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HIGH PRECISION ABUNDANCES OF FGK STARS WITH (NEO)NARVAL

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Abstract. Chemical abundances of low-mass FGK stars probe the physical processes which drive evolution in the Milky Way. Chemical elements that remain unaltered in the stellar atmosphere through the lifetime of a star are those useful for these type of studies because we assume that the chemical information of the star's birthplace is recorded in its photosphere. Open Clusters are useful for this purpose because they provide ages and distances with good precision. (Neo)NARVAL is among the best instruments to obtain such abundances because of its high resolution and large wavelength coverage.

Keywords: stars: abundances, techniques: spectroscopic, open clusters and associations: general

1 Introduction

To advance towards a broader understanding of the chemical evolution of the Milky Way, detailed element abundances from high-quality spectroscopic data and precise ages are needed. Well studied open clusters (OCs) are frequently been used for this purpose because their age and distances are very precise compared to field stars. Our aim in the latest years has been to obtain detailed and highly precise chemistry of a large sample of open clusters Casamiquela et al. (2017, 2019, 2020). We present here two results which came out of this effort. In Sect. 3 we analyse the chemical homogeneity of three clusters in our sample. OCs have long been thought to be chemically homogeneous(e.g. Friel et al. 2002) as a result of the hypothesis that the cloud from which the cluster was formed was uniformly mixed. Thanks to the good precision in the abundances, our results show some chemical inhomogeneities at the level of 0.02-0.03 dex. In Sect. 4 we investigate the dependency of different abundance ratios with cluster age. The fact that not all chemical elements are produced in the same way or in the same timescale across cosmic times implies that some combinations of elements may have strong dependences on stellar age (see e.g. Nissen 2015; Delgado Mena et al. 2019; Jofré et al. 2020). These have been dubbed as chemical clocks, and can be informative for chemical evolution models to help to understand the variables that control it, like supernovae yields, the star formation rate, or feedback mechanisms.

2 Sample and method

We gathered high signal-to-noise spectra of more than 300 stars in 47 different clusters, from archival data and own observations. Our final sample contains data from the following instruments: UVES@VLT, FEROS@2.2mMPG, HARPS@3.6mESO, HARPS-N@TNG, FIES@NOT, ESPaDOnS@CFHT, ELODIE@1.93mOHP, NARVAL@TBL (several observing programs in 2018 and 2019), and recently in NeoNARVAL@TBL during semesters 2020A and 2020B.

We use the tool iSpec (Blanco-Cuaresma et al. 2014; Blanco-Cuaresma 2019) to perform a spectroscopic analysis to the obtained spectra, normalised and previously homogenised in terms of wavelength coverage and spectral resolution. An example of a NARVAL spectrum can be found inf Fig. 1. Our pipeline uses iSpec to derive precise radial velocities, and also stellar atmospheric parameters and individual line abundances of 25 chemical species using spectral synthesis fitting. Finally, we perform a strictly line-by-line differential analysis of twin stars, which allows to reach a high precision in abundances typically below 0.02 dex. Details of the pipeline are explained in detail in Casamiquela et al. (2020).

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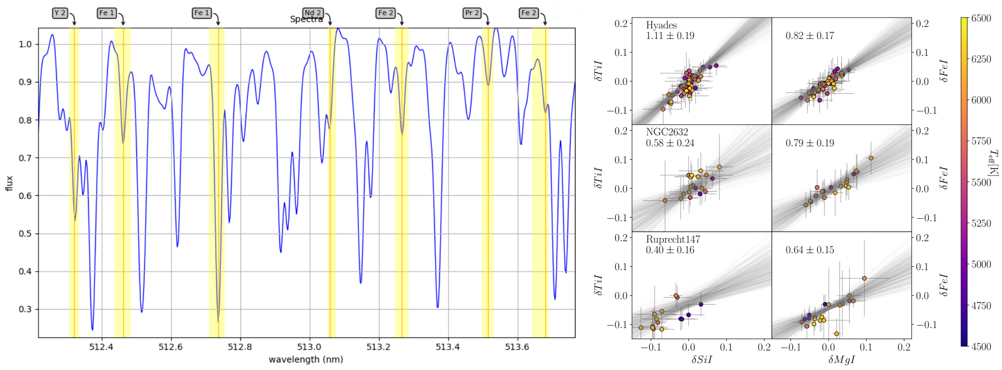

Fig. 1. Left: example of a normalised spectrum from NARVAL, where some of the used lines for the abundance computations are highlighted. Right: abundances of Ti versus Si, and Fe versus Mg for stars in the Hyades, Praesepe (NGC 2632) and Ruprecht 147.

3 Chemical homogeneity

We investigated the level of chemical homogeneity of three of our clusters (the Hyades, Praesepe and Ruprecht 147), the ones for which we have the largest number of stars. We obtain large amplitudes in all chemical species, compared with our uncertainties, and dispersions of the order 0.02-0.03 dex in the Hyades. Moreover, very significant correlations are found for almost all pairs of elements with low dispersions (see an example in Fig. 1). This is a sign of internal chemical inhomogeneity (Casamiquela et al. 2020). Our analysis confirms the previous study by Liu et al. (2016) for 16 stars in the Hyades, including now three times more stars, and two additional clusters.

4 Chemical clocks

Using the sample of clusters inside a 1 kpc bubble around the Sun, we find 19 different combinations of elements $[X_1/X_2]$ that have strong correlations with age in our metallicity range($-0.2 < [Fe/H] < 0.2$). Particularly we find that all combinations involve elements produced via the *s*-process (Casamiquela et al. 2021). We find that Y, Zr and Ba (which have a large contribution to the *s*-process) always produce correlations when combined with α-elements. In Casamiquela et al. (2021) we investigate the validity of the abundance-age relations outside the local bubble. We see that a larger scatter introduced when using the full sample of clusters (half of them farther than 1 kpc). We interpret this as a hint that the chemical clocks may not be as universal as thought, but instead they probably have a dependence on the spatial volume analyzed.

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