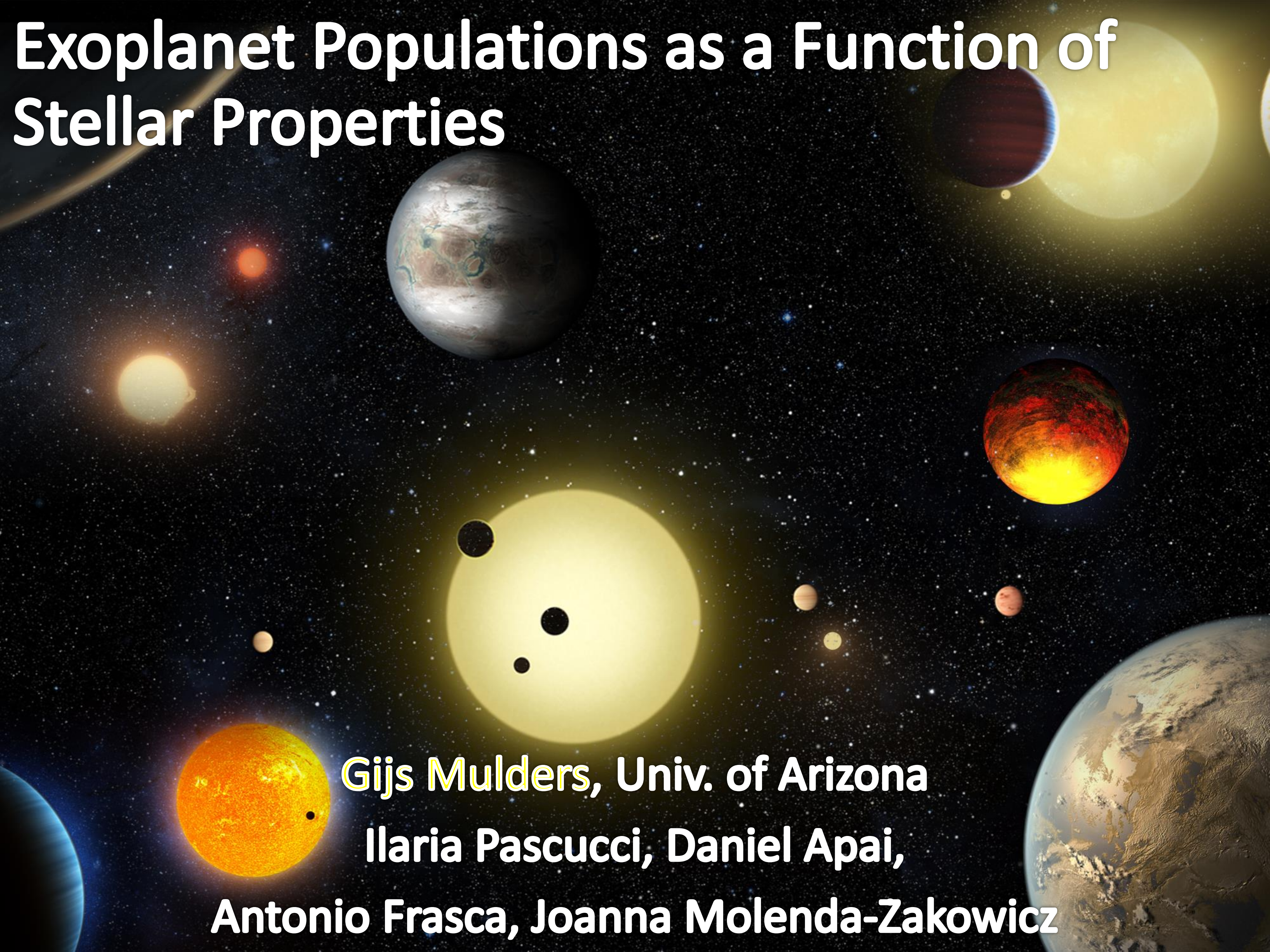
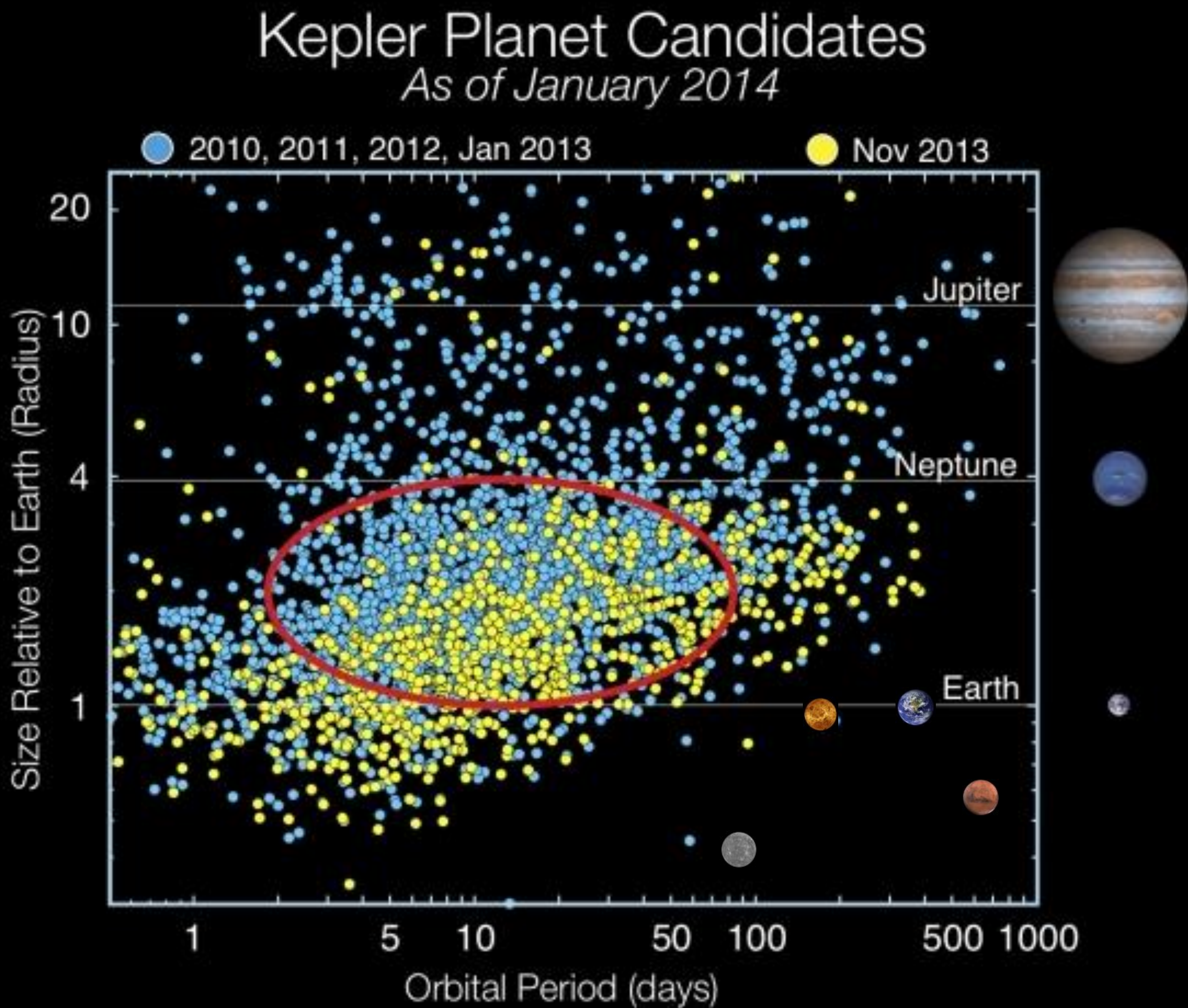
Exoplanet Populations as a Function of Stellar Properties

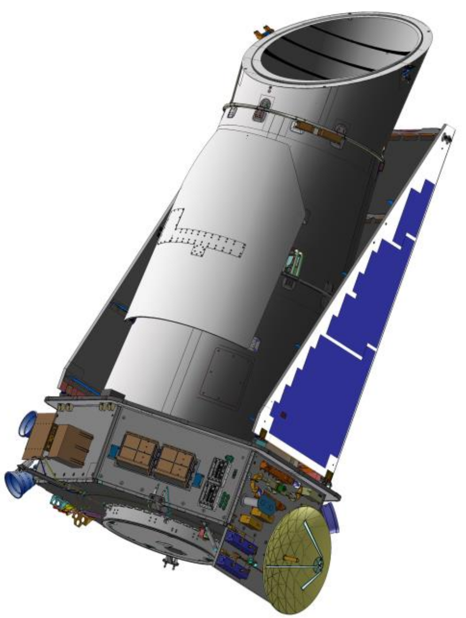


Gijs Mulders, Univ. of Arizona
Ilaria Pascucci, Daniel Apai,
Antonio Frasca, Joanna Molenda-Zakowicz


Kepler Planet Candidates
As of January 2014
2010, 2011, 2012, Jan 2013
Nov 2013
Jupiter
Neptune
Earth
20
10
4
1
Size Relative to Earth (Radius)
1
5
10
50
100
500
1000
Orbital Period (days)

Kepler Mission Goals

- "Determine the percentage of terrestrial and larger planets that are in or near the habitable zone of a wide variety of stars"
- …
- "Determine the properties of those stars that harbor planetary systems."

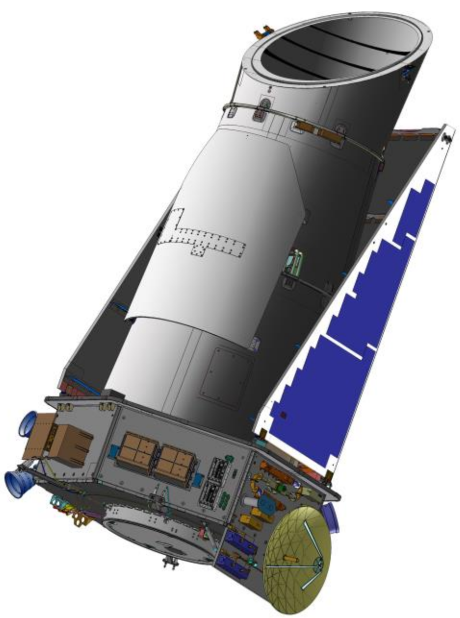


Kepler: exoplanet statistics

Earth-sized habitable zone planet around sun-like star:

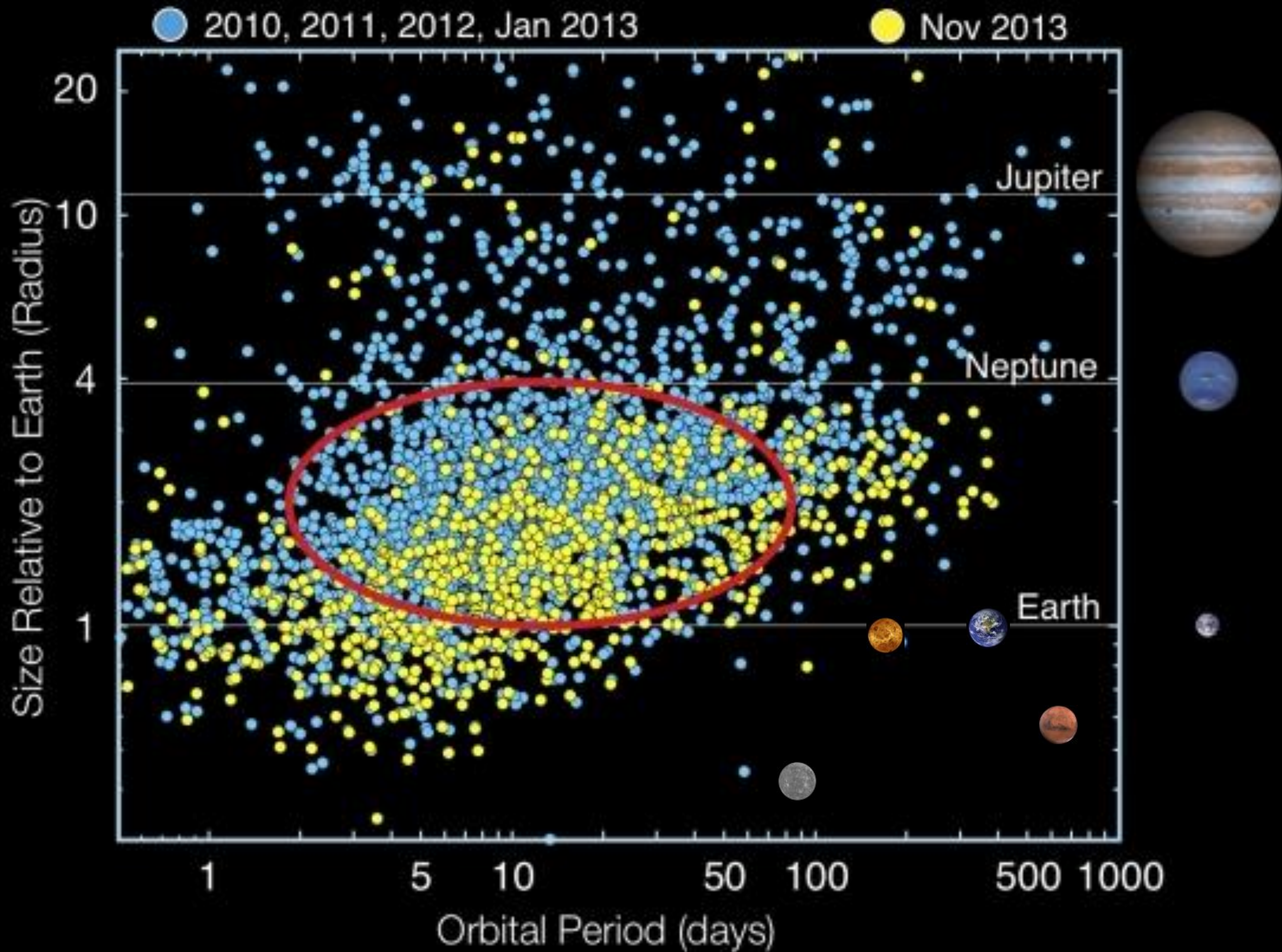
- 0.5 % transit probability
- ~10% (?) detection efficiency
- 10% planet occurrence rate

Need to monitor 20,000 stars to find a single planet!



Kepler Planet Candidates

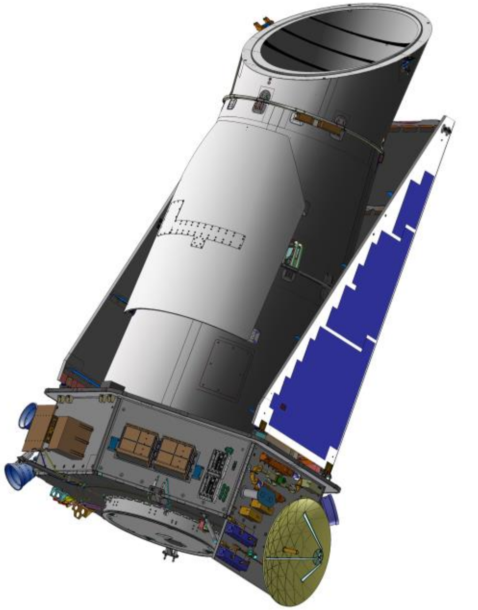
As of January 2014



Planet occurrence rate

- Average number of planets per star
  (< fraction of stars with planets)
  ~1 planet per star
  ~10% stars have earth-sized planet in the habitable zone.

  Why occurrence rate?
  - Exoplanet discovery mission yield
  - Planet Formation /Evolution



Why Exoplanet Host Star Properties?

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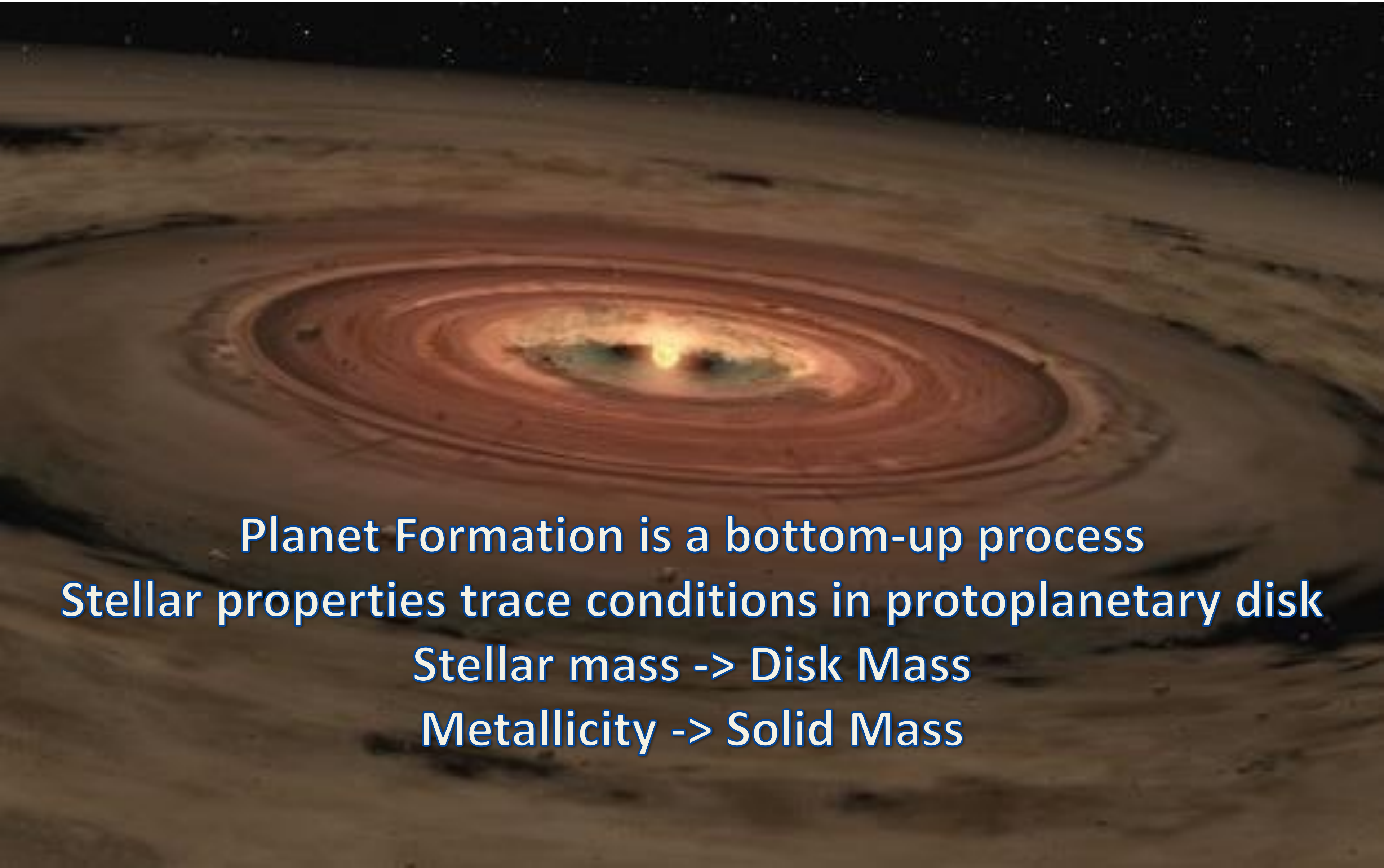


Planet Formation is a bottom-up process

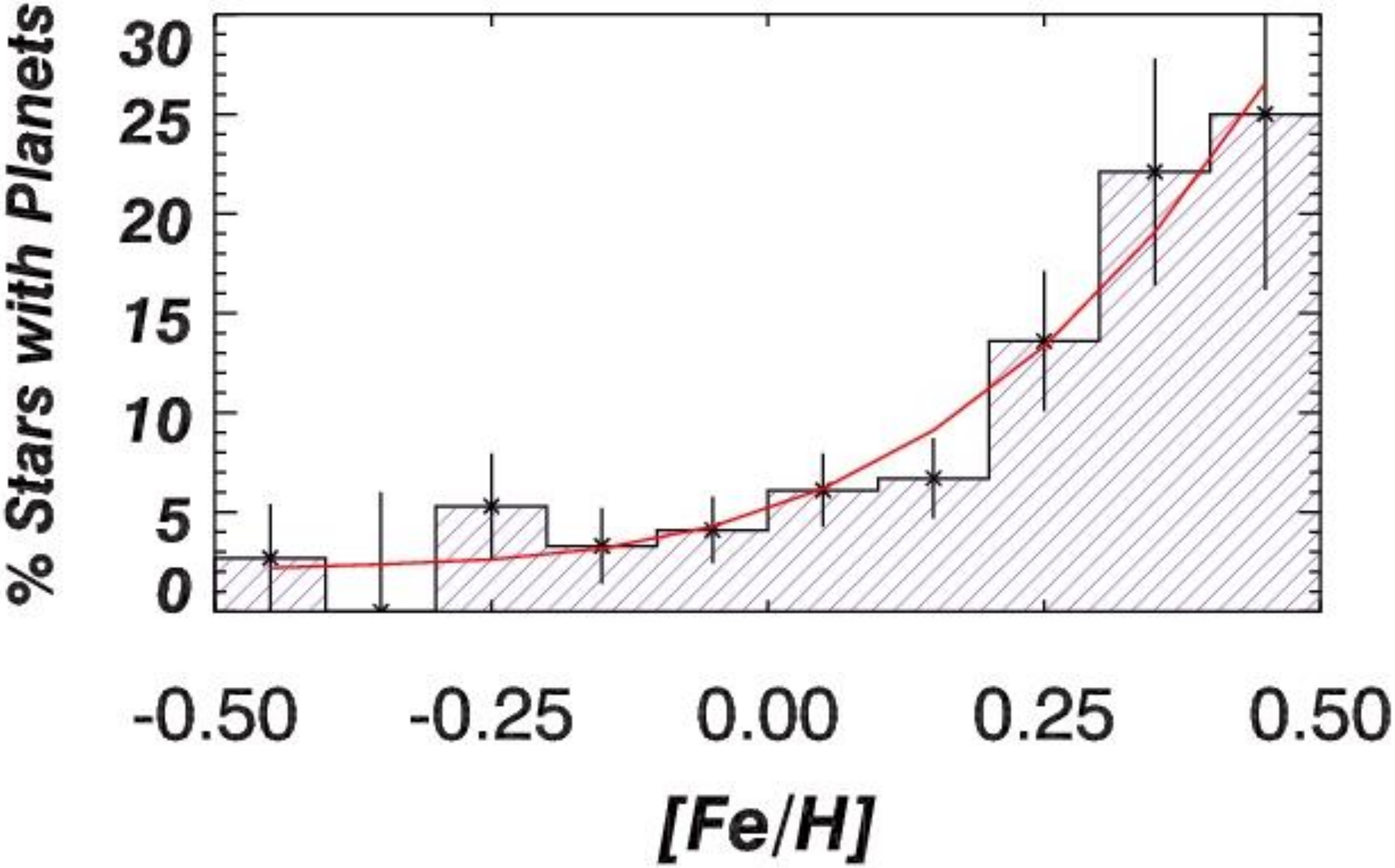
Stellar properties trace conditions in protoplanetary disk

Stellar mass -> Disk Mass

Metallicity -> Solid Mass

Why Exoplanet Host Star Properties?

Stellar-mass dependencies can constrain planet formation mechanisms

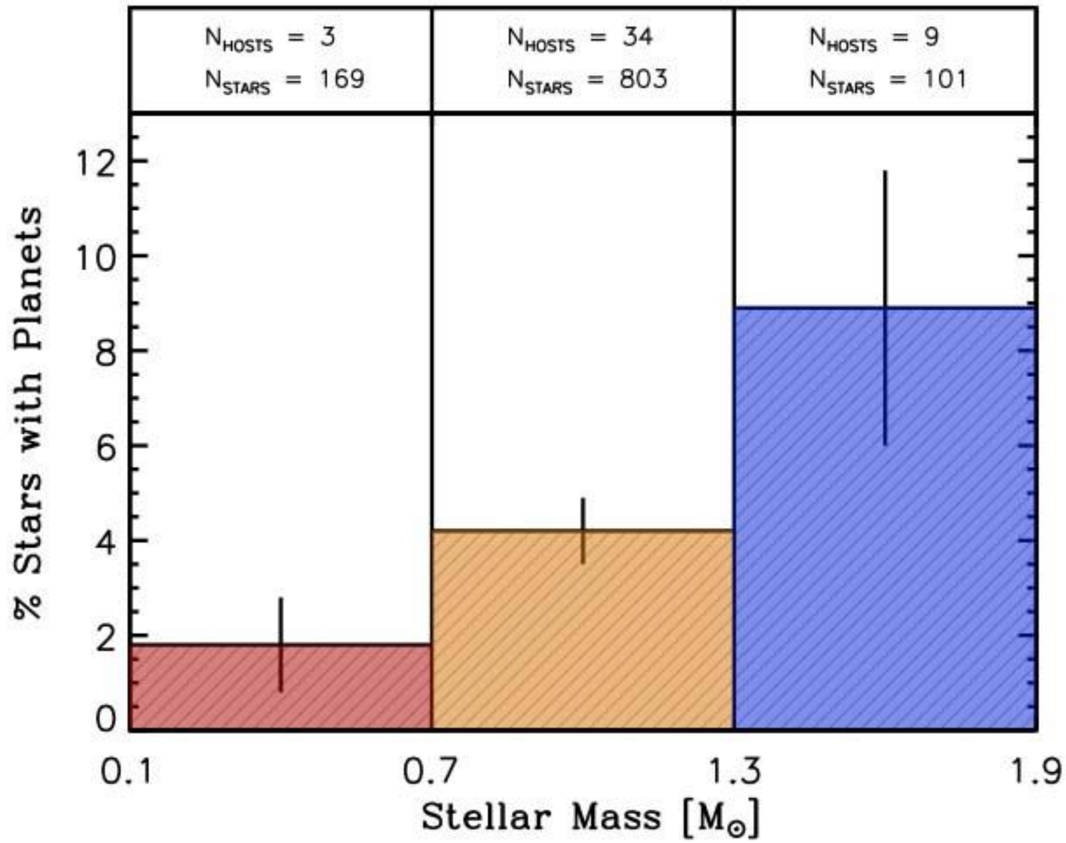


More **giant** planets around metal-rich stars

Fischer & Valenti 2005

Why Exoplanet Host Star Properties?

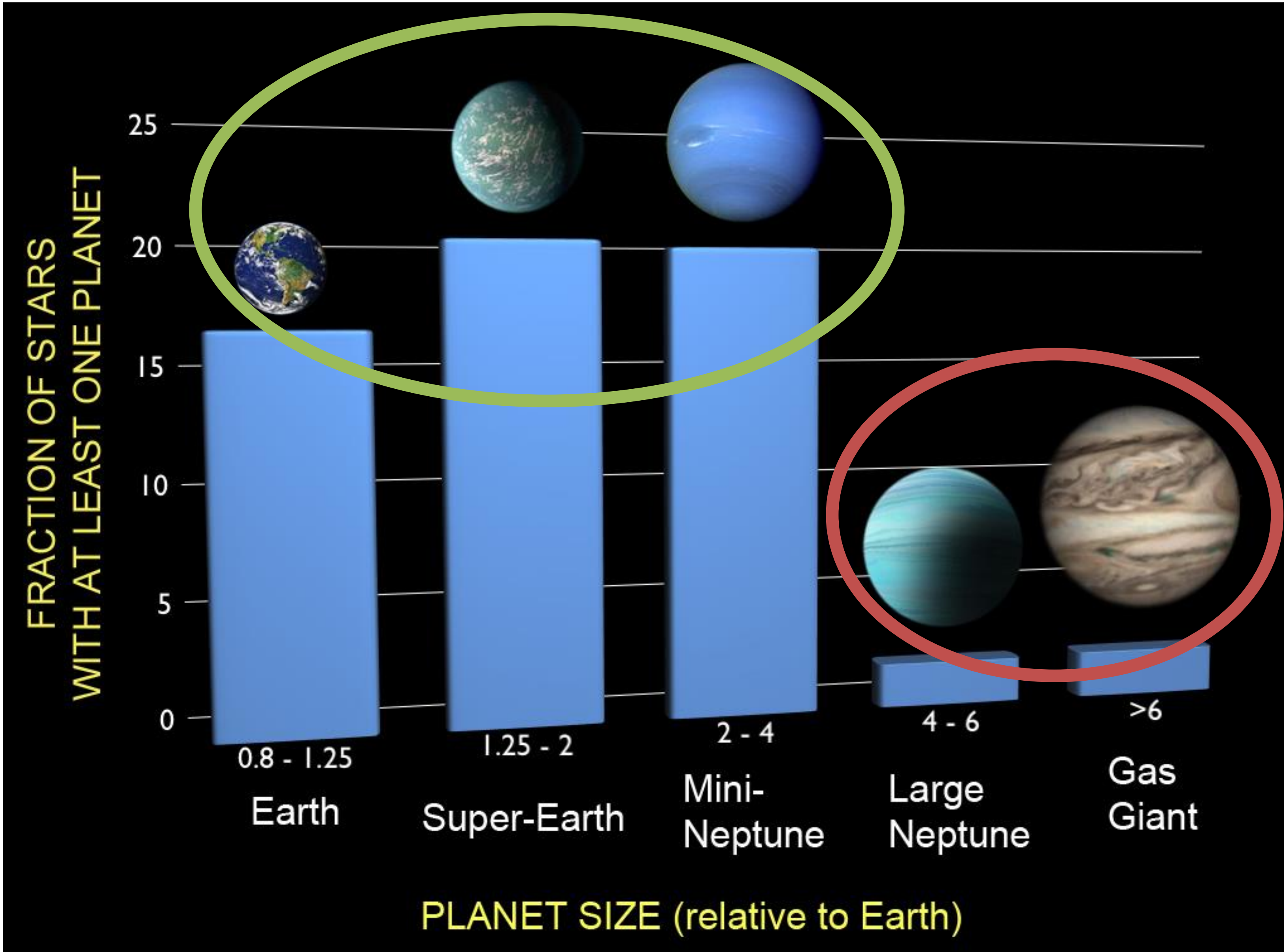
Stellar-mass dependencies can constrain planet formation mechanisms



More **giant** planets around more massive stars

Johnson et al. 2007

Kepler: Most planets are small

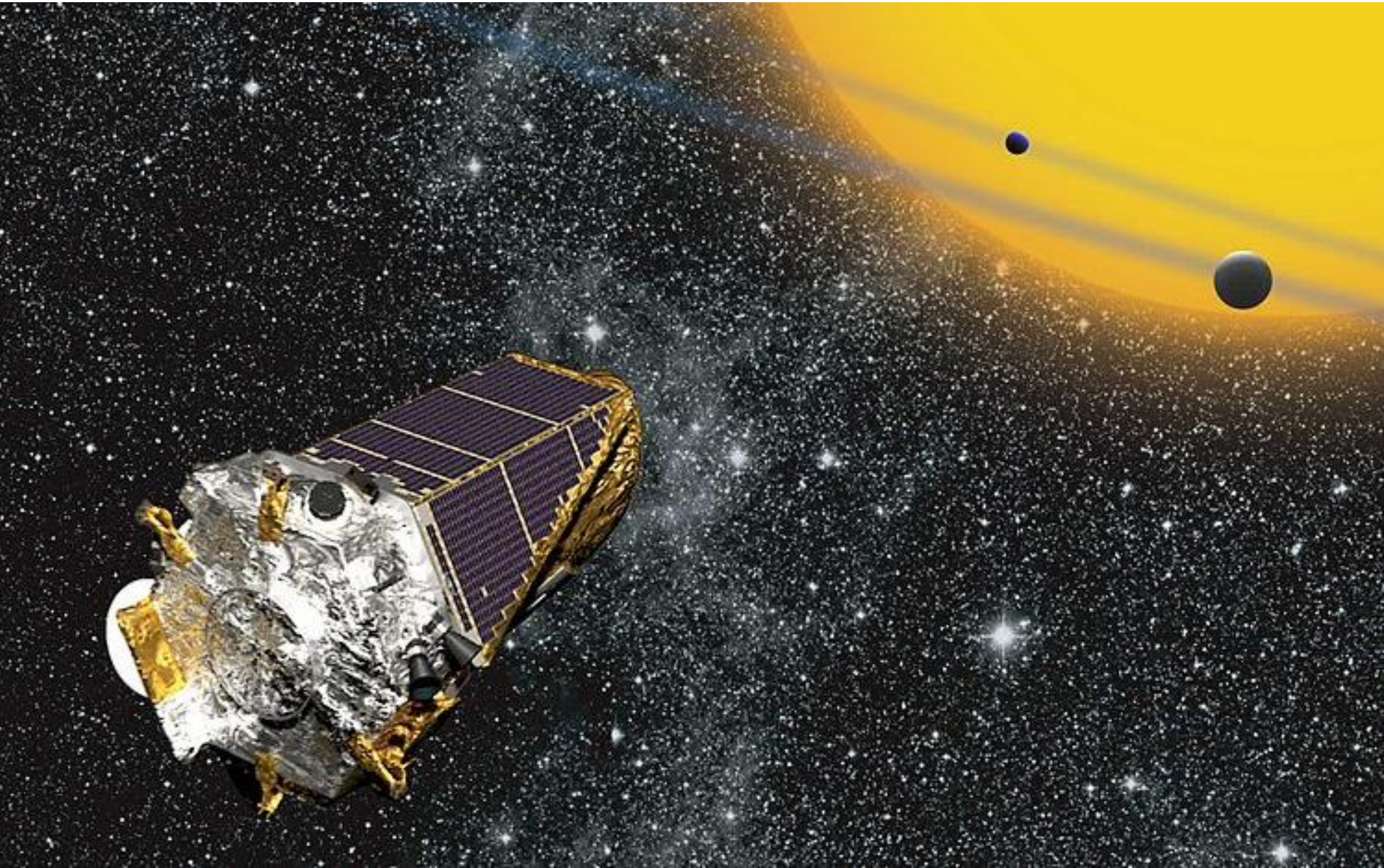


Fressin et al. 2013. RV: Howard et al. 2010

Talk Outline

1. Planet Population
2. Stellar mass
3. Stellar metallicity (LAMOST!)

Kepler: Exoplanet Transits

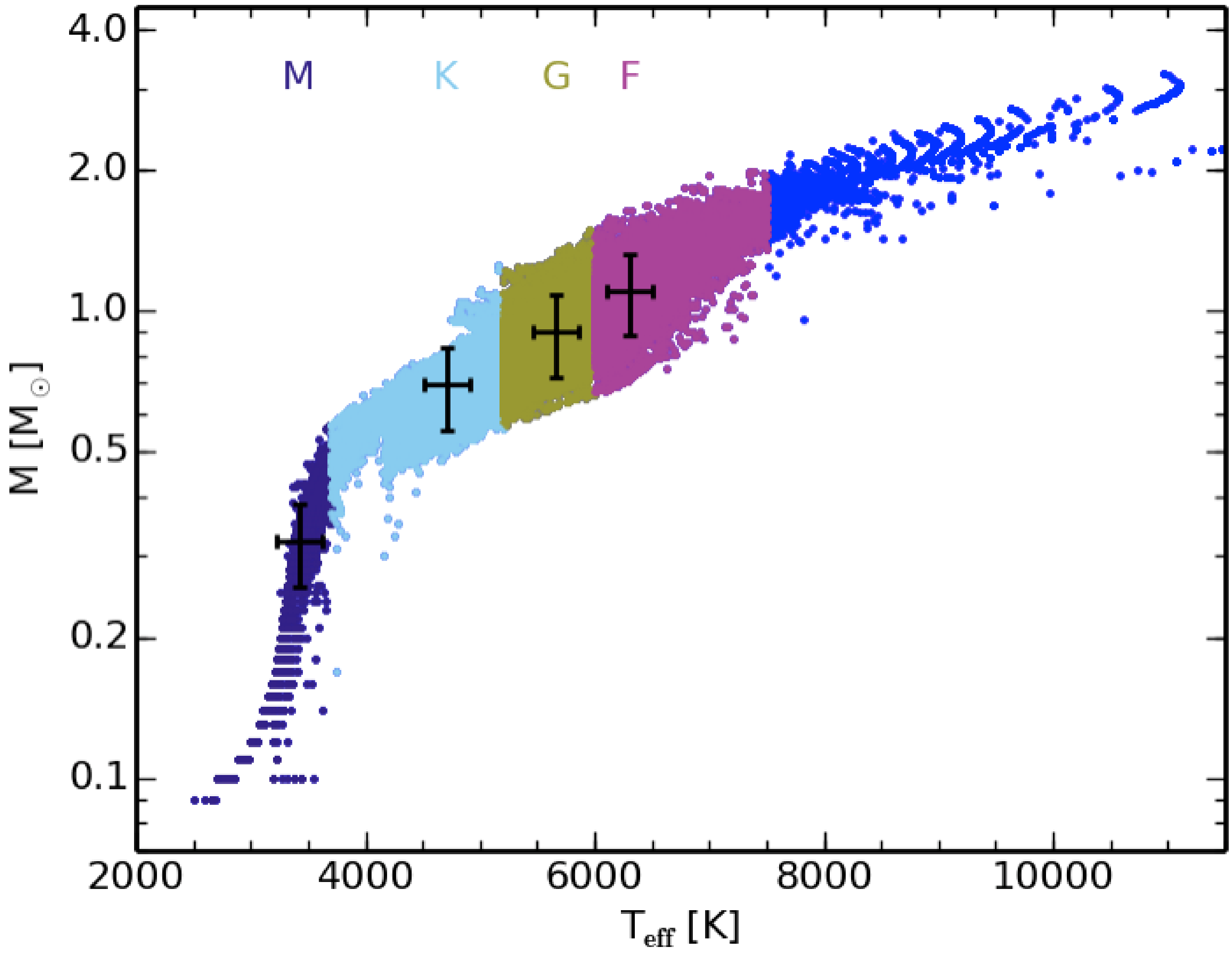


Planet population: Occurrence rate

$$f_{\rm occ} = \frac{N_{\rm planets}}{N_{\rm stars}\ f_{\rm eff}}$$

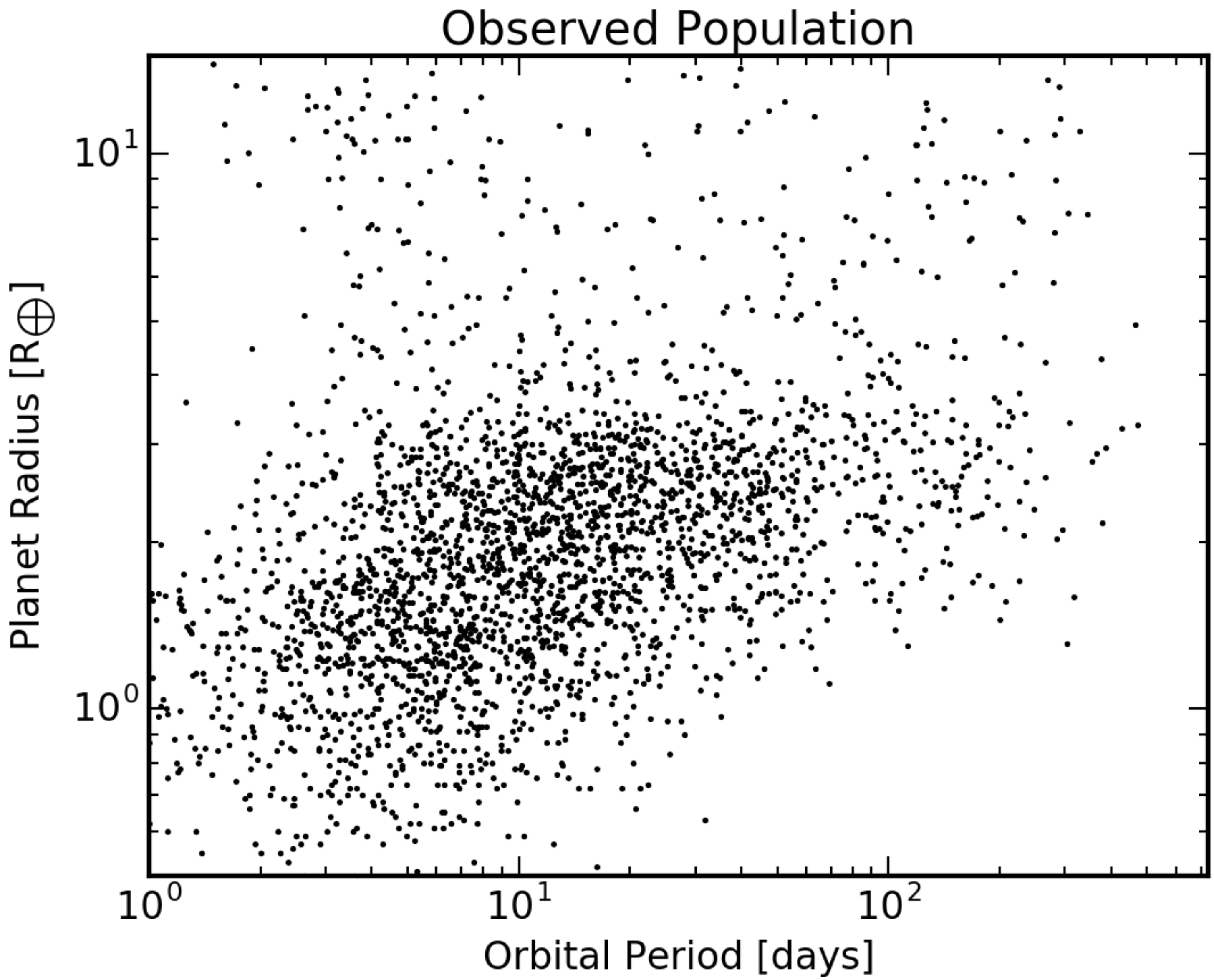
1. Stars
2. Planets
3. Detection efficiency
   & Transit probability

1. Stars



Huber et al. 2014, Dressing & Charbonneau 2013

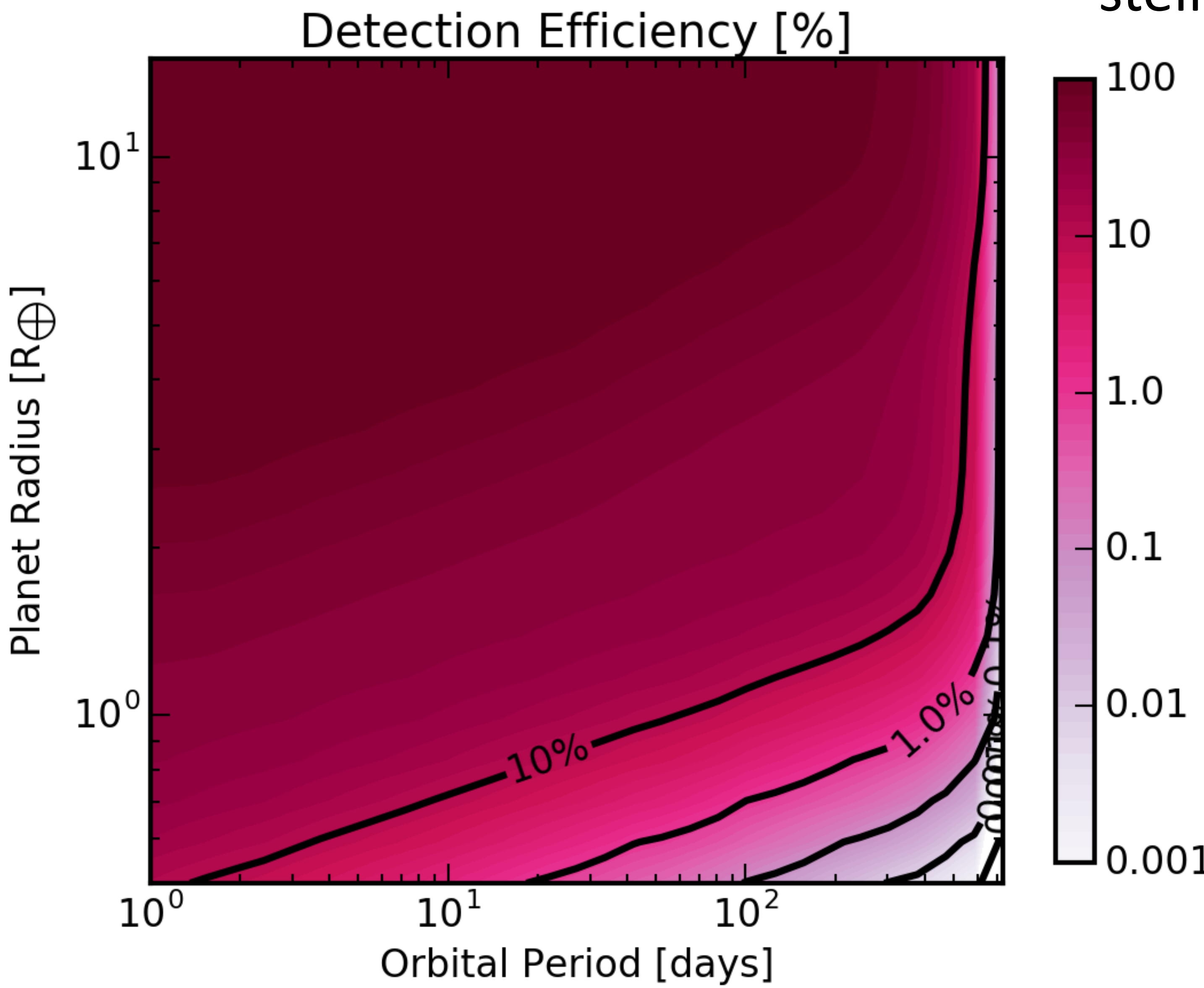
2. Planets



Observed Population
Planet Radius [R⊕]
Orbital Period [days]
10^0
10^1
10^2

3. Detection efficiency

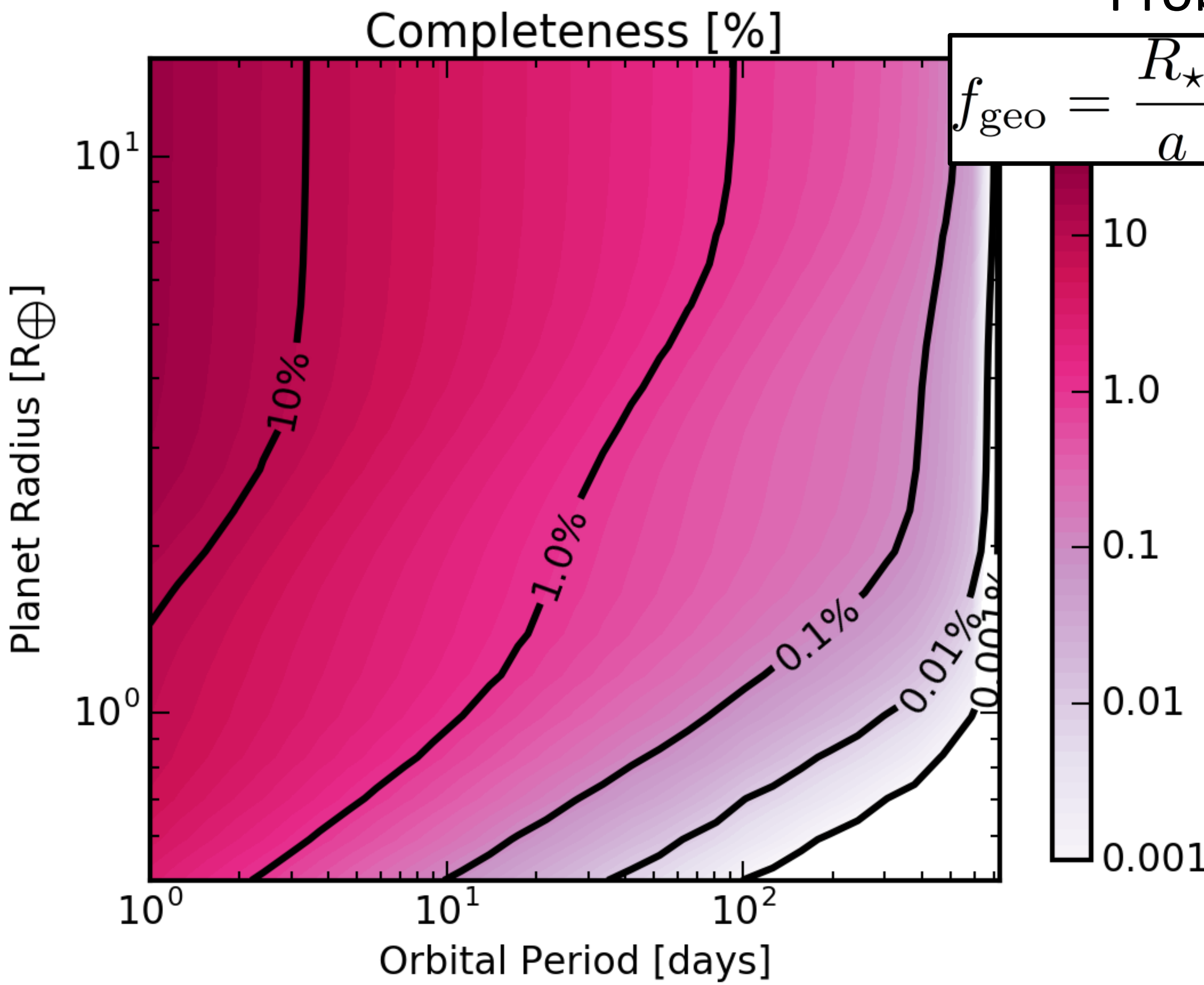
S/N ratio:
transit depth
stellar noise



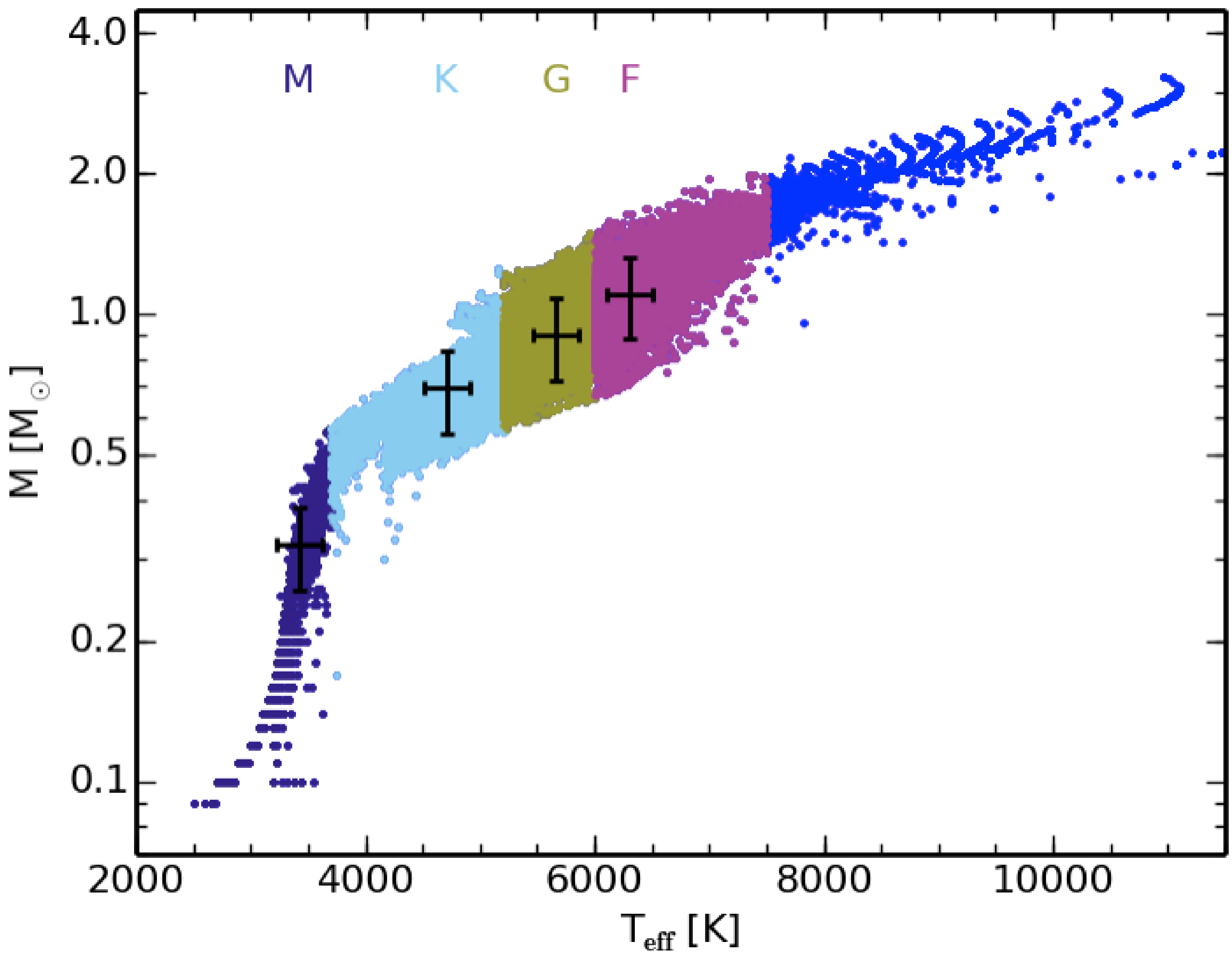
3. Detection efficiency

Geometric Transit Probability

$$f_{\rm geo} = \frac{R_\star}{a} = \frac{R_\star}{P^{1.5}}$$

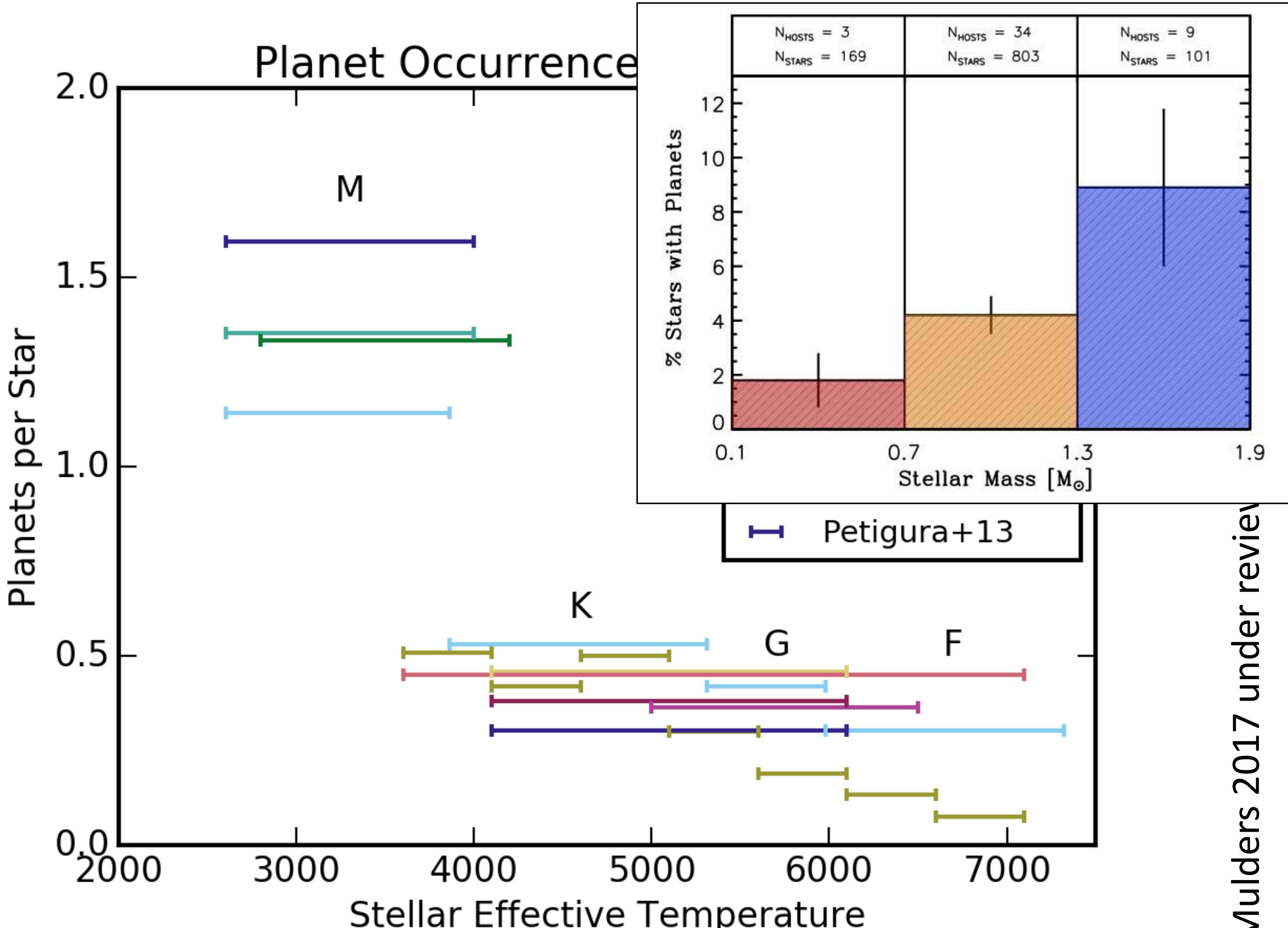


1. Stars



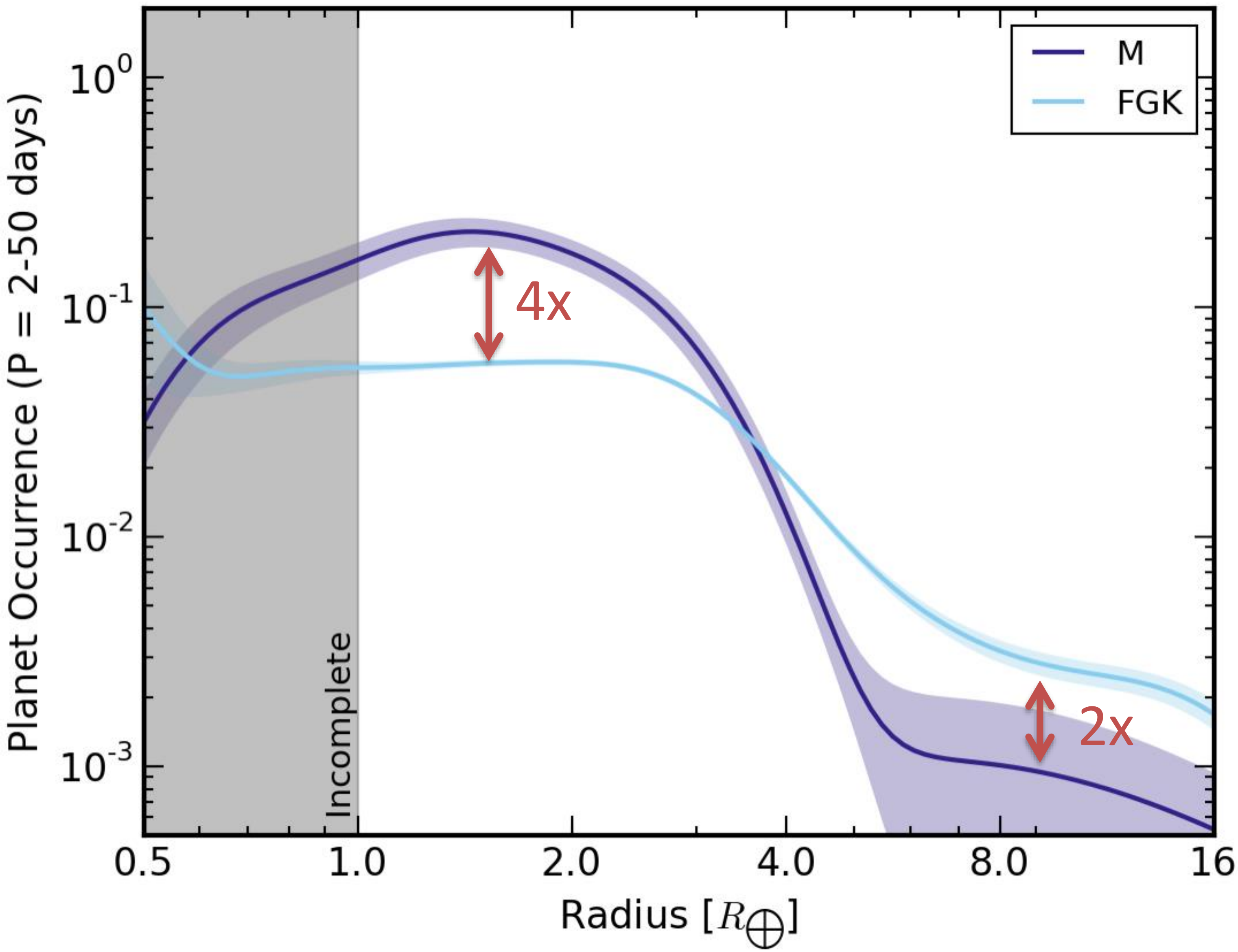
Huber et al. 2014, Dressing & Charbonneau 2013

M dwarfs have more planets



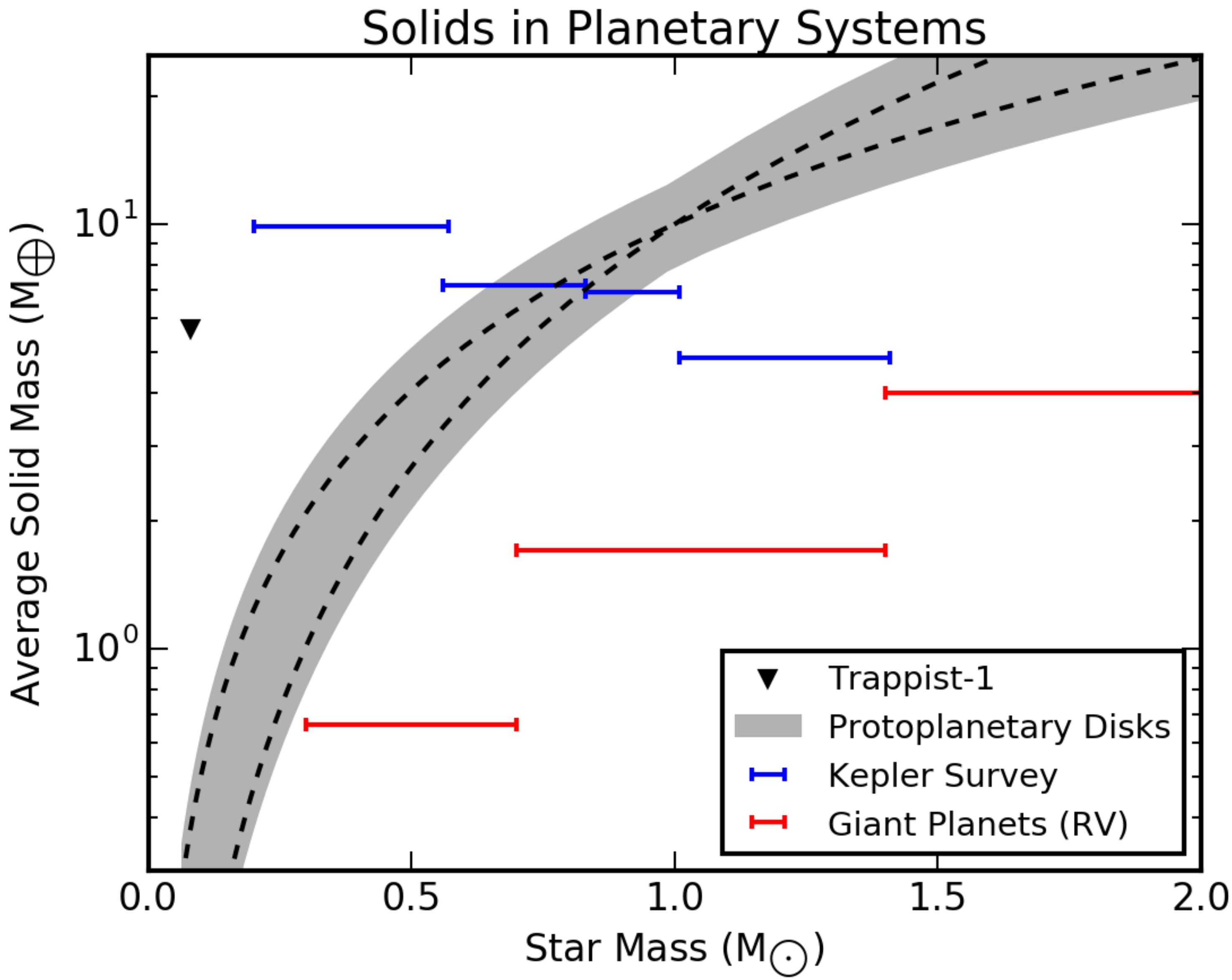
Mulders 2017 under review

More small planets, fewer giants

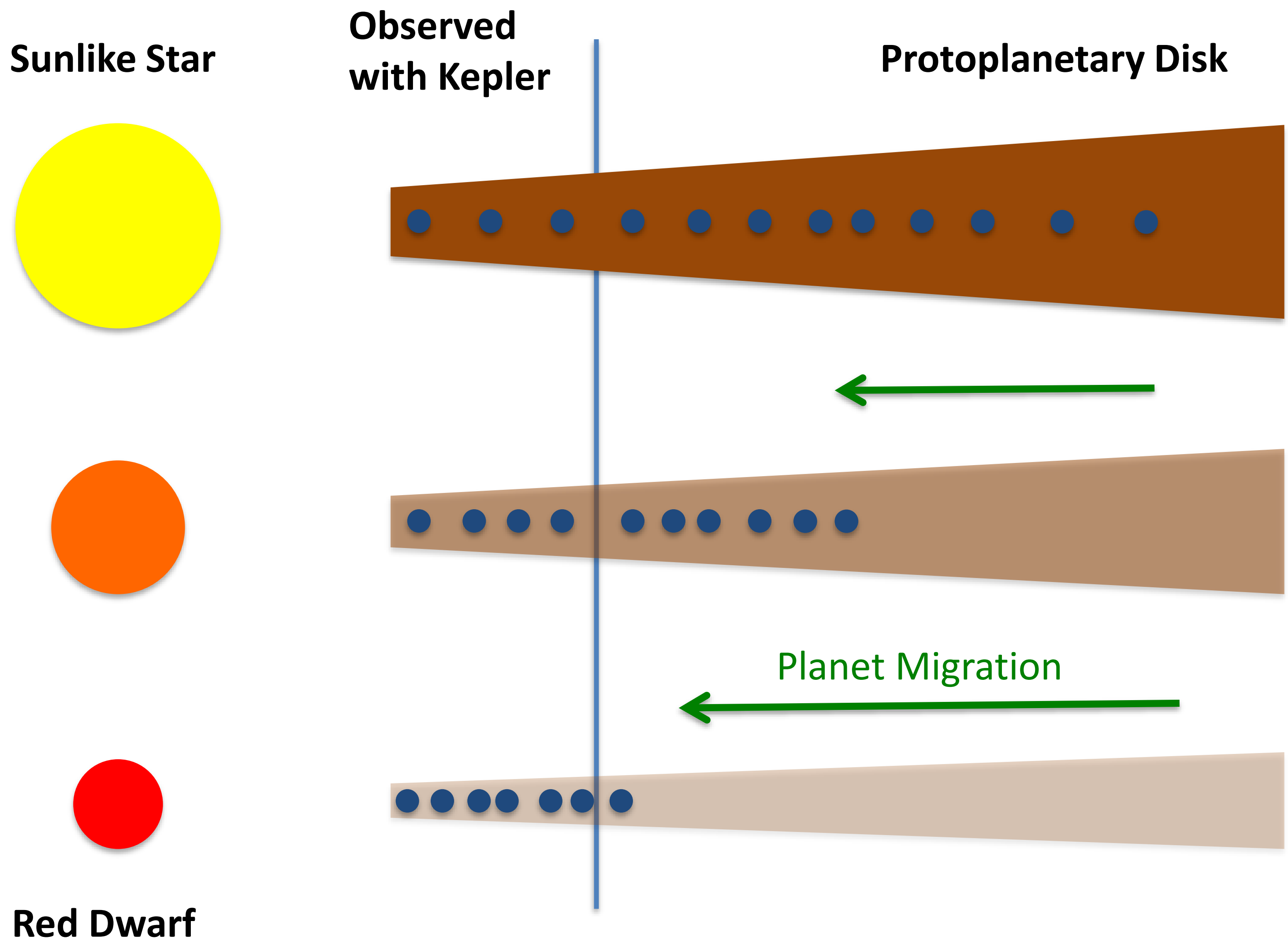


Mulders et al. 2015b

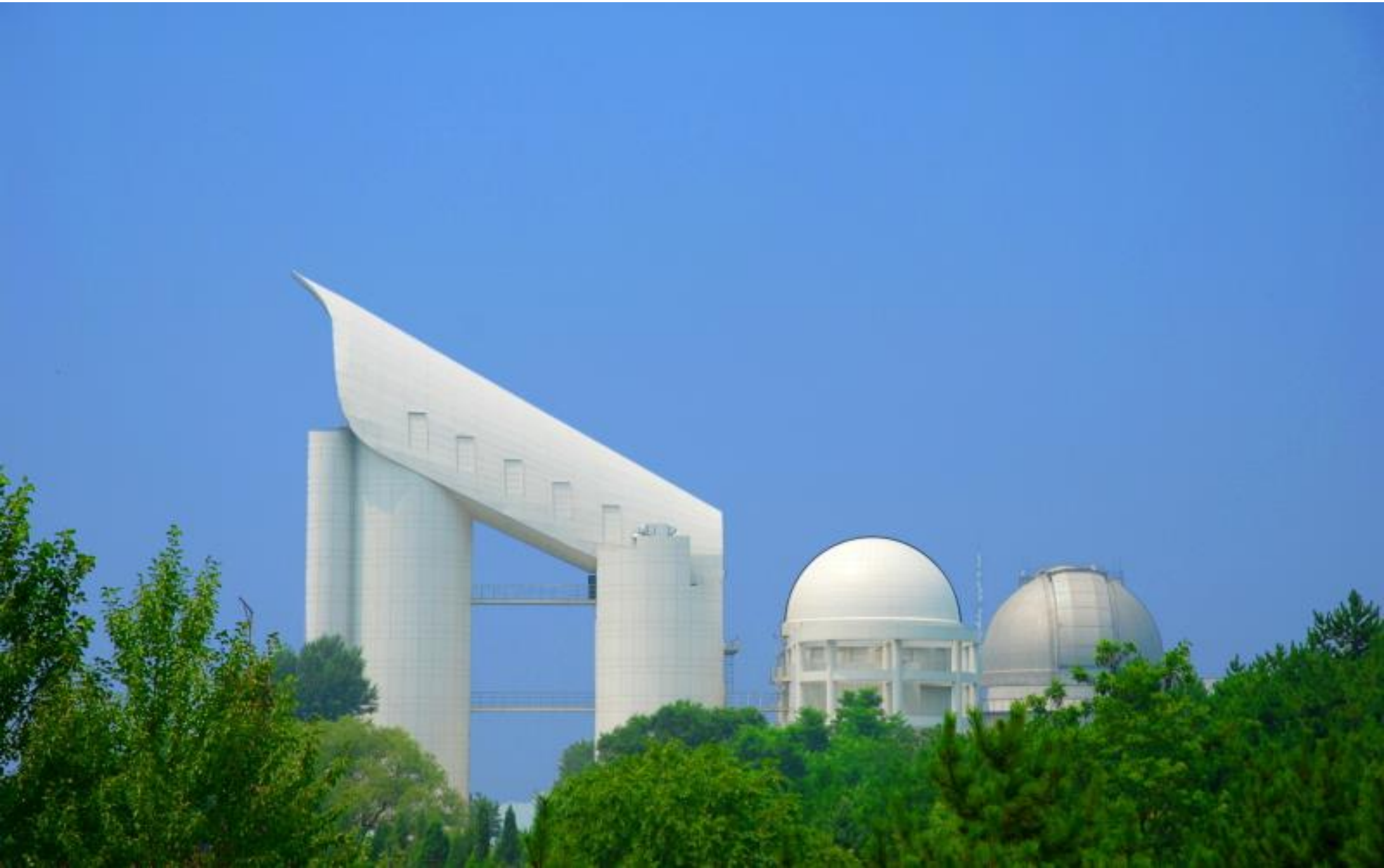
Comparison with disk solids



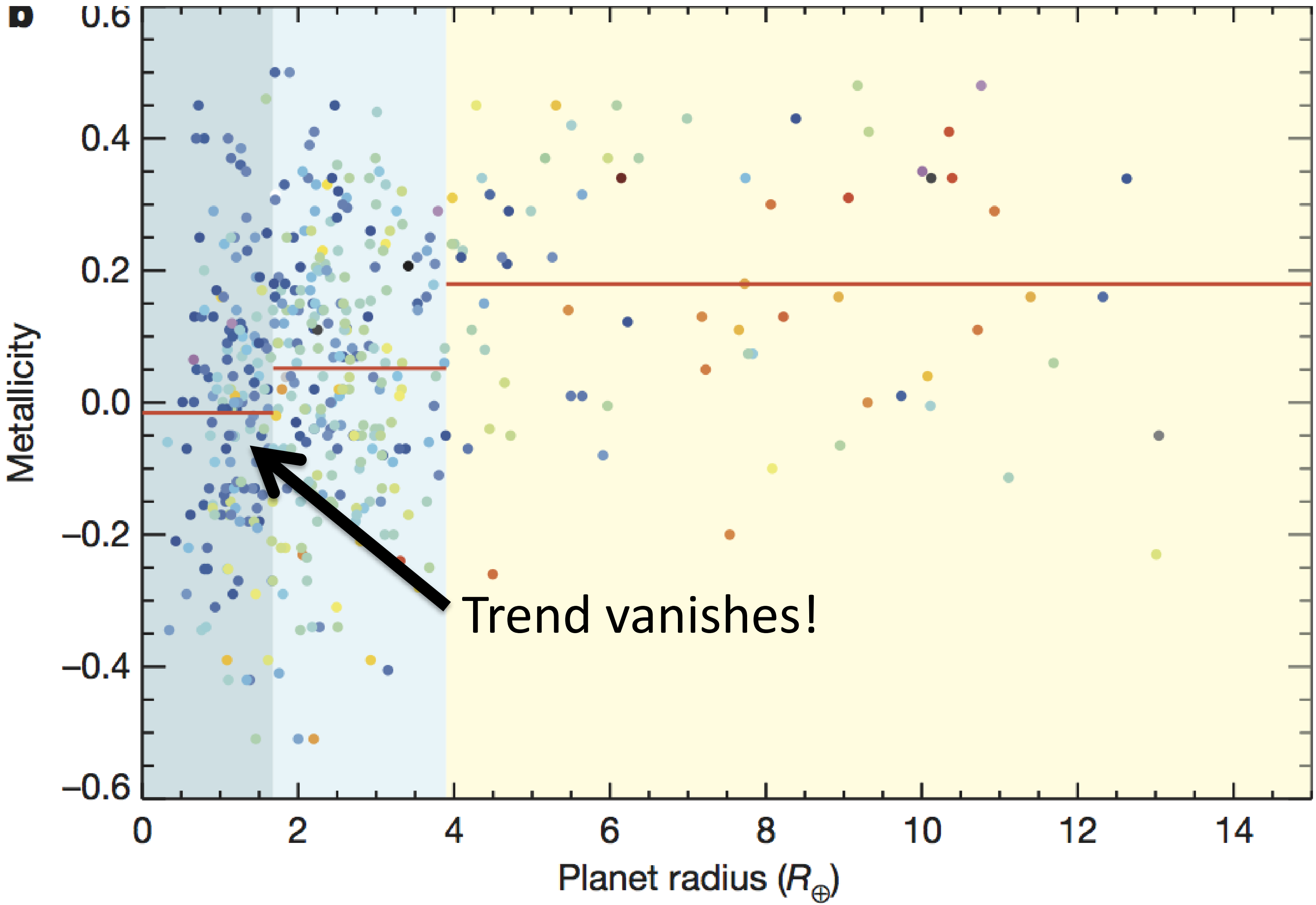
Mulders et al. 2015c. Disk mass: Pascucci et al. 2016


Sunlike Star
Observed with Kepler
Protoplanetary Disk
Planet Migration
Red Dwarf

Dependence on Metallicity

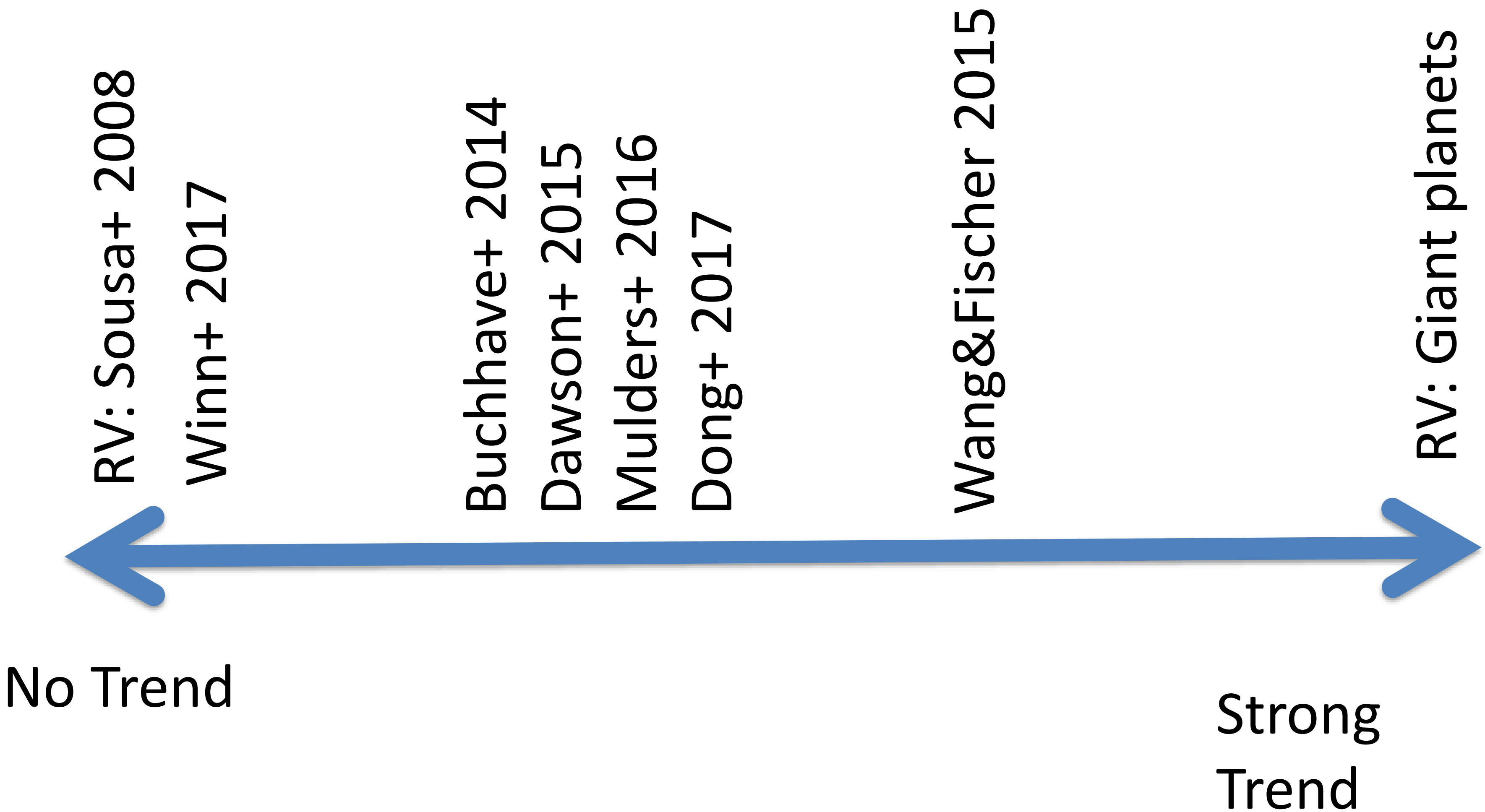


Host Star Metallicity (CPS)



Bucchave et al. 2014

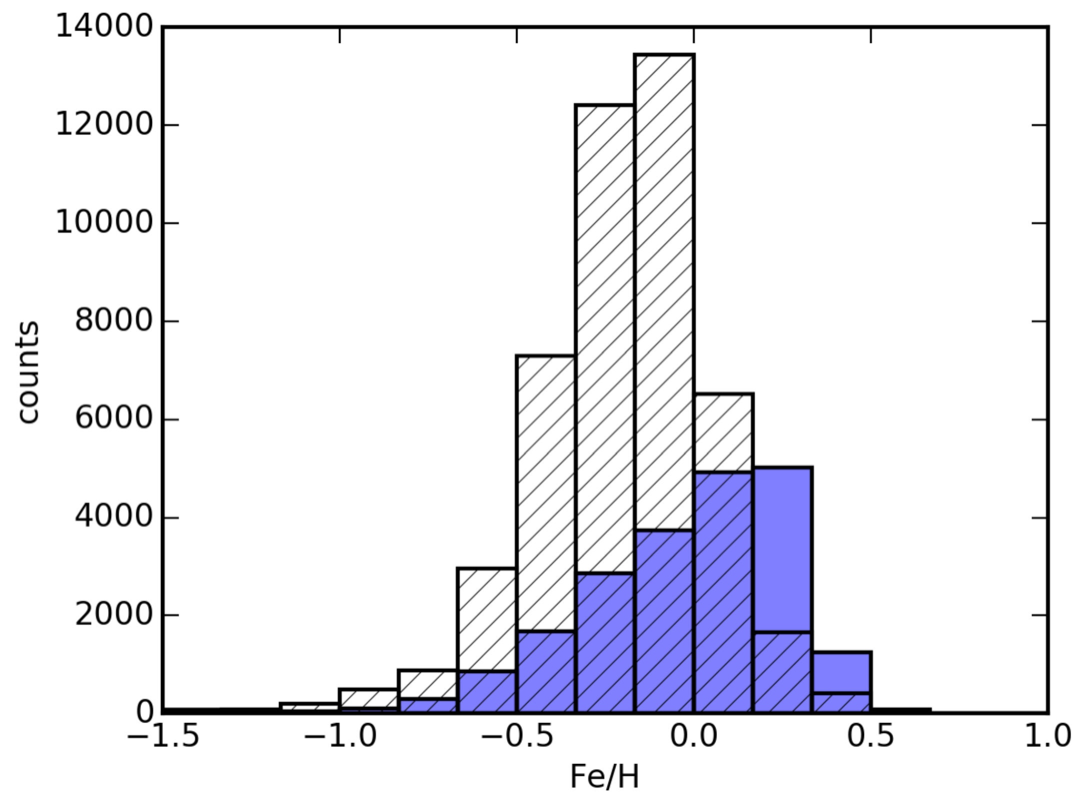
Metallicity Dependence of sub-Neptunes



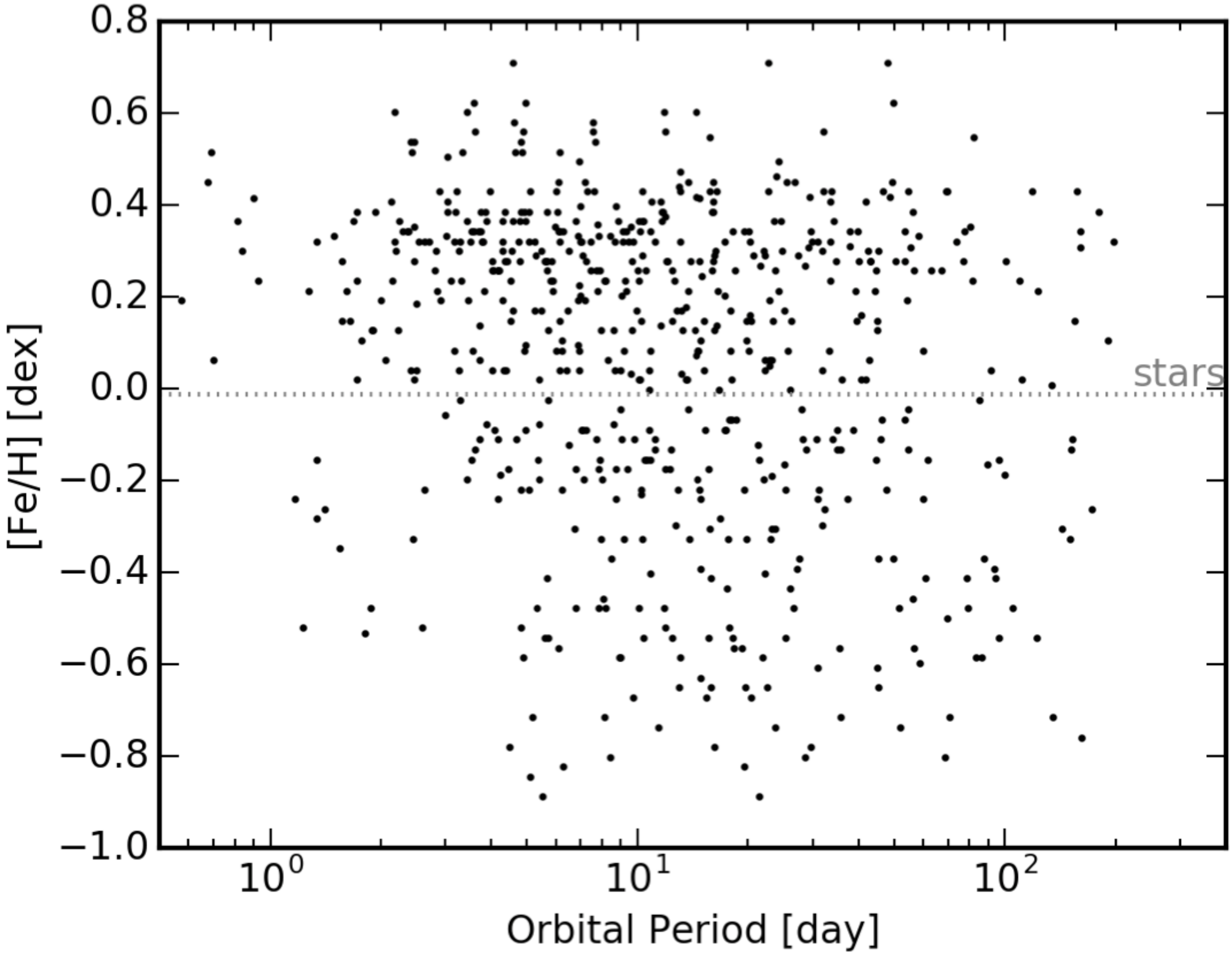
LAMOST Stellar Metallicities

[Fe/H] from ROTFIT pipeline (Frasca et al. 2016)

- 51,385 stars
- 20,863 MS stars
- 665 planet hosts

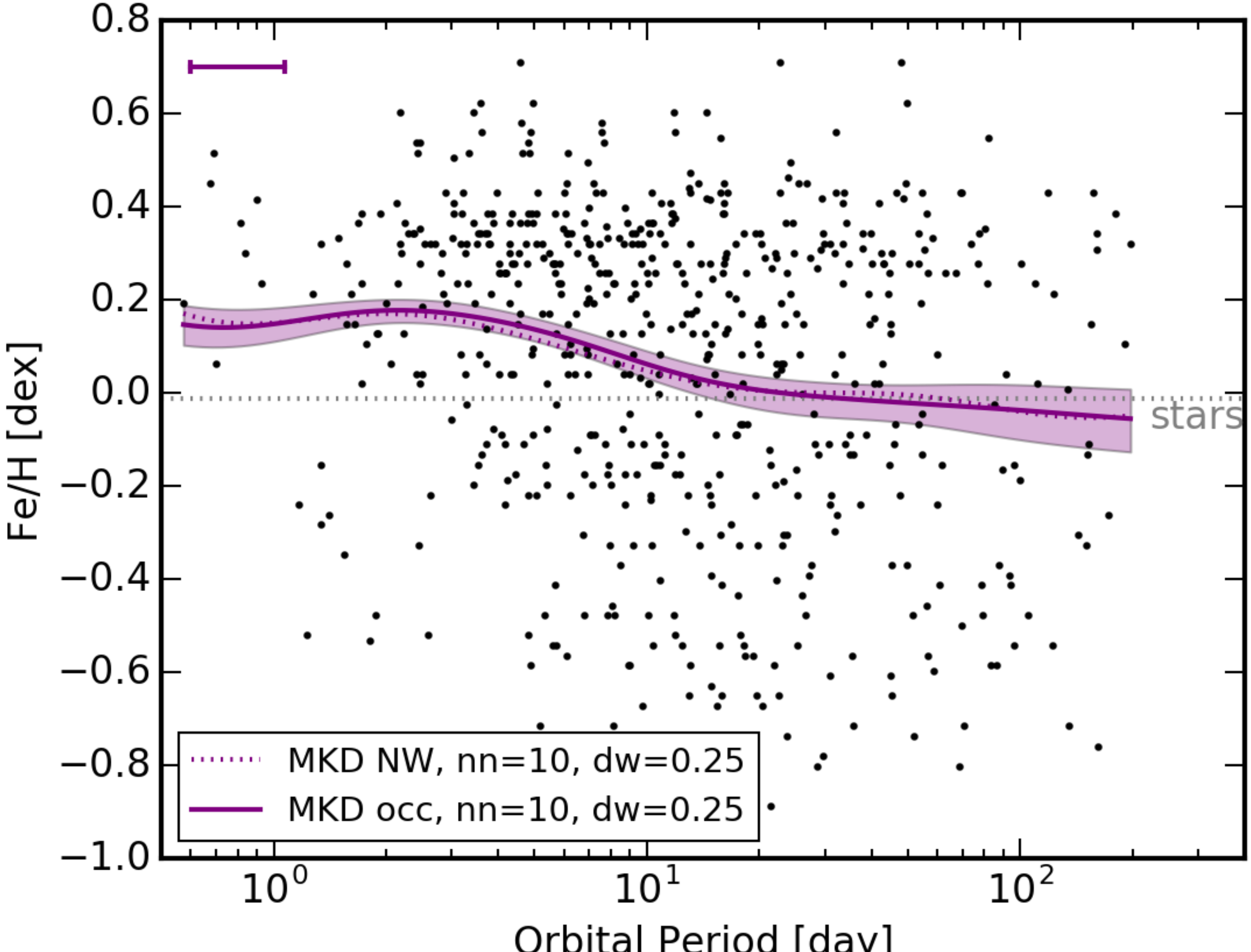


Metallicity versus orbital period



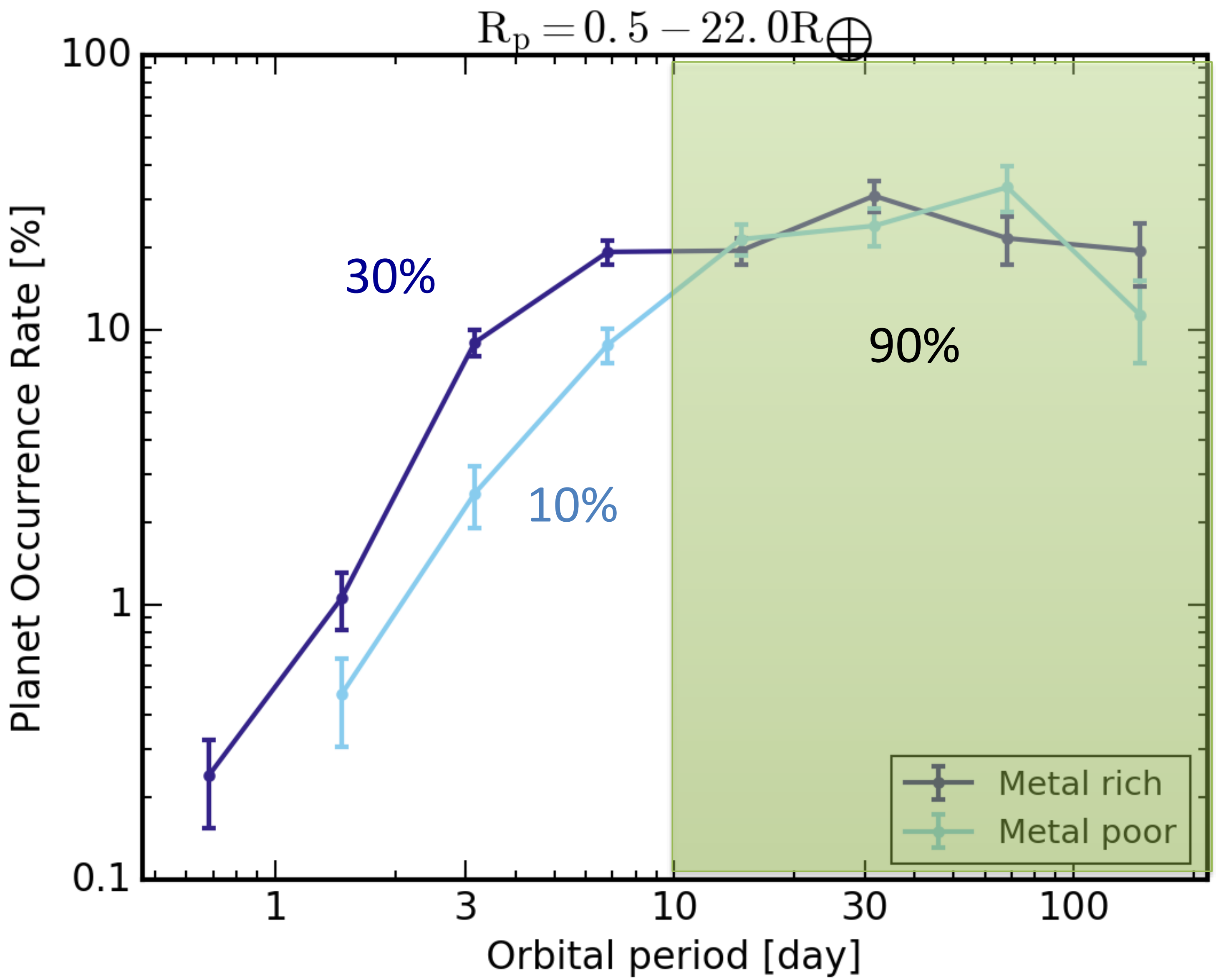
Mulders et al. 2016

Metallicity versus orbital period



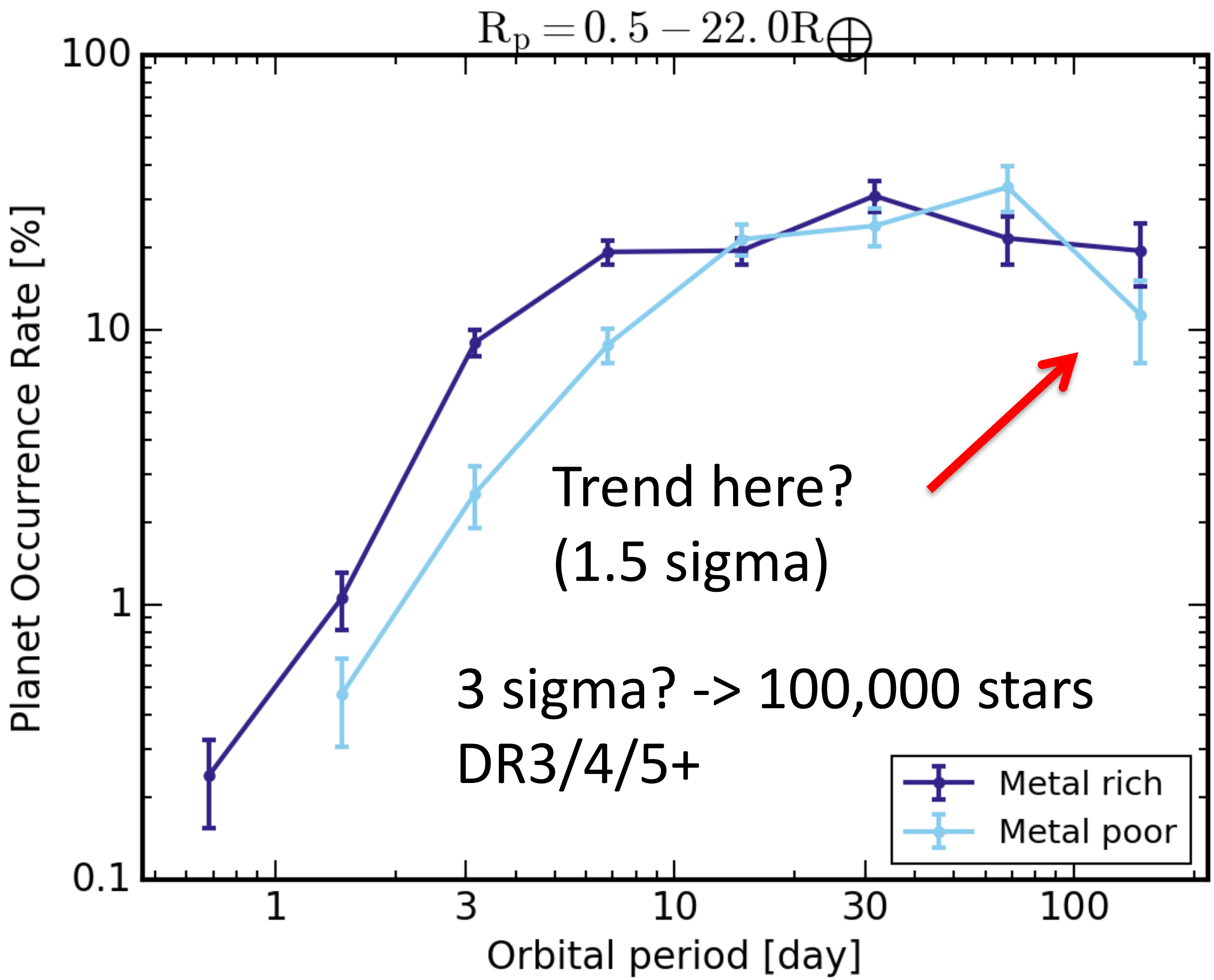
Mulders et al. 2016, also Dong et al. 2017

Small Impact on Planet population



Mulders et al. 2016

Small Impact on Planet population



Mulders et al. 2016, Adibekyan et al. 2016

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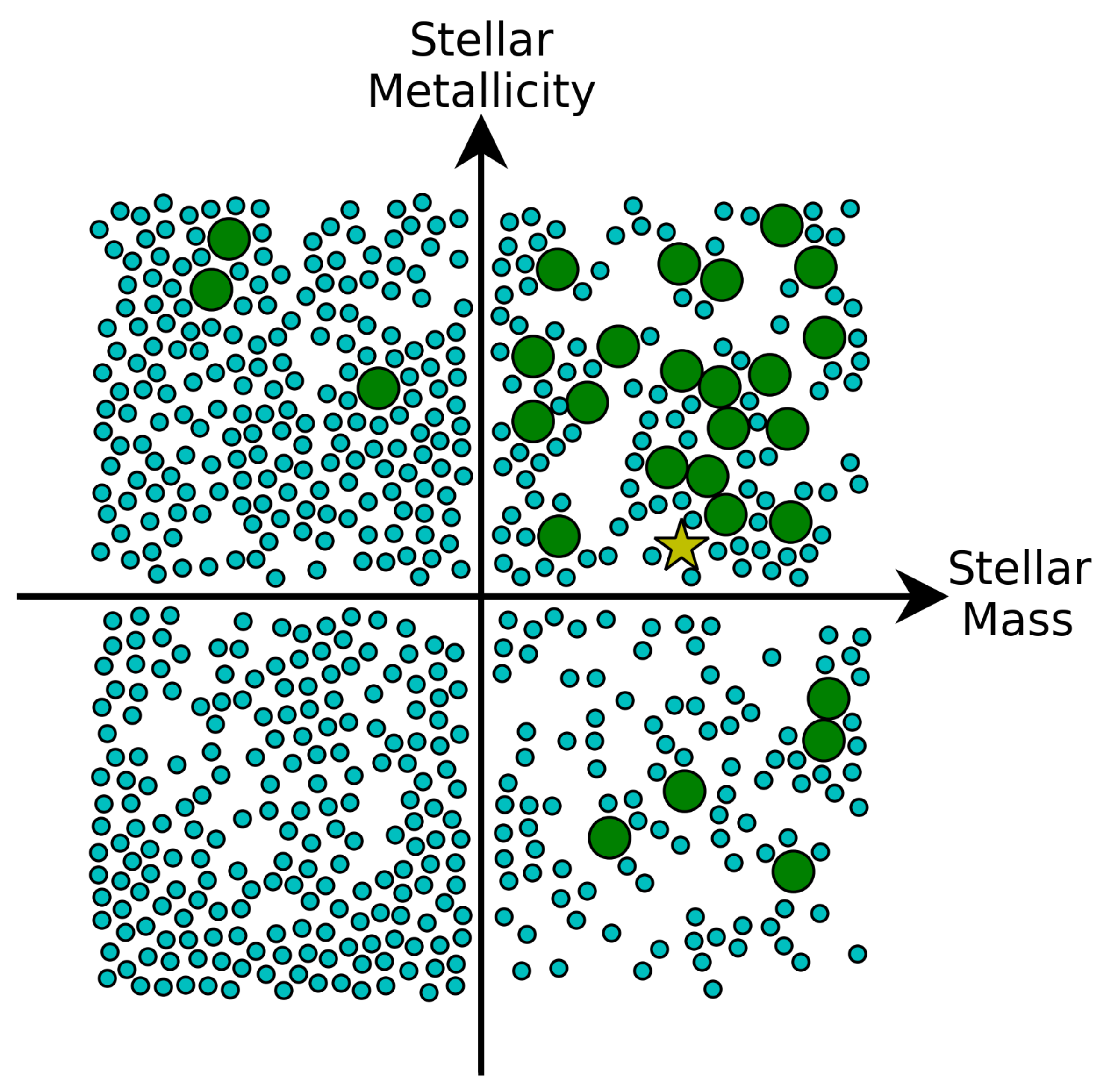

Future Outlook

- Transit surveys to study exoplanet populations (Kepler, K2, TESS)
- Stellar characterization needed for determining planet parameters
- Stellar parameters of non-planet hosts to calculate planet occurrence rates
- LAMOST provides additional information (metallicity) not provided by other surveys.