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The globular clusters of the Large Magellanic Cloud: chemical abundances and ages.

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Abstract. The Large Magellanic Cloud clusters represent a gold-mine of information about the history of the stellar populations in this irregular galaxy. This project is aimed at determining homogeneous metallicities and ages for a representative sample of template LMC clusters by combining high-resolution spectroscopy and photometry. We present the first results about the intermediate-age LMC clusters, an age class still poorly investigated.

Key words. Stars: abundances – Stars: atmospheres – Stars: Population I – Galaxy: globular clusters – Galaxy: abundances

1. Introduction

The Large Magellanic Cloud (LMC) is the nearest galaxy with a present-day star-formation activity and it represents a formidable laboratory for the study of stellar populations. Its globular cluster (GC) system shows a wide distribution of ages, metallicities and integrated colors. In particular, we can distinguish three main stellar populations: an old and metal poor population, the analogous of the Galactic halo GCs, an intermediate-age population (~1-3 Gyr) and a young population, with clusters younger than 1 Gyr.

With the ultimate goal of constructing a homogeneous age-metallicity scale for the LMC clusters, we started a program which makes use of the last generation of instruments (imager and multi-object spectrograph) in order to perform an appropriate study of age, metal content and structural parameters for a number of pillar clusters. The first results of this project, about the intermediate-age population, have been already published (Ferraro et al. 2006; Mucciarelli et al. 2007a,b, 2008).

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2. The chemical composition of the LMC intermediate-age clusters

The observations of 4 intermediate-age LMC clusters (namely NGC 1651, NGC 1783, NGC 1978 and NGC 2173) were performed by using the multi-object spectrograph FLAMES@VLT (Pasquini et al. 2002), in the UVES+GIRAFFE/MEDUSA combined mode for a total of 8 UVES and 132 MEDUSA fibres. Here we present the results of the UVES Red Arm survey which provides high resolution (R~ 47000) spectra in the 4800-6800 $\AA$ wavelength range of 6-7 stars in one shot.

All these intermediate-age LMC clusters turn out to be metal-rich, with a typical iron content of [Fe/H]~ -0.4 dex. This finding results to be in well agreement with the Ca II triplet spectroscopical survey of red giant stars in the LMC bar discussed by Cole et al. (2005) that derived a metallicity distribution function peaked at the median value of [Fe/H]= -0.37 dex. In the following we summarized some abundance ratios ([α/Fe], [Al/Fe] and [Ba/Y]) that distinguish the chemical composition of these stellar populations with respect to other enviroments. We compared our results with the high-resolution spectroscopic database of Venn et al. (2004) (Milky Way stars), Pompeia et al. (2006) (LMC field giants), Bonifacio et al. (2000), Monaco et al. (2005), Monaco et al. (2007) and Sbordone et al. (2007) (Sagittarius dwarf Spheroidal giants).

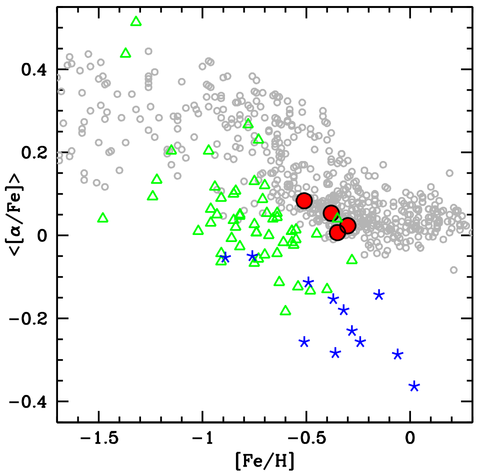

Fig. 1. The trend of the average [α/Fe] ratio as a function of [Fe/H] for the 4 analysed LMC clusters (red points) and in comparison with the previous determination for the LMC field (green triangles) from Pompeia et al. (2006), the Milky Way (little grey points) by Venn et al. (2004) and Sagittarius dwarf Spheroidal (blue asterisk) by Bonifacio et al. (2000), Monaco et al. (2005), Monaco et al. (2007) and Sbordone et al. (2007)

2.1. α-elements

The [α/Fe] ratio represents a powerful diagnostics to clarify the relative role played by SNII (producers of α-elements) and SNIa (main producers of Fe) in the chemical enrichment process. Indeed, there is time delay (Tinsley 1979) between the explosion of SNII, occurring since the onset of the star formation event, and SNIa, which happen later on (Greggio 2005a). The roughly solar [α/Fe] abundance ratios measured in the LMC GCs (see Fig. 1) well match those found in the LMC field and MW thin disk intermediate-age populations and are consistent with a standard scenario, where SNIa had enough time to significantly enrich the gas with iron. Some depletion of [Mg/Fe], [Ca/Fe] and [Ti/Fe] is observed in the Sgr stars.

2.2. The strong depletion of [Al/Fe]

Fig. 2 shows the trend of the [Al/Fe] ratio of the target clusters as a function of the iron content [Fe/H]. All these LMC clusters exhibits a strong depletion of this abundance ratio, with a typical value of [Al/Fe]~ -0.40 dex, This element is likely connected to the SNII, because its main production site is the Ne burning. Also, since the Al yields depend on the neutron excess and increase with metallicity (Pagel 1997), under-abundant [Al/Fe] ratios suggest that the gas from which the LMC clusters formed, should have been enriched by relatively low-metallicity SNII.

2.3. Neutron-capture elements

The behaviour of the s-process elements in the LMC clusters appears to be *dichotomic*, with a deficiency of light s-elements (Y and Zr) and an enhancement of heavy ones (Ba, La and Nd), with the only exception of Ce, that shows a solar [Ce/Fe] abundance ratio . The [Ba/Y] abundance ratio represents a powerful diagnostic of the relative contribution of the heavy to the light s-process elements (see Venn et al. 2004). Fig. 3 shows the results for this abundance ratio for our target clusters, where the [Ba/Y] ratio is enhanced by ~0.9-1 dex. Such a values have been observed also in the LMC field (Hill et al. 1995; Pompeia et al. 2006) and in Sgr (Sbordone et al. 2007), but not in the MW, where the [Ba/Y] ratio is solar at most. The interpretation of these abundance patterns is complicated by the complexity (and uncertainty) of the involved nucleosynthesis. Theoretical models (Busso, Gallino & Wasserburg 1999;

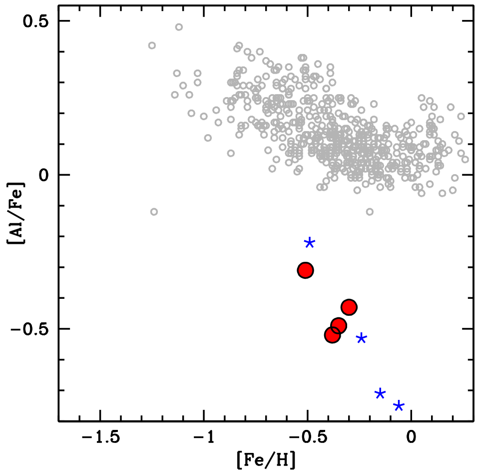

Fig. 2. The trend of the [Al/Fe] ratio as a function of [Fe/H] for the 4 analysed LMC clusters (same symbols of Fig. 1).

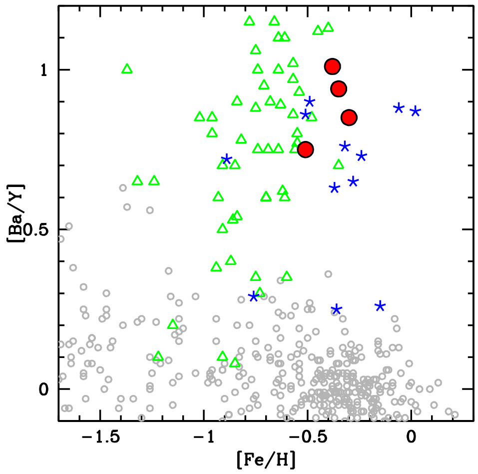

Fig. 3. The trend of the [Ba/Y] ratio as a function of [Fe/H] for the 4 analysed LMC clusters (same symbols of Fig. 1).

Travaglio et al. 2004) indicate that the AGB yields could be metallicity-dependent. In particular, the heavy-s elements have their maximum production factor at lower metallicities than the light-s ones. Hence, a high [Ba/Y] ratio could suggest a major pollution of the gas by low-metallicity AGB stars.

3. The ages: first results

Accurate ages from the measurement of the Main-Sequence (MS) Turn-Off (TO) region are still sparce and very model (i.e. isochrones) dependent. The only homogeneous age-scale available uptodate still relies on the so called s-parameter (Elson & Fall 1988), an empirical quantity related to the position of the cluster in the dereddened (U-B) vs (B-V) color-color diagram. We have began an accurate study of the main photometric properties of a sample of LMC clusters by using Hubble Space Telescope data. Fig. 4 and 5 show the Color-Magnitude Diagrams for the 2 LMC clusters NGC 1978 and NGC 1783, respectively, obtained with the ACS camera.

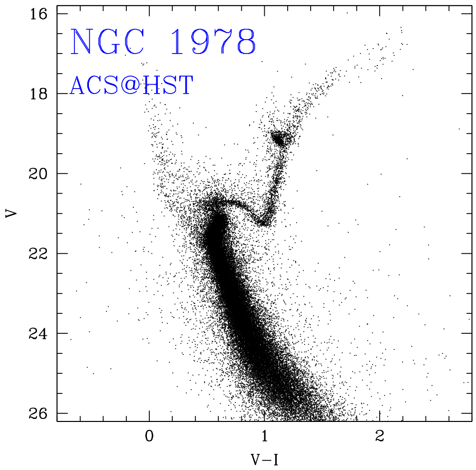

Fig. 4. The Color-Magnitude Diagram of the LMC cluster NGC 1978.

In these diagrams we identify the typical morphological features of a intermediate-age populations: (1) the TO region shows a hook-like shape, typical of the evolution of intermediate-mass stars (M>1.2 $M_{\odot}$) that develop a convective core; (2) a narrow, flat Sub-Giant Branch; (3) the Red Giant Branch is fully populated; (4) the Helium-Clump, cor-

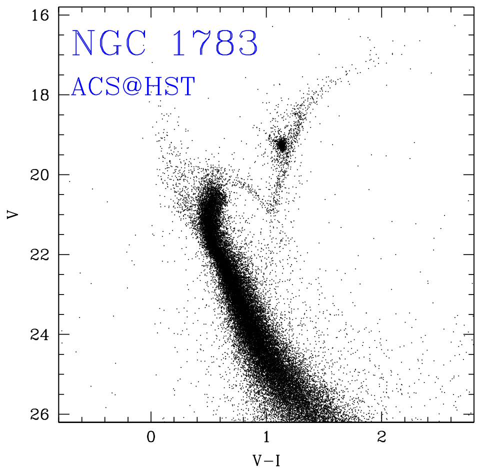

Fig. 5. The Color-Magnitude Diagram of the LMC cluster NGC 1783.

responding to the Helium-burning phase. The morphology of the evolutionary sequences and the population ratios have been compared with the expectations of different theoretical models (Pisa Evolutionary Library, Padua database and BasTI database) in order to derive reliable ages and to quantify the effect of convective overshooting. We derive an age of 1.9±0.1 and 1.4±0.2 Gyr for NGC 1978 and NGC 1783, respectively, adopting the PEL isochrones by Castellani et al. (2003) and including an amount of overshooting.

4. Conclusions

The chemical analysis of these clusters provides an overall picture of the metal-rich, intermediate-age population of the LMC GCs system remarkably different with respect to the Galactic field population of similar ages and metallicities. Our results point toward a scenario of chemical evolution dominated by previous generations of low metallicity stars. The future extension of this analysis to younger and older LMC GCs will allow to disentangle several aspects of the chemical evolution in the LMC.

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