A calibration of Geneva photometry for B to G stars in terms of T_{eff} , $\log g$ and $[M/H]$

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Abstract. We have used recent Kurucz models and numerous standard stars to improve the calibration of the Geneva photometric system proposed a few years ago. A new photometric diagram for the classification of intermediate stars ($8500 \leq T_{\text{eff}} \leq 11000$ K) is proposed and fills a gap that the previous calibration had left open. Evidence is given for a clear inadequacy of the new Kurucz models in the region of the parameter space where convection begins to take over radiation in the star's atmosphere. This problem makes the determination of the surface gravity difficult, but leaves that of the other parameters apparently unaffected. The determination of metallicity is considerably improved, thanks to the homogeneous spectroscopic data published recently by Edvardsson et al. (1993). Instead of showing the traditional diagrams, we chose to publish the diagrams of the physical parameters with the inverted grids inside, i.e. the lines of constant photometric parameters

Key words: stars: general; atmospheres; fundamental parameters

1. Introduction

The determination of the fundamental atmospheric parameters of stars remains an everlasting preoccupation of most stellar astronomers. The imminent release of the Hipparcos results certainly makes this problem especially acute. On the other hand, new and hopefully more realistic atmosphere models have become available in the last few years (Kurucz 1991, 1993, 1994), as well as a large amount of precise, homogeneous $[\text{Fe}/\text{H}]$ values (Edvardsson et al. 1993). We found it worthwhile, therefore, to revise the already published calibrations (North & Nicolet 1990, hereafter NN90; Kobi & North 1990, hereafter KN90) and

to take this opportunity to fill the gap that existed for stars with effective temperatures between 8500 and about 10500 K. The efficiency of the Geneva system is similar to that of the widely-used *uvby* β one, so it would be a pity not to exploit it fully. The only drawback of the Geneva system, compared to the *uvby* β one, is its sensitivity to interstellar reddening for A and cooler stars.

In the following, we shall present successively the three temperature domains which are treated separately (as in the *uvby* β system), discussing together the reference (or standard) stars and the theoretical grids. The possible applications and limits of this calibration are discussed in the conclusion.

2. The B stars

2.1. Methods and results

Following Cramer & Maeder (1979), we use here the reddening-free parameters X and Y which have, as these authors showed, the optimum efficiency for determining the effective temperature and the surface gravity respectively. Although the definition of the X and Y parameters is given in several papers (Cramer & Maeder 1979; NN90), we recall it here for convenience:

$$X = 0.3788 + 1.3764 U - 1.2162 B1 - 0.8498 B2 - 0.1554 V1 + 0.8450 G \quad (1)$$

$$Y = -0.8288 + 0.3235 U - 2.3228 B1 + 2.3363 B2 + 0.7495 V1 - 1.0865 G \quad (2)$$

where U , $B1$, $B2$, $V1$ and G stand for the Geneva colour indices $[U-B]$, $[B1-B]$, $[B2-B]$ etc. Let us recall that the Z parameter allows the separation of the Bp stars (mostly of the Si and SiCr types) from the normal B stars (Cramer & Maeder 1980); it will not be used here, however.

The synthetic colours U , $B1$ etc. have been computed by one of us (BN) using recent Kurucz models with scaled

solar metallicities and a constant microturbulent velocity $\xi_t = 2 \text{ km s}^{-1}$ (Kurucz 1993). The passbands used were those determined by Rufener & Nicolet (1988). The X and Y parameters computed in this way are very similar to those obtained for older models, because the additional line opacity of the new models affects essentially the ultraviolet rather than the visible part of the energy distribution. As before, these synthetic parameters do not reproduce exactly the observations and should be corrected. However, we adopted for this particular point another philosophy than that generally adopted to date (Lester et al. 1986; Moon & Dworetzky 1985 etc.). Instead of comparing the observed colour indices with those interpolated in the “direct” grids of synthetic colours from the known fundamental parameters, we preferred to compare the fundamental physical parameters with those interpolated in the inverted grid from the observed colours. Briefly, the inversion of a grid implies an iterative, two-dimensional spline interpolation in the “direct” grid (where colours are given for regularly spaced values of physical parameters like T_{eff} and $\log g$) and results in an “inverted” grid giving the physical parameters for regularly spaced values of the *photometric* parameters. In other words, we first invert the grid of the synthetic X and Y parameters once and for all, following the method described by NN90; then, we obtain for the standard stars interpolated physical parameters, which can be compared with the fundamental ones. For effective temperature, we use the quantity $\theta_{\text{eff}} = 5040/T_{\text{eff}}$ rather than T_{eff} itself because θ_{eff} varies linearly with the X parameter and the range of T_{eff} is large. In this way, the rms scatter around the mean trend is roughly constant, while it would vary strongly if we used T_{eff} directly; this is much safer from the point of view of the least-squares fit, and is equivalent to give a lower weight to the high effective temperatures. We obtain

$$\Delta\theta_{\text{eff}} = \theta_{\text{eff}}(\text{interpolated}) - \theta_{\text{eff}}(\text{fundamental}) \quad (3)$$

and we plot $\Delta\theta_{\text{eff}}$ vs. $\theta_{\text{eff}}(\text{fundamental})$ in Fig. 1. The trend can be fitted by a straight horizontal line in the present case, because the slope indicated by the least-squares method is smaller than its uncertainty. The interpolated reciprocal effective temperature will then be corrected using the formula:

$$\theta_{\text{eff}} = \theta_i - 0.008 \quad (4)$$

where θ_i stands for the interpolated value of θ_{eff} . The advantage of this method over the previous one is that the grids need to be inverted only once, while different corrections can be tried thereafter, for example as new fundamental data are published. The fundamental stars are those used by NN90, supplemented by new data from Adelman (1988) and Adelman et al. (1993). The Adelman effective temperatures cannot be considered as purely fundamental because they are partly based on a comparison between the observed energy distribution and a theoretical

one. However, the Balmer lines were also used to estimate these temperatures, which appear a posteriori quite consistent with the purely fundamental ones of Code et al. (1976). In any case, these temperatures are evidently independent from any possible systematic error in the passbands of the Geneva system.

Fig. 1. Difference between interpolated and fundamental θ_{eff} values vs. fundamental θ_{eff} for the hot stars. The fitted horizontal line is shown; see Table 1 for the key to the symbols

The fundamental T_{eff} values are listed in Table 5, together with the interpolated and corrected values. The uncertainties of the fundamental values are quoted from their authors, while those of the interpolated values are estimated from the photometric errors (for a photometric weight $P = 1$), as described in NN90. The θ_{eff} and T_{eff} values obtained from the observed colours by interpolation in the *corrected* grids are compared with their respective fundamental values in Figs. 2a and 2b.

One clearly sees in Fig. 2b that for T_{eff} , the scatter increases strongly towards small values of the X parameter, i.e. towards high temperatures, where the sensitivity of the photometry to temperature is known to strongly decrease. On average, the rms scatter of the difference amounts to 751 K. For $X > 0.4$ ($T_{\text{eff}} \leq 21000 \text{ K}$), the scatter reduces to 386 K, while it increases to 1388 K for $X < 0.4$. This scatter is mostly attributable to errors in the fundamental data. Their contributions amount to about 96% of the total scatter. Photometric errors induce only a small dispersion. There is a small systematic zero-point shift of -73 K , essentially due to the hot stars, which were weighted differently by using θ_{eff} instead of T_{eff} to define the correction. A shift of about -180 K was present with the previous calibration of NN90.

Fig. 2. **a)** Difference between photometric and fundamental θ_{eff} values vs. the X parameter. The continuous line is the mean while the broken lines define the average rms scatter; see Table 1 for the key to the symbols. **b)** Same as **a)**, but for T_{eff} . The horizontal line is arbitrarily set to zero. Notice the large increase of the scatter towards small values of X , i.e. towards the hotter stars

The difference between the interpolated and fundamental $\log g$ values follows the trend shown in Fig. 3, and the interpolated values have to be corrected according to the equation

$$\log g = \log g_i + 0.46 - 4.83 \cdot 10^{-5} T_{\text{eff}}^* \quad (5)$$

where $\log g_i$ is the interpolated surface gravity while T_{eff}^* is the interpolated and corrected T_{eff} . The fundamental values are listed in Tables 2 and 3, as well as the interpolated and corrected ones with their standard deviations. Table 2 lists the eclipsing binaries, for which the most fundamental values of $\log g$ can be determined, and the non-eclipsing but well-known stars Sirius and Vega. In Table 3 we list the members of the Orion OB1 association, whose surface gravity is inferred from the models of internal structure of Schaller et al. (1992) for isochrones with $\log t = 6.8$

Fig. 3. Difference between interpolated and fundamental $\log g$ values vs. the photometric T_{eff} for the hot stars. The regression line is the adopted correction

Fig. 4. Difference between photometric and fundamental $\log g$ values vs. the X parameter. The continuous line is the mean while the broken lines define the average rms scatter

(subgroup c) and 5.7 (subgroup d). Compared with the values given by NN90, the fundamental $\log g$ values given here are about 0.06 dex smaller. This is due to the new opacities used by Schaller et al. (1992). Figure 4 compares the photometric and fundamental values of $\log g$; we see that a very good accuracy can be achieved, of the order of 0.10 dex, provided the star is not too hot. On the whole range of B stars, the rms scatter of the residuals is only

$\sigma = 0.09$ dex and it is chiefly due to errors in photometric data.

Finally, the inverted and corrected grid for solar metallicity is shown in Fig. 5, in the form of a diagram $\log g$ vs. T_{eff} containing the lines of constant X and constant Y parameters. Although such a diagram is unusual, it allows graphical interpolation with the same efficiency as the usual photometric diagrams where lines of constant physical parameters are shown.

2.2. Accuracy of the numerical interpolation

The reliability of the inverted grids and of the bicubic spline interpolation used to determine the physical parameters has been tested in the following way. Knowing the synthetic colours of each atmosphere model, we determined the corresponding physical parameters T_{eff} and $\log g$ by interpolation in the inverted, but *uncorrected* grid. Then, we could verify that the interpolated T_{eff} and $\log g$ values correspond to those defining the model to within 1 K for T_{eff} and 0.01 dex for $\log g$. This holds true not only for this particular grid, but also for all other grids presented below; the metallicity $[M/H]$, for cool stars, is also interpolated with an accuracy better than 0.01 dex.

3. The intermediate stars

With the previous calibrations, the stars whose effective temperature lies between 8500 and about 10500 K could not be properly dealt with. This is why we have defined new photometric parameters we call pT and pG , which are sensitive to effective temperature and surface gravity respectively. These parameters have been defined in a similar way as the a_0 and r ones of the $uvby\beta$ photometry, and have about the same sensitivity to the corresponding physical parameters. However, pT and pG are *not* reddening-free, contrary to a_0 and r , because the Geneva system lacks an equivalent to the β index for the intermediate and cool stars. Therefore, the interstellar reddening must be either negligible or known and corrected to make the calibration meaningful. These parameters are defined by:

$$pT = B2 - V1 + 0.1 X + 0.0635 (Y - 0.2 d) - 0.006 \quad (6)$$

$$pG = Y - 0.2 d + 1.1 (B2 - V1 + 0.1 X) + 0.31 \quad (7)$$

which is equivalent to:

$$pT = -0.2075 + 0.1455 U - 0.2383 B1 + 1.0452 B2 - 0.9676 V1 + 0.0155 G \quad (8)$$

$$pG = -0.4771 + 0.2749 U - 1.9706 B1 + 3.0568 B2 - 0.3676 V1 - 0.9935 G \quad (9)$$

and their values for solar-composition Kurucz models (not corrected by standard stars) are represented in Fig. 6. This

figure can be compared with Fig. 4 of Moon & Dworetzky (1985). If the colour excess $E(B2 - V1)$ is known, the correction of the pT and pG parameters has to be done through the relations

$$pT_0 = pT - E(B2 - V1) \quad (10)$$

$$pG_0 = pG - 1.1 E(B2 - V1). \quad (11)$$

The standard stars used to correct the grid for T_{eff} are listed in Table 4 while those used to correct $\log g$ are listed in Table 5-8. The standard stars for T_{eff} are taken from essentially the same sources as for the B stars. Table 5 lists the eclipsing binaries already used by Moon & Dworetzky (1985) while Tables 6-8 give the members of the Orion association, of the Pleiades and of IC 2391 respectively. The colour excess of the stars in Orion was determined from the intrinsic colours of Cramer (1982), and the pT and pG parameters were corrected for it. For the Pleiades, the pT and pG parameters have been corrected for a mean colour excess $E(B2 - V1) = 0.052$ (Nicolet 1981) and for IC 2391, they have been corrected for $E(B2 - V1) = 0.005$ (North & Cramer 1981). For the Pleiades and IC 2391, the fundamental $\log g$ values were deduced from the estimated effective temperatures using the isochrones at $\log t = 8.0$ and 7.7 respectively. The differences between the fundamental T_{eff} and $\log g$ and their values interpolated in the (uncorrected) inverted grids from the observed Geneva colours of the standard stars are shown in Figs. 7 and 8 respectively. For effective temperatures, we obtain:

$$T_{\text{eff}} = 778 + 0.9009 \times T_i \quad (12)$$

and for $\log g$:

$$\log g = \log g_i + 3.38 - 5.975 \cdot 10^{-4} T_i + 2.46 \cdot 10^{-8} T_i^2. \quad (13)$$

The inverted and corrected grids themselves are represented for the three metallicities $[M/H] = -1, 0, +1$ in Figs. 9-11. We show these three diagrams, just to make clear the effect of the metallicity on the T_{eff} and $\log g$ estimates. As in the case of the X and Y parameters, we represent the *physical* parameters $\log g$ vs. T_{eff} with the lines of constant pT and pG parameters, rather than the reverse. Note that for these stars, the metallicity is assumed to be known a priori so that the most relevant grid can be used; the colours are not sensitive enough to metallicity to give a significant estimate of it, except perhaps for a few hot Am stars.

The comparison between the fundamental and photometrically determined T_{eff} and $\log g$ is shown in Figs. 12 and 13 respectively. The residual rms scatter is $\sigma(T_{\text{eff}}) = 197$ K for the effective temperature, and $\sigma(\log g) = 0.135$ dex (c.g.s.) for the logarithmic surface gravity respectively. As for the hot stars, $\sigma(T_{\text{eff}})$ is mostly due to errors in the fundamental data and in the same proportion. This scatter represents the uncertainty in the determination of these physical parameters, but we insist that interstellar reddening must be negligible or corrected for.

Fig. 5. Inverted and corrected grid with solar metallicity for the hot stars. Roughly horizontal lines are those of constant values of the Y photometric parameter, while the vertical ones are lines of constant X parameter. The iso- X lines are separated by an interval of 0.05 magnitudes, while the iso- Y lines are separated by 0.025. For clarity, not all lines are labelled

Fig. 6. Direct, usual grid showing the (uncorrected) iso- T_{eff} and iso- $\log g$ lines in the pG vs. pT diagram. These lines are nicely orthogonal, apart from a small region at high gravity and small T_{eff} . This diagram is quite similar to the r^* vs. a_0 one of the $wby\beta$ photometry

Fig. 7. Difference between interpolated and fundamental T_{eff} values vs. fundamental T_{eff} for the intermediate stars. The regression line is shown. See Table 4 for the key to the symbols

Fig. 8. Difference between interpolated and fundamental $\log g$ values vs. photometric T_{eff} for the intermediate stars. The line is the fitted least-squares parabola

4. The cool stars

This category includes the late A, the F and the early G stars. We did not explore the cooler stars although Kurucz models now exist for them, because their calibration is a delicate matter and was already explored by Grenon (1978, 1982) and Grenon & Golay (1979). The philosophy of the present calibration is roughly the same as in KN90: it uses the d vs. $B2 - V1$ and the m_2 vs. $B2 - V1$ diagrams,

which are sensitive to effective temperature, surface gravity and metallicity.

4.1. Effective temperature and surface gravity

The $B2 - V1$ index is mainly sensitive to T_{eff} , while the reddening-free parameter d is sensitive to both T_{eff} and $\log g$. The new Kurucz models seem more realistic than the previous ones in the sense that the synthetic $B2 - V1$ indices computed from them are closer to the observed values.

In the d vs. $B2 - V1$ diagram, however, there was a conspicuous change in slope of the iso- $\log g$ lines for $T_{\text{eff}} \approx 8000$ K at high gravity and $T_{\text{eff}} \approx 6500$ K at $\log g \approx 2.5$. This change in slope seems to be linked with the onset of convection in the superficial layers of the star's envelope, and was especially conspicuous in the c_1 vs. $b - y$ diagram of Strmgren's photometry (see e.g. Kurucz 1991). Since then, a conceptual error has been detected in the ATLAS9 code by Dr. F. Castelli (1996). The changes in slope occur when the convective flux is zero at the last depth in the model because the convection zone is wholly contained in the atmosphere. The program computed convection differently depending on whether the last value was zero or not. The program has now been changed to be consistent and the change in slope has been greatly reduced or removed. Kurucz has recomputed the convective models and fluxes and will distribute them on CD-ROMs (Kurucz 1996a, b). We have computed new Strmgren and Geneva colours (the new Geneva colours were kindly computed for us by Dr. David Bersier). Figure 14 shows a comparison between the new grid (full lines) and the "old" one (i.e. before the change to ATLAS9, dotted lines) in the d vs. $B2 - V1$ diagram for solar metallicity: there is a significant difference, the new grid looking much smoother. The grids represented in this figure have not been corrected to match any standard star. Although the differences involve essentially the cool stars, the "intermediate" grids are also concerned in the vicinity of their cool edge, i.e. for $T_{\text{eff}} = 8000$ up to 8750 K. Therefore the intermediate grids have also been recomputed.

Now, although the problem of the slope discontinuity of the iso- $\log g$ lines has been solved in the models, yet another problem remains in the observed main sequence of the Hyades. The same grid for the new models is represented in Fig. 15 together with the observed main sequence of the Hyades cluster: one clearly sees a sudden change of slope in the observed sequence around $B2 - V1 = 0.16$ or $T_{\text{eff}} = 7000$ K, which is not reproduced by the models. This feature is not seen only in the Hyades, since it is present also in the Praesepe cluster. It had not been noticed by KN90, because these authors used only the Pleiades cluster, where the scatter is larger. Though the internal structure models foresee a very small and gradual decrease of $\log g$ with increasing mass and decreasing T_{eff} on the isochrone, they are quite unable

Fig. 9. Inverted and corrected grid $\log g$ vs. T_{eff} for the intermediate stars having $[M/H] = -1.0$. The iso- pT and iso- pG lines are the vertical and horizontal lines respectively

Fig. 10. Same as Fig. 9, but for $[M/H] = 0.0$, i.e. solar metallicity

Fig. 11. Same as Fig. 9, but for $[M/H] = +1.0$. Notice that the metallicity effects are non-negligible at the low- T_{eff} end of the grid

to account for the sharp decrease around 7000 K the observed sequence would imply if the atmosphere models were entirely realistic. Therefore, something is missing in the atmosphere models.

The standard stars with known T_{eff} are listed in Table 9 with their sources. They are taken essentially from Blackwell & Lynas-Gray (1994), who relied on the infrared flux method. We did not use temperature estimates based on spectrophotometry, since they generally use a fit to the same Kurucz models and are therefore not fundamental nor independent from our photometric approach. The difference between the interpolated T_{eff} and the fundamental one is shown in Fig. 16. The interpolation was done taking luminosity effects into account, using $\log g$ estimates essentially from the previous version of our calibration, i.e. from KN90. The conspicuous gap seen between $T_{\text{eff}} = 7400$ and 7900 K is that of Böhm-Vitense (1970), corresponding to the onset of convection (see also Mendoza 1956; Böhm-Vitense & Canterna 1974; Jasiewicz 1984). Since this gap represents a kind of physical discontinuity, we have fitted two different functions to either side of it: a horizontal straight line for the hot side (and the gap itself), and a regression line for the cool side. The correction in T_{eff} takes the form:

$$T_i \leq 6905 : \Delta T_{\text{eff}} = -640 + 0.12 T_i \quad (14)$$

$$T_i > 6905 : \Delta T_{\text{eff}} = 193. \quad (15)$$

Figure 17 compares the fundamental and photometric values of T_{eff} . The rms scatter of the differences amounts to 54 K. The scatter induced by photometric errors is negligible in comparison with errors in the fundamental data. The contribution are respectively 7% and 93%.

The standard stars with known $\log g$ are listed in Tables 10 and 11, and belong to the Hyades and IC 2391 open clusters respectively. Their $\log g$ values have been determined from the models of Schaller et al. (1992) assuming ages $\log t = 8.8$ for the Hyades and $\log t = 7.7$ for IC 2391. The needed effective temperature was estimated from the previous calibration of KN90; the interstellar reddening was considered negligible for the Hyades, while a marginally significant colour excess $E(B2 - V1) = 0.005$ (North & Cramer 1981) was assumed for IC 2391. In Tables 10 and 11, the last two columns give the $\log g$ values and their uncertainty respectively, obtained from the grids *corrected* by Eqs. (14-15) above, not from the uncorrected grids. This holds for all tables where standard stars are listed, for all three physical quantities T_{eff} , $\log g$ and $[M/H]$.

The difference $\Delta \log g$ between the interpolated and fundamental values is represented in Fig. 18a for the Hyades and IC 2391 clusters, as a function of T_{eff}^* , the corrected effective temperature. A dip about 0.3 dex deep is clearly visible at $T_{\text{eff}} \approx 7000$ K, which reflects the change of slope of the observed sequence mentioned above.

Fig. 12. Difference between the photometric and fundamental effective temperatures for the intermediate stars (assumed to have solar metallicities). The solid line is the mean and the broken lines define the rms scatter

Since the members of the Hyades cluster draw an iso-metallicity line in the $\Delta \log g$ vs. T_{eff}^* diagram (except for the Am stars of course), it is not possible to explore the possible effects of metallicity with these stars alone. Using other old clusters is of little help because their range in metallicity is small. Therefore, we used the numerous field F and G stars studied spectroscopically by Edvardsson et al. (1993, hereafter EAGLNT93), which span about 1.2 dex in $[\text{Fe}/\text{H}]$ and have empirical surface gravities derived from Strömgren photometry. Even if their $\log g$ values are not fundamental *stricto sensu*, they are much better than nothing as shown in Figs. 18b, c and d. In Fig. 18b, where only the stars of EAGLNT93 with $[\text{Fe}/\text{H}] \geq 0.1$ are shown together with those of the Hyades, one sees that the field stars of EAGLNT93 are very well superposed on the Hyades, which tends to validate a posteriori the surface gravities given by EAGLNT93. In Figs. 18c and d are represented the EAGLNT93 stars with $-0.1 \leq [\text{Fe}/\text{H}] \leq +0.1$, and $-0.5 \leq [\text{Fe}/\text{H}] \leq -0.3$: clearly, the correction $\Delta \log g$ is very much dependent on metallicity for these cool stars. Fortunately, the metallicity dependence becomes vanishingly small at high effective temperatures (i.e. $T_{\text{eff}} > 6600$ K), so that the correction of $\log g$ can be safely defined by the cluster stars in that range of T_{eff} .

The correction is not very simple, and we had to fit several different functions of the type:

$$\log g = \log g_i + a + b T_i^* + c T_i^{*2} \quad (16)$$

where T_i^* stands for the interpolated *and corrected* effective temperature. The coefficients a , b and c are listed in

Fig. 13. Difference between the photometric and fundamental $\log g$ values for the intermediate stars (assumed to have solar metallicities). The solid line is the mean and the broken lines define the rms scatter

Table 12. For $T_{\text{eff}} > 6916$ K, we fitted a straight line rather than a parabola, so that the c coefficient is identical with zero there. Strictly speaking, this correction is valid only in the case of *unevolved* stars. The surface gravity of F giants will not be estimated correctly with this calibration. We made many different attempts to extend the validity of our calibration to giants, using e.g. very old clusters or well-classified field F giants, but none proved satisfactory. The present calibration in terms of $\log g$ must then be considered as being limited to unevolved, or only very slightly evolved stars. As a rule of thumb, we may say that it is valid for $\log g \geq 4.0$. The comparison between the interpolated and fundamental values is shown in Fig. 19. The rms scatter of the differences is $\sigma = 0.15$ dex. But the scatter is larger for the cool stars than for the hotter ones, because the iso- $\log g$ lines come closer together as T_{eff} diminishes. The stronger dependence on metallicity effects for cool stars probably also contributes to the larger σ .

4.2. Metallicity $[M/H]$

As in KN90, the metallicity is determined using the m_2 vs. $B2 - V1$ diagram. Fortunately, the recent Kurucz models are much more realistic in this diagram than were the preceding ones. In Fig. 10 of KN90, one sees how the grid of iso- T_{eff} and of iso- $[M/H]$ lines folds again as $[M/H]$ increases from +0.5 to +1.0; at the same time, T_{eff} varies strongly as $[M/H]$ increases (at given $B2 - V1$). Such complicated behaviour induced severe problems for the grid inversion as well as in the final 2-d interpolation of the physical quantities, even though KN90 dropped the most perturbing points. Furthermore, it was impossible

Fig. 14. Comparison between the models before (dotted lines) and after the correction (solid lines) proposed by Castelli (1996). Notice the much smoother iso-log g lines. These grids are the original ones, i.e. they have not been corrected to fit any standard star

Fig. 15. Comparison between the models after the correction, and the observed main sequence of the Hyades cluster. Notice how the observed sequence crosses the line $\log g = 4.0$ near $T_{\text{eff}} = 7000$ K. The grid is not corrected to fit any standard star

Fig. 16. Difference between interpolated and fundamental T_{eff} values vs. fundamental T_{eff} for the cool stars. Notice the gap of Böhm-Vitense between 7400 and 7900 K. The correction is fitted by a horizontal line at high T_{eff} and across the gap, and by a regression line at low T_{eff} . See Table 9 for the key to symbols

Fig. 17. Difference between photometric and fundamental T_{eff} values vs. $B2 - V1$ for the cool stars. The solid line is the mean and the broken lines define the rms scatter. See Table 9 for the key to symbols

Fig. 18. **a)** Difference between interpolated and fundamental $\log g$ values vs. photometric T_{eff} for the Hyades. Notice the conspicuous dip at $T_{\text{eff}} = 7000$ K. **b)** Same as **a)**, but for field stars of EAGLNT93 having $[M/H] > 0.1$ (triangles), for the hotter Hyades stars (full dots) and for members of the young cluster IC 2391 (crosses). **c)** Same as **b)**, but for field stars of EAGLNT93 having $-0.1 < [M/H] < +0.1$. **d)** Same as **b)**, but for field stars of EAGLNT93 having $-0.5 < [M/H] < -0.3$. Notice the very strong metallicity effect

to obtain straightforward estimates of the physical parameters of Am stars. On the contrary, the new models show no more folding, i.e. the iso- T_{eff} curves now have a monotonous behaviour and they are, furthermore, remarkably straight.

The standard stars used have been taken essentially from the huge work of EAGLNT93, which contains homogeneous, high-resolution spectroscopic results for 189 F and G stars. 157 of these stars have been measured in the Geneva photometric system, which allows an excellent calibration of our diagram in terms of $[\text{Fe}/\text{H}]$ (we consider here $[\text{Fe}/\text{H}]$ to be equivalent to $[M/H]$, although

Fig. 19. Difference between the photometric and fundamental values of $\log g$ vs. $B2 - V1$ for the cool stars. The solid line is the mean and the broken lines define the average rms scatter. Notice the larger scatter at large $B2 - V1$. In the key to symbols, “Ed” stands for “Edvardsson et al. (1993)”

it is not quite true for very metal-deficient stars). These standard stars are listed in Table 13. Some other, hotter objects taken from other sources (Perrin et al. 1977; Cayrel de Strobel et al. 1992 and especially Burkhart & Coupry 1989) are listed in Table 14. To correct the grid, we had to use a more complicated method than that of KN90. We first defined a preliminary correction $\Delta[M/H]_0$ as a function of T_{eff}^* (the interpolated and corrected T_{eff}), which is the only step KN90 had done. A plot of $\Delta[M/H]_0$ vs T_{eff}^* does not show any trend, only a zero point-shift

$$\Delta[M/H]_0 = 0.148 \quad (17)$$

where the subscript 0 refers to this zeroth-order correction, while T_{eff}^* is the temperature obtained by interpolation in the grids corrected by Eq. (14). This correction is shown in Fig. 21. In a second step, we plotted the residual $\Delta[M/H]$ against the spectroscopic values $[\text{Fe}/\text{H}]$: there is a clear trend, as shown in Fig. 20. This trend varies slightly with effective temperature, according to the relation:

$$[M/H] = 0.260 + 1.193 [M/H]_0 - 3.4 \cdot 10^{-5} T_{\text{eff}}^* \quad (18)$$

where $[M/H]_0$ is the interpolated metallicity, corrected by Eq. (17) above; this relation was found using a least-squares fit. Therefore the difference $\Delta[M/H]$ is not so much a function of $B2 - V1$ or temperature, but chiefly of metallicity $[M/H]$ itself. The latter dependence had been overlooked by KN90, essentially because of the much smaller number of standard stars they used. This correction allows us to obtain a photometric metallicity of the

Fig. 20. Difference between the photometric (i.e. interpolated and corrected by Eq. (16)) and fundamental values of $[M/H]$ vs. photometric $[M/H]$, for stars with $5600 \leq T_{\text{eff}} \leq 6500$ K. Notice the remaining trend

Hyades cluster which agrees well with the accepted spectroscopic value: we obtain $[M/H] = +0.08$, while Cayrel et al. (1985) give $[\text{Fe}/\text{H}] = +0.12 \pm 0.03$ for the same stars.

It is now possible to treat Am and other metallic stars like any other stars: for the typical Am star 63 Tau = HR 1376, we obtain $T_{\text{eff}} = 7247 \pm 59$ K, $\log g = 4.09 \pm 0.08$ and $[M/H] = +0.55 \pm 0.06$. The effective temperature we find is in excellent agreement with the value $T_{\text{eff}_1} = 7250 - 7400$ K estimated by Smalley (1993a), who uses the infrared flux method and corrects for the presence of a cool companion. The surface gravity agrees perfectly with that obtained by Smalley (1993b) from the $uvby\beta$ colours ($\log g = 4.13$). Our metallicity is a bit smaller than, but still agrees well with that of Smalley (1993b) who found $[M/H] = 0.651 \pm 0.095$. Notice that he adopted $T_{\text{eff}_1} = 7570$ K, which seems too high, and lowering T_{eff_1} would imply a lower $[M/H]$ as well. On the other hand, Burkhart & Coupry (1989) found $[\text{Fe}/\text{H}] = +0.4$ on the basis of high-resolution spectroscopy, in very good agreement with our estimate.

The difference between our photometric $[M/H]$ and the fundamental $[\text{Fe}/\text{H}]$ values is shown in Fig. 22. The average rms scatter of the differences amounts to $\sigma = 0.097$, which is similar to, though slightly larger than the scatter found by EAGLNT93 (their Eqs. (13-15)) for the differences between their $[\text{Fe}/\text{H}]$ values and the $[M/H]$ values derived from $uvby\beta$ photometry. When only the stars studied by EAGLNT93 are considered, our rms scatter drops to a value quite similar to theirs. Therefore the

Fig. 21. Difference between the interpolated and fundamental $[M/H]$ vs. photometric T_{eff} . The regression line corresponding to Eq. (16) is shown. The key to the symbols is explained in Table 14; “Ed” stands for “Edvardsson et al. (1993)”

Fig. 22. Difference between the photometric and fundamental $[M/H]$ vs. $B2 - V1$ for the cool stars. The symbols are the same as in Fig. 18. The solid line represents the mean while the broken lines define the rms scatter

capability of the Geneva system to estimate metallicities is excellent; in this regard, this system is quite competitive with the *uvby* β one.

The inverted and corrected grids are shown in Figs. 23 and 24. Figure 23 is a $\log g$ vs. T_{eff} diagram, showing the solar-metallicity grid with lines of iso- $B2 - V1$ and iso- d parameters. Figure 24 is a $[M/H]$ vs. T_{eff} diagram for $\log g = 4.0$, showing the iso- $B2 - V1$ and iso- m_2 lines.

5. Conclusion

We have presented an updated and complete calibration scheme of the Geneva photometric system in terms of effective temperature, surface gravity and metallicity for all B to mid-G stars of the main sequence or just above it. This calibration can be applied to giant B, A and F stars but not to red giants, and it will not give a reliable estimate of the surface gravity of giant F stars. It cannot be used either for B to G supergiants, since it is based on LTE atmosphere models and no supergiant has been included in our set of standard stars. Reddened B stars can be dealt with (provided the reddening is not too large, i.e. not greater than about $E[B - V] \approx 0.6$ and the reddening law is standard). For cool stars ($T_{\text{eff}} \lesssim 7000$ K), metallicities can be safely estimated in the range $-2.0 \lesssim [M/H] \lesssim +0.3$ dex, and the upper limit of this range extends to about $+0.6$ in the case of Am stars, which are hotter (7000 – 8000 K).

The new features of this calibration are:

- A new, simpler way of fitting the theoretical grids to the standard stars

- The possibility to estimate the physical parameters of intermediate stars
- The use of new, generally more realistic Kurucz models
- A more reliable estimate of the metallicity of cool stars, thanks to the large number of metallicity standards and to the smoother behaviour of the new Kurucz models in the m_2 vs. $B2 - V1$ diagram
- The possibility to estimate the physical parameters of metallic-line stars

The weakness of our calibration lies in the inadequacy of the atmosphere models around the transition between radiative and convective atmospheres, i.e. near $T_{\text{eff}} \sim 7000$ K. We have tested different ways of treating the convection, but found no simple way to reproduce the change of slope of the cluster sequences. We also checked whether a change of the micro-turbulent velocity V_{turb} could account for that; this is a reasonable assumption, since it is known empirically that V_{turb} increases with T_{eff} up to about 8000 K (EAGLNT93, Coupry & Burkhart 1992). But, the increase of V_{turb} from cool (5500 K) to hot (7000–7500 K) stars being observationally both small (about 2 km s^{-1}) and smooth, it cannot account for the observed sequence of the Hyades in the $d/B2 - V1$ diagram, since this sequence has a slope which increases abruptly around 7000 K. One would have to make both V_{turb} increase e.g. from 2 to 4 km s^{-1} and overshooting disappear at $T_{\text{eff}} = 7000$ K, to reproduce the observed sequence, but this would appear extremely ad hoc. Therefore, the cure

Fig. 23. $\log g$ vs. T_{eff} diagram for the cool stars with solar metallicity, showing the inverted and corrected grids with iso- d and iso- $B2 - V1$ lines. $B2 - V1$ varies here between -0.125 and $+0.475$ and d between 0.5 and 2.0 . Notice the tightening of the lines around $T_{\text{eff}} \approx 7000$ K, which reflects the change in slope of the observed Hyades' sequence

Fig. 24. $[M/H]$ vs. T_{eff} diagram for the cool stars with $\log g = 4.0$, showing the inverted and corrected grids with iso- m_2 and iso- $B2 - V1$ lines. $B2 - V1$ varies between -0.05 to $+0.50$ by steps of 0.05 magnitudes. m_2 varies between -0.18 to -0.58 by steps of 0.04 magnitudes

seems far from straightforward. As a result, the photometrically estimated surface gravities of cool stars are not so reliable as one would expect from the accuracy and homogeneity of the Geneva data. The most reliable values are those obtained for unevolved, solar-metallicity stars.

The calibration we have just presented is not complete in the sense that it does not give explicitly the absolute magnitude, bolometric correction, mass, colour excess and distance of the star. In particular, we have dropped the determination of the mass which was offered by NN90 and KN90; the reason is that the Barcelona group (Prof. F. Figueras and co-workers) has devised a code which interpolates the mass and age of a star from its effective temperature and gravity, in evolutionary tracks from various authors including Schaller et al. (1992). We had no reason to duplicate their work. The other physical parameters can be found using calibrations published by other authors. For the intrinsic colours (hence interstellar reddening) of O, B and early A stars (hereafter “hot stars”), see Cramer (1993), who updated an earlier work (Cramer 1982). Intrinsic colours of B2 to M0 stars have also been estimated by Hauck (1993). The bolometric correction of the hot stars can be obtained from a formula given in Appendix by Cramer (1984a); a formula giving T_{eff} as a function of X is also given in that paper, but it should be considered as superseded by our work. A calibration of the X and Y parameters in terms of Crawford’s β index is worth mentioning too (Cramer 1984b): it allows to detect H_{β} emission when both Geneva and β photometric data are available. The absolute magnitude of hot stars can be obtained from a recent work by Cramer (1994), which supersedes an earlier calibration (Cramer & Maeder 1979). The absolute magnitude of A and F stars (excluding supergiants) can be obtained from the calibration of Hauck (1973). The intrinsic colours of A and F supergiants have been estimated by Meynet & Hauck (1985). Finally, the Geneva system has been calibrated for G, K and M-type stars essentially by Grenon (1978, 1982) and Grenon & Golay (1979), as mentioned above in Sect. 4.

A fortran code has been written, which applies our calibration to stars measured in the Geneva system. This code is available by anonymous ftp at the Centre de Données de Strasbourg (CDS), following the instructions given in A&A 280, E1-E2 (1993). This code uses several ascii files containing the inverted grids, which are, of course, also available. The (uncorrected) Geneva colours of the Kurucz models are also available at the CDS.

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Table 1. Standard stars of effective temperature (hot stars)

HD	HR	X	Y	T_{eff}	$\pm\sigma$	$\log g$	Sources	Remarks	T_{eff} from X, Y	$\pm\sigma$
22928	1122	0.891	0.054	13827	223	3.80	L	3,5	13958	70
32630	1641	0.645	0.008	17317	1012	4.15	L	3,5	16380	148
33904	1702	1.071	0.037	12500		3.50	A(93)		12699	49
35468	1790	0.360	0.010	21580	790	4.20	C	3	21679	250
38899	2010	1.430	0.027	10825		3.90	A(93)		10764	61
44743	2294	0.190	0.031	25180	1130	4.00	C	3	26421	309
47105	2421	1.773	0.075	9260	310	3.65	C	3	9267	84
48915	2491	1.530	-0.038	9927	96	4.25	C,L	3,4,5	9915	104
80007	3685	1.859	0.136	9240	220	3.29	C	1	9180	406
87901	3982	1.153	0.082	12175	260	3.80	C,L	3,4,5	12286	54
97633	4359	1.738	0.046	9250		3.55	A(88)		9287	92
106625	4662	1.191	0.087	12450	530	3.70	C	3	12088	48
111123	4853	0.145	0.027	27600	1110	4.00	C	3,6	28057	388
116658	5056	0.210	0.012	23930	840	4.25	C	3,6	25791	464
118716	5132	0.250	0.015	25740	1190	4.20	C	3	24555	272
120315	5191	0.619	-0.017	17512	1190	3.90	L,Le	3,4,5	16581	156
135742	5685	1.198	0.116	11700	750	3.59	Le	1	12069	44
143275	5953	0.127	0.009	31460	1970	4.50	C	3,6	28787	763
143807	5971	1.387	0.041	11250		3.65	A(93)		11035	70
144206	5982	1.413	-0.044	11900		3.50	A(93)		12073	49
147394	6092	0.807	0.027	15249	685	4.00	L,Le	3,4,5	14632	87
149757	6175	0.071	0.018	31776	1913	4.55	C,Le	3,4	31606	619
169022	6879	1.752	0.216	9460	220	2.91	C	1	9871	32
172167	7001	1.646	-0.015	9660	91	3.95	C,L,Le	3,4,5	9375	184
176437	7178	1.751	0.261	9970	540	3.50	Le	2	9865	37
186882	7528	1.555	0.116	9781	182	3.68	L	1,5	10478	51
193432	7773	1.544	0.061	10137	162	3.90	A,L(93)	3,4,5	10338	69
193924	7790	0.559	0.001	17880	680	4.25	C	3,7	17610	169
209952	8425	0.944	0.013	13910	235	4.20	C,L	4,5	13465	63
214994	8641	1.695	0.061	9600		3.60	A(88)		9594	80

A(93): Adelman et al. (1993). A(88): Adelman (1988). C: Code et al. (1976).

L: Lanz (1987). Le: Leggett et al. (1986).

1. $\log g$: calibration of North & Nicolet (1990).

2. $\log g$: Cayrel de Strobel et al. (1992).

3. $\log g$: taken from North & Nicolet (1990), Table 1.

4. Weighted mean of the results of the sources mentioned in column 8.

5. Lanz's temperatures have been increased by 1.15%.

6. Observed Geneva colours corrected for the contribution of the visual companion.

Table 2. Eclipsing binaries and other stars used as surface gravity standards (hot stars)

HD	HR/DM	X	Y	T_{eff}	$\log g$	Sources	Remarks	$\log g$ from X, Y	$\pm\sigma$
25833	+33°785	0.627	-0.016	16885	4.20	HH	1,3	4.32	0.14
34364	1728	1.385	-0.006	11000	4.30	MD		4.35	0.06
40183	2088	1.682	-0.027	9200	4.01	MD		3.94	0.12
48915	2491	1.530	-0.038	9900	4.32	MD		4.26	0.04
65818	3129	0.140	-0.003	28870	4.07	HH	1	4.26	1.08
71581	3335	1.535	-0.004	9500	4.09	MD	3	4.18	0.04
86118	-57°2418	0.286	-0.014	23110	4.15	ACNR	1	4.26	0.32
156247	6414	0.688	0.024	16000	4.12	MD		3.98	0.15
161783	6622	0.532	0.010	18000	4.01	MD	3	4.03	0.16
172167	7001	1.646	-0.015	9500	3.90	MD		4.00	0.06
185507	7474	0.490	0.017	18710	4.10	HH	1	3.93	0.17

MD: Moon & Dworetsky (1985). HH: Habets & Heintze (1981).
ACNR: Andersen et al. (1983).

1. T_{eff} estimated from the X parameter and Cramer's (1984b) calibration.
2. Individual $\log g$ are 3.47 and 3.18 for the primary and the secondary components respectively. The adopted $\log g$ value is a mean, weighted by the respective visual luminosities.
3. Observed Geneva colours corrected for the contribution of the visual companion.

Table 3. Stars of the Orion association used as surface gravity standard (hot stars)

HD	Brun number	X	Y	T_{eff}	$\log g$	Sub-group	$\log g$ from X, Y	$\pm\sigma$
36629	25	0.404	-0.015	20245	4.22	c	4.25	0.16
36655	50	1.241	0.011	11770	4.30	c	4.34	0.08
36842	246	0.854	-0.006	14757	4.29	c	4.34	0.12
36883	330	0.854	-0.012	14757	4.29	c	4.39	0.11
36899	342	1.546	-0.059	9450	4.31	c	4.28	0.04
	414	1.444	0.002	10550	4.31	c	4.27	0.05
36918	417	0.825	-0.003	14994	4.29	c	4.30	0.12
36939	437	1.196	0.013	11940	4.31	c	4.33	0.09
36936	440	0.735	0.002	15781	4.28	c	4.21	0.13
36939	442	1.099	0.018	12300	4.30	c	4.27	0.10
36958	480	0.609	-0.005	17093	4.27	c	4.21	0.14
	508	1.161	0.026	11900	4.30	c	4.24	0.10
36983	520	1.360	0.014	11080	4.31	c	4.28	0.07
36998	529	1.326	0.028	11290	4.31	c	4.23	0.08
37000	552	0.562	-0.012	17689	4.26	c	4.26	0.14
36999	581	0.950	-0.013	14015	4.29	c	4.44	0.11
37025	621	0.652	-0.020	16609	4.27	c	4.37	0.13
37017	632	0.432	-0.028	19702	4.24	c	4.39	0.16
37059	736	1.251	0.003	11580	4.31	c	4.38	0.08
37062	760	0.616	-0.014	17011	4.29	d	4.30	0.14
37058	761	0.443	0.001	19376	4.23	c	4.09	0.16
37060	776	1.487	0.017	10350	4.31	c	4.17	0.05
37114	920	1.369	-0.012	10970	4.31	d	4.39	0.06
37129	940	0.506	-0.001	18255	4.25	c	4.13	0.15
37150	980	0.418	-0.006	19968	4.27	d	4.16	0.06
37174	992	1.402	-0.015	10580	4.31	d	4.37	0.05
37334	1109	0.485	-0.008	18789	4.25	c	4.20	0.15

Table 6. Stars of the Orion association used as surface gravity standards(intermediate stars)

HD	Brun number	$pT_{\odot}$	$pG_{\odot}$	T_{eff}	$\log g$	$E(B2 - V1)$	$\log g$ from pT, pG	$\pm\sigma$
36655	50	-0.109	-0.030	11770	4.31	0.035	4.32	0.11
36899	342	-0.026	-0.024	9450	4.31	0.031	4.37	0.10
	414	-0.061	-0.005	10550	4.31	0.032	4.26	0.10
36939	437	-0.125	-0.039	11940	4.31	0.137	4.33	0.12
	508	-0.123	-0.026	11900	4.30	0.035	4.22	0.13
36983	520	-0.090	-0.018	11080	4.31	0.034	4.30	0.11
37000	529	-0.098	-0.013	11290	4.31	0.042	4.23	0.12
37059	736	-0.102	-0.030	11580	4.31	0.041	4.35	0.11
37060	776	-0.061	0.002	10350	4.31	0.054	4.22	0.10
37114	920	-0.091	-0.040	10970	4.31	0.045	4.45	0.10
37174	992	-0.077	-0.030	10580	4.31	0.029	4.41	0.10

Table 7. Stars of the Pleiades used as surface gravity standards(intermediate stars)

HD	H Nbr.	$pT_{\odot}$	$pG_{\odot}$	T_{eff}	$\log g$	$\log g$ from pT, pG	$\pm\sigma$
23155	153	0.034	0.000	8671	4.31	4.23	0.10
23194	232	0.078	0.009	8297	4.30	4.42	0.23
23489	1028	0.006	-0.006	9039	4.31	4.26	0.09
23886	2289	0.050	-0.019	8462	4.31	4.40	0.10
23924	2415	0.080	-0.011	8207	4.30	4.86	1.67
23948	2488	-0.014	-0.053	9252	4.32	4.54	0.10
	3307	-0.019	0.000	9243	4.32	4.23	0.09
	3316	0.047	-0.015	8447	4.31	4.35	0.11
	3322	0.054	0.003	8447	4.31	4.30	0.10
	3328	0.045	0.008	8521	4.31	4.19	0.09

Table 8. Stars of IC 2391 used as surface gravity standards (intermediate stars)

HD	Nbr.	$pT_{\odot}$	$pG_{\odot}$	T_{eff}	$\log g$	$\log g$ from pT, pG	$\pm\sigma$
73681	3	0.020	-0.015	8947	4.30	4.32	0.10
73904	6	0.029	0.027	8812	4.30	4.06	0.10
74516	29	-0.020	-0.004	9395	4.30	4.25	0.09
74537	33	0.118	0.069	7856	4.30	4.38	0.54
74678	39	0.033	0.023	8748	4.30	4.09	0.10
74762	40	0.106	0.053	7827	4.30	4.38	0.24
74956	41	0.029	0.013	8817	4.30	4.15	0.09
75202	49	0.104	0.072	7962	4.30	4.01	0.24
73064	77	0.085	0.032	8156	4.30	4.28	0.15
74739	80	0.051	0.017	8513	4.30	4.14	0.09

Table 9. Standard stars of effective temperature (cool stars)

HD	HR	$(B2 - V1)_0$	d	m_2	T_{eff}	$\pm\sigma$	$\log g$	$[M/H]$	A_V	Sources	Remarks	T_{eff}	$\pm\sigma$
												from grids	
432	21	0.132	1.144	-0.487	6847		3.49	0.18	0.01	B(94)	1,2	6808	52
4614	219	0.335	0.629	-0.451	6044		4.39	-0.19	0.00	B(94)	3,4	5966	28
5448	269	-0.048	1.415	-0.495	7959		3.82	0.02	0.00	B(94)	1,2	8027	76
6961	343	-0.036	1.359	-0.474	7949		3.91	0.09	0.02	B(94)	1,2	7992	74
9826	458	0.293	0.721	-0.436	6205		4.00	-0.16	0.00	B(94)	3,4	6186	31
11443	544	0.245	0.857	-0.473	6327		3.90	-0.05	0.01	B(94)	1,2	6333	34
19373	937	0.329	0.731	-0.391	6042		4.50	0.10	0.00	B(91)	1,2	6039	27
20630	996	0.405	0.560	-0.363	5732		4.45	0.12	0.00	B(94)	3,4	5748	22
22484	1101	0.335	0.696	-0.442	5977		3.98	0.02	0.00	B(94)	3,4	5971	27
27819	1380	-0.033	1.340	-0.483	7957		3.96	0.01	0.00	B(94)	1,2	7995	74
33276	1676	0.100	1.290	-0.491	6909		3.14	0.24	0.04	B(94)	1,2	6871	55
34411	1729	0.361	0.634	-0.396	5947		4.17	0.19	0.00	B(94)	3,4	5917	25
37507	1937	-0.039	1.401	-0.513	8034		3.82	-0.11	0.00	B(94)	1,2	7953	75
50019	2540	-0.065	1.556	-0.519	8040		3.45	0.05	0.00	B(94)	1,2	7995	80
58946	2852	0.119	1.023	-0.509	6974		4.11	-0.14	0.00	B(94)	1,2	7046	61
61110	2930	0.205	1.039	-0.490	6531		3.34	0.19	0.02	B(94)	1,2	6436	37
61421	2943	0.206	0.926	-0.495	6500		4.03	0.03		MD	3,4	6495	38
116842	5062	-0.020	1.289	-0.485	7971		4.05	-0.05	0.01	B(94)	1,2	7951	74
117176	5072	0.442	0.571	-0.357	5488		3.75	-0.11	0.00	B(94)	3,4	5596	20
118098	5107	-0.064	1.389	-0.512	8287		4.00	-0.12	0.00	B(94)	1,2	8250	83
120136	5185	0.251	0.747	-0.439	6389		4.40	0.14	0.00	B(94)	1,2	6398	33
121370	5235	0.329	0.731	-0.391	6091		4.17	0.38	0.00	B(94)	3,4	6054	26
123999	5304	0.296	0.765	-0.453	6204		3.98	-0.09	0.00	B(94)	1,2	6130	30
124850	5338	0.284	0.791	-0.470	6175		4.00	-0.06	0.00	B(94)	3,4	6156	31
125161	5350	0.016	1.190	-0.473	7766		3.91	0.01	0.00	B(94)	1,2	7750	73
126660	5404	0.258	0.763	-0.465	6230	130	4.28	-0.04	0.02	Le	1,2	6317	33
128167	5447	0.159	0.904	-0.521	6763		4.40	-0.40	0.00	B(94)	3,4	6805	55
129502	5487	0.173	0.940	-0.506	6677	180	3.98	-0.09	0.00	B(94), Le	1,2	6685	46
132052	5570	0.119	1.110	-0.507	7026		3.75	-0.01	0.00	B(94)	1,2	6954	56
134083	5634	0.209	0.826	-0.486	6617		4.50	0.10	0.00	B(94)	3,4	6547	39
142860	5933	0.249	0.777	-0.485	6320	130	4.00	-0.14	0.02	Le	1,5	6332	35
144284	5986	0.288	0.783	-0.432	6169		3.93	0.23	0.00	B(94)	1,2	6191	31
147547	6095	0.054	1.338	-0.479	7104	270	3.20	0.24	0.05	B(94), Le	1,2	7179	60
157950	6493	0.174	0.943	-0.499	6666		4.02	-0.04	0.00	B(94)	1,2	6684	45
159561	6556	-0.035	1.379	-0.491	7932	171	3.77	0.01	0.02	C, Le	1,5	7948	73
161797	6623	0.469	0.576	-0.308	5521		4.47	-0.18	0.00	B(94)	1,2	5571	17
165777	6771	-0.049	1.374	-0.501	8083		3.97	-0.07	0.00	B(94)	1,2	8106	77
173667	7061	0.241	0.822	-0.481	6380		4.00	-0.14	0.00	B(94)	3,4	6364	35
185395	7469	0.172	0.886	-0.483	6713		4.40	-0.02	0.00	B(94)	3,4	6750	49
215648	8665	0.274	0.780	-0.487	6225		4.10	-0.20	0.00	B(94)	3,4	6189	32
219080	8830	0.090	1.106	-0.497	7101		4.00	-0.04	0.00	B(94)	1,2	7202	63
220657	8905	0.349	0.770	-0.423	6050		3.61	-0.12	0.00	B(94)	1,2	5904	26

B(94): Blackwell et al. (1994). B(91): Blackwell et al. (1991). Le: Leggett et al. (1986).

MD: Moon et Dworetzky (1985). C: Code et al. (1976).

1. $[M/H]$: calibration of Kobi & North (1990).
2. $\log g$: calibration of Kobi & North (1990).
3. $[M/H]$: Cayrel de Strobel et al. (1992).
4. $\log g$: Cayrel de Strobel et al. (1992).
3. $\log g$: taken from Kobi & North (1990), Table 1.

Table 10. Stars of the Hyades used as surface gravity standards (cool stars)

Nbr.	HD/DM	$(B2 - V1)_\odot$	d	m_2	T_{eff}	$\log g$	$\log g$ from grids	$\pm\sigma$
1	20430	0.314	0.657	-0.392	6072	4.45	4.28	0.13
2	20439	0.359	0.637	-0.390	5869	4.49	4.31	0.14
6	24357	0.133	0.984	-0.484	7023	4.27	4.51	0.12
8	25102	0.200	0.846	-0.469	6625	4.33	4.32	0.13
9	+19°641	0.433	0.566	-0.364	5609	4.55	4.32	0.16
10	25825	0.346	0.632	-0.410	5916	4.49	4.41	0.14
11	26015	0.179	0.907	-0.470	6736	4.32	4.21	0.13
13	26345	0.192	0.853	-0.467	6679	4.32	4.37	0.13
14	26462	0.137	0.975	-0.481	7003	4.27	4.50	0.13
15	26736	0.387	0.568	-0.356	5762	4.52	4.71	0.14
16	26737	0.201	0.838	-0.473	6615	4.33	4.39	0.13
17	26756	0.413	0.548	-0.337	5750	4.54	4.70	0.15
18	26767	0.381	0.613	-0.380	5784	4.51	4.30	0.14
19	26784	0.279	0.728	-0.442	6134	4.43	4.27	0.12
20	26911	0.177	0.883	-0.462	6785	4.31	4.39	0.16
22	27130	0.459	0.521	-0.313	5517	4.57	4.47	0.18
23	27149	0.408	0.572	-0.350	5687	4.54	4.49	0.15
24	27176	0.073	1.143	-0.474	7428	4.23	4.21	0.07
26	27250	0.448	0.511	-0.295	5531	4.57	4.85	0.17
27	27282	0.447	0.529	-0.322	5550	4.57	4.52	0.18
29	27383	0.303	0.673	-0.415	6113	4.43	4.40	0.12
30	27397	0.076	1.149	-0.480	7377	4.23	4.19	0.07
31	27406	0.306	0.671	-0.417	6097	4.44	4.42	0.12
32	27429	0.161	0.958	-0.478	6833	4.30	4.22	0.16
33	27459	0.025	1.225	-0.470	7524	4.22	4.25	0.06
34	27483	0.230	0.787	-0.459	6461	4.36	4.35	0.12
35	27524	0.203	0.816	-0.467	6620	4.33	4.47	0.13
36	27534	0.220	0.816	-0.465	6522	4.35	4.28	0.13
37	27561	0.189	0.847	-0.472	6696	4.32	4.45	0.13
38	27628	0.101	1.104	-0.463	7171	4.25	4.10	0.08
39	27685	0.415	0.552	-0.350	5664	4.54	4.55	0.16
40	27691	0.311	0.677	-0.416	6073	4.45	4.35	0.12
44	27731	0.228	0.786	-0.456	6464	4.36	4.36	0.13
45	27749	0.078	1.108	-0.433	7266	4.23	4.09	0.08
47	27819	-0.030	1.340	-0.483	8096	4.16	4.23	0.06
48	27808	0.273	0.712	-0.432	6230	4.41	4.38	0.12
49	27835	0.344	0.610	-0.391	5929	4.48	4.64	0.13
50	27836	0.351	0.622	-0.405	5896	4.49	4.45	0.14
51	27848	0.216	0.804	-0.457	6545	4.35	4.36	0.13
52	27859	0.350	0.609	-0.400	5901	4.49	4.58	0.14
53	27901	0.162	0.975	-0.477	6818	4.30	4.09	0.16
54	27934	-0.055	1.432	-0.488	8235	4.14	4.05	0.05
55	27946	0.047	1.207	-0.479	7582	4.22	4.20	0.07
57	27991	0.261	0.747	-0.457	6264	4.40	4.33	0.13
58	27989	0.402	0.560	-0.340	5705	4.53	4.61	0.15
59	28034	0.302	0.687	-0.422	6112	4.43	4.35	0.12
61	28069	0.269	0.728	-0.450	6206	4.41	4.37	0.12
62	28033	0.285	0.701	-0.421	6199	4.41	4.31	0.12
63	28068	0.384	0.578	-0.376	5774	4.52	4.57	0.15
64	28099	0.396	0.565	-0.357	5729	4.53	4.65	0.15
65	28205	0.300	0.687	-0.431	6114	4.43	4.39	0.12

Table 10. continued

Nbr.	HD/DM	$(B2 - V1)_0$	d	m_2	T_{eff}	$\log g$	$\log g$ from grids	$\pm\sigma$
66	28237	0.309	0.656	-0.421	6080	4.44	4.54	0.12
67	28226	0.066	1.157	-0.466	7269	4.24	4.17	0.08
68	28294	0.119	1.075	-0.489	7056	4.26	4.25	0.09
69	28291	0.446	0.529	-0.311	5551	4.57	4.63	0.17
72	28319	-0.015	1.355	-0.311	7928	4.19	4.10	0.06
73	28344	0.355	0.595	-0.390	5884	4.49	4.68	0.14
74	28355	0.003	1.266	-0.461	7815	4.20	4.23	0.07
76	+26°722	0.467	0.513	-0.284	5498	4.57	4.65	0.19
77	28394	0.263	0.743	-0.452	6228	4.41	4.33	0.12
78	28406	0.231	0.795	-0.466	6466	4.36	4.32	0.13
80	28485	0.120	1.080	-0.478	7076	4.26	4.16	0.10
81	28483	0.239	0.760	-0.450	6381	4.37	4.40	0.13
82	28527	-0.018	1.335	-0.483	7986	4.18	4.18	0.06
83	28546	0.046	1.162	-0.452	7642	4.21	4.24	0.07
84	28556	0.054	1.172	-0.472	7457	4.23	4.23	0.07
85	28568	0.213	0.838	-0.471	6547	4.34	4.25	0.13
86	28608	0.239	0.760	-0.459	6411	4.37	4.45	0.12
87	28593	0.465	0.513	-0.307	5502	4.57	4.62	0.18
88	28635	0.304	0.681	-0.424	6101	4.44	4.40	0.12
89	28677	0.122	1.043	-0.480	7077	4.26	4.31	0.10
90	28736	0.199	0.844	-0.461	6646	4.33	4.33	0.14
92	28805	0.455	0.524	-0.307	5524	4.57	4.58	0.18
94	28911	0.203	0.824	-0.464	6622	4.33	4.41	0.13
95	28910	0.045	1.203	-0.479	7607	4.22	4.22	0.07
97	28992	0.363	0.603	-0.387	5851	4.50	4.55	0.14
100	29169	0.166	0.931	-0.471	6821	4.30	4.30	0.17
101	29225	0.197	0.804	-0.444	6711	4.32	4.53	0.15
102	29310	0.338	0.621	-0.394	5955	4.47	4.56	0.13
103	29375	0.099	1.109	-0.476	7229	4.24	4.16	0.08
104	29388	-0.065	1.397	-0.480	8415	4.10	4.19	0.05
105	29419	0.327	0.629	-0.404	6004	4.46	4.61	0.13
106	29461	0.383	0.573	-0.358	5777	4.52	4.65	0.14
107	29499	0.041	1.167	-0.445	7677	4.21	4.23	0.07
108	29488	-0.035	1.377	-0.481	8094	4.16	4.14	0.06
110	29621	0.419	0.569	-0.355	5652	4.55	4.36	0.16
111	30034	0.052	1.172	-0.477	7581	4.22	4.27	0.07
112	30210	-0.023	1.301	-0.441	7218	4.24	4.32	0.06
113	30311	0.326	0.652	-0.427	5999	4.46	4.45	0.13
114	30355	0.438	0.536	-0.319	5582	4.56	4.62	0.17
118	30589	0.326	0.637	-0.404	6009	4.46	4.53	0.13
119	30676	0.311	0.670	-0.420	6071	4.45	4.42	0.12
120	30712	0.443	0.536	-0.318	5564	4.56	4.56	0.17
121	30738	0.261	0.744	-0.450	6232	4.40	4.33	0.12
122	30810	0.294	0.694	-0.435	6133	4.43	4.38	0.12
123	30780	0.024	1.276	-0.482	7684	4.21	4.13	0.06
124	30869	0.253	0.787	-0.446	6244	4.40	4.09	0.12
127	31609	0.445	0.514	-0.300	5547	4.57	4.83	0.17
128	31845	0.214	0.798	-0.460	6566	4.34	4.43	0.13
129		-0.036	1.388	-0.482	8088	4.16	4.11	0.06
130	33254	0.027	1.202	-0.434	7207	4.24	4.15	0.07
132		0.081	1.125	-0.439	7221	4.24	4.04	0.08

Table 10. continued

Nbr.	HD/DM	$(B2 - V1)_\odot$	d	m_2	T_{eff}	$\log g$	$\log g$ from grids	$\pm\sigma$
137	25202	0.111	1.056	-0.482	7152	4.25	4.36	0.08
139	27570	0.395	0.587	-0.398	5730	4.53	4.43	0.13
141	28052	0.041	1.288	-0.477	7543	4.22	3.95	0.08
142		0.390	0.552	-0.353	5751	4.52	4.84	0.14
143		0.282	0.710	-0.434	6167	4.42	4.36	0.12
146		0.297	0.768	-0.463	6082	4.44	3.88	0.13
149	31622	0.369	0.573	-0.408	5822	4.50	4.79	0.15
154		0.193	0.849	-0.464	6679	4.32	4.38	0.14
158		0.359	0.650	-0.404	5865	4.49	4.15	0.14
160		0.164	0.946	-0.502	6767	4.31	4.38	0.16
162		0.432	0.515	-0.325	5601	4.55	4.78	0.16
169		-0.024	1.306	-0.480	8084	4.17	4.31	0.06

Table 11. Stars of IC 2391 used as surface gravity standards (cool stars)

HD	Nbr.	$(B2 - V1)_\odot$	d	m_2	T_{eff}	$\log g$	$\log g$ from grids	$\pm\sigma$
73681	3	-0.099	1.343	-0.498	8947	4.30	4.37	0.03
73904	6	-0.098	1.407	-0.514	8812	4.30	4.20	0.04
74044	11	0.029	1.199	-0.486	7751	4.30	4.38	0.06
74145	15	0.050	1.155	-0.482	7601	4.30	4.36	0.07
74438	27	0.050	1.153	-0.488	7586	4.30	4.39	0.07
74537	33	0.012	1.240	-0.485	7856	4.30	4.35	0.06
74665	38	0.013	1.306	-0.505	7725	4.30	4.19	0.06
74678	39	-0.089	1.377	-0.519	8748	4.30	4.28	0.04
74762	40	-0.008	1.289	-0.475	7827	4.30	4.27	0.06
74956	41	-0.094	1.376	-0.511	8817	4.30	4.28	0.04
75202	49	-0.013	1.321	-0.490	7962	4.30	4.20	0.06
73064	77	-0.023	1.261	-0.490	8156	4.30	4.44	0.05
74739	80	-0.066	1.333	-0.502	8513	4.30	4.36	0.04

Table 12. Coefficients a , b and c of Eq. (15), for the correction of $\log g$ in the case of cool stars

Range of T_{eff}	a	b	c	Range of $[M/H]$
> 6916	-2.4676	2.7064×10^{-4}	—	all
≤ 6916	63.314	-1.970×10^{-2}	1.537×10^{-6}	≥ 0.1
	48.074	-1.517×10^{-2}	1.201×10^{-6}	$[-0.1, +0.1[$
	39.705	-1.274×10^{-2}	1.025×10^{-6}	$[-0.3, -0.1[$
	31.292	-1.034×10^{-2}	8.452×10^{-7}	$[-0.5, -0.3[$
	22.873	-7.788×10^{-3}	6.603×10^{-7}	< -0.5

Table 13. Stars of Edvardsson et al. (1993) used as metallicity and surface gravity standards (cool stars)

HD	HR/DM	$(B2 - V1)_\odot$	d	m_2	T_{eff}	$\log g$	$[M/H]$	$\log g$	$\pm\sigma$	$[M/H]$	$\pm\sigma$
										from grids	
400	17	0.271	0.744	-0.478	6192	4.13	-0.35	4.31	0.13	-0.22	0.09
693	33	0.270	0.764	-0.492	6204	4.07	-0.38	4.20	0.13	-0.35	0.10
739	35	0.221	0.805	-0.482	6577	4.26	-0.10	4.42	0.13	-0.08	0.09
2454	107	0.229	0.856	-0.514	6488	4.08	-0.37	4.02	0.13	-0.44	0.11
2615	-33�163	0.244	0.826	-0.519	6255	3.93	-0.58	4.03	0.13	-0.55	0.11
3158	140	0.248	0.782	-0.478	6408	4.18	0.05	4.29	0.12	-0.13	0.09
3268	145	0.292	0.778	-0.491	6176	4.06	-0.25	3.86	0.13	-0.41	0.10
4307	203	0.365	0.644	-0.435	5809	4.06	-0.28	4.27	0.14	-0.28	0.09
4614	219	0.335	0.629	-0.451	5946	4.47	-0.31	4.67	0.14	-0.32	0.10
4813	235	0.285	0.713	-0.468	6254	4.32	-0.15	4.39	0.13	-0.19	0.09
5015	244	0.306	0.716	-0.438	6196	3.98	0.00	4.11	0.13	-0.01	0.08
6434	-40�239	0.361	0.605	-0.463	5813	4.42	-0.54	4.65	0.16	-0.58	0.11
6920	340	0.349	0.745	-0.444	5804	3.88	-0.21	3.54	0.14	-0.23	0.08
7439	366	0.226	0.833	-0.501	6474	4.10	-0.32	4.23	0.13	-0.28	0.10
7476	368	0.214	0.881	-0.494	6517	4.01	-0.24	4.04	0.14	-0.18	0.09
7570	370	0.323	0.656	-0.411	6081	4.26	0.12	4.44	0.12	0.10	0.08
9562	448	0.382	0.642	-0.380	5820	3.84	0.09	4.06	0.15	0.07	0.08
9826	458	0.293	0.721	-0.436	6212	4.17	0.09	4.20	0.12	0.06	0.08
10307	483	0.362	0.614	-0.396	5898	4.31	-0.02	4.43	0.14	0.01	0.08
12042	573	0.265	0.740	-0.490	6239	4.25	-0.34	4.43	0.13	-0.31	0.10
13555	646	0.224	0.822	-0.485	6358	4.07	-0.32	4.29	0.13	-0.12	0.09
14214	672	0.337	0.671	-0.412	6045	4.12	0.06	4.19	0.13	0.04	0.08
15335	720	0.350	0.704	-0.456	5857	4.06	-0.22	3.89	0.14	-0.35	0.09
15798	740	0.229	0.864	-0.492	6436	3.94	-0.25	3.96	0.13	-0.20	0.09
16673	784	0.279	0.695	-0.456	6287	4.37	0.02	4.58	0.13	-0.07	0.09
16895	799	0.261	0.740	-0.458	6309	4.30	-0.02	4.38	0.13	0.00	0.09
17548	-2�491	0.302	0.693	-0.501	5977	4.27	-0.59	4.39	0.14	-0.59	0.11
19994	962	0.319	0.694	-0.416	6104	4.10	0.09	4.18	0.12	0.09	0.08
20807	1010	0.356	0.593	-0.429	5889	4.41	-0.20	4.78	0.14	-0.27	0.09
22001	1083	0.185	0.913	-0.506	6769	4.10	-0.11	4.24	0.14	-0.24	0.09
22484	1101	0.335	0.696	-0.442	5981	4.15	-0.11	4.07	0.13	-0.16	0.09
22879	-3�592	0.313	0.677	-0.509	5826	4.27	-0.84	4.46	0.15	-0.75	0.12
23754	1173	0.207	0.887	-0.490	6739	4.11	0.09	4.09	0.13	-0.12	0.08
25621	1257	0.274	0.797	-0.454	6301	3.97	0.04	3.85	0.13	-0.01	0.08
25704	-57�612	0.324	0.696	-0.514	5844	4.43	-0.85	4.21	0.15	-0.85	0.12
26491	1294	0.384	0.596	-0.409	5732	4.16	-0.18	4.46	0.15	-0.21	0.09
30562	1536	0.373	0.636	-0.373	5886	3.98	0.14	4.13	0.14	0.15	0.08
30649	+45�992	0.351	0.642	-0.464	5736	4.22	-0.51	4.36	0.15	-0.48	0.10
30743	1545	0.231	0.816	-0.510	6425	4.11	-0.33	4.26	0.13	-0.40	0.11
33256	1673	0.234	0.867	-0.520	6442	4.05	-0.30	3.87	0.13	-0.53	0.11
33608	1687	0.231	0.801	-0.448	6596	4.15	0.26	4.19	0.13	0.19	0.08
34411	1729	0.361	0.634	-0.396	5889	4.12	-0.03	4.28	0.14	0.03	0.08
35296	1780	0.292	0.700	-0.457	6152	4.36	0.00	4.44	0.13	-0.12	0.09
38393	1983	0.259	0.739	-0.470	6398	4.29	-0.07	4.47	0.12	-0.10	0.09
39587	2047	0.349	0.602	-0.420	5953	4.46	-0.03	4.72	0.14	-0.14	0.09
41330	2141	0.355	0.679	-0.454	5917	4.14	-0.24	4.05	0.14	-0.37	0.10
43042	2220	0.218	0.793	-0.465	6587	4.27	0.04	4.44	0.12	0.10	0.09
43318	2233	0.263	0.814	-0.479	6347	4.07	-0.17	3.90	0.13	-0.19	0.09
45701	2354	0.399	0.581	-0.363	5803	4.17	0.13	4.45	0.15	0.04	0.09
48938	2493	0.309	0.718	-0.494	6063	4.24	-0.38	4.11	0.13	-0.53	0.11
49933	2530	0.180	0.876	-0.513	6595	4.16	-0.43	4.57	0.15	-0.31	0.09
50223	2548	0.235	0.838	-0.494	6460	4.06	-0.20	4.07	0.13	-0.24	0.10

Table 13. continued

HD	HR/DM	$(B2 - V1)_0$	d	m_2	T_{eff}	$\log g$	$[M/H]$	$\log g$	$\pm\sigma$ from grids	$[M/H]$	$\pm\sigma$
51530	2601	0.288	0.782	-0.490	6025	3.94	-0.56	3.88	0.13	-0.39	0.10
51929	-56�1199	0.341	0.633	-0.480	5845	4.28	-0.64	4.57	0.15	-0.60	0.11
55575	2721	0.342	0.646	-0.459	5963	4.48	-0.28	4.44	0.14	-0.39	0.10
59984	2883	0.313	0.723	-0.512	5976	4.18	-0.75	4.06	0.14	-0.75	0.12
60532	2906	0.290	0.811	-0.472	6167	4.09	-0.18	3.64	0.13	-0.23	0.08
61421	2943	0.206	0.926	-0.495	6704	4.03	-0.02	3.86	0.14	-0.18	0.09
62301	+39�1998	0.311	0.694	-0.499	5895	4.19	-0.69	4.30	0.14	-0.61	0.11
63077	3018	0.343	0.665	-0.499	5822	4.42	-0.78	4.31	0.15	-0.79	0.12
66573		0.372	0.593	-0.453	5730	4.37	-0.58	4.66	0.16	-0.55	0.10
67228	3176	0.380	0.629	-0.379	5779	4.20	0.04	4.19	0.14	0.07	0.08
68461	3222	0.223	0.828	-0.499	6536	4.13	-0.26	4.29	0.13	-0.25	0.10
69611	-3�2288	0.356	0.649	-0.479	5795	4.29	-0.58	4.29	0.15	-0.64	0.11
69897	3262	0.247	0.754	-0.483	6365	4.35	-0.26	4.48	0.13	-0.18	0.10
70110	3271	0.347	0.681	-0.404	5955	4.07	0.07	4.03	0.14	0.07	0.08
74011	+34�1885	0.345	0.665	-0.473	5741	4.15	-0.65	4.21	0.15	-0.50	0.10
76151	3538	0.402	0.580	-0.369	5763	4.37	0.01	4.39	0.15	-0.01	0.09
76932	3578	0.318	0.708	-0.523	5965	4.37	-0.82	4.17	0.15	-0.93	0.13
78558	-14�2757	0.377	0.602	-0.441	5767	4.28	-0.40	4.51	0.15	-0.44	0.10
78747	-49�4142	0.346	0.639	-0.478	5824	4.45	-0.64	4.46	0.15	-0.59	0.11
79028	3648	0.349	0.653	-0.419	5881	4.18	-0.08	4.30	0.13	-0.08	0.08
82328	3775	0.250	0.846	-0.489	6380	4.09	-0.20	3.84	0.13	-0.25	0.09
84737	3881	0.361	0.647	-0.398	5899	4.12	0.04	4.17	0.14	0.03	0.08
86728	3951	0.398	0.598	-0.350	5746	4.02	0.10	4.24	0.15	0.16	0.08
89125	4039	0.275	0.728	-0.486	6158	4.30	-0.38	4.42	0.13	-0.31	0.09
89707	-14�3093	0.323	0.681	-0.492	5989	4.42	-0.42	4.30	0.15	-0.60	0.11
89744	4067	0.286	0.767	-0.433	6320	4.07	0.18	3.92	0.12	0.11	0.08
91347	+49�1966	0.325	0.652	-0.473	5872	4.24	-0.48	4.53	0.14	-0.43	0.10
91889	4158	0.296	0.711	-0.467	6140	4.22	-0.24	4.30	0.13	-0.22	0.09
95128	4277	0.364	0.610	-0.403	5882	4.34	0.01	4.51	0.14	-0.06	0.08
98991	4395	0.214	0.917	-0.491	6643	3.98	-0.10	3.81	0.14	-0.16	0.09
102574	4529	0.338	0.711	-0.414	6083	4.04	0.16	3.86	0.14	0.03	0.08
102634	4533	0.273	0.740	-0.434	6387	4.18	0.24	4.19	0.12	0.15	0.08
102870	4540	0.311	0.705	-0.424	6176	4.14	0.13	4.16	0.12	0.07	0.08
106516	4657	0.253	0.744	-0.524	6247	4.38	-0.70	4.50	0.14	-0.66	0.12
108309	4734	0.411	0.585	-0.366	5776	4.20	0.10	4.29	0.16	-0.03	0.09
109358	4785	0.352	0.616	-0.438	5879	4.52	-0.19	4.63	0.14	-0.29	0.09
110897	4845	0.330	0.643	-0.477	5795	4.15	-0.59	4.55	0.15	-0.50	0.10
112164	4903	0.362	0.677	-0.369	5953	4.00	0.24	3.71	0.15	0.24	0.07
114642	4981	0.237	0.843	-0.481	6375	3.94	-0.17	4.00	0.13	-0.11	0.09
114710	4983	0.334	0.652	-0.427	6029	4.38	0.03	4.43	0.13	-0.07	0.08
114762	+18�2700	0.319	0.685	-0.507	5871	4.24	-0.74	4.33	0.15	-0.75	0.12
114837	4989	0.247	0.780	-0.489	6314	4.25	-0.28	4.32	0.13	-0.24	0.10
115383	5011	0.323	0.669	-0.409	6021	4.15	0.10	4.32	0.12	0.12	0.08
115617	5019	0.433	0.533	-0.342	5590	4.23	-0.03	4.73	0.16	-0.11	0.10
121370	5235	0.329	0.731	-0.391	6068	3.83	0.19	3.62	0.14	0.23	0.07
124570	5323	0.298	0.763	-0.439	6237	4.04	0.07	3.85	0.13	0.02	0.08
124850	5338	0.284	0.791	-0.469	6177	3.94	-0.11	3.84	0.13	-0.18	0.08
125184	5353	0.441	0.584	-0.322	5562	3.92	0.13	3.98	0.19	0.15	0.08
126512	+21�2649	0.345	0.681	-0.485	5753	4.20	-0.63	4.09	0.15	-0.61	0.11
128167	5447	0.165	0.904	-0.521	6767	4.27	-0.41	4.67	0.17	-0.40	0.10

Table 13. continued

HD	HR/DM	$(B2 - V1)_0$	d	m_2	T_{eff}	$\log g$	$[M/H]$	$\log g$	$\pm\sigma$ from grids	$[M/H]$	$\pm\sigma$
128620	5459	0.434	0.587	-0.325	5720	4.27	0.15	3.98	0.19	0.17	0.08
130551	-60°5530	0.246	0.808	-0.526	6237	4.25	-0.62	4.13	0.13	-0.65	0.12
131117	5542	0.343	0.678	-0.409	6001	4.09	0.13	4.08	0.13	0.05	0.08
136064	5691	0.311	0.753	-0.450	6172	4.12	-0.02	3.88	0.13	-0.11	0.08
136351	5698	0.271	0.818	-0.465	6341	4.04	0.01	3.80	0.13	-0.10	0.08
137052	5723	0.231	0.875	-0.487	6532	3.93	-0.13	3.86	0.13	-0.16	0.09
141004	5868	0.359	0.633	-0.416	5937	4.21	-0.04	4.40	0.14	-0.12	0.08
142373	5914	0.339	0.699	-0.479	5843	4.34	-0.52	3.97	0.14	-0.50	0.10
142860	5933	0.254	0.777	-0.485	6333	4.25	-0.16	4.26	0.13	-0.22	0.09
143761	5968	0.367	0.643	-0.439	5782	4.24	-0.26	4.27	0.14	-0.33	0.09
144585	5996	0.392	0.612	-0.351	5831	4.03	0.23	4.07	0.16	0.21	0.07
148211	-21°4360	0.326	0.676	-0.492	5899	4.17	-0.65	4.32	0.15	-0.61	0.11
148816	+4°3195	0.317	0.690	-0.502	5867	4.26	-0.74	4.29	0.14	-0.67	0.11
150177	6189	0.266	0.798	-0.517	6200	3.98	-0.56	3.97	0.13	-0.60	0.11
150453	6202	0.221	0.908	-0.514	6442	3.86	-0.37	3.78	0.13	-0.43	0.10
151769	6243	0.252	0.872	-0.467	6435	3.80	0.00	3.61	0.13	-0.06	0.08
153597	6315	0.239	0.732	-0.458	6284	4.38	-0.17	4.64	0.13	0.08	0.09
156098	6409	0.268	0.839	-0.458	6480	3.94	0.09	3.63	0.13	-0.03	0.08
157089	+1°3421	0.345	0.665	-0.476	5795	4.15	-0.59	4.21	0.15	-0.53	0.10
157214	6458	0.377	0.615	-0.432	5676	4.33	-0.41	4.42	0.15	-0.35	0.10
160032	6569	0.197	0.875	-0.507	6675	4.15	-0.27	4.32	0.13	-0.27	0.10
162396	6649	0.305	0.722	-0.485	6088	4.24	-0.34	4.15	0.13	-0.41	0.10
165401	+4°3589	0.363	0.614	-0.447	5758	4.31	-0.47	4.53	0.15	-0.41	0.10
165908	6775	0.304	0.712	-0.498	6020	4.48	-0.56	4.21	0.14	-0.55	0.11
168151	6850	0.214	0.836	-0.508	6587	4.09	-0.31	4.36	0.13	-0.32	0.10
169830	6907	0.282	0.760	-0.441	6382	4.15	0.13	4.02	0.12	0.07	0.08
173667	7061	0.241	0.822	-0.479	6369	4.02	-0.11	4.10	0.13	-0.11	0.09
175317	7126	0.216	0.842	-0.475	6655	4.16	0.21	4.22	0.13	0.00	0.09
177565	7232	0.433	0.547	-0.346	5625	4.21	0.03	4.57	0.16	-0.09	0.10
184499	+32°3474	0.347	0.676	-0.472	5711	4.15	-0.61	4.09	0.14	-0.49	0.10
187013	7534	0.236	0.798	-0.472	6379	4.21	-0.13	4.28	0.13	-0.03	0.09
187691	7560	0.305	0.708	-0.426	6146	4.14	0.09	4.19	0.12	0.08	0.08
188815	-46°13313	0.273	0.754	-0.519	6181	4.29	-0.58	4.21	0.13	-0.66	0.12
193307	7766	0.323	0.686	-0.469	5964	4.22	-0.36	4.29	0.13	-0.36	0.10
196378	7875	0.310	0.744	-0.487	5991	4.09	-0.44	3.92	0.13	-0.45	0.10
198044	-23°16508	0.294	0.718	-0.485	6093	4.15	-0.31	4.29	0.13	-0.38	0.10
198084	7955	0.308	0.744	-0.432	6188	4.13	0.12	3.89	0.13	0.04	0.08
199289	-48°13728	0.313	0.677	-0.529	5894	4.38	-1.03	4.52	0.16	-1.02	0.15
199623	8027	0.254	0.779	-0.498	6285	4.20	-0.37	4.26	0.13	-0.35	0.10
199960	8041	0.377	0.612	-0.367	5813	4.20	0.11	4.31	0.14	0.15	0.08
200790	8077	0.308	0.743	-0.455	6166	4.05	-0.07	3.97	0.13	-0.14	0.08
200973	-31°18080	0.246	0.838	-0.513	6301	3.90	-0.52	3.92	0.13	-0.49	0.11
201099	-6°5683	0.332	0.670	-0.483	5872	4.06	-0.50	4.30	0.15	-0.55	0.11
201891	+17°4519	0.310	0.681	-0.534	5867	4.46	-1.06	4.52	0.16	-1.08	0.15
203608	8181	0.278	0.723	-0.520	6139	4.34	-0.67	4.40	0.14	-0.71	0.12
207978	8354	0.225	0.852	-0.526	6285	4.09	-0.66	4.09	0.14	-0.58	0.11
210752	-7°5727	0.316	0.641	-0.489	5910	4.25	-0.64	4.72	0.15	-0.58	0.11
210855	8472	0.269	0.802	-0.445	6249	3.86	0.06	3.85	0.13	0.08	0.08
215257	+3°4763	0.306	0.700	-0.514	5983	4.37	-0.65	4.32	0.14	-0.76	0.12
215648	8665	0.274	0.780	-0.487	6228	4.15	-0.32	4.06	0.13	-0.31	0.09
216385	8697	0.259	0.810	-0.482	6288	3.97	-0.25	3.97	0.13	-0.20	0.09
217014	8729	0.396	0.590	-0.353	5755	4.18	0.06	4.38	0.15	0.14	0.08
219623	8853	0.303	0.697	-0.442	6134	4.21	0.00	4.30	0.13	-0.04	0.08
221830	+30°4982	0.365	0.630	-0.438	5707	4.16	-0.52	4.40	0.14	-0.33	0.09
222368	8969	0.281	0.745	-0.467	6255	4.16	-0.17	4.21	0.13	-0.15	0.09

Table 14. Additional standard stars for metallicity (cool stars)

HD	HR/DM	$(B2 - V1)_0$	d	m_2	T_{eff}	$\log g$	$[M/H]$	Source	$[M/H]$ from grids	$\pm\sigma$
2151	98	0.367	0.664	-0.428	5730	3.80	-0.31	Per	-0.20	0.08
11007	523	0.322	0.695	-0.457	6000	4.09	-0.24	Per	-0.24	0.09
11257	534	0.108	1.062	-0.513	7190	4.04	-0.29	Feh	-0.31	0.11
16234	763	0.286	0.739	-0.485	5930	3.95	-0.49	Per	-0.34	0.09
19373	937	0.334	0.650	-0.399	5930	4.09	0.05	Per	0.14	0.08
19445	+25°495	0.268	0.740	-0.590	5930	3.80	-2.00	Per	-2.03	0.26
20630	996	0.405	0.560	-0.363	5660	4.45	0.08	Per	-0.03	0.09
23194	+24°540	-0.038	1.273	-0.477	8300	4.30	-0.20	Feh	-0.04	0.14
23924	+23°567	-0.029	1.212	-0.465	8210	4.30	-0.30	Feh	0.14	0.11
27628	1368	0.101	1.104	-0.463	7171	4.25	0.20	BC	0.29	0.08
27749	1376	0.078	1.108	-0.433	6398	4.37	0.40	BC	0.55	0.06
27819	1380	-0.030	1.340	-0.483	8220	4.00	0.17	Feh	-0.15	0.15
28546	1428	0.046	1.162	-0.452	7642	4.21	0.40	BC	0.37	0.07
30652	1543	0.233	0.773	-0.470	6380	4.50	0.17	Per	0.00	0.09
33254	1672	0.027	1.202	-0.434	7537	4.07	0.60	BC	0.51	0.07
37513	-76°329	0.315	0.680	-0.443	6220	4.28	0.04	And	-0.11	0.09
39091	2022	0.339	0.600	-0.394	5660	3.94	0.00	Per	0.10	0.08
40136	2085	0.134	1.022	-0.509	7410	4.00	-0.20	Per	-0.23	0.10
52711	2643	0.345	0.628	-0.425	5860	4.47	-0.15	Per	-0.13	0.09
72905	3391	0.361	0.589	-0.412	5790	4.40	-0.08	Boe	-0.15	0.09
74000	-15°256	0.238	0.819	-0.595	6209	4.13	-1.81	Ber	-2.05	0.31
76932	3578	0.318	0.708	-0.523	5916	4.15	-1.02	Ber	-0.93	0.13
90277	4090	0.047	1.315	-0.481	7610	3.48	0.13	Ber	0.04	0.08
90839	4112	0.289	0.675	-0.453	6070	4.41	-0.23	Per	-0.10	0.09
91324	4134	0.275	0.781	-0.493	6070	3.90	-0.60	Per	-0.37	0.10
94028	+21°2247	0.263	0.741	-0.557	6138	4.44	-1.53	Ber	-1.22	0.17
104731	4600	0.200	0.867	-0.501	6630	4.00	-0.21	Feh	-0.21	0.09
105452	4623	0.129	1.007	-0.518	6900	4.20	-0.57	Per	-0.36	0.11
108177	+2°2538	0.252	0.762	-0.580	6162	4.41	-1.76	Ber	-1.68	0.21
115043	+57°1425	0.356	0.593	-0.410	5930	4.26	-0.10	Per	-0.11	0.09
134083	5634	0.209	0.826	-0.486	6500	4.46	0.00	Feh	-0.08	0.08
139798	5830	0.147	0.972	-0.503	6940	4.11	-0.13	Feh	-0.16	0.10
146233	6060	0.385	0.583	-0.384	5860	4.18	0.02	Peh	-0.01	0.09
150366	6193	0.007	1.260	-0.478	7920	3.84	-0.08	Feh	-0.04	0.10
180777	7312	0.105	1.063	-0.503	7210	4.06	-0.03	Feh	-0.16	0.10
186427	7504	0.402	0.576	-0.368	5790	4.13	0.10	Per	-0.01	0.09
189567	7644	0.393	0.569	-0.412	5730	4.08	-0.28	Per	-0.36	0.10
201891	+17°4519	0.310	0.681	-0.534	5943	4.50	-1.13	Ber	-1.08	0.15
219617	-14°6437	0.280	0.699	-0.557	6062	4.65	-1.50	Ber	-1.33	0.18

And: Andersen et al. (1989). Feh: Cayrel de Strobel et al. (1992). Ber: Berthet (1990).

Boe: Boesgaard (1989). Per: Perrin et al. (1977). BC: Burkhart & Coupry (1989).