The Magnetic and Velocity Fields of Solar Active Regions
ASP Conference Series, Vol. 46, 1993
Harold Zirin, Guoxiang Ai, and Haimin Wang (eds.)

CHANGES WITH HEIGHT OF LONGITUDINAL MAGNETIC FIELD IN ACTIVE REGIONS

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Results of a study of longitudinal magnetic fields in active regions are presented. The observed magnetic field strength increases with height in the photosphere. The maximum of the magnetic field intensity coincides with the level where the central parts of λ5324,2 Å FeI and λ5269,5 FeI line profiles are formed. On the H_β formation level the observed magnetic field intensity is smaller as compared with the potential one calculated on the basis of the observed field in FeI λ5253,5Å line. The difference between the observed magnetic field and potential one is explained in terms of transverse electric currents. The current value can mount to 3×10^{11} A.

https://doi.org/10.1017/S0252921100028700 Published online by Cambridge University Press

It is known well that the intensity of the magnetic field measured with the magnetograph in different photospheric spectral lines is not identical. Harvey and Livingston (1969) were the first who revealed that the measured intensity of longitudinal magnetic field in the Fe I λ5250 Å line is systematically twice as low as in the Fe I λ5233 Å line. This discrepancy was ascribed to the higher temperature sensitivity of the Fe I λ5250 Å line (Harvey and Livingston, 1969) and to Zeeman saturation (Stenflo, 1971; Gopasyuk et al. 1973).

Moreover it is possible to indicate also other effects that cause the discrepancies between magnetic field measured in differed spectral lines. We selected four spectral lines of the iron namely: λ5217,4 Å; λ5253,5 Å; λ5302,3 Å and λ5324,2 Å lines. These spectral lines belong to the same multiplet (n_o 553), every of them is the normal Zeeman triplet with the Lande factor g=1,5. The excitation potential of the lower level is $\chi \approx 3,2$ eV. The only distinction between the lines is the equivalent width W.

The magnetic field recordings in active regions (AR) were made with the double-channel Crimean magnetograph in two lines simultaneously. The value intensity of the magnetic field in λ5253 Å was taken as a "standard". The scanning aperture was 1"×4". The exit slits for all lines were the same transmitting light between 21 and 56,5 mÅ from the line center , in both wings of the lines.

Our observations (Gopasyuk and Severny, 1983) are illustrated in Figure 1. Figure 1 shows that the observed magnetic field intensity in the photosphere (outside sunspot) $H_{\parallel}(\lambda_l)/(H_{\parallel}(5253)$increases with equivalent width W of a spectral line. Observational data in the λ5269,5 FeI (g=1,2) and H_β (g=1,07) lines are presented also in Figure 1. (The λ5269,5 Å and H_β lines have an anomalous Zeeman splitting.) The measurements ware taken for the ARs situated near the central meridian. The same result was obtained by Semel (1981) who used spectral lines which belong to different multiplets. The results shown in Figure 1 mean that the magnetic field intensity increases with height in the photosphere (Gopasyuk, 1985).

The observed increase of longitudinal magnetic field toward higher heights in the photosphere in particular may be caused by a loss of a magnetic flux during observations in weak spectral lines. But it is possible provided on the levels where the central parts of λ5324,2 Å and λ5269,5 Å line profiles are formed gorisontal (transverse) electric currents flow.

Magnetic fields of these currents intensify background magnetic fields (Gopasyuk, 1985; Gopasyuk et al., 1991). The current value can mount to 3×10^{11} A.

We see (Figure 1) that intensity of longitudinal magnetic field measured in H_β is lower as compared with the field in λ5253 Å .

What is the physical nature of this discrepancy?

For this study we (Abramenko et al., 1992a,b) used the observations of longitudinal magnetic field of three ARs situated near the center of the solar disk. The scanning aperture was 1"×4". Exit photometer slits were between 35 and 90 mÅ from the center of the Fe I λ5253 Å line and between 100 and 200 mÅ from center of the H_β line.

Our investigations of the observed chromospheric field structure are based on comparing it with the potential field. Naturally, all deviations of the observed field from the potential one should be cause by electric currents. The potential field vector was calculated according to Neumann boundary value problem for the Laplace equation (Abramenko and Gopasyuk, 1987) using the observed longitudinal photospheric field. The potential magnetic field structure was computed at the set of levels until 6" above the Fe I λ5253 - line formation level on the net with the cell 2"×4".

The structure of longitudinal component of the potential field at every level (within the interval 0"-6") was compared with the longitudinal field, observed in H_β.

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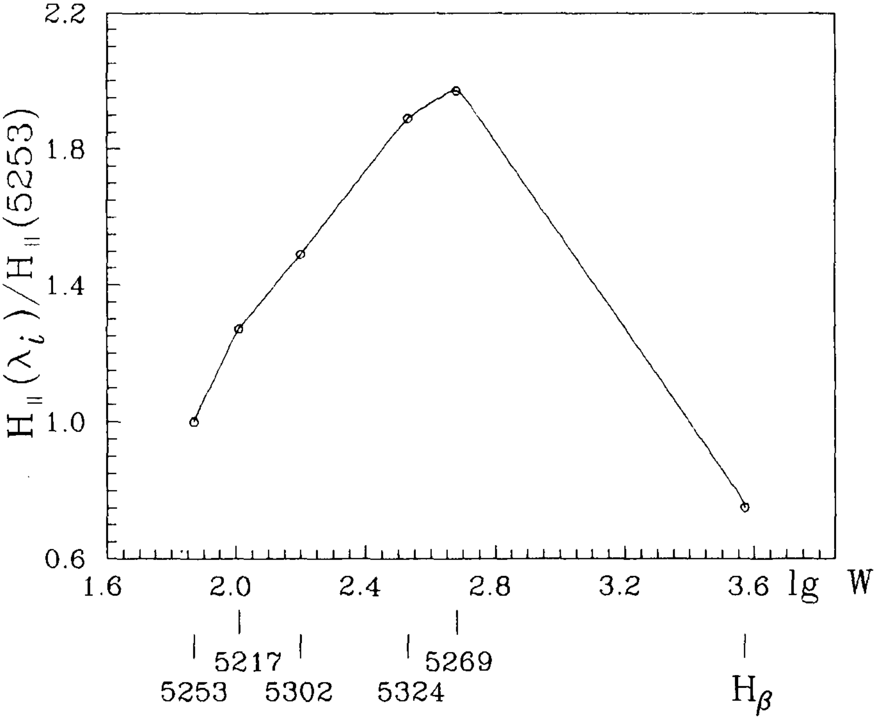

Fig.1 The relative magnetic field intensity $H_{\parallel}(\lambda_i)/H_{\parallel}(5253)$ observed in different spectral lines as a function of their equivalent width $W(\lambda_i)$.

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The correlation between these magnetic field structures was calculated. Results are shown in Figure 2 (curve 1) for AR July 7 , 1991 ($L=8^{\circ}W$, $\varphi=24^{\circ}$). The error of correlation did not exceed ± ,0015. A smooth maximum is mounted at the height 1,5"-2" for this AR.

We suggested that the relative H_{β} line formation height (above the Fe I λ5253 Å line formation level) corresponds to that height at which the correlation mounts the maximum. Of course, the difference between the line formation levels is different for spots, flocculi and areas outside flocculi; besides, it seems to be intrinsic for each active region.

For every height the average (over the map) difference between the moduli of the potential field and observed in H_{β} field $\langle\Delta B\rangle=|B_{pot}|-|B_{H}|$ was calculated (curve 2 Figure 2). We see that at the relative H_{β} line formation height the observed in H_{β} field is smaller then the potential field. The difference was about 15G. So the potential field decreases with height slower than real field in an AR, in other words, the chromospheric field is not the potential.

The discrepancy between the observed field and potential one may be caused by electric currents. To reduce the longitudinal component of the potential field, these currents must be transverse flowing parallel to the solar surface. Since the potential field exceed the observed one, the field of currents must be antiparallel to the potential field. In the magnetic hills ΔB is greater. Hence a magnetic hill seems to be surrounded by transverse current being roughly supposed as circular one. To produce the 200G field on the axis of a circular current with radius $r\approx10^{4}$km the current value should be about 3×10^{11} A, what is in accordance with the value of vertical electric currents in an AR (Severny, 1965).

Our observations of two ARs show that more rapid decrease of the observed longitudinal field with height are connected with more intensive flare activity.

Circular transverse currents should have clockwise

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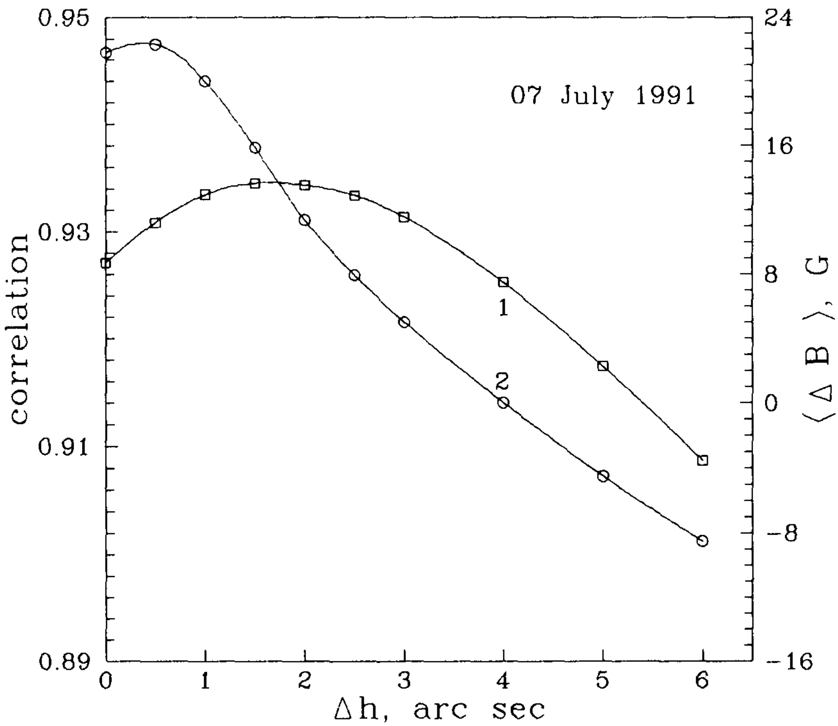

Fig.2 The correlation (curve 1) and the average (over the map) difference between the potential field and the observed in H_β field <ΔB> (curve 2) plotted as a function of the difference in height between the Fe I λ5253 Å line formation level and the level of a potential field calculation.

https://doi.org/10.1017/S0252921100028700 Published online by Cambridge University Press

direction in the N field, and the opposite direction in the S field. Electric currents may be originated by: plasma pressure gradient, gravitational force, specific features of magnetic flux emerging and plasma motions. But it is possible that the magnetic field in the lower chromosphere is a force-free magnetic field.

If transverse electric currents are caused by plasma pressure gradient, the plasma pressure should be larger inside a magnetic hill than outside. The relationship between the current field energy and difference in plasma pressure at a flux tube (magnetic hill) center an its periphery can be estimated from the simple expression:

$$P - P_o = \frac{(\Delta B)^2}{8\pi}$$

P and P_o are the plasma pressure inside a flux tube and outside, respectively. For example, for the magnetic field $\Delta B = 200G$ $\Delta P = P - P_o = 1600\ \mathrm{dyn \cdot cm^{-2}}$.

If currents are caused by the gravitational force the connection between the plasma potential energy (ρgh) and energy field of currents (ΔB) is given by:

$$\rho gh \approx \frac{(\Delta B)^2}{4\pi}$$

In those places of an AR, where the magnetic field is strongly inclined, the current due to gravitational drift may be important.

The method suggested by Abramenko et al. (1992 a,b) allows us to obtain the information on transverse electric currents in the chromosphere, to estimate the plasma pressure gradient in magnetic flux tubes and to derive the pressure and density fields in an AR.

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