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THE INFLUENCE OF STELLAR EFFECTIVE TEMPERATURE ON THE MnI 5394.7 Å LINE PARAMETERS

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Abstract. The synthetic profiles of the MnI 5394.7 Å spectral line for several hypothetical stars with different effective temperature are calculated. The hyperfine structure of the manganese line is taken into account. The parameters (equivalent width, central depth and full width at half maximum) of these line profiles are determined. The change of the MnI 5394.7 Å line profile parameters with effective temperature and temperature gradients are evaluated. Using these gradients, the temperature sensitivity of the MnI 5394.7 Å line parameters for the solar effective temperature is determined and compared with the corresponding observed values.

1. INTRODUCTION

The observed parameters (equivalent width (EW) and central depth (CD)) of the MnI 5394.7 Å spectral line profile in solar spectra have shown unusually high degree of variation with solar cycle (Livingston 1992, Vince and Erkapic 1998). This high degree of variation could be partly due to its high temperature sensitivity. Because of that we investigated the temperature sensitivity of this line. Our simplified theoretical calculation of temperature sensitivity of the MnI 5394.7 Å line (we did not take into account its hyperfine structure), that was done by changing the temperature in solar atmosphere model (Erkapić and Vince 1993) and the temperature sensitivity of this line obtained experimentally by measuring its parameters from observed spectra of solar-like stars with different effective temperatures (Vince et al. 1998 and Vince and Vince 2000) show large discrepancy. In order to investigate this discrepancy we calculate the synthetic spectrum of the MnI 5394.7 Å spectral line taking into account its hyperfine structure for stellar models with different effective temperature. From these results we determine the temperature sensitivity of the line parameters (EW, CD and full width at half maximum (FWHM)) and compare them both with the results of the theoretical calculation obtained by Erkapić and Vince (1993) and with the results obtained from observations made by Vince et al. (1998) and Vince and Vince (2002).

Table 1: The relative wavelength and gf factors of hyperfine structure components

	λ(Å)	log (gf)
1	5394.624	-4.261
2	5394.659	-4.300
3	5394.688	-4.400
4	5394.712	-4.450
5	5394.729	-4.680
6	5394.741	-5.180

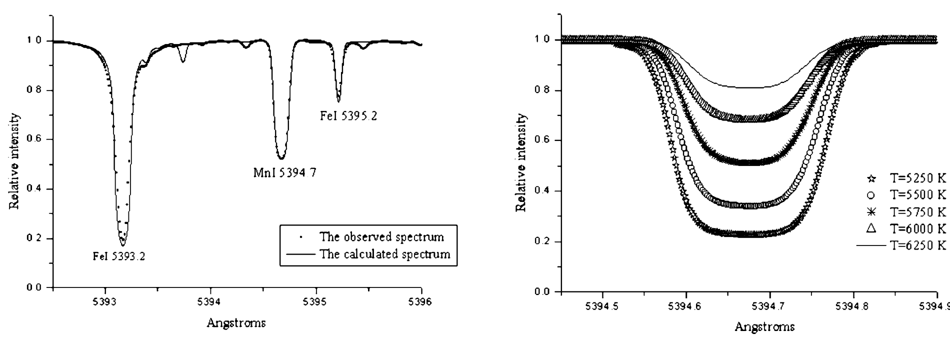

Figure 1: Comparison of the observed and calculated solar spectra in the vicinity of the MnI 5394.7 Å spectral line (left; Vitas et al. 2002) and the calculated profiles of the MnI 5394.7 Å spectral line for different effective temperatures (right).

2. CALCULATION AND REDUCTION

The synthetic spectrum of the MnI 5394.7 Å line profile was calculated using SPECTRUM (a PC-based Stellar Synthesis Program made by R. O. Gray) program package with stellar atmosphere models of Robert Kuruz as an input. As input parameters for microturbulent velocity, manganese abundance and surface gravity we used 1.5 km/s, 6.62 and 4.5, respectively. The hyperfine structure data of the MnI 5394.7 Å spectral line were taken from Vitas et al. (2002). Their values are presented in Table 1.

The observed and calculated solar spectra in the vicinity of the MnI 5394.7 Å spectral line are presented in Fig. 1 (left). (The observed solar spectrum was taken from High Resolution Solar Spectrum Atlas after Delbouille et al., 1972, 1981). We can notice a very good agreement between the calculated and observed manganese line profiles.

Using the gf values for six hyperfine structure components from Table 1. the synthetic spectrum was calculated for different stellar effective temperatures within the interval 5250 K to 6250 K with step of 250 K. The manganese line profiles for these temperatures are presented in Fig. 1 (right). Determination of the line parameters (EW, CD, and FWHM) of these profiles is implied by SPE reduction program package. The temperatures and the determined line profile parameters are presented in Table 2.

Table 2: The determined line profile parameters for different temperatures

T(K)	EW (Å)	CD	FWHM (Å)
5250	0.14583	0.226274	0.18799
5500	0.11207	0.339514	0.16943
5750	0.076455	0.510720	0.15576
6000	0.047045	0.682651	0.14697
6250	0.027470	0.809558	0.14209

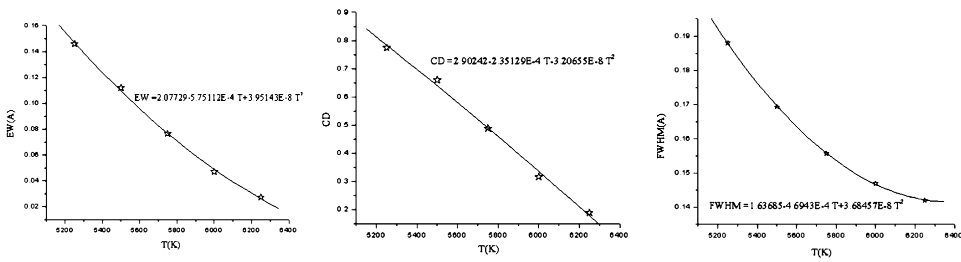

Figure 2: Variation of the MnI 5394.7 Å spectral line parameters with effective temperature

The runs of these parameters with effective temperature are given in Fig. 2.

3. RESULTS AND CONCLUSION

The best 2nd order polynomial fits of obtained parameters are:

$$EW = 2.07729 - 5.75112 \times 10^{-4} T + 3.95143 \times 10^{-8} T^2,$$

$$CD = 2.90242 - 2.35129 \times 10^{-4} T - 3.20655 \times 10^{-8} T^2,$$

$$FWHM = 1.63685 - 4.6943 \times 10^{-4} T + 3.68457 \times 10^{-8} T^2. \qquad (1)$$

As can be seen from both Fig. 2 and above formula, the line profile parameters decrease with increasing effective temperature. The temperature gradients of all of these parameters are negative.

For the solar effective temperature (T_{eff}=5726 K) the temperature gradients of MnI 5394.7 Å spectral line profile parameters are:

$$d(EW)/dT = -1.2259 \times 10^{-4} [\text{Å}/K],$$

$$d(CD)/dT = -6.0234 \times 10^{-4} [1/K],$$

$$d(FWHM)/dT = -4.6328 \times 10^{-5} [\text{Å}/K].$$

The most temperature sensitive parameter at solar effective temperature is the central depth of spectral line. It is by about a factor of 5 more sensitive than the equivalent width and about 13 times as the full width at half maximum.

The values of line parameters for the solar temperature (obtained from Eqs. (1)) are $EW_\odot$= 0.07976 Å, $CD_\odot$=0.50474 and $FWHM_\odot$=0.15696 Å, respectively. Therefore, for the relative temperature sensitivity of the MnI 5394.7 Å spectral line profile parameters in the vicinity of the solar temperature we obtained:

$$1/EW_\odot \cdot d(EW)/dT = -1.54 \times 10^{-3}[1/K],$$

$$1/CD_\odot \cdot d(CD)/dT = -1.19 \times 10^{-3}[1/K],$$

$$1/FWHM_\odot \cdot d(FWHM)/dT = -3.02 \times 10^{-4}[1/K].$$

The relative sensitivity of EW is about 30% higher than that of CD and 5 times than that of the FWHM.

On the other hand, on the basis of a simplified theoretical calculation, by varying the temperature in a solar model, Erkapić and Vince (1993) found that the relative change of EW is:

$$1/EW_\odot \cdot d(EW)/dT = -9.4 \times 10^{-4}[1/K].$$

This is about 60% lower than we obtained in this work.

From spectra of a sample of solar-like stars observed at Mt. John Observatory (New Zealand) Vince et al. (1998) obtained the following relative changes of EW and CD:

$$1/EW_\odot d(EW)/dT = -1.1 \times 10^{-3}[1/K],$$

$$1/CD_\odot d(CD)/dT = -7.9 \times 10^{-4}[1/K].$$

The observed relative change of EW is about 40% and that of CD is about 50% less sensitive to temperature variation than our corresponding theoretical values.

From spectral observations of solar-like stars at Rozhen Observatory (Romania) we obtained the following relative gradients of EW and CD (Vince and Vince 2002):

$$1/EW_\odot d(EW)/dT = -3.9 \times 10^{-3}[1/K],$$

$$1/CD_\odot d(CD)/dT = -4.4 \times 10^{-4}[1/K].$$

The observed relative change of EW is about 2.5 times larger and that of CD is nearly 3 times smaller in comparison with our corresponding theoretical values.

All these results show large disagreement between different calculations and observations. The temperature sensitivity of EW given by Erkapić and Vince (1993) is probably underestimated because the hyperfine structure of the MnI 5394.7 Å line was not taken into account. We plan to repeat these calculations with hyperfine structure. The discrepancies between observations taken at Mt. John and Rozhen observatories are due to large scattering (systematic errors) in reduced data caused probably by not taking into account the influence of metalicity and rotational velocity on the line profiles in spectra of observed stars. We plan to revise reduction of all of these observed data taking these effects into account.

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