SOME CHARACTERISTICS OF THE MAGNETIC FIELD AND PHOTOSPHERIC STRUCTURE DEVELOPMENT IN THE AUGUST 1972 PROTON-FLARE REGION

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Abstract: Some of the preliminary results obtained during the investigation of the August 1972 proton-flare active region are summarized. The development of the region in the frame of the magnetic field distribution, as well as the changes of the sunspot structures in connection with the magnetic field increase are discussed. Variations in appearance of photospheric details surrounding the positions of main white-light flare knots of August 7 are demonstrated. The relation between active filaments, chromospheric threads, fibrils and small photospheric nuclei, dark interpenumbral and intergranular spaces, or rudimentar penumbra is not only shown, but also investigated with the aid of computed models of the horizontal component of the magnetic vector simulating the real distribution of magnetic fields in the studied region.

Introduction

Some interesting facts concerning the morphology of the photospheric magnetic field and the structure development, and some important moments in the growth of the large August 1972 active region have been found. This region, the evolution of which has been accompanied by the occurrence of several particle-emitting flares, has been observed at our observatory in a very complex manner, including magnetic field and velocity measurements, and high resolution photospheric and medium resolution chromospheric photography. Some of the observed data have already been evaluated and, together with results published elsewhere, discussed. In the present report we would like to give a preliminary summary of some of our most interesting results.

Magnetic Field Development

(a) Large-scale

As it has been demonstrated earlier (in the list of references see, e.g., Bumba, Sýkora, in the present volume, p. 231 that the location of large, particle-emitting flares is closely related to a characteristic large-scale pattern in the magnetic field distribution with a life-time of the order of about 10 rotations. This situation may be seen again in the case of the August 1972 proton-flare region in relation to the large-scale magnetic field distribution development (Bumba, 1973a). The first appearance of the pronounced elliptical body in both negative and positive polarity fields may be seen during rotations 1585 and 1586. This elliptical feature is extended for about 70° in heliographic longitude and occupies both hemispheres. The second eastward ellipse, visible in the negative polarity field in the northeast part of which the proton-flare region developed, started to form at the same time, but only reached its best visibility during the time of the proton-flare region occurrence. The whole characteristic body of negative polarity extends more than 100° in heliographic longitude. As in practically all of the cases yet studied, it is characteristic that the whole pattern desintegrates rapidly during the one or two solar rotations following the rotation with the proton-flare region.

(b) Scale of the Active Region

It has already been found (Bumba et al., 1968a; Bumba et al., 1968b) that the formation of a „gulf" on a boundary of the two polarities of an active region magnetic field, observed with a relatively low resolution (10″—20″), which takes place usually in the centre of a sunspot group having the Zurich classification type of at least *C* complexity, is as a rule related to a sudden increase of group flare activity. The proton-flare region of August 1972 may be used as an example of such a development (Bumba, 1973b): during the rotations they preceded the rotation with the particle-emitting events in the studied region of the Sun, nothing very unusual in the distribution of the field and polarities was detected. (The leading polarity in the northern hemisphere is the negative one.) During the most important passage (rotation No. 1590) of the region across the visible disk the change of polarity distribution is striking — both polarities we observed one rotation before as widely separated, are now pushed together with the main boundary between them being tilted towards the equator. The positive polarity is now in the leading position. The main part of the negative polarity, in which the studied sunspot group developed as an island of positive polarity, now plays the role of a following polarity. During the next rotation (No. 1591) the magnetic situation does not show great changes except for the decrease of gradients, the joining of the island with the main positive polarity area, and the development of a new positive polarity island. During rotation No. 1592 the distribution of polarities due to several renewals of activity is again normal. During the subsequent rotations in the studied area not only the divergence of both polarities, but also fast disintegration and very soon the disappearance of practically all magnetic fields is again striking.

(c) Medium-scale, Distribution of Magnetic Fields in Sunspot Group

The development of the positive polarity island, described above, is reflected in the unusual situation in the polarity distribution seen on the outlines of the visible sunspot nuclei in the proton-flare group, drawn from the high resolution photospheric photographs (Bumba, 1973b). The greatest number of visible spots have the positive (following) polarity. During the whole passage across the disk only small changes in the negative (leading) polarity spots are seen, while the greatest and fastest changes involve the positive polarity spots, where their continuous divergence and diminution is apparent. At the same time, the most stable magnetic field with the highest intensity has the negative polarity spot.

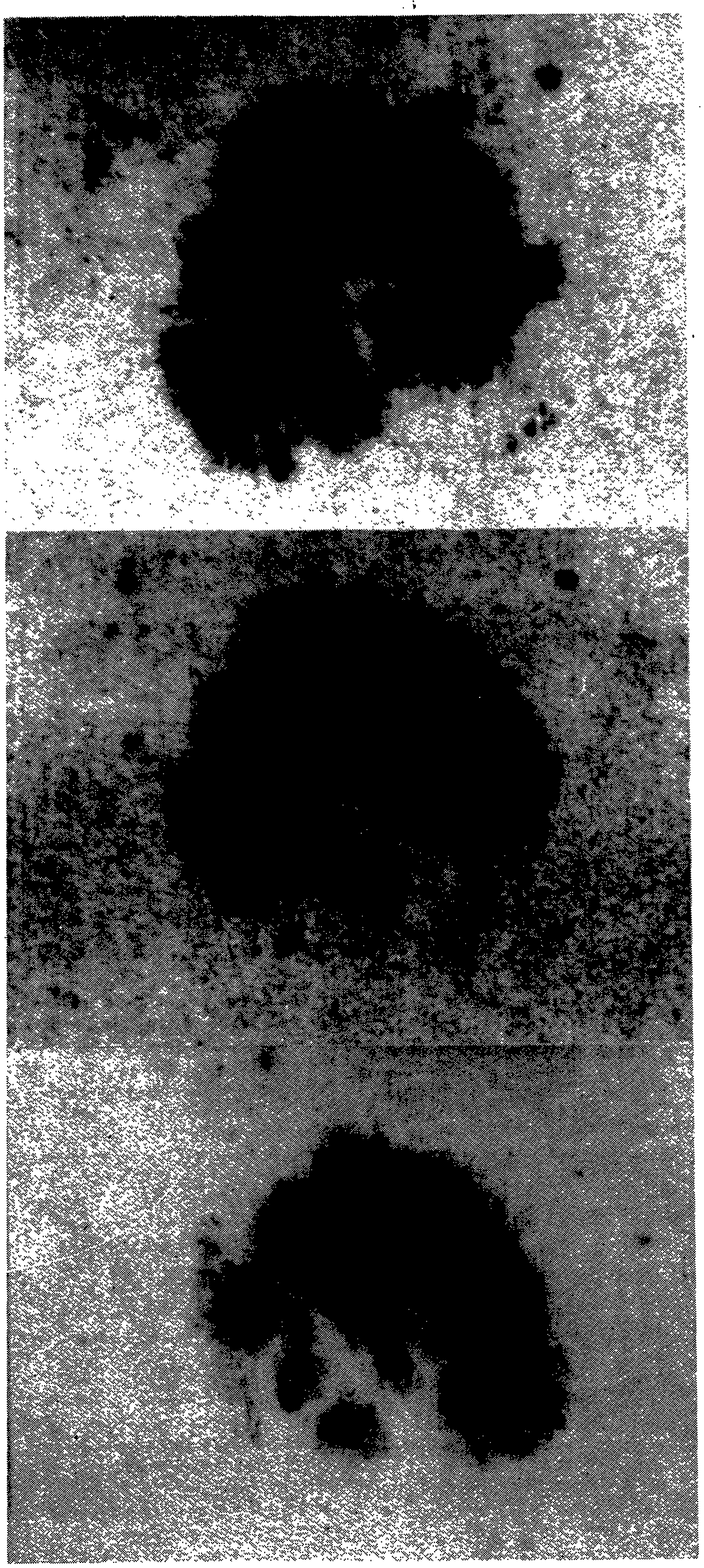
Development of the Sunspot Group

In the photosphere the group was characterized morphologically by several large umbrae and by an extensive penumbra, the greatest part of which was irregular with enclosed many small umbral nuclei or darker, elongated spaces in between the bright penumbral fibrils. The penumbra had also irregular boundary with the photosphere which penetrates into it in the form of gulfs, unusually bright filaments, chains of granules, light bridges, etc. Only a smaller part of this umbra was more or less regular, with radial fibrils and a relatively sharp boundary with the photosphere. One of the most interesting features in the studied group were the light bridges of several different forms, some of them developing so vigorously that they crushed the largest umbra and pushed its pieces apart (August 4). (See Fig. 1.) Some of these light bridges, in the form of a penumbra with very elongated, slightly curved fibrils, coincide with the magnetic field polarity boundary which is very unusual.

Changes in the Photosphere Possibly Related to the August 7 Proton-flare

Having the exact position of the white-light flare knots of August 7 during the phase of maximum brightness from the photograph taken at the Sacramento Peak Observatory (Rust, 1972), we were able to search for the changes in the organization of the photospheric fine structure elements in the neighbourhood of these knots (Bumba and Suda, 1973). If we try to characterize the general trend of the group development, comparing the photographs obtained during an interval of several days around the proton-flare of August 7 occurrence, we have to state that generally there were small changes in the group between the August 5 and 6, but there were changes between the August 6 and 7 such that several spots diminished in area and the influence of a process of spot disintegration could be observed. This process of disintegration may be

Fig. 1. Photographs of the photosphere in the August 1972 active region taken in Ondřejov on August 3 at $14^{h}17^{m}25^{sec}$ UT, on August 4 at $12^{h}38^{m}05^{sec}$ UT and on August 5 at $13^{h}34^{m}15^{sec}$ UT. The vigorous development of the main light bridge is demonstrated. North is on the top, west on the right side of the figure.



observed in the northern part of the group. There we may see a diminishing area of the penumbra, and a light bridge, which was clearly visible during August 5 and 6, was transformed into a region of the normal photosphere. This region of the photosphere continuously grew in area throughout the whole of August 7 (Fig. 2). The fastest changes may be seen in the northern part of the group on the photographs taken at 11^{59} and 15^{09} UT where, instead of the original light bridge around the northeast spot (minus polarity), a strip of rudimentary penumbra with elements similar to photospheric granulation may be seen as a prolongation of the gulf of the photosphere from the northern and southern sides of this strip. This region also coincided well with the area where the relatively large photospheric radial velocities change their direction from upward to downward (Macák, 1973).

In the centre of the group, where the brightest knot of the white-light flare was situated, the changes seem to have a different character. At this location a very fast development of a double chain of small nuclei and of a spatial form light bridge had taken place during the preceding days. The form of this region did not change very much from August 6 to August 7, only the influence of a disintegration process may again be seen. Near this region, in the southern part of the group, a strong magnetic field gradient was observed between the two most southwestern spots. The gradient seems to be largest on August 5 and afterwards it seems to decrease. It seems that there was only a remnant of this gradient on August 7. Small nuclei surrounding the brightest knot of the flare demonstrated small changes in form, position and area. There were changes in the form of the neighbouring light bridge, especially during the afternoon hours of August 7. Again, close by, a small region with radial motions in both directions was detected (Macák, 1973).

The most evident changes occurred in the group during the night of August 7—8. The most interesting fact is that the changes in the northern region of the group led practically to the restoration of the situation to the stage which was observed during the morning hours of August 7. In the region of the main knot of the white-light flare the very complicated figure of the light bridge and small nuclei simplified so much that the mutual merging of the main northern and western spots and with the new formations, which developed mostly during August 4 in the northern part of the group, could be seen. Again, only very small changes outside the main white-light flare regions are detectable.

Fig. 2. Photographs of the same active region taken on August 6 at $7^h23^m46^{sec}$ UT, and on August 7 at $5^h32^m02^{sec}$ UT and at $15^h09^m36^{sec}$ UT. The changes in the northern part of the group may be seen. North is to the left.

The Relation Between Some Chromospheric and Photospheric Structures in the Studied Group

Using our good quality and high resolution photographs of the August 1972 proton-flare region in the photosphere and the Big Bear Solar Observatory Flare Film 1972 taken for the major part in the Hydrogen Hα-line, we also investigated the mutual relations of the active filaments, chromospheric threads and fibrils to the underlying morphological details of the sunspots, their penumbras and the surrounding photosphere (Bumba, Ambrož, 1973).

The active region filaments and fibrils, indicating the distribution of magnetic field lines in the active region and its vicinity, coincide with the boundary of polarities inside the studied group on the place with the highest gradient of magnetic field and, therefore, with the region of elongated, slightly curved, bright fibrils of the penumbra, forming the special form of light bridge mentioned above. The individual fibrils of this filament join the groups of small umbral nuclei of opposite polarity, located close to the polarity boundary in regions with fast spot-configuration changes due to the development, as well as to the disintegration. An exact comparison of the position of the ends of the individual fibrils, threads, and filament fibrils shows that the most of them in the closest neighbourhood of the group is closely related to the very small nuclei, or darker elongated spaces placed inbetween the penumbral bright fibrils, or in small spots and nuclei without penumbra, or even in darker enlarged intergranular space, or rudimentar penumbra in the vicinity of the great spots, or in secondary small spot groups developed around the main group.

What can we deduce from this? The intensity of the magnetic field in such photospheric objects is at least of the order of 1000 Gauss (Bumba, 1967). These objects are relatively unstable. Their lifetime seems to be of the order of hours, although the region in which they occur lasts for days. Usually one considers these features to be of "secondary" importance in an active region. Is then the morphology of the chromosphere above an active region influenced mainly by these "secondary" photospheric elements — which, of course, may serve as indicators of changing magnetic flux — and so little affected by the huge umbras with very high values of magnetic flux?

To elucidate at least some aspects of this question we have calculated, in potential approximation (Schmidt, 1963), two models of the distribution of directions of the horizontal component of the magnetic vector a little above the studied group, simulating the real distribution of the solar magnetic fields for August 4, 1972 in two ways: (a) by a matrix in which the magnetic field is represented by magnetic points with the same intensity the polarity distribution of which corresponds to that of the map obtained photo-electrically (Livingston, 1973); (b) by a matrix corresponding to the real magnetic field intensity and polarity distribution obtained photographically (Roma Photographic

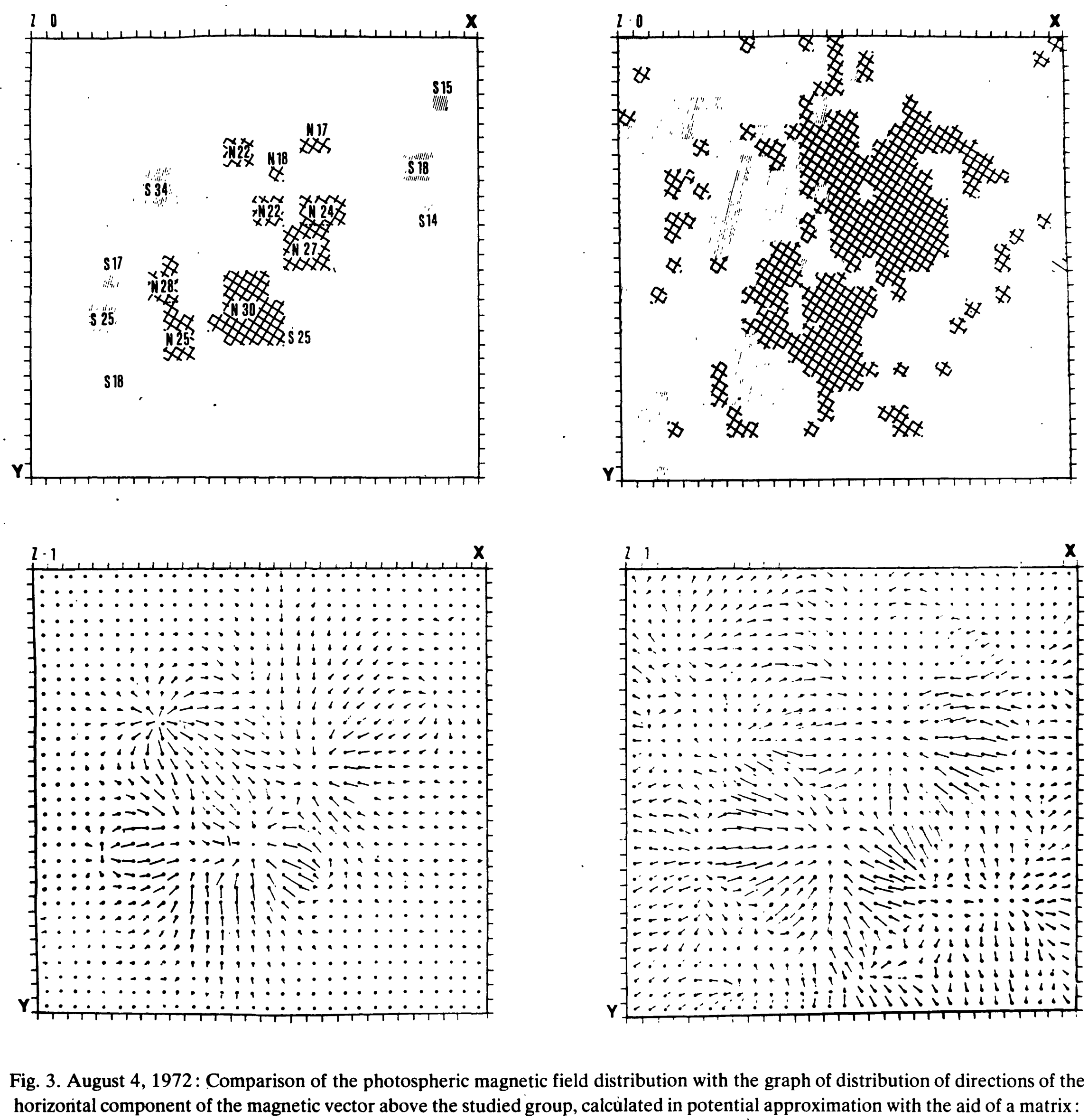


Fig. 3. August 4, 1972: Comparison of the photospheric magnetic field distribution with the graph of distribution of directions of the horizontal component of the magnetic vector above the studied group, calculated in potential approximation with the aid of a matrix:
a) corresponding to the photographically obtained magnetic field intensity and polarity distribution (to the left);
b) in which the magnetic field is represented by magnetic points with the same intensity, polarity distribution corresponding to that of a magnetogram (Livingston, 1973) (to the right). The scale and orientation of all pictures is the same.

Journal of the Sun). Comparing the obtained graphs with the photospheric and chromospheric situation, we may see that in such a static model the magnetic fields of all magnetic features, small as well as large, enter into play (Fig. 3). The agreement of the first magnetic map in which the role of the smaller magnetic elements is underlined by the photospheric and chromospheric morphology is better than in the case when only the larger spots are taken into account.

Conclusion

We are of the opinion that all that has been said above allows us to draw the conclusion that the systematic study of the magnetic field, photospheric and chromospheric morphology and its development may still yield new valuable observational information which is far from being theoretically interpreted.

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