CHEMICAL EVOLUTION OF THE MAGELLANIC CLOUDS

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1. Introduction.

Chemical evolution studies of the Clouds based on detailed abundance analyses are essentially limited nowadays to young objects like HII regions (Dufour 1984; Garnett et al. 1995), planetary nebulae (e.g. de Freitas Pacheco et al. 1993), supernova remnants (Russell & Dopita 1990) and supergiant stars either of F-K type (Hill et al. 1995) or B ones (e.g. Rolleston et al. 1996 and references therein). One exception to this was presented by Dopita et al. (1997) where HST data permitted to date planetary nebulae nuclei and to present an age vs. metallicity model.

Otherwise, high-resolution abundance analyses of individual stars of old populations are awaiting for the availability of 8m telescopes in the southern hemisphere, in which case stars of V > 16 will be feasible.

The large number of star clusters in the Clouds make them interesting probes to check chemical evolution models of these nearby galaxies (Olszewski et al. 1991), since these clusters have ages between a few million years up to 14 Gyr. Many of these clusters have ages estimated from colour-magnitude diagrams (CMD), and metallicities derived from analyses of individual stars.

In the present work we apply SSP models that we have developed in the past few years to MC clusters (Borges et al. 1995). The accuracy of our age and

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metallicity determinations based on integrated indices is checked against well-determined ages obtained with Colour-Magnitude Diagrams (CMDs) and metallicities derived from spectroscopy of individual stars. This is an ongoing project, where for the moment we have observed an initial sample of 14 objects amongst those most well studied clusters in the Clouds. These well-known clusters are used to check our procedure, which will be applied in the future to unstudied clusters.

Besides, a chemical evolution model is also proposed, where a star formation rate based on information from the field population is adopted. The model is compared to our star clusters data.

2. Studies of field populations

The old populations can be studied either through the field or the star cluster populations.

Recently, great attention is given to the field populations. Through imaging and extraction of colour-magnitude diagrams of field populations in the LMC mainly with HST, but also with NTT, a number of authors (Bertelli et al. 1992; Ardeberg et al. 1997; Westerlund et al. 1995; Gallagher et al. 1996; Vallenari et al. 1996; Elson et al. 1997; Stappers et al. 1997) have found essentially 3 stellar populations: an old population covering the age range $5 < \tau < 14$ Gyrs, an intermediate age of $2 < \tau < 4$ Gyrs, and a young population ($\tau < 1$ Gyr) near the LMC bar.

These data can be explained by an initial steady star formation rather than a star formation history dominated by intense bursts, as previously assumed in the literature. One burst would have occurred at 2-4 Gyrs, when about 30% of the total number of stars were formed.

3. Star clusters

The star clusters are bright suitable tracers, and they are numerous in the Clouds. However, for the LMC there are no clusters in the metallicity range -1.8 < [Fe/H] < -0.7, which is equivalent to a gap in the age interval $4 < \tau < 12$ Gyr. In the SMC there are clusters at all metallicities and ages. The age and metallicity distribution in the LMC has misled authors, until recently, as concerns its star formation history: a history of bursts had been favoured. In fact, due to the metallicity (age) gap, clusters can be used as tracers of chemical evolution but not of star formation rate. For the star formation rate, the data on field stars, now available, are appropriate.

Most studies of clusters were based on integrated photometry (Searle et al. 1980; Frenk & Fall 1982; Elson & Fall 1988; Girardi & Bica 1993; Girardi et al. 1995). These authors have shown that the age gap is difficult to detect in colours since, for example Δ(U-B) = 0.03 for ages between 12 and 4 Gyr.

It is interesting to note that essentially no studies were carried out based on integrated spectroscopy, with the exception of that by Bica et al. (1990) for young clusters ($\tau < 0.5$ Gyr). The present work consists of observations and interpretation of integrated spectra of star clusters in both Clouds.

4. Present method

An initial sample of 6 clusters in the SMC and 8 ones in the LMC were respectively observed at the *Laboratório Nacional de Astrofísica* (LNA), Brazil and at the *European Southern Observatory* (ESO), Chile. This is an ongoing project, and observations of a much larger sample are planned.
The indices Hβ, Mg_2, Fe5270, Fe5335 and NaD were measured using the continuum and central bandpasses defined by Faber et al. (1985).
Using relations between <Fe>, Hβ vs. stellar parameters (T_{eff}, log g, [Fe/H], [α/Fe]) integrated indices for single stellar populations (SSPs) were build up, using Padova evolutionary tracks and a Salpeter's law for the IMF.

For <Fe> and Hβ indices, and (B-V) colours, the relations for SSPs (where ages are given in Gyrs) are from Borges et al. (1995):

$$<Fe> = 2.319 + 0.283 \ln \tau + 1.968[Fe/H] + 0.393[Fe/H]^2$$

$$H\beta = \exp(1.219 - 0.343 \ln \tau - 0.344[Fe/H] + 0.015[Fe/H]*\ln \tau$$

$$(B-V)_o = 0.726 + 0.091 \ln \tau + 0.269[Fe/H] - 0.032[Fe/H]*\ln \tau$$

In the present work the colour $(V - K_{CIT})$ was synthesized using the same procedure, adopting the temperature scale, $\log g$ and $(V - K_{\rm CIT})_0$ from the work by Frogel et al. (1983), since the $(V - K_{\rm CIT})$ data for the MC clusters by Persson et al. (1983) were obtained in the same photometric system. The following relation is obtained:

$$(V-K_{CIT}) = 2.676 + 0.180 \ln \tau + 0.547[Fe/H]$$

5. Chemical evolution models

The models consider yields by Nomoto et al. (1984) for C-deflagration models of SNIa (10-60$M_\odot$), and from Thielemann et al. (1996) for SNII.
The adopted constraints for the LMC are: a present fraction of gas $f_{gas}^{present}$ = 0.11, a present star formation rate $SFR^{present} = 0.12\ M_\odot$/yr and the present oxygen-to-iron ratio of $[O/Fe]^{present}$ = -0.2 (Hill et al. 1997). For the SMC the constraints are: $f_{gas}^{present} = 0.33$ (Lequeux 1993), SFR $\propto M_{gas}$, $SFR^{present} = 0.052\ M_\odot$/yr.

Based on a star formation history as indicated by the field population (Sect. 2), the age-metallicity relation for the LMC is shown in Fig. 1, where our sample clusters are also plotted.

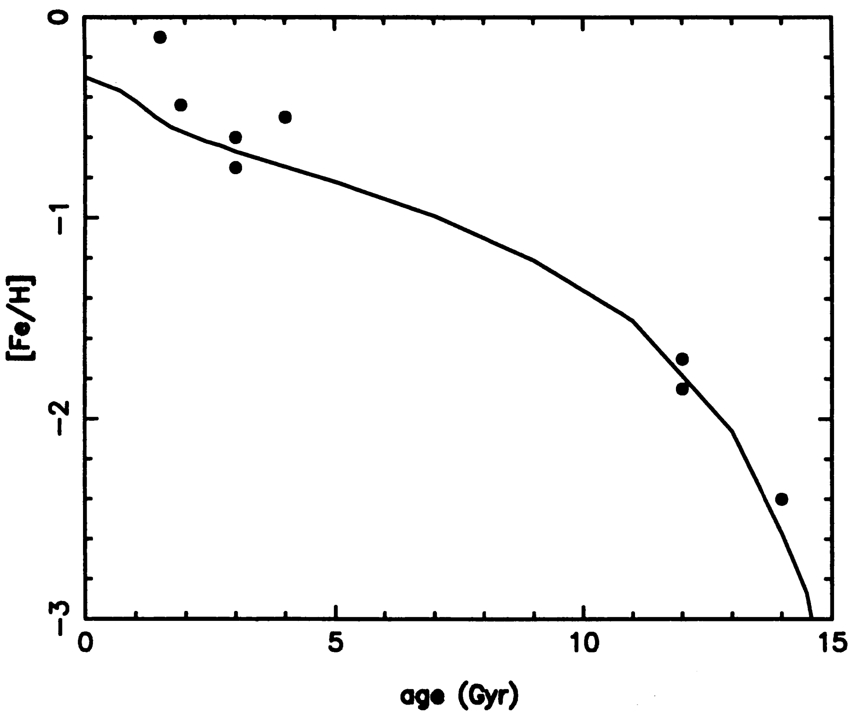

Figure 1. LMC: **Chemical evolution model (solid line) compared to age and metallicity data for the present sample clusters** (NGC 1466, NGC 1783, NGC 1795, NGC 1978, NGC 2121, NGC 2173, NGC 2210, Hodge 11)

6. Conclusions

We have obtained integrated spectra for 14 clusters in the Magellanic Clouds, on which the spectral indices Hβ, Mg_2, Fe5270, Fe5335 were measured.

Selecting indices whose behaviour depends essentially on age and metallicity (Hβ and $< Fe >$), together with (B-V) and (V-K) colours, we were able to determine age and metallicities for these clusters, using calibrations based on single stellar population models (Borges et al. 1995).
A chemical evolution model which follows a star formation history as indicated by the field population is checked with the age and metallicity data for our sample star clusters.

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