Horizonal-Branch Stars:
Their nature and their absolute magnitude

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Abstract. Horizontal-branch stars play an important rôle in defining the absolute distance scale in the universe. For that one has to know $M_V$ at relevant $B-V$ with well defined $[M/H]$ for each type of horizontal-branch star. The nature of the horizontal-branch stars is reviewed with emphasis on all the open questions regarding evolution and structure, questions which show that these stars are not the easiest objects in the distance scale discussions.

Using the HB stars with the best Hipparcos parallaxes, the HB at $(B-V)_0 = 0.20$ and $[\text{Fe/H}] = -1.5$ has $M_V = +0.71$. Assuming the $[\text{Fe/H}]$ to $M_V$ relation for RR Lyrae stars to be valid for HB stars too, one finds $M_V \simeq 1.00$ for $[\text{Fe/H}] = 0$.

1. The stars

Stars of the horizontal branch (HB) are post red giant (RG) stars which burn helium in their core. The mass of the He in the core is thought to be $\simeq 0.5 \, M_\odot$. Along the HB in the colour-magnitude diagram (CMD) one recognizes (from hot to cool) the types sdOB, sdB, HBB, HBA, RR Lyr, and RHB (for definitions see nomenclature review by de Boer et al. 1998). Depending on the initial parameters of the progenitor main sequence star (initial mass, metal content, etc.) as well as on aspects of the RG mass loss phase, the star will retain a hydrogen shell of a certain mass. If sufficient hydrogen remained there is also a hydrogen burning shell.

The HB stars have a low to normal atmospheric metal content. Naturally, the colour of the star is determined by the atmospheric structure $(T_{\text{eff}}, \log g, [M/H])$. HB stars show no or only very slow rotation (Peterson 1983).

A large variety of models for HB stars have been calculated (e.g., Sweigart & Gross 1976; Sweigart 1987; Dorman 1992) all indicating that total mass is positively correlated with luminosity and redness. At the very blue end of the HB the mass of the stars is $\simeq 0.5 \, M_\odot$ (vanishingly thin H shell, no shell burning), at the red end it may amount to $\simeq 1.0 \, M_\odot$ or more (thick shell and well established H shell burning).

In metal poor globular clusters the HB is populated at the blue end, while in more metal rich globular clusters the HB stars group together in a small colour range at the red end, there forming a ‘red clump’ seemingly associated with the red giant branch. However, this picture is rather simple and observations
show that further parameters are required to also explain those globular clusters deviating from that scheme.

2. Evolutionary history and the HB stars as a group

What is the evolutionary history of stars now being in the HB phase? With which mass did these stars start on the main sequence? Models indicate that all stars initially having $0.8 \leq M \leq 3 \, M_{\odot}$ do become HB-like stars. This range immediately implies that the HB stars intrinsically span a wide range in age and thus probably also in metal content. A star starting with $3 \, M_{\odot}$ will evolve into an HB star within $\simeq 10^9$ y. It must thus be regarded as ‘young’ and have formed in the disk from material with most likely ‘solar’ composition. Stars starting with $0.8 \, M_{\odot}$ will need $\geq 10^{10}$ y to become HB like, can thus be regarded as ‘old’ objects and therefore must have formed from material substantial poorer in metals than the Sun.

Since it is virtually impossible to determine the age of an individual field star with any certainty, one cannot discriminate a young from an old field HB star, except perhaps when assuming some age-metallicity relation. We must acknowledge that the field HB stars we have access to are a mix of young and old stars. With a more or less constant star formation rate in the Milky Way the HB star group forms a continuum in age but the older ones are likely to dominate in number.

3. HB star metal content and its consequences

The determination of the metal content in the atmospheres of stars is with present day technology in principle not very difficult. Spectroscopic investigations show that the sdB stars have near normal Si with somewhat low He (Heber et al. 1984). The HBA stars, among which are the long known classical field HB stars, range in metal content from solar to $[\text{M/H}] \simeq -2.0$ using photometric methods (e.g. Gray et al. 1996), while spectroscopic determinations (naturally for just a few stars) indicate generally low metal abundances, such as small $[\text{Fe/H}]$, in part as low as in metal poor globular cluster giants (Kodaira & Philip 1984; Adelman & Philip 1994). RR Lyr stars are known to spread over a large range in metal content (see e.g. Lambert et al. 1996, Layden 1994) with a predominance of metal poor ones. The RHB stars have not been studied intensively yet.

Many metal abundance values are based on the measurement of some line index, like the Ca index, or are based on the $\Delta S$ method, giving a metallicity index to be denoted with $[\text{M/H}]$. The index is then calibrated with the help of spectroscopic $[\text{Fe/H}]$ values (Lambert et al. 1996, Layden 1994). Such studies lead, for RR Lyrae stars, to a relation of $M_V$ versus $[\text{Fe/H}]$ in which $M_V$ is taken from Baade-Wesselink methods (see Fernley 1994). However, one has to acknowledge that such metallicity indices are often not very accurate. When metallicities are given one always should trace their origin (are they photometric

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1 Only when Fe lines are seen and analysed indeed, the use of $[\text{Fe/H}]$ is justified
or spectroscopic values?) and one should be wary of too many decimals which often come only from a numerical transformation using rather uncertain input values.

Also for globular clusters the photometric indices are problematic. This is of relevance here, since spectroscopic abundance determinations are available only for a limited number of clusters. Also the $Q_{39}$-index gives ambiguous results (de Boer 1988). This can be seen in Fig. 12 of Zinn & West (1984), in which the discrepancy between the metallicity from the $Q_{39}$-index and that from spectroscopy is seen to range from $\Delta[\text{Fe/H}]$ of $-0.3$ to $+0.3$, depending on the metallicity and type of cluster. The discrepancies for clusters with blue HBs show a clear trend. The reason is, of course, that the photometry uses the entire cluster in which the various star types (red giants, main-sequence stars, red and blue HB stars) contribute according to their brightness and their number in the cluster (in particular a blue or a red HB), thus mixing stars of widely differing temperature and gravity into one photometric index measurement. The widely used Zinn & West (1984) metallicity scale clearly is of limited accuracy (de Boer 1988).

Can one use the abundance values to estimate the age of each star? Unfortunately, these abundances are not necessarily giving the intrinsic metal content of the stars. HB-like stars have a rather stable atmosphere. This means that in particular in conditions of high surface gravity, such as in sdOB and sdB stars, the heavy elements can diffuse downward and sink out of the atmosphere so that the star looks more metal poor than it is intrinsically. The effect was first explained for White Dwarfs by Michaud et al. (1984). In the RHB stars on the other hand, with low surface gravity, the radiation field may levitate the heavy elements (see Cassisi et al. 1997), so that their atmospheres may look richer in metals than the star really is. Furthermore, due to convection during the RGB phase He may be mixed into the surface layers of the star, possibly producing He-rich HB stars. For such He enriched HB star atmospheres, Sweigart (1997) speculates that the mixing in of He results in a bluer HB morphology (see also Sect. 9), possibly an enlarged RR Lyrae period shift, and lower surface gravities in blue HB stars.

According to model calculations, the absolute magnitude $M_V$ of HB-like stars depends on $[\text{M/H}]$ in the sense that metal poor stars are brighter than metal rich stars. This is caused by an intricate interplay between internal opacity and the luminosity of the H-burning shell (Dorman 1992) and has no detailed relation with the metal content in the photosphere (see further Sect. 9).

Summarizing, the determination of the abundance of the elements leads to knowledge about the composition of the stellar surface. For inhomogeneous envelopes these atmospheric abundances are not related with the overall $[\text{M/H}]$ of the star. The stellar structure models must take these inhomogeneities into account, lest they predict brightnesses and colours which do not conform with reality. Vice-versa, interpretation of the observed colour and brightness with current models may lead to faulty atmospheric and structural parameters.

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2Also spectroscopic abundances may have substantial uncertainties; when the $T_{\text{eff}}$ chosen for the analysis is different from reality, the line excitation model is off too, leading to errors in metal abundances easily of the order of 0.1 dex
4. Are ‘red HB stars’ really red HB stars?

The location in the CMD where red HB stars appear contains numerous other kinds of stars. Therefore, knowing if a red field star is a RHB star is not easy, because the appearance of a star with colour and magnitude like that of a red HB star is not sufficient proof.

The red part of the HB crosses the red giant branch (RGB). This is well known from the study of the redder (less metal poor) globular clusters, where in some cases the RHB stars group together into the ‘red clump’. For the field stars the above must be true, too.

It has become clear from models that the evolution on the RG branch has temporal irregularities (depending on which parameter one considers). This is related to the passage of the H-burning shell through the chemical discontinuity left by the convective envelope during the first dredge up phase (see e.g. Cassisi et al. 1997). It results in a so called RGB bump, a location where the RGB is (relatively) overpopulated (at $M_V \simeq +0.5$ mag).

Due to the above coincidence, the RHB and the RGB bump appear to lie almost at the same $L$ and $T$ (depending on the age and the metallicity of the star group) and thus at virtually the same position in the CMD. This implies that it is for field stars almost impossible to discriminate between a RG star and a RHB star.

A further problem is that blue loop stars (more massive stars which land in a more luminous core He burning phase) appear in colour magnitude diagrams very close to where the HB is. At the reddest and faintest point, these stars lie at $M_V = -0.5$ mag.

The mentioned evolutionary states lead in complicated ways to an enhancement of stars in the CMD, as nicely illustrated by Gallart (1998). A summary of evolutionary details is given by Girardi et al. (1998). Clearly, stars in the RHB domain of a colour magnitude diagram for field stars cannot simply be taken to be RHB stars indeed.

5. Gaps and other structure on the HB

Newell (1970) presented the first evidence for an irregular distribution of stars along the horizontal branch. In fact, he showed that there is evidence for two ‘gaps’, regions on the HB with reduced numbers (or even devoid) of stars. This has been corroborated since then many times in newer and more extensive data sets, such as those collected for the sdB studies in Bonn (Aguilar Sánchez 1998). The gaps are also present in the $T_{\text{eff}}$ versus log $g$ diagram. Globular cluster HB’s show gaps as well. A recent detailed study is that by Ferraro et al. (1998). The cause for the gaps is largely unclear and several possibilities are being investigated.

One possibility is that, in globular clusters, HB stars are present with two different mass ranges. Catelan et al. (1998) have simulated globular cluster HB distributions using both unimodal and bimodal mass distributions. The gaps do seem to be present but not with great significance. Even in the unimodal mass distribution sparse regions can occur.
Another possibility for the occurrence of gaps is that the HB stars behave such that certain ranges of $T_{\text{eff}}$ (or of $B-V$) are not present. I speculate that a gap may result from a small discontinuity in the burning in the hydrogen shell. If the energy production in a marginally burning shell is temporarily decreased (e.g. by stochastic fluctuations) the ensuing drop in temperature may be sufficient for the burning not to come up to the original level any more, and the hydrogen burning may extinguish altogether. The atmosphere then would become more compact and the colour of the star more blue than before. Thus at that HB location a gap in the smooth distribution along the HB may be created.

A further possibility for the gaps to emerge is when the HB is populated by stars having different evolutionary origins. If the genesis of HB stars follows different routes, such as one kind directly from the RGB, the other through some binary star evolution (see e.g. Iben & Tutukov 1985), the two routes may lead to different final masses and possibly to preferred locations on the HB.

HB stars do seem to deviate in colour from expected values in certain cases, too. Grundahl et al. (1998) noted from Strömgren photometry that the shape of the distribution of the stars on the HB in the $u-y$ colour in the globular clusters M 13, NGC 288 and 6752, deviates from that of theoretical models. Either the stars are brighter than expected over a part of the blue HB, or they are bluer than expected. They speculate that there are two populations even for HB stars within a globular cluster.

New HST data on a few metal rich globular clusters have shown that these clusters do have a population of blue HB stars, in contrast to established beliefs for metal rich clusters (Rich et al. 1997). Not only that, the HB’s appear to become brighter toward the blue, in stark contrast to what has thusfar been found.

Summarising, the shape of the observed HBs has large variations which the standard models cannot explain. What consequences have the gaps, the in-cluster differences, and the different possible origins of the HB stars for our understanding of field HB stars?

6. HB star mass and absolute magnitudes

Models indicate that the mass of HB stars runs from 0.50 $M_\odot$ at the blue end to $\simeq$ 1.0 $M_\odot$ at the red end of the HB. The luminosity runs from log $L = 1.2$ to 1.7 $L_\odot$, respectively. Both mass and luminosity can only be found for stars with known distance.

In spectroscopic studies, which result in $T_{\text{eff}}$, log $g$, and the apparent luminosity $L$, masses of the HB stars in globular clusters (distance known) have been determined. It was found that the HBB stars in NGC 6397 (de Boer et al. 1995) and the sdB stars in M 15 (Moehler et al. 1995) have a mass of $\simeq 0.4$ $M_\odot$, much lower than the canonical value of 0.5 to 0.6 $M_\odot$ for such stars. Both NGC 6397 and M 15 have the very low metallicity ([M/H] $\simeq -2$ dex).

Masses for RR Lyrae stars can be calculated from the relations of period, luminosity and mass. Here the luminosity is based on the distance from Baade-Wesselink methods. Carney et al. (1992) found masses as low as 0.45 $M_\odot$ for low metallicity ([M/H] $\simeq -1.8$ dex) field RR Lyr stars, but $M \simeq 0.55$ $M_\odot$ for larger [M/H], still all below the theoretical expectation.
In a first study using Hipparcos data, de Boer et al. (1997a) tried to resolve the $T_{\text{eff}}, \log g$ and mass problem of the HB stars. Using the 8 best Hipparcos observed field HBA and sdB stars de Boer et al. (1997a) showed that they apparently have the low mass of $\approx 0.4 \, M_\odot$ as well. The similarity of the mass of the cluster HB stars and the field HB stars can be seen in Fig. 2 of de Boer et al. (1997b).

It has been claimed that there is a difference in $M_V$ between cluster RR Lyr stars and field RR Lyr stars (see Gratton 1998). Catelan (1998) doubts that such a difference exists and speculates that uncertainties in the basic stellar parameters and in the methods to derive them lie at the base of such claims.

The absolute magnitude of the blue HB stars depends in a very sensitive way on the luminosity and the surface temperature. When going to hotter stars, $M_V$ will be fainter dramatically, leading to ‘drooping’ HBs. Thus the bluest part of the HB is not useful to calibrate $M_V$ of the HB.

7. **Kinematics indicates two populations of HB stars**

The studies of the kinematics of HB-like stars indicate that these stars form a rather inhomogeneous group.

Using spectroscopic distances, radial velocities, and proper motions, de Boer et al. (1997c) showed that the sdB stars have, by and large, disk like orbits. As a sample the stars rotate along with the disk rather well with an asymmetric drift of only $-36 \, \text{km s}^{-1}$. The scale height of the sdB stars is of the order of 300 pc (Aguilar Sanchez 1998).

Altmann et al. (1998) investigated the kinematics of HBA stars. The orbits of several of these extend to large $z$. The asymmetric drift of their sample is nearly $-200 \, \text{km s}^{-1}$, indicating these stars are rather on halo like orbits.

RR Lyrae stars as a group show the wide range of disk like to halo like orbits. The velocity in the direction of galactic rotation can be correlated with metallicity, giving the trend that metal rich RR Lyrae partake in the rotation of the disk, the metal poor stars (the majority) do not (Layden et al. 1996).

The existence of *differences* in kinematic behaviour of RR Lyr and HBA stars on one hand and that of sdB stars on the other hand may indicate that the field HB star population differs significantly from the globular clusters. So is it allowed to assume that the field HB stars and the cluster HB stars are identical? Would it be possible to take the kinematic behaviour as an indication for $[\text{M/H}]$ in the stars, and thus as indication for what $M_V$ ought to be?

8. **Brightness bias in data samples due to evolution and metallicity**

One has to take care of a brightness bias based on metallicity and on evolution when determining averages from samples.

HB stars become brighter when evolving from the zero-age HB (ZAHB). Slowly the luminosity gets larger while the surface temperature stays almost the same. This means that HB stars cover a range in absolute magnitude. Inspection of the evolutionary tracks of Dorman (1992) shows the rise in $M_V$ amounts to about 0.07 mag. Thus, when studying a sample of field HB stars one is not
dealing with a sample of the same $M_V$ for a given $B-V$. A nice example of the significance of this aspect can be found in the ultraviolet CMD and the derived $L$, $T_{\text{eff}}$ diagram for M 13 (Parise et al. 1998).

The metal content of the stars has an effect on $M_V$. Lambert et al. (1996), basing themselves on numerous previous studies, arrive at a metal dependence of $M_V = 0.93 + 0.17 \times [\text{Fe}/\text{H}]$ for RR Lyr stars (in which $[\text{Fe}/\text{H}]$ really is only $[\text{M}/\text{H}]$). Thus $M_V$ may vary (for $-2 < [\text{Fe}/\text{H}] < 0$) over $\simeq 0.34$ mag, also for field HB stars.

The sum of the effects of evolution and of metallicity (assuming that the metallicity relation applies also to the star types adjacent to the RR Lyrae) is that the metal poor evolved HB stars are the brightest, brighter by 0.4 mag than the metal rich ZAHB stars. The latter may thus be underrepresented in samples.

9. What do models tell us?

The end of the RGB phase is marked by the ignition of He in the core of the star, leading to the transformation of the star into a ZAHB star. The He mass is then thought to be $\simeq 0.5 \, M_\odot$. The reddest HB stars have retained a rather heavy hydrogen shell and thus a non-negligible amount of hydrogen shell burning.

Depending on the overall metallicity the H-burning contributes more or less to the overall luminosity. Here the details of CNO to Fe variations lead to considerable variations in luminosity (Dorman 1992). At $T_{\text{eff}} = 10^4$ K, e.g., one finds (see his Fig. 7) a $0.55 \, M_\odot$ star of $[\text{M}/\text{H}]=-0.47$ dex to have log $L = 1.48$ while for a $0.68 \, M_\odot$ star existing at the same temperature with $[\text{M}/\text{H}]=-2.26$ dex the luminosity is log $L = 1.58$.

The core luminosity itself depends on the total mass of the star, as well as on the He-core mass. Rotation of the RGB star may lead to higher core masses (Mengel & Gross 1976) with later a larger HB star core luminosity. However, this does not directly translate into a larger overall luminosity since the consequent larger mass loss at the RGB tip will lead to a lower H-shell luminosity. Modelling the effect of a larger He core mass (Caloi et al. 1997; Sweigart & Catelan 1998) one finds for metal poor clusters brighter and bluer ends of the HB.

Diffused He will alter the structure of the HB stars and the shape of the horizontal branch. Metal rich RHB stars with enhanced He will evolve away from the ZAHB into very extended blue loops, thereby producing a HB sloping up to brighter stars toward the blue (Sweigart & Catelan 1998). Here the HB may be as bright as $M_V = 0$ mag.

At the cooler end ($\log T_{\text{eff}} = 3.85$) Cassisi et al. (1997) investigated the brightness of the RHB and the RGB bump. The absolute magnitude of the ZAHB varies from $M_V = 0.51$ mag for $[\text{M}/\text{H}]=-2.04$ to $M_V = 0.86$ mag for $[\text{M}/\text{H}]=-0.57$. The $M_V$ of the RGB bump is then $-0.20$ and $1.12$ mag, respectively. It shows that the brightness difference between ZAHB and RGB bump changes over more than 1 mag in this metallicity range (Cassisi et al. 1997). Such models make clear that, due to the possible confusion of RHB stars with clump stars, candidate field RHB stars are utterly useless to calibrate the HB.
Table 1. Field Horizontal Branch stars and RR Lyr

| Name     | V     | B − V | A_V | [Fe/H] | π     | σ_π   | d     | M_V ± ΔM_V |
|----------|-------|-------|------|--------|-------|-------|-------|------------|
| HD 86986 | 7.99  | +0.12 | 0.09 | −1.9   | 3.78  | 0.95  | 265   | +0.79 ± 0.55 |
| HD 109995| 7.62  | +0.04 | 0.00 | −1.8   | 4.92  | 0.89  | 205   | +1.08 ± 0.40 |
| HD 130095| 8.13  | +0.08 | 0.31 | −2.0   | 5.91  | 1.08  | 170   | +1.68 ± 0.40 |
| HD 139961| 8.85  | +0.10 | 0.31 | −2.0   | 4.50  | 1.19  | 220   | +1.81 ± 0.60 |
| HD 161817| 6.96  | +0.16 | 0.06 | −1.6   | 5.81  | 0.65  | 170   | +0.72 ± 0.25 |
| RR Lyr   | 7.66  | +0.25 | 0.09 | −1.4   | 4.38  | 0.59  | 228   | +0.78 ± 0.29 |

HB star data from de Boer et al. (1997a), RR Lyr from Fernley et al. (1998). ΔM_V given is due to the uncertainty in the parallax only.

Figure 1. The HB derived from stars with good Hipparcos parallaxes (π/σ_π ≳ 4) is presented. Absolute magnitudes for HB stars are given for the prototype HB’s (●) from de Boer et al. (1997a). RR Lyr (filled ◆), the only RR Lyrae star with good parallax (Fernley et al. 1998), is plotted at B − V = 0.25 with an errorbar in the colour. Using the M_V versus [M/H] relation for RR Lyr stars, the HB for solar metallicity (Δ) and for [M/H] = −2 (∇) is indicated.

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10. What does Hipparcos tell us about the HB?

With Hipparcos about a dozen blue HB stars were measured of which only few have parallaxes accurate enough to be used to determine \( M_V \) for the individual stars. These are essentially only the long known prototype HBA stars whose \( M_V \) were presented by de Boer et al. (1997a). Their data \( (\pi/\sigma_\pi \gtrsim 4) \) are given in Table 1.

Several stars with colour and brightness like RHB stars are present in the Hipparcos data base. Given the risks of confusion with stars in different states of evolution (see Sect. 5) we will ignore these objects.

Stars of the blue HB, the red HB and RR Lyrae type have been used in an analysis by Gratton (1998). Many of these stars have less accurate parallaxes and thus deteriorate the quality of the ultimate averaged \( M_V \). He assumes the HB should have a shape like that of M 5 (does M 5 have the same history as the field stars?) and looks at the brightness differences between the field and the cluster HB shape. Then, his error weighting procedure is flawed (Popowski & Gould 1998), and the analysis should have resulted in an absolute magnitude \( \simeq 0.1 \) mag fainter.

A large number of RR Lyr type stars have been observed with Hipparcos. Only RR Lyr has a parallax large enough \( (\pi/\sigma_\pi \gtrsim 4) \) to be included in Table 1. The absolute magnitude for the RR Lyraes as a group is not based on parallaxes but on the detected proper motions together with a model for their kinematics (Fernley et al. 1998). Since RR Lyrae stars have a range of metallicity and other intrinsic parameters, it is not proper to treat them as a single kinematic group. Thus, only RR Lyr is of use.

Clearly, working directly with the best parallaxes (Table 1) provides the least ambiguous result. Plotting these best \( M_V \) values one can see the HB for the field stars (Fig. 1).

An extrapolation to the blue edge of the RR Lyr strip, taking the plotted data at face value, gives \( M_V \simeq 0.75 \) mag (Seggewiss 1998).

Assuming that the [M/H] values for these prototype HBA’s are accurate, the \( M_V \)’s can be translated (using the relation found for RR Lyr stars, see Sect. 8) into the solar metallicity HB. The observed stars so indicate that for [M/H]=0 and \( (B-V)_0 = 0.20 \) the \( M_V \simeq 1.00 \) mag, and for [M/H]=−2 (at \( (B-V)_0 = 0.20 \)) that \( M_V \simeq 0.65 \) mag (see Fig. 1).

11. Consequences for studies of field HB stars

From all of the above one must conclude that the assumption to be able to find one ultimate \( M_V \) for HB-like stars is most likely wrong.

- HB stars in the field form a mix of old and metal poor stars with young and normal metallicity stars, thus intrinsically form a very inhomogeneous group. This is supported by the kinematic data for HB stars. The absolute magnitude of a star must therefore be normalised to a reference [M/H]. But, is [M/H] in the atmospheres of the observed stars the same as the original [M/H] (diffusion, levitation, convection)? Is then surface metallicity really correlated with \( M_V \)? Or can one assume that all stars which kinematically are disk stars have normal [M/H] and that halo orbit stars have low [M/H]?
• For most stars the listed [Fe/H] values are based on a photometric index. This means that substantial uncertainties are present in the value for individual stars. For all the complexities see Layden (1994) and Lambert et al. (1996).
• The luminosity of the stars depends on the total mass and on the core mass. If the masses are different (smaller/larger) than the canonical \( \sim 0.5 \, M_\odot \) then also the \( M_V \) must be different (fainter/brighter).
• Observations indicate the existence of globular cluster horizontal branches sloping down as well as up toward the blue. Variations of He abundance may explain all these slopes. The differences in slope underline the possibility of large variations in \( M_V \) for field HB stars.
• The nature of the gaps on the HB points to possibly different evolutionary routes and thus to possibly differences in \( M_V \).
• Very blue HB stars have a large and very temperature sensitive range in \( M_V \); they are not useable.
• Red HB stars are better to be avoided for general calibration work.

12. Concluding remarks

After the first paper dealing with \( M_V \) for field HB stars based on Hipparcos parallaxes (de Boer et al. 1997a) numerous investigations came to different conclusions about the absolute magnitude of the HB. My suspicion is that all of the above discussed aspects of the intrinsic properties of the HB stars lie at the base of the discrepancies. Unfortunately, only better parallaxes and for more stars, such as hopefully will be obtained in the planned missions DIVA (Röser et al. 1997) and GAIA (Perrymann et al. 1997), can resolve the problems without ambiguity.

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