Characterisation of exoplanet host stars

A window into planet formation

Nuno C. Santos

Instituto de Astrofísica e Ciências do Espaço, Portugal
Departamento de Física e Astronomia, Fac. Ciências, University of Porto, Portugal

Outline of the talk

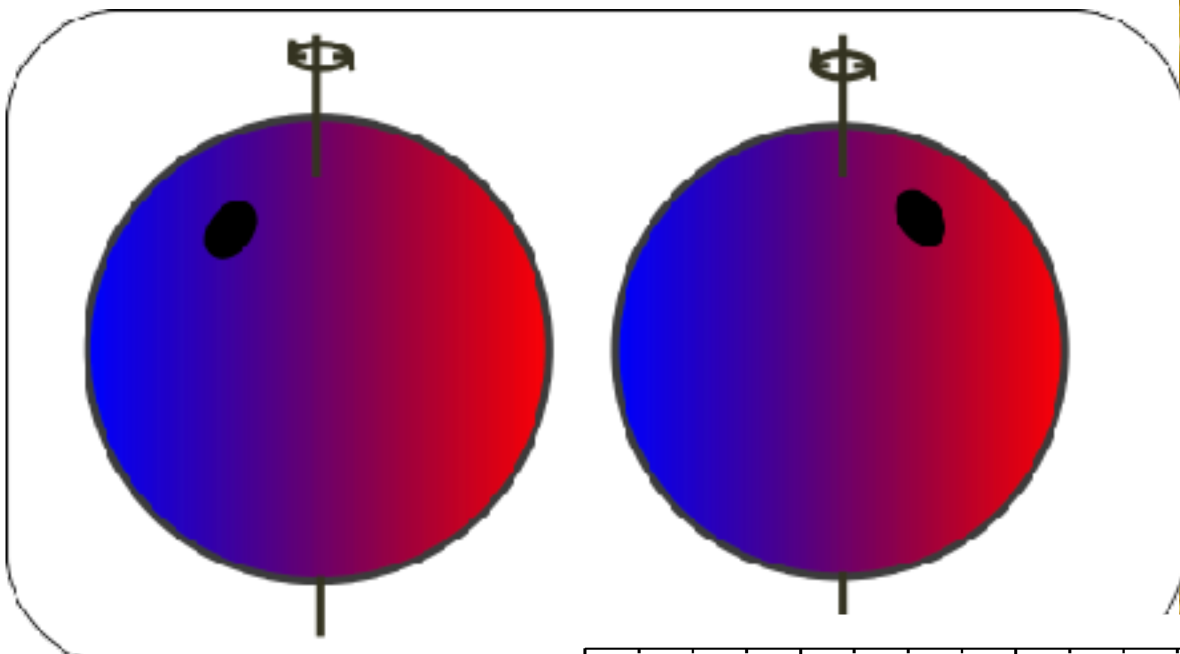
- Introduction:
  - The importance of stellar parameters in exoplanet research
  - A quick overview of exoplanet discovery status
- The metallicity-planet connection *(the "background")*
- Stellar chemistry and planet architecture
- The star-planet connection in the GAIA era

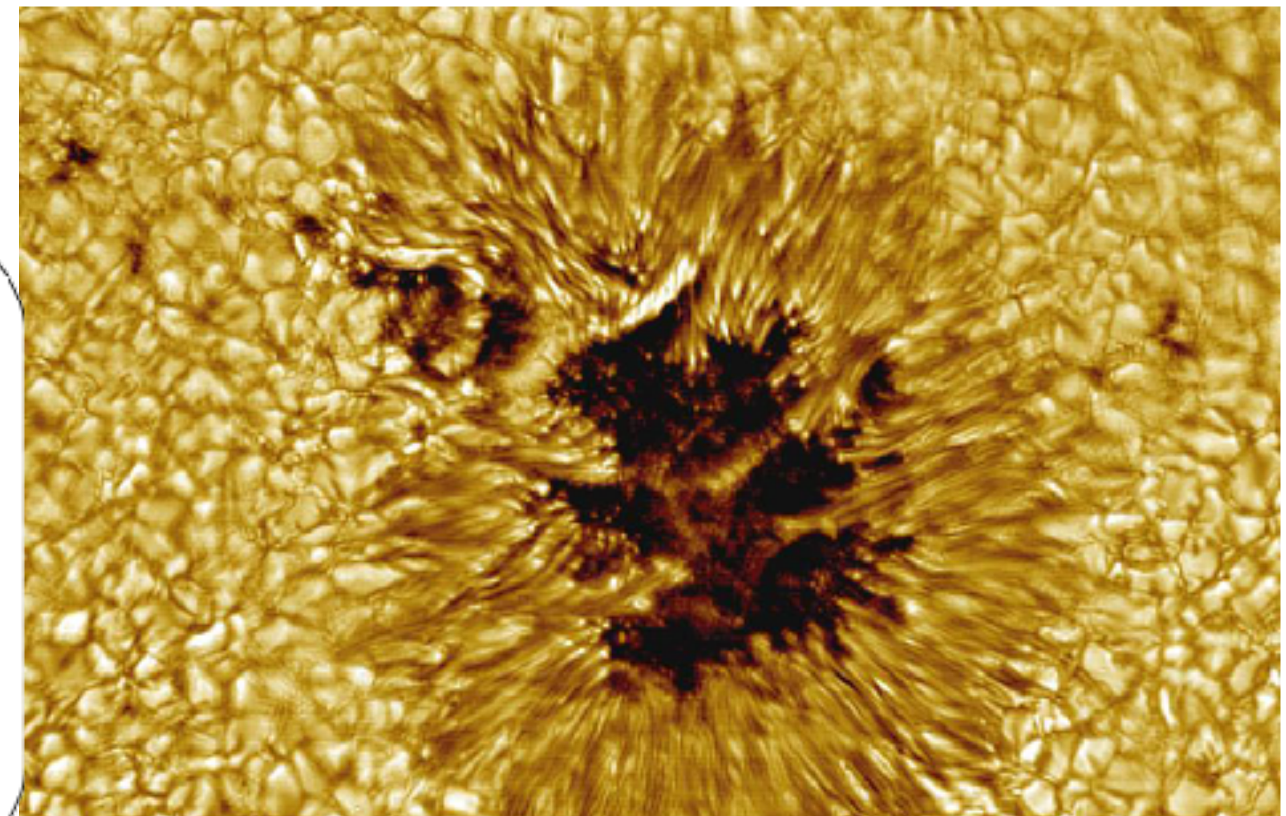
Nuno C. Santos
nuno.santos@astro.up.pt

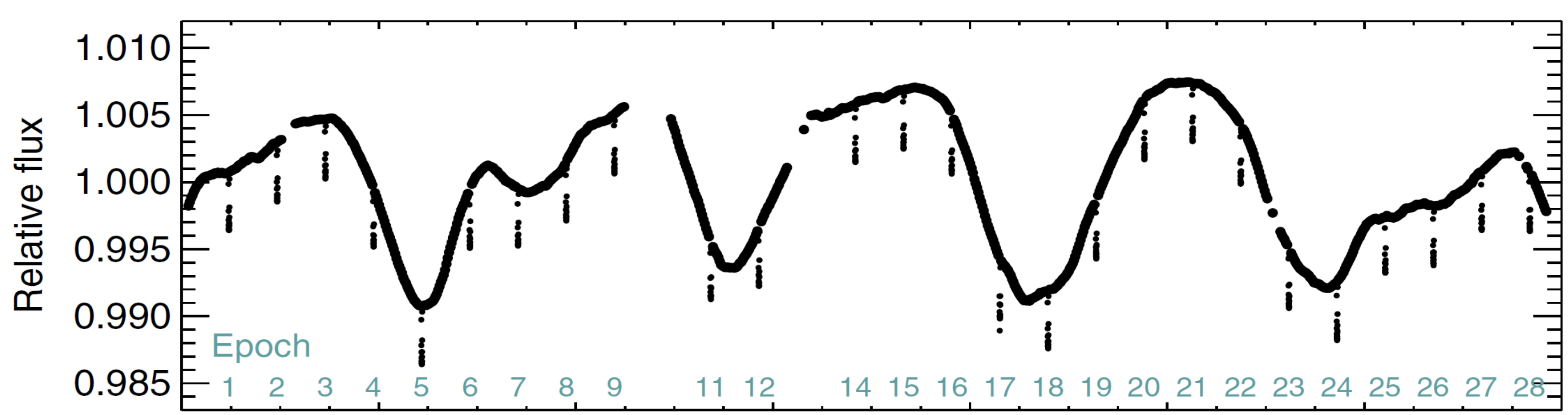
Why we stellar parameters are important in exoplanets

- Stellar properties may influence the capacity to detect planets (e.g. spectral type, activity, ...)

(See e.g. Dumusque et al. 2011, Oshagh et al. 2013)





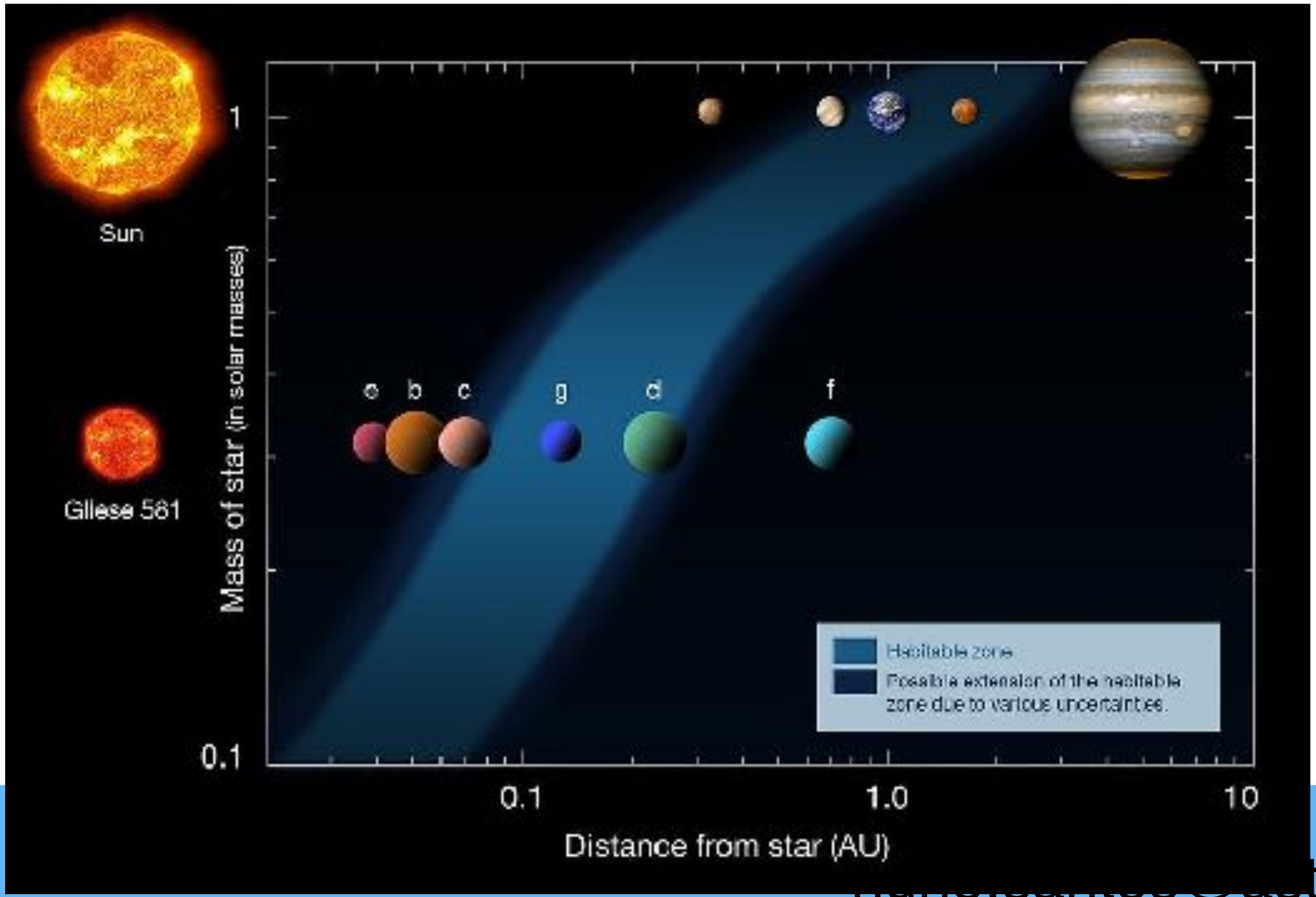


Institute of Astrophysics and Space Sciences

Nuno C. Santos
nuno.santos@astro.up.pt

Why we stellar parameters are important in exoplanets

- Stellar properties may influence the capacity to detect planets (e.g. spectral type, activity, ...)
- Stellar parameters and determination of planet properties
  - Planet mass, radius, mean density => stellar mass and radius
  - System's age => stellar age
  - Habitability => stellar irradiation (temperature, luminosity, activity...)



Why we stellar parameters are important in exoplanets

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- Stellar parameters and determination of planet properties
  - Planet mass, radius, mean density => stellar mass and radius
  - System's age => stellar age
  - Habitability => stellar irradiation (temperature, luminosity, activity, composition...)
- Observed correlations between planet and stellar properties are observed (clues to formation/evolution):
  - Stellar properties: abundances, luminosity class, mass, ...
  - Planet properties: internal structure (metallicity), composition, radius, orbital parameters...

Nuno C. Santos
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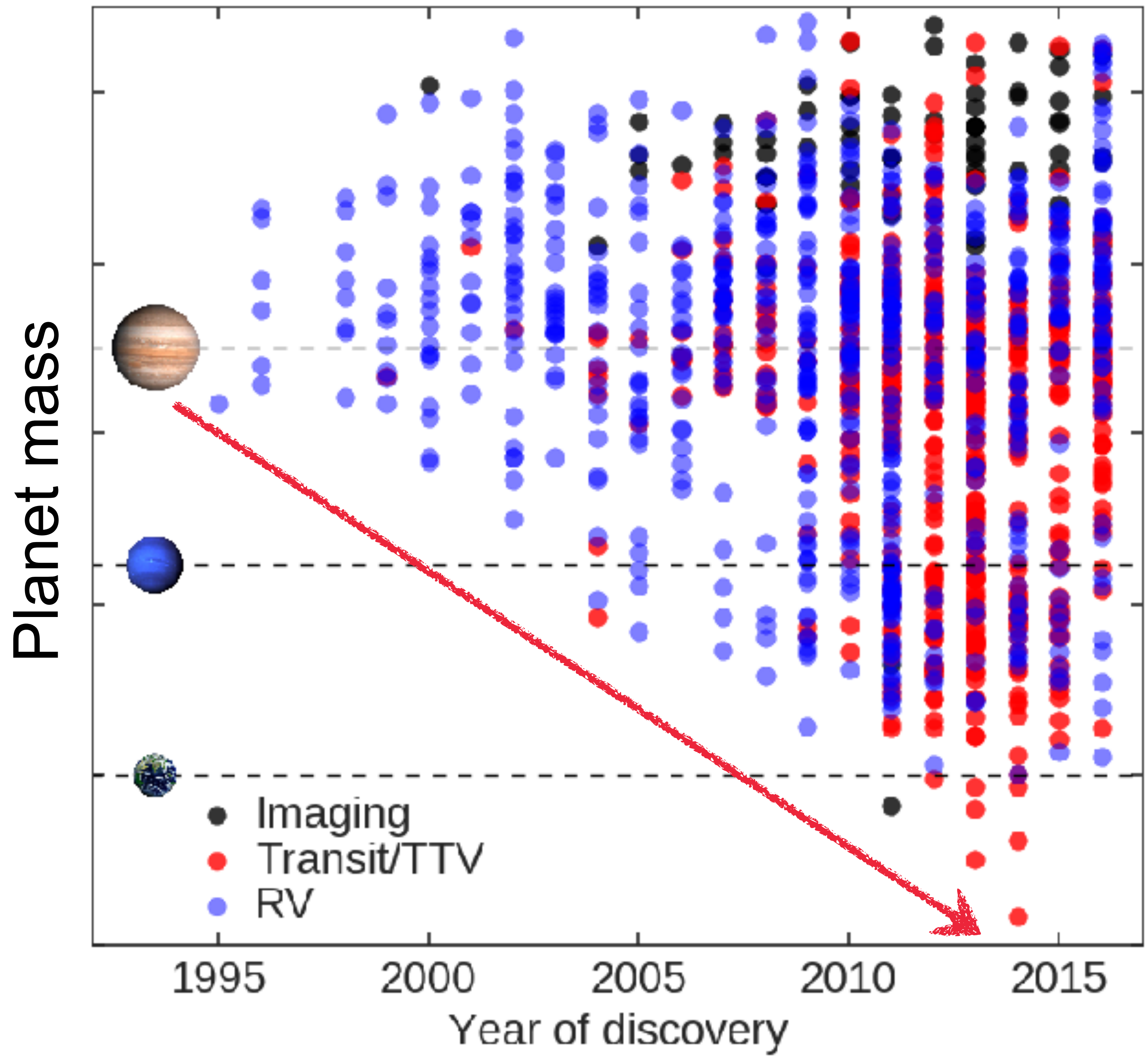
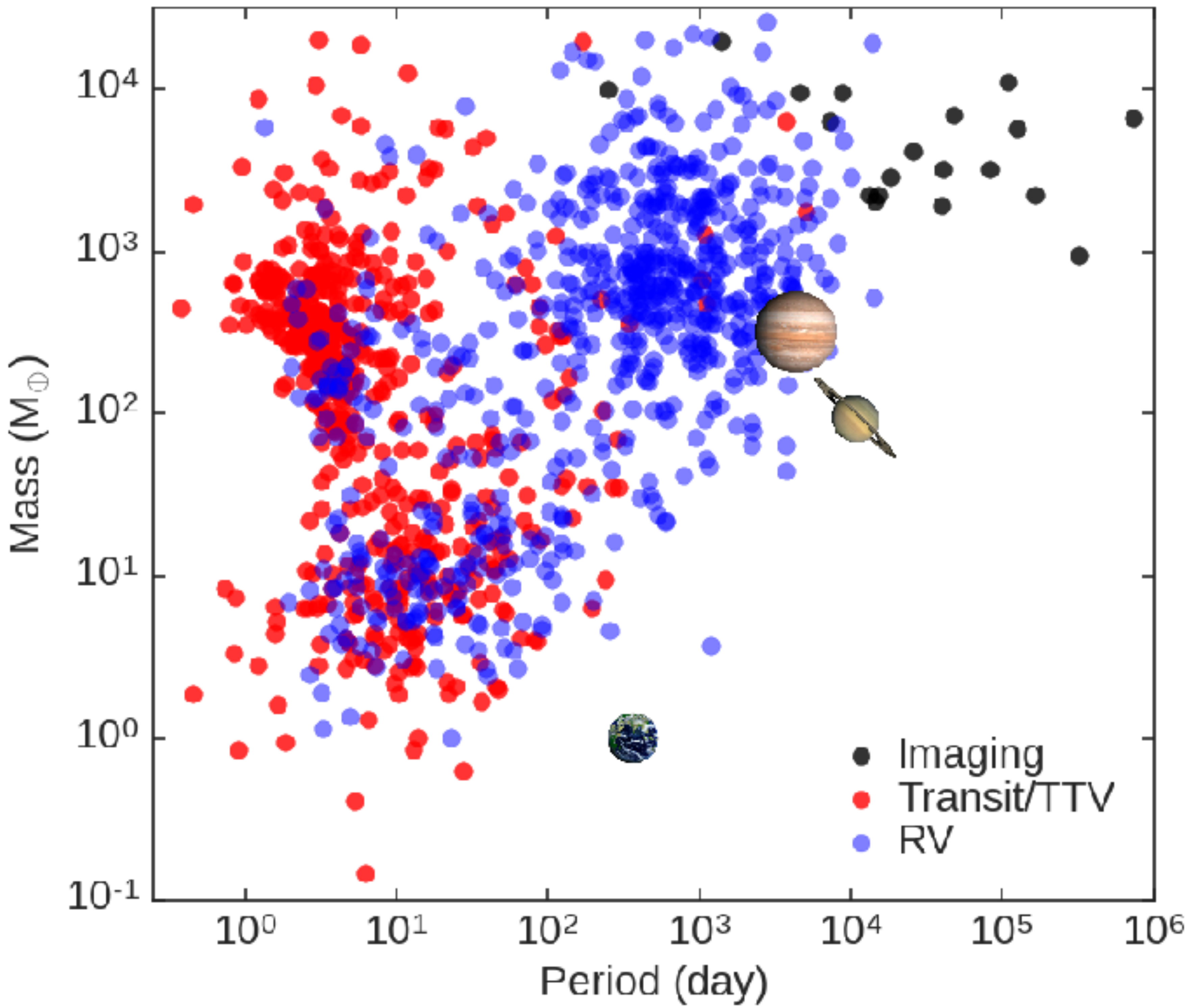
Exoplanet discovery status



~3500 exoplanets
(e.g. exoplanet.eu)

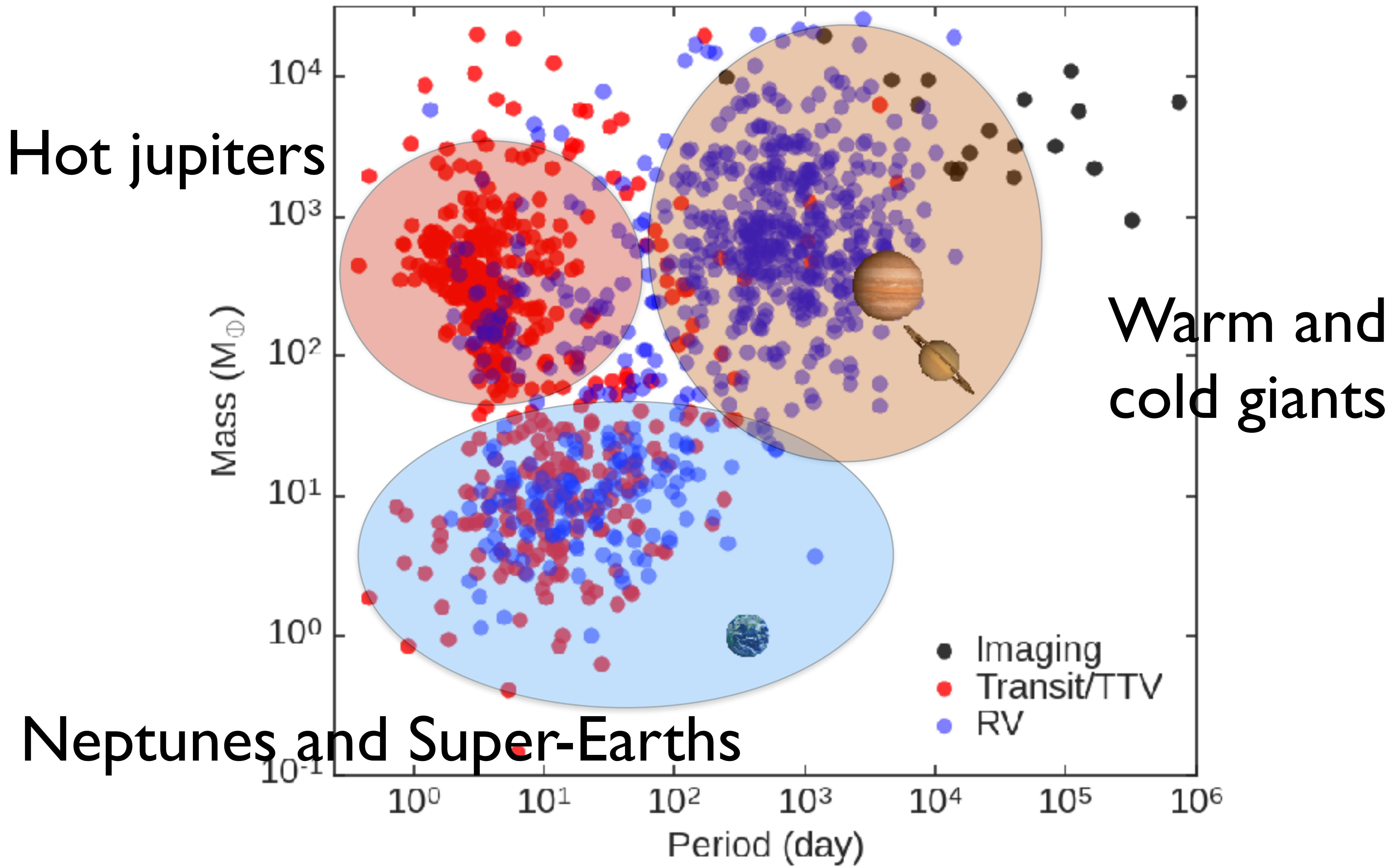
Nuno C. Santos
nuno.santos@astro.up.pt

Exoplanet discovery status



Nuno C. Santos
nuno.santos@astro.up.pt

Exoplanet discovery status



Nuno C. Santos
nuno.santos@astro.up.pt

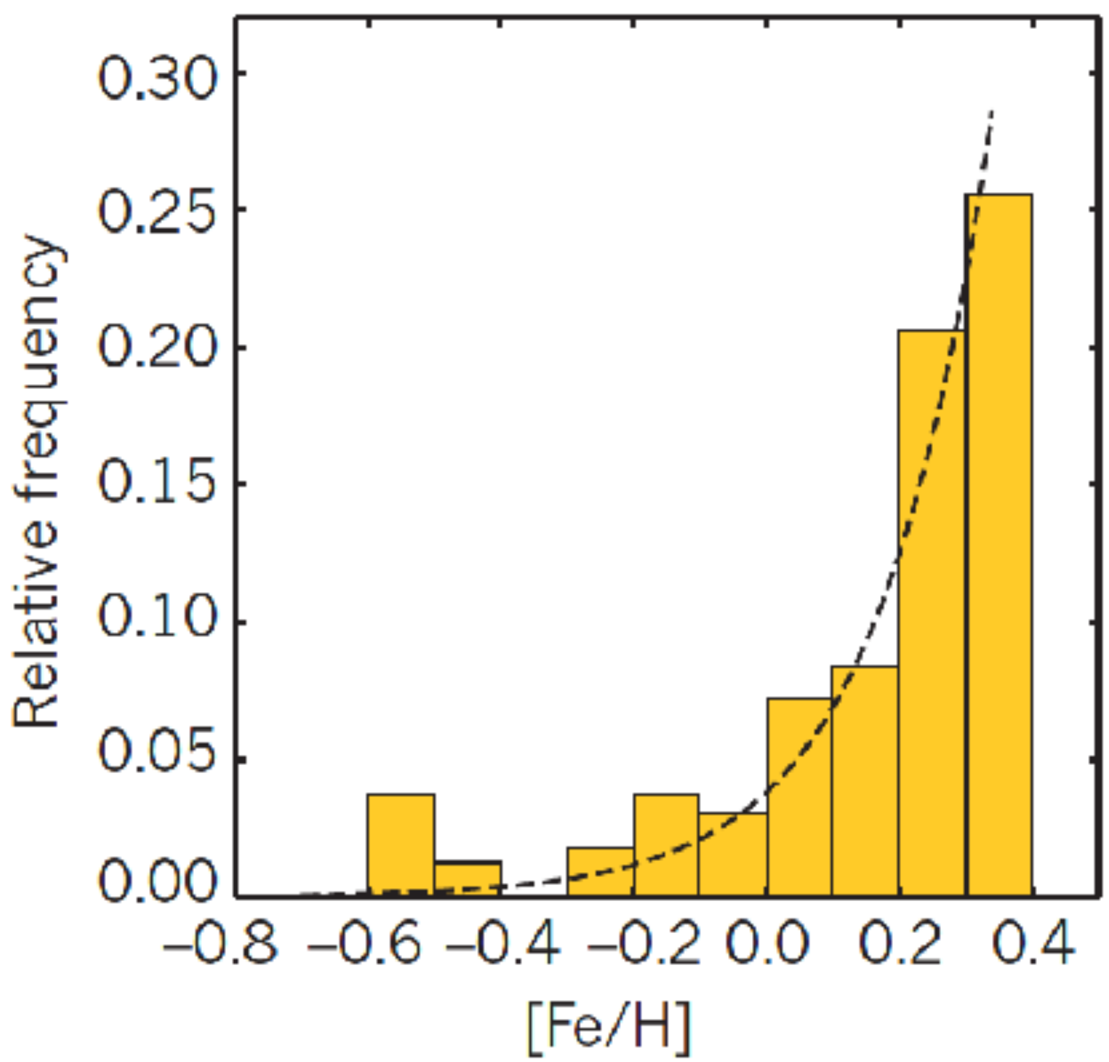
Metallicity-planet correlations

Nuno C. Santos
nuno.santos@astro.up.pt

The metallicity-planet correlation: clues for formation

- Results from radial-velocity surveys

Jovian companions



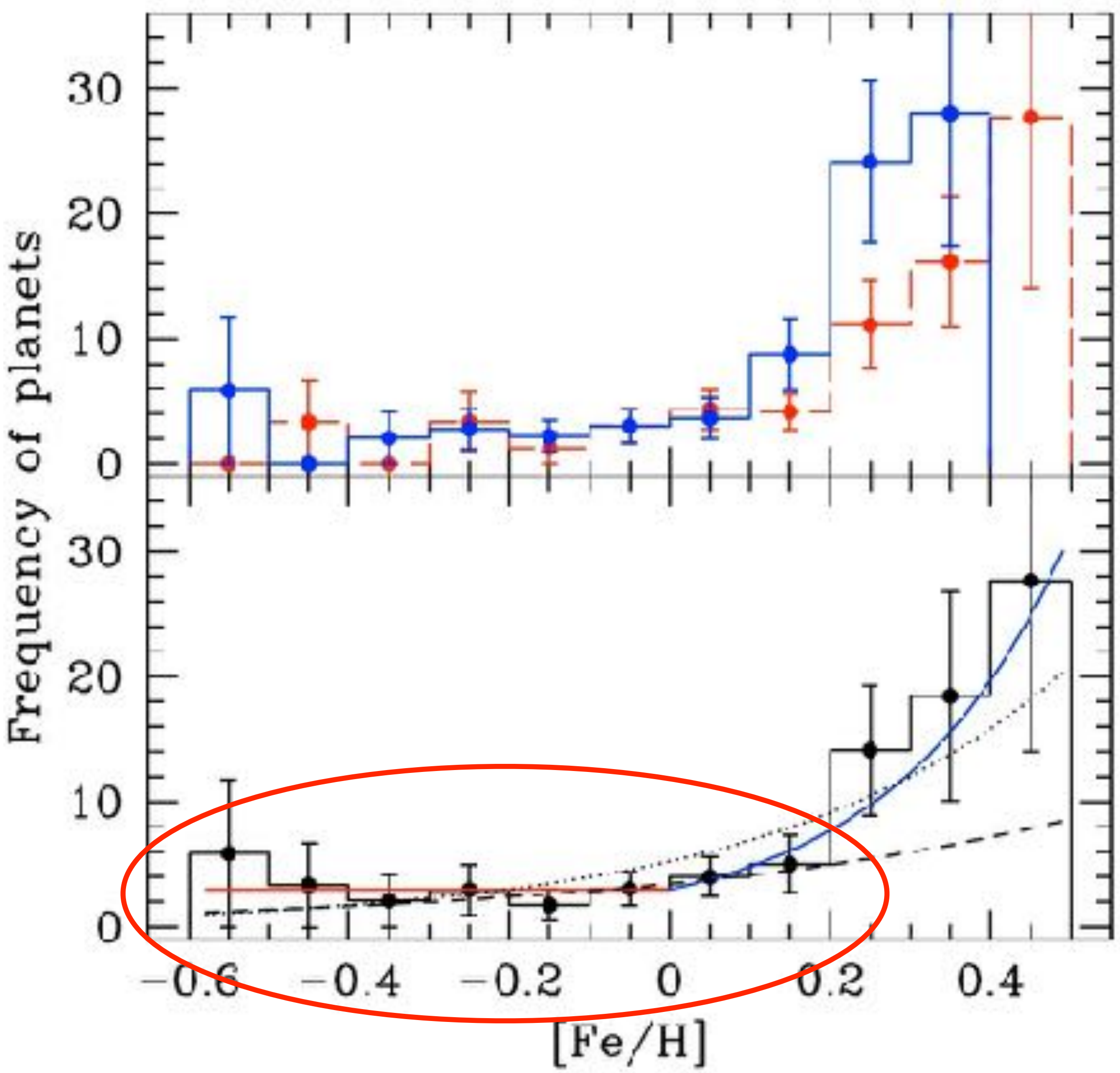
See also:
Gonzalez et al. 1997,
Santos et al. 2001, 2004,
Fischer & Valenti 2005,
Sousa et al. 2008, 2011
(…)

Data from Sousa et al. (2011)

The Functional Form for *giant* planets: the "discussion"

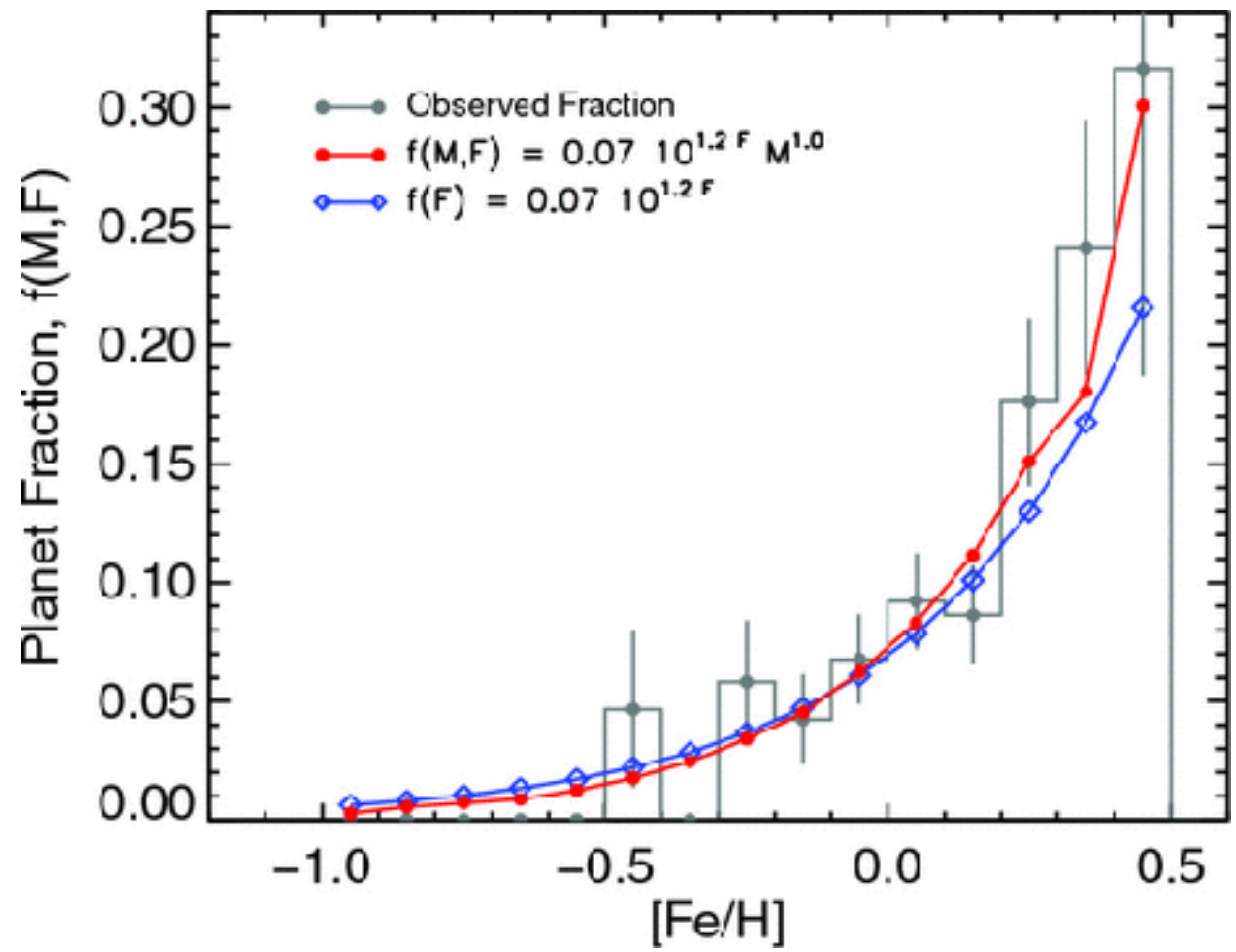
- Contradictory results exist: different formation processes at different metallicity? (for a discussion see e.g. Mortier et al. 2014)

A flat tail for low metallicities?



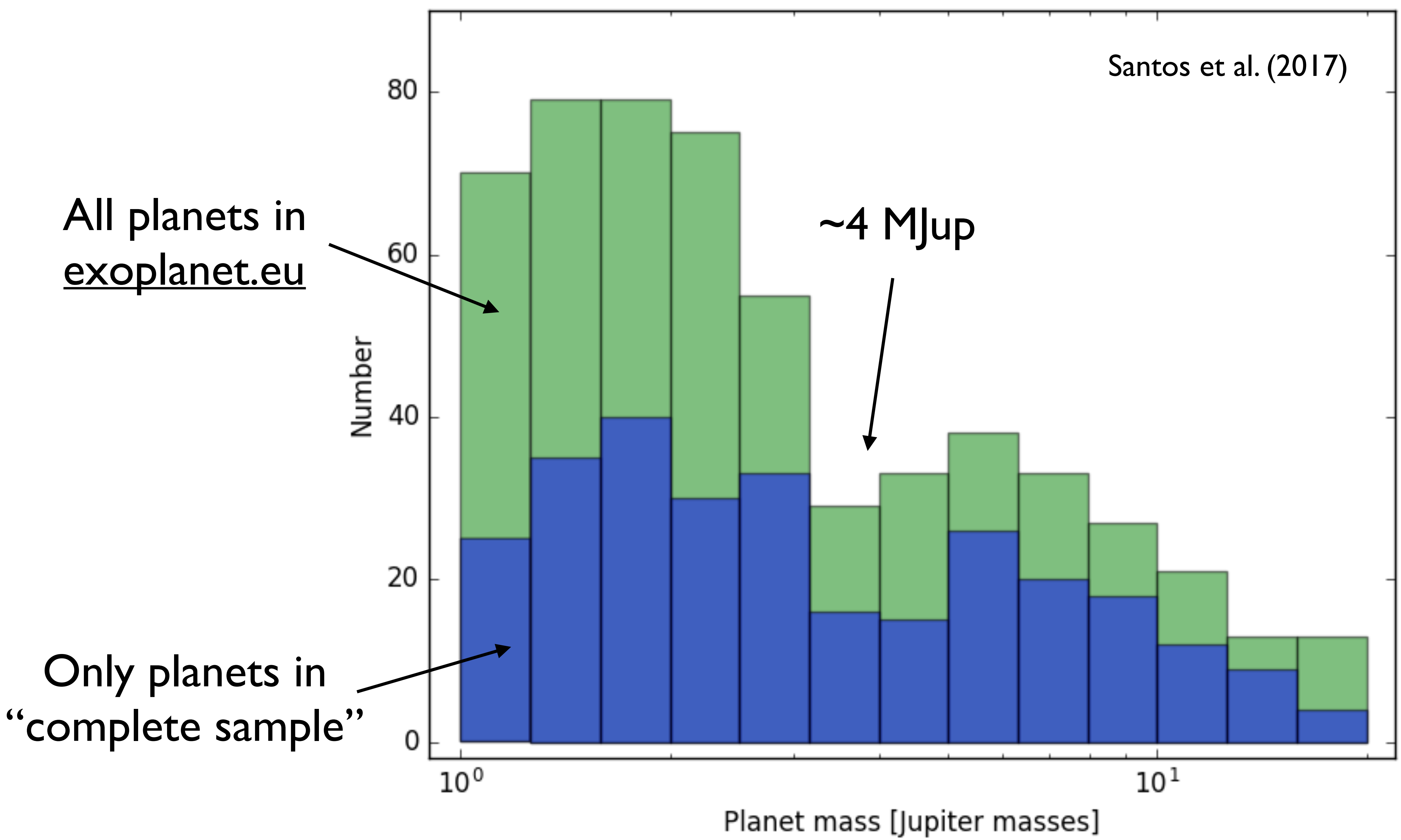
Udry & Santos (2007)

A simple power-law?



Johnson et al. (2010)

Planet mass distribution: two giant planet populations?



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SWEET-Cat (http://www.astro.up.pt/resources/sweet-cat)

SWEET–Cat: a catalog of stellar parameters for stars with planets

SWEET–Cat: a catalog of stellar ...

https://www.astro.up.pt/resources/sweet-cat/

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Centro de Astrofísica da Universidade do Porto

SWEET-Cat: a catalog of stellar parameters for stars with planets

SWEET-Cat is a catalogue of stellar parameters for stars with planets listed in the Extrasolar Planets Encyclopaedia. It compiles sets of atmospheric parameters previously published in the literature (including Teff, logg, and [Fe/H]) and, whenever possible, derived using the same uniform methodology (see e.g. Santos et al. 2004; Sousa et al. 2008).

The catalog is described in Santos et al. 2013. However, it is continuously being updated as new planets are announced and new stellar parameters derived. If major changes occur concerning the structure of the catalog they will be described here or in a subsequent paper.

SWEET-Cat is built from literature data, either published or to be published soon. Although we do not encourage, we understand that for simplicity the user may wish to cite only the catalog presentation paper if using it in a statistical way. However, we strongly encourage the user to give the propper credit to the original source of stellar parameters.

(click on any specific header to sort, a detailed description of each field can be found here)

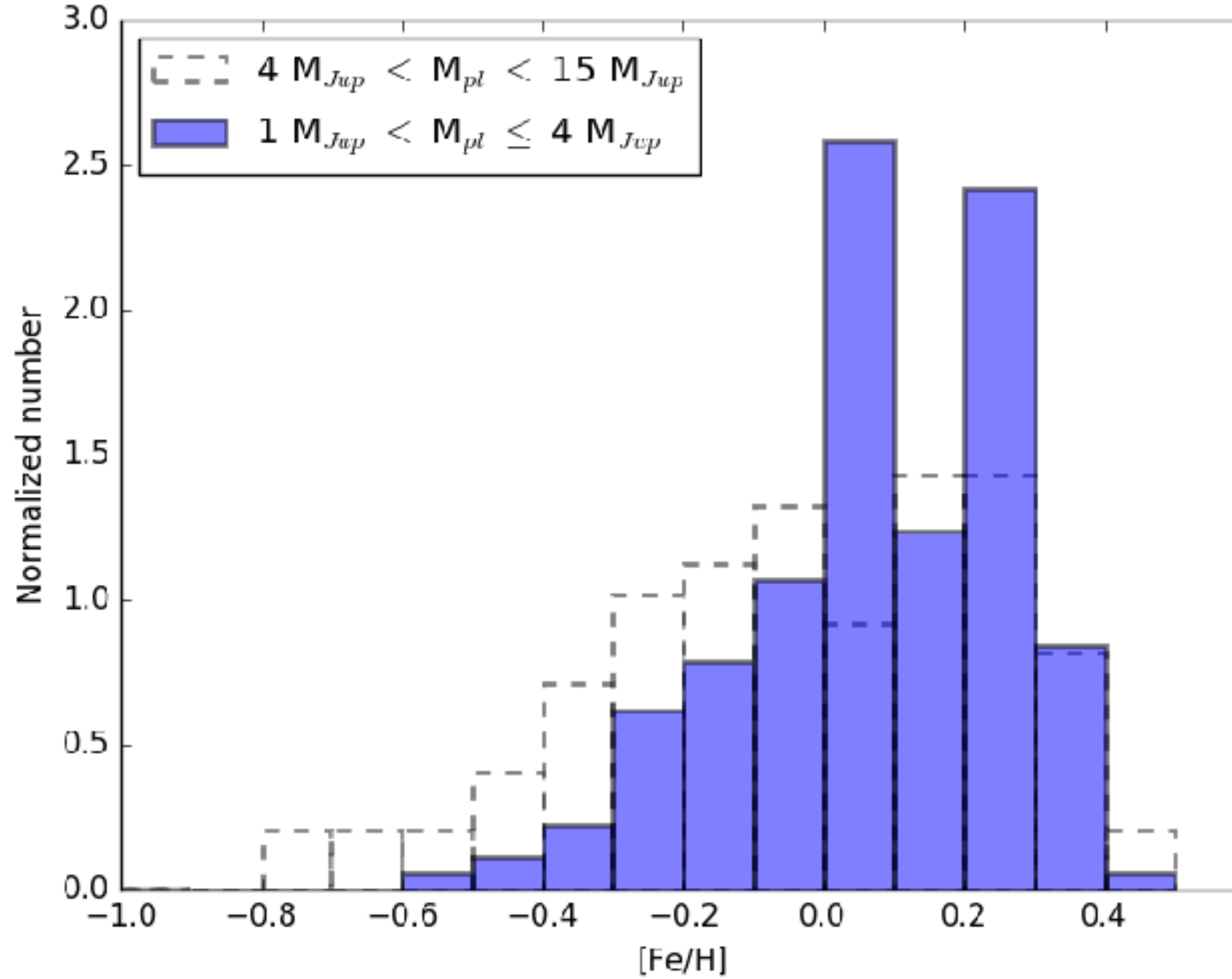
(Santos+ 2013; Andreasen+ 2017)

Download Data

Name	HD number	RA	Dec	Vmag	σ(Vmag)	π	σ(π)	Source of π	Teff	σ(Teff)	logg	σ(logg)	LC logg	σ(LC logg)	Vt	σ(Vt)	[Fe/H]	σ([Fe/H])	Mass	σ(Mass)	Reference
11 Com	107383	12 20 43.02	+17 47 34.33	4.74	0.02	11.25	0.22	Simbad	4830	79	2.61	0.13	-	-	1.70	0.10	-0.34	0.06	2.00	0.29	Mortier et al. 2013b
11 UMi	136726	15 17 05.88	+71 49 26.04	5.02	-	8.19	0.19	Simbad	4340	70	1.60	0.15	-	-	1.60	0.80	0.04	0.04	1.80	0.25	Dollinger et al. 2009
14 And	221345	23 31 17.41	+39 14 10.30	5.22	-	12.63	0.27	Simbad	4773	100	2.53	0.10	-	-	1.64	0.30	-0.26	0.11	1.45	-	Luck & Heiter 2007
14 Her	145675	16 10 24.31	+43 49 03.52	6.67	-	56.91	0.34	Simbad	5311	87	4.42	0.18	-	-	0.92	0.10	0.43	0.08	0.95	0.09	Santos et al. 2004
16 Cyg B	186427	19 41 51.97	+50 31 03.08	6.20	-	47.14	0.27	Simbad	5772	25	4.40	0.07	-	-	1.07	0.04	0.08	0.04	1.00	0.07	Santos et al. 2004
18 Del	199665	20 58 25.93	+10 50 21.42	5.52	-	13.28	0.31	Simbad	5076	38	3.08	0.10	-	-	1.32	0.04	0.00	0.03	2.33	0.05	Mortier et al. 2013b
24 Sex	90043	10 23 28.37	-00 54 08.09	6.44	0.01	12.91	0.38	Simbad	5069	62	3.40	0.13	-	-	1.27	0.07	-0.01	0.05	1.81	0.08	Mortier et al. 2013b
30 Ari B	16232	02 36 57.74	+24 38 53.02	7.09	-	24.52	0.68	Simbad	6377	170	4.49	0.05	-	-	-	-	0.14	0.18	1.16	0.04	Guenther et al. 2009
4 Uma	73108	08 40 12.81	+64 19 40.57	4.60	-	12.74	0.26	Simbad	4564	100	2.28	0.10	-	-	1.69	0.30	-0.16	0.13	1.48	-	Luck & Heiter 2007
42 Dra	170693	18 25 59.13	+65 33 48.52	4.83	-	10.36	0.20	Simbad	4513	100	2.24	0.10	-	-	1.59	0.30	-0.39	0.12	1.74	-	Luck & Heiter 2007
47 Uma	95128	10 59 27.97	+40 25 48.92	5.04	0.05	71.11	0.25	Simbad	5954	25	4.44	0.10	-	-	1.30	0.04	0.06	0.03	1.04	0.08	Santos et al. 2004
51 Peg	217014	22 57 27.98	+20 46 07.79	5.46	0.05	64.07	0.38	Simbad	5804	36	4.42	0.07	-	-	1.20	0.05	0.20	0.05	1.04	0.08	Santos et al. 2004

Planet mass distribution: two giant planet populations?

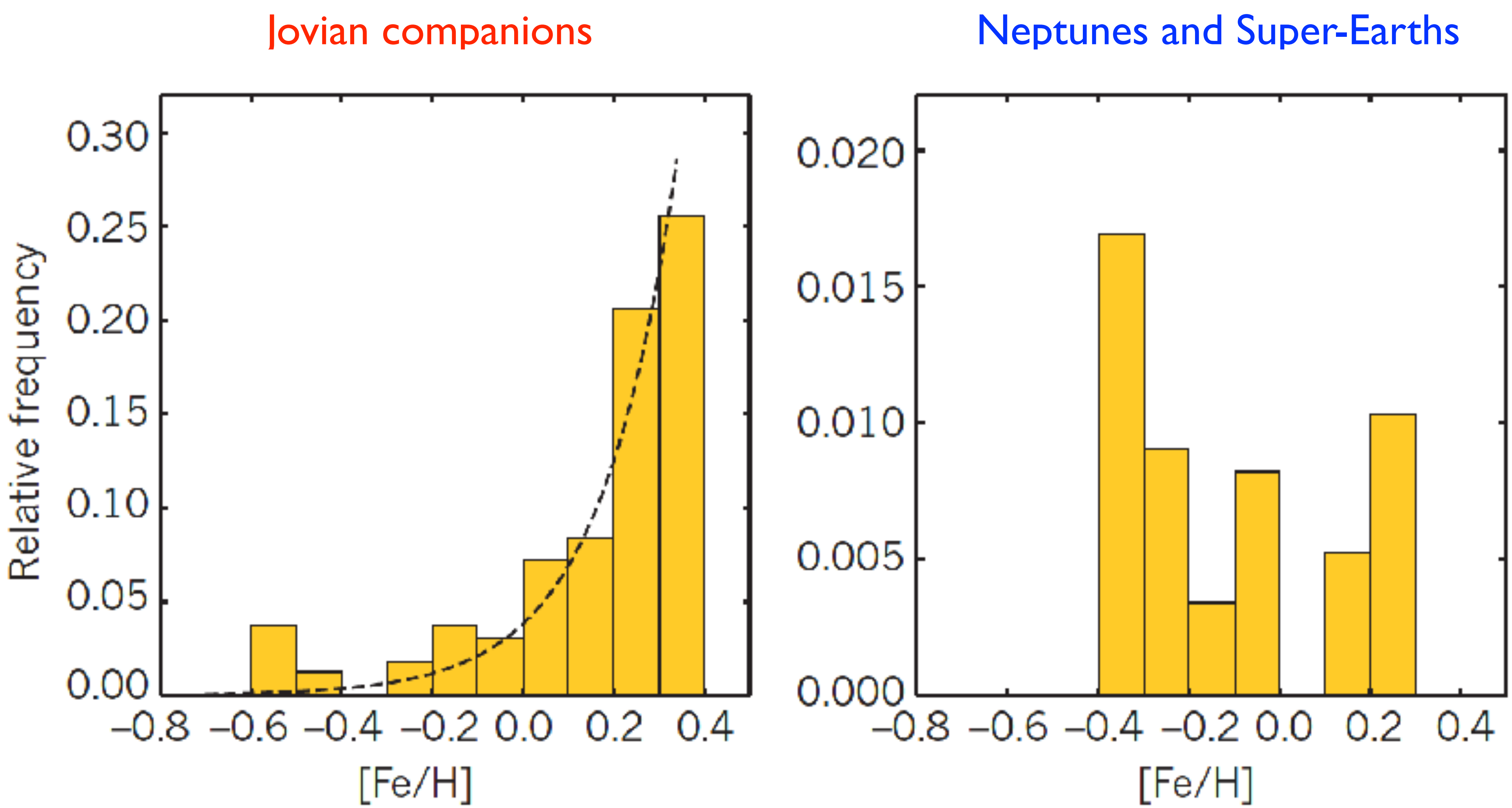
Higher mass planets orbit lower [Fe/H] stars: evidence for different formation processes?



Santos et al. (2017)

The metallicity-planet correlation: clues for formation

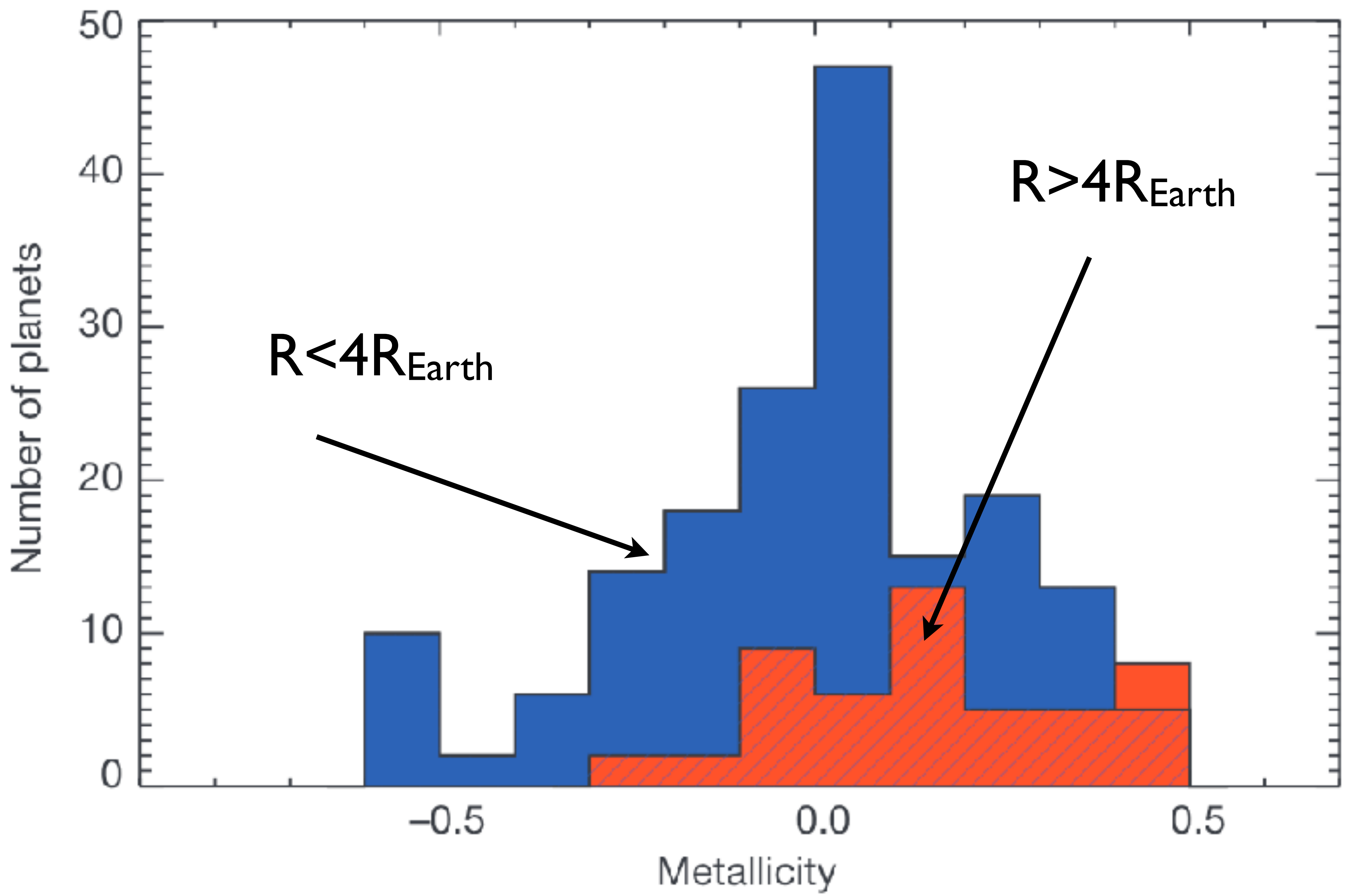
- Results from radial-velocity surveys



Data from Sousa et al. (2011)

Kepler results are similar

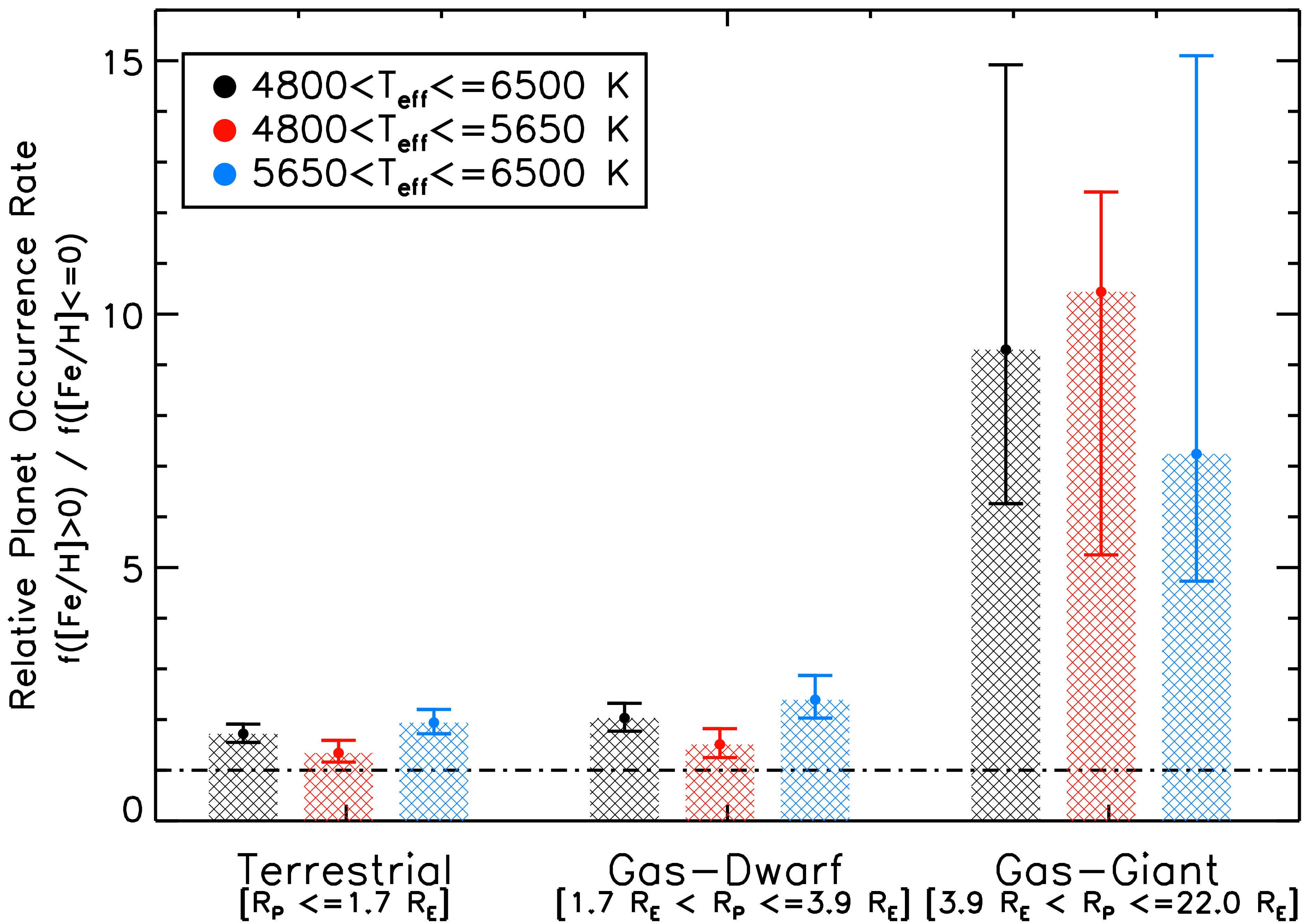
- Kepler: no correlation found for Neptune-**sized** planets



(Buchhave et al. 2012)

But…

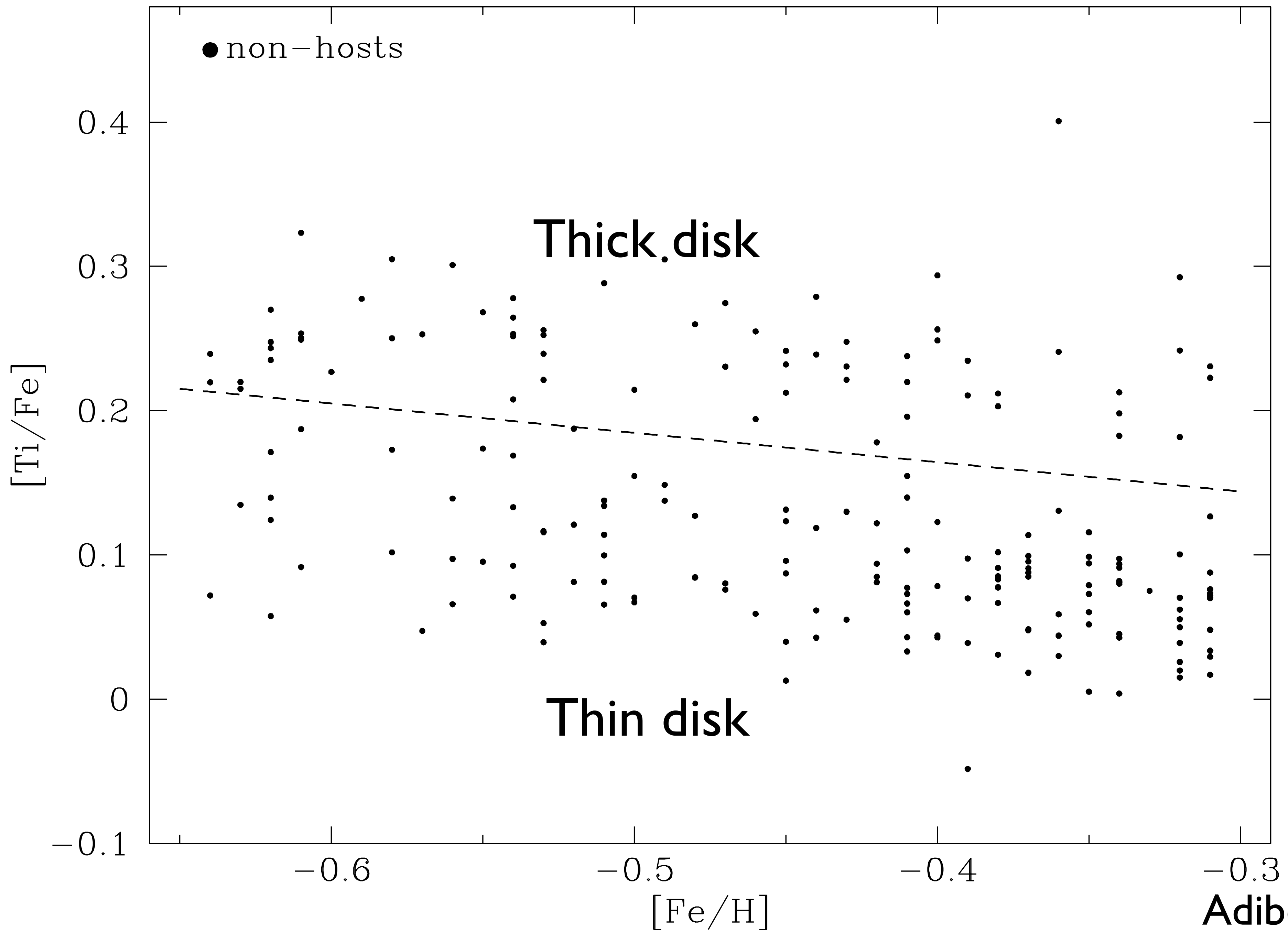
- Still a small correlation?



See also Zhu et al. 2016

(Wang & Fischer 2015)

Clues from the alpha elements

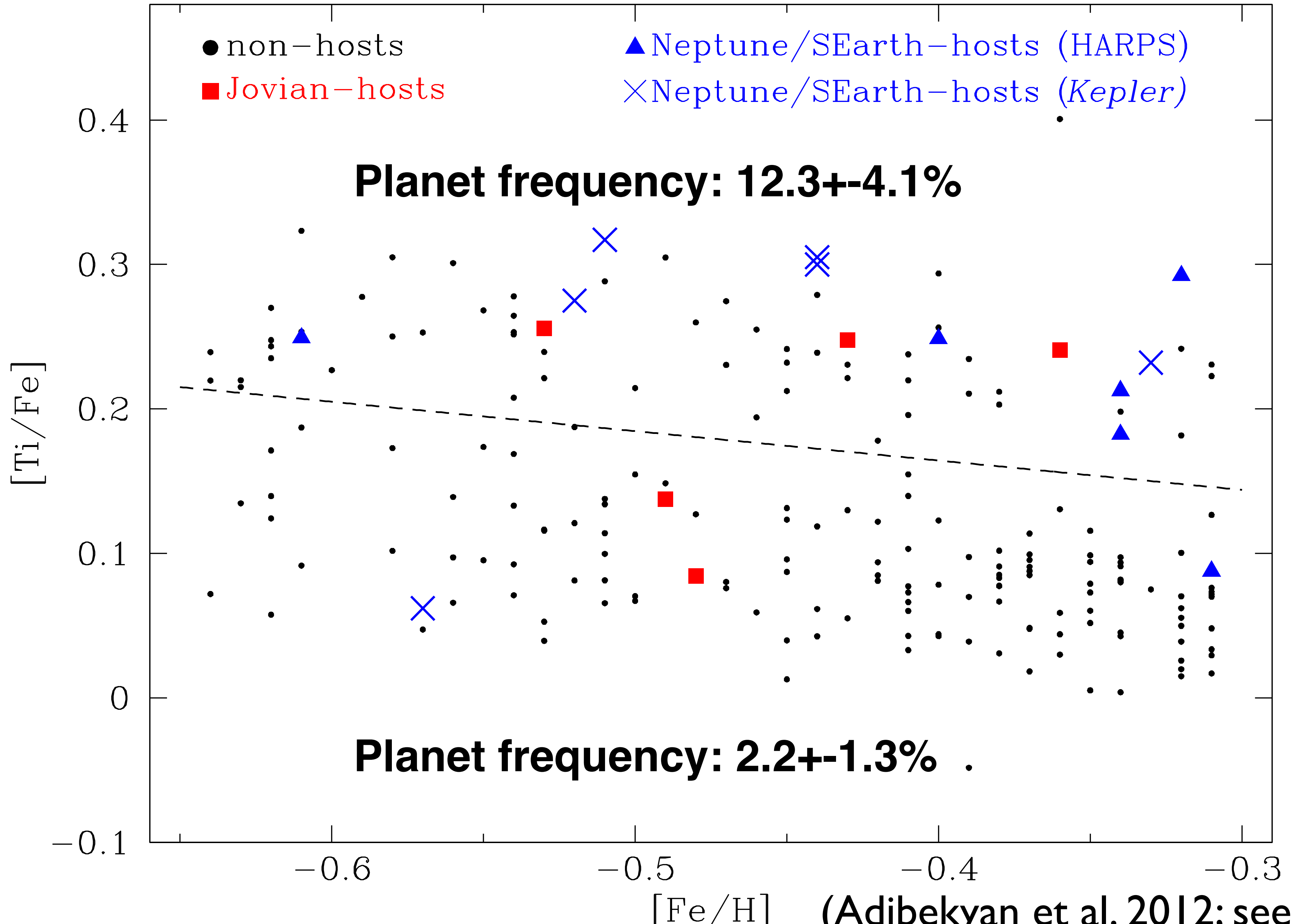


Adibekyan et al. (2012)

Nuno C. Santos
nuno.santos@astro.up.pt

Clues from the alpha elements

- Result 1: higher frequency of planets if star is rich in alpha element Ti
- Restul 2: metals critical in metal-poor stars even for low mass planet formation



(Adibekyan et al. 2012; see also Haywood 2008)

Nuno C. Santos
nuno.santos@astro.up.pt

Stellar chemistry and planet architecture.

Nuno C. Santos
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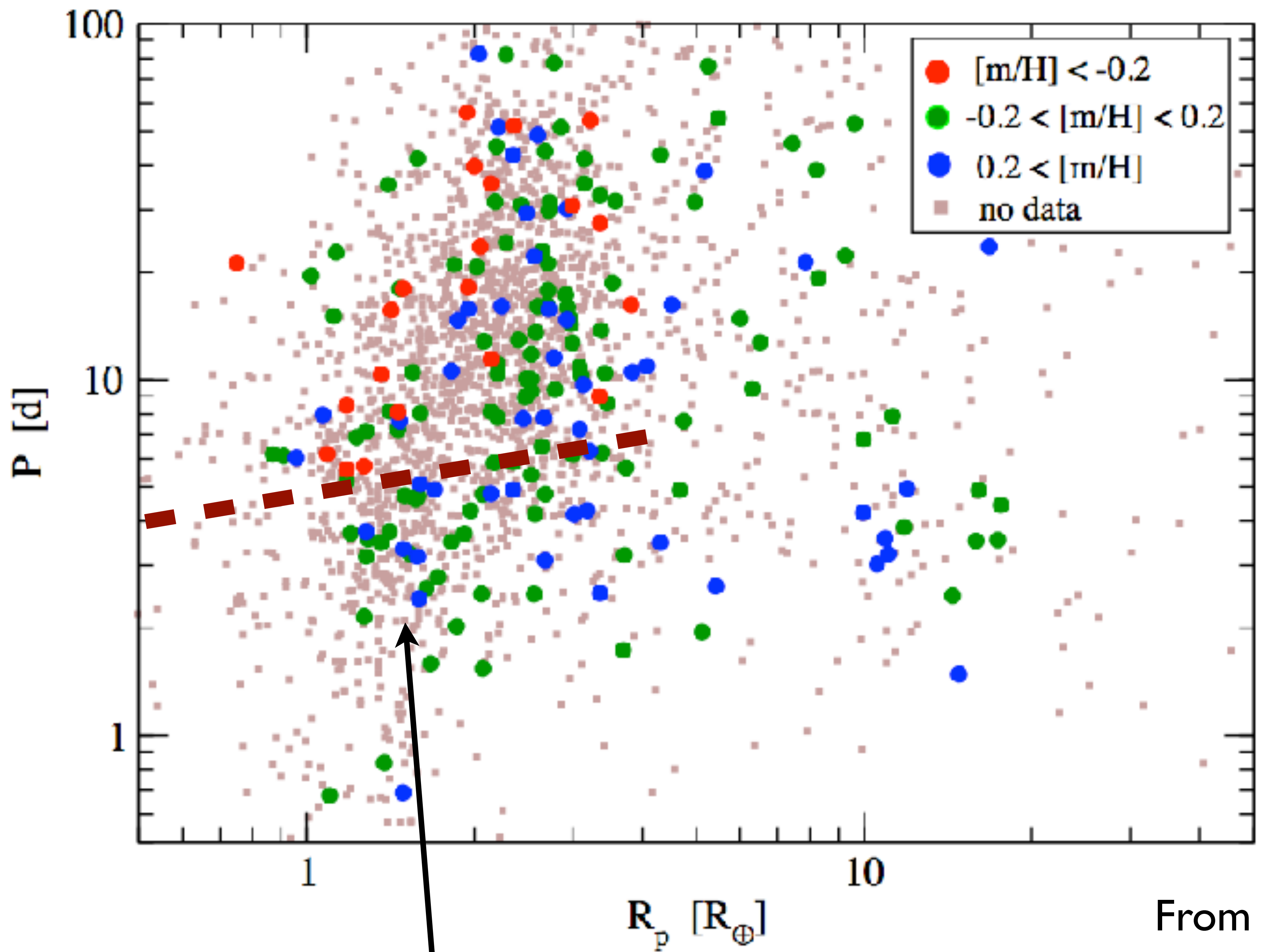
Metallicity in the mass-period diagram

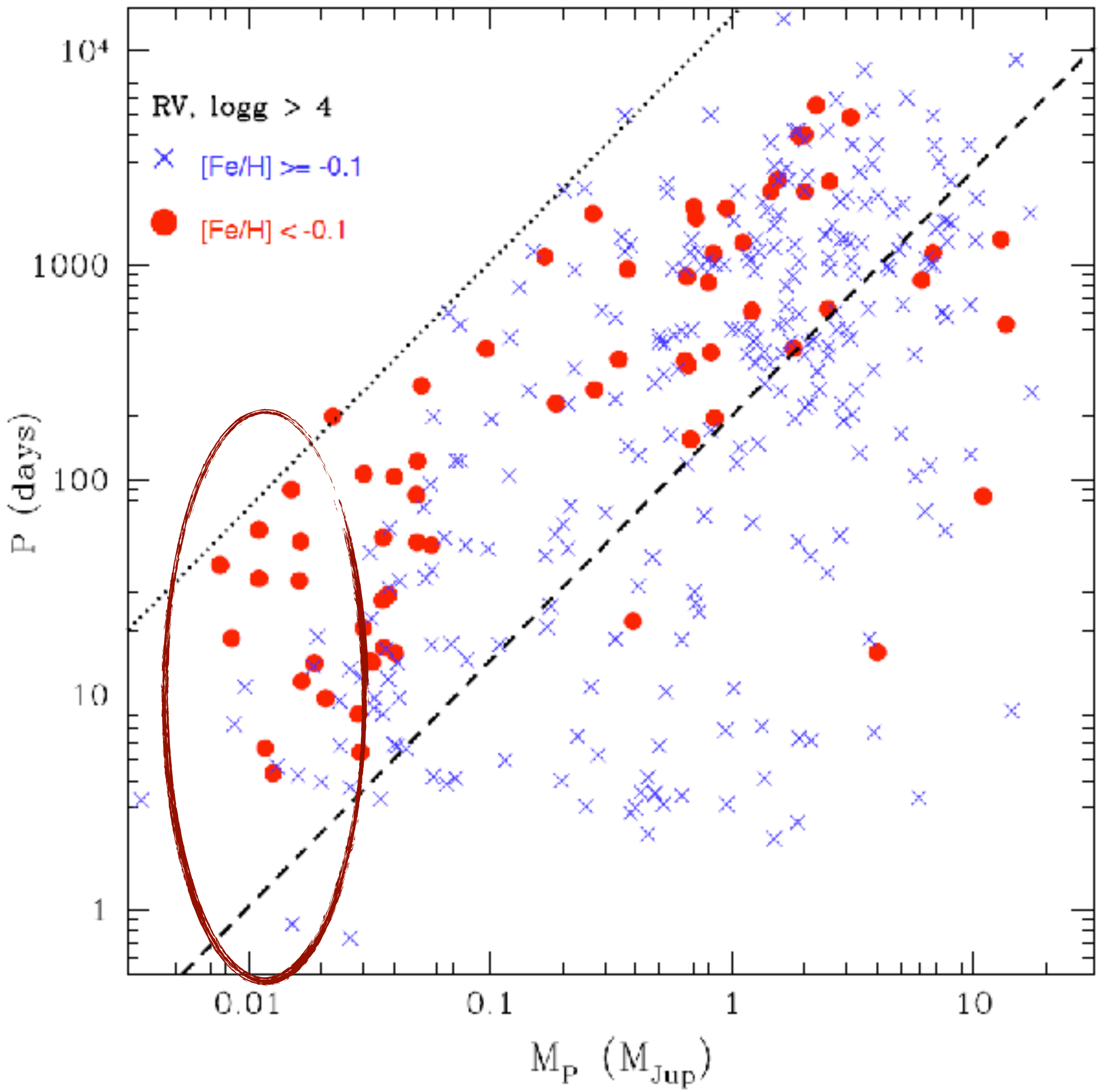


Kepler data: lack of short period (P<5 days) planets with $R<4R_{Earth}$ around low-[Fe/H] stars

From Beaugé & Nesvorny (2013)

No red points here

Metallicity in the mass-period diagram

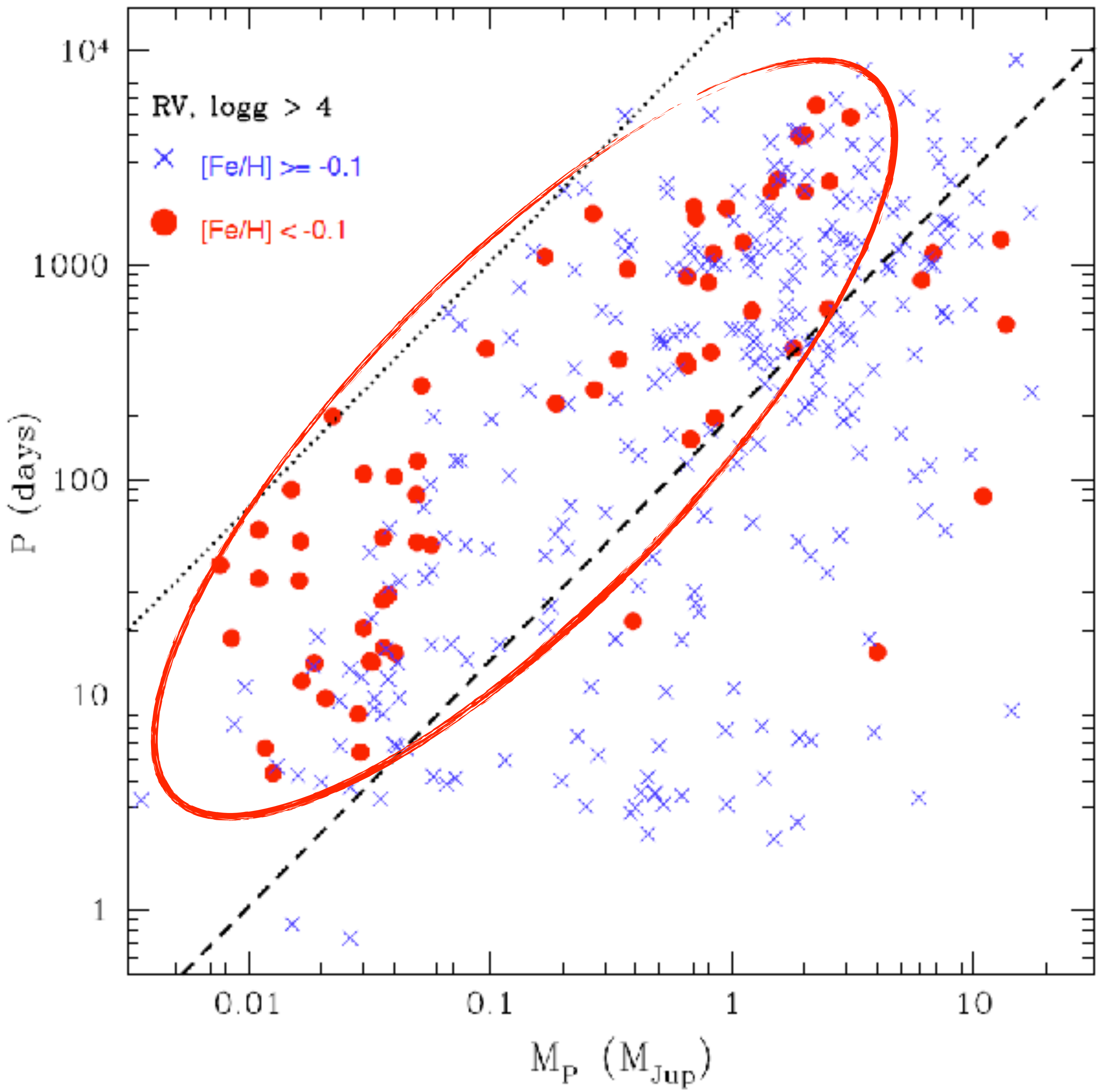


Radial velocity planets:

In the low-mass planet regime, we find no metal-rich stars with long period planets

From Adibekyan et al. (2013)

Metallicity in the mass-period diagram



For all masses: statistically, metal-poor stars host longer period planets.

Hints about migration?

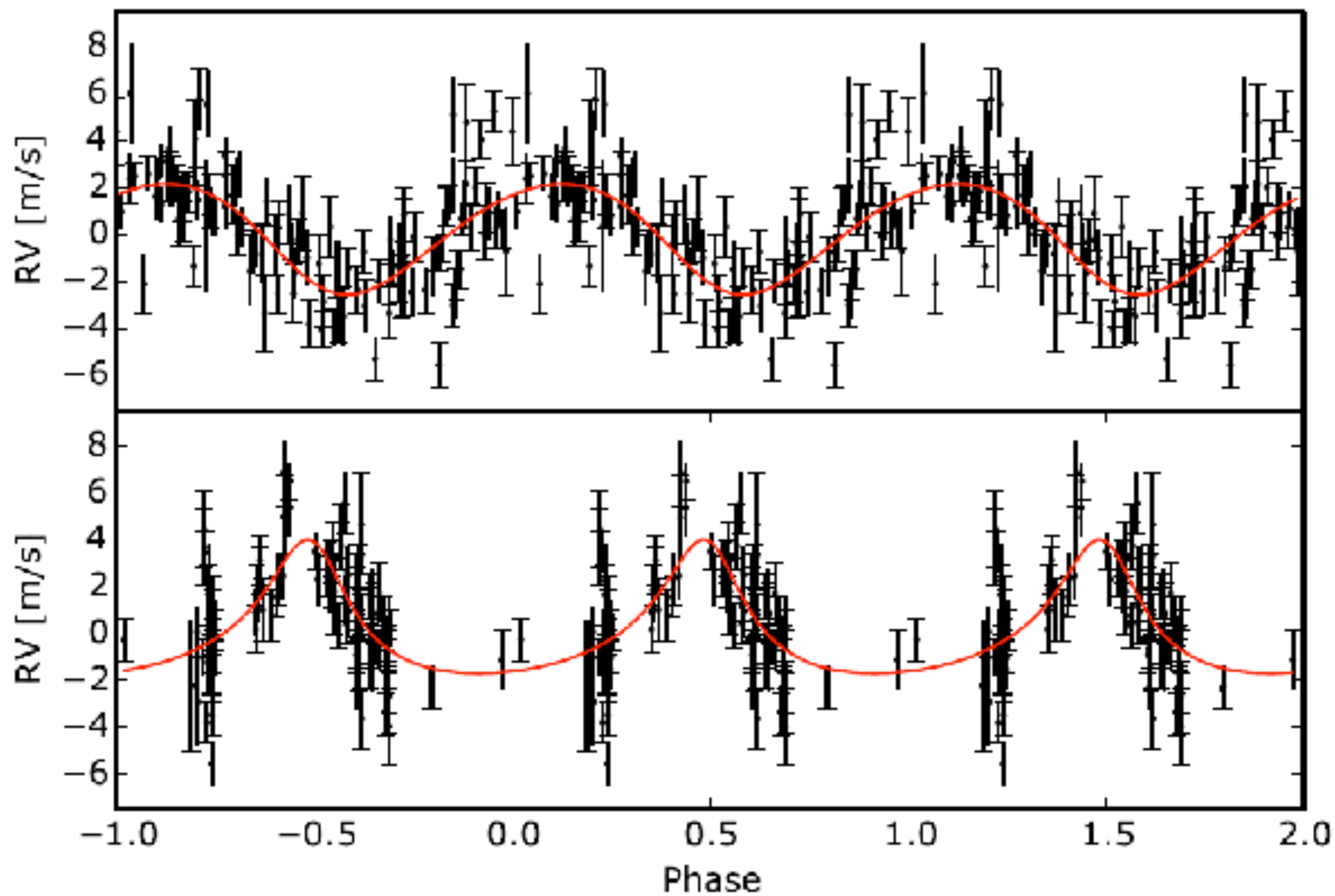
Planets form further out in metal-poor systems?

From Adibekyan et al. (2013)

A Large program to find super-Earths around a sample of metal-deficient stars

- A test for planet formation: is the frequency of Super-Earths higher/lower than in solar metallicity stars?
- Some very low mass candidates announced (e.g. Mortier et al. 2016, Faria et al. 2016)

A 2-planet system (HD175607)



Mortier et al. (2016)

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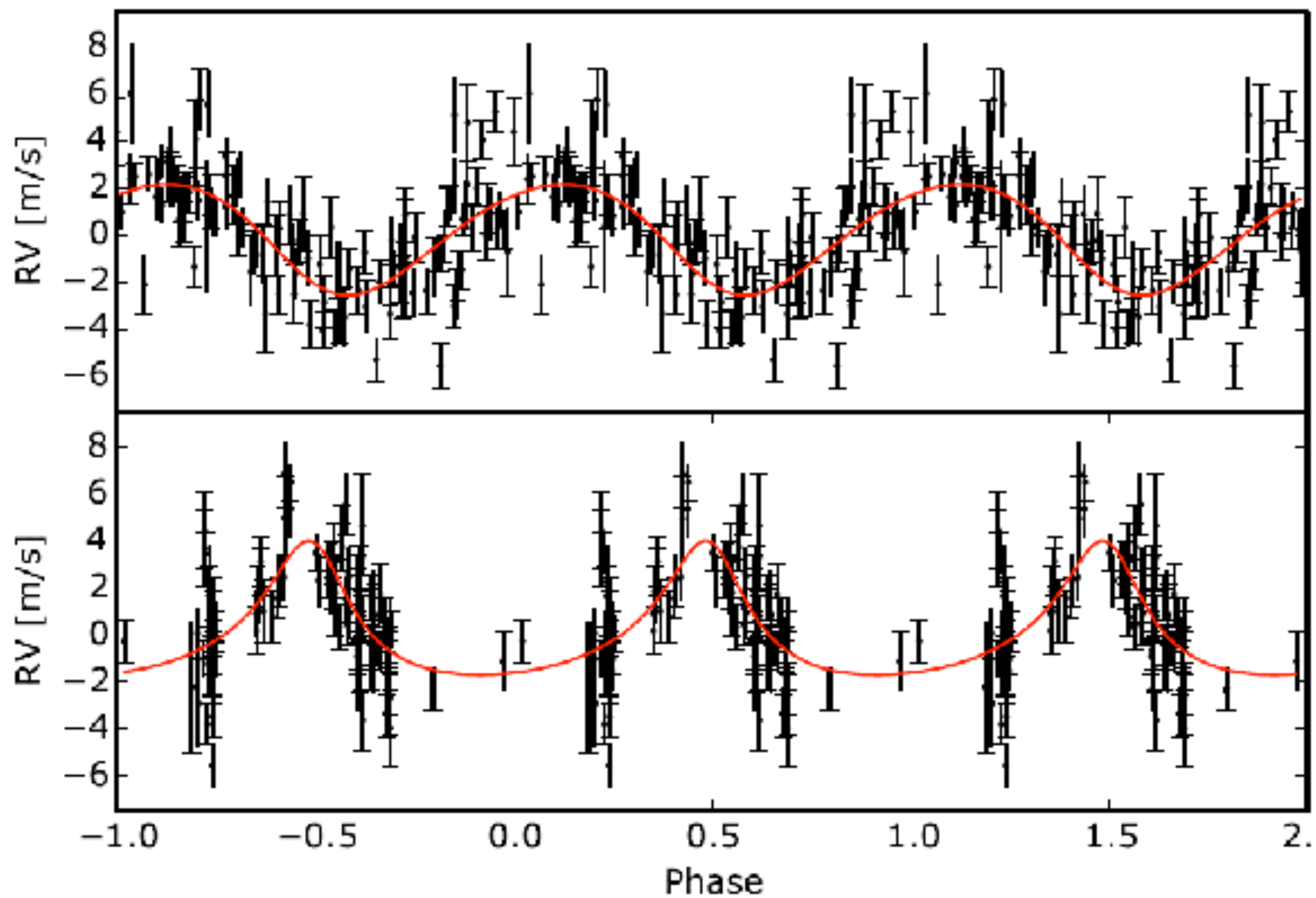
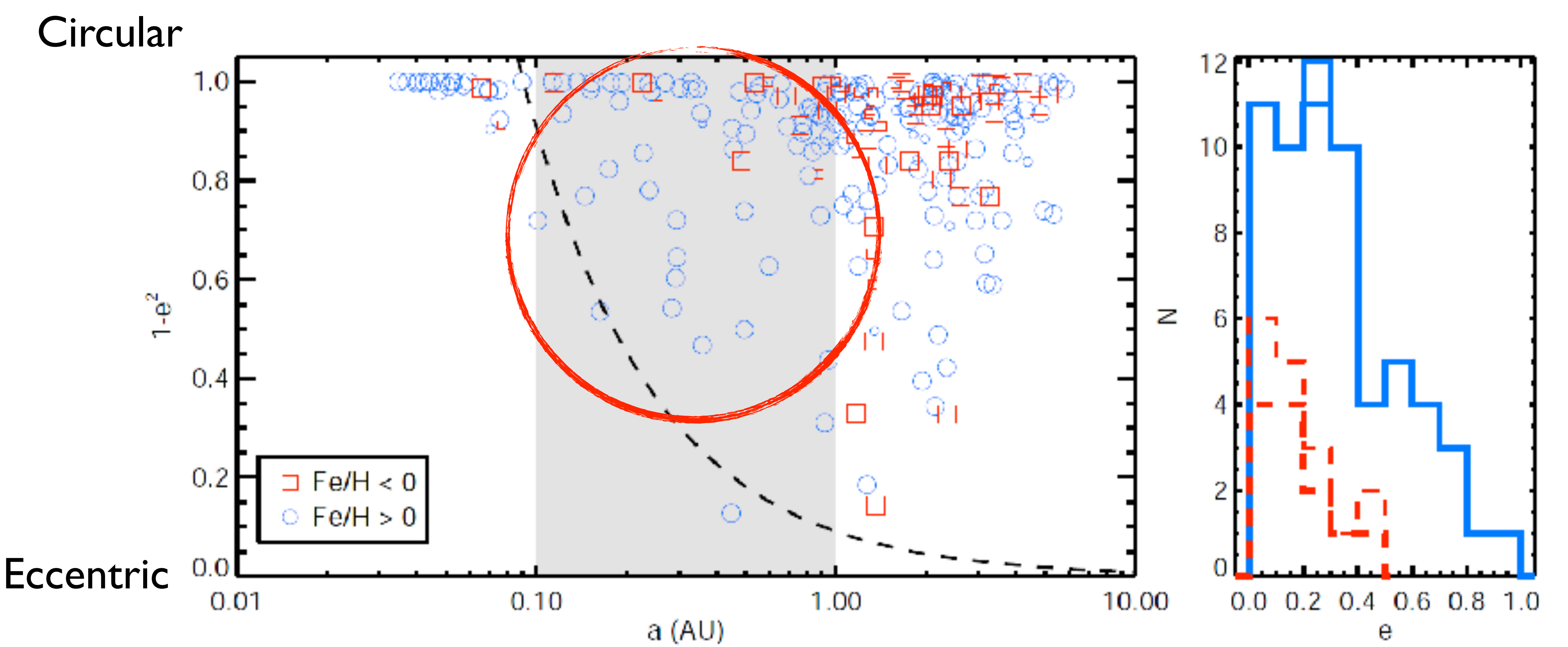


Mortier et al. (2016)

No short period planets found yet!

Planets, metallicity, and eccentricity

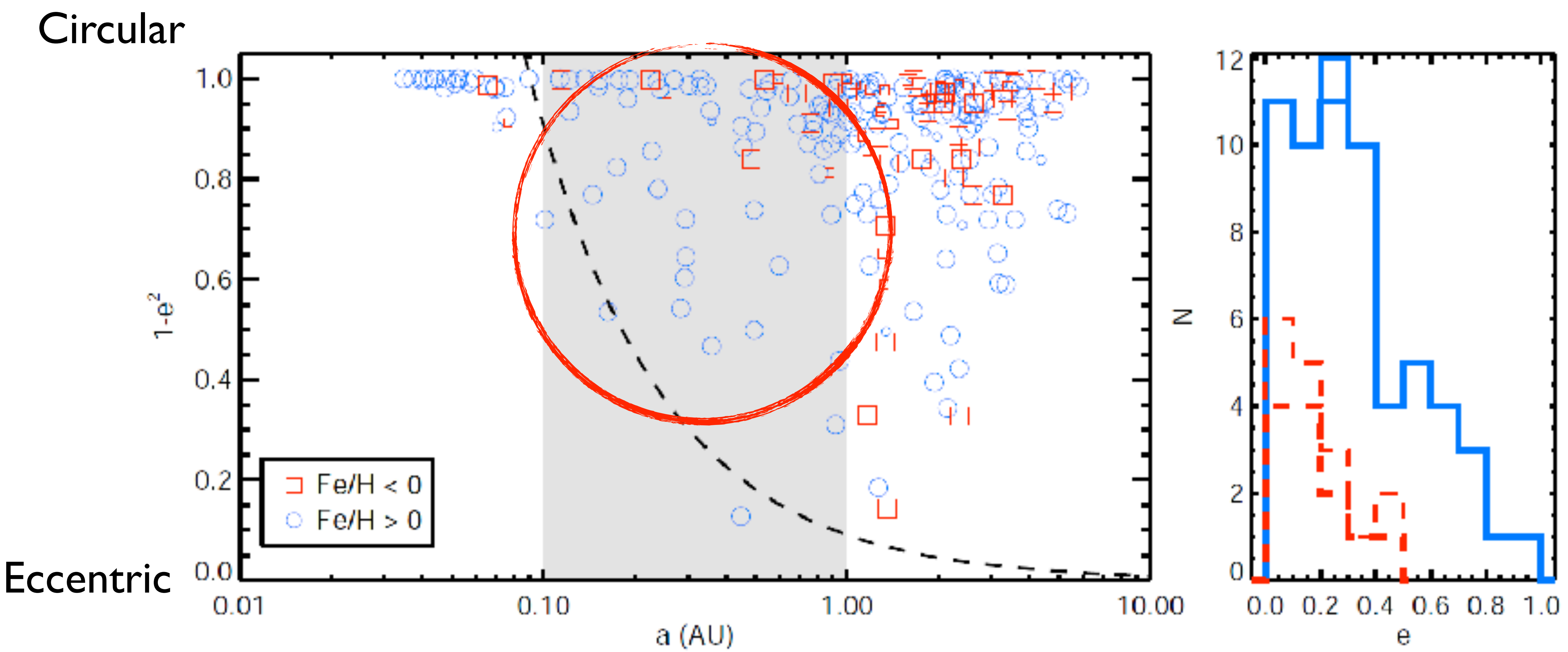


Dawson & Murray-Clay (2013)

Hints for higher eccentricity for planets orbiting higher [Fe/H] stars

Nuno C. Santos
nuno.santos@astro.up.pt

Planets, metallicity, and eccentricity



Dawson & Murray-Clay (2013)

Effect of planet-planet scattering?
Disk interaction/migration depends on [Fe/H]? (Tsang et al. 2014)

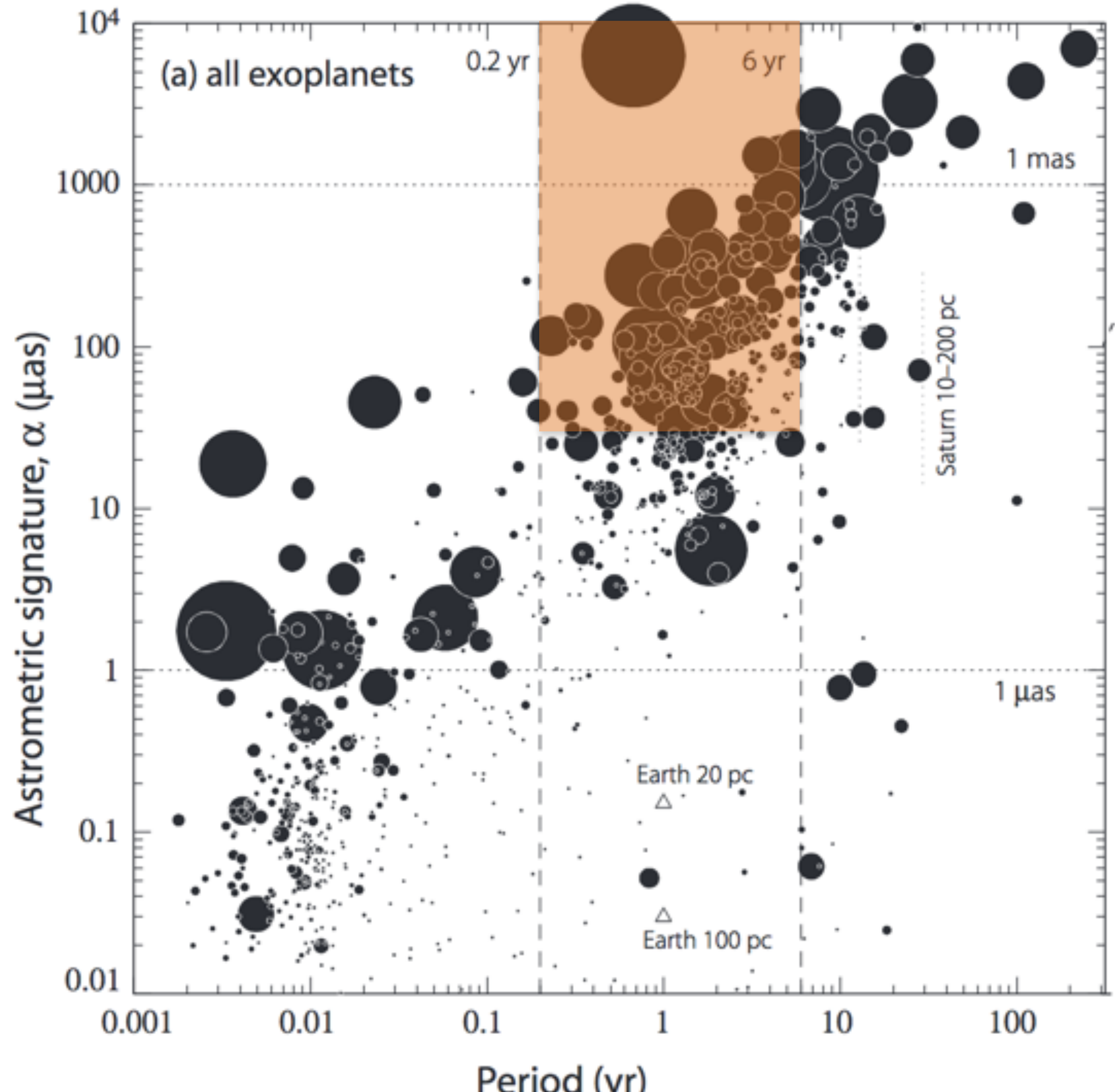
Nuno C. Santos
nuno.santos@astro.up.pt

The star-planet connection in the GAIA era

Nuno C. Santos
nuno.santos@astro.up.pt

What GAIA will bring: new planet detections

- Astrometric orbits for many known giant planets
- New planets: ~20 000 (e.g. Sozzetti+2014; Perryman+2014)
  - Even transiting ones! (e.g. Dzigan & Zucker 2014)
  - Preference to longer periods and higher masses
  - **Probe a different planet populations and properties in different stellar populations**

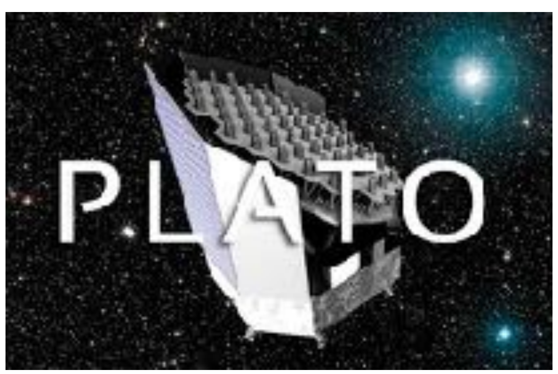


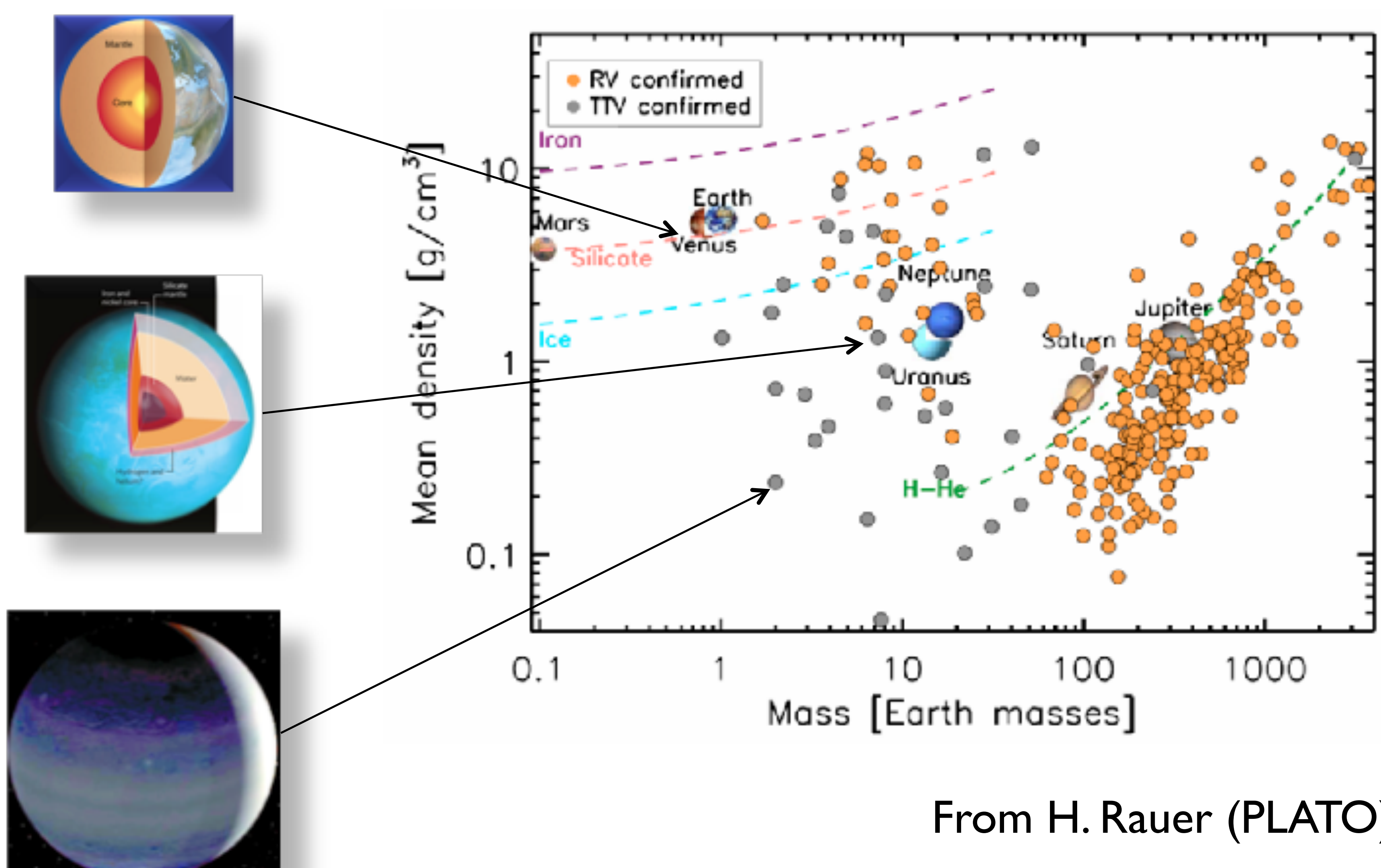
Perryman et al. (2014)

Nuno C. Santos
nuno.santos@astro.up.pt

What GAIA will bring: better stellar/planet parameters

- Better stellar/planet radii for transiting planets (e.g. Stassun et al. 2017)
- Specially important for K and M-dwarfs (asteroseismology does not "work")
- Still need accurate Teff (problematic for M-dwarfs?) and precise abundance





From H. Rauer (PLATO)

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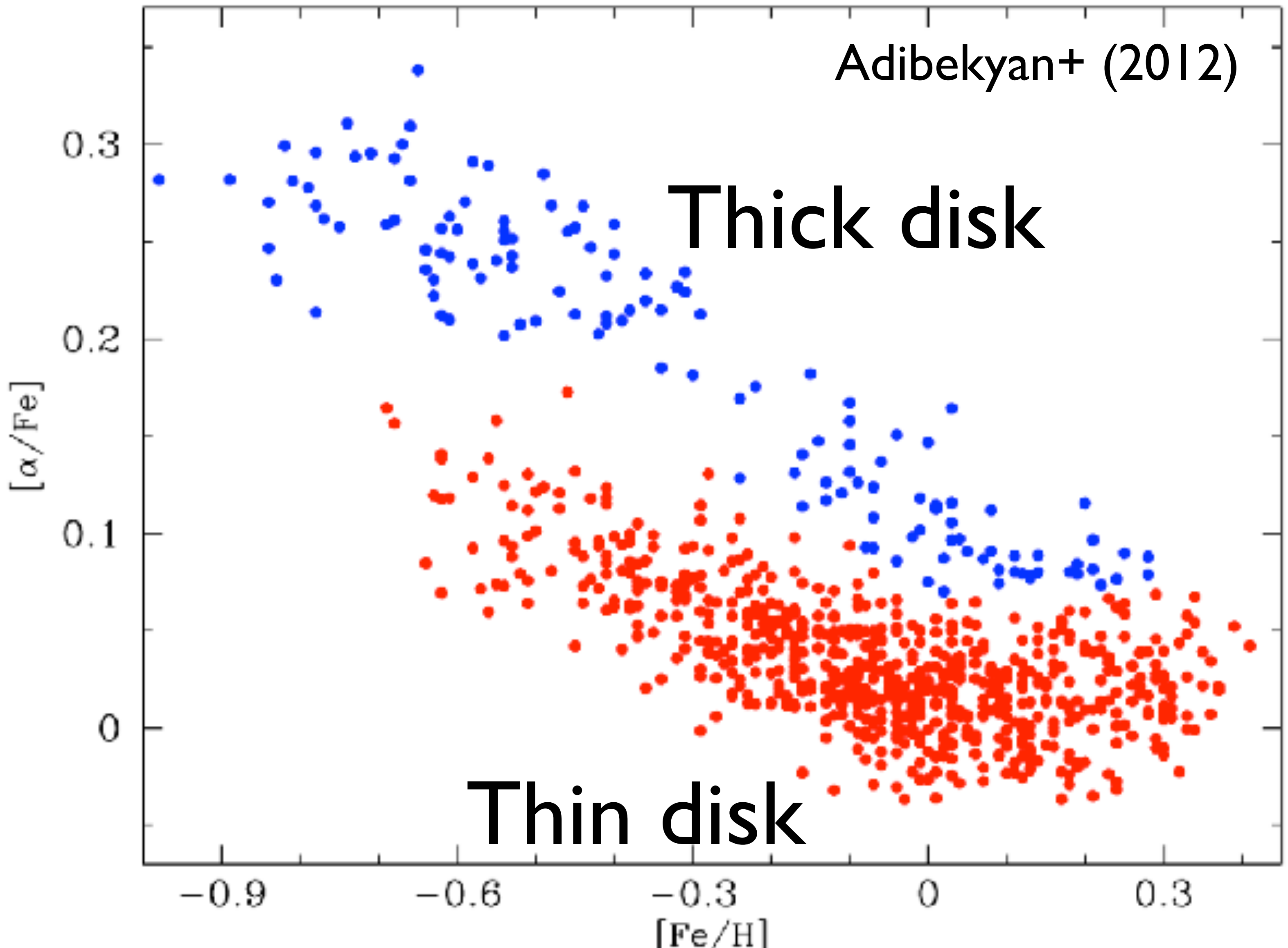
Nuno C. Santos
nuno.santos@astro.up.pt

Planet composition: connection with stellar abundances

- Different stars present different abundance ratios
- How can these alter the formation/composition of the planets?



Abundance ratios vary factor of ~2!

[see also Friday talk by E. Delgado-Mena]

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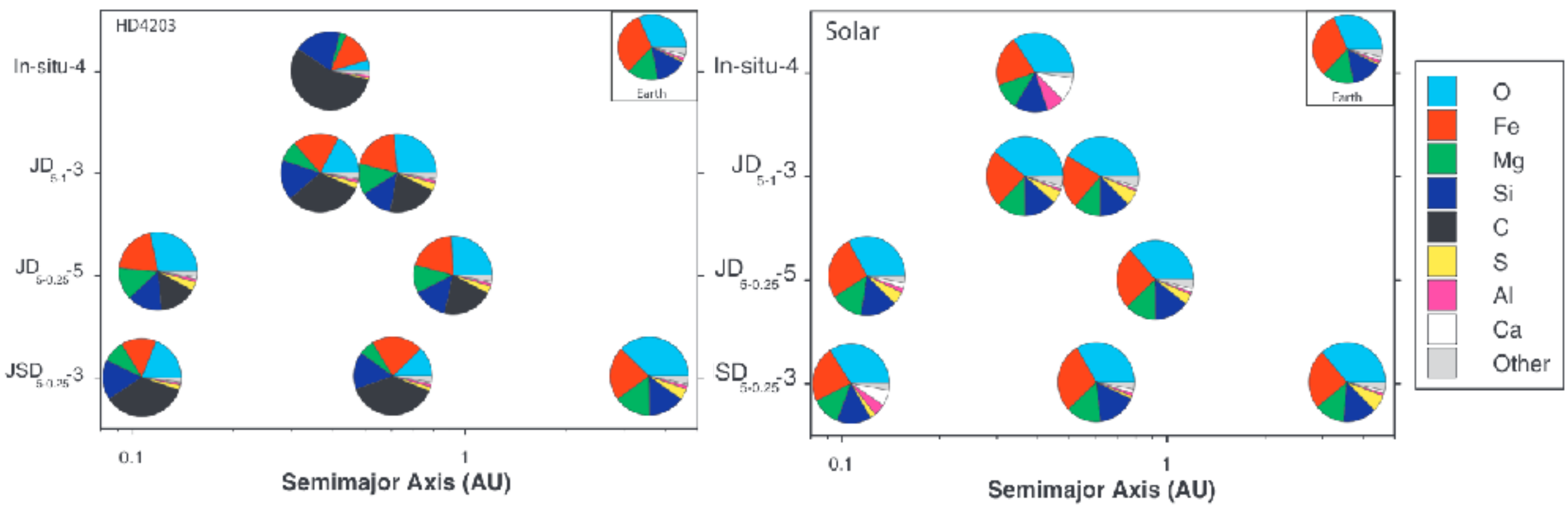
nuno.santos@astro.up.pt

Different disk abundances => different planets!

- Simulated planets considering different C/O ratios



See e.g.: Delgado-Mena et al. (2010), Carter-Bond et al. (2013), Alibert et al. (2015), Dorn et al. (2015), Santos et al. (2015), Adibekyan et al. (2016)

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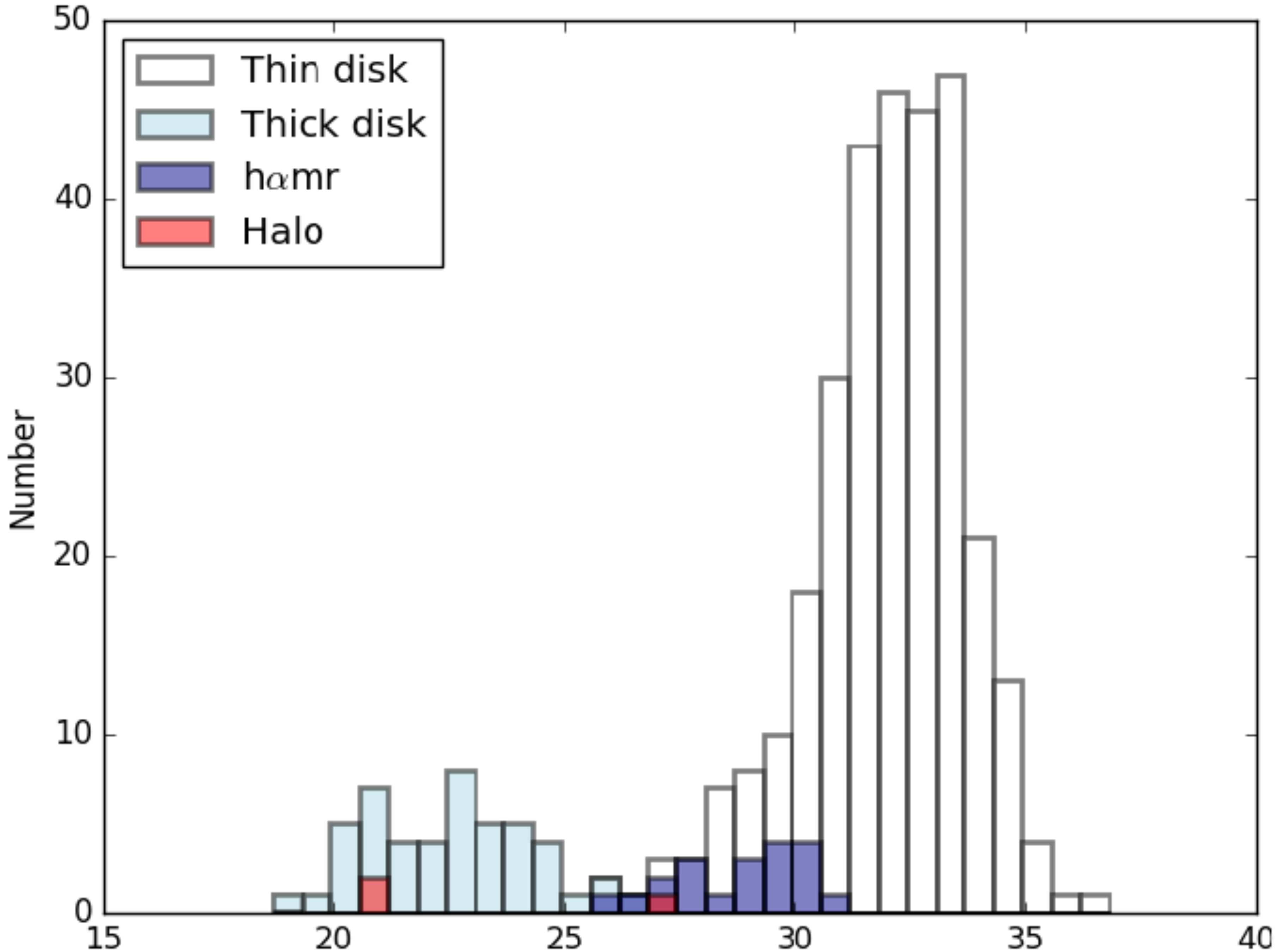
Nuno C. Santos
nuno.santos@astro.up.pt

Different galactic populations => different planets!



Iron mass fraction (Fe/Silicates)

Santos et al., in prep.

Nuno C. Santos
nuno.santos@astro.up.pt

Summary

- The study of stars is providing important clues for exoplanetology, including:
  - Planet frequency in the galaxy
  - Planet architecture
  - Planet composition
  - Planet formation processes!
- Many questions open: still a lot to learn!
- GAIA will certainly bring important new value to this research

Nuno C. Santos
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Thank you!

Questions?