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INFLUENCE OF PHOTOSPHERIC PARAMETERS ON SOLAR SPECTRAL LINE PARAMETERS

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Abstract. Spectral line profiles for 31 solar spectral line from the Belgrade observational program have been synthesized previously. We gave a short review on the sensitivity of those spectral lines examining the behaviour of some line profile parameters (equivalent width, central residual flux, full-half width) induced by independent variations of temperature, gas pressure and electron density gradient in the atmosphere model. The results displayed as gradients of line profile parameters have shown high sensitivity of spectral lines to the temperature and a negligible sensitivity to the pressure and electron density change.

1. INTRODUCTION

A long-term observational program of 31 selected solar spectral line profiles has been carried out at Belgrade Observatory since 1987 (Vince *et al.*,1988). The so far obtained results have shown that long-term changes of spectral lines are present and related probably to solar activity (Skuljan *et al.*, 1992). In several previous papers (Erkapić and Vince, 1993a, 1993b, 1994) we examined theoretically the influence of photospheric physical parameters on the spectral line profiles from our observational program. In this paper we present the averaged results in comparative form.

2. METHOD OF CALCULATIONS

Our analysis is based on the synthetic spectral line profiles referring to integrated solar flux radiation obtained with OSLO-HARVARD model of solar atmosphere (Maltby *et al.*, 1986) under the assumption of LTE.

By independent variations of temperature, gas pressure and electron density gradient in the atmosphere model up to $\breve{a} = \pm 5\%$ we calculated relative changes of different line profile parameters. Parameters were normalized to their unchanged model values. Among all parameters equivalent width, central residual flux and full-half width were of main interest. Three spectral lines were excluded from further analysis for all photospheric parameters and the CrI 529.83 line for temperature changes because the non-LTE affects them prominently.

3. RESULTS AND DISCUSSION

In Table I we give the results of our calculations as gradients of equivalent width, central residual flux and full-half width ($\delta EW_n/\delta\breve{a}$, $\delta F_{cn}/\delta\breve{a}$, $\delta FW_n/\delta\breve{a}$) for the positive change of temperature, gas pressure and electron density gradient (T, P_g, N_e). In the case of negative change of photospheric parameters we have the opposite behaviour.

TABLE I

Gradients of equivalent width, central residual flux and full-half width of the synthesized line profiles for the change of temperature, gas pressure and electron density gradient in the OH model

	$\delta EQ_n/\delta\breve{a}$ (10^{-3}/ %)			$\delta F_{cn}/\delta\breve{a}$ (10^{-3}/ %)			$\delta FW_n/\delta\breve{a}$ (10^{-3}/ %)		
λ (nm)	T	P_g	N_e	T	P_g	N_e	T	P_g	N_e
CaI 526.17	-22.98	-0.61	-0.93	21.46	2.71	2.34	-10.87	0.38	0.19
CaI 558.20	-22.39	-0.73	-1.10	18.91	2.63	2.31	-10.43	0.35	0.13
CaI 560.13	-22.23	-0.73	-1.12	18.62	2.64	2.33	-10.38	0.34	0.12
CrI 529.67	-31.55	-0.10	-0.62	25.51	3.18	2.86	-16.76	0.51	0.28
CrI 529.74	-30.08	-0.49	-0.44	23.82	2.36	2.05	-12.48	0.41	0.36
CrI 529.80	-31.56	-0.49	-0.40	25.78	2.02	1.72	-12.21	0.45	0.41
CrI 529.83	–	0.08	-0.63	–	3.57	3.24	–	0.55	0.24
FeI 519.79	-37.81	0.31	0.08	23.16	0.13	0.13	-5.60	0.29	0.17
FeI 519.87	-28.14	0.34	-0.79	14.54	3.89	3.68	-15.27	0.58	0.08
FeI 525.02	-38.70	-0.25	-0.39	45.03	1.78	1.74	-18.07	0.57	0.47
FeI 527.32	-29.17	1.08	-0.81	10.11	3.98	3.79	-14.72	0.85	-0.07
FeI 527.34	-24.45	-0.21	-0.94	18.53	3.33	3.18	-12.72	0.37	0.06
FeI 530.74	-32.49	-0.33	-0.63	33.64	2.00	1.96	-14.63	0.50	0.34
FeI 539.83	-20.18	-0.49	-1.16	13.93	2.46	2.40	-8.29	0.35	0.03
FeI 557.61	-26.73	0.71	-1.05	10.09	3.56	3.44	-12.85	0.70	-0.14
MnI 539.47	-101.33	2.32	2.27	51.50	-1.14	-1.14	-8.92	0.30	0.28
MnI 543.25	-120.92	3.08	2.99	43.12	-1.10	-1.08	-8.92	0.30	0.28
NaI 538.26	-25.52	-1.10	-0.61	17.37	2.41	2.08	-9.77	0.35	0.40
NaI 568.82	-24.20	-1.09	-0.61	15.25	2.85	2.51	-9.52	0.45	0.25
NiI 519.72	-43.78	1.43	0.54	14.10	-0.41	-0.19	-2.43	0.11	0.01
CI 538.03	105.31	-5.31	-10.55	-19.99	0.99	1.97	11.65	-0.63	-1.24
CrII 523.73	39.43	-1.71	-5.66	-24.00	0.13	3.48	8.68	-0.17	-1.10
CrII 530.59	55.54	-0.66	-7.07	-14.74	0.14	1.84	4.24	-0.20	-0.63
FeII 519.76	20.36	-2.64	-4.77	-7.89	5.91	4.85	13.97	0.24	-1.58
FeII 542.53	30.03	-2.02	-5.01	-23.56	2.31	4.21	10.24	0.19	-1.34
ScII 523.98	15.16	-0.11	-4.40	-9.78	0.33	3.19	4.38	0.22	-0.75
ScII 552.68	12.95	-1.38	-3.92	-9.72	3.06	4.24	7.23	0.21	-1.34
TiII 533.68	11.96	-1.17	-3.79	-9.61	2.63	4.22	6.33	0.22	-1.14

Our calculations were done for positive and negative change of photospheric gradients separately. The obtained values of normalized line profile parameters and appropriate gradients show behaviour that is not quite linear. Here we neglect that fact and Table uppercase i contains gradients averaged over positive and negative changes of photospheric parameters. The behavior of line profile parameters remain unchanged.

Spectral lines are most sensitive to the temperature changes with equivalent width as the most sensitive parameter. The full-half width is the least sensitive parameter for almost all spectral lines. Compared to that the sensitivity of these lines to the pressure and electron density changes is negligible with central residual flux as the most sensitive parameter for almost all lines. (Gradient value $\delta A_n/\delta\breve{a} = 0.001/\%$ is equal to the change of 0.1% of the line profile parameter A_n).

According to the general behavior of the line parameters with the change of temperature, we can divide our spectral lines into two groups. First group, consisted of all single-ionized atom lines and the CI 538.03 neutral atom line, have increasing EW_n and FW_n and decreasing F_{cn} with positive change of temperatu-e gradient. The rest of neutral atom lines belong to the second group that shows the opposite behaviour. This can be explained on the basis of simplified line formation theory (Gray, 1976), according to which the gradient of equivalent width depends on excitation energy of the transition lower level for the first group of lines and on the difference of excitation and ionization energy for the second group.

The change of central residual flux hides in itself mixed behaviour of continuum and central absolute flux. Continuum flux has approximately the same gradient value over the whole wavelength ($\lambda\lambda 519 - -569$nm) interval slightly decreasing with increasing wavelength for positive temperature change. Continuum flux gradient is greater than central absolute flux gradient for the first group of lines and less for the second group of lines. Low value of $\delta F_{cn}/\delta\breve{a}$ always implies that continuum and central absolute flux gradients have similar values. Great value of $\delta F_{cn}/\delta\breve{a}$ implies great difference between continuum and central absolute flux gradient. In the second group of lines the main reason for decreasing intensity with increasing temperature is ionization of absorbing atoms, and in the first the increase in the hydrogen ionization.

Among all spectral lines the most sensitive are two manganese lines and the CI 538.03 line. The neutral carbon line shows high sensitivity to the temperature change because it has the highest lower level excitation energy ($E_l = 7.68eV$). Also it is formed deep in the photosphere (almost coincident with the con‘inuum), where temperature gradient is relatively high. Two manganese lines owe their high sensitivity to the large difference of excitation and ionization energy ($E_l - E_i = 7.44eV$).

In the case of pressure and electron density changes most of the spectral lines have negligible sensitivity, but the prevailing behaviour is decreasing equivalent width with positive change of pressure and electron density. This can be explained also according to the same simplified theory of Gray, that claims that all single-ionized and neutral atom lines from the elements, that are mainly in that same stage of ionization in the solar atmosphere, decrease in intensity with positive change of pressure gradient and electron density gradient. This is mainly due to increasing opacity in continuum flux. This is valid for our single-ionized spectral lines and the CI 538.03 line. According to the same theory all neutral lines from the elements that are mainly ionized in the solar atmosphere should be insensitive to the pressure (gas and electron) change. Judging from the values of gradient of line profile parameters in Table I this is also true for most of our neutral lines. However, there are several number of exceptions.

Two manganese lines and nickel line have significant positive changes of EW_n with increasing pressure and electron density of the magnitude similar to that of single-ionized atom lines. These three lines represent the only cases where the continuum flux gradient is less than central absolute flux gradient. The same remarks concerning relation of continuum and central absolute flux gradient with temperature change are valid here also.

Clear graphical dependence between behaviour of line profile parameters and atomic parameters can be seen only for temperature changes between the gradients of EW_n and the excitation energy of the lower level in the transition : the higher the excitation level, the larger the $\delta EW_n/\delta \breve{a}$. Every other combination of line profile parameter gradient and other atomic parameters (ionization energy, effective principal quantum number, $\log g_l f_{lu}$ *etc.*) shows spreading of data and inconclusive picture. This means that all atomic parameters are working simultaneously.

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