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The SUMO project: a SUrvey of Multiple pOpulations in globular clusters

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Abstract. We present the first results of the SUMO project, aimed at studying multiple populations in globular clusters. For this purpose we obtained wide-field photometry in a large sample of clusters using both archival and proprietary U, B, V, and I data from ground-based telescopes. We have defined a new photometric index $c_{\rm U,B,I}$=$(U-B)$–$(B-I)$, that we show is very effective to split multiple sequences along the red giant branch (RGB). We found a direct connection with the chemical properties of different sequences, that display different abundances of light elements.

Key words. globular clusters: general – techniques: photometric Galaxy: globular clusters

1. Introduction

The existence of multiple populations in globular clusters is now a well established ob-

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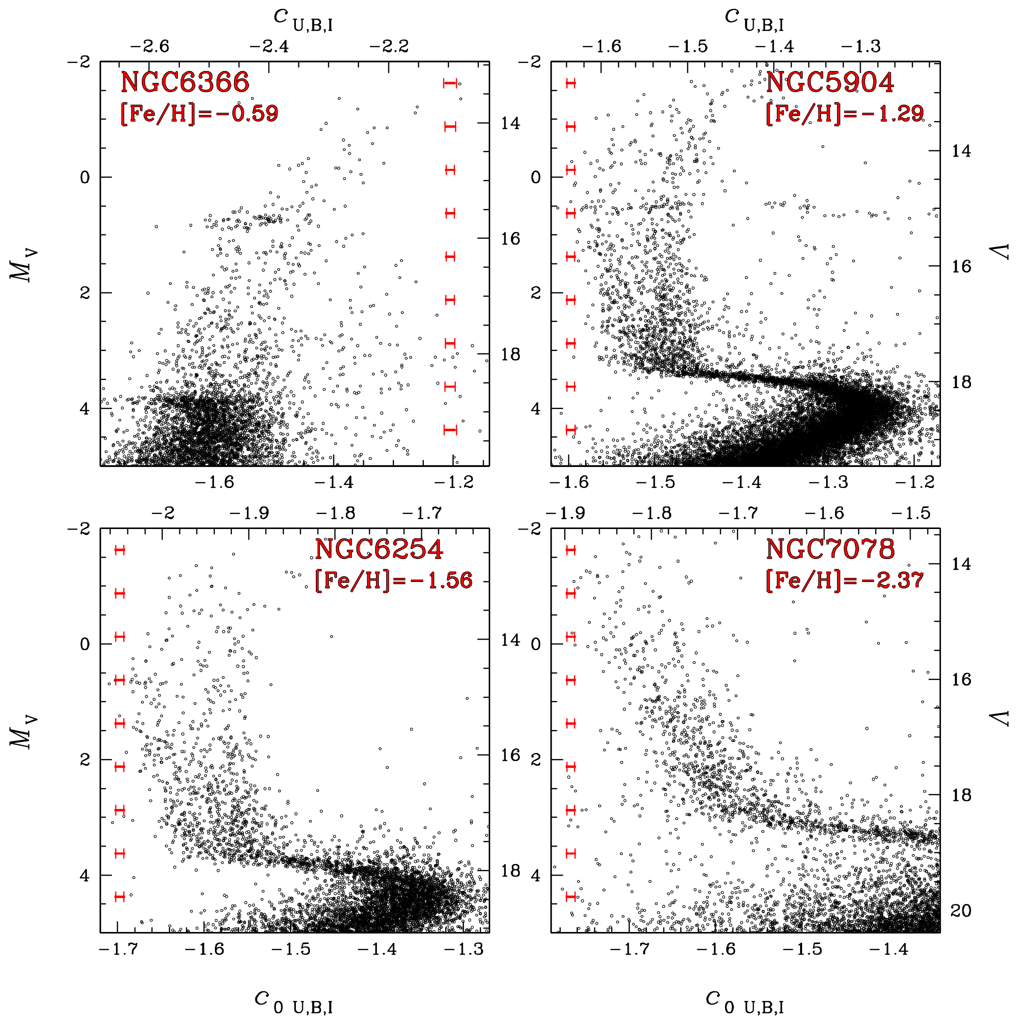

Fig. 1. (M_V, $c_{0\,\mathrm{U,B,I}}$) pseudo-CMD for four GCs covering a wide range of metallicities. Note the complex morphology of the RGB, with a large colour spread (NGC 7078) or well-defined multiple sequences.

servational result. Though the star-to-stars abundance variations of light elements have been known since the seventies (e.g. Osborn 1971; Kraft 1978), it's only during the last decade that exquisite data from the *Hubble Space Telescope* allowed to identify multiple sequences in the colour-magnitude diagrams (CMDs) of a large number of clusters (e.g. Bedin et al. 2004; Milone et al. 2010, 2012a,b; Piotto et al. 2012). As it turned out, multiple cluster sequences show up in all the clusters studied with appropriate filters. In particular, the use of filters sampling the ultra-violet portion of the spectrum is very powerful to detect multiple populations (e.g. Marino et al. 2008), due to the large effect that the CN and NH abundance variations have at these wavelengths.

However, despite the increasing amount of recent results, a global view on the multiple populations phenomenon is still lacking. To overcome this, we designed a survey, the SUMO project - a SUrvey o Multiple pOpulations. We present here a brief description of the project and the first results. A full description of the project can be found in Monelli et al. (2013, submitted). Also note that we are developing a dedicated web-page, *http://www.iac.es/project/sumo*, where we plan to make available to the community a large number of deliverables, such as reddening maps and plots.

2. The SUMO project

This project has the aim of collecting homogeneous, wide-field photometric and spectroscopic data of GCs, with the main objective of characterizing and understanding the multiple populations phenomenon. The survey is such to be complementary to the high-resolution HST data available for the central regions of GCs. In particular, we are conducting the observations using two ground-based telescopes, the INT and the MPG/ESO 2.2m, which are equipped with a wide-field camera and the Johnson set of filters. The wide area covered is important to trace the behaviour of different generations of stars at large radii, which is mandatory to shed light on their formation mechanism (D'Ercole et al. 2008). So far, $UBVI$ data have been secured for 21 northern and 13 southern clusters. The observations were optimized to have high signal-to-noise ratio for main sequence stars 1 mag below the turn-off. These data have been complemented by archival data from the archive maintained by P.B. Stetson, in such a way to have a homogeneous reduction (ALLFRAME, Stetson 1994), and calibration (Stetson 2000, 2005).

The calibrated catalogues have been corrected for differential reddening following the procedure described in Milone et al. (2009), while contaminating sources such as foreground stars and background galaxies have been removed using the $((U-V), (B-I))$ colour-colour plane (Bono et al. 2010).

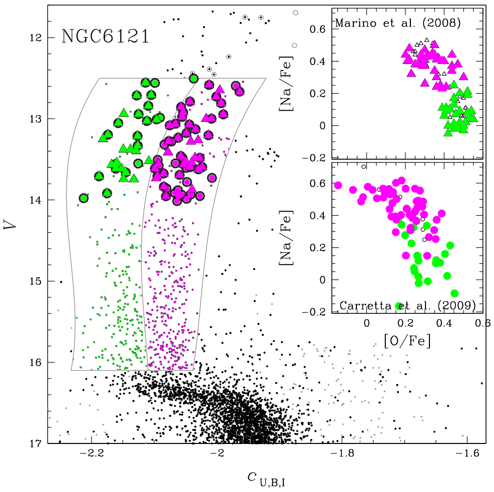

Fig. 2. Correlation between the photometric and spectroscopic properties of multiple sequences detected in the $c_{\rm U,B,I}$plane. In this example showing NGC 6121 we identified two sequences, coloured with green and magenta symbols. The Na and O abundances from the literature are plotted in the two small panels. The stars identified in our catalogue are coloured according to the photometric selection: stars belonging to the two sequences have systematically different Na and O abundances.

3. First results of the SUMO project

The identification of multiple populations has been done following previous works (e.g. Marino et al. 2008), and taking advantage of the U-band photometry. In particular, we introduced a new photometric index, $c_{\rm U,B,I}$, defined as $(U-B)-(B-I)$, that maximizes the separation among stars with different helium and light-elements content.

As an example, Fig. 1 presents the $(M_V,\ c_{0\,\rm U,B,I})$ pseudo-CMD for four clusters: NGC 6366, NGC 5904, NGC 6254. and NGC 7078. In this metallicity range, the evolutionary features appear reversed with respect of a typical CMD: the main sequence moves to larger (less negative) colours for increasing brightness, while the sub-giant branch bends toward more negative $c_{\rm U,B,I}$index. The slope of the RGB appears to be very sensitive to metallicity: in particular, the $c_{\rm U,B,I}$index of the brightest stars gets more negative for decreasing metallicity. Also note the peculiar morphology of the horizontal branch: the red part overlaps with the RGB, while the blue tail crosses it toward less negative $c_{\mathrm{U,B,I}}$values, as clearly seen in the case of NGC 5904. However, the most important feature disclosed by the figure is that the RGB morphology is complex, and presents either a large colour spread, as in the case of NGC 7078, or evident substructures and multiple sequences as for the other clusters. Interestingly, the RGB of every cluster seems to be different: the number of sequences and the distribution of stars between different sequences varies in every object. A detailed analysis of these features will help understanding the relative contribution of generation of stars, giving insights on the formation mechanisms.

To interpret the detected sequences in terms of chemical abundances, we took advantage of spectroscopic measurements available in the literature. Fig. 2 shows the example of NGC 6121. The plot presents the (V, $c_{\mathrm{U,B,I}}$) plane, where we identified two sequences along the RGB, shown by the green and magenta dots. The two insets show the [Na/Fe] v_s [O/Fe] anti-correlation for RGB stars from Marino et al. (2008) (upper, triangles) and Carretta et al. (2009) (lower, circles). We identified the stars in common with our photometry, and coloured their symbols in the insets according to their position in the $c_{\mathrm{U,B,I}}$plane. It immediately results that stars belonging to different sequences have systematically different abundance of Na and O. In particular, stars that have more negative $c_{\mathrm{U,B,I}}$index are O-rich and Na-poor, while stars with larger $c_{\mathrm{U,B,I}}$index present lower O and larger Na abundances.

This occurrence has been verified for 15 clusters for which light-elements abundances are available. This supports that the $c_{\mathrm{U,B,I}}$index is not only an effective tool to identify multiple populations in the RGB, but it gives an estimate of the Right element abundance of each generation of stars.

4. Conclusions

We introduced the SUMO project, aimed at studying the multiple populations phenomenon in globular clusters. The new photometric index we introduced, $c_{\mathrm{U,B,I}} = (U - B) - (B - I)$, turned out to be very efficient to disentangle multiple sequences of stars along the RGB. Moreover, we found that the $c_{\mathrm{U,B,I}}$index of RGB stars correlates with the chemical abundance of light elements, in particular Na and O. Future developments of the project include spectroscopic follow-ups and the study of the spatial distribution of the detected populations, in order to constrain the formation mechanisms.

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