# Age and metallicity of star clusters in the Small Magellanic Cloud from integrated spectroscopy

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## Abstract

Analysis of integrated spectra of star clusters in the Magellanic Clouds and derivation of their ages and metallicities can bring information for studies on the chemical evolution of the Clouds. The aim is to derive ages and metallicities from integrated spectra of 15 globular clusters in the Small Magellanic Cloud (SMC). We are looking, in particular, for old or intermediate age globular clusters. Making use of a full spectrum fitting technique, we compared the integrated spectra of the sample clusters to three different sets of single stellar population models available in the literature. We obtained ages and metallicities for the sample clusters employing the codes STARLIGHT and ULySS. We derive the ages and metallicities of 9 old/intermediate age clusters, some of them previously unstudied, and 6 young clusters. We point out the interest of the newly identified as old/intermediate age clusters HW1, NGC 152, Lindsay 3, 11 and 113. We also confirmed the old ages of NGC 361, NGC 419, Kron 3, and of the very well-known oldest SMC cluster NGC 121.

## 1. Introduction

### Why to study star clusters in the Small Magellanic Clouds?

- They form a rich system ( > 3700 objects) (Bica *et al.* 2008) that have been used to probe the dynamical and chemical evolution of these neighboring and interacting dwarf irregular galaxies;
- They are very precious templates to test and to calibrate Single Stellar Population (SSP) models for combinations of age and metallicity that are not found in the Milky Way (Santos Jr. & Piatti 2004);
- Harris & Zaritsky (2004) based on ~6 billion SMC stars found four main epochs of star formation in the SMC:
  1. a significant epoch of star formation with ages older than 8.4 Gyr;
  2. a long quiescent epoch between 3 and 8.4 Gyr;
  3. a continuous star formation started 3 Gyr until the present;
  4. in period 3, three main peaks of star formation should have occurred at 2-3 Gyr, 400 Myr and 60 Myr.
- We searched for clusters from epoch 2, which are classified as intermediate-age clusters.

## 2. Full spectral fitting

### How to derive star clusters parameters from integrated spectroscopy?

- The classical method is based on measurements of equivalent widths of the CaII triplet, so that these values can be applied into a relation to [Fe/H] previously calibrated (e.g. Cole *et al.* 2004).
- Another method is to measure the same indices of an observed spectrum and of a synthetic spectrum from a SSP basis and compare these results to each other (e.g. Bruzual & Charlot (2003), hereafter BC03; Charlot & Bruzual (*in prep.*), hereafter CB08; Le Borgne *et al.* (2004), PEGASE-HR team; Vazdekis *et al.* (*in prep.*)
- With the advances in computational and statistical tools, today it is possible to fit directly the full spectrum, pixel-by-pixel, with a whole SSP basis and determine the best combination of age and metallicity that matches the spectra. Some codes allow to fit a set of theoretical spectra from the SSP basis to the integrated spectra.

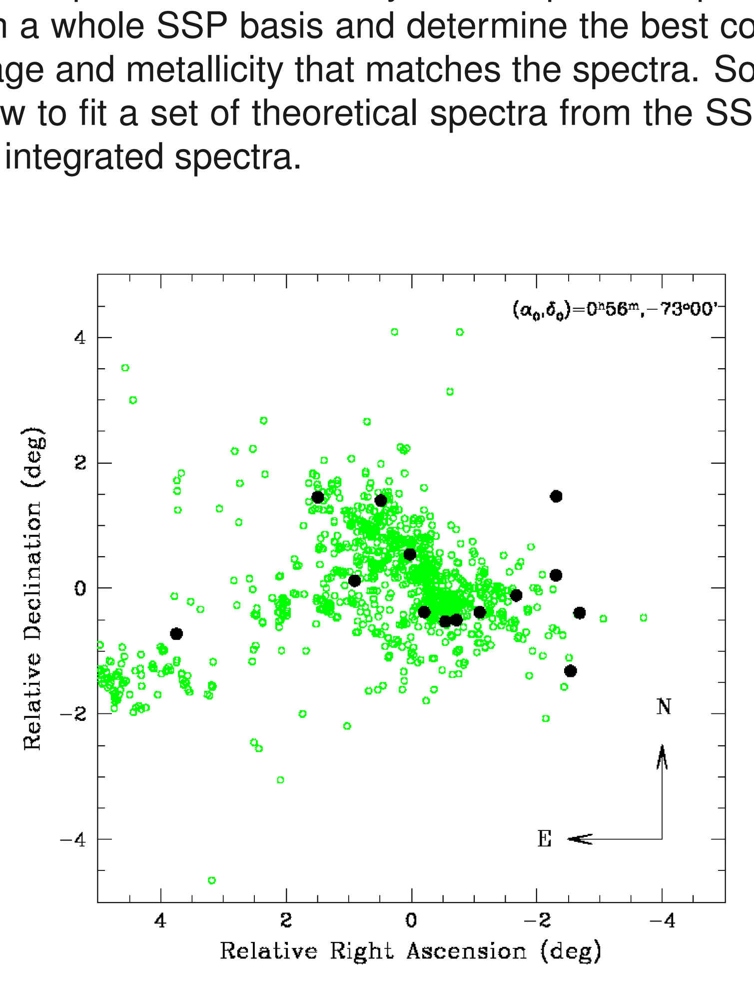


**Figure 1:** *Distribution on the sky of the 15 SMC clusters analyzed in this work (large full circles) overplotted on the star clusters listed in (Bica & Schmitt 1995 and Bica et al. 2008) (small green circles).*

- We use the STARLIGHT (Cid-Fernandes *et al.* 2005, 2009) and ULySS (Koleva *et al.* 2009) codes combined with three sets of SSPs: CB08 or BC03, Pegase-HR, Vazdekis.

## 3. Results from STARLIGHT and ULySS

In Figure 1 we show the location of our 15 sample clusters overplotted in Bica & Schmitt (1995) and Bica *et al.* (2008) lists of star clusters.

Figure 2 comparing results obtained with ULySS combined with Pegase-HR and BC03, and literature, showed to be satisfactory, except for a few cases, in particular regarding young clusters such as NGC 222.

Figure 3 gives the age and metallicity of literature data for well studied clusters, that is based on lists by Carrera et al. (2008), and the results for our sample clusters derived with ULySS+PEGASE-HR. Pagel & Tautvaisiene 1998 chemical evolution model is overplotted. A good agreement is seen between our data and literature, and also with the model.

As discussed for example in Da Costa & Hatzidimitriou (1998), we see a relatively rapid rise in metallicity in the first 3 to 5 Gyr (assuming that chemical evolution started at 15 Gyr), and a slow increase of the metallicity from [Fe/H]≈-1.1 to -1.3 to the present value of [Fe/H]≈-0.7.

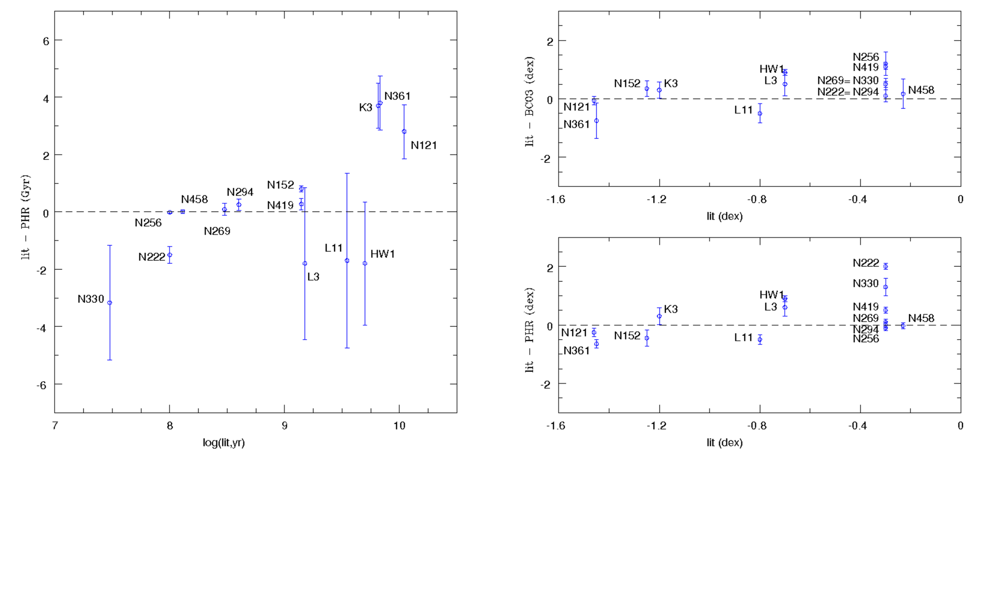

**Figure 2:** *Left panel: Ages from the literature (given in log age(yr)) in the abscissa, vs. difference of age from literature and the result from ULySS run with Pegase-HR (given in Gyr), in the ordinate. Right panel: Metallicity from the literature vs. the difference of metallicity between literature and the results from ULySS, run with BC03 and Pegase-HR.*

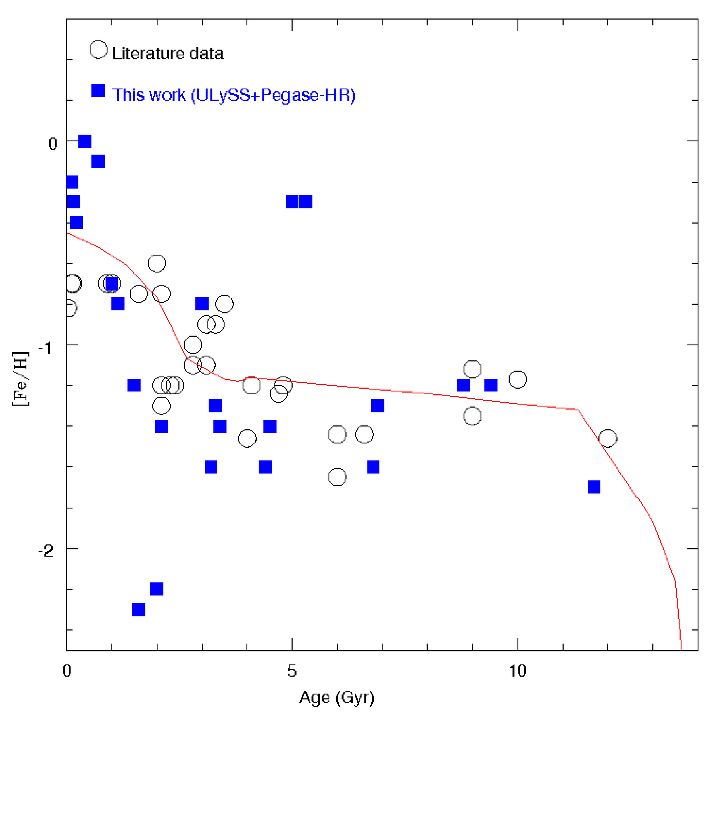


**Figure 3:** *Age-metallicity data for selected studied clusters. Symbols: open circles literature data; filled squares: present results based on PEGASE-HR SSPs combined with the ULySS code. The chemical evolution model by Pagel & Tautvaisiene (1998) is overplotted.*

## 4. Highlights on important clusters

### Kron 3

- Glatt *et al.* (2008a) derived an age of 6.5 Gyr, whereas Rich *et al.* (1984) found an age od 5-8 Gyr.
- STARLIGHT and ULySS found intermediate ages in the range 2.8 to 4.8 Gyr, and [Fe/H]≈-1.6 dex
- High resolution spectroscopy of individual stars of this cluster would be of great interest.

### NGC 121

- Glatt *et al.* (2008b) derived ages in the range 10.5 to 11.8 Gyr based on isochrone fitting method.
- STARLIGHT gives ages of 12.5 < t(Gyr) < 13.0 and metallicities of -1.4 dex, that is a very good determination.
- ULySS gives lower ages of 8.1 < t(Gyr) < 8.6 and compatible metallicities of -1.4 < [Fe/H] < -1.2.

### HW 1

- There were no literature data on this cluster before this work.
- From ULySS we obtained an intermediate age (~7 Gyr) and low metallicity (~-1.7 dex), consistent among the three sets of SSPs.

### NGC 361

- After clean field contaminations of younger stars, Mighell *et al.* (1998) based on CMD methods give an age of 6.8 Gyr, and [Fe/H]=-1.45 dex
- STARLIGHT results from CB08 and PHR are compatible with Mighell *et al.* (1998), in the case of ages (~6 Gyr) and show higher metallicities of ~-0.2 dex.
- ULySS gave [Fe/H]≈-0.8 with the three sets of SSPs. With PHR was found an age of 3 Gyr, and with BC03 and Vazdekis was found younger ages of ~0.18 Gyr.
- These results make evident the young field contamination present in the spectrum.

### NGC 419

- Glatt *et al.* (2008a) demonstrated clearly the presence of multiple stellar populations in this cluster with ages between ~1.0 and ~3.0 Gyr.
- STARLIGHT recovered the expected ages expected above, and also the metallicity from CaT method of ~-0.7 dex.
- ULySS gave an age of 1.1 Gyr and a metallicty of -0.8 dex, for PHR, and ~8 Gyr for BC03 and Vazdekis *et al.*
- These differences in age can be explained by the existence of the double turn-off in the CMD.

## 5. Conclusions

- Among the less well-studied clusters, we highlight the interest of further studying the intermediate age clusters HW1, L3, L11, NGC 152, NGC 361, NGC 419, and L113.
- We also confirm the intermediate age of Kron 3, and old age of NGC 121.
- The STARLIGHT and ULySS results compared with the literature present good agreement, with few exceptions, in particular for young clusters.
- Our results are in good agreement with the age-metallicity relation from literature data and the chemical evolution model of Pagel & Tautvaisiene (1998).
- It is interesting to note that a number of clusters show metallicities lower than [Fe/H]<-1.0, whereas planetary nebulae of ages older than 1 Gyr show [Fe/H]=-1.0±0.2 with very few exceptions (Idiart *et al.* 2007). Therefore it seems that metal-poor clusters have no counterpart on the planetary nebulae population.

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