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# The galactic disc age-metallicity relation

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**Abstract.** New ages are computed for stars in the Solar Neighbourhood from the Edvardsson et al. (1993) data set. Distances derived from the Hipparcos parallaxes were adopted to obtain reliable ages (uncertainty less than 12%) for a subset of stars. There is no apparent age-metallicity relation for stars with an age less than 10 Gyr. Only if we consider older stars a slope of $\sim$0.07 dex/Gyr appears. This relation is compared with those obtained from other methods, i.e. galactic open clusters, stellar population synthesis (star counts), and chemical evolution models.

## 1. Introduction

In the Solar Neighbourhood the metallicity of the stars can be studied in high detail. Distances need to be known to a 5% level to get a sub-sample of stars with reliable ages. In this respect, the age and metallicity determination for open clusters (Carraro et al. 1997) is more reliable, since one is dealing with a group of stars and the result is less susceptible to individual errors.
An age-metallicity relation (AMR) can be obtained from star counts studies, based on the population synthesis technique (Bertelli et al. 1995, 1996; Ng et al. 1995, 1996, 1997). In such studies all the stars along the line of sight are considered. The disc is sampled with respect to age and metallicity in layers with specific effective thickness. In this way indications are obtained for the disc's chemical evolution.
*Our aim is to compare the AMR obtained from various methods and to discuss the probable causes for the differences found.*

## 2. Solar Neighbourhood

Ng & Bertelli (1997) computed new ages for the stars from the Edvardsson et al. (1993) data set. First we studied the effects due to a change of isochrones. Then the ages were derived using the distances obtained from the Hipparcos parallaxes (ESA 1997). Figure 1 shows the resulting AMR, which has a slope of $\sim$0.07 dex/Gyr.

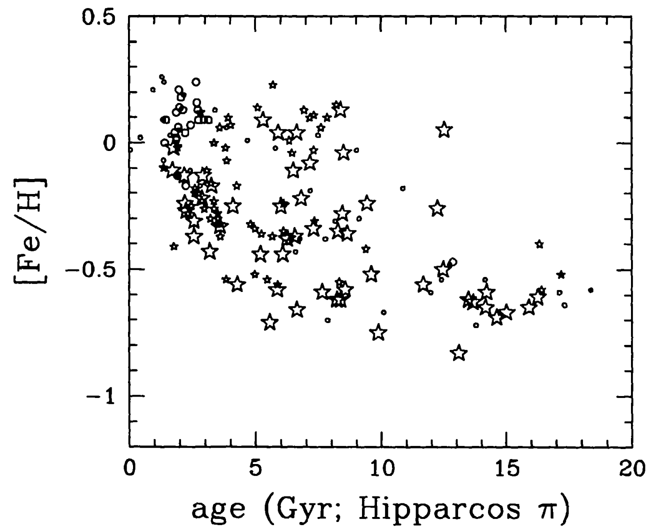


Figure 1. The age-metallicity relation for the stars with metallicities from Edvardsson et al. (1993) and ages by Ng & Bertelli (1997). The open circles denote main sequence stars and the asterisks denote sub-giant branch stars. The big symbols denote the stars with 'reliable' ages for which the uncertainty is less than 12%.

## 3. Open clusters

An updated compilation of open clusters can be found in Carraro et al. (1997). The ages for the clusters are all determined from fits with the Bertelli et al. (1994) isochrones, using the synthetic CMD technique. The main advantage of this compilation is the homogeneity of the sample: ages, metallicities and positions in the galactic plane are all obtained in the same fashion. This homogeneity is not guaranteed in other, larger samples. However, it is not possible to gather a complete sample for the old, open clusters in the galactic disc, because of strong selection effects mainly related to the past dynamical history of the galactic disc: disruption of the clusters.

By means of Multivariate Data Analysis we studied the correlations among the cluster parameters. We considered the four-dimensional parameter space of age, metallicity, $z$-coordinate and radial distance R from the galactic centre. The results indicate that all four parameters have a non-negligible weight. Details of the analysis and their planar projections are presented in Carraro et al. (1997).

## 4. Stellar population synthesis

Synthetic Hertzsprung-Russell diagrams (HRDs) are generated with the stellar population synthesis technique. This is a powerful method in studies of the properties of resolved stellar populations. The so-called HRD galactic software telescope (HRD-GST) is developed to study the stellar populations in our Galaxy (Ng et al. 1995). The basis is formed by the latest evolutionary tracks calculated by the Padova group (Bertelli et al. 1994 and references cited therein). Through a galactic model synthetic Colour-Magnitude diagrams are generated.

The primary goal of the HRD-GST is to determine the interstellar extinction along the line of sight and to obtain constraints on the galactic structure and on the age-metallicity of the different stellar populations distinguished in our Galaxy. The results obtained thus far are reported in various papers (Bertelli et al. 1995, 1996; Ng et al. 1995 – 1997).

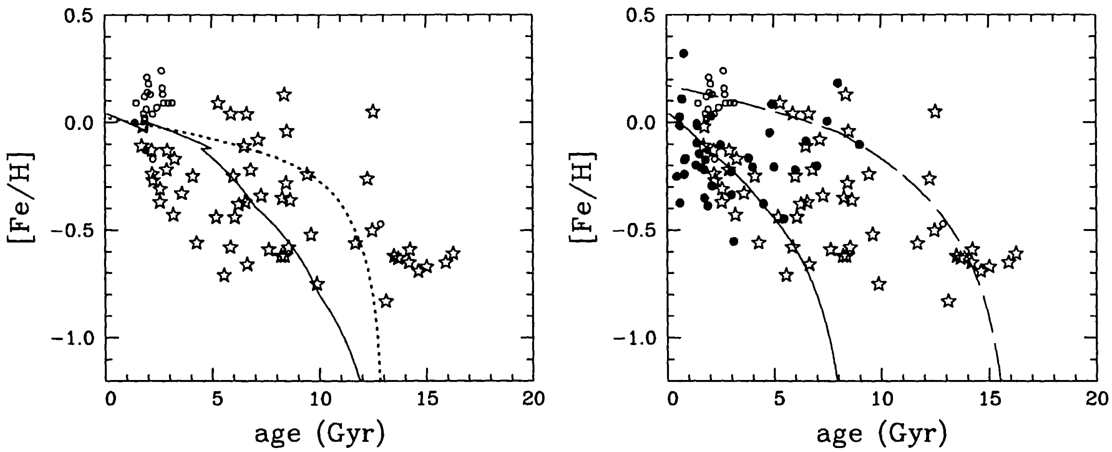


Figure 2. *Left panel*: AMR for the stars in the Solar Neighbourhood together with the prediction of a chemical evolution model from Portinari et al. (1997; dotted line), and the relation for the galactic disc from galactic structure studies by Ng et al. (1997; solid line).
*Right panel*: AMR for the stars in the Solar Neighbourhood together with the relation for open clusters and a suggested improvement for the HRD-GST. The open clusters are corrected for a radial metallicity gradient of $-0.07$ dex kpc$^{-1}$.

## 5. Chemical evolution models

The AMR for nearby stars is a standard constraint for chemical evolution models of the Solar neighbourhood. Chemical models are aimed at reproducing the enrichment history of our and other galaxies, giving clues about poorly known processes like star formation, infall and so forth. In our Galaxy the resolution on the AMR and on other observational constraints is high enough to calibrate model parameters like the star formation rate, the initial mass function, the infall time-scale. With suitable choices of such parameters, all chemical models are basically able to reproduce the average AMR (see Fig. 2, left panel); the major problem is to reproduce the observed scatter about the average relation (van den Hoek & de Jong 1997). Chemo-dynamical models seem to be a promising improvement.

## 6. On gradients and galactic evolution

Details about the comparison of the various AMRs can be found in Carraro et al. (1997). Here we only focus on a few points. A comparison of the AMR obtained from the HRD-GST with the one obtained for the Solar Neighbourhood indicates that the HRD-GST tends to follow the metal-poorer trend, which is more populated and is therefore given a larger weight in star counts (Fig. 2, left panel). The large spread in metallicity at any particular age is likely intrinsic to the disc. It cannot be due to the overlap of other galactic components, because their contribution is negligible. Figure 2 (right panel) displays two relations, which cover respectively the lower and upper metallicity ends of the AMR. It suggests that the scatter can be studied by means of the HRD-GST adopting a two-component description. The first component can be associated with the beginning of Galaxy formation, 13 – 16 Gyr ago (note that the ages of the oldest stars might be overestimated, Ng & Bertelli, 1997). The second component was formed 8 – 9 Gyr ago and is possibly induced by the formation of the galactic 'bar' (Ng et al. 1996).

Figure 2 (right panel) also displays the AMR of the open clusters after correction for the present day radial gradient. An unweighted least-squares fit to the clusters younger than 2 Gyr yields $-0.07$ dex $\mathrm{kpc}^{-1}$; within the uncertainties the average correction is independent of age (Carraro et al. 1997). We did not apply any correction for the vertical gradient, since its value or even its existence are not clearly established; an apparent vertical gradient is likely due to insufficient discrimination between age groups. Figure 2 (right panel) shows that the AMRs of open clusters and stars are in good agreement, both showing a similar trend in the scatter. Both relations show a lack of scattered points in the metal-rich side in the age range 3 – 5 Gyr and/or an excess of relatively metal-rich objects in the range 5 – 9 Gyr. This apparent 'U-shape' might provide clues about infalling and/or merger events.

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