MAIN PHASES OF ACTIVE REGION'S MAGNETIC FIELD DEVELOPMENTS

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ABSTRACT. Three main evolutionary stages of a magnetic local field development are characterized.

ОСНОВНЫЕ ФАЗЫ РАЗВИТИЯ МАГНИТНЫХ ПОЛЕЙ АКТИВНЫХ ОБЛАСТЕЙ.
Характеризируются три основные фазы развития магнитного локального поля.

HLAVNÍ FÁZE VÝVOJE MAGNETICKÝCH POLÍ AKTIVNÍCH OBLASTÍ.
Jsou charakterizovány tři hlavní fáze vývoje magnetického lokálního pole.

1. INTRODUCTION

Magnetic field of an active region plays in its relation to the background field practically a dual role: the active role of the local field as long as it is young enough and connected with the source of magnetic field generation and then the role of a component of the background field, when it is old, influencing nevertheless the topology of the background field as long as its energy will last.

But the local field displays in the volume of the solar atmosphere that it occupies its own life-story, before it becomes the more passive part of the background field. We would like to describe the individual evolutionary phases of its life, generalizing some of our earlier obtained results.

2. THE PHASE OF APPEARANCE OF AN ACTIVE REGION

If we follow the formation of the new local field in the scale of an active region only, we may say that in the greatest number of cases this process starts by the appearance of an area of opposite polarity in the closest neighbourhood of the old field. This old field usually does not change its position and flux value for several days preceeding the new field appearance (Bumba, 1981). In no case is the birth of a new magnetic flux seen on the magnetograms as the intensification of the preexisting following and leading polarities (Bumba, Howard, 1965). The new field enlarges fast its area and intensity. In the region with the new field nearest to the old field of opposite polarity the field gradient strengthens. As soon as the new magnetic field appears, the old opposite polarity field in its closest neighbourhood starts to be activated as well - also its area and intensity grow. Both processes of the new field appearance and the old field activation are closely bound to the supergranular and granular network (Bumba, Howard, 1964; 1965; Bumba, Godoli, 1968; Bumba et al., 1973).

During this first stage of new active region development its magnetic flux is unbalanced. Also the interaction of the new and old field systems seems to be observable only several days later. The equilibrium stage of the new system does not seem to be reached before the maximum of the local field development, characterized by the complete stop of the new flux addition to both polarities or by greater active regions, morphologically by the formation of penumbrae in their main sunspots (Bumba, 1981).

One more detail is to be mentioned: the new magnetic flux development starts from the future, practically geometric centre of the active region's sunspot group, characterized in the photosphere by fast forming and changing small spots or rudimentary penumbra, lying in the gulf of the magnetic field boundary separating both polarities, usually identical with the sector boundary of the background field. Further development proceeds mostly in the direction of the following part of the region (Bumba, Howard, 1965; Knoška, 1976a; 1977) and only one-two days later in the direction of the leading part (Bumba, 1983).

3. MAXIMUM STAGE OF AN ACTIVE REGION DEVELOPMENT

In the case of small active regions which do not continue their development behind the types A and B, the new flux addition stops very early (in one to three days) in a bipolar balanced stage. But also during their first evolutionary stage the new unbalanced flux appears close to the boundary, usually in form of a small following polarity island, inside a gulf of a larger area of a leading field. It concerns mostly the small local fields representing short-lived secondary bipolar features formed during the dissipation and redistribution process in a complicated magnetic pattern of older complexes of activity (Bumba, Suda, 1983). In such a case we measure the magnetic flux (from the longitudinal component only!) of the order of $2\text{-}4.10^{19}$ Maxwells ($2\text{-}4.10^{11}$Wbs) in an area of the order $1\text{-}2.10^{18}$ cm^2, which means that the radius of the flux tube is of the order of $6\text{-}8.10^3$km. The intensity of the local field concentration does not reach often the value necessary for the formation of a penumbra (Knoška, 1976b).

Although the active regions the sunspot groups of which develop to the higher types C, D, E etc., pass through this very first bipolar balanced stage, the magnetic flux addition in their centres continues or resumes sometimes even several times during the period of several following days. In the photosphere this magnetic activity is seen as the formation of new small spots or penumbra pieces, developed usually in certain "portions", shifted afterwards to both the following and leading parts of the region (Bumba, Suda, 1984a,b). Let us once more summarize its main characteristics (Bumba et al., 1968; Bumba, 1986): it is highly probably a magnetohydrodynamical process of magnetic field strengthening or new magnetic flux generation. It is closely related to a specific singularity in the local magnetic field topology at the inner field boundary not far from the centre of the group, where the gulf of one polarity is compressed inbetween the boundary curvature of the field of opposite polarity and where large radial velocities may be observed. This is the region, where new peaks of both the leading and the following polarities in a special orthogonal organization of the new toward the old tubes of lines of force develop, where the greatest field gradients are formed. At the same time the flare frequencies and importances correlate well with the stage of complexity of magnetic field topology in this situation. Magnetic flux in this region serves apparently as an energetic reservoir for various modes of solar activity in this volume of the solar atmosphere, inside, possibly below and above the observed photospheric levels. Fast growth and again almost equally fast vanishing of magnetic flux of the order of 10^{20-22}Maxwells (10^{12-14} Wbs) in this volume has to be followed by fast changes in the photospheric, chromospheric and coronal structures in this space (Bumba, 1961; Bumba et al., 1982; Bumba, Suda, 1984a,b; Bumba et al., 1986). The area occupied by the field is of the order of $1\text{-}5.10^{18-19}cm^2$.

4. POST-MAXIMUM STAGE OF AN ACTIVE REGION DEVELOPMENT

As soon as the magnetic and spot activity in the centre of the group stops, the whole active region begins to die. The early post-maximum stage of a normal active region with a sunspot group of at least type C is characterized (Bumba, 1983a) not only by a stop to the new magnetic flux and spot formation in its centre, but also by the simplification of the magnetic field boundary and usually by the development of a small part of a quiescent filament in a characeteristic form and configuration. The post-maximum stages of such a region are also typical by the continuous growth of the distance between two opposite polarities and in the shape and distribution of both leading and following parts of active region's magnetic field, resembling the wings of a butterfly. Also during this stage the field, as always, follows the convectional patterns.

In the case of large complex active regions the most complicated configuration of magnetic field lines, bulging out from the lower photosphere into the upper layers of the solar atmosphere has to be dissolved. Most of these complicated spatial field line and plasma systems must be consumed during the high flare- and radioactivity in accordance with the individual trends of flare production, related to the real changes in this magnetic field energy reservoir during the field simplification (Bumba et al., 1986).

During the late post-maximum stage in such cases (Bumba et al., 1986) the observed extended intense facular fields and the distribution of the magnetic background fields in subsequent rotations demonstrate that the photospheric roots of those spatial, heavily simplified patterns remain in the observed layer of the photosphere for several months without further drastic changes.

In the case of proton-flare regions, just after the period of proton-flares occurence, not only the main proton-flare region disintegrates, but the whole

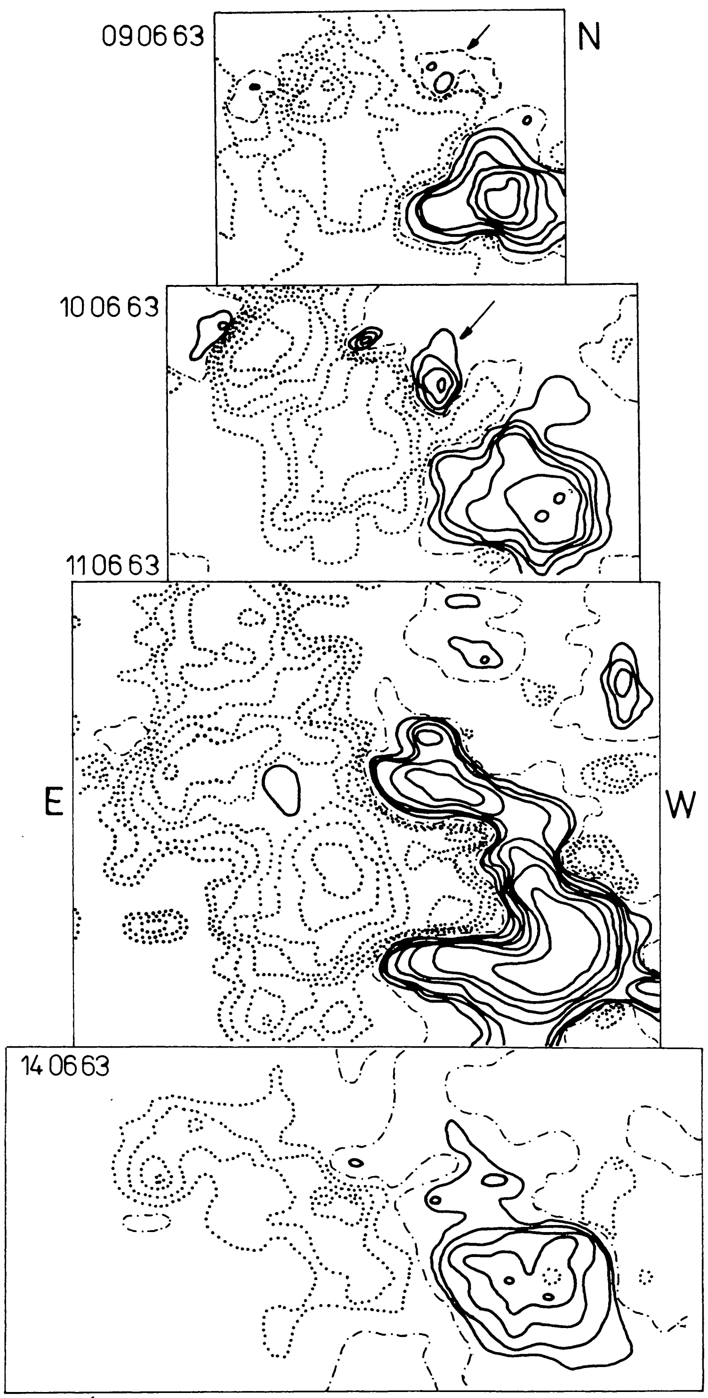

Fig. 1
Series of photoelectric magnetic maps of the magnetic field longitudinal component for the June 1963 active region (C.M.P. June 12.1), obtained at the Crimean Astrophysical Observatory of the Academy of Sciences of the U.S.S.R.. Positive fields are indicated by full lines, the negative fields by dotted ones.

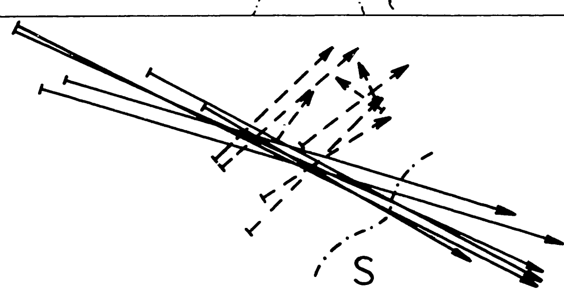

Fig. 2
Scheme of lines connecting the centers of gravity of old and newly induced magnetic fields, taken from the first figure. The lines connecting centers of gravity of opposite polarities of old fields are drawn as full lines, those connecting new fields by dashed lines. Two systems of newly induced fields are visible.

complex magnetic field body disintegrates too. Instead of the enlargment of the field area and gradual weakening of its intensity, the field dissipation is much faster, the field disappearing in various places of the region simultaneously. The process which in the normal active regions takes place during many rotations, is accelerated substantially.

The same phenomenon seems to occur also in the scale of the whole visible solar disk, where three or four rotations only are sufficient for the large-scale background field to be fully reorganized, disintegrated and nearly totally dissipated. It should be emphasized: during this field dissipation period no photospheric or chromospheric activity including flares is observed.

At the same time all described processes represent the effort of all local magnetic fields-acting as soon as the field appears on the solar surface - to simplify their topology and to transform their most complicated form during this last evolutionary stage into a simple bipolar field.

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DISCUSSION

J. Staude

In different models of sunspot formation, the authors assume magnetic flux concentration at supergranular boundaries. If the flux concentration exceeds a certain limit, then a change of the usual convective pattern occur; a convective ring cell - "moat" is formed around the spot. Are there new observed data in favour of such a model ?

V. Bumba

I do not see any contradictions in our observations with this model.

Г.В. Куклин

Можете ли Вы сказать, являются остаточные фоновые магнитные поля генетически связанными с магнитными полями активных областей или же они результат трансформации фоновых полей под действием возникновения в них активных областей ?

V. Bumba

Без остаточных магнитных фоновых полей нет новых локальных полей. Одновременное присутствие новых локальных полей не только трансформирует фоновые поля, но и добавляет им новый магнитный поток, так что я думаю, что генетическая связь фоновых и локальных полей настолько большая, что оба типпа полей только две разные стороны одного явления.

M.A. Mogilevsky

Являются ли наблюдаемые изменения в активной области "поверхностными" или проявлением глубинных процессов выхода и погружения магнитных полей ?

V. Bumba

Я думаю, что в первой фазе развития активной области играют большую роль и более глубокие слои фотосферы (конвекция), но к усилению или генерации поля в "центре" могут вести динамические процессы в подфотосферном или прямо фотосферном слоях (наблюдаются относительно быстрые движения радиальные и в плоскости фотосферы.