Towards the characterization of planet hosts with WST: the case of Ariel

WST

INAF
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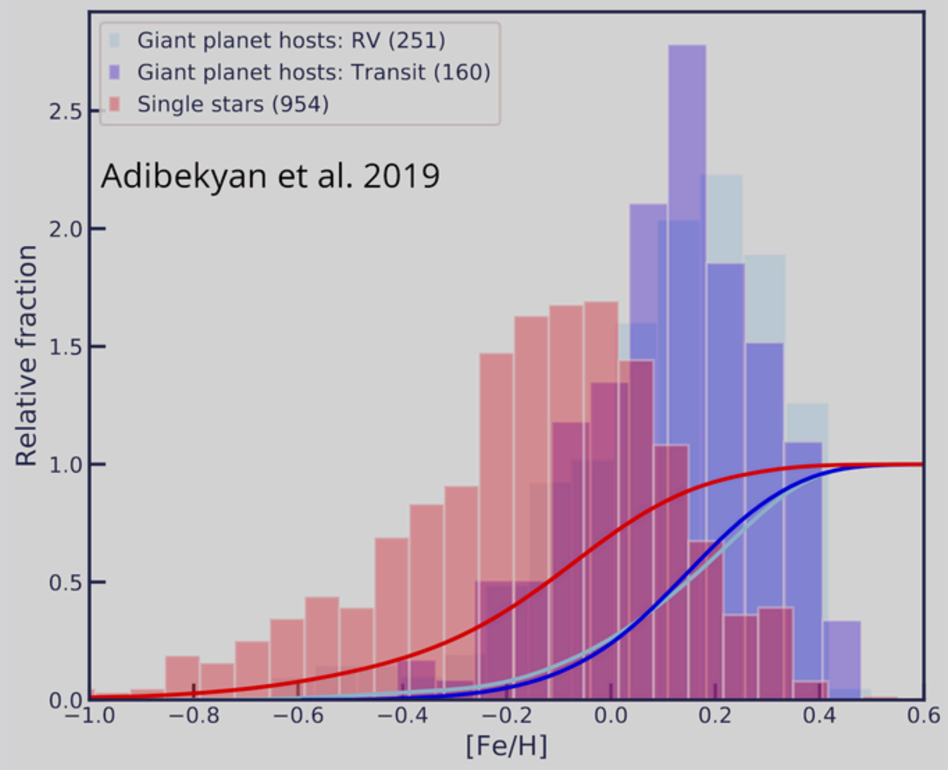
DI ASTROFISICA

OSSERVATORIO ASTROFISICO DI ARCETRI

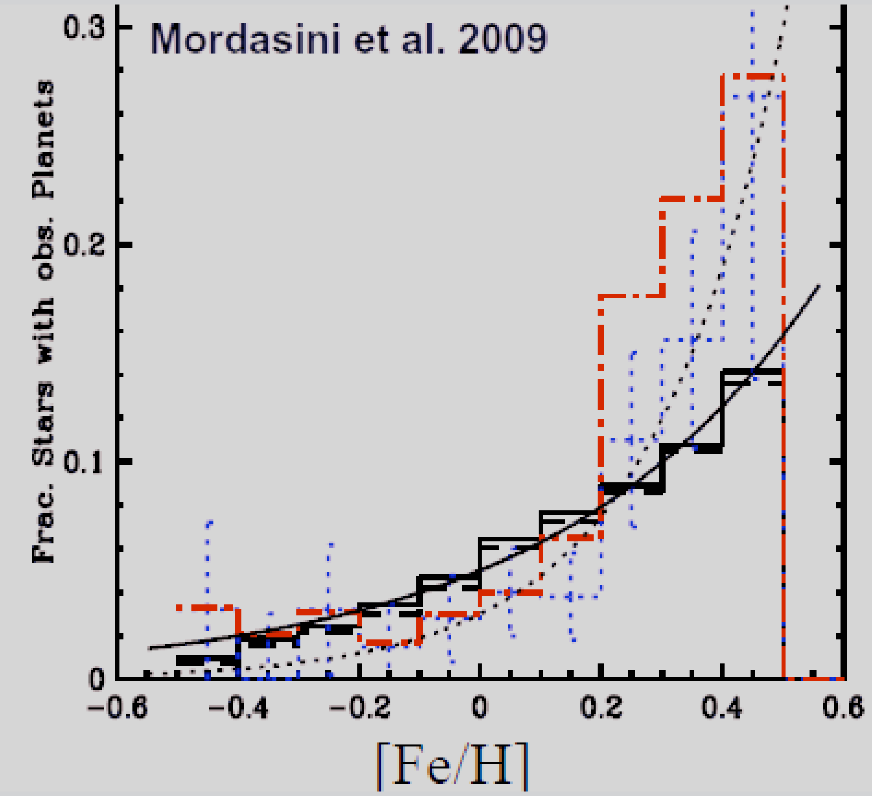
Maria Tsantaki
& the Ariel stellar characterization group

Know the star, know the planet

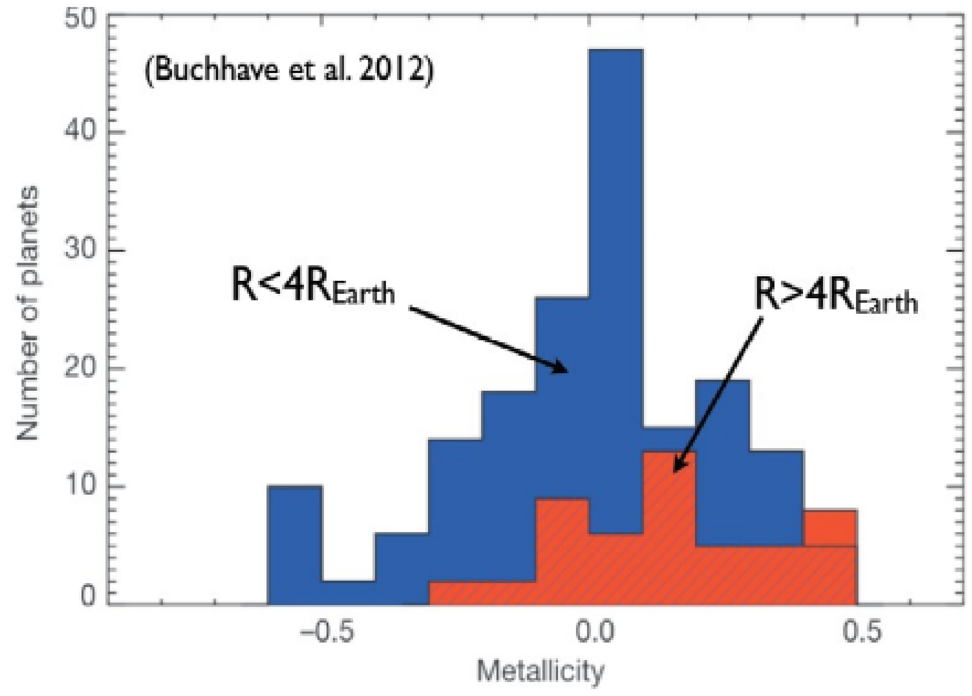
- **Observations**: Well-established *giant* planet - stellar [Fe/H] relation



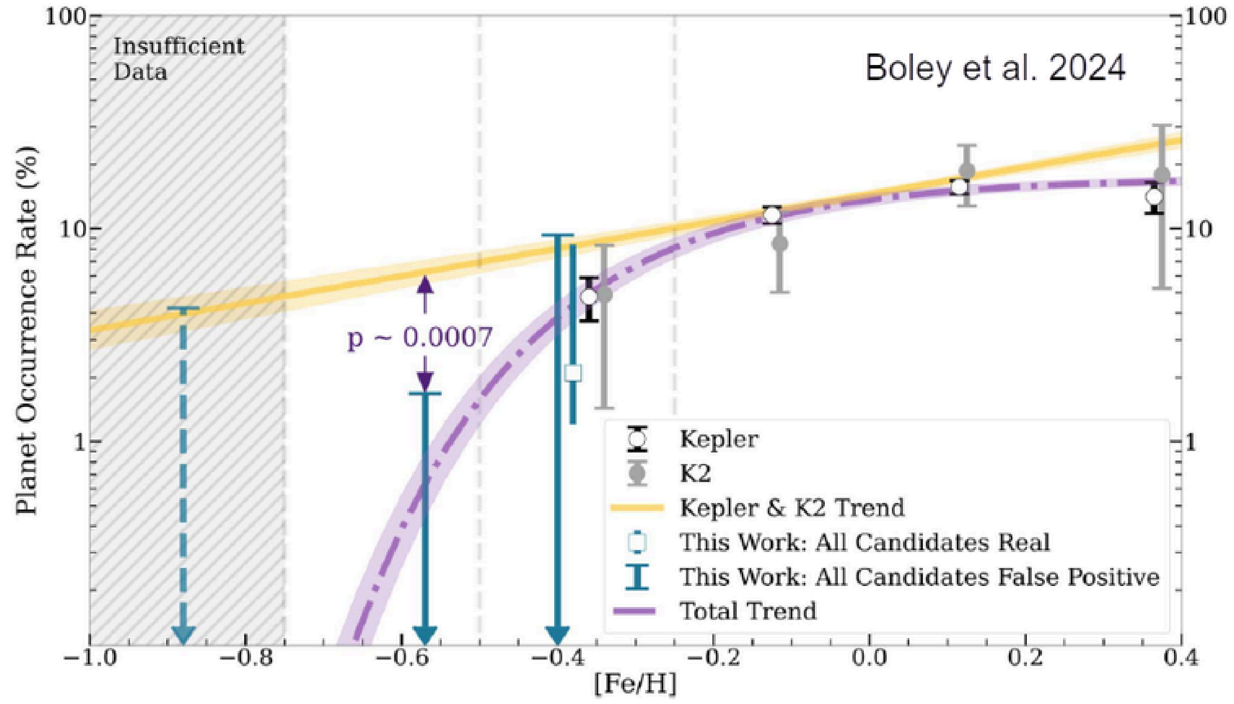
- **Theory**: Clear argument in favor of the accretion model



- **Observations**: Hosts with *small* sized-planets have weaker [Fe/H] metallicity dependence.

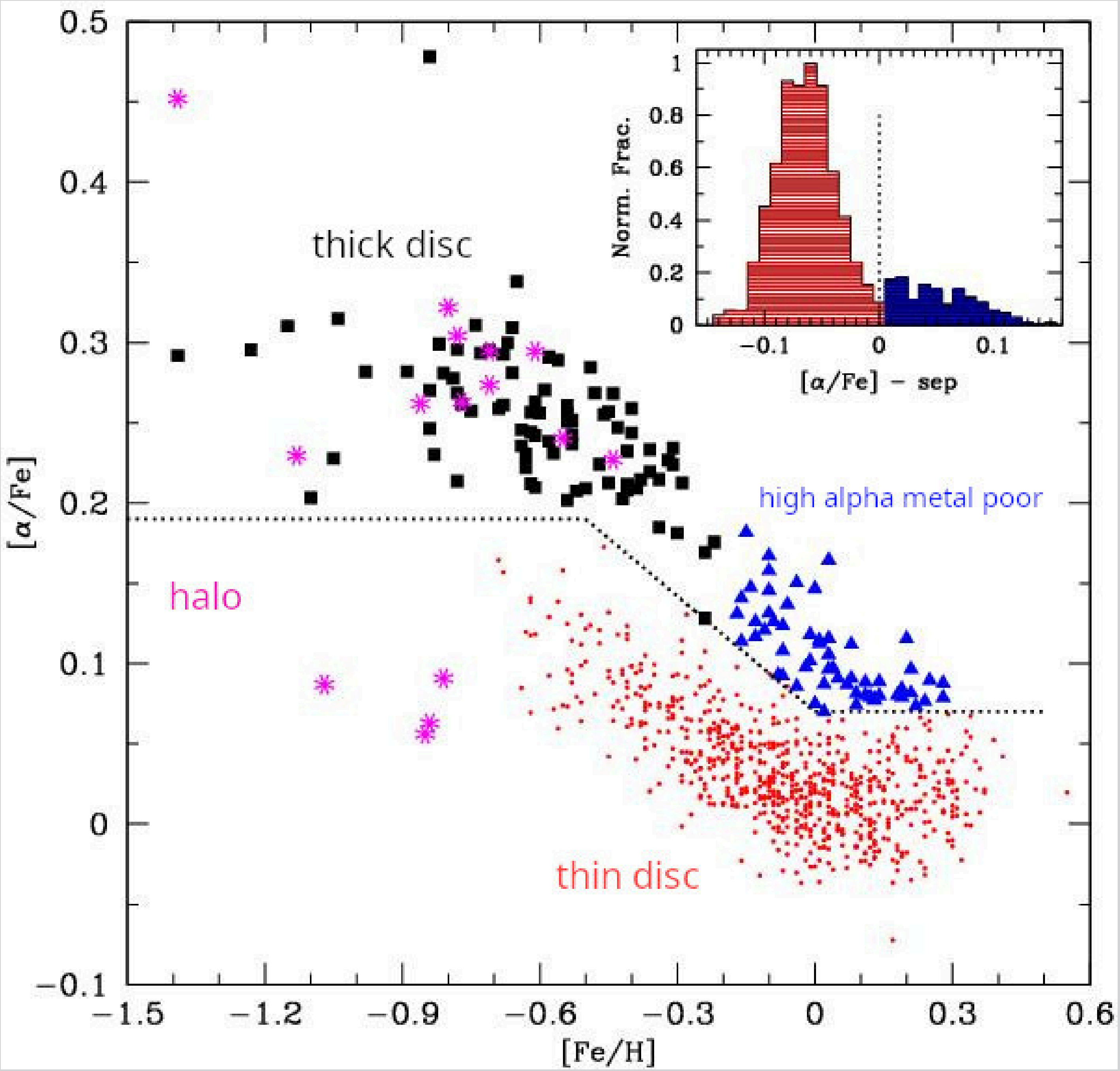


- The critical [Fe/H] below small planets can form is still not understood.



Where do planets live in our Galaxy?

Chemical separation of the discs
(HARPS-GTO sample Adibekyan+ 2012)

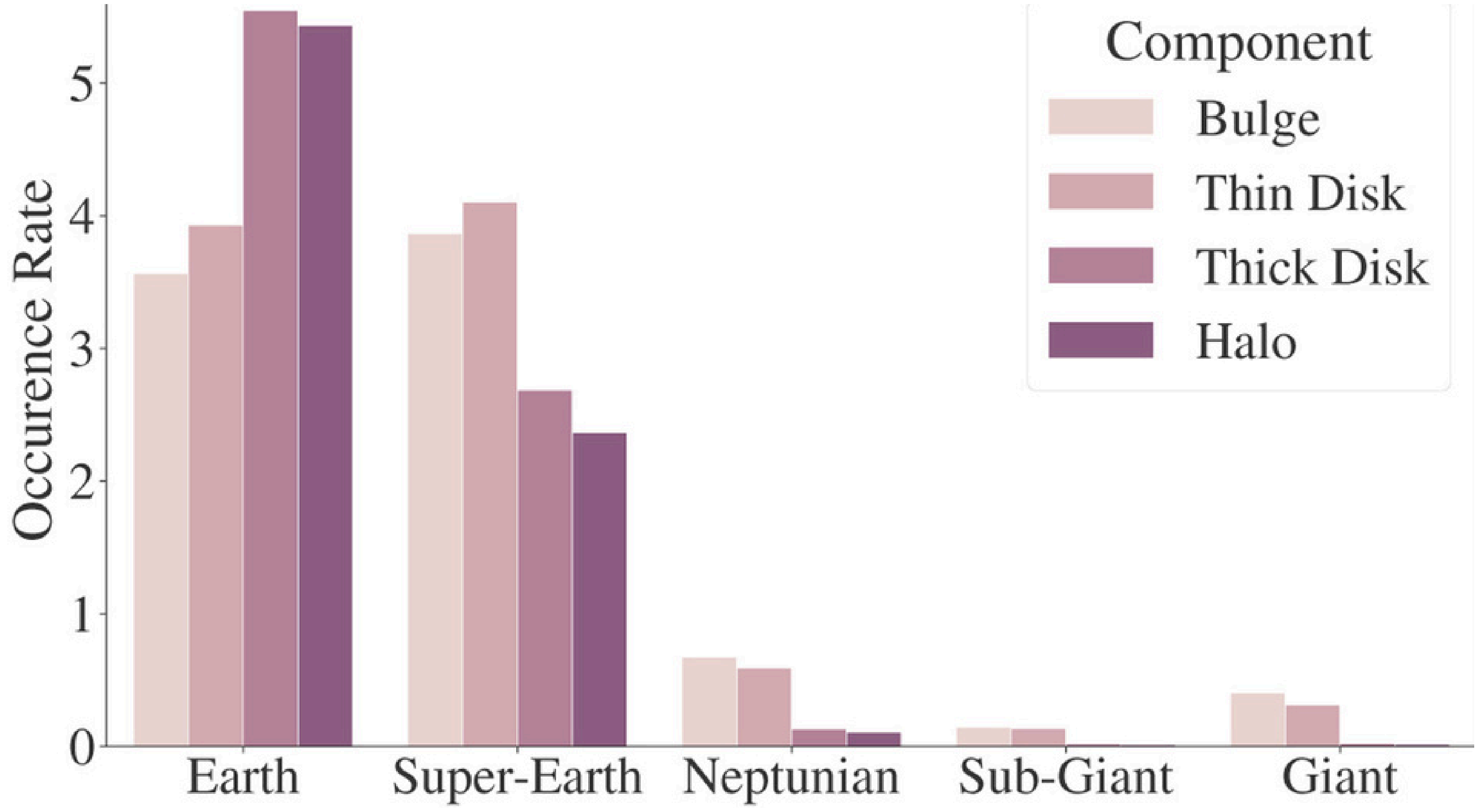


Galactic chemical evolution could profoundly affect planet demographics throughout the Galaxy.

Planet population model (NGPPS) + Milky Way analog (1Msun):

- Planets in [bulge & thin disc], [thick disc & halo] are very similar but with different **ages**
- **Giants:** 20x more common around **thin** disc & **bulge** stars
- **Earths:** 1.5x more common around **thick** disc & **halo** stars

Boettner et al. (2023)



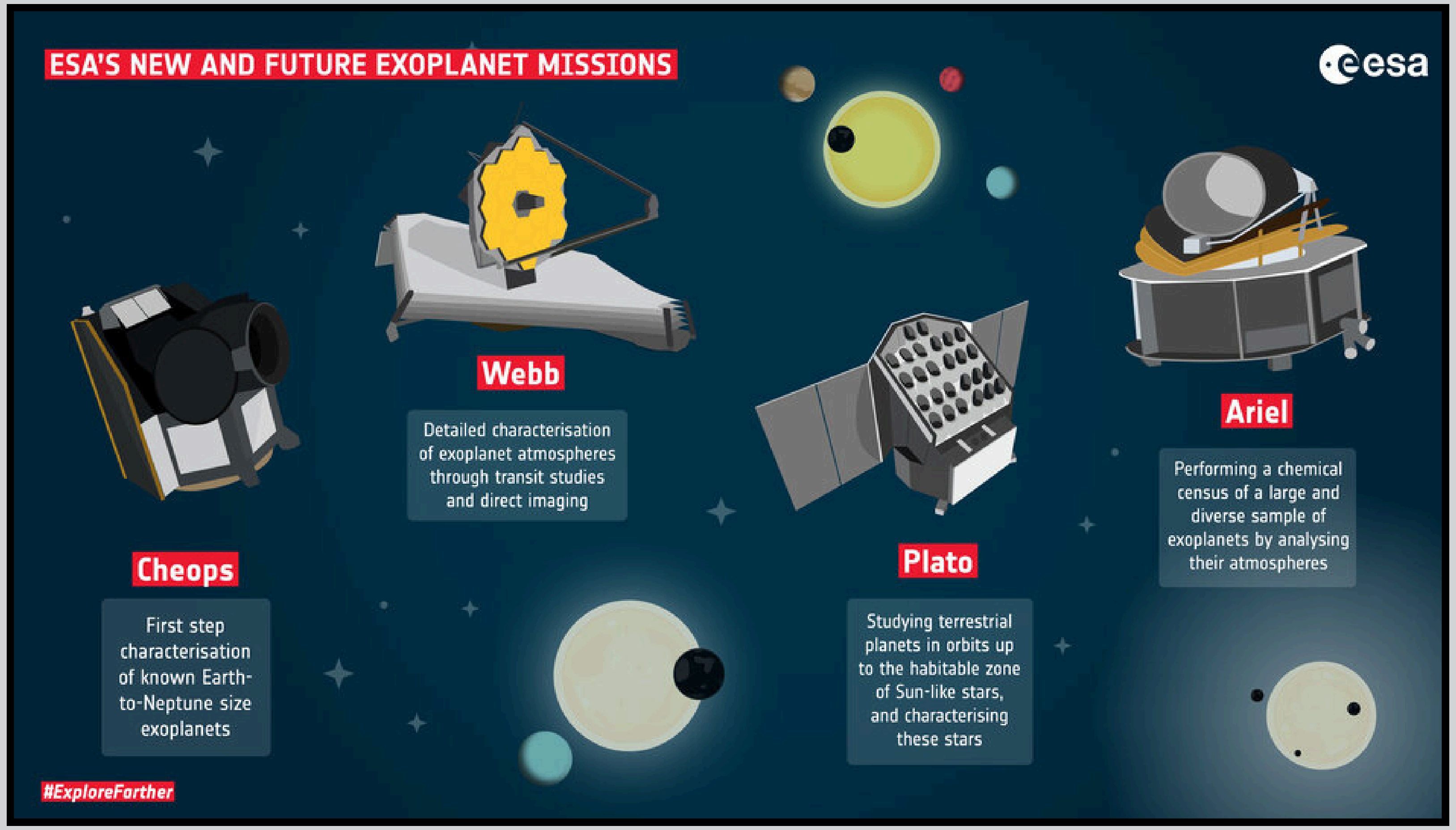
see also Nielsen et al. (2023), Bitsch & Battistini (2020), Cabral et al. (2023)

Where do planets live in our Galaxy?

From the observational point of view

Planned launch: 2029

Mission theme: Ariel will study the composition of **1000 exoplanets** from rocky to giants & provide a chemical census of by **analysing their atmospheres.**



STELLAR CHARACTERISATION WG Ariel

THE NEED OF AN HOMOGENEOUS CHARACTERISATION

Methodology

know the star, know the planet

https://sites.google.com/inaf.it/arielstellarcatalogue

00 Stellar characterization
~1000 planet hosts
A-FGK-M types

01 Observations
High resolution & S/N
(ESPRESSO, HARPS, UVES, SALT, LBT)

02 Atmospheric parameters
Magrini+22
Tsantaki+25

03 Activity indexes

04 Abundances
CNO, refractory, Li
da Silva+ 23,
Delgado-Mena+ in prep.
Tsantaki+ in prep.

05 Masses Ages
Bossini+ in prep.

Homogeneous stellar parameters for 358 FGK planet hosts with high resolution spectroscopy

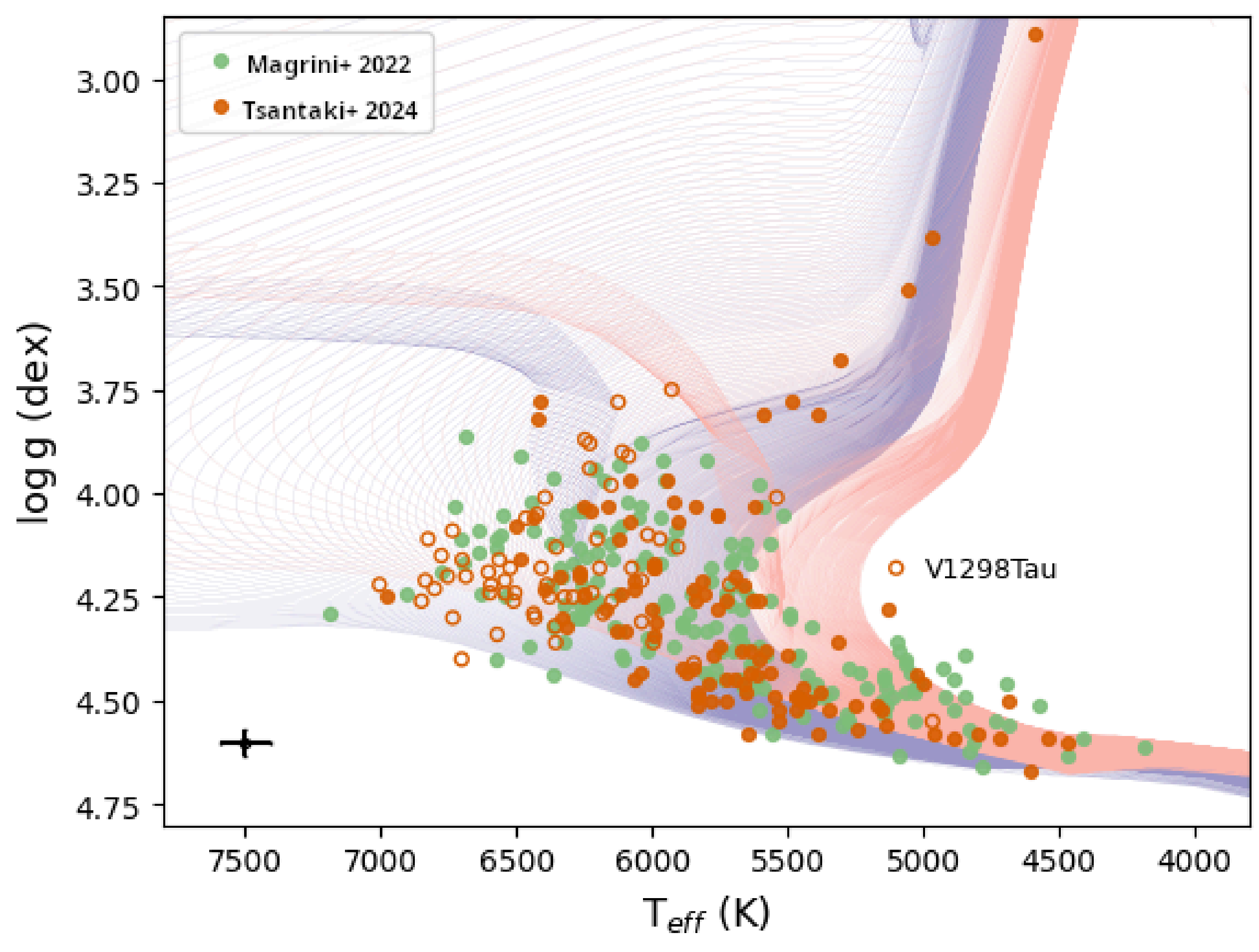
Methods:

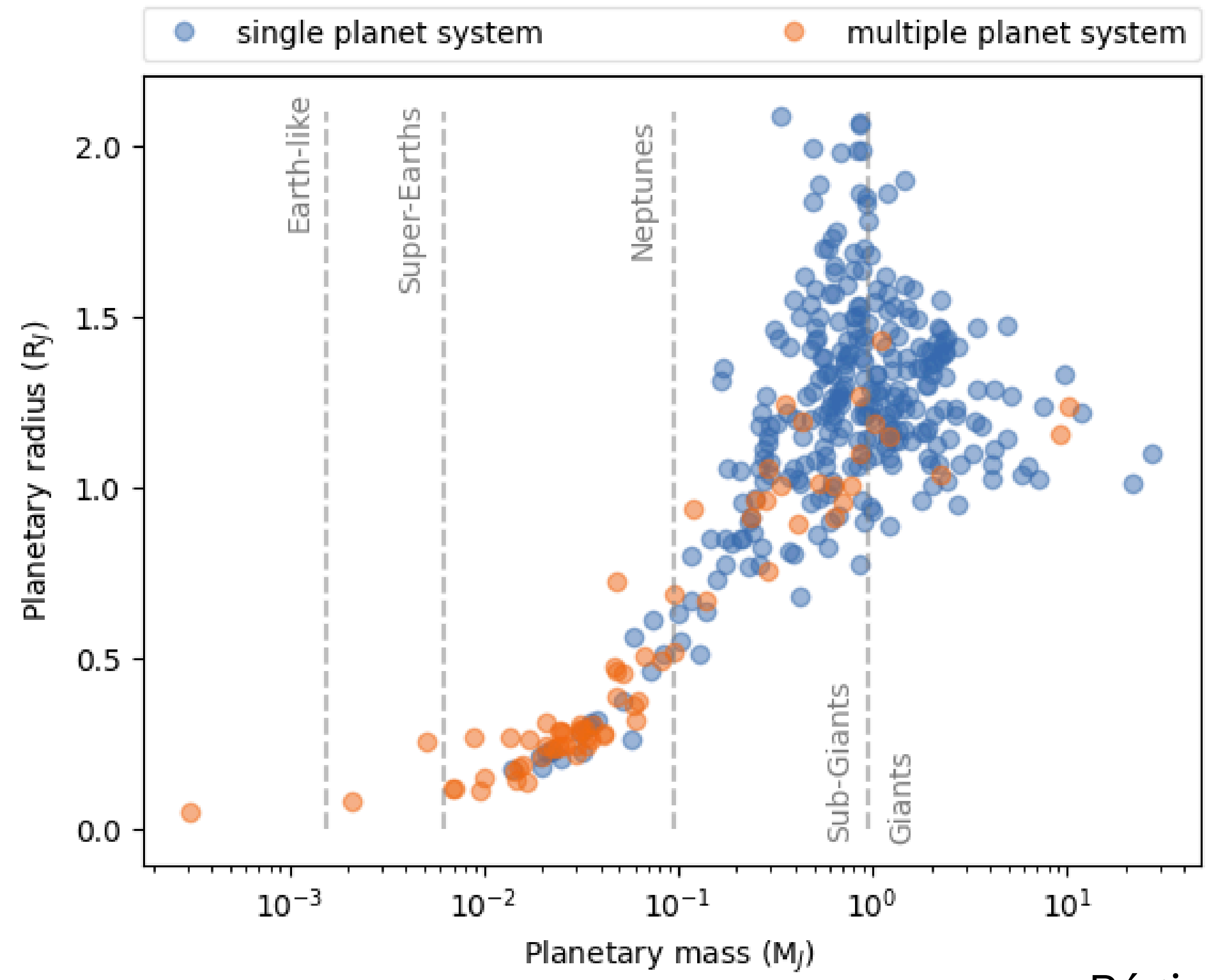
1. Equivalent Widths of Fe Lines (Magrini+ 22)
2. Spectral Synthesis Technique for Fast Rotators (Tsantaki+ 25)

To ensure consistency, the same ingredients were utilized: radiative transfer, atomic data, model atmospheres, & fixed log g.

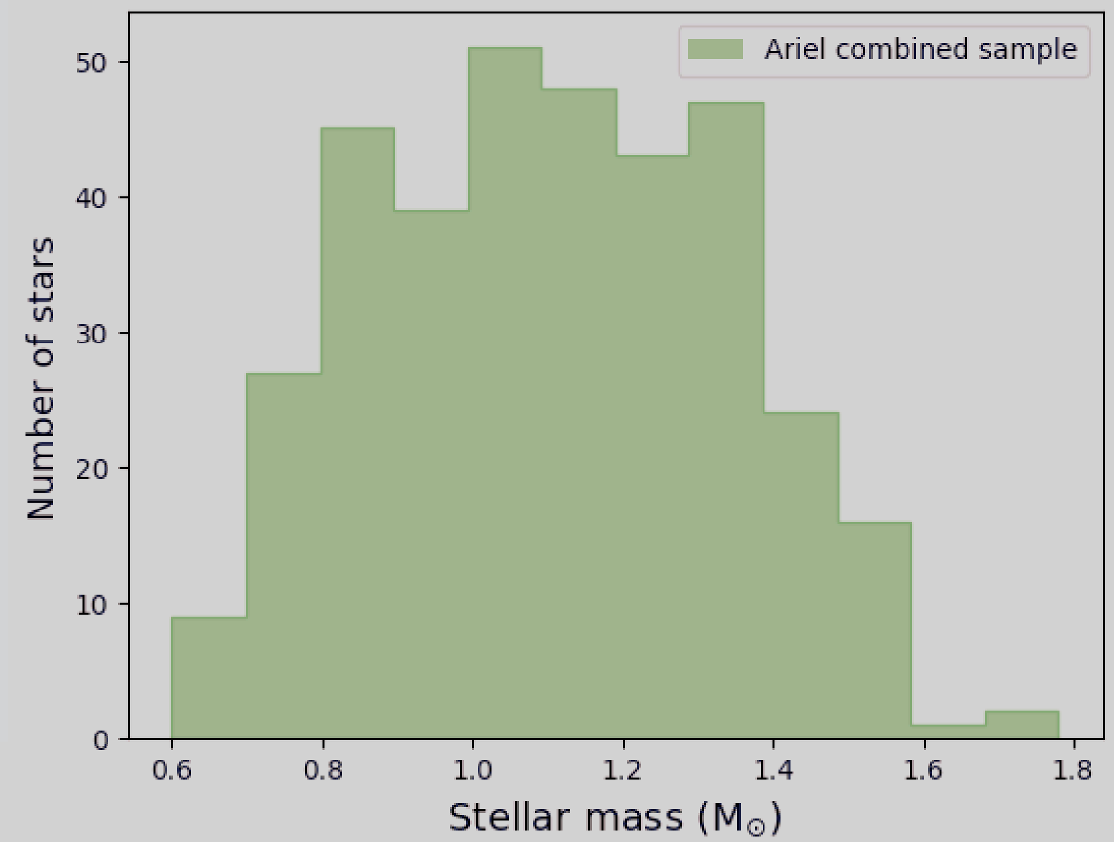
Combined dataset: **358 FGK-type stars & 446 planets**:

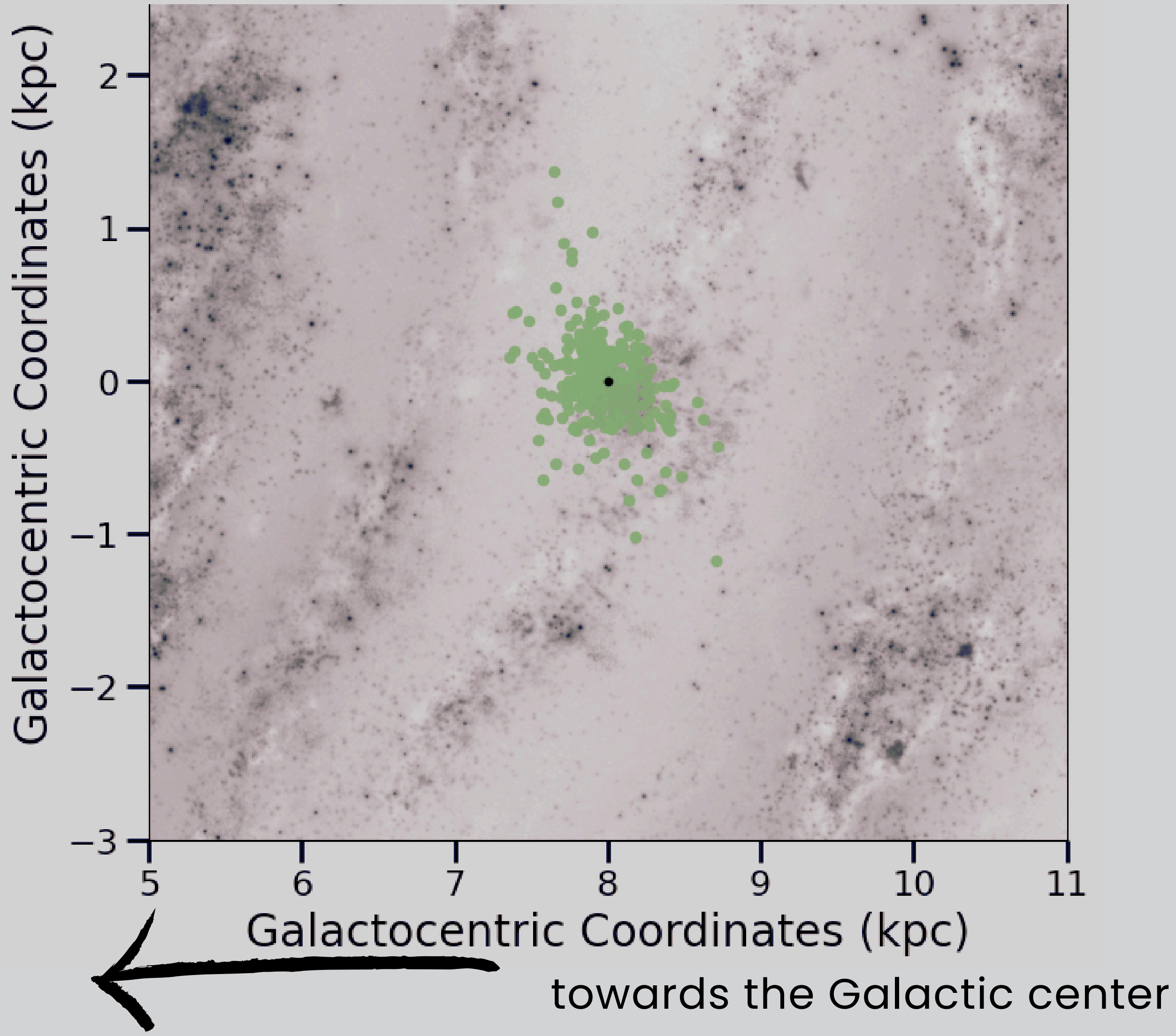
- 4184 ≤ Teff ≤ 7103 K
- 2.89 ≤ log g ≤ 4.57 dex
- -0.58 ≤ [Fe/H] ≤ 0.54 dex
- 0.60 ≤ M⋆ ≤ 1.78 Msolar

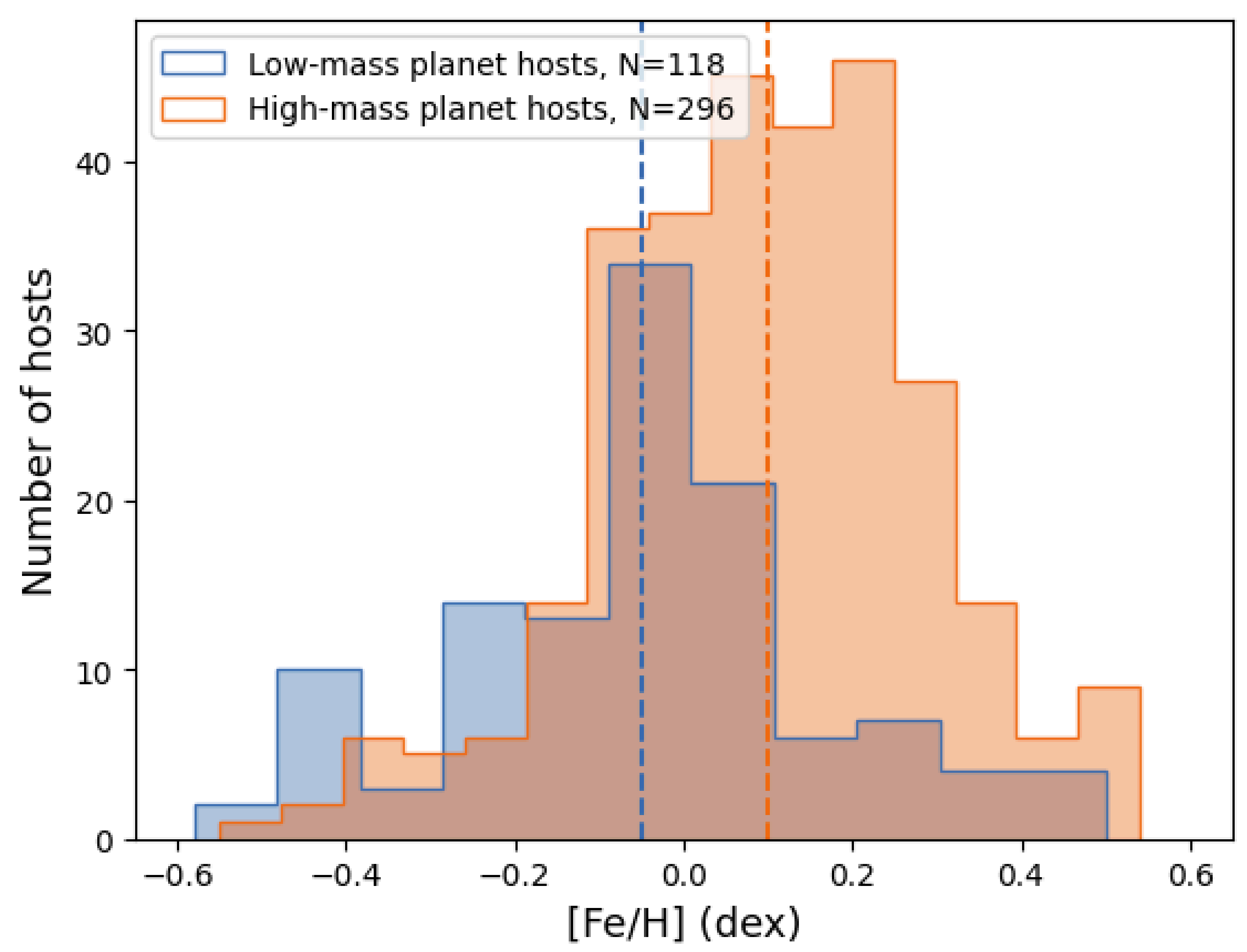




The Ariel Mission Candidate Sample so far







<[Fe/H]_lowmass > = –0.06 ± 0.03 dex

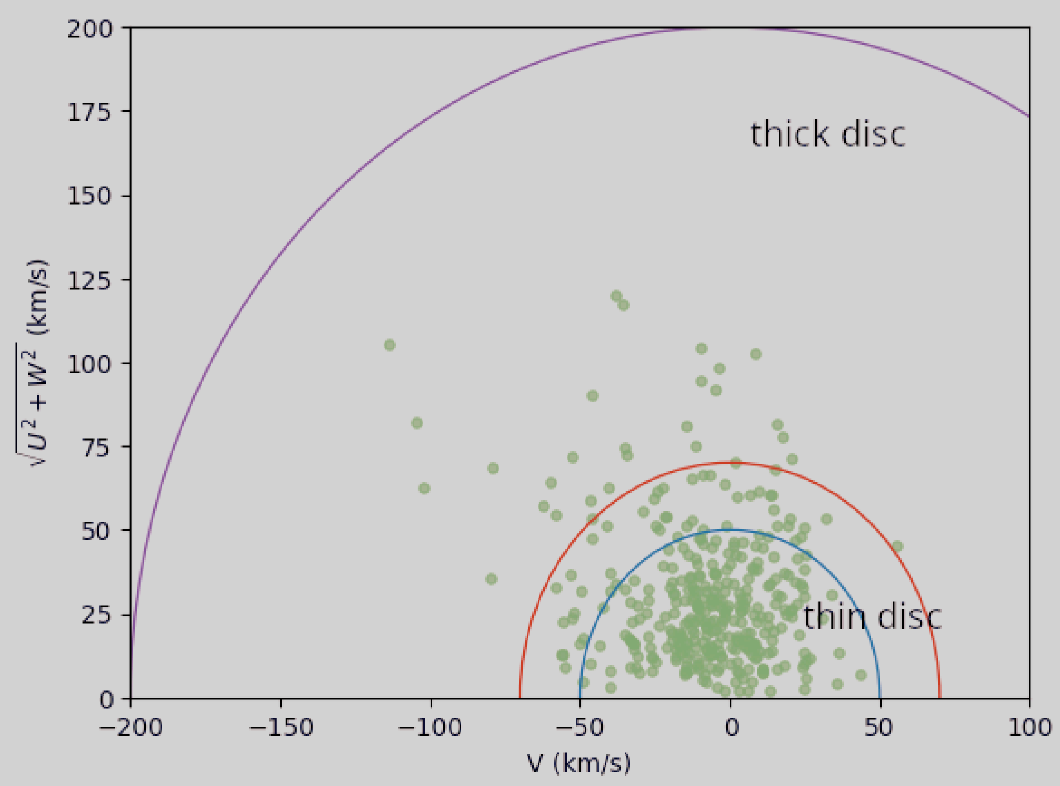
<[Fe/H]_highmass> = 0.10 ± 0.01 dex

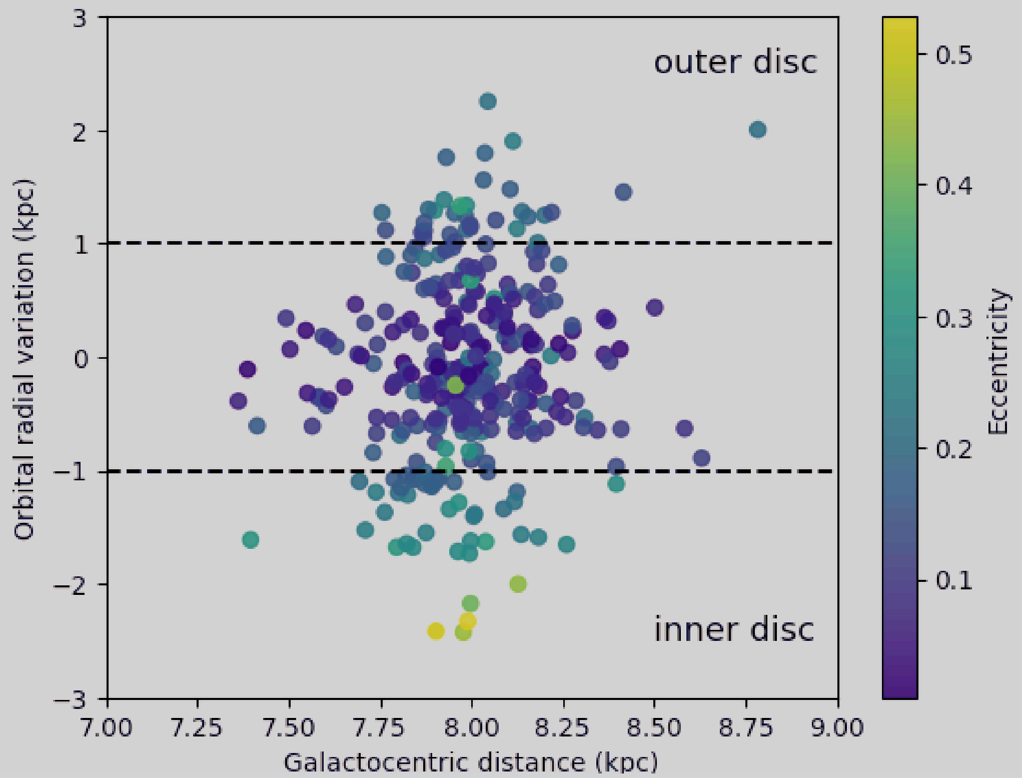
Low-mass planets are found in a wider range of [Fe/H].

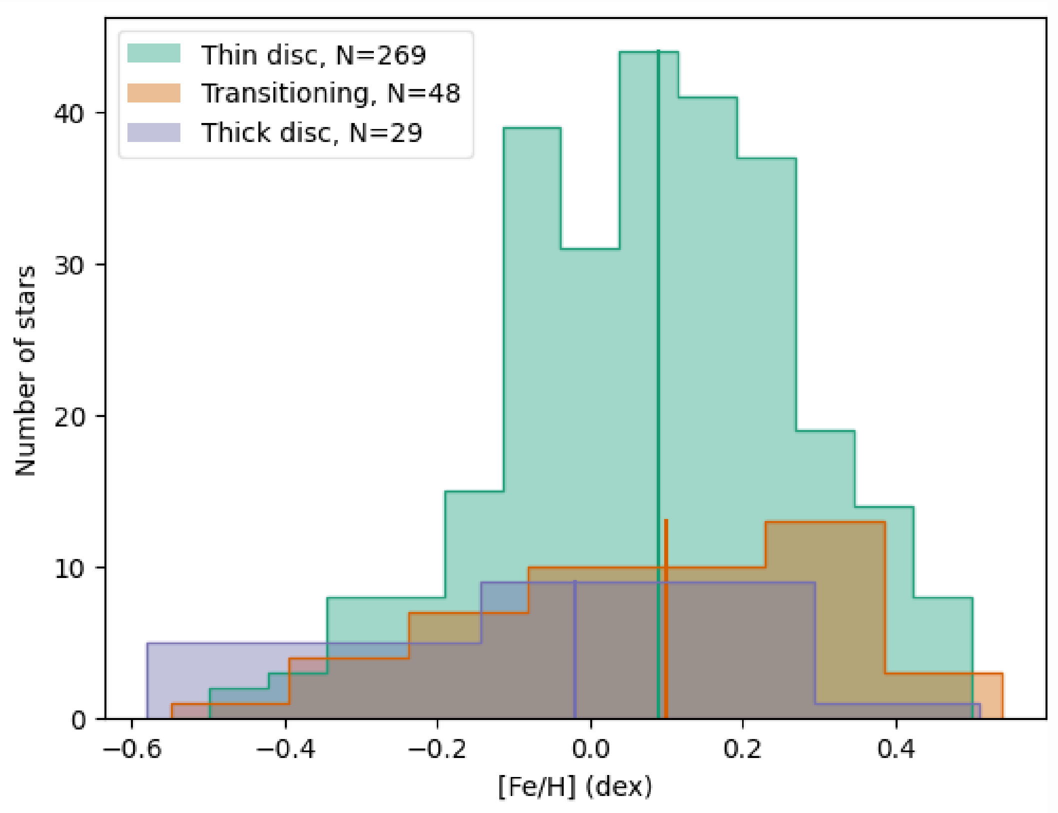
(extensive literature, see review Adibekyan 2019)

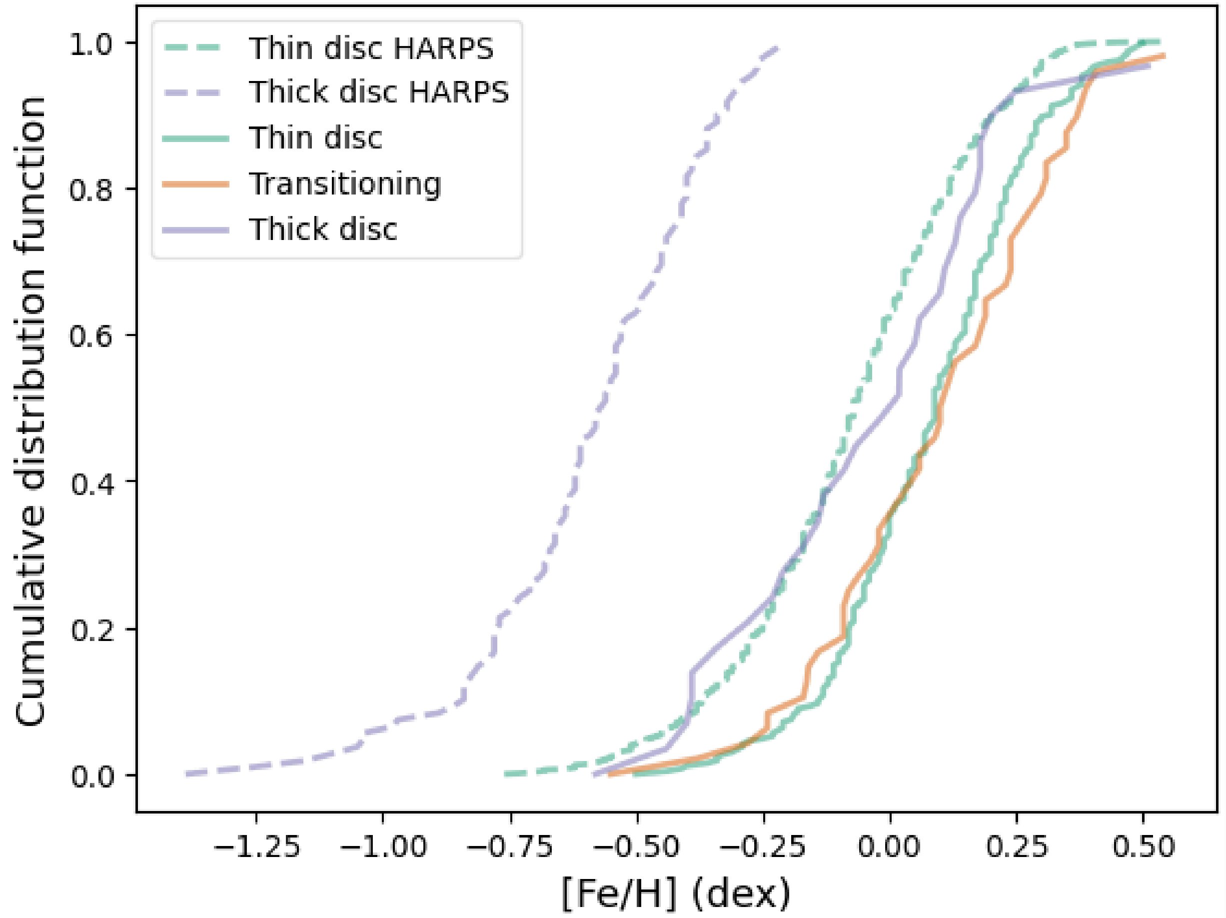
The Ariel Mission Candidate Sample so far

Kinematic separation for the thin & thick disc using Gaia DR3.



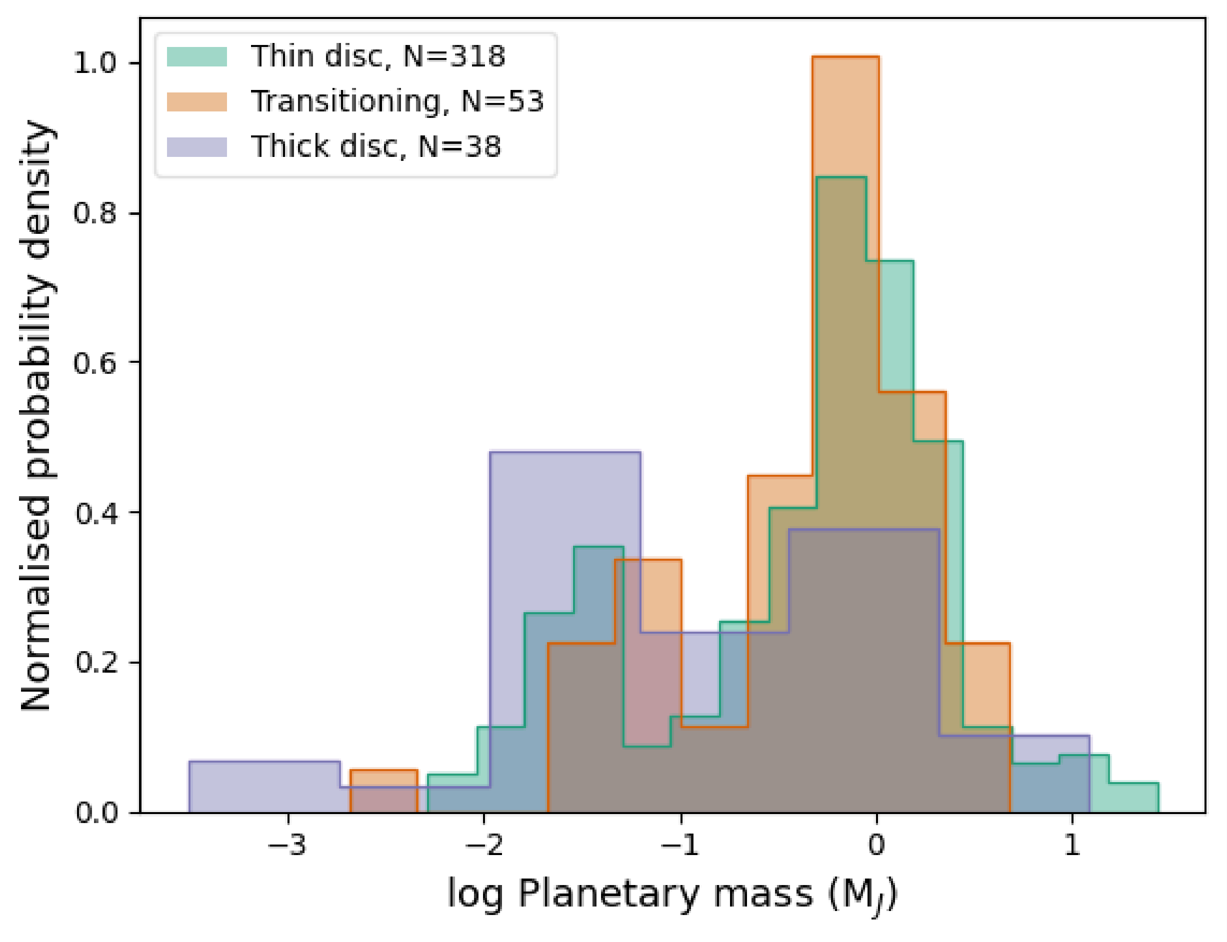


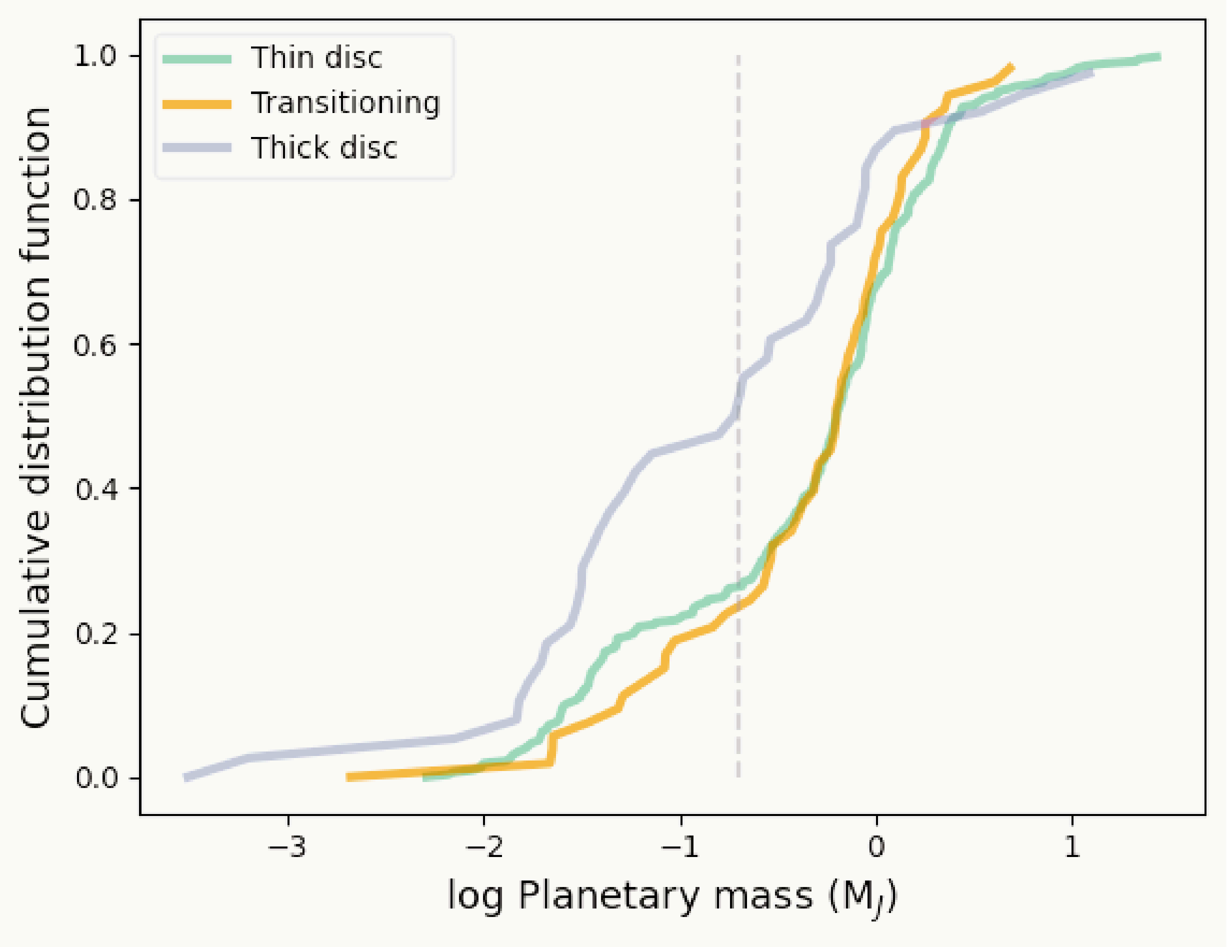




Planet hosts do not follow the metallicity distribution of their populations.

The Ariel Mission Candidate Sample so far





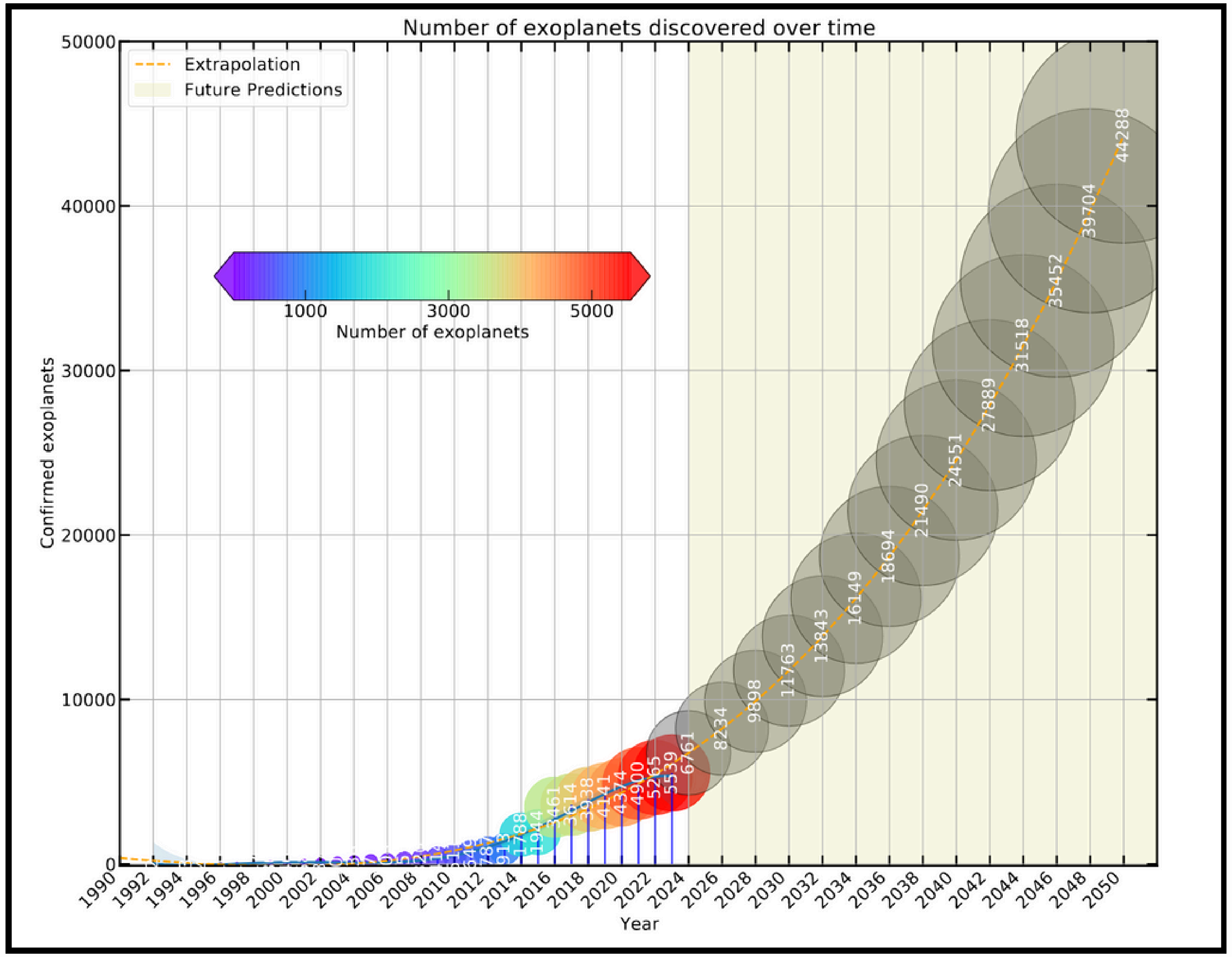
More massive planets are formed predominantly around [Fe/H]-rich stars and are mainly located in the thin disc.

- Thin disc stars due to the relationship between age and metallicity are metal rich and should also be the **youngest**.
- As stars get more chemically enriched over time, the formation of more massive planets is enhanced as well.

(see also Adibekyan+ 2012; Biazzo+ 2022; Swastik+ 2022)

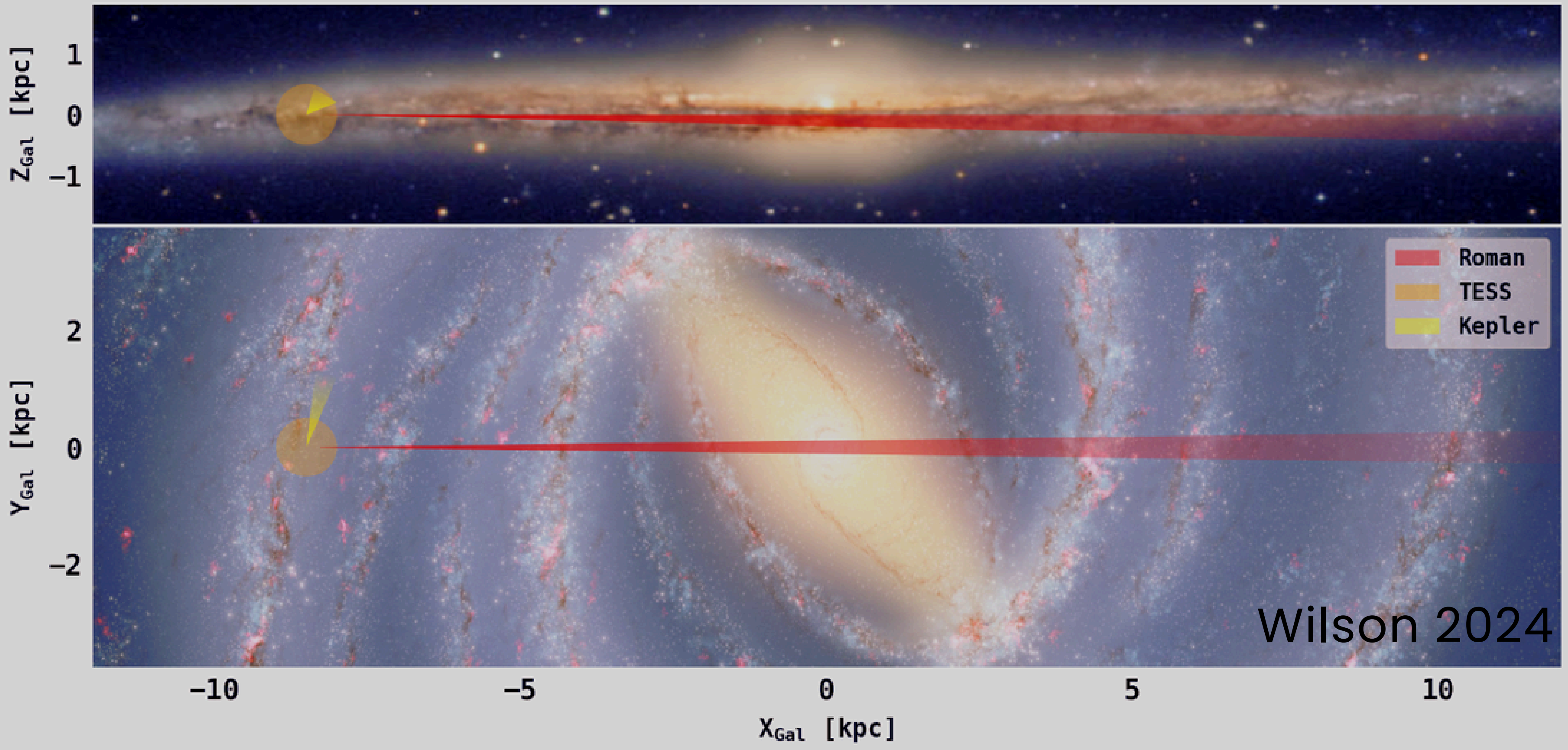
Caution on the detection biases of low-mass planets.

The future exoplanet missions:
planet demographics cross Galactic environments

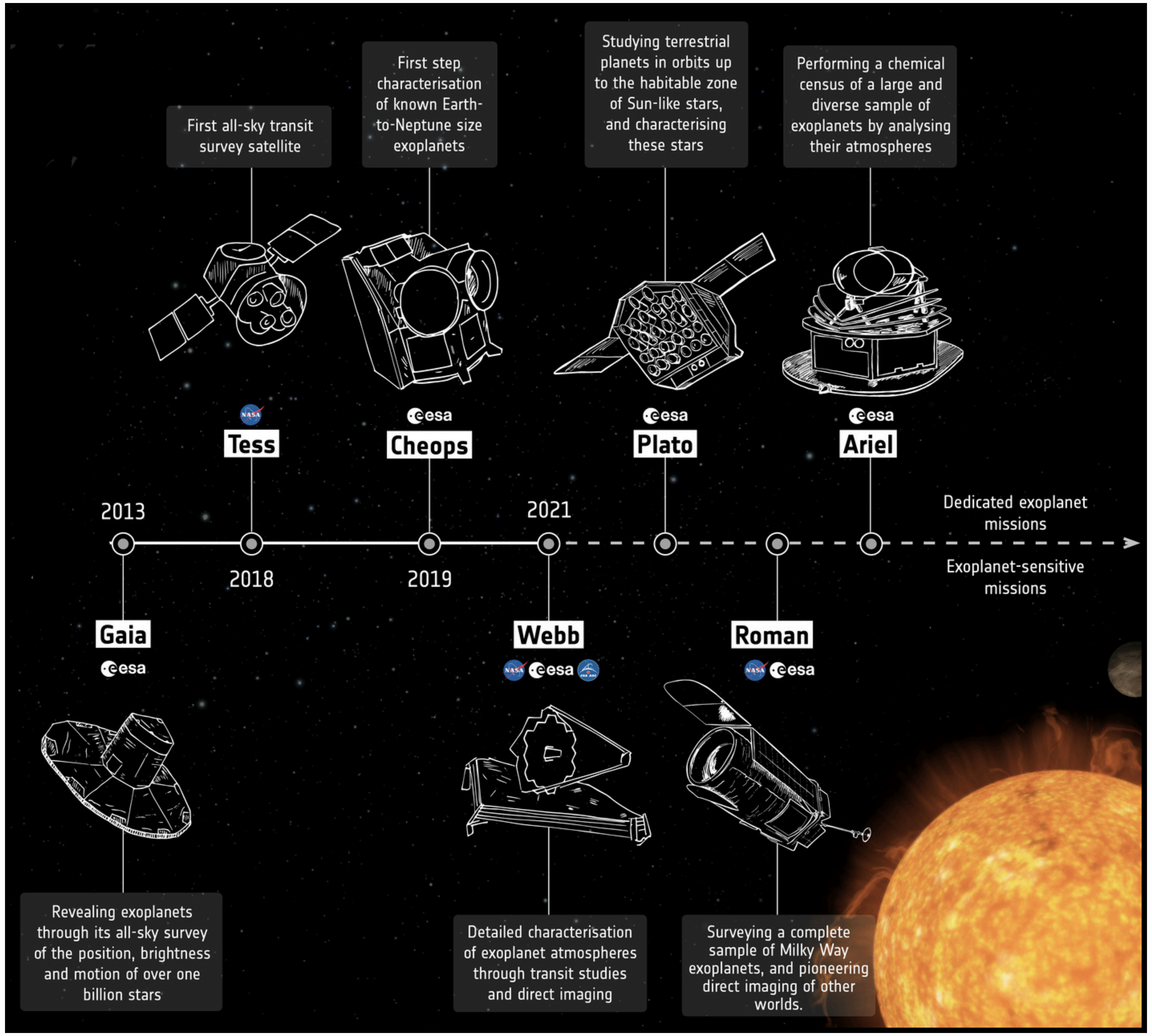


credit: WST white paper

- **TESS**: 7×10^{3} candidates around bright stars (G<12mag)
- **Gaia**: $\sim10^{4}$ - 10^{5} giant planets in DR4 (2026) in a magnitude limited sample (G≈9–13mag) unbiased by stellar mass, chemical composition & age
- **PLATO**: $\sim4\text{-}7\times10^{3}$ planets around dwarf & giant stars with G<13mag, launch 2026
- **Roman**: $>10^{5}$ exoplanets in the thin/thick disk, bulge, and dense fields (faint stars <21mag nIR), launch 2027



The future exoplanet missions: planet demographics cross Galactic environments



credit: ESA

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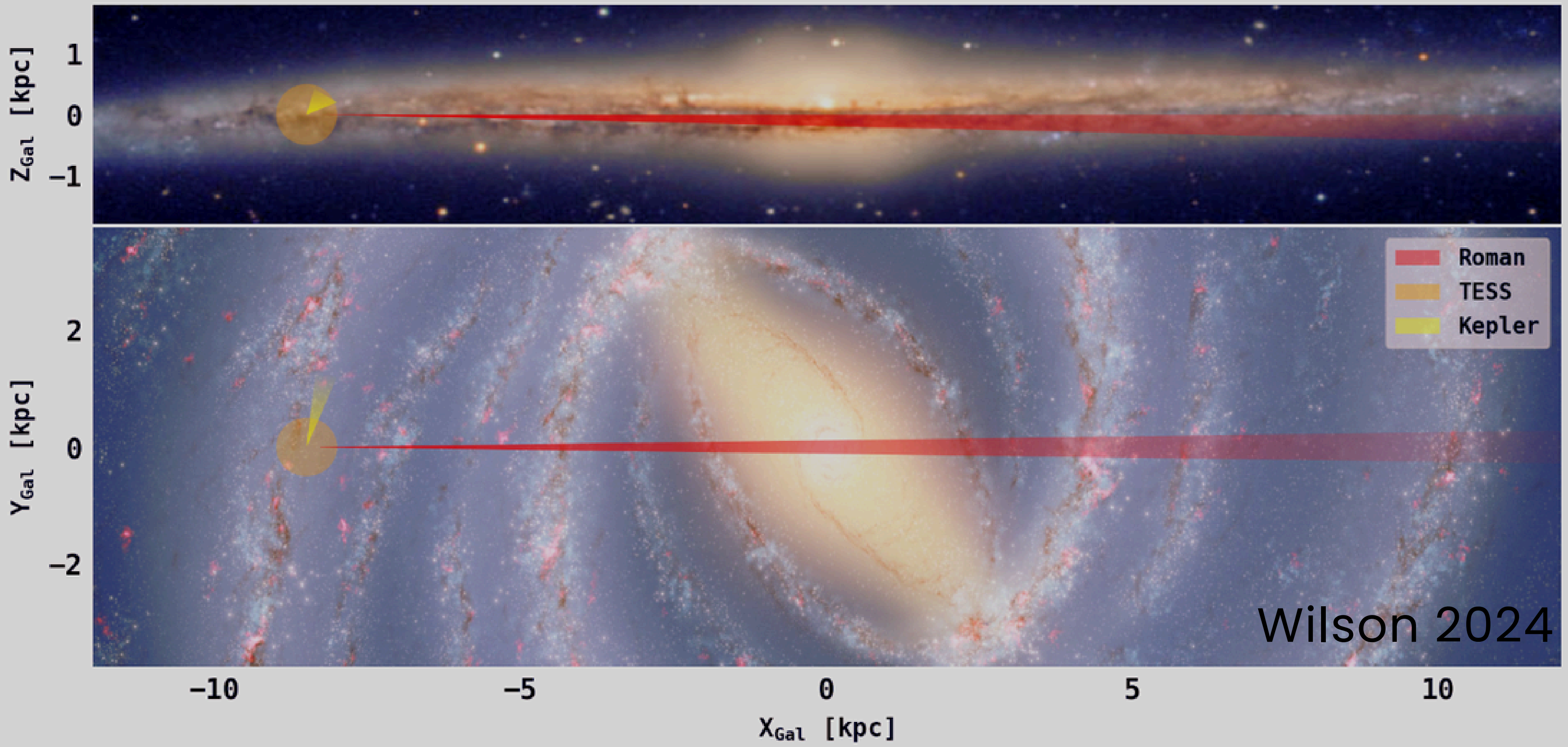
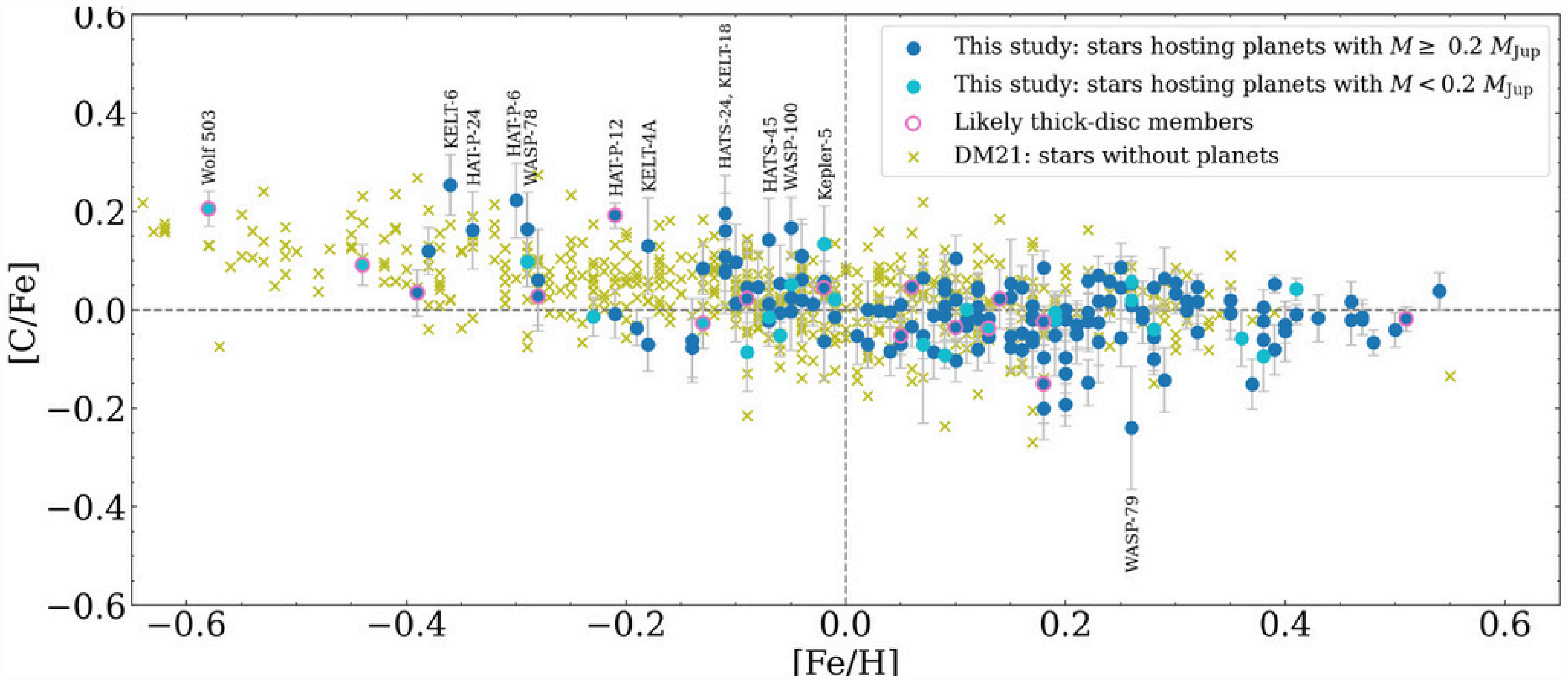
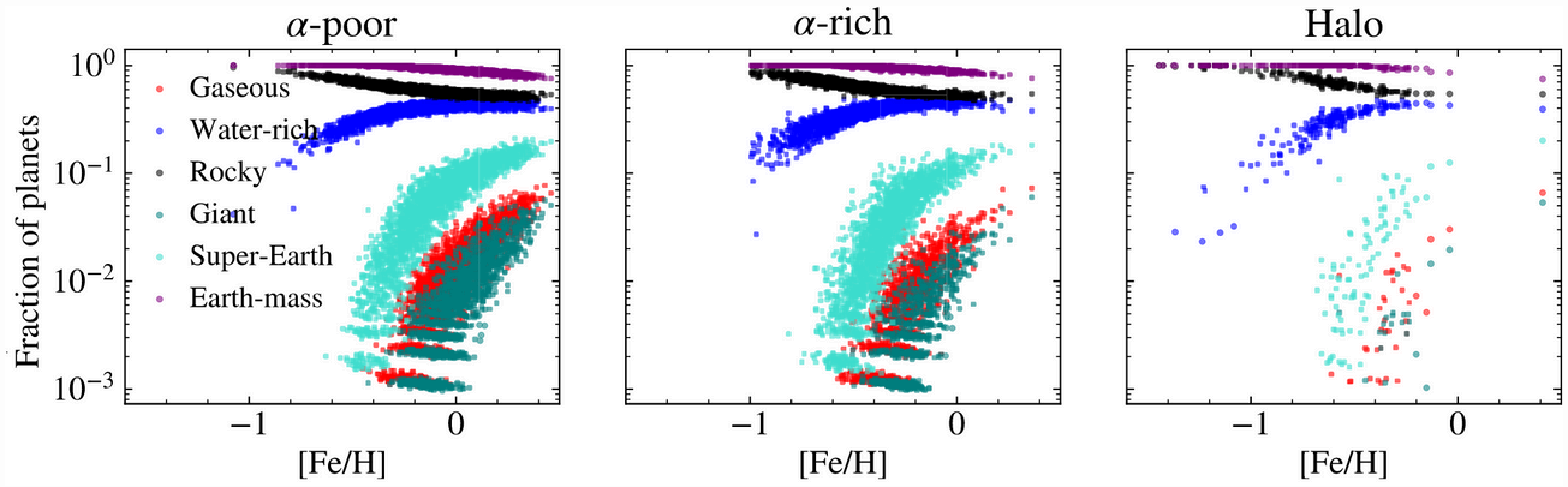


Planets in the Galactic context: the role of WST





Ariel CNO abundances (daSilva+2024): We yet cannot distinguish whether the enhancement in C is a consequence of planet hosts belonging to the thick disk or whether it is a factor favoring the formation of planets as for higher abundances of planet building materials such as Fe, Mg and Si.

Planet models in Galactic environments (Nielsen et al. 2023): Planetary mass & composition depend on both [Fe/H] & a-element content of the host imposing constraints on *Galactic habitability zone.*

- Precise and accurate abundances with errors **~0.05 dex** in high resolution for elements important for planet formation: Fe, C, N, O, Mg, Si
- Synergies with the statistical planet search missions (PLATO, Gaia, Roman) in particular for the faintest hosts
- MOS spectrographs are most suitable for follow-up planet/host demographics
- **Goal: WST planet host homogeneous catalog**

SUMMARY

- The Ariel stellar characterization WG has provided an online catalog with ***homogeneous*** stellar parameters & chemical abundances.

- **High-mass planets orbit more [Fe/H]-rich stars which belong to the thin disc and could be younger. The lower-mass planets can be found in more [Fe/H]-poor environments and are more likely to be hosted in the thick disc.**

- The Galactic environment plays a very important role in shaping the planetary system. These effects on planet demographics have so far been largely unexplored.

- **WST can play a role in the planet host characterization in the 2040s era.**

Ariel stars

THANK YOU

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