MAD Science Demonstration Proposal

Towards the determination of the Galactic Bulge formation timescale

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Abstract:
We propose deep J, K observations to estimate the age of the Bulge Globular Cluster (GC) NGC 6441 from the direct measurement of the Main Sequence Turn Off (MS-TO).
The age of NGC 6441 will represent an important step towards a detailed and quantitative characterization of the Bulge cluster population, and a better understanding of Bulge formation time-scale.
Moreover, a direct comparison between MAD data and the existing optical space-based observations (WFPC2@HST) will also give useful insight into the spatial resolution and photometrical capabilities that we will be able to reach with next generation ground-based telescope equipped with MCAO systems.

Scientific Case:
As we now properly realize the Bulge globular clusters (GCs) are part of a distinct sub-system, there is the need to properly characterize their evolutionary sequences and to determine their ages and chemical composition. Bulge GCs are *key templates* of simple stellar populations to study the stellar and chemical evolution in the high metallicity domain (see e.g. McWilliam 1997, ARA&A, 35,503; Matteucci, Romano & Molaro 1999, A&A, 341, 458; Wyse 2000, APSS, 267, 145) and for accurate population synthesis of giant elliptical galaxies. Furthermore, inferring the main properties of the Bulge and comparing them to those of other components of the Galaxy is a fundamental step to unveiling the process of Galaxy formation.
However, the observational information available on the chemistry, kinematics and age of the Bulge clusters population is still quite incomplete, especially when comparing them with the well studied Halo GCs system. This is mainly due to the fact that the Bulge is heavily obscured by dust and contaminated by stars associated to the foreground disk. The high and extremely non-uniform extinction over most of the Bulge extension, makes optical observations difficult or even impossible along most lines of sight (the extinction ranges from 1 to 50 visual magnitudes in the Galactic center). For this reason the IR spectral range is the most suitable to study these regions.

While in the last decade a major step forward had been achieve in order to better establish the chemical composition and the photometric properties of the Bulge GC system, the ages of many clusters are still poorly known. In fact, up to date only 5 Bulge clusters have relatively good age determinations from the Turn-Off (TO) photometry obtained by using WFPC2 and NICMOS on board HST (see Ortolani et al. 1995, Nature 377, 701; Heasley et al. 2000, AJ 120, 89; Ortolani et al. 2001, A&A 376, 878, Zoccali et al. 2001, AJ 121, 2638; Cohn et al. 2002, ApJ 571, 818). These works suggest that at least this sub-sample of clusters, namely NGC 6528, NGC 6553, Ter 5, NGC 6624 and NGC 6637, should be coeval with the well studied Halo GC 47 Tuc. So, more precise dating is still lacking and more effort on this problem is warranted in order to try to establish a scale of relative and absolute ages for the Bulge GCs system, as that already existing for the Halo system (see Rosenberg et al. 1999, AJ, 118, 23006; Rosenberg 2000, PASP, 223, 575; De Angeli et al 2005, AJ, 130,116).

Targets and integration time

NGC 6441 is a high density (logρ=5.8, Djorgovski 1993), massive (M_V=-9.64, Harris 1996) and moderately reddened (E(B–V)=0.52, Valenti, Ferraro & Origlia 2007) cluster located in the outer Bulge region. Since the discovery by Rich et al. (1997) of an extended blue HB in its HST CMD, NGC 6441 has been subject of several optical photometric studies (see e.g. Moehler et al 1999; Piotto et al. 2002; Busso et al. 2007; and reference therein) aimed at explaining this puzzling feature. In fact, given its high metallicity ([Fe/H]=-0.50, Origlia, Valenti & Rich 2008), one would expect for this cluster a canonical HB morphology such a red clump, compressed against the RGB, and not a component that extends blueward across the instability strip and terminates in a blue tail. None of the photometric studies available in the literature have explored this cluster down to the MS-TO.

Here we propose a program which exploits the potential of MAD to derive the age of this Bulge GC from the direct measure of the TO level. For this reason we need deep and high resolution photometry down to J=22.5 and K=21.5 of a 1'×1' field located 47" from the cluster center.
The presence of several RR Lyrae variables in this clusters will also allow us to obtain an accurate estimate of the distance modulus, thus reducing significantly the error on the derived age. In fact, by splitting the observations in long exposures - to reach 2 mag below the TO - and short exposures - in order to not saturate the HB - we could have at least three phase points of the bright known RR Lyrae variables. In particular, we plan to perform the short exposures by using the *"mosaic template"* with 5 pointing, in order to cover an area of 2'×2'. Due to very low light curve amplitudes in K band, these few phase-points will be enough to fix the K mean magnitudes, allowing us to accurately derive the distance modulus with an uncertainty less than 0.07 mag by using the Period-Luminosity-[Fe/H] relation in K band (Dall'Ora et al. 2007).
So these observations will not only provide the first determination of the age, but also the most accurate distance modulus, providing very solid basis for further studies of this very peculiar bulge GC.
Only with the high spatial resolution and diffraction limited performances provided by MAD over a moderate-large FoV (1'×1') we can obtain very deep and accurate photometry of such a crowded and reddened field. We plan to use those date to test a new version of STARFINDER (Diolaiti in prep.), software specifically designed to perform PSF-fitting of crowed field AO images, and comparing the results obtained on different instrument images, such NACO.

Target	**RA**	**DEC**	**Filter**	**Magnitudes**	**Total integration time** (sec)	**Field** (arcmin)
NGC 6441	17 50 09.55	-37 03 28.90	J	J=16-22.5	1200	1
NGC 6441	17 50 09.55	-37 03 28.90	K	K=15-21.5	3600	1
NGC 6441	17 50 09.55	-37 03 28.90	J	J=14-20	100	2x2+1
NGC 6441	17 50 09.55	-37 03 28.90	K	K=13-19	100	2x2+1

Guide stars list and positions

The distance of the guide stars from the center of the target, and their V magnitudes are listed in the table below. Note that we are aware that the magnitude of the stars named GS2 and GS3 are very close to the limit *"exceptionally considered"* for the AO stars (see User Manual, § 5), but given the difficulty in finding a good bright asterism in V band in this reddened environment, we agree on a degradation of the typical correction performance.

Target: NGC 6441			
	$\mathbf{RA}''_{rel}$	$\mathbf{DEC}''_{rel}$	**V Mag**
GS1	-20.0	-29.8	10.26
GS2	-13.8	15.3	12.70
GS3	27.2	18.0	13.00

Time Justification:

As already mentioned above, we are planing to perform *i)* deep J,K imaging of an area of 1'×1' (i.e. only one pointing), and *ii)* short exposure observations to map a field of 2'×2' (i.e. five pointing), centered about 47" from the cluster center.
By using the ISAAC ETC Version 3.2.1 with a 0.1" seeing and 1.2 airmass, adopting DIT=10s for the deep observations, 600s and 1800s are required to get S/N≥25 at $J = 22.5$ and $K = 21.5$, respectively. For the short exposures, we will need only 50s, both in J and K. Given the crowdedness of the field, we need to observe sky offset positions for background subtraction purpose. Following the formula listed in the MAD User Manual, for a total of four OBs (two per band), we estimate ∼6000s of overheads. Considering the science exposures time and the overheads (acquisition included), the total time required to completed the project is **3.5 h**.