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Hipparcos and the distance scale to local halo stars

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Abstract. We present stellar parameters for a set of 10 local halo stars ($-2.3 <$ [Fe/H] < -1) and compare the inferred spectroscopic distances with the Hipparcos astrometry. The spectroscopic distance scale turns out to be fully compatible with Hipparcos parallaxes clearly demonstrating the reliability of pressure-broadened lines of Mg I as a gravity indicator at intermediate and low metallicities.
Recent studies employing non-LTE Fe I/II ionization equilibria fail to be in accord with Hipparcos at the 1σ level.

1. Introduction

The accurate knowlegde of *unbiased* stellar parameters is a prerequisite not only for stellar age determinations. We are also dependent on them if we aim to disentangle the chemical evolution of the Galaxy and its different populations (cf. Fuhrmann 1998a, his Fig. 16). Furthermore, *unbiased* effective temperatures are crucial for deriving the primordial lithium abundance, *unbiased* gravities for (potentially primordial) beryllium.
In the Hipparcos era, astrometry serves to separate the wheat from the chaff.

2. The data

Using Foces on the Calar Alto 2.2m telescope, spectra of local halo stars out to about 500 pc were aquired in the course of the last 5 years. They cover the optical and near-IR wavelength range (4000 − 9000 Å), have $R \sim 40\,000 - 60\,000$ and signal-to-noise ratios of > 200 at Hα. In this contribution we present the results for the 10 programme stars closest to the Sun: the analyses of 3 of these (HD 45282, HD 194598 and HD 84937) are taken from Fuhrmann (1998a; 2000), the other 7 are either new analyses or re-analyses using better spectra.

3. The methodology

The method of determining stellar parameters from spectroscopy employed here is discussed in detail by Fuhrmann et al. (1997) and Fuhrmann (1998a). We give a brief account of the gravity determination below.

Gravities

Balancing Fe I and Fe II in LTE has been shown to yield gravities that are *incompatible* with Hipparcos for stars hotter than the Sun, in particular when they are also metal-poor and/or in an advanced stage of evolution (Fuhrmann

1998b; Allende Prieto et al. 1999). We attribute this effect to an extreme ionization balance which invalidates LTE as an approach for Fe I.
Alternatively, $\log g$ can be derived from pressure-broadened lines of e.g. Mg (*strong line method*): in a first step the Mg abundance is derived from weak lines (e.g. Mg I 5711), the gravity is then deduced from the profiles of the strong Mg I*b* lines at 5172 Å and 5183 Å (Fuhrmann et al. 1997).

4. The results

Columns 2 – 5 of Table 1 list the stellar parameters of the 10 programme stars. Columns 6 – 8 compare the spectroscopic distance scale with that of HIPPARCOS and give $\Delta_{\rm HIP} = 100 \cdot ({\rm d_{spec}} - {\rm d_{HIP}})/{\rm d_{HIP}}$. $\rm d_{spec}$ is calculated using $\log \pi_{\rm spec} = 0.5\,([g]-[M]) - 2\,[T_{\rm eff}] - 0.2\,(V + {\rm BC_V} + A_{\rm V} + 0.26)$ with $[X] := \log(X/X_\odot)$. Masses are interpolated from the tracks of VandenBerg et al. (2000), BCs from Alonso et al. (1995) and $A_{\rm V}$ from the Strömgren data of Mermilliod, Mermilliod & Hauck (1997) using the calibration of Schuster & Nissen (1989).

Table 1. The stellar parameters of the 10 programme stars and the resulting distance scale in comparison with HIPPARCOS.

star	$T_{\rm eff}$ [K]	$\log g$	[Fe/H]	[Mg/Fe]	$\rm d_{spec}$	$\rm d_{HIP}$ [pc]	$\Delta_{\rm HIP}$ [%]
HD 103095	5110	4.66	−1.35	+0.28	9.05	9.16	−1.2
HD 201891	5943	4.24	−1.05	+0.41	36.35	35.39	2.7
HD 19445	6052	4.44	−1.99	+0.47	38.71	38.68	0.1
HD 94028	6022	4.28	−1.47	+0.47	48.97	52.00	−5.8
HD 194598	6058	4.27	−1.12	+0.29	57.59	55.74	3.3
HD 140283	5810	3.67	−2.29	+0.41	56.97	57.34	−0.7
HD 84937	6353	4.03	−2.07	+0.36	78.33	80.39	−2.6
G 20-8	6204	4.31	−2.15	+0.51	108.35	119.76	−9.5
HD 45282	5282	3.12	−1.52	+0.37	137.92	136.24	1.2
G 165-39	6330	4.03	−1.96	+0.29	180.02	186.22	−3.3
all stars	(an iterative 2σ clipping eliminates G 20-8)						$-0.7 \pm 2.9\,(1\sigma)$
$\sigma_\pi/\pi < 0.09$							$-0.6 \pm 3.1\,(1\sigma)$

4.1. Interpretation

From this analysis, there is no evidence for a halo distance scale at variance with the HIPPARCOS astrometry: Disregarding Lutz-Kelker corrections, the two distance scales are concordant to within 1 % ± 3 % (1σ) corresponding to an uncertainty in *physical* gravities of less than 0.05 dex.
Note that the temperature scale of Balmer lines is also confirmed: the two coolest programme stars (HD 45282 and HD 103095 = Gmb 1830) are analysed using the Fe I/II ionization equilibrium which introduces a strong coupling between $T_{\rm eff}$ and $\log g$ of the order of 50 K per 0.1 dex. If $T_{\rm eff}$ is in error, so is $\log g$ and vice versa leading to noticeable discrepancies with HIPPARCOS.

5. Other studies

Recently, two collaborations have presented elaborate statistical equilibrium (non-LTE) calculations for Fe I/II:

Thévenin & Idiart (1999) find significant departures from LTE in Fe I of metal-poor stars. These translate into non-LTE gravities 0.22 ± 0.13 (1σ) higher than the LTE counterparts if one considers the complete sample of 137 stars with $-3.82 \leq$ [Fe/H] ≤ 0.13. For the subsample extracted here for direct comparison and presented in Table 2 the difference is much larger, 0.36 ± 0.10 (1σ).
Gratton et al. (1999) find non-LTE *abundance* corrections of less than 0.1 dex for stars close to the main sequence of any metallicity. Thus, they *do not* modify the stellar parameters for their large sample of metal-poor stars.
Table 2 presents the statistical properties of the stars in common between Thévenin & Idiart (1999), Gratton et al. (1996) = Carretta et al. (2000) and this work. Bolometric corrections were rederived individually, masses for the Thévenin & Idiart stars were not available and therefore taken from this work (slightly inconsistent), for Gratton et al. (1996) from Allende Prieto et al. (1999).

Table 2. Comparison with other studies.
Δ is in the sense (study − this work), $\Delta_{\rm HIP}$ as in Table 1.

study	Thévenin & Idiart	Gratton et al.	this work
n(stars)	7	12 (multiple entries)	10
stars missing	201891, 20-8, 45282	20-8, 45282, 165-39	–
$\Delta\ T_{\rm eff}$ [K]	-151 ± 44 (1σ)	-4 ± 30 (1σ)	–
$\Delta\ \log g$	$+0.13 \pm 0.11$ (1σ)	$+0.21 \pm 0.22$ (1σ)	–
Δ [Fe/H]	-0.13 ± 0.05 (1σ)	-0.03 ± 0.10 (1σ)	–
$\Delta_{\rm HIP}$ [%]	-19.0 ± 10.7 (1σ)	-15.9 ± 13.5 (1σ)	-0.7 ± 2.9 (1σ)

Except for $\Delta\, T_{\rm eff}$ (Gratton et al. = IRFM) and Δ [Fe/H] (Gratton et al.) there is little concordance to be found. Most importantly, both studies quoted fail to be in accord with HIPPARCOS at the 1σ level.
In conjunction with the large scatter these biases will cause substantial artifacts in the abundances to be derived and the conclusions to be drawn from them.

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