TOWARD PRECISION PHOTOMETRY FOR THE ELT ERA: THE DOUBLE SUBGIANT BRANCH OF NGC 1851 WITH THE GEMINI/GeMS MCAO SYSTEM


THE ACS SURVEY OF GALACTIC GLOBULAR CLUSTERS. III. THE DOUBLE SUBGIANT BRANCH OF NGC 1851


Kimihiro Yamazaki
Akiyama group M2
1. INTRODUCTION
1.1 GeMS

*Gemini Multi-conjugate Adaptive Optics System*

- First facility-class Multi-Conjugate Adaptive Optics (MCAO) instrument on the Gemini South Telescope on Cerro Pachón (Chile)
- Two deformable mirrors (DMs) and five sodium laser guide stars (LGS)
- Corrected field of view of 83” × 83”
- Gemini South Adaptive Optics Imager (GSAOI) Mosaic of 2 × 2 HAWAII-2RG chips
  Pixel scale of 0”.01962/px
2. SCIENCE TARGET – NGC1851

THE ACS SURVEY OF GALACTIC GLOBULAR CLUSTERS. III. THE DOUBLE SUBGIANT BRANCH OF NGC 1851


First identification of the double subgiant branch feature of NGC1851
2.1 Background

For many decades, globular clusters (GCs) have been considered the simplest stellar populations.

- Stars located at the same distance, formed at the same epoch, from the same material

However, this paradigm has been seriously challenged by the discovery of multiple evolutionary sequence.

ex) ω Centauri, NGC2808 ⇒ the presence of multiple main sequence

Hubble Space Telescope (HST) Treasury program GO-10755 (Serajedini et al. 2007) provides a unique opportunity to search for anomalies in the different evolutionary sequence of Galactic GCs.

⇒ one other candidate: NGC1851
2.2 Observations

- HST Advanced Camera for Surveys (ACS) imaging
  Wide Field Channel (WFC) images in the F606W and F814W bands
  Taken for GO-10775 (PI: A. Sarajedini)

- HST Wide Field Planetary Camera 2 (WFPC2) archive data
  GO-05696 (PI: R. C. Bohlin)
  Extend the wavelength range to the blue
  Obtain proper motions

**TABLE 1**
Description of the Data Sets Used in This Work

<table>
<thead>
<tr>
<th>Date</th>
<th>Exposures (s)</th>
<th>Filter</th>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WFPC2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1996 Apr 10</td>
<td>4 x 900</td>
<td>F336W</td>
<td>5696</td>
</tr>
<tr>
<td><strong>ACS WFC</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006 Jul 1</td>
<td>20 + 5 x 350</td>
<td>F606W</td>
<td>10775</td>
</tr>
<tr>
<td>2006 Jul 1</td>
<td>20 + 5 x 350</td>
<td>F814W</td>
<td>10775</td>
</tr>
</tbody>
</table>
2.3 Result
Color Magnitude Diagram

① Color Magnitude Diagram (CMD) F336W magnitudes (WFPS2) & F814W magnitudes (ACS)
② Proper-motion diagram
③ magnitude of proper-motion vector
④ CMD of proper-motion-selected sample

Isolate the stars that have member-like motion (Left of the line)
CMD around the SGB
SGB Population Ratios

- Fitted Gaussians to magnitude distributions of the bSGB and fSGB

bSGB : 55%
fSGB : 45%
Spatial Distribution of the SGB stars

- Stars from both groups have similar spatial distributions.
- Cumulative radial distribution: this large would occur 11% (Kolmogorov-Smirnov statistic).
- Two SGBs have the same distribution.
The Horizontal-Branch Stars

- Bimodal Horizontal Branch (HB)
  - Red HB: 63% ± 7%
  - Blue HB: 37% ± 9%

- Cumulative radial distribution
  \[ \Rightarrow \text{this large would occur 17\% (Kolmogorov-Smirnov statistic)} \]

No indication of a difference
2.4 The Age of the Two Populations

- A narrow MS (the dispersion is less than 0.04 mag) implies the following hypothesis

  1. Two SGB population have some combination of abundances that results in no MS split

- SGB split
- Narrowness of the MS
- No evidence of red giant branch (RGB)

As a mere working hypothesis,\

- Increase \([\text{Fe/H}]\) by 0.2 dex
- Change helium abundance \(Y\) from 0.247 to 0.30

⇒ However, the HB feature seems to be rule out such a unlikely coincidence

2. Two SGB population have the same metallicities and the same helium abundances

Two SGBs are separated vertically by ~0.1 mag in F606W
⇒ corresponds to an age difference of =1 Gyr, with the fSGB older than the bSGB
2.5 Discussion

- The SGB split is not the only observational evidence of the presence of multi-population in NGC1851.
  - Bimodal HB (⇒ age difference of 2 – 3 Gyr)
  - Three out of eight of their bright RGB stars show “extraordinarul strong” CN bands (Hesser et al. 1982)
  - Broadest RGB (bimodality) in the CMD published by Grundahl et al. 1999, based on Strömgren photometry
    - (Increased CNO abundance (⇒ possible consequence for a second generation of stars))
- NGC1851 is the third GC for which we have direct evidence of multiple stellar generations.
2. DATA

- NGC1851 image
  - GeMS/GSAOI Science Verification phase (2012)
  - J (λ=1.235μm) and Ks (λ=2.159μm) bands

- Cross-matching every detection to the catalogue from ACS Survey of HHCs (Sarajedini et al. 2007)
- Median seeing : 0″.77
- Average corrected FWHM : 0″.06
- 12 dithered sub-exposures of 160s
  ⇒  total time = 75 minutes
- 2 short exposures of 21s & 90s
- Reddening correction
  ⇒  E(B-V)=0.02 , Harris 1996, 2010 edition

↑ Obtained NGC1851 image
3. RESULT

Position of the three NGSs

Position of the five LGSs

Field of view of 83” × 83”

Spatial resolution of Gemini in the NIR and HST in the optical is comparable.
CMD for NGC1851

Main sequence turnoff (TO)

Knee
Double SGB Branch

“The fact that this feature is visible in the center of NGC1851 using the $K_s$ band data from GeMS is a verification of our small photometry uncertainties which demonstrates significant promise for the successful exploitation of MCAO”
4. CONCLUSION

- We present first result from a study of the core of NGC1851 using the GeMS MCAO system on Gemini South.
  - We have used this cluster as a benchmark of the quality of the MCAO photometry
- In Color-Magnitude Diagram (with the HST F606W band)
  - “Knee” in the lower main sequence
  - Double SGB feature
- This study implies that high precision photometry can be achieved from the ground and can inform the development of data processing techniques and observing strategies to ensure the ELT deliver their full scientific promise over extended field of view.