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Multiple populations in Galactic globular clusters: a survey in the Strömgren system

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Abstract. We are coming to believe that stellar populations in globular clusters are not as simple as they were once thought to be. A growing amount of photometric and spectroscopic evidence shows that globular clusters host at least two different stellar populations. In our contribution to these proceedings we present the first results of a survey we are conducting to look for the presence of multiple populations in a significant number of Galactic globular clusters, using the Strömgren system. We intend to photometrically separate these populations and characterize their radial distributions and extensions.

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

1. Introduction

Variations in the light element composition among the brightest stars of some Galactic globular clusters (GCs) have been known for several decades now (Freeman & Norris 1981; Norris & Smith 1983; Kraft 1994, and references therein). But only recently, thanks to the results of extensive high-resolution spectroscopic surveys in many Galactic GCs (Carretta et al. 2009; Johnson & Pilachowski 2012; Cohen & Kirby 2012; Mucciarelli et al. 2012), have we found this to be the rule in these ob-

Send offprint requests to: J. Alonso-García jects. The presence of such star-to-star chemical differences in GCs is not restricted to the brightest, most evolved stars. Non-evolved, main-sequence and turn-off stars also show these variations (Briley et al. 1994; Gratton et al. 2001), which suggests a primordial origin. The most extended explanation suggests a self-enrichment scenario with at least two star-formation episodes, where stars from later generations are chemically enriched with respect to the first generation (Valcarce & Catelan 2011, and references therein), but the mechanism of self-enrichment and its extension is still a matter of current discussion and debate (Gratton et al. 2012, and references therein).

Photometry has also proved to be very useful in tackling the problem of disentangling the multiple populations of GCs, by observing and examining their features in the color-magnitude diagram (CMD), such as the presence of several red giant branches (RGBs; e.g., NGC 288 - Roh et al. 2011; NGC 1851 - Han et al. 2009), several horizontal branches (HBs; e.g., Terzan 5 - Ferraro et al. 2009), several subgiant branches (SGBs; e.g., NGC 1851 - Milone et al. 2008; NGC 362, NGC 5286, NGC 6656, NGC 6715 and NGC 7089 - Piotto et al. 2012), or even several main sequences (MSs; e.g., NGC 2808 - Piotto et al. 2007). Photometry provides a means to increase enormously the limited spectroscopic sample size, covering the whole population of the brightest stars in the GC in much shorter times than spectroscopy, and reaching dimmer stars in the more crowded, more central GC environments. Observations using the Strömgren filters, especially the ones in the ultraviolet wavelength range, have been suggested to be more efficient in showing the effects of different stellar populations, due to sensitivity of their passbands to strong molecular bands such as CN, NH, or CH (e.g., Grundahl et al. 2002; Yong et al. 2008; Sbordone et al. 2011; Carretta et al. 2011).

2. Our survey

We have recently started a survey of Galactic GCs, searching for the photometric imprints of the separate populations present in them. 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 obtained the PSF photometry from the images using an updated version of Dophot (Schechter et al. 1993; Alonso-García et al. 2012). We are calibrating the photometry using a set of GCs with previous well-calibrated Strömgren photometry (Grundahl et al. 1999), and Stetson (2000) photometric standard stars in *I*. Also we have astrometrized our observations by comparison with bright stars obtained in each field from the Two Micron All Sky Survey (2MASS; Skrutskie et al. 2006) catalog.

We have generated CMDs for the GCs in our sample for the different available magnitudes and color-indices. We have found that for our reddest color-indices we obtain CMDs with narrow, well-defined evolutionary sequences (see figure 1, left panels). These CMDs, while adequate to obtain information about the global GC parameters (e.g., distance, age, reddening), do not allow us to separate stars into different populations. On the other hand, the CMDs generated with our bluest color-indices, especially those that contain the ultraviolet *u* passband, show significant broadenings in their RGBs (see figure 1, right panels). When we overplot on our bluest CMDs the stars that have been spectroscopically separated in different populations (Carretta et al. 2010), we observe that stars from different populations group in different sides of the RGB, with only a few exceptions (e.g., NGC 2808, NGC 7078). This is a clear indication of a correlation among spectroscopic and photometric separations. A few of the clusters in our sample also show broadenings and separations in their SGBs (see figure 2; Milone et al. 2008; Piotto et al. 2012). These photometric separations have been associated with the small percentage of clusters that

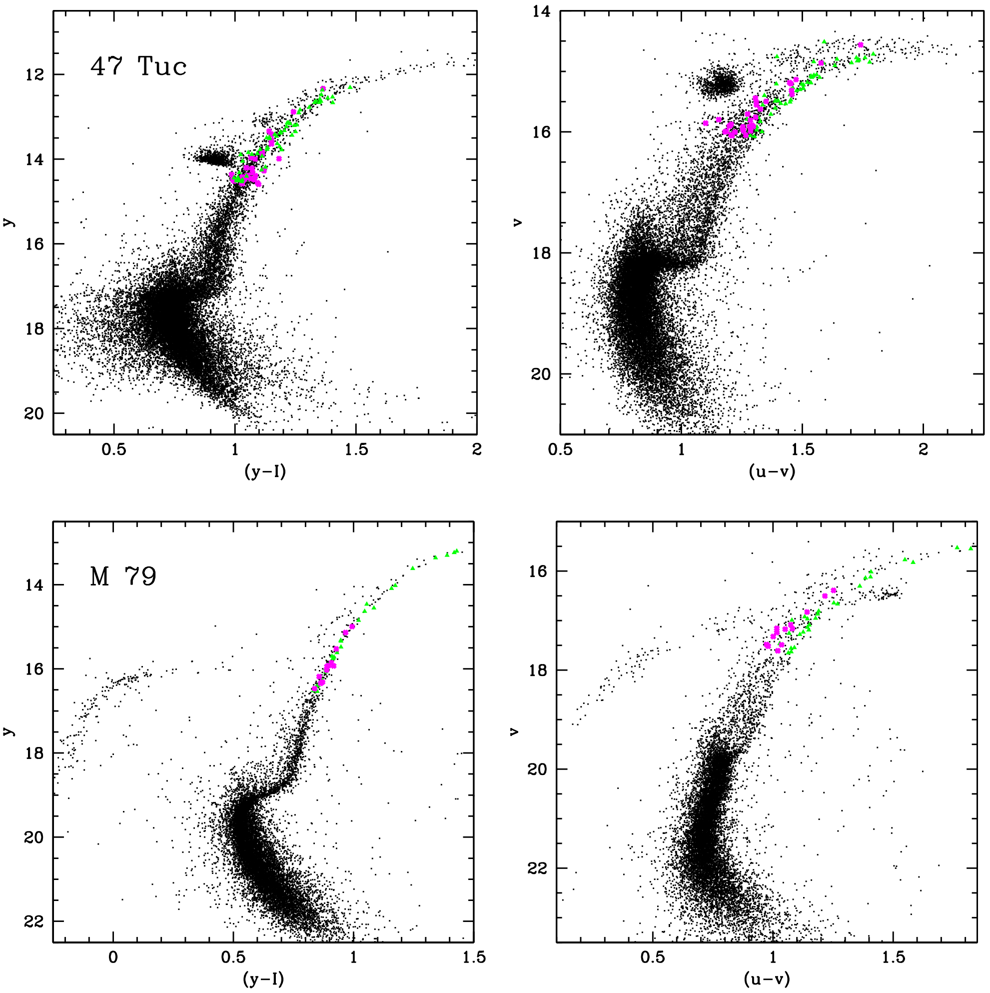

Fig. 1. CMDs for 47 Tuc (upper panels) and M 79 (lower panels). Despite the difference in metallicities between both clusters ([Fe/H]=-0.72 vs. [Fe/H]=-1.60; Harris 1996), we observe for both broadenings on the RGB sequences in our bluest filters (right panels) that are not present in our reddest filters (left panels). 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.

show variations in Fe and s-process elements (Marino et al. 2009; Milone et al. 2012).

3. Summary

We are currently conducting a photometric survey of a significant sample of Galactic GCs in the Strömgren system using the 4.1m SOAR telescope. We are searching for signatures of multiple stellar populations. First results are encouraging, showing a clear correlation between the broadenings we find in the evolutionary sequences of the sampled clusters' CMDs and the spectroscopic separations reported in the literature. We aim to disentangle these populations, and to study their radial distribution

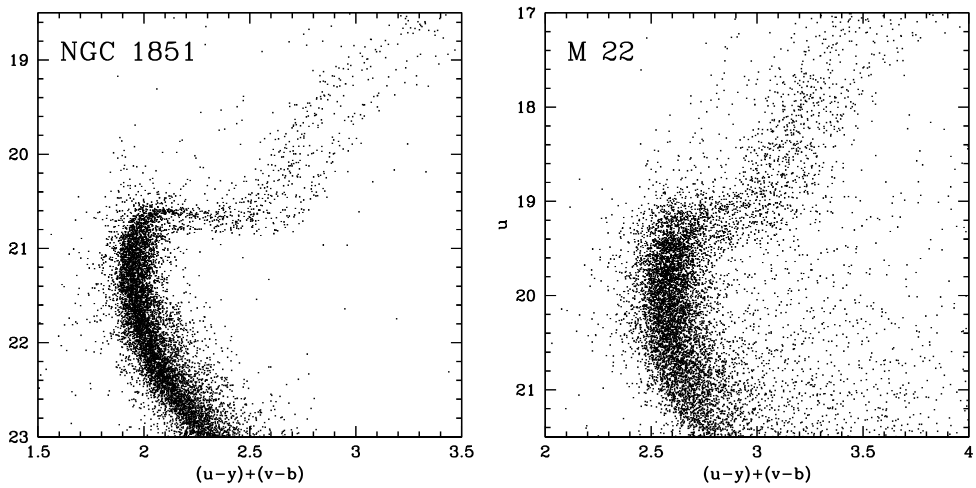

Fig. 2. CMDs for NGC 1851 (left panel) and M 22 (right panel). The separation in the populations is clearly visible in the SGB and RGB using the color index $(u - y) + (v - b)$ introduced by Lardo et al. (2012).

and proportion ratios from the cluster center out to the outskirts of every cluster in our sample.

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