SPA - not only clusters

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Introduction

Traditional Archaeology:

- Study of fossilized records
- Understand history of our planet, civilisation and animal evolution

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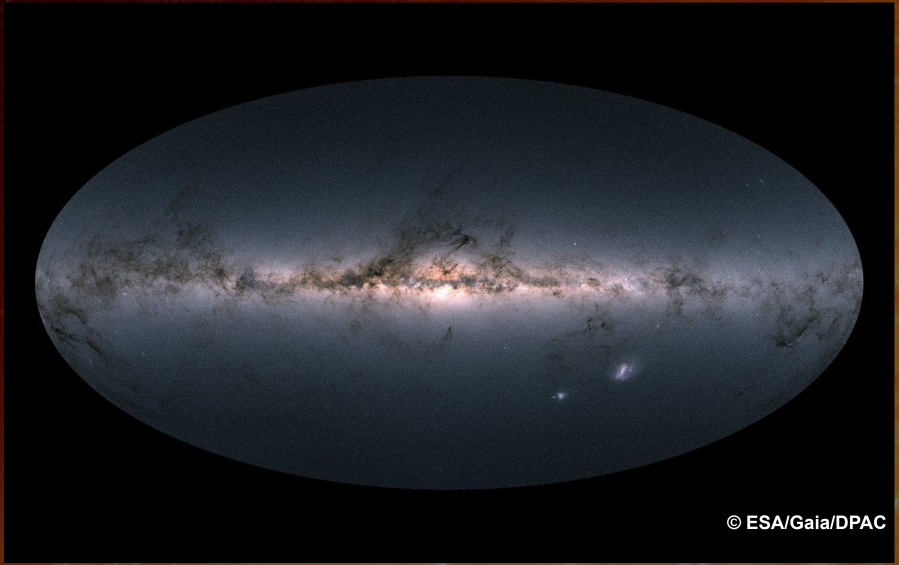
Similarly, in astronomy we have:

Galactic Archaeology:

- Formation and evolution of Milky way
- Stellar properties and chemical compositions



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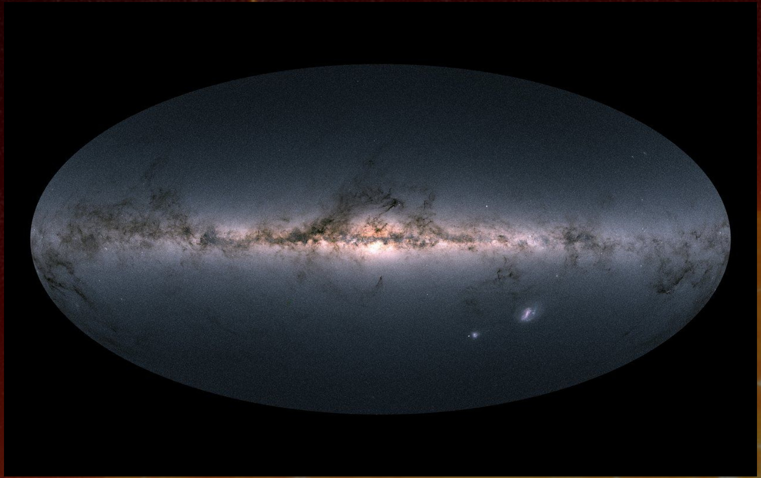
Stellar ages:

- Stellar age - Important parameter
- Usual technique - Isochrone fitting
- Works well for clusters



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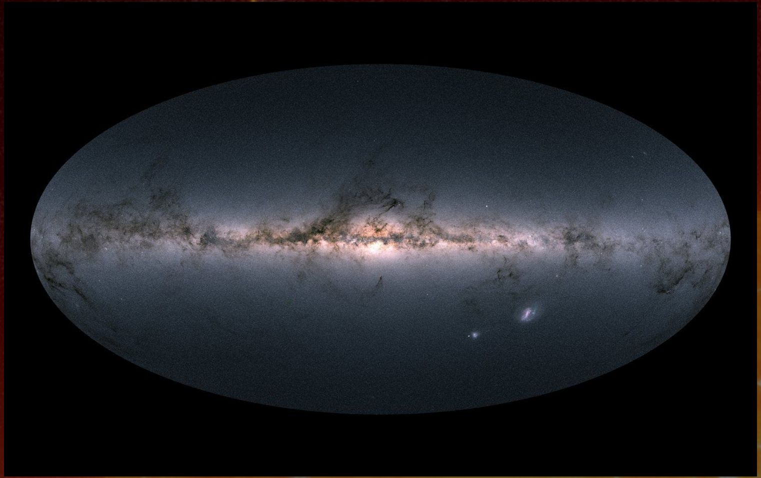
Determination of ages for field stars is not trivial



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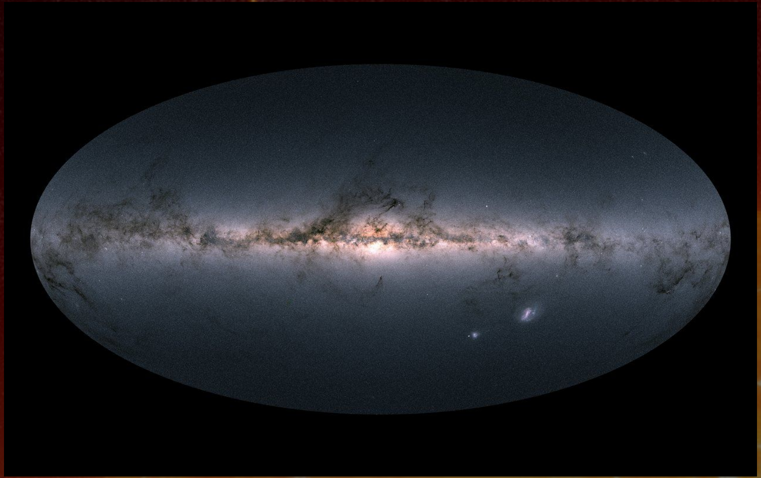
Asteroseismology



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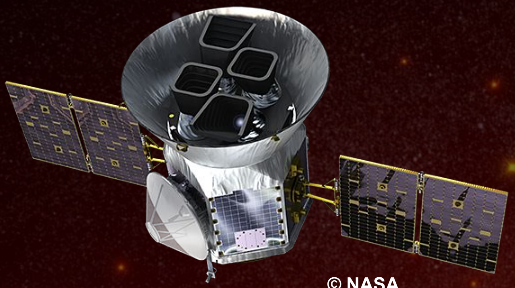
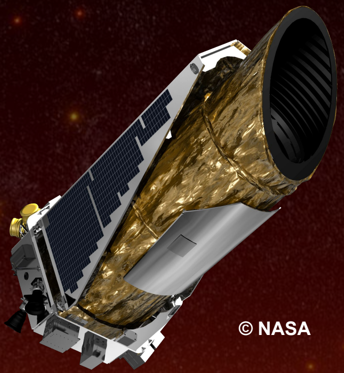
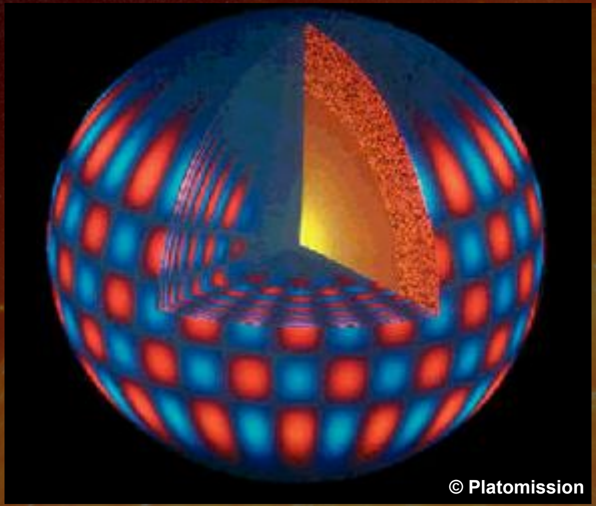
Asteroseismology:

- Study of stellar oscillations
- Large amount of high precision space photometry
  - Kepler
  - TESS
  - Plato (upcoming)







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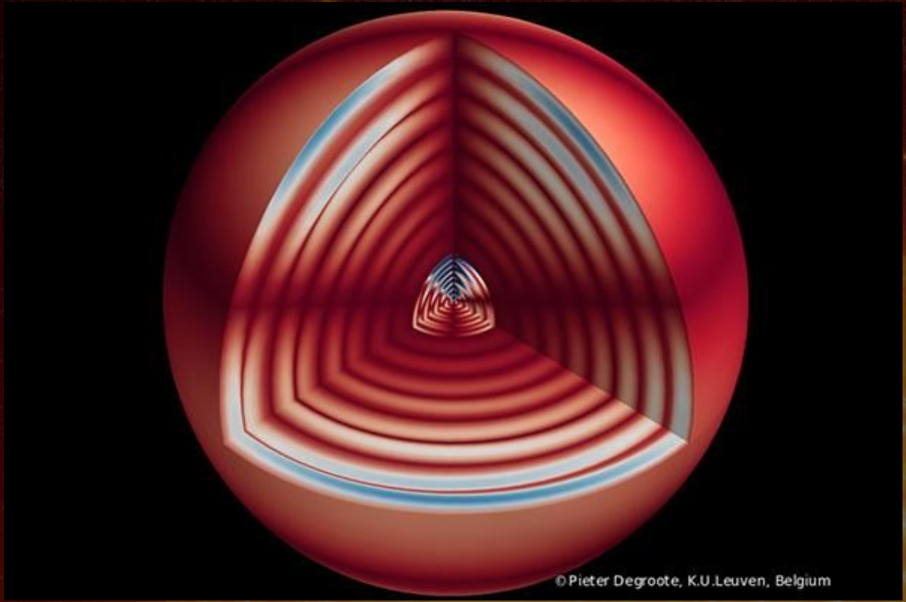
- Observation with models = parameters



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Observables (photometry)

Bellinger (2020)

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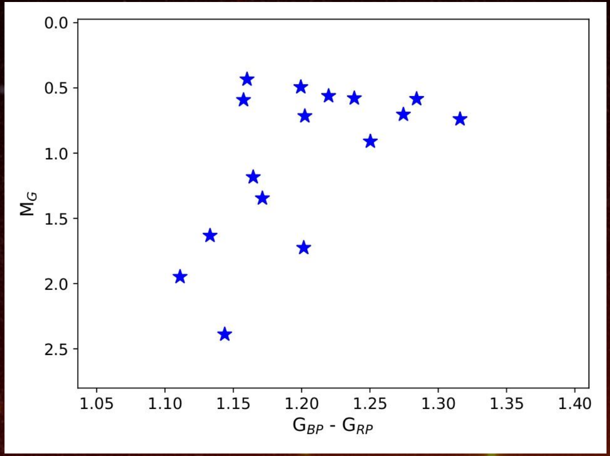
In this work, we combine asteroseismology with high-resolution spectroscopy

Observation

Sample:

- 16 stars (lower RGB and red clump)
- Nearby and within K2 fov
- Field stars (Gaia info and color indices)
- Homogeneous and warm



CMD of the sample

Observation

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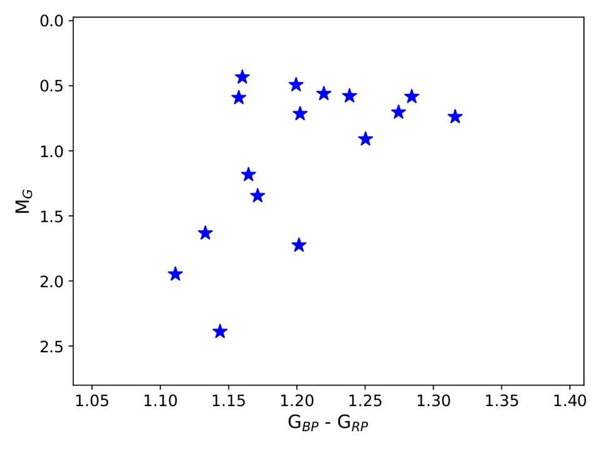
Data:

- Optical and IR spectrum from TNG
- Optical: 3800 - 6900 A and R = 140000
- IR: 9700 - 24000 A and R = 50000
- SNR > 100 (some > 300)



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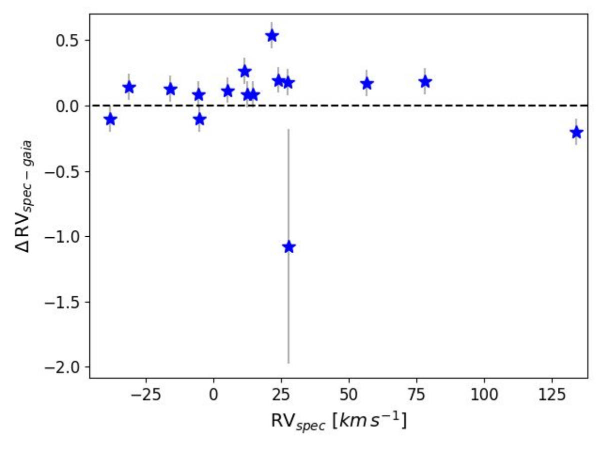
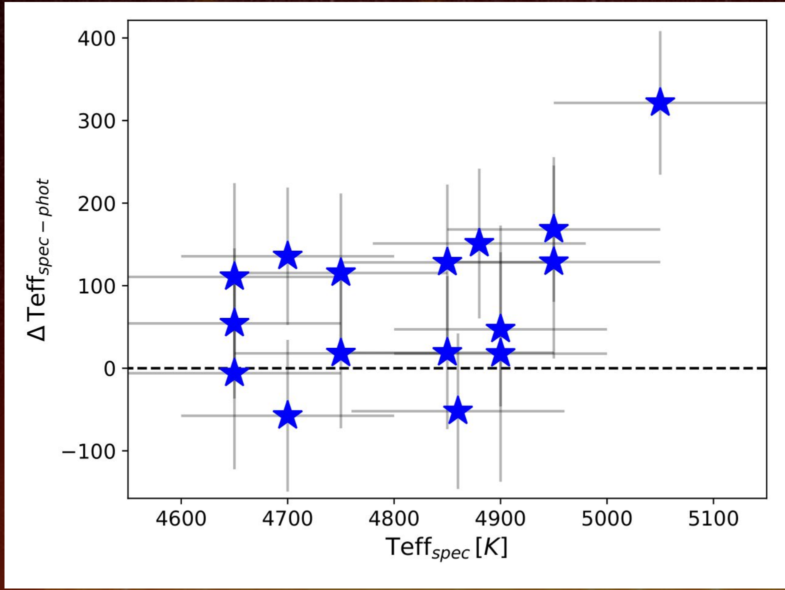


Comparison of radial velocities

Analysis

Stellar parameters:

- Excitation equilibrium of Fe lines
- Initial guesses:
  - Teff : Photometric colors Mucciarelli & Bellazzini (2020)
  - log(g) : Isochrone (0.5 Gyr, -0.1dex) Bressan et al. (2012)
  - [Fe/H] : - 0.1 dex
  - Vmic : 1.5 km/s
- EW from ARES Sousa et al. (2007)



Comparison of effective temperatures

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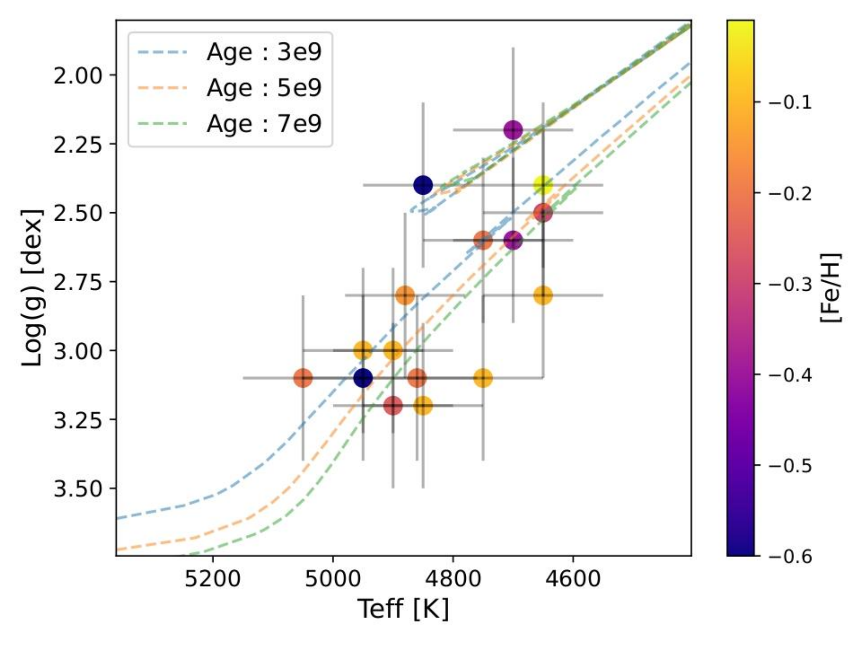
- EW from ARES
- PyMOOGi (abfind driver) Sneden (1973)
- Validation:
  - Arcturus Ramirez & Allende Prieto (2011)
  - Q2 analysis Ramirez et al. (2014)



Kiel diagram

Analysis

Gaia Collaboration (2022)
Hardegree-Ullman et al (2020)
Jonsson et al. (2020)
Ting et al. (2018)

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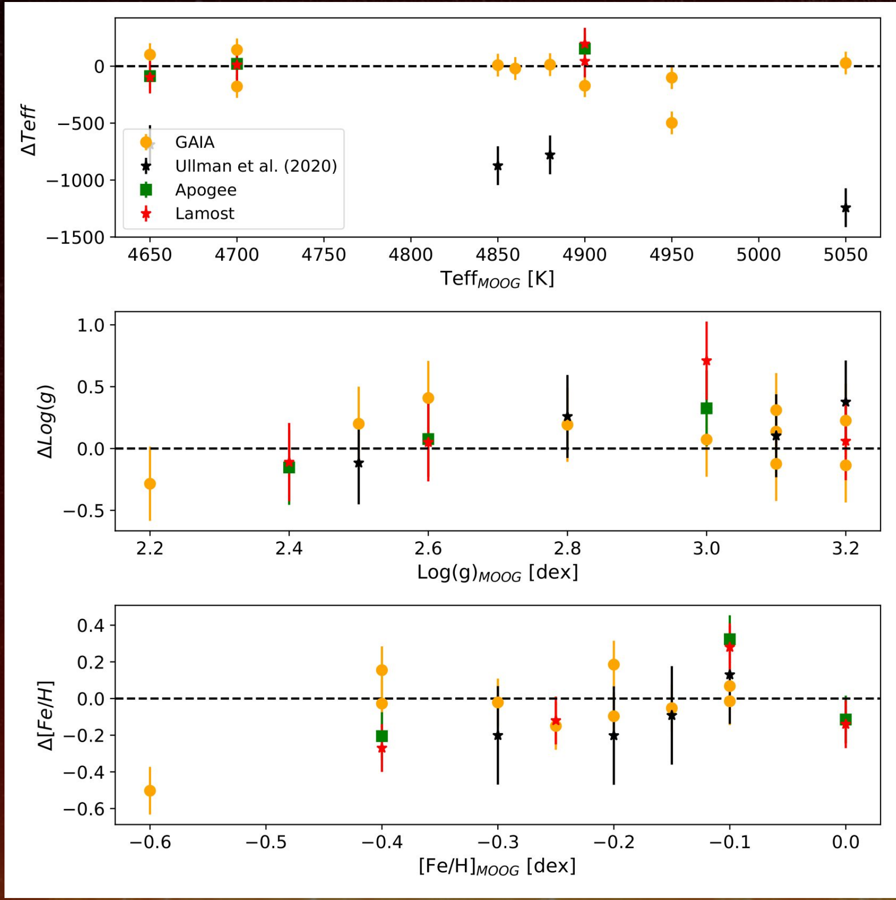
Consistent with literature, Gaia, Apogee and Lamost



Comparison of stellar parameters

Analysis

Abundance analysis:

- Affected by evolution : CNO, Li, and $^{12}C/^{13}C$
- Chemical Mixing : ↑N and ↓C
- Lithium:
  - Extremely sensitive to Teff
  - A(Li) depends on age and mass
  - ↓ as star ascends RGB (mixing)
- α-, Fe-peak elements and Fluorine

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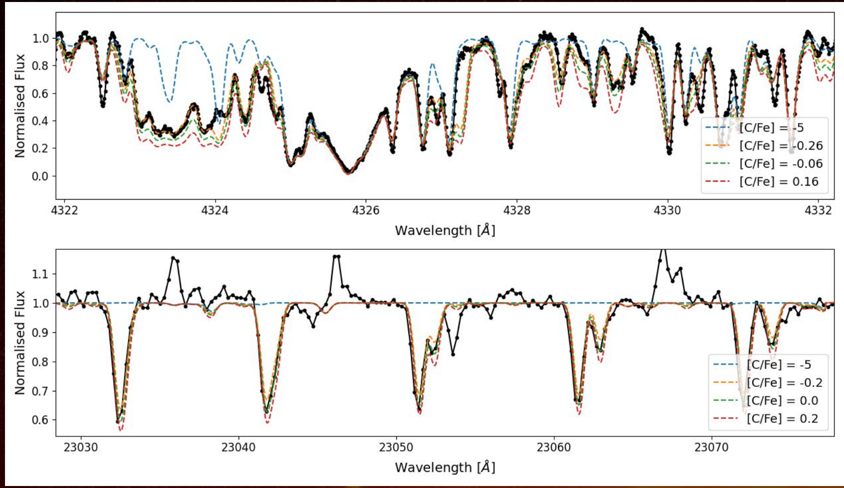
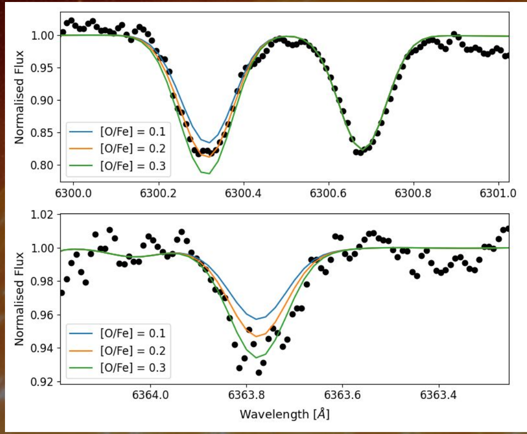
- α-, Fe-peak elements and Fluorine
- PyMOOGi used:
  - EW method (α- and Fe-peak)
  - Synthetic spectrum fitting (CNO, Li, F)



Fitting of CH (top) and CO (bottom) molecular bands



Fitting of O lines

Analysis

Abundance analysis:

- ➔ Carbon, Nitrogen and Oxygen:
  - C from CH (4300 A) and CO (23000 A)
  - N from CN (5100 A and 15000 A)
  - O from forbidden lines (6300 and 6363 A) and OH (23000 A)

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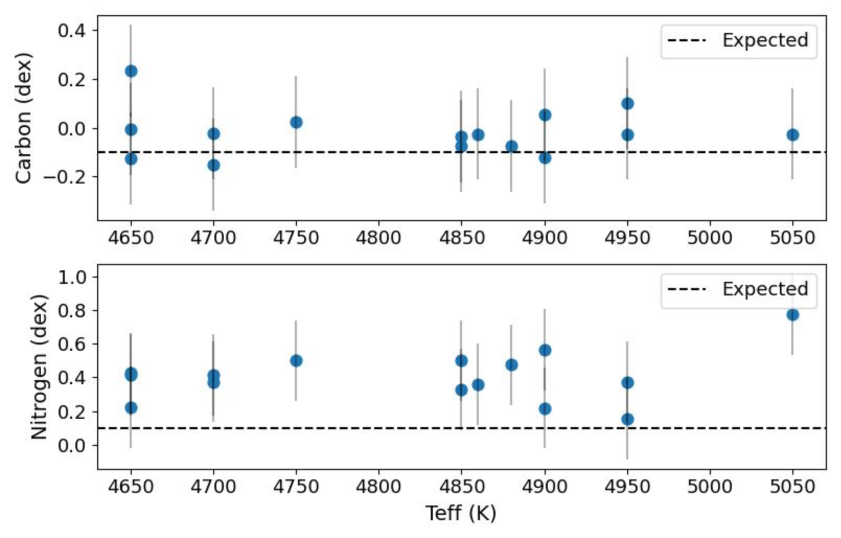
- IR > optical
- C and N are higher

Gratton et al. (2000)



Average abundance of C and N

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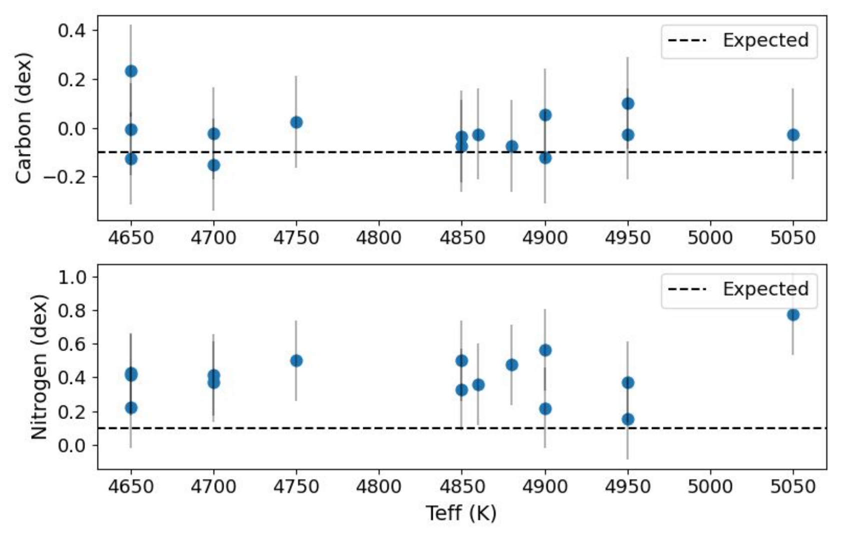
- $^{12}C/^{13}C$ between 4 and 15



Average abundance of C and N

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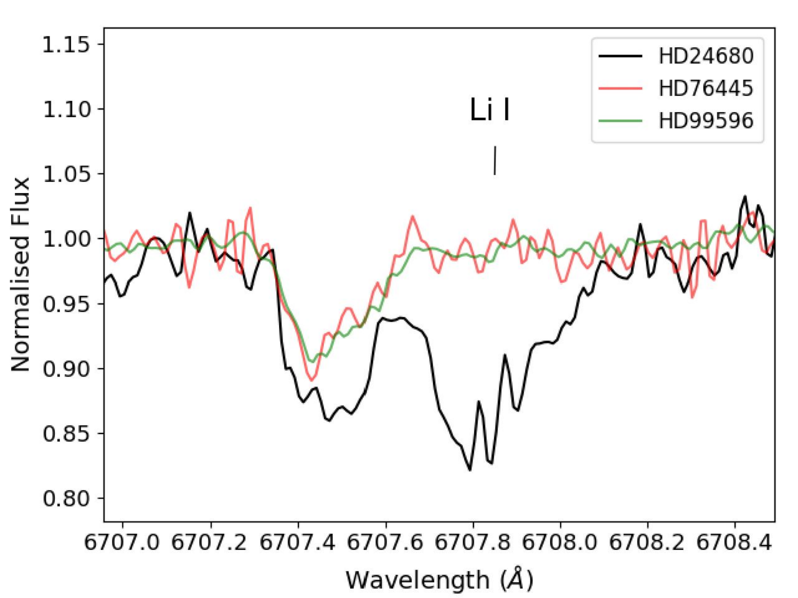
Abundance analysis:

➔ Lithium:

- Stars being RGB - weak lines expected
- 14 out of 16 stars - upper limit on A(Li)
- HD 24680 - Li rich giant (A(Li) = 1.46 + 0.20 dex)



Li I line strength between three stars

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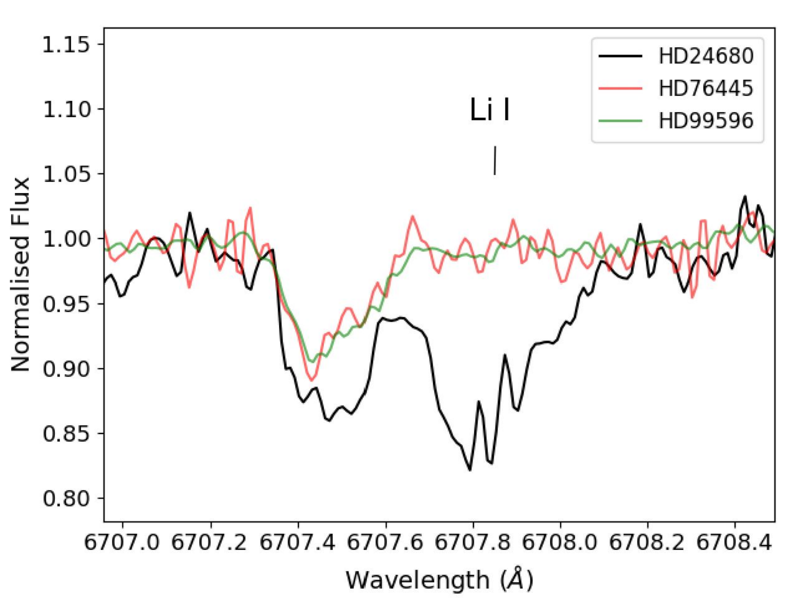
    - High Li and N
    - SB1 system
    - Elevated Y, Zr, La and Na
    - Marginal increment in Eu and Al



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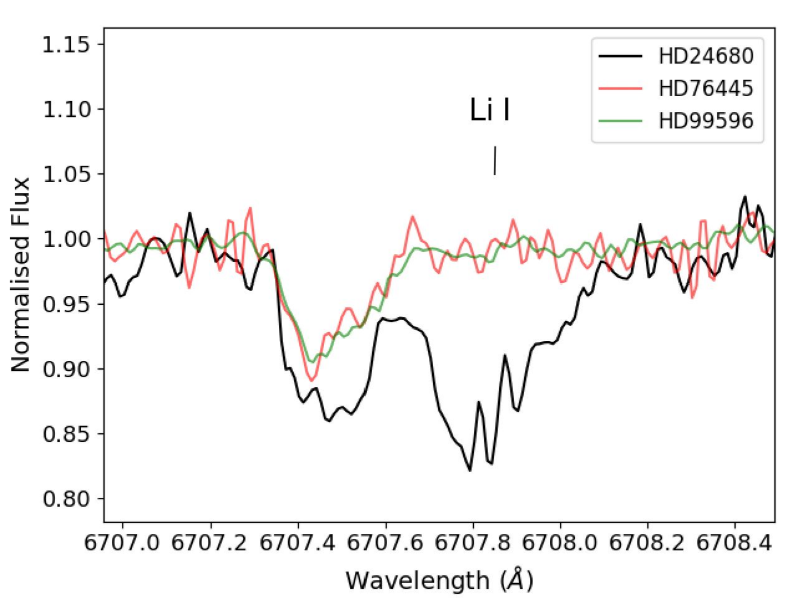


Li I line strength between three stars

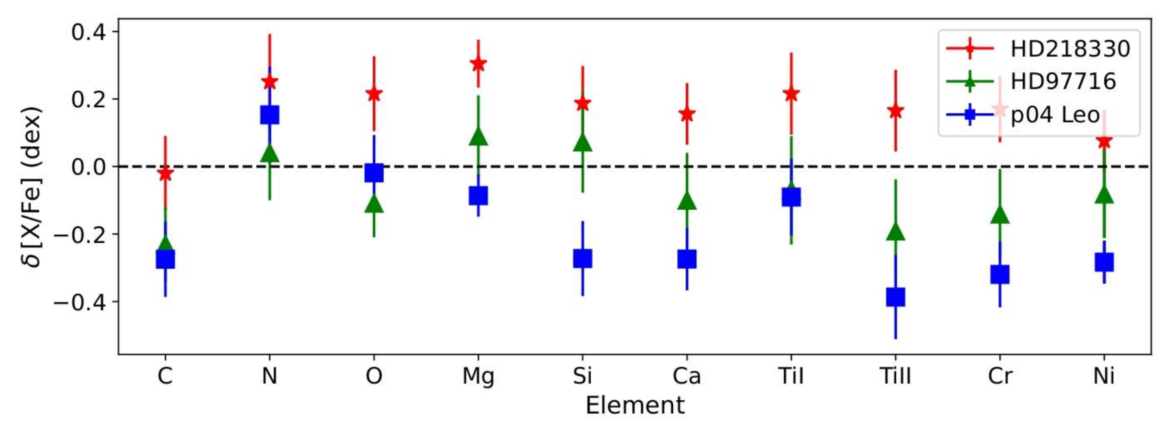
Likely to be a product of mass transfer from low to intermediate mass AGB companion.

Analysis

Abundance analysis:

➔ α- and Fe-peak elements:

- 14 of the 16 stars show super-solar ratios
- Likely to be part of thin disk
- 2 of them show sub-solar ratio
- APOGEE offset - difference in [Fe/H]



Abundances in comparison with Apogee

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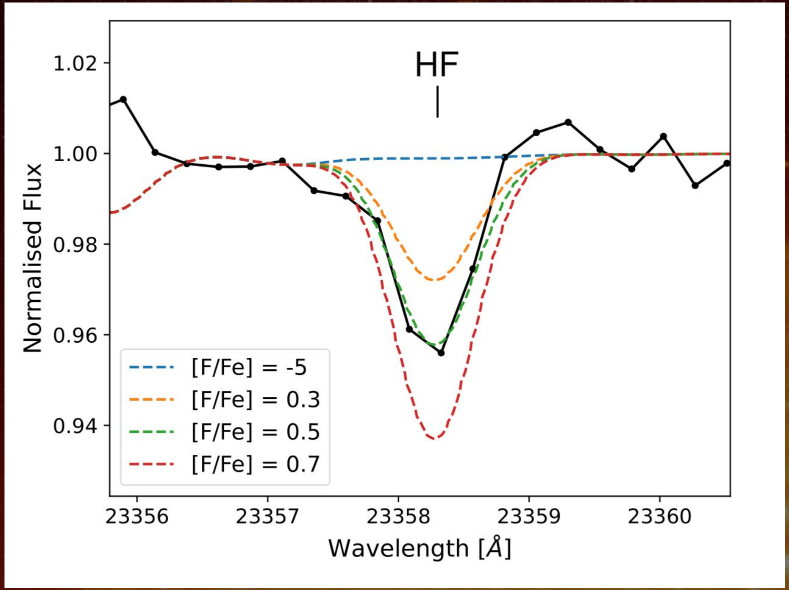
➔ Fluorine:
- Challenging to measure
- Two measurements obtained



Fitting of HF line

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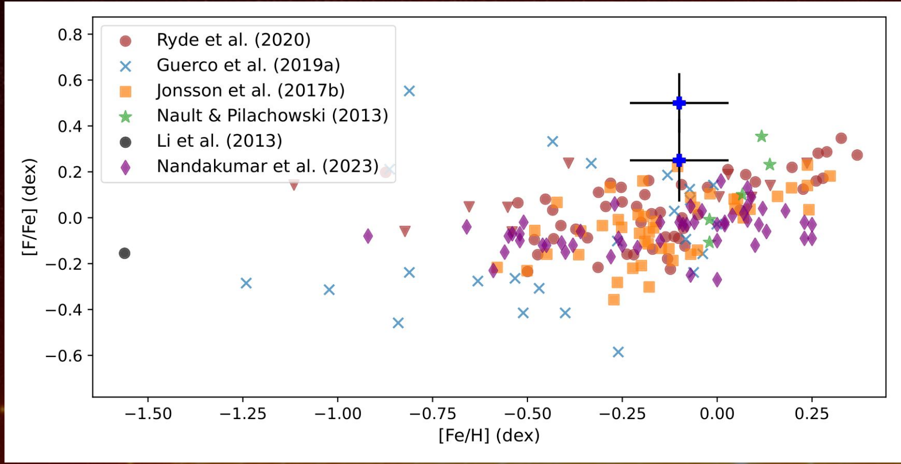

Metallicity vs Fluorine

Analysis

Comparison of ages:

- Asteroseismic parameters from Reyes et. al (2022)
- Asteroseismic ages from scaling relations — Bellinger (2020)
- Theoretical ages also from MIST isochrones — Dotter (2016)
- Ages from chemical clocks - [Y/Mg] and [C/N] — Berger et al. (2022), Casali et al. (2019)

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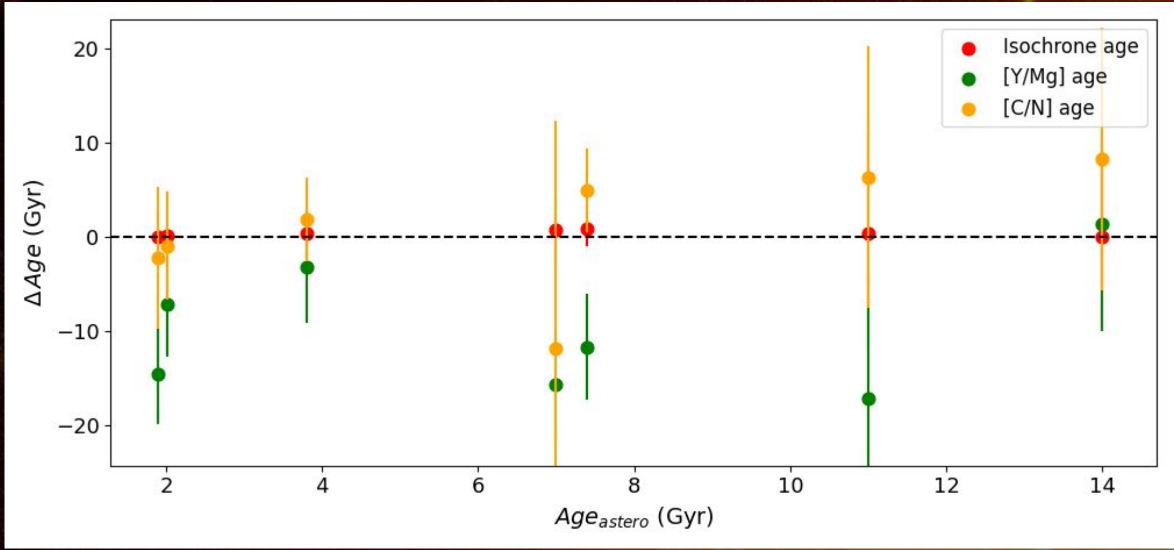

Comparison of four sets of ages

Conclusion:

- Spectroscopic analysis on a sample of 16 nearby RGB stars
- Stellar properties derived confirm the evolutionary stages of the stars
- Abundance analysis - CNO, Li, α- and Fe-peak, F and Y
- Some chemical peculiarities observed
- HD 24680 likely to be a post mass transfer Li rich giant
- Theoretical ages in good agreement with asteroseismic ages but not with chemical clocks of [C/N] and [Y/Mg]