Observation of Magnetic Field Vector in Solar Active Regions

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The vector magnetograph at Okayama Astrophysical Observatory (a branch station of Tokyo Astronomical Observatory, University of Tokyo) has been in operation since 1982. The instrument is equipped on the 65cm coude telescope. Instrumental polarizations are compensated for by plane parallel glass plates and Babinet plates. The polarization signals are obtained by measuring the blue/red wing intensities of Fe 5250 Å line. Typically one observing run takes one hour to scan the area of 500" x 500" with a 10" step. The data are processed by a minicomputer and are displayed on a color CRT (Fig.1).

The conversion from the observed polarization degrees to the magnetic field components is made by using Unno's formula (1956) applied to a homogeneous magnetic field. The existence of unresolved flux tubes is therefore not taken into account currently. Based on the observed longitudinal fields, the magnetic field lines above the solar surface are calculated by assuming that the magnetic field is current-free (Sakurai, 1982), and can be displayed superposed on the magnetogram. The difference, if any, between the observed field structure and the computed potential magnetic field would indicate the existence of electric currents.

In deriving the transverse magnetic fields, the azimuth of the field vector has an ambiguity of 180°. Of the two possible directions of the transverse field, we selected the one that is closer to the direction of the potential magnetic field which is calculated by using the observed longitudinal field component. (Fig.2a) We may then derive the line-of-sight component of electric currents (Fig.2b) from the observed transverse magnetic fields by:

\[ J_z = \frac{c}{4\pi} \left( \frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y} \right) \]

Based on the derived distribution of electric currents, the force-free magnetic field is calculated (Sakurai, 1981), and the energy stored in the atmosphere can be evaluated. For the example shown here (Fig.3), the free energy (energy associated with electric currents in the chromosphere/corona) is \(4 \times 10^{29}\) ergs while the energy of the potential magnetic field (energy of current systems below the solar surface) is \(7.5 \times 10^{31}\) ergs. Therefore the difference between the force-free field and the potential field in this example is very small. It is expected, however, that prior to large flares a significant deviation from the potential field (and a large amount of free energy) would be observed.

References
Fig. 2 (a) Observed magnetic field vector. Solid and dotted contours show positive and negative longitudinal fields, respectively, with levels ±10, 20, 50, 100, 200, 500G. Arrows indicate the transverse field vector. (b) Distribution of electric currents derived from (a). Contour levels are ±20, 40, 60, 80, 100G/10^4km. Both positive and negative currents exist within one magnetic polarity.
Fig. 3 Potential field lines (a) and force-free field lines (b). Potential field lines are calculated from the observed longitudinal magnetic field, while force-free field lines are computed by using the distribution of electric currents (Fig. 2b). Field lines in these two figures have the same footpoints.