VARIATIONS OF THE FIELD STRENGTHS IN THE SUNSPOTS OF 1982 JUNE AND JULY GROUPS AND 1984 JUNE GROUP

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ABSTRACT: The behaviour the magnetic field in sunspots belonging to 3 active groups was studied in detail during their development. Two of these groups were included in the international cooperative programs. The variation of the magnetic field strength in two groups had a cyclic character with typical time scales of 35, 106, 124, 126 and 140 minutes.

КОЛЕБАНИЯ НАПРЯЖЕННОСТИ МАГНИТНОГО ПОЛЯ СОЛНЕЧНЫХ ПЯТЕН В ИЮНЬСКОЙ И ИЮЛЬСКОЙ ГРУППАХ 1982г. И ИЮНЬСКОЙ ГРУППЕ 1984г.: Изучено детально поведение магнитного поля солнечных пятен в трех активных группах, две из которых были включены в международные кооперативные программы. Изменения напряженности магнитного поля в двух группах в течение их развития имеют циклический характер с типическими временными масштабами 35, 106, 124, 126 и 140 минут.

VARIÁCIE MAGNETICKEJ INDUKCIE SLNEČNÝCH ŠKVŔN Z JÚNA - JÚLA 1982 A Z JÚNA 1984: V práci sú analyzované časové zmeny magnetickej indukcie v slnečných škvrnách, nachádzajúcich sa v troch vyvíjajúcich sa aktívnych oblastiach (z toho dve skupiny boli predmetom medzinárodných kooperatívnych programov). V dvoch skupinách mali zmeny magnetickej indukcie cyklický charakter, s charakteristickou periódou 15, 106, 124, 126 a 140 minút.

The sunspot group No. 189 (1982) (Solnechnye Dannye numeration) appeared on the solar eastern limb on June 2 and had the latitude of $8^{\circ}.5$S. It consisted of 5 spots with the total area of 853 millionths of the solar hemisphere. Its maximum development begun on June 8, when its total area reached 1067 millionths and the number of spots reached 65. Flare activity reached its maximum on June 5, at that day several flares of importance 2 were observed.

In the right upper part of Figure 1 the group drawing for June 6 is shown and two spots of different polarity in the same penumbra are marked. The maxi-

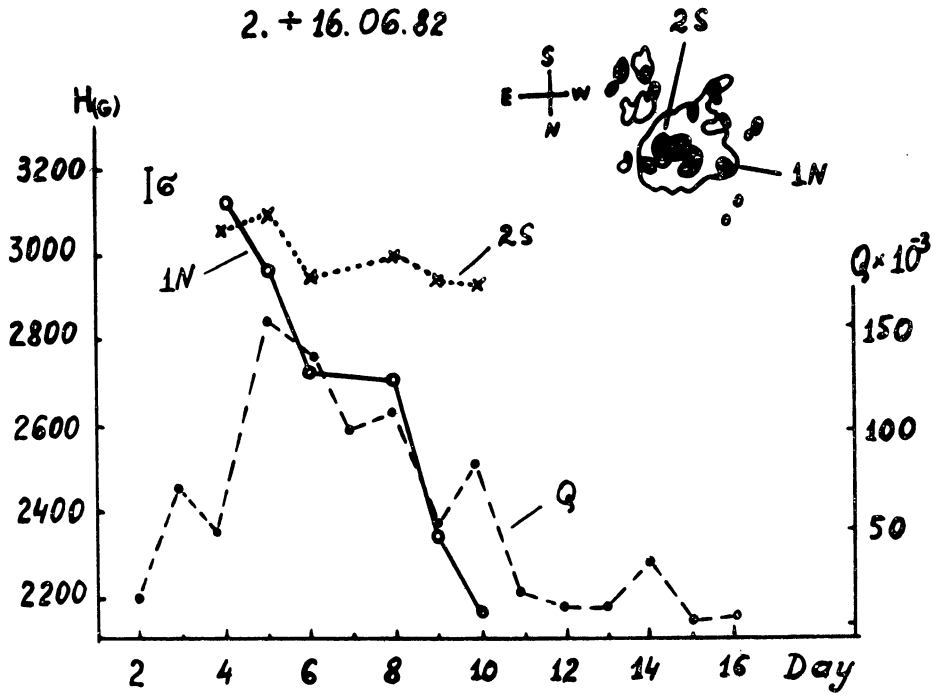

Fig. 1: Time variations of the magnetic field strength of the sunspots 1 and 2 of the group No. 189 for the period June 4 - June 8, 1982 and flare index Q . In the right upper part the group drawing for June 6 is shown.

mum field strength was measured for these two spots and its time variation was investigated in detail. The curves of Figure 1 give the magnetic field variation of the marked spots and the change of flare activity index Q for the period June 4 - June 8, σ being the mean-square error of one measured value of strength. The left ordinate scale corresponds to the field strength (in Gauss) and right scale gives Q index, which is equal to the product sum of the flares duration (in min.) on the area (in millionths of the solar hemisphere) for every day (Solar Geophysical Data data).

The curves of Figure 1 show that the field strength of spot 2 was changing little and at the same time the field strength of a small spot of polarity N decreased rather quickly (with gradient 155 G/d). But an interesting peculiarity on the curve for the spot 1 is that in spite of sharp general fall the field strength did not change from June 6 to June 8. It can be explaned by strength rising during the time of separation of this umbra from the main spot on June 7.

Just the same situation occured on July 21, 1971 in the group No. 252

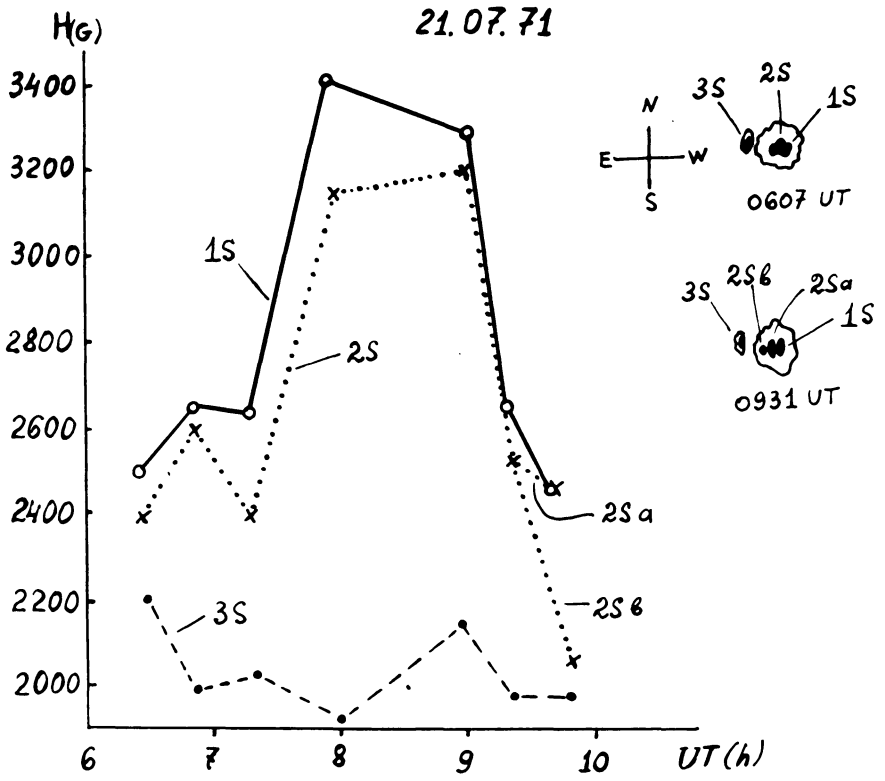

Fig. 2: Time variations of the magnetic field strength of the sunspots 1, 2 (a and b) and 3 of the group No. 252, 1971. In the right upper part the group drawings for 0607UT and 0931UT are shown.

under separation of a large spot umbra into two parts. The field strength of both parts of this umbra rised sharply in the moment of separation and fell after it again to an original level. The reality of this sharp strength peak is confirmed by practically constant field intensity of a small sunspot situated near the large one (Figure 2, spot 3). It is illustrated in Figure 2, where for the Group No. 252 the time variation of the field strength in two umbrae of one large spot (1 and 2) and in a small spot 3 are given. In Figure 2 two groups are presented twice: before separation of the spot umbra (0607 UT) and after it (0931 UT).

Returning to Figure 1 note another pecularity - there is a synchronous falling of the field strength in the spot 1 and the flare activity of the group No. 189.

On June 4, 1982 during about two hours the field strength in the umbrae 1 and 2 was measured every 10 min. by photographic method. The results of me-

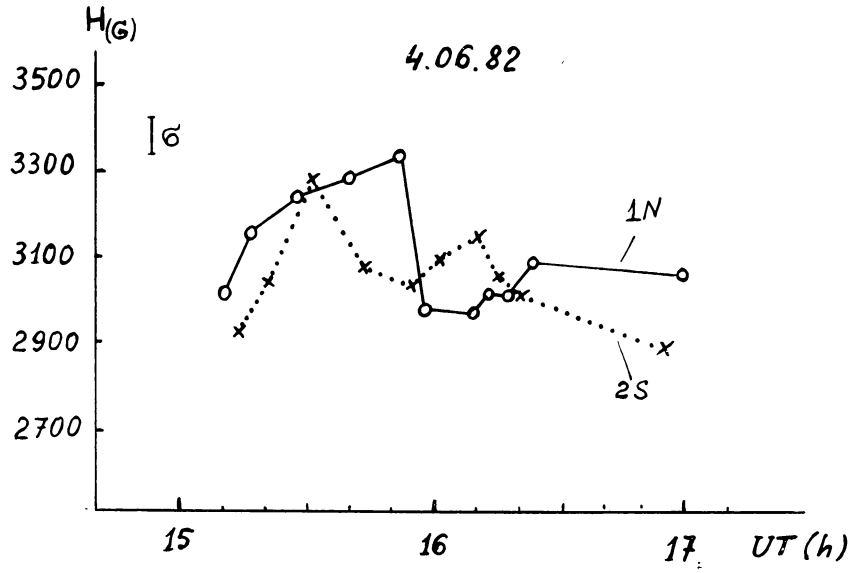

Fig. 3: Time variations of the magnetic field strength of the sunspot 1 and 2 of the group No. 189 on June 4 for period 1500 - 1700 UT.

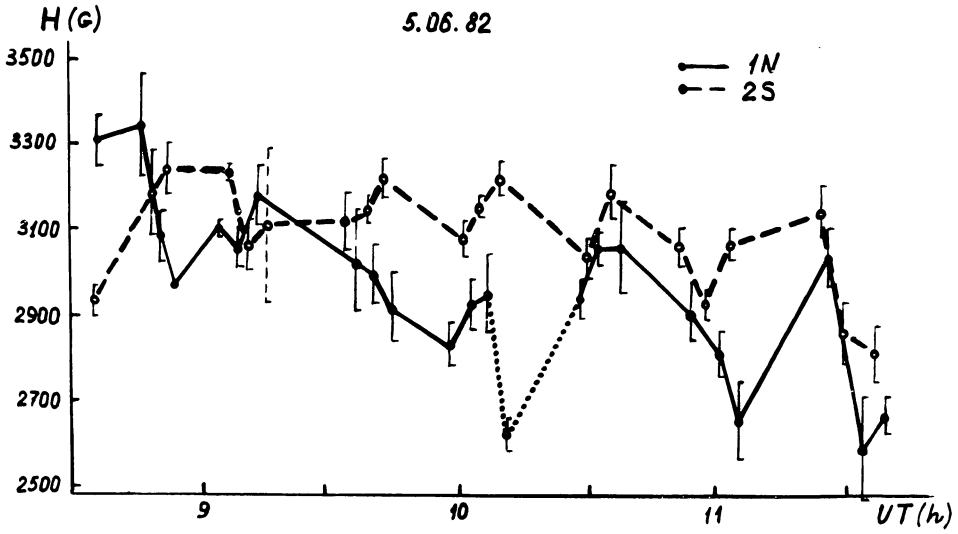

Fig. 4: Time variations of the magnetic field strength of the sunspots 1 and 2 of the group No. 189 on June 5, 1982 during period 0800 - 1200 UT.

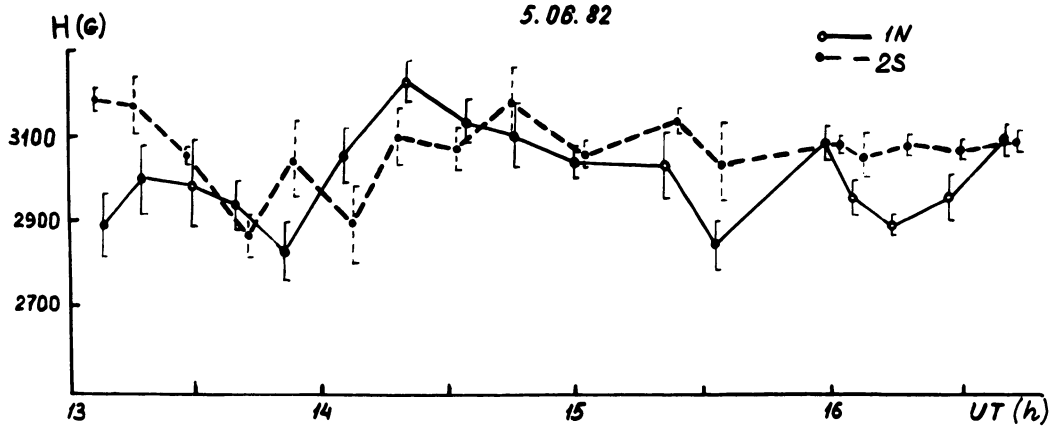

Fig. 5: Time variations of the magnetic field strength of the sunspots 1 and 2 of the group No. 189 on June 5 during period 1300 - 1700 UT.

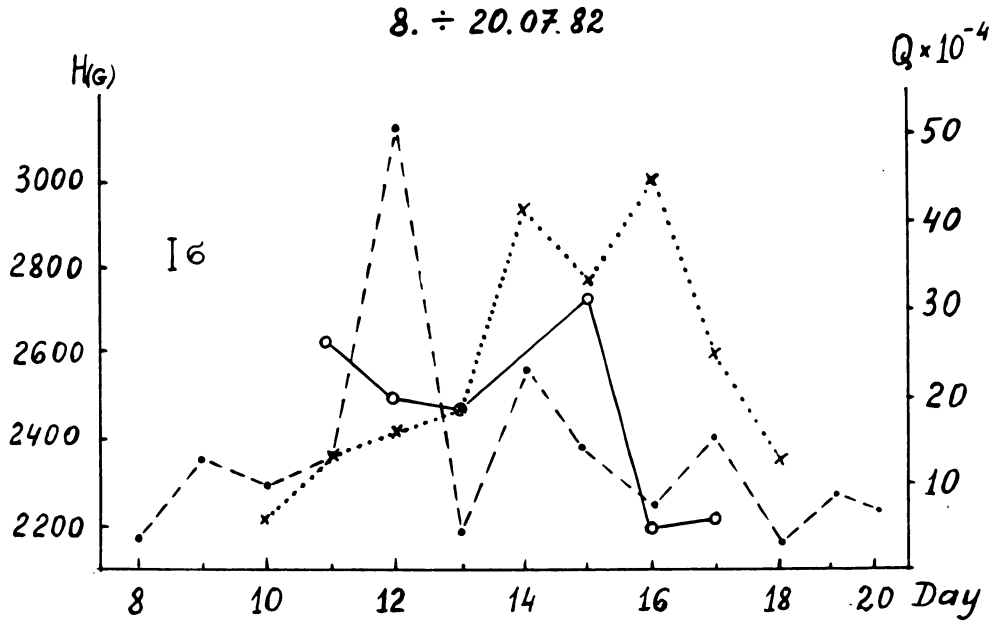

Fig. 6: Time variations of the magnetic field strength of the sunspots 1 and 2 of the group No. 229 for period July 8 - July 18, 1982 and flare index .

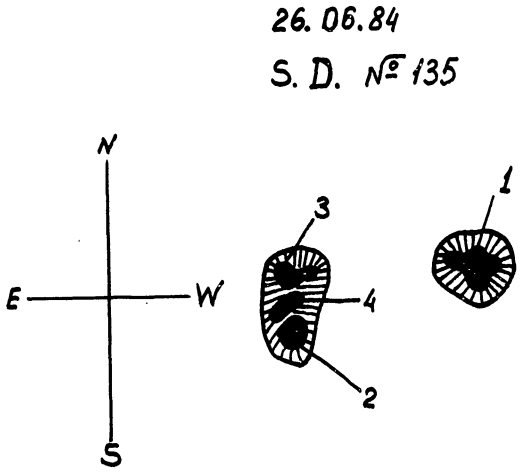

Fig. 7: The group drawing No. 135 on June 26, 1984 is shown with numeration of the spots.

asurements are shown in Figure 3 together with the corresponding r.m.s. error bars (6 measurements for each value). Figure 3 shows that significant real changes of the magnetic field occured only in spot 1. It was confirmed by statistical method.

On June 5 the same umbrae were examined every 10 - 20 min. during two time periods (Figure 4 and Figure 5). In 0810 - 1140 UT the sunspot 1 had significant field variations, corresponding to variations of the sunspot 2 in opposite sense. In 1310 - 1640 UT there were no similar field variations. For explanation of these observations we used the Kopecký and Kuklin method (1971). It appears that the field variations of the spot 1 has definite time scales: 32, 106 and 140 min. For the spot 2 these time scales are 23, 35 and 109 min. We calculated the multiple correlation coefficients of real and model curves of the field variations supposing this process to be poliharmonic, and also level of probability of their unaccidental difference from null. The periods of the field variation, the correlation coefficient R and the probability $P = 1 - (1 - R^2)^{\frac{N-3}{2}}$ (where N is the point number) are presented in Table 1. We note that the time scales equal to 35 and 109 min are the nearly multiple scales.

Comparing the field variations of two sunspots (1 and 2) during the time period June 4 - June 10 with the flare activity one can find preferable appearance of major flares (or in any case when the flare activity rised) in those moments when the strength difference between two spots was minimal. It confirms the results obtained by Kuklin and Nikiforova (1973).

Table 1

Periods of the field variations of the group No. 189 on June 5

Period (min)	P	R	N sunspot
32	0.946	0.50	1
106	0.948	0.51	
140	0.948	0.67	
23	0.881	0.51	2
35	0.996	0.67	
109	0.968	0.62	

Another fact of interest is the following. The field variations of the spot 1 with the period 35 min came after the major flares of importance 2B, which happened nearly 1 - 1.5 hour before our observations. We can suppose that the cyclic field variations are the typical feature of the relaxation process in sunspots as a result of the energy outburst during the flare event.

The sunspot group No. 228 + 229 (1982) was studied in July by many authors in different aspects. We could observe it only once a day and nevertheless one feature was revealed in the field behaviour for the largest umbrae of different polarity. From the curves of the field variations during July 10 - July 18, 1982 (Figure 6) we can see that for two spots of different polarities the field strength changes are not parallel and from one day to another they have sharp jumps which are probably connected with increased flare activity.

The group No. 135 (1984) was investigated on June during the programm "Active region birth". We observed it on June 26 at Pulkovo and Kislovodsk mountain station simultaneously measuring maximal field strength for the leading spot (S-polarity) and for several umbrae in the following spot of N-polarity (Figure 7). The spot areas were measured as well.

Curves of the field variations with time for this group (Figure 8) shows synchronous changing of the field strength of the umbrae 1 and 3 belonging to different spots of this bipolar group. The areas of the umbrae 3 and 4 were oscillating with opposite phase. It might be explained in terms of one umbra, divided by one bright bridge. The area variation of the spot 1 is probably real, because the other spots had little area variations what could mean that the error of measurements was small (Figure 9).

In Figure 10 the time variation of magnetic flux F calculated as a product of the field strength and the spot area is shown. From Figure 10 we can see that magnetic flux of the spots under consideration changed in general little. But there are fluctuations of the flux from the spot 1 against the general decreasing of the flux value, which was due to the fact that this group had already passed its peak in development (this group had its maximal area on June 25).

The comparison of Figure 8 with Figures 9 and 10 shows that the field

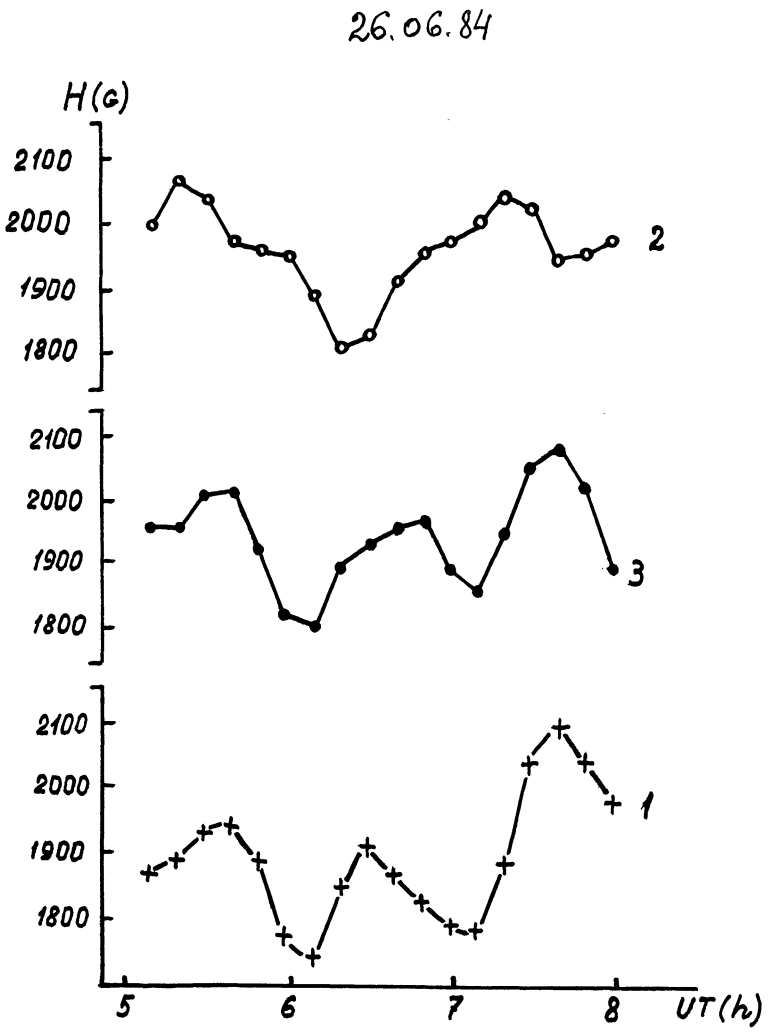

Fig. 8: Time variations of the magnetic field strength of the sunspot 1, 2 and 3 of the group No. 135 on June 26, 1984 for period 0500 - 0800 UT.

strength variation with time at least for the spots 1 and 3 are general due to variation in the spot area. Besides the field strength could also change by other reasons, such as for example the probable vertical motion of magnetic tube.

Using the correlation periodogramm-analysis we calculated for the group No. 135 the characteristic time scale (periods) of the field and area variation. Table 2 lists these time scales, P and R being the probability and correlation coefficient. The mean values of the periods are 155 min. for the mag-

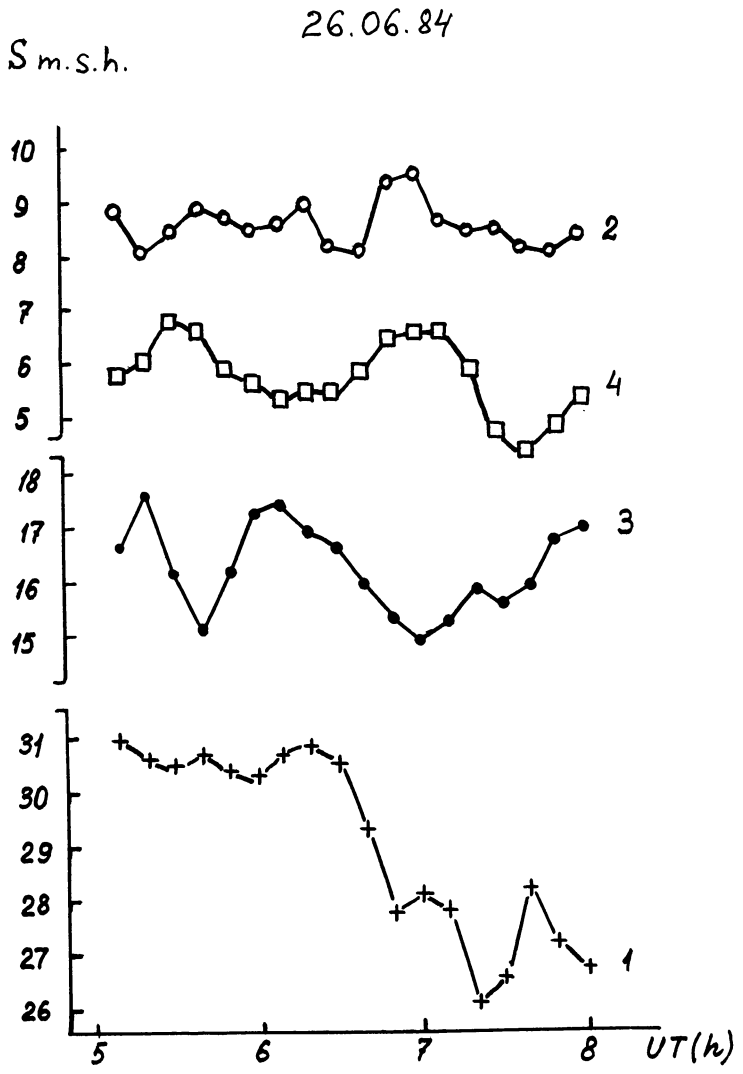

Fig. 9: Time variations of the area of sunspots 1, 2, 3 and 4 of the group No. 135 on June 26, 1984. Scale of area is millionths of the solar hemisphere.

netic field and 146 min. for the area. The mean scale of the field strength and area variation is 150 min. In calculation only periods having maximal correlation coefficients were used. In spots 2 and 3 with the same polarity both characteristics have nearly similar behaviour. In the spot 1 the periods of the field and area variation also are nearly equal, but their values are about two times as much as the variation periods in the spots 2 and 3.

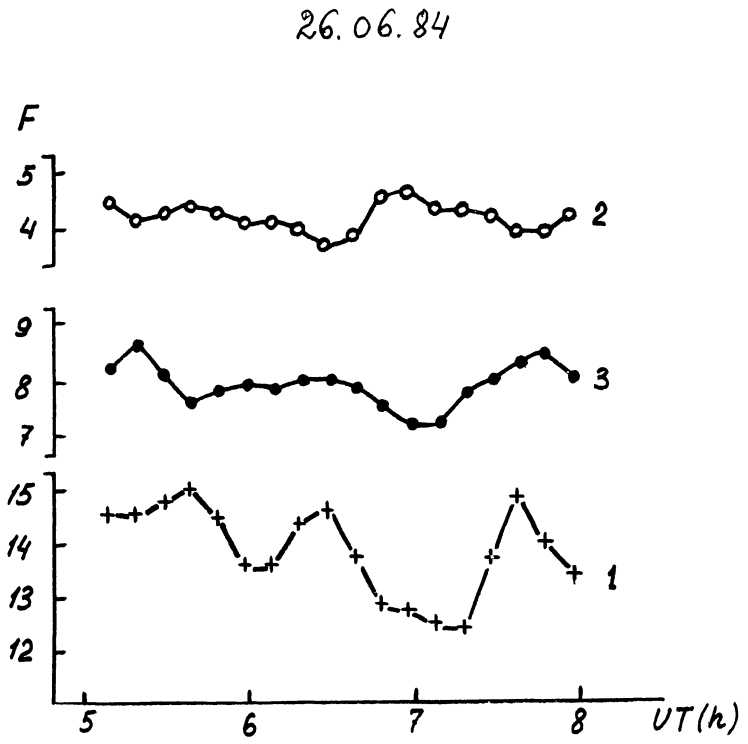

Fig. 10: Time variations of the magnetic flux F of the sunspots 1, 2 and 3 of the group No. 135 on June 26, 1984 in units of 1.22 x 10^{20}Mx.

Table 2

Characteristic time scale of the field and area variation

N sunspot Group 135	Strength H Area S	Period (min)	P	R
1	H	98	0.954	0.49
		214	1.000	0.79
	S	200		0.94
2	H	124	1.000	0.90
	S	66	0.979	0.60
		114	0.981	0.61
3	H	73	0.990	0.58
		126	1.000	0.84
	S	100		0.65
		124	0.999	0.76

Comparing the Tables 1 and 2 and the Figures 4 and 6 we see that the quiet sunspot group No. 135 has the cyclic variations of the field lasting from 66 to 214 minutes. We suggest them to be as some intrinsic property of the quiet group. In the active group No. 189 these periods become shorter - from 23 to 140 minutes - as a consequence of flares in the group.

On Figure 6 in another active group No. 229 discussed above we can see rather long term variations of about 2 - 3 days. In our paper Vyalshin (1983) we have already found such variations for the flare-active group. These variations can be due to some general state of the flare activity in the sunspot groups.

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