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Can we really use chemical properties of red-giant stars as age indicators?

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Abstract. The cornerstone mission of the European Space Agency, Gaia, together with forthcoming complementary surveys (CoRoT, Kepler, K2, APOGEE and Gaia-ESO), will revolutionize our understanding of the formation and history of our Galaxy, providing accurate stellar masses, radii, ages, distances, as well as chemical properties for a very large sample of stars across different Galactic stellar populations. Using improved population synthesis approach and new stellar evolution models we attempt to evaluate the possibility to derive ages of clump stars from their chemical properties. A new version of the Besançon Galaxy models (BGM) is used in which new stellar evolutionary tracks are computed from the stellar evolution code STAREVOL. The effects of mixing on chemical composition of the stellar photosphere has a significant impact on the determined stellar age from the observed [C/N] ratio. We clearly show that transport processes occurring in red-giant stars should be taken into account in the determination of ages for future Galactic archaeology studies.

Keywords. stars: abundances, stars: evolution, instabilities, Galaxy: stellar content

1. Introduction

Recent studies (e.g. Martig *et al.* 2015, 2016, Masseron & Gilmore (2015)) have proposed to use [C/N] to determine stellar ages of red-giant stars. However, these studies do not take into account the effects of mixing occurring in the stellar interiors, stellar input physics, and possible changes of these relations at different evolutionary stages. Considering standard stellar evolution models only, [C/N] seems to be a good proxy to determine stellar ages along the red giant branch and during the He-burning phase. Although the [C/N] ratio at the stellar surface is directly related to the stellar properties (mass or metallicity), we point out the difficulty in determining an accurate stellar age from these properties. As discussed by Lebreton *et al.* (2014), stellar evolution models are still affected by several uncertainties (e.g. [Fe/H], α-enhancement, solar mixture, initial He-abundances, transport processes) which can significantly change the determination of stellar ages from the chemical properties of stars. We propose here to show how thermohaline mixing occurring in red-giant stars can affect this determination.

2. Models

The Besançon Galaxy Model (BGM, e.g. Robin *et al.* (2003)) is a model using the population synthesis approach that simulates observations with errors and biases. We use a new version of the BGM (Lagarde *et al.* (2017)), including a new grid of stellar evolution models computed with the code STAREVOL (e.g. Lagarde *et al.* (2012)). This new stellar grid provides the global properties (e.g. surface gravity, effective temperature), chemical abundances (for 54 stable and unstable species), and seismic diagnostics ($\Delta\nu$,

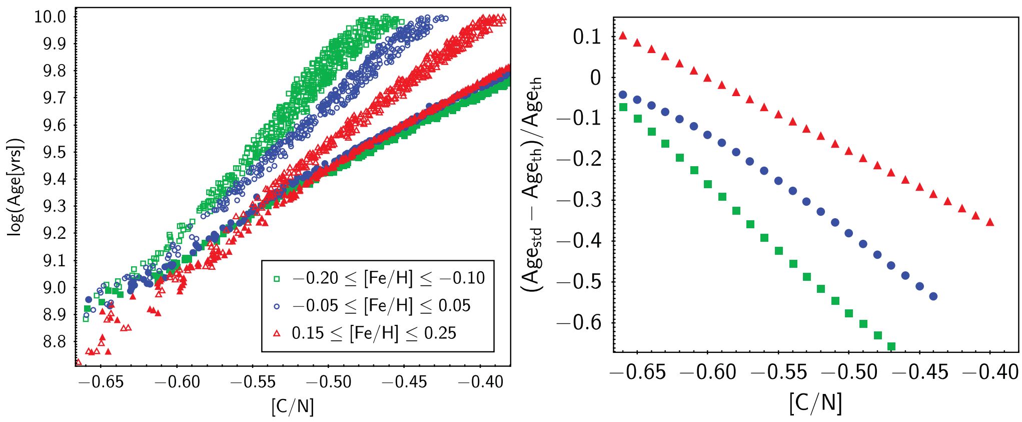

Figure 1. *Left panel:* Stellar ages of clump stars deduced from standard (open symbols) and models including thermohaline mixing (fill symbols) as a function of [C/N] for a synthetic thin disc computed with the BGM. *Right panel:* Comparison between the two age-determinations. Stars are divided in three metallicity bins: 0.15⩽[Fe/H]⩽0.25 (triangles), -0.05⩽[Fe/H]⩽0.05 (circles), -0.20⩽[Fe/H]⩽-0.10 (squares).

ν_{max}, $\Delta\Pi_{(\ell=1)}$). These models take into account the effects of thermohaline instability during the red-giant branch (e.g. Charbonnel & Lagarde (2010)).

3. Determination of age using [C/N] ratio

As discussed in the literature (e.g. Lagarde *et al.* (2012), Henkel *et al.* (2017)), thermohaline instability changes the surface abundances in C and N after the bump on the red giant branch, implying a large dispersion of [C/N] with age for upper-RGB stars (see Fig. 5 of Lagarde *et al.* (2017)). Figure 1 (left panel) shows [C/N]-dependency with stellar ages, with and without thermohaline instability (fill and open symbols) for thin-disc clump stars. Contrarily to previously derived relationships published in literature, ours take into account the natural spread in mass and metallicity of the underlying population, and allows for the inclusion of selection biases in the surveys. However, these relations are directly related to the physics included in stellar evolution models. The relative difference between stellar ages derived from standard models and from models taking into account thermohaline instability can be up to ∼50% depending on the stellar metallicity (see right panel of Fig1).

We clearly show that transport processes occurring in red-giant stars should be taken into account in the determination of ages for future Galactic archaeology studies.

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