THE INFLUENCE OF HYPERFINE STRUCTURE ON THE SOLAR Mn I 543.25 nm LINE PROFILE

N. Vitas[1], **O. Vince**[2], **I. Vince**[1,2]

[1] *Dept. of Astronomy, Faculty of Mathematics, Belgrade, Yugoslavia*
e-mail: nikola@matf.bg.ac.yu

[2] *Astronomical Observatory, Belgrade, Yugoslavia*

ВЛИЯНИЕ СВЕРХТОНКОЙ СТРУКТУРЫ НА ПРОФИЛЬ СОЛНЕЧНОЙ ЛИНИИ Mn I 543.25 нм, Витас Н., Винче О., Винче И. – Спектральная линия Mn I 543.25 нм имеет необычно широкий профиль, обусловленный сверхтонкой структурой. В этой работе мы представляем результаты расчетов в приближении ЛТР модельных профилей линии Mn I 543.25 нм. Мы использовали Оксфордские данные для сил осцилляторов как первое приближение для сверхтонкой структуры. Наблюдательные данные были взяты из Льежского атласа солнечного спектра. Относительные интенсивности шести компонентов сверхтонкой структуры варьировались, чтобы получить хорошее согласование с наблюдательными данными.

The Mn I 543.25 nm spectral line has unusually broad line profile due to its hyperfine structure. Here we present the results of LTE calculation of the synthetical profile of the Mn I 543.25 nm line in the solar spectrum. We used the Oxford total absorption oscillator strength measurements as the first approximation for hyperfine structure. The observed spectrum was taken from the High Resolution Solar Spectrum Atlas. The relative intensities of six hyperfine components were varied to obtain a good fit with the observed line profile.

INTRODUCTION

The Mn I 543.25 nm spectral line is formed in transition between ground state ^6S and excited state $^8P^0$, together with the Mn I 539.47 nm line and thus one can suppose that their behavior are very similar. Observations of the Mn I 539.47 nm line on the sun as a star showed its activity cycle variation of about 2 % [3]. For explanation of this unusually high degree of variation it was introduced several hypotheses [4]. Recently, this behavior, qualitatively explained by depopulation of the ground state of the manganese atom by photons of the Mg II k lines [5]. According to this paper, the Mn I 543.25 nm line has to behave very similarly to the Mn I 539.47 nm line. Obviously, these two lines could be used as an optical replacement for the measurement of the UV Mg II k line flux (Mg II k – index), but this requires a knowledge of their behavior in detail. It has been already shown some similarity on behavior of these two lines (*e.g.*, the sensitivity to temperature changes in solar photosphere [6]). On the other hand, the influence of another parameters of the solar atmosphere has been examined only for the Mn I 539.47 nm. Our observations have shown, for instance, that the intensity of the Mn I 539.47 nm line in plages strongly depends on strength of magnetic field [7]. However, it to take into account the hyperfine structure of the Mn I 539.47 nm line, we have found theoretically that the influence of magnetic field has not an important role in variation of intensity of this line in plages [8]. We concluded that the intensity variation of this line in plages was not due directly to changes of magnetic field strength, but to changes of other physical parameters in plages. It is interesting to study the influence of the same features on the Mn I 5543.25 nm line profile. The goal of this paper is to study the influence of hyperfine structure and magnetic field on the solar Mn I 543.25 nm line profile and to compare the results with corresponding ones obtained for the Mn I 539.47 nm line.

METHOD OF CALCULATIONS

The synthetic spectrum near Mn I 543.25 nm line is calculated by using R.O. Gray's program package SPECTRUM (PC–based Stellar Spectral Synthesis Program). Obtained results are compared with the observed spectrum taken from High Resolution Solar Spectrum Atlas [2]. We calculated the synthetic spectrum neglecting hyperfine structure and compared it with the observed in Fig. 1. There is an obvious difference between two spectra.

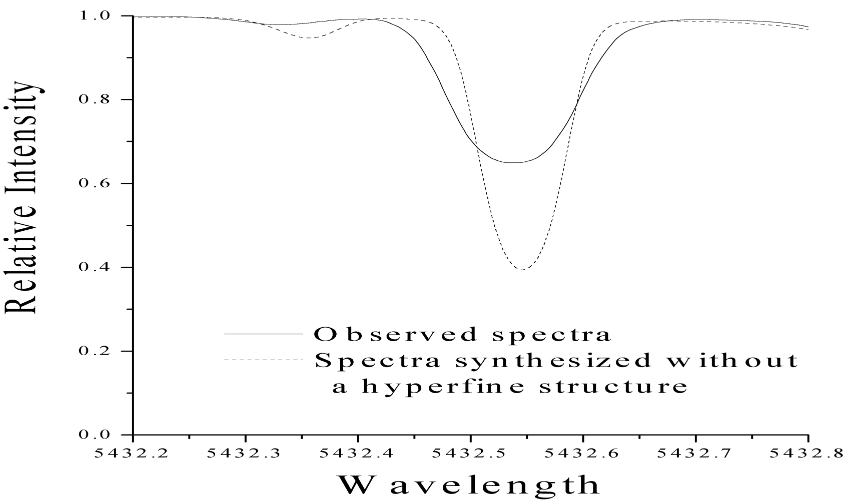

Figure 1. The Mn I 543.25 nm line: Observed spectrum and spectrum synthesized neglecting a hyperfine structure

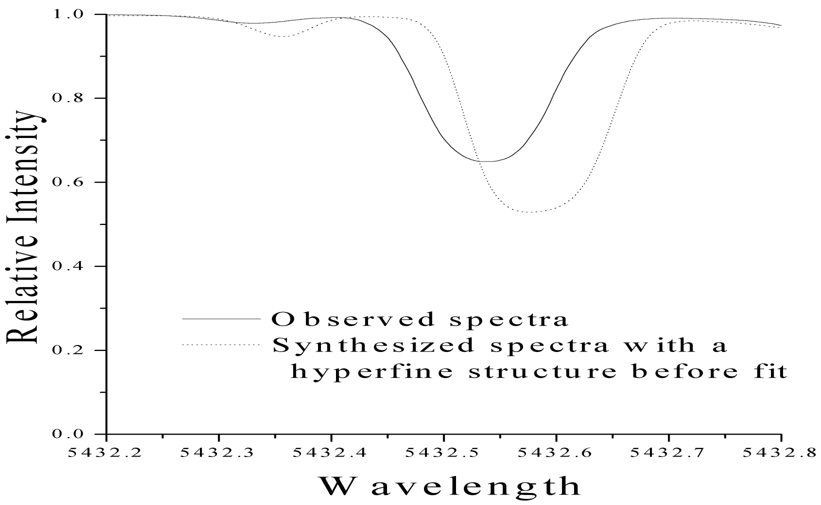

Figure 2. The Mn I 543.25 nm line: Observed spectrum and spectrum synthesized taking into account a hyperfine structure (data from Oxford total absorption oscillator strength measurements are used as the first approximation)

Table 1. Hyperfine components of Mn I 543.25 nm

λ (nm)	lg(gf)
5432.501	–4.455
5432.534	–4.608
5432.557	–4.710
5432.570	–4.840
5432.582	–5.100
5432.610	–5.260

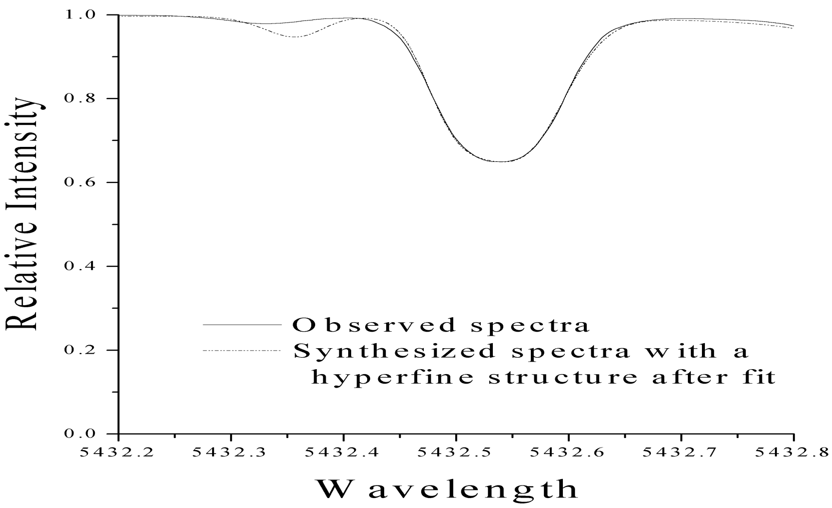

Figure 3. The Mn I 543.25 nm line: Observed spectrum and spectrum synthesized with a hyperfine structure parameters fitted

We have used Oxford total absorption oscillator strength measurements [1] as the first approximation of the hyperfine structure data (relative intensities and wavelengths). Then we calculated the spectrum with these data (the result of synthesis is shown in Fig. 2).

The relative intensities, *i.e.*, gf-factors and wavelengths of six components of hyperfine structure have been changed and the spectrum is calculated again to obtain good fit of the observed one. The final values for final manganese abundance of 6.65 and microturbulence velocity of 1.5 km/s are represented in Table 1. The data from this table had been used for the synthesis shown in Fig. 3.

In the presence of the magnetic field the spectral lines (observed perpendicular to the direction of magnetic field) is splitted in two components. Their wavelength splitting $\Delta\lambda$ (in nm) could be determined according to the well-known formula:

$$\Delta\lambda = \pm 4.668 \cdot 10^5 \cdot \lambda^2 \cdot H,$$

where g is the Gaunt factor (for the line Mn I 543.25 nm, $g = 1.86$), λ is the wavelength in m, and H is the magnetic field strength expressed in Gauss. The components of hyperfine structure of the spectral lines split in the same way according to the same formulae. The oscillator strengths of components decrease by a half. To illustrate this effect in the presence of magnetic field strength $H = 1000$ G we calculated profiles of 12 component lines that together compose the profile of Mn I 543.25 nm line.

Similar procedure was repeated for different values of magnetic field in the range from 100 to 1000 G. The obtained results for three values of H (100 G, 500 G, 1000 G) are shown in Table 2 and in Fig. 4.

Table 2. Calculated wavelength splitting $\Delta\lambda$ of hyperfine structure components for different values of magnetic field

λ (nm)	$\Delta\lambda$, pm		
	$H = 100$ G	$H = 500$ G	$H = 1000$ G
543.2501 543.2534 543.2557 543.2570 543.2582 543.2610	$\pm$ 0.26	$\pm$ 1.28	$\pm$ 2.56

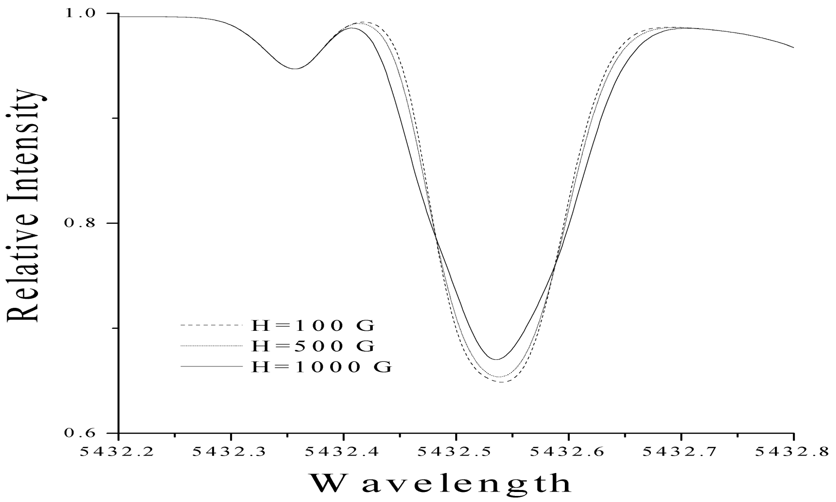

Figure 4. Profiles of 543.25 nm line synthesized for different magnetic field strength (H = 100 G, 500 G, 1000 G)

Table 3. Line parameters of the synthesized Mn I 543.25 nm line for different values of magnetic field strength H

H (G)	EW (nm)	LD	$FWHM$ (nm)
100	0.04537	0.64628	0.12451
200	0.04545	0.64860	0.12549
300	0.04557	0.64860	0.12598
400	0.04568	0.64860	0.12695
500	0.04588	0.65093	0.12891
600	0.04603	0.65325	0.12988
700	0.04628	0.65558	0.13232
800	0.04653	0.65791	0.13477
900	0.04678	0.66256	0.13818
1000	0.04709	0.66954	0.14355

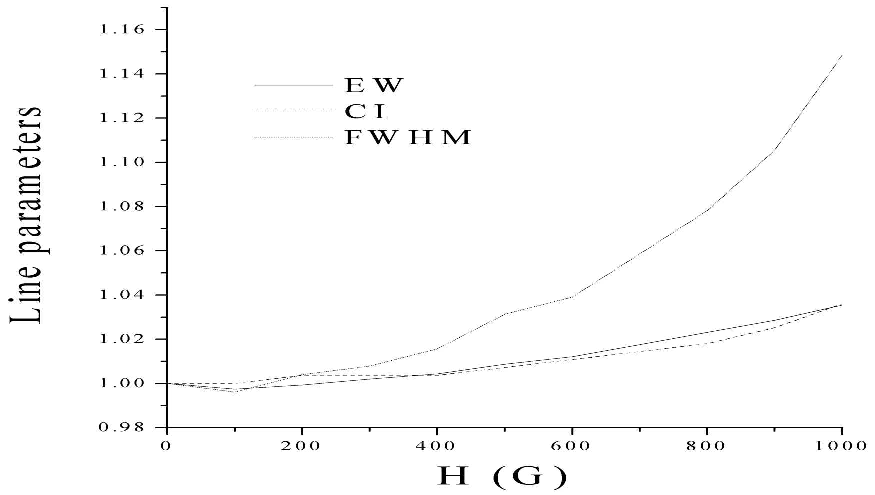

Figure 5. Dependence of line parameters of the synthesized Mn I 543.25 nm line on magnetic field strength H

The line parameters, namely, equivalent width EW, line depth LD and $FWHM$, of the synthesized Mn I 543.25 nm line are represented in Table 3 and are shown in Fig. 5.

CONCLUSION

This paper presents the results of analysis of the Mn I 543.25 nm line parameters (equivalent width EW, line depth LD, and $FWHM$). The analysis took into consideration the hyperfine structure and followed the change of the profile with the change of magnetic field strength. It is evident that the observed parameters do not manifest strong change, such as, for example, the one observed by Vince *et al.* [7] in the other manganese line, Mn I 539.47 nm. On the other hand, the values for Mn I 543.25 nm calculated in this way manifest similar behavior to the values of the mentioned Mn I 539.47 nm line when they are calculated in the same way. It is necessary to carry out measurements of parameters of Mn I 543.25 nm line for different values of H, which is our intention to do in future.

Acknowledgements. Ministry of Science, Technology and Development of the Republic of Serbia (Contract N 1951) supported our work. One of the authors (I. Vince) acknowledges the support of the "Arany János Közalpítvány".

[1] *Booth A. J., Shallis M. J., Wells M.* Hyperfine Structure Measurements for Lines of Astrophysical Interest in Mn I // Mon. Notic. Roy. Astron. Soc.–1983.–**205**.–P. 191.

[2] *Delbouille L., Roland G., Neven L.* Photometric Atlas of the Solar Spectrum from λ 3000 to λ 10000.– Liege: Institute d'Astrophysique de l'Universite de Liege, 1973.

[3] *Livingston W.* Observations of Solar Spectral Irradiance Variations at Visible Wavelengths // Proc. on the Solar Electromagnetic Radiation Study for Solar Cycle 22, US Department of Commerce / Ed. R. F. Donnelly.–1992.–P. 11.

[4] *Vince I., Erkapić S.* On the Chromospheric Behaviour of Photospheric Mn I 539.47 nm Spectral Line // Int. Astron. Union Symp.–1998.–N 185.–P.469.

[5] *Doyle J. G., Jevremović D., Short C. I., et al.* Solar Mn I 5432/5395 A Line Formation Explained // Astron. and Astrophys.–2001.–**369**.–P. L13.

[6] *Erkapić S., Vince I.* Influence of Photospheric Parameters on Solar Spectral Line Parameters // Publ. Obs. Astron. Belgrade.–1995.–**49**.–P. 159.

[7] *Vince I., Gopasyuk O., Gopasyuk S., Vince O.* The Observed Mn I 539.47nm Line Profiles in Solar Plages // SPIG 20th / Eds Z. Petrović, M. Kuraica, G. Malović.–Belgrade: Institute of Physics, 2000.– P. 507.

[8] *Vitas N., Vince I., Vince O.* The Hyperfine Profile of the Mn I 539.47 nm Solar Spectral Line // Solar Researches in the South-Eastern European Countries: Present and Perspectives: Proc. Regional Meet. on Solar Physics / Eds G. Maris, M. Messerotti.–Éditions de l'Académie Roumaine, 2002.–P. 147–151.