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THE ACTIVE REGION MAGNETIC FLUX CORRELATION WITH FLARES APPEARANCE

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Abstract. Association of the active region magnetic flux and powerful solar flares (class X) are investigated for active regions AR 10486 and AR 10365. These regions traveling along the solar disk produced several powerful flares. The flares appeared when magnetic flux is exceeded 10^{20} Maxwell. During all flares accept one the magnetic flux has been unchangeable. During this flare the magnetic flux decreased by 10%. Such flux decreasing occurred also without flares. The magnetic energy transfer from photosphere to corona during a flare was not occurred. Such behavior of the magnetic field in active regions is in agreement with the idea of explosive release that has been accumulated in a current sheet created above the active region.

Introduction

In the last three hundred years the solar activity demonstrates the 11 year period. The powerful solar flares appear during the years of solar activity. Solar flares are produced above active regions, where the magnetic field can reach thousands Gauss. There are many attempts to development observed solar date to find out any regularity in sola activity directed to solar activity prediction in future. Such attempts achieve seeming success in prediction of previous (23-th) cycle development.

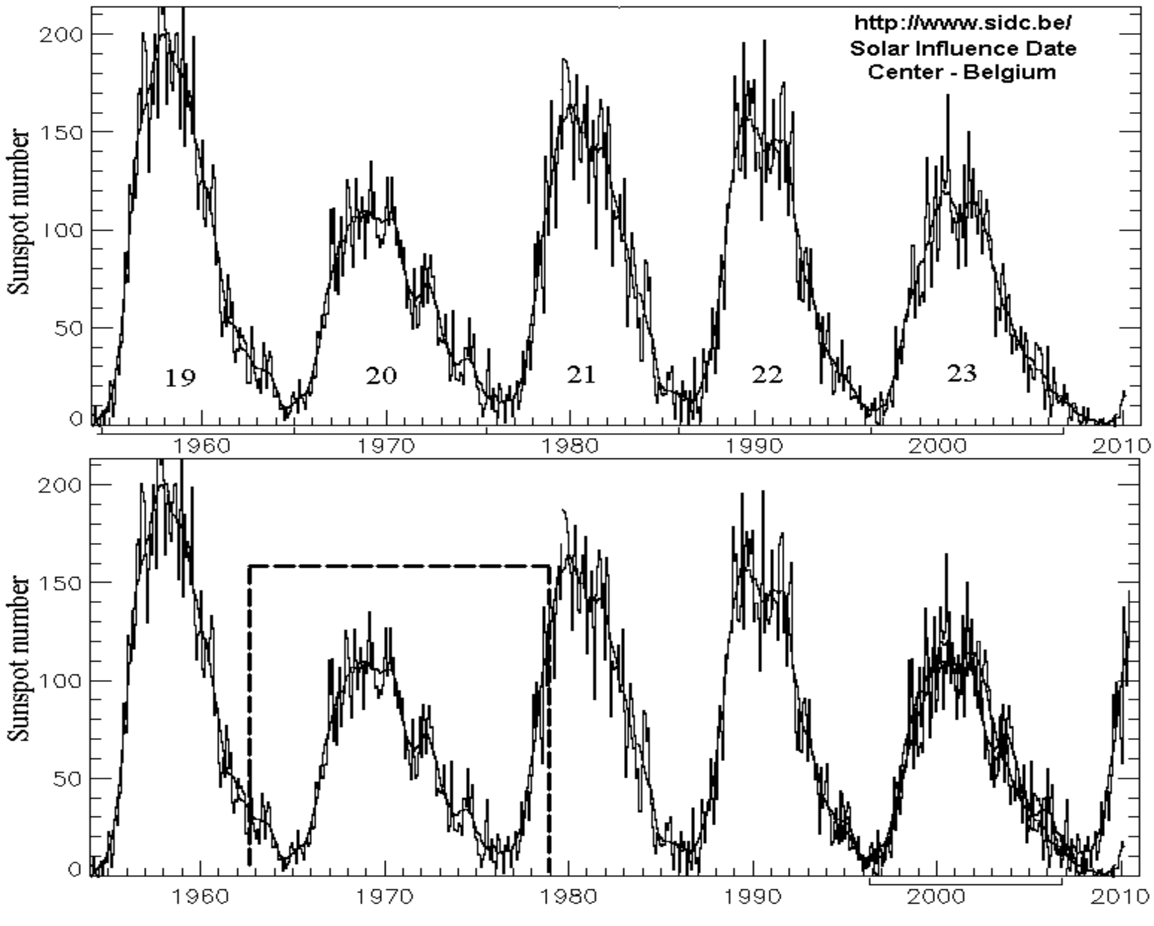

Fig. 1. a). Time dependence of solar activity (sunspot number). b). Cycle 20 shown by broken lines is overlapped on cycle 23.

However, the expected increasing of solar activity after minimum activity predicted in 2007 is not occurs. In the next 3 years the active regions have not appeared on the solar disk. The dependence of sunspot number according to Belgium Solar Influence Center is shown in fig. 1a. The deep minimum after cycle 23 and cycle 24 delay is seen. In fig. 1b the cycle 20 is overlapped on cycle 23. These cycles have the same magnitude. Tremendous sunspots difference in 2010 is seen. The figure shows that if 11 year cycle period is conserved, the solar activity in 2010 y should be very high. But instead of all predictions the solar activity is still very low. This unexpected situation has initiated conclusions that instead of a global warming, the global cooling similar to a little boulder period in the Mouder solar activity minimum is expected [1]. The situation shows that for solar activity prediction, it is necessary to understand all link of the chain of phenomena responsible for flare generation. Here we consider one of the links, namely, association of magnetic field dynamic in the active regions and solar flare creation. In our previous Apatity seminar reports we have considered the mechanism of energy accumulation for a flare in the current sheet magnetic field and the possibility of explosive release of this energy [2, 3].

The association of the active region magnetic field and flares has been investigated many years. The necessity of the big magnetic flux in an active region for flare production has been pointed out by Ishkov [4]. The main topic of investigation is slow evolution of an active region that initiates a flare and a possible fast change of the magnetic field on the photosphere during a flare. The review of such investigation has been published by Wang [5]. Most of the flares appear above active regions after slow magnetic field increasing. The results of detection of fast magnetic disturbances are rather conflicting. Several flares usually are produced during a strong active region moves across the solar disk.

The flare class of elementary flares in the set can change in three orders of magnitude. During the set of flares the magnetic field configuration in an active region slowly changes and magnetic field fluctuations occurs in some points of the active region. The SOHO MDI photospheric magnetic maps of the component directed along the line of sight are published every 1.5 hours in http://soi.stanford.edu/magnetic/index5.html. Each SOHO magnetic map possesses its peculiarities, but main elements of active regions are conserved several hours. Sometimes short time magnetic field fluctuations occur. The problem arises about association of active region magnetic field change and flares appearing. Some researches [5] report about different photospheric magnetic field behavior at flares, but there are no certain opinion about such effects. The most outstanding local magnetic disturbances in the active region have been reported in [5]. Drops of the magnetic field of the order of 100 Гаусс are observed during the flare 20.01.2005 in active region AR10720. Field decreasing is starting at ~2 hours before this flare. The work [5] contains many references that reported active region disturbance during flares, but there are no agreements between these data. There are many attempts to find a correlation between situations on the photosphere and flare appearance.

According to theoretical data [6-8] and results of RHESSI measurements [9, 10] the primary energy release occurs in the corona above an active region. The active region can be considered as local solar magnetosphere with magnetic field of several thousand Gauss. The energy for a flare is accumulated in a current sheet appeared above active region. This energy release occurs due to current sheet explosive decay. Such solar flare scenario is similar to substorm development in the Earth magnetosphere. Change of photospheric magnetic field cannot produce strong influence on flare dynamics. The similar manner, Earth magnetic field does not influence on substorm development.

The authors of [5] suppose that observed effect is associated with a magnetic rope, which influences on current sheet instability. It is necessary to emphasize that measurements in [4] has been carried out in the rather complicated conditions, at the active region AR 10720 location near the Western limb (N12 W56). The line of sight angel with solar surface has been too little and the results of measurements" untangled by combining intuitive geometric analysis and a transformation of the magnetogram into the heliographic coordination system". The aim of the present work is analysis of the normal magnetic field in active region and search for possible connection the photospheric magnetic field with flare generation. The SOHO MDI measurements of the line-of-sight magnetic component are used. But the line-of-sight magnetic field component is strongly depends on the active region position on the disk. The first task of investigation is calculation of the normal to the solar surface magnetic component from SOHO data.

Flares in the active region 10486

AR 10486 has been observed in October-November 2003 y. It produces several powerful flares, including four X-class flares. Two other X-class flares have been observed near Eastern and Western limbs (23.10.2003 X5.4 S18E88 и 4.11.2003 X30.6 S18W88), their location does not permit to get a magnetic map containing all active region. Magnetic field dynamic is determined by development of SOHO MDI date (http://soi.stanford.edu/magnetic/index5.html). The time interval between the measurements is 1.5 hours. The measured magnetic distribution in a region near solar disk centre almost coincides with the distribution of the normal magnetic component. However such distributions are considerably different for an active region displaced from the centre. The normal magnetic field distributions are obtained from potential field distribution above the active region. The potential field is calculated by solving Laplace equation with the oblique derivative as the boundary conditions. The PERESVET code is used in which the procedure of Laplace equation solving with the oblique derivative is inserted. This method is developed in [10]. The potential field is calculated in big dolmen for to minimize the errors connected with uncertainty of boundary condition in the corona. Such method is available, because the magnetic field distribution on the photosphere is not distorted by a current sheet situated high in the corona. The fig. 2 shows line of sight SOHO MDI distribution and distribution of calculated normal magnetic field, when the active region AR10486 has been located about 30^o from the East solar limb. The northern Φ_N and southern Φ_S magnetic fluxes are shown below. The calculations have been carried out in the domain $4 10^{10}$ см × $4 10^{10}$ см, when the active region is displaced from the East limb in ~30^O. The figure shows that the line-of sight magnetic field distribution is rather different from distribution of the normal magnetic component.

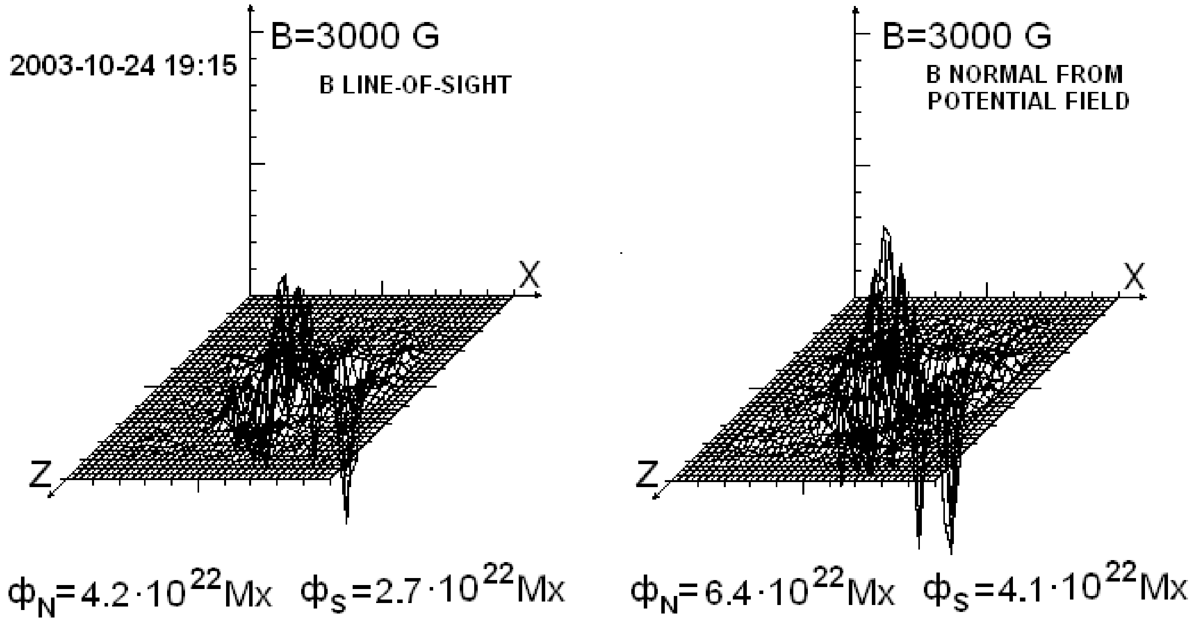

Fig. 2. a) Line of sight SOHO MDI (http://soi.stanford.edu/magnetic/index5.html, in the active region AR10486 (24.10.2003 19:15). б) Calculated magnetic field distribution of the normal magnetic field component.

For calculation of the normal magnetic field the method of Laplace equation with inclining derivative solving are used [10]. The area domain 4×10^{10}cm$\times4\times10^{10}$cm is bigger than the active region, and errors in setting nonphotospheric boundary condition does not influence strongly on results. Such method permits to obtain the normal magnetic component during all time of active region traveling across the solar disk.

The active region AR10486 appears on the solar back side. It travels from 26.10.2003 to 3.11.2003 on the visible disk. Evolution of the normal North and South magnetic flux components are shown in fig. 3.

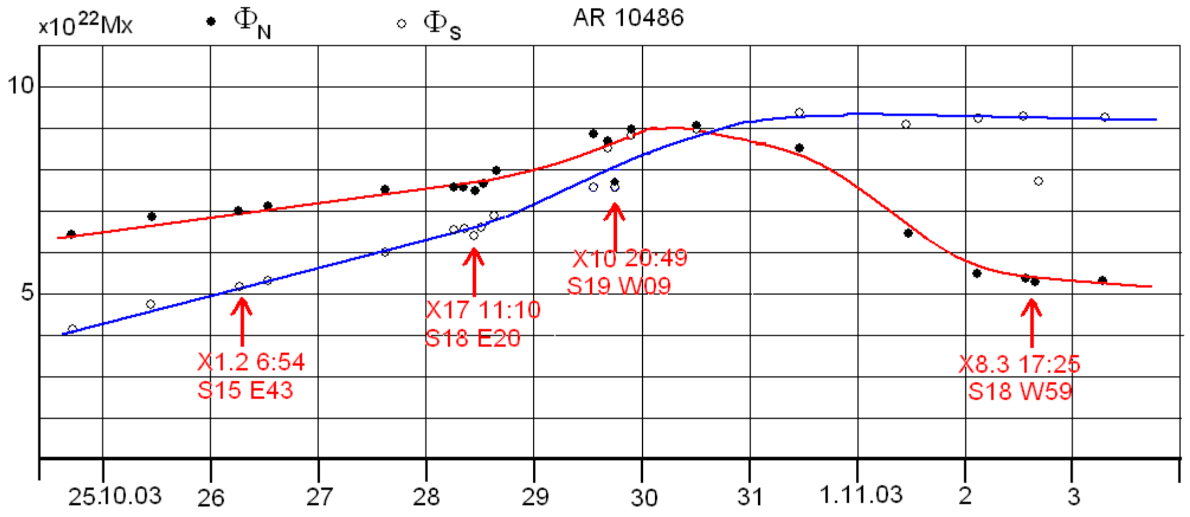

Fig. 3. Normal components of North and South magnetic fluxes of AR10486**.**

At the beginning Φ_N and Φ_S increase linearly. Linear extrapolation 23.10.2003 shows that the X5.4 flare occurs at $\Phi_N \sim 510^{22}$ Mx и ~ 310^{22} Mx. The magnetic field configuration changes only weakly. At that time $d\Phi_N/dt \sim 4\ 10^{16}$ Mx/s and $d\Phi_S/dt \sim 8\ 10^{16}$ Mx/s.
The SOHO data for AR10486 are very convenient for investigation of the active region magnetic field at the flare appearing. The time of magnetic map measurements has coincided with the most powerful flare (X17, S18E20, 28.10.2003, t_{max}-11:10) with accuracy of 1 s. The magnetic flux of the AR10486 both magnetic components (N and S) remain constant during the flare. Magnetic field distributions around the flare are presented in fig. 4. The change of the magnetic flux is less than 1 percent per hour. Only noticeable peculiarity is a narrow local field maximum at the flare time which does not produce valuable change of the magnetic flux. This maximum is marked by the arrow. But such fluctuations occur during time of all active region evolution. It is impossible to exclude that such maximum can initiate current sheet instability.

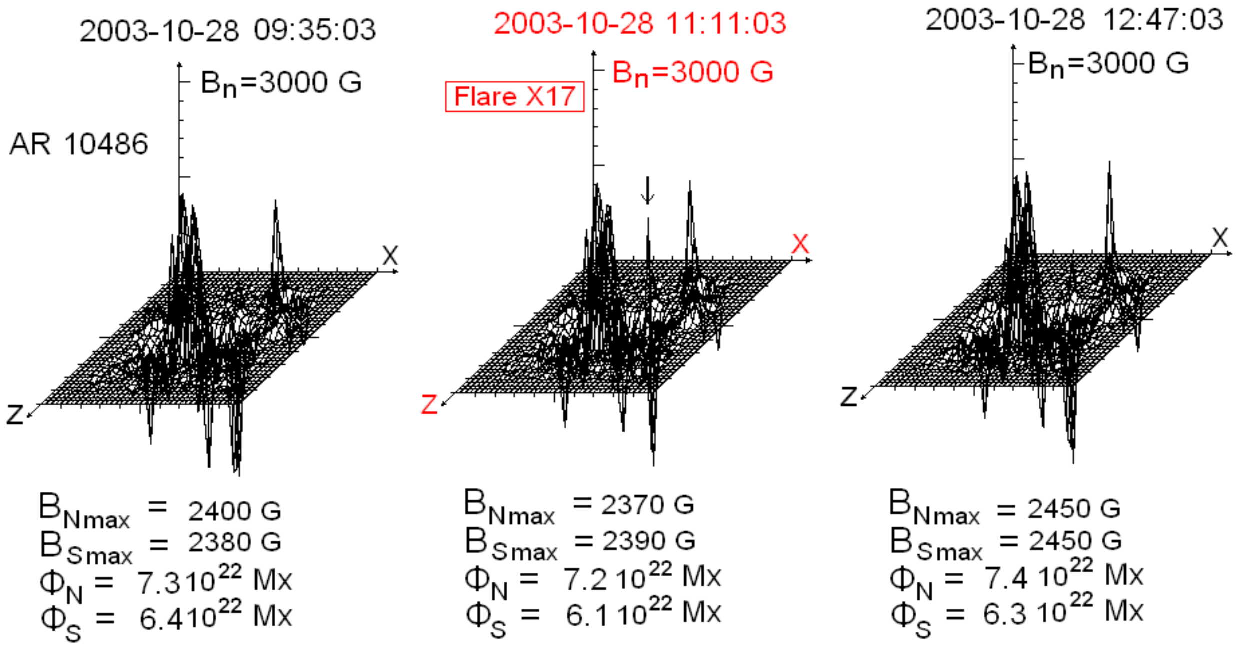

Fig. 4. Magnetic field distribution in the active region before the powerful solar flare, in the flare time, and after the flare.

Conclusion

The powerful solar flares appeared above AR10486 at magnetic flux bigger than 10^{22} Mx. Similar results shows investigations of others active regions. Magnetic field distribution during flares, including X17 flare, does not show any change that can be associated with energy input from the photosphere to flaring region. This result can be considered as an independent evidence of slow energy accumulation in the corona before the flare. Energy explosive release occurs producing the flare. Such scenario is in agreement with the electrodynamical solar flare model [6 - 8].

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