Deep NIR photometry of NGC 5904 with GeMS/GSAOI

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Introduction

Here, we study the intermediate-metallicity globular cluster (GC) NGC 5904 (M5) from deep near-infrared (NIR) band (J, Ks) imaging taken with the Gemini multi conjugate adaptive optics system (GeMS). This globular cluster is a part of an ambitious ongoing survey to provide a comprehensive database of deep NIR photometry of galactic globular clusters and to map their internal proper motions when combined with archival HST ACS imaging. Internal proper motions can be used to study any orbital anisotropy to determine the cluster's geometric distance, search for signatures of rotation, and possibly provide constraints for a central intermediate mass blackhole. NIR photometry doesn't suffer from differential reddening and the lower part of the color magnitude diagram (CMD) shows a characteristic "S" shape known as main-sequence knee (MSK) which serves as absolute age indicator due to its independence on distance, extinction and photometric calibration. In recent *Hubble Space Telescope (HST) surveys* many GCs have been found to be harboring multiple stellar populations (MSP) with different chemical abundances challenging our basic assumption of stellar evolution models of GCs formed of coeval stars with virtually same chemical composition. The lower main sequence in NIR-CMD can be used to look for binary fractions and mass segregation which provide a dynamical fingerprint of the formation epoch and evolution of MSPs (see Piotto et al, 2015 and reference therein). In this poster we present our preliminary photometric analysis of NGC 5904 which also known to harbors MSPs, including the deepest NIR CMD obtained from ground.

Observation

Data was obtained in 2014 along with other six GCs. It contains 8 exposures of 160 second, single exposure of 90 second and 21.5 second for each J and Ks band. Below we show an exemplary image of the M5 taken with GeMS detector which is made of four chips. The combined field of view (FOV) of the detector is 85"x85".

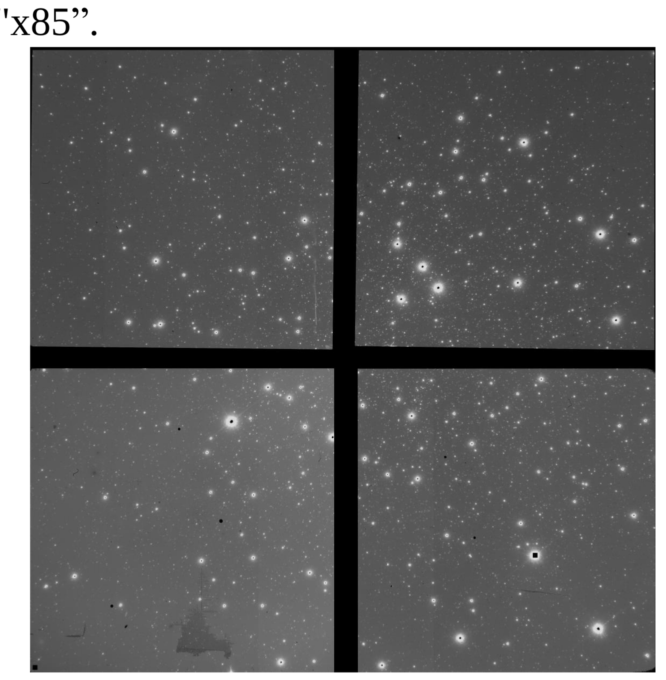

Figure 1: A typical image of M5 from GeMS infrared camera.

Method

A combination of Gemini IRAF package and DAOPHOTII was used for data analysis. The methods used here are described in Turri et al. (2017) and briefly summarized below.

PSF Variability

Unlike classical adaptive optics (AO), multi-conjugate adaptive optics (MCAO) systems provide a relatively uniform, near-diffraction-limited correction over a wider FOV. However, there is still variation in the point spread function (PSF) across the GeMS FOV, especially at the edge of the field where the MCAO correction starts to drop off. We can see this by comparing the center and edge of FOV as shown in the Figure 2. Considering this, we used a quadratically variable PSF model.

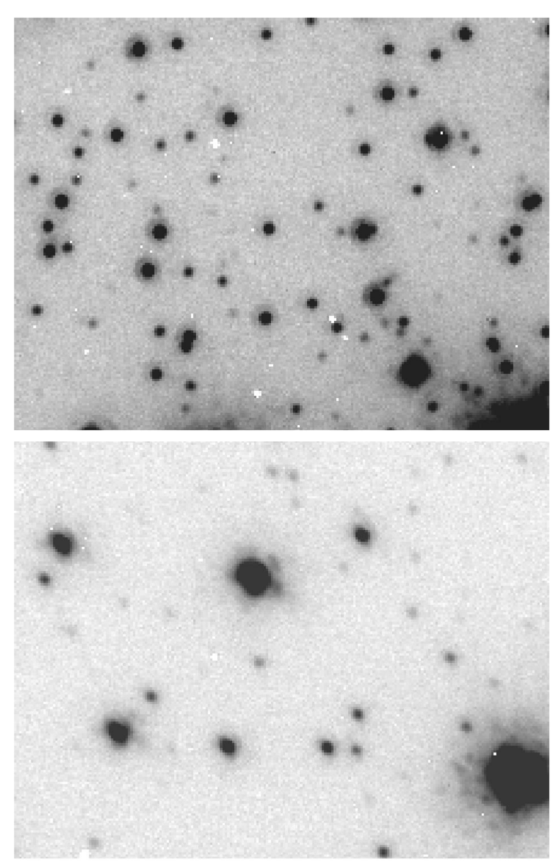

Figure 2: Portion of a chip at the center (top) and at the edge (bottom) of field of view. We can see that in the center, the PSF has a round shape while it is elongated at the edge of the chip.

Photometry

Profile-fitting photometry was performed in sequential steps to obtain the best PSF model for each chip and exposure. In the first step we allowed DAOPHOT to select the PSF stars automatically which are used to model the PSF for the whole field. However, it didn't perform optimal photometry due to crowding of the field, so we selected 100 PSF stars manually from each chip that were better suited for modelling the PSF. These PSF stars were selected on the criteria that they were not too faint (>2500 ADU) or too bright (< half of threshold ADU value used), weren't too close to bright or saturated stars and were distributed uniformly across the FOV (see fig. 3).

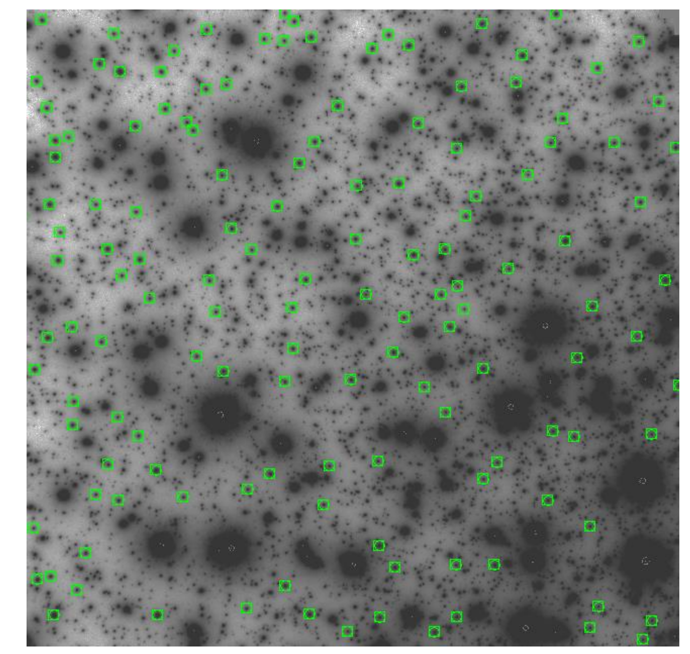

Figure 3. Selection of PSF stars in one chip.

In Figure 4, we show example images of chip #3 for J and Ks band before and after the PSFs have been fitted and stars removed from the field. As expected, J band photometry has higher residual comparing to Ks due to the relatively poor Strehl ratio of the AO corrections.

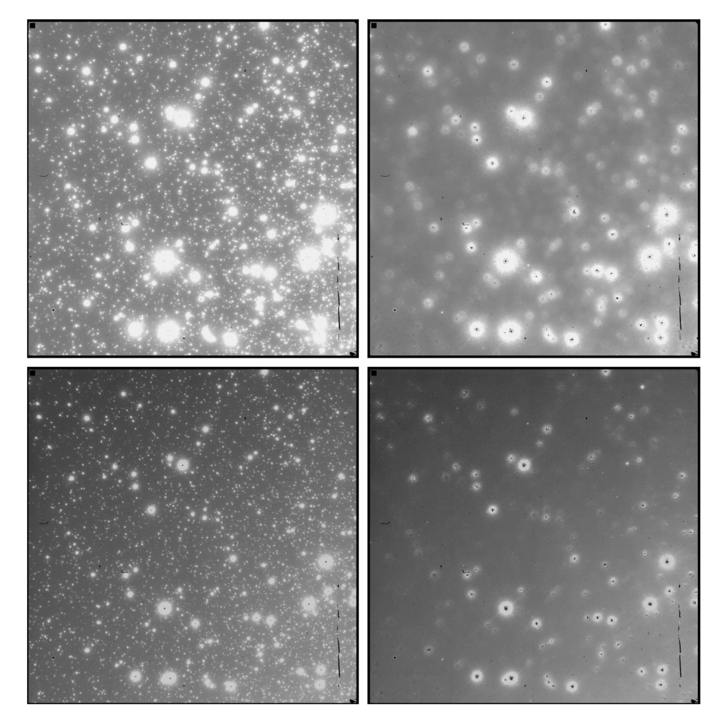

Figure 4: Top panels (left to right): J band image before and after the PSF subtraction for one of the exposures of chip 3. Bottom panels (left to right) show the same for Ks band.

Photometric calibration

A standard photometric catalogue was matched with GeMS instrumental magnitude catalogues for each chip and exposure using daophot package to find stars common in both catalogues. However, due to the crowding of the region and seeing limitation, groups of neighbouring stars that were resolved in GeMS FOV remained unresolved in the photometric catalogue. Therefore, multiple stars in GeMS catalogues were falsely detected as a single star in photometric catalogue. This can be seen as the spurious region towards the fainter magnitude in the figure 6. These false detection contaminated the final photometry and currently we are working to mitigate this issue.

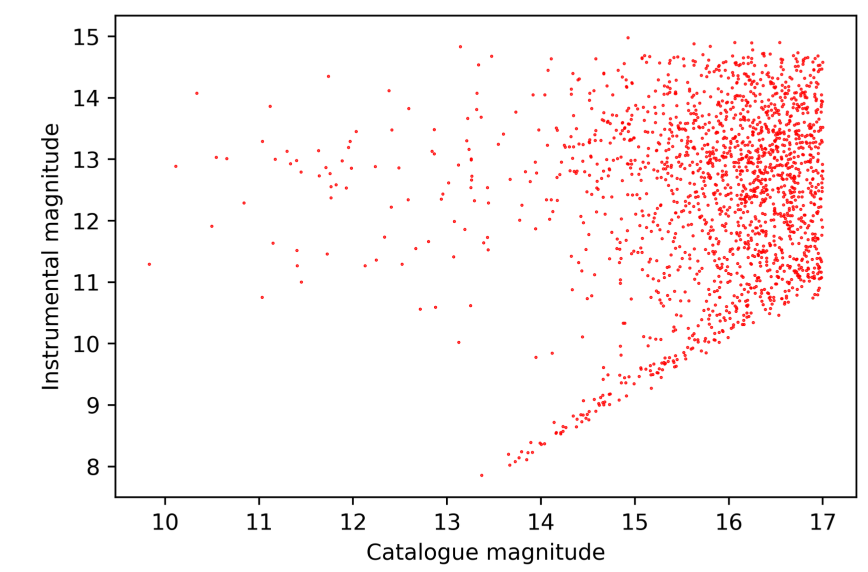

Figure 5: Instrumental vs catalogue magnitude obtained for a single chip GeMS. Beyond the expected linear correlation we can see a significant false detection.

Result and discussion

In the Figure 6, we present the photometric calibrated deepest NIR CMD in J-Ks band fitted with Dartmouth isochrone with parameters close to standard values available from literature (Horta et al. 2020, Coppola et al. 2011). Despite errors due to photometric calibration, our CMD fits well with standard parameters and reaches deep enough to clearly show the main sequence knee (MSK) that is not seen before. Recent surveys of 4 globular clusters in NIR using the *Hubble Space Telescope* has revealed that MSK for all clusters split into multiple sequences due to different abundances of Y, C, N and O, and can be associated with corresponding MSPs observed earlier in UV-visible band. In the Figure 7 (adapted from Milone et al., 2019) we have shown lower part of CMD in NIR (F110W, F160W) for NGC 6752 showing multiple sequences which is also known to harbor MSPs in earlier *HST UV-VIS legacy survey*.

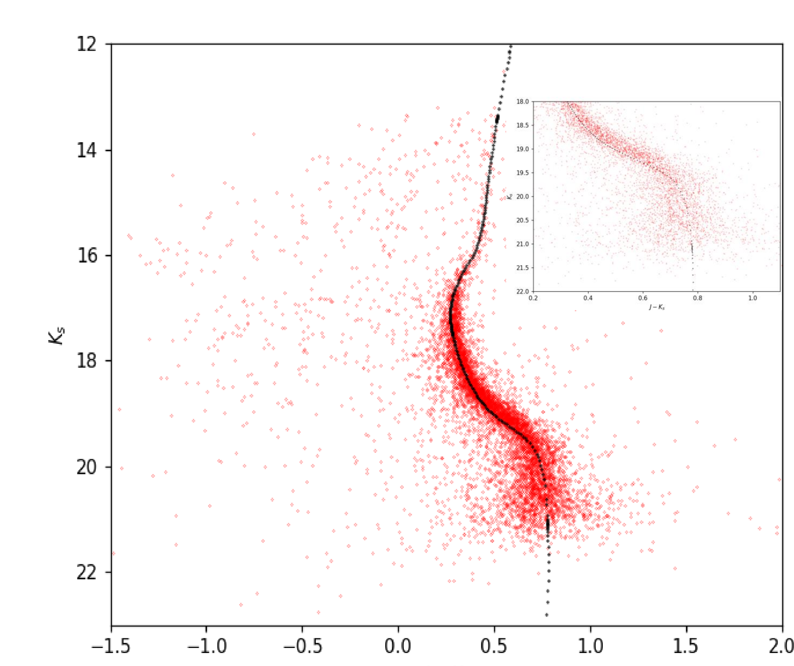

Figure 6: Left panel: Deepest CMD in JKs band with Dartmouth isochrone fitted with following para-meters: distance = 14.2 mag, age = 11.5 Gyr, [Fe/H] = -1.20, Y = 0.33 and [α/Fe]=0. Inset zooms in on MSK.

From the same survey NGC 5904 is known to harbor MSPs and it is possible that its MSK (inset in fig. 6) corresponds to multiple sequences with different chemical abundances suggesting a more complex formation history.

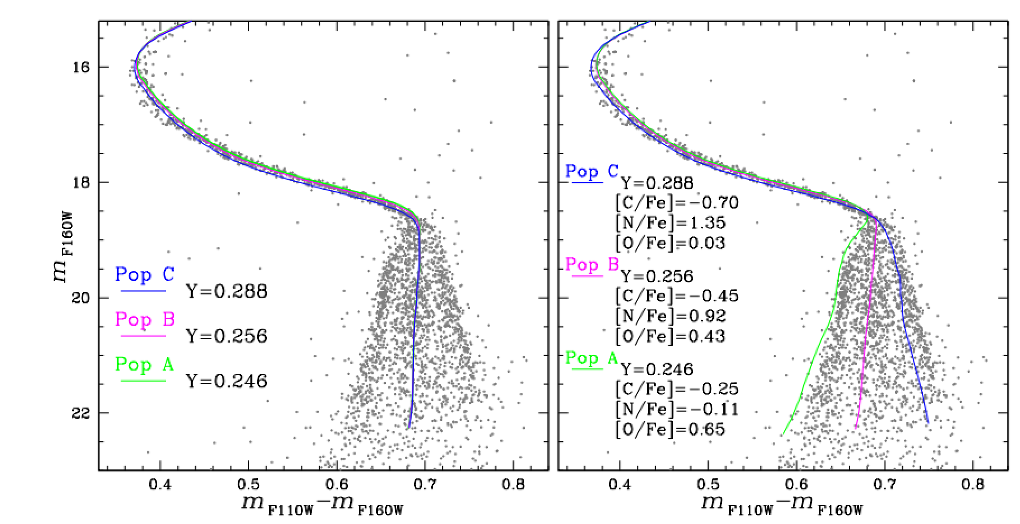

Figure 7: CMD of NGC 6752 in HST F110W, F160W filters with Dartmouth isochrones overimposed with different helium abundance. In the left panel, we assume the same abundances of C, N and O. In the right panel isochrones account for the C, N and O abundances of multiple populations (figure adapted from Milone et al. 2019)

Future work

- Combining our data with exquisite HST photometry of M5 in visible band to study the lower main sequence.
- Creating the first ground based internal proper motion map of member stars by combining two epochs of NGC 5904 observed with GeMS.

Acknowledgement

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Background image:
https://www.nasa.gov/content/hubbles-messier-5