STATE OF PLASMA AND MOTIONS IN CHROMOSPHERIC AND PHOTOSPHERIC PARTS OF THE FLARE H_α LOOP

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The velocity field and the matter state at the chromospheric and photospheric levels in the course of flare development were investigated. To study the physical parameters of the matter in the flare, we used the chromospheric H_α line and some Fraunhofer lines formed at different levels in the photosphere. The observations at the Peak Terskol allowed us to determine the velocities and physical conditions in different parts of the flare H_α loops. The blue shift of the H_α line was recorded only at the impulsive phase and only at the top of the loop. The velocities decrease during one minute and their sign changes at the H_α maximum. Positive line–of–sight velocities were found both in the photosphere and chromosphere at the footpoint of a flaring loop. The velocities drop from 23 km/s in the chromosphere to 0.7 km/s in the middle photosphere. Such motion type points to the flare H_α loop lifting during impulsive phase and downward motion of a matter along the loop branch.
The simulation reveals a condensation arised in the temperature minimum region during impulsive phase at the base of the flare loop. This condensation moves downward. The temperature excess in the flare H_α maximum was about 1000 K and magnetic field strength was 250 G.

INTRODUCTION

The spectral investigations of a flare velocity field allow us to check reliability of theoretical flare models. The spectral line profiles formed in the low-temperature layers of the flare atmosphere, their Doppler shifts, asymmetry give us information about properties of non-thermal particle beams and the hydrodynamical processes in the lower layers of the flare atmosphere (Fisher, 1990; Canfield *et al.*, 1990; Falchi, Qui and Cauzzi, 1997). Unfortunately, the velocity field at the photospheric levels are poorly studied. The preflare increasing of blue shifts of some photospheric lines have been reported in some papers (Rust, 1973; Redjuk, 1985; Falchi, Falchiani and Smaldone, 1992). The ascending motions of the photospheric matter in the impulsive phase were recorded by some authors (Harvey and Harvey, 1976; Redjuk, 1985; Cauzzi *et al.*, 1996). But in the gradual phase only descending motions with velocities of 1-3 km/s were observed in the photosphere (Janssen and White, 1970; Redjuk, 1985; Cauzzi *et al.*, 1996). The observational data on solar flares stored during the last decades show that all the layers of the solar atmosphere take part in flare process. It may be taking into account when the realistic hydrodynamical models are built. Unfortunately, the theoretical models of the hydrodynamical response ignore the photospheric layers of the flare atmosphere and semiempirical models are scanty and they describe the state of the high levels of the photosphere only.

OBSERVATIONS

We study here the velocity field and state of the matter at the chromospheric and photospheric levels in different parts of the flare H_α loop of the faint solar flare sf/c5 on August 2, 1990 (flare beginning – 05:45 UT, max – 05:49 UT, end – 06:03 UT). The photographic spectral observations were carried out at the Horizontal Solar Telescope at the Peak Terskol (h = 3200 m) of the Main Astronomical Observatory of the NASU. The observations period involved the flare H_α maximum and gradual phase. The H_α images of the active region were recorded with TV-camera. The flare was seen as some H_α loops near the spot-leader. The spectrograph slit crossed the east branches of two loops including the regions near the loop tops and their bases.

The photometry was made with an automatic digital two-coordinate microphotometer. The spatial resolution along the slit is of $2\overset{''}{.}3$ and spectral resolution is of 1 pm for H_α and 0.5 pm for Fraunhofer lines. The spectrograms demonstrate that the knot with a central reversal were located near the flare kernels with H_α emissions at the line centre.

1. LINE–OF–SIGHT VELOCITIES

The chromospheric H_α line and some Fraunhofer lines formed in the high and middle photosphere ($200 < h <$ 450 km) were used for determination of the line-of-sight (LOS) velocities in the flare atmosphere. The line shifts were measured with respect to telluric lines. Thus, the LOS velocities were obtained for different moments of the flare evolution and for different photometric sections. The LOS velocities were corrected for the Earth's rotation and revolution around the Sun.

Fig. 1 shows the LOS velocities in the chromosphere (a) and photosphere (b) during the flare for the loop top (dashed line) and base (solid line).

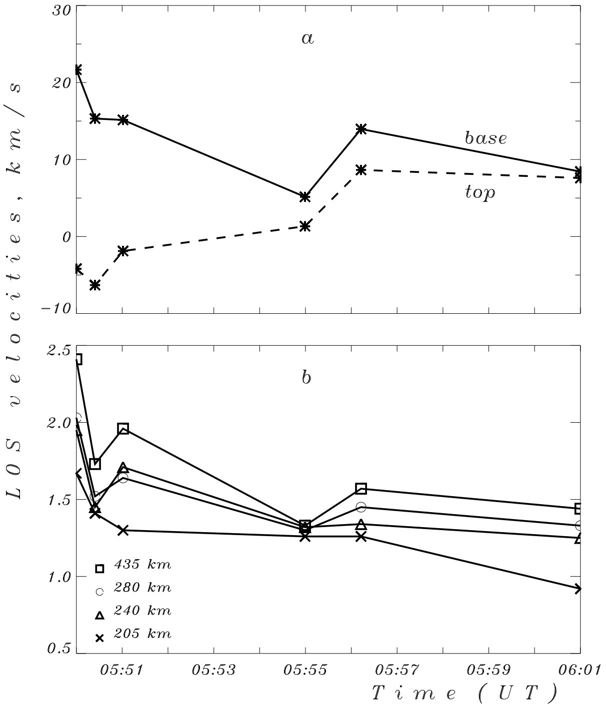

Figure 1: LOS velocities in the chromosphere (a) and photosphere (b) during the flare

In the chromosphere the ascending motions with velocities up to –7 km/s were observed at the top of the loop and during the impulsive phase only. In our opinion, the blue shift of the H_α line is due to upward motion of the loop. This assumption is confirmed by H_α images. In the gradual phase the downward motions of a matter with velocities less than 10 km/s were observed (Fig. 1a). At the loop base the LOS velocities were positive through the all period of flare observation. The maximum velocity was at the H_α maximum at the outer edge of the loop base.

An analogous result was obtained by Falchi *et al.* (1992, 1997) from their study of the velocity field in the high photosphere. Our results are in accordance with the data of Canfield *et al.* (1992) as well. They revealed that H_α red shifts coincide with footpoints of the loop, but not the loop top feature.

In our case the character of the chromospheric velocity field may serve as confirmation of the gradual magnetic reconnection (Forbes and Acton, 1996). Since the velocities did not exceed 30 km/s we consider that the particle beam energy was $< 10^{10}$ erg/(cm^2 s) (Fisher, Canfield and McClymont, 1985).

Fig. 1b shows the LOS velocities at different heights in the photosphere at the base of a flaring loop for different moments of the observation. All the velocities were positive. This points out to the downward motions of the photospheric matter. As in the chromosphere the maximum velocities were at the outer edge of the loop base. The velocities decrease with depth. These variations of the velocities are possible if the flare disturbance propagates from the high layers to the bottom.

2. SEMIEMPIRICAL PHOTOSPHERIC SIMULATIONS

We calculated the semiempirical models of the photospheric part of the flare loop as the distributions of temperature (T), electron (P_e) and gas (P_g) pressure, LOS velocities (v) and longitudinal component of the magnetic field ($H_\parallel$) with optical depth τ_5. The LTE inversion code SIR (Ruiz Cobo, del Toro Iniesta, 1992) allow us to obtain the thermodynamic and magnetic properties of the structures by fitting the whole shape of the observed line profiles.

The dependence T, P_e, P_g, and $H_{\|}$ on $\log\tau_5$ in the impulsive phase are shown in Fig. 2 for the flare loop base. As one can see the distributions of physical parameters reveal some inhomogeneities at the level $-4 < \tau < -1.5$. The temperature excess relatively to VAL–F model equals to 1000 K at the flare H_α maximum. The gas pressure of this condensation is higher than that in the undisturbed atmosphere by two orders. Besides, there are regions of a low pressure. The electron pressure shows the similar picture. The magnetic field strength was up to 250 G. The other peculiarity of these models is a gradual displacement of the condensations to the lower layers. This fact gives an evidence on disturbance penetrating into the photosphere from above.

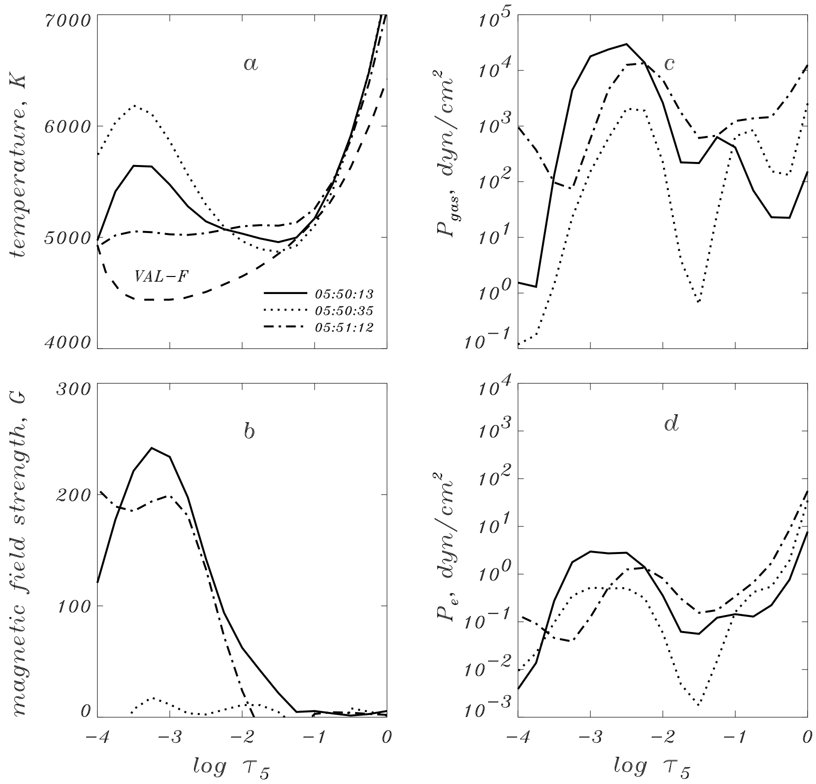

Figure 2: The distributions of temperature (a), longitudinal component of the magnetic field (b), gas (c) and electron (d) pressure with optical depth τ_5 for the flare loop base

The hydrodynamical flare models predicts the formation of the condensation in the impulsive phase moving from the corona to the chromosphere and dissipate there. Fisher, Canfield and McClymont (1985) identify this condensation with a shock wave. According to our study this condensation can penetrate to the photosphere.

CONCLUSIONS

- The upward motions of the chromospheric matter with velocities up to –7 km/s were detected at the loop top at the impulsive phase of the flare only. These motions are due to the loop lifting.
- The change of the velocity sign took place 1 min after the H_α maximum.
- The downward motions were observed both in the chromosphere and photosphere at the loop base during the whole flare. The maximum values of the velocity refer to the outer base edge.
- The downward velocities of the matter varied with height from 23 km/s in the chromosphere to 0.7 km/s in the middle photosphere.
- The model of magnetic reconnection of Forbes and Acton (1996) is the most appropriate for our case.
- A common feature of semiempirical photospheric models is the presence of inhomogeneous layers. At the impulsive phase these inhomogeneities move downward.
- This disturbance of the flare photosphere may be of a wave nature.

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