Trazing the way back:
Planet-metallicity correlation (PMc) and abundance pattern in PMS stars

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PMc in MS stars

- PMc: giant planets more prevalent around solar-type stars with high [Fe/H]

- PMc also holds for M (Neves et al. 2013) and massive, $M_{*}>1.5\ M_{\odot}$, stars (Maldonado et al. 2013)

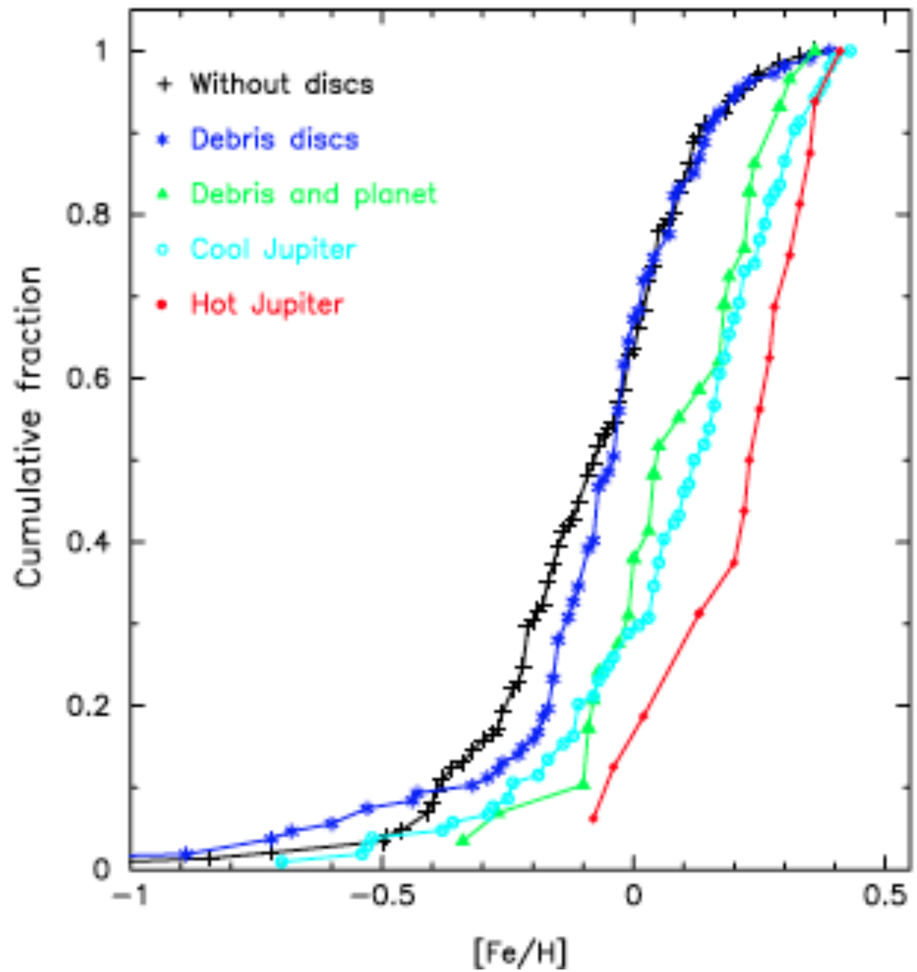
- Little or no dependence on [Fe/H] for low-mass planets (Mayor et al. 2011)

→ [Fe/H] major role in giant planet formation efficiency

❖ Mass of the planet governs the "metallicity behaviour" of "complete" planetary systems, i.e. Including debris disk stars (Maldonado et al. 2012, 2015)

- PMc interpreted in the frame of the core-accretion scenario (Pollack et al. 1996)

"Final mass of the cores via oligarchic growth Increases with the solid density in protoplanetary disk" (Kokubo &Ida 2002, Mordasini et al. 2912)



Abundances

Planet host solar-type star atmospheres can be enriched/depleted in refractory elements (Tc ≈ > 900 K) depending on: i) type of planet -hot/cool Jupiter; low-/high mass; ii) with/without debris disk; planet/non-planet (Maldonado et al. 2015)

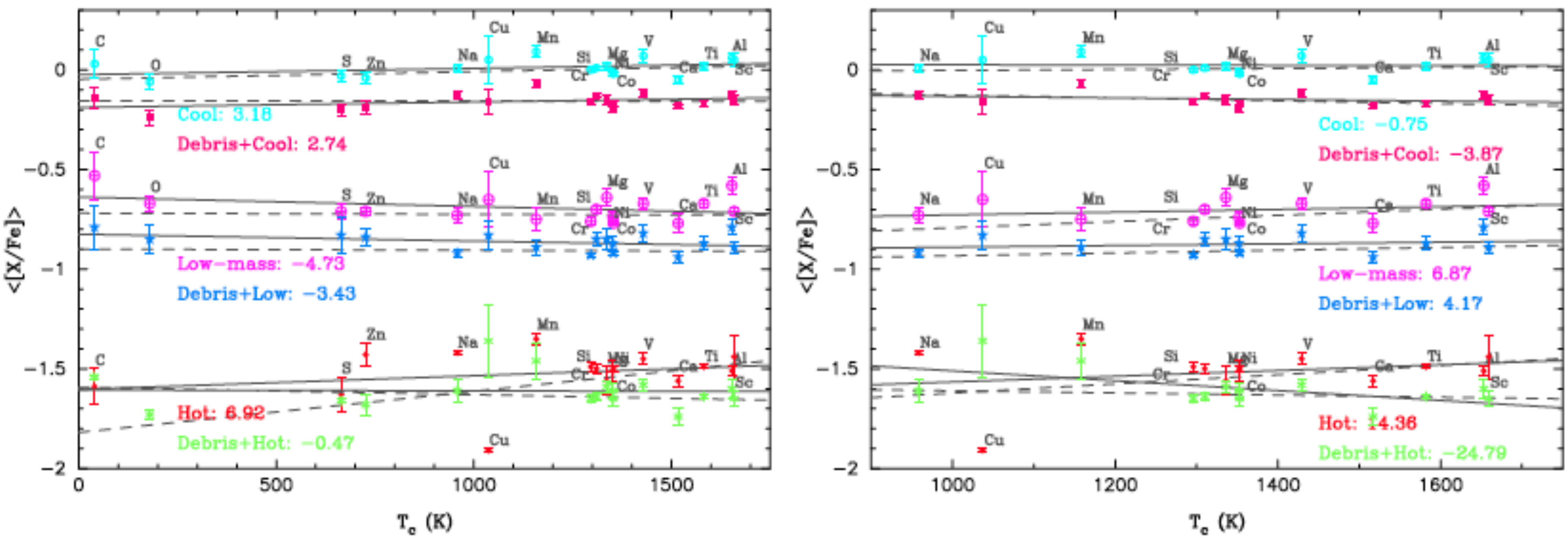


Fig. 8. $\langle[X/Fe]\rangle - T_C$ trends for planet host stars. The stars are divided into six categories, three corresponding to stars with known planets but no debris discs, namely, stars hosting cool Jupiters (light-blue open circles), low-mass planet hosts (pink earth symbols), and stars hosting hot Jupiters (red filled circles). The SWDP sample is divided into the same categories: stars with debris discs and cool Jupiters (pink filled squares), debris discs and low-mass planets (cyan filled stars), and stars harbouring debris discs and hot Jupiters (light green asterisks). Each planet host subsample is shown against its corresponding SWDP subsample (e.g. stars with cool Jupiters vs. stars with discs and cool Jupiters) with an offset of −0.15 between the samples for the sake of clarity. The offset between the samples of cool, low-mass, and hot Jupiters hosts is −0.75. Unweighted fits are shown by continuous lines, while weighted fits are plotted in dashed lines. For guidance, the derived slopes from the unweighted fits are shown in the plots (units of 10^{-5} dex/K). The *left panel* shows the $\langle[X/Fe]\rangle - T_C$ trends when all elements (volatiles and refractories) are taken into account whilst the *right one* shows the $\langle[X/Fe]\rangle - T_C$ trends when only refractories are considered.

Abundance versus T_c
(<[X/Fe]> - T_c) trends: Scenarios

i) Planet engulfment or significant accretion of rocky material would enrich the stellar atmospheres

ii) H-depleted rocky material locked in terrestrial planets would result in the depletion of heavy elements relative to H in the stellar photosphere

iii) High metallicity and abundance patterns reflect the primordial abundance.

Any scenario has pros/cons !!!!!

λ Boötis stars

- ❖ A/F (early) stars with an underabundace of refractory elements

  - Origin ?????

- Most popular argument: selective accretion and refractory elements locked in dust grains

  # Accretion (from the underabundance ISM) is large,
  ~ $10^{-10} – 10^{-14}\ M_{\odot}$/year
  # Presumably short-lived (2% of A-type stars) → recent
  - but ≈1 Gyr stars show λ-Boö characteristics

- Recently: apparent correlation with debris disks

  # but i) not all λ-Boö stars have debris disks
  ii) neither all debris disks are λ-Boö stars
  e.g. β Pic is not a λ-Boö star

Kind of summary

- Both λ-Boö stars and stars hosting low-mass planets present an underabundance of refractory elements
- PMc convincingly demonstrated for stars hosting massive planets

Origin of this behaviour?

i) Primordial origin in the molecular cloud?

ii) Accretion of depleted/enriched-related phenomena altering the relative abundance of H/volatiles/refractories?

iii) Is it coincidental? (in the sense that the cause is internal to the stars themselves)

iv) Is it due to the evolution of the stars and their potentially associated planetary systems?

◆ Study of the metallicity/abundance pattern of young PMS stars (in particular those with planets) might help to yield some light/answers to this perplexing issue of the formation and evolution of planetary systems

What we know:
PMS λ-Boö stars
and PMS stars with planets

- Around 30% of HAeBe stars are λ-Boö type (2% MS A-type stars)

- Abundance peculiarity seems to preferently show up in transition disks
  # depletion not observed in flat disks

- λ-Boö behaviour has been suggested to be caused by Jupiter-like planets blocking the accretion of dust while gas flows onto the stars

- PMS stars with Jupiter-like candidates:
  # Some λ-Boö behaviour (2), some normal abundances (4)
  # None shows the PMc correlation found in the MS

→ We are back: Origin of the PMc/abundance pattern in MS stars?

How to proceed?

- ❖ *Systematic study of the metallicity/abundances in PMS stars (very small numbers up to now)*

- Points to be considered?

  # Stars should not be "too young" to avoid veiling effects
  # In a first instance → Weak T Tauri stars preferently with F/G types (but not too frequent)
  # (known) PMS- stars with planets candidates should be analysed, e.g. spectra in archives
  # Also, very young A stars as well as WTTs of early-M type should be considered

- ❖ *Sample difficult to define to get "succesfull observing proposals"*

How to proceed?

❖ Tool: GAIA

- will observe young pms stars in young cluster/associations and star forming regions, in particular WTTs, post-Ttauri stars, young A and HAeBe stars (the later not/hardly affected by veiling)
- will provide metallicities
- will provide abundances of α-elements

Important to think about: Sample

i) criteria for selection of regions
ii) identification of the aforementioned stars

A second step → CTTs