MAD Science Demonstration Proposal

The absolute age of the Galactic Globular Clusters

Investigators	Institute	EMAIL
A. Di Cecco	Rome II Univ.	dicecco@roma2.infn.it
G. Bono, A. Calamida	INAF–OAR	bono/calamida@mporzio.astro.it
R. Buonanno, N. Sanna	Rome II Univ.	buonanno/sanna@roma2.infn.it
E. Marchetti	ESO	emarchet@eso.org
M. Monelli	IAC	monelli@iac.es
S. Ortolani	Padua Univ.	sergio.ortolani@unipd.it
B. Stetson	DAO	Peter.Stetson@nrc-cnrc.gc.ca
A. Walker	CTIO	awalker@ctio.noao.edu

Abstract:
We plan to collect accurate and deep J, K-band photometry of the Galactic Globular Clusters (GGCs) NGC 6752 and NGC 7099. The new NIR data will provide the unique opportunity to constrain their absolute age with an accuracy of the order of 1 Gyr. The new NIR data together with deep optical data (HST, ground-based) will provide robust constraints on the nature of several X-ray sources that have already been identified using Chandra images in these GCs.

Scientific Case:
The absolute age of GGCs is the crossroad of several astrophysical problems. It provides (a) a lower limit to the age of the universe, (b) robust constraints on stellar evolutionary models, and (c) the chronology for the assembly of the halo, bulge and the disk of the Milky Way (Buonanno et al. 1998, A&A, 333, 505; Stetson et al. 1999, AJ, 117, 247; Rosenberg et al. 1999, AJ, 118, 2306; Salaris et al. 1998, A&A, 335, 943; Gratton et al. 1997, ApJ, 491, 749; de Angeli et al. 2005, AJ, 130, 116). The GC NGC 6752 is a corner-stone in the estimate of the absolute age of GCs. Estimates of its distance (DM_0=13.05) were provided using the white dwarf cooling sequence (Renzini et al. 1996, ApJ, 465, 23) and the main-sequence fitting (Gratton et al. 2003, A&A, 408, 529). Measurements of reddening (E(B–V)=0.04), iron ($[Fe/H] = -1.4$) and α-elements ($[\alpha/Fe] \sim 0.4$) are available. The absolute age of the extremely metal-poor ($[Fe/H] = -2.1$) GC NGC 7099 were provided by Bergbusch (1996) using isochrones and the luminosity function. Estimates of distance ($DM_V \sim 14.83$) and reddening (E(B–V)=0.03) are available. However, the estimates of the absolute age of GCs is still hampered by uncertainties affecting the distance modulus and the reddening. The problem of the cluster distance is even more severe for GCs including only a few (3, NGC 7099) or no (NGC 6752) RR Lyrae stars (blue HB morphology). We selected NGC 7099 and NGC 6752, since we already have accurate and deep optical photometry (see Fig. 1).
Based on NIR photometry collected with MAD@VLT for the NGC 3201— a GC affected by differential reddening— our group showed that the hook of the lower MS, caused by the H_2 opacity, can be used to estimate the absolute age of GCs (see Fig. 2). The difference in color between this feature and the turn-off (TO) is strongly correlated with the cluster age. This method presents several advantages: *i)* it is minimally affected by distance and reddening uncertainties, since the color excess E(J–K) is ≈ 2.5 smaller than the color excess in E(V–I); *ii)* the hook does not depend on the cluster age and it is a robust prediction, since in this mass range ($\leq 0.3 M_{\odot}$) the convection is adiabatic (no mixing lenght).
The image quality and the spatial resolution of MAD are mandatory to perform accurate photometry in crowded regions of post-core-collapsed GCs. Our group has already been involved in the reduction of J, K_s-band data collected with MAD and provided the deepest $K, J-K$ CMDs for ω Cen and NGC 3201.

Immediate objectives

• The new NIR data and the method outlined above will allow us to constrain the **absolute** age with an accuracy of ≈ 1 Gyr. We also plan to cross-correlate optical and NIR catalogs and to provide indipendent **absolute** age estimates using the TO region in the $K, V-K$ CMD. We plan to collect MAD data for six GCs covering a wide range in metallicity: NGC 3201, NGC 288 already observed, NGC 6352, NGC 6496 are the subject of companion proposal (PI: N. Sanna). The homogeneity of the NIR-optical data will allow us to constrain age differences to ≈ 1 Gyr.

• The new NIR data and the time coverage of our optical data will allow us to constrain the nature of the X-ray sources in NGC 6752 (19, Pooley et al. 2002) and NGC 7099 (13, Lugger et al. 2007).

• The stronger temperature sensitivity of the $V-K$ color will allow us to constrain the binary fraction and the accuracy of current color-temperature relations.

Targets and integration time

Target	RA	DEC	Filter	Magnitudes	Total integration time (sec)	Field (arcmin)
NGC 6752	19 10 52.0	-59 59 05	J, K_s	$10-21$	2×6240	2×1
NGC 7099	21 40 22.0	-23 10 45	J, K_s	$10-21$	2×7200	2×1

Guide stars list and positions:

Note that we listed only five guide stars per GC, but we found within 2 arcmin 11 guide stars with $V \leq 12$ for NGC6752 and 7 with $V \leq 13$ for NGC7099.

NGC 6752	RA''_{rel}	DEC''_{rel}	V	NGC 7099	RA''_{rel}	DEC''_{rel}	V
GS1	**+21**	**-10**	**11.36**	**GS1**	**-25**	**+35**	**11.99**
GS2	**+24**	**+47**	**11.56**	**GS2**	**-5**	**+50**	**12.42**
GS3	**-43**	**+29**	**11.63**	**GS3**	**+35**	**+20**	**12.04**
GS4	**-32**	**-21**	**10.76**	**GS4**	**-51**	**-8**	**12.55**
GS5	**-8**	**+42**	**10.80**	**GS5**	**+34**	**-23**	**12.78**

Time Justification:

We plan to collect NIR data in two pointings located across the cluster centres. For each pointing we plan to collect J, K_s-band data four magnitudes below the TO with $S/N \approx 10$. Based on our experience with NGC 3201 data, we estimate the following exposure time per field for NGC 6752 ($\mu \sim 13.05$):
t(K_s)= 5 (images) $\times$ [10×24 (target) + 10×24 (sky)] + 1200 (acquisition)=3600 sec
t(J) = 3 (images) $\times$ [10×24 (target) + 10×24 (sky)] + 1200 (acquisition)=2640 sec
and for NGC 7099 ($\mu \sim 14.8$) are:
t(K_s)= 6 (images) $\times$ [10×24 (target) + 10×24 (sky)] + 1200 (acquisition)=4080 sec
t(J) = 4 (images) $\times$ [10×24 (target) + 10×24 (sky)] + 1200 (acquisition)=3120 sec
The total time per pointing are 1.73 h (NGC 6752) and 2 h (NGC 7099), thus the total time we request for the two clusters is $t_{tot} = 7.5$h.

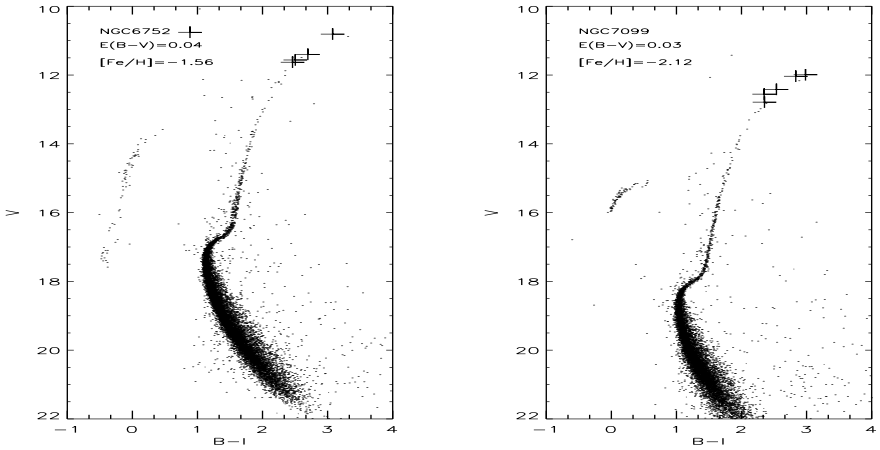

Figure 1: $V, B-I$ Color-Magnitude Diagrams of NGC 6752 (left) and NGC 7099 (right) based on our ground-based photometry. The plus signs mark the position of the guide stars.

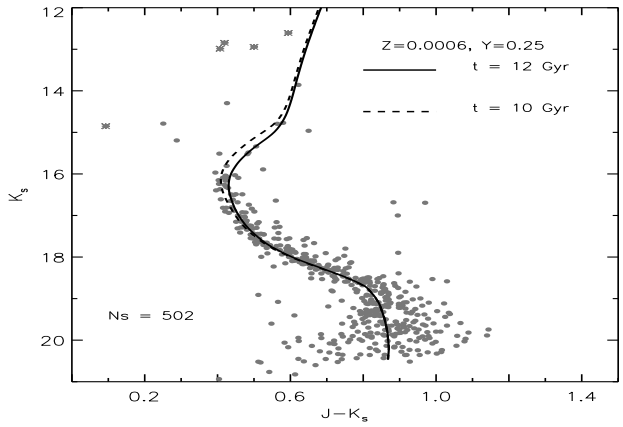

Figure 2: Color-Magnitude Diagram of NGC 3201 based on a single MAD pointing. Both data reduction and calibration are preliminary. The dashed and solid lines show two cluster isochrones (10, 12 Gyr) at fixed chemical composition (Castellani et al. 2007). The asterisks display HB stars.The hook in the lower MS is located at $K_s \sim 19$ and $J - K_s \sim 0.85$ mag.