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A Search for Spectroscopic Binaries in the Globular Cluster M4

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Abstract. We present preliminary results from an observational campaign aimed at the study of the binary fraction and binary radial distribution in Galactic globular clusters. In particular, we concentrate on the ongoing observational campaign for the search of spectroscopic binaries.

Keywords. binaries: spectroscopic, globular clusters

1. Introduction

Within the MODEST collaboration, we are conducting a multi-instrument observational campaign aimed at deriving the present day fraction and radial distribution of the binaries in the Galactic globular cluster (GC) M4. With the GRAPE-DR computer technology under development, N-body realistic modeling of GCs with up to 5×10^5 particles will be feasible. At that point, observational inputs, and the comparison of models with the observed parameters will become of fundamental importance to understand the evolution of a GC. Most of them are already available for the two closest clusters, M4 and NGC6397, except the fundamental information on their binary population. It is now the right time to start covering this gap. M4 is our first target for several reasons: 1) we expect to find a large fraction of binaries; 2) it has an extended and relatively uncrowded core, where the proportion of binaries should be highest; 3) it is nearby, which allows the study of binaries also below the turn-off (TO), and these are pristine tracers, as binaries containing giants, might be destroyed by internal mass transfer. We are following three complementary approaches, using the most up-to-date instrumentation: *i*) on ACS/HST images of the central $200'' \times 200''$, we are measuring the photometric binary fraction, mass distribution, and spatial distribution; *ii*) on adaptive Optics NACO/VLT observations of the inner core of M4 we search for binaries with massive companions on the basis of their wobble around the center of mass; *iii*) we are searching for spectroscopic binary systems through the radial velocity variations. Here, we present the first results from the multi-epoch high resolution spectroscopic campaign with FLAMES+GIRAFFE@VLT.

2. Observations and data reduction

We observed 2684 stars from the red giant branch tip to a couple of magnitudes below the main sequence turn-off (see Fig. 1, left panel). Our sample also cover most of the cluster extension, from the inner core, out to the cluster outskirts.

The first epoch data were taken with FLAMES+GIRAFFE@VLT in 2003. The second epoch was taken in 2006 for all targets, and for ∼484 stars we repeated the observations

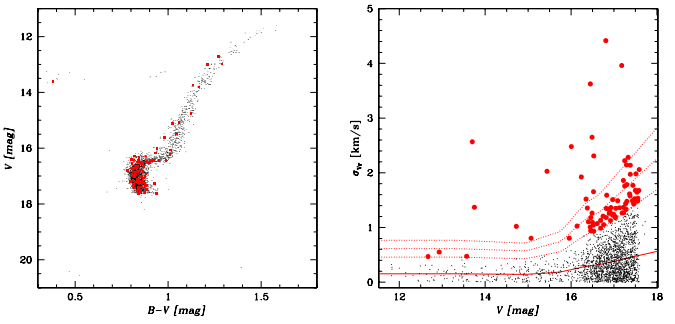

Figure 1. *Left panel:* The color-magnitude diagram of all the selected targets in M4 observed with FLAMES. The binary star candidates are indicated with large squares. *Right panel:* For all the stars in M4 which have been observed both in two epochs, we show the r.m.s. weighted by the fitting error to the cross-correlation function. The solid line is the average weighted r.m.s., which is the indication of the precision of the radial velocity measurement for non-variable stars. The dotted lines indicate 3, 4, and $5\sigma_{\rm Vr}$ of the scatter around the mean as a function of magnitude. The candidates are indicated with large dots.

after few weeks. The second run is used to detect soft binary candidates with long periods from the cluster center to its outskirts, and the third run to identify hard binaries with short periods inside the cluster core. All stars were observed with HR9 setup centered at 525.8nm. This instrumental configuration allows the highest spectral resolution (R = 25800) and the best radial velocity accuracy (Royer *et al.* 2002). The data reduction was done with the GIRAFFE BaseLine Data Reduction Software (girBLDRS 1.13, Blecha *et al.* 2000). The radial velocities were calculated by cross-correlating the stars' spectra with a numerical mask constructed from the solar spectrum. The mean radial velocity for the sample is 70.1±0.3 km/s.

3. Results

To search for a first, preliminary sample of candidate spectroscopic binary systems we plotted the r.m.s ($\sigma_{\rm Vr}$) in radial velocity as a function of magnitude. We paid attention to minimize all of the possible measurement errors (wavelength calibration, errors due to cosmic rays or bad pixels in the spectra, errors due to scattered light from cluster background and simultaneous lamp fibers). The stars presenting velocity differences more than $3\sigma_{\rm Vr}$ from the average for their magnitude were considered binary star candidates. In this preliminary analysis we found 95 candidates, which would imply lower limit for the binary fraction f = $8.2 \pm 2\%$ (8 binaries out of 97 targets) for r $\leqslant r_c$ (r_c is the cluster core radius), and f = $3.6 \pm 2\%$ (87/2372) $r > r_c$. Interestingly enough, in the parallel project for the search of photometric binaries, we found similar binary fractions. The binary candidates are shown in Fig. 1 (left panel) in the color magnitude diagram and Fig. 1 (right panel) with larger dots. The present reduction allowed us to identify binaries with velocity variations greater than 0.2 km/s for the brightest stars, and 0.5 km/s for the fainter TO stars. For the binary candidates, we plan follow-up observations for the orbital solution.

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