MAGNETIC FIELDS AND THERMODYNAMICAL CONDITIONS IN THE M6.4/3N SOLAR FLARE ON JULY 19, 2000

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We present the semi-empirical model of a powerful solar flare on July 19, 2000 based on spectral observations in the Fe I, Fe II, Cr I, and Ti II lines. Our calculations show the existence of a very narrow (≤ 100 km) and sharp magnetic field peak at photospheric level ($\log \tau_5 \approx -2$). It is possible that this peculiarity is indicative of the local magnetic field amplification due to specific process during the flare. Yet another interesting detail of the model is two discrete hot flare layers related to the middle photosphere and temperature minimum zone.

INTRODUCTION

Solar flares are very attractive but complicated objects for magnetic field measurements. Due to essential non-magnetic changes of the spectral lines during the flares, ordinary magnetographic measurements could give unreliable data [7]. In order to obtain sufficiently reliable measurements, methods based on the full pictures of the Stokes profiles are needed. Some of the following methods were proposed earlier in [2, 6, 7] for observations of the 22nd solar activity cycle flares. In this work we analyse new data related to a flare of the current 23th cycle.

OBSERVATIONAL DATA AND SELECTED SPECTRAL LINES

Observational data were derived with the horizontal solar telescope of the Astronomical Observatory of the Kyiv National Taras Shevchenko University. Table 1 gives selected spectral lines used in our investigation.

Table 1. List of spectral lines used and some their parameters

Element, N	λ, Å	EP, eV	g_{eff}	h, km	r_0
Fe I 816	6302.51	3.67	2.49	381	0.34
Fe I 816	6301.51	3.65	1.67	489	0.28
Fe I 686	5576.09	3.42	0	–	0.22
Fe I 66	5250.65	2.19	1.50	493	0.20
Fe I 1	5250.21	0.12	3.00	409	0.28
Fe I 1	5247.05	0.09	2.00	415	0.28
Fe II 49	5425.27	3.19	1.25	179	0.57
Fe II 35	5132.67	2.69	1.38	132	0.73
Fe II 42	4923.92	2.88	1.70	–	0.43
Ti II 69	5418.80	1.57	1.03	245	0.49
Cr I 18	5247.56	0.96	2.50	417	0.25
Fe I 16	5123.72	1.01	0	–	0.17

The flare had the coordinates 14° S and 15° E, and its importance was M6.4/3N. Ten echelle Zeeman-spectrograms of the flare were obtained from 6:54 to 8:30 UT, but here we study the spectrogram for 7:21 UT only, which relates to time close to the flare peak. Many bright emissions in Balmer and metallic lines were observed, but below we present the data related to the metallic emissions only. The following parameters are listed in Table 1: N is the multiplet number, g_{eff} is effective Lande factor, h is the depth of line formation [5], and r_0 is the central intensity of lines from [4].

SEMI-EMPIRICAL MODEL OF FLARE

Magnetic field measurements using the "centre of gravity" method show that an obvious dependence of the effective magnetic field B_{eff} on magnetic sensitivity factor $g\lambda^2$ takes place. This in an evidence for unresolved elements with very strong (kG range) magnetic fields. For more concrete conclusions, model calculations similar to presented earlier (in papers pointed above [7]) are needed.

The flare model was calculated using Baranovsky's program [1] and twelve lines listed in Table 1. The model C (average quiet Sun) from [8] was used as initial undisturbed photosphere. Calculations were made for two cases: i) taking into account lines both of ionized and neutral atoms and ii) for neutral lines only.

According to the calculations, there are two maxima on the distribution of the flare temperature with the atmosphere height (Fig. 1). In the first one temperature increased to 6560 K and in the second one to 5500 K. Exactly, if we keep the data for neutral lines only, the flare temperature decreases by 500 K in the first temperature maximum, which is determined by the Fe II λ 492.39 nm line intensity. The temperature minimum between them is 4400 K, which is 200 K less than in undisturbed model.

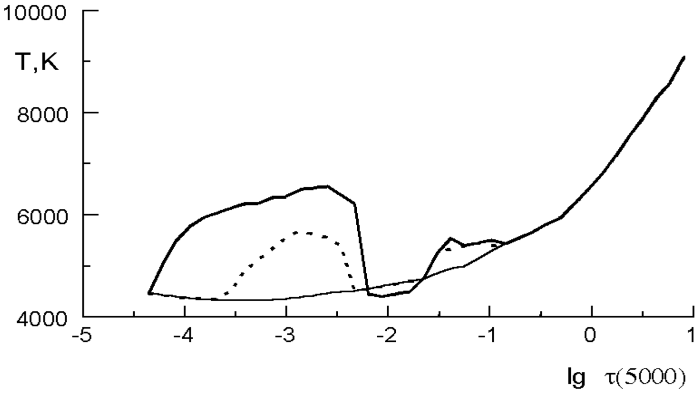

Figure 1. Temperature distribution of the undisturbed photosphere model (thin line), flare (thick line), and flare in case of contribution of neutral lines only (dashed line)

Other flare parameters, such as hydrogen density and turbulent velocity, are changed as well. The density does not change in the second case, but decreases in the first temperature maximum region by half order. Turbulent flare velocity distribution has a maximum of 6.60 km/s, six times more than in undisturbed model. Flare extent is approximately 450 km, undisturbed model is 650 km. So, the flare is more compact, hot, and turbulent.

Figure 2 illustrates the most interesting peculiarity of the model. We can see a sharp narrow peak of magnetic field with scale width about 90 km in the region of the flare temperature minimum. The magnetic strength peak is 1600 G, and it is determined mainly by the Fe I λ 525.02 nm line width. This value corresponds to the measurements using the "centre of gravity" method.

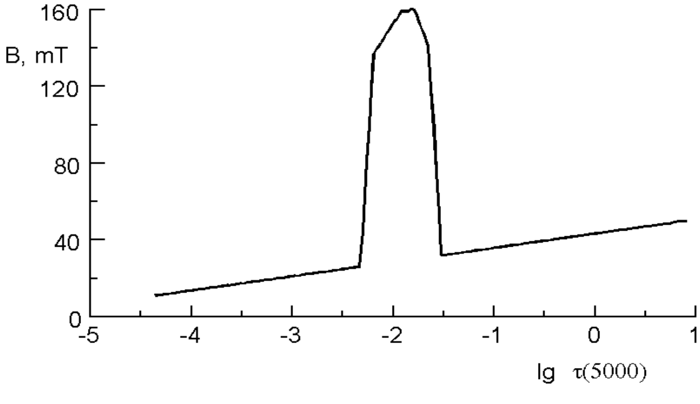

Figure 2. Magnetic field distribution of the flare model for the case when the angle between line of sight and field vector is 30°

CONCLUSIONS

The temperature flare model in comparison with undisturbed photosphere consists of two temperature maxima and the minimum between them.

The density decrease coexists with the first temperature maximum, and increase with the temperature minimum.

Turbulent velocity increased to 7 km/s in comparison with undisturbed photosphere model. The velocity distribution was determined mainly by the Fe II $\lambda\,492.3$ nm line wings.

Maximum of the magnetic field coexists with the temperature minimum. The magnetic field value reached 160 mT in about 100 km interval and had sudden increase and decrease. Without such sudden changes the Fe II $\lambda\,492.3$ nm and Fe I $\lambda\,513.22$ nm line widths should be very large.

Above presented magnetic field peculiarity on $\log\tau_5 \approx -2$ (Fig. 1) is in surprisingly good agreement with [2, 6, 7] for other flares. As to details, in our case the field peak is more narrow and places deeper in atmosphere than it was found in [2, 6, 7]. In addition, conclusions 1–3 are in good agreement with the main features of the flare model considered by Chornogor and Alikaeva [3].

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