2. MAGNETICALLY ACTIVE REGIONS ON THE SUN*

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The most pronounced magnetic activity is observed in sunspot groups of complex polarity which are the seats of solar flares. The very appearance of flares may be considered as a manifestation of magnetic activity.

We should like to summarise briefly our present observational data relating to magnetic fields connected with such violent processes as flares (1).

1. The first appearance of a flare practically coincides with a neutral point of crossed magnetic fields of a spot group ($H = 0$, $\nabla H \neq 0$). Flares appear when the gradient of the longitudinal field at this point is sufficiently high (greater than about 5×10^{-2} gauss/km). This was observed in 54 cases of 61; in the 7 cases the discrepancy is larger than possible errors, but can be ascribed to the uncertainty of the data about the onset of a flare and especially to the uncertainty in the localization of neutral points near the *limb*.

2. The comparison of fields *before* and *after* a flare showed in 7 cases out of 8 the simplification of the fields—the reduction of ∇H, the vanishing of nearby magnetic hills, the disappearance of neutral points. I mean that at least one of these effects is observed.

Gapasuk of the Crimean Observatory has recently found an appreciable re-arrangement of magnetic hills connected with flares (2). In 9 cases he found well pronounced shifts of these magnetic hills (of a given field strength) when comparing their location *before* and *after* a flare. At the same time the magnetic configuration remains steady in groups undisturbed by flares. There is also some evidence found by Gapasuk (2), Antalova (3) and Gnevishev (4) that some small spots are shifted in connection with flares. Michard, from spectrographic observations, found considerable decrease in total energy of the field integrated over the active region and diminution of field gradients and of the strength of magnetic fields, when comparing the fields *before* with that *during* and immediately *after* the flare of 1960 April 23 (5). He also observed that two magnetic hills were moved a little after this flare. Leroy, who used a polarimetric technique, reported a 'destruction' of the field in the vicinity of a flare, whereas the field in the regions of the flare itself remains practically unchanged (6). The Crimean observations, as those of the French astronomers, do not as yet permit the determination of when these changes occur, before or during a flare. This circumstance is obviously connected with the low time-resolving power of the technique used. We can only record with a time resolution of 15^{m} the rapid changes of the field in a small region near a neutral point where moustaches appeared (7). Babcock and Howard were fortunate to get successive records of magnetic fields *after* the onset of a 3^{+} flare 1959 July 16 with a time resolution of 15^{m}, and they found no appreciable changes in the process of the flare development (8). But our examination of the prints of their records show the disappearance of a magnetic hill at C and the reversal of polarity in the vicinity of a neutral point (Figure 1).

Zirin and Severny have recently found that fields of considerable strength (200-300 gauss) can be transferred by limb flares to a considerable height into the chromosphere (9).

Of special interest are the magnetic fields connected with great flares and especially those of proton flares. The magnetic fields in these cases are very peculiar—we sometimes observe the conjunction of several very strong magnetic poles of different polarities in a narrow region. The penetration of the strong field of one magnetic polarity into the very depth of the field of opposite polarity is also observed. These complex configurations are probably extremely unstable and undergo appreciable changes over the period of several hours.

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* This paper was illustrated by many magnetograms (not here reproduced), showing the changes in the magnetic fields after a flare and other phenomena. Most of them can be found in *Publ. Crim. astrophys. Obs.*

The disappearance of the striation pattern during some great flares observed by Ellison (**10**) is also very suggestive, being considered as a rapid re-arrangement or destruction of the field surrounding the flare region. This effect is confirmed by the careful inspection of the Hα films for these flares obtained with the Crimean coronograph.

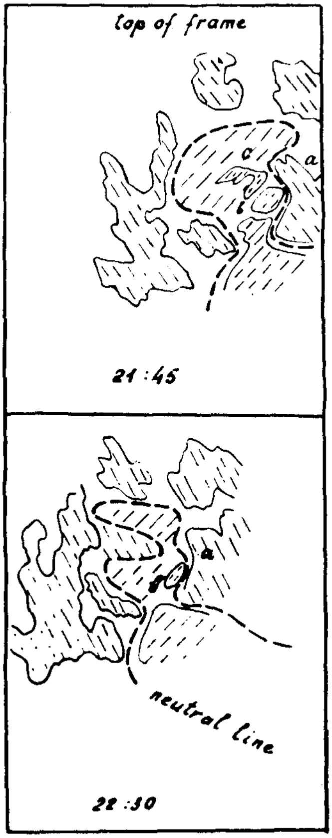

Fig. 1

The instability of the plasma near neutral points (being interpreted as a kind of pinch-effect) is also revealed on records of line-of-sight velocities which can be obtained simultaneously with the records of magnetic fields. These records show that neutral points of H are practically always (in 30 cases out of 37) found on the neutral lines of velocity maps—in places where two motions have opposite velocities. This fact can easily be explained if we assume that contraction or expansion of plasma exists in two predominantly opposite directions with some velocity gradient along these directions. This can be confirmed also by examination of Hα films and spectrograms of flares; Hα films of limb flares show the appearance of cumulative jets out of flares with some velocity gradient along the jet (**11**). Moreover, the observed run of hydrogen emission in the far wings of Balmer lines is in good agreement with the theoretical run of emission in a jet broadened by the velocity gradient along the jet (**12**). But sometimes the mechanism of Stark broadening describes quite adequately the observed broadening. Our recent experiments with laboratory pinch in hydrogen showed clearly that hydrogen emission is mainly broadened by Stark-effect when observing *across* the axis of the discharge tube and by velocity gradients when observing *along* the axis (**13**). (These gradients are obviously connected with the "sausage instability" of pinch and with the ejection of plasma through the hole in electrodes at the phase of maximal contraction.) Therefore, the character of broadening of hydrogen emission in flares being interpreted as pinch-effect can depend on the directions of the line of sight and the neutral line. In this way we can probably explain the striking discrepancy between different spectral observations of flares.

The formation of cone-like tops in most limb flares and the ejection of plasma out of flares implies the idea that the heated flare plasma is trapped in a kind of magnetic bottle possessing a rather cusped field geometry (Figure 2). This assumption is in good agreement with the magnetic field maps over flares in active groups, showing in the majority of the cases the conjunction of three polarities of considerable strength.

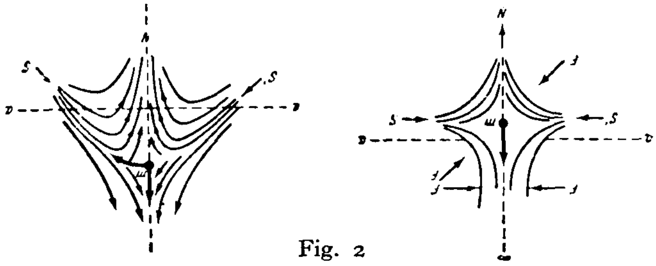

Fig. 2

In conclusion we should like to say a few words on the fields of sunspots themselves. The vortex structure around some sunspots discovered by Hale (14), the spiral-like motions in some prominences (Roberts *et al.* (15)), the fine structure of magnetic fields inside *umbrae* of sunspots (16) and some considerations on the instability of pure longitudinal fields (17), lead to the

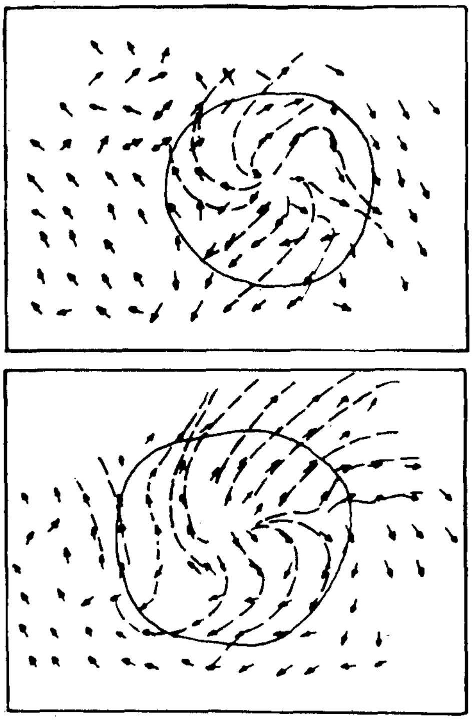

Fig. 3

conclusion that magnetic fields in active regions and especially the fields of sunspots may possess an *azimuthal* component, or that they have the character of a force-free field. To solve this question, Stepanov and myself made an attempt to record the *transverse* component of the magnetic fields in some spot-groups by using the modulating magnetograph (0, $\frac{1}{2}\lambda$). The reduction of these records together with the usual records for the longitudinal component is quite an elaborate process. As an example, Figure 3 shows the field of directions of the transverse component in a sunspot. In some active regions the azimuthal component is a well pronounced feature. The same conclusions have been recently obtained by Bumba, who found that the lines of force are arranged in the tubes coming out from the umbra in a form of spirals. The existence of the azimuthal component can explain the more or less permanent existence of such magnetic tubes of force as sunspots. At the same time, the rapid close approach of two tubes of force with opposite direction of the azimuthal field can eliminate the protection against instability and can lead to the pinch-effect as suggested by Gold and Hoyle (**18**) and Severny and Shabansky (**19**).

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DISCUSSION

H. W. Babcock. Dr. Severny's measurements of transverse magnetic fields are extremely important. The small field changes we observed three years ago may not necessarily be real, but may be due to seeing and instrumental effects. The present equipment has still to be improved. For this reason, perhaps no discrepancy at all exists between your and our measurements.

L. Biermann. How large is the observational error in the localization of the neutral points?

A. B. Severny. At the disk's center the error is about 10-20 seconds of arc. It becomes large near the limb.

G. Wallerstein. Could the depth distribution of the magnetic fields be determined by measuring the Zeeman effect in lines formed at different optical depths?

A. B. Severny. An effort is planned for determining the depth dependence of the fields by using the sodium D lines.

H. Alfvén. It certainly would be extremely important to measure the Zeeman effect in lines originating in different atmospheric levels.