SMALL-SCALE MAGNETIC FLUX TUBE DIAGNOSTICS IN A SOLAR FLARE

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Abstract. $I \pm V$ profiles of the Fe I 5247 and 5250 lines in the 2B flare of June 16, 1989 have been analyzed. A bright knot of the flare outside the sunspot where the central intensity of Hα reached a peak value of 1.4 (relative to the continuum) has been explored. The Fe I 5250/Fe I 5247 magnetic line ratio based on the Stokes V peak separations of these lines at five evolutionary phases of the flare (including the start of the flare, the flash phase, the peak and 16 min after the peak) has been analyzed. It was found that the Stokes V peak separation for the Fe I 5250 line was systematically larger than that of the Fe I 5247 line. This is evidence for the presence in the flare of small-scale flux tubes with kG fields. The flux tube magnetic field strength was about 1.1 kG at the start of the flare and during the flash phase, 1.55 kG during the peak, and 1.38 kG 16 min after the peak. The filling factor, α, appears to decrease monotonically during the flare.

1. Introduction

Solar flares are attractive but uncomfortable objects for magnetic field measurements. The attractiveness is connected with the circumstance that a major transformation of magnetic energy into other different kinds of energy in the solar atmosphere can be expected. Some theories for this transformation (e.g., Heyvaerts, Priest, and Rust, 1977; Somov and Syrovatskij, 1979; Hood and Priest, 1980; Mogilevskij, 1980) have been tried, but the observational data have not yet allowed investigators to decide between them. Even the basic effect of a magnetic energy reduction during the flare has not been recorded in all flares. The first positive results were obtained by Severny (1960). He showed that in a large flare the magnetic flux of the active region really decreased, such that the magnetic energy reduction approximately corresponded to the energy of the optical flare (Mayfield and Chapman, 1972; Rust, 1973). However, for weak flares the magnetic field changes often do not differ from the evolution of the active region (Ribes, 1969; Rust, 1976). Recent magnetic field measurements of the 3B/X5.7 flare in the infrared Mg I 12.3 μm line using a Fourier spectrometer also did not reveal any significant (more than 100 G) changes of the magnetic field strength (Deming *et al.*, 1990).

On the other hand, the observational claims for the existence of a magnetic energy reduction during solar flares should be examined. Solar magnetograph data of the Babcock (1953) type are a main concern. Instead of directly measuring the Zeeman splitting, $\Delta\lambda_H$, these instruments determine the product $\Delta\lambda_H(\partial I_\lambda/\partial\lambda)$, where $\partial I_\lambda/\partial\lambda$ is the intensity gradient of the profile of the magneto-sensitive spectral line. During the flare the $\partial I_\lambda/\partial\lambda$ parameter of some lines (e.g., the Fe I

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5324.2 Å line) has been shown to change substantially. Therefore magnetograph data are unreliable (Lozitskaya and Lozitskij, 1982a; Moore *et al.*, 1984). For this reason a Fourier transform spectrometer (Brault, 1978) should be used for direct measurements of the magnetic field of the flare rather than a magnetograph. Traditional spectral observations using a polarized-light analyzer are also suitable for this purpose. Though such data are inferior to those of a Fourier transform spectrometer in sensitivity and precision, they allow faster recording of a wide spectral range, which is of importance for flares.

The first observations of flares with a circular polarization analyzer have been made by Abdusamatov (1971) and Koval' (1974). The field strength was found to reach 300 G in Hα and about 1 kG in the D_1 and D_2 Na I lines. Kilogauss (B = 1–3 kG) magnetic fields have been detected with Fe I lines (Lozitskaya and Lozitskij, 1982a; Lozitskaya *et al.*, 1982).

Such strong magnetic fields in the flares were confirmed later by Koval' and Stepanyan (1983). Evidence for a small-scale inhomogeneity of the flare field has been obtained (Lozitskaya and Lozitskij, 1988; Lozitskij, 1989). In particular, a two-component flare emission in metal lines has been found. All flare emission could easily be divided into polarized and unpolarized components. A relation between equivalent emission width and measured magnetic field has indicated the existence of many sub-telescopic flux tubes in the flare, which rapidly expand with height. The magnetic field gradient $\partial B/\partial h$ in such flux tubes was found to be about -10 G km^{-1} (Soloviev and Lozitskij, 1986).

The magnetic field strength modulus B can be determined when the Zeeman splitting, $\Delta\lambda_H$, is larger than the half-width, $\Delta\lambda_{1/2}$, of each σ-component. When $\Delta\lambda_H \ll \Delta\lambda_{1/2}$ and the field is homogeneous, then the longitudinal magnetic field $B_{\parallel}$ can be determined. However, when the field is intermittent (flux tubes), then $\alpha B_{\parallel}$ is obtained instead. α is the magnetic filling factor (Howard and Stenflo, 1972). To eliminate dependence on α and find the field modulus B in the small-scale structures, special techniques need to be used.

The best of such methods is the line-ratio technique (Stenflo, 1973), which uses the ratio between the Stokes V signals recorded simultaneously in two spectral lines of the same multiplet and formation level but with different Landé factors. This method has been applied to flares by Frazier and Stenflo (1978), who found possible differences between the physical parameters of the flux tubes inside and outside the flare regions. In similar work by Venglinskij *et al.* (1990) the flux tube field strength was found to be about 0.5 kG larger in the flash-phase than in solar faculae.

In the present work we also use the line-ratio technique for flux tube diagnostics in a flare. Our results are based on analysis of Echelle Zeeman spectrograms obtained at different times in a 2B flare. The treatment is basically the same as that of Stenflo, Solanki, and Harvey (1987) for Fourier-transform-spectrometer measurements.

2. Observational Data

The observational data were obtained with the Echelle spectrograph of the horizontal solar telescope of the Kiev University Observatory (Kurochka *et al.*, 1980). This instrument can record the solar spectrum simultaneously from 3800 to 6600 Å with a dispersion from 0.4 Å mm^{-1} in the violet to 0.8 Å mm^{-1} in the red during an exposure of a few seconds. The total half-width of the instrument profile is 30 mÅ in the green and 50 mÅ in the red (Lozitskaya and Lozitskij, 1982b). Since the half-width of most narrow solar lines is about 0.1 Å, our spectra are resolved although slightly broadened. For example, Fe I 5250 Å is broadened by about 5%. To accurately determine the intrinsic line profiles, we basically use the Gurtovenko (1966) technique to remove the instrumental broadening.

To obtain solar spectra in orthogonal circular polarizations, i.e., Zeeman spectrograms, a quarter-wave plate was placed in front of the spectrograph entrance slit, while an Iceland spar prism splitter was behind the slit. In this case total (100%) modulation of the circular polarization occurs over the whole green region, while in the violet and red regions the modulation is about 95–97% (Baranovskij, Lozitskaya, and Lozitskij, 1991).

We began to obtain Echelle Zeeman spectrograms of flares in 1981 during the International FBS/SERF Program. In 1981–1991 spectra of about 40 flares were recorded. For each flare we tried to begin the series of spectrograms as early from the flare start as possible, but only for two or three flares did our observations really cover practically all evolutionary phases. The strongest of these flares, of June 16, 1989, is analyzed in the present work.

The 2B flare had coordinates 17° S and 04° E. It began at 5 h 12 min UT, reached its peak at 5 h 30 min and was practically over at 6 h 30 min. Thirteen Zeeman spectrograms were obtained, but only 5 of them might refer to the same region of the Sun. These 5 are examined here.

The spectra have been recorded on ORWO WP3 plates (exposures from 2.5 to 10 s). The effective spatial resolution of the spectrograms is mainly determined by the image motions and is about 3 arc sec. A microphotometer MF-4 was used to scan the spectrograms.

3. Line Profiles

The magnetosensitive Fe I 5247.1 and 5250.2 Å lines with Landé factor $g = 2.0$ and 3.0 have been investigated. These lines have practically the same heights of formation and temperature sensitivity, which is particularly important when the line-ratio technique is being used (Stenflo, 1973).

The data obtained refer to the photosphere outside sunspots, where the bright knot of the flare appeared. At maximum brightness at this location the core of Hα reached an intensity of 1.4 in units of the continuum intensity. According to Švestka (1976) this intensity is representative of a major flare.

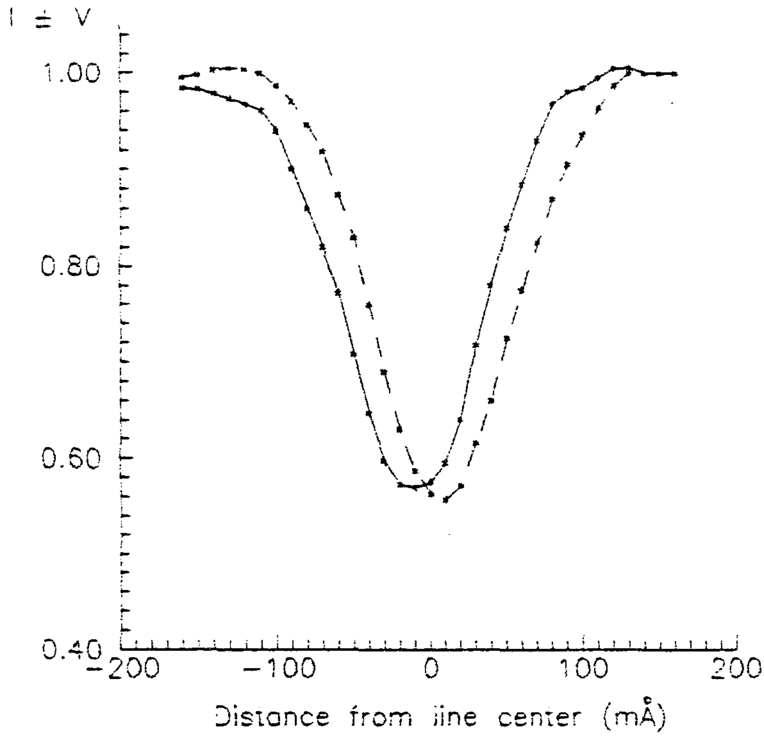

Fig. 1. Observed $I \pm V$ line profiles for Fe I 5250 in the flare of June 16, 1989, at 5 h 22 min (flash phase).

During all phases of the flare the observed $I \pm V$ profiles of the Fe I 5247 and 5250 lines had no emission peaks in their cores (Figure 1). The central residual intensity of the Fe I 5250 line was in the range 0.5–0.6, which is similar to the value of Harvey and Livingston (1969) for a magnetic region outside sunspots and flares.

Significant broadening of the Fe I line profiles has been detected (Table I). To analyze this broadening we use the following parameters: $\Delta\lambda_{1/2,I}$, the full half-width of the Stokes I profile and, $\Delta\lambda_V$, the Stokes V peak separation. As can be seen from Table I, in the beginning of the flare the Fe I 5247 line has a half-width of about 90 mÅ, the Fe I 5250 line 110 mÅ. During the peak the corresponding values are 103 and 120 mÅ. For comparison, in the quiet atmosphere the half-widths of both lines are the same and equal to 84 mÅ (Delbouille, Roland, and Neven, 1973).

The Stokes V peak separation, $\Delta\lambda_V$, was 90 mÅ at flare maximum for Fe I 5247 and 122 mÅ for Fe I 5250. These values are appreciably larger than 80 and 100 mÅ found by Stenflo *et al.* (1987) in solar faculae at the center of the disk. If the magnetic field were weak and the lines were formed in the undisturbed atmosphere, then we would have $\Delta\lambda_V = 72$ mÅ for both lines.

TABLE I
Full half-widths and Stokes V peak separations

Time (UT) h min	Phase of flare	$\Delta\lambda_{1/2,I}$ (mÅ) Fe I 5247	$\Delta\lambda_{1/2,I}$ (mÅ) Fe I 5250	$\Delta\lambda_V$ (mÅ) Fe I 5247	$\Delta\lambda_V$ (mÅ) Fe I 5250
5 15	start	88	113	81	94
5 22	flash phase	98	103	84	98
5 29.5	peak	103	121	90	122
5 31.5	peak	103	120	92	122
5 46	post-peak surge	100	113	90	112

TABLE II
Average longitudinal field strengths and line ratios

Time (UT) h min	$B_\parallel^*$ Fe I 5247	$B_\parallel^*$ Fe I 5250	$\frac{2}{3}\frac{V_m(5250)}{V_m(5247)}$	$\frac{\Delta\lambda_V(5250)}{\Delta\lambda_V(5247)}$
5 15	460	420	0.66	1.16
5 22	290	290	0.70	1.17
5 29.5	460	460	0.78	1.36
5 31.5	460	360	0.65	1.33
5 46	260	260	0.70	1.24

4. Diagnostic Parameters

To diagnose the magnetic field, let us first consider $B_\parallel^*$, the longitudinal magnetic field strength averaged over the resolution element. It may be measured as the relative shift of the centers of gravity of the $I + V$ and $I - V$ profiles and equals

$$B_\parallel^* = \int_{\lambda_1}^{\lambda_2} \lambda V \, d\lambda \Big/ \left(4.67 \times 10^{-13} g \lambda^2 \int_{\lambda_1}^{\lambda_2} I \, d\lambda\right) . \quad (1)$$

$B_\parallel^*$ is in G and λ in Å.

The physical meaning of this parameter is close to longitudinal magnetic flux, in particular when lines with a small Landé factor and low temperature sensitivity are used (Howard and Stenflo, 1972). If the magnetic flux is intermittent in the form of flux tubes with field strength B and filling factor α, then $B_\parallel^* = \alpha B \cos\gamma$, where γ is the angle between the field line and the line of sight.

As may be seen in Table II, the flare region observed was in an area with average longitudinal fields of the moderate strength 260–460 G (with error bars ±75 G for

Fe I 5247 and ±50 G for Fe I 5250). Almost at all times during the flare, $B_{\parallel}^{*}$ is the same in both lines. This reflects the fact that equivalent Stokes V separations are in general proportional to the Landé factors of the lines.

Another Stokes V characteristic, its amplitude V_m, does not exhibit such a proportionality. As seen from Table II, the ratio $2V_m(5250)/3V_m(5247)$ is substantially smaller than unity. If B were $\leq$100 G and the line profiles were similar to those from the Delbouille *et al.* (1973) atlas, $2V_m(5250)/3V_m(5247)$ would be 0.97, since the Fe I 5250 line profile is weaker than that of Fe I 5247. The circumstance that during the flare this ratio differs more from unity indicates the existence of kG fields, in which the Zeeman components are partly or fully split. In particular, if the Zeeman components of both lines were fully split, then $V_m(5250) \approx V_m(5247)$ and the mentioned ratio would be about $\frac{2}{3}$.

Stenflo *et al.* (1987) have measured $2V_m(5250)/3V_m(5247) \approx 0.75$ in faculae at the center of the solar disk. As at certain phases of the flare this ratio was decreased to 0.65–0.70, the corresponding magnetic fields in the flare should be stronger than those in faculae.

This is also confirmed by the ratios of the Stokes V peak separations listed in column $(\Delta\lambda_V(5250)/\Delta\lambda_V(5247))$ in Table II. In the beginning of the flare and during the flash phase, this ratio was 1.16–1.17 and coincided with the value 1.20 obtained by Stenflo *et al.* (1987) for faculae within the error limits ($\sim$ ±0.05). However, during the peak phase (5 h 29.5 min) the ratio was as high as 1.36, while after the peak phase (5 h 46 min) it was 1.24.

5. The Model

To draw more quantitative conclusions about the field strength in the flare, let us consider a simple model according to which the small-scale flux tubes with field strength B are embedded in a non-magnetic ($B = 0$) plasma. In this case the observed line profile $I_0(\lambda)$ can be obtained from the known flux tube profile $I_f(\lambda)$ and the 'background' profile $I_b(\lambda)$ via the formula

$$I_0(\lambda) = \alpha I_f(\lambda) + (1 - \alpha) I_b(\lambda) , \quad (2)$$

where α is the filling factor.

Then for the Stokes V parameter

$$V_0(\lambda) = \alpha V_f(\lambda) , \quad (3)$$

since it is assumed that $V_b(\lambda) = 0$. Our observed spectra are represented by $I_0(\lambda) \pm V_0(\lambda)$ obtained from Equations (2) and (3).

According to this simple model the Stokes V shape depends on the flux tube magnetic field, whereas Stokes I also depends on the physical characteristics of the surroundings. In particular, the Stokes V peak separation, $\Delta\lambda_V$, is a measure of the field strength B in the flux tube. If the average magnetic field $B_{\parallel}^{*}$ is evaluated from Equation (1) then the filling factor α can also be obtained by

$$\alpha \approx B^*_{\|}/B \tag{4}$$

(assuming $\gamma = 0$; cf. Section 7.3).

This relation is approximate because $B^*_{\|}$ depends not only on the average magnetic flux but also on 'magnetic saturation' and temperature line weakening inside the flux tubes (Howard and Stenflo, 1972). To reduce the effect of magnetic saturation we use

$$\alpha \approx B^*_{\|}(5247)/B \, . \tag{5}$$

The calculations on the basis of this model have been made with Unno's (1956) theory. The parameters of the theory are: B is the field strength; γ, angle of inclination with respect to the line of sight; $\Delta\lambda_{\mathrm{D}}$, Doppler width of the spectral line; η_0, relative absorption coefficient.

Figure 2 shows the change in the relative Stokes V peak separation, $\Delta\lambda_V/\Delta\lambda_{\mathrm{D}}$, with increasing relative Zeeman splitting, $v_H = \Delta\lambda_H/\Delta\lambda_{\mathrm{D}}$. When $\eta_0 = 0.5$ and $v_H < 0.5$, then $\Delta\lambda_V/\Delta\lambda_{\mathrm{D}} \approx$ const., whereas when $v_H > 1.5$, then $\Delta\lambda_V/\Delta\lambda_{\mathrm{D}} \approx 2v_H$. For $0.5 < v_H < 1.5$ the ratio $\Delta\lambda_H/\Delta\lambda_{\mathrm{D}}$ is a nonlinear function of v_H. In this interval the field strength, B, may not be determinated directly from the splitting, $\Delta\lambda_V$, but from a comparative study of the splittings of lines with different Landé factors.

Corresponding determinations of the value of B is difficult, because $\Delta\lambda_V/\Delta\lambda_{\mathrm{D}}$ depends not only on the parameter v_H but also on γ (Figure 2). The latter dependence becomes stronger when η_0 increases. However, when $\eta_0 \ll 1$ this dependence vanishes completely, but as we will see below, this case is not relevant.

Since there are actually two unknown quantities (B and γ), additional data should be used. Such data can be the half-widths of the V-parameter peaks, $\Delta\lambda_{1/2,V}$, which depend on v_H (Figure 3). This parameter also depends on both v_H (i.e., B) and γ.

The observations can be interpreted using Figures 2 and 3 since we can always assume that $v_H(5250) = 1.5v_H(5247)$, while $B(5250) = B(5247)$ and $\gamma(5250) = \gamma(5247)$. This is the idea behind the line-ratio technique.

6. Results

Calculations for $0.1 \leq \eta_0 \leq 2.2$ have been made taking into account that in the undisturbed atmosphere the parameter η_0 is close to 2.2, while inside flux tubes it may be considerably smaller (Stenflo, 1973). Using theoretical dependencies of the kind shown in Figures 2 and 3 and observational data on $\Delta\lambda_V$ and $\Delta\lambda_{1/2,V}$ for the Fe I 5247 and Fe I 5250 lines, the values of v_H and γ have been derived.

At the start of the flare the observed value of the parameter $\Delta\lambda_{1/2,V}$ was 58 mÅ for Fe I 5247 and 67 mÅ for Fe I 5250. During the flash phase it was 59 and 75 mÅ, respectively, during the peak phase 75 and 80 mÅ, respectively. These data are averages of the red and blue Stokes V peaks.

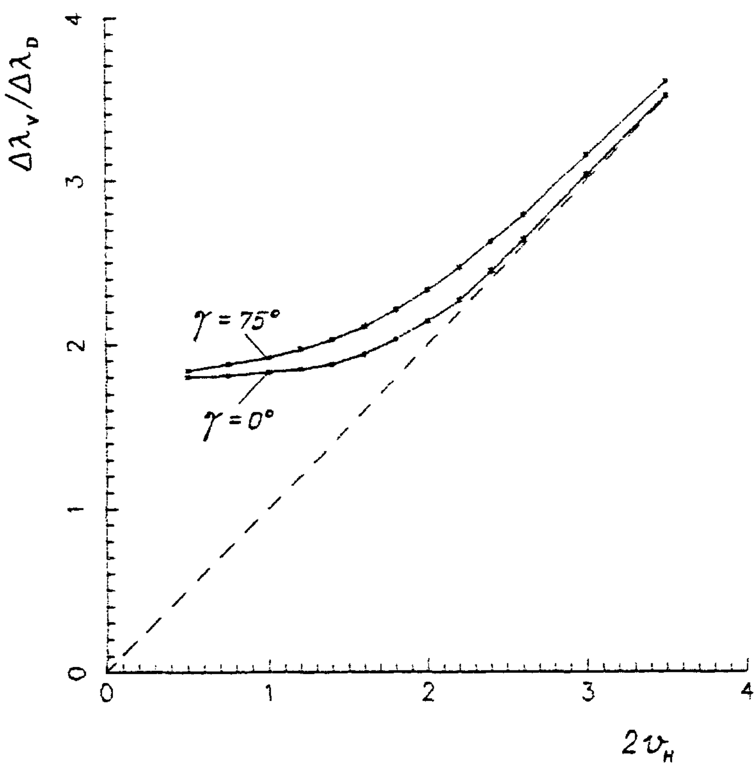

Fig. 2. Calculated Stokes V peak separation, $\Delta\lambda_V/\Delta\lambda_D$, as a function of $2v_H$, the relative Zeeman splitting, for $\eta_0 = 0.5$ (see text).

Comparison of the empirical values of $\Delta\lambda_V$ and $\Delta\lambda_{1/2,V}$ with the theoretical ones have shown that (i) very small values of η_0 are not acceptable, but values in the range $0.5 \leq \eta_0 \leq 2.2$ should be used; (ii) the value of v_H obtained from the ratio of the $\Delta\lambda_{1/2,V}$ parameter is systematically a few percent larger compared with that obtained from the ratio of the $\Delta\lambda_V$ values. For example, at time 5 h 29.5 min it was $v_H(5250) = 2.0$ for $\Delta\lambda_{1/2,V}$ and 1.9 for $\Delta\lambda_V$. At times 5 h 22 min and 5 h 46 min v_H has been evaluated from $\Delta\lambda_V$ alone, because for these spectra the ratios $\Delta\lambda_{1/2,V}(5250)/\Delta\lambda_{1/2,V}(5247)$ were 1.27 and 1.34, respectively, which could not be explained by our model; (iii) available data only allow us to determine with sufficient accuracy the parameter B, whereas for η_0 and γ only a range of possible values can be defined. In particular, it was found that for almost all flare phases $20° \leq \gamma \leq 75°$.

The empirically determined parameters B and α are given in Table III and Figure 4. They show that the field strength, B, is practically constant from the start to the flash phase of the flare. It then increases by 400–500 G and reaches in a few minutes 1.55 kG at the peak of the flare. After the peak the field strength inside

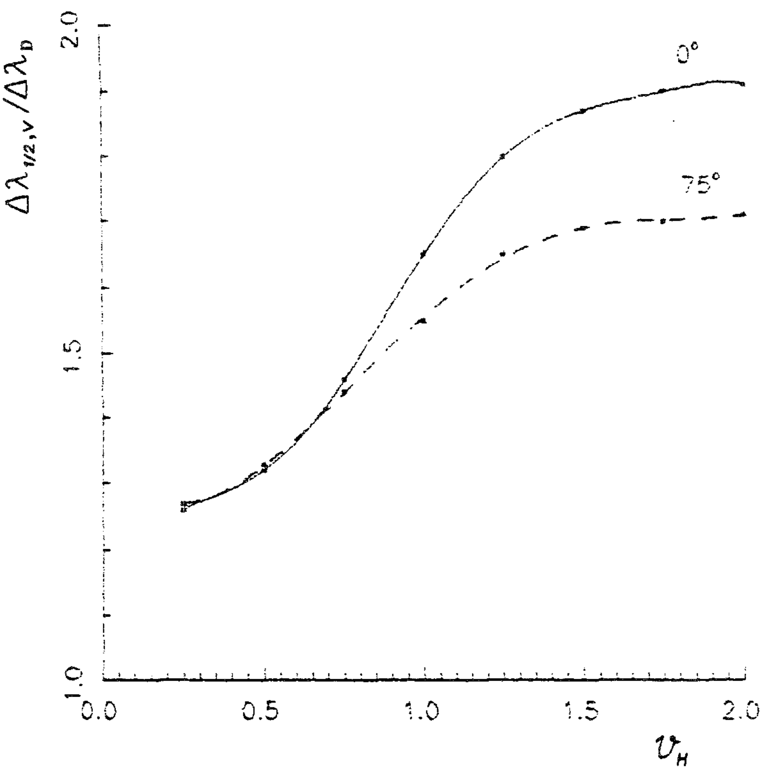

Fig. 3. Calculated relative Stokes V peak half-width, $\Delta\lambda_{1/2,V}/\Delta\lambda_D$ vs v_H for $\eta_0 = 0.5$.

TABLE III
Derived field strengths and filling factors

Time (UT) h min	B (kG)	α
5 15	1.05 ± 0.05	0.44 ± 0.07
5 22	1.15 ± 0.07	0.25 ± 0.07
5 29.5	1.55 ± 0.03	0.30 ± 0.05
5 31.5	1.53 ± 0.03	0.30 ± 0.05
5 46	1.38 ± 0.05	0.19 ± 0.06

the flux tubes decreased, although significantly slower than the increase before the peak. In contrast the filling factor, α, changed practically monotonically. During half an hour it decreased by a factor of two.

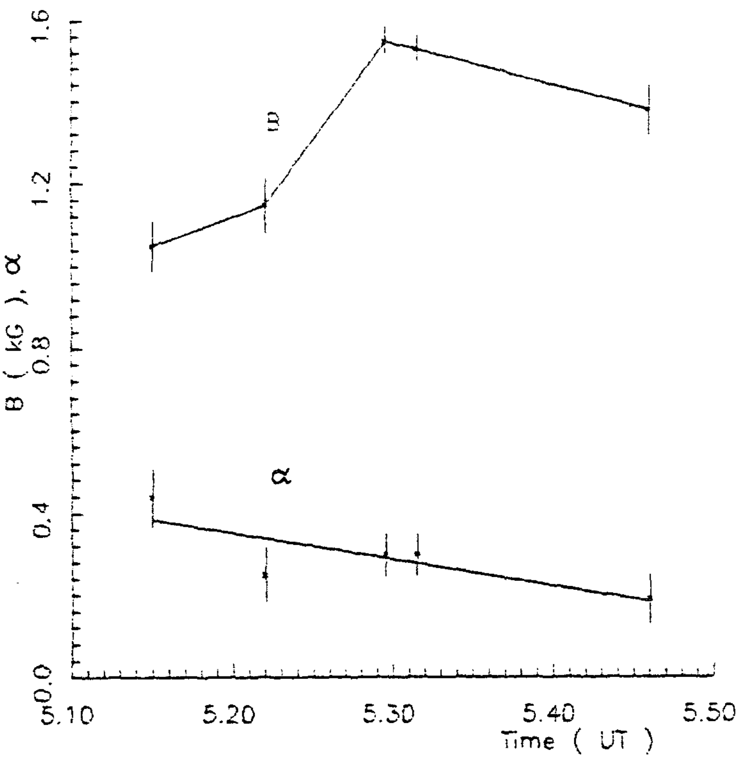

Fig. 4. Evolution of the flux tube magnetic field strength, B, and filling factor, α, during the flare.

7. Discussion

7.1. Field strength B

Of the three extracted parameters ($B_{\parallel}^{*}$, B, and α) the determination of B is the most reliable one. Note however that in reality the measured values of B are affected not only by the flux tubes but also partly by the surroundings. It has recently been shown by Stenflo (1992), on the basis of direct observations of the Zeeman splitting in the infrared (near 1.6 μm) at geometrical height zero ($\tau = 1$), that discrete magnetic elements with field strengths of few hundred G occur adjacent to the normal kG flux tubes with magnetic polarity that can be both the same and opposite to that of the adjacent magnetic component. Sometimes the presence of such elements generates 'pathological' Stokes V profiles with two 'red' and two 'blue' peaks. The existence of a strong mixed-polarity background field was suggested by Lozitskij (1986).

If a mixed-polarity background field existed in the flare of June 16, 1989, then it should influence both the half-widths of the Stokes V peaks, $\Delta\lambda_{1/2,\,V}$ and their separations $\Delta\lambda_V$. This must affect the ratio between the Fe I 5247 and Fe I 5250 lines, because they have different Landé factors.

At all times during the flare, with the exception of 5 h 22 min and 5 h 46 min, our analysis shows that the observed V-profile deformations could be reproduced by our simple model with one magnetic component. At times 5 h 22 min and 5 h 46 min the ratios $\Delta\lambda_{1/2,V}(5250)/\Delta\lambda_{1/2,V}(5247)$ were 1.27 and 1.34, respectively, which is too much according to our model. At these times (i.e., the flash phase and the emergence of the surge) the structure of the magnetic field was probably more complex so that additional broadening of the Fe I 5250 line resulted due to the larger Landé factor of this line. At 'quiet' moments of the flare the magnetic field was probably simpler.

7.2. Average Longitudinal Field, $B^*_{\parallel}$

Since the Fe I 5247 and Fe I 5250 lines are very temperature sensitive, the measured values of $B^*_{\parallel}$ in the flare may be substantially underestimated. To estimate this effect it is necessary to compare lines of different temperature sensitivity.

We have thus compared Fe I 5247 ($EP = 0.09$ eV) and Fe I 5253.5 ($g = 1.5$, $EP = 3.27$ eV) lines. It turns out that for all phases of the flare the values of $B^*_{\parallel}$ are the same within the error limits (± 75 G for Fe I 5247 and ± 100 G for Fe I 5253.5). Thus the measured values of $B^*_{\parallel}$ indicate a negligible effect of the flare at the heights of formation of Fe I 5247 and Fe I 5250. Thus the measured values of $B^*_{\parallel}$ indicate a negligible temperature effect of the flare at the heights of formation of Fe I 5247 and Fe I 5250. This conclusion agrees with the interpretation of $I \pm V$ profiles of Fe I, Fe II, Hα, and Hγ in the flare of June 8, 1989, using non-LTE programs (Baranovskij, Lozitskaya, and Lozitskij, 1991). It was found that in the lower photosphere below the flare ($\tau_c > 4 \times 10^{-2}$) the temperature and density are practically the same as in the undisturbed atmosphere.

If the measured values of $B^*_{\parallel}$ actually represented the average magnetic flux, then they could be used to estimate the magnetic energy changes during the flare. We take the field intermittence into account and use the B and α values of Table III. The magnetic energy density is thus $\alpha B^2/8\pi = BB^*_{\parallel}/8\pi$. At the start of the flare (5 h 15 min) $B^*_{\parallel} = 460$ G whereas after the peak (5 m 46 min) it is smaller by 200 G (Table II). Using the observed horizontal size of the flare knot of 5 arc sec = 3.6×10^8 cm and assuming a vertical extension of 10^8 cm, the magnetic energy change is 6×10^{28} erg. This value is similar to the energy of optical solar flares (Kurochka, Lozitskij, and Paluš, 1987).

7.3. Filling Factor α

The accuracy of filling factor measurements depends entirely on the accuracy of $B^*_{\parallel}$ and B, because we have used $\alpha \approx B^*_{\parallel}/B$ in Equation (4). We then implicitly assumed that the inclination, γ, was zero. More correctly,

$$\alpha \approx B^*_{\parallel}/B\cos\gamma\,. \tag{6}$$

However, since in our case the value of γ remains undetermined, we have had to use Equation (5) instead of (6). Accordingly changes in γ may result in spurious changes of α.

Therefore we must be careful when interpreting data on α. From Figure 4 one can see that the flare has caused a gradual disappearance of the magnetic flux tubes. However, this may be due to our assumption that $\gamma \approx$ const. To clarify this issue new observations of flares with recordings of not only Stokes V but Stokes Q and U need to be made in the future.

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