SURFACE GRAVITIES OF METAL-POOR STARS DERIVED FROM HIPPARCOS PARALLAXES

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ABSTRACT

Surface gravities of metal-poor stars have been derived from the basic relations $g \propto M/R^2$ and $R^2 \propto L/{T_{\rm eff}}^4$ using Hipparcos parallaxes to determine luminosities. The method has been applied to 54 metal-poor stars with [Fe/H] < -1.0 and $\sigma(\pi)/\pi < 0.2$ selected from the photometric study of Schuster & Nissen (1989). $T_{\rm eff}$ is determined from the Strömgren color index $(b-y)$ and the mass is derived by fitting 14 Gyr isochrones to the distribution of the stars in the $M_V - T_{\rm eff}$ plane. The gravities have statistical errors $\sigma(\log g) < 0.20$ dex and systematic errors within ± 0.10 dex. Comparison with gravities, derived from the requirement that Fe I and Fe II lines should provide the same iron abundance, shows that such 'spectroscopic' gravities are often in error by a factor of 2 to 3. The importance of the parallax-based gravities for setting the metallicity scale of metal-poor stars and for deriving accurate abundances of key elements in nucleosynthesis studies is emphasized.

Key words: Surface gravities; Stellar atmospheres; Stellar abundances.

1. INTRODUCTION

The surface gravity, g, of a star is one of its fundamental parameters. The gravity controls the pressure in the stellar atmosphere and affects the degree of ionization of atoms, and hence the line and continuous absorption coefficients, κ_l and κ_c. As the depth of absorption lines depends on the ratio κ_l/κ_c, studies of element abundances also require a good knowledge of g except is those cases where κ_l and κ_c depend in the same way on pressure.

In the case of F and G stars, including metal-poor subdwarfs and subgiants, the main contribution to the continuous absorption coefficient comes from H^-, i.e. $\kappa_c \propto P_e$, the electron pressure. Elements with an ionization potential lower than about 9 eV, e.g. iron, are predominantly in the first ionization stage. Thus the number of neutral atoms is also proportional to P_e. The equivalent width of a weak Fe I line is therefore insensitive to variations in P_e, whereas a weak Fe II line is roughly proportional to P_e^{-1}. As the gravity of a star is normally not a well known parameter, the standard procedure in determinations of element abundances in F and G stars has been to determine the iron abundance from Fe I lines and to estimate g by requiring that Fe I and Fe II lines should provide the same iron abundance. These so-called 'spectroscopic' gravities are then used in the determination of abundances of elements for which one is forced to use lines from the dominant ionization stage or molecular lines, like in the case of Be, C, N, and O, because no other lines are available.

This procedure of abundance determinations is, however, affected by several uncertainties, which are particularly important in the case of metal-poor stars. The iron abundance derived from Fe I lines is sensitive to $T_{\rm eff}$ and as discussed by e.g. Nissen et al. (1994) the $T_{\rm eff}$-scale of metal-poor stars is uncertain by ± 150 K causing errors in [Fe/H] of about ± 0.12 dex and errors in the spectroscopic gravities of the order of 0.3 dex. Uncertainties in the temperature structure of the model atmospheres due to an inadequate theory of convection correspond to a similarly large uncertainty. Ryan et al. (1996) showed that the new ATLAS9 models of Kurucz (1993) with convective overshoot lead to Fe abundances about 0.1 dex higher than models without overshoot. The iron abundance derived from Fe I lines is also affected by non-LTE effects. The 'over-ionization' of Fe I has been estimated to be of the order of 0.05 to 0.10 dex by Axer et al. (1995) on the basis of plane parallel atmospheres, but could be larger due to thermal inhomogeneities induced by convection in the atmosphere as discussed by Kurucz (1995). Finally, the oscillator strengths of the Fe I and Fe II lines pose a potential problem, although much improved experimental values have been published in recent years. Altogether, this makes iron abundances derived from Fe I lines rather uncertain with a correspondingly high uncertainty of the spectroscopic gravities.

As shown in the next section, the Hipparcos parallaxes enable us to determine surface gravities for a significant number of metal-poor subdwarf and subgiant stars. This in turn allows us to determine more accurate abundances of elements that play a key role in nucleosynthesis theories. Furthermore, the parallaxes give a good estimate of the evolutionary stages of the stars, which is of special importance for the interpretation of the abundances of the light elements Li, Be, and B. Their abundances in stellar atmospheres may be affected by depletion processes, which depend critically on the mass and evolutionary stage of the star.

2. THE PARALLAX-BASED GRAVITIES

From the relations $g \propto M/R^2$ and $L \propto R^2 {T_{\rm eff}}^4$, where M is the stellar mass, R the radius and $T_{\rm eff}$ the effective temperature, we get:

$$\log \frac{g}{g_\odot} = \log \frac{M}{M_\odot} + 4 \log \frac{T_{\rm eff}}{T_{\rm eff\,\odot}} + 0.4(M_{bol} - M_{bol,\odot}) \quad (1)$$

Here the absolute bolometric magnitude is given by:

$$M_{bol} = V_0 + BC + 5 \log \pi + 5, \quad (2)$$

where V_0 is the visual magnitude of the star corrected for interstellar absorption, BC the bolometric correction and π the parallax in arcsec. Furthermore, using $M_{V,\odot} = 4.83$ (Allen, 1973) and adopting $BC_\odot = -0.12$ (to be consistent with Bergbusch & VandenBerg (1992), from which the bolometric corrections for the stars were taken) we get the following expression for the surface gravity:

$$\log \frac{g}{g_\odot} = \log \frac{M}{M_\odot} + 4 \log \frac{T_{\rm eff}}{T_{\rm eff\,\odot}} + 0.4V_0 + 0.4BC + 2\log\pi + 0.12 \quad (3)$$

The metal-poor stars were selected from the list of Schuster & Nissen (1989, Table 1) according to the condition $\sigma(\pi)/\pi < 0.2$, where π is the trigonometric parallax and $\sigma(\pi)$ its standard error as given in the Hipparcos Catalogue (ESA 1997). The list of Schuster & Nissen is based on Strömgren *uvby*-β photometry of high velocity and metal-poor stars and contains 220 stars with a photometric metallicity [Fe/H] < -1.0 of which 62 have Hipparcos parallaxes with a precision better than 20 per cent. Eight of these stars are known to be binaries and were excluded from the analysis.

The effective temperature was determined from the color index $b-y$ using the recent calibration of Alonso et al. (1996, Equation 9), who derived $T_{\rm eff}$ for a large sample of metal-poor stars using the infrared flux method. From the photometric errors of the Strömgren photometry we estimate that differential values of $T_{\rm eff}$ for stars with about the same metallicity can be determined within ± 70 K. The systematic errors in the calibration of $T_{\rm eff}$ versus $b-y$ may, however, be as large as ± 150 K. Still, this corresponds to an error of only ± 0.04 dex in $\log g$ as seen from Equation 3.

The mass of a star was estimated from its position in the $M_V - \log T_{\rm eff}$ diagram by interpolating in the set of oxygen enhanced isochrones by Bergbusch & VandenBerg (1992) assuming an age of 14 Gyr for all stars. As seen from Figures 1 and 2, the majority of

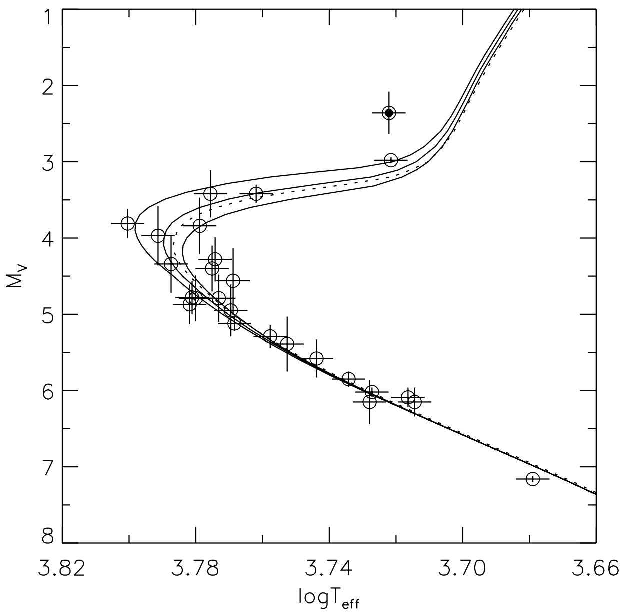

Figure 1. Absolute visual magnitudes versus $\log T_{\rm eff}$ *for the group of stars with* $-2.5 <$ *[Fe/H]* < -1.4*. Individual error bars of* M_V *corresponding to the error of the Hipparcos parallax are indicated. The error bars of* $\log T_{\rm eff}$ *correspond to* $\sigma(T_{\rm eff}) = \pm 70$ *K. The isochrones of Bergbusch & VandenBerg (1992) with [Fe/H] = −1.78, [O/Fe] = 0.66, Y = 0.236, and ages of 12, 14 and 16 Gyr are shown with solid lines. The dotted line is the 14 Gyr isochrone with [Fe/] = −1.66. A possible subgiant binary is shown with an encircled dot.*

stars are in fact well fitted by the 14 Gyr isochrones, and changing the assumed age by ± 4 Gyr changes the mass by only 8 per cent. Furthermore, different input physics for the stellar models has only a small effect on the masses derived; the α-enhanced models of Chaboyer et al. (1992) give practically the same masses as the Bergbusch & Vandenberg models. We conclude that the mass of the metal poor stars can be estimated within an accuracy of 10 per cent corresponding to an error of $\log g$ of ± 0.04 dex.

It should be noted that the isochrones of Bergbusch & VandenBerg (1992) have been shifted by a constant in $\log T_{\rm eff}$ in order to get the best possible fit between the unevolved stars and the corresponding part of the isochrones. This is allowed because the stellar models contain a free parameter, α, the ratio of the mixing length to pressure scale height, which controls the radius of the stellar models and hence $T_{\rm eff}$. In the work of Bergbusch & VandenBerg (1992), α was fixed to a value of 1.5 by requiring that the isochrones should fit one unevolved subdwarf, Gmb 1830 = HD 103095; see discussion by VandenBerg (1992). Gmb 1830 was at that time the only unevolved metal-poor star ([Fe/H] = −1.4) with a sufficiently accurate parallax value. Now, with the Hipparcos data there are many more stars available for the calibration of α. The fit to the unevolved stars has been obtained for a shift of the isochrones by $\Delta\log T_{\rm eff} = -0.022$ (Figure 1) and $\Delta\log T_{\rm eff} = -0.012$ (Figure 2). As seen from the paper of VandenBerg (1983) this corresponds to a decrease of α from 1.5 to values below 1.0. Part

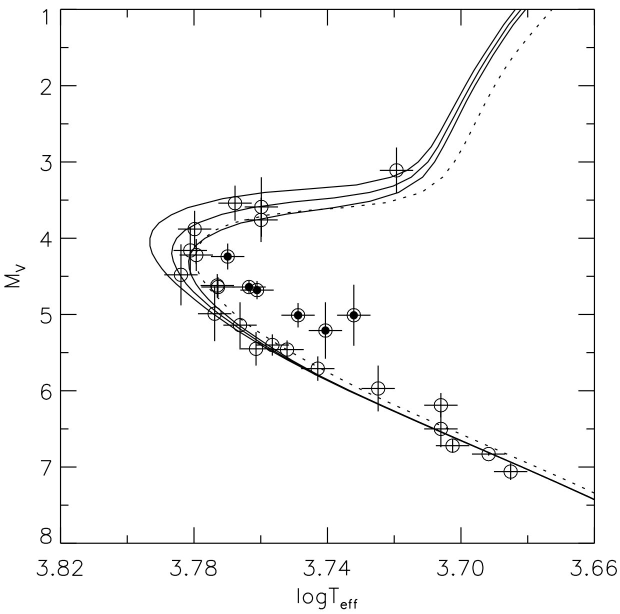

Figure 2. As Figure 1, for stars with −1.4 < [Fe/H] < −1.0. Isochrones of Bergbusch & VandenBerg (1992) with [Fe/H] = −1.26, [O/Fe] = 0.55, Y = 0.237, and ages of 12, 14 and 16 Gyr are shown with solid lines. The dotted line is the 14 Gyr isochrone with [Fe/H] = −1.03. Probable binaries are shown with encircled dots.

of the shift may, however, be due to a systematic error in the $T_{\rm eff}$ calibration, which as mentioned earlier could be as large as ±150 K corresponding to ±0.011 in log $T_{\rm eff}$.

As seen from Figures 1 and 2 a few stars lie significantly above the isochrones. These stars are likely to be binaries, and consequently the magnitude in Equation 3 may be too bright by up to 0.75 mag, and the derived gravity too small by up to 0.3 dex. Clearly, these stars should be carefully checked to see if they are indeed spectroscopic binaries. If not, their position in the $M_V - \log T_{\rm eff}$ diagram is a fundamental problem.

The bolometric correction was taken from the tables of Bergbusch & VandenBerg (1992), who determined BC on the basis of the old MARCS models by Gustafsson et al. (1975) as discussed in VandenBerg & Bell (1985). The values are somewhat model dependent. The BC's of Alonso et al. (1995) based on the ATLAS9 models are 0.05 to 0.10 smaller than those of Bergbusch & VandenBerg, although the same normalization ($BC_\odot = -0.12$) was applied. Thus, it seems that possible errors in the bolometric corrections for metal-poor stars can lead to errors in log g of ±0.04 dex.

With the exception of very nearby stars, the term $2\log\pi$ gives by far the largest contribution to the error of the gravity as determined by Equation 3, and it is only with the publication of accurate Hipparcos parallaxes that the method becomes of interest for metal-poor stars. For the large majority of stars selected for the present study $\sigma(\pi)/\pi$ is between 0.10 and 0.20 causing errors of log g ranging from 0.09 to 0.18 dex. Hence, the statistical error of the gravity determination is totally dominated by the uncertainties in the parallax. The possible systematic error, on the other hand, arises mainly from the uncertainties in the stellar mass, $T_{\rm eff}$ and the BC, which add up to a total systematic error of about ±0.10 dex.

The data used in Equation 3 and the resulting log g values and errors are given in Table 1. When combining the individual log g values in any statistical analysis, one must take into account a possible bias towards overestimating the parallax measurements. In the case of a uniform stellar space distribution, i.e. a parallax distribution $P(\pi) \propto \pi^{-4}$, Lutz & Kelker (1973) calculated quite large corrections, e.g. $\Delta M_V = -0.28$ at $\sigma(\pi)/\pi = 0.15$ corresponding to a correction $\Delta(\log g) = -0.11$. However, the sample of Schuster & Nissen (1989), from which the present 54 stars were drawn according to the criteria $\sigma(\pi)/\pi < 0.20$, is by no means uniformly distributed in space. It has a nearly flat distribution of $\sigma(\pi)/\pi$. Hence, any statistical correction should be rather negligible.

3. COMPARISON WITH SPECTROSCOPIC GRAVITIES

As mentioned in the introduction surface gravities of cool stars are usually determined by requiring that Fe I and Fe II lines should provide the same iron abundance. For metal-poor dwarfs and subgiants with $T_{\rm eff}$ in the range from 5000 K to 6500 K the iron abundance derived from Fe I lines is practically insensitive to variations in log g, whereas $\Delta\log(\mathrm{Fe/H}) \simeq 0.4\Delta(\log g)$ if Fe II lines are used. Hence, it is clear that the spectroscopic gravities are quite sensitive to errors in the derived iron abundances; an error of 0.1 dex in log(Fe/H) corresponds to an error of 0.25 dex in log g.

Figures 3, 4 and 5 show a comparison of the parallax-based gravities with spectroscopic gravities from some recent and often cited studies of metal-poor stars. Stars estimated to be binaries from their position in the $M_V - \log T_{\rm eff}$ diagram have been excluded. In Figure 3 the comparison is made for stars in common with Tomkin et al. (1992), who made a careful LTE analysis of 12 weak Fe I and 4 weak Fe II lines. As seen there is a satisfactory agreement between the two sets of gravities considering the error estimate of Tomkin et al. The agreement may, however, be somewhat fortuitous, because the Fe II oscillator strengths used by Tomkin et al. are rather uncertain.

Figure 4 shows the comparison with Magain (1989), who derived gravities by analyzing about 50 weak Fe I lines and 10 Fe II lines assuming LTE. As seen, the spectroscopic gravities are systematically smaller than the parallax-based gravities by about 0.4 dex, but the scatter in the comparison is quite small. The reason for the offset is somewhat unclear. The effective temperature scale used by Magain is about 50 K lower than the scale of Alonso et al. (1996), but this corresponds to a change in log g of −0.10 dex only. Part of the explanation may be that Magain used old and quite uncertain oscillator strengths for the Fe II lines.

Finally, Figure 5 shows the comparison with Axer et

Table 1. Input data and resulting values and errors of $\log g$ *as calculated from Equation 3. The* V *and* $(b-y)$ *values of HD 132475 has been corrected for interstellar absorption and reddening. [Fe/H] is the photometric metallicity from Schuster & Nissen (1989). The last column gives an estimate of the evolutionary stage of the star: MS, main sequence; TO, turnoff; SG, subgiant. In addition some stars have been marked as possible binaries according to their position in the* $M_V - \log T_{\rm eff}$ *diagram. For these stars the gravity is rather uncertain.*

Star	V	$(b-y)$	[Fe/H]	$T_{\rm eff}$ (K)	$M/M_\odot$	BC	π (mas)	$\sigma(\pi)/\pi$	$\log g$	$\sigma(\log g)$	Type
HD3567	9.26	0.332	−1.18	6040	0.82	−0.09	9.57	0.14	4.17	0.13	TO
CD−61 0282	10.12	0.365	−1.10	5772	0.76	−0.11	11.63	0.10	4.57	0.10	MS
G074-005	8.77	0.390	−1.04	5607	0.73	−0.13	17.66	0.07	4.32:		MS, BIN?
HD19445	8.05	0.352	−1.91	5866	0.73	−0.12	25.85	0.04	4.44	0.05	MS
G246-038	9.93	0.455	−1.98	5180	0.63	−0.17	17.58	0.09	4.56	0.09	MS
HD24418	9.10	0.454	−1.32	5239	0.83	−0.18	6.34	0.14	3.47	0.13	SG
HD25329	8.49	0.533	−1.63	4774	0.59	−0.28	54.14	0.02	4.75	0.05	MS
HD284248	9.24	0.328	−1.41	6040	0.79	−0.10	12.84	0.10	4.40	0.10	MS
HD29907	9.94	0.452	−1.81	5204	0.64	−0.18	17.00	0.06	4.54	0.07	MS
HD34328	9.48	0.371	−1.61	5724	0.72	−0.12	14.55	0.07	4.46	0.07	MS
G102-020	10.19	0.435	−1.29	5305	0.67	−0.18	14.30	0.14	4.55	0.13	MS
HD250792	9.35	0.401	−1.18	5502	0.69	−0.15	14.86	0.17	4.33:		MS, BIN?
HD45282	8.03	0.451	−1.51	5274	0.82	−0.16	7.34	0.13	3.19:		SG, BIN?
CD−33 3337	9.08	0.334	−1.21	6022	0.82	−0.09	9.11	0.11	4.06	0.10	TO
HD59392	9.73	0.335	−1.45	6009	0.81	−0.09	6.66	0.17	4.03	0.15	SG
HD64090	8.28	0.428	−1.69	5336	0.67	−0.15	35.29	0.03	4.59	0.05	MS
HD233511	9.71	0.342	−1.43	5930	0.77	−0.11	10.36	0.14	4.36	0.13	MS
HD74000	9.67	0.311	−1.69	6184	0.80	−0.09	7.26	0.18	4.13	0.16	TO
HD84937	8.33	0.303	−2.14	6314	0.80	−0.08	12.44	0.09	4.10	0.08	TO
HD298986	10.05	0.324	−1.32	6080	0.79	−0.10	7.68	0.19	4.29	0.17	TO
G119-032	10.27	0.377	−1.51	5657	0.73	−0.12	10.55	0.17	4.49	0.15	MS
HD94028	8.23	0.343	−1.32	5925	0.77	−0.11	19.23	0.06	4.30	0.06	MS
G119-064	9.80	0.319	−1.49	6129	0.79	−0.10	8.11	0.18	4.25	0.16	TO
HD99383	9.08	0.343	−1.63	5945	0.76	−0.11	10.99	0.13	4.15	0.12	MS
HD102200	8.74	0.333	−1.32	6016	0.82	−0.09	12.45	0.10	4.19	0.09	TO
G176-053	9.91	0.397	−1.44	5543	0.71	−0.13	13.61	0.11	4.51	0.11	MS
HD106038	10.18	0.342	−1.09	5940	0.79	−0.10	9.16	0.16	4.46	0.15	MS
HD108177	9.67	0.330	−1.80	6051	0.74	−0.12	10.95	0.12	4.40	0.11	MS
HD126681	9.30	0.400	−1.16	5532	0.70	−0.14	19.16	0.08	4.55	0.08	MS
G166-045	9.73	0.336	−2.04	6026	0.76	−0.11	10.28	0.14	4.38	0.13	MS
HD132475	8.36	0.355	−1.32	5857	0.83	−0.10	10.85	0.11	3.87	0.10	SG
HD134439	9.06	0.484	−1.33	5040	0.64	−0.24	34.14	0.04	4.72	0.06	MS
HD134440	9.42	0.524	−1.24	4842	0.61	−0.32	33.68	0.05	4.73	0.06	MS
HD140283	7.21	0.380	−2.49	5779	0.81	−0.11	17.44	0.06	3.79	0.06	SG
G180-024	9.88	0.340	−1.46	5957	0.77	−0.10	8.03	0.14	4.21	0.13	MS
HD145417	7.52	0.509	−1.22	4917	0.62	−0.29	72.75	0.01	4.68	0.05	MS
HD149414	9.61	0.476	−1.38	5081	0.63	−0.23	20.71	0.07	4.51	0.08	MS
G020-008	9.95	0.356	−2.03	5872	0.73	−0.12	8.35	0.20	4.22	0.17	MS
HD160617	8.73	0.347	−1.94	5964	0.81	−0.10	8.66	0.14	3.85	0.13	SG
HD163810	9.64	0.423	−1.40	5396	0.66	−0.17	11.88	0.19	4.19:		MS, BIN?
CD−36 12201	10.20	0.430	−1.80	5344	0.67	−0.14	15.45	0.13	4.65	0.12	MS
G140-046	10.35	0.474	−1.34	5082	0.64	−0.24	17.00	0.11	4.64	0.11	MS
HD179626	9.21	0.373	−1.08	5751	0.84	−0.11	7.52	0.18	3.86	0.16	SG
HD181743	9.69	0.351	−1.89	5881	0.73	−0.13	11.31	0.16	4.38	0.14	MS
G125-013	10.24	0.355	−1.39	5836	0.71	−0.13	9.55	0.14	4.43	0.12	MS
HD188510	8.83	0.416	−1.57	5422	0.67	−0.15	25.32	0.05	4.55	0.06	MS
BD+23 3912	8.90	0.372	−1.29	5752	0.83	−0.11	9.38	0.13	3.92	0.12	SG
HD193901	8.66	0.383	−1.32	5650	0.72	−0.13	22.88	0.05	4.50	0.06	MS
HD194598	8.35	0.344	−1.11	5929	0.79	−0.10	17.94	0.07	4.31	0.07	MS
HD196892	8.25	0.353	−1.14	5886	0.75	−0.11	15.78	0.08	4.11:		MS, BIN?
HD199289	8.30	0.368	−1.09	5769	0.76	−0.12	18.94	0.05	4.26:		MS, BIN?
HD201891	7.39	0.363	−1.08	5800	0.76	−0.11	28.26	0.04	4.25:		MS, BIN?
HD205650	9.05	0.375	−1.10	5708	0.75	−0.12	18.61	0.07	4.52	0.07	MS
HD211998	5.28	0.450	−1.51	5265	0.82	−0.15	34.60	0.02	3.44	0.04	SG

al. (1995). As seen the scatter is very large with several stars deviating by about 0.6 dex, i.e. many times the errors estimated by Axer et al. This is surprising, because Axer et al. made a careful study determining $T_{\rm eff}$ from profiles of hydrogen lines, and taking into account non-LTE effects on the Fe I lines when deriving the gravities. One reason may be that the oscillator strengths of the lines were determined by synthesizing the lines in the solar spectrum. Although the lines are weak in the spectra of metal-poor stars, they

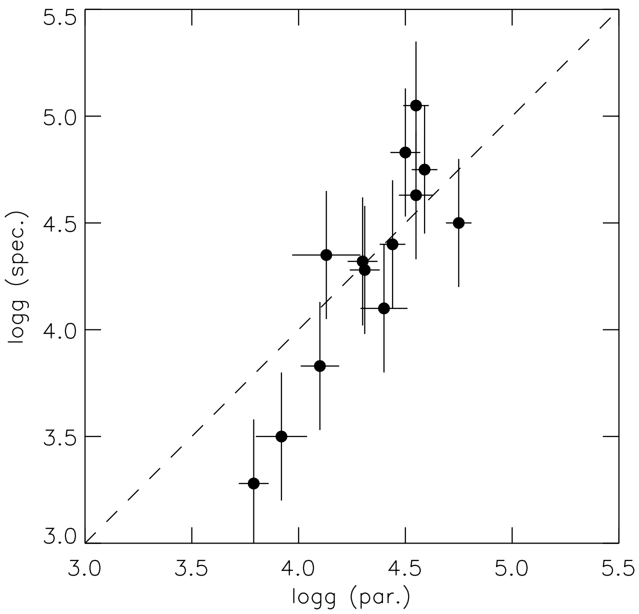

Figure 3. Spectroscopic gravities of Tomkin et al. (1992) versus gravities based on Hipparcos parallaxes. The error bars on the parallax-based gravities are derived as discussed in Section 2. The error of the spectroscopic gravities is estimated by Tomkin et al. to be ± 0.30 dex.

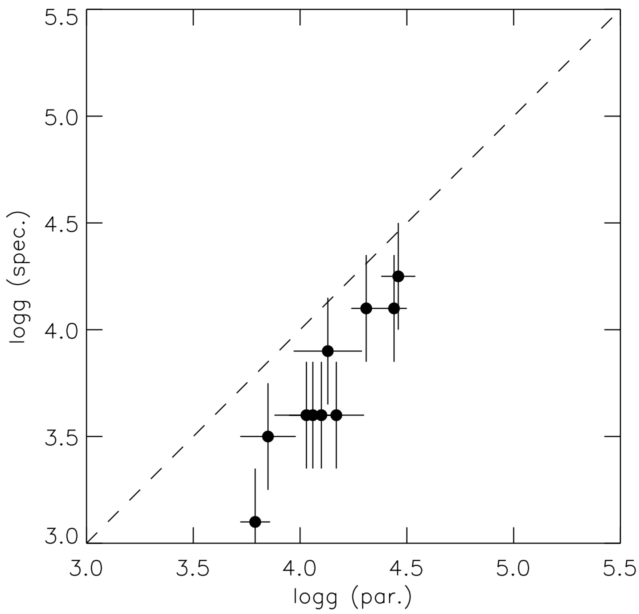

Figure 4. Spectroscopic gravities of Magain (1989) versus gravities based on Hipparcos parallaxes.

are rather strong in the solar spectrum. Hence, the derived gf-values become sensitive to assumptions about the broadening of the spectral lines. Furthermore, the accuracy of $T_{\rm eff}$ derived from Balmer line profiles may not be as good as claimed by Axer et al. As shown by Castelli et al. (1997), the profiles are very sensitive to the convection theory used in the model atmospheres.

4. DISCUSSION

The Hipparcos parallaxes have made it possible to derive surface gravities for some fifty metal-poor F and G dwarfs and subgiants to an accuracy better than ±0.20 dex and in many cases as good as ±0.10 dex. Comparison with spectroscopic gravities shows that these are often affected by random or systematic errors amounting to a factor of 2 to 3.

The consequences of these new gravities are several. First, they allow us to derive more accurate metallicities of metal-poor stars, important for stellar modeling and age determinations. As argued in the introduction, metallicities based on Fe I lines are subject to a number of basic uncertainties: the $T_{\rm eff}$-scale, the effect of convection on the temperature structure in the atmosphere and deviations from LTE. Fe II lines are much less sensitive to these problems simply because more than 90 per cent of the iron is in the ionized stage in the atmospheres of F and G stars. For example, a change of $T_{\rm eff}$ by 200 K changes the derived Fe/H ratio by 0.03 dex only.

In order to check the metallicity scale of metal-poor stars, weak Fe II lines were used to derive [Fe/H]-values for 13 of the stars listed in Table 1. The equivalent widths were measured from echelle spectra observed with CASPEC at the ESO 3.6m telescope. gf-values were taken from the new experimental works of Biémont et al. (1991), Heise & Kock (1990) and Hannaford et al. (1992), which all have led to a solar iron abundance in close agreement with the meteoritic abundance. The results show that the new [Fe/H] values are systematically about 0.15 dex higher than the Fe I-based values of Zhao & Magain (1990) and Nissen et al. (1994). The new [Fe/H]-values are on the other hand about 0.15 dex lower than the metallicities of Axer et al. (1994). Hence, the Fe II-lines and the Hipparcos-based gravities point to a metallicity scale that lies in between the extreme scales published in recent years.

It is, of course, only for the metal-poor stars having accurate parallaxes that we can use the Fe II lines to determine metallicities. For these stars we may, however, also make a thorough study of the problems connected to the use of Fe I lines as abundance indicators. Hopefully, the neutral iron lines can then be used for more distant stars with unknown gravities to derive accurate metallicities.

The Hipparcos-based gravities have also an important impact on the field of nucleosynthesis by allowing us to determine more accurate abundances of some important elements, e.g. Be, C, N, and O, for which the spectral lines used are sensitive to the gravity parameter. In the case of beryllium the only lines available are the Be II doublet at 3130 Å, and as discussed by Gilmore et al. (1991) an error of $\Delta\log g = 0.40$ implies $\Delta\log(\mathrm{Be/H}) \simeq 0.20$. Another example is oxygen. Its abundance in metal-poor stars can be determined from OH lines in the near-UV; in this case $\Delta\log g = 0.4$ implies $\Delta\log(\mathrm{O/H}) \simeq -0.15$ (Nissen et al. 1994). Alternatively, the oxygen-triplet at 7774 Å may be used, which leads to a similar sen-

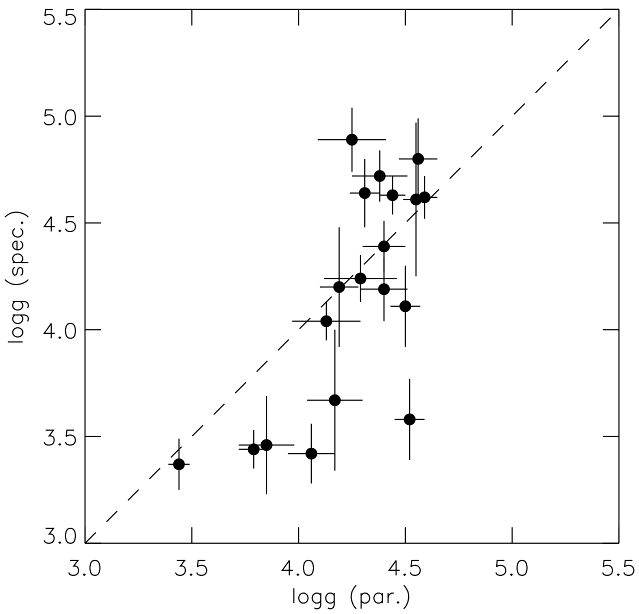

Figure 5. Spectroscopic gravities of Axer et al. (1995) versus gravities based on Hipparcos parallaxes. Individual error bars of log g (spec.) are taken from Axer et al.

sitivity to log g but with the opposite sign. In both cases the oxygen abundance determinations are made difficult by other problems ($T_{\rm eff}$-scale, atmospheric models and non-LTE effects), but clearly it is a great help if the gravity can be eliminated as an unknown parameter.

Finally, it should be emphasized that the Hipparcos parallaxes are of great importance for the interpretation of Li, Be, and B abundances in metal-poor stars. These elements may be affected by depletion processes, which depend critically on the mass and evolutionary stage of the star. In particular, it has been much discussed if the lithium abundance in the atmospheres of stars on the 'Spite' plateau equals the primordial ^{7}Li abundance (see e.g. Deliyannis et al. 1993). In this connection the probable detection of ^{6}Li in HD 84937 ($T_{\rm eff} \simeq 6300$ K, [Fe/H] $\simeq -2.2$) by Smith et al. (1993) and Hobbs & Thorburn (1994) is crucial (Lemoine et al. 1997). The measured isotopic ratio, ^{6}Li/^{7}Li $\simeq 0.05$ can be explained by cosmic ray production of ^{6}Li and standard Big-Bang production of ^{7}Li, provided that the star is an upper turnoff star with only a mild degree of ^{6}Li depletion and negligible ^{7}Li depletion. As discussed by Chaboyer (1994) the ground-based parallax of HD 84937, $\pi = 27.7 \pm 6.5$ mas (van Altena et al. 1994) indicates that HD 84937 is a dwarf star with $M_V = 5.55$, for which the depletion of ^{6}Li is predicted to be nearly complete in disagreement with the observations. The Hipparcos parallax, $\pi = 12.44 \pm 1.06$ mas, on the other hand, implies $M_V = 3.80$ showing that HD 84937 is an upper turnoff star (see Figure 1), for which the ^{6}Li depletion is predicted to be of the order of 50 per cent only (Chaboyer 1994). Consequently, there is no contradiction between the observed lithium isotope ratio and standard stellar models for lithium depletion.

REFERENCES

Allen C.W. 1973, in 'Astrophysical Quantities', The Athlone Press, p. 200

Alonso A., Arribas S., Martínez-Roger C. 1995, A&A 297, 197

Alonso A., Arribas S., Martínez-Roger C. 1996, A&A 313, 873

Axer M., Fuhrmann K., Gehren T. 1994, A&A 291, 895

Axer M., Fuhrmann K., Gehren T. 1995, A&A 300, 751

Bergbusch P.A., VandenBerg D.A. 1992, ApJS 81, 163

Biémont E., Baudoux M., Kurucz R.L., Ansbacher W., Pinnington E.H. 1991, A&A 249, 539

Castelli F., Gratton R.G., Kurucz R.L. 1997, A&A 318, 841

Chaboyer B. 1994, ApJ 432, L47

Chaboyer B., Sarajedini A., Demarque P. 1992, ApJ 394, 515

Deliyannis C.P., Pinsonneault M.H., Duncan D.K. 1993, ApJ 414, 740

ESA, 1997, The Hipparcos and Tycho Catalogues, ESA SP–1200

Gilmore G., Edvardsson B., Nissen P.E. 1991, ApJ 378, 17

Gustafsson B., Bell R.A., Eriksson K., Nordlund Å. 1975, A&A 42, 407

Hannaford P., Lowe R.M., Grevesse N., Noels A. 1992, A&A 259, 301

Heise C., Kock M. 1990, A&A 230, 244

Hobbs L.M., Thorburn J.A. 1994, ApJ 428, L25

Kurucz R.L. 1993, CD-ROM 13, Smithsonian Astrophys. Obs.

Kurucz R.L. 1995, ApJ 452, 102

Lemoine M., Schramm D.N., Truran J.W., Copi J.C. 1997, ApJ 478, 554

Lutz T.E., Kelker D.H. 1973, PASP 85, 573

Magain P. 1989, A&A 209, 211

Nissen P.E., Gustafsson B., Edvardsson B., Gilmore G. 1994, A&A 285, 440

Ryan S.G., Norris J.E., Beers T.C. 1996, ApJ 471, 254

Schuster W.J., Nissen P.E. 1989, A&A 222, 69

Smith V.V., Lambert D.L., Nissen P.E. 1993, ApJ 408, 262

Tomkin J., Lemke M., Lambert D.L., Sneden C. 1992, AJ 104, 1568

van Altena W.F., Lee J.T., Hoffleit E.D. 1994, The General Catalogue of Trigonometric Parallaxes, 4th Edition, Yale University Observatory, New Haven

VandenBerg D.A. 1983, ApJS 51, 29

VandenBerg D.A. 1992, ApJ 391, 685

VandenBerg D.A., Bell R.A. 1985, ApJS 58, 561

Zhao G., Magain P. 1990, A&A 238, 242