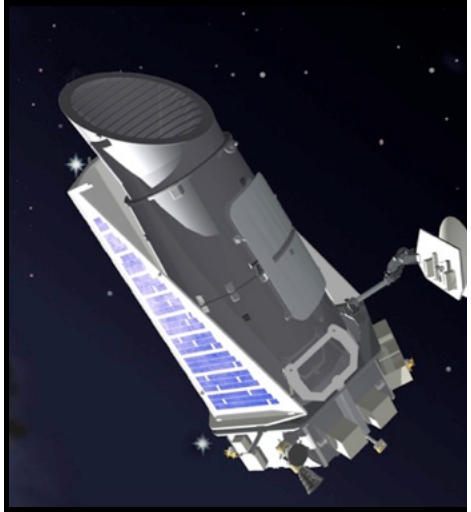
Mayor et al. 2011

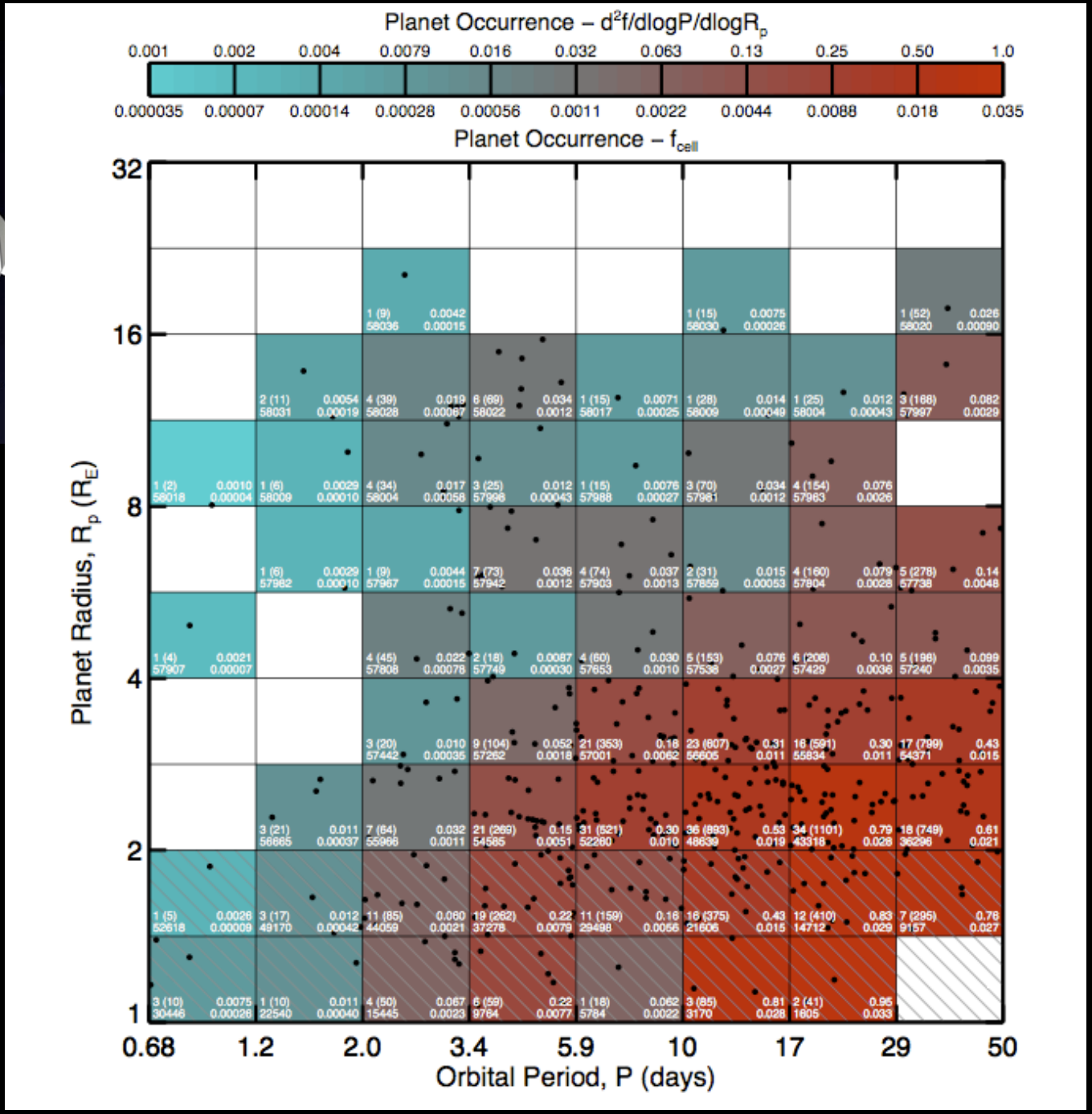
Super Earths

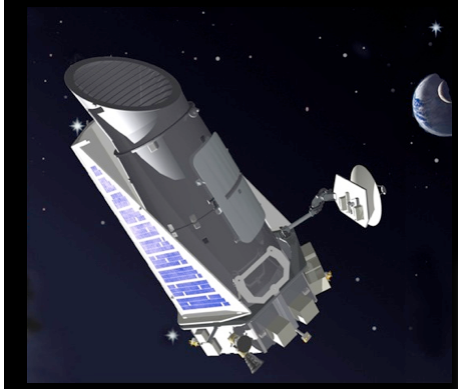


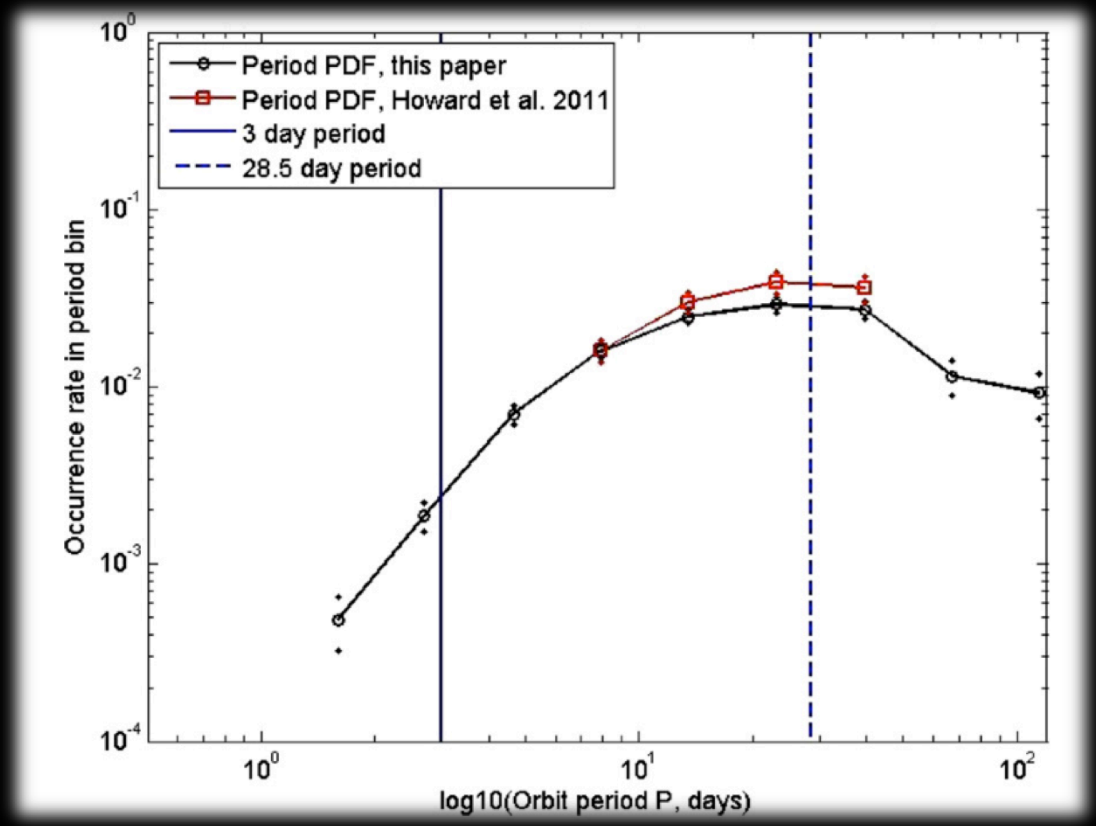
Mayor et al. 2011

Howard et al 2011



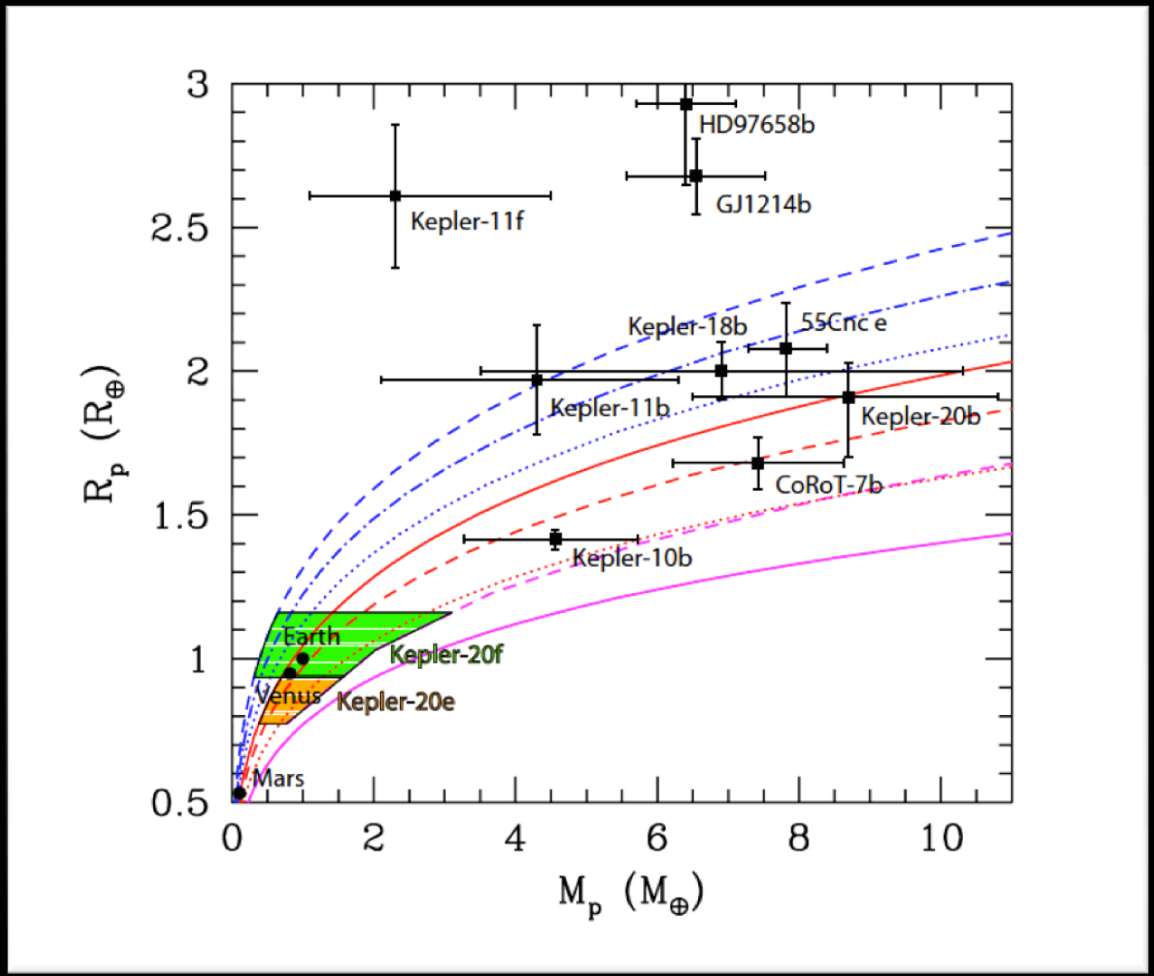




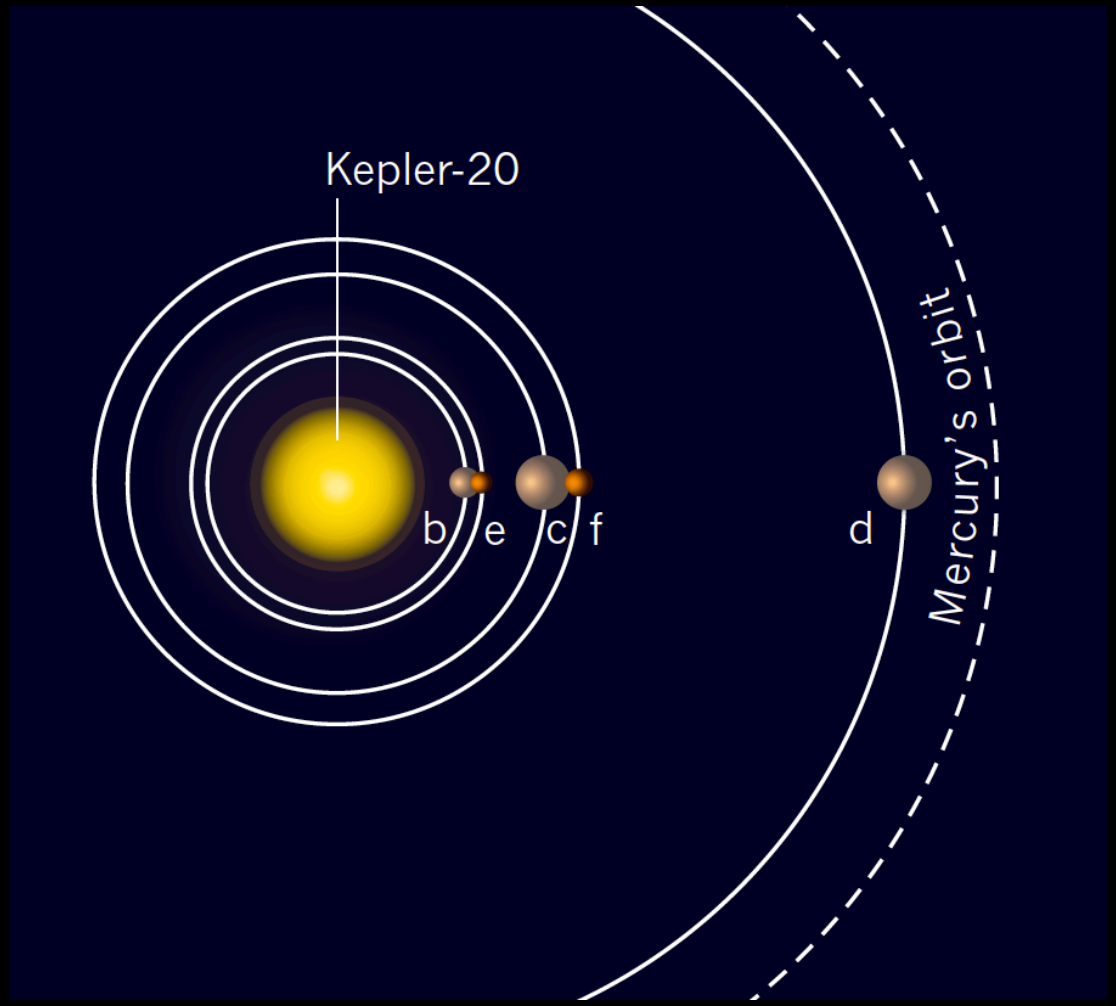


Cazantsakis & Shao 2011

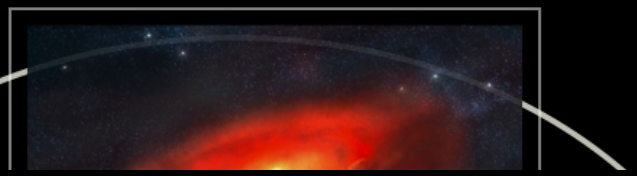
Super-Earths are ?



Fressin et al. 2012


Kepler-20
b
e
c
f
d
Mercury's orbit

- Companion are detected up to 30 Jupiter mass
- Rate of occurrence significantly increases below 30 Me
- Traces of dynamic and secular effects are everywhere!
  - Hot Jupiter as an extreme outcome!
  - « Compact » and resonant planetary systems
- Migration is one of the many effects at play
- Hierarchy between Inner and Outer planets of the Solar system is so far not observed
- At least 50% of stars hosts planetary systems that are NOT like our Solar system:
  - Super Earth are a highly mixed population tracing a wide range of formation tracks



May tell us little on the configuration of most of the planetary systems