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Chemical and dynamical analysis of Open Clusters from OCCASO data. The case of NGC 6705.

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Abstract. The OCCASO survey targets intermediate-age and old OCs visible from the Northern hemisphere. OCCASO provides homogeneous radial velocities, atmospheric parameters, and individual abundances from high-resolution spectroscopy (R>65,000) of Red Clump stars. We present a first insight into the homogeneously analyzed chemical abundances obtained fror 18 Northern OCs from OCCASO data. Our sample includes an interesting inner disk OC, NGC 6705, analyzed in the literature with inconclusive results about its α abundances. From OCCASO data this is an α-enhanced OC from the analysis of Si, Ca, Ti, Mg and O, despite its young age.

1. Introduction

Enormous efforts have been invested to unravel the Galaxy's chemodynamical history. One of the most used observables to constrain the Galaxy evolution models is the variation of chemical abundances across the Galactic disk. In comparison to other tracers, OCs provide the most reliable ages and distances from photometry (see Friel 1995), and they cover a wide range of ages and Galactocentric radius. These properties make OCs valuable objects to study the chemical profiles of the Galactic disk and their evolution with time.

In the last years several large ground-based high-resolution spectroscopic surveys are targeting OCs to provide homogeneous samples with the purpose to study the Milky Way disk from the chemical point of view. The Gaia-ESO Survey (GES, Gilmore *et al.* 2012) in the Southern hemisphere which provides R∼20,000 and R∼47,000; APOGEE (Frinchaboy *et al.* 2013) in the Northern hemisphere R∼22,500 in the infrared; GALAH (de Silva *et al.* 2015)) in the South with R∼28,000; among others.

OCCASO (Casamiquela *et al.* 2016) is obtaining high-resolution spectra (R$\gtrsim$65,000) in the optical range for Red Clump stars in Northern OCs. This survey is systematically targetting OCs with at least 6 stars per cluster, and with a minimal signal-to-noise ratio (SNR) of 70.

2. OCCASO

In Casamiquela *et al.* (2017) we analysed 115 stars in 18 OCs (75% of the survey) covering Galactocentric distances between 6.8 and 10.7 kpc, and ages between 300 Myr and 10.2 Gyr. We determined atmospheric parameters using two different analysis methods to perform an accurate chemical analysis. We also refined the membership selection

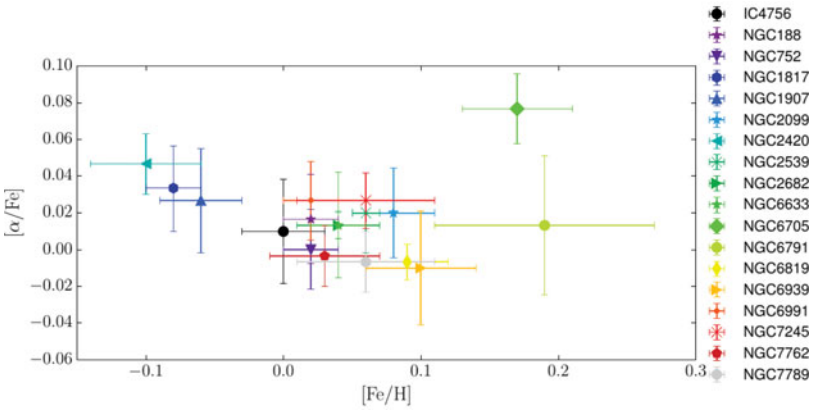

Figure 1. Mean [α/Fe] abundances (calculated as the mean of [Si/Fe], [Ca/Fe] and [Ti/Fe]) as a function of the [Fe/H] of the 18 studied clusters.

taking into account the derived epoch radial velocities, mean radial velocities and [Fe/H] abundances.

With a well defined sample of member stars per cluster we determined mean cluster [Fe/H] with typical dispersions of 0.01-0.05 dex. We also analyzed abundances for other iron-peak elements (Ni, Cr), and α elements (Si, Ca, Ti) obtaining uncertainties per star of around 0.04-0.05 dex in [X/H]. Internal cluster dispersions in [X/Fe] range between 0.01-0.03 (Ni), 0.01-0.06 (Cr), 0.01-0.05 (Si), 0.01-0.07 (Ca) and 0.01-0.05 (Ti).

The mean abundances for the three analyzed α elements are shown in Fig. 1. A dependence of [α/Fe] with metallicity is seen between [Fe/H]= -0.1 and 0.1. NGC 6791 seems to be slightly above it. Clearly NGC6705 is an outlier in this trend, showing high [α/Fe] for its metallicity. We analyze more in detail this cluster in the next section.

3. NGC 6705

NGC 6705 is a young OC located in the inner disk $(l, b) = (27.307°, -2.776°)$, at a Galactocentric distance of around 6.5 kpc and close to the plane at $z = -90$ pc. It has a well defined age from isochrone fitting of 316 ± 50 Myr (Cantat-Gaudin *et al.* 2014). In OCCASO we have determined abundances for 7 member stars. We have obtained a clear enhancement in Si, Mg and O, and a rough enhancement (above uncertainties) of Ca and Ti, above expectations. See Fig. 2 (Casamiquela *et al.* 2018, submitted)

This OC has been targetted by GES and APOGEE. From GESDR1, Magrini *et al.* (2014) found [Mg/Fe]= 0.20 ± 0.09 but did not find enhancement in Si, Ca and Ti. From GESDR2, Tautvaišienė *et al.* (2015) found [O/Fe]= 0.13 ± 0.05. Later from DR2/DR3 results Magrini *et al.* (2015) analyzed again Si, Mg and O abundances concluding that the enhancement >0.1 dex in these three elements is genuine and not due to NLTE effects. From APOGEE DR13 results (Holtzman *et al.* 2015) we have selected a sample of 12 member stars using radial velocities and abundances. We have obtained remarkable enhancement only in [Si/Fe]= 0.10 ± 0.04.

3.1. *High α young stars?*

From OCCASO data seems unelusive that this is an α-enhanced OC. However, the existence of α rich stars at such a young age is not predicted by chemical evolution models, where α-enhancement is typically assigned to old thick disk population Fuhrmann 2011.

Other young α rich field stars have been analyzed in Chiappini *et al.* (2015) and Martig

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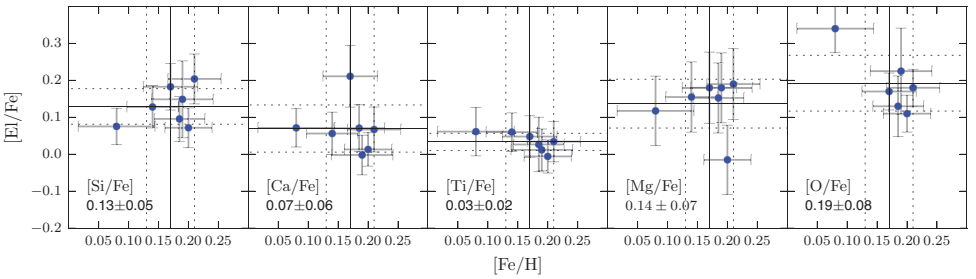

Figure 2. Si, Ca, Ti, Mg and O abundances over Fe for the member stars of NGC 6705. Mean abundances and spreads are overplotted in each pannel. The solid lines shows the mean value and the dotted lines indicate the 1σ level.

et al. (2015). In particular, in Chiappini *et al.* (2015) the CoRoGEE sample is analyzed, where ages are obtained from asteroseismology with CoRoT (Miglio *et al.* 2013), and α abundances from APOGEE (Holtzman *et al.* 2015). They find at least 14 stars that are α-enhanced ([α/Fe]>0.13) and younger than 6 Gyr. They also emphasize that the majority of these stars are found towards the inner Galaxy.

Different explanations can be given to this phenomenon, among which is the ambiguity of determining ages from masses in asteroseismology. In this case (i) it could be that young α-rich stars were blue stragglers, therefore, their age estimates would not be representative of the real age of the progenitors. NGC 6705 is the first cluster that shares this characteristic but has a different and more reliable age determination. Another interpretation (ii) could be that these stars were born from a recent gas accretion event. It also exists the possibility (iii) that these stars were born near the corrotation of the bar where gas could be kept inert for a long time, and then they were kicked to their current location. In the next section we do a further insight to the third hypothesis.

4. Orbit computation of NGC 6705

We do a first attempt to see if this OC comes from the inner Galaxy and so would be consistent with the third explanation stated in the previous section. To do so we compute the orbit of the cluster until the age of birth using a model of the gravitational potential for the Milky Way that features spiral arms and bar (Pichardo *et al.* 2004, Pichardo *et al.* 2003). We assume the mean radial velocity derived from OCCASO (Casamiquela *et al.* 2016) and 3 sets of proper motions and distances: Data1 and Data3 use TGAS results with two different membership selections; Data2 uses proper motions and distances from Dias *et al.* (2002).

We take into account uncertainties in proper motions, distances, age and radial velocity by doing 1000 realizations of the orbit assuming Gaussian errors. We also take into account different assumptions for the free parameters of the gravitational potential (mass, pattern speed, etc, of the spiral arms and bar) sampling 91 different models. From our results of the birth radius distribution (see Fig. 3) this cluster is unlikely to come from a region inner than 6.8 kpc.

5. Conclusions

Using data from the OCCASO survey (R>65,000, SNR$\sim$70) we have derived Ni, Cr, Si, Ca and Ti abundances for 115 stars in 18 OCs in an homogeneous way. We obtain small cluster dispersions of around 0.01-0.07 dex for all elements in [X/Fe].

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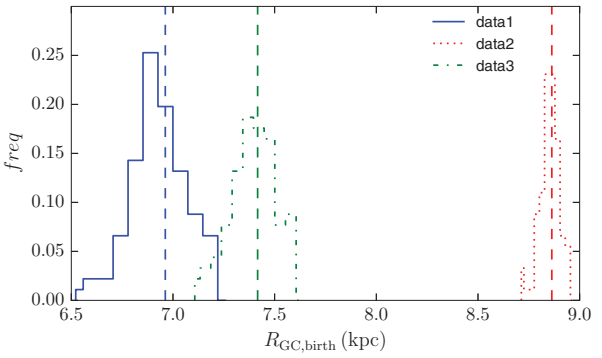

Figure 3. Normalized distribution of the birth Galactocentric radius of the orbits given the 91 models, for the three datasets specified in the text. The mean values of the distributions are plotted as vertical dashed lines.

A detailed study of NGC 6705 shows that this is a metal rich and clearly α-enhanced cluster for its young age (300 Myr). This is the only cluster with this characteristic, common with young α rich stars in the Galactic disk found by Chiappini *et al.* (2015). We compute its orbit with three different determinations of proper motions and distances, and taking into account errors in these quantities, and errors from the assumed free parameters of the gravitational potential model. We obtain that this cluster was probably born near its current position (slightly inside the solar radius).

From this study the explanation for the α-enhancement of NGC 6705 remains uncertain.

Acknowledgements

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