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Chemical anomalies in LMC globular clusters

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Abstract. Chemical anomalies in the light elements have been observed in all the Galactic Globular Clusters studied so far and recognized as the signature of a self-enrichment process occurring in these dense environments. We discuss the results concerning the chemical abundances in the Globular Clusters of the Large Magellanic Cloud. In a similar way to the Milky Way globulars, the old, metal-poor Magellanic clusters exhibit Na-O and Mg-Al anticorrelations. This finding points out that the chemical anomalies are a universal feature of the old, massive Globular Clusters, irrespective of the parent galaxy. On the other hand, the Magellanic clusters younger than ~2 Gyr do not show evidences of anticorrelations, suggesting that these clusters (despite of their high present-day mass) do not experience self-enrichment process.

Key words. Stars: abundances – Stars: abundances – galaxies: Magellanic Clouds – galaxies: star clusters

1. Introduction

Stars in Galactic Globular Clusters (GCs) are known to be homogenous in their overall metal content. However, in the recent years significant star-to-star abundance variations of some light elements (namely Li, C, N, O, Na, Mg, Al) have been discovered (see e.g. Gratton, Sneden & Carretta 2004), suggesting that Galactic GCs harbor at least two subpopulations with different chemical abundance ratios. The widely accepted scenario invoked to explain the observed patterns (and in particular the anti-correlation between Na and O and between Mg and Al) is that the anomalous stars have formed from the ashes of a previous generation able to pollute the pristine gas with material processed by proton-capture reactions. Two possible polluters have been discussed: (i) intermediate-mass (3–8 $M_{\odot}$) AGB stars (Ventura et al. 2001) and (ii) fast rotating massive stars (Decressin et al. 2007). Theoretical models by D'Antona & Caloi (2008) suggest that the second generation of polluted stars should be a significant fraction of the entire cluster population (~50-70%) and also He enriched. We discuss the metal content (and in particular the abundances of the elements involved in the anticorrelations) of a sample of Large Magellanic Cloud (LMC) GCs. The chemical analysis is based on high-resolution optical spectra of giant stars collected with the ESO facility FLAMES@VLT. These clusters sample the entire age range covered by the LMC cluster system and include young (~100-200 Myr), intermediate-age (~1-2 Gyr) and old (~12-13 Gyr) GCs.

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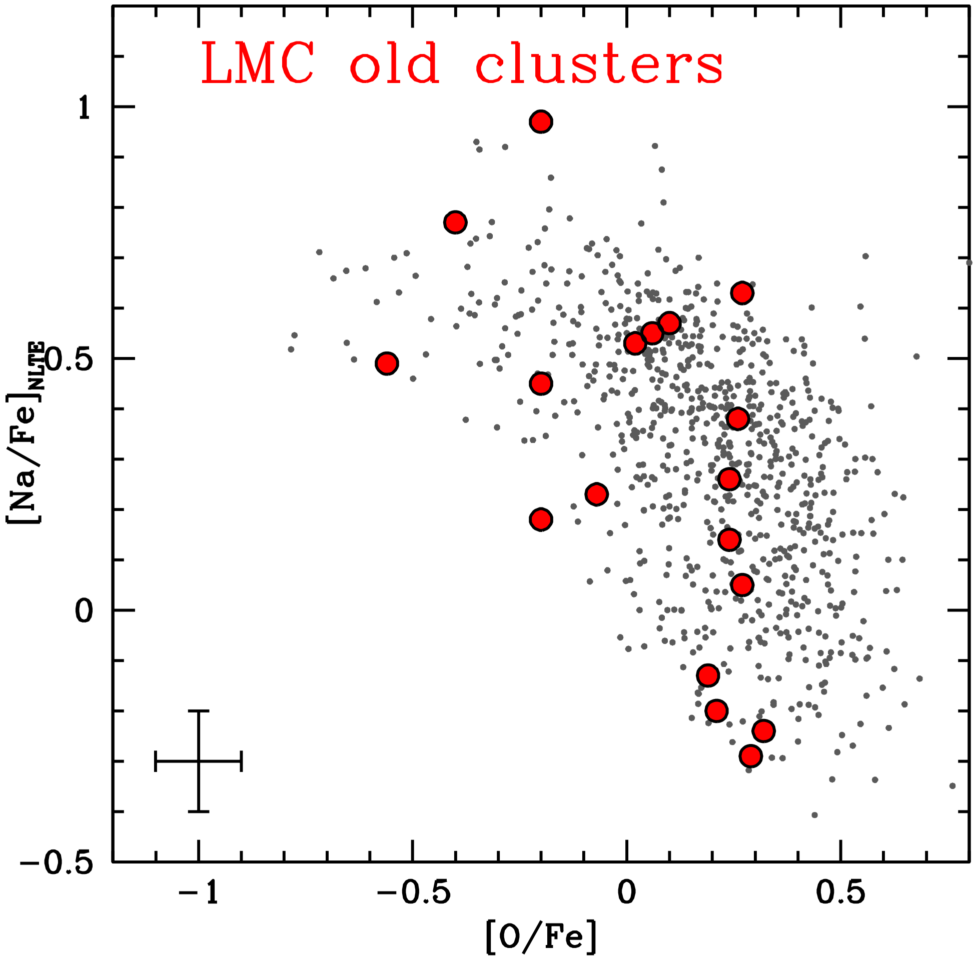

Fig. 1. Behaviour of [Na/Fe] as a function of [O/Fe] for the target stars in the old LMC clusters NGC 1786, NGC 2210 and NGC 2257 (red points). In comparison, the abundances of individual stars in several Galactic GCs are plotted (grey points).

2. Chemical anomalies in old LMC clusters

We measured chemical abundance ratios for 3 old, massive LMC clusters, namely NGC 1786, NGC 2210 and NGC 2257. All these objects turn out to be metal-poor, with [Fe/H] ranging from ∼–2 to ∼–1.5 dex, with a high degree of homogeneity for iron, iron-peak and α-elements. On the other side, large star-to-star variations in Na, O, Mg and Al content in a given cluster (variations not compatible with the uncertainties) have been detected. Fig. 1 shows the cumulative distribution in the [O/Fe]–[Na/Fe] plane of all the individual stars in these 5 clusters (red points). In comparison, the abundances of individual stars in several Galactic GCs are also plotted (grey points, by Carretta et al. 2009).

The main results are summarized as follows:

(i) all the old LMC GCs analyzed so far ex-

hibit Na-O and Mg-Al anticorrelations, similar to those observed in the Milky Way clusters;
(ii) the mean locus defined by the LMC stars of these old globulars well resembles that traced by the stars in the Galactic clusters;
(iii) in the LMC cluster NGC 1786, 2 super-O-poor stars (with [O/Fe]<–0.2 dex) have been detected. This class of cluster stars has been detected only in the Galactic cluster NGC 2808 and M 13.

In order to quantify the correlation between the observed abundances, we measured the Spearman rank coefficient finding C_S = –0.65 between [O/Fe] and [Na/Fe] and C_S = –0.50 between [Mg/Fe] and [Al/Fe], corresponding to a probability of ~ 99% and ~ 95%, respectively, that the two set of abundance ratios be anti-correlated. A confirmation of the real presence of intrinsic differences in the metal content of stars of a given LMC GC is provided in Fig. 2, where spectral portions of two giant stars in NGC 1786 are compared. These two stars share the same iron content and atmospherical parameters, but clearcut differences around Na, O and Al lines can be appreciated.

Chemical anomalies and anticorrelations detected in Galactic GCs are currently interpreted in a scenario where the anomalous stars have formed from the ashes of a previous generation able to pollute the pristine gas with material processed by proton-capture reactions. Our findings demonstrate that this scenario can apply also to the old GCs in the LMC, enforcing the self-enrichment scenario and point out that the anticorrelations are ubiquitous and universal features of all the old globular clusters, regardless of the parent galaxy.

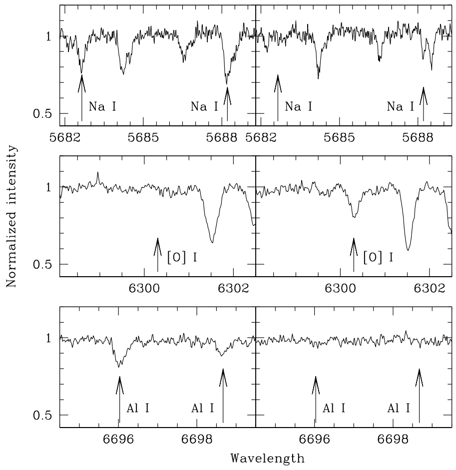

Fig. 2. Comparison between the spectra of two giant stars in NGC 1786 around the Na doublet (upper panels), O forbidden line (middle panels) and Al doublet (lower panels). The errorbar indicates the typical uncertainty computed by taking into account the error in the EW measurements and in the atmospheric parameters.

3. Chemical anomalies in young LMC clusters

The bulk of the LMC globular cluster system is represented by the clusters younger than ~2 Gyr. The typical present-day mass of this class is of about 10^5 $M_\odot$, basically higher than the mass of coeval Galactic open clusters and in some cases comparable with the mass of the Galactic GCs ($\sim 5 \cdot 10^5 M_\odot$). The clusters in the age range 100 Myr – 2 Gyr are metal-rich, with an iron content of ~–0.4 dex. Each cluster shows a high level of homogeneity for all the measured elements, including Na, O, Mg and Al. In fact, LMC clusters younger than 2 Gyr seem to do not undergo self-enrichment processes, also in cases of high cluster mass. For example, the intermediate-age cluster NGC 1978 (with an age of 1.9 Gyr and an iron content of [Fe/H]=–0.38 dex) has a present-day mass of $2–3 \cdot 10^5 M_\odot$, comparable with the typical mass of the Galactic globulars and the mass of the old LMC clusters discussed above. Also in this case, there are no hints of intrinsic dispersion in the O, Na, Mg and Al content.

Fig. 3 shows the mean locus (blue box) described by the stars in the young and intermediate-age LMC GCs in our sample in the [Na/Fe]–[O/Fe] plane. A point to recall is that the [Na/Fe] and [O/Fe] abundances in these clusters well resemble those observed in the LMC field stars at the same metallicity (see e.g. Pompeia et al. 2008), pointing out that all these cluster stars belong to the first generation, while second generation (pol-

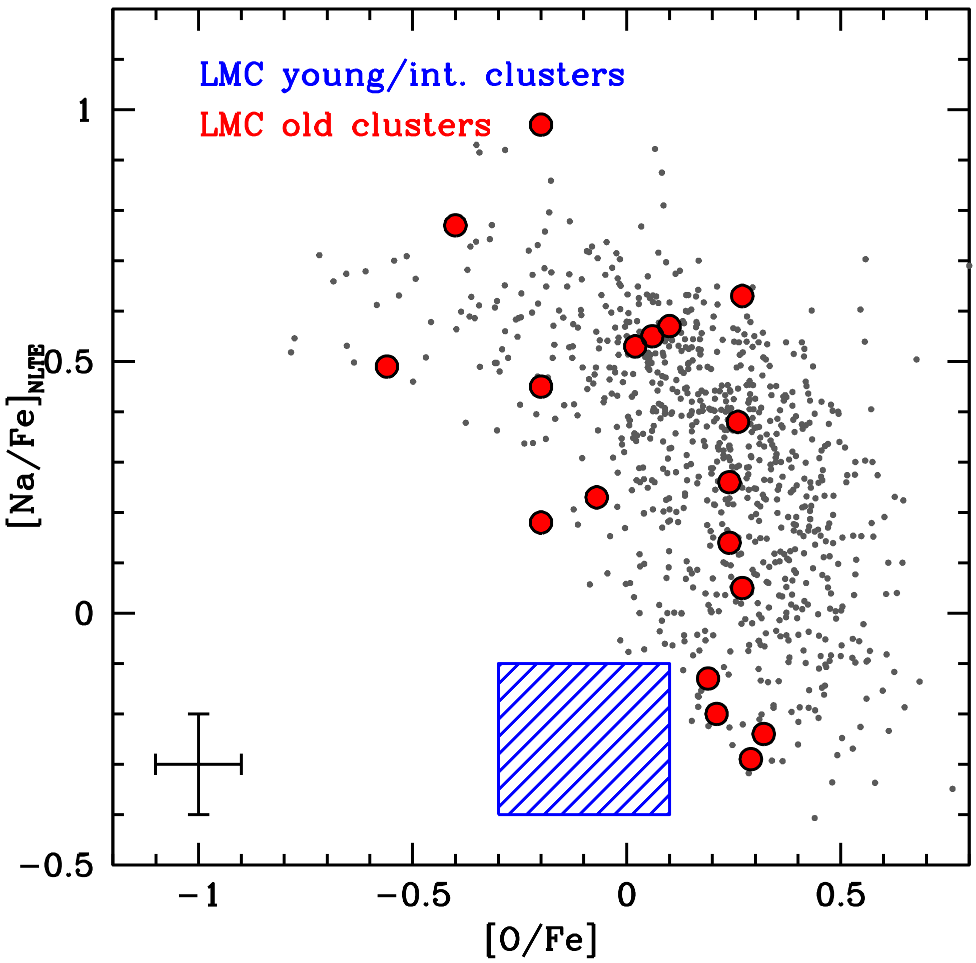

Fig. 3. Behaviour of [Na/Fe] as a function of [O/Fe] for the target stars in the old LMC clusters NGC 1786, NGC 2210 and NGC 2257 (red points). In comparison, the abundances of individual stars in several Galactic GCs are plotted (grey points). Blue box indicates the mean locus defined by the individual stars observed in young and intermediate-age LMC clusters analyzed in this work.

luted) stars are lacking. The fact that, at variance with the older LMC and Galactic GCs, the intermediate-age LMC clusters do not show clear chemical abundance anomalies could be explained as a combined effect of high metallicity and moderate mass. It is worth noticing that these intermediate-age clusters are old enough to have already experienced self-enrichment (if any), because the pollution by AGB should work within the first 100 Myr of the cluster life.

Also, several cluster parameters affect the development and the extension of the anticorrelations, i.e. density, mass, metallicity, orbital parameters. Chemical anomalies have been detected exclusively in the Galactic GCs (with a clearcut correlation between cluster mass and the [O/Na] distribution) and not in the less massive and dense Open Clusters (OCs) or in the field stars, pointing out that the environment density and mass play a key role in retaining the ejecta of the first generation.

4. Conclusions

Concerning the anti-correlations and the chemical anomalies involving the light-elements, we can identify a clear-cut dichotomy in the LMC GCs:
(1) old, metal-poor GCs: this class of GCs exhibit Na-O and Mg-Al anticorrelations similar to those already detected in all the Galactic GCs studied so far (see Mucciarelli et al. 2009). Thus, we can consider the old LMC GCs as the ideal *twins* of the Milky Way clusters;
(2) young/intermediate-age, metal-rich GCs: although their high mass ($\sim 10^5 M_{\odot}$, comparable with the mass of the old LMC and Milky Way GCs), these clusters do not show hints of chemical anomalies, suggesting that they do not undergo self-enrichment process (see Mucciarelli et al. 2008).

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