Abundances of heavy elements in exoplanet hosts stars

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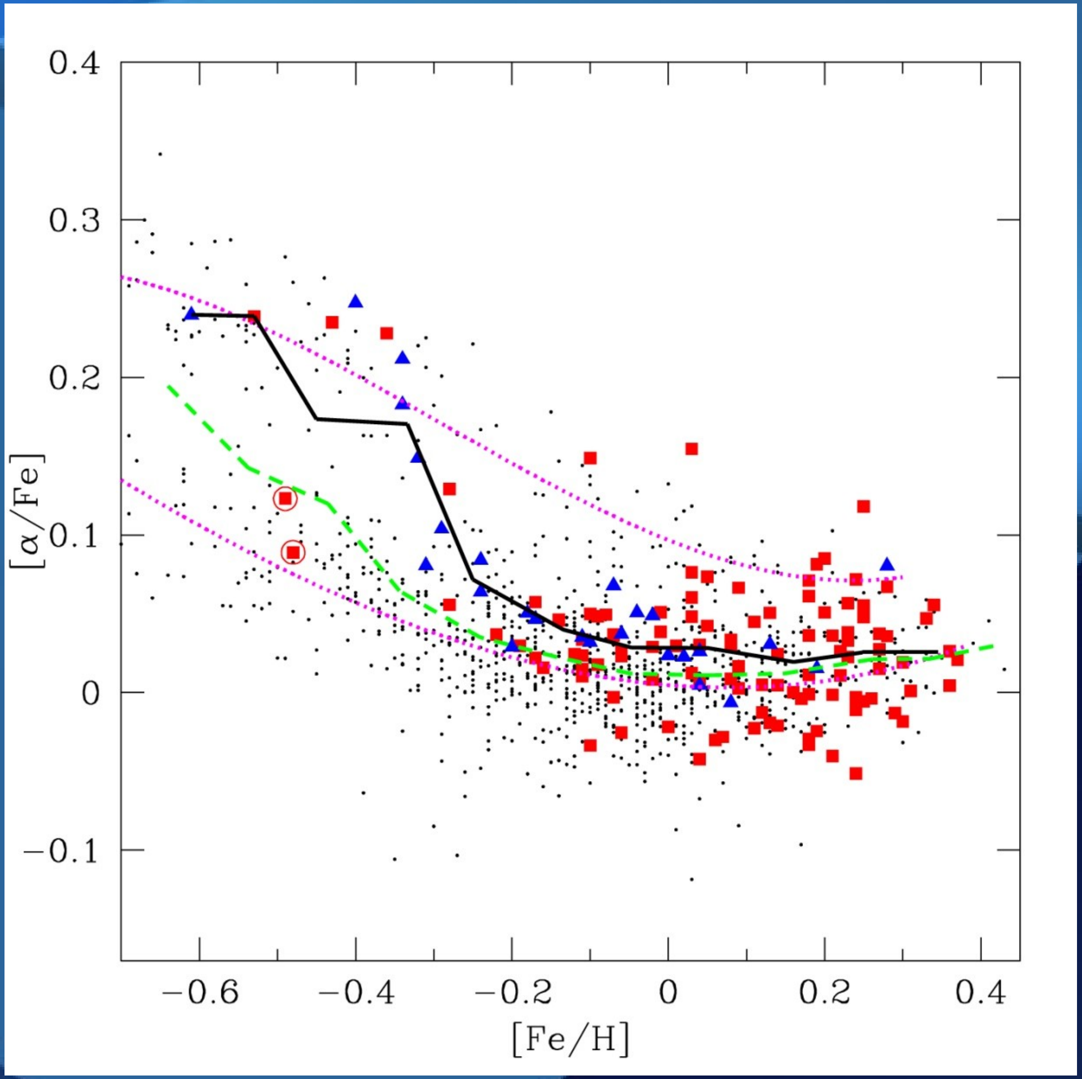
Alpha elements

Planet hosts at lower [Fe/H] show an enhancement in α elements (Adibekyan et al. 2012)

Most important elements for planet formation: Fe, O, Si, Mg.

What about heavier elements? Bond et al. 2008, Da Silva et al. 2015, Jofre et al. 2015, Mishenina et al. 2015 found a Ba underabundance in planet hosts.



The importance of heavy elements

Elements heavier than iron would require energy to be created by stellar fusion → neutron captures, which can be slow or rapid, followed by β decay:

- ***s*-process**: long timescales between consecutive captures, low density of neutrons: produce most of elements with *A*<150
- ***r*-process**: short timescales, high density of neutrons: produce elements like Eu
- *p*-process: proton rich nuclei, marginal contribution

Production sites:

- **Weak *s***-component, 60 < *A* < 90 : produced during He-core and C-shell burning in massive stars
- **Main *s***-component, 90 < *A* < 204: produced in between thermal pulses in AGB stars (mainly low mass)
- r-process: probably associated to explosive conditions in supernovae

The importance of heavy elements

The contribution from each process varies among different elements and change with age/metallicity → constrains to models of GCE

Estimations of *s*-process contribution for the Solar System composition by several authors (Cameron 1973, Arlandini et al. 1999, Bisterzo et al. 2016, etc…)

- Light-*s* elements: Sr (67%), Y (70%), Zr (64%)
- Heavy-*s* elements: Ba (83%), Ce (81%), Nd (56%)
- Eu (7%) → considered as pure *r*-process element

Previous works on heavy elements: Allende Prieto et al. 2004, Reddy et al. 2006, González Hernández et al. 2010, Mishenina et al. 2013, Bensby et al. 2014, Battistini&Bensby 2016, Mikolaitis et al. 2017, etc...

Stellar spectra and abundances

1111 stars in the HARPS GTO sample (R ~ 115000):

Volume limited sample (within 60pc, no selection based on kinematics), V < 12, slow rotators, no binaries, no very active stars

28 stars hosting neptunians, 121 stars with jupiters, **909** stars without planets

4400K < T_{eff} < 6800K   -1.40 < [Fe/H] < 0.55

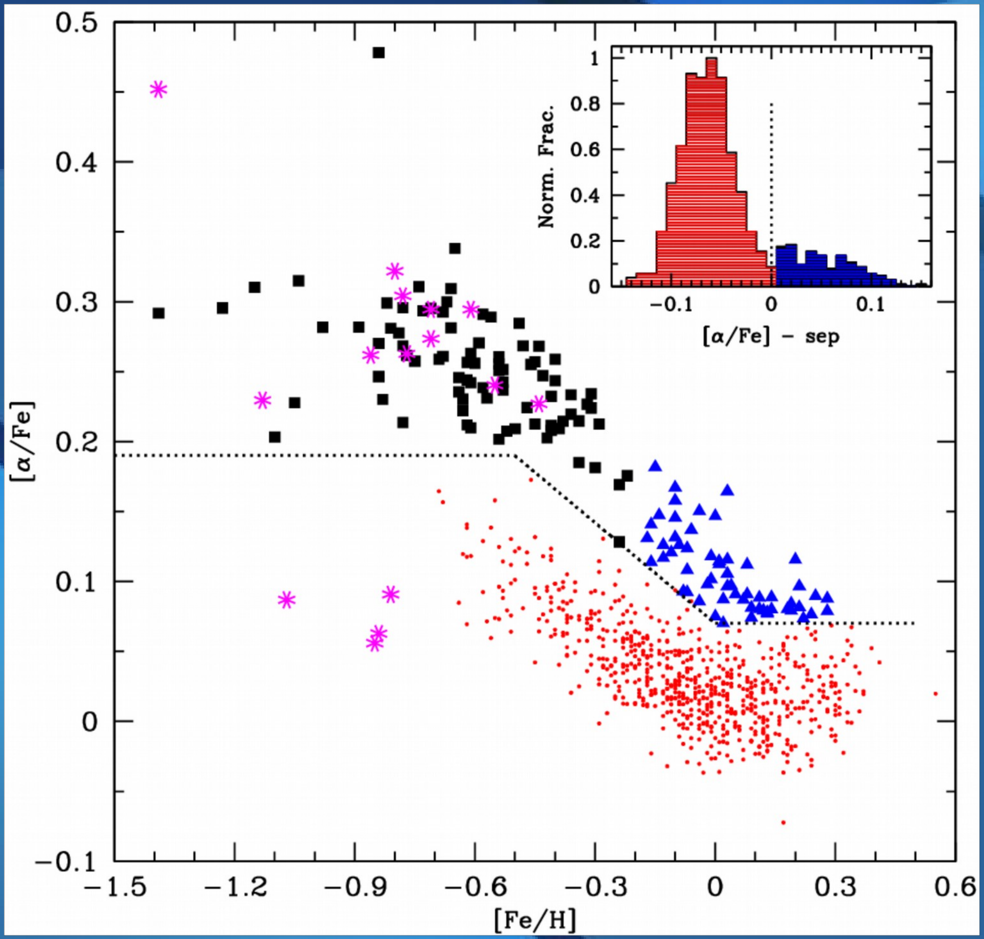
55% spectra S/N > 200

Stellar parameters from Sousa et al. (2008, 2011) corrected for cool stars using linelist from Tsantaki et al. (2013)

Chemical abundances for **α- and iron peak elements** in Adibekyan et al. (2012), **lithium** in Delgado Mena et al. (2014,2015), **oxygen** in Bertran de Lis (2015) and **carbon** in Suarez-Andres et al. (2016)

Abundances of **Cu, Zn, Sr, Y, Zr, Ba, Ce, Nd and Eu** using EWs, HFS, Kurucz ATLAS model atmospheres and the LTE code MOOG:
Delgado Mena et al. 2017, accepted by A&A → arXiv:1705.04349

Chemical separation



Based on α-elements (Mg, Si and Ti)

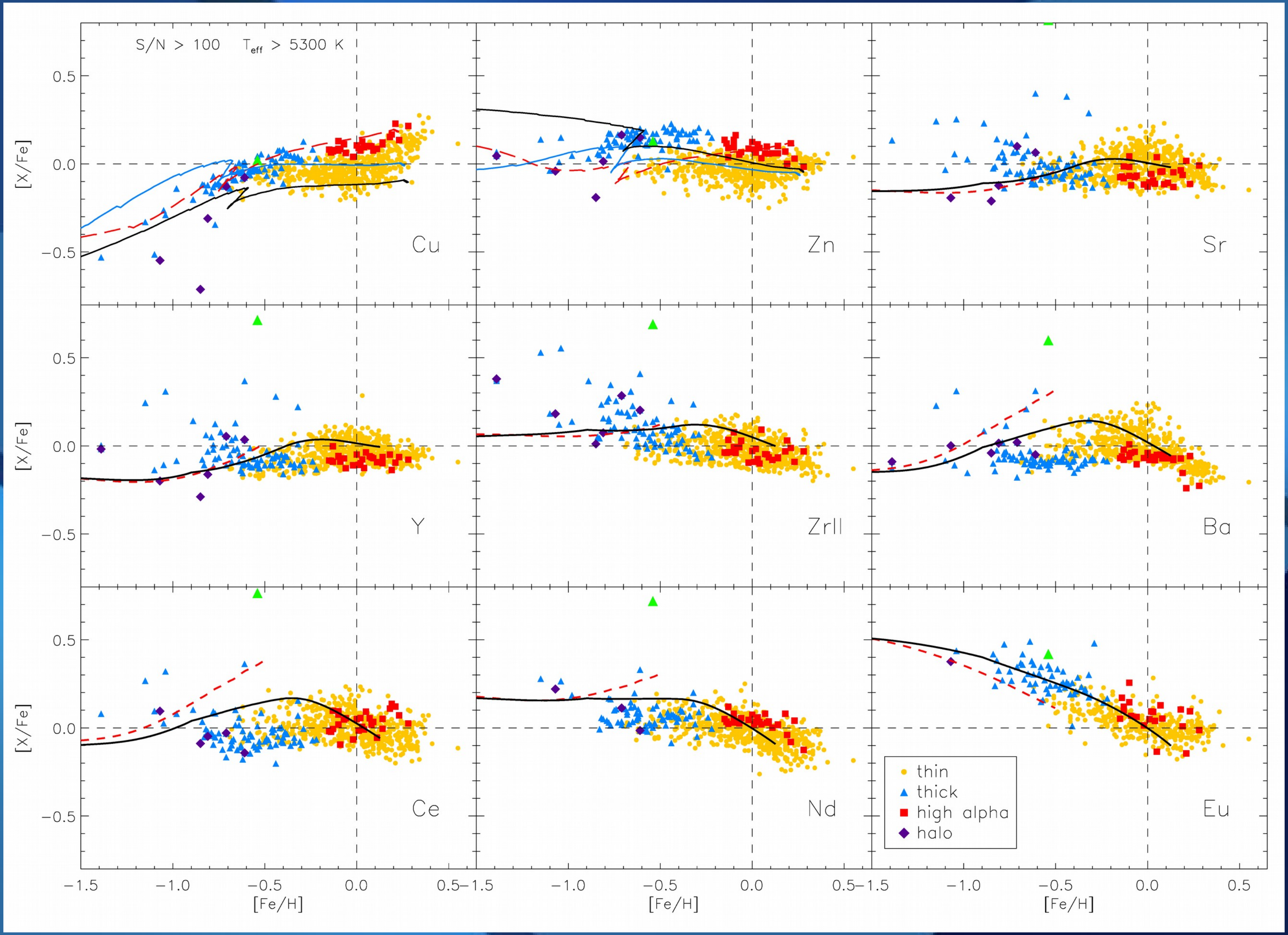
- 882 thin disk stars
- 108 thick disk stars
- 8 halo stars (kinematically selected)
- 60 hαmr stars (older than thin disk stars and with intermediate orbits between the thin and thick disk stars)

→ originated from the inner disk?

Definition based in chemistry, separation both in [α/Fe] and [Fe/H]

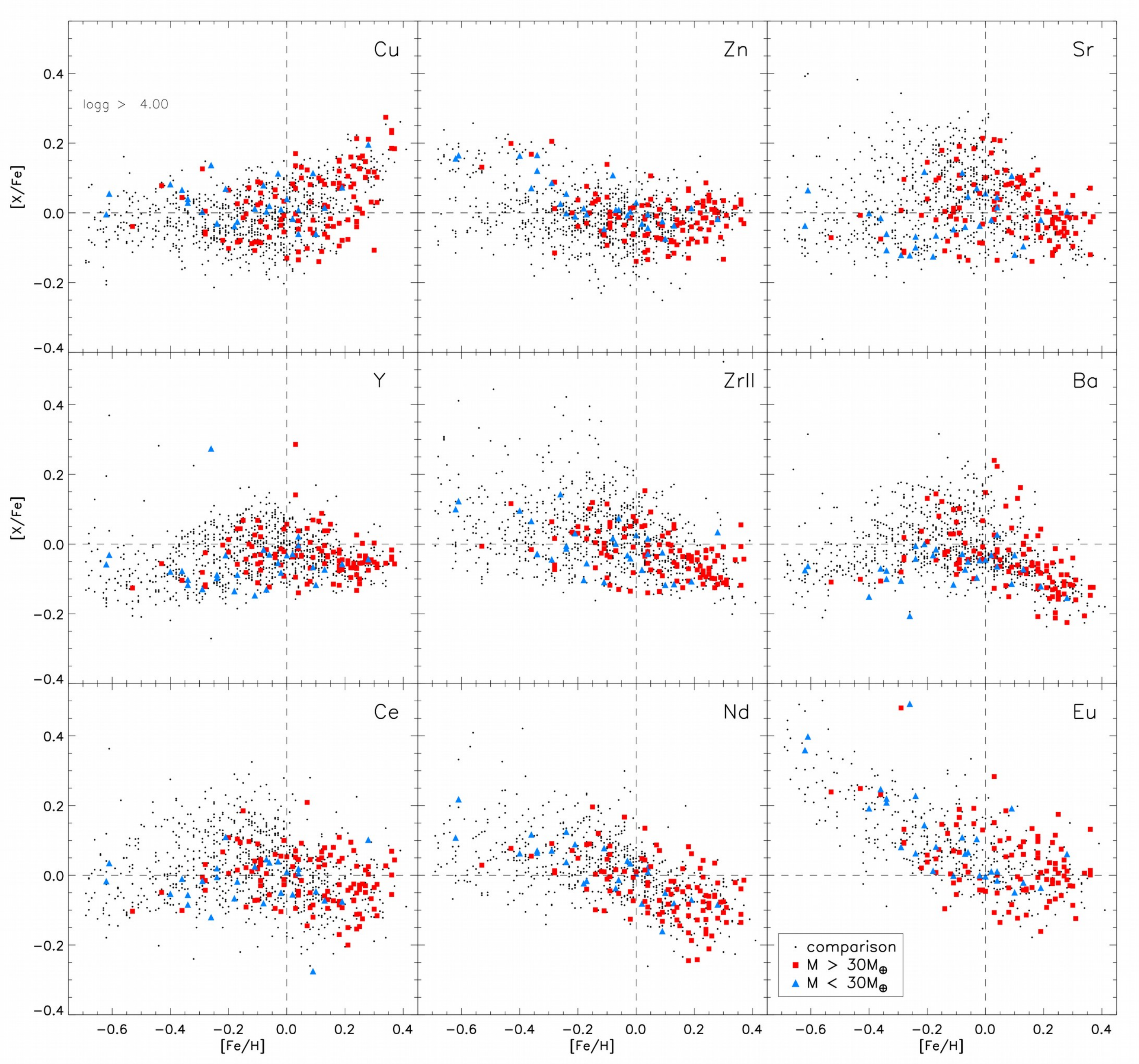
Adibekyan et al. (2011, 2013)

[X/Fe] vs [Fe/H] trends



Cu and Zn models by Romano et al. (2010), rest from Bisterzo et al. 2017

[X/Fe] vs [Fe/H] trends

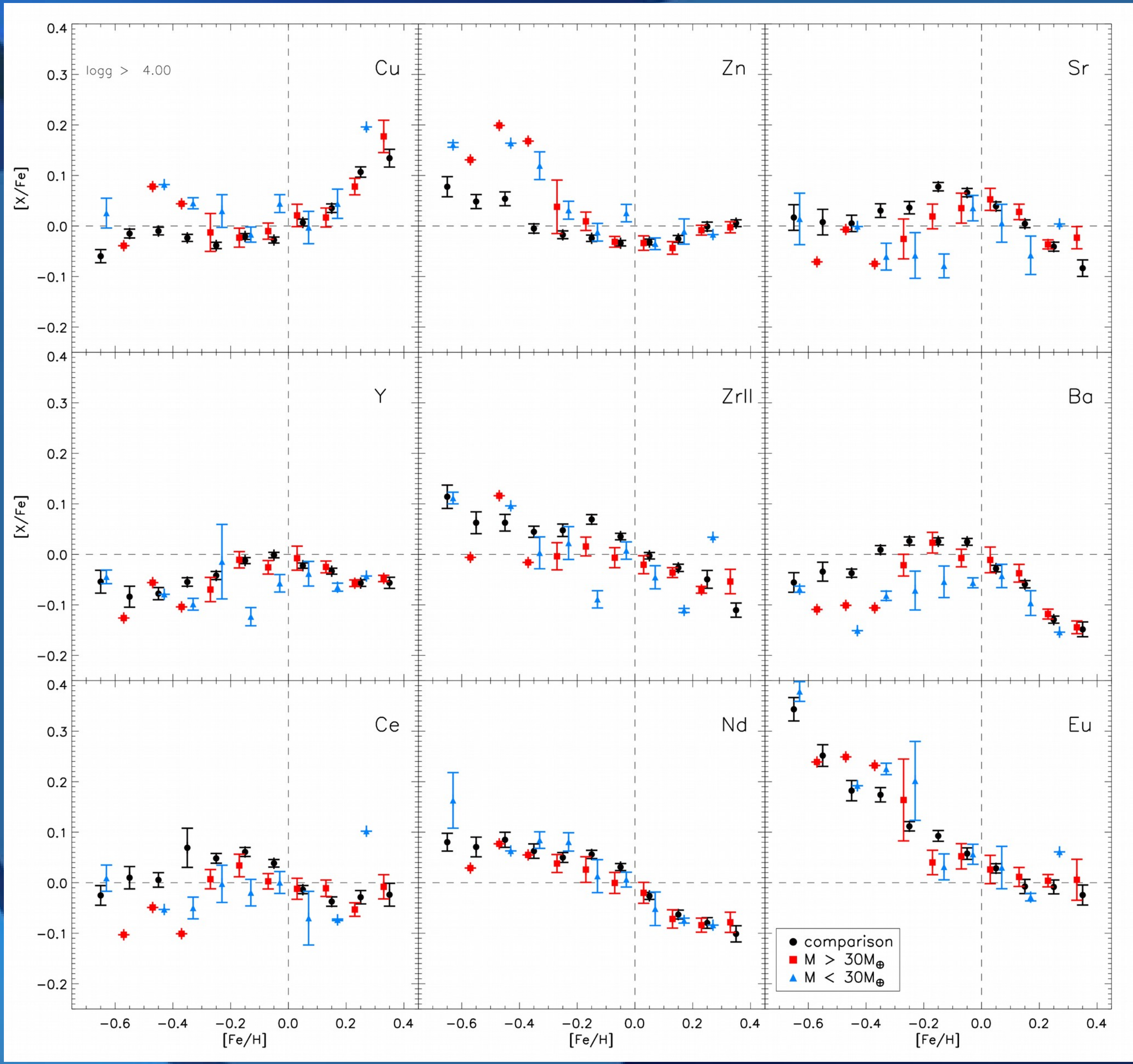


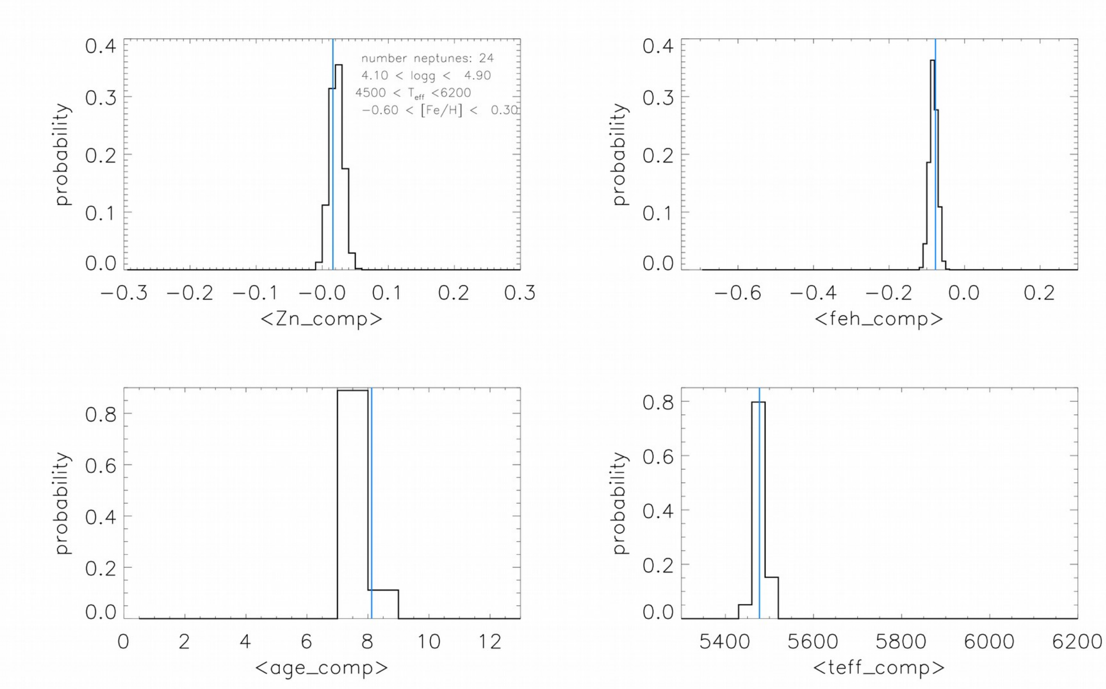
[X/Fe] vs [Fe/H] trends

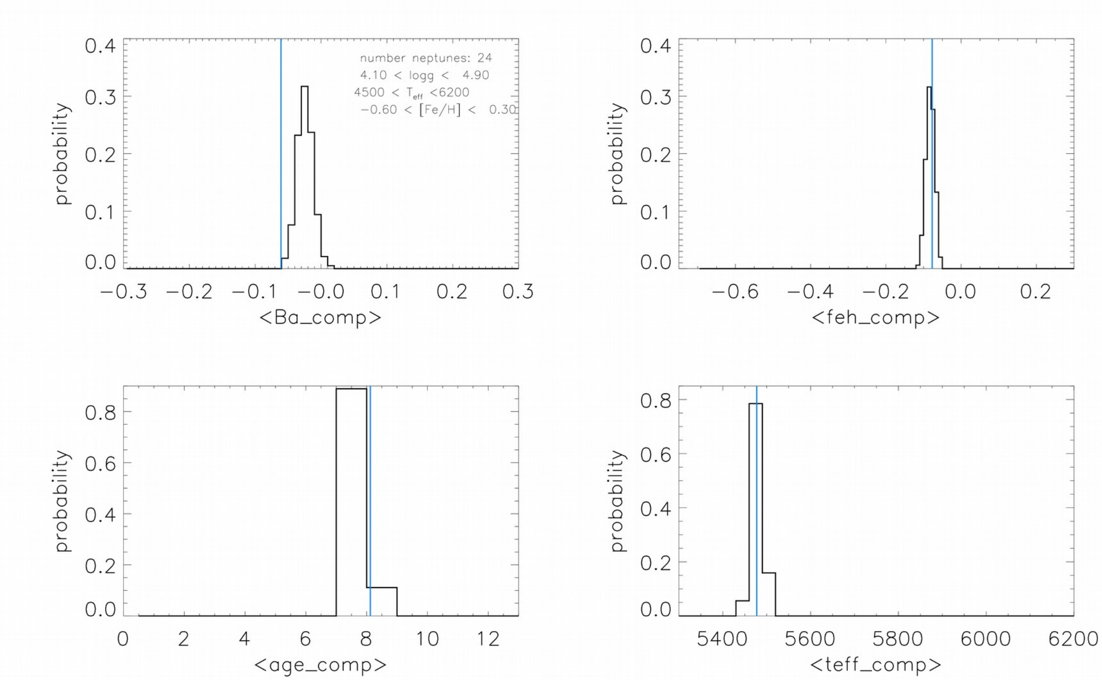
Zn overabundance in planet hosts at low [Fe/H]

Sr and Ba underabundance for planet hosts

Neptunian hosts are older on average:
Biases in stellar parameters or ages?







Randomly selected comparison stars to match neptunian hosts properties

Zn overabundance disappears by comparing similar stars

Ba underabundance remains

Sr differences are at the level of errors

For jupiter hosts the differences disappear

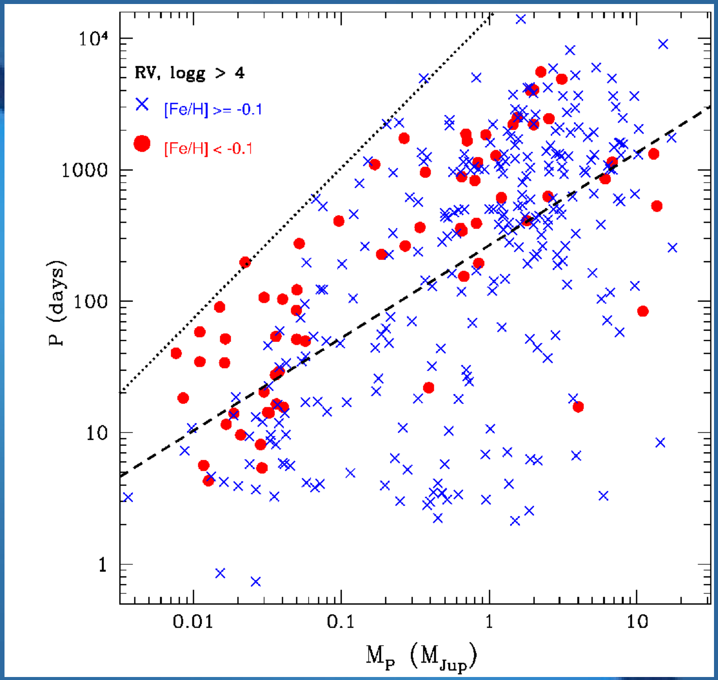
Summary

- We need to understand and correctly characterize (GCE, populations, ages) our planet hosts in order to search for differences with respect to non hosts
- Heavy element abundances are necessary to constrain models of GCE and to understand the yields of both massive and low-mass stars → need of high quality data to analyze these elements. Do these elements play a role in planet formation?
- Overabundance of Zn in planet hosts can be explain by the fact these stars belong to the thick disk. Underabundance of Ba in neptunian hosts seems significant but more tests need to be done (multivariate regression fitting)
- If this difference is confirmed these elements might need to be considered in future theoretical works modeling planet formation.

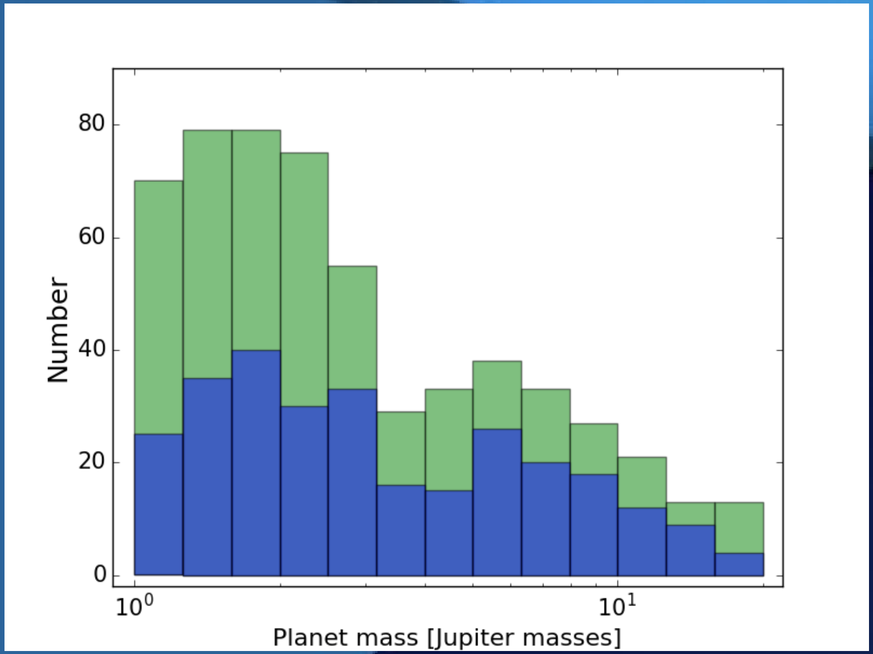
Sweet-Cat: a catalogue for stellar parameters of exoplanets

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

Homogeneous parameters for 75% FGK planet hosts with V<12 (mostly with HARPS and UVES *R*>100000 spectra) → Santos et al. 2013



Adibekyan et al. 2013



Santos et al. 2017


Thanks