SOLAR LOCAL MAGNETIC FIELDS AND THEIR RELATIONS TO THE BACKGROUND FIELDS

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ABSTRACT. Generalization of some our recent results concerning the close mutual relation of solar magnetic background and local fields is presented. Dependence of local field formations on sector structure and through it on Magnetic Active Longitudes, influence of differential rotation and convectional elements and the role of local fields in the background field dynamics are decribed.

СОЛНЕЧНЫЕ ЛОКАЛЬНЫЕ МАГНИТНЫЕ ПОЛЯ И ИХ СВЯЗЬ С ФОНОВЫМИ ПОЛЯМИ. Приводится генерализация некоторых результатов автора, касающихся тесной взаимосвязи солнечных магнитных фоновых и локальных полей. Описывается зависимость образования локальных полей от секторной структуры и тем самым от магнитных активных долгот, влияние дифференциального вращения, конвективных элементов и роль локальных полей в динамике фоновых полей.

SLUNEČNÍ LOKÁLNÍ MAGNETICKÁ POLE A JEJICH VZTAH K POZAĎOVÝM POLÍM. Jsou zobecněny některé z autorových posledních výsledků týkajících se těsných vzájemných vztahů slunečních magnetických pozaďových a lokálních polí. Je popsána závislost vzniku lokálních polí na sektorové struktuře a tím i na magnetických aktivních délkách, vliv diferenciální rotace, konvektivních elementů i úloha lokálních polí v dynamice pozaďových polí.

1. INTRODUCTION

The development of magnetic local fields giving birth to individual active regions is a global quality of the entire system of solar magnetic fields. The new magnetic fluxes are the same parts of the background fields as the old wide dispersed or, on the contrary, strongly compressed fields - remnants of earlier formed active regions. The new magnetic flux never appeared outside the region of weak residues of the old magnetic fields (Bumba, Howard, 1965). Thus the dynamics of the background magnetic field changes is strongly influenced not only by the density, intensity, topology, dissipation and mutual interaction processes of old fields, but also by the location, frequency, modes of growth of new flux formations and by the close correlation and later interference of old and new fields.

Recently we have studied the solar magnetic background field distribution by statistical means using the computing technique (Bumba, Hejna, 1986) and the evolution of magnetic fields which formed the May 1981 solar flare complex (H.R. 17644) in the frame of the background fields (Bumba, 1986; Bumba et al., 1986). We would like to generalize some of the obtained results adding also some of our very preliminary findings from the studies of the Stanford Solar Observatory synoptic magnetic maps.

2. MAGNETIC ACTIVE LONGITUDES, SECTOR STRUCTURE, DIFFERENTIAL ROTATION AND NEW ACTIVE REGION FORMATIONS

Most characteristic features of the integrated, statistically evaluated Hα - magnetic synoptic charts (McIntosh, 1975; Stepanyan, 1982; 1983) in integrated latitudinal intervals are the concentrations of one polarity areas into several intervals of heliographic longitudes 20° - 60° wide, one of which is usually much more outstanding. In the subsequent rotations these intervals of field concentration are repeated in the same longitudes or they are slightly shifted east- or westward. Thus long strips of the single polarity field - the "Magnetic Active Longitudes" (MAL) become visible. The existence of MALs was demonstrated earlier by several authors (Dodson, Hedeman, 1968; Bumba, Howard, 1969; Bumba, 1976; Sýkora, 1969; Ambrož et al., 1971; Ambrož, 1973; McIntosh, 1980; Bumba, Hejna, 1982). On our new graphs of field distribution they persist usually for 20 - 40 consecutive rotations displaying their own distinct internal structure not only in the heliographic longitudes, but also in their temporal development.

From the inclinations of individual MALs in the Carrington coordinate system the changes of their synodical rotations and their dependences on the phase of solar cycle have been estimated, demonstrating that there are many more agents influencing the value of this rotation than the shift of activity in the heliographic latitude only. Earlier (Bumba, Howard, 1969) we proved that once an active region is formed it rotates with the velocity of the surface layers for its latitude. But in a strong background field pattern the influence of the neighbouring fields is so strong that the region may rotate with the whole pattern as a solid body. The same has been shown by Stepanyan (1983), who also pointed out that the irregularity in rotational periods might be associated with large structures in background fields. From the study of Stanford Solar Observatory synoptic maps of weak magnetic fields distribution (Bumba, Hejna, 1987) we see that the normal course of the differential rotation in the photosphere is most often disturbed by the existence of circular patterns which seem to be convectional elements of a substantially greater diameter than that of supergranules (with the diameter of the order of 40° or 60°) and by the discontinuity and activity of sources in which the field is generated or from which it rises to the photospheric surface (Fig. 1). And the existence of MALs seems to reflect this discontinuity in the first place.

We showed earlier (Bumba, Tomášek, 1980; Bumba, 1981) that the evolution of new magnetic flux was linked to the evolutionary dynamics of the gulfs of the field boundaries separating the individual unipolar sectors of the background field, influenced by the differential rotation. During the period of minimum in 1953 - 1954 this boundary formed a wave around the equator bringing large gulfs of the opposite polarity areas into the opposite solar hemispheres (Bumba, 1981). In this way the leading polarity brought from the opposite solar hemisphere had the opposite sign in relation to the majority of its surrounding fields, with all physical consequences resulting from this fact. And vice versa, the new following polarity coincided with the predominant polarity in the given hemisphere. The same was true during the formation of the May 1981 complex, where might be seen a clear connection of the equatorial positive polarity sectors (leading in the northern hemisphere) with the positive polarity polar fields from the southern hemisphere as well as the relation of the equatorial negative polarity sectors to the negative polar fields around the northern pole (Bumba, 1986). Similarly, Stepanyan (1982) demonstrated that the number of magnetic large-scale structures of polarity opposite to that of the polar fields grew when approaching the equator.

The clearly observable extensions in the studied time interval, before all of the positive polarity fields from the southern into the northern hemisphere, use to be related to the development of active regions or complexes with enhanced activity, which are reflected in the internal structure of the MALs as sudden changes in their shapes or shifts. The sector structure formed in this way in the equatorial zone of the background fields correlates also with the existence of the MALs (Bumba, Hejna, 1986), the latter being the product of the local activity development (Bumba, 1986). The formation of coronal holes in some sectors seems to be the latest stage of a complex of activity existence (Bumba, 1986).

3. THE CLOSEST RELATIONS OF THE BACKGROUND AND LOCAL MAGNETIC FIELDS

The development of local magnetic field is usually a part of at least a complex of activities and as such it is also related to the global redistribution of solar background fields, manifested through the interference or mutual interaction of many individual local developments in various stages of evolution at various places of solar surface. The process of a complex evolution may be therefore taken as a partial modulation of a more powerful and longer lasting process in the global background field dynamics. The complex's magnetic field is on the one hand a subordinated part of a more complicated pattern, but on the other hand, at the same time, it also plays the role of a very important component of this pattern development, influencing and in a certain degree predetermining its future formation by the newly produced magnetic fluxes.

4. ROLE OF NONMAGNETIC FORCES

As we have mentioned, the shape and distribution of the magnetic field background patterns is strongly influenced by the differential rotation. We demonstrated many times the role of the whole hierarchy of convectional elements in the magnetic field distribution. From the study of Stanford Solar Observatory synoptic magnetic charts it seems, that the very large - possibly convectional cells - not only exist, but their influence is not limited only to the passive field distribution and the smooth course of differential rotation. They seem to play, parallel with the discontinuity of magnetic field sources, an important role in the active magnetic flux or solar activity distribution.

Thus the formation of a local magnetic field is brought about by nonmagnetic forces acting simultaneously with the electromagnetic forces in the photosphere and probably also at least in the lower layers of the chromosphere. Parallel with convection and differential rotation we have to count the buoyancy of magnetic fluxes, various organized motions observable in the photosphere (Bumba, 1983), Corriolis force and possibly still several other forces of nonmagnetic origin. But before all we have to take into account the exchange of energies among the electromagnetic and nonmagnetic forces.

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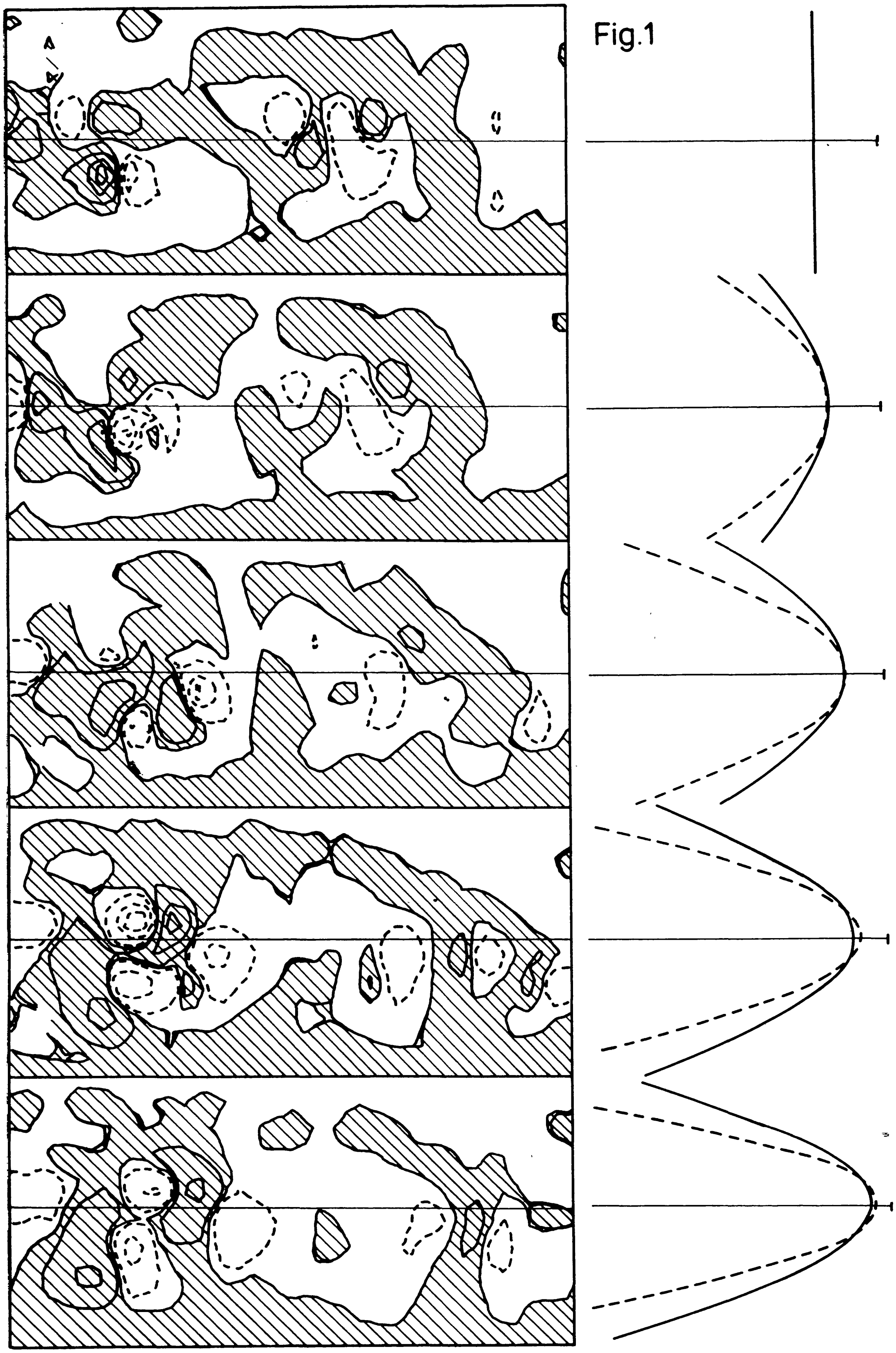
Fig.1

ДИСКУССИЯ

Л. Крживский

Из примеров на картах вытекает, что корональные дыры находились в областях между противоположными полярностями. Всегда это так бывает ?

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В исследуемом случае это действительно так. Но у меня пока мало случаев для точного ответа. То что образование корональной дыры является последней фазей развития большого комплекса активности, таких случаев у меня пока имеется несколько.

A. Antalová

Can local MF change the boundary of the sector ?

V. Bumba

It seems to depend on the power of active region's activity and of course of its magnetic field. In the first stage of the LF (local field) evolution the boundary, which is a part of a sector boundary, forms the described gulfs, than it simplifies being still the part of the sector boundary. In the case of very active LF the boundary may change succesivelly its form to become later a part of another boundary or to belong to another large-scale field pattern.