20 years of exploration of the giant planets population

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Bigs are beautiful..

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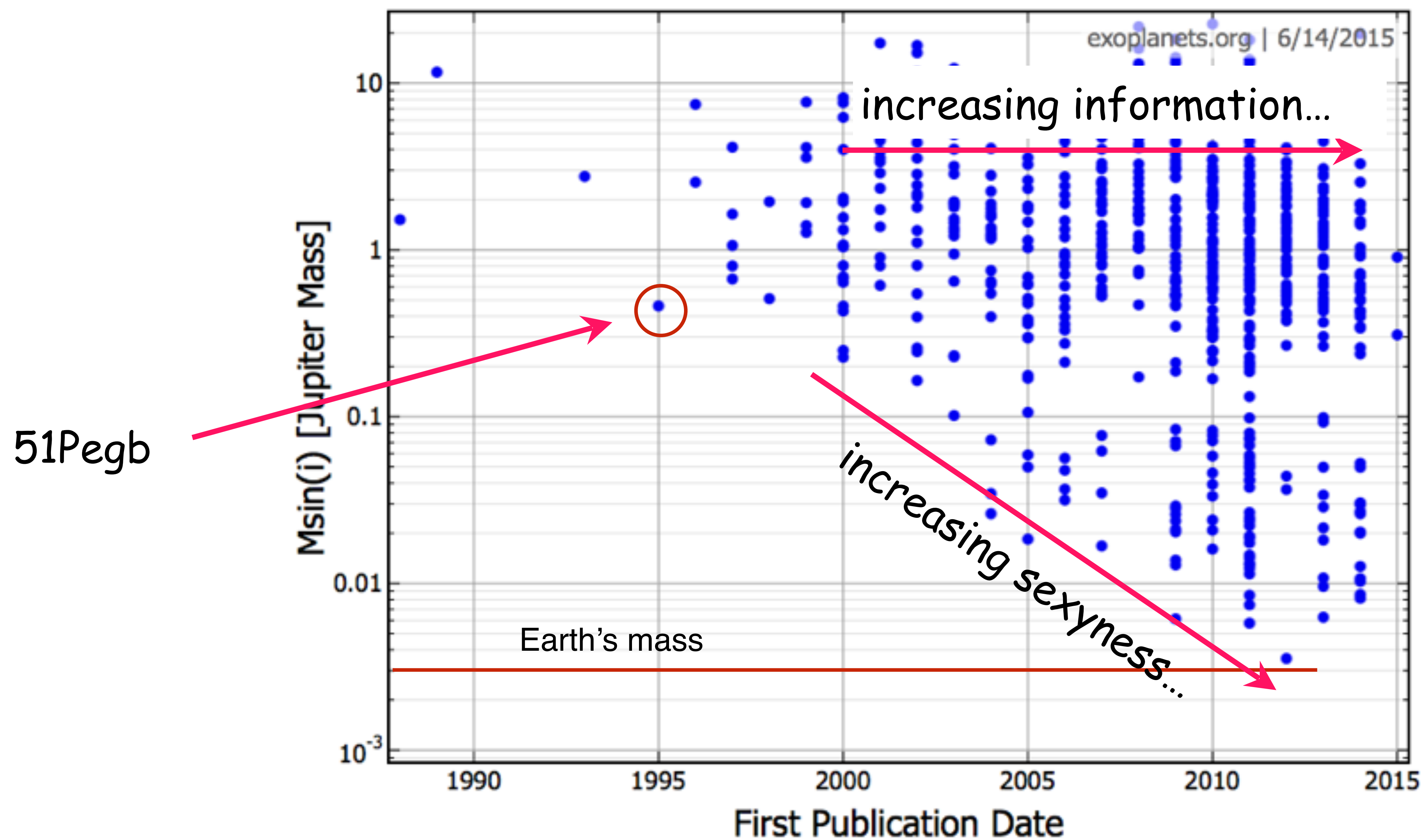
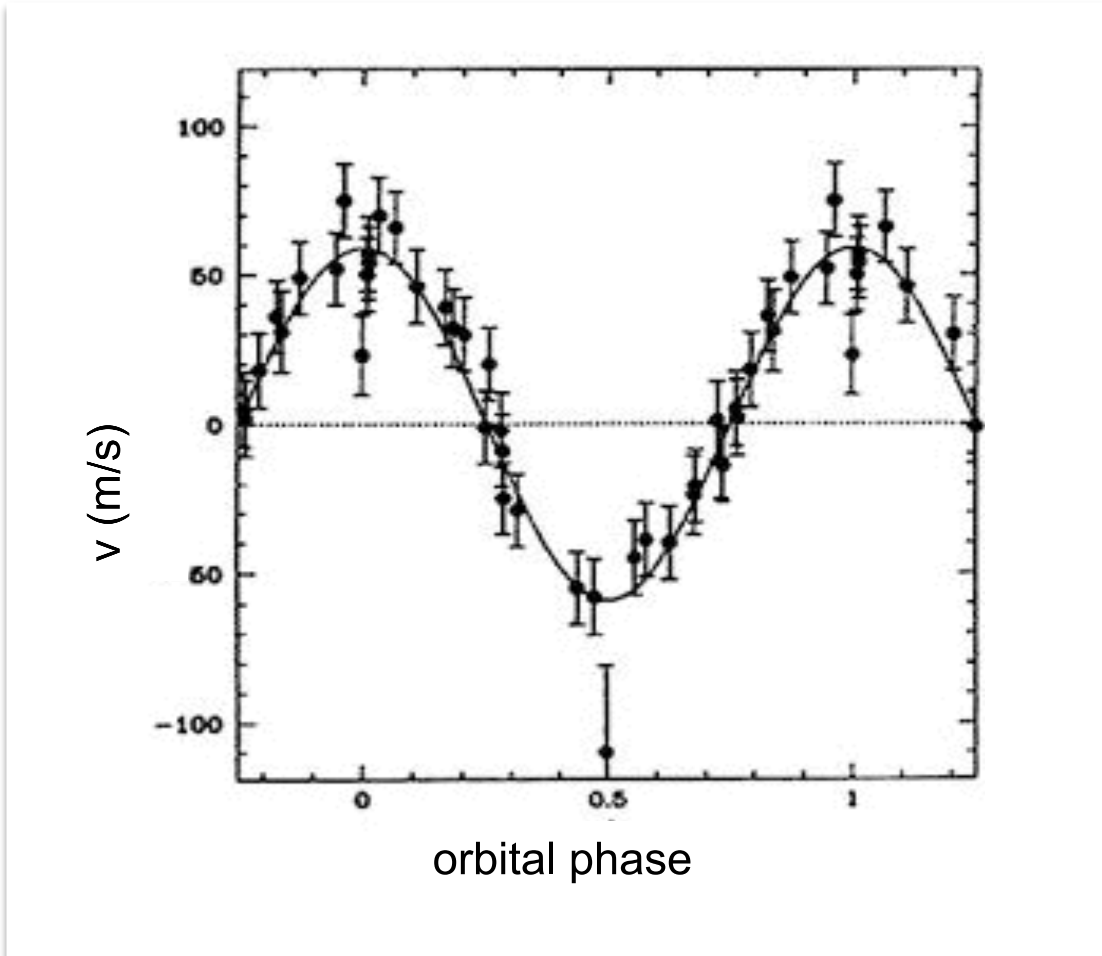
Giants: pro and.. con

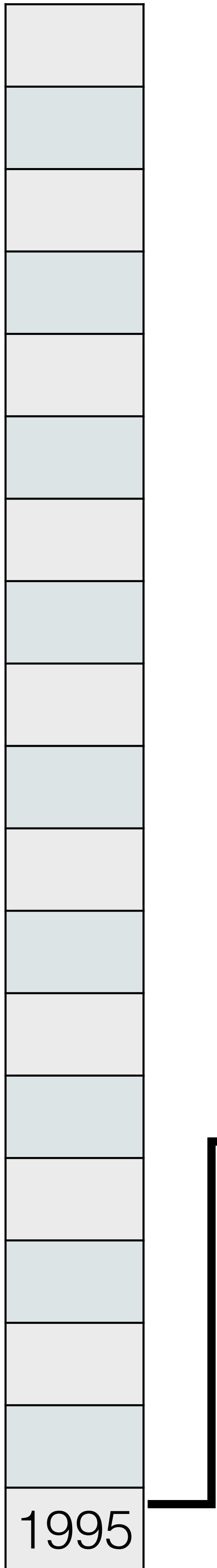
- easy to detect

  Jupiter: $\Delta F/F \sim 10^{-2}$; $K \sim 10$ m/s ; $F_{\odot}/F_{Jup} \sim 7.08\ 10^{8}$

- easier to characterize: combination of methods from the ground or from space, precision on their parameters





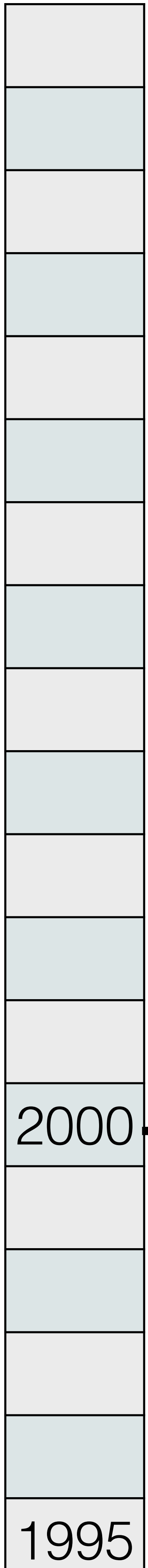


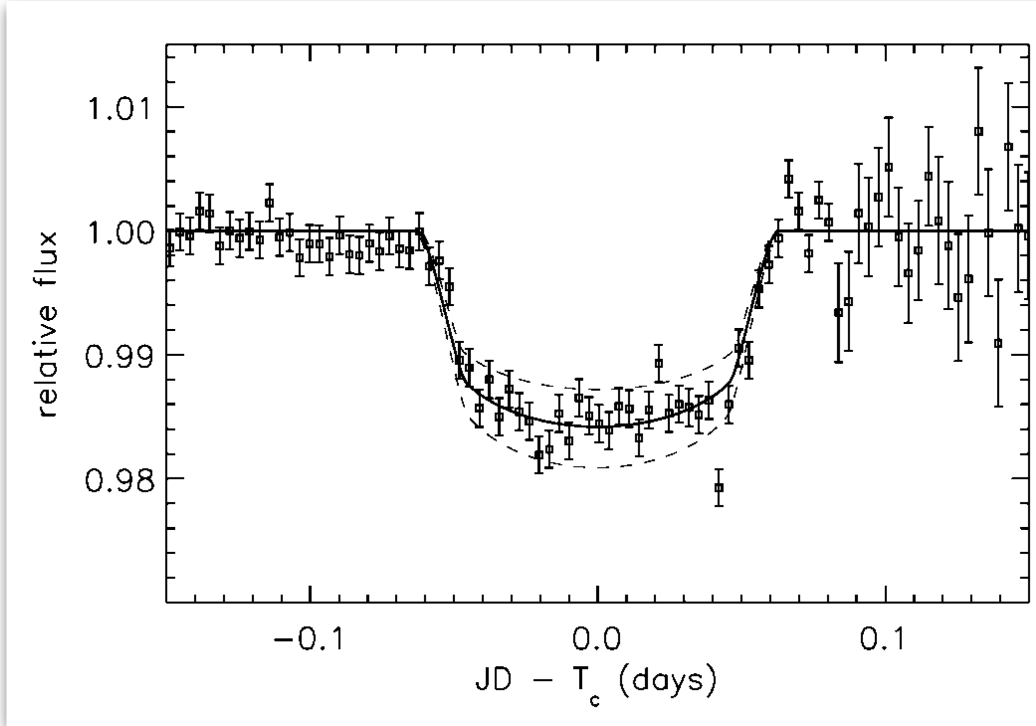
51 Pegb: first discovery around a solar type star

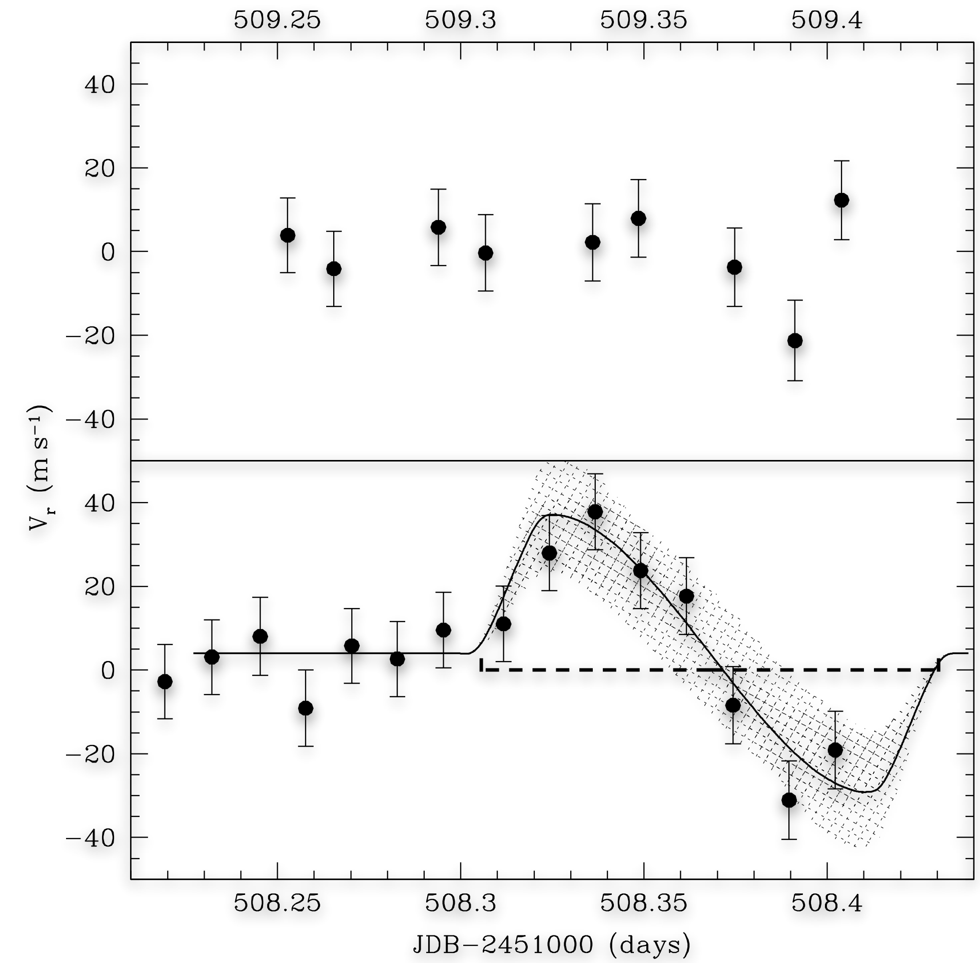
$M_p sini = 0.46\ M_{Jup}$

P = 4.2308 days

Mayor & Queloz, 1995







- **HD 209458 first photometric transit**

R_p = 1.27 R_{Jup} Mp = 0.63 MJup and ρ ~ 0.38 g/cm^{-3}

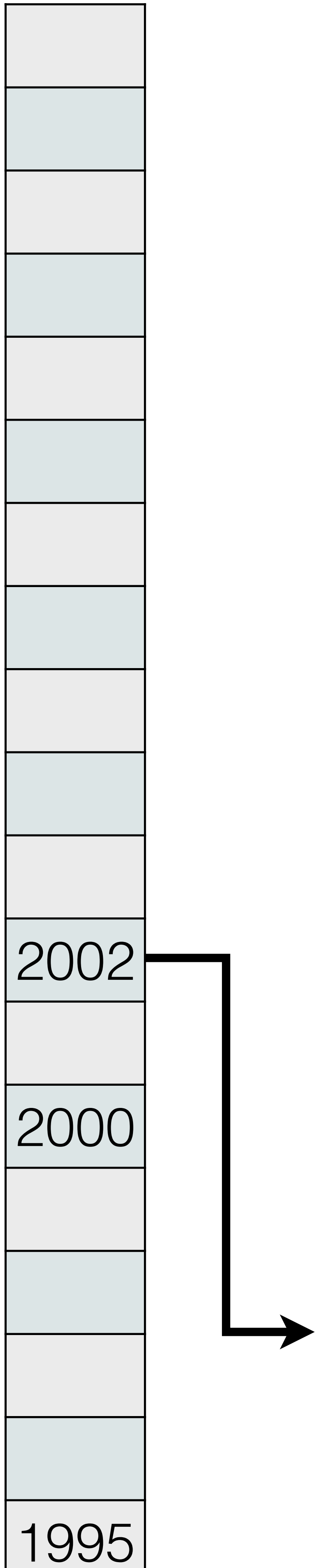
P = 3.525 days

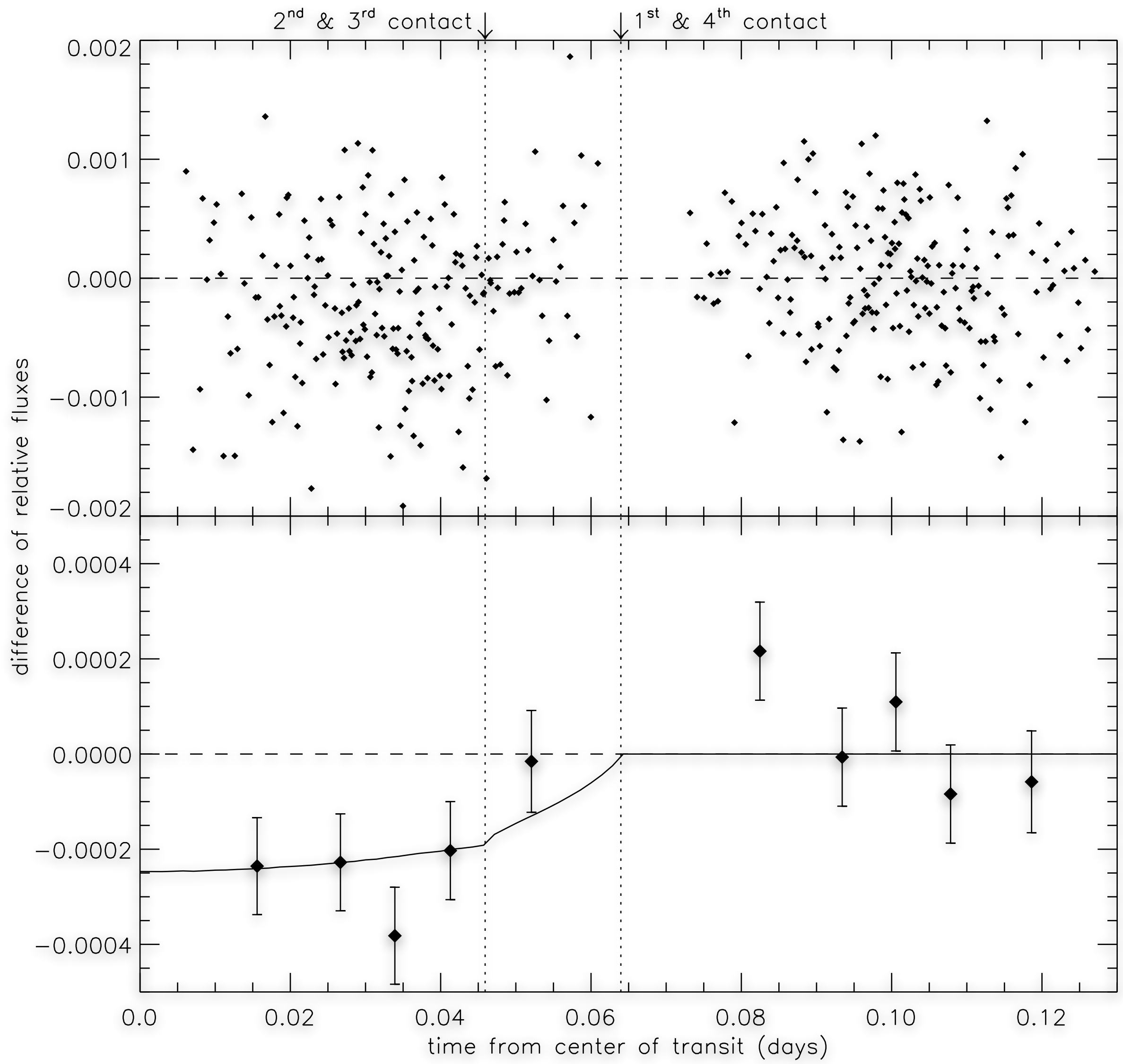
Henri et al., 2000; Charbonneau et al, 2000

- **HD 209458b first spectroscopic transit (Rossiter McLaughlin spectroscopic effect)**

α = 3.9° and vsini = 3.75 +/- 1.25 km/s

Queloz et al., A&A 2000





HD209458b, first atmospheric component detected

NaI 4-σ detection

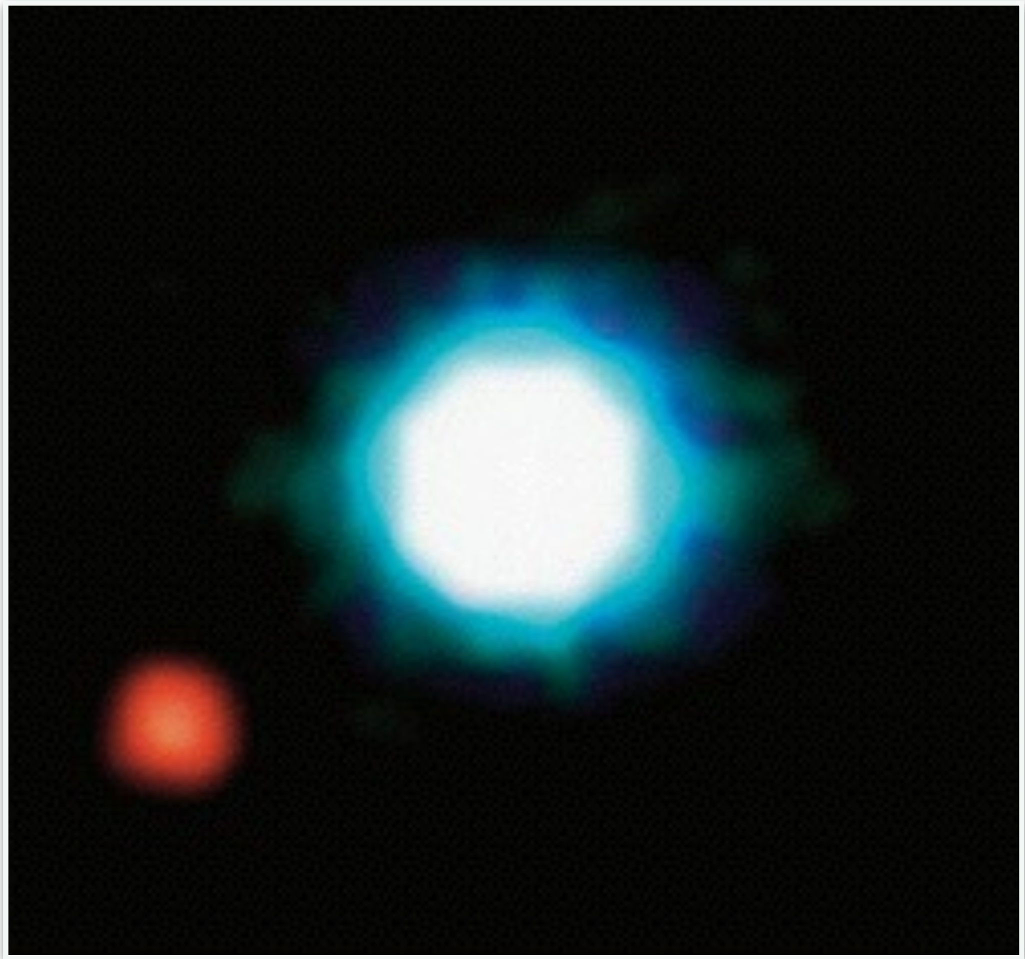
Charbonneau et al. 2002

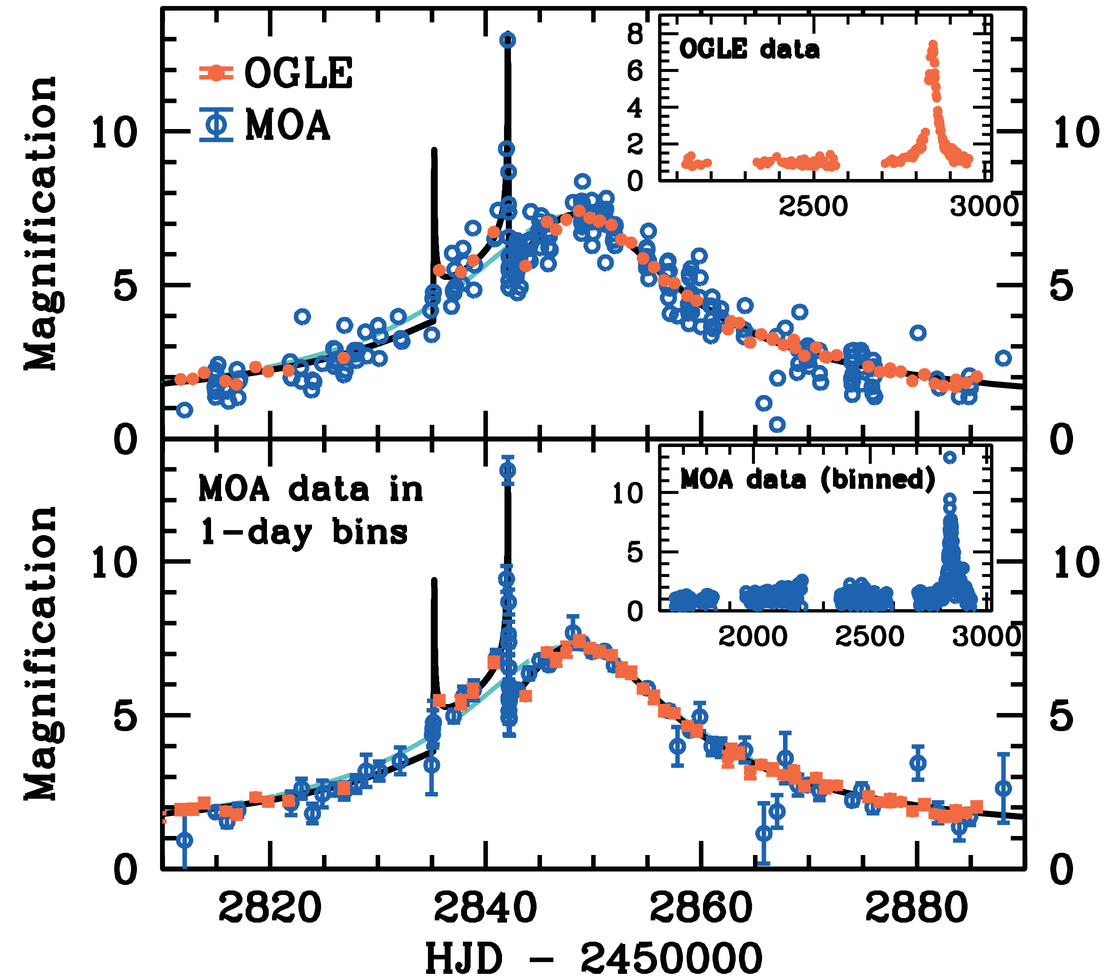
2004

2002

2000

1995





- **First imaged companion, 4 M_{Jup} at 55 AU**

Schneider et al., 2004

- **microlensing: first massive companion at ~ 3AU**

Bond et al., ApJ 2004

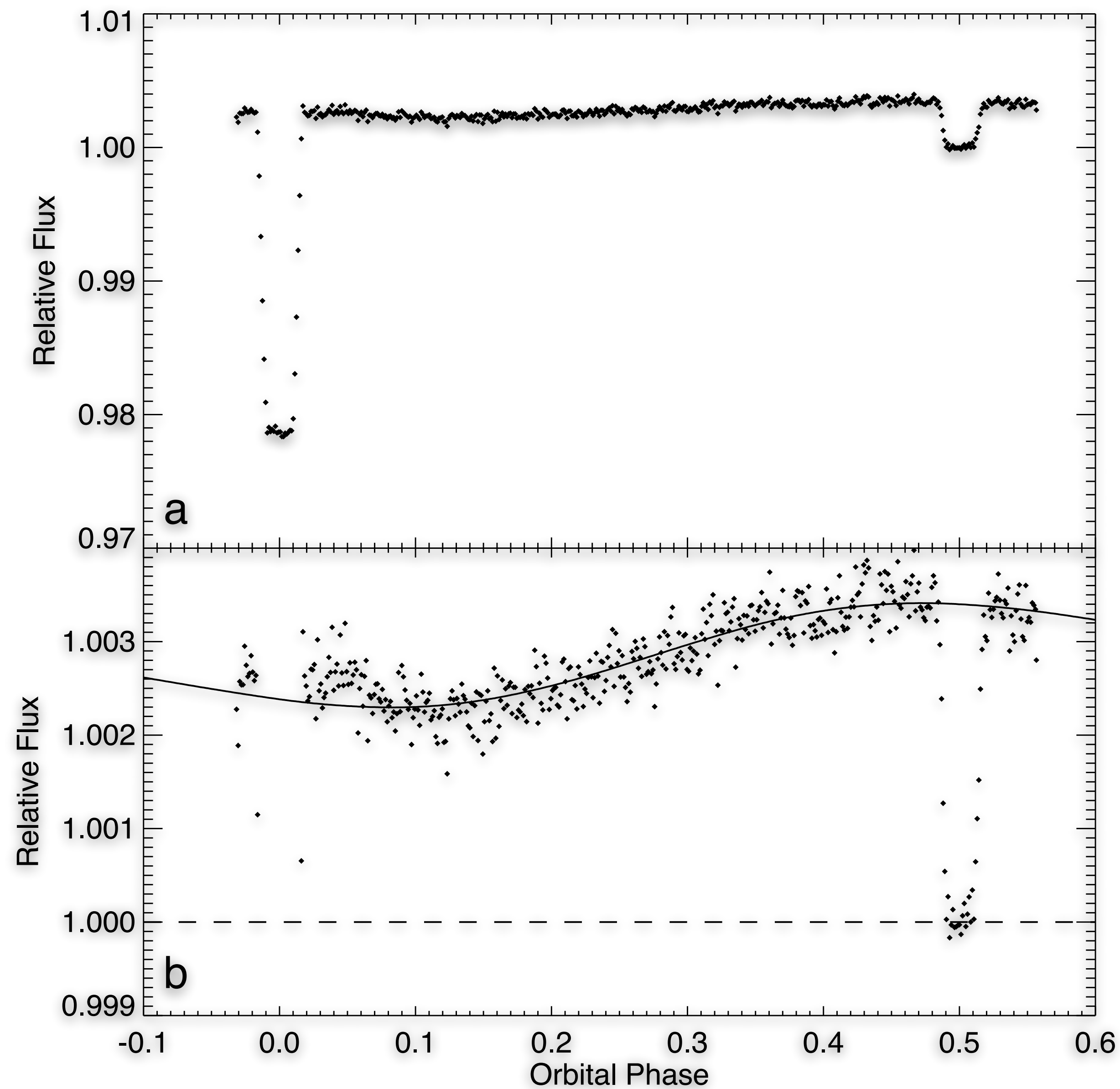
2007

2004

2002

2000

1995



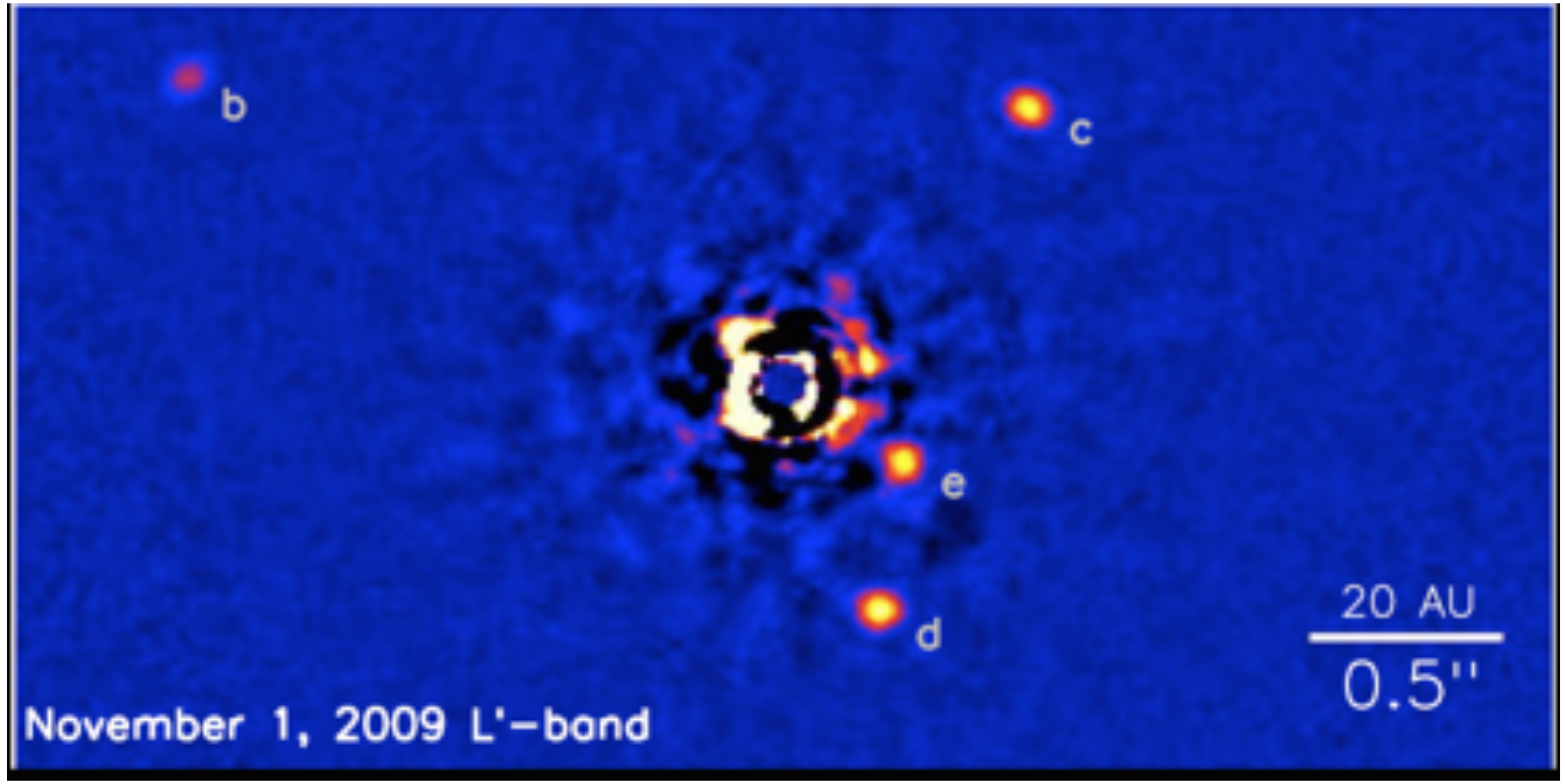
HD 189733b: map of the day-night contrast

Spitzer observation at 8μm:

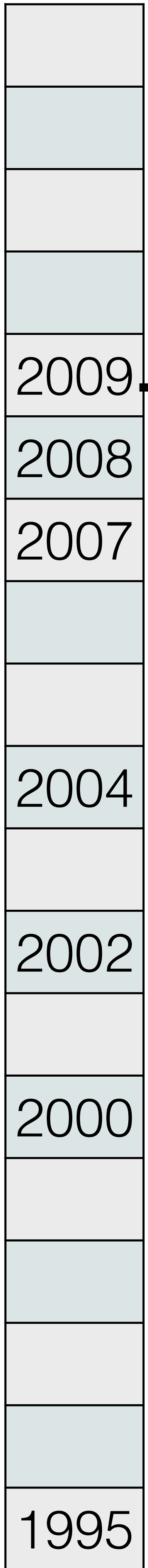
$Tb_{min} =$ 973±33 K and T_{bmax} = 1212±11 K

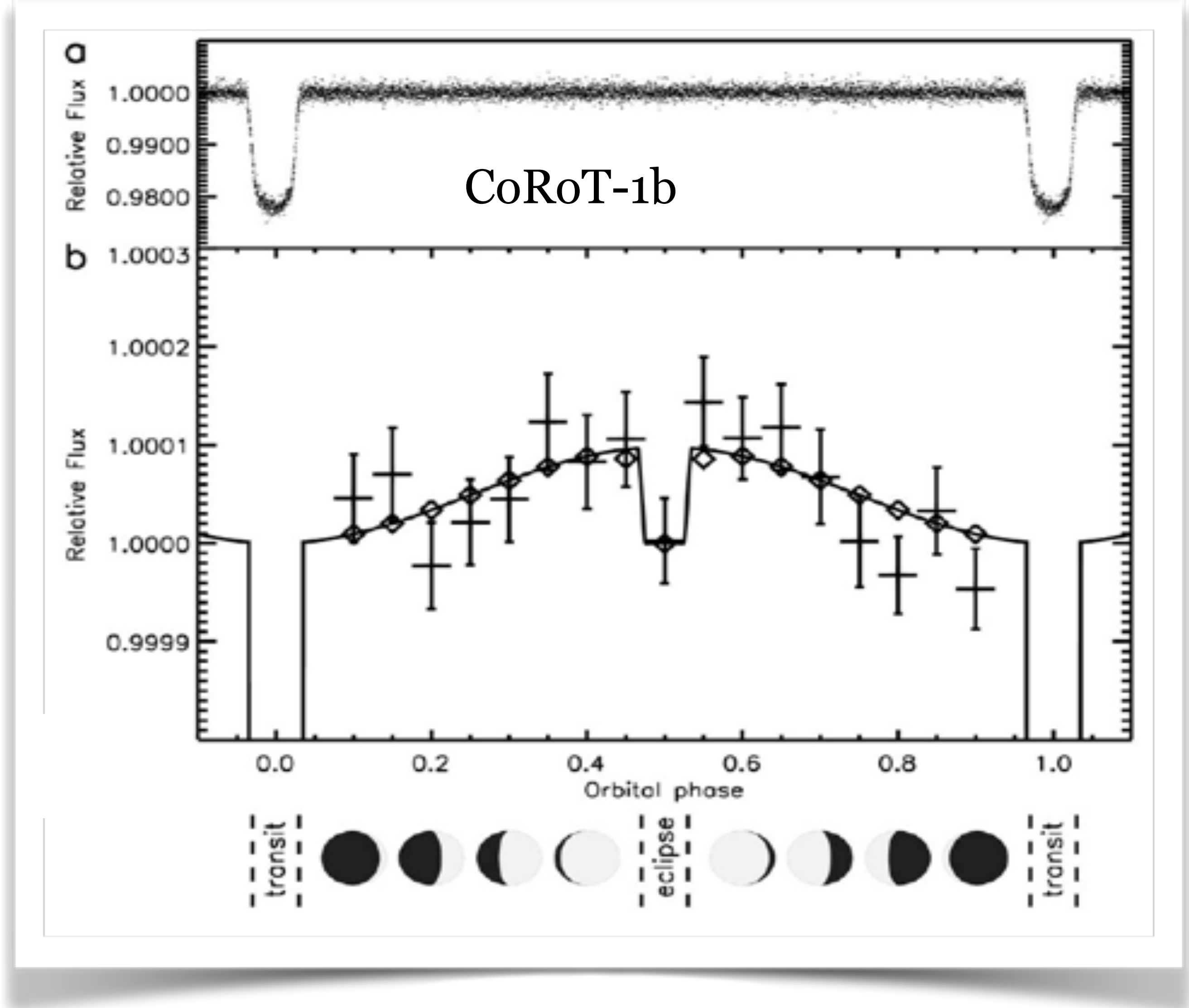
Knutson et al. 2007

2008
2007
2004
2002
2000
1995



HR8799, first imaged planetary system,
masses from 7 to 10 M_{Jup}, 15-70 AU
Marois et al., 2008





- **CoRoT-1b, first phase curve in the visible**

Ag < 0.20

Snellen et al., 2009, Nature

2013

2009

2008

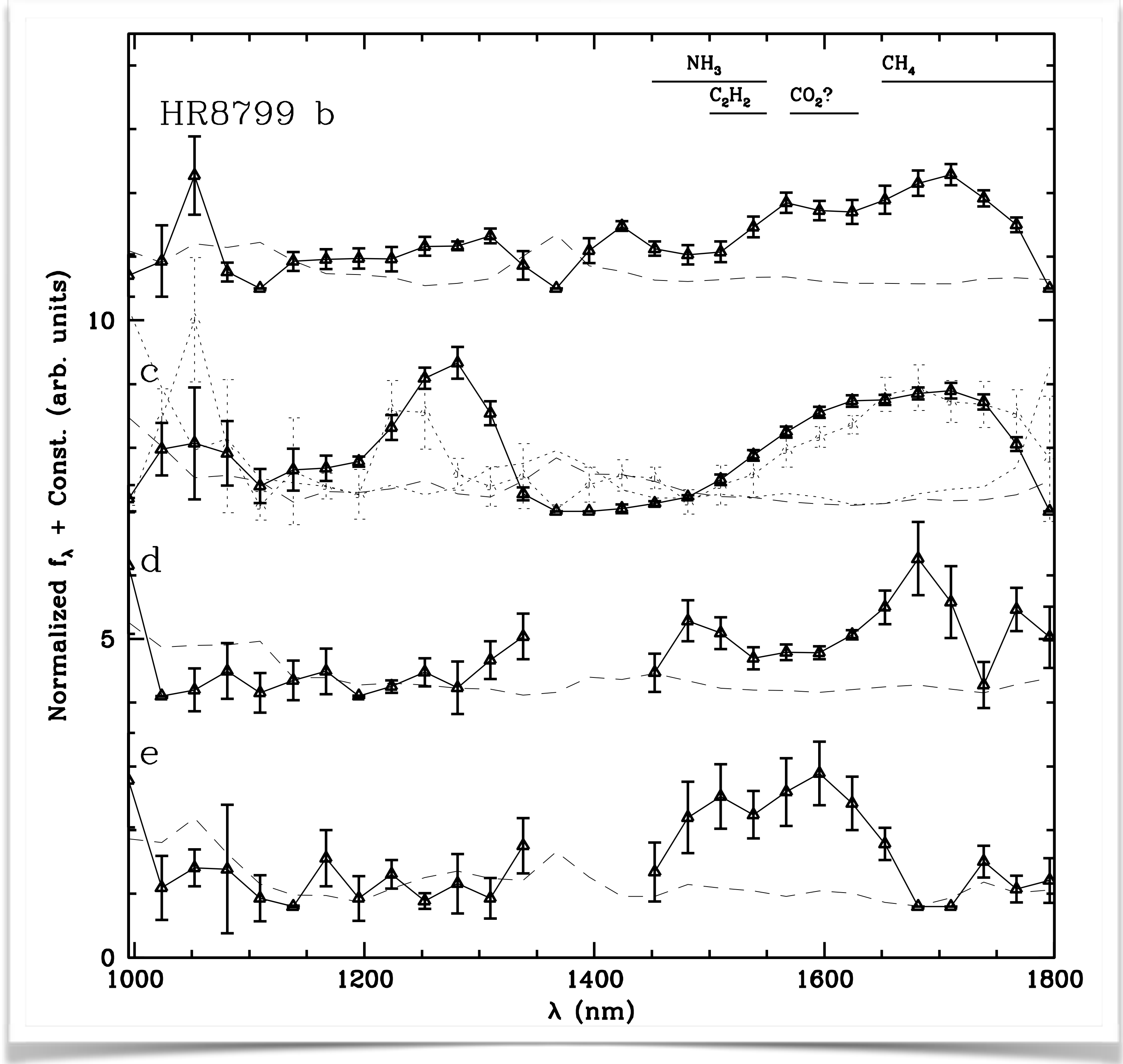
2007

2004

2002

2000

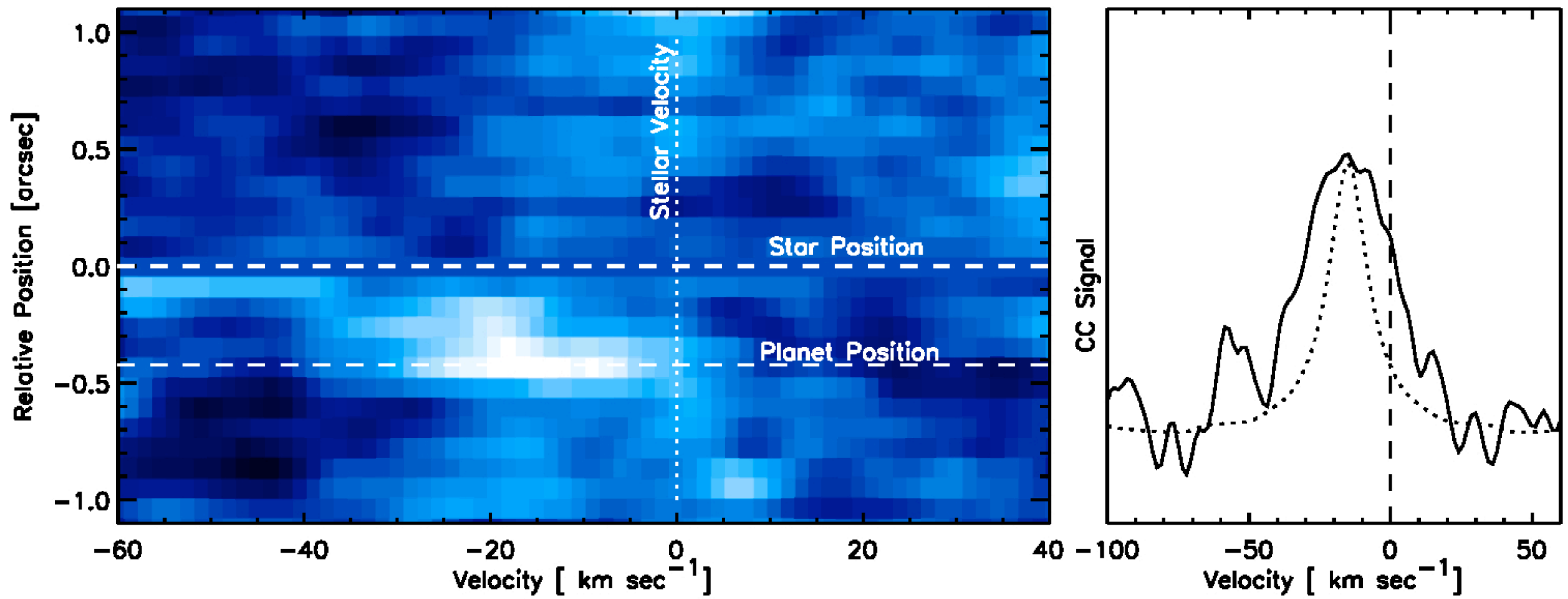
1995



- **HR8799a, b, c and d spectra**

Oppenheimer et al., ApJ 2013

2014
2013
2009
2008
2007
2004
2002
2000

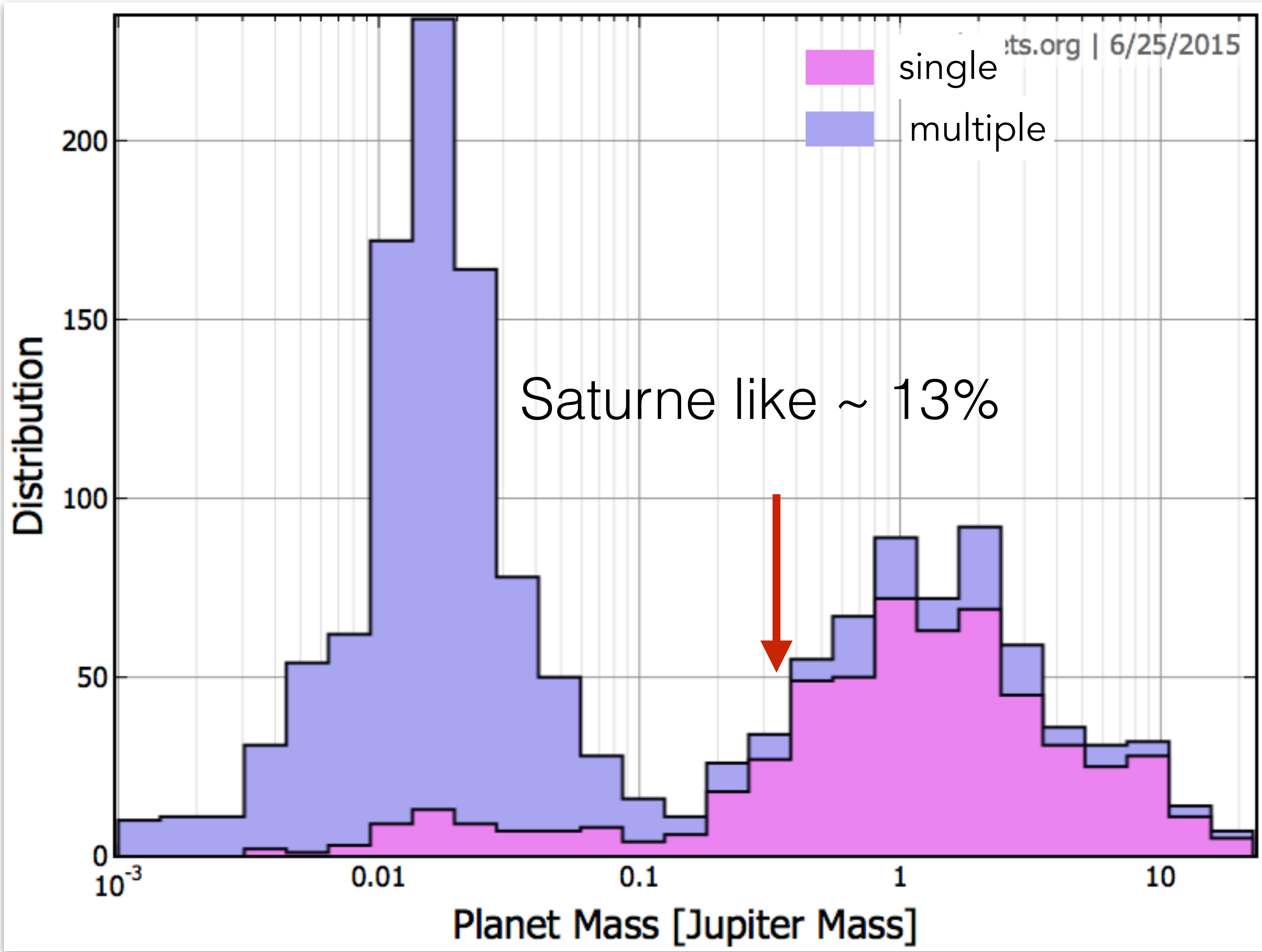


- **beta Picb fast spin**

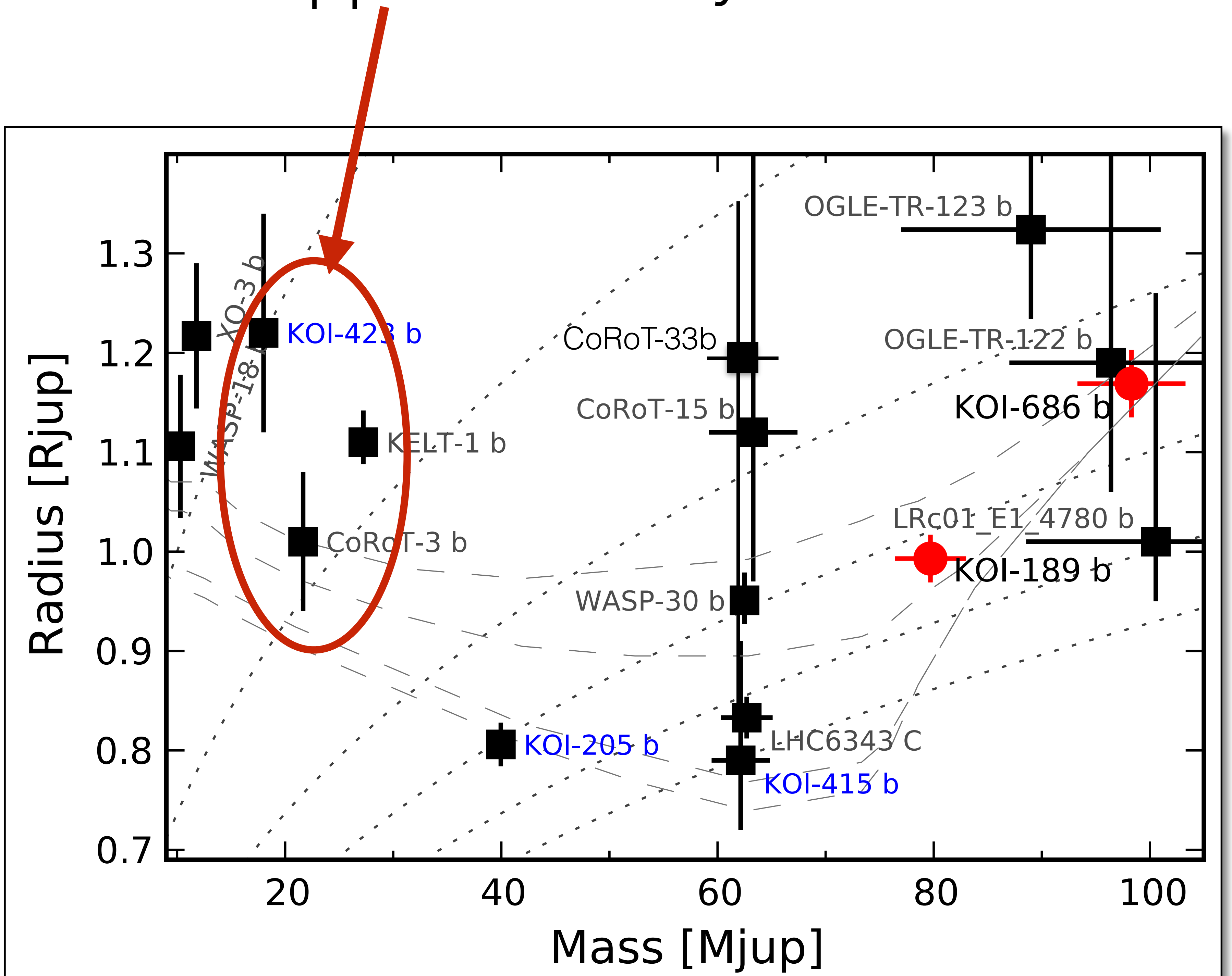
Snellen et al., Nature 2014

Giants:

- Saturn-like $M_p \in [0.15, 0.45[$
- Jupiter-like $M_p \geq 0.45$ and ?..

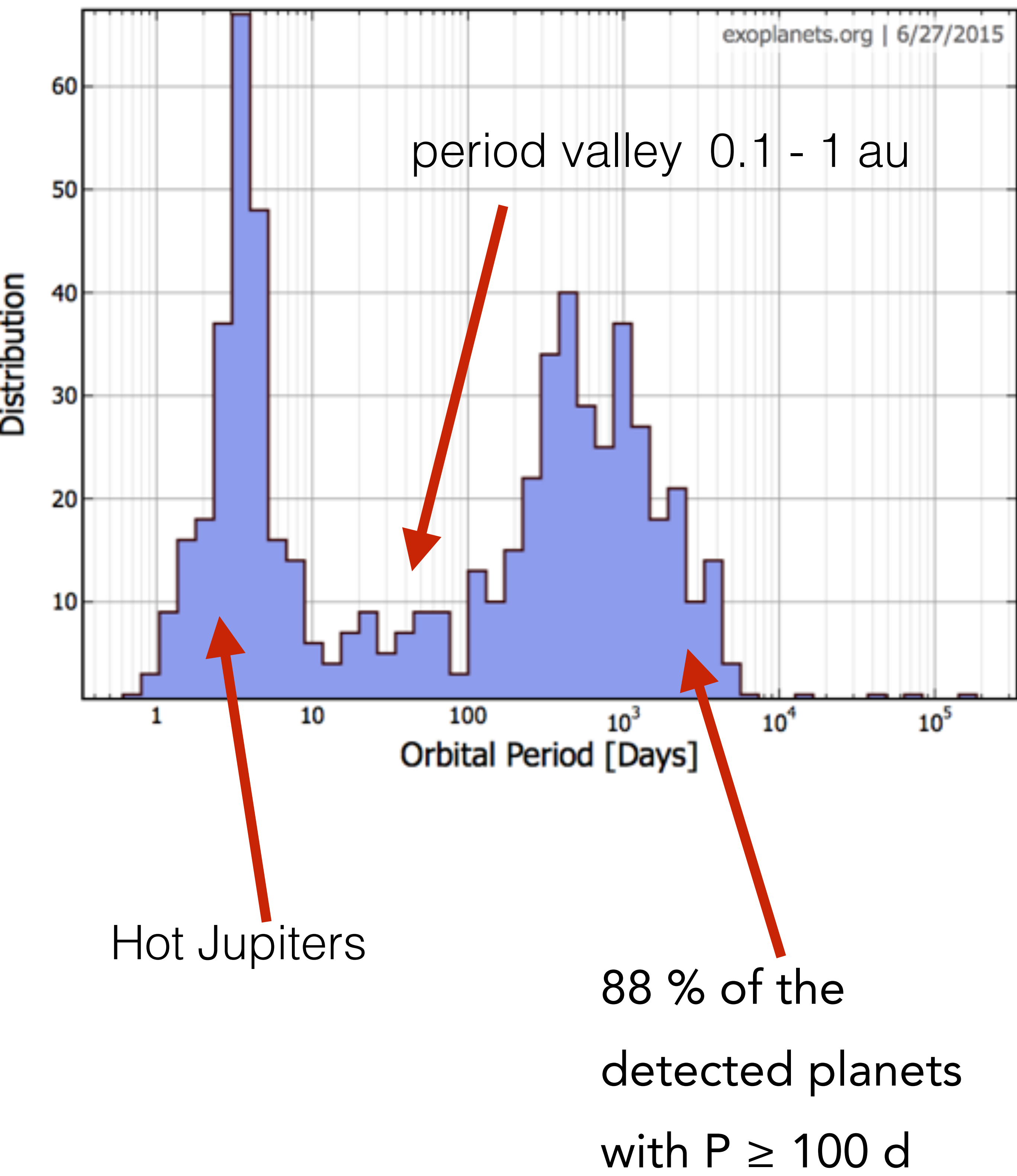


Mass upper boundary??



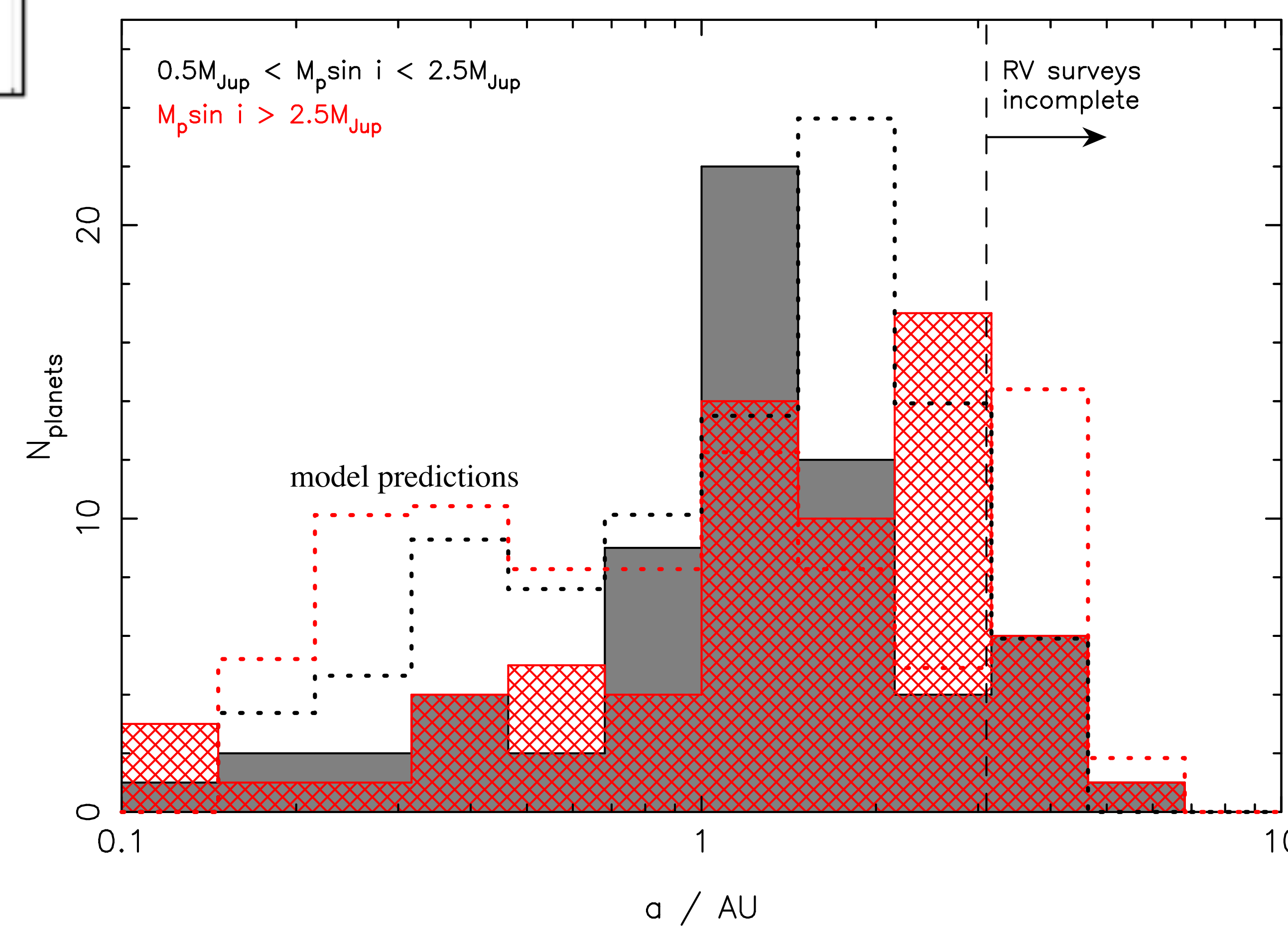
Deleuil et al., 2008; Bouchy et al., 2010, Johnson et al., 2011, Bouchy et al., 2011, Moutou et al., 2012, Diaz et al., 2013; Csizmadia et al., (submitted)

Udry et al., 2002

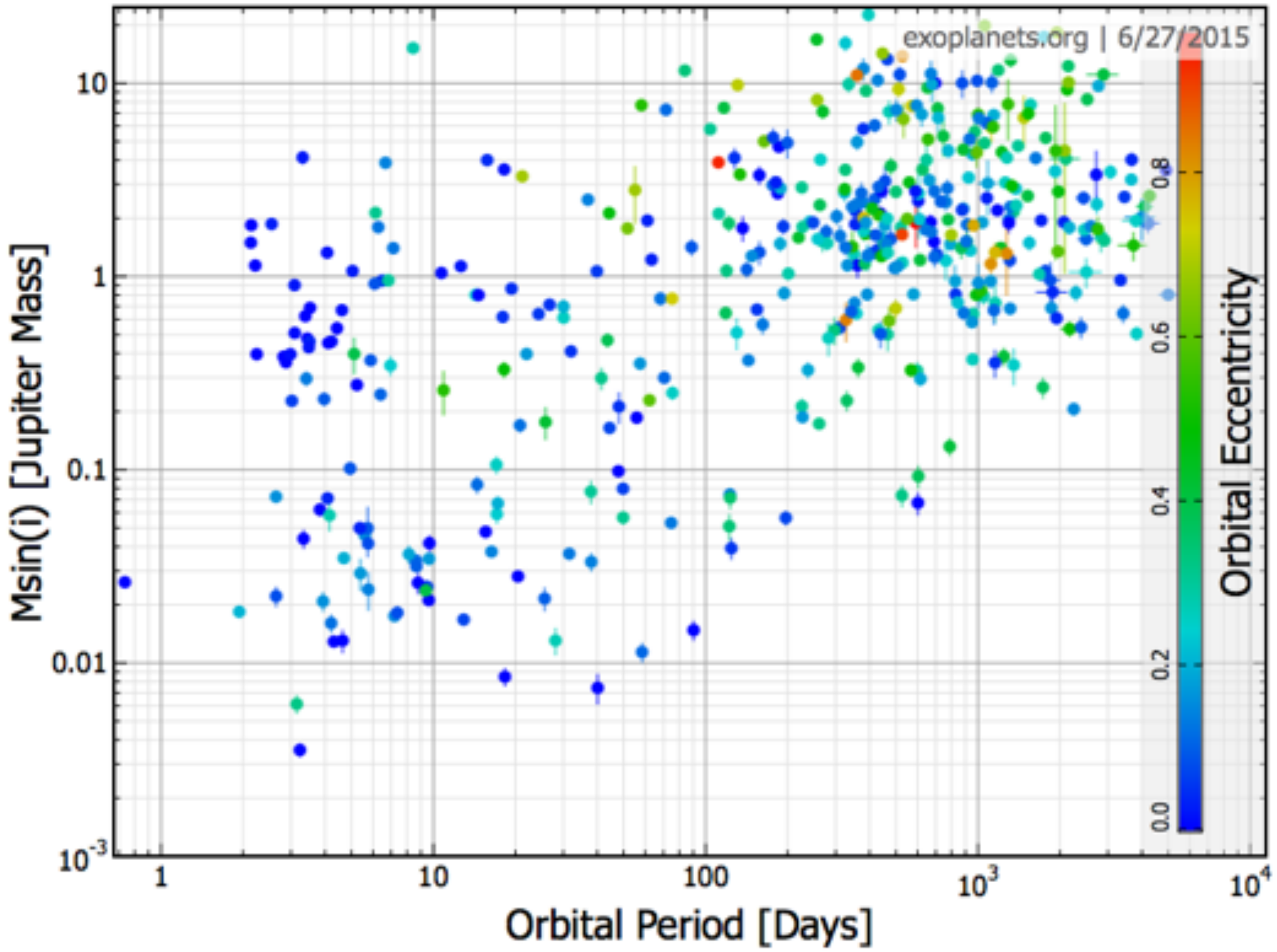


- pile-up at 3 days:
- excess of planets beyond 1 AU
- excess of planets beyond 1 AU

Formation beyond the snow line and migration



Alexander & Pascucci 2012



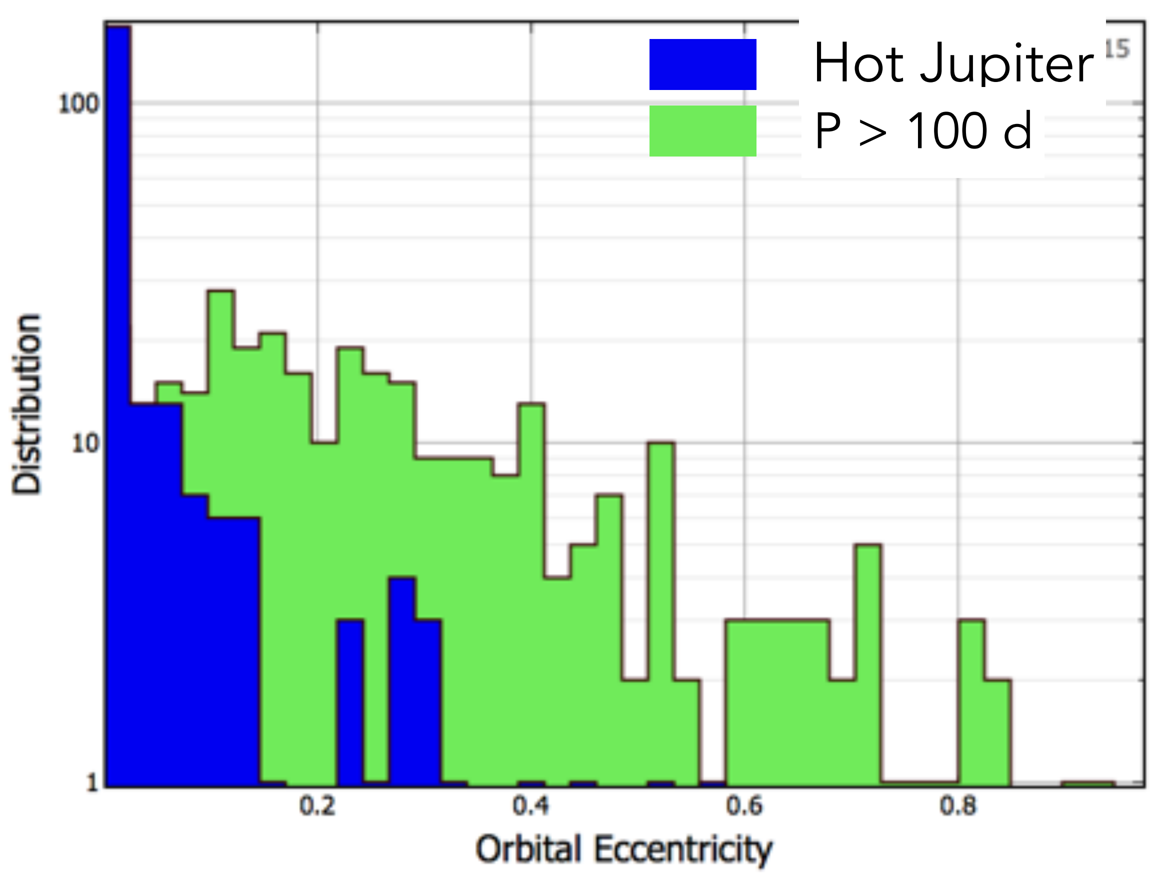
● **CoRoT-23b**

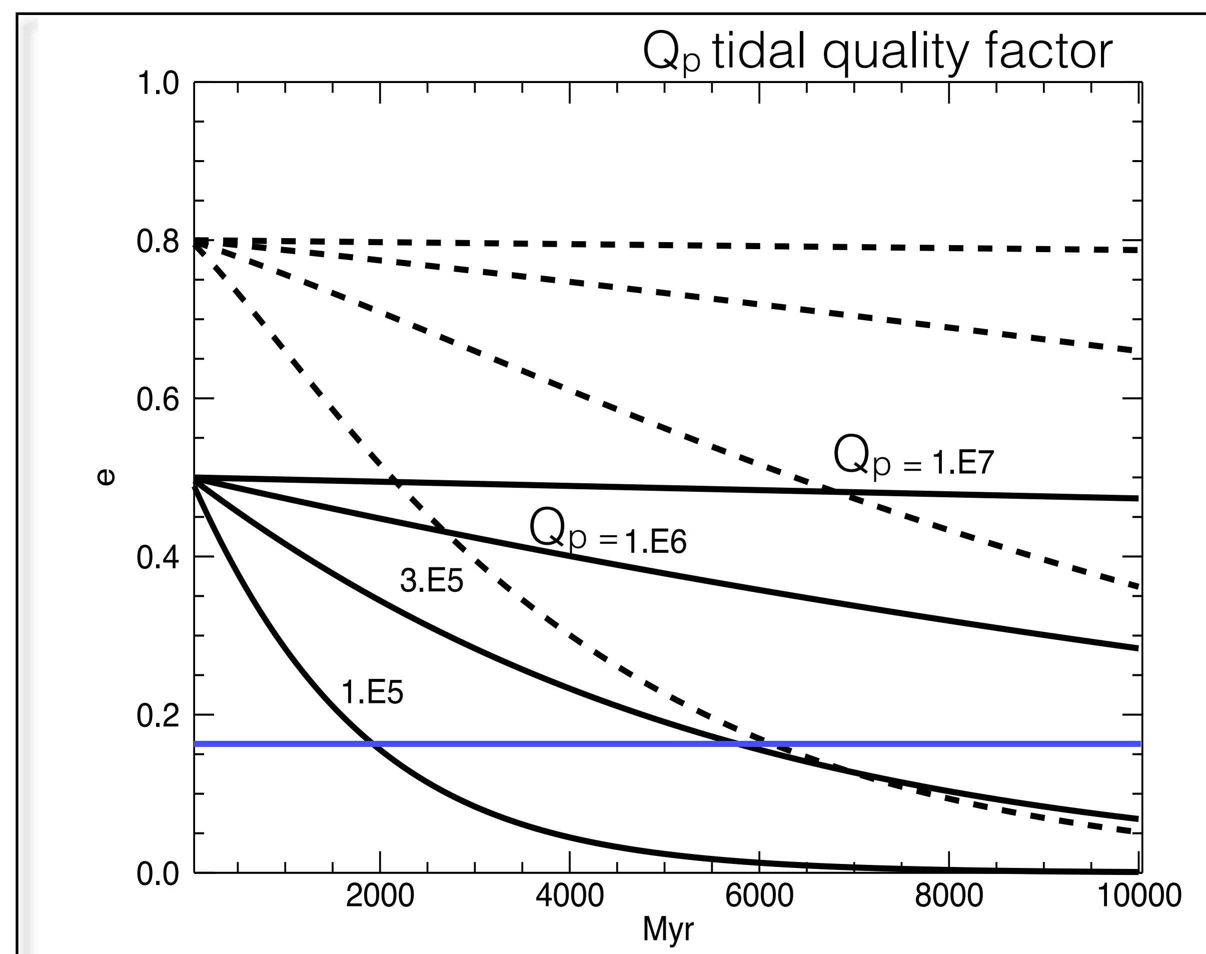
Mp = 2.8 ± 0.3 MJup

Rp= 1.05 ± 0.13 RJup

P = 3.6314 days

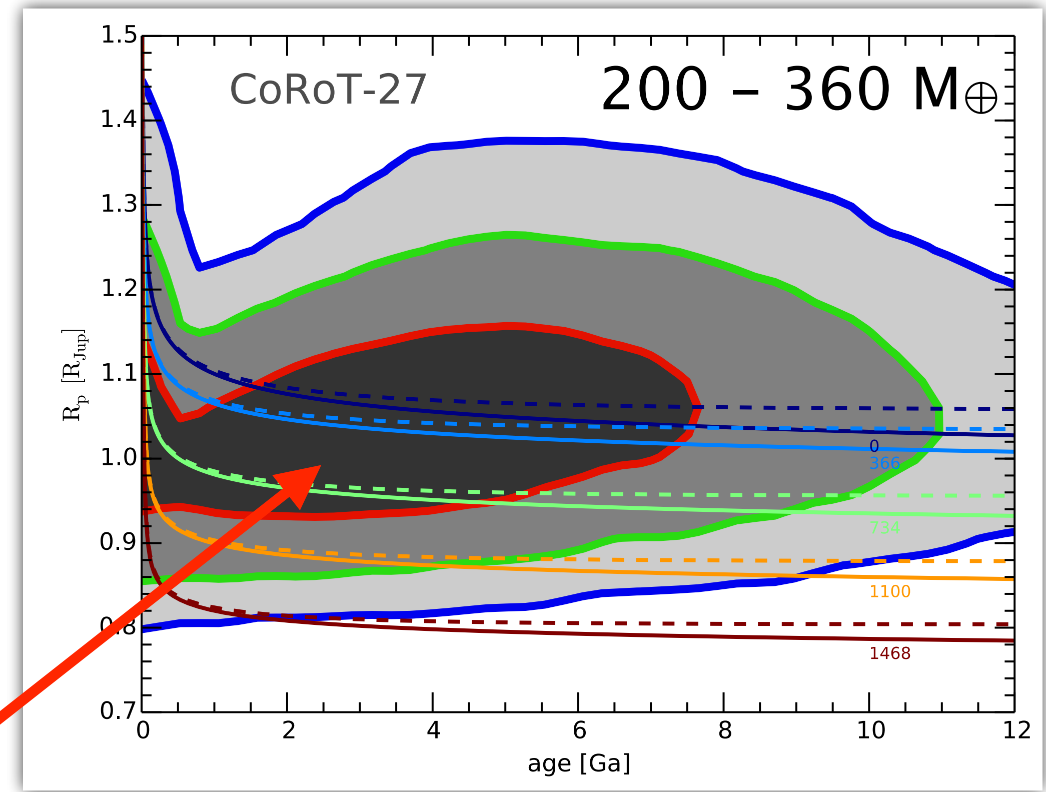
e = 0.16 Rouan et al., 2011



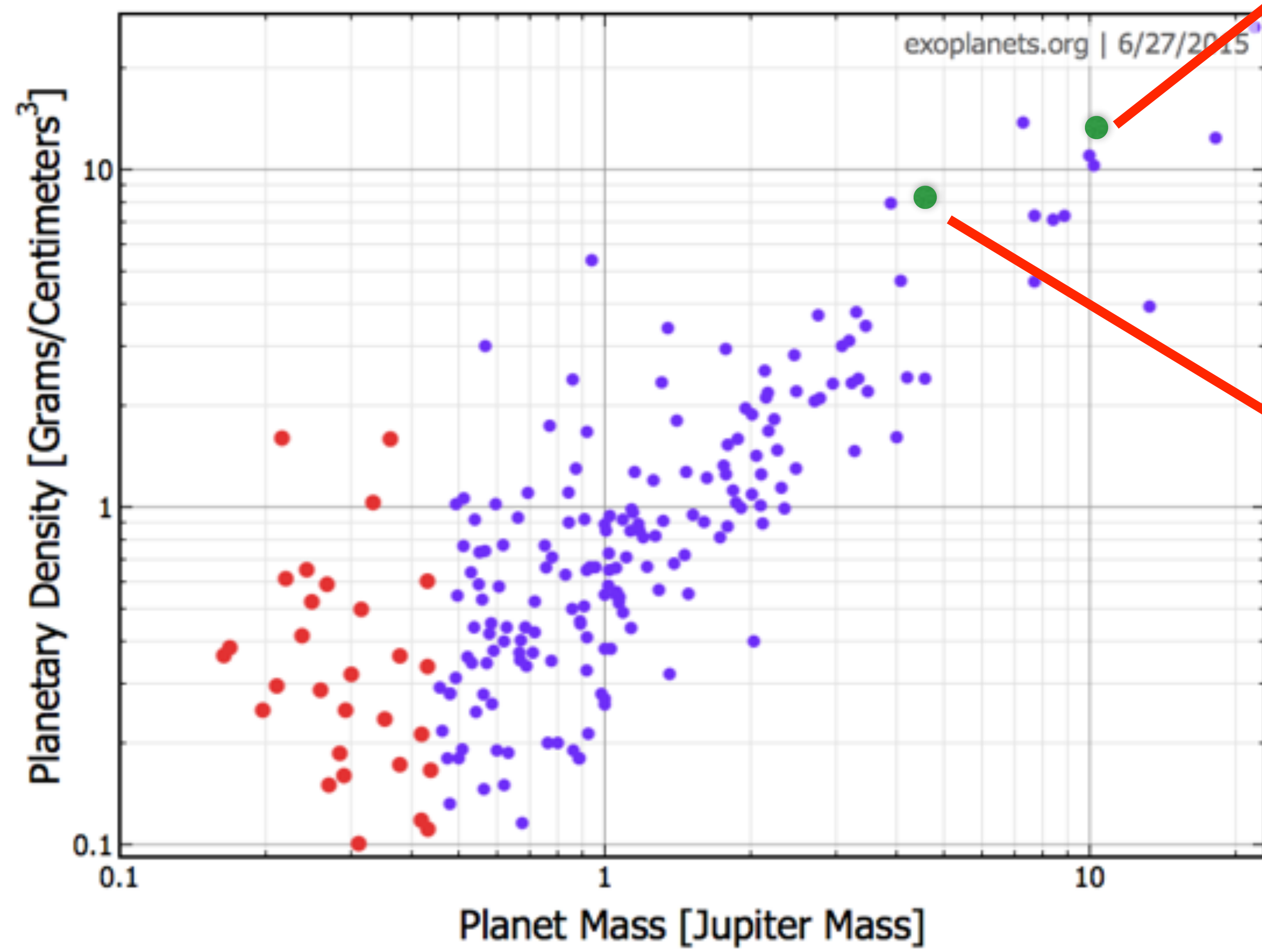


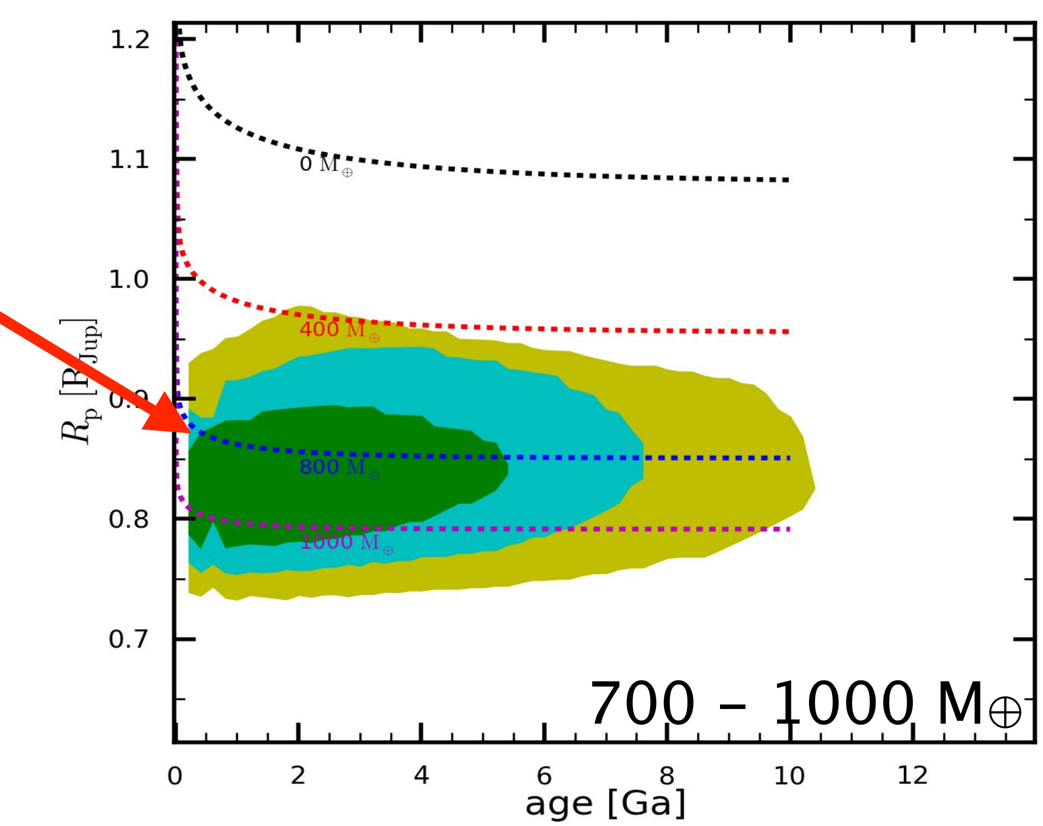
The hot Jupiter population

- Large diversity
- A population of gas giants with large amount of heavy elements has been found. Mechanism of formation?



Parviainen et al., 2013

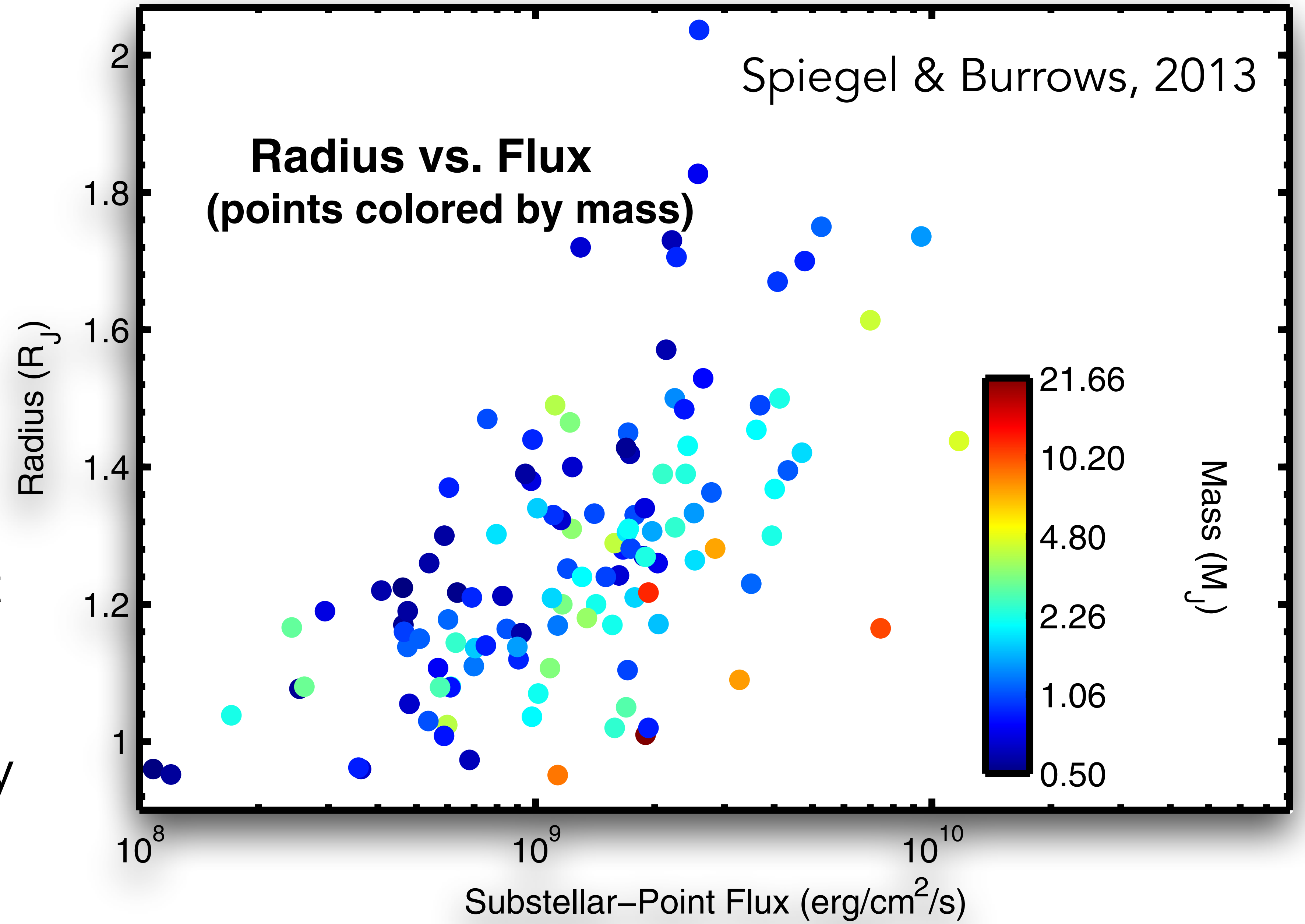




Deleuil et al., 2012

Inflated hot Jupiter

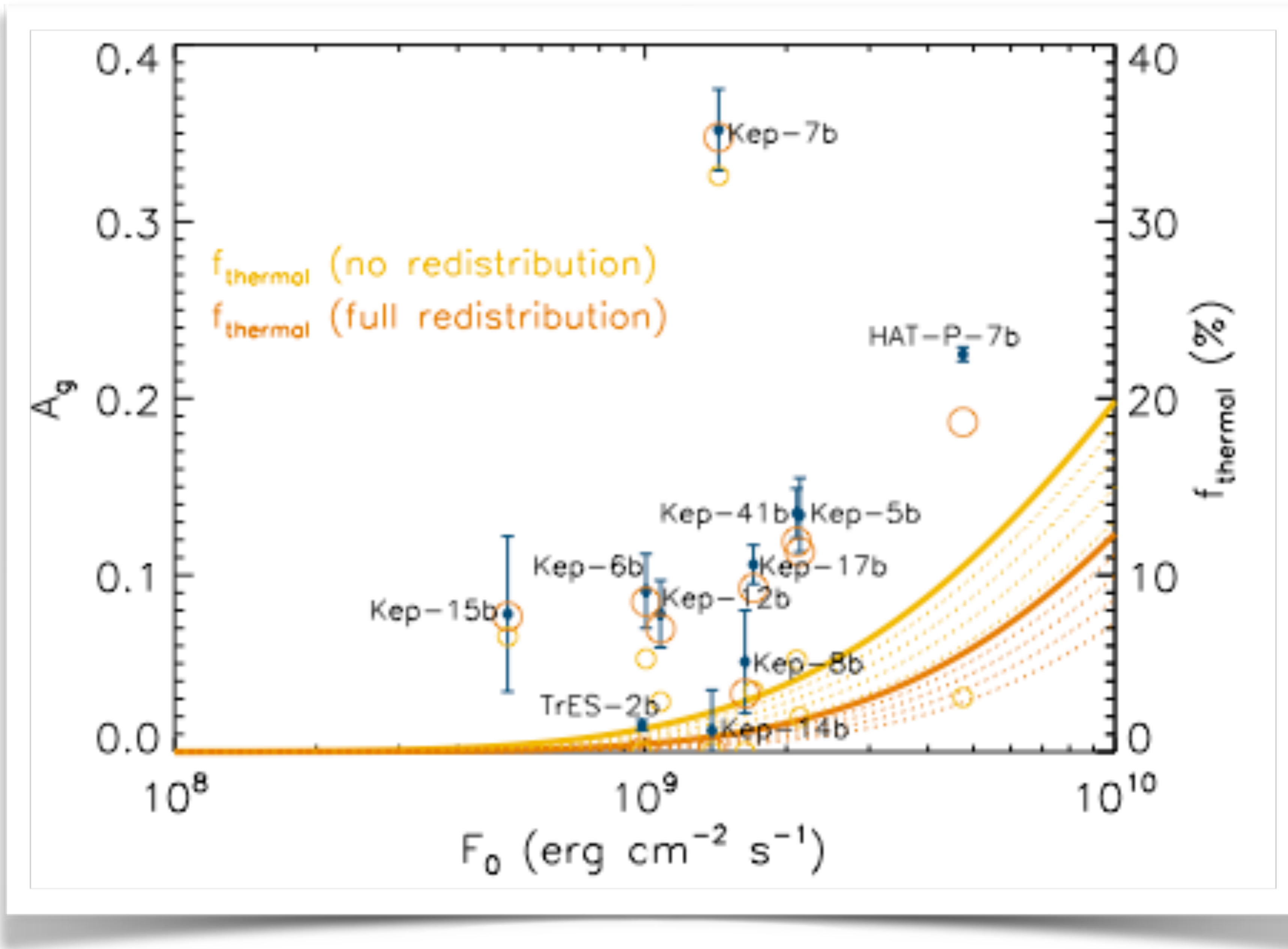
- additional energy deposit
  - tidal dissipation
  - ohmic or kinetic energy
- planet's properties
  - enhanced atmospheric opacities
  - double diffusive convection
  - coupling of the day and night sides



Bodenheimer et al. 2001; Guillot & Showman 2002; Burrows et al. 2007; Chabrier & Baraffe 2007; Leconte & Chabrier 2012; Youdin & Mitchell 2010; Batygin & Stevenson 2010 …

Dark hot Jupiters

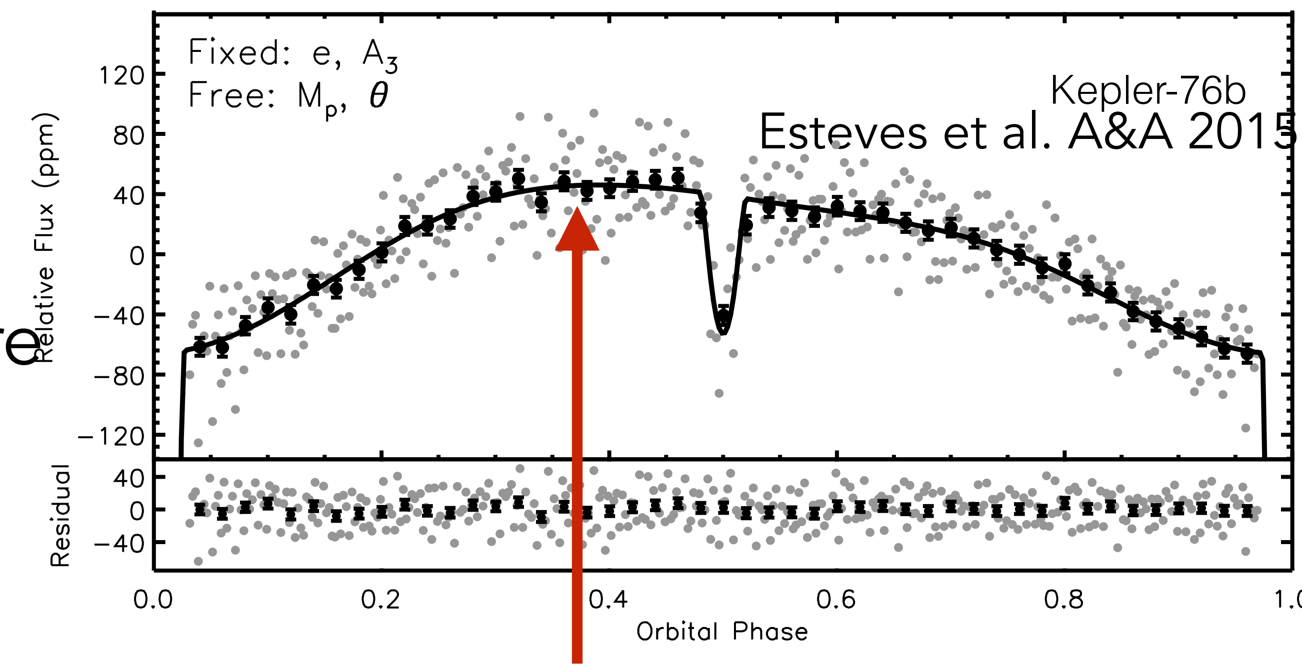
- albedo lower than giants in the solar system
- no correlation with the irradiation

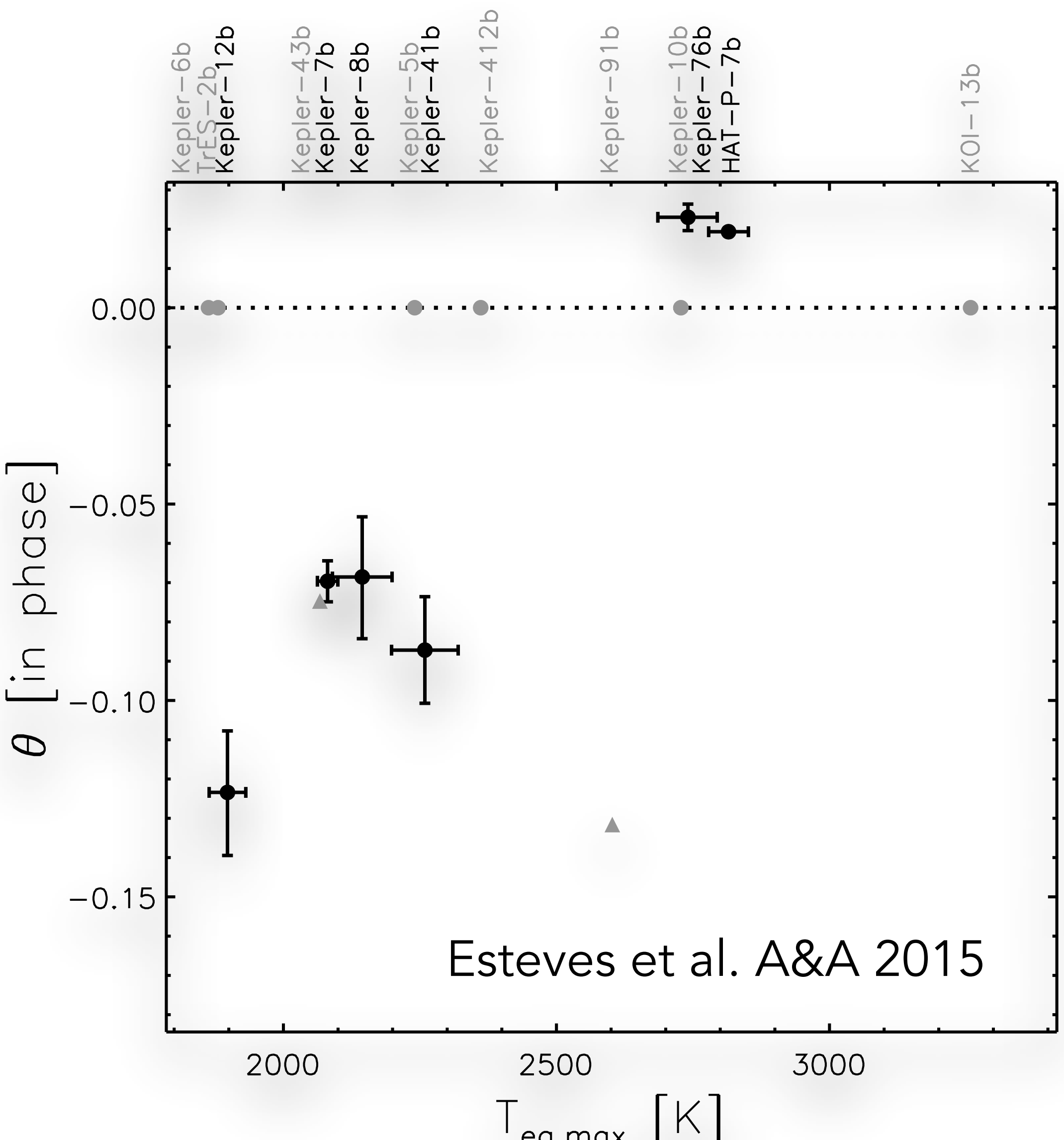


Heng & Demory, 2013 A&A

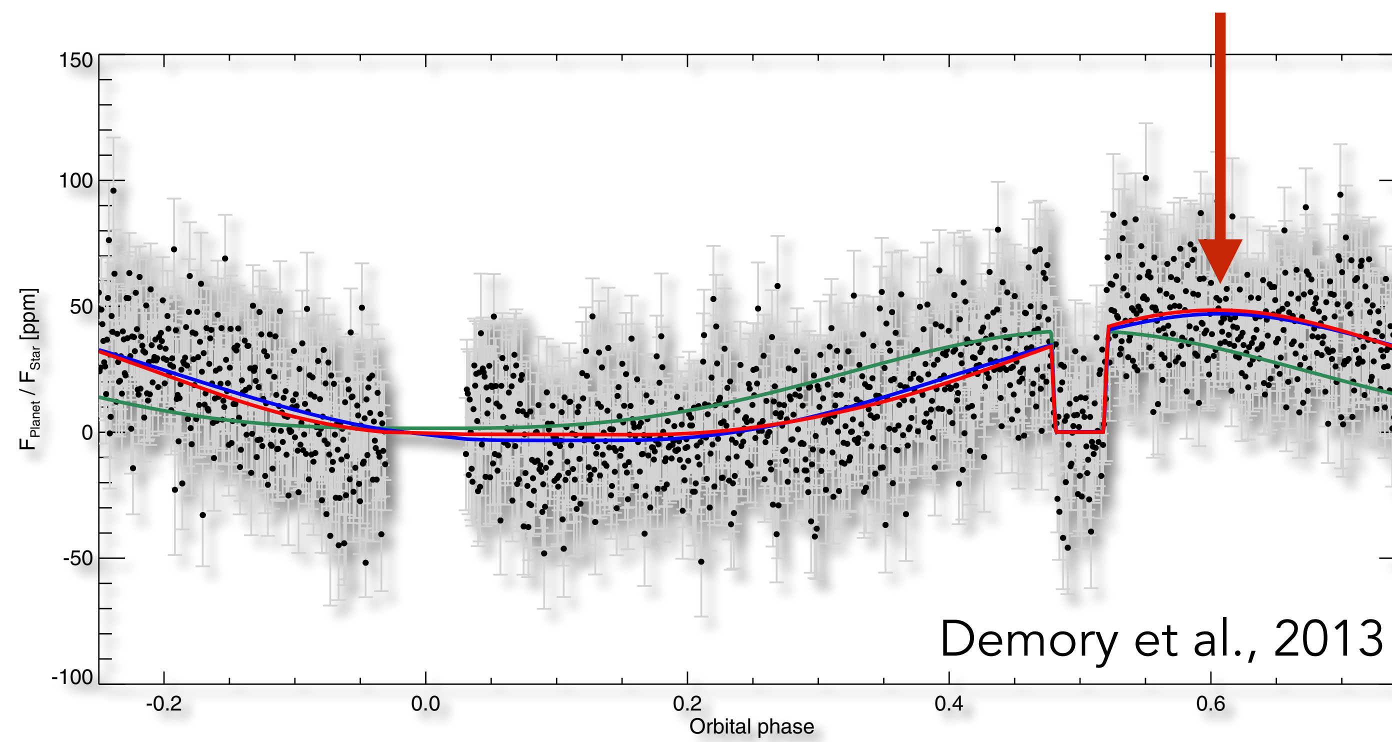
Dark hot Jupiters

- albedo lower than giants in the solar system
- no correlation with the irradiation
- heterogeneity in atmosphere structure and circulation





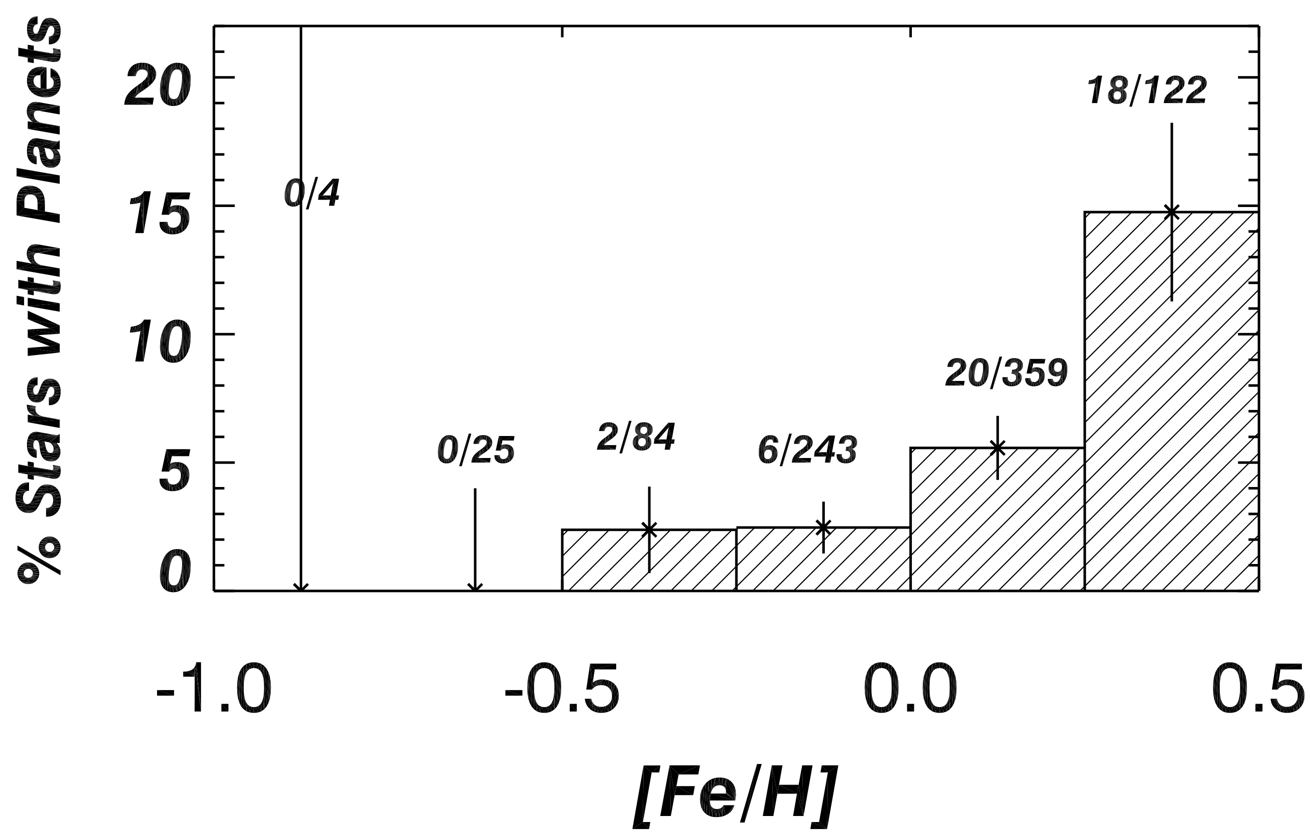
Shporer & Hu 2015



Angerhausen et al. 2014

The hot Jupiter population

- Strong correlation between the host-star metallicity and giants occurence frequency
- Favors core accretion formation

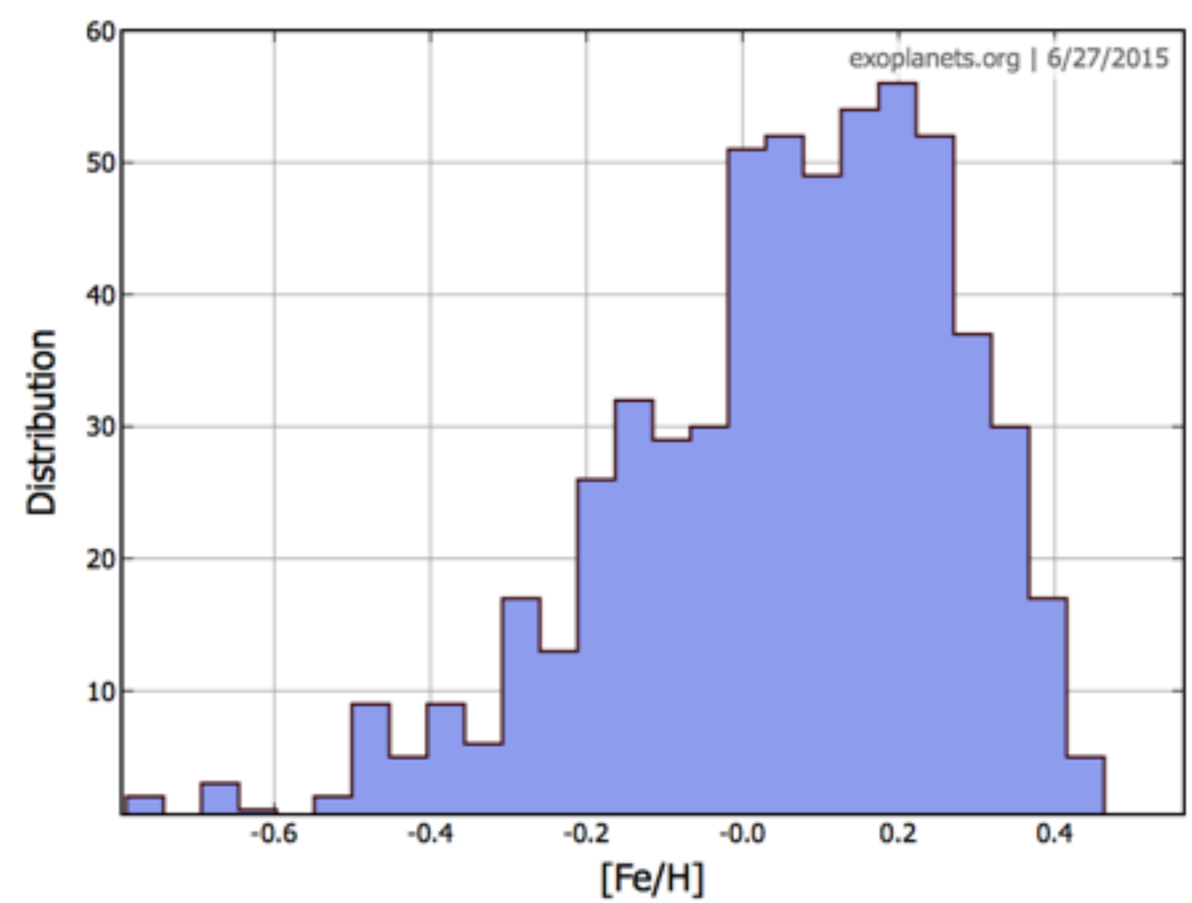


Gonzalez, 1997

Santos et al., A&A 2001, 2004,

Fisher & Valenti ApJ 2005

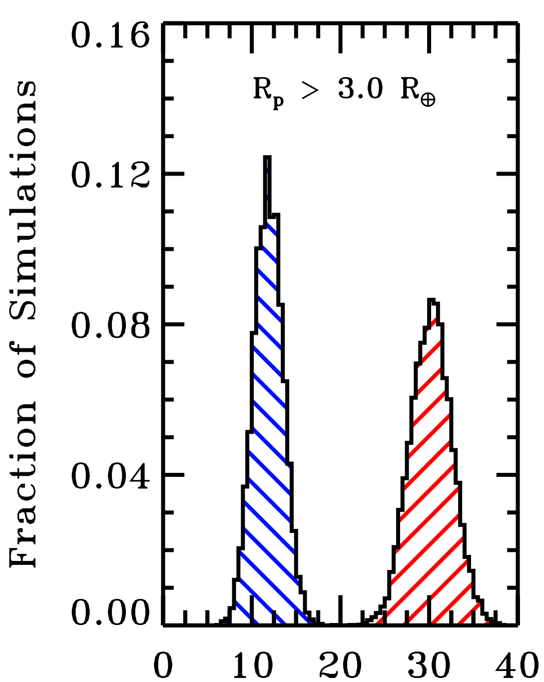
Sousa et al., A&A 2008



Hot Jupiter occurence

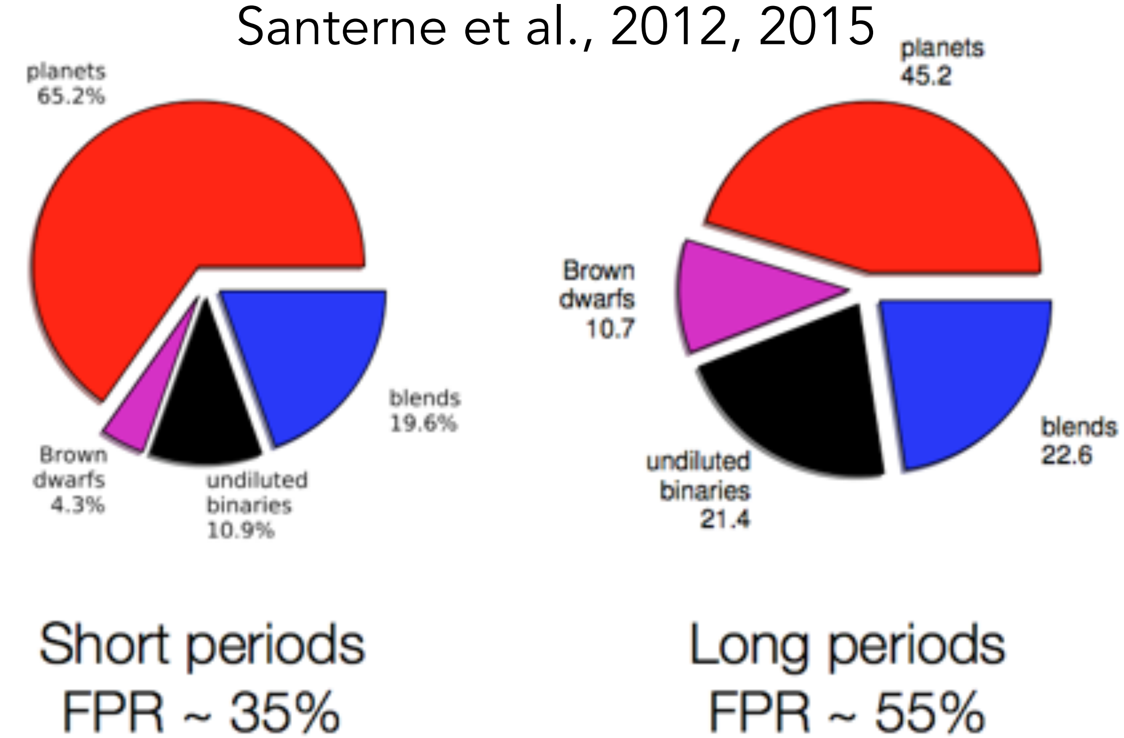
- FGK dwarfs solar neiborhood
  - Mayor et al., 2011: 0.89% ± 0.36
  - Wright et al., 2012: 1.2 ± 0.38 (Marcy et al., 2005: 1.2% ± 0.1%)

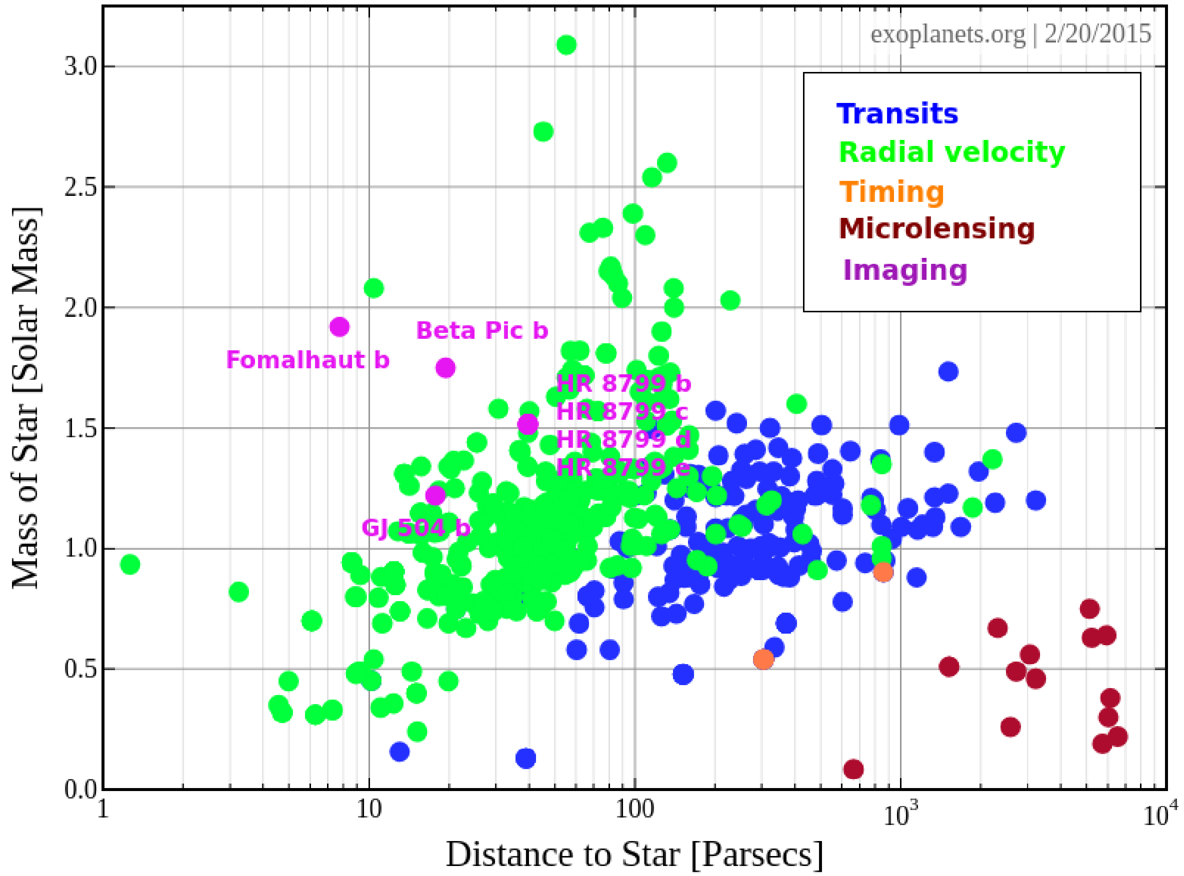
- FGK dwarfs transit surveys
  - Howard et al., 2012: 0.41% ± 0.1
  - Fressin et al., 2013: 0.43% ± 0.05
  - Santerne et al., 2012: 0.57% ± 0.7 from radial velocity observations of Kepler candidates
  - Ciardi et al., 2015; Wang et al., 2015: HJs are misidentified as smaller planets due to photometric dilution:



Ciardi et al., 2015

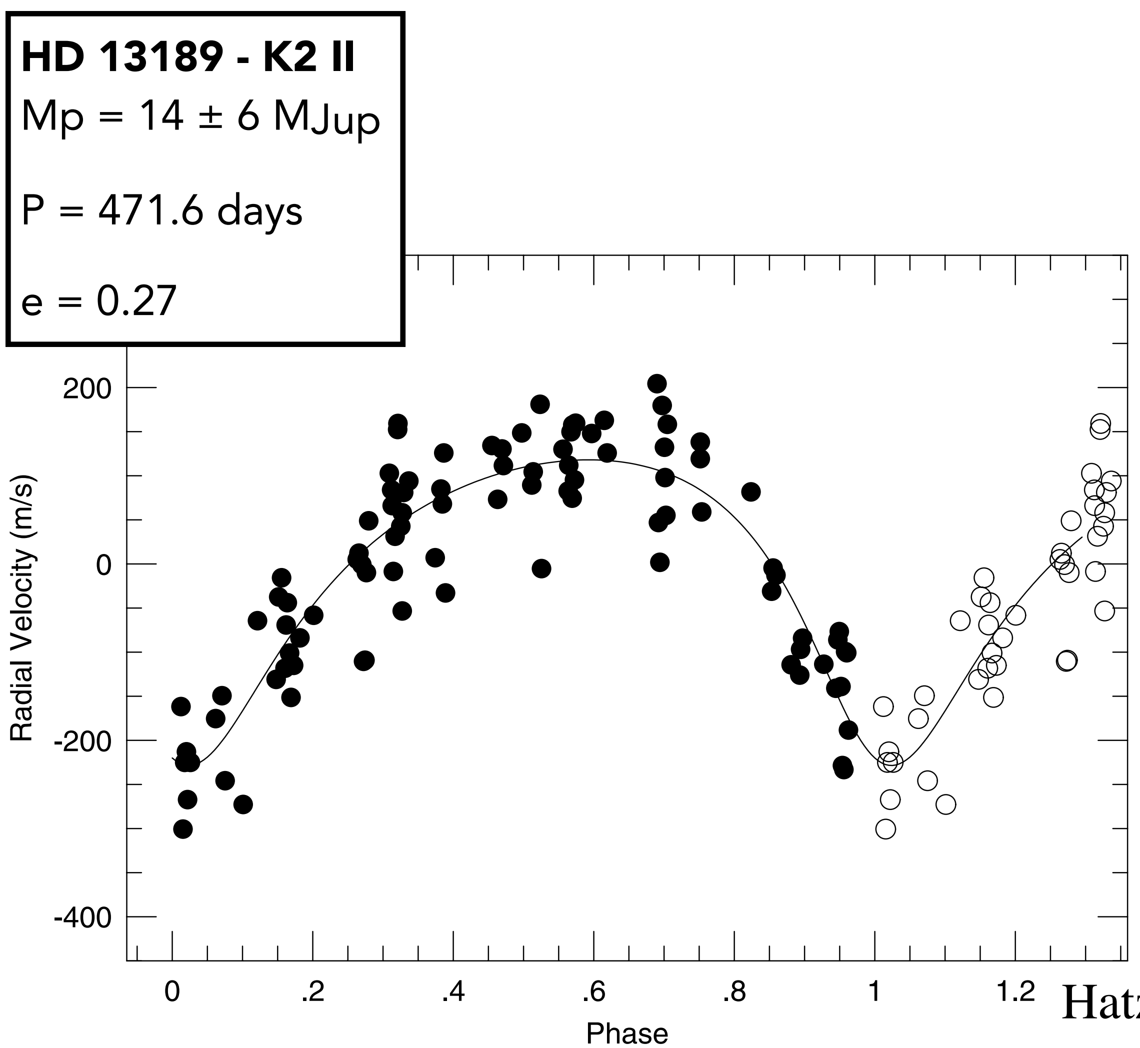
Santerne et al., 2012, 2015



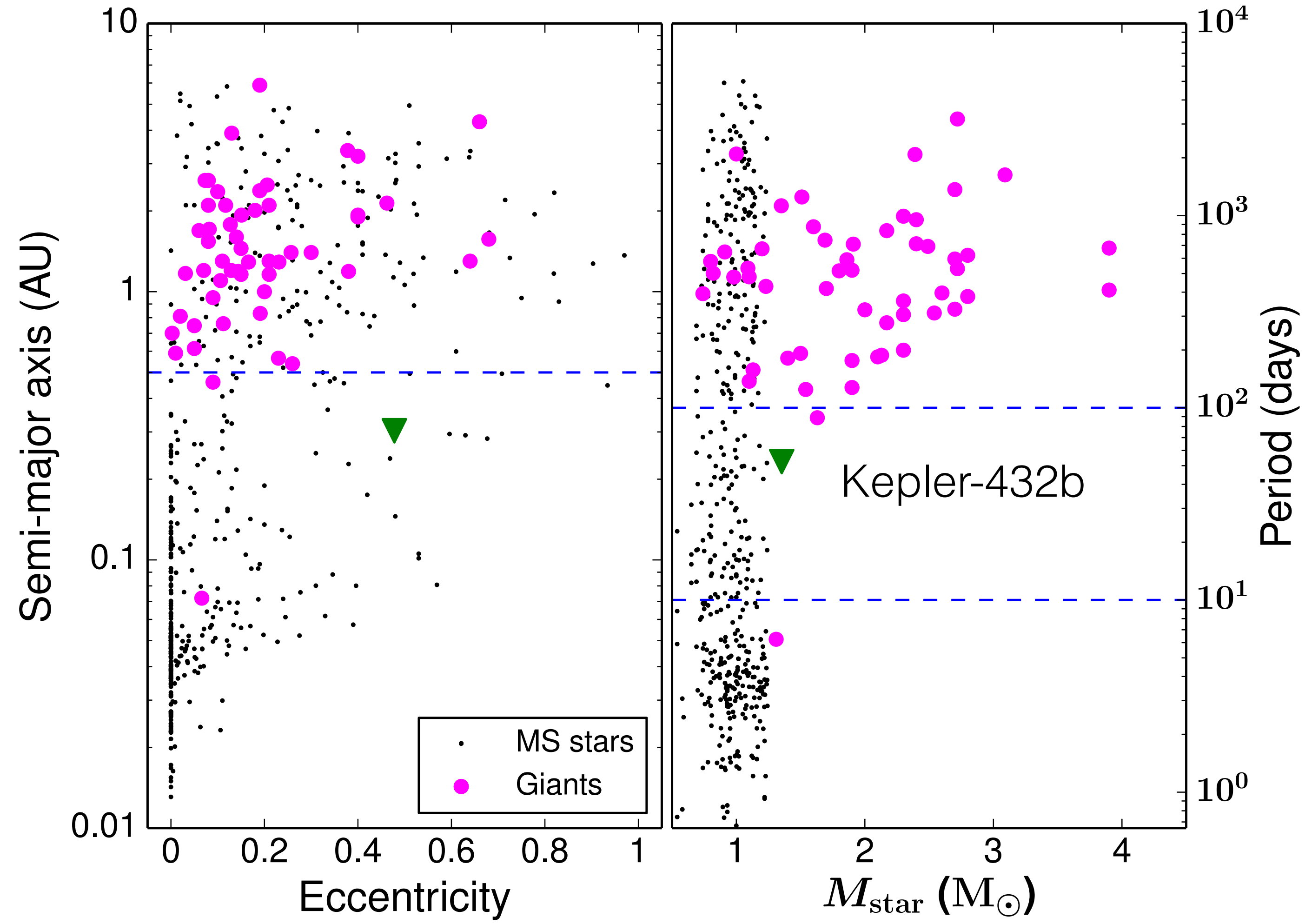


Giants around evolved stars

- Hot Jupiters are rare
- Lower eccentricities than giants around MS
- Most are long-period giant planets



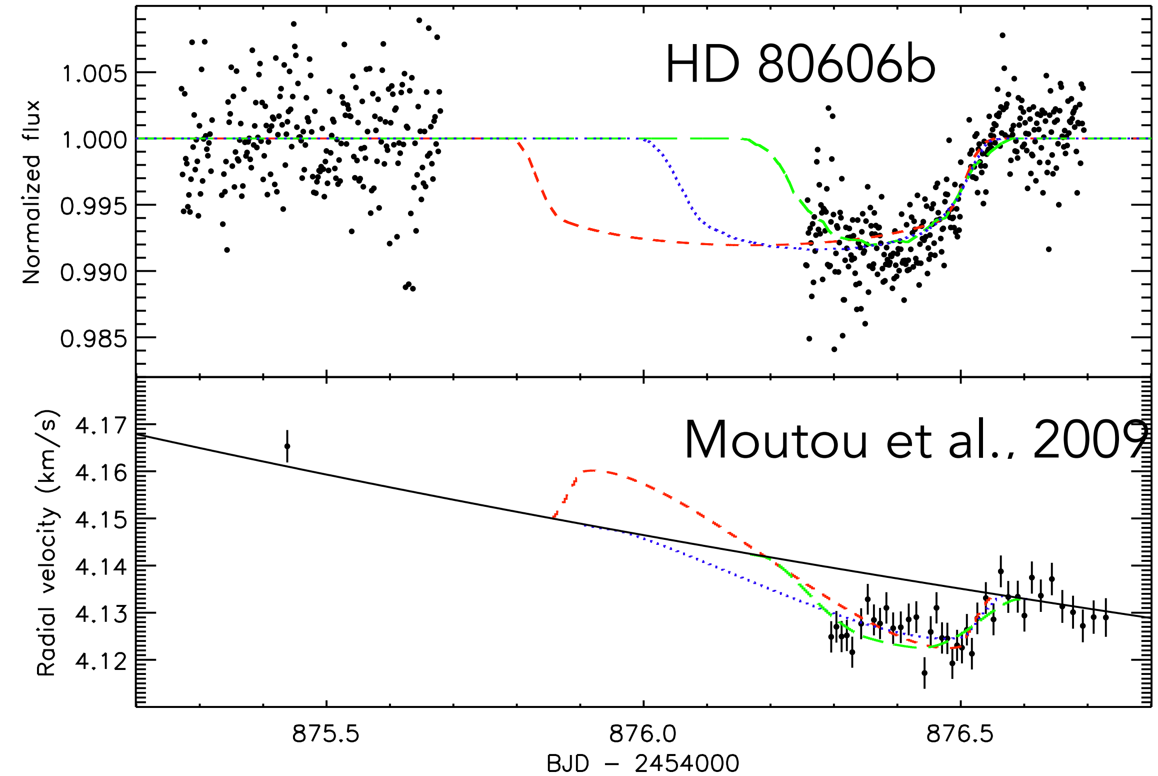
Hatzes et al., 2005

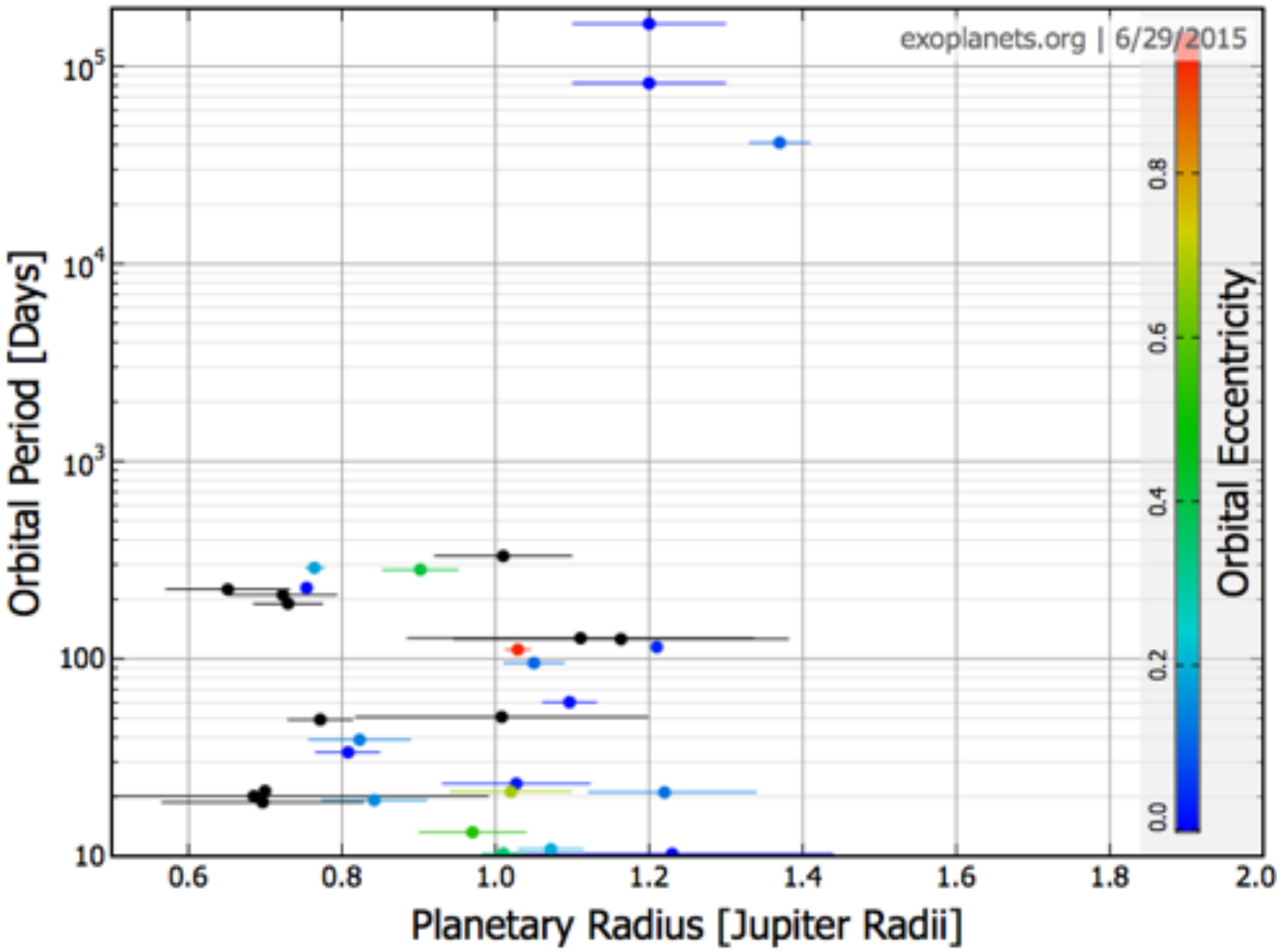


Ortiz et al., 2015

Giants at long orbital period

- very few planets with radius measured
- large dispersion in eccentricities





HD 80606b

$R_p = 0.98 \pm 0.03\ R_{Jup}$

$M_p = 3.94 \pm 0.11\ M_{Jup}$

$\rho = 7.95 \pm 0.69\ g/cm^3$

P = 111.43 days

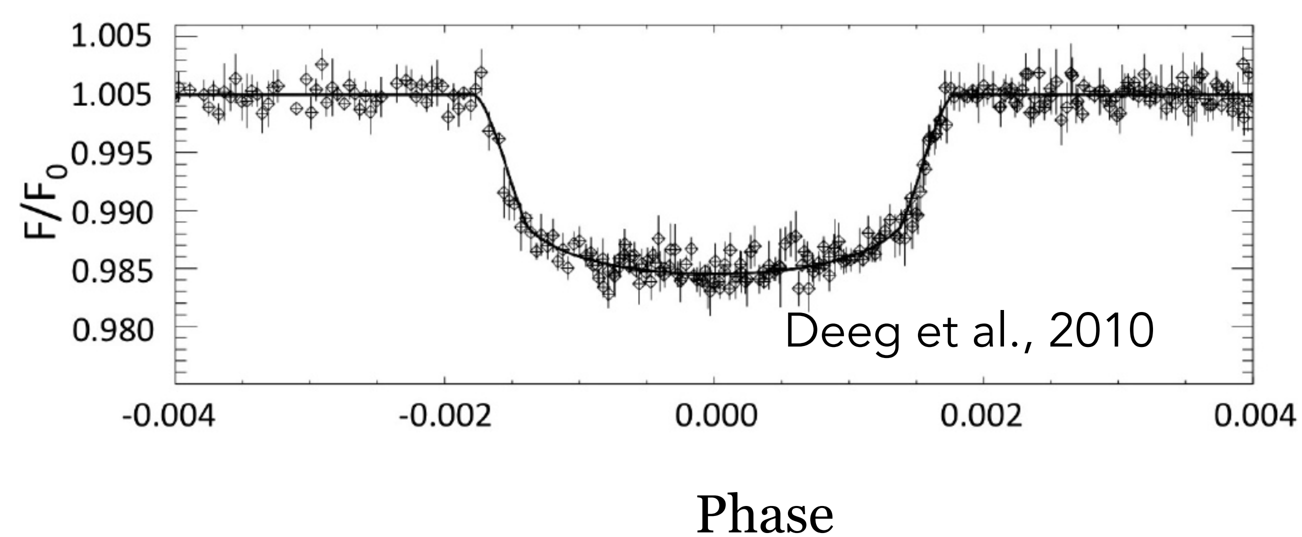
CoRoT-9b

$R_p = 1.05 \pm 0.04\ R_{Jup}$

Mp = 0.844 ± 0.072 MJup

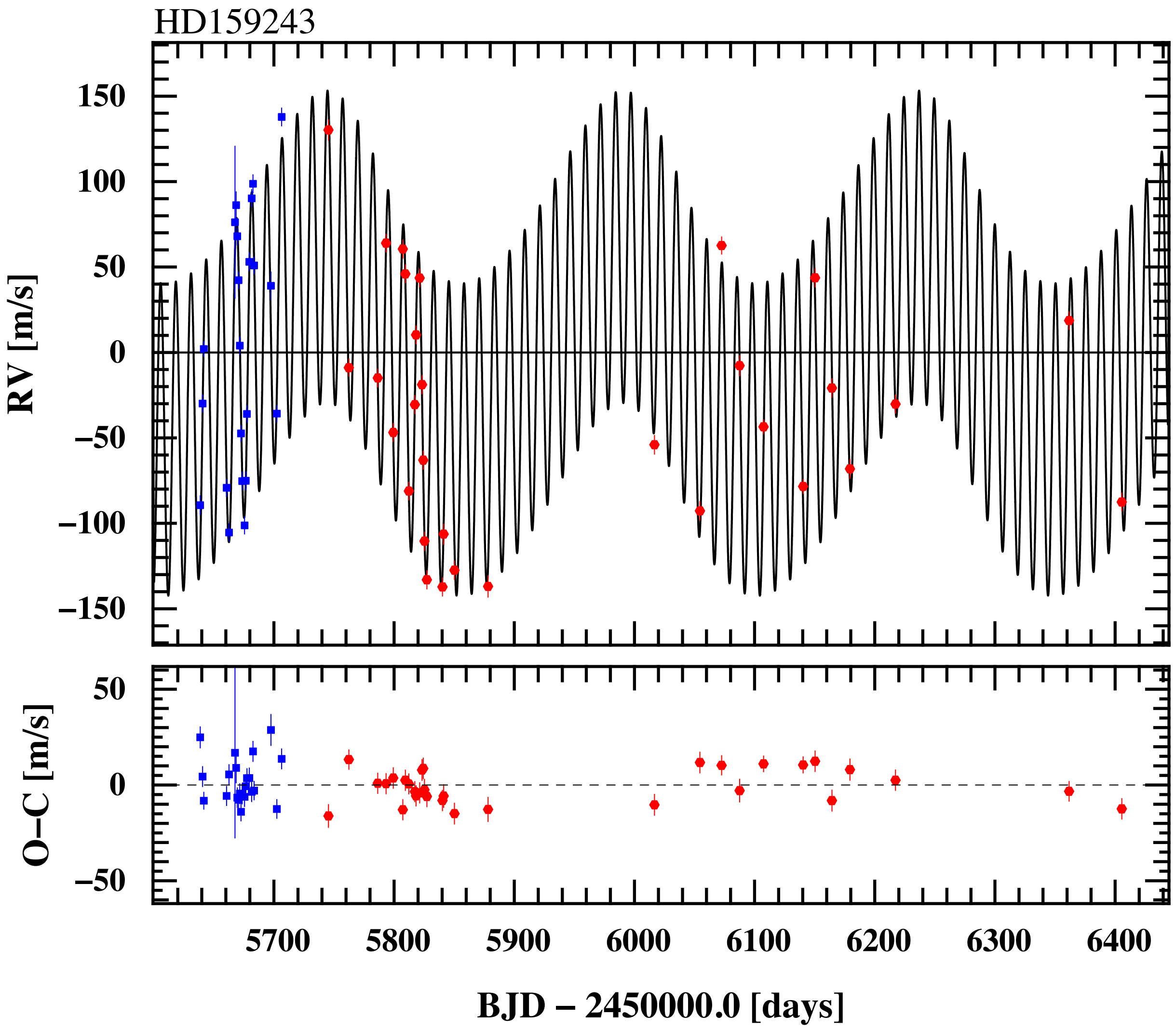
$\rho = 0.9 \pm 0.13\ g/cm^3$

P = 95.27 days



Moutou et al., A&A 2014

Hot Jupiters can belong to multisystems



- HD 159243

$m_2 \sin i_b$ = 1.13 ± 0.05 M_{Jup},

P_b = 12.620 ± 0.004 days

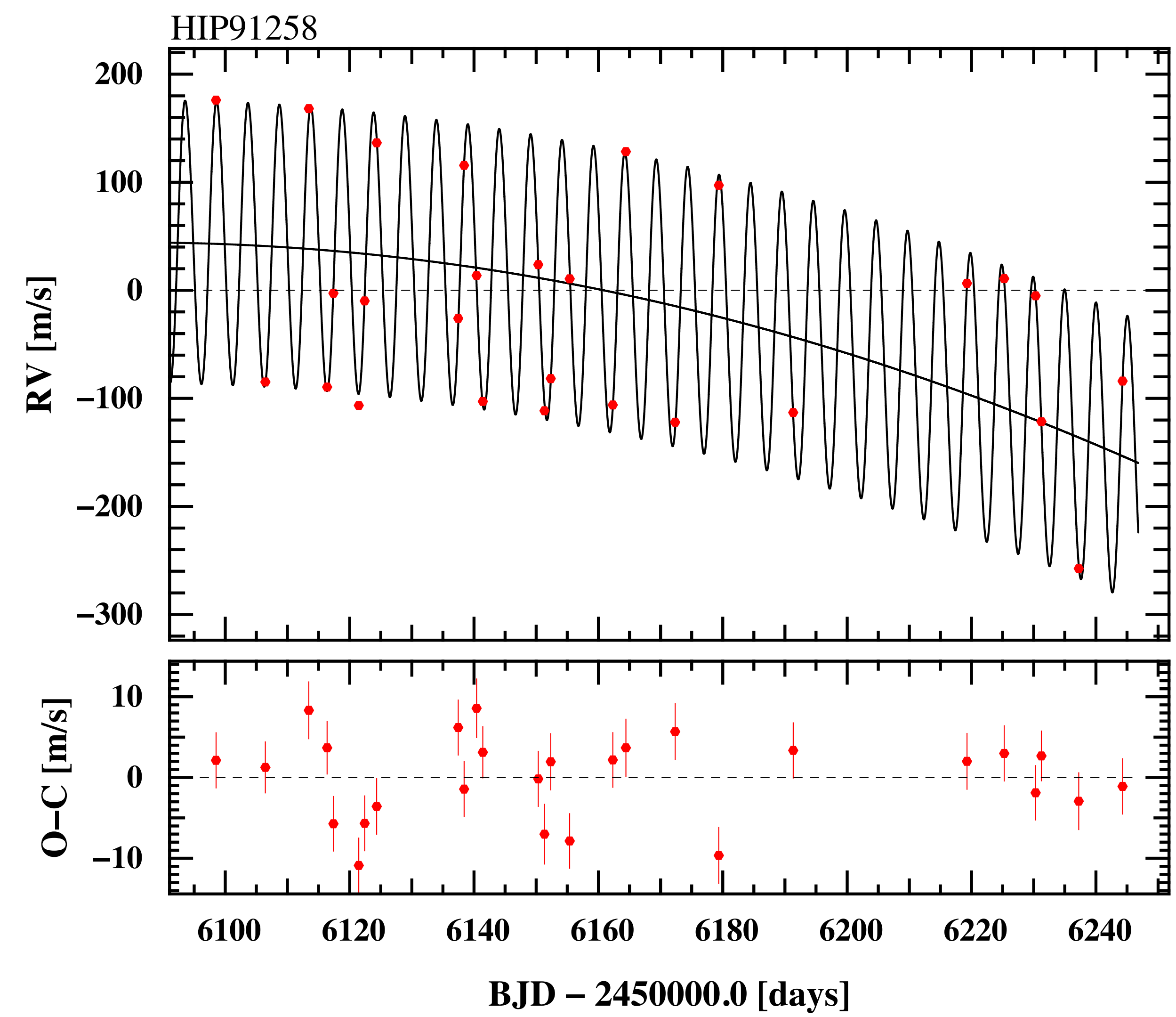
$m_2 \sin i_c$ = 1.9 ± 0.13 M_{Jup} ,

P_c = 248.4 ± 4.9 days

- HIP 91258b

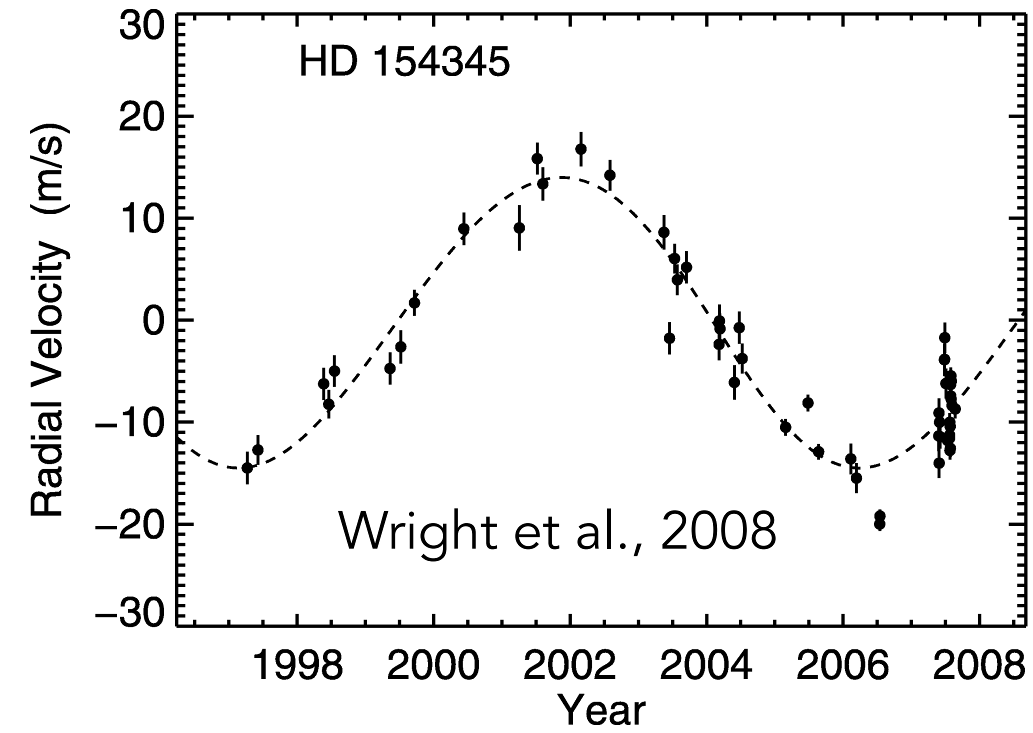
$m_2 \sin i$ = 1.068 ± 0.038 M_{Jup}, P = 5.050 days

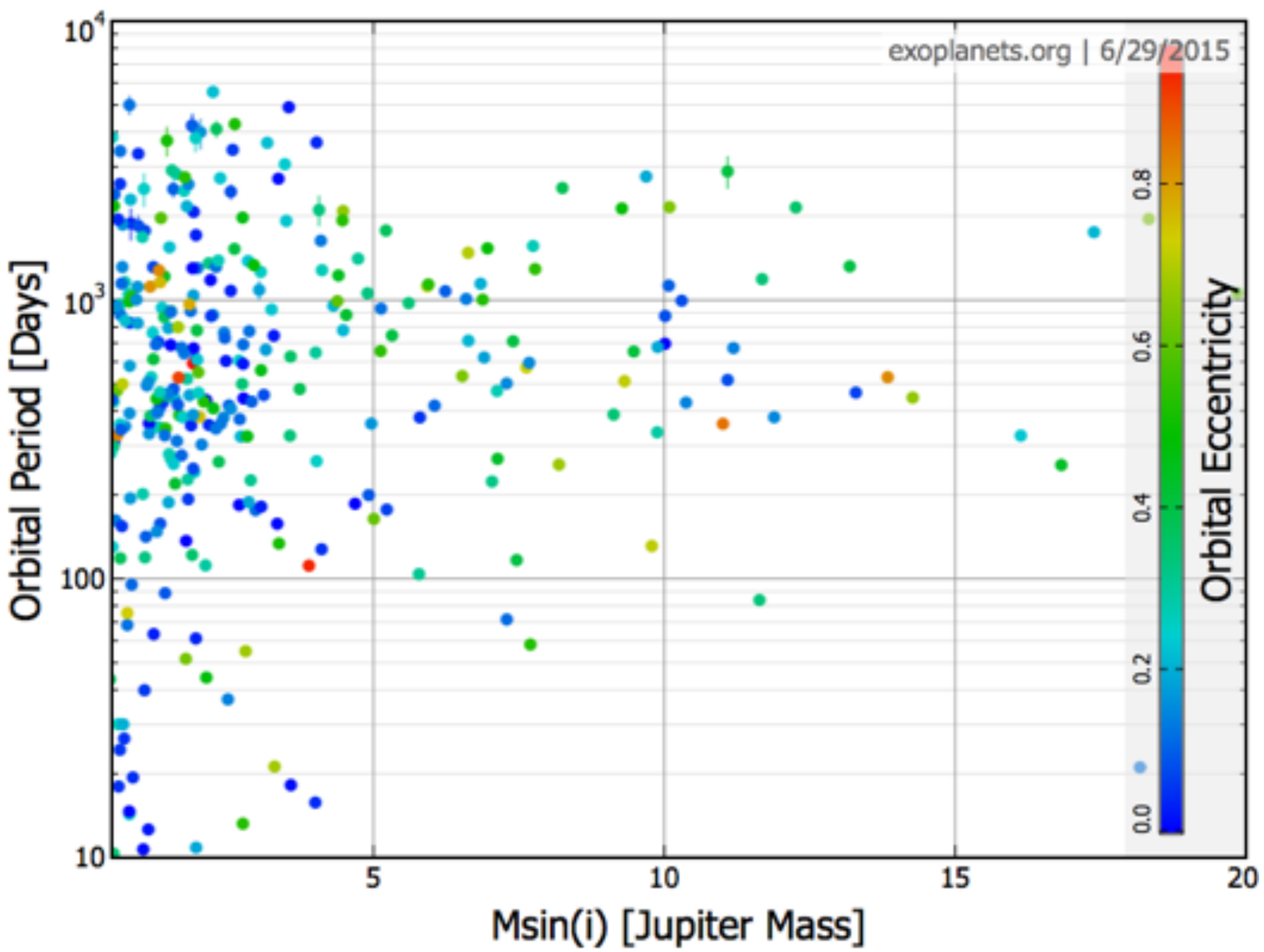
$m_2 \sin i$ > 2.5 M_{Jup} , P > 150 days

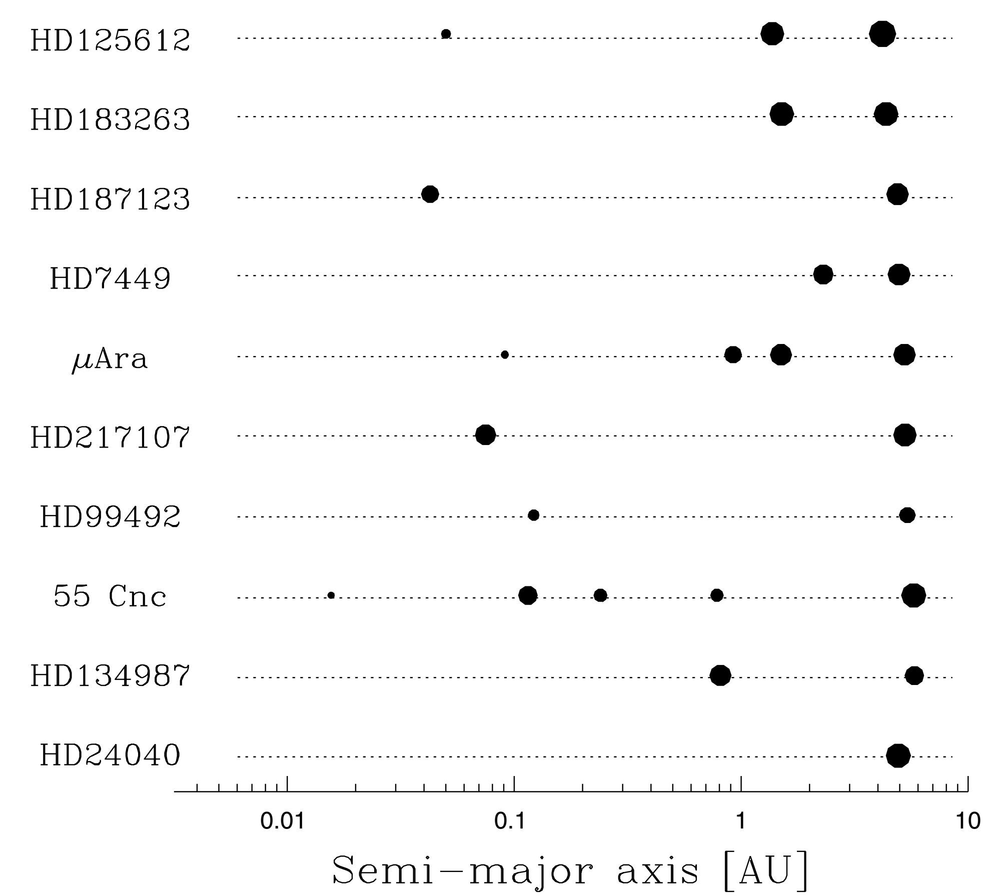


Jupiter analogs

- no radius measured
- large dispersion in eccentricities - still
- multi planet systems







Boisse et al., 2012,
Marmier et al., 2013

Summary

- Not a complete and exhaustive review!
- majority of giants are Jupiter like planets
- still account for the large majority of the planets detected at large orbital period
- Large diversity in orbital and physical properties
- Hot Jupiters are extremely rare
- environment enriched in heavy material favours hot jupiter formation
- paucity of packed multiple systems in the presence of giant planets
- hot Jupiters are not necessarily single
- the gas-giant planet population around evolved stars possesses different orbital properties than the population orbiting main-sequence stars
- very (too) few giants characterized at long orbital period
- still the tip of the population .. long term monitoring still needed