Age and metallicity of globular clusters in the SMC from integrated spectra

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Abstract

Integrated spectra of SMC globular clusters were observed at resolutions of FWHM - 4 to 4.5 Å. The STARLIGHT code is used with 3 sets of Single Stellar Populations to derive their ages and metallicities. By a comparison with the literature, the efficiency of the method is confirmed for intermediate/old clusters.

1. Introduction

Studies of globular clusters in external galaxies is carried out through their integrated spectra. In the case of the Magellanic Clouds, these studies can be improved by a combination of Colour-Magnitude Diagrams, spectroscopy of bright individual stars, and integrated spectroscopy. In this project, we intend to analyse integrated spectra of 12 globular clusters of the Small Magellanic Cloud (SMC), using population synthesis models. Other kinds of studies, involving abundance derivations for individual stars were presented in (e.g. Hill et al. 1997) or using HII regions (Garnett et al. 1995) and planetary nebulae (e.g. Idiart et al. 2007).

The star formation history (SFH) of the Small Magellanic Cloud was studied by Harris & Zaritsky (2004), based on a UBVI catalog of 6 million stars located in 351 SMC regions (Zaritsky et al. 1997). They find evidence for a) a significant epoch of star formation with ages older than 8.4 Gyr; b) a long quiescent epoch between 3 and 8.4 Gyr; c) a continuous star formation started 3 Gyr ago until the present; d) in period c), 3 main peaks of star formation should have occurred at 2-3Gyr, 400 Myr and 60 Myr

In order to verify if the star formation gap (item b) above) is reflected as well in the globular cluster population, we analyse candidates to be of intermediate age. We present the analysis of 12 globular clusters, several of which still have very uncertain determinations of age and metallicities.

We use the full spectrum fitting code STARLIGHT (Cid-Fernandes et al. 2005) to compare the integrated spectrum of the clusters to three sets of simple stellar population (SSP) models, in order to derive their age and metallicity. We obtain ages of these globular clusters that are in the range 10^7 age (yr) $- 10^{10}$, and [Z/Z$_{sun}$] in the range $\sim$ -2.0 $-$ -0.5. Previously we observed 14 clusters (6 in the SMC and 8 in the LMC), and results were presented in de Freitas Pacheco et al. (1998).

2. Observations

Observations were carried out at the 1.60m telescope of the National Laboratory for Astrophysics (LNA, Brasópolis, Brazil) and at the 1.52m of the European Southern Observatory (ESO, La Silla, Chile).

At the LNA, a SITe CCD camera of 1024x1024 pixels was used, with pixel size of 24 μm. A 600 l/mm grating allowed a spectral resolution of 4.5 Å FWHM. Spectra were centered in the region of the Mgb λ5170, including the indices Hβ λ4861, Fe $\lambda\lambda$ 5270,5335, Mg$_2$ and NaD λ5893. At ESO, a Loral/Lesser CCD camera of 2688x512 with pixel size of 15 μm and a grating of 600 l/mm were used, allowing a spectral resolution of 4 Å FWHM. This configuration covers the spectral range 4800 - 9000 Å.

Long east-west slits were used in all observations (3' at LNA and 4.1' at ESO). For each cluster, from 2 to 6 individual measures were taken, covering mainly its brightest region. Integration times used were between 20 and 50 min. each, and slits of 2 arcsecs width were used in both observatories.

Data reduction was carried out using the IRAF package, and followed the standard procedure for longslit CCD spectra: correction of bias, dark and flat-field, extraction, wavelength and flux calibration. For flux calibration, we observed at least three spectrophotometric standard stars each night. Atmospheric extinction was corrected through mean coefficients derived for each observatory.

After reduction the spectra were filtered in order to minimize high frequency noise, lowering their resolutions to about 7 Å FWHM.

3. Full spectrum fitting

We aim at obtaining age and metallicity for the sample clusters through the comparison of their integrated spectra to SSP models available in the literature. Modern techniques of spectral fitting allow the comparison of observations and models on a pixel-by-pixel basis, and we adopted the code STARLIGHT (http://www.starlight.ufsc.br) for this purpose. STARLIGHT (Cid-Fernandes et al. 2005, 2008) is a multi-purpose code that combines N spectra from a user-defined base (usually SSP models) in a search for the linear combination which best matches an input observed spectrum. A STARLIGHT run returns the best population mixture that fits the observed spectrum, in the form of the light fraction contributed by each of the SSPs in the base. Technical details on the procedures by STARLIGHT are given in Cid-Fernandes et al. (2005).

For the present study we adopted three different bases of SSPs:

- preliminary models by Charlot & Bruzual (in prep., hereafter CB08) which are an extension of the models presented in Bruzual & Charlot (2003). The models employed here were based on the empirical stellar spectra by Sánchez-Blázquez et al. (2006, hereafter MILES) and evolutionary tracks by Bertelli et al. (1994). The models cover ages in the range $10^5 <$ t(yr) $< 8x10^{10}$, metallicities 0.0001 $<$ Z $<$ 0.05, in the wavelength interval 350 - 740 nm, at FWHM $\sim$ 2.3 .
- models by the PEGASE-HR team (http://www2.iap.fr/pegase/pegasehr/), as presented by Le Borgne et al. (1994). The models cover ages and metallicities in the range $10^7 <$ t(yr) $<$ 2x10^{10} yr, 0.0004 $<$ Z $<$ 0.05, wavelength 400-680 nm at FWHM $\sim$ 0.55 .
- preliminary models by Vazdekis et al. (in prep.; see also Vazdekis et al. 2007), which are an extension of the models by Vazdekis (1999) using the MILES library and the isochrones by Girardi et al. (2000). The models cover ages $10^8 <$ t(yr) $<$ 2x10^{10}, metallicities 0.0004 $<$ Z $<$ 0.03, wavelength interval 350 -740 nm, at FWHM $\sim$ 2.3 .

By the use of three different sets of SSP models, we obtain results that are not biased towards the input data and calculations of a specific set of SSP models. In all cases, the models were convolved to match the resolution of the observed spectra.

In the absence of major errors in the models and given enough S/N in the observed spectrum, it is expected that only one SSP in the base will fit the integrated spectrum of a cluster, as it is generally accepted that the majority of stellar clusters can be represented by a SSP. In this ideal case, the best model fit by STARLIGHT should return only one SSP with non-zero light-fraction contribution. In practice however, often the grid of SSPs is not fine enough (usually the age is well sampled, but not the Z) and the S/N is not ideal, and as a consequence multiple populations can appear as the best model fit for a cluster. Besides, contamination from background or foreground field stars cannot be ruled out, specially in the case of sparse clusters.

Figure 1 illustrate the population mixture returned by STARLIGHT for the cluster L113. The mixture is dominated by a peak centered in [Z/Z$_{sun}$] $\sim$ -1.6 and old ages, but there are smaller contributions from several other SSPs. Therefore, throughout this work we adopt as the result for each cluster the light-weighted mean age and Z of the SSPs which contribute with more than 10% in the best model fitted by STARLIGHT (light-fraction x$_j \geq$ 0.1).

STARLIGHT seeks a single best solution and does not attempt to map the full probability distribution function of the possible solutions, and therefore it does not estimate errors in the parameters found. We chose then to report the individual results obtained with each base model, in order to have an estimation of the errors in the parameters derived. We also analysed separately observations from a same cluster observed in different epochs.

4. Discussion

Tabela 1: *Parameters based on Vazdekis SSPs for a sub-sample of selected clusters. References: 1 Da Costa 1999; 2 Da Costa & Hatzidimitriou 1998; 3 Mighell et al. 1998; 4 Mackey & Gilmore 2003; 5 Chiosi et al. 2006; 6 Piatti et al. 2005; 7 Hill 1999.*

Cluster	Average age (Gyr)	[Z/Z$_{sun}$]	age (Gyr)	[Fe/H]	ref.
	STARLIGHT		Literature		
AM3	0.37	-0.9	5	-1.0	1
HW1	0.35	-1.0	–	–	–
K3	3.1	-1.6	9	-1.12	2
L113	4.9	-1.6	6	-1.44	2
			4	-1.24	3
NGC121	9.6	-1.4	12	-1.46	2
NGC152	0.68	-0.3	1.4	-0.94	4
NGC256	0.34	-0.6	0.1	–	5
NGC269	0.11	-0.9	0.6	-0.7	6
NGC294	0.27	-0.7	0.3	-0.7	6
NGC 330	1.9	-1.4	0.025	-0.82	7
NGC419	2.8	-1.4	1.2	-0.7	6
NGC458	0.85	-1.4	0.13	-0.23	6

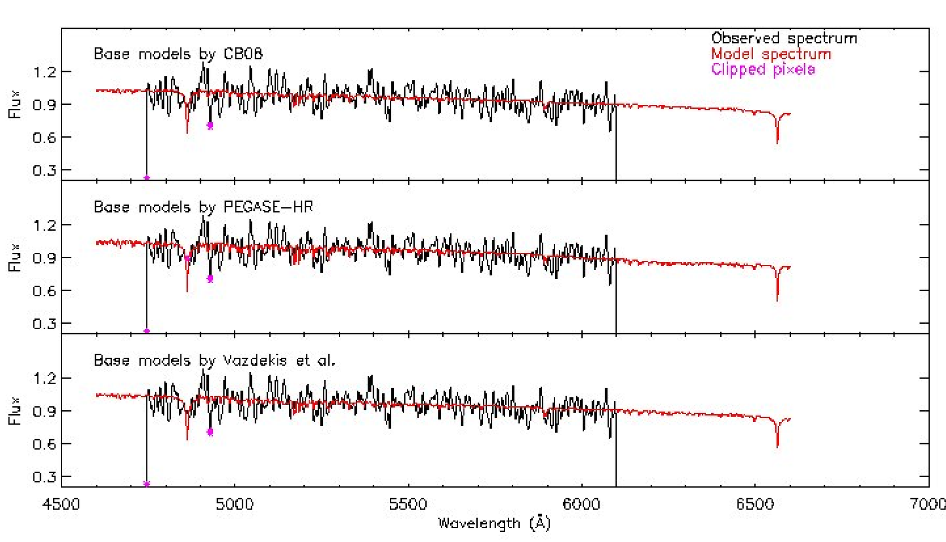

Figure 1: *Observed spectrum (black line) for the cluster L113, and the best model fitted by STARLIGHT (red line) for each of the SSP bases adopted (indicated in each panel). Pixels indicated as magenta symbols were clipped by the fitting process.*

In Fig. 2 is shown the age metallicity relation plotted for present results based on Vazdekis et al. models, compared to literature data according to results listed in Carrera et al. (2008) (references given in the Table). From the comparison between literature data and present results, the method seems appropriate for intermediate age clusters, however discrepancies were detected for young clusters, such as for NGC 330, for which an age of 1, 2 and 1.9 Gyr with CB08, Pegase and Vazdekis et al. SSPs, respectively, are obtained. For the older clusters, our calculations confirm the presence of a few clusters in the age gap at 3 $<$ t(Gyr) $<$ 8.4, as defined by Harris & Zaritsky (2004), in particular for the well-studied clusters K3 and L113, for which however some controversy on ages are still to be solved.

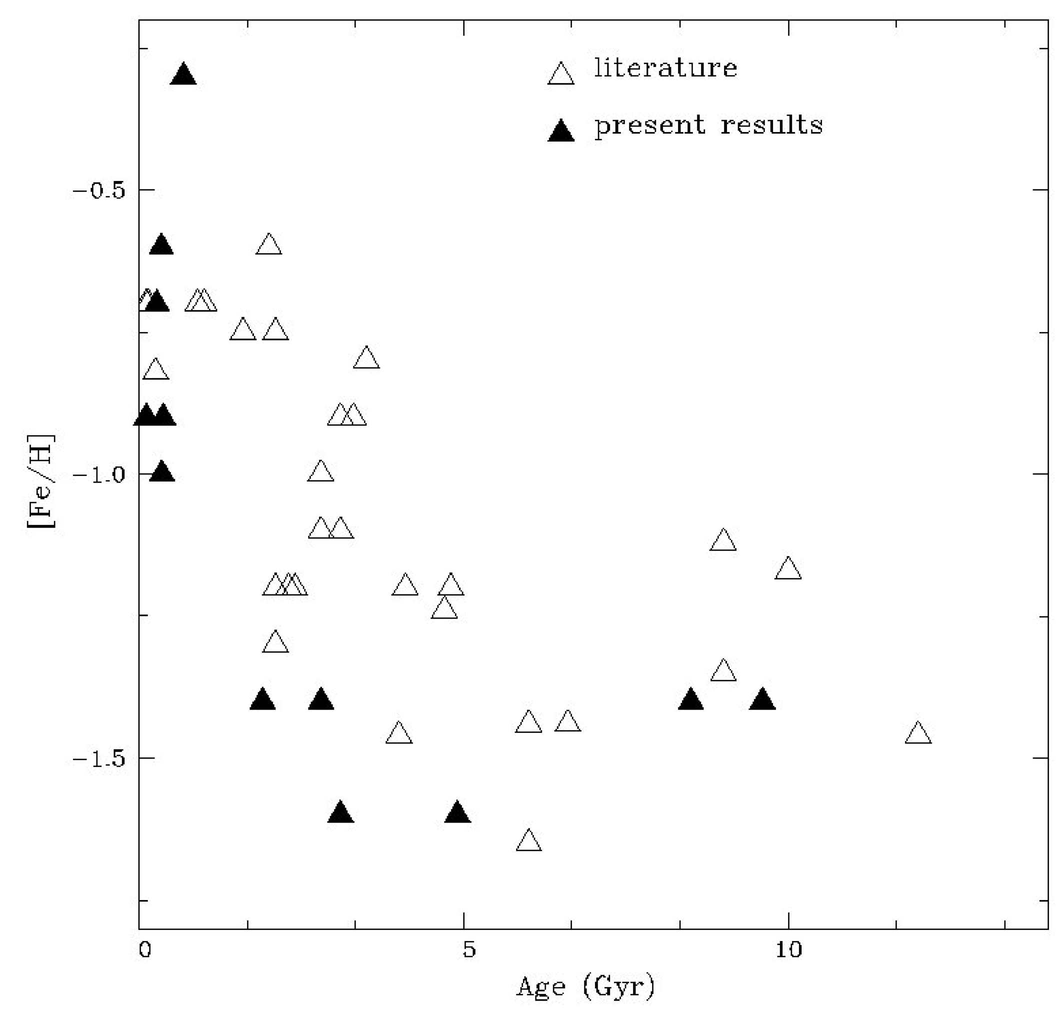

Figure 2: *Age-metallicity relation with data from well-known globular clusters (open triangles) and present results (filled triangles).*

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IAU Symposium 256, The Magellanic System: Stars, Gas, and Galaxies. 28 July - 1 August 2008, Keele University (UK)