ON THE RELATIONSHIP BETWEEN STRONG FLUCTUATIONS OF SOLAR ACTIVITY AND REARRANGEMENTS OF BACKGROUND MAGNETIC FIELDS OF THE SUN

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ABSTRACT. The relationship between strong fluctuations of solar activity and rearrangements of solar background magnetic fields is discussed. Methods of determining a statistical relation between the times of appearance of different types of event are outlined. It is found that to an accuracy of ±1 solar rotation, the extrema of 80% of strong fluctuations coincide with the onsets of rearrangements of background magnetic fields on the Sun.

О СВЯЗИ МЕЖДУ СИЛЬНЫМИ ФЛУКТУАЦИЯМИ СОЛНЕЧНОЙ АКТИВНОСТИ И ПЕРЕСТРОЙКАМИ ФОНОВЫХ МАГНИТНЫХ ПОЛЕЙ СОЛНЦА. Обсуждается связь сильных флуктуаций солнечной активности с перестройками солнечных фоновых магнитных полей. Изложены методы выявления статистической связи между моментами возникновения событий разных типов. Установлено, что с точностью до ±I оборота Солнца экстремумы 80% сильных флуктуаций совпадают с началами перестроек фоновых магнитных полей на Солнце.

VZTAH MEZI SILNÝMI FLUKTUACEMI SLUNEČNÍ ČINNOSTI A PŘESTAVBOU SLUNEČNÍCH POZAĎOVÝCH MAGNETICKÝCH POLÍ. Je diskutován vztah mezi silnými fluktuacemi sluneční činnosti a přestavbou slunečních pozaďových magnetických polí. Jsou popsány metody umožňující nalézt statistický vztah mezi okamžiky vzniku událostí různých typů. Je nalezeno, že s přesností do ±1 otočky Slunce extrémy 80% silných fluktuací souhlasí s počátkem přestavby pozaďových magnetických polí.

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There is now no common opinion about the role of solar activity in the formation and evolution of large-scale background magnetic fields on the Sun. Various authors (Bohlin and Sheely, 1978; Levine, 1977; Timothy et al., 1975/ have reported that the presence of active regions is apparently a rule rather than an exception in the formation of new unipolar regions of the magnetic field. We shall consider events of the same time scale in background magnetic fields (LMFs) and solar activity variations. In the case of LMFs, these events are rearrangements covering a large part of the solar surface within latitude intervals $\pm(60^{\circ} \div 70^{\circ})$ and longitude interval $0^{\circ} \div 360^{\circ}$, and in the case of the solar activity variations they are strong fluctuations of the Wolf numbers (Vitinsky, 1973).

Synoptic maps of solar photospheric magnetic fields obtained at the Mt. Wilson observatory were used as the source LMF data, and these were treated using the following method (Plyusnina, 1983).

1. The magnetic field polarity in each area $5^{\circ}x5^{\circ}$ in latitude and longitude is determined. Areas occupied by compact BMRs (bipolar magnetic regions) remain empty if the 10 G isoline encloses an area of less than 15° in longitude. The result is a map of the magnetic field polarity distribution with 5° step in the latitude and longitude and with gaps in the places of BMRs.

2. The largest parts of the surface with dominating polarity are contoured. The empty areas containing compact BMRs are assigned the same polarity as the surrounding background. All UMRs (unipolar magnetic regions) whose size exceeds 10° in longitude are then contoured.

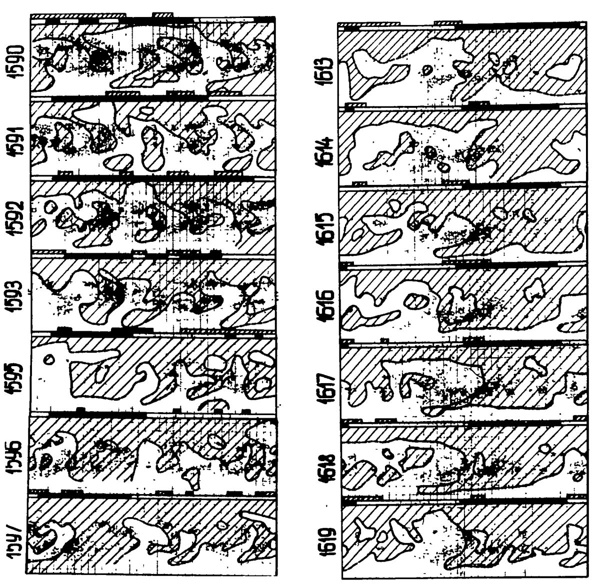

Fig. 1 Examples of the LMF sign distribution maps obtained using Plyusnina's method (1983).

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These magnetic field maps reflect the LMF sign distribution with strongly weakened input of active regions. An example of a sequence of these maps is presented in Fig. 1.

We call the time intervals in which the longitudinal distribution of LMFs inside the latitude zone $\pm 40^{o}$ changes essentially from one rotation to the next rearrangement periods. After the rearrangement, a quasi-stable distribution with characteristic dimensions of no less than 60^{o} in longitude exists for a number of rotations and then changes, as a rule, with the new rearrangement. A list of such rearrangements of LMFs during the years 1969-1980 is given in Table 1.

Table 1

List of LMF rearrangements.

Rearrangement	Stable state	Rearrangement	Stable state
	Carrington rotations		
1551	1552 - 1561	1630 - 1631	1632 - 1638
1562 - 1569	1570 - 1575	1639 - 1640	1641 - 1643
1576 - 1577	1578 - 1581	1643 - 1645	1646 - 1668
1581 - 1582	1583 - 1588	1669 - 1672	1673 - 1679
1589 - 1594	1595 - 1603	1680 - 1681	1682 - 1686
1604 - 1606	1607 - 1629	1687 - 1695	1696 - 1698

A list of strong positive and negative Wolf number fluctuations for the same time interval was compiled using the Vitinsky's data (1981) (Table 2). The method of detecting strong fluctuations was described by Vitinsky (1973, 1980). To facilitate comparison with the LMF rearrangements, these data were converted from calendar dates to Carrington rotation numbers. The total error of dating caused by the fluctuation detection method and by converting the date is apparently not less than one rotation.

Table 2

List of strong fluctuations of Wolf numbers.

Fluct. sign	Begin.	Extrem.	End	Fluct. sign	Begin.	Extrem.	End
Pos	1543	1545	1546	Pos	1633	1634	1635
Pos	1555	1557	1558	Pos	1638	1639	1641
Pos	1559	1561	1562	Neg	1640	1643	1644
Neg	1573	1575	1576	Neg	1651	1652	1656
Pos	1583	1584	1586	Neg	1660	1661	1663
Pos	1587	1589	1590	Neg	1669	1671	1672
Pos	1604	1605	1606	Pos	1675	1677	1680
Pos	1615	1617	1618	Neg	1679	1680	1682
Neg	1625	1627	1630	Pos	1685	1686	1692
Pos	1629	1631	1632				

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It is known that the strong positive fluctuations are closely related to sequences of very large sunspot groups (Kopecky and Kuklin, 1986), whose maximum area exceeds 500 millionths of the visible hemisphere, appearing practically simultaneously on the whole Sun in the course of 1-2 rotations (Kopecky and Kotrč, 1974). Since, according to current concepts, sunspot groups are places where strong toroidal magnetic field emerge on the solar surface, they must be observed most frequently close to meridionally oriented polarity inversion lines (PILs) of LMFs. Therefore, the appearance of large sunspot groups on the whole Sun simultaneously must be connected with the formation of new meridionally oriented PILs, i.e. with the rearrangements of the longitudinal LMF distribution in the "royal" zone.

In the case of strong negative fluctuations, the significant decrease in the number of sunspot groups may be related to the growing complicatedness of the PIL pattern and decrease of the total length of its meridionally oriented parts, because the probability of sunspot groups being generated along PILs oriented parallel to the equator is small. Therefore, during this time the longitudinal LMF distribution does not show well pronounced large-scale elements. After the decay of the strong negative fluctuation, the appearance of new sunspot groups which, generally speaking, need not necessarily appear at the same places where the solar activity was concentrated before the negative fluctuation began, is obviously connected with the formation of the new meridionally oriented PILs, i.e. with the rearrangement of the longitudinal LMF distribution.

Thus, it is naturally to expect both statistical and physical relationships between the strong fluctuations of the solar activity and the LMF rearrangements. A method of detecting the relationship between discrete events on the basis of the renewal theory (Cox and Smith, 1967) was developed with a view to applying it to the problem of the reality of sympathetic flares (Kuklin, 1978). We have used this technique and compared the rearrangement beginnings, on the one hand, and the extrema and beginnings of strong fluctuations, on the other. It was ascertained that there is a non-stochastic relationship between the rearrangement beginnings and fluctuation extrema with a probability of 0.84: they are separated by about 1 rotation. For the beginnings of rearrangements and fluctuations, the maximum probability of the non-stochastic relationship is equal to 0.19 and corresponds to a distance between them of 3 rotations. Since the average duration of the ascending branch for the considered fluctuations is equal to 1.6 rotations, we may conclude that the beginnings of the strong fluctuations may lead the beginnings of the LMF rearrangements by 1 to 3 rotations. But the data used (19 fluctuations and 12 rearrangements) include cases of superposition of neighbouring fluctuations on one and the same rearrangement, which is proving detrimental to our estimates.

For a more detailed analysis of the distribution of the beginnings and extrema of fluctuations relatively to the beginnings of the rearrangements, we have constructed the corresponding histograms (Fig.2) taking into account only the events closest to each rearrangement beginning and considering all fluctuations together, and positive and negative ones separately.

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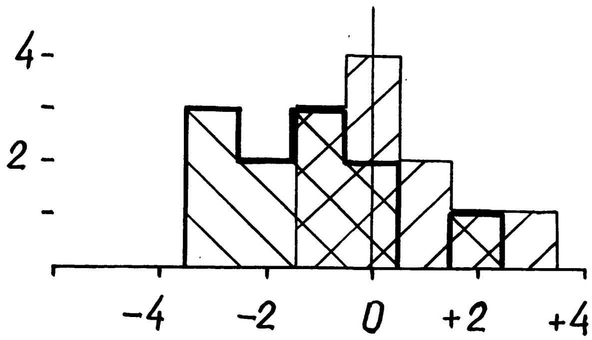

Fig. 2 The histogram of the distribution of the events relative to the zero rotation (rearrangement beginning). A thick line corresponds to the fluctuation beginnings, a thin line corresponds to the fluctuation extrema. Abcissae are intervals in solar rotations.

If there no relationship exists, the considered events (beginnings and extrema) may occur arbitrarily, i.e. with an equal probability in any of the free rotations. The number of the latter is equal to the sum of the number of rotations not covered by fluctuations and the number of separate events (overlapping fluctuations, for example the negative and positive, are considered as one event but the adjacent ones as separate events). Therefore, the probability π of an event occuring in a certain rotation is determined by the ratio of the number of separate events to the number of free rotations. Let ℓ be the number of rotations, distributed relative to the rearrangement beginnings in the certain way, which contains m events of the total number of n according to the histogram. Then, in the case of any rearrangement beginning during these ℓ rotations one event occurs with the probability m/n and significance of this result to be non-stochastic 1 - P is estimated with the help of the binomial distribution

$$P = C_n^m (\ell\pi)^m (1-\ell\pi)^{n-m}.$$

The results of the computations according to this way allow the following conclusions to be drawn. Firstly, the optimal combination of the best reliability of the result and the largest part of the sample corresponds to the situation when the fluctuation extremum coincides with the rearrangement beginning with an accuracy of up to ± 1 rotation indepedently of the fluctuation sign. This is fulfilled for 80% of fluctuations approximately with a reliability of no less than 0.97. Secondly, in 75-80% of the cases the fluctuation beginning precedes the rearrangement beginning by 1-2 rotations with an accuracy of up to ± 2 rotations. This is correct in the case of the positive fluctuations for

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75% of the events with the reliability equal to 0.90 and in the case of the negative ones for 100% of the events with the reliability equal to 0.99.

Thus for the considered time interval and investigated small sample the appearance of strong fluctuations of solar activity is a predictor of the rearrangement beginnings in 80% of cases with the reliability no worse than 0.90.

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