DIAGNOSTICS OF LOCAL MAGNETIC FIELDS IN SOLAR FLARES USING FeI 5383 AND MgI 5528 LINES

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ABSTRACT. Main purpose of the present work is to estimate upper limit of the local magnetic field strength in solar flares using spectral lines FeI 5383 and MgI 5528. These lines like FeI 5233 have low Landé factors (1.12 and 1.00, respectively) and relatively large spectral width (0.2–0.3 Å). On this account, even in a case of very strong fields (3-4 kG) they must show the simple picture of the Zeeman splitting, with parallel to each other the bisectors of profiles I+V and I – V. In actual fact, another picture was found for nine flares: bisectors of these lines have maximums of splitting on certain distances from line center, what must not be in the homogeneous magnetic field. In particular, both lines have peak of bisector splitting on distance 150–170 mÅ from line center. If we assume the Zeeman nature of named peculiarities then necessary fields are 11.2 kG for FeI 5383 and 10.5-11.2 kG for MgI 5528. Likely, this agreement of field values is a new argument to reality of such very strong magnetic fields in flares.

Keywords: Sun: magnetic fields – solar flares: spatially unresolved structures – spectral diagnostics: local strength

1. Introduction

At present it is not clear what is the maximum possible magnetic field strength in the photosphere. More recently, van Noort et al. (2013) analysed SOT/SP observations of a sunspot penumbra in Fe I 6301.5 and 6302.5 Å. lines and found indications of magnetic field of around 7 kG. Lozitsky (2009, 2014) considered the fine structure of Zeeman splitting in Fe I lines with very small Landé factors (about 0.01) and found direct indications that magnetic field up to ~10^4–10^5 G might be present in the solar flares. Likely, such lines allow to estimate the order of field strength – no exact field values. For the named purpose, it is necessary to use the spectral lines with larger magnetic sensitivity. Lozitsky and Staude (2008) had used FeI 5233 line (g_{eff} = 1.26) and found narrow extremums of bisector splitting of $I \pm V$ profiles which indicate the unacceptability of weak field approximation in case of two solar flares. An alternative is that such peculiarities present the observational evidences of multi-component magnetic field structures with strengths 1.3–1.5, 3.9–4.0 and 7.4–7.8 kG at level of middle photosphere in the spatially unresolved magnetic elements.

From this point of view, it is interesting to use another non-blended spectral lines like FeI 5233 to exclude possible instrumental effects (e.g. narrow molecular blends). This is main reason why we use FeI 5383 and MgI 5528 in the present work.

2. Observations and Selected Lines

We have used observational data obtained with the Echelle spectrograph of horizontal solar telescope of the Astronomical Observatory of Taras Shevchenko National University of Kyiv (Kurochka et al., 1980). In this short paper, we do not point list of observed flares; some data on these flares are presented in Table 1 in article by Lozitsky (2014). More exactly, the following nine flares were studied from this Table: Nos. 1,2,4,5,6,7,8,9 and 10. These flares had importance from C5 to X1.4. It is useful to remember, in article by Lozitsky (2014) the FeI 5123.7 and 5233 lines were studied (no FeI 5383 and MgI 5528). In all nine cases the spectra were taken in locations with highest Hα intensities. All these locations were outside sunspot umbras, where the observed Zeeman splittings measured by $I \pm V$ 'centers of gravity' method were found to be in the range about several hundred of gauss.

Some parameters of two selected spectral lines are presented in Table 1 below.

Table 1: List of selected spectral lines

Wave-length (Å)	Element and multiplet number	Equivalent width *W* (mÅ)	Excitation potential (eV)	Effective Landé factor
5383.380	FeI-1146	204	4.31	1.124
5528.418	MgI-9	293	4.34	1.000

According to Moore et al. (1966), these lines do not have intensive spectral bleds in range ±300mÅ from line center. In particular, first line has nearest blends 5383.07 and 5383.766 Å with equivalent width *W* =1 an 2 mÅ, respectively; second line has nearest blends 5528.086 and 5528.905 Å (*W* = 3 an 22 mÅ, respectively).

3. Method and Results

We found that in all flares both lines have nearly normal Fraunhofer profiles without emission peaks in their cores. However, their observed Zeeman splitting was found, in general, some different on different distances from line center (Fig. 1). Obviously, this can reflect two effects simultaneously: a) possible presence of Zeeman perturbations and b) noise effects. As for Zeeman perturbations, they should occur at the same distances from the line center for different flares if magnetic field strengths in different flares are the same. As to noise effects, they should be irregular, and their influence is expected to be decreasing if we average large volume of observational data.

Analysis of bisector splitting in both lines was made similarly to described by Lozitsky (2014). As first step, the bisector splitting function (BSF) was found and its linear trend (see, for instance, Fig. 2). Then we find the standard deviation of the local values of BSF from the linear trend (SDFLT) and averaged them over all nine flares. The noise effects were estimated by telluric line H_2O 5919.644 Å observed in the case of big air mass (≈20). Fig. 3 presents the example of comparison of SDFLT for MgI 5528 line for nine flares (solid line) and errors of measurements (dashed). One can see that for distances from line center $\Delta\lambda < 120$ mÅ , perturbations of bisectors in flares correspond to expected errors, but in range $120 < \Delta\lambda < 230$ mÅ observed effect in flares exceeds the error level. Theoretically, in a case of quasi-homogeneous and moderate magnetic field (< 1 kG), standard deviation from linear trend should be similar to distribution for errors of measurements.

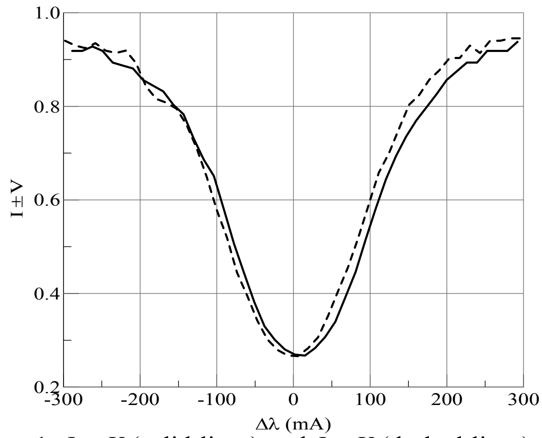

Figure 1: $I + V$ (solid lines) and $I - V$ (dashed lines) profiles of Fe I 5383 observed in 1B flare of 14 July 2000.

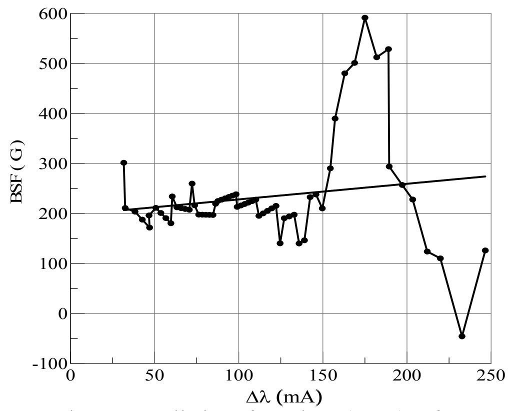

Figure 2: Bisector splitting function (BSF) of $I \pm V$ profiles for 1B flare of 14 July 2000.

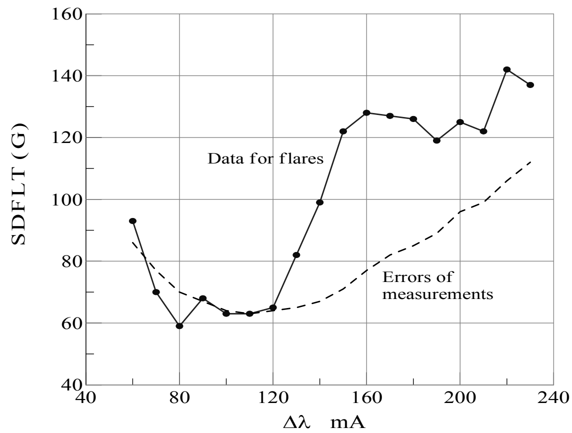

Figure 3: Comparison of SDFLT for MgI 5528 line for nine flares (solid line) and errors of measurements (dashed line).

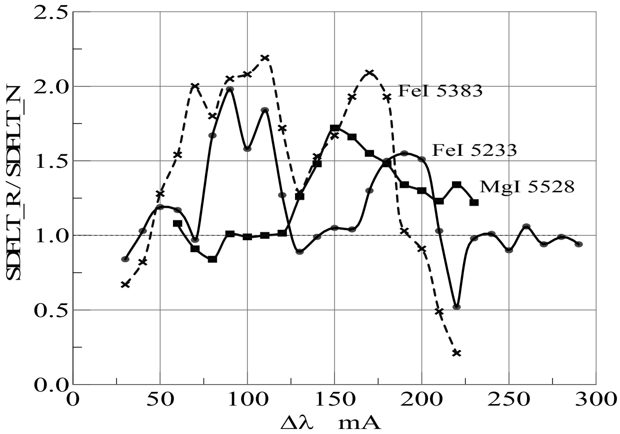

Figure 4: Flares-to-noise ratio for averaged SDFLT.

Flares-to-noise ratio for averaged SDFLT for both lines together with similar data for 5233 according to Lozitsky (2014) is given on Fig. 4. One can see that both FeI lines demonstrate similar distributions with two peaks on about 70-120 mÅ and 170–190 mÅ. MgI line has one single peak on 150–160 mÅ. It is interesting to note that second peaks (placed on 150–190 mÅ) correspond to approximately the same magnetic field strengths by all lines, namely 11.8 kG and 11.2 kG by FeI 5233 and 5383, and 10.5-11.2 kG by MgI 5528. Likely, this agreement is a new argument to reality of such very strong magnetic fields in flares.

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