ELECTRIC CURRENTS AND Hα EMISSION IN TWO ACTIVE REGIONS ON THE SUN

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Abstract. We investigated the structure of magnetic field and vertical electric currents in two active regions through a comparison of the observed transverse field with the potential field, which was computed according to Neumann boundary-value problem for the Laplace equation using the observed Hα-value. Electric currents were calculated from the observations of the transverse magnetic field.

There exist two systems of vertical electric currents in active regions: a system of local currents and a global one. The global current is about $2 \times 10^{12}$ A. In the leading part of the active regions it is directed upward, and in the tail downward.

Flare activity is closely connected with the value and direction of both local and global currents: the flares tend to appear in places with upward currents. The luminosity of Hα flocculi is also connected with vertical electric currents; the brighter the flocculi, the more frequently they appear in places of upward electric currents.

The sensitivity of Hα emission to the sign of the current suggests that charged particles accelerated in the upper parts of magnetic loops may be responsible for these formations. Joule heating might be important for flocculi, if plasma conductivity is about $5 \times 10^8$ c.g.s.

A model of a flare is suggested based on current redistribution in a system of emerging loops due to changes of loop inductance.

1. Introduction

Magnetic field evolution in active regions (AR) is closely connected with changes of electric current. Electric currents in the magnetic field probably lead to various plasma instabilities causing flare activity, too. Flares tend to appear in places with sufficiently high current density (about $10^4$ A km$^{-2}$), according to Moreton and Severny (1968) and Zvereva and Severny (1970). Therefore, investigation of electric currents is of vital importance. It should allow us to broaden our understanding of the physics of flare activity and of the events related to it.

Here we present the results of investigations of electric current systems and their relations with flares and flocculi in active regions.

2. Observations and Data Processing

The data used herein represent measurements of the magnetic field vector and Hα features of two AR: 21–26 October, 1968 ($\lambda = -29^\circ, +37^\circ; \varphi = 16^\circ$) and 8–14 July, 1969 ($\lambda = -23^\circ, +52^\circ; \varphi = -14^\circ$). The latter one was highly developed during the observations, and the first one decayed. The Hα observations lasted for 4 to 6 hours per day. In order to obtain complete data on solar flares we used the Solar Geophysical Data bulletins together with Hα films.

All components of the magnetic field were recorded simultaneously in the 
25250 Å FeI line with the Crimean vector magnetograph (Nikulin, 1967). The reliability
of the transverse magnetic field data has been tested many times by comparing the
orientation of the transverse magnetic field and filament structure of spot penumbras
and Hα-fibrils (Kuklin and Stepanov, 1963; Tsap, 1965; Steshenko, 1969; Kalman,
1976). In particular, Kalman performed his investigation using the same material that
is being used in the present paper. These investigations showed good reliability of the
transverse magnetic field measurements carried out with the Crimean vector magneto-
graph.

The vector components are shown in a coordinate system in which the Z-axis
coincides with the normal to the solar surface. For the first AR 10 recordings of the
magnetic field were obtained during 6 days of observations, for the second 7 recordings
for 7 days.

Our investigations of the observed magnetic field structure are based on comparing
it with the potential field. Naturally, all deviations of the observed structure from the
potential should be caused by electric currents. The computation of the potential field
is based on solving the Neumann boundary value problem for the Laplace equation
using the observed $H_z$-value.

Vertical electric currents were calculated from the measured magnetic field transverse
component on the basis of the following expression:

$$j_z = c/(4\pi S) \oint_C H_\perp \cdot dr,$$

where $S$ is the surface enclosed by contour $C$. For our measurements $S$ is the pixel
$3\,\text{arcsec} \times 6\,\text{arcsec}$.

The potential field structures and electric currents were computed for each day of
observations.

3. Global Electric Current

Comparison of the observational data with the computed fields showed that the vector
$H_\perp$ of the observed transverse field is turned relative to the potential $H_\perp^0$ practically
over the whole active region. This turn has a regular nature. We decomposed the
observed transverse field vector $H_\perp$ into one component $H_\perp^\parallel$ parallel to the vector $H_\perp^0$
and another component $H_\perp^\perp$ that is perpendicular. The deconvolution method used
here was proposed by Abramenko and Gopasyuk (1987). The component $H_\perp^\perp$ is
caused only by the presence of an electric current and shows the rotation of the observed
vector $H_\perp$ relative to the potential $H_\perp^0$. Its direction is indicated by arrows in Figure 1.
A structure similar to the one presented in Figure 1 was found for all recordings of the
magnetic field.

The predominant pattern of arrows forms two systems of closed curves centred at
A and B, i.e., two systems of vortices in the observed magnetic field $H_\perp$. The boundary