New insights on the relation between stellar metallicity and the architectures of planetary systems

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1. Background

- The planet-metallicity correlation depends on planet size and orbital period (e.g., Petigura et al. 2018)
- Metallicity distributions for singles and multis discovered by Kepler are similar (e.g., Weiss et al. 2018)

2. Motivation

- Independent analysis to further investigate the correlations between stellar metallicities and planetary systems' architectures
- Important to further constrain models of planet formation

3. Analysis

- "Clean" sample of 663 stars from the California-Kepler Survey (CKS; Petigura et al. 2017)
- HIRES spectra with R ~ 60,000 and typical S/N ~ 60
- We determined stellar metallicities [Fe/H] (Figure 1) using a classical LTE spectroscopic analysis (Ghezzi et al. 2018; Martinez et al. 2019)

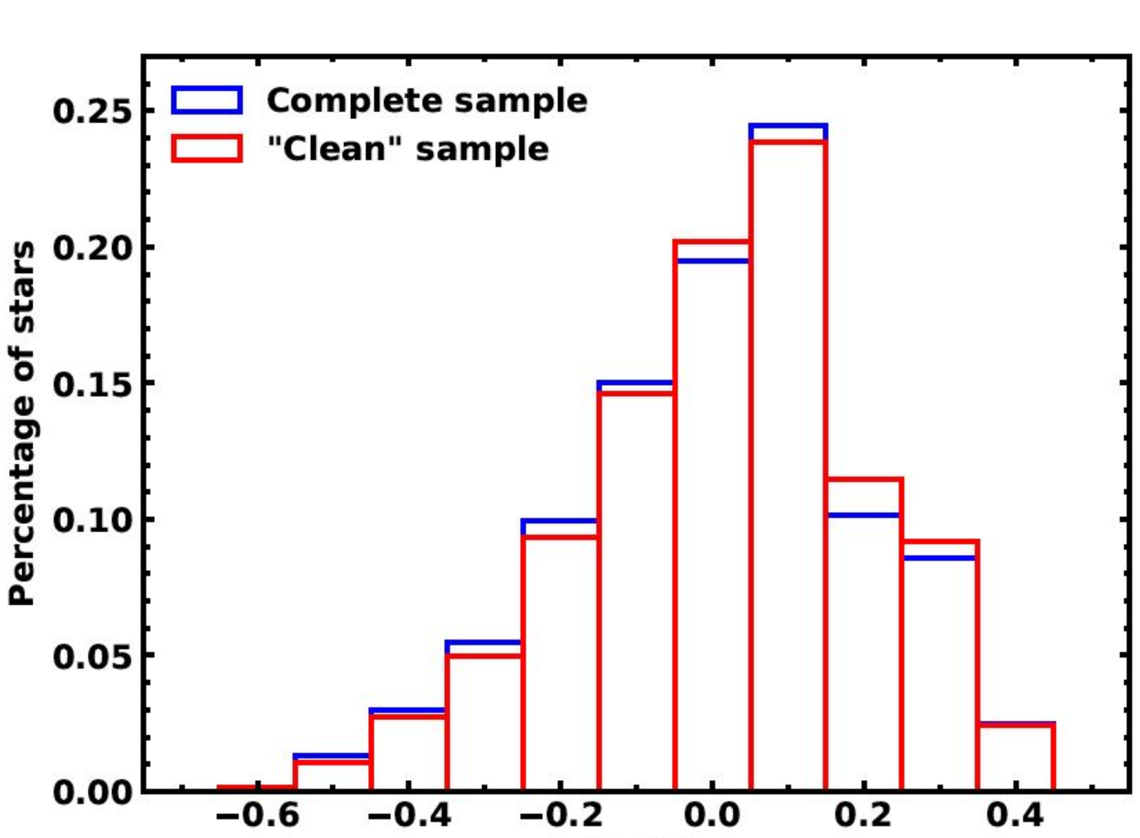

Figure 1: [Fe/H] distributions for the complete (blue) and "clean" (red) samples of planet hosting stars. The "clean" sample contains stars with precise radii (better than 8%) that host planets with $b \leq 0.7$ and $P \leq 100$ d.

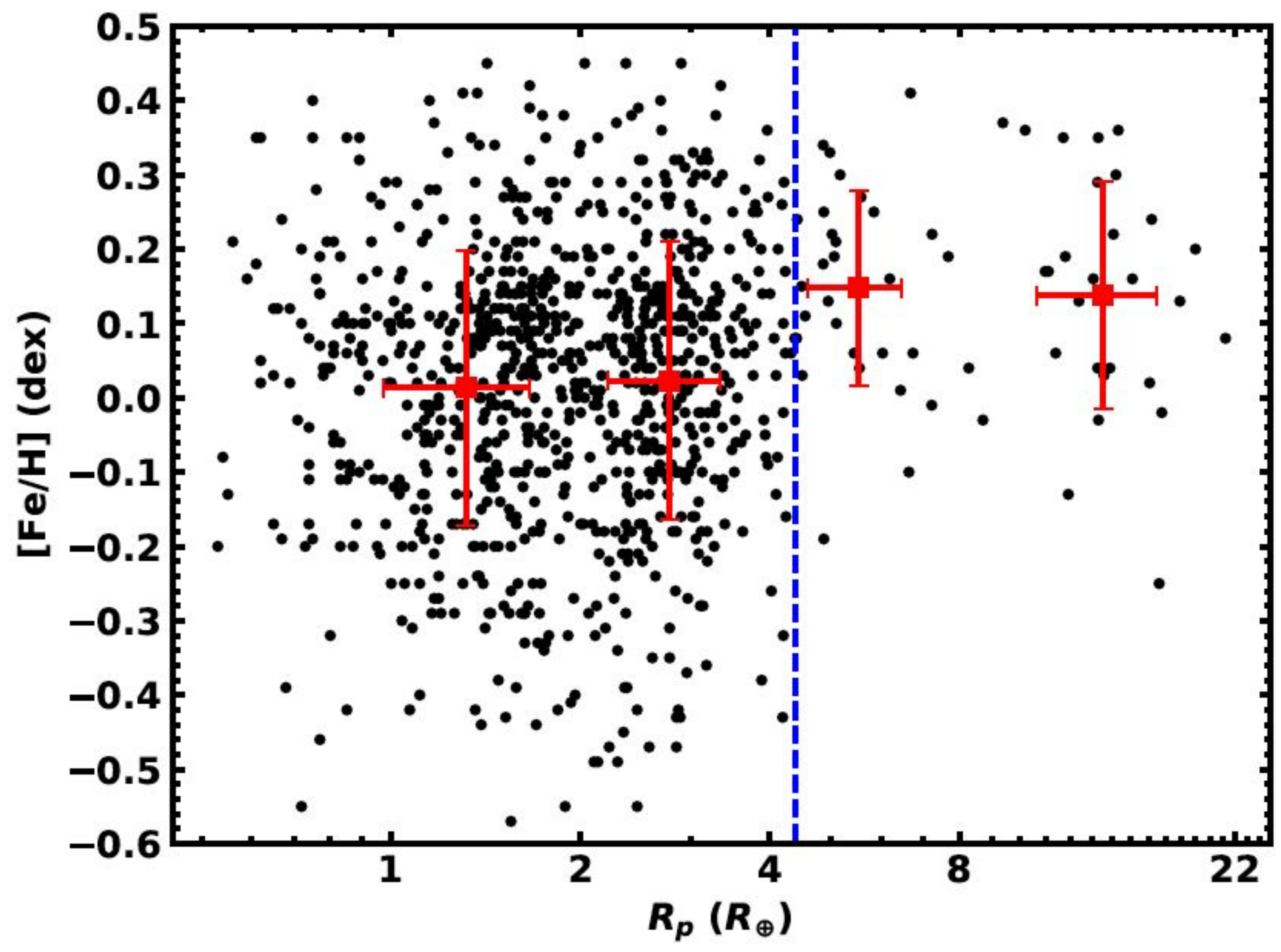

Figure 2: Stellar [Fe/H] versus planet radii. The blue line is the boundary between small and large planets at 4.4 $R_\oplus$.

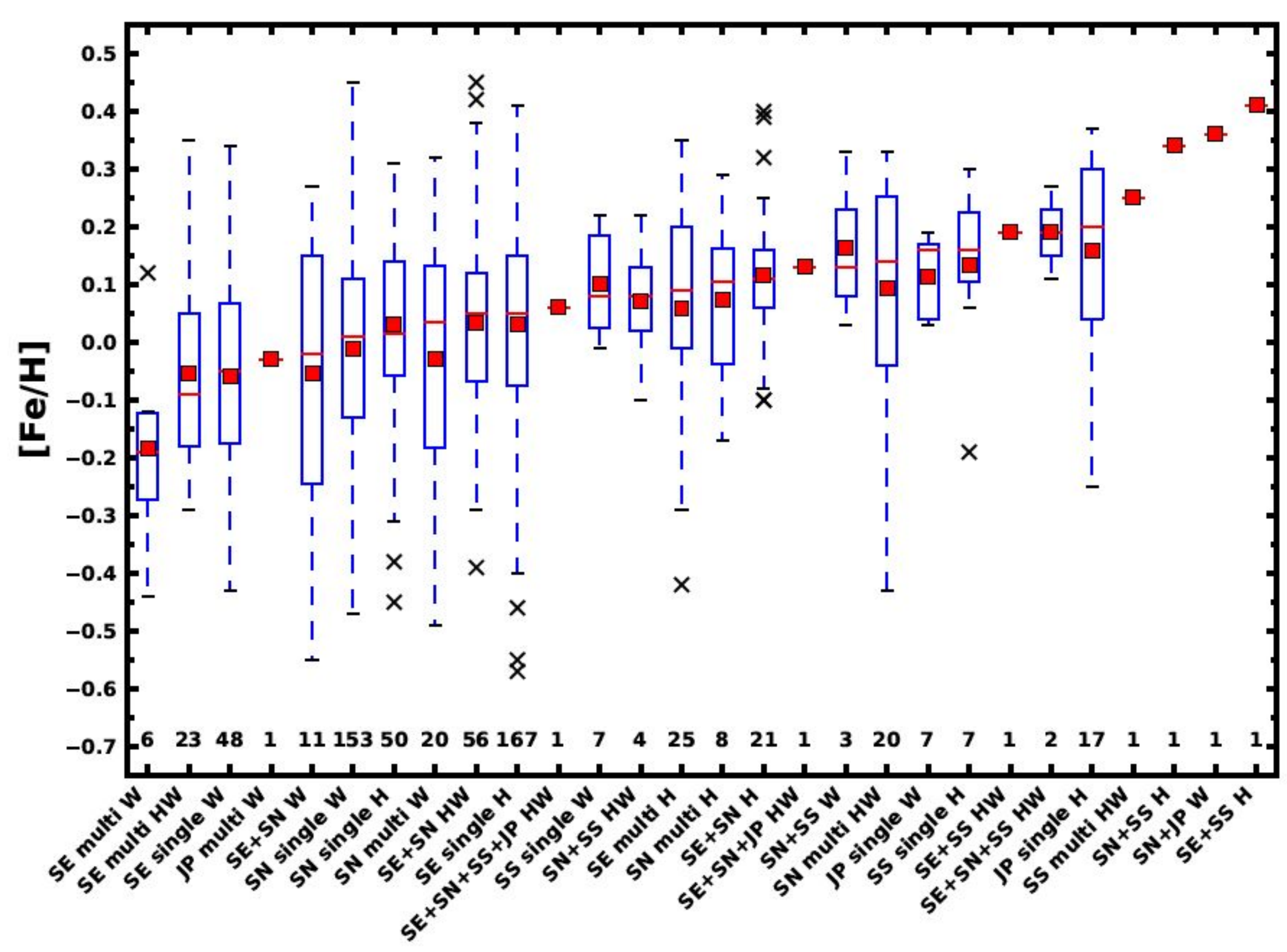

Figure 3: Box plots for the [Fe/H] distributions of systems segregated into classes according to their architectures.

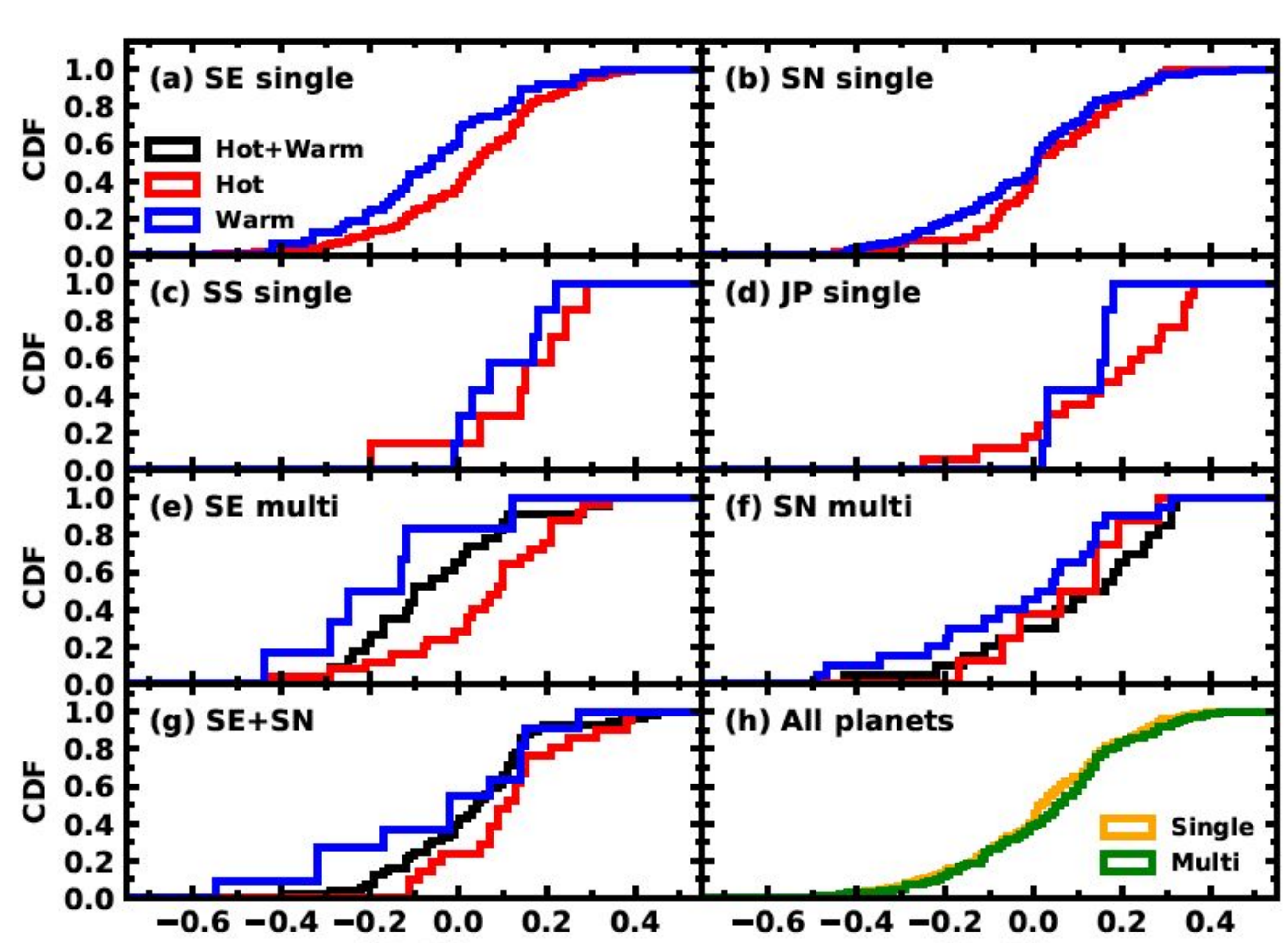

Figure 4: Cumulative distribution functions (CDFs) for the [Fe/H] of systems with different architectures.

4. Boundary Small - Large Planets

- We compared metallicity distributions for samples of small and large planets
- Different radii tested for the boundary small - large planets → 4.0 - 5.0 $R_\oplus$ with steps of 0.1 $R_\oplus$
- Statistical tests (Mann-Whitney U, Cucconi and K-S) show that the boundary lies at 4.4 $R_\oplus$ (blue dashed line in Figure 2)

5. [Fe/H] Distributions

Architectures in Figure 3 consider:

- Planet radius:
  - Super-Earths (SE): < 1.9 $R_\oplus$
  - Sub-Neptunes (SN): 1.9 - 4.4 $R_\oplus$
  - Sub-Saturns (SS): 4.4 - 8.0 $R_\oplus$
  - Jupiters (JP): ≥ 8.0 $R_\oplus$
- Multiplicity: single or multiple
- Orbital period:
  - Hot (H): ≤ 10 d
  - Warm (W): 10 - 100 d

6. Results

- Metallicities are higher for systems with large planets (Figure 3)
- Within a given class, metallicities are higher for systems with hot planets (Figure 4)
- Δ[Fe/H]$_{Median}$ (Hot - Warm)
  - → 0.06 ± 0.04 for singles
  - → 0.17 ± 0.08 for multiples
  - → 0.28 for SE multi

7. Conclusions

- Differences between median metallicities of systems with only hot or warm planets are larger for systems with multiple relative to single planets
- These differences are larger for systems with only Super-Earths relative to those with only Sub-Neptunes, suggesting a possible distinction within the small planet regime