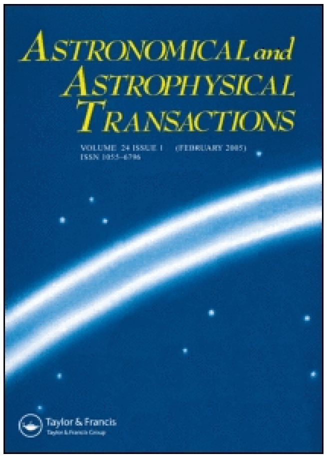

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THE MANIFESTATION OF ELECTRIC FIELDS IN MAGNETIC LOOPS BY MEANS OF H-ALPHA AND X-RAY EMISSION

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The results of investigations which show that the onset and development of flares visible in H_α are affected by the direction of electric current (electric field) are presented. The observed asymmetry in hard X-ray emission of flares is similar to that derived for the H_α emission. The lower limit of the electric voltage between the top of the magnetic loop (the source of energetic particles) and its footpoints (the site of H_α or X-ray emission) was estimated.

KEY WORDS The Sun, active regions, magnetic fields, flares

1 INTRODUCTION

Magnetic field evolution in an active region is closely connected with changes of an electric current. Severny (1965) has used observations of a photospheric magnetic field vector to show by direct calculation that electric currents flow in the photosphere. Moreton and Severny (1968) found that flares tend to appear in places with a high enough current density. Electric currents flowing in the magnetic loop can show variations during a flare. An attempt is made to show how hard X-ray images of flares can be used to estimate an electric voltage in magnetic loop.

2 METHOD

We (Abramenko *et al.*, 1987, 1991) have studied the relationship between vertical electric currents and H_α emission of flares. Electric currents were calculated from the measured magnetic field transverse components. The magnetic field vector was recorded in the $\lambda 5250$Å Fe I line with the Crimean vector magnetograph (Stepanov and Severny, 1962; Nikulin, 1967). The H_α observations lasted for 4 to 6 hours per day.

3 RESULTS AND DISCUSSION

3.1 H_α Emission

Our investigations showed that flares appeared most frequently in the places with strong electric currents ($\sim 10^4$ A km^{-2}). This confirmed the earlier results obtained by Moreton and Severny (1968) and Zvereva and Severny (1970). We also found that flare knots (kernels) in places of upward electric currents were about 48%, whereas in places with downward currents they reached nearly 25%. The rest, 27%, of the events occurred on the boundary between areas with opposite directions of current. The area difference between regions with opposite current direction was rather small (2–10%). In 75% of cases the brightness and lifetime of knots located in places with upward electric currents were greater than in the regions with downward currents. Thus, the onset and development of flares visible in H_α are affected by the value and direction of electric currents. This asymmetry of H_α emission suggests that charged particle fluxes are responsible for H_α emission. The bright plages appeared also most frequently in the places with electric currents directed upward. The asymmetry of H_α emission would then be caused by the vertical component of the electric field acting on charged particles in the vertical direction. It is reasonable to suppose that the sources of charged particle fluxes and the sites of the flare emission in H_α are separated at a height. In those places where the current is directed upward, the electric field facilitates electron motion from the corona to the chromosphere and impedes it in places with downward-directed current. For positive ions the situation is inverted.

Our data confirm the flare model proposed by de Jager (1969) and results obtained from observations on the *SMM* and *HINOTORI* satellites that the primary site of energy release (site of acceleration of particles) is situated near the top of a coronal magnetic loop (Dennis, 1985; Tsuneta, 1983). Accelerated particles propagate down to the footpoints of a magnetic loop. They have lost their energy and produce the observed X-rays and emission in spectral lines. A sudden heating of the chromosphere by a beam of accelerated particles and the plasma emission in spectral lines were first discussed by the present author (Gopasyuk, 1962) and Dubov (1963). Abramenko *et al.* (1991) used the observational data to estimate the applied voltage between the top of the magnetic loop (the source of energetic particles) and its footpoints (the site of H_α emission). We obtained that this voltage might be of the order 10 kV (for electric current density $J_z \approx 3 \times 10^3$ cgse, electric conductivity $\sigma \approx 10^{11}$ cgse, and for a loop 10^4 km long). Such a field completely impedes the electron with energy < 10 keV in the leg with downward electric currents (without taking into account both the losis of its energy by Coulomb collisions and the magnetic mirror effect). For the particle with markedly higher energy a field with a voltage of 10 kV would not create a noticeable anisotropy.

3.2 X-ray Emission

The X-ray emission begins to be produced as soon as the electrons are energized. This is why the X-rays can give us information on the voltage between the source of energy particles and the site of X-ray emission in the magnetic loop during the flare. The *SMM* and *HINOTORI* observations (Hoyng *et al.*, 1981; Tsuneta, 1983; MacKinnon *et al.*, 1985) showed that separated bright patches of hard X-ray emission do occur from the footpoints of magnetic loops. The contrast and the size of these patches are different. On the basis of published data we (Abramenko *et al.*, 1993) carried out an analysis of X-ray images of 13 impulsive flares. The flares which provided information of the X-ray emission in a few energy ranges covering 3–30 keV were taken. For these flares the difference in hard X-ray fluxes from the footpoints of one magnetic loop occurred. We can see that the observed asymmetry in hard X-ray emission of flares is similar to that derived for the H_α emission. Therefore we suggest that this asymmetry can also be caused by the electric field in the magnetic loop. In this way the lower limit of the electric voltage between the top of the magnetic loop (the source of energetic particles) and its footpoints (the site of hard X-ray emission) was estimated. In accordance with our estimations this value would be no less than 30 kV. We see that hard X-ray images of flares obtained with high special resolution give us information on large-scale electric fields in magnetic loops during a flare. Electric fields can change during a flare. These data can provide us with the important information required to understand the energy release process.

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