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# The evolution of the Galactic discs revealed by the Gaia APOGEE Kepler giant stars

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## AIMS

We investigate the properties of the double sequences of the Milky Way discs visible in the  $[\alpha/\text{Fe}]$  versus  $[\text{Fe}/\text{H}]$  diagram, which are usually associated to the chemical thin and thick discs at the solar circle. In the framework of Galactic formation and evolution, we discuss the complex relationships between age, metallicity and the vertical components of the space velocities.

## DATA

In this study, we use observational properties coming from:

- **Asteroseismology:** accurate ages deduced from the aster-seismic measurements are available for all stars in our sample. We consider the APOKASC catalog published by *Pinsonneault et al. (2018)* as well as the seismic sample based on *Miglio et al (2021, hereafter M21)*
- **Spectroscopy:** we use the spectroscopic parameters ( $[\text{Fe}/\text{H}]$  et  $[\alpha/\text{Fe}]$ ) from APOKASC which are taken from APOGEE DR14.
- **Astrometry and Photometry:** the Galactic velocities and coordinates have been computed using the StarHorse distances computed by *Queiroz et al (2020)* and following the same method developed by *Gaia Collaboration et al. (2018b)*.

## Forward modelling using Besançon Galaxy Model

Galactic stellar populations synthesis models can be used to provide a forward modelling allows to make mock catalogue simulations where selection bias on observable parameters can be accurately reproduced, allowing to identify possible bias in inferred distributions. We use the comprehensive description of Galactic stellar populations provided by BGM (e.g., *Lagarde et al. 2017*) to produce a realistic data simulation. More details on the model description in *Lagarde et al. (2021)*

The following selection are applied on both the BGM-simulation and the observations.

### APOKASC sample

- $7.4 \leq H < 10.8$
- $T_{\text{eff}} < 5300 \text{ K}$
- $0.4 < \Delta v < 20 \mu\text{Hz}$  and  $2 < v_{\text{max}} < 250 \mu\text{Hz}$
- Only single stars are selected.

### M21 sample

- APOKASC selection +
- The mass of clump stars,  $M_{\text{Clump}} \geq 1.2 M_{\odot}$
- The radius of RGB stars,  $R_{\text{RGB}} < 11 R_{\odot}$

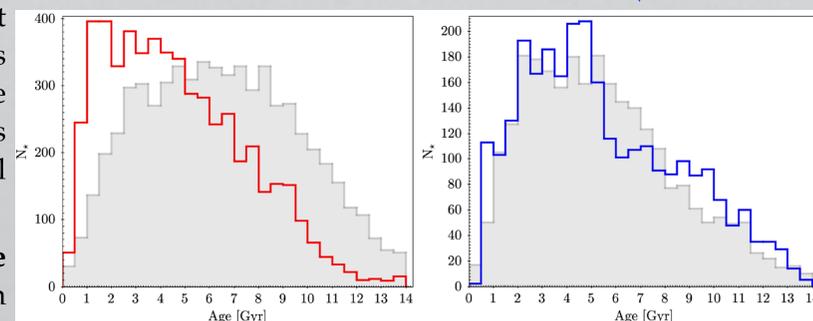


Fig.1: The age distribution from the APOKASC catalogue (left panel) and the M21 catalogue (right panel) compared to the corresponding BGM simulation (grey shaded regions).

★ **APOKASC sample** shows a peak around 1-2 Gyr that is not seen in the **M21** age distribution, as well as not simulated by the BGM (Fig.1). => We suggest that this peak is created by the strong dependency of the age determination for red clump stars on the physics included in stellar models (e.g., hydrodynamical processes, mass loss or accretion, binarity).

★ We find a good agreement between the age distribution of **M21** and the BGM simulation within small statistical fluctuations.

★ A small hint for SFR enhancement between 2-5.5 Gyr in both samples remains to be confirmed with larger seismic samples.

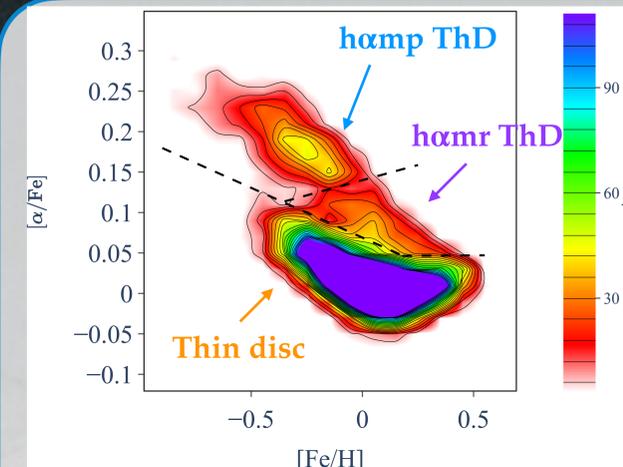


Fig.2: Distribution of stars in the  $[\alpha/\text{Fe}]$  vs.  $[\text{Fe}/\text{H}]$  plane. The dashed lines show the limits used to separate the three disc populations: **hamp**, **hamr** thick discs and thin disc

★ Using the density distribution in the  $[\alpha/\text{Fe}]$  vs.  $[\text{Fe}/\text{H}]$  plane (Fig.1), we separate our sample into 3 stellar populations: **the thin disc**, **high- $\alpha$  metal-poor thick disc** (**hamp** ThD), and **high- $\alpha$  metal-rich thick disc** (**hamr** ThD).

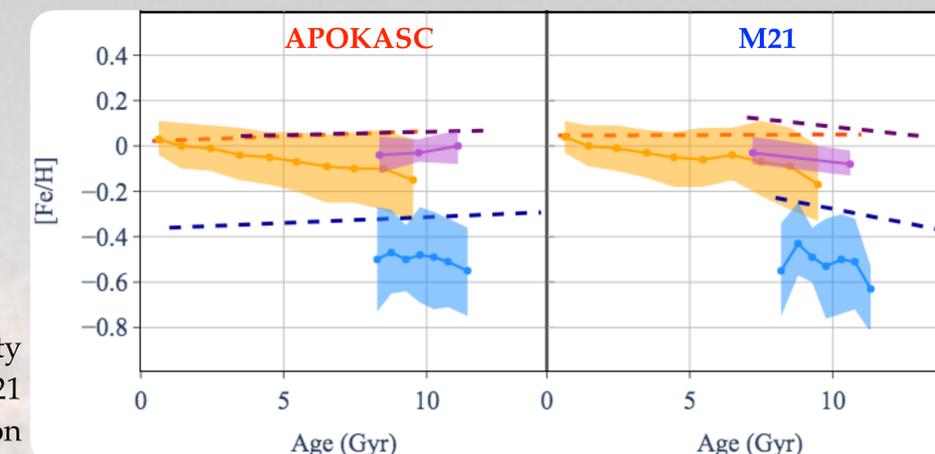


Fig.3:  $[\text{Fe}/\text{H}]$  as a function of stellar age in our sample taking into account stellar ages from APOKASC and M21. BGM predictions corresponding to observations and represented by solid lines. The  $\pm 1\sigma$  error bars are shown with shadow regions. Linear fits done for observations are plotted with dashed lines.

★ **Thin disc:** both samples show a flat age-metallicity relation

★ **hamr thick disc:** No correlation between the stellar age and metallicity

★ **hamp thick disc:** While for the age-metallicity relation is flat for the APOKASC sample, the M21 sample shows a **negative gradient**. The comparison with the BGM simulations cannot explain these differences. This suggests that **important processes** such as radial migration and accretion due to mergers do play an important role in shaping our Galaxy.

## Galactic disc formation

**Different behaviours of the dispersion of the vertical velocity with age in the BGM simulations and in the observations (Fig.4).**

The simple assumptions in the model do not explain the inversion in the  $\sigma_z$  vs age for the **hamp** thick disc around 8 Gyr that we observe.

These comparisons underlined the need for a **more complex chemo-dynamical scheme** to explain the data, including probably **mergers and radial migration effects** as discussed previously by *Minchev et al. (2014a)*, *Belokurov et al. (2020)* and *Miglio et al. (2021)*.

Fig. 4: The dispersion of the vertical velocity as a function of stellar ages from BGM (left panel) and from observations using the APOKASC sample (right panel). The whole thick disc (**hamp** + **hamr** thick discs) is also shown with the green dashed line.

