

Synthetic photometry for J-PLUS and S-PLUS and the multiple populations in globular clusters

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Abstract. The question of multiple populations in galactic globular clusters (GCs) is a matter of intense study and research nowadays. In recent years, both photometric and spectroscopic studies show that GCs are not the simple stellar populations we once believed they were: we observe stars with different abundance patterns in a same cluster. This work consists in developing a Python code which allows one to study isochrones (stellar evolution prescriptions) in magnitudes and colors as they will be observed from the surveys J-PLUS and S-PLUS. As multiple populations in GCs can be represented as a superposition of isochrones with different abundances and ages, this code will allow us to study the combination of filters in J-PLUS and S-PLUS which better highlight the existence of multipopulations.

Resumo. A questão das populações múltiplas em aglomerados globulares galácticos (GCs) é uma questão de intenso estudo e pesquisa nos dias de hoje. Nos últimos anos, evidências por estudos de fotometria e espectroscopia mostram que GCs não são as populações estelares simples conhecíamos: observamos estrelas com diferentes padrões de abundância em um mesmo aglomerado. Este trabalho consiste em desenvolver um código Python que permite estudar isócronas (prescrições de evolução estelar) em magnitudes e cores, pois serão observados a partir das pesquisas J-PLUS e S-PLUS. Como múltiplas populações em CGs podem ser representadas como uma superposição de isocronos com diferentes abundâncias e idades, o código nos permitirá estudar a combinação de filtros em J-PLUS e S-PLUS que melhor destaca a existência de multipopulações.

Keywords. globular clusters: general – Hertzsprung-Russell and C-M diagrams – Astrochemistry

1. Introduction

Globular clusters (GC) are systems of hundreds of thousand of stars born out of a common molecular cloud and mass distribution according to a initial mass function. Historically they were considered to be Simple Stellar Population (SSP) – all stars being chemically homogeneous and coeval – being represented by a single isochrone on the Color-Magnitude Diagram (CMD). However, recent studies have shown, that GCs of the Galaxy are constituted by multiple stellar population, e.g. the Main Sequence (MS) of the NGC 2808 (Fig. 1), whereas it's needed more than one isochrone to represent the system (Piotto et al. 2007; Milone et al. 2012). The S-PLUS (Southern Photometric Local Universe Survey) is a project inspired by the J-PLUS survey, which consists of observations in 12 filters covering the optical range from 3.000 to 11.000 Å, being 5 broad bands (similar to that of the SLOAN, 'ugriz') and 7 narrow bands. The assertive combination of its filters may show how differences in the chemical abundances of the stars affects the CMD.

2. Objectives

This work consists in creating a code in Python that simulate synthetic photometry based on the stellar library BaSeL (Westera et al. 2002), convolving it with all the S-PLUS filters. By selecting the stars over an isochrone of interest from BaSTI (Pietrinferni et al. 2006), we could convert the stellar parameters from the theoretical plane to the observational plane, i.e., the CMD. The main goal of this work is to understand how a population of stars with variations in Helium and abundances of C, N, O, and Na (commonly found in multiple populations in GCs) affect the CMD for different GC metallicities.

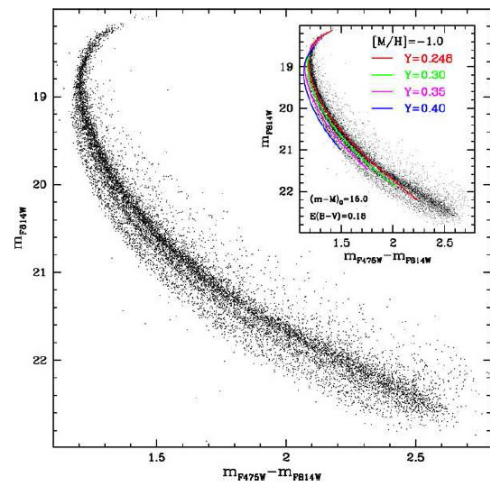


FIGURE 1. Four isochrones, with variation of the Helium abundance and same metallicity, to represent the apparent branches in the MS of the Globular Cluster NGC 2808 (Piotto et al. 2007).

3. Metodology

First, all the stars in BaSeL were convolved with the S-PLUS filters using the PySynPhot¹ package for Python in order to obtain their integrated flux on each filter. Then the stars were selected based on their location ($\log T_{eff} \times \log g$) in the Hertzsprung-Russell Diagram (HRD) in comparison with an isochrone of interest from BaSTI (Fig. 2). Here, we used the GCs M15

¹ <http://pysynphot.readthedocs.io/en/latest/>

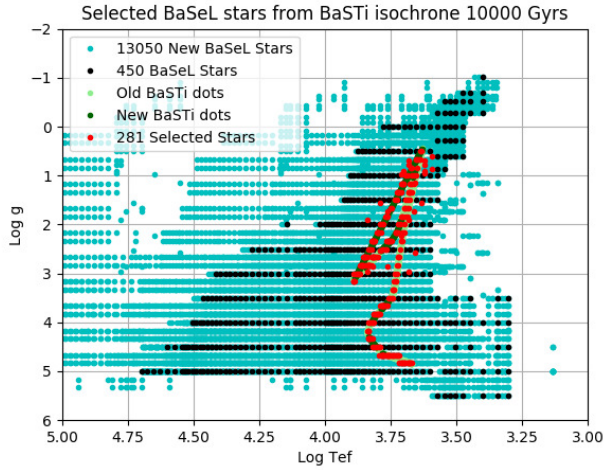


FIGURE 2. HR-Diagram showing all BaSeL original stars in black, the new interpolated stars in cyan, the BaSTi α -enhanced isochrone of 10 Gyrs, $[\text{Fe}/\text{H}] = -2.14$, in lightgreen and its interpolated points in dark-green. The selected stars are represented in red and vary depending on the used isochrone of reference.

($[\text{Fe}/\text{H}] = -2.30$) and 47 Tuc ($[\text{Fe}/\text{H}] = -0.70$) as reference (Bonatto et al. 2017).

The data points from the BaSeL were interpolated in order to have a finer grid of points in the HR. Values of integrated flux on each filter were found by 2D linear interpolation in T_{eff} and $\log g$. After the stars were selected, the fluxes were converted to the ABMAG system of magnitudes and the CMD produced as observed by Bonatto et al. (2017), whereas the Color is defined as $(F0410 - F0660)$ and Magnitude as $(F0410)$.

4. Results and Discussion

As seen on Fig. 1, it is expected that with the increasing variation of the Helium abundance one should find an increasing magnitude. This is reproduced on the panels (a) and (b) from Fig. 3, for both metallicities, $[\text{Fe}/\text{H}] = -0.70$ and $[\text{Fe}/\text{H}] = -2.14$, where in blue is the α -enhanced population and the color gradient in red is the population with Helium abundance. Regarding variations in the light-elements abundance (CNONa), it is also verified on the panels (c) and (d), from Fig. 3 that the magnitude is increased (reducing brightness). Fig. 4 shows two populations with difference in both Helium and light-elements abundances. The same effect in the CMD is observed, like the other cases.

5. Conclusions and Perspectives

Our code manage to illustrate how the variation in the abundances of Helium and CNONa affects the CMD by lowering the brightness of the population of stars and that Multiple Populations of stars in GC may be represented by more than one isochrone, reflecting the discrepancy in their chemical abundances, as expected from the literature. These are preliminary results and the code needs improvement on the selection of stars and a better 2D interpolation of the CMD would highlight the difference between the populations. We plan to expand the study using other stellar libraries besides BaSeL. A comparison with Bonatto et al. (2017) work for the M15 case will show if this results are consistent with observations.

References

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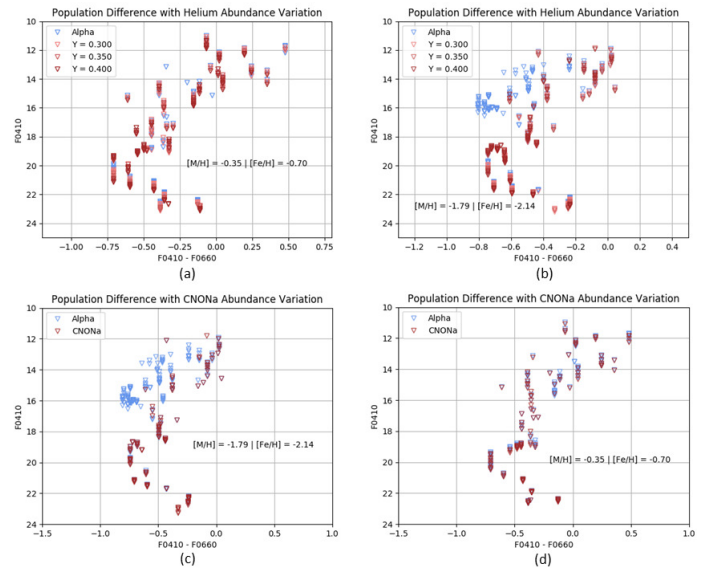


FIGURE 3. Populations of stars in different abundances variations in the CMD for two different metallicities: $[\text{Fe}/\text{H}] = -0.70$ and $[\text{Fe}/\text{H}] = -2.14$. (a) and (b) shows the effects of the variation in the Helium abundance for two different metallicities. (c) and (d) shows the effects of the variation of light-elements (CNONa) for two different metallicities.

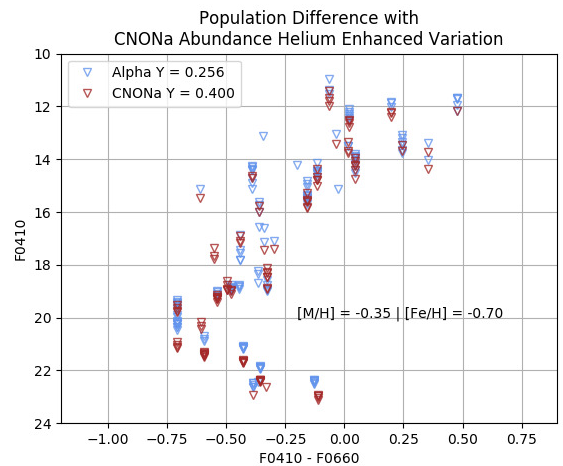


FIGURE 4. CMD of a population with $[\text{Fe}/\text{H}] = -0.70$ and both variations in Helium and light-elements, as expected in observations such as in Fig. 1

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