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New results of magnetic field diagnosis in HgMn stars and normal late B-type stars

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Abstract. We suggested in a previous paper that three HgMn stars, HD 175640, HD 178065, and HD 186122, may be suspected to possess a magnetic field that could be larger than 2 kG. We report here new observations of these three stars, three more HgMn stars, and four normal late B-type stars. The search was carried out by measuring the equivalent width of the Fe II $\lambda\,6147.7$ Å line relative to the equivalent width of the Fe II $\lambda\,6149.2$ Å line. The observed relative differences between the equivalent widths of these Fe II lines are compared with those derived from synthetic spectra computed by neglecting magnetic field effects. To investigate the effect of oscillator strength uncertainties on the results, we computed equivalent widths by using both Fe II log gf-values taken from Kurucz & Bell (1995) and Fe II log gf-values taken from Raassen & Uylings (2000). The comparison of the computed and observed equivalent widths based on the Kurucz & Bell (1995) atomic data leads us to conclude that all the stars of our sample, except HD 175640, are very likely to possess a magnetic field. On the other hand, the comparison of the computed and observed equivalent widths based on the Raassen & Uylings (2000) log gf-values suggests the possible presence of magnetic fields only in three stars, the HgMn star HD 16717 and the two normal B-type stars HD 179761 and HD 186568. The latter two are those in the sample with the largest $v\sin i$ (15 km s^{-1} and 18 km s^{-1}, respectively), so that the results for them are the most uncertain ones.

Key words. stars: abundances – stars: atmospheres – stars: chemically peculiar – stars: magnetic fields

1. Introduction

HgMn stars constitute a well-defined sub-group of chemically peculiar (CP) stars of B spectral type in the temperature range 10 000–14 000 K. These stars exhibit marked abundance anomalies of several elements: e.g., overabundances of Hg, Mn, Ga, Y, Cu, Be, P, Bi, Sr, Zr, and deficiencies of He, Al, Zn, Ni, Co. The HgMn stars differ from the classical Bp stars, which share the same temperature range, because they generally have neither extreme overabundances of rare earths, nor significant overabundances of Si. In fact, the excess of Si is the most obvious anomaly in classical Bp stars. The He-weak stars constitute another group of peculiar stars which overlap in temperature the hottest HgMn stars, in that their $T_{\rm eff}$ ranges from about 13 000 K to about 17 000 K. The He-weak stars are defined as stars having abnormally weak helium lines. In analogy with the HgMn stars they may show enhanced lines of Mn and Hg.

In contrast with Bp and He-weak stars, the HgMn stars do not show conspicuous intensity variations of the spectral lines. Large-scaled organized magnetic fields were measured in both classical Bp and He-weak stars, while they have not been definitely detected in HgMn stars. Although Babcock (1958) had reported about weak longitudinal fields in some HgMn stars, this finding was never confirmed in later studies (e.g., Conti 1970; Landstreet 1992). However, weak magnetic fields, with a longitudinal component less than a few hundred Gauss, or complex in structure, can not be excluded a priori for HgMn stars, owing to the limitations of the usual spectropolarimetric techniques.

We have shown in a previous paper (Hubrig et al. 1999, Paper I) that three HgMn stars, HD 175640, HD 178065, and HD 186122, were suspected to possess a magnetic field with complex and/or toroidal structure. To detect magnetic fields we have applied a simple method introduced by Mathys (1990) which uses the relative magnetic intensification $\Delta W/\overline{W}$ of the two Fe II lines of mult. 74, $\lambda\,6147.7$ Å and $\lambda\,6149.2$ Å. $\Delta W/\overline{W}$ is defined as the ratio of the

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difference of the equivalent widths of the two Fe II lines to the average of the two equivalent widths. The two Fe II transitions have approximately the same intensity under normal conditions and observations of normal A-type stars have shown that the equivalent widths of the two lines do not differ in these stars more than 2.5% (Mathys & Lanz 1990). Differences larger than 10% in the equivalent widths were observed in magnetic Ap and Bp stars by Mathys (1990). They were explained by Takeda (1991) as due to magnetic intensification produced by different magnetic desaturations induced by different Zeeman–split components. Takeda (1991) also showed that the relative intensification is roughly correlated with the strength of the magnetic field, so that it is potentially a powerful tool for detecting magnetic fields which have a complex structure and are difficult to detect by polarization measurements.

The method was successively applied by Lanz & Mathys (1993) to detect magnetic fields in Am stars, after Mathys & Lanz (1990) measured a relative intensification of 5.2% in the Am star o Peg. Among the 18 Am stars examined, they found two stars affected by magnetic fields according to their measured $\Delta W/\overline{W}$, whose values were larger by 0.03–0.04 than the predicted ones.

The same method was used in this paper with the aim to continue the search for magnetic fields in HgMn stars performed in Paper I. In the previous study we examined nine HgMn stars. All the stars except one (HD 141556) were observed on a single occasion. In order to confirm the results from Paper I and/or assess the possible variability of magnetic fields, we have reobserved four HgMn stars. We added two new HgMn stars, and five normal late B-type stars to be used as comparison stars. All the spectra analyzed in this paper were obtained on one night in August 1999 at the CFHT with the high-resolution coudè spectrograph (Gecko) and have a higher S/N ratio than the spectra adopted for Paper I, which were taken at ESO with the 1.4 m CAT telescope.

Because the Mathys method can be applied only to stars having $v \sin i$ low enough to avoid blends of the two Fe II lines at 6147.7 Å and 6149.2 Å each other and with other components, we observed only sharp-lined stars. As mentioned in Paper I, the line Fe II $\lambda\,6149.248$ Å is severely blended in HgMn stars with the line Hg II at $\lambda\,6149.475$ Å and therefore the applied method can provide a satisfactory diagnosis only for very slowly rotating HgMn stars observed at high resolution, so that the Fe II and the Hg II features are not blended. All the HgMn stars in our sample (HD 16727, HD 27295, HD 175640, HD 178065, HD 186122, and HD 193452) are slowly rotating stars with $v \sin i \leq 5$ km s^{-1} and they are not known to be spectroscopic binaries.

Five late B-type stars, HD 179761, HD 186568, HD 196426, HD 209459, and HD 219927, were observed as comparison stars because they have a sharp-lined spectrum and were not found to show chemical peculiarities and magnetic fields (Cowley 1972; Cowley & Aikman 1980). Three out of the five stars (HD 179761, HD 196426 and HD 209459) have been frequently used as comparison standards in other studies (e.g., Smith & Dworetsky 1993; Dworetsky & Budaj 2000). The Hg II line is not a problem for the normal B-type stars. Mercury abundances ≤2.5 dex were derived by Smith (1997) in normal late B-type stars from the analyis of Hg II at 1942 Å observed in co-added IUE spectra. We verified by computing synthetic spectra for $\log\epsilon(\mathrm{Hg}) = 2.5$ that no Hg II line at $\lambda\,6149.475$ Å is predicted in late B-type stars for this mercury abundance.

Table 1. Journal of observations.

HD	HR	Other id.	V	Sp. type	S/N
		HgMn stars			
16727	785	11 Per	5.7	B7 HgMn	320
27295	1339	53 Tau	5.5	B9 HgMn	250
175640[1]	7143		6.2	B9 HgMn	390
178065[1]	7245		6.6	B9 HgMn	375
186122[1]	7493	46 Aql	6.3	B9 MnHg	360
193452[1]	7775		6.1	B9 HgMn	350
		Superficially normal stars			
196426[1]	7878		6.2	B8 III	460
209459	8404	21 Peg	5.8	B9.5 V	380
		Normal stars			
179761	7287	21 Aql	5.1	B8 II-III	370
186568	7512		6.1	B9 II	420
219927	8873		6.3	B8 III	320

[1] Stars studied also in Hubrig et al. (1999) (Paper I).

2. Observations

The observations were made on 1999 August 29 at the CFHT with the GECKO spectrograph at a resolving power of $R = 125\,000$ and grating settings corresponding to the wavelength interval 6105−6190 Å. Programme stars are listed in Table 1, where we give the HD number and other identifiers in Cols. 1–3, the V magnitude and the spectral type (both from the catalog of Renson 1991) in Cols. 4 and 5. The spectra were reduced with the help of D. A. Bohlender. A set of IRAF macros written by Bohlender et al. (1998) was used. Special care was taken in order to eliminate the scattered light from the spectra.

The achieved signal-to-noise ratios in the continuum are given in Col. 6 of Table 1. They were measured after reduction in portions of the spectrum apparently devoid of lines: accordingly the derived values must be regarded as upper limits of the S/N ratio actually obtained. The typical value of the signal-to-noise ratio of our spectra is larger than 300.

The spectra, normalized to the continuum, are shown in Fig. 1 for the region 6146–6150 Å. The CFHT spectra of HD 175640, HD 178065, HD 186122, HD 193452, and HD 196426 are compared with the spectra observed

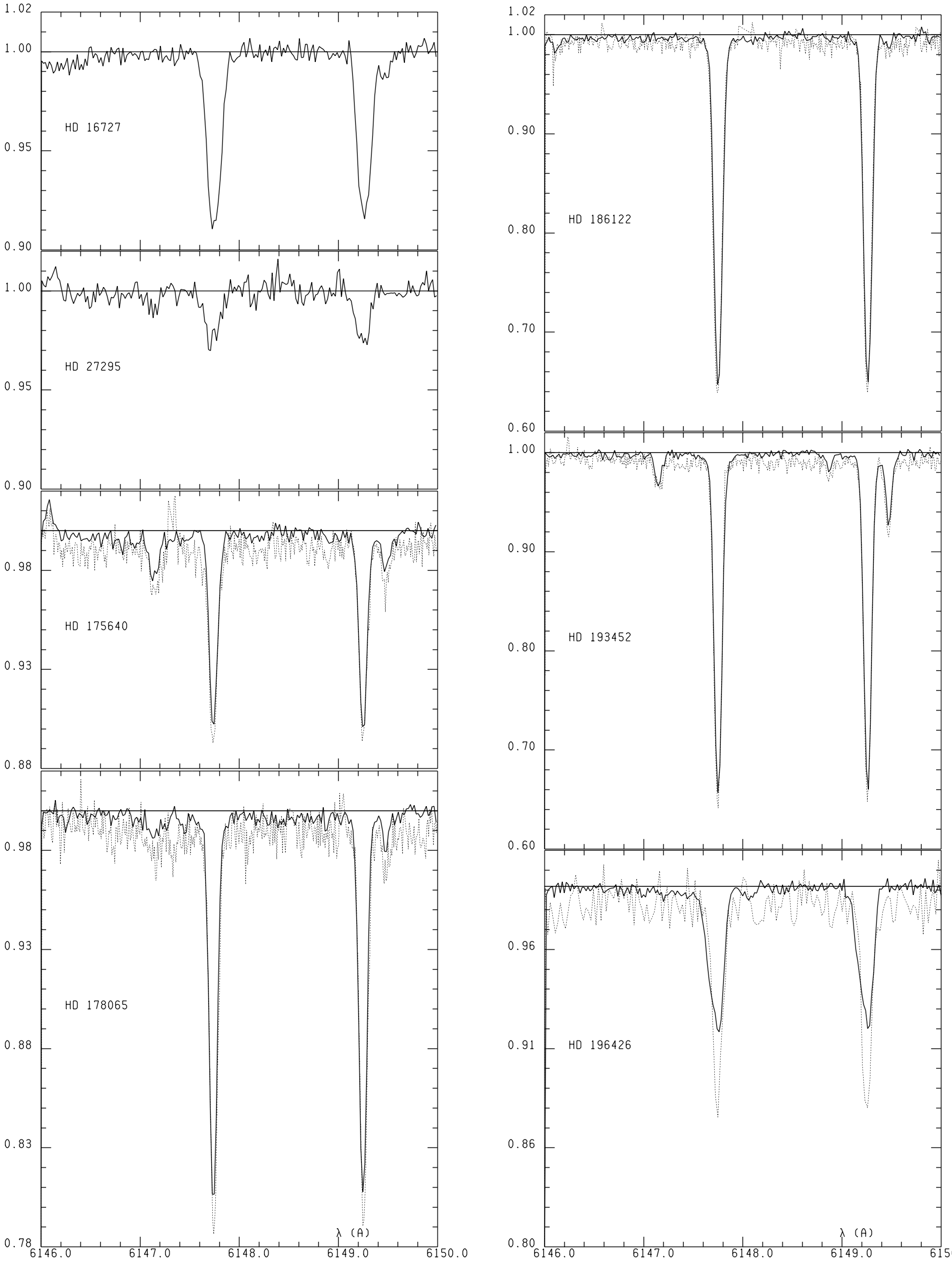

Fig. 1. The observed spectra normalized to the continuum. For HD 175640, HD 178065, HD 186122, HD 193452, and HD 196426, the CFHT spectra (full lines) are compared with the CAT spectra (dashed lines) used in Paper I. The vertical scale is reduced by one half for HD 186122 and HD 193452. Absorption lines are Cr II mult. 105 at 6147.154 Å, Fe II mult. 74 at 6147.741 Å together with Fe II at 6147.775 Å, Fe II mult. 74 at 6149.258 Å, and Hg II at 6149.5 Å.

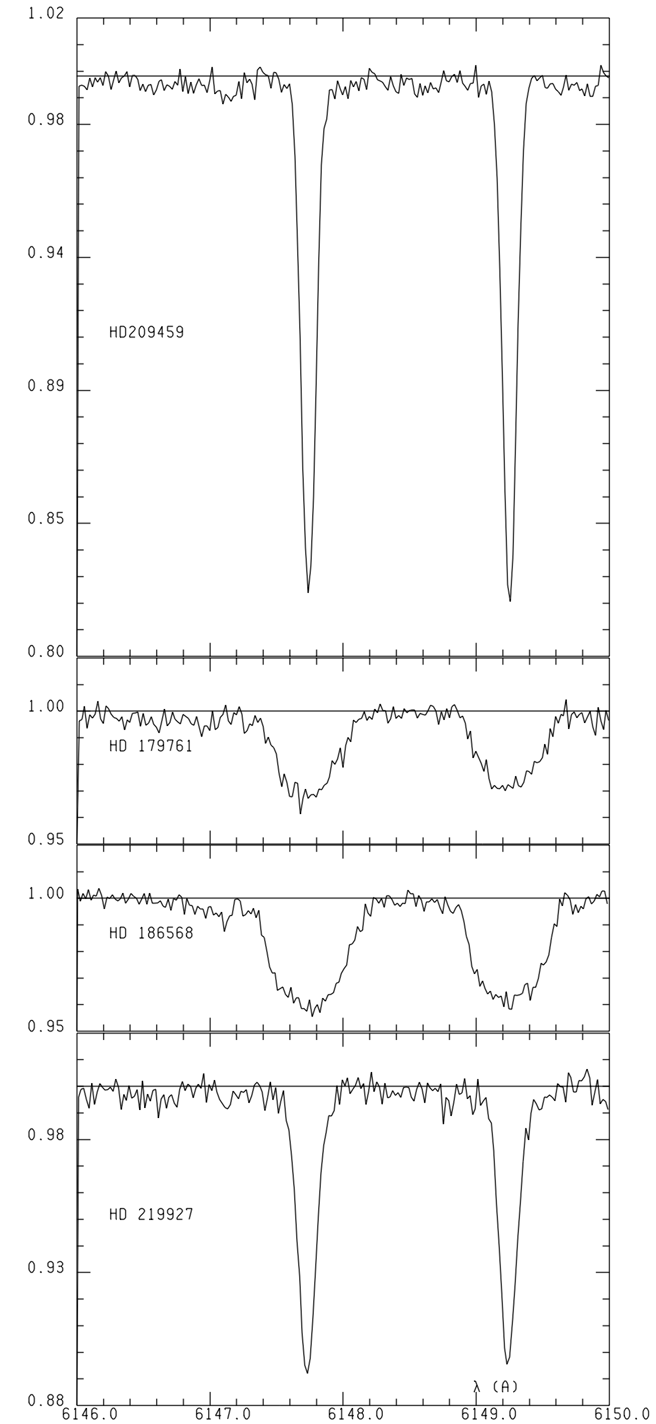

Fig. 1. continued.

at CAT and used in Paper I. The larger noise of the CAT spectra is evident in the figure. The superficially normal late B-type star HD 196426, used in Paper I as a comparison star, turned out to be a spectroscopic binary. Both Fe II lines show very asymmetric profiles in the CFHT spectrum, with red wings much steeper than blue wings. As a consequence, this star was not used in this paper.

3. The method

The analysis was performed as in Paper I. We searched for a possible intensification of the line Fe II 6147.7 Å relative to the line Fe II 6149.2 Å by measuring the equivalent widths of the two absorption profiles. Then, we derived an intensification index in according to Mathys (1990):

$$\Delta W/\overline{W} = \frac{W(6147.7) - W(6149.2)}{0.5(W(6147.7) + W(6149.2))}.$$

Because Fe II 6147.741 Å may be blended with Fe II 6147.775 Å, the measured intensification could be due to the blend of the two Fe II lines at 6147.7 Å rather than to the effect af a magnetic field. We therefore simulated the observed spectrum with synthetic spectra which consider all the possible predicted contributions to Fe II 6147.741 Å. Then we measured the equivalent widths of the computed profiles at 6147.7 Å and at 6149.2 Å and we derived the computed intensification index. The difference between the observed and computed $\Delta W/\overline{W}$ ratios yields the amount of the intensification of Fe II 6147.7 Å over Fe II 6149.2 Å due to the magnetic field.

4. The measured equivalent widths and the measured $\Delta W/\overline{W}$ ratio

The equivalent widths W of the Fe II lines at 6147.7 Å and 6149.2 Å were measured both by Gaussian fitting and by direct integration of the line profiles using the IRAF package. For the most rapidly rotating stars, HD 179761 and HD 186568, we kept only the measurements performed by direct integration, because of the non-Gaussian form of the rotational broadening function.

In the spectra examined with IRAF any preselected continuum disappears, so that it may be differently fixed each time a line is measured. Therefore, we also used a code written by F.C., which keeps the preselected continuum and yields equivalent widths measured by direct integration. A further shortcoming affecting the measurement of the equivalent widths is the requirement that the width of the profile has to be fixed at the level of the continuum. Owing to the spectral noise, the choice of the blue end and of the red end of a profile may be a difficult decision especially when very accurate equivalent widths are required. Since the CFHT spectra are taken at high S/N ratio, Fig. 1 shows that this is not a serious problem for some stars in our sample. However, for other stars, such as HD 178065, HD 209459, and HD 186568, the fixing of the width of the profiles is a completely subjective decision. A further uncertainty occurs in HgMn stars for the equivalent width of Fe II 6149.25 Å, when the line is blended with Hg II 6149.48 Å.

To be more definitive about uncertainties in the equivalent widths, the measurements were performed independently by each author. Table 2 lists the measured equivalent widths: $(W_{\rm g,c})$ and $(W_{\rm g,h})$ are the equivalent widths from the fit to Gaussians measured by F.C. and S.H. respectively; ($W_{\rm i,c}$) and ($W_{\rm i,h}$) are the equivalent widths measured by direct integration by F.C. and S.H. respectively; ($W_{\rm i,c1}$) indicates the equivalent widths measured by F.C. by direct integration by means of her code. The average of all five determinations together with the rms values for $W(6147)$ and $W(6149)$ are given in Cols. 12 and 13. Finally, Col. 14 shows the ratio $(\Delta W/\overline{W})_{\rm obs}$ with the associated uncertainties. The equivalent widths in Table 2 are given in mÅ.

HD 27295 yields an example of the uncertainty in $\Delta W/\overline{W}$ related with different placements of the continuum. This star exhibits the faintest Fe II lines. Equivalent widths which differ more than 1.0 mÅ were measured by F.C. and S.H., respectively. In Table 2, the first row for HD 27295 lists all the measured equivalent widths and their average, while the two successive rows list the separate measurements and show that systematic differences in the placement of the continuum may lead to differences on the order of 0.02 for the $\Delta W/\overline{W}$ ratio. If we exclude HD 27295, the uncertainty on $\Delta W/\overline{W}$ is less than 0.03. The typical difference between several measurements of the equivalent widths in the same spectrum with the same continuum is on the order of 0.3–0.4 mÅ.

Unfortunately, all the spectra were obtained during a single night, and we do not have several spectra for any star to verify the noise statistics across the measured lines. On the other hand, we have already shown (Paper I) for the star HD 141556 that the ratio $\Delta W/\overline{W}$ derived from the repeated observations is almost the same, differing by only 0.003 when the direct integration method was used.

For nine out of the ten stars examined the equivalent width of Fe II λ6147.7 Å is larger than that of Fe II λ6149.2 Å. This behaviour is similar, even if less conspicuous, to that observed by Mathys & Lanz (1992) for the magnetic Ap stars. Only for the HgMn star HD 175640, the equivalent width of Fe II λ6149.2 Å is larger by 0.1 mÅ than that of Fe II λ6147.7 Å. In Paper I this star was suspected to possess a magnetic field. Figure 1 shows that the profiles in the CAT spectrum are slightly stronger than those in the CFHT spectrum. The difference is reduced if the continuum in the CAT spectrum is lowered. The slightly higher continuum placement and the rather strong noise are probably the cause of the larger measured equivalent widths in the CAT spectrum. The results from Paper I are compared in more detail with those from this paper in Sect. 7.

5. The computed quantities

5.1. Model parameters

The model parameters $T_{\rm eff}$ and $\log g$ were derived from observed Strömgren indices and also from spectrophotometry, when available.

Observed Strömgren indices were taken from the catalog of Hauck & Mermilliod (1998) and were dereddened by means of the UVBYLIST code of Moon (1985), which yields $E(b{-}y)$, and therefore $(b{-}y)_0 = (b{-}y) - E(b{-}y)$, $m_0 = m_1 + 0.33E(b{-}y)$, and $c_0 = c_1 - 0.19E(b{-}y)$; the last two relations, as well as $E(B{-}V) = E(b{-}y)/0.724$ for $R_V = 3.1$, are taken from Crawford & Mandwewala (1976). The reddening $E(B{-}V)$ was used for dereddening the spectrophotometric observations, which are available for HD 27295 (Adelman & Pyper 1979), HD 209459 (Adelman & Pyper 1983), HD 179761 (Adelman 1978), and HD 219927 (Breger 1976). For each star of the sample, Table 3 lists the observed Strömgren indices, the reddening $E(b{-}y)$, and the reddening $E(B{-}V)$.

Because our spectra have too few lines in order to derive the microturbulent velocity ξ, we searched for it in the literature. The available ξ and the corresponding source are given in Cols. 8 and 9 of Table 3. All the microturbulent velocities are lower than 2 km s^{-1}, in agreement with Adelman & Rayle (2000), who stated that "Trends in recent elemental abundances studies indicate for normal main sequence band stars with $T_{\rm eff} \geq 10\,500$ K that their microturbulence is 0 km s^{-1}..." and in agreement with Adelman (1994) who showed that most HgMn stars have little or no microturbulent velocity. We investigated the effect of the microturbulent velocity on the stellar parameters by deriving them from fluxes and colors based on two different grids of models, namely AP00K0NOVER and AP00K2NOVER. The first grid was computed for $\xi = 0.0$ km s^{-1}, while the second grid was computed for $\xi = 2.0$ km s^{-1}. The metallicity is [M/H] = 0.0 for both grids. The grids are available at the Kurucz website[1] in the subdirectory "gridp00nover" of the directory "grids of model atmospheres". The models in the grids were obtained by merging the models computed by Castelli for $T_{\rm eff} \leq 8750$ K with the models computed by Kurucz for $T_{\rm eff} > 8750$ K. More details about these grids are given by Castelli (1999). The grids of fluxes and the grids of synthetic Strömgren colors used for this paper were computed from the above models and are available in the same directories of the grids of models. The grids of fluxes are FP00K0NOVER (for $\xi = 0.0$ km s^{-1}) and FP00K2NOVER (for $\xi = 2.0$ km s^{-1}), while the grids of synthetic Strömgren colors are UVBYBETAP00K0NOVER (for $\xi = 0.0$ km s^{-1}) and UVBYBETAP00K2NOVER (for $\xi = 2.0$ km s^{-1}). The synthetic $uvby\beta$ indices were computed according to Lester et al. (1986) except for the normalization: instead of using five stars (γ Gem, α CMi, β Leo, η UMa, and Vega) for the normalization of the indices as did Lester et al. (1986), the $uvby$ indices were normalized using only Vega, while the β indices were normalized by using both Vega and the Sun. The possible problems due to the use of η UMa to normalize the indices are discussed by Castelli (1991).

Parameters $T_{\rm eff}$ and log g from Strömgren photometry were derived by interpolating the dereddened observed indices in the grids of synthetic indices. Those for $\xi = 0$ km s^{-1} are given in Cols. 2 and 3 of Table 4, while

[1] http://kurucz.harvard.edu

Table 2. Measured equivalent widths in mÅ and the $\Delta W/\overline{W}$ ratio.

HD	$W_{\rm g,c}$	$W_{\rm i,c}$	$W_{\rm i,c1}$	$W_{\rm g,h}$	$W_{\rm i,h}$	$W_{\rm g,c}$	$W_{\rm i,c}$	$W_{\rm i,c1}$	$W_{\rm g,h}$	$W_{\rm i,h}$	$\overline{W}_{\rm obs}$	$\overline{W}_{\rm obs}$	$(\Delta W/\overline{W})_{\rm obs}$
			6147					6149			6147	6149	
							HgMn stars						
16727	15.6	15.4	15.2	15.3	15.1	14.1	13.3	13.7	13.4	13.0	15.32 ± 0.09	13.50 ± 0.19	0.126 ± 0.015
27295	4.8	4.7	4.8	6.1	6.0	4.5	4.5	4.5	5.6	5.6	5.28 ± 0.33	4.94 ± 0.28	0.066 ± 0.081
	4.8	4.7	4.8			4.5	4.5	4.5			4.77 ± 0.00	4.50 ± 0.00	0.058 ± 0.007
				6.1	6.0				5.6	5.6	6.05 ± 0.05	5.6 ± 0.00	0.077 ± 0.008
175640	10.3	10.4	10.5	10.3	10.3	10.4	10.5	10.7	10.2	10.2	10.36 ± 0.04	10.40 ± 0.09	-0.004 ± 0.010
178065	19.9	20.1	20.3	20.1	20.2	19.3	19.3	19.6	19.2	19.4	20.12 ± 0.07	19.36 ± 0.07	0.039 ± 0.005
186122	38.1	38.2	38.4	37.8	38.1	36.7	36.4	36.9	36.4	36.1	38.12 ± 0.10	36.50 ± 0.14	0.043 ± 0.005
193452	33.7	34.0	35.1	33.6	34.4	33.5	33.0	33.5	32.5	32.6	34.16 ± 0.27	33.02 ± 0.21	0.034 ± 0.010
							Normal stars						
209459	24.4	24.2	24.5	25.1	25.1	24.1	24.1	23.9	24.0	24.0	24.66 ± 0.19	24.02 ± 0.04	0.026 ± 0.008
179761		16.0	16.3		16.4		14.7	14.6		14.9	16.23 ± 0.12	14.73 ± 0.09	0.097 ± 0.009
186568		24.2	24.4		23.9		21.6	21.9		21.3	24.17 ± 0.14	21.60 ± 0.17	0.112 ± 0.002
219927	18.3	18.4	19.5	19.6	19.8	17.6	17.6	17.8	18.2	18.4	19.12 ± 0.32	17.92 ± 0.16	0.066 ± 0.019

those for $\xi = 2$ km s^{-1} are listed in Cols. 4 and 5. The largest difference in $T_{\rm eff}$ is 77 K for HD 16727, while the largest difference in log g is 0.02 dex for HD 209459. Column 9 in Table 4 specifies which indices were used to obtain $T_{\rm eff}$ and $\log g$. The errors associated with the parameters were derived by assuming an uncertainty of ± 0.015 mag for all the observed indices (Relyea & Kurucz 1978), except for β, for which an error of $\pm$ 0.016 mag was adopted. It is the largest error in β for the sample of stars. In fact, errors in β, as taken from the catalog of Hauck & Mermilliod (1998), range from 0.001 mag for HD 219927 to 0.016 mag for HD 175640, while, for all the stars, the errors in c are less than the error adopted by us.

Parameters for HD 27295, HD 209459, HD 179761, and HD 219927 were also derived by fitting the dereddened spectrophotometric observations to the grids of synthetic fluxes FP00K0NOVER and FP00K2NOVER. The fitting procedure is based on that described by Lane & Lester (1984). The search for the minimum rms difference between the observed and computed energy distributions is made by interpolating in the grids of computed fluxes. The computed fluxes are sampled in steps of 50 K in $T_{\rm eff}$ and in steps of 0.1 dex in log g, so the finer sampling was obtained by linear interpolation. Columns 7 and 8 of Table 4 show the parameters derived from the spectrophotometry by using fluxes computed for $\xi = 0$ km s^{-1}. For the four stars, the temperature derived from fluxes computed for $\xi = 2.0$ km s^{-1} is 50 K lower than $T_{\rm eff}$ derived from fluxes computed for $\xi = 0.0$ km s^{-1}, while the gravity does not change.

Temperatures from Strömgren indices and from the spectrophotometry corresponding to $\xi = 0$ km s^{-1} differ no more than 104 K (HD 209459), while the differences in log g are as large as 0.4 dex (HD 27295).

The adopted parameters for the sample of stars are given in Cols. 9 and 10 of Table 4. They approximate the determinations listed in Cols. 2–5, 7, and 8.

The last two columns of Table 4 list, for comparison, the parameters derived by Smith & Dworetsky (1993) for the stars in common and which were derived by them from Strömgren photometry, Geneva photometry, spectrophotometric scans, and H_γ profiles. The agreement with our determinations from Strömgren photometry is very good.

5.2. The synthetic Fe II profiles

The iron abundance needed for computing the synthetic Fe II profiles was derived for each star from the measured equivalent width of the line Fe II λ 6149.2 Å and from the ATLAS9 (Kurucz 1993a) model computed for $\xi = 0.0$ km s^{-1}, solar metallicity, and parameters given in Cols. 9 and 10 of Table 4. The WIDTH code of Kurucz (1993a) was used to obtain the iron abundance.

The line Fe II λ 6149.2 Å was assumed as unblended in all the stars, although this hypothesis could be questionable for HD 179761 and HD 186568, the most rapidly rotating stars of the sample ($v \sin i = 15$ km s^{-1} and $v \sin i = 18$ km s^{-1}, respectively). However, if some unpredicted line contributes to the equivalent width of Fe II at 6149.2 Å, the actual magnetic intensification should be larger than that measured by us and listed in Table 2 (i.e. a blend with Fe II λ 6149.2 Å serves to reduce $\Delta W/\overline{W}$).

For each star, the same atmosphere model used in WIDTH and the iron abundance obtained from WIDTH were then used in the SYNTHE code of Kurucz (1993b) to compute a synthetic spectrum at 1.2×10^6 resolution. As in Paper I, the lines of the gf0800.100 line list from Kurucz & Bell (1995) were adopted, except for the Hg II line at 6149.47 Å, which was replaced by the Hg II isotopic components given in Paper I and reported here in Table 5. The $\Delta W/\overline{W}$ ratios were computed by assuming solar abundances for all the elements except for iron.

The synthetic profiles were broadened for an instrumental resolution of 125 000 and for the rotational velocity

Table 3. Strömgren indices, reddening, microturbulent velocity, and rotational velocity.

HD	$(b-y)$	m_1	c_1	β	$E(b-y)$	$E(B-V)$	ξ	Ref.	$v\sin i$
				HgMn stars					
16727	−0.050	0.114	0.471	2.729	0.016	0.022	–		4.50
27295	−0.036	0.129	0.738	2.799	0.004	0.055	0.0	(1)	5.00
175640	+0.001	0.103	0.747	2.771	0.044	0.061	1.0	(2)	2.50
178065	+0.073	0.077	0.729	2.718	0.119	0.164	–		1.70
186122	−0.019	0.094	0.641	2.729	0.035	0.048	0.0	(2)	0.00
193452	−0.007	0.138	0.909	2.845	0.017	0.023	0.0	(2)	0.75
				Normal stars					
209459	−0.011	0.112	1.023	0.796	0.008	0.011	0.5	(2)	3.70
179761	−0.010	0.084	0.629	2.700	0.046	0.063	0.0	(3)	15.00
186568	−0.008	0.088	0.814	2.724	0.032	0.044	–		18.00
219927	−0.008	0.095	0.637	2.718	0.045	0.062	–		5.00

References for ξ: (1) Adelman & Pyper (1979); (2) Smith & Dworetsky (1993); (3) Adelman (1984).

Table 4. Stellar parameters $T_{\rm eff}$(K) and log g.

HD	$T_{\rm eff}$(K) $uvby\beta(\xi=0.0)$	$\log g$	$T_{\rm eff}$(K) $uvby\beta(\xi=2.0)$	$\log g$	C.I.	$T_{\rm eff}$(K) flux$(\xi=0.0)$	$\log g$	$T_{\rm eff}$(K) adopted	$\log g$	$T_{\rm eff}$(K) SD[1]	$\log g$
				HgMn stars							
16727	$14\,080\pm150$	4.24 ± 0.15	$14\,003\pm150$	4.23 ± 0.15	c_1-β			14 050	4.25		
27295	$11\,939\pm100$	4.18 ± 0.15	$11\,909\pm100$	4.18 ± 0.15	c_1-β	12000	3.8	11 950	4.00	12 000	4.25
175640	$11\,992\pm100$	3.95 ± 0.15	$11\,958\pm100$	3.95 ± 0.15	c_1-β			12 000	3.95	12 100	4.00
178065	$12\,246\pm100$	3.54 ± 0.15	$12\,193\pm100$	3.54 ± 0.15	c_1-β			12 250	3.55		
186122	$12\,780\pm120$	3.80 ± 0.15	$12\,717\pm120$	3.80 ± 0.15	c_1-β			12 750	3.80	13 000	3.65
193452	$10\,803\pm400$	4.09 ± 0.15	$10\,776\pm400$	4.10 ± 0.15	a-r^{*}[2]			10 800	4.10	10 800	3.95
				Normal stars							
209459	$10\,455\pm400$	3.52 ± 0.15	$10\,422\pm400$	3.54 ± 0.15	a-r^{*}[2]	10 400	3.7	10 450	3.60	10 450	3.5
179761	$12\,896\pm150$	3.54 ± 0.15	$12\,821\pm150$	3.54 ± 0.15	c_1-β	13 000	3.8	12 900	3.70	13 000	3.5
186568	$11\,596\pm120$	3.39 ± 0.15	$11\,564\pm120$	3.39 ± 0.15	c_1-β			11 600	3.40		
219927	$12\,835\pm120$	3.71 ± 0.15	$12\,767\pm120$	3.71 ± 0.15	c_1-β	12800	3.7	12 800	3.70		

[1] SD: Smith & Dworetsky (1993).
[2] The definition of the indices a and r^* can be found in Strömgren (1966) and in Moon & Dworetsky (1985).

$v\sin i$ listed in the last column of Table 3. For each star, the rotational velocity is that which best reproduces the observed Fe II λ 6149.2 Å profile, when the synthetic profile is computed by using the adopted model parameters given in Table 4 and the corresponding iron abundance listed in Table 6.

The wavelength sampling in the synthetic spectra corresponding to the resolution of 1.2×10^6 was selected in order to provide accurate equivalent widths from the synthetic profiles integrated by means of a simple Simpson rule for a constant step-size. The computed equivalent widths in WIDTH are obtained by a generalized Simpson rule for a step-size which increases with the increasing of the distance from the line center. The two different integration methods give differences in the computed equivalent widths on the order of 0.1 mÅ. Because the computed profiles are free from any noise, the equivalent widths obtained by direct integration are not affected by the uncertainty related to the choice of the blue and red ends of the profile as in the case of the equivalent widths measured on the observed profiles, provided that the stars have low $v\sin i$. In fact, for the two most rapidly rotating stars of the sample, HD 179761 and HD 186568, the predicted lines of Ni II at 6148.246 Å, Ni II at 6148.674 Å, and Fe II at 6148.848 Å cause a lowering of the continuum on the order of 0.1% in the region 6148.20–6148.85 Å, so that it is impossible to know where exactly the red wing of the 6147.7 Å line ends and where the blue wing of the 6149.2 Å line starts. By looking at the numbers giving the residual flux, we assumed for HD 179761 that the blue wing of Fe II 6147.7 Å ends at 6148.1899 Å and that the red wing of Fe II 6149.2 Å starts at 6148.8384 Å. The corresponding equivalent widths are 15.55 mÅ and 14.82 mÅ. For the same star, we derived slightly different wavelength limits from the visual inspection of the plotted profiles, corresponding to equivalent widths of 15.37 mÅ and 14.80 mÅ. The $\Delta W/\overline{W}$ ratios corresponding to two cases are 0.048 and 0.038, respectively. They are both much lower than the observed ratio 0.097.

For HD 186568, the equivalent widths derived by fixing the limits of the profiles by looking at values of the residual flux are 22.57 mÅ for Fe II 6147.7 Å and 21.85 mÅ for Fe II 6149.2 Å. When the limits of the profiles were fixed from the visual inspection of their shape we derived 22.23 mÅ and 21.68 mÅ for the two Fe II lines. The $\Delta W/\overline{W}$ ratios corresponding to the two measurements are 0.032 and 0.025, respectively. Both values are lower than the observed ratio 0.112.

The lines of the region 6147–6150 Å which have a computed residual flux at the line center equal or less than 0.999 are listed in Col. 3 of Table 5. They are taken from the Kurucz & Bell (1995) line list. The log $gf = -2.519$ adopted in Paper I for Fe II 6147.775 Å is replaced in this paper by log $gf = -0.819$ from Kurucz & Bell (1995). The log gf adopted in Paper I was fixed from the requirement that the difference between the computed equivalent widths of Fe II 6147.741 Å and Fe II 6149.258 Å be not larger than 0.1 mÅ for HD 196426, in agreement with the measured equivalent widths. The computed contribution of Fe II 6147.775 Å to Fe II 6147.741 Å was suppressed when log $gf(6147.775) = -2.519$ was adopted. In Paper I, HD 196426 was considered to be a normal B-type star, therefore free from any magnetic intensification. For this reason, it was adopted as a comparison star for the sample of HgMn stars. The finding that HD 196426 is very likely a spectroscopic binary makes now the lowering of the log gf value very arbitrary, all the more so, as Table 2 shows, that the measured equivalent widths of the profiles at 6147.7 Å and 6149.2 Å are different also in normal B-type stars.

In order to investigate the effect on the computed equivalent widths of Fe II log gf-values different from those of Kurucz & Bell (1995), we also used the Fe II oscillator strengths from Raassen & Uylings (2000). They are listed in the fourth column of Table 5.

In all the stars, Fe II at 6147.741 Å is blended with Fe II 6147.775 Å, whichever is the source of the Fe II log gf-values, Kurucz & Bell (1995) or Raassen & Uylings (2000). In HD 193452 and in HD 209459, Fe II 6147.741 Å is also blended with Fe I 6147.829 Å. The residual flux at the line center of the unbroadened Fe I profile is 0.995 for HD 193452 and 0.997 for HD 209450, when log gf-values from Kurucz & Bell (1995) are considered; it is 0.996 and 0.998 when log gf-values from Raassen & Uylings (2000) are adopted. The Fe II line at 6149.258 Å is unblended in all the stars, except in HD 186568 when the Kurucz & Bell (1995) log gf-values are used. In this case, the Fe II line at 6148.848 Å contributes to the Fe II 6149.258 Å with a residual flux at the line center equal to 0.997. The contribution of Fe II 6148.848 Å disappears when the Raassen & Uylings (2000) data are used.

5.3. The computed $\Delta W/\overline{W}_{calc}$ ratios

Five different computed intensification indices $(\Delta W/\overline{W})_{\rm calc}$, based on the Kurucz & Bell (1995) log gf-values, are listed for each star in Col. 8 of Table 6. The first one is computed from synthetic profiles corresponding to the adopted model parameters (Cols. 9 and 10 of Table 4). The other four $(\Delta W/\overline{W})_{\rm calc}$ ratios are computed by assuming errors in the model parameters on the order of ±500 K in $T_{\rm eff}$ and ±0.5 dex in log g. For all the stars these errors are much larger than those estimated in Sect. 5.1.

Column 2 in Table 6 lists the average measured equivalent width $\overline{W}_{\rm obs}(6149)$ of the observed line at $\lambda\,6149.2$ taken from Table 2; Cols. 3 and 4 list the model parameters, Col. 5 gives the corresponding iron abundance $\log(N_{\rm elem}/N_{\rm tot})$ derived with the WIDTH code. The adopted hydrogen abundance, needed for the conversion on the scale where $\log\epsilon({\rm H}) = 12.00$, is $N_{\rm H}/N_{\rm tot} = 0.911$. The next two columns list the equivalent widths of the two Fe II synthetic profiles at 6147.7 Å and 6149.2 Å, corresponding to the iron abundance given in col. 5. We point out that the computed ratios $(\Delta W/\overline{W})_{\rm calc}$ given in Col. 8 do not include magnetic field contributions, so that they should correspond to those observed in non-magnetic stars having similar stellar parameters. The last column of Table 6 lists for comparison the observed ratios $(\Delta W/\overline{W})_{\rm obs}$ taken from Table 2.

As mentioned in Sect. 4, the star HD 27295 shows the largest uncertainty in $(\Delta W/\overline{W})_{\rm obs}$ related with different placements of the continuum. The fractional errors of the equivalent widths $\overline{W}_{\rm obs}(6147)$ and $\overline{W}_{\rm obs}(6149)$ derived by averaging all the five measurements available for each line are so large that they indicate the meaninglessness of averaging equivalent widths based on very different continua. We therefore considered the separate measurements performed for this star. The two different sets of data for HD 27295 given in Table 6 correspond to the meaurements made by F.C. and to the measurements made by S.H, respectively. Both separate measurements show evidence of relative intensification.

Table 6 indicates that the computed intensification indices depend only marginally on $T_{\rm eff}$ and log g, so that large errors in the adopted parameters do not affect the results in a significant way.

Table 7 lists the intensification indices computed for the adopted model parameters when the Fe II profiles are computed by using log gf-values from Raassen & Uylings (2000).

6. Comparison between the observed and computed $(\Delta W/\overline{W})$ ratios

The observed and computed $(\Delta W/\overline{W})$ ratios listed in Table 6 are compared in Fig. 2, where the full black symbols show the computed intensification indices as function of $T_{\rm eff}$ and the white open symbols show the observed $(\Delta W/\overline{W})_{\rm obs}$ ratios together with the estimated errors.

Table 5. Lines in the 6147–6150 Å region which produce a predicted residual flux at the line center $F_\lambda/F_c \leq 0.999$.

Ion	λ(Å)	log gf(KB)[1]	log gf(RU)[2]	$E_{\rm low}$ (cm^{-1})	$E_{\rm up}$ (cm^{-1})	isotope
Cr II	6147.154	−2.843		38 362.430	54 625.620	
Fe II	6147.741	−2.721	−2.827	31 364.440	47 626.076	
Fe II	6147.775	−0.819	−0.974	90 638.822	106 900.379	
Fe I	6147.829	−1.700		32 873.619	49 135.022	
Ni II	6148.246	0.173		103 653.030	119 913.330	
Ni II	6148.674	0.143		105 439.850	121 699.020	
Fe II	6148.848	−1.496	−4.037	88 614.520	104 873.230	
Fe II	6149.258	−2.724	−2.841	31 368.450	47 626.076	
Hg II	6149.419	−1.047		95 714.408	111 971.460	199
Hg II	6149.451	−0.757				201
Hg II	6149.461	−0.680				204
Hg II	6149.469	−0.042				202
Hg II	6149.477	−0.153				200
Hg II	6149.483	−0.518				198
Hg II	6149.504	−0.570				199
Hg II	6149.513	−0.978				201

[1] KB: log gf from Kurucz & Bell (1995), except for Hg II (see text).
[2] RU: log gf from Raassen & Uylings (2000).

The two separate $(\Delta W/\overline{W})_{\rm obs}$ ratios for HD 27295 are plotted, while only one $(\Delta W/\overline{W})_{\rm calc}$ ratio is shown, owing to the negligible differences between the two separated computed intensification factors.

The computed intensification indices plotted in Fig. 2 are those given in the first row of Table 6 for each star, while the small error bars indicate the $\Delta W/\overline{W}$ ratios derived from models computed for gravities which differ by ±0.5 dex from the adopted log g. These are given in Table 6 for each star in the fourth and fifth rows. An error of −0.5 dex in log g does not change the value of the intensification index for most stars, so that there is no error bar in Fig. 2 for $\Delta\log g = -0.5$.

The $(\Delta W/\overline{W})_{\rm calc}$ ratios corresponding to errors of ±500 K in $T_{\rm eff}$ and listed for each star in Col. 8 of Table 6, in the second and thirth rows, are so close to those computed for the adopted parameters that Fig. 2 does not change in a significant way if models with $T_{\rm eff}$ increased or decreased by 500 K are used.

The full line plotted in Fig. 2 shows the computed intensification index as function of $T_{\rm eff}$, when $\Delta W/\overline{W}$ is computed from unbroadened profiles predicted for $T_{\rm eff}$ ranging, at steps of 500 K, from 10 000 K to 15 000 K, log g = 3.5 and solar iron abundance (log $N_{\rm Fe}/N_{\rm tot} = -4.54$). A gravity change from log g = 3.5 to log g = 4.0 gives a maximum difference of 0.003 in $(\Delta W/\overline{W})_{\rm calc}$. A change of microturbulent velocity from 0 km s^{-1} to 2 km s^{-1} gives a maximum difference of 0.002 in $(\Delta W/\overline{W})_{\rm calc}$.

Figure 3 shows the same comparison plotted in Fig. 2, but, in this case, all the computations, which are listed in Table 7, are based on the Fe II log gf-values taken from Raassen & Uylings (2000). The sample of stars showing magnetic intensification consists now only of three stars instead of nine stars, as we obtained when we used the Kurucz & Bell (1995) Fe II log gf-values. The three stars are the HgMn star HD 16727 and the two normal stars HD 179761 and HD 186568. We note that the two normal stars are those of the sample having the highest rotational velocity.

7. The mercury abundance and some comparisons with Paper I

There are five stars in our sample in common with the stars analyzed in Paper I. For the normal B-type star HD 196426 we already pointed out in Sect. 2 that the spectrum taken at ESO is so different from that taken at CFHT, that the star is suspected to be binary.

All the HgMn stars of our sample, except HD 27295, show a moderately strong line at 6149.45 Å, which we identified as Hg II. Table 8 compares the mercury abundance of the four HgMn stars analyzed both in Paper I and in this paper and gives also the mercury abundance for HD 16727 obtained in this study. The mercury abundance was derived from the comparison of the observed profiles with profiles computed taking into account the isotopic composition, which was discussed in Paper I. The model parameters are those adopted for the stars and given in Cols. 9 and 10 of Table 4; the rotational velocities $v\sin i$ used for computing the synthetic profiles are given in the last two columns of Table 8. There is an excellent agreement between the $v\sin i$ values from this paper and Paper I.

The mercury abundances derived in this paper, and listed in Col. 2 of Table 8, are lower than those derived in Paper I, which are given in the third column of Table 8.

Table 6. The $(\Delta W/\overline{W})_{\rm calc}$ ratios computed by using the Kurucz & Bell (1995) log gf-values.

Star	$\overline{W}_{\rm obs}(6149)$	$T_{\rm eff}$	log g	$\log(N({\rm Fe})/N_{\rm tot})$	$W(6147)_{\rm calc}$	$W(6149)_{\rm calc}$	$(\Delta W/\overline{W})_{\rm calc}$	$(\Delta W/\overline{W})_{\rm obs}$
				HgMn stars				
HD 16727	13.50	14 050	4.25	−4.342	14.10	13.39	0.052	0.126 ± 0.015
		14 550	4.25	−4.231	14.24	13.41	0.060	
		13 550	4.25	−4.437	14.02	13.42	0.044	
		14 050	3.75	−4.371	14.12	13.41	0.052	
		14 050	4.75	−4.271	14.14	13.42	0.052	
HD 27295[1]	4.50	11 950	4.00	−5.251	4.61	4.48	0.029	0.058 ± 0.007
		12 450	4.00	−5.208	4.63	4.48	0.033	
		11 450	4.00	−5.281	4.60	4.48	0.026	
		11 950	3.50	−5.387	4.61	4.48	0.029	
		11 950	4.50	−5.098	4.62	4.48	0.031	
HD 27295[2]	5.60	11 950	4.00	−5.146	5.74	5.58	0.028	0.077 ± 0.008
		12 450	4.00	−5.103	5.77	5.58	0.033	
		11 450	4.00	−5.176	5.72	5.57	0.027	
		11 950	3.50	−5.282	5.74	5.58	0.028	
		11 950	4.50	−4.993	5.75	5.57	0.032	
HD 175640	10.40	12 000	3.95	−4.842	10.65	10.35	0.029	-0.004 ± 0.010
		12 500	3.95	−4.795	10.70	10.35	0.033	
		11 500	3.95	−4.873	10.62	10.35	0.026	
		12 000	3.45	−4.974	10.65	10.36	0.028	
		12 000	4.45	−4.690	10.67	10.35	0.030	
HD 178065	19.36	12 250	3.55	−4.552	19.79	19.26	0.027	0.039 ± 0.005
		12 750	3.55	−4.468	19.85	19.24	0.031	
		11 750	3.55	−4.608	19.71	19.25	0.024	
		12 250	3.05	−4.635	19.78	19.26	0.027	
		12 250	4.05	−4.425	19.79	19.24	0.028	
HD 186122	36.50	12 750	3.80	−3.889	37.42	36.37	0.028	0.043 ± 0.005
		13 250	3.80	−3.793	37.59	36.37	0.033	
		12 250	3.80	−3.957	37.30	36.38	0.025	
		12 750	3.30	−3.960	37.40	36.38	0.028	
		12 750	4.30	−3.772	37.49	36.38	0.030	
HD 193452	33.02	10 800	4.10	−4.083	33.57	32.90	0.020	0.034 ± 0.010
		11 300	4.10	−4.038	33.62	32.92	0.021	
		10 300	4.10	−4.160	33.60	32.92	0.020	
		10 800	3.60	−4.409	33.43	32.92	0.015	
		10 800	4.60	−3.964	33.71	32.89	0.024	
				Normal stars				
HD 209459	24.02	10 450	3.60	−4.527	24.31	23.90	0.017	0.026 ± 0.008
		10 950	3.60	−4.489	24.34	23.90	0.018	
		9950	3.60	−4.599	24.31	23.91	0.017	
		10 450	3.10	−4.673	24.27	23.90	0.015	
		10 450	4.10	−4.400	24.37	23.90	0.019	
HD 179761	14.73	12 900	3.70	−4.588	15.55	14.82	0.048	0.097 ± 0.009
		13 400	3.70	−4.483	15.55	14.82	0.048	
		12 400	3.70	−4.670	15.48	14.79	0.045	
		12 000	3.20	−4.636	15.53	14.81	0.047	
		12 900	4.20	−4.492	15.81	15.04	0.050	

The difference is about 0.2–0.4 dex, except for HD 186122. In fact, in Paper I we estimated as a pure noise the signal observed in the CAT spectrum of HD 186122, so that we assumed meteoritic abundance for this star.

Table 6. continued.

Star	$\overline{W}_{\rm obs}(6149)$	$T_{\rm eff}$	log g	$\log(N({\rm Fe})/N_{\rm tot})$	$W(6147)_{\rm calc}$	$W(6149)_{\rm calc}$	$(\Delta W/\overline{W})_{\rm calc}$	$(\Delta W/\overline{W})_{\rm obs}$
HD 186568	21.6	11 600	3.40	−4.587	22.57	21.85	0.032	0.112 ± 0.002
		12 100	3.40	−4.530	22.58	21.86	0.032	
		11 100	3.40	−4.621	22.60	21.78	0.037	
		11 600	2.90	−4.707	22.57	21.85	0.032	
		11 600	3.90	−4.438	22.45	21.80	0.029	
HD 219927	17.92	12 800	3.70	−4.486	18.41	17.81	0.033	0.066 ± 0.019
		13 300	3.70	−4.384	18.51	17.81	0.038	
		12 300	3.70	−4.562	18.33	17.82	0.028	
		12 300	3.20	−4.541	18.41	17.82	0.033	
		12 300	4.20	−4.382	18.42	17.81	0.034	

[1] $(\Delta W/\overline{W})_{\rm obs}$ and $(\Delta W/\overline{W})_{\rm calc}$ are based on the equivalent widths measured by F.C.
[2] $(\Delta W/\overline{W})_{\rm obs}$ and $(\Delta W/\overline{W})_{\rm calc}$ are based on the equivalent widths measured by S.H.

Table 7. The $(\Delta W/\overline{W})_{\rm calc}$ ratios computed by using the Fe II log gf-values from Raassen & Uylings (2000).

Star	$\overline{W}_{\rm obs}(6149)$	$T_{\rm eff}$	log g	$\log(N({\rm Fe})/N_{\rm tot})$	$W(6147)_{\rm calc}$	$W(6149)_{\rm calc}$	$(\Delta W/\overline{W})_{\rm calc}$	$(\Delta W/\overline{W})_{\rm obs}$
				HgMn stars				
HD 16727	13.50	14 050	4.25	−4.220	14.42	13.51	0.065	0.126 ± 0.015
HD 27295[1]	4.50	11 950	4.00	−5.134	4.71	4.48	0.050	0.058 ± 0.007
HD 27295[2]	5.60	11 950	4.00	−5.029	5.86	5.57	0.051	0.077 ± 0.008
HD 175640	10.40	12 000	3.95	−4.725	10.85	10.35	0.047	-0.004 ± 0.010
HD 178065	19.36	12 250	3.55	−4.435	20.07	19.26	0.041	0.039 ± 0.005
HD 186122	36.50	12 750	3.80	−3.772	37.71	36.37	0.036	0.043 ± 0.005
HD 193452	33.02	10 800	4.10	−3.966	32.92	31.88	0.032	0.034 ± 0.010
HD 209459	24.02	10 450	3.60	−4.410	24.66	23.90	0.031	0.026 ± 0.008
HD 179761	14.73	12 900	3.70	−4.471	15.79	14.73	0.069	0.097 ± 0.009
HD 186568	21.6	11 600	3.40	−4.470	22.88	21.62	0.057	0.112 ± 0.002
HD 219927	17.92	12 800	3.70	−4.369	18.67	17.81	0.047	0.066 ± 0.019

[1] $(\Delta W/\overline{W})_{\rm obs}$ and $(\Delta W/\overline{W})_{\rm calc}$ are based on the equivalent widths measured by F.C.
[2] $(\Delta W/\overline{W})_{\rm obs}$ and $(\Delta W/\overline{W})_{\rm calc}$ are based on the equivalent widths measured by S.H.

Table 8. The mercury abundance and the rotational velocity $v \sin i$ from this paper (II) and Paper I (I).

HD	$\log(N_{\rm Hg}/N_{\rm tot})$ (II)	(I)	$v \sin i$ (II)	(I)
16727	−7.25	–	4.50	–
175640	−6.75	−6.50	2.50	2.50
178065	−7.05	−6.85	1.70	1.50
186122	−7.45	−10.95	0.00	0.00
193452	−5.70	−5.31	0.75	0.75

Table 9 compares results for iron from Paper I and from this paper for the four HgMn stars analyzed in both studies. In particular, it compares the measured equivalent widths of Fe II 6149.2 Å, the corresponding iron abundances $\log(N_{\rm Fe}/N_{\rm tot})$, the computed equivalent widths $W(6147)_{\rm calc}$ and $W(6149)_{\rm calc}$ of Fe II 6147.7 Å and Fe II 6149.2 Å, respectively, and the computed and measured intensification factors $(\Delta W/\overline{W})_{\rm calc}$ and $(\Delta W/\overline{W})_{\rm obs}$. Computations performed in this paper by using both the Kurucz & Bell (1995) (KB) log gf-values and the Fe II log gf-values from Raassen & Uylings (2000) (RU) are considered.

For three stars (HD 175640, HD 178065, and HD 193452) the equivalent widths of Fe II λ 6149.258 Å are systematically smaller in the CFHT spectra than in the ESO spectra taken at the higher spectral resolution ($R = 135\,000$). The opposite is true for HD 186122.

A few factors could be responsible for the different intensity of the Hg II and Fe II profiles observed in the CAT and CFHT spectra (see Fig. 1): for instance, the different spectral resolution, the placing of the continuum, or the residual scattered light in the Gecko spectrograph, which could have been not completely removed. The lower Fe II equivalent widths measured in this paper could be also due to the more accurate measurements performed in this second analysis. In fact, in Paper I, the equivalent widths used to derive the iron abundance were measured only by gaussian fitting, whereas for the present paper we used the average of five measurements.

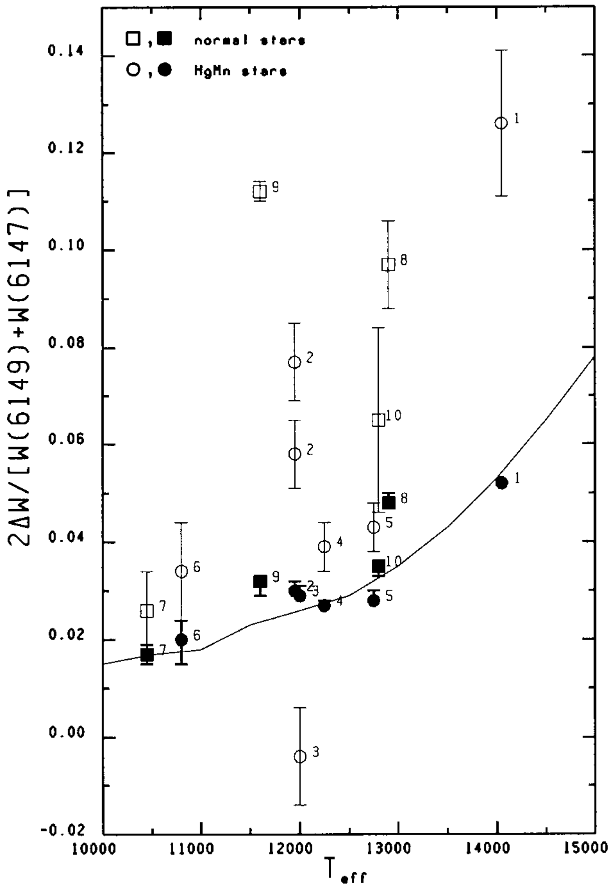

Fig. 2. Comparison of the observed intensification indices (open circles and open squares) with those computed by using the Kurucz & Bell (1995) log gf-values (full circles and full squares). The correspondence of each number to each star is: 1 = HD 16727, 2 = HD 27295, 3 = HD 175640, 4 = HD 178065, 5 = HD 186122, 6 = HD 193452, 7 = HD 209459, 8 = HD 179761, 9 = HD 186568, 10 = HD 219927. The full line shows the computed intensification index derived from unbroadened Fe II lines computed for log $g = 3.5$, zero microturbulent velocity, and solar iron abundance.

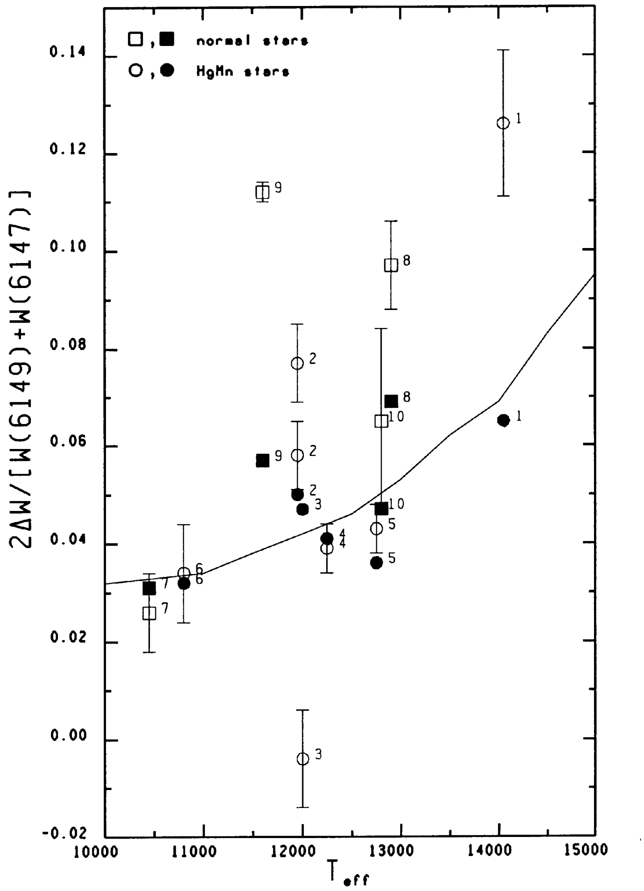

Fig. 3. Comparison of the observed intensification indices (open circles and open squares) with those computed by using the Raassen & Uylings (2000) log gf-values for Fe II (full circles and full squares). The correspondence of each number to each star is: 1 = HD 16727, 2 = HD 27295, 3 = HD 175640, 4 = HD 178065, 5 = HD 186122, 6 = HD 193452, 7 = HD 209459, 8 = HD 179761, 9 = HD 186568, 10 = HD 219927. The full line shows the computed intensification index derived from unbroadened Fe II lines computed for log $g = 3.5$, zero microturbulent velocity, and solar iron abundance.

For all the four HgMn stars, the measured intensification factors are lower in this paper than those obtained in Paper I and they are very close to the intensification factors computed by using the Raassen & Uylings (2000) log gf-values for Fe II, so that the suggestion of the presence of a magnetic field for HD 175640, HD 178065, and HD 186122 can not be confirmed by the present results.

8. Discussion

Table 6 and Fig. 2 show that the intensification indices computed by using log gf-values from Kurucz & Bell (1995) are lower than the observed intensification indices for all the stars in our sample, except HD 175640. For HD 193452 and HD 209459 the differences lie within the error limits, but for five stars, HD 16727, HD 27295, HD 179761, HD 186568 and HD 219927, the differences are larger even when the observational and computational uncertainties discussed in the previous sections are taken into account. Especially striking is the outcome of measurements in the star HD 186568 with the largest value of $v \sin i$. The difference between the equivalent widths of Fe II 6147.7 Å and Fe II 6149.2 Å is expected to be 0.72 mÅ, whereas we have measured 2.57 mÅ.

Our calculations show that large errors in the adopted parameter $T_{\rm eff}$ and log g do not affect the results in a significant way. However, if Fe II log gf-values from Raassen & Uylings (2000) are used to compute the Fe II profiles, the intensification indices become by about 2% higher and the comparison between the calculated and observed $\Delta W/\overline{W}$ ratios suggests the possible presence of magnetic fields in only three stars, the HgMn star HD 16727 and the two normal late B-type stars HD 179761 and HD 186568.

We must deduce from the above results that the used diagnosis method heavly depends on uncertainties of the atomic data. Karlsson et al. (2001) demonstrated that experimental log gf-values of Fe II better agree with the

Table 9. Comparison of results from Paper I (I) and this paper (II) for Fe II and for the computed and measured intensification indices $\Delta W/\overline{W}$: (KB) are the results obtained by using the Kurucz & Bell log gf-values for Fe II; (RU) are the results related with the Raassen & Uylings (2000) log gf-values for Fe II.

	Paper	HD 175640	HD178065	HD 186122	HD 193452
$W(6149)_{\rm obs}$	I	10.7	20.4	35.2	33.6
	II	10.40 ± 0.09	19.36 ± 0.07	36.50 ± 0.14	33.02 ± 0.21
$\log(N_{\rm Fe}/N_{\rm tot})$	I	−4.82	−4.53	−3.93	−4.07
	II (KB)	−4.84	−4.55	−3.89	−4.08
	II (RU)	−4.73	−4.44	−3.77	−3.97
$W(6147)_{\rm calc}$	I	11.06	20.89	36.17	34.30
	II (KB)	10.65	19.79	37.42	33.57
	II (RU)	10.85	20.07	37.71	32.92
$W(6149)_{\rm calc}$	I	10.76	20.35	35.17	33.64
	II (KB)	10.35	19.26	36.37	32.90
	II (RU)	10.35	19.26	36.37	31.88
$(\Delta W/\overline{W})_{\rm calc}$	I	0.027	0.026	0.028	0.019
	II(KB)	0.029	0.027	0.028	0.020
	II(RU)	0.047	0.041	0.036	0.032
$(\Delta W/\overline{W})_{\rm obs}$	I	0.090	0.067	0.086	0.041
	II	-0.004 ± 0.010	0.039 ± 0.005	0.043 ± 0.005	0.034 ± 0.010

log gf-values computed by Raassen & Uylings (2000) than with those computed by Kurucz & Bell (1995), and recommend the use of the Raassen & Uylings (2000) data. As a consequence, we have to conclude that our claim for magnetic field detection can be held only for few stars. In particular, we can not confirm any magnetic field for the three stars studied in Paper I, HD 175640, HD 178065, and HD 186122.

The differences between the measurements made in this paper and those from Paper I could be related with instrumental effects and data reduction problems, as we discussed in Sect. 7. However, we can not exclude a priori the presence of weak magnetic fields of complex structure which change with time. They could be responsible for the differences in the observed intensification indices and for the small differences in the measured equivalent widths of Fe II and Hg II of the stars observed both at CAT and at CFHT, in particular of HD 175640 (Tables 8 and 9). In fact, Takeda (1991) shows that the magnetic intensification may become negative for particular magnetic field configurations.

The most intriguing result would have been to recognize the presence of magnetic fields in normal late B-type stars that have been selected by us as standards on the basis of previous studies on their nature. Whereas the observed and computed intensification indices agree within the estimated errors for the normal stars HD 209459 and HD 219927, the other two normal stars, HD 179761 and HD 186568, show rather high observed relative differences between the equivalent widths of the two Fe II lines compared with those derived from synthetic spectra. However, the rather high rotational velocity of HD 179761 (15 km s^{-1}) and HD 186568 (18 km s^{-1}) makes the results from the Mathys method somewhat uncertain. In fact, as we discussed in Sect. 5.2, it is difficult to compute accurate equivalent widths for the rotationally broadened profiles, owing to the depressed continuum in the range 6148.20−6148.85 Å, due to the presence of very weak lines (Table 5).

No large-scale magnetic fields were ever detected for normal upper-main-sequence stars (O9.5-F6) (Landstreet 1982). There is only a little information in the literature about the normal late B-type stars studied in this paper. Previous studies of the four normal stars in our sample revealed only very mild peculiarities and the possibility that they may be regarded as superficially normal stars is still viable. In particular, Babcock (1958) observed the star HD 186568 photographically, but no magnetic field was found.

Bohlender & Landstreet (1990) searched for magnetic field in the star HD 209459 with the Hβ Zeeman analyser technique. Measurement errors have been typically few hundred Gauss and no definite field detections have emerged. Sadakane (1981) determined abundances of 15 elements in this star and found that the metal abundances are nearly solar or slightly underabundant except for Mn, Y and Ba, which may be overabundant. Cowley (1980) mentioned a weakness of Sc II relative to lines of other ions and suggested that HD 209459 may be related to hot Am stars.

Cowley(1980) also studied the star HD 219927 and describes it as nearly normal. No search for magnetic field has been carried out for this star.

The star HD 179761 is one of the hottest stars for which Babcock (1958) has found a longitudinal field. Three out of four measurements performed by him revealed a magnetic field ranging from −500 to −600 Gauss at the level of 3.5σ to 5σ. No peculiar elements have been detected in our spectrum. However, Cowley (1972) noticed that the character of the hydrogen wings suggests that this star could be similar to HgMn stars.

No variation of radial velocity $V_{\rm r}$ has been reported for the stars HD 186568 and HD 209459. Our measurement of radial velocity of the star HD 186568 ($V_{\rm r} = -8.4$ km s^{-1}) agrees well with the value measured by Morse et al. (1991) ($V_{\rm r} = -8.6$ km s^{-1}). The stars HD 179761 and HD 219927 show variable $V_{\rm r}$ and they are probably spectroscopic binaries. However, only very few radial velocity measurements are available at the moment for them. For HD 179761 Morse et al. (1991) measured $V_{\rm r} = -5.0$ km s^{-1} whereas we measured $V_{\rm r} = -19.6$ km s^{-1}. Wolff (1978) found that the radial velocity of HD 219927 varies from −3.1 km s^{-1} to 4.9 km s^{-1}. We measured for this star $V_{\rm r} = -11.4$ km s^{-1}. Spectral lines from the companions have not been detected in our data.

HgMn stars still remain interesting objects for future studies on the presence of magnetic fields for them. Further high resolution and high signal-to-noise ratio spectra are needed to state whether the equivalent width variations and the intensification indices found for both HgMn and normal late B-type stars are due to weak variable magnetic fields or are rather due to instrumental effects and measurement techniques. For instance, in addition to the two Fe II lines of mult. 74 used in this paper, other pairs of magnetically sensitive lines could be observed and analyzed. Takeda (1991) pointed out the existence of another pair of Fe II lines at 4416.8 Å and 4385.4 Å with the same Zeeman patterns. Among the other elements different from iron, there is a pair of Cr II lines at 5620.918 Å and 5622.468 Å, which have identical patterns.

Other independent approaches to study weak magnetic fields in normal late B-type stars and HgMn stars would be the moment technique in order to look for possible differential broadening of spectral lines having different magnetic sensitivities (Mathys 1995; Mathys & Hubrig 1997), or the multi-line Stenflo-Lindegren (1977) technique, which can be very powerful if it is applied to a suitable sample of spectral lines. Magnetic field detections might also be valuably attempted through the observation of linear polarization in spectral lines. To our knowledge, such observations have never been done for normal late B-type stars and HgMn stars.

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