The metallicity distribution function of the galactic halo

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Introduction

One of the key observables for constraining models of the formation and chemical evolution of the Galaxy is the Metallicity Distribution Function (MDF) of the constituent stars of its various components (bulge, disk, halo). The MDF provides critical information on the enrichment history of those components with heavy elements. In the case of the halo, early enrichment may have been provided by the very first generations of massive stars, formed from material of primordial composition shortly after the Big Bang (i.e., Pop. III stars).

The observed MDF

Candidate metal-poor stars are selected in the Hamburg/ESO Survey (HES) in the Ca II K index (KP) versus $(B-V)_0$ parameter space. A cutoff line is chosen such that all stars with $[\mathrm{Fe/H}] < -2.5$ are selected (see Fig. 1). The selected stars are then vetted by moderate-resolution ($\Delta\lambda = 2$ Å) spectroscopy, and [Fe/H] is determined using the methods of Beers et al. (1999).

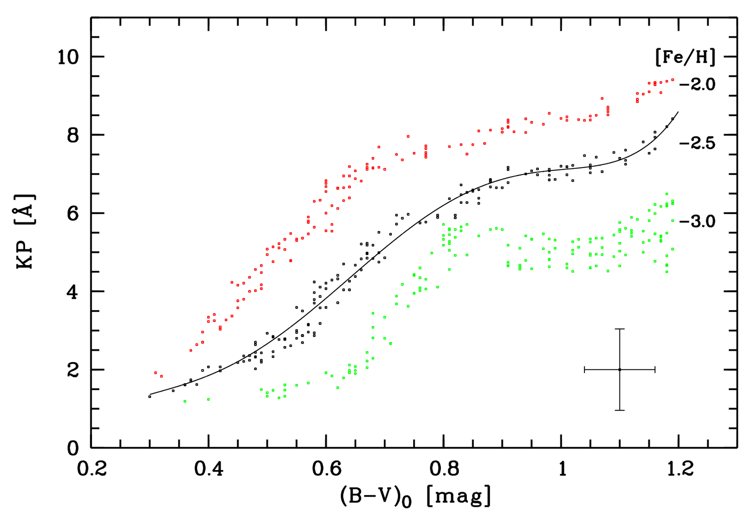

Fig. 1: Cutoff line for selection of metal-poor candidates in the KP versus $(B\text{-}V)_0$ parameter space. The error bars illustrate the 1-σ-uncertainties of the measurements of these parameters in HES spectra.

The quantitative selection criteria allow to determine for any given $(B-V)_0$ colour the fraction of selected stars as a function of [Fe/H] (see Fig. 2). That is, the contamination of the sample with higher [Fe/H] stars as well as completeness can be quantified.

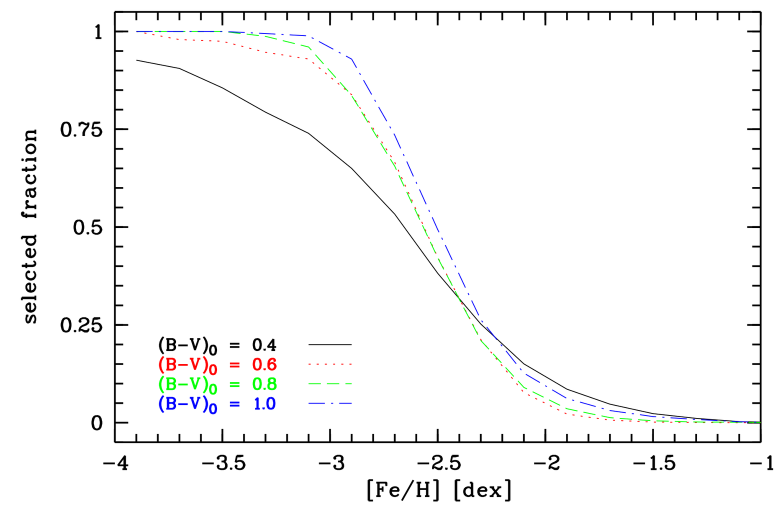

Fig. 2: Fractions of stars selected by the criteria used in the HES as a function of [Fe/H], for different $(B-V)_0$ colours.

We have constructed a MDF using 1236 stars from HES fields in which at least 50 % of the selected candidates have been observed at moderate resolution. The HES sample is currently being enlarged by completing the follow-up observations in more HES fields.

Simulation of metal-poor star samples

We have simulated samples of stars following MDFs predicted by various galactic chemical evolution models. Observational (gaussian) errors were applied to KP- and $(B-V)_0$-values before the sample underwent the same selection criteria as used in the HES. The resulting selected sample then shows the theoretical MDF as it would be observed in the HES, which allows comparisons with our observational data (see Fig. 3a–d).

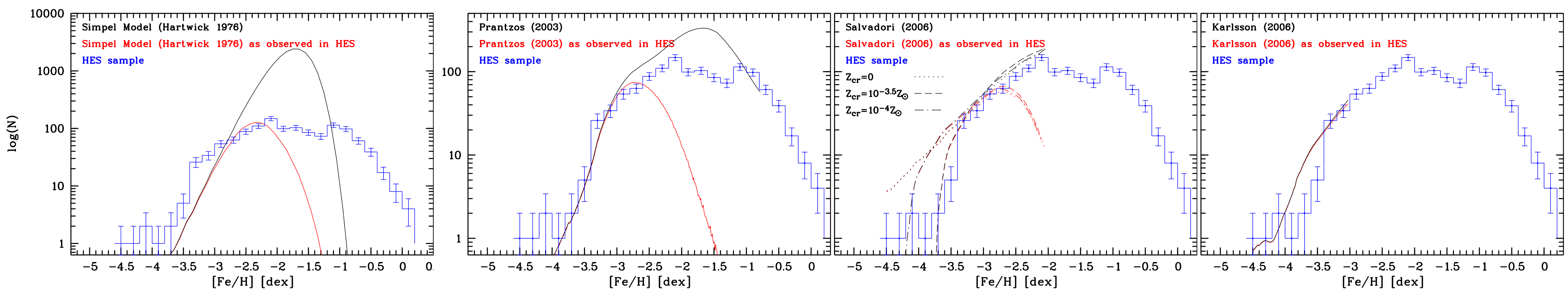

Fig. 3a-d: Comparison of simulated samples of metal-poor stars following theoretical models with the observed HES sample (blue histogram). The plots show samples following the theoretical models (black line) and samples which underwent the same selection criteria as used in the HES (red line). These selected samples show how the distribution would be observed in the HES. Stars from the galactic disk dominate the HES sample at $[\mathrm{Fe/H}] \geq -2.0$

Results and conclusions

The halo MDF as determined from the HES sample is characterized by

- a sharp drop at $[\mathrm{Fe/H}] \sim -3.5$
- a tail continuing to $[\mathrm{Fe/H}] \sim -4.5$ (note that the two stars known at $[\mathrm{Fe/H}] < -5.0$ are not part of this sample).

Neither of the MDFs shown in Fig. 3a–d predicted by various GCE models can reproduce these two features simultaneously, although the model by Karlsson predicts the existence of a tail, and the model of Salvadori et al. with $Z_{\mathrm{cr}} = 10^{-3.5} Z_{\odot}$ and the model of Prantzos predict a MDF cutoff approximately at the right position.

It remains to be explored how changes of the physical parameters of the models or improvements of the models themselves might rectify the discrepancy between theory and observations.

References

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