LINE PROFILES AND MAGNETIC FIELDS IN THE EXCLUSIVELY POWERFUL SOLAR FLARE OF OCTOBER 28, 2003: PRELIMINARY RESULTS

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We investigate the X17.2/4B solar flare of October 28, 2003 which has been occupying *the third place* among X-ray fluxes since 1975. The echelle Zeeman spectrograms obtained at the Kyiv University Astronomical Observatory allow us to conclude the following: a) observed flare emission in some magnetosensitive metallic lines *can produce a false magnetographic signal of opposite polarity* in case of Babcock's or filter magnetograph, b) *considerable both horizontal and vertical magnetic field inhomogeneity* existed in the flare. The longitudinal mean magnetic field strength $B_{||}$ was maximal at chromospheric level, which follows from a comparison of data in the Fe I λ 630.25 nm, He I D_3, Na I D_1 and D_2 lines. In particular, the line ratios $B_{||}(D_2)/B_{||}(630.25) \approx 3.2$ and $B_{||}(D_3)/B_{||}(630.25) \approx 2.0$ were derived.

DATA FROM OTHER OBSERVATORIES AND SATELLITES

The observed flare has been occupying *the third place* among X-ray fluxes since 1975. Let us give a list of the most powerful X-ray flares (see Table 1 based on the data of the Web site [http://www.spaceweather.com/solarflares/topflares.html]).

Table 1. List of the most powerful X-ray flares since 1975

Ranking	Day/Month/Year	X-Ray Class
1	04/11/2003	X 28
2	02/04/2001	X 20.0
2	16/08/1989	X 20.0
3	28/10/2003	X 17.2
4	06/03/1989	X 15.0
4	11/07/1978	X 15.0
5	15/04/2001	X 14.4

The flare arose in the active region NOAA 10486, the largest one during the current 23th cycle. This region had a magnetic delta-configuration and atypical distribution of the N- and S-polarities.

As it follows from the GOES satellite data, X-ray flare emission started at 10:18:00 UT, reached its peak at 11:10:00 and stopped at 11:45:00. The X-ray flare coordinates were S18, E20.

The flare triggered a large filament eruption and sent a very large solar storm towards the Earth. On the next day, October 29, estimated K_p-index reached its maximal value ($K_p = 9$).

GOES 11 proton flux increased by 3–4 order, exceeding a value of 10^4 particles $\mathrm{cm}^{-2}\,\mathrm{s}^{-1}\,\mathrm{sr}^{-1}$ in the range greater than, or equal to, 10 MeV. Due to such intensive proton flux, astronauts aboard the International Space Station went into service module for radiation protection [6]. FAA issued first-ever alert on radiation doses received by airplane passengers at a height of above 25 000 feet. Power system failure in Malmo, Sweden (October 30). NOAA 17 AMSU-A1 lost scanner. The ACE and Wind solar wind satellites lost plasma observations, electron sensors of the GOES satellite in geosynchronous orbit saturated. Chandra satellite observations halted on October 28 autonomously because of radiation. Kodama data relay satellite in geosynchronous orbit had safe mode, noisy signal, recovery unknown (October 29). The RHESSI satellite had two more spontaneous

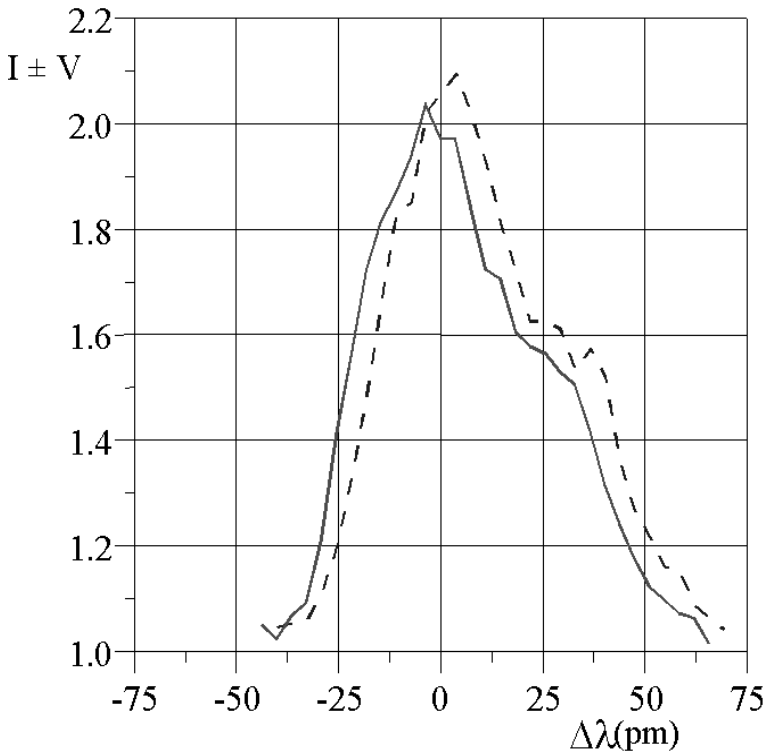

Figure 1. Observed Stokes $I \pm V$ profiles of the D_3 He I line in the flare of October 28, 2003, for 11:13 UT (see the text)

resets of CPU (October 28 and October 29). The CHIPS satellite computer went off-line on October 29, and a contact with the spacecraft was lost for 18 hours.

The list of anomalies presented above is not full. One can find an additional information in the paper of Webb and Allen [6]. It is also interesting to note that many beautiful auroras were observed on these dates at high and middle latitudes of the Earth north hemisphere.

DATA ON SPECTRAL OBSERVATIONS PERFORMED AT THE KYIV UNIVERSITY ASTRONOMICAL OBSERVATORY

The flare was observed at the Kyiv University Astronomical Observatory by V. G. Lozitsky and N. I. Lozitska with the use of the echelle spectrograph of the horizontal solar telescope. Eighteen Zeeman spectrograms were obtained from 10:07 to 11:22 UT. Stokes $I \pm V$ profiles of the Fe I, Fe II, D_3 He I, D_1 and D_2 Na I, and Balmer lines were analysed. An interest was focused on a bright flare knot outside the sunspots where the averaged magnetic field $B_{||}$ measured from the splitting of the "center of gravity" of the Fe I $\lambda\,630.25$ nm line was 20–40 mT and had S-polarity.

The photometrical investigation of spectrograms showed that the line center-to-continuum ratio for flare emission was about 2.0 for the D_3 He I line (Fig. 1).

The visual inspection of the spectrograms showed that very bright, narrow, and splitted flare emissions present in many metallic lines including the Fe I $\lambda\,532.42$ nm line which was used for the first videomagnetographic observations of the magnetic transients in flares [7]. Such emissions can produce the false magnetographic signal of opposite polarity in case of Babcock's or filter magnetograph [1]. However, we did not find similar narrow and splitted emissions in the Fe I $\lambda\,525.02$ nm and Ca I $\lambda\,610.27$ nm lines often used for magnetic field measurements.

Our direct measurements of the Zeeman splitting in different spectral lines showed that considerable both horizontal and vertical magnetic field inhomogeneity had existed in the flare. First type of the inhomogeneity follows from the line ratio $B_{||}(630.15)/B_{||}(630.25)$. Both these Fe I lines have practically the same height of formation and temperature sensitivity, but different Lande factors, $g = 1.67$ and 2.49, respectively. So, these lines are suitable for the small-scale magnetic field diagnostics [2, 3, 5]. For the brightest place of flare knot we measured the ratio $B_{||}(630.15)/B_{||}(630.25) = 0.61$. This is an evidence for a strong (kG range) unresolved magnetic field of *opposite polarity.* In fact, in case of homogeneous field we can expect $B_{||}(630.15) \approx B_{||}(630.25)$ or $B_{||}(630.15)/B_{||}(630.25) \approx 1.0$. If unresolved structures have a strong field of the same polarity, it should be measured $B_{||}(630.15)/B_{||}(630.25) > 1$. Since in our case $B_{||}(630.15)/B_{||}(630.25) < 1$, the magnetic polarity should be opposite, *i.e., N* for the investigated region. A similar case was considered earlier in [4] for X1.7/1B flare on March 29, 2001, where some observational evidences for an unresolved magnetic field of -550 mT were found.

Another interesting effect is partly illustrated by Fig. 1. One can well see mutually visible shift of the Stokes profiles $I+V$ and $I-V$ due to Zeeman effect, which correspond to a magnetic field of 73 ± 10 mT. In the same place of spectrogram the magnetic field strength measured in the photospheric Fe I λ 630.25 nm line was 36 ± 5 mT only, *i.e.,* the strength line ratio $B_{||}(D_3)/B_{||}(630.25) \approx 2.0$. For the other chromospheric line, D_2 Na I, we obtained the following ratio: $B_{||}(D_2)/B_{||}(630.25) \approx 3.2$ (in the same place on spectrogram). Considering that the Fe I λ 630.25 nm line forms in middle photosphere, D_2 line in low chromosphere, and D_3 line in high chromosphere, it is likely that these data are indicative of a nonmonotonous field distribution versus height. It is clear that these line ratios could be as evidences for the local magnetic field amplification ("collapse"?) at chromospheric level. Similar phenomenon was described in [3] for another flare, and it needs an extended study in the future.

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