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Multiple populations in Galactic globular clusters from a Strömgren perspective

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Abstract. Our view of the stellar populations in globular clusters has radically changed in the last years. Now we are coming to believe that all globular clusters host at least two distinct stellar populations. We present in this contribution preliminary results of a photometric survey we are currently conducting to disentangle photometrically the several populations in a significant number of Galactic globular clusters, using the Strömgren system, aiming to characterize their relative ratios and their radial distributions.

Key words. (Stars:) Hertzsprung-Russell and C-M diagrams – Stars: abundances – Stars: atmospheres – Stars: Population II – (Galaxy:) globular clusters: general – Galaxy: abundances

1. Introduction

The discovery of multiple stellar populations inside globular clusters (GCs) has triggered a renewal in the interest in these objects over the last few years. The presence of stars with different chemical abundances has been known in some of these objects for a long time (Freeman & Norris 1981; Norris & Smith 1983; Kraft 1994, and references therein), but only recently extensive high-resolution spectroscopic surveys of significant samples of stars have been able to show that differences in the light elements seem to be present in all globular clusters, both Galactic and extragalactic, in all the different stages of the stellar evolution, from the main-sequence to the red giant branch and the horizontal branch (Carretta et al. 2009; Mucciarelli et al. 2009; Pancino et al. 2010). In addition to this, the stars of some globular clusters seem to also show variations in their heavy-elements composition (e.g., NGC 6656 - Marino et al. 2009; NGC 1851 - Yong et al. 2008). Most popular explanations for these differences in the stellar chemistry involve a self-enrichment scenario with at least two star-formation episodes, in which stars from the primordial population enriched the medium for stars in subsequent populations (Valcarce & Catelan 2011, and references therein). The most common suspects to act as pollutants are evolved asymptotic giant branch (AGB) stars (D'Ercole et al. 2008), fast-rotating massive stars (Decressin et al. 2007), and massive interactive binaries (de Mink et al. 2009).

These chemical differences among GC stars also appear in photometric studies as spreads or even splits in the different evolutionary sequences present in the color-magnitude diagrams (CMDs) of these objects, particularly when the bluest filters available in the ACS and WFC3 at the *Hubble Space Telescope* are used (Milone et al. 2012, 2013). Unfortunately, both photometry from space over the complete field of the GCs and high-resolution spectroscopy from the ground of hundreds of GC stars are quite expensive, almost prohibitive in terms of telescope time. But theoretical work suggests that the use of the right combination of Strömgren filters, paying special attention to the bluest ones, also provides a means to successfully disentangle any distinct stellar population present in the GCs (Sbordone et al. 2011; Cassisi et al. 2013).

2. Our survey

With these theoretical works in mind, we have begun a survey in the Strömgren photometric system to sample a significant number of Galactic GCs. To carry out our observations, we are using the SOI camera installed in the 4.1m SOAR telescope, located in Cerro Pachón, Chile. The SOI field of view (FOV) is $5.25' \times 5.25'$, with a pixel scale of $0.154''$. This FOV is too small to cover the whole field of the clusters, so for every cluster we are performing several different pointings, from their centers to their outer regions. We are using four Strömgren filters (u, v, b, and y), plus the Bessel I for a more complete wavelength coverage. So far we have been able to observe 30 Galactic GCs. We have extracted the PSF photometry using Dophot (Schechter et al. 1993; Alonso-García et al. 2012) and have been able to build the CMDs for the different colors available from our filters. As suggested by the theory and from previous observational work (Carretta et al. 2011), the use of the bluest colors and color indices (those containing the u filter), proved very successful in separating the different stellar populations contained in them (see figure 1), especially for the more evolved sequences like the RGB.

In order to better measure the broadenings in the sampled GCs' RGBs we have followed a method similar to the one by Monelli et al. (2013): we have obtained the GC ridgelines and measured $\Delta(u-v)$, the variation in the $(u-v)$ color of every star in the RGB with respect to the $(u-v)$ color of the ridgeline at the magnitude of the star. Details on the specifics of the method will be provided in a future article, but here we just wanted to show the clear (anti-)correlation of $\Delta(u-v)$ with ([O/Fe]) [Na/Fe] ratio (see figure 2), along with the potential of this technique to calculate the relative proportion of any distinct populations (see figure 3).

3. Summary

We have shown the first results of a Strömgren photometric survey of Galactic GCs we are currently conducting with the 4.1m SOAR telescope, aiming to disentangle any distinct stel-

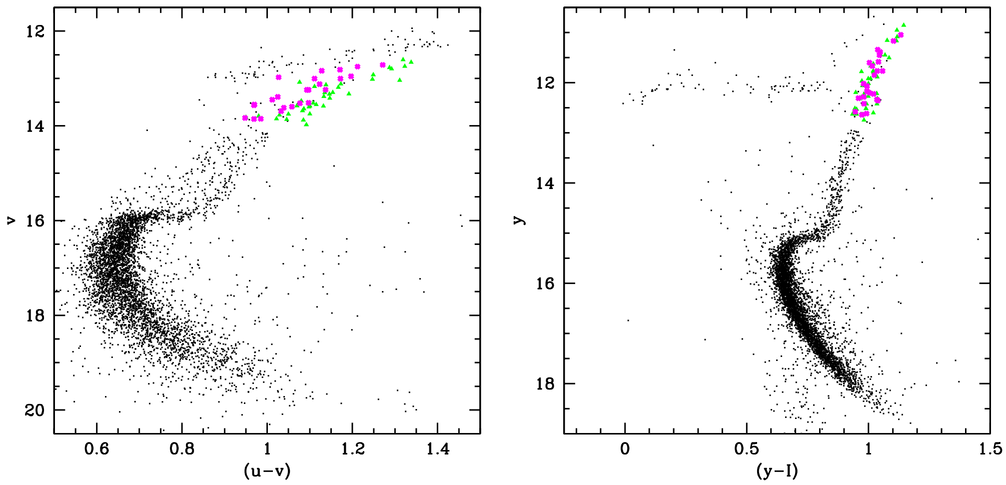

Fig. 1. CMDs for M 4 (NGC 6121). The broadening on the RGB sequence in our bluest filters (left) is not present in our reddest filters (right). Magenta crosses and green triangles represent stars from primary and secondary populations as defined spectroscopically by Carretta et al. (2010). While in our reddest filters these different populations are mixed, they are clearly correlated with the photometric separation observed using our bluest filters.

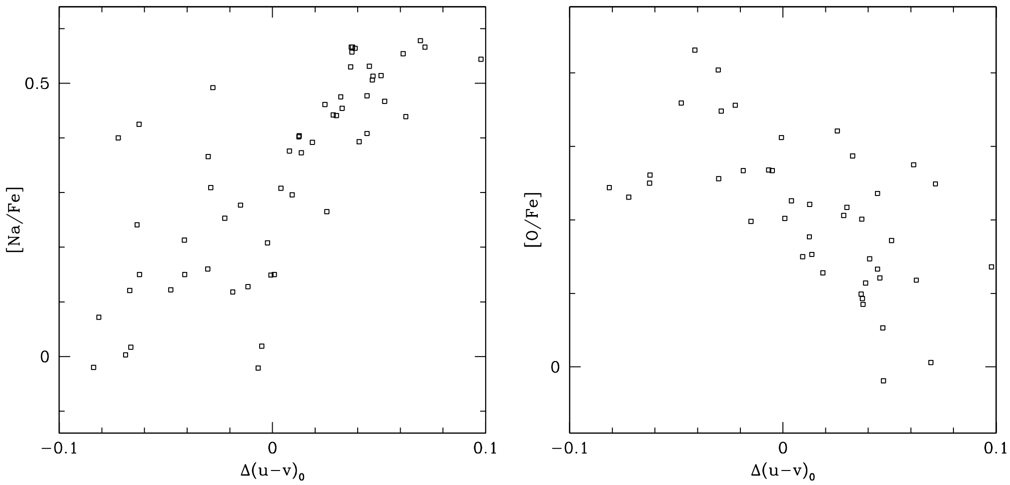

Fig. 2. On the left, $\Delta(u - v)$ vs. [Na/Fe] ratio correlation and on the right, $\Delta(u - v)$ vs. [O/Fe] ratio anti-correlation, using the stars with high-resolution spectroscopically measured abundances by Carretta et al. (2010).

lar populations in them. We can see that the use of the CMDs with colors containing the bluest Strömgren filters is very successful in separating the different populations, and can be used to calculate such characteristics as their relative ratios and distributions in the GCs.

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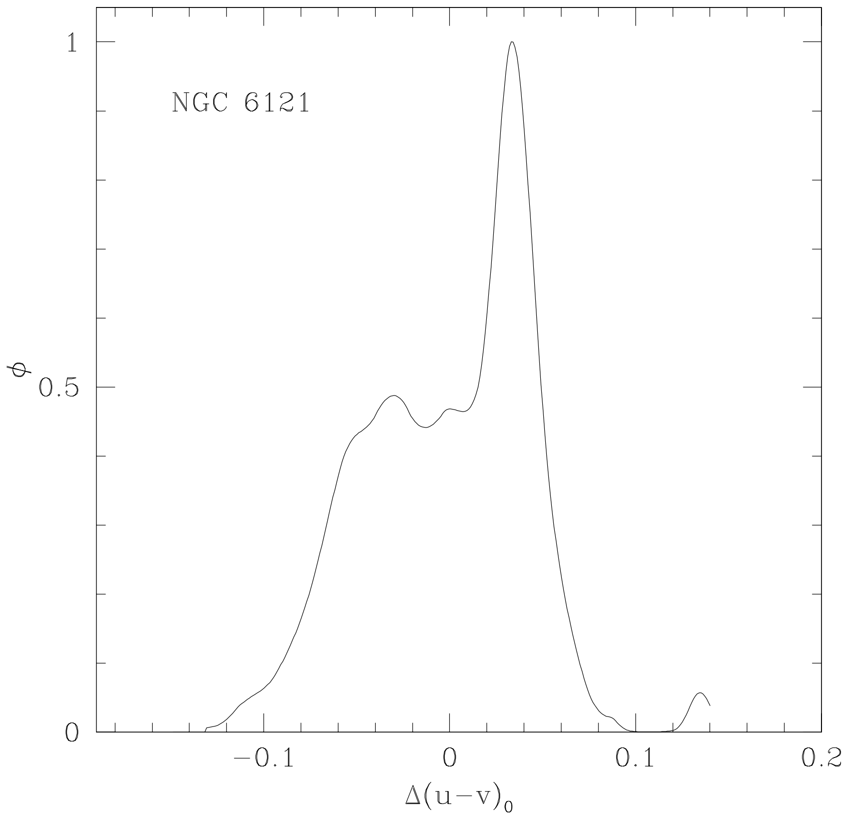

Fig. 3. Density distribution of the M 4 RGB stars, normalized to the maximum, with respect to $\Delta(u-v)_0$, the variation of the $(u-v)_0$ of the stars in the CMD with respect to the $(u-v)_0$ of the ridgeline (see text).

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