The Legacy of High-precision Asteroseismology for Chemical Clock Dating and Galactic Archaeology

Thibault Boulet: thibault.boulet@astro.up.pt
Supervisors: Tiago Campante, Vardan Adibekyan, Aldo Serenelli

Introduction

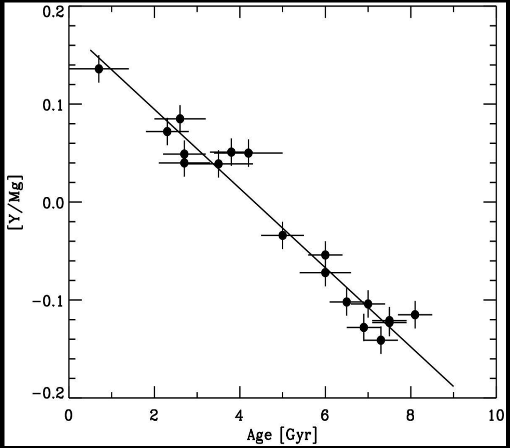
- What is a chemical clock ?

Why looking for chemical clocks ?

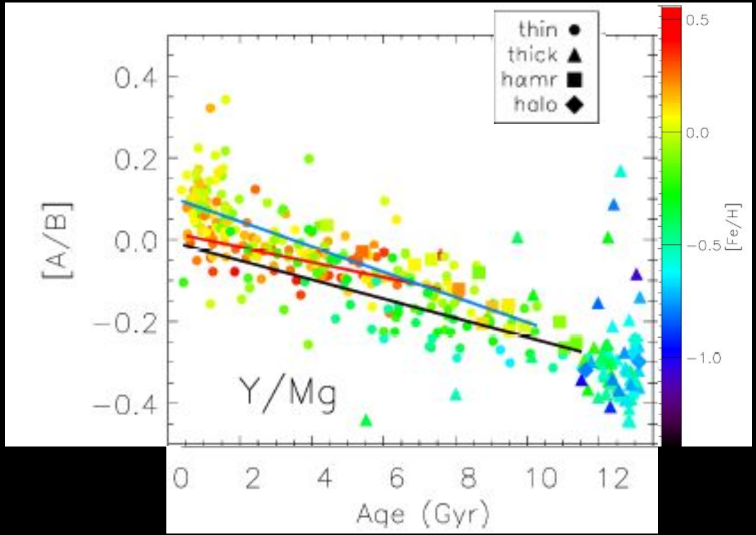
- Sources in GAIA DR1: 1,142,679,769
- Sources in GAIA DR2: 1,692,919,135
- Sources in GAIA EDR3: 1,811,709,771

Introduction

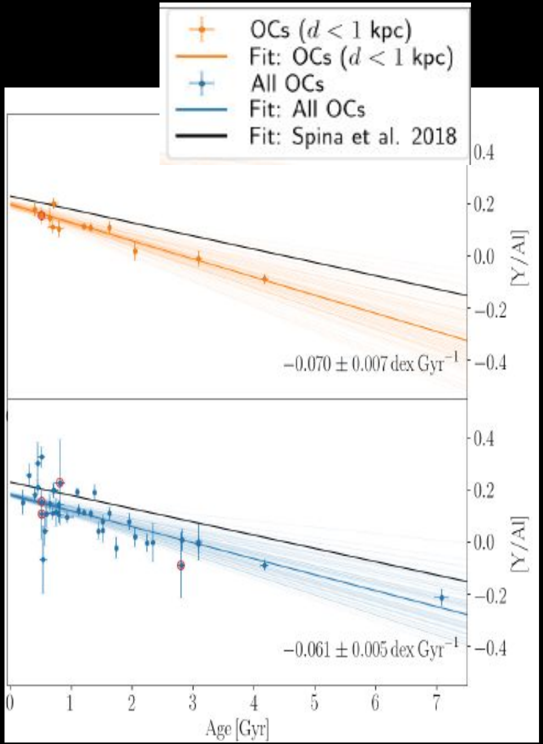
- Ages computed by means of isochrone fitting



Nissen 2015
[Y/Mg] relation



Delgado-Mena et al 2019:
[Y/Mg] relation



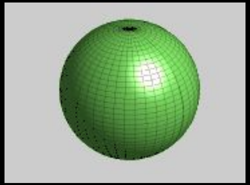
Casamiquela 2021 et al:
[Y/Al] relation

Other works: Feltzing et al 2017, Casali et al 2020, Spina et al 2020

The potential of small samples of seismic giants : Good calibrators

Why Giants ?

- Probes of Galactic Stellar populations
  - Most stars go through that phase
  - Intrinsically bright, so observable up to the kiloparsec regime (Hayden et al 2015)



Example of a stellar oscillation mode

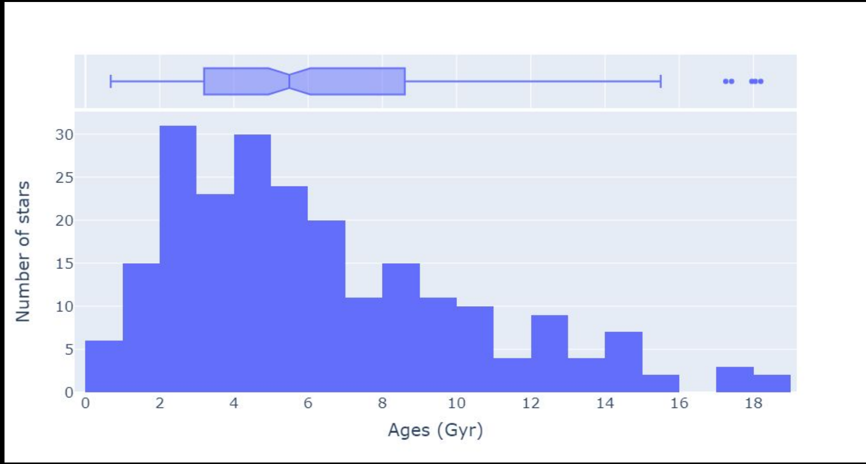
Why Seismic Giants ?

- Low fractional uncertainties on Ages
  - ~20% (Rendle, B. M., et al. 2019, Silva Aguirre, V., et al. 2020,Mackereth, J. T., et al. 2021, Zinn, J. C et al 2021)
  - Tight age-initial mass seismic constraints
  - For a given brightness, the red giant will have higher mode amplitude than a solar-type star.

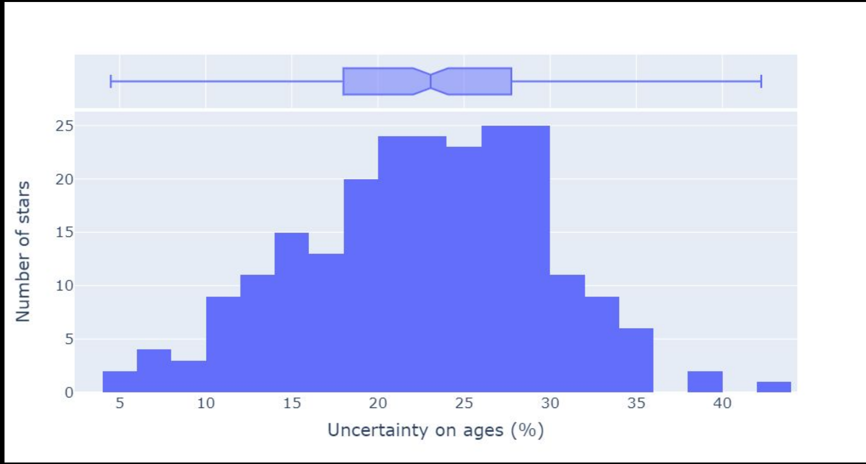
  - Previous exploratory work with K2 giants and GALAH abundances : Zinn, J. C. et al 2021

Description of the sample

- TESS SCVZ Mackereth et al 2021
- Gaia magnitude < 11
- Sub- sample of 227 giants

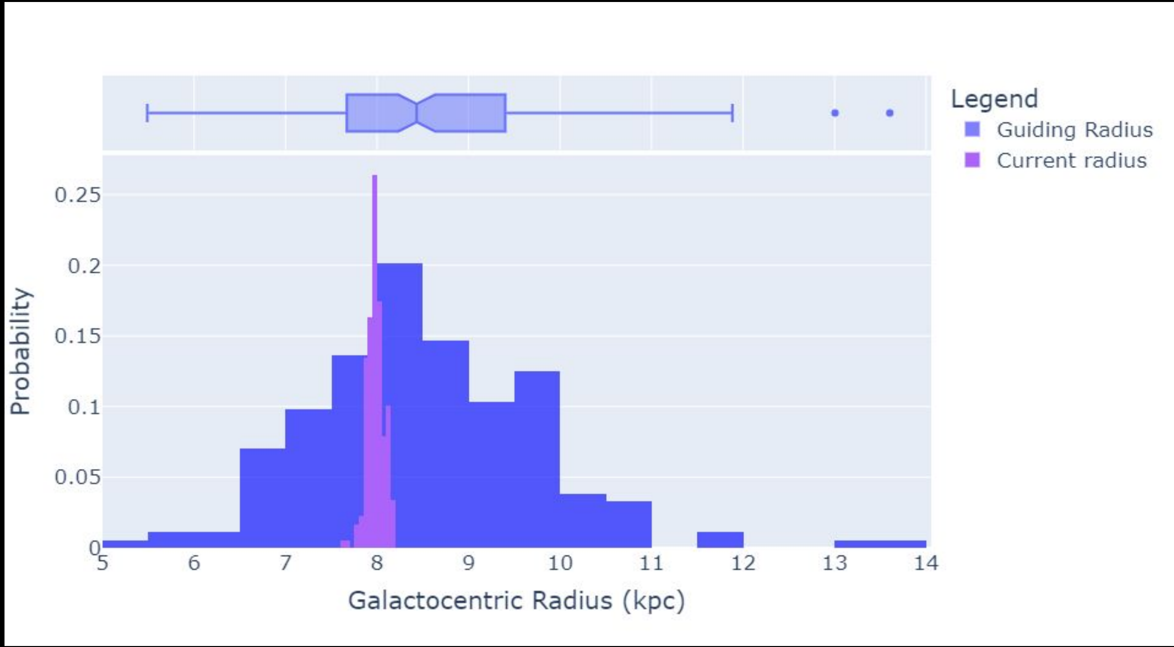


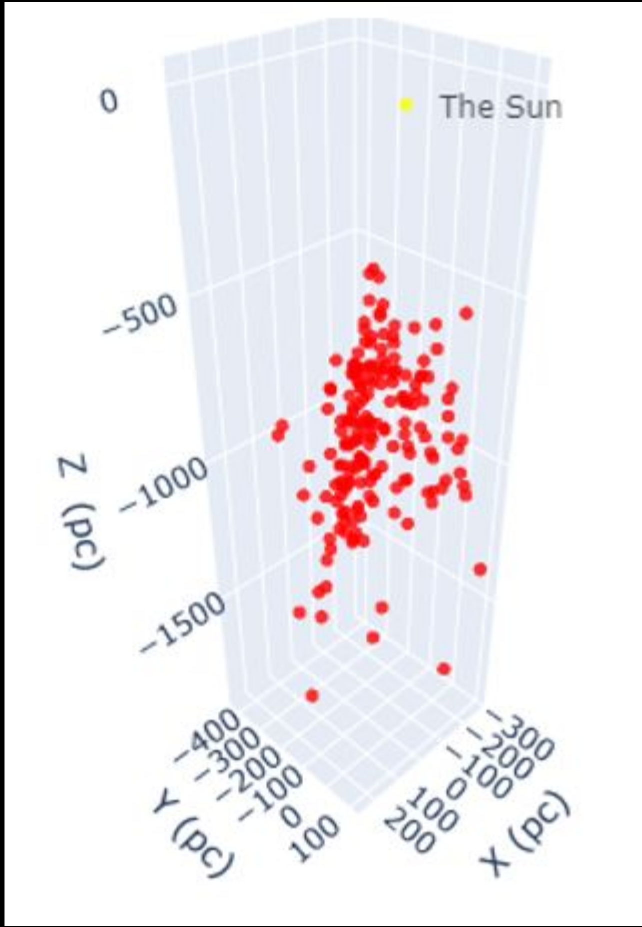
Age histogram



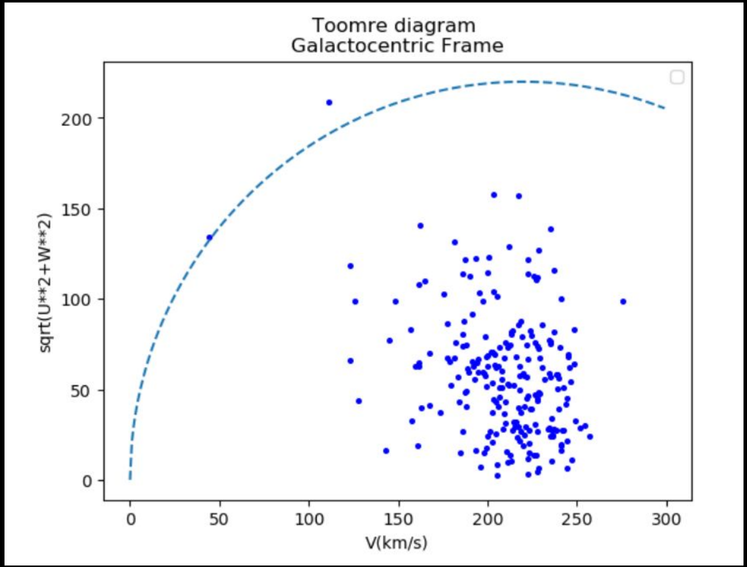
Uncertainty histogram on ages

Current and Past locations

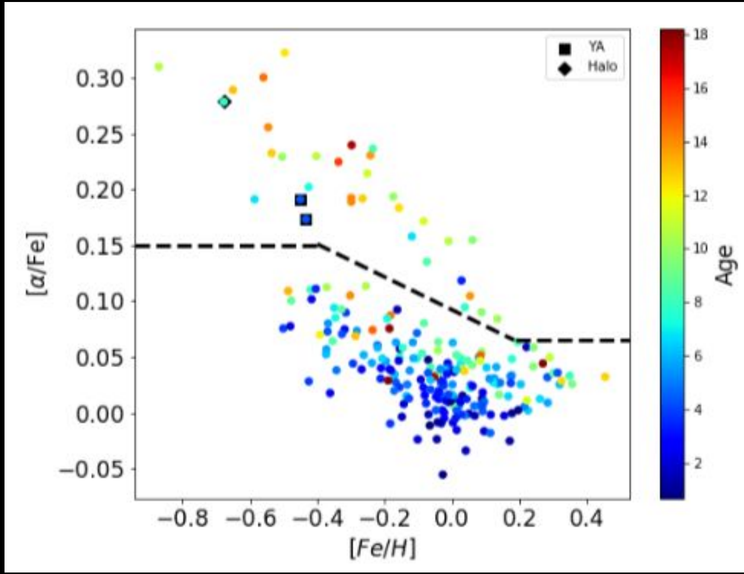




Kinematics and Chemistry



Toomre Diagram

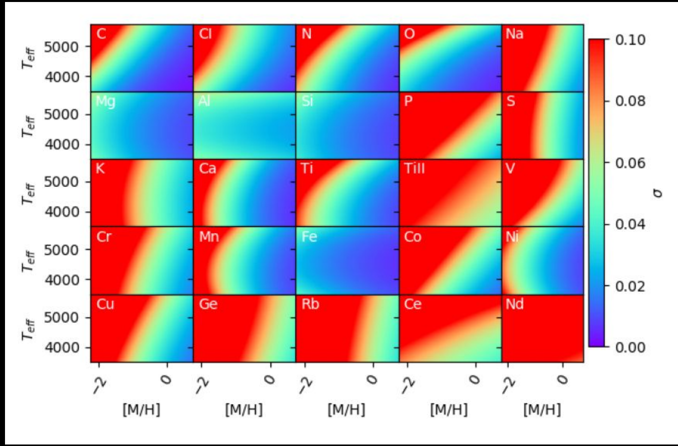


Chemical Dissection Plot

APOGEE 2 DR16

- Sample Size ~ 430 000 stars
- H band : 1.51-1.70 μm
- Spectral resolution ~ 22500
- Abundance precision: ~ 0.1 dex

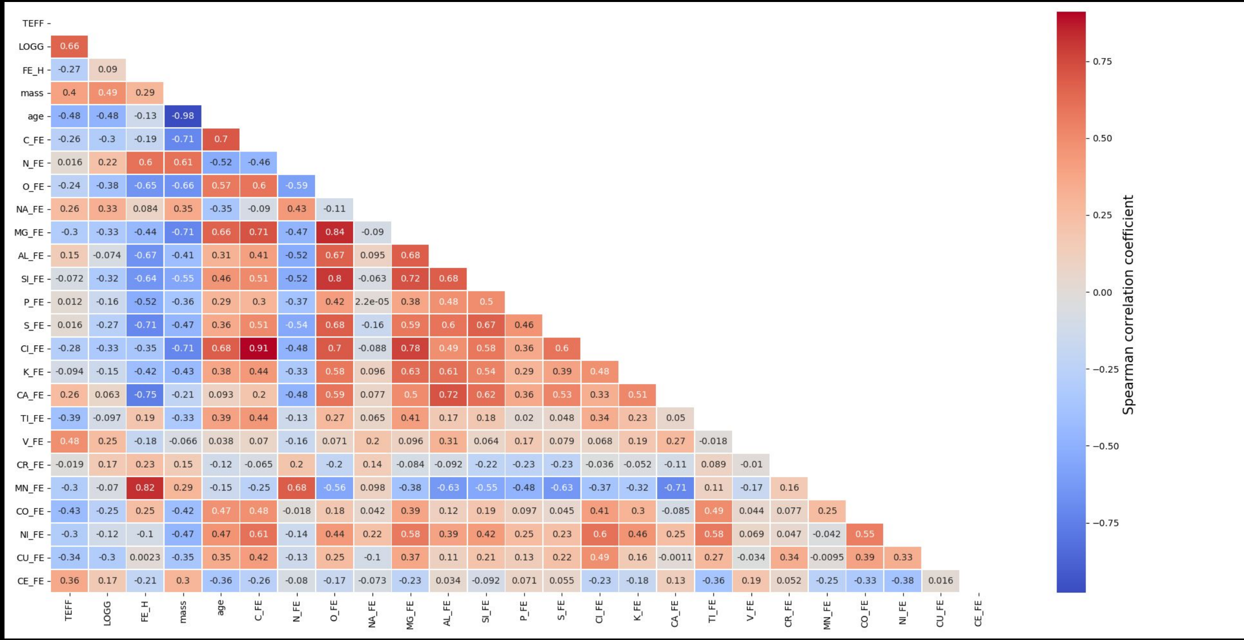
Overview of the APOGEE survey



Jönsson et al 2020

APOGEE 2 DR16 internal uncertainties for the case S/N =125

Computation of the correlations with Age



Spearman Correlations

Anti-Correlation

Correlation with age

[X/Fe]	ρ
[N/Fe]	-0.52
[Ce/Fe]	-0.36
[Na/Fe]	-0.35
[C/Fe]	0.70
[Mg/Fe]	0.66
[O/Fe]	0.57
[Co/Fe]	0.47
[Ni/Fe]	0.47
[Si/Fe]	0.46
[K/Fe]	0.37
[S/Fe]	0.36
[Cu/Fe]	0.35
[Al/Fe]	0.31

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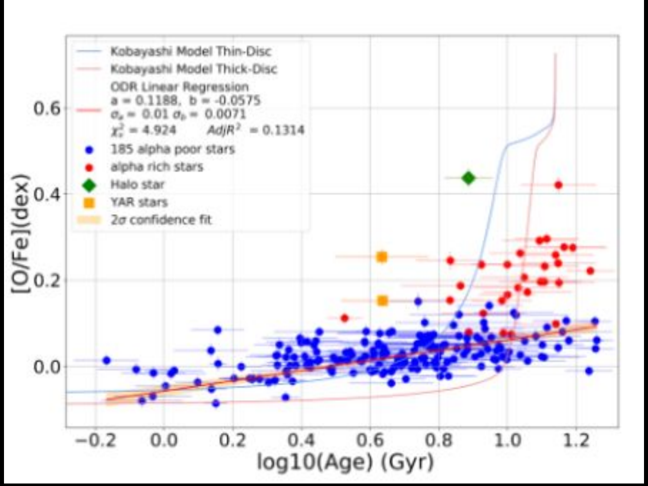
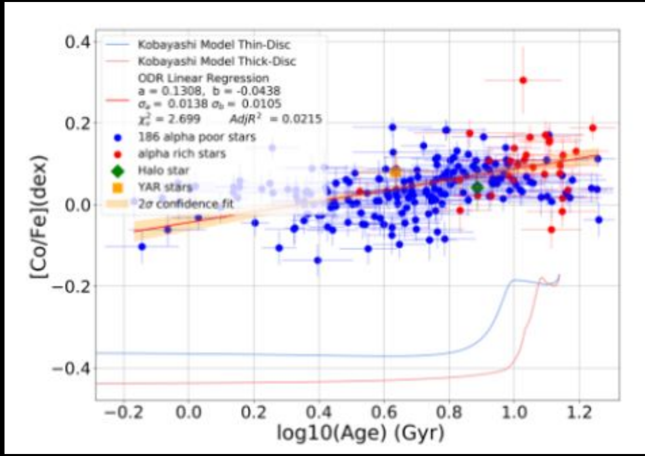
Retained chemical elements

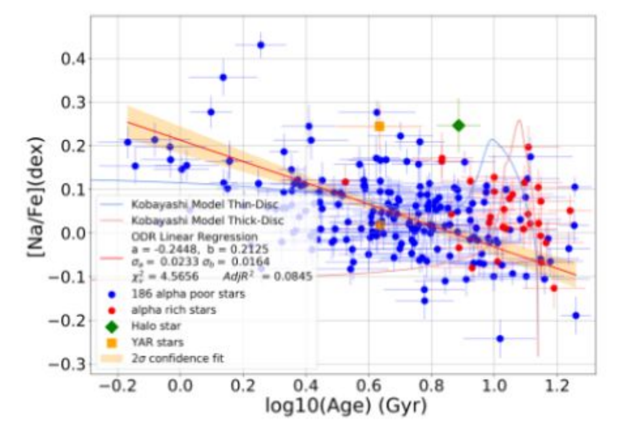
Analysis of the sample: Trends with log(Age)



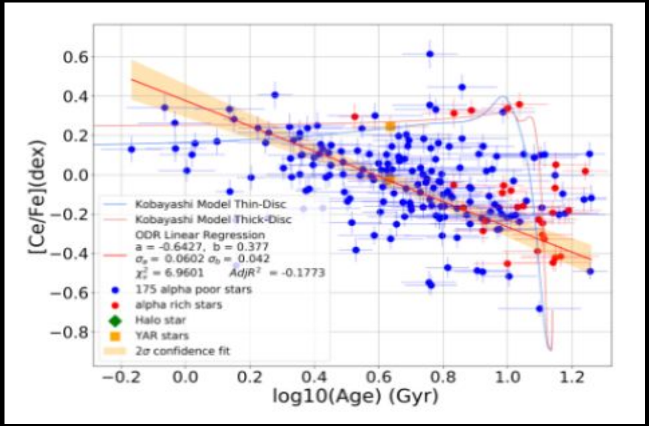
Alpha



Fe-Peak

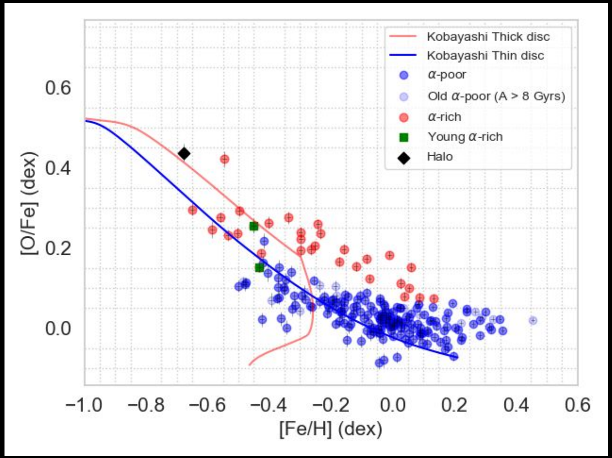


Odd-Z

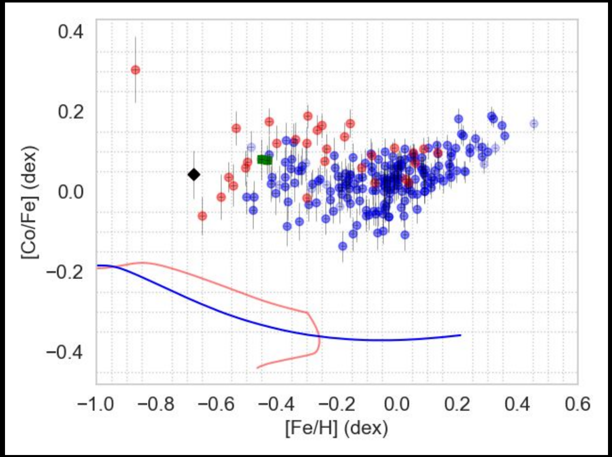


heavy-s proc

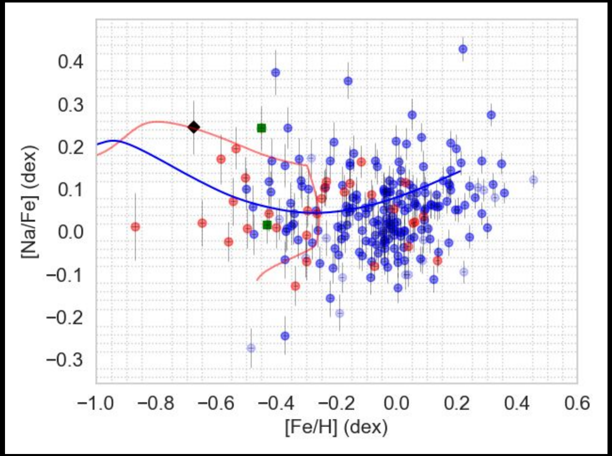
Analysis of the sample : Trends with [Fe/H]



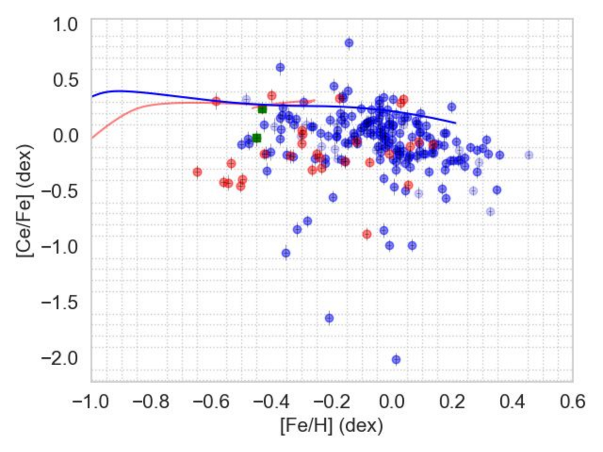
Alpha



Fe-Peak

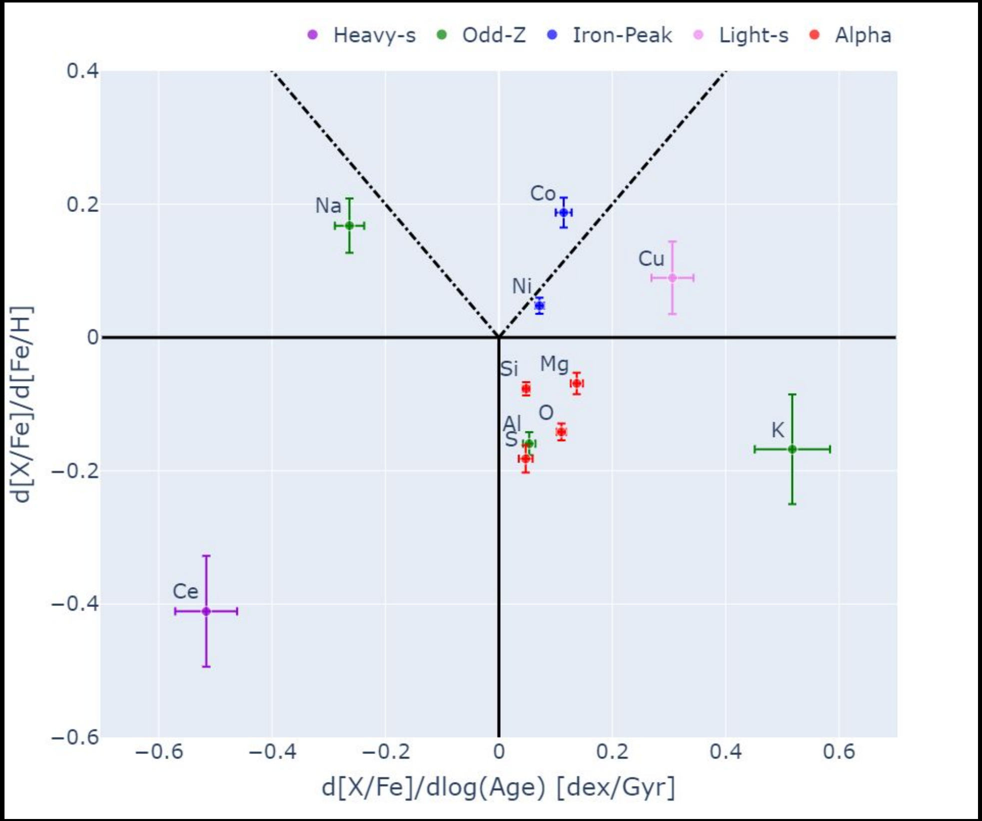


Odd-Z

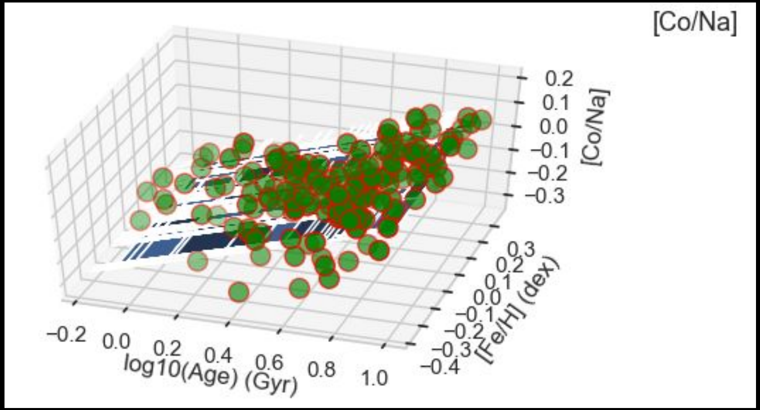


heavy-s proc

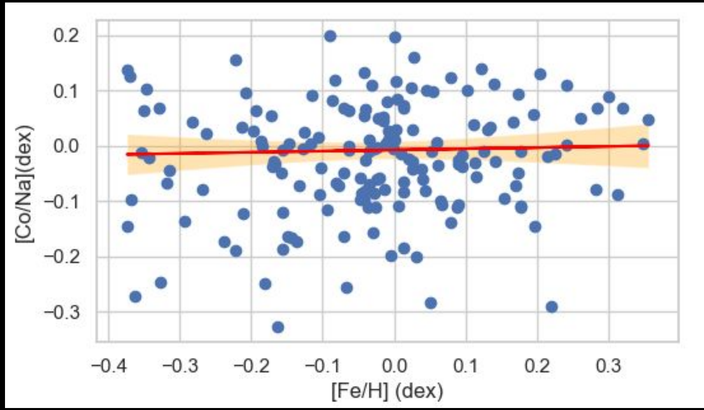
Summary of the [X/Fe] trends



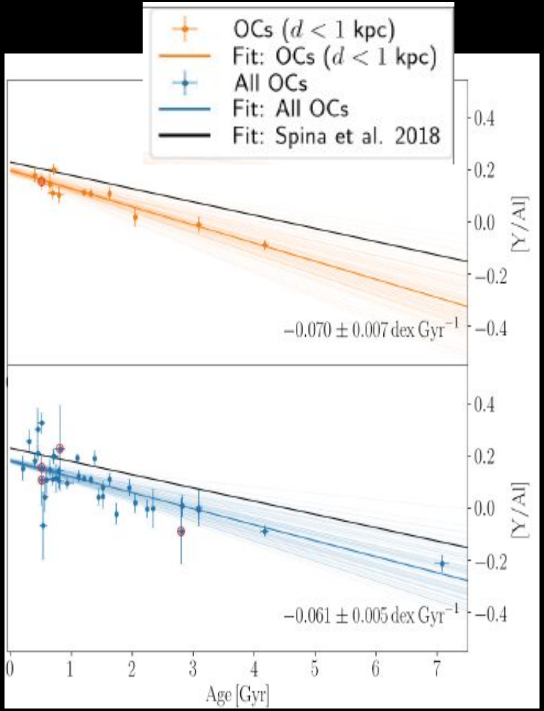
Novel [X/Y] chemical clocks



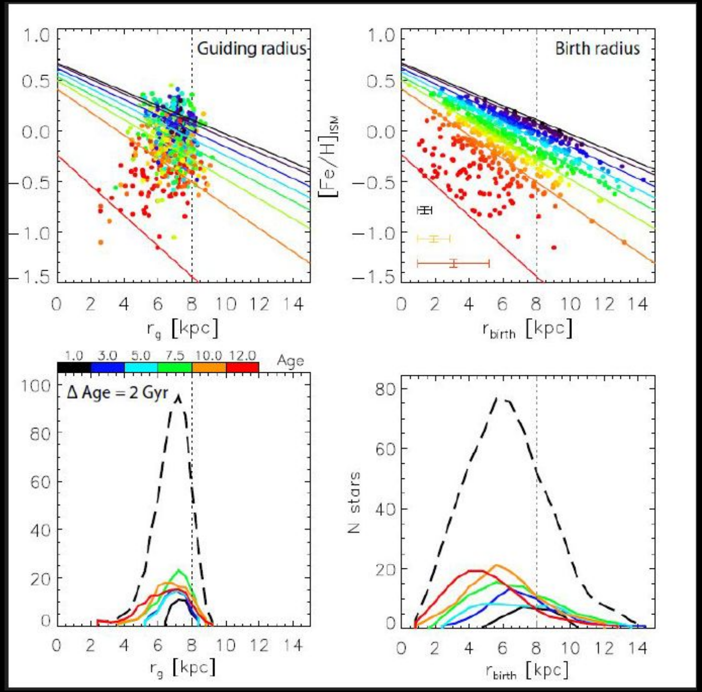
[X/Y]	Adj-R2	Best-Fit
[Co/Na]	*0.3522*	2p-AT
[O/Na]	*0.3386*	2p-AM
[Al/Na]	*0.3293*	2p-AM
[Co/Ce]	*0.3281*	2p-AM
[Mg/Na]	*0.3168*	2p-AM
[Ni/Na]	*0.2472*	2p-AM
[S/Na]	*0.2392*	2p-AM
[Cu/Ce]	*0.2389*	2p-AM
[Si/Na]	*0.2194*	2p-AM



Analysis of trends with Birth-Radius



Casamiquela et al 2021 [Y/Al] relation



Minchev et al 2018

Birth-Radius = f (Age, [Fe/H])

Summary and Conclusion

- Sample
  - 227 field seismic red giant stars
  - volume up to 2kpc
  - Mean fractional uncertainty on Age : 22 %
- Eighteen chemical abundances with low uncertainties: ~0.1 dex from APOGEE
- Several new potential chemical clocks implying Na and Ce ratios
- [Co/Na] and [Cu/Na] insensitive to [Fe/H]
- Dependence on birth radius implicitly taken into account
- Work in progress:
  - Calibration to benchmark samples
  - Comparing precisions of my estimates with previous works on chemical clocks
  - Adoption of RGB stars when calibrating these relations (since the RC age uncertainties are likely underestimated).