Multiple stellar populations from the HST UV Legacy Survey in the moderately metal-poor Bulge globular clusters NGC 6717, NGC 6723 and NGC 6652

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Abstract. In the present work we selected three Bulge globular clusters with blue (NGC 6717 and NGC 6723) and red (NGC 6652) horizontal branches, all of them moderately metal-poor ([Fe/H] ≈ -1.00). We analysed optical and ultraviolet images obtained in the UV-Legacy Survey programs GO-13297 and GO-10775 with the Hubble Space Telescope (HST). Color-magnitude diagrams (CMDs) for the globular clusters NGC 6717 ([Fe/H] = -1.26), NGC 6723 ([Fe/H] = -1.10) and NGC 6652 ([Fe/H] = -0.81) are built, applying the artificial colors. Using BaSTI stellar evolutionary models and statistical isochrone fits on the optical CMDs, we recovered the main physical parameters for each cluster. We also obtained evidence of multiple stellar populations in these clusters, through the so-called Chromosome Maps and they are of Type I.

Keywords. Galaxy: bulge – Methods: statistical – globular clusters: individual: NGC 6652, NGC 6717 and NGC 6723

1. Introduction

Globular clusters (GCs) are physical systems of typically hundreds of thousands of stars that are being held together by gravity. Since they were formed during the first Gyrs of the universe they can be used as tracers of the early formation and evolution of the Milky Way. Among the GCs, those located in the most central and obscure Galactic structural component – the Bulge – are still the less studied ones. Furthermore, the Bulge GCs are probably the oldest objects of the Galaxy, especially those moderately metal-poor with blue horizontal branch (HB).

For a long time astronomers believed that GCs were made of only one stellar population (stars with the same age/chemical composition), but the Hubble Space Telescope provided evidence of more than one population in almost any GC. So the study of multiple stellar populations in GCs has been revolutionizing the understanding of the formation and evolution of stellar systems in general.

High-resolution spectroscopy have been demonstrated that there are significant chemical abundances variations from one stellar population to other, supporting the multiple population scenario. An appropriate choice and combination of UV filters is very sensitive to CNO variations, clearly splitting the multiple stellar population.

Color-magnitude diagrams (CMDs) combining optical and ultraviolet (UV) filters allow us to investigate the presence of multiple stellar populations in star clusters as well as their physical parameters such as age, metallicity, distance, reddening and helium abundance. In the present work we selected three bulge globular clusters with blue (NGC 6717 and NGC 6723) and red (NGC 6652) horizontal branches, all of them moderately metal-poor. This project consists to characterize the galactic GCs as in terms of astrophysical parameters as well in terms of multiple stellar populations.

2. HST Data

The data were obtained from HST by means the UV Legacy Survey (GO-13297, PI Piotto) and ACS GCs Treasury Program (GO-10775, PI Sarajedini) programs.

We used the UV filters (F275W, F336W, F438W) of the Wide Field Camera 3 (WFC3) and the optical filters (F606W, F814W) of the Wide Field Camera of Advanced Camera for Survey (WFC/ACS). A correlation for CNO elements abundances is clearly observed using the UV filters (see Piotto et al. 2015, their Fig. 1).

3. Methods

Since the UV filters are very sensitive to the variations in the C, N and O abundances, they are very appropriate to detect the presence of multiple stellar populations within each GC. Using the so-called Chromosome map method (Milone et al. 2017) it is also possible to determine the fraction of stars in each stellar population. More details about this method can be found in the R.A.P Oliveira et al. contribution in this proceedings.

To characterize the ages, distances, reddening and helium abundance of the GCs in our sample we employed isochrones from BaSTI stellar evolutionary models (Pietrinferni et al. 2006). An isochrone contains a set of astrophysical parameters well defined, in this way it is an appropriate model to describe some
of the main properties of each GC. The isochrone fitting was made from the statistical method of Maximum Likelihood, it is the product between the color and magnitude gaussians distributions:

\[ L = \prod_{i=1}^{N} \prod_{j=1}^{1190} e^{-\frac{(\text{color}_{\text{obs}} - \text{color}_{\text{Iso}})^2}{2\sigma_{\text{color}}^2}} \times e^{-\frac{(\text{Mag}_{\text{obs}} - \text{Mag}_{\text{Iso}})^2}{2\sigma_{\text{Mag}}^2}} \]

where \( \text{obs} \) index represents the CMD information, \( N \) the number of observed stars and 1190 is the total points computed from BaSTI isochrones. For simplicity we adopt the \( \text{ln}(L)_{\text{MAX}} \).

The final solutions were determined using a Markov-chain Monte Carlo (MCMC) algorithm (Foreman-Mackey et al. 2013).

4. Results

Through the rotation of Chromosome Map it is possible to obtain the fraction of stars of different populations. For NGC6717 the fraction of population 1 is higher than fraction of population 2 whereas for NGC6723 and NGC6652 population 2 is dominant (Fig. 1).

![Figure 1](image1.png)

**Figure 1.** Results for multiple populations. The red bars represents the fraction of first population, the blue bars represents the second population and the grey bars represents the total number of stars.

The results from the isochrone fitting are presented on Fig 2 and Table 1.

**Table 1.** Results from Markov-Chain.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>NGC 6652</th>
<th>NGC 6717</th>
<th>NGC 6723</th>
</tr>
</thead>
<tbody>
<tr>
<td>[Fe/H]</td>
<td>-0.70</td>
<td>-1.31</td>
<td>-1.01</td>
</tr>
<tr>
<td>Age (Gyr)</td>
<td>11.38</td>
<td>13.05</td>
<td>12.85</td>
</tr>
<tr>
<td>E(B-V)</td>
<td>0.11</td>
<td>0.06</td>
<td>0.24</td>
</tr>
<tr>
<td>(m-M)₀</td>
<td>14.85</td>
<td>14.4</td>
<td>14.18</td>
</tr>
</tbody>
</table>

![Figure 2](image2.png)

**Figure 2.** Results from the isochrone fitting. The left presents the best solutions, whereas the right panels show the corner plots with the 1d and 2d posterior probability distributions.

5. Conclusions

The preliminar results for the \( \text{ln}(L)_{\text{MAX}} \) indicate a helium enhancement for the NGC6723 and NGC6652. These results are consistent with those from the Chromosome Map method.

Acknowledgements. São Paulo Research Foundation (FAPESP)

References

Piotto, G. et al. 2015, AJ, 149, 91