AGE AND MORPHOLOGY OF THE MAIN SEQUENCE FROM HIPPARCOS HR DIAGRAM DATA

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ABSTRACT

With the help of new recent stellar models, we have studied the distribution in the HR diagram of 2170 stars from the Hipparcos database, subdivided into different groups according to their total velocities with respect to the local Keplerian reference frame and into different groups of metallicity. We discuss the morphology of the main sequence at the boundary between radiative and convective stellar envelopes ($B - V \simeq 0.3$) and the age of the disk and halo stars.

Key words: HR diagram; stellar models; age of the disk.

1. INTRODUCTION

We obtained two sets of data from the Hipparcos data base: the stars with $0.2 < B - V < 0.6$ and radial velocity $v_r \leq 40$ km s^{-1}, and all the stars with $v_r > 40$ km s^{-1}, luminosity classes IV and V. The first sample should allow us to study the morphology of the main sequence, in relation to different models for the turbulent convection, the second one to study the turnoff of different classes of space velocity and possibly metallicities. Preliminary results are shown here.

2. THE SAMPLE AT $0.2 < B - V < 0.6$

This sample included originally 1554 stars, from which a preliminary sample of 1065 stars has been extracted, after excluding the stars with unplausible parallax, the variable stars, and the binaries (including both the already known ones and the newly discovered or suspected by Hipparcos). The HR diagram is shown in Figure 1, compared with two main sequences of age 10^8yr with helium mass fraction $Y = 0.27$ and metal mass fractions $Z = 0.01$ and $Z = 0.02$. The Canuto & Mazzitelli (CM) 1991 model for convection has been employed in these models,

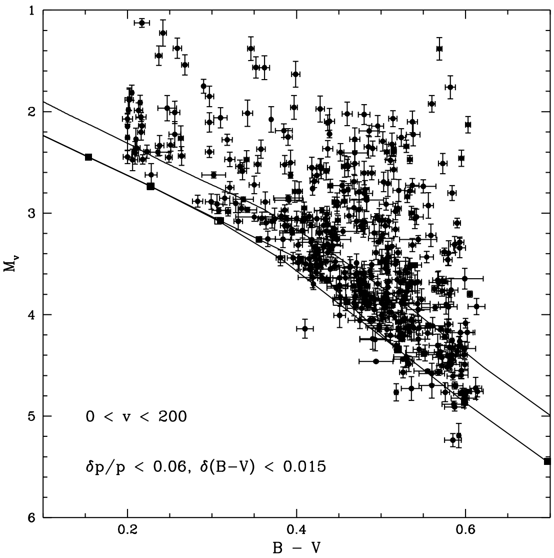

Figure 1. Stars from our sample, selected to have small errors both on the parallax and on the colour. Three main sequences from D'Antona & Mazzitelli (1997) models, transformed into the observational plane by Kurucz 1993 model atmosphere, are shown: full squares are CM models, open squares are MLT models for $Z = 0.01$, the upper line is the MS for $Z = 0.02$.

but also models of $Z = 0.01$ employing the Mixing Length Theory (MLT) are shown. It can be seen that both evolved and main sequence stars appear in the sample, so that it is necessary to separate it into classes of different age and metallicity to study it. To get an idea of the age, we separate the stars into groups of different total velocity v with respect to the Local Stardard of Rest (LSR), for which we take the solar velocity components to be $(\mathrm{U}_\odot, \mathrm{V}_\odot, \mathrm{W}_\odot)$ equal to (+9, +12, +7)km s^{-1}. In fact, as we will see also later on, young stars (age $\simeq 10^8$yr) constitute a noticeable fraction of the sample only for the range v ≤ 40 km s^{-1}.

Unfortunately, only for a very small sample it is pos-

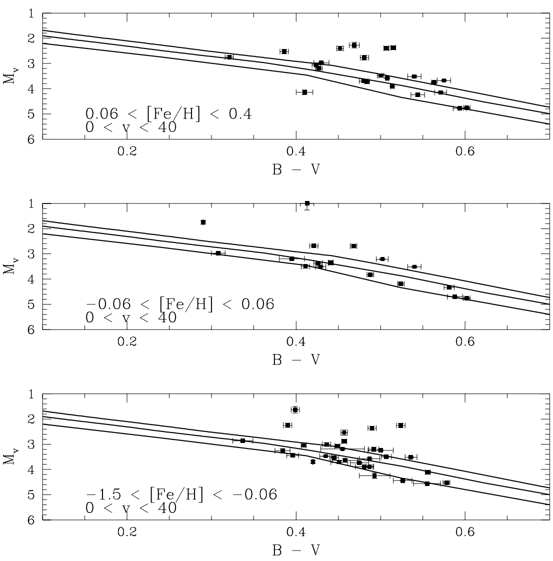

Figure 2. Stars selected in [Fe/H] from Cayrel et al. 1992 catalogue. In addition to the main sequences for Z = 0.01 and Z = 0.02, also the MS for Z = 0.03 is shown.

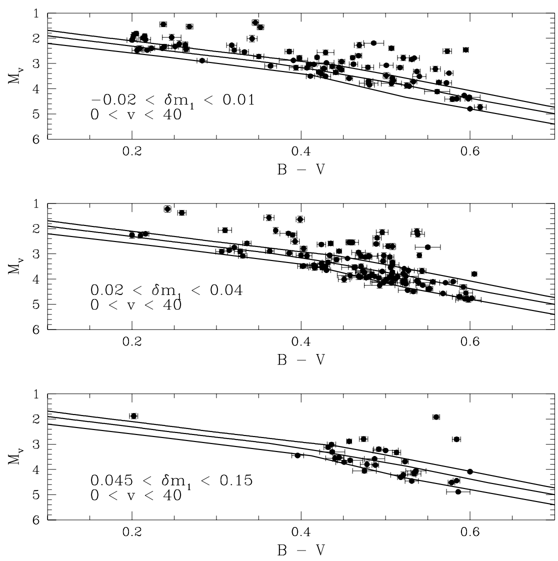

Figure 3. Stars selected in δm_1 from Hauck & Mermilliod 1989 catalogue. The larger δm_1, the smaller the metallicity (see, e.g. Edvardsson et al. 1993 calibration).

sible to obtain high resolution spectroscopic determinations of $[Fe/H]$. This is shown in Figure 2, based on Cayrel et al. 1992 catalogue, together with three MS, for $Z = 0.01$, 0.02 and 0.03. In the figure we have selected only the stars with low total space velocity. It can be seen that, qualitatively, the lower metallicity stars sample is closer to the $Z = 0.01$ lower boundary than the other samples, but certainly there is no strict relation: the observational main sequences seem to be less separated in colour than the theoretical ones. This result is confirmed by dividing the stars into groups of different δm_1 (Crawford 1975), based on their Strömgren colours derived from the Hauck & Mermilliod 1989 version of Hauck & Mermilliod 1985 catalogue (Figure 3).

The relation between high dispersion spectra metallicity and δm_1 is certainly significant, but has a large sigma, so δm_1 must be used only as a statistical indicator of metallicity. Figure 3, however, shows that the $Z = 0.01$ MS can be regarded as a reasonable lower envelope of the main sequences of different metallicity. We show in Figure 4 the HR diagram of the 'best' stars of our sample, with low total space velocities with respect to the LSR (0 < v < 40 km s^{-1}), compared with this lower envelope of models, in the MLT and CM turbulence treatment. The difference between the models resides in the small triangle between the open and full squares, at $B - V \simeq 0.4$. It is not possible to say which models are more appropriate, at this stage of the analysis.

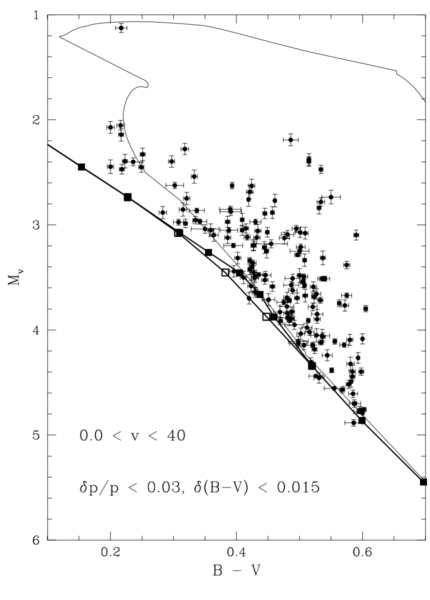

Figure 4. Final HR diagram: only stars with low space velocity are shown, so to populate also the upper MS. CM models (full dots) reproduce well the lower MS observational boundary, but certainly this first analysis can not exclude MLT models.

3. THE OLD DISK

We use a sample of 419 stars from the original sample of 616 stars with $v_r > 40$ km s^{-1}, in conjunction with our sample of 1065 stars with $v_r < 40$ km s^{-1} and $0.2 < B - V < 0.6$. In this way, in the region in which the turnoffs of the disk population are most evident, our sample includes all stars measured by Hipparcos with luminosity classes IV and V. Figures 5–8 show the sample divided into velocity groups. We have left also the stars with large errors on the parallax, to show that practically all the

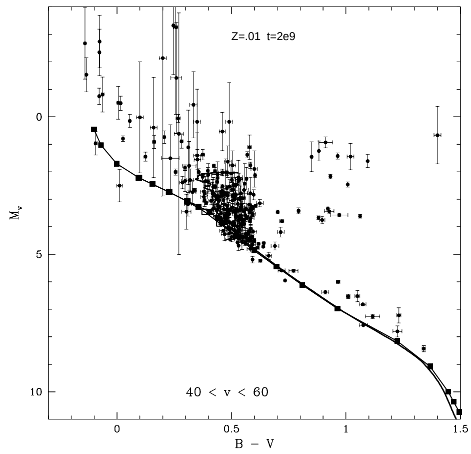

Figure 5. HR diagram of stars having 40 < v < 60 km/s, in both our samples. Together with the $t = 10^8$ yr MS of Z = 0.01, we show the isochrone of t = 2 Gyr, which provides a lower boundary to the average age of this sample.

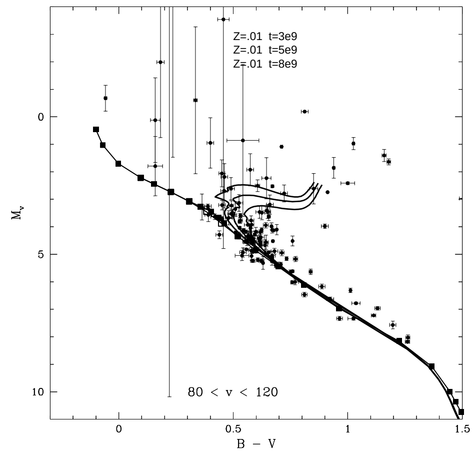

Figure 7. HR diagram of stars having 80 <v<120 km/s, in both our samples. Isochrone from t = 3 Gyr to t = 8 Gyr (Z = 0.01) are shown. Stars of lower metallicity (halo population?) begin to appear at B–V ∼ 0.5.

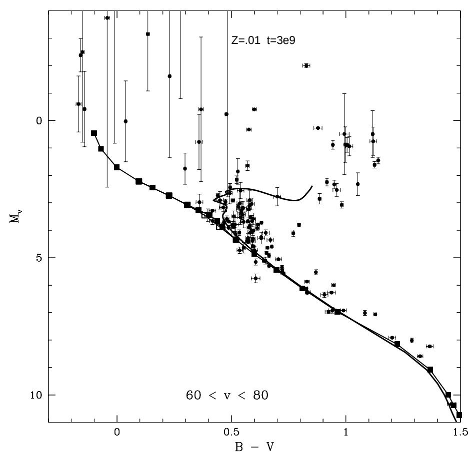

Figure 6. HR diagram of stars having 60 <v<80 km/s, in both our samples. Here the boundary isochrone is the one for Z = 0.01, t = 3 Gyr.

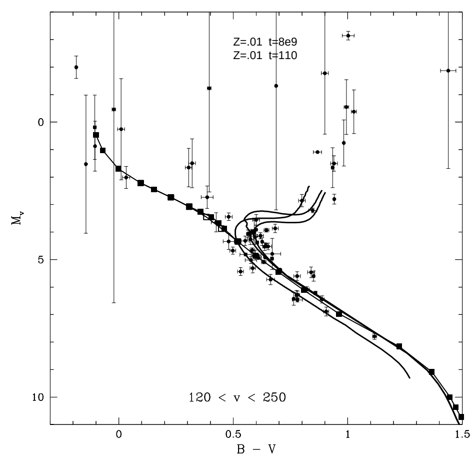

Figure 8. HR diagram of stars having 120 <v<250 km/s. Isochrones of t = 8 Gyr and t = 10 Gyr (Z = 0.01) are shown, along with an isochrone of t = 10 Gyr from D'Antona et al. 1997, having $Z = 4.10^{-3}$ and Y = 0.24. It is evident that an emerging population of about 10 Gyr is present in this sample, containing halo stars.

samples include some young stars. The stars having 40 < v < 60 present a clear turnoff at ages larger than ∼ 2Gyr. The turnoff age increases with increasing velocity (a well known result, see, e.g. Cardini et al. 1977, Edvardsson et al. 1993). At 60 < v < 80 km s^{-1} the limiting age is ∼ 3Gyr, the sample 80 < v < 120 km s^{-1} includes a turnoff at ages ∼ 3 − 5Gyr, but also shows the appearence of a lower metallicity population (the halo?) in the presence of some subdwarfs at $B - V \sim 0.5$, which apparently show a much older turnoff (8–10 Gyr). The stars at $v > 120$ km s^{-1} are substantially halo stars, well represented by the isochrone of D'Antona et al. 1997 having $Z = 4 \times 10^{-3}$ (47 Tuc type population) and by the 10Gyr $Z = 0.01$ isochrone. We tentatively conclude that the lower age of halo stars in the vicinity of the Sun is at least 10Gyr.

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