SOLAR GLOBAL BACKGROUND MAGNETIC FIELD CHANGES ACCOMPANYING
THE DEVELOPMENT OF THE WHITE-LIGHT FLARE REGION OF APRIL 1984 (NOAA 4474)

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Received 30 April 1987

ИЗМЕНЕНИЯ СОЛНЕЧНОГО ГЛОБАЛЬНОГО ФОНОВОГО МАГНИТНОГО ПОЛЯ,
СОПРОВОЖДАЮЩИЕ РАЗВИТИЕ АКТИВНОЙ ОБЛАСТИ СО ВСПЫШКОЙ
В БЕЛОМ СВЕТЕ В АПРЕЛЕ 1984 г. (НОАА 4474)

Изучая изменения в распределении солнечных крупномасштабных фоновых магнитных полей в широком интервале времени около возникновения этой сложной активной области мы показали, что ее развитие нужно рассматривать как часть глобального процесса в солнечной атмосфере. Мы нашли полную реорганизацию узоров магнитных активных долгот и, конечно, секторной структуры солнечных магнитных полей, ясно связанные с максимальной фазой этого развития. Мы также показали, что одновременно с этим происходила редиструктурализация корональных дыр. Исследовались также связи крупномасштабных нейлообразных элементов поля с этим развитием. Мы сделали заключение, что образование этой мощной активной области со вспышкой в белом свете имело причинную связь с перестройкой глобального солнечного магнитного поля.

In investigating the large-scale distribution changes of solar background magnetic field during a wide time interval around the formation of this very complex region, we demonstrated that this development must be taken as part of a global process in the solar atmosphere. We found a complete reorganization of the Magnetic Active Longitude patterns and, of course, of the solar magnetic field sector structure clearly related to its maximum stage. We also showed that, at the same time, restructurization of coronal holes took place. The relation of large-scale cellular-like structures to this development is studied too. We concluded that the formation of this mighty white-light flare region was causally related to the rebuilding of the global solar magnetic field.

Key words: Sun: magnetic fields, active longitudes, redistribution, large activity.

1. Introduction

During the descending phase of the twenty first cycle of solar activity one of the largest flares of the cycle occurred in NOAA Active Region No 4474. It was the 3B/X13-0 white-light flare, observed near the eastern solar limb on 24—25 April 1984. The very complex and mighty active region (extending in heliographic longitudes from about 310° to about 355° in the southern hemisphere), in which the event took place, consisted, at the beginning, of four and, at the end, of six bipolar sunspot groups (Gesztesy and Kalman 1986).

Just recently we found certain indications that the occurrence of large active regions producing mighty particle — emitting flares seems to be connected with large sudden disturbances of MAL structures which often affect more than one half of the solar activity zone (Bumba and Hejna 1986, 1987). In other words it seems that the formation of very topologically complex local magnetic fields generating proton-flares is related, within the frame of the large-scale distribution of magnetic background fields, to a global redistribution practically of the whole background field pattern. Moreover, several years ago (Bumba 1980, Bumba and Hejna 1981, Bumba et al. 1982) we demonstrated for two large proton-flare regions that, as soon as their proton-flare activity stopped, not only the extended and very complex fields of both regions, but also the background field patterns simplified into a bipolar feature at least on more than one half of the solar surface and then almost disappeared during three — five solar rotations.

Now we would like to investigate to what degree the development of such a complex local magnetic field influenced the distribution of the background magnetic fields and their changes in time not only in the closest neighbourhood of the region, but over the whole surface of the Sun. For the study we used, as usual, magnetic synoptic charts in their original complete appearance, as well as their individual equatorial...
(ϕ = ±20°) strips, mounted consecutively in long
time series, demonstrating the longitudinal concen-
trations of single-polarity magnetic fields in the form
of Magnetic Active Longitudes (MALs). Successively
we use all available observational materials to construct
the whole picture of the physical relationship of the
magnetic field and activity in space and time during
the development of these might geocactive phenomena.
As a first step we investigate the large-scale magnetic
field and activity structures.

2. Variations of the Magnetic Active Longitude
(MAL) Patterns

First of all, we had at our disposal the picture of the
development of characteristic MAL patterns on a series
of successively mounted equatorial strips of solar
magnetic synoptic charts constructed at the J. M.
Wilcox Solar Observatory in Stanford (Solar-Geo-
physical Data prompt reports and Hoeksema and
Scherrer, 1986), obtained with a high degree of inte-
gration (Fig. 1). We see that, during the extended
period of time around April 1984 (Carrington’s
rotation No 1748 (March 30, 71 – April 26, 98)),
the strips of MALs, formed from the positive polarity
fields, are more conspicuous. As if their very character-
estic and distinct forms were created on the background
of the more vague negative polarity fields. Just
recently, we showed that this behaviour is more general
at least in the present cycle of solar activity, and that
the sign of this “shape-made” polarity changed with
polar field reversal (Bumba and Hejna 1987, Bumba
1987). Let us study the longitudinal distribution of
MALs and their inclinations caused by parts of the
background fields being carried away by differential
rotation before, during and after the development of the
local complex field studied

At least ten solar rotations before Carrington
rotation No 1748, during which the maximum stage
of activity of the investigated complex region was
reached, two main positive polarity MALs (four
sectors in the background field: two positive and two
negative) were observed. Each of them had its relatively
complicated fine structure which sometimes indicated
that it was divided into one or two additional second-
ary strips. If we study the second positive MAL,
which was in the longitudinal interval of 250°–330°
during rotation No 1748, the magnetic field in this
interval having given birth to the investigated complex
situation, we see that its patterns changed strongly
around the time the white-light flare region occurred.
One rotation earlier (No 1747) it split into two branches
the inclinations of which differed. The main eastern
branch with slow westward shift in Carrington’s
coordinate system approached the other positive
MAL in such a way that they almost joined about
ten rotations later. The secondary western branch,
changing quickly its form and velocity of its shift
due to the action of differential rotation, decreased
its distance to a third positive MAL, formed newly
around rotation 1736 westward of the MAL which
included the region studied. This new MAL, very
weak and narrow at the beginning, now formed
jointly with the positive field MAL, in which the
studied region occurred, a very broad MAL occupying
practically one half of the solar longitudes, thus
forming two sector structures.

We witnessed a complete reorganization of the
MAL patterns (changes of the background field
sector structure mode) accompanying the formation of
the studied complex local field situation which
at the same time, was a part of this process of field
rebuilding.

If we study the development of the investigated
complex field within the frame of the MAL pattern,
we see that as long as intensive magnetic fields of both
polarities are observable inside the MAL structure,
it rotates almost as fast as Carrington’s system of
coordinates. But as soon as the field intensity dimi-
nishes and the field maxima disappear, the MAL
formed of weak fields is shifted faster around the
equator due to solar rotation, changing the inclination
and form of the MAL strip (see also Bumba and

3. Development of the Studied Complex Local Field
in the Frame of the Background Fields

Studying the global situation in the large-scale
distribution of background magnetic fields during
the rotations preceding the formation of the complex

Fig. 1. Magnetic Active Longitude patterns and their changes during the investigated time interval. Equatorial (ϕ = ±20°)
strips of Stanford solar magnetic synoptic charts are successively mounted in time. Numbers of Carrington rotations are given
on the l. h. s., heliographic longitudes are indicated at the bottom of the picture. Positive polarity magnetic fields are plotted as
full lines and their areas are hatched. Negative polarity isogauss lines are dotted. The four sectors and two sectors of the solar
magnetic field are indicated in rotations No 1741 and 1749, respectively. The position of the white-light flare region is indicated
by an arrow.
situation (see for example rotations Nos 1745, 1746 on Fig. 2), we see an almost symmetrical distribution of the positive polarity field patterns in heliographic longitudes. There are two large-scale structures formed of positive fields, the centers of gravity of which are 160° and 200° apart (practically on opposite

Fig. 2. Changes of the background magnetic field distribution during two rotations preceding and two rotations following the maximum stage of the white-light flare region development. Full Stanford magnetic synoptic charts drawn as in Fig. 1 are shown. The change of four magnetic field sectors into two and again into four is demonstrated by underlining the positive and negative field body with bold full and dotted lines. The large-scale positive field elements and their structural changes and simplifications are well visible too.
Fig. 3. Development of the network of the large-scale cellular-like elements formed from the positive polarity fields before and after the maximum stage of the white-light flare region was formed. The parts of the synoptic charts are drawn in the same manner as in Fig. 1 and 2. The position of the main region is indicated by an arrow. The cellular-like elements are shadowed. The westward progression of the process is clearly visible.
hemispheres of the Sun, causing a quadruple structure of the background field), in the area of which magnetic flux is supplied to the photosphere. Their positive fields are the main components of the two above discussed main MALs. We have studied more generally the creation of such structures just recently (Bumba 1987).

Both structures are in different stages of their development. We are more interested in the western large-scale feature which generated the white-light flare situation. It may be followed for more than fifteen rotations before this process. The only difference is in the position of its center of gravity which shifts step by step in the westward direction through the continuous redistribution of its fields. Its internal structure is formed of regular circularly shaped cellular-like features (Bumba 1987). At the beginning of the time interval demonstrated in Fig. 3 we see such a feature at a position around $L \approx 270^\circ$. During rotations Nos 1744–1746 another similar circular feature developed westward of the first one with its center around $L \approx 310^\circ - 320^\circ$. During rotation No 1747 around position $L \approx 330^\circ$ an indication of another such element appeared, but did not develop fully. Its formation strongly influences the positive field rim of the previous ones. During rotation No 1748 the white-light flare discharged in it. All the three mentioned regular structures with diameters of about $30^\circ - 40^\circ$ appeared in the southern solar hemisphere, although large part of their fields reached across into the northern hemisphere. During rotation No 1750, two rotations after the proton-flare, the fourth complete feature was formed in the northern hemisphere as the closest neighbour of the previous structures. During that time the global magnetic situation changed its symmetrical character into patterns, the fields of which were distributed more irregularly in hemispheric longitudes.

The consequence of this was that the background field lost its clearly indicated sector structure formed of two positive and two negative sectors. In each of these sectors the polar fields were stretched across the equator into the opposite hemisphere: the positives field from the southern pole into the northern hemi-

Fig. 4. The restructurization of coronal holes accompanying the development of mighty white-light flare active region. The coronal holes and changes of their forms and positions were taken from the Solar-Geophysical Data prompt reports. Coronal holes connected with positive polarity fields are plotted as full lines and hatched like the positive fields in Figs 1, 2 and 3, the holes related to the negative polarity fields are plotted as dotted lines and are hatched in the opposite direction. The position of the studied region is indicated by a frame and an arrow.
sphere and the negative field from the northern pole to the south. This redistribution, which started just at the time the studied complex field was forming, was concluded about ten rotations later, when a single positive field structure covering practically one half of the Sun was formed. Only two sectors – almost a bipolar Sun appeared. This large positive superstructure disintegrated around rotation No 1759 again into two structures, very similar to those we saw at the beginning of the investigated processes: the four-sector mode had been formed again.

4. Restructuralization of Coronal Holes

Studying the Hα magnetic synoptic charts we obtain additional information concerning the global magnetic field situation, reflected in the coronal activity distribution. During many rotations preceding the appearance of the white-light flare in both negative polarity sectors, coronal holes developed (see Fig. 4). We may even describe the history of their development (Bumba 1986). After rotation No 1748, during which the mighty flare process occurred, they almost disappeared from the equatorial zone. But already during rotation No 1751 the southern polar coronal hole connected up with the positive polarity fields, reaching the equatorial region in both discussed positive field large-scale structures, indicating that their activity was practically extinct. During this rotation a new negative polarity coronal hole appeared in the equatorial zone with the forming of a new negative polarity sector (see again Fig. 4).

5. Conclusions

From what has been demonstrated above, we may conclude, at this stage of our investigation, that the formation of the studied complex local field, which generated a white-light flare in April 1984, is a very complicated process which cannot be considered on its own, but which constitutes a component of a still more complex process. Moreover, the complete reorganization of the MAL patterns together with the background field sector structure accompanying this development, the fact that a similar development took place on the other half of the Sun with a certain time lag only, and the fact that the formation of the complex local field has its prehistory which lasted many rotations and developed as part of the internal network of a complicated large regularly formed feature in the large-scale distribution of the "form-shaped" polarity, have but a single explanation: the studied process must be causally related to the global reorganization of the whole background magnetic field. The observations, testifying to the moment of the maximum phase of the studied complex local field development also being connected with the reorganization of the whole system of coronal holes in the solar atmosphere, speak, together with the above-mentioned results, in favour of the suggestion that the studied process also indicates sudden changes in solar activity production or in its phase shift. In accordance with our earlier results (Bumba 1980, Bumba and Hejna 1981, Bumba et al. 1982), as if the long-lasting phase of gradual preparation and maturing of the proton-flare situation were concluded with the discharge of the flare. Another process again representing a new substantially different component of the cycle of activity may start its preparatory phases with the constitution of this new global magnetic situation.

REFERENCES

— 1986 Studia Geophys. et Geod. 30, 158.