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Letter to the Editor

Observation of the linear polarization in the flare with a powerful surge

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Abstract. An investigation of the linear polarization in the flare with a powerful surge revealed an unusual behavior of the Stokes parameter profiles along the dispersion. We discuss the probability that photons propagating from the flare and passing through the surge generate a linearly polarized radiation of the surge.

Key words. sun: flare – polarization

1. Introduction

Observations of the linear polarization of Hα line in solar flares have been interpreted as evidence for the impact polarization resulting from the excitation of hydrogen atoms by protons with an anisotropic velocity distribution function (Vogt & Henoux 1996, 1999; Karlicky et al. 1996; Vogt et al. 1997). Observations of chromospheric flares with polarization instruments usually gives the linear polarization in the line centre (Henoux et al. 1996a, 1996b; Firstova & Boulatov 1996; Firstova et al. 1997). The linear polarization in the June 29, 1999 flare was investigated in several flare kernels. A distinguishing characteristic of this flare was the presence of a surge with a maximum velocity of mass motion of 160 km s^{-1}. This brief communication is devoted to the discussion of the unusual form of the Stokes parameter profiles along the dispersion in the case where both the flare and the surge were observed simultaneously.

2. Observations and results

Spectra of the importance SF flare in the AR 8603 (S15E08) were taken with the Large Solar Vacuum Telescope of Baikal Astrophysical observatory (Skomorovsky & Firstova 1996) on June 29, 1999. The linear polarization measurements of the Hα region spectrum were made using the Wollaston prism and two achromatic half-wave plates. One half-wave plate is placed behind the Wollaston prism and it is used to balance intensity of ordinary and extraordinary rays. The half-wave plate, installed in front of the spectrograph slit, allows to obtain the images of the Stokes parameters Q and U. When half-wave plate is oriented in position to the slit 0° we get image corresponded to Q; by turning half-wave plate to 22.5° we get U. The interval between these two expositions is at the average 0.7 s. The angle between the spectrograph slit and the direction flare – the solar disk center is equal to 30°. Basic performance data of the instruments are listed in Table 1.

As a whole 121 image frames were obtained in 7 flare kernels. We don't show the results of polarization investigation in flare in this paper. The purpose of this report is only to call attention to difference of the polarization parameters in the flare and in surge. Figure 1 presents the original CCD-images of flare kernels, and of one flare kernel with the surge in two orthogonally polarized spectral bands. Cuts of intensity I_1 and I_2 were made along the dispersion in both spectral bands, and the Stokes parameter profiles were obtained by the formula

$$Q/I; U/I = \frac{I_1 - I_2}{I_1 + I_2}.$$

Figure 2 exemplifies the usual form of the Stokes parameter profiles along the dispersion for the flare – a maximum linear polarization lies in the line center. However, the Stokes parameters for the flare with the surge had an unusual shape: in the line center their values were essentially positive, while in the short-wavelength wing of the line they had significant negative values, as shown in Fig. 3. It is quite obvious that the polarization in the line center refers to the flare itself, whereas the polarization in the short-wavelength wing is associated with the surge. We observed the surge for four min, and obtained 32 spectral images of the flare with the surge. Only during

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Table 1. Observation parameters.

Spectrograph slit width	100 μm–0.5 arcsec
Spectrum order	2 left
Dispersion	0.6 Å/mm = 0.013 Å/pixel
Theoretical spectral resolution	0.014 Å
Height of one spectrum band	40 arcsec = 228 pixels
Exposure time	0.1 s
Spectrum detector	CCD detector TEK512 × 512
Time resolution	∼7 s
Error of determination of Q/I and U/I	0.5%
Duration of the flare observation	$05^{\rm h}06^{\rm m}14^{\rm s}$–$05^{\rm h}29^{\rm m}10^{\rm s}$ UT

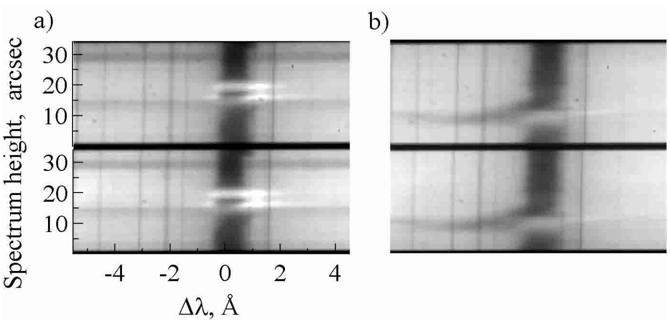

Fig. 1. Images of two opposite spectral bands. **a)** The flare kernels in maximum phase; **b)** the flare kernels with the surge.

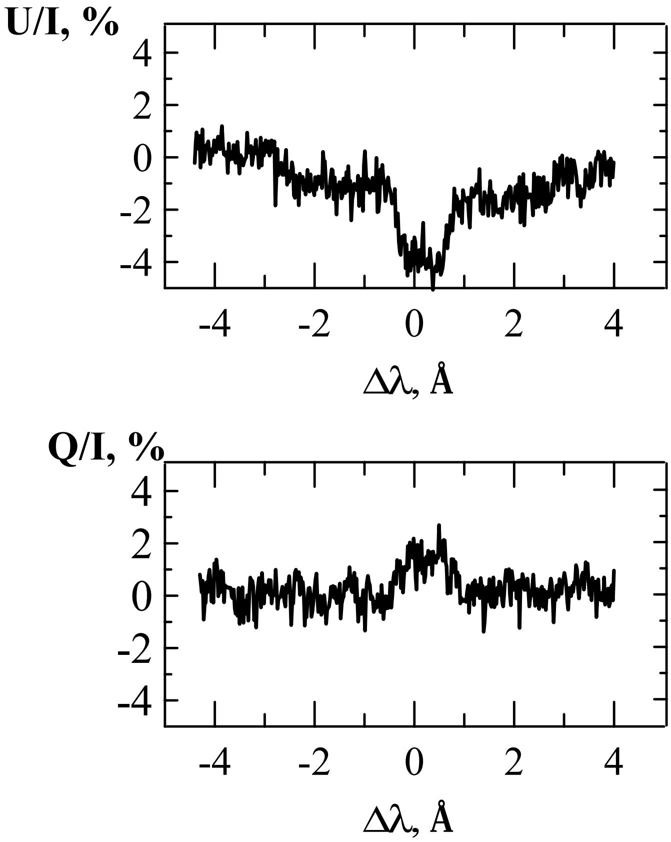

Fig. 2. Example of the determination of Stokes parameters in the flare.

the one minute, from $5^{\rm h}09^{\rm m}12^{\rm s}$ to $5^{\rm h}10^{\rm m}05^{\rm s}$ (6 frames), the degree of polarization in the flare and the surge exceeded 1.5% and reached 4%. We obtained the azimuth of polarization in relation to the direction of the disk center in these objects: $\chi_{\rm f} = +18° \pm 2.4°$ (in the flare) and $\chi_{\rm s} = -60° \pm 3.5°$ (in the surge). Thus, the polarization direction was radial in the flare and was tangential in the surge.

We processed these frames in the following manner. For each frame, we obtained two images: one of them corresponded to the intensity averaged over two spectral bands, and the other referred to the Stokes parameters. To obtain the latter image we employed the same formula as used in obtaining the Stokes parameter profiles along the dispersion, with the axis of ordinates corresponding to the height of the spectrograph slit. The upper panel of Fig. 4 presents the intensity image along the dispersion and along the spectrograph slit, and the lower panel shows the image of the Stokes parameters along the same axis.

In the images of the Stokes parameters (Fig. 4, lower panel), all Fraunhofer lines, except for Hα, are lacking because the linear polarization in them is zero. The polarization in the flare kernel and in the surge appears white and black, respectively, and the grey background represents no polarization. The polarization in the surge, as well as in the flare, occurs in the line center, with the only exception that the line itself in the surge is shifted due to Doppler effect. So, Fig. 4 shows that the polarization in the surge has nearly always the opposite sign of polarization in the flare. However, sometimes the surge consists of opposite polarized streaks (white polarity adjacent in parallel to the dark polarity).

3. Discussion

The flare under consideration was rather faint and was almost at the centre of the solar disk (S15 E08). Both of these facts did not favour the measurements of the impact polarization. However, the polarization of Hα line during the solar flare exceeding 1.5% was observed in 21 of 121 frames. The duration of this polarization did not exceed a minute. The orientation of the polarization plain on moment of the maximum phase of the flare is most

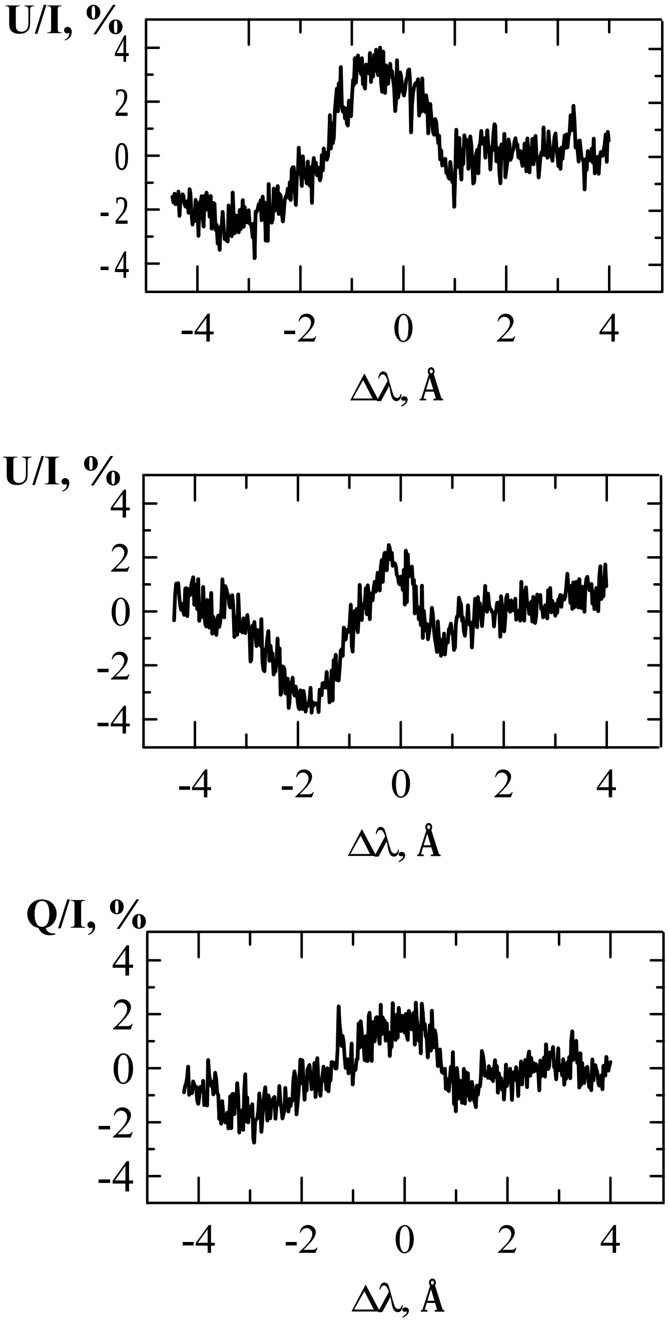

Fig. 3. Polarization in the flare and surge.

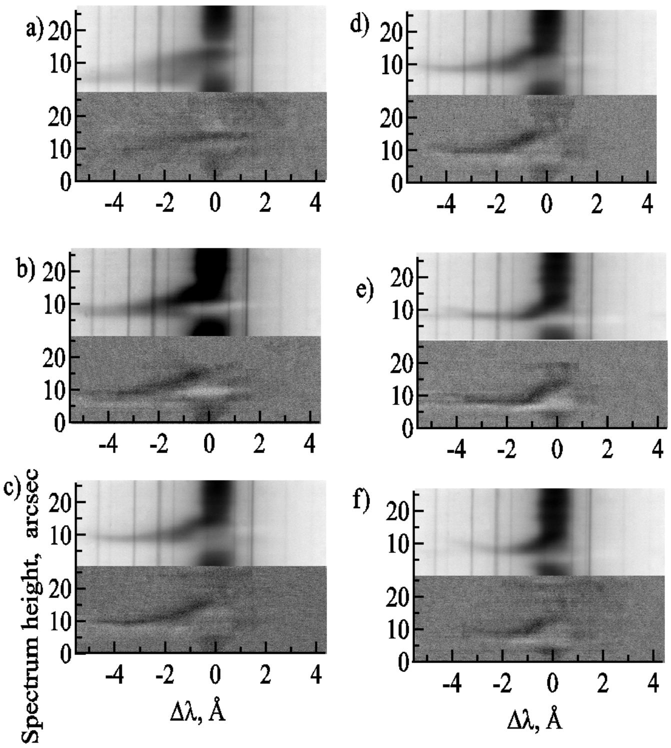

Fig. 4. Intensity and polarization images for flare kernels with surge at different times: **a)** $05^{h}09^{m}49^{s}(Q/I)$; **b)** $05^{h}09^{m}55^{s}(U/I)$; **c)** $05^{h}10^{m}07^{s}(U/I)$; **d)** $05^{h}10^{m}19^{s}(U/I)$; **e)** $05^{h}10^{m}55^{s}(U/I)$; **f)** $05^{h}11^{m}12^{s}(Q/I)$.

likely radial. Thus, it is commonly accepted that the observed polarization is the impact polarization which is due to the collisional excitation of atoms by energetic particles with an anisotropic velocity distribution.

The origin of the surge with the velocity about 160 km s^{-1} fell on moment of the maximum phase of the flare. The orientation of the polarization plain is most likely tangential, i.e. orthogonal to the polarization azimuth of the flare This gives the impression that some of the flare emission passes through the surge that was produced in the flare and propagated rapidly upward. The polarization observed in the surge can be accounted for by the resonance scattering caused by the emission of the flare. Here we do not offer any explanation for the fact why the polarization in the flare and in the surge is opposite in sign. It is pertinent to note, however, that the Hα line in the flare and in the surge was observed in the emission and in the absorption, respectively. Conceivably this accounts for the orthogonal character of the polarization in the flare and in the surge.

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