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Abundance ratios & ages of stellar populations in HARPS-GTO sample

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Abstract. In this work we present chemical abundances of heavy elements (Z>28) for a homogeneous sample of 1059 stars from HARPS planet search program. We also derive ages using parallaxes from Hipparcos and Gaia DR1 to compare the results. We study the [X/Fe] ratios for different populations and compare them with models of Galactic chemical evolution. We find that thick disk stars are chemically disjunt for Zn adn Eu. Moreover, the high-alpha metal-rich population presents an interesting behaviour, with clear overabundances of Cu and Zn and lower abundances of Y and Ba with respect to thin disk stars. Several abundance ratios present a significant correlation with age for chemically separated thin disk stars (regardless of their metallicity) but thick disk stars do not present that behaviour. Moreover, at supersolar metallicities the trends with age tend to be weaker for several elements.

Keywords. stars: abundances - stars: fundamental parameters - Galaxy: evolution - Galaxy: disk - solar neighborhood

1. Introduction

In the era of large spectroscopic surveys such as APOGEE, Gaia-ESO Survey or RAVE, among others, the contribution of smaller samples with high-resolution and high quality spectra is of great importance to understand the Galactic Chemical Evolution (GCE). In this work we have derived abundances for Cu, Zn, Sr, Y, Zr, Ba, Ce, Nd and Eu (Delgado Mena *et al.* 2017) for 1111 stars within the volume-limited HARPS-GTO planet search sample in order to complement our previous works for light elements (Delgado Mena *et al.* 2014, Delgado Mena *et al.* 2015, Suárez Andrés *et al.* 2016, Bertrán de Lis *et al.* 2015), α- elements and Fe-peak elements (Adibekyan *et al.* 2012). The main purpose of this work is to evaluate the GCE evolution of those heavier elements and the dependence on stellar ages of different abundance ratios.

2. Stellar ages

We derive the masses, radii and ages with the PARAM v1.3 tool† using the PARSEC isochrones (Bressan *et al.* 2012) with our values for Teff and [Fe/H], the V magnitudes from the main Hipparcos catalogue (Perryman *et al.* 1997)) and the parallaxes from

† http://stev.oapd.inaf.it/cgi-bin/param

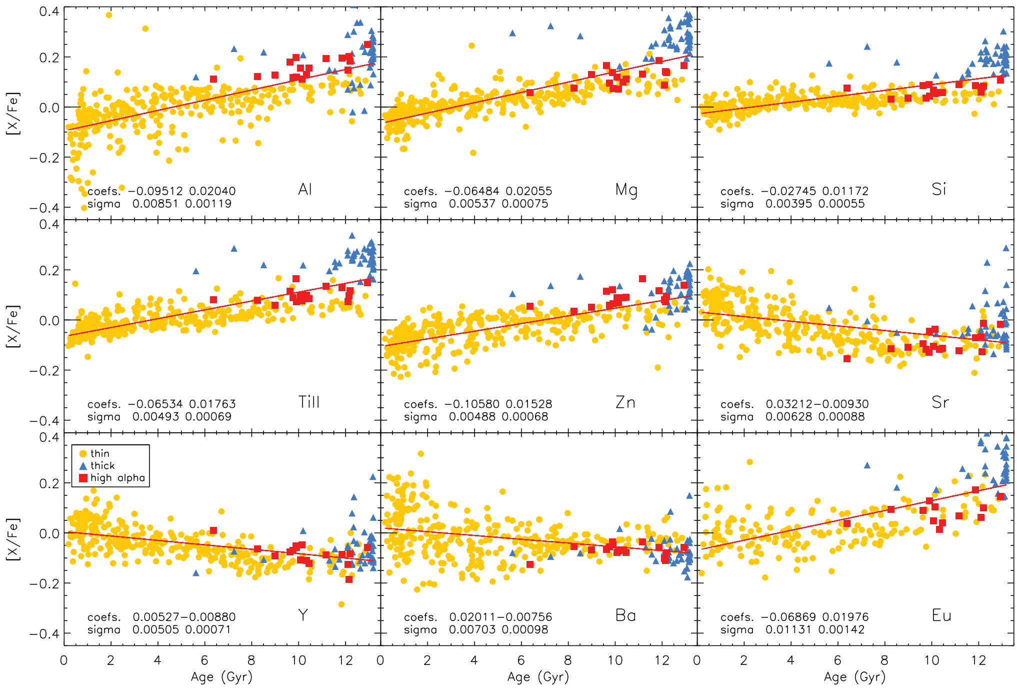

Figure 1. General [X/Fe] ratios as a function of age for the reduced sample with reliable ages. Thin disk stars, thick disk stars and *hαmr* are depicted with dots. triangles and squares, respectively. The linear fit to all the stars just serves as eye guiding.

the Hipparcos new reduction (van Leeuwen 2007) or from the first release (DR1) of Gaia (Lindegren *et al.* 2016). We note that we added a systematic error of 0.3 mas to the formal error of the Gaia DR1 parallaxes as recommended by the Gaia collaboration. Meanwhile Hipparcos provides parallaxes for 1051 out of the 1059 stars within our sample, only 923 stars have parallaxes in GAIA DR1. Moreover, there are significant differences in many cases, leading to non-negligible differences in age. In order to have a sample with ages as reliable as possible we decided to select the Hipparcos ages with a difference less than 1 Gyr with respect to the ages derived with GAIA parallaxes and with an error in age lower than 2 Gyr. This final sample is composed by 377 stars belonging to the thin disk, thick disk and high-α metal-rich stars (hereafter *hαmr*, a population with high α abundances at [Fe/H] > -0.2 dex discovered by Adibekyan *et al.* 2011).

3. Abundance ratios vs age

In Fig. 1 we can see how several elements depend on age. By combining elements that increase and decrease with age, respectively, it is possible to have steeper and more constrained trends. For example, [Mg/Fe] shows a tight increasing trend with age, meanwhile [Eu/Fe], [Zn/Fe] and [Al/Fe] also show this dependency though with more dispersion. This trend is expected since these elements are mainly formed by massive stars which started to contribute to the Galaxy chemical enrichment earlier than the lower mass stars responsible for Fe production. On the other hand, the light-*s* process elements Y and Sr show the most clear decreasing trends with age. These elements are formed by low-mass AGB stars so we can expect them to increase with time (for younger stars) due to the increasing and delayed contribution of low-mass stars as the Galaxy evolves. In Figs. 2 and 3 we show different combinations of previously mentioned elements at different

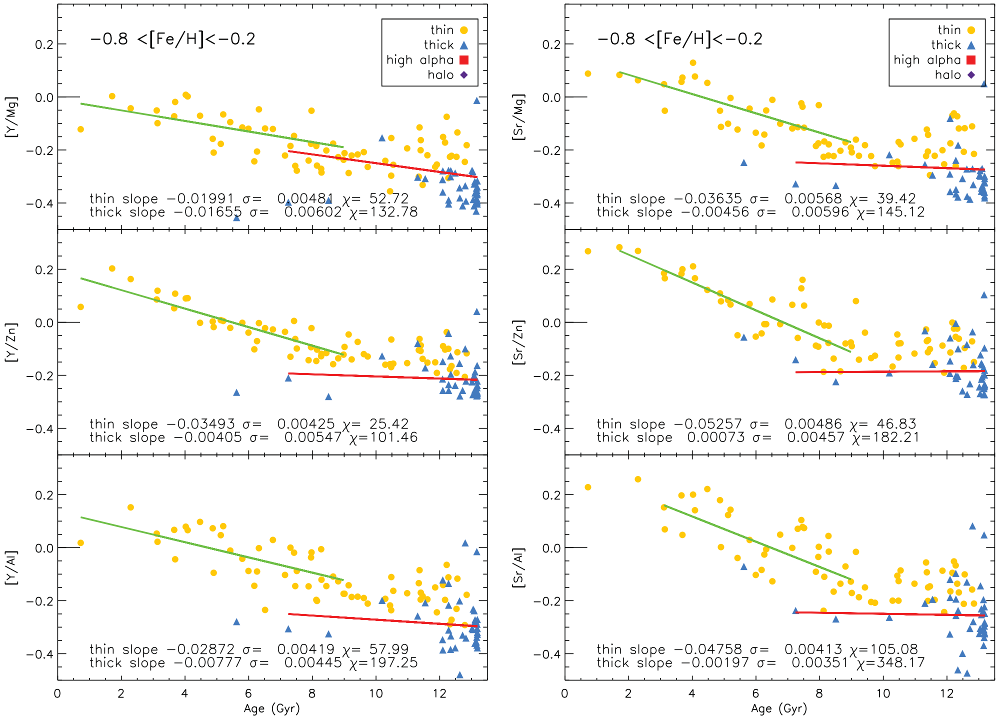

Figure 2. [Y/Mg],[Y/Zn],[Y/Al] and [Sr/Mg],[Sr/Zn],[Sr/Al] for -0.8<[Fe/H]<-0.2. Symbols as in Fig 1.

metallicity regions. Previous works have explored and confirmed the tight correlation of these abundance ratios with age (e.g. da Silva *et al.* 2012), Nissen 2015, Spina *et al.* 2016) but only using solar twins or solar analogues. However, Feltzing *et al.* (2017) noted that [Y/Mg] clock is not valid at [Fe/H] $<$ -0.5 dex. In our sample we find that still at [Fe/H] $<$ -0.5 dex the different abundance ratios show a correlation with age (steeper for [Sr/X] than for [Y/X]) but this is only valid for thin disk stars. We note however that our sample of thick disk stars with reliable ages is quite small. It is also clear that the trends become flat at ages $\gtrsim 8$ Gyr. On the other hand, at higher metallicities, in the bin -0.2 $<$ [Fe/H] $<$ 0.2 dex, the abundance ratios of Y and Sr (with respect to Mg, Zn and Al) present similar slopes. Nevertheless, we remark that meanwhile [Sr/Fe] presents a constant correlation with age at different metallicities, [Y/Fe] becomes flatter as [Fe/H] increases. Moreover, we can observe that thin disk stars present mostly no dependence on age for ages $\gtrsim 8$ Gyr but *hαmr* stars show a continuous dependence in the full age range for [Y/X] ratios. The improvement of parallaxes from GAIA DR2 will help to determine more precise ages for our stars increasing the sample size and allowing us to better understand the behaviour of the abundance-age trends for different populations in the Galaxy.

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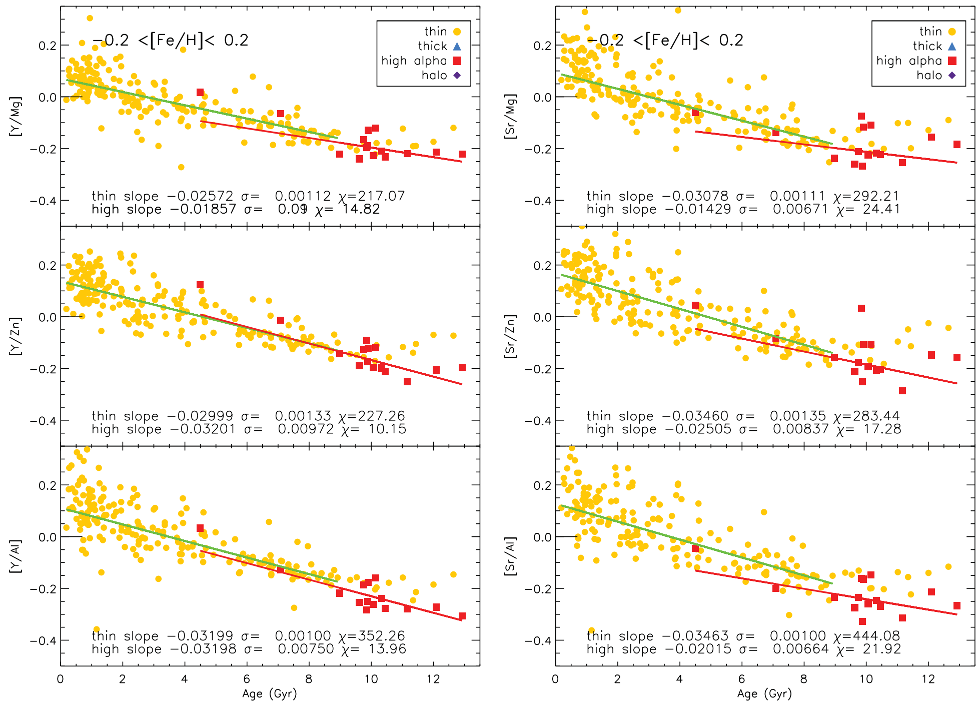

Figure 3. [Y/Mg],[Y/Zn],[Y/Al] and [Sr/Mg],[Sr/Zn],[Sr/Al] for -0.2<[Fe/H]<0.2. Symbols as in Fig 1.

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