ROTATION OF INDIVIDUAL BACKGROUND MAGNETIC FIELD COMPONENTS DURING THE FORMATION OF THE WHITE-LIGHT FLARE REGION OF APRIL 1984 (NOAA 4474)

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ПОТЯЖКА ОТДЕЛЬНЫХ ЧАСТЕЙ ФОНОВОГО МАГНИТНОГО ПОЛЯ
В ТЕЧЕНИЕ ОБРАЗОВАНИЯ ОБЛАСТИ СО ВСПЫШКОЙ В БЕЛОМ СВЕТЕ
В АПРЕЛЕ 1984г. (NOAA 4474)

In this paper we continue the comprehensive investigation of the circumstances leading to the formation of the white-light flare region of April 1984 ($L \approx 340^\circ$, $\varphi \approx -10^\circ$). From the distribution of chromospheric filaments we see the difference in activity and in rotation rates of strong and weak magnetic fields. We also observe the wavy form of the magnetic boundary surface dividing, during the time of the maximum evolutionary stage of the region, the negative northern hemisphere fields from the positive polarity southern fields in interplanetary space. We observe the rigid body rotation of “pivot points” and of the strongest magnetic fields in the studied time interval, summarizing the results into the requirement of yet another study of the global and local activity development in this last portion of the 21st solar activity cycle.

Key words: Sun: magnetic fields, rotation

1. Introduction

In our first paper (Bumba and Gesztelyi, 1988) concerning the solar global background magnetic field changes accompanying the development of the white-light flare region of April 1984 (NOAA 4474; $L \approx 340^\circ$, $\varphi \approx -10^\circ$), we found a complete reorganization of the Magnetic Active Longitude (MAL) patterns and also of the background field sector structure connected with this development. At the same time, coronal holes were also restructured. All this must mean that the process of formation of the white-light flare region’s complex magnetic field must be causally related to the global changes of the whole solar background magnetic field.

We saw that, during the restructuring of the field and reorganization of the MAL patterns, very strong local magnetic fields of both polarities seemed to rotate almost as fast as Carrington’s system of coordinates, while the weak fields, usually remnants of earlier strong local fields, were shifted much faster and much more differentially due to solar rotation. We also tried to determine the role of the regular circularly shaped cellular-like features studied earlier (Bumba, 1987a, b) during the structural background field changes.

In the present continuation of our study of processes related to the development of the white-light flare region of April 1984, we would like to pay greater attention to the problem of rotation rates of certain components of the background magnetic field, constituting the main patterns of the weak as well as strong fields, from three points of view: as they are demonstrated by the distribution of chromospheric filaments, from point of view of the existence of so-called “pivot points” (Mouradian et al., 1987), and of the rotation of the strongest magnetic flux sources.

2. Changes in the Background Magnetic Field Distribution and Rotation, as They are Reflected in the Patterns of Chromospheric Filaments

Using the “Cartes Synoptiques de la chromosphère solaire...” (Martres and Zilicar, 1984; 1986), issued by the Paris Meudon Observatory, we studied the long-term behaviour of the solar chromospheric filaments during the period of July 1983 to January 1985. By superimposing successive synoptic charts we can investigate the changes of the positions of the filaments (Fig. 1 see Plate 1) which characterize not only the rotation rate of the corresponding region of the solar atmosphere, but which can provide information concerning the changes in the underlying photospheric magnetic fields, as well as the intensity of activity – the greater power of which causes the greater density and richness of filament forms, due to the greater condensation of chromospheric matter above and around the most active regions. In this way we can also investigate the possible correlations between the appearance of activity and anomalies in solar rotation.

During this period of the descending phase of the 21st solar activity cycle, there were two main positive polarity MALs in action in the solar photosphere (Bumba and Gesztelyi, 1988), with an increase of activity between Carrington’s rotations Nos 1744 and 1748 (January—February, 1984, Fig. 2 and Table 1). Firstly, considerable activity appeared in the eastern MAL (with its center of gravity in the northern hemisphere) during rotations Nos 1744 and 1745, then in the western MAL (mostly acting in the southern hemisphere) during rotation No 1748 (this was the white-light flare region of April 1984, see Fig. 3 on Plate 4).

Investigating Fig. 1, which demonstrates the distribution of filaments and their positions in more detail, we see that, until rotation No 1749, the individual chromospheric synoptic charts contain a much greater number of filaments than during the subsequent rotations. The same seems to be true of the organization of filaments over the whole field of view of the synoptic chart. At the beginning of the investigated time-interval, one sees that strong magnetic fields force the filaments to form more regular structu-

<table>
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<tr>
<th>Synodic Rotation Numbers</th>
<th>Date of Commencement</th>
<th>International Relative Sunspot Numbers</th>
<th>Mean Solar Flux at 2800 MHz (adjusted)</th>
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Computed from
Solar-Geophysical Data prompt reports Numbers 476, 486, 488,
Part I. and Numbers 491—496, Part II.
res, while during the last few rotations (since rotation No 1750) the filaments are more chaotically distributed, shorter and less frequent. All this is caused by the fast decrease of activity during the last third of the studied time interval.

![Graphs](image)

Fig. 2. Activity indices in the period of July 1983—January 1985 (between the synodic rotation numbers 1738—1757) computed for the synodic rotation periods from the daily data (SGD) — Compare to Table 1.
a) Mean International Relative Sunspot Numbers; b) Mean solar flux at 2800 MHz adjusted to 1 AU; c) Numbers of grouped solar flares.

As concerns rotation, the most conspicuous is the fast westward shift of the wedge-like configuration of the filaments in the middle part of first three systems of synoptic charstps, in their equatorial regions. This is due to the faster rotation around the equator and may be observed practically until rotations Nos 1748—1749, indicating the same rotation rates we saw in our preceding paper, related to the fast rotational shift of weak remnants of much stronger magnetic fields many rotations earlier (Bumba and Gesztelyi, 1988) in accordance with our previous results (Bumba and Hejna, 1987a, b).

The distribution of solar magnetic field polarities can be judged from the distribution of chromospheric filaments. In the very middle sequence of Fig. 1, demonstrating the distribution of filaments during Carrington’s rotations Nos 1746—1749, we can see the main line around which most filaments are concentrated, forming a sinusoidal wave. At a heliographic longitude close to 0° it starts at high northern latitudes, then crosses the equator between \( L \approx 180° \) to \( 240° \) and forms its southern branch, in this case not far from the equator. This southern part of the wave is underlined by the presence of high activity in the white-light flare region. This wave-like sinusoidally formed line, if interpreted as the boundary between the magnetic field polarities, might mean that the global magnetic field of the Sun is bipolar during this time period, with negative northern and positive polarity southern hemispheres. In the eastern half of synoptic charts, the positive polarity extends from the southern hemisphere to about latitude \( +50° \) in the northern hemisphere and, in the western half of the maps, the northern hemisphere negative polarity fields extend beyond the equator to about latitude \( -20° \). In interplanetary space, the global solar magnetic field boundary sheet thus has a rather complicated, also wave-like form, highly asymmetric about the equator. In favor of this speaks also the fact that both mentioned mighty activity centers, existing during rotations Nos 1744 — 45 and No 1748, are almost antisymmetric with respect to the center of the Sun.

3. The Rigid Rotation of “Pivot Points“

It was pointed out earlier (Mouradian et al., 1987) that in several cases the emergence of active centers is preceded by the appearance of a so-called “pivot point”, defined as a limited solar area having a rigid Carrington’s rotation rate in whatever latitudinal interval. The new active center will then emerge close to the “pivot point” and this may destroy or displace this associated “pivot point”.

![Graph](image)

Fig. 4. “Pivot point” in the western MAL (\( L = 326°, \varphi = -21° \)) before the burst of peak activity.

Several rotations before the burst of peak activity in the investigated situation, a “pivot point” was observed to exist in the vicinity of the western MAL. As we may see in Fig. 4, this was during rotations Nos 1738—1742 around the heliographic position:
position of this filament changed in accordance with d’Azambuja’s rule, but in rotation No 1751 the filament stopped shifting and, during rotations Nos 1751–1757, a “pivot line” existed, pointing to the position of the former large active center again. This must mean that a rotational anomaly in the form of rigid-body rotation existed in these relatively high southern latitudes and that it lasted for at least seven rotations.

In the eastern MAL the situation was somewhat similar: in the higher northern latitudes there was no sign of a rigid rotation till rotation No 1745. During rotations Nos 1742–1745 (See Fig. 1) a long-lived filament shifted eastward, as a result of differential rotation. But since rotation No 1746 a “pivot line” formed, again pointing to the region of former high activity. It could be observed for eight rotations, till rotation No 1753.

What seems to be interesting is the fact that, before the burst of peak activity, the rigid-body rotation can be seen in the vicinity of the active region, but no sign of rigid rotation at higher latitudes can be observed. Two – three rotations after the peak activity, the rigid rotation of a relatively high latitudinal zone can be observed and this seems to be a long-lived feature of the solar atmosphere.

4. Rotation of Areas with the Strongest Magnetic Field Intensities

The rigid-body rotation of the investigated “pivot points” led us to the study of rotation rates of areas with the strongest magnetic field intensities on the magnetic synoptic charts constructed at the J. M. Wilcox Solar Observatory in Stanford (Solar-Geophysical Data prompt reports; Hoeksema and Scherrer, 1986). We investigated the rotation of all magnetic areas of both polarities from the third iso gauss line shown on the synoptic charts (with intensity \( \geq \pm 500 \) microtesla). All of them were connected with active regions most closely related to the actual high activity.

The positions of these areas are plotted in Fig. 6 separately for the northern (Fig. 6a see Plate 2) and southern (Fig. 6b see Plate 3) hemispheres.

The following conclusions can be drawn from our graphs: first of all, it seems that the magnetic activity is higher in the southern hemisphere. Then again we can see that the first of the main MALs, the eastern one, is mostly formed by the activity in the northern hemisphere, while the second, the western MAL, is more closely connected with the activity in the southern hemisphere. As already mentioned, both centers of magnetic activity are almost antisymmetric, although the distance of both centers in heliographic longitude is not the full 180° but only 120° – 140°.

As regards the rotation rate, as can best be seen in Fig. 6b, where the changes in position of locations with the largest magnetic flux can be observed from one rotation to the next in the southern, more active hemisphere, the areas with the largest magnetic field strengths do not change their heliographic longitudes in Carrington’s network almost at all. If positions can be seen to change, the changes take place only westward and not as a continuous shift in longitude, but as a sudden stepwise change of longitude to the west, in steps of about 50° – 80°. This well-defined pattern seems to be a little distorted in the northern hemisphere. These results are in full agreement with our distribution of MAL patterns, obtained previously (Bumba and Gesztelyi, 1988). They may be summarized as follows: the areas with the strongest magnetic fields rotate as a rigid body in Carrington’s system of coordinates. They may survive at the given heliographic longitude for at least 5 rotations. After several rotations they may appear again at the same position, or new, usually bipolar, strong magnetic regions may develop at a certain distance westward of the old position.
5. Conclusions

First of all, we can see that the occurrence of the studied complex white-light flare region represented the manifestation of practically the last large impulse of solar activity in the 21st cycle. This is substantiated not only by Figs. 1 and 2 of our previous paper (Bumba and Gesztelyi, 1988), displaying the rapid simplification of the organization of magnetic fields, as well as their complexity and strength: with the increasing number of Carrington’s rotation all the synoptic magnetic charts display, above all, their increasing simplicity and the occurrence of magnetic field areas with an even lower level of isogauss lines. The same can be observed in our present Fig. 1 in the decrease of the density and occurrence frequency in the synoptic distributions of chromospheric filaments.

What is also interesting, is the almost antisymmetric distribution of the activity during this last double peak of solar activity (January—February and April 1984) and the source of the main boundary between magnetic field polarities of the whole Sun, connected with it, which passes not far from the equator. In this way the Sun forms a large bipolar feature with negative polarity mainly occupying the northern and the positive polarity the southern solar hemispheres. This boundary line becomes a boundary surface as it extends into interplanetary space, it undulates and its largest amplitude recedes from the equator toward the north pole in the eastern half and toward the south pole in the western half of the synoptic charts. This solar global magnetic field organization can be observed during the maximum phase of this last peak of solar activity not only in the distribution of filaments in Fig. 1 but also distinctly on the synoptic charts of solar magnetic fields constructed from the Mt. Wilson Observatory observations, published in the Quarterly Bulletin on Solar Activity (the International Astronomical Union).

As regards the rotation rates of different components of the solar background magnetic fields, on the one hand, we can see the fast westward shift around the equator and the eastward at high heliographic latitudes of earlier, much stronger, but currently very weak fields and, on the other hand, practically a rigid-body rotation of very strong fields and of the so-called “pivot points” without any change of rotation rate with different latitudes. We do not understand the physics of the “pivot points and lines” yet. The only fact we should like to draw attention to is the well-known relation of filaments, indicating the position of “pivot points”, to the boundary between the polarities of older magnetic field areas, expanded due to differential rotation. At the same time, while the preceding as well as the following magnetic fields at these latitudes are strongly, but differently influenced by rotation, their boundary line, forming an axis between their fast receding areas, seems to rotate more or less without changing its form and course with latitude. This may mean, in accordance with Ambrož’s (1986) recent results, that this rigid-body rotation is the consequence of a very complicated velocity field and of the distribution of the individual vectors of motion in and above the photosphere.

To understand the rigid-body rotation of the strongest magnetic fields, we have to find their relations to the large-scale regular structures — possible giant cells of convection (Bumba, 1987a, b) which still seem to be relatively frequent in the first half of our observational series, on the one hand, and to the individual active region developments, on the other hand. We hope that the investigation of such relationships may help us to understand better which process of magnetic field generation is more probable and at what depth of the solar atmosphere it takes place: If it is the dynamo action in the deepest layers of the photosphere with a subsequent redistribution of the field through the hierarchy of convective elements, or if it is the action of a local dynamo or of both dynamos combined, or if the vortex motions in the upper layers of the solar atmosphere (Ambrož, 1986), resembling the dynamics of Jupiter’s red spot, are even more important.

All this has led us to the conclusion that we have to investigate the developments of this white-light flare region in its relation to the global magnetic field and activity evolution once more.

REFERENCES