Part VII

PROTON FLARE PROJECT (PFP)

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PROTON FLARE PROJECT

Introduction and Summary

reported by

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All contributions presented at the Friday morning session concerned results of the Proton Flare Project (PFP), which was organized by the IAU Commission 10 under the sponsorship of the IQSY Committee, from May 1 to September 30, 1966. As explained by Z. Švestka in his introductory talk, this project had four main aims:

(1) To observe proton flares shortly after the minimum of the solar activity, when, on the rising part of the solar cycle, some proton flares already appear, but not too many of them, so that the individual proton flare phenomena are fairly isolated. This makes it easy to study all the effects of such a proton flare in the interplanetary space and in the Earth's surroundings, and particularly, it allows a detailed study of the isolated active region, in which the proton flare appears.

(2) To get some practical experience in the forecasts of proton flares and verify the reliability and the practical use of them.

(3) With the aid of these forecasts, to give to the solar and geophysical observatories and to the launching sites the possibility to get prepared for the coming event. It was hoped that in this way one might get very detailed observations of the proton-flare active region, of the proton flare itself, and of its effects in the interplanetary space and in the Earth's magnetosphere and ionosphere.

And finally, it has been intended to publish all the results of such a study in one homogeneous series of publications, so that the final result would be a fairly complete picture of the whole proton-flare event, including not only the proton flare itself and its effects, but also a study of the birth and development of the active region in which the proton flare appeared.

The main burden of the organization of this project was carried by Dr. Simon and his co-workers at the Meudon Observatory in France. Dr. Simon served as the chief coordinator of the project and he was also responsible for the forecasts of proton flares and for the collection of the results.

The first PFP proton-flare alert was announced on July 5, for a new solar region, which developed very fast in the Northern solar hemisphere. A SPARMO balloon was launched in evening hours on July 6, and 4 hours later, shortly after midnight, a proton flare actually appeared in the suspected active region. This was a very favourable event from the point of view of the PFP programme, because the proton flare

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occurred in a quiet period as a completely isolated event, and the active region in which this flare appeared was born a few days before in the visible hemisphere of the solar disk. The proton flare was also associated with a small but distinct GLE. Therefore, this event has been selected for a detailed study.

The results of this study will be published in Volume 3 of the *IQSY Annals*, which also will contain, in other two volumes, the Proceedings of the IQSY Symposium, which was held in July in London. Following the wish of many participating scientists, however, two meetings on the PFP results were organized before this publication, the first one during the COSPAR meeting in London, on July 27 and 28, 1967, and the second one in Budapest, during this IAU Symposium, on September 8. The London meeting was mainly concerned with the effects of the proton flare in the solar corona, interplanetary space, and the Earth's surroundings, as measured by the space techniques. In Budapest, on the contrary, the preference has been offered to ground-base observations of the solar active region, in which the proton flare formed.

Since all PFP papers will be published in the *IQSY Annals*, including those presented in Budapest, we do not consider it useful to publish these contributions here in full. Instead, we have decided to publish in these Proceedings only a brief summary of the PFP session in Budapest, to give to the readers general information on the results reported here, and anybody who is interested in them can find the full text of all the contributions in the *IQSY Annals*, Volume 3 (published under the auspices of the IQSY Committee by the MIT Press in 1968).

The programme of the Friday morning session on PFP results concerning the structure and development of the active region which produced the proton flare of July 7, 1966 was as follows (in the following Summary these papers are referred to by their series numbers):

1. A. B. Severny (Crimea): Magnetic fields and proton flares (The evolution of the magnetic field).
2. G. Brückner (Göttingen) and M. Waldmeier (Zürich): Distribution of magnetic fields in photospheric and chromospheric layers and its correlation to the flare event of July 8, 12^h53^m–13^h40^m UT. (Presented by E. v. P. Smith.)
3. P. S. McIntosh (Boulder): Birth, evolution and fine structure of proton-flare associated sunspots.
4. G. Newkirk, R. T. Hansen, and S. Hansen (Boulder): Development of the white-light corona in the proton region.
5. A. Krüger (Berlin): Remarks on the S-component of the radio emission.
6. M. J. Martres and M. Pick (Meudon): Summary on the development of the active region, based on papers 1–5, and on the following contributions, which were not presented verbally in Budapest:
   6a. C. Popovici and A. Dimitriu (Bucharest): The H-alpha plage.
   6b. T. Fortini and M. Torrelli (Rome): The calcium plage.

6c. J. L. Leroy (Pic-du-Midi): Photométrie des raies coronales 5303 Å and 6374 Å.
6d. M. N. Gnevyshev (Kislovodsk): Coronal observations.
6e. H. Friedman and R. W. Kreplin (Washington): The slowly varying component of X-ray emission.
6f. H. Tanaka, T. Kakinuma, and S. Enome (Nagoya): The S-component of the radio emission.

7. A. Bruzek (Freiburg): Flares in the active regions.
8. L. Křivský (Ondřejov): Complex study of energy loss of the active region.
9. V. A. Banin (Irkutsk), L. D. de Feiter, and A. D. Fokker (Utrecht): Summary on the activity of the active region, based on papers 7 and 8, and on the following contributions, which were not presented verbally in Budapest:

9a. B. Valníček (Ondřejov), G. Godoli (Catania), and F. Mazzucconi (Arcetri): The West-limb activity in the H-alpha line.
9b. J. L. Leroy (Pic-du-Midi): Photographie en H-alpha, H-beta et D_3 de la protubérance active du 9 juillet 1966.
9c. G. Stiber (Saltsjöbaden): Polarization measurements of the July 11th event.
9d. E. Hurtovenko, N. Morozhenko, and A. Rachubovsky (Kiev): Active prominences on July 9 and 11, 1966.
9e. K. Kai (Mitaka) and O. Yudin (Gorky): Radio bursts.
9f. H. Friedman and R. W. Kreplin (Washington): The X-ray emission events preceding the flares.
9g. H. W. Dodson-Prince (Michigan): The behaviour of the active region prior to the proton flare based on λ sweep records.
9h. R. R. Fisher and G. R. Mann (Haleakala): Variations in the active region.
9i. A. Caldwell (Culgoora) and M. McCabe (Haleakala): Optical observations of the proton flare.

10. L. B. Demkina, B. A. Ioshpa, E. I. Mogilevsky, and V. N. Obridko (Moscow): Local magnetic field decay.
11. H. W. Dodson-Prince and E. R. Hedeman (Michigan): Late activity of the active region.

Apart from these 11 contributions two more papers were presented during the Friday morning session, by C. Sawyer and J. H. Kinsey. These papers were partly related to the PFP July 7 event, but they discussed other flares as well, and therefore they are published separately from the following summary.

Summary

On June 25 and 26 at 33°N a large region, which covered almost 30° in longitude, was passing the East limb of the Sun. It was an old expanding region and the McMath active region No. 8362, which later on produced the proton flare on July 7, was born on June 28 on the Eastern periphery of this area (6b). This is in agreement with the general conclusions by Bumba and Howard (1965) that new active regions form inside or very close to old expanding magnetic fields.

The development of this new active region in the following days also closely resembled the scheme described by Bumba and Howard. The region expanded along the borders of three supergranular cells (6b) and the first spots also formed along

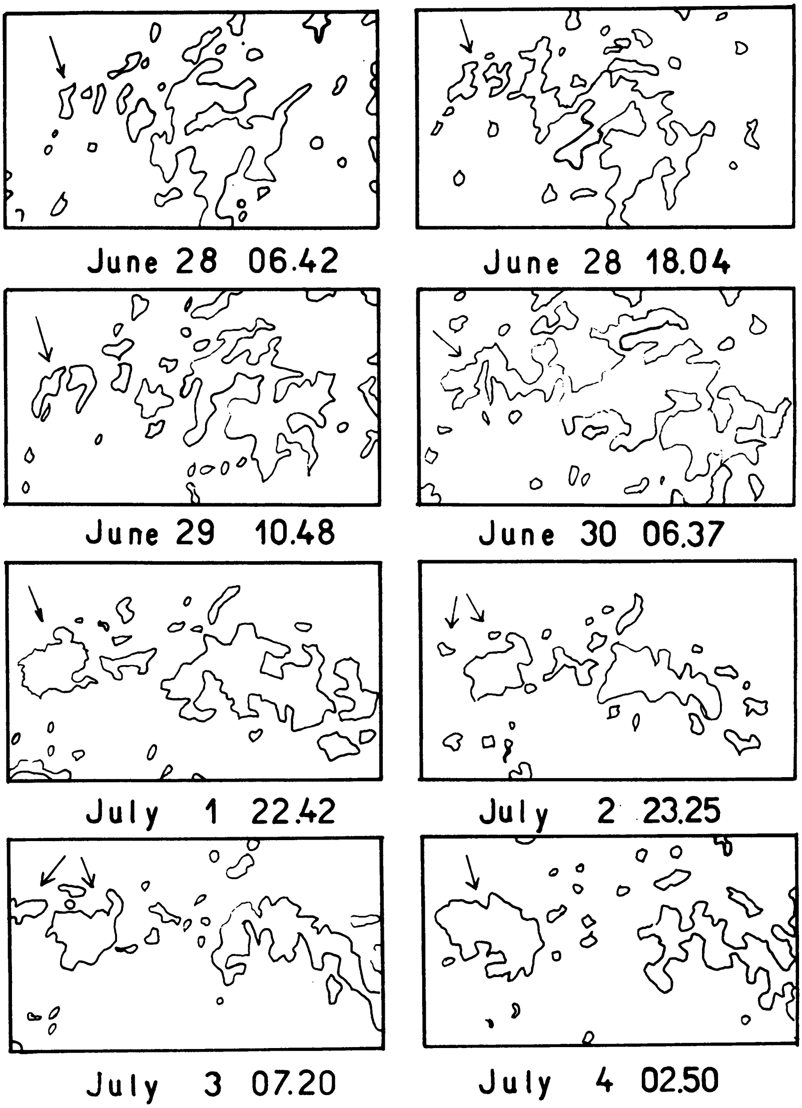

FIG. 1. *Development of the calcium plage during the first days of life of the active region. The newly born active region No. 8362 is marked by an arrow (Fortini and Torrelli, 6b).*

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supergranular boundaries (3). The development of the calcium plage is drawn in Figure 1, according to photographs (6b) which the reader can find in the *IQSY Annals*. The increase of the active region was fairly slow until a new luminous grain appeared on July 2, 2° East of the older plage and merged with it on July 4. At about the same time, on July 3 afternoon, the Hα plage also took a compact and elongated form, which developed to its maximum brightness on July 6 (6a).

The first spots (3) were observed on June 30 and all possessed the magnetic polarity of following spots in the Northern hemisphere. The evolution of the sunspot group proceeded with the successive development of two bipolar groupings of spots East of the original spots, and the follower polarity was the first to appear in each of these pairs. McIntosh emphasizes that in both pairs the leader spots were North of the followers, contrary to the normal occurrence. The appearance of the second bipolar pair coincided with the commencement of rapid growth of the entire region on July 3.

The respective positions of these groups were quite remarkable (6). Since their appearance, the sunspots constituted two ranges of inverse polarity, with the neutral line roughly parallel to the equator (Figure 2). Between 14^h on July 4 and 8^h on July 5, the δ configuration was built up, characterized by spots of inverse polarity within the same penumbra. Finally, between July 5 and 6, the proton-flare active A configuration (Avignon *et al.*, 1963) was definitely built up. After about 12^h UT on July 6 everything seemed to be prepared for a proton-flare occurrence: The sunspot group was formed by two parallel rows of spots of opposite magnetic polarity embedded in a common penumbra, and the Hα plage (6a) began to exhibit two bright ribbons which had a symmetrical disposition with respect to the axis of the group and just covered the penumbra of the two ranges of spots (Figure 3).

These twelve hours preceding the proton flare (which appeared at 0^h26^m on July 7) are quite interesting from several points of view. First, it is of interest that during this time the Hα plage already possessed a shape very similar to the shape of the proton flare itself (6a). The penumbra between the large umbrae in the central part of the group developed exceptionally dark and thick filaments parallel to the rows of umbrae (3). Eighteen λ-sweep records in the Hα line made during this period at McMath-Hulbert Observatory (9g) showed heavy absorption in the active region and in its surroundings and motions of absorbing material closer and closer to the large spot of Northern polarity. There was a continuous production of small flares with increasing area from one subflare to the following one, but no larger flare appeared during this period. Another peculiar characteristic of this phase of development was the occurrence of small bursts at around 10000 Mc/s, partly associated with the subflares, which had no counterpart at lower frequencies, below 8000 Mc/s (9, 9e, 9g). It is noteworthy that the production of these high-frequency bursts was not in the least disturbed by the occurrence of the proton flare itself. A somewhat similar burst of activity was observed in the proton-flare active region which passed the central meridian on July 13·8, 1961, but we hardly know any other previous centres of

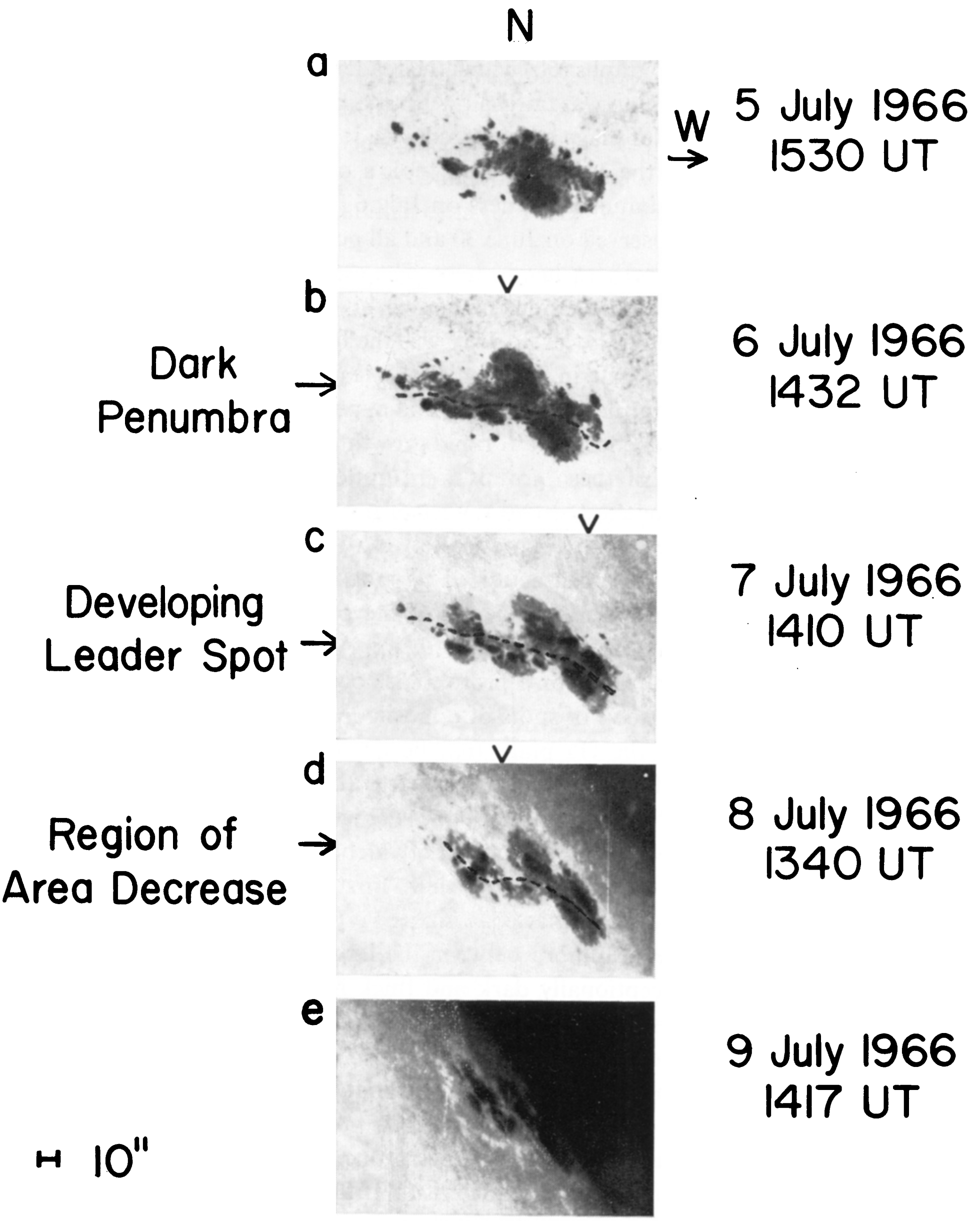

FIG. 2. *Development of the sunspot group, with neutral line of the magnetic field drawn inside the group (McIntosh, 3; Martres and Pick, 6).*

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FIG. 3. *The Hα plage on July 7, at 0^h18^m UT, a few minutes before the proton-flare appearance (Banin et al., 9).*

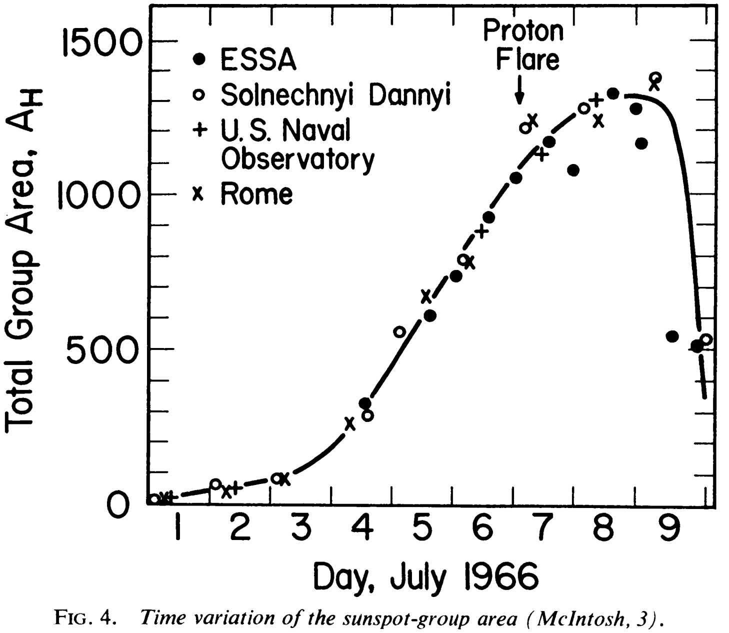

FIG. 4. *Time variation of the sunspot-group area (McIntosh, 3).*

activity that produced so persistently bursts that were so systematically restricted to very high frequencies (9).

The total area of the sunspot group (3) began to increase at a fast rate since July 3, as one can see from Figure 4. Contrary to some previous observations of proton-flare regions, this increase continued for at least 2 days following the proton flare. However, the large umbrae near the centre of the group, which underlaid the brightest parts of the proton flare, began to decay within half-a-day of the time of the flare, which might have been related to its occurrence (3; Sawyer, 1968).

From July 4 to July 7, 27 records of the magnetic field of the active region were obtained at the Crimean Observatory (1). The comparison of longitudinal-field maps for different days shows that they are very similar (an example is shown in Figure 5): on each map we can identify the same three strong magnetic 'hills', As, Bs, Cs of Southern polarity in the Northern part of the map, and 2–3 A_N, B_N, C_N not so strong

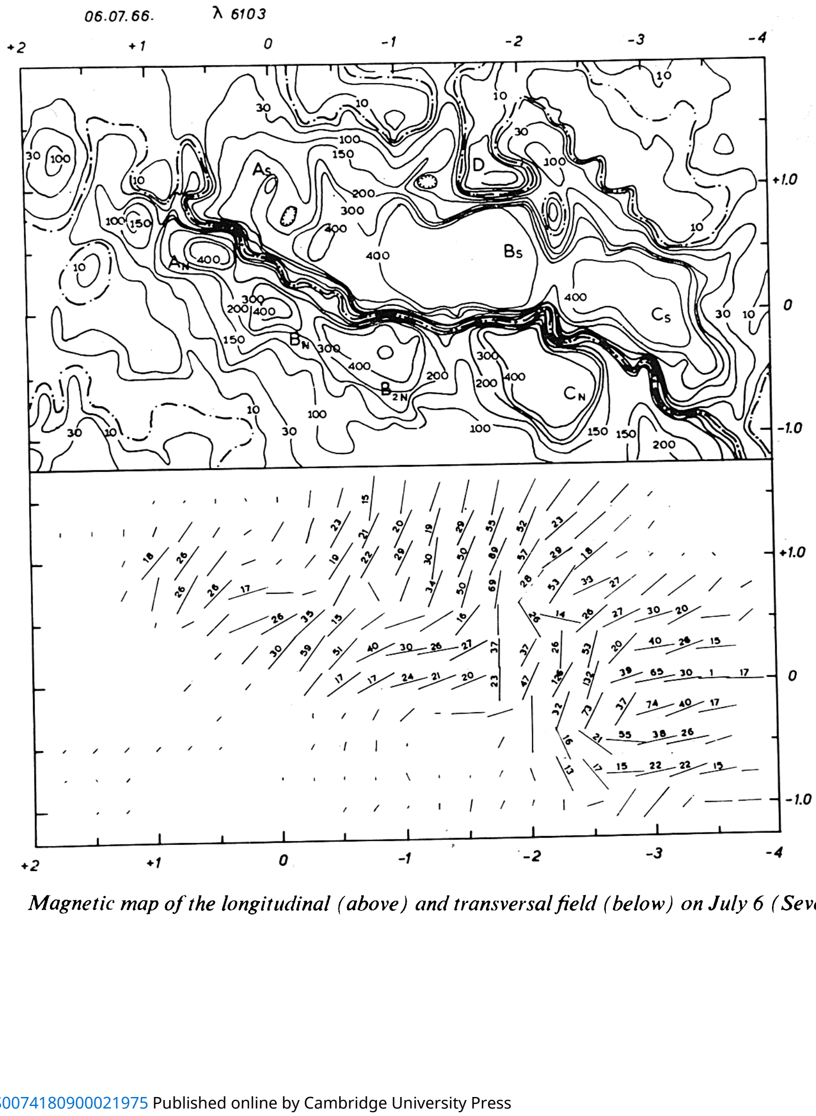

FIG. 5. *Magnetic map of the longitudinal (above) and transversal field (below) on July 6 (Severny, 1).*

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'hills' of Northern polarity located to the South just opposite to the preceding ones.

The total magnetic energy of the active region was increasing from $1–2 \times 10^{32}$ ergs on July 4·3 up to 20×10^{32} ergs on July 6·4, and decreased back to about the initial value after the proton-flare occurrence (Figure 6). Also the gradients of the longitudinal magnetic field along the straight lines joining the magnetic hills A, B, C, show the same behaviour, increasing, on an average, from initial values of about 0·1 gauss/km to the peak value of ~ 1 gauss/km on July 6·2 and decreasing again to 0·1–0·2 gauss-km on July 7·2. When comparing measurements in $\lambda 5250$ and $\lambda 6103$ lines Severny found the magnetic flux as well as the gradient and the relative increase of these quantities larger in the deeper layer ($\lambda 5250$ Å). The general character of the magnetic field inside the sunspot group was very similar to that one observed in the group which produced the proton flare of July 16, 1959 (Howard and Severny, 1963). Due to the gap in

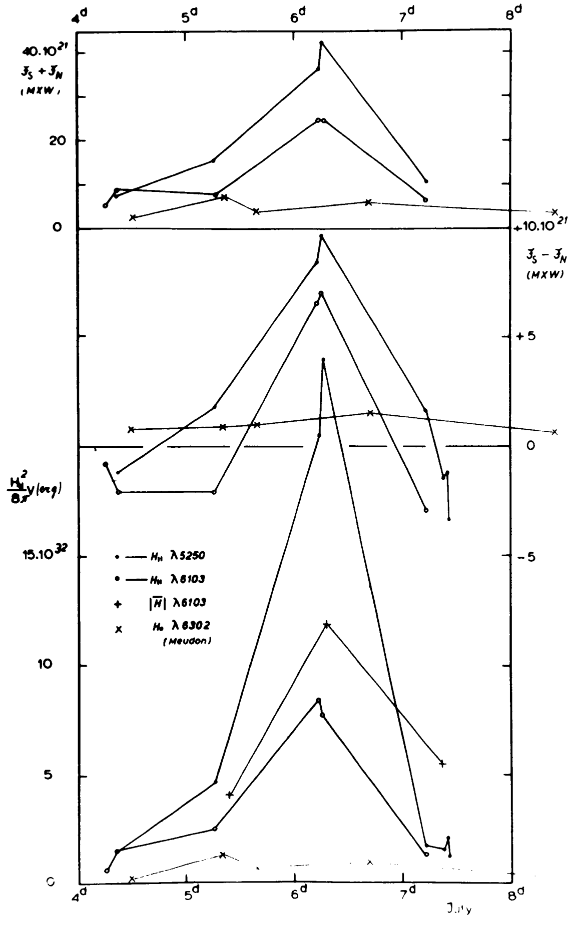

FIG. 6. *Time variation of the magnetic flux and total magnetic energy in the active region (Severny, 1).*

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observations between July 6·4 and 7·2, however, one cannot say whether the decrease of the magnetic flux and of the gradients closely preceded or followed the proton-flare appearance.

Figure 5 also shows a representative map of the transversal field as it looked according to the Crimean measurements, before the proton-flare appearance. Appreciable difference in directions of the transverse field first appeared on the maps obtained on July 7, 5 hours after the flare onset. While the directions had formed roughly something like a cross in the middle of the map before the flare appearance (Figure 5), on July 7 Severny found instead of it a stream of purely horizontal di-

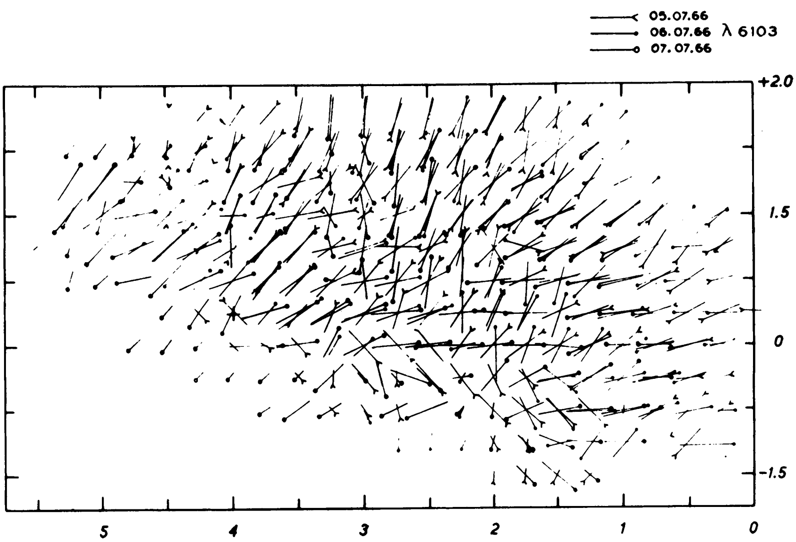

FIG. 7. *Comparison of the directions of the transversal magnetic field before the proton flare (July 5 and 6) and after its occurrence (July 7) (Severny, 1).*

rections (in E–W orientation) as if the proton flare had forced the directions to be parallel to its bright ribbons, and to the neutral line $H_{\|}=0$ (Figure 7). Thus, we find a rotation by 90° of vector fields in the central part of the region between July 6 and July 7, during the night when the proton flare appeared, a phenomenon which Severny (1964) already observed and described earlier for other solar flares. The fact that all six maps of the transversal field obtained on July 7 are similar, including those for the lowest level (λ4808 Å), leads to the conclusion that there were no appreciable changes in the vector field of $H_{\perp}$ during the morning hours of July 7, so that all observed changes indeed must be attributed to the night of 6 to 7 July, when the proton flare appeared.

Severny also constructed 10 isogauss maps of the total vector of the magnetic field $|\mathbf{H}|$ based on observed maps of $H_{\|}$ and $H_{\perp}$. Examples of these maps are on

Figure 8 and show the main process of the fission of large magnetic tubes of force into small pieces, the process observed recently by Gopasyuk (1967) for decaying groups. One also can see from this figure that isogauss contours (for a given strength) are broader in $\lambda 4808$ than in $\lambda 5250$ indicating that the magnetic flux and energy at the lower level was higher than at the upper one. Severny concludes from it that the magnetic field of the active region was concentrated at deep layers of the solar atmosphere.

The slowly varying component of the radio emission associated with the proton-flare active region (5, 6f) began to increase on July 3, and the general evolution of the radio flux was quite similar to the development of the sunspot area: The flux was

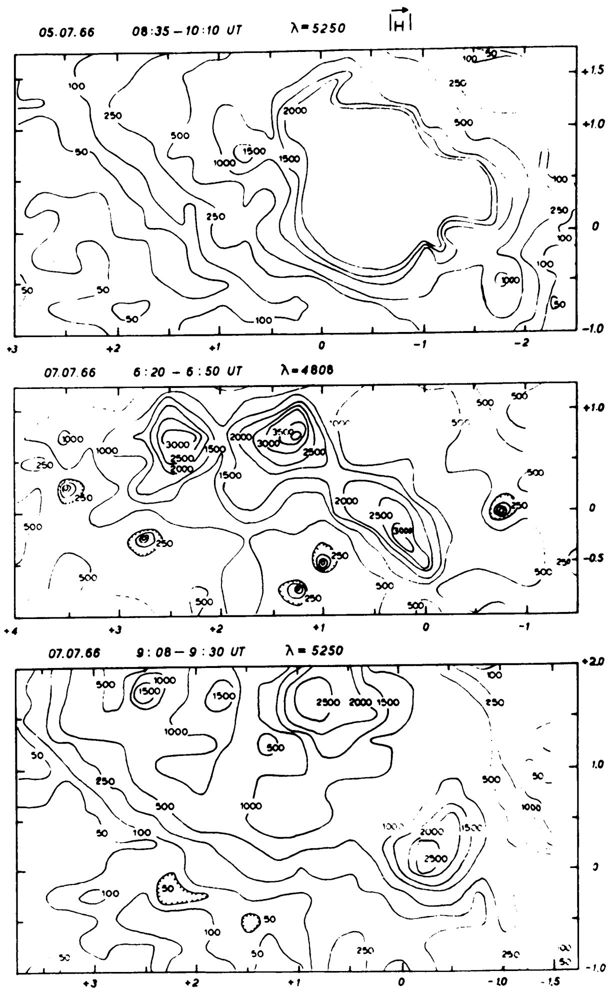

FIG. 8. *Total vector magnetic maps of July 5 and 7 (Severny, 1).*

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increasing up to July 8 and rapidly decreased on the following days. During this period, however, the spectral distribution of the radio intensity changed quite substantially, as one can see from Figure 9. Until July 4·5, the flux density decreased with the increasing frequency between 4 and 9·4 GHz, as commonly observed for the majority of the active centres (Swarup *et al.*, 1963). Between July 4·5 and 5·0, however, the flux at 9·4 GHz increased substantially so that the spectrum became relatively flat in the 4–9·4 GHz frequency interval for all the remaining days until July 8. Such a behaviour is in agreement with the generally observed spectral characteristics of

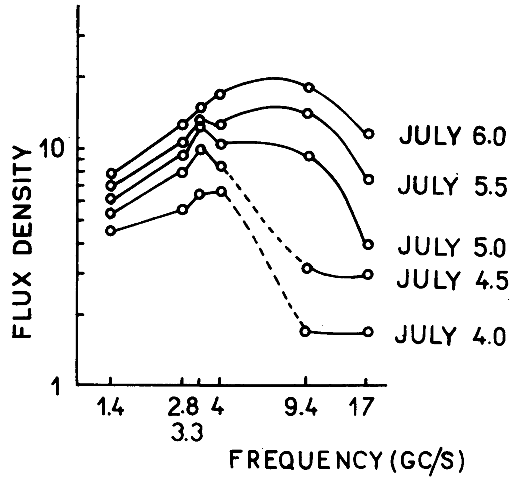

FIG. 9. *Time variation of the spectrum of the s-component from July 4 to July 8 (Tanaka et al., 6f).*

proton-flare active regions, as reported before by Tanaka and Kakinuma (1964). The sudden increase of the flux on July 5 indicates that this enhancement of 3 cm radiation is not associated with the increase of the sunspot area, as is the case with longer wavelengths, but it is due to a characteristic change of the magnetic structure of the active region (6).

X-ray observations show (6e, 9f), that the X-ray flux began to increase slightly on July 4, and significantly after July 5·5. By 6 July, X-ray flux levels had increased by factors of 15, 5, and 1·6 in the 0–8, 8–20 and 44–60 Å bands, respectively. The X-ray records on this date and on the following days are conspicuous by considerable fluctuations even during the period of one telemetry pass (i.e. approximately 10 min). The emission spectrum also became much harder.

The density of the corona above the active region increased dramatically between June 27 and July 10 (Figure 10) when the active region passed the Eastern and Western limbs of the Sun, as one can see from measurements both of the white-light corona (4) and of coronal line intensities (6c, 6d). Both Gnevyshev and Newkirk *et al.* confirm

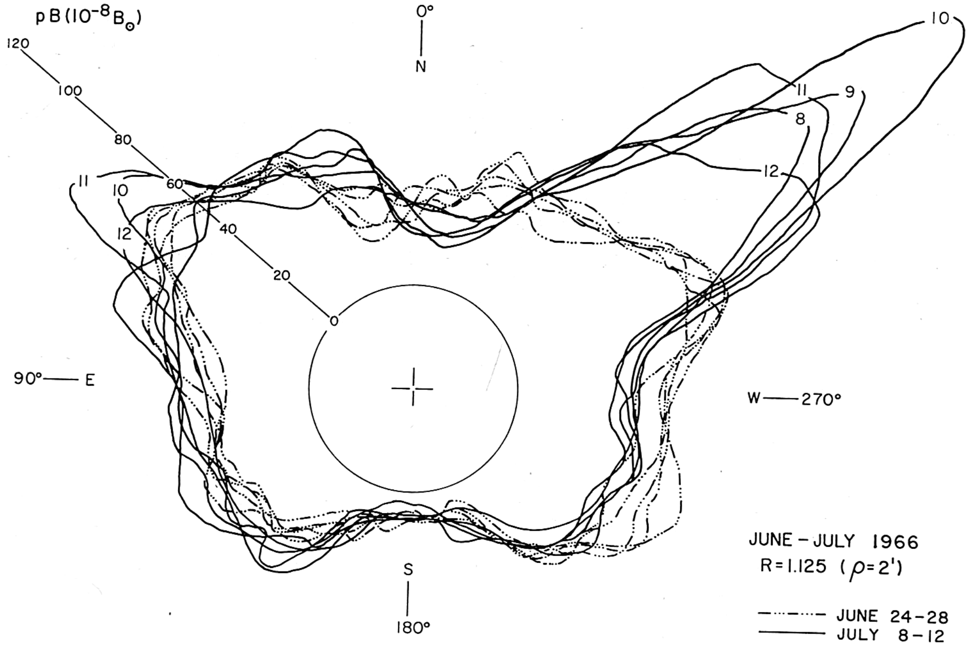

FIG. 10. *A superposition of radial plots of K-coronameter data for the limb passages of the active region on June 24–28 and July 8–12 for a scan height of $R = 1{\cdot}125\ R_{\odot}$. Dates for the individual traces in July are indicated (Newkirk et al., 4).*

that the maximum of coronal intensity did not coincide exactly with the position of the proton flare, but it was shifted a few degrees to the North.

The deduced coronal electron density on July 10 (i.e., 3 days after the proton event) was only slightly larger than over other active regions within the range of heights above 0·3 solar radii, but it significantly exceeded the density in other active regions in the low coronal layers (4). This observation of a unique, low-elevation coronal condensation (also found for the limb passage on September 5, shortly after the two other PFP proton-flare occurrences) suggests that proton flares eject material into the corona. Newkirk *et al.* think that the expanding series of loop prominences and the expanding condensation represent different aspects of the same phenomenon brought on by the emergence of a magnetic dome from the lower atmosphere.

Flare activity (7) began on July 3 and increased parallel to the growth of the active region. On July 6 through July 9 the flare activity (including subflares) took place during about 50% of the time, but it was relatively low as well as for the importance of the largest flares as for the number of flares other than subflares. No really large event (importance-3 or 4 flares) took place in the visible hemisphere. Three class-2b flares only occurred on the disk, the proton flare of July 7 being the most important of them. A total of 74 subflares, 34 importance-1 flares and three importance-2b flares were observed in the active region from July 3 through July 10. A conspicuous eruptive limb event on July 11 (Figure 11) is of particular interest, but the importance of the flare associated with it unfortunately is not known because it occurred on the far side of the Sun. This large prominence first had an explosive character, and spectral lines showed a number of condensations with different line-of-sight velocities (9d). Later on, however, the line profiles gradually changed into forms similar to those for loop prominences.

Place of origin and initial shape of the major flares did not differ very much, and parallel strands were formed at least in a rudimentary shape in a number of flares (7). Various flares, however, developed and expanded in rather different ways. The proton flare of July 7 was brightest of them, and it also was the only one which covered all the spots completely, for at least 1 hour.

All the flares preceding the proton flare were of minor importance, so that the proton flare was the first major event in the group. The next major flare following the July 7 proton flare occurred on July 8 at 12^h36^m UT. In its maximum the Northern (i.e. the South-polar) row of umbrae was covered almost completely by the flare, while the Southern (North-polar) spots remained still partly visible in Hα. The second largest flare in this active region occurred on July 9 at 03^h05^m UT. All large spots except the Southern leader (which had North-polarity) were covered by the flare within a few minutes, and since 03^h29^m one could observe loop prominences developing from the flare region (see an example in Švestka, 1968).

Comparing the 'non-proton' July 9 flare with the July 7 proton flare we find an appreciable difference in shape and development, which may partly be due to different arrangement of the spots. Bruzek emphasizes that the July 9 flare, surprisingly, looked much more like the proton flares as they were observed in past years than the July 7 flare did. The areas of the two flares were about the same size at maximum brightness. The July 7 flare, however, was much brighter and it expanded much more and for a longer period finally covering all spots in the group (7).

It is well known that loop-prominence systems are closely associated with proton flares (Bruzek, 1964). It is of interest that in this case loop prominences did not accompany the proton flare itself, but another large flare produced by the same active region 2 days later. This seems to confirm Švestka's (1968) conclusion that loop-prominence systems are associated with proton-flare active regions and not directly with proton flares themselves.

The great eruptive prominence of July 11 (Figure 11) was an outstanding phenomenon and its form seems to demonstrate the existence of a complex magnetic-field structure above the active region (9a). At the beginning of its development the prominence was divided in two parts which developed separately. One part developed approximately in a direction parallel to the limb and towards the observer. The other part, which was the main one, developed in a direction inclined at 40° to the limb and its velocity exceeded 300 km/s. The main part of the prominence, however, as

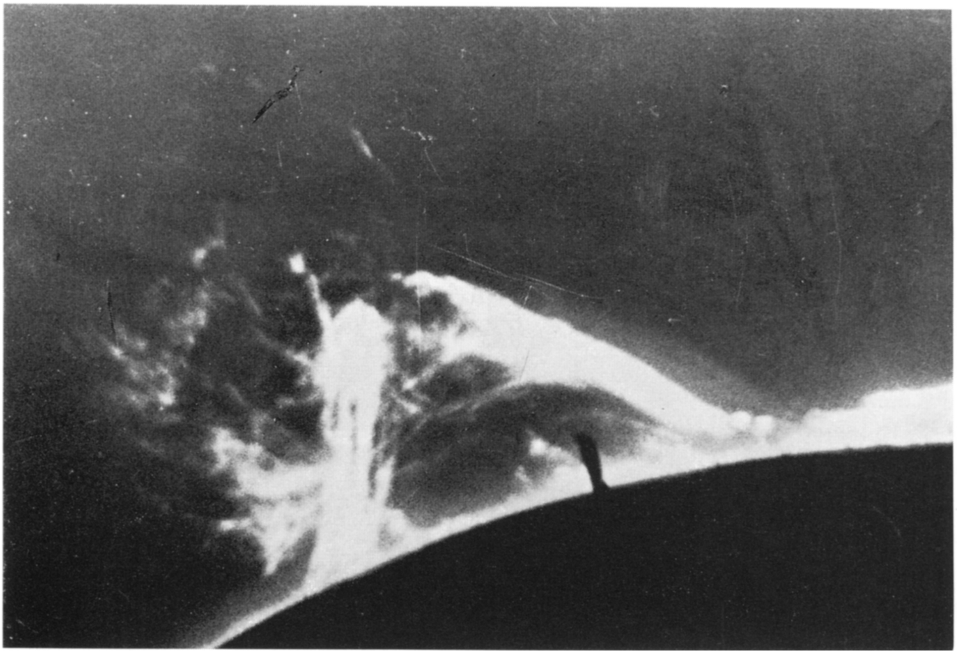

FIG. 11. *The eruptive prominence of July 11, photographed in the Hα line at* 9^h52^m *UT (Valníček et al., 9a).*

well as the hypothetic large flare below it, remained behind the solar limb. Valníček and his co-authors come to the conclusion that we meet here with a twisted prominence, which started in a direction parallel to the plane of the disk and after completing a twist returned to the chromosphere in a direction nearly perpendicular to the initial direction.

In the radio-frequency range, until July 5 only occasional bursts with small intensity were observed (9e). Since 12^h UT on July 5 bursts began to occur more frequently and the number of bursts had the maximum at 15^h–24^h on July 6. As we mentioned above, however, most of them were observed at 3 cm only, without any counterpart at longer wavelengths, though observations were carried out continuously at many frequencies. The number of flares does not show such a maximum. High radio-emission activity continued after the proton-flare appearance and its fall was slower than its rise which, in fact, took 1 day only.

The July 7 proton-flare event was associated with an outstanding type-IV burst. Apart from it, other four significant bursts were produced by the proton-flare region: The next greatest one to the burst associated with the proton event occurred on July 9 at 02^h30^m UT and accompanied the large flare which was already described above. The spectral diagram of this burst could also be classified as a type-IV event, its flux

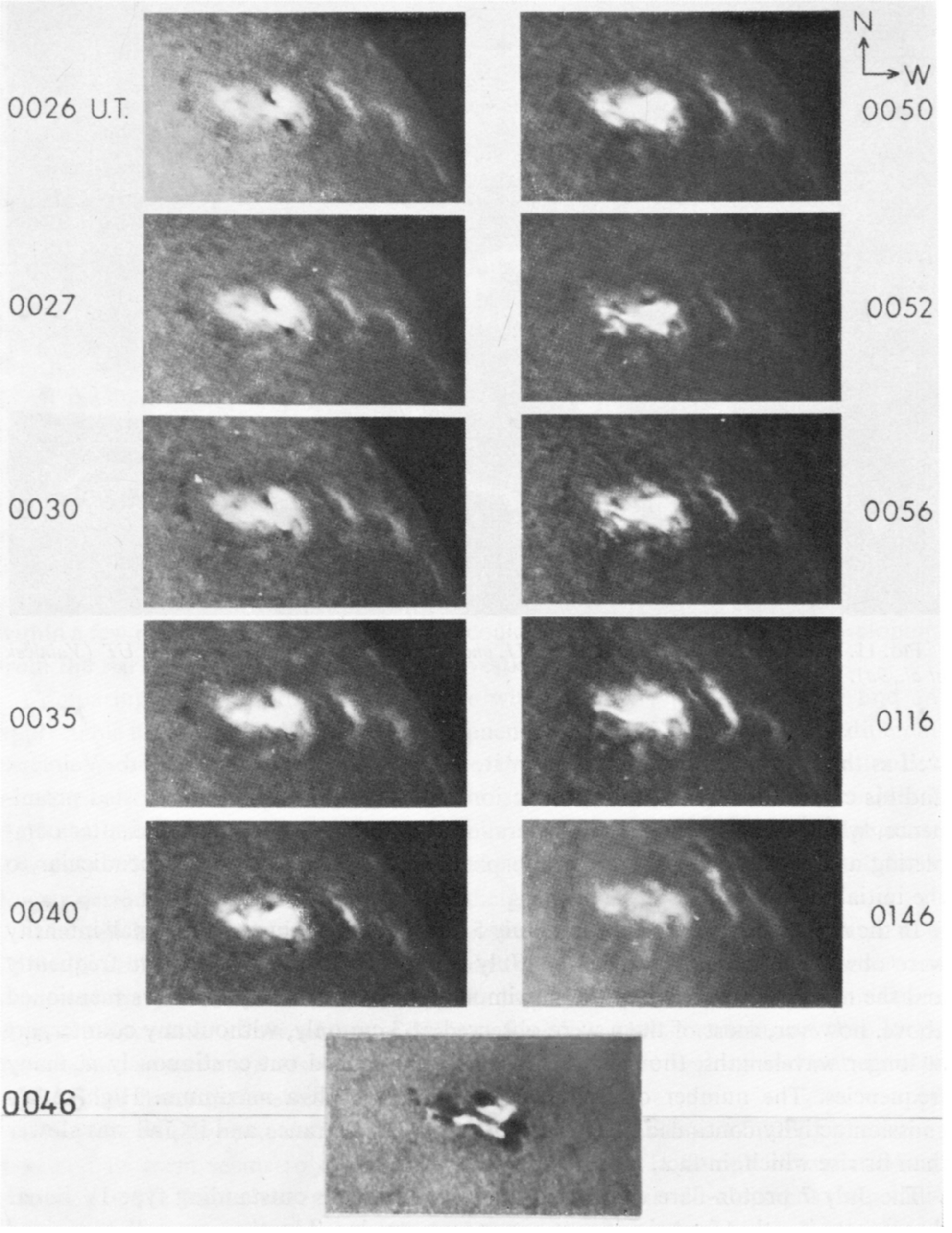

FIG. 12. *Time development of the proton flare in the Hα line (Caldwell and McCabe, 9i). The off-band picture at the bottom taken at 0^h46^m UT shows the position of the two bright ribbons amongst the spots (Dodson-Prince, 9g).*

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density, however, was much smaller than on July 7. The other greater bursts were associated with two flares of importance 1B and 2B on July 8, and with the large eruptive prominence on July 11.

X-ray bursts also occurred very frequently on July 6. On ten telemetry passes (9f) the X-ray intensity was observed to change within a period of 5–15 min, in some cases dramatically, and in most cases these rapid variations were clearly associated with solar flares from the proton-flare active region. During the proton flare all of the photometer amplifiers were heavily saturated until 01^h57^m and then the flare X-ray emission decayed slowly until 9^h UT on July 7. During this decay-time no variability of the X-ray flux was recorded, but it started again in the UT afternoon on July 7.

Křivský (8) constructed a summation curve of all SID effects produced by the proton-flare region from values $I \times D$ (where I is the SID-event importance and D its duration) and demonstrated the slope of this summation curve as a characteristic of the time distribution in the 'energy loss' of the active region. The slope started to increase on July 3 and changed remarkably in the UT morning hours of July 6. Since that time the slope remained fairly constant until July 10. This again confirms that the character of the activity in the region changed substantially on July 6 after the A-configuration of the sunspots had been built. Martres and Pick (6) distinguish two phases in the development of the active region before the proton-flare occurrence: The first phase leads to the formation of the appropriate structure, whereas the second phase, which begins somewhere between the 5th and 6th of July is the elaboration of the proton flare itself.

The proton flare itself (Figure 12) occurred as a flare event of importance 2B at 0^h26^m UT on July 7, when the active region was about 50° West from the central meridian. The heliographic coordinates of the flare were 35 N 47 W. It commenced as two small bright areas adjacent to the larger spots and the areas expanded rapidly within the plage (9i). Finally, the shape of the flare kept the form of two, parallel, bright filaments stretched along the spot rows, i.e. the typical proton-flare formation discovered by Ellison *et al.* (1961). The Southern flare filament was longer than the Northern one and emission covered almost completely the umbrae (6, 6i). The structure of the flare and its relationship to the sunspots is seen more clearly in sketches made from off-band pictures (Figure 13). No flare nimbus nor loop prominences could be detected in association with the proton flare (6i).

During the lifetime of the flare an activation of filaments and of sympathetic flares was observed (6, 6i). Two filaments to the East of the active region disappeared abruptly and the large dark filament in this region disappeared gradually. In the same active region or close to it, two flares appeared during the life of the flare, one at 0^h31^m (position 35 N 62 W) and the other one at 0^h50^m (position 35 N 56 W).

Figure 14 shows a superposition of the area occupied by the proton flare, on the combined magnetic map containing the main 'hills' of the longitudinal field and the directions of the transversal one as recorded by Severny (1) on July 7 between 5^h and

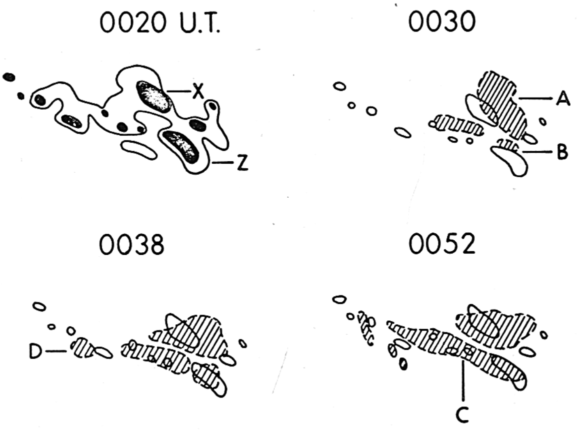

FIG. 13. *Sketches of the flare made from Hα off-band pictures (Caldwell and McCabe, 9i).*

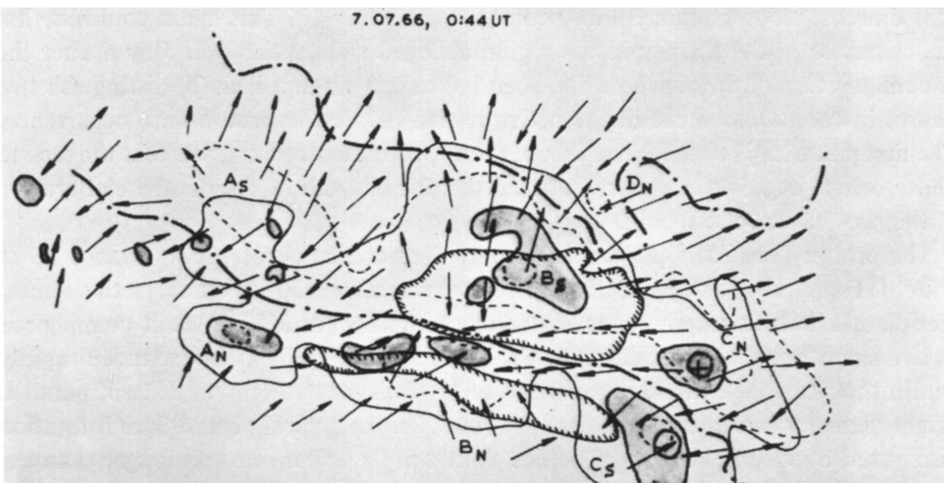

FIG. 14. *Superposition of the proton flare (contoured area) on the maps of the longitudinal and transversal magnetic field. $H_{\parallel} = 0$ is the neutral line and the dark areas represent sunspots (Severny, 1).*

6^h UT. One can clearly see that the two bright ribbons of the proton flare appeared simultaneously in regions of opposite magnetic polarity. One of the flare areas is just to the North of the neutral line $H_{\parallel} = 0$ and in contact with it, and the other ribbon is about 8″ to the South from the neutral line. This distribution of the flaring areas is in full agreement with the recent results obtained by Moreton and Severny (1968) for the very active group of September 17–26, 1963.

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Both ribbons were parallel to the neutral line. The flare as a whole appeared in the region of crossing or bifurcation of directions of the transverse field, which again is in agreement with earlier results of Moreton and Severny (1968) and Severny (1964). Severny points out that particular interest is given by the position of the flare on a map showing distribution of vertical electric currents j_z calculated with the aid of observed data on $H_{\parallel}$ and $H_{\perp}$ from the relation

$$\mathbf{j} = \frac{c}{4\pi} \operatorname{rot} \mathbf{H} .$$

Examples of these maps for July 6 and 7 are presented in Figure 15. The demarcation line between positive and negative currents is parallel to the line $H_{\parallel} = 0$ in the middle of the region and sometimes coincides with this line, so that, taking also into account the directions of $H_{\perp}$, it is not excluded that electric currents are connecting the magnetic regions of opposite polarity and form a pattern similar to the pattern of magnetic lines of force. Severny's maps show clearly that both areas of the flare were just above places with the strongest electric currents, in accordance with the recent results of Moreton and Severny (1968). Severny thinks that this gives support to the Alfvén and Carlqvist (1967) theory of flares as interruptions in electric-current filaments.

The distribution of magnetic fields in photospheric and chromospheric layers after the proton-flare appearance was also studied by Brückner and Waldmeier (2). They used $\lambda 5250$ and Hα lines, and their results are generally in agreement with Severny's conclusions. Their measurement was carried out on July 7, at $12^{\mathrm{h}}00^{\mathrm{m}}$ UT, and they found tremendous differences of the photospheric and chromospheric field strength. The Hα fields strike only 80 gauss, while the photospheric fields go up to 2000 gauss. Some parts of the region, particularly in the centre of the group and in parts of the two large preceding spots, also showed opposite polarity of the Hα and $\lambda 5250$ fields. In the centre of the group, the third polarity had a tendency to join the magnetic-field regions of the same polarity lacing the opposite polarity region. The authors tried to superpose the flare of July 8 on their magnetic map. Even when the flare occurred only 1 day later, the flare bright knots could be identified with the largest field gradients in the neighbourhood of the large spots.

The active region that produced the proton flare of July 7, continued through at least two subsequent rotations (11). In the first of these, in late July, spot area and radio emission were greatly diminished but the calcium plage had increased in area by 50%. Flares continued to occur in the region and the major flare of July 28, at $22^{\mathrm{h}}16^{\mathrm{m}}$ UT is of special interest. Its importance was 2B or greater, and again, as the major flares of July 7, 8, and 9, it consisted primarily of two bright ribbons. It differed, however, from these flares in this respect that the Hα-flare emission was far from all spots. Nevertheless, the flare was associated with an enhancement of radio emission for more than 2 hours, most intense at lower frequencies, and it also produced a

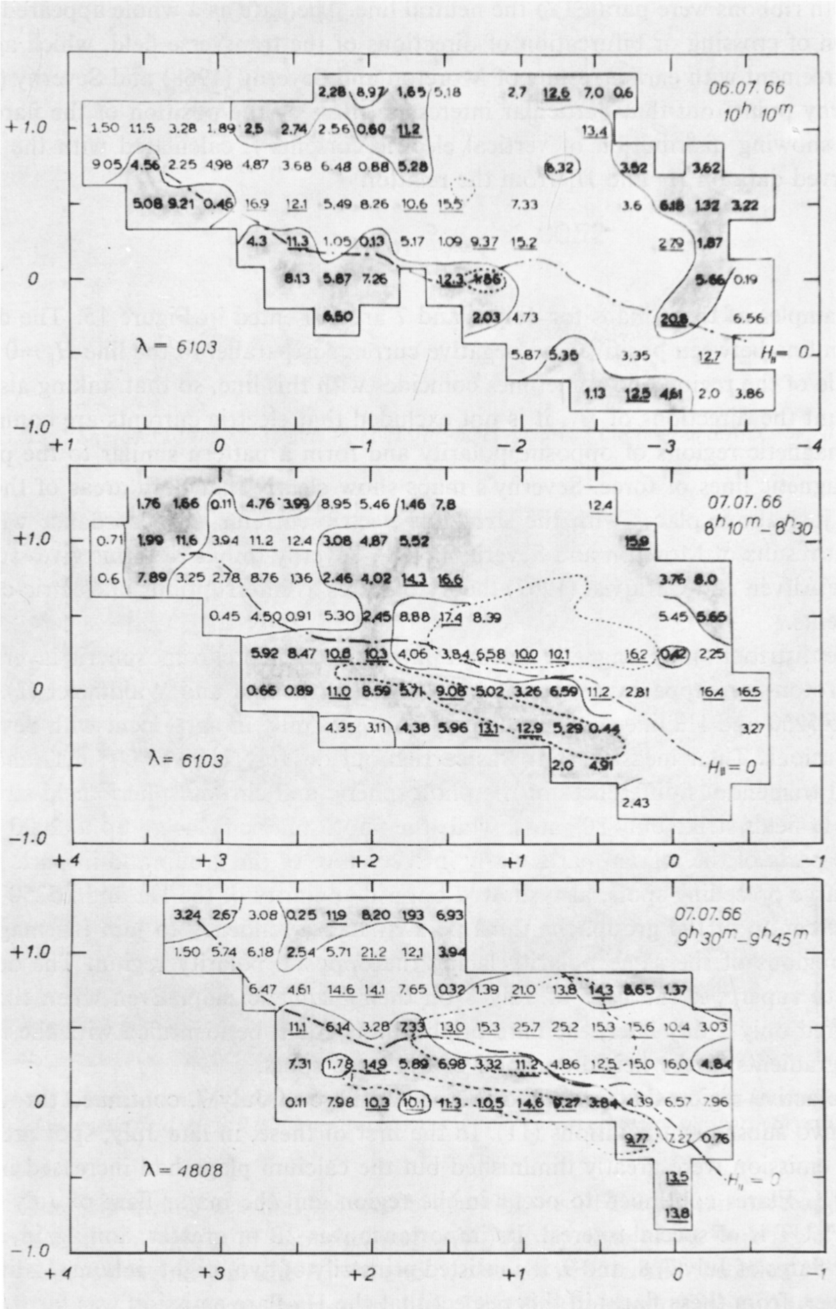

FIG. 15. *Maps showing the distribution of vertical electric currents j_z. Black and white areas are regions of oppositely directed current density (Severny, 1).*

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strong X-ray emission, of about one half of the intensity of the X-ray enhancement associated with the July 7 proton-flare event. It is clear that even in late July, the region was still capable of producing a major flare.

In the August rotation, as Dodson and Hedeman point out, the post-proton flare region of July, at latitude N33 through differential rotation became colongitudinal at 182°, with a previously following region in latitude N22. This region at lower latitude produced major proton flares on August 28 and September 2, during the second active PFP period.

Demkina *et al.* (10) investigated the magnetic-field decay of the active region after the proton-flare appearance. While before the July 7 flare an approximate equality of magnetic fluxes had been conserved in the sunspot group, after the proton flare a sudden growth of the Southern-polarity magnetic flux and considerable decrease of the Northern-polarity flux was observed. After that the active region came to the opposite invisible side of the solar disk, but one can suppose that this run of development continued, since in the next rotation in late July the group looked like a relatively stable unipolar spot of Southern polarity, with the magnetic class αp. It may be of interest to note that the area of the remaining spot was near to the area of a supergranule at this time (10). On 6 days during this late July transit, small ephemeral spots of the opposite polarity were observed following the large spot making the spot group on those days of magnetic class βp (11). Magnetographic measurements at Mount Wilson showed that the extensive and relatively bright plage associated with the sunspot group was bipolar. On the third rotation in late August only a small α-type spot without penumbra was remaining in the active region, and the calcium plage, though greatly fragmented and reduced in intensity, was still a detectable feature (11).

At this time, however, the activity already was shifted to the second proton-flare region, located at lower latitude in the close vicinity of the active region discussed in this summary. Obviously, both these regions appeared in one complex of activity, which dominated solar activity during the entire second half of 1966 (11). Already in the late July rotation, the activity of the studied region was observed in its tail part situated close to this neighbouring active region, which fully developed only during the next rotation in August (10). Demkina *et al.* suggest that this subsequent rapid development of this neighbouring group, which was a fairly inactive small group during the three previous rotations, might have been stimulated by the magnetic field of the decaying high-latitudinal group which produced the proton flare on July 7.

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DISCUSSION

Fokker: For centres of activity far from the centre of the solar disk (i.e. relatively close to the limb) the neutral line, as it is observed, does not, in principle, correspond with the line at which the magnetic field is parallel to the solar surface. I should like to ask, how large the difference in position between the observed neutral line and the true line of horizontal magnetic field can be. At what distance to the centre of the disk does the difference become important?

Severny: My experience shows that the best is simply to avoid recording the regions very near to the limb. But practically we should not have essential differences due to projection effect if region is not more far than 60°–70°. It can be checked by comparing Hα m.f. records with those in λ5250 to show whether we have effects of such a kind or not.

McIntosh: Did I interpret your slide correctly that the dissolution of the magnetic field into smaller parts occurred only after the proton flare?

Severny: Observations were made a day apart and were not near time of proton flare. I cannot say exactly when the dissolution occurred.

Švestka: I would like to point out that there were made only two measurements, widely apart, on July 6 and shortly after the flare on July 7. The magnetic energy and the gradients were high on July 6 and much decreased on July 7. But one cannot decide whether this decrease occurred before or after the proton-flare occurrence.

Severny: There are examples in the past, according to the Crimean measurements, that the decrease already occurred before the proton-flare appearance.

Krat: At what place in the profile of Hα were set the slits of the magnetograph when Brückner and Waldmeier measured the magnetic field?

Wiehr: The Hα-magnetograms were taken with the magnetograph similar to that designed by Babcock. The two exit slits covered the region from the line centre to $\pm 0{\cdot}8$ Å.

Krat: Then in fact the magnetograms were not measured in the chromosphere but in the photosphere.

Smith: I do not agree that even that part of the Hα-line profile is formed in the photosphere. It is almost entirely from the chromosphere.

Krat: I think that due to superposition of emission and absorption in the central part of Hα at every place on the solar disk and especially in flares no reliable values of the magnetic-field strength can be obtained in this way.

Severny: As far as I can guess from the private talk with Dr. Brückner our results relating to the magnetic field in the proton-flare region of July 7 are in general agreement. But frankly speaking I do not believe that measurements of magnetic fields in Hα we are doing in Crimea as well as that of Dr. Brückner are reliable because of the very strong influence of emission on measurements of magnetic fields in the case of active regions filled up with the emission from plages and flares.

Newkirk: The features which McIntosh mentions as occurring in the proton-flare regions may well be characteristic of *every* region of intense activity. Have you any evidence that such features are unique to proton-flare regions?

McIntosh: I have not examined enough material to give a good answer to your question. I have looked at two other proton regions photographed at Mt. Wilson and they also show similar features. A number of sunspot drawings also indicate similar features. I do not recall ever seeing such features in non-proton regions.

Neupert: Could the observations of an electron-density component low in the corona mentioned by Newkirk be associated with the possible existence of a permanent or sporadic condensation?

Newkirk: The resolution of the K coronameter (1 min of arc) is not sufficient to define the size of this component accurately. However, it appears to be larger than the typical permanent condensation as defined by Waldmeier and is comparable in size to what is considered to be the 'active region enhancement'.

Sawyer: Examining the sunspot drawings with magnetic-field measurements made at various observatories, I was struck by a single spot umbra with rather strong field with both polarities present. This umbra was on the equator side of the group, just East of the large leading spot. On July 6, several different observatories recorded both polarities in this umbra, and I expected to hear some discussion of this situation at these meetings.

Smith: Did I understand Dr. Severny to say that longitudinal neutral lines through the umbrae of sunspots are often observed, even for non-proton flare regions?

Severny: Oh yes, there are many such cases. I remember the maps for sunspot groups in September 1961, May 1962, September 1963 and others having this feature. It is quite a common occurrence. But note that this only refers to the longitudinal fields, the transverse fields may be strong and complex and the occurrence of line $H_{\parallel} = 0$ inside umbrae can simply mean that we have inclusion of strong transverse field there.

Öhman: With reference to our paper describing the limb event of July 11, 1966, I want to add, that Stiber has completed now his discussion of the material selected for the purpose of measuring the polarization of the continuous spectrum. The polarization is found to be somewhat smaller than that predicted by the theory of electron scattering, particularly near the limb. This suggests that also other mechanisms produce the continuous spectrum. From a discussion of his intensity and polarization measurements Stiber finds an electron density of 3×10^{11} per cm^3.

Severny: We should be extremely careful with conclusions obtained with a magnetograph for July 8 and the following days, because the active region considered was very near to the limb, and effect of projection could possibly produce the apparent decay. The conclusion of decay contradicts also the observation that area proceeded to increase after proton flare, and moreover an important flare appeared also on July 11 at the very limb.