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Deep NIR photometry of the globular 47Tuc

L. Troisi[1,2], G. Bono[1,2], M. Dall'Ora[3], A. Calamida[4], A. Di Cecco[1,2], G. Iannicola[2], N. Sanna[1,2], P. B. Stetson[5], R. Buonanno[1], F. Caputo[2], C. E. Corsi[2], S. Degl'Innocenti[6], I. Ferraro[2], M. Nonino[7], M. Monelli[8], P. G. Prada Moroni[6], M. Romaniello[4], A. R. Walker[9], and M. Zoccali[10]

[1] Università di Roma "Tor Vergata", Via della Ricerca Scientifica 1, I-00133 Rome, Italy
e-mail: Licia.Troisi@roma2.infn.it
[2] INAF – OAR, Via di Frascati 33, I-00040 Monte Porzio Catone, Italy
[3] INAF – OAC, Salita Moiariello 16, I-80131Naples, Italy
[4] ESO, Karl-Schwarzschild-Str. 2, D-85748 Garching bei Muenchen, Germany
[5] DAO, HIA-NRC, 5071 W. Saanich Road, Victoria, BC V9E 2E7, Canada
[6] Università Pisa, Dipartimento di Fisica, Largo B. Pontecorvo 2, I-56127 Pisa, Italy
[7] INAF – OAT, Via G.B. Tiepolo 11, I-40131 Trieste, Italy
[8] IAC, Calle Via Lactea, E38200 La Laguna, Tenerife, Spain
[9] CTIO–NOAO, Casilla 603, La Serena, Chile
[10] PUC, Departamento de Astronoma y Astrofsica, Casilla 306, Santiago 22, Chile

Abstract. We performed accurate and deep NIR (J, K) photometry of the Globular Cluster (GC) 47Tuc using data collected with SOFI at New Technology Telescope (NTT) (ESO, La Silla). Data cover a significant fraction of the innermost regions of the cluster and the Color Magnitude Diagram (CMD) ranges from the red HB down to the lower Main Sequence (MS). In the faint magnitude limit, we clearly detected the knee, along the MS, caused by the Collision Induced Absorption. We found that this feature is located at $J\sim$ 18.45 and $J-K\sim$ 0.68 mag.

Key words. globular clusters: general, 47Tuc – Stars: fundamental parameters

1. Introduction

The determination of the absolute age of GCs is a key parameter in astrophysics, since it provides a lower limit to the age of the universe (Buonanno et al. 1998; Stetson et al. 1999; Gratton et al. 2003), robust constraints on the input physics adopted in stellar evolutionary models (Salaris & Weiss 1998; Cassisi et al. 1999; Castellani & Degl'Innocenti 1999; Dotter et al. 2007; VandenBerg et al. 2008) and on the timescale of the Milky Way formation. However, the age of GCs is still affected by uncertainties on distance modulus and reddening (Renzini 1991; Bono et al. 2008), on chemical composition (Gratton et al. 2004), metallicity scale (Rutledge et al. 1997; Kraft & Ivans 2003) and on photometric zero points (Stetson 2005). To overcome some of the quoted difficulties it has been suggested (Calamida et al. 2009) a new method based

Send offprint requests to: L. Troisi

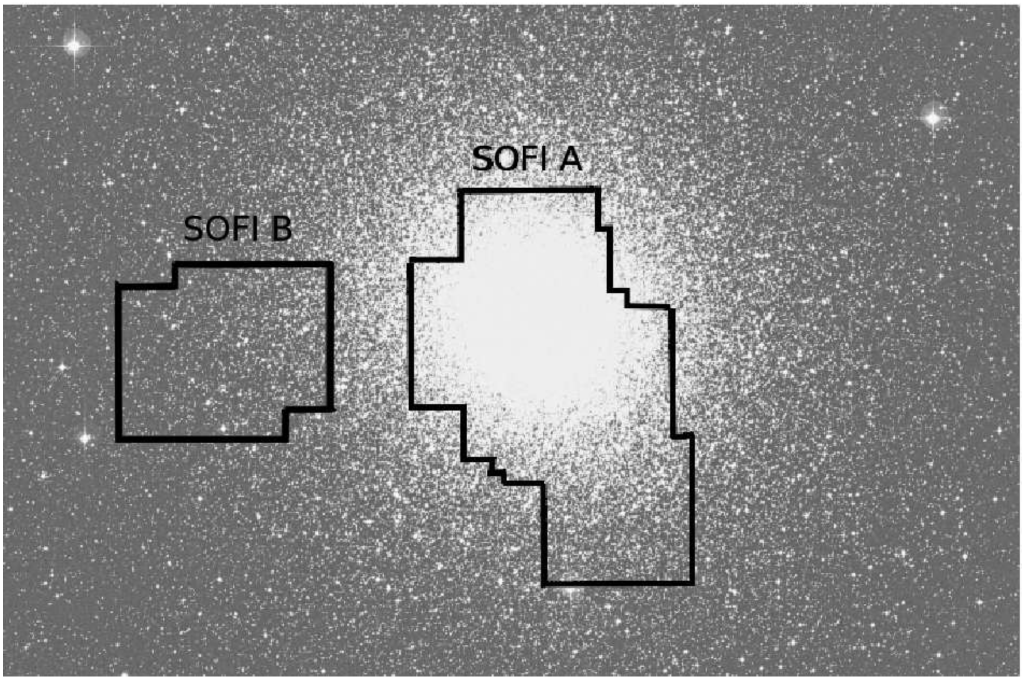

Fig. 1. The black solid lines display the central (right, SOFI A) and the off-center (left, SOFI B) pointing superimposed on a DSS image of 47Tuc.

on the magnitude/color difference between the MS Turn-Off (MSTO) and the MS knee (MSK) located in the faint portion of the MS. The presence of this bending along the MS is more evident in NIR CMDs (K,$J-K$), but it is also present in optical-NIR (K,$I-K$; K,$V-K$) and in some optical (I,$V-I$) CMDs.

The bending takes place in the low-mass regime ($M \lesssim 0.4 M_{\odot}$). The increase in the surface gravity and the decrease in the effective temperature cause an increase in the collision between neighboring H_2 molecules (Saumon et al. 1994). This phenomenon is called Collision Induced Absorption (CIA) and affects both the lower MS and the cooling sequence of white dwarfs (Richer et al. 2000). The knee along the MS was already detected in the GCs ω Cen and M4 (Pulone et al. 1998, 1999) and in the Galactic bulge (Zoccali et al. 2000) using accurate and deep J, H-band data collected with the NIR camera NICMOS available at the Hubble Space Telescope (HST). The color/magnitude difference between the MSTO and the MSK is correlated with the cluster age, since the latter feature minimally depends on the age. This means that the age estimates based on this method do depend neither on the distance modulus nor on the reddening and are minimally affected by uncertainties on cluster metallicity. The method has already been applied to the open clusters M67 (Sarajedini et al. 2009) and to the metal-intermediate GC NGC 3201 (Calamida et al. 2009). The latter authors found that current predicted NIR ($J-K$) colors appear systematically bluer (hotter) when compared with observations. The GC 47Tuc is a very good testing ground to constrain the quoted discrepancy, since it is a nearby system (μ_0=13.6 mag, see Harris 1996) suffering a modest reddening ($E(B-V)$ = 0.04, see Bono et al. 2008). Moreover, it is metal-rich ($[Fe/H]$ = −0.7), and has a slightly younger age ($\sim 11 Gyr$, see

Table 1. Seeing conditions of the SOFI data

Date	J-band	K-band
Nov. 2000	$0.64 \div 0.90''$	$0.61 \div 0.83''$
July 2002	$0.96 \div 1.69''$	$0.93 \div 1.47''$
July 2005	$0.78 \div 0.96''$	$1.02 \div 1.45''$

Gratton et al. 2003) when compared with typical Galactic GCs.

2. Observations and data reduction

Our data belong to two different data sets. The first one, SOFI A, covers the cluster center (see Fig. 1). The images were collected in three different runs: November 2000 (15J, 12K), July 2002 (60J, 60K) and July 2005 (4J, 11K). The second one, SOFI B, is off-center (see Fig. 1) and the images were collected in July 2005 (14J, 29K). All data were collected using the SOFI camera (Field of View, FoV, 5×5 $arcmin^2$, pixel scale=0.29 arcsec/pixel) available at the New Technology Telescope (NTT, ESO, La Silla). The seeing conditions of the different observing runs are listed in Table 1. We performed the photometry on each image using the `DAOPHOT VI/ALLSTAR` package, and simultanelously over each data set using `ALLFRAME` (Stetson 1994). A preliminary calibration was performed using a large sample of local standard stars (Stetson 2000). We ended up with two catalogs containing 19,074 (SOFI A) and 6,230 (SOFI B) stars, respectively.

3. Discussion and conclusions

The CMDs of the two data sets are shown in Fig. 2 (SOFI A) and in Fig. 3 (SOFI B). Data plotted in the former figure show that the CMD covers evolved (red horizontal branch [$J \approx 12.5$, $J - K \approx 0.4$-0.6], red giant branch bump [$J \sim 12.7$, $J - K \sim 0.65$]) and MSTO ($J \approx 16.7$) stars. The limiting magnitude of this CMD is shallower than for the SOFI B due to the severe crowding of the innermost regions. The CMD of the SOFI B field (see Fig. 3) is less rich than the CMD of the SOFI A field in the evolved phases, but it is a couple of magnitude deeper. Moreover, data plotted in Fig. 3

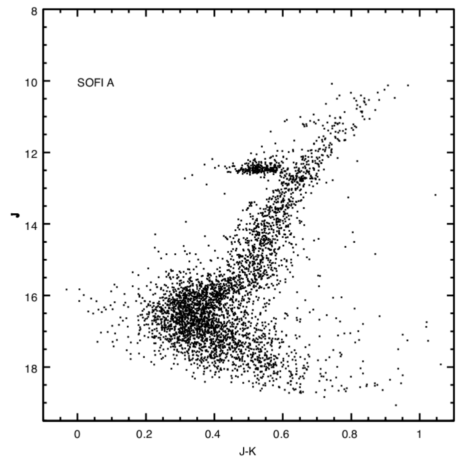

Fig. 2. CMD obtained for the SOFI A data set. Stars plotted in the CMD were selected according to photometric error (σ J<0.1, σ K <0.1) and sharpness (-0.1<sh <0.1)

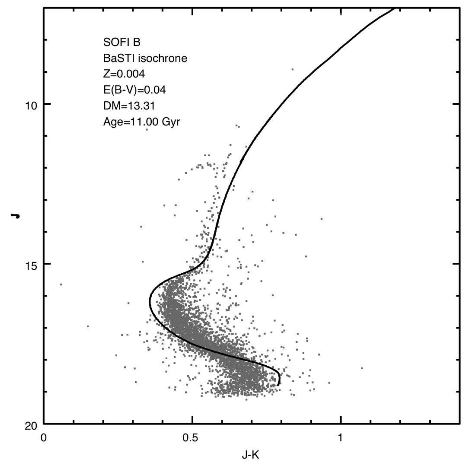

Fig. 3. CMD obtained for the SOFI B dataset. The solid line shows an isochrone from the BaSTI data set at fixed composition. The stars plotted were selected according to photometric error (σ J<0.04, σ K<0.04)

clearly show the occurrence of the MSK, that is the located at $J \sim 18.45$ and $J - K \sim 0.68$ mag.

To compare theory with observations we adopted the α-enhanced cluster isochrones

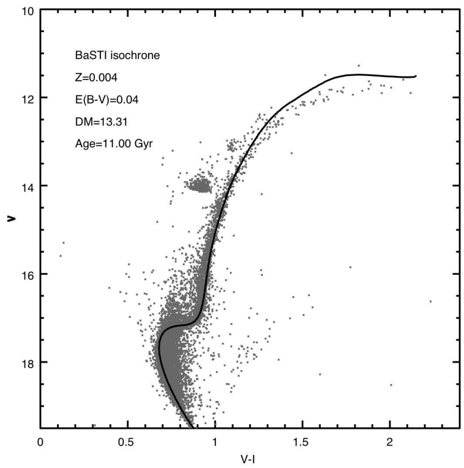

Fig. 4. Optical CMD of 47Tuc (Stetson 2000). The solid line shows the same isochrone of Fig. 3. The stars plotted were selected according to photometric error and sharpness.

available in the BaSTI database[1]. The solid line in Fig. 3 shows an isochrone at fixed age (t=11Gyr) and chemical composition (Y=0.251, Z=0.004). The isochrone was plotted assuming recent estimates of both distance and reddening (Bono et al. 2008). The comparison shows quite clearly a significant discrepancy between predicted and observed colors in the MSTO and in the MSK region.

To validate the cluster isochrone plotted in Fig. 3 we performed the same comparison using optical (V, I) data of 47Tuc (Stetson 2000). Fig. 4 shows the comparison with the same isochrone, but in the $V, V-I$ CMD. Data plotted in this figure show that the isochrone accounts not only for the color of MSTO stars, but also for the evolved evolutionary phases.

This finding supports the evidence that the discrepancy between theory and observations in the NIR CMD is mainly caused by the color-temperature (CT) relations adopted to transform predictions into the observational plane.

In the near future we plan to improve both the coverage and the precision of our photometry supplementing the current data with new deep NIR data collected with MAD and with HAWK-I available at Very Large Telescope (VLT, ESO, Paranal). The NIR data together with optical data available to our group will allow us to provide an accurate estimate of the absolute age of 47Tuc and to constrain the precision of current CT relations.

[1] Evolutionary models can be download from http://www.oa-teramo.inaf.it/BASTI

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