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Determining ages and metallicities of LMC and SMC star clusters using integrated colours in the S-PLUS photometric system

P. Westera[1], G. F. de Souza[2], L. Kerber[3,2], C. Mendes de Oliveira[2], J. A. Hernández-Jiménez[2], M. V. Costa Duarte[2], & L. M. Sampedro Hernández[2]

[1] UFABC; e-mail: pieter.westera@ufabc.edu.br
[2] IAG, Universidade de São Paulo; e-mail: gabriel.fabiano.souza@usp.br, claudia.oliveira@iag.usp.br, joseaher@gmail.com, mvcduarte@gmail.com, lauramariash@gmail.com
[3] UESC; e-mail: lekerber@gmail.com

Abstract. During its test time, T80-South observed parts of the Large and Small Magellanic Clouds (LMC and SMC) and the goal of this project is to use these data for analysis of well-known clusters. Star clusters in the LMC and SMC have been well studied in the literature and their derived ages range from a few Myr to ∼ 13 Gyr. Furthermore, the young and intermediate-age clusters are very complementary to the Galactic open clusters since they have subsolar metallicities. This large dynamic range makes them ideal simple stellar population (SSP) benchmarks, to calibrate age and metallicity determination methods that can then be extended to other galaxies. We use measured aperture magnitudes in the 12 S-PLUS bands of well-known stellar clusters in the SMC and LMC and some of the Milky Way. The positions of these clusters in multi-dimensional colour-colour diagrams can be compared with the predictions of stellar population synthesis models to determine their population parameters, that is, age, metallicity, and, at a later stage, foreground interstellar extinction. This way, we are able to determine the ideal observing strategy, that is, the combination of S-PLUS bands that optimises the determination and disentanglement of the population parameters for a given amount of telescope time available. We present the results of a preliminary study reproducing the population parameters of synthetic SSPs, varying the noise level and the weights of the colours in the best fitting procedure, in order to find the best combination of colour-colour diagrams that recover the input synthetic SSPs, and give an outlook on future developments of the project.

Resumo. Durante a sua fase de testes, o T80-South observou partes das Grande e Pequena Nuvens de Magalhães (LMC e SMC) e a meta deste projeto é usar estes dados para a análise de aglomerados bem conhecidos. Aglomerados estelares nas LMC e SMC têm sido estudados bem na literatura a as suas idades derivadas vão de poucos Manos a ∼ 13 Ganos. Além disso, os aglomerados jovens e de idade intermediária são muito complementares a aglomerados abertos Galácticos, já que eles têm metalicidades sub-solares. Esta grande faixa dinâmica os torna referências ideais para estudos de populações estelares simples (SSPs), para calibrar métodos de determinação de idade e metalicidade que podem então ser extendidos para outras galáxias. Usamos magnitudes de apertura medidas nas 12 bandas S-PLUS de aglomerados estelares bem conhecidos nas SMC er LMC e alguns na Via Láctea. As posições destes aglomerados em diagramas cor-cor multidimensionais podem ser comparadas com as previsões de modelos de síntese de populações estelares para determinar os seus parâmetros de população, isto é, idade, metalicidade e, num estágio mais pra frente, extinção interestelar. Desta maneira, conseguiremos determinar a estrategia observacional ideal, isto é, a combinação de bandas S-PLUS que otimiza a determinação e o desembaraçamento dos parâmetros de população para um dado montante de tempo de telescópio disponível. Apresentamos os resultados de um estudo preliminar reproduzindo os parâmetros de população de SSPs sintéticas, variando o nível de ruído e os pesos das cores no procedimento de melhor ajuste, para achar a melhor combinação de diagramas cor-cor que recuperam as SSPs sintéticas de entrada, e damos uma perspectiva de desenvolvimentos futuros do projeto.

Keywords. Magellanic Clouds – Galaxies: star clusters: general – Galaxies: stellar content

1. The Age-Metallicity Degeneracy

It is well known (Worthey 1994; de Meulenaer et al. 2013, 2014; Asa′d et al. 2016), that age and metallicity have very similar effects on the integrated (broad-band) colours of Simple Stellar Populations, causing a degeneracy in two-colour diagrams for SSPs of varying ages and metallicities, making it difficult to disentangle these effects and determine the two parameters from integrated colours of SSPs, such as stellar clusters. Similar degeneracies occurr, when interstellar extinction is included as an additional parameter.
However, these authors also showed that this degeneracy can be broken by using certain narrow-band colours centered on important spectral lines, that is, age and metallicity have different effects on these colours, such that the effects can be disentangled and the two parameters, determined from such integrated colours. Since the S-PLUS Survey uses 7 such narrow bands, it is ideal for this purpose.

2. The S-PLUS system's ability to break the degeneracy

We tested the ability of the S-PLUS photometric system to determine an SSP′s age and metallicity by applying a χ^2 fit to PARSEC (Bressan et al. 2012) predictions of S-PLUS colours of SSPs of known age and metallicity with random noise added. In this best fitting method, equal weight was attributed to all 11 colours with respect to the g band. For noise up to 0.02 in the S-PLUS magnitudes, the fit recovers the age within 10 %, and the metallicity, within 0.3 dex (Fig. 1).

3. Application to Magellanic Cloud stellar clusters

During its test time, T80-South observed parts of the Large and Small Magellanic Clouds. Star clusters in the LMC and SMC have been well studied in the literature and their derived ages range from a few Megayears to ∼ 13 Gyr (e.g., Bertelli et al. 1992; Harris & Zaritsky 2004; Baumgardt et al. 2013;

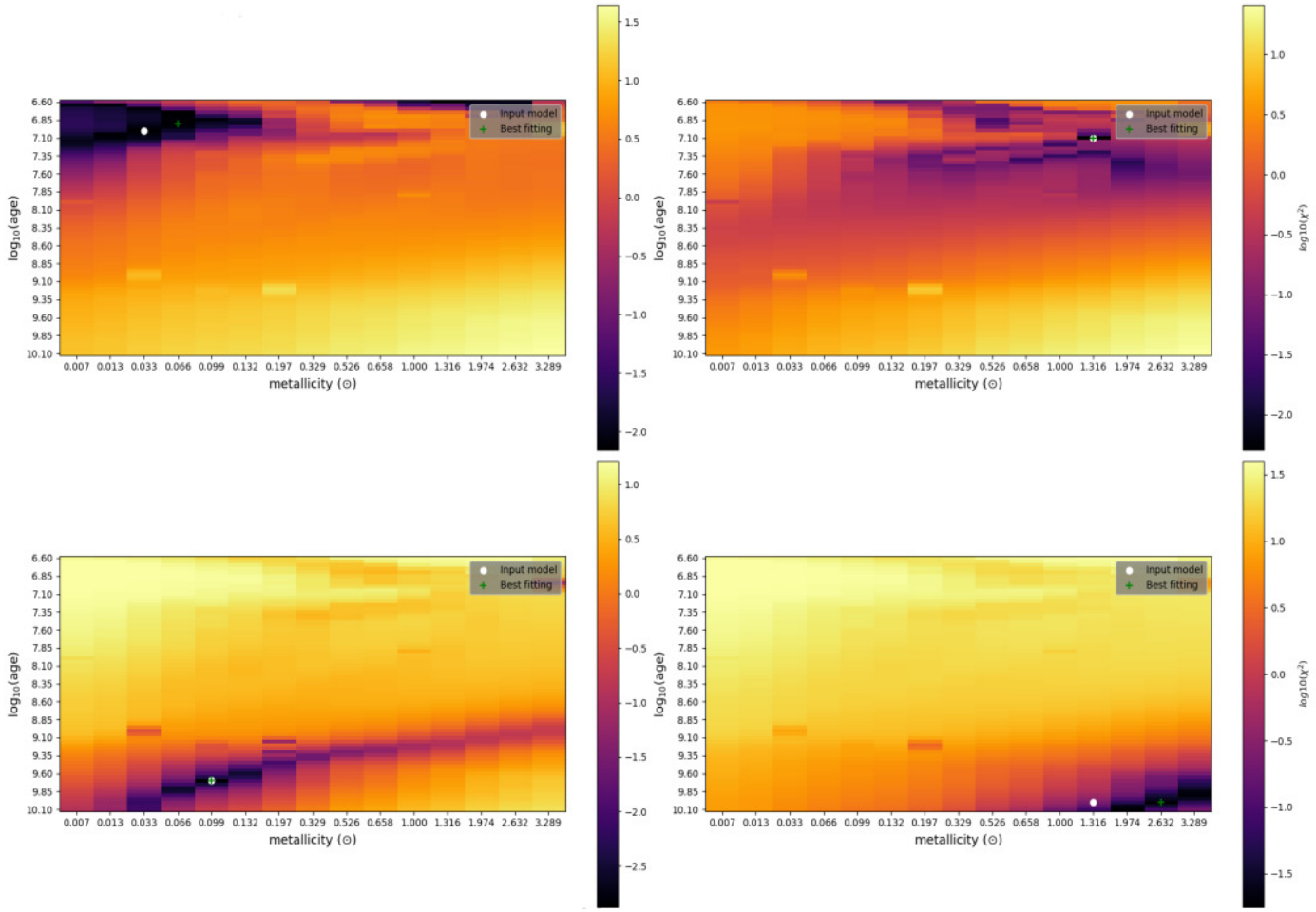

Figure 1. χ^2 maps for the best fitting procedure applied to SSPs from different regions of the age-metallicity parameter space. The maps show the χ^2 values colour-coded as indicated in the scales to the right. The parameters of the input models are shown as white dots, and the ones of the models that best reproduce the colours of the input models plus noise up to $\sigma = 0.02$ are shown as green crosses.

Bitsakis et al. 2018). The young and intermediate-age clusters have sub-solar metallicities, and thus are very complementary to the Galactic open clusters. This large dynamic range in ages and metallicities makes the Magellanic Clouds almost ideal simple stellar population benchmarks, which can be used to expand current age and metallicity determination methods to other galaxies. As the S-PLUS photometric system comprises 12 bands covering the entire range from the near UV to the IR, it reveals the shape of a cluster spectrum in more detail than other photometric systems. Furthermore, 7 of the S-PLUS bands are narrow bands centered on important spectral lines, enabling us to break the degeneracies between age, metallicity and interstellar extinction. For instance, colours in the S-PLUS photometric system for well-known star clusters in the SMC and LMC (and one may also extend this to Galactic clusters) can be placed in multi-dimensional colour-colour diagrams, which can be compared with the predictions of stellar population synthesis models to search for optimised, non-degenerated combination of bands for the determination of stellar population parameters.

4. Conclusions & Further Steps

We present the results of a preliminary study reproducing the ages and metallicities of synthetic SSPs from their integrated colours in the S-PLUS photometric system, varying the noise level. In a next step, we will include interstellar extinction as a third parameter. After that, we plan to determine the ideal observing strategy, that is, the combination of S-PLUS bands that optimises the determination and disentanglement of the population parameters for a given amount of telescope time available, possibly with the help of machine learning. The method will be calibrated using well-known stellar clusters from the Magellanic Clouds and the Galaxy, and can then be extended to other galaxies.

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