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ВЕНГЕРСКОЙ АКАДЕМИИ НАУК

A MAGYAR TUDOMÁNYOS AKADÉMIA
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VOL. 4 No. 1

SUNSPOT GROUP DEVELOPMENT

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DIRECTOR, HELIOPHYSICAL OBSERVATORY OF
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* * *

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* * *

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THE BIRTH AND DEVELOPMENT OF A REGULAR BIPOLAR SUNSPOT GROUP

I. NAGY and A. LUDMÁNY

Abstract: *An example is given of how the evolution of a typical sunspot group takes place through spot motions. It is shown that rapid convergent motions of small spots and pores of the same magnetic polarity form some larger spots by coalescence.*

Возникновение и эволюция регулярной биполярной группы солнечных пятен

И. Надь и А. Лудмань

Абстракт: *Приведен пример, как проходит развитие типичной группы солнечных пятен путем собственных движений. Показано, что быстрые сходящиеся движения малых пятен и пор одинаковой магнитной полярности образуют болшие пятна своим слиянием.*

Egy szabályos bipoláris napfoltcsoport születése és kifejlődése

Nagy Imre és Ludmány András

Összefoglalás: *Tipikus napfoltcsoport foltmozgások révén történő kialakulására adunk példát. Megmutatjuk, hogy nagyobb napfoltok azonos mágneses polaritásu kis foltok és porusok gyors konvergáló mozgásával és összeolvadásával jönnek létre.*

INTRODUCTION

It stands to reason that it is worth trying to compare the emergence, development and motion of sunspots with the relevant magnetic field variations. This is why the Einstein--tower Solar Observatory of Potsdam and the Debrecen Observatory decided to do detailed work on some of their series of magnetograms and heliograms respectively, which were taken more or less simultaneously. In July 1975 both observatories obtained adequate observational material of the sunspot group No. 55/1975 (using the designation of the *Solnechnye Dannye*). Here we summarize our results based mainly on the position measurements of sunspots.

OBSERVATIONS AND MEASUREMENTS

The full-disk photoheliograms, used for the measurements, were taken at our observing station in Gyula. The objective of the heliograph was generally stopped down to 7 or 8 cm. The solar diameter at the secondary focus was about 10 cm. The heliograms were mostly photographed through a yellow metal interference filter (passband about 70 Å, maximal transparency at 5540 Å) on Kodalith films of 14 x 14 cm size, but in a few cases Schott GG 11 yellow filter and Agfa-Gevaert diapositive plates were used. The majority of the observations was obtained by L.Győri, the rest by L.Márki-Zay and Zsuzsa Kiss.

The sunspot heliographic positions were determined from our heliograms by means of an Ascorecord coordinate measuring instrument. For the orientation at the principal focus of the heliograph two spider-wires are fixed and, for the sake of high accuracy, their directions are permanently controlled. In each heliogram the image of the wires is shown. From the measurements the Carrington coordinates, the heliographic longitudes (L) and latitudes (B) were calculated, also taking some corrections for the atmospheric differential refraction and the distortion of the enlarging system of the heliograph into account.

For some of the most important spots the heliographic coordinates for each single measurement are shown in *Figures 18-20* only, their daily averages in *Figure 15* and their mean values over periods given in *TABLE 1* in *Figures 16* and *17*. (In the latter cases the effective times of observation used are in the first column of *TABLE 1*.)

We measured the positions of all well-defined pores and spots (if possible always the center of umbrae), but in this paper we use only those objects which could be identified with absolute certainty and could be followed for a reasonable period on successive heliograms. All measured objects are denoted by a number or by a combination of numbers and letters. If the first, i.e. the principal (larger), number of designation of two or more objects is the same, within the p (or f) polarity part of the sunspot group, it shows that they are in close relationship, i.e. at some time coalescent or at least close to each other. The denotation of the coalescent spots follows a logical pattern. Those spots which could be followed by measurements only over a single day have also a letter in their designation. A dash above a number shows that the relevant data relate to two or more near objects.

THE HISTORY OF THE SUNSPOT GROUP

We could observe the sunspot group S.D.No.55/1975 on each day during its whole passage across the sun's disc (*Figs.1-14;* all spots marked were measured, i.e. their L and B coordinates determined). The first spot appeared on July 4 near the east solar limb at the southern part of a photospheric facular region extended roughly south-north. It was a spot of north (plus) magnetic polarity, i.e. an f polarity spot.

Our spot group was born in the McMath-Hulbert plage region No.13750, which rotated onto the sun's disc on July 3. It was the return of region 13722 of former rotation, born near the middle of the solar disc, in which only a small bipolar sunspot group (S.D.No.48/1975 = Mt.Wilson group No.19578) had been seen for some days.

At Mt.Wilson the principal parts of our group 55/1975 received the serial No.19548, and the *p* polarity spots *Va*, *Vb* (see *Figs.5-6*) and *IV* (see *Figs.5-8*) have been considered the main components of two separate spot groups (Mt.Wilson Nos. 19586 and 19587).

The development of our sunspot region may be divided into two well-defined periods, the spots of the first period are denoted with roman numbers and those of the second period with arabic ones. The first period of spot emergence ranges from July 4 to July 9. On 5 July the sunspot group gains a bipolar feature with the peculiarity of having an unusually big angle between the *p-f* axis of the group and the direction of solar rotation, nevertheless this angle diminishes in the course of time. This first period is also divided into two parts by the following event: on July 8, in the *p* polarity part of the group, spot *II* disappeared (last observation: 11:15 UT) and spot $\overline{III}$ appeared (first observation: 13:32 UT). It is remarkable that spot $\overline{III}$ was born relatively far from *IV* and nearly simultaneously with it, and they became the largest dominant spots of the region for three days.

In the second period of the development of the active region, beginning with July 10-11, the former spots disappeared while an entirely new sunspot group of much faster development arose almost in the same place by July 11-12 (cf. *TABLES 2-3*). The *f* part of the first period totally disappeared by the evening of July 10, while the *p* part died out by July 12. Some umbrae of *f* polarity of the second period (1_1, 1_2, 1_3) first became visible on July 10. But in the early morning of July 11 a lot of pores and spots of the new group had already appeared. From this time onward both parts of the group began to develop rapidly and the formation of larger spots took place through motion and coalescence of smaller spots. A regular bipolar sunspot group of average size grew almost in two days and then the group had reached its phase of maximal area development. On July 13, at 5:08 UT the sum of umbra areas of the group was 98 millionth of the solar hemisphere and the whole area of the group (i.e. umbra + penumbra areas) 476. The life history of the spots, whose positions were measured, is indicated in the synoptical *TABLES 2* and *3*.

The spot group passed the west solar limb on July 16 and probably the remnant of its large *p* spot returned once more after two weeks on the east limb, embedded in the eastern part of a composite spot group (in McMath region No.13786). At Mt.Wilson the new and main part of this group was taken for a separate group and received the serial No.19596, while the old part was given the designation No.19597. Soviet colleagues considered the two sunspot groups to be only one (S.D.No.64/1975).

BRIEF DISCUSSION OF THE MOTION OF SPOTS

The most important spot motions indicated by variation in coordinates are revealed in *Figures 15-20* and the determined characteristic spot velocities are given in *TABLES 4* and *5*. It may be seen how the evolution of a sunspot region took place where spot motions played a great role or perhaps even became decisive for the whole development, and rapid convergent motions of small spots and pores of the same magnetic polarity form some larger spots by coalescence. Earlier, several similar examples have already been found in our observatory, for instance by Á.Kovács (1977).

Two long enough series of observations, obtained on July 11 and 13, afforded the possibility to follow several small fast-moving spots in the *p* part of the group which showed a striking development. *Figures 18* and *19* display well-defined convergent motions of spots of high velocity. On July 11 some of these spots of negative polarity merged with spot *11* during the day. This fact is clearly seen in *Figure 21*.

ACKNOWLEDGEMENTS

Thanks are due to Prof.L.Dezső for suggesting this work and for much helpful advice, and to. Dr.K.Pflug for his kind cooperation who put Potsdam magnetograms generously at our disposal. We are also grateful to Ágnes Kovács for much help in analysing the data and in preparation of this paper.

R e f e r e n c e

Kovács,Á.: 1977, *Publ. Debrecen Obs.* Vol.3, *p.207*.

TABLE 1

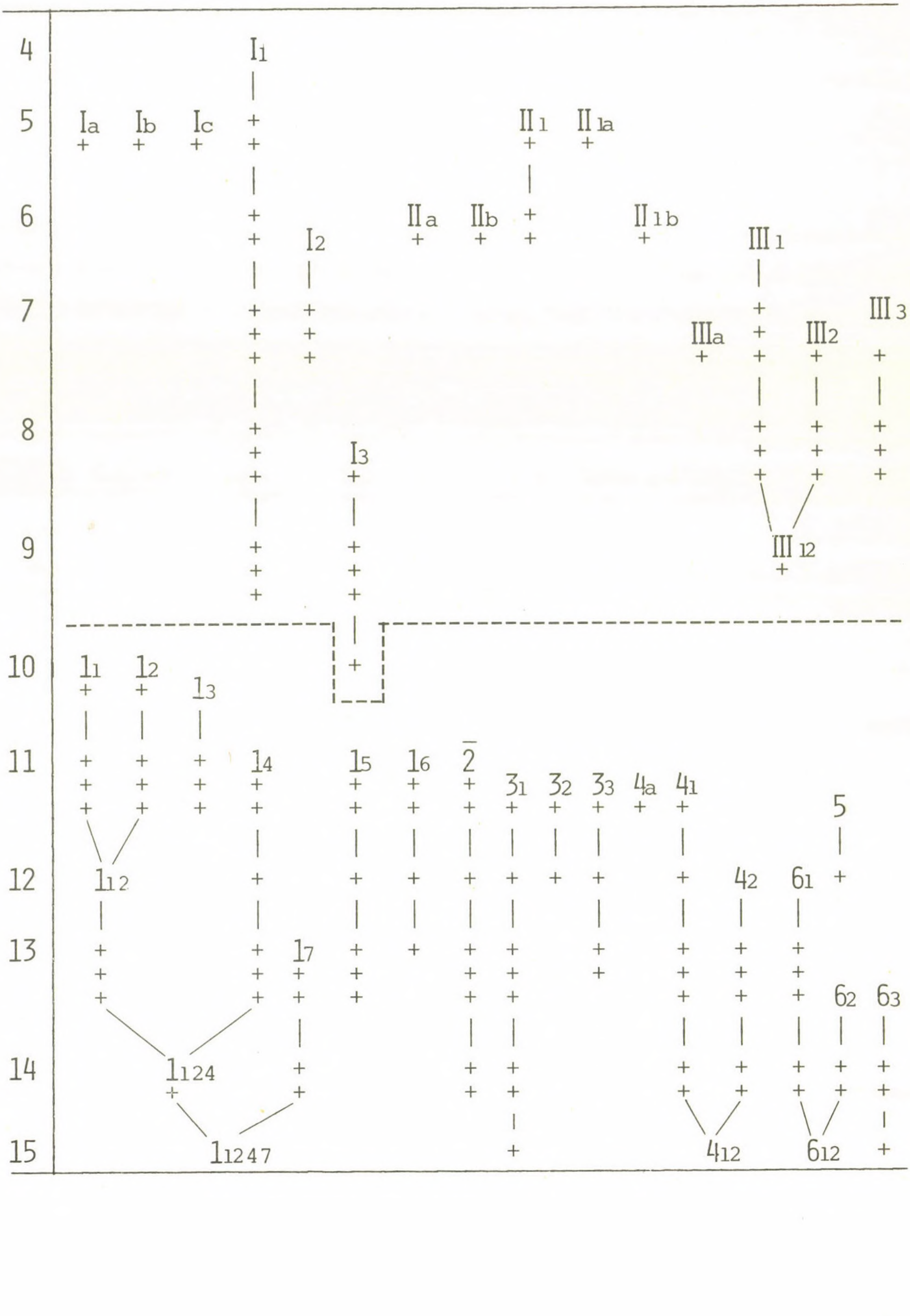
The periods of observations, in universal time (UT) and the number (*n*) of heliograms used.

1975 VII.	*d* - *d*	*h:m* *h:m*	*n*
4.664	.610 - .717	14:39 - 17:12	4
5.283	.188 - .374	4:30 - 8:59	6
5.490	.450 - .560	10:48 - 13:27	6
6.255	.192 - .335	4:37 - 8:02	5
6.467	.426 - .499	10:13 - 11:58	5
7.272	.181 - .341	4:21 - 8:11	7
7.435	.378 - .480	9:04 - 11:31	8
7.628	.563 - .706	13:30 - 16:56	6
8.239	.202 - .312	4:51 - 7:29	3
8.444	.392 - .469	9:24 - 11:15	4
8.632	.564 - .711	13:32 - 17:04	6
9.244	.176 - .306	4:14 - 7:21	8
9.441	.365 - .485	8:46 - 11:38	8
9.596	.531 - .683	12:45 - 16:23	6
10.237	.176 - .302	4:13 - 7:15	7
10.571	.453 - .712	10:53 - 17:05	9
11.241	.183 - .286	4:24 - 6:52	7
11.382	.312 - .450	7:29 - 10:48	11
11.535	.457 - .611	10:58 - 14.40	9
12.528	.515 - .542	12:21 - 13:00	4
13.331	.214 - .403	5:08 - 9:40	8
13.461	.426 - .519	10:14 - 12:28	4
13.676	.644 - .713	15:28 - 17:06	6
14.355	.300 - .412	7:12 - 9:53	4
14.522	.463 - .601	11:05 - 14:26	4
15.469	.322 - .706	7:43 - 16:57	8
			163

TABLE 2

The periods of position measurements of spots in the f part of the group between July 4-15.

(The daily periods of observations are given in *Table 1*.)



T A B L E 3

The periods of position measurements of spots
in the p part of the group between July 4-15.
(The daily periods of observations are given in *Table 1.*)

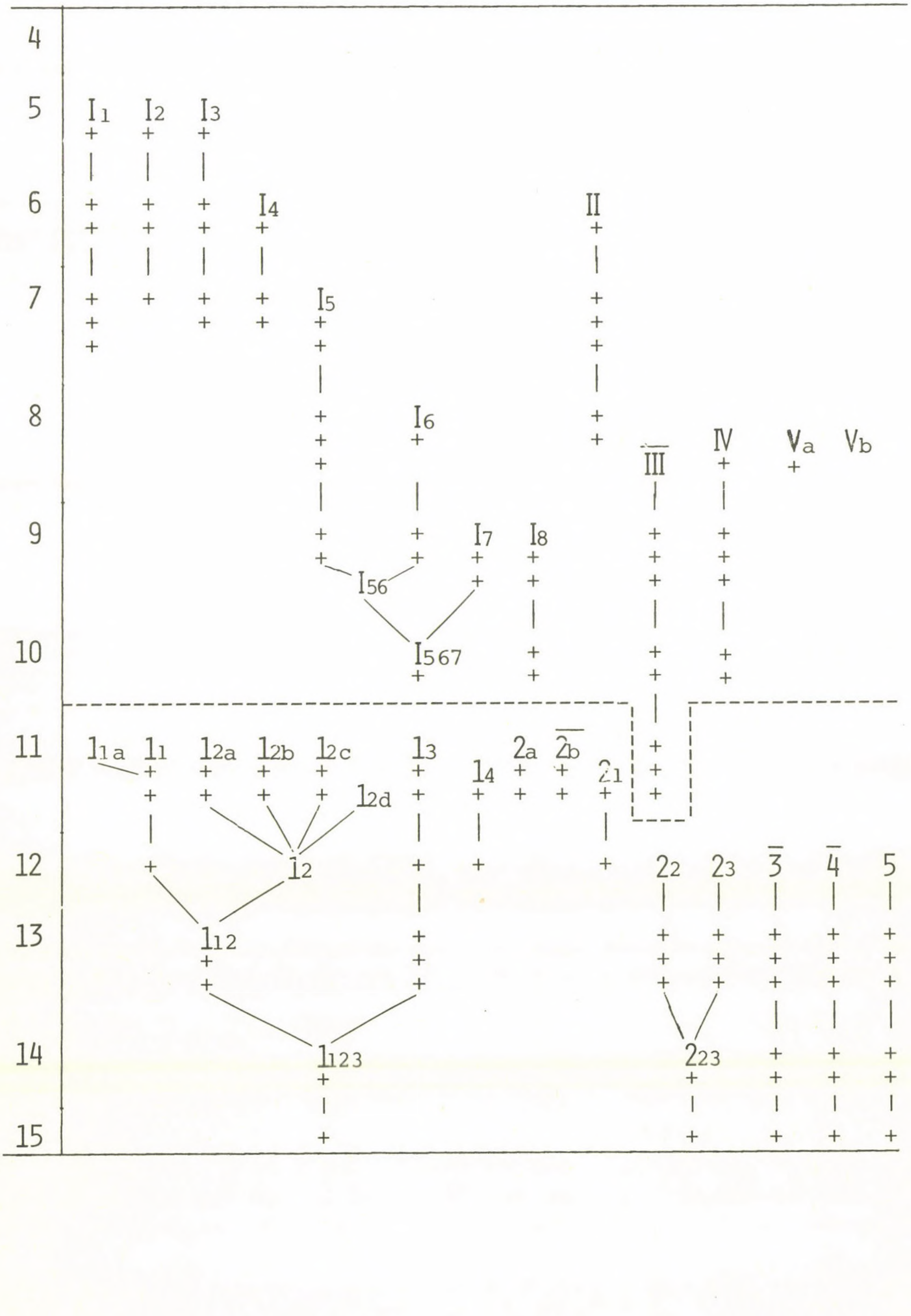


TABLE 4

Spots of high average velocity.

All spots are shown every time their average velocity of motion parallel to the solar equator (v_L) or along a solar meridian (v_B) exceeded 0.05 km s^{-1} overnight. The direction of motion (to W,E,N,S resp.) are indicated in the headings.

	July	~ 0.1 km s^{-1}		~ 0.2 km s^{-1}	~ 0.3 km s^{-1}
v_L		W		W	W
p spots	5- 6	I_2 I_3			
	6- 7	I_1 I_2 I_3 I_4 II			
	7- 8	II			
	8- 9	I_5 I_6		$\overline{III}$ IV	
	9-10	$\overline{III}$			
	10-11	$\overline{III}$			
	11-12	2_1		1_1 1_3	
	12-13			1_1 1_3 2_2 5	2_3 $\overline{3}$ $\overline{4}$
	13-14			2_2 $\overline{3}$ $\overline{4}$ 5	
v_L		E	W	E	
f spots	5- 6		I_1		
	6- 7				
	7- 8	I_1			
	8- 9	I_1		I_3	
	9-10				
	10-11	1_1			
	11-12	1_5 $\overline{2}$ 4_1			
	12-13	1_5 4_1 4_2 6_1			
	13-14	$\overline{2}$ 6_1		6_2	
v_B		N	S		
f spots	5- 6		I_1		
	6- 7				
	7- 8				
	8- 9	I_1 I_3			
	9-10				
	10-11	1_1			
	11-12		3_2		
	12-13	1_{12} 1_5 $\overline{2}$ 4_1 4_2			
	13-14	$\overline{2}$ 4_1 4_2			

The approximate velocities (in km s^{-1}) indicated above, (uppermost heading) are accurately as follows:

$$0.06 \le 0.1 < 0.15$$
$$0.16 \le 0.2 < 0.25 \quad \text{km s}^{-1}$$
$$0.26 \le 0.3 < 0.35$$

The relevant velocities (in respect of the Carrington coordinate network) were obtained from the daily mean position of two consecutive days.

T A B L E 5

High velocities parallel to the solar equator,
in respect of Carrington's zero meridian, determined from data given
in Figs.18-20.

July 11 (11.2-11.6 UT)			July 13 (13.2-13.7 UT)		
	v_L			v_L	
SPOT	$\Delta L°/d$	km s^{-1}	SPOT	$\Delta L°/d$	km s^{-1}
1_1	1.6	0.23	1_{12}	0.9	0.13
1_{1a}	2.6	0.36	2_2	2.0	0.28
1_{2a}	3.3	0.47	2_3	2.1	0.30
1_{2b}	2.5	0.35	$\bar{3}$	2.6	0.37
1_{2cd}	1.5	0.21	$\bar{4}$	1.9	0.26
1_4	5.1	0.72			
1_3	1.3	0.18	1_3	1.8	0.25
2_a	2.7	0.38			
$\bar{2}_b$	1.6	0.22			

T A B L E 6

Some measured umbra areas, in 10^{-6} of the solar hemisphere

1975 July	UT	$\overline{III}$	IV	Σp	Σf
8	11:15	0			
	13:32	3	2		
	17:02	10	4		
9	6:32	5	3		
10	12:42	4	1	0	
11	5:45	3	0	8	
	12:24	1		12	
12	12:21	0		23	
13	5:08			60	38.
	15:28			52	
14	13:15			52	

Σp (or Σf) is the sum of the areas of umbrae
in the p (or f) part of the "second" spot group

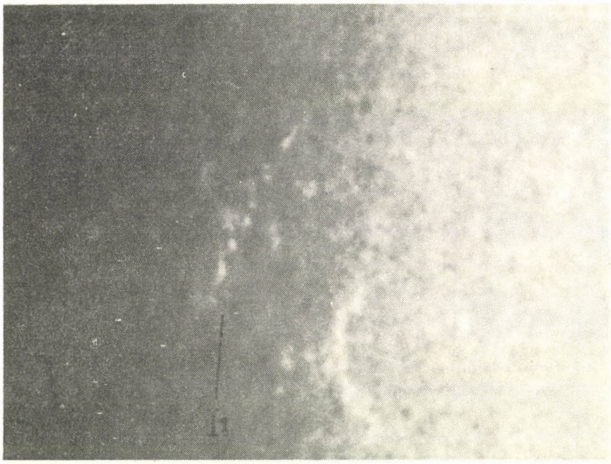


Figure 1. The first spot seen in the spot group S.D.No.55/1975 on July 4 at 14:46 UT, near the solar limb. (N top, E left. Orientation and scale the same as in Figs. 2-14.)

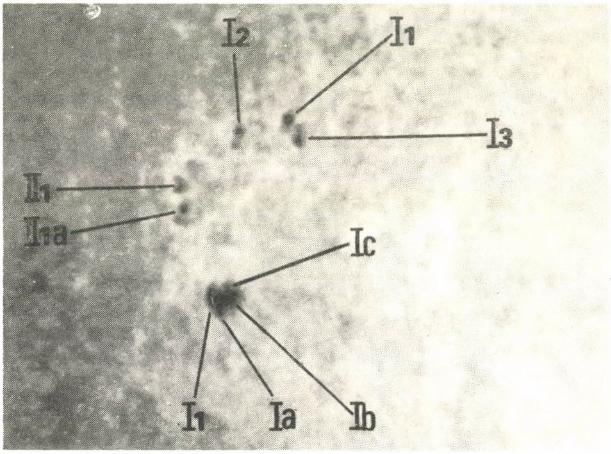


Figure 2. The spot group on July 5 at 13:19 UT.
In this and in other similar photos (Figs. 3-14) all spots marked could be followed for position measurements on several consecutive heliograms. The *p* polarity spots I_1, I_2 and I_3 are in the upper part.

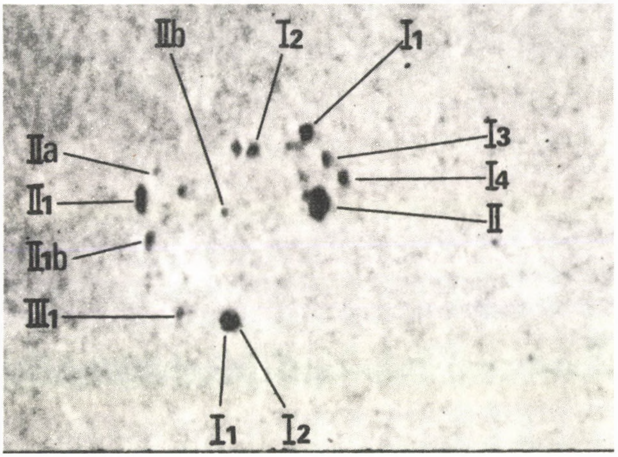


Figure 3. The spot group on July 6 at 11:42 UT.
In the middle the spot IIb belongs to the *f* part of the group.

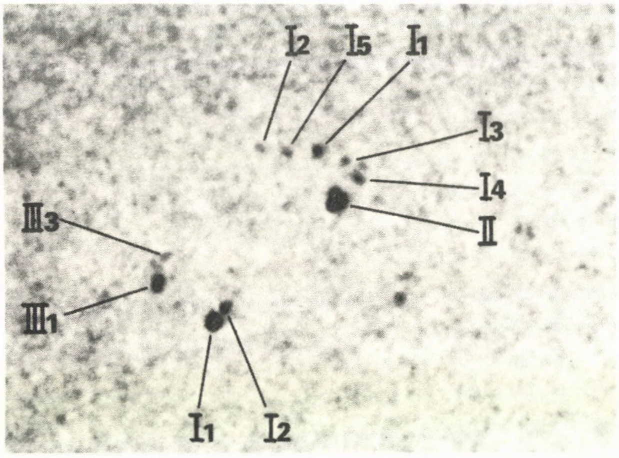


Figure 4. The spot group on July 7 at 5:58 UT.

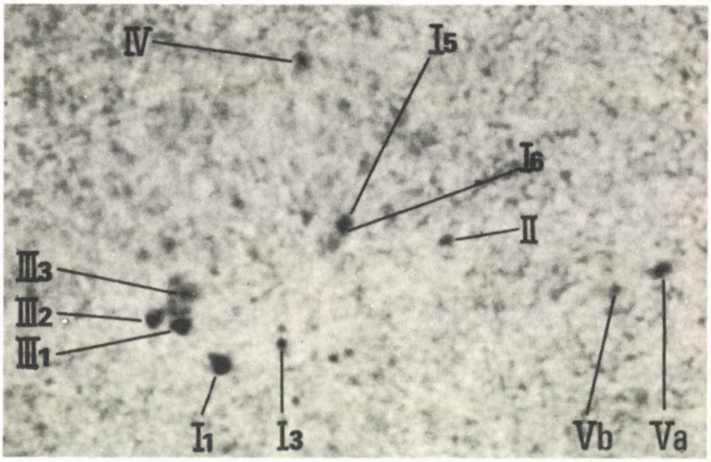


Figure 5. The spot group on July 8 at 11:15 UT.

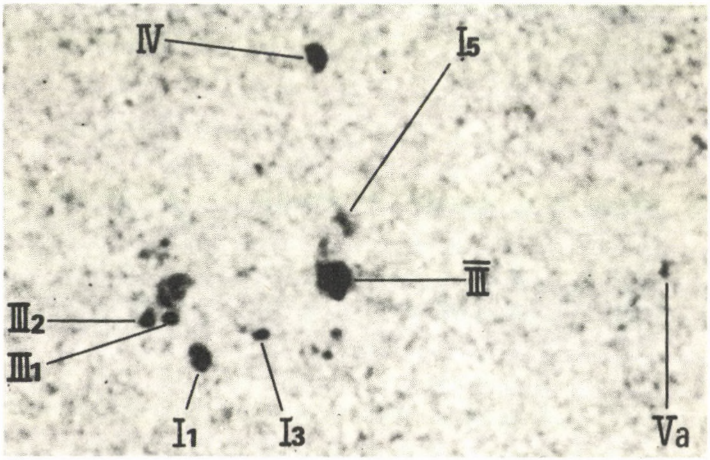


Figure 6. The spot group on July 8 at 17:02 UT.

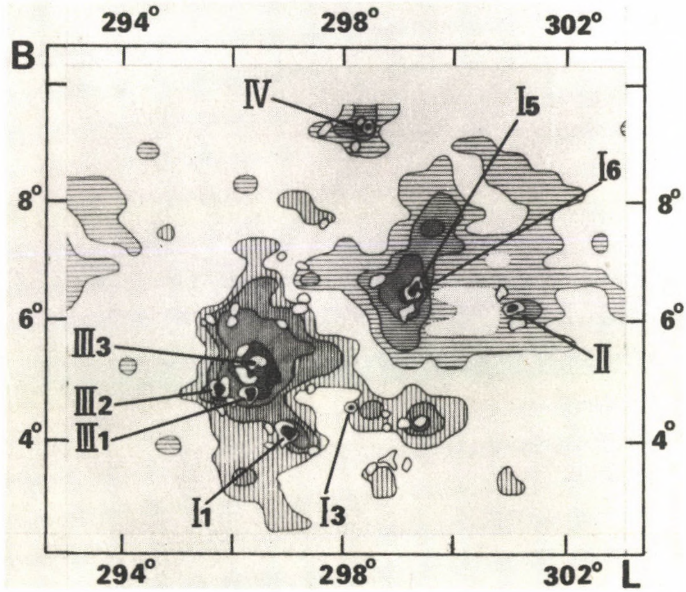


Figure 5a. Potsdam magnetogram obtained on July 8 at 11:00 UT.
Spots drawn according to Debrecen heliogram taken at 11:06 UT.

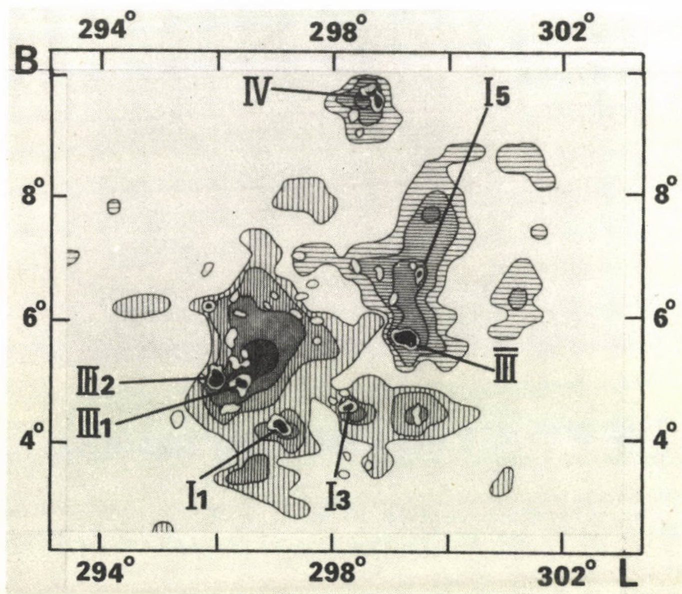


Figure 6a. Potsdam magnetogram obtained on July 8 at 13:20 UT.
Spots drawn according to Debrecen heliogram taken at 13:32 UT.

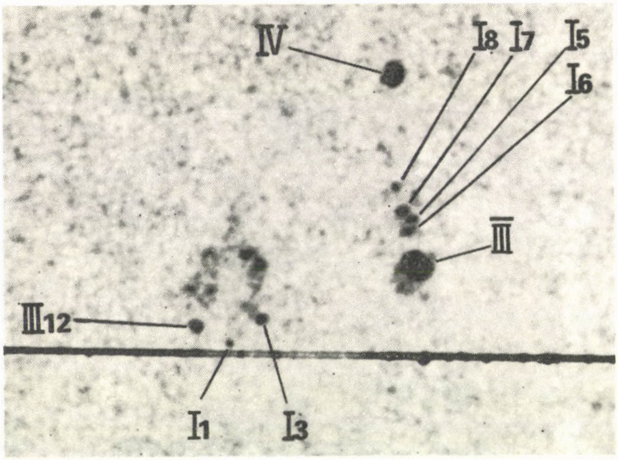


Figure 7. The spot group on July 9 at 6:32 UT.
All spots still belong to the "first" group.

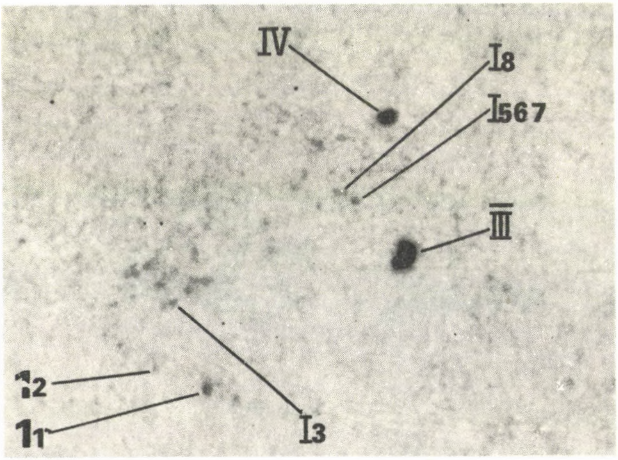


Figure 8. The spot group on July 10 at 7:15 UT.
l_1 and l_2 are the first spots of the new "second" group.

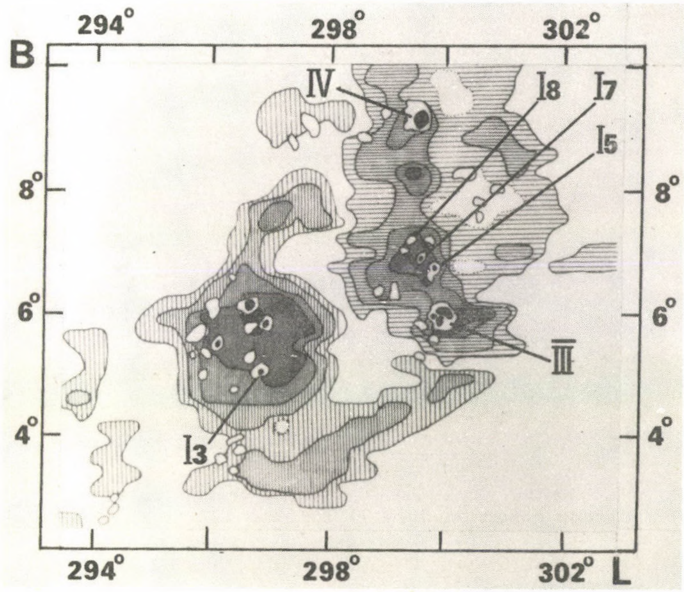


Figure 7a. Potsdam magnetogram obtained on July 9 at 9:10 UT.
Spots drawn according to Debrecen heliogram taken at 8:53 UT.

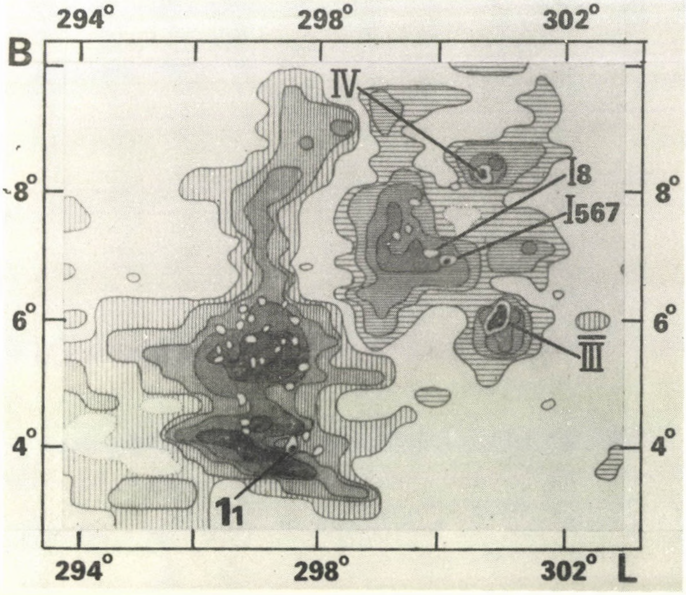


Figure 8a. Potsdam magnetogram obtained on July 10 at 8:10 UT.
Spots drawn according to Debrecen heliogram taken at 8:12 UT.

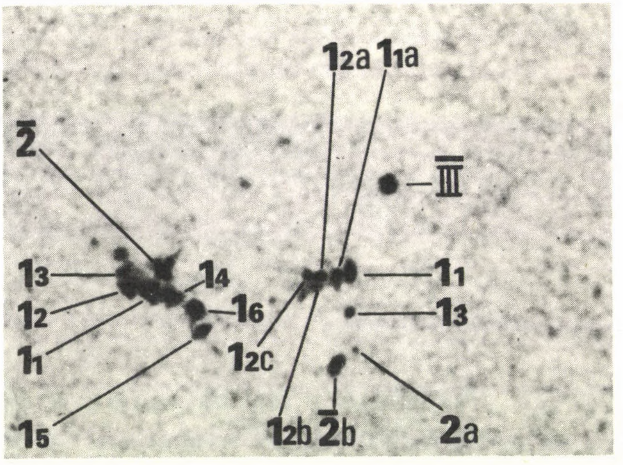


Figure 9. The spot group on July 11 at 5:45 UT.

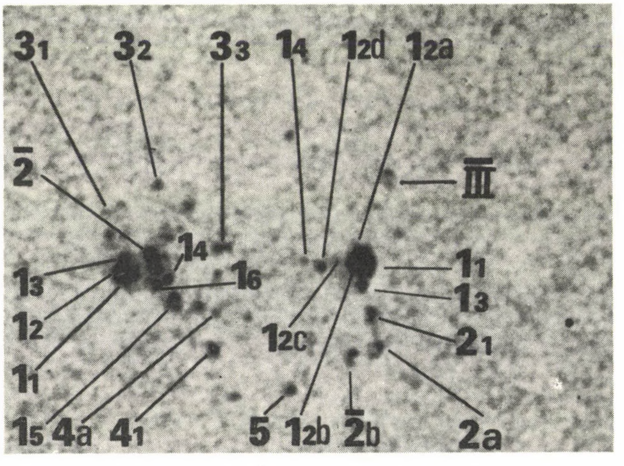


Figure 10. The spot group on July 11 at 12:24 UT.
On this day the double-spot $\overline{III}$ is the only remnant of the "first" group.

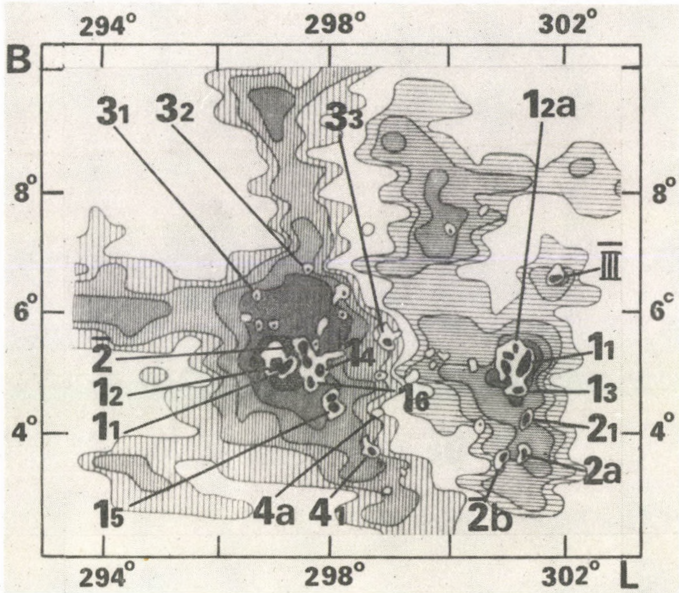


Figure 10a. Potsdam magnetogram obtained on July 11 at 10:45 UT. Spots drawn according to Debrecen heliogram taken at 10:44 UT.

Horizontally and vertically striped areas mark the negative (S) and positive (N) polarity regions respectively. Intensity scale in Fig.10b. Within the stronger magnetic regions the smaller roundish white patches are pores or penumbrae, their black nucleus, if any, are the umbrae. These remarks also refer to all similar Figures (5a, 6a, 7a and 8a).

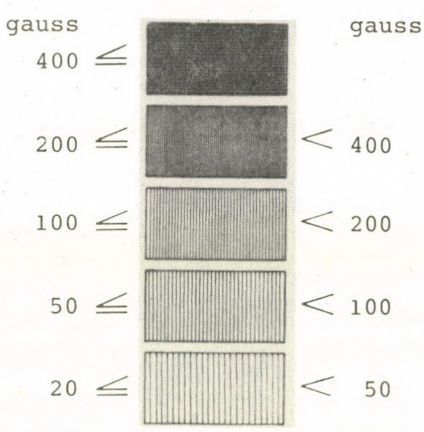


Figure 10b. Intensity scale for the Potsdam magnetograms (Figs.5a, 6a, 7a, 8a and 10a).

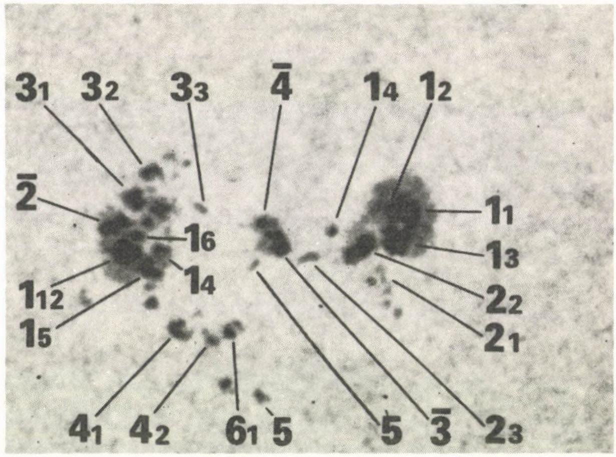


Figure 11. The spot group on July 12 at 12:21 UT.

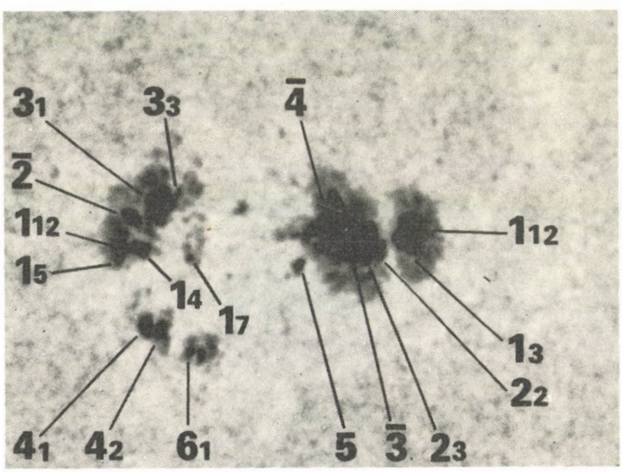


Figure 12. The spot group on July 13 at 10:14 UT.
(The group reached its maximum development on this day.)

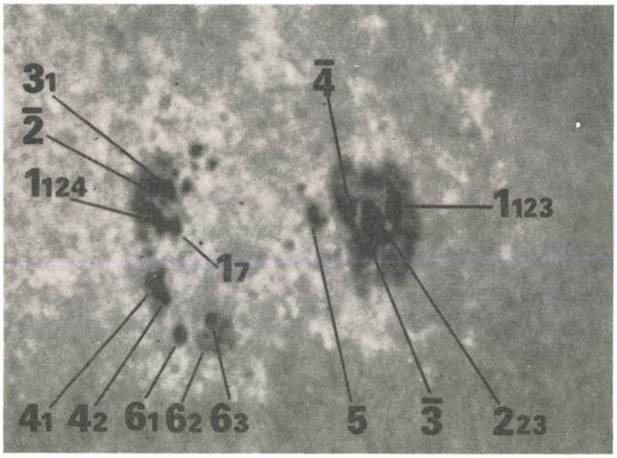


Figure 13. The spot group on July 14 at 7:13 UT.

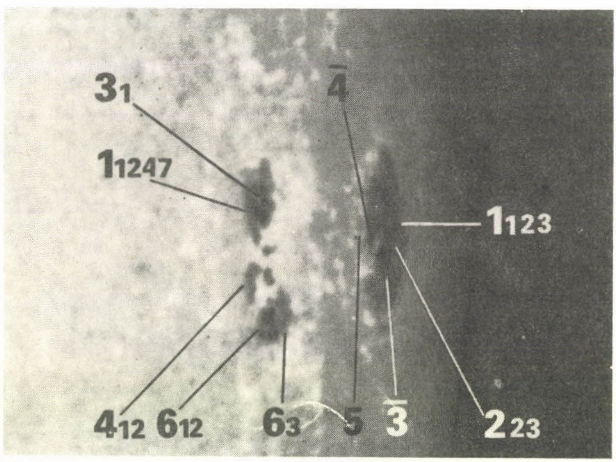


Figure 14. The spot group on July 15 at 9:03 UT.
(The group passed round the solar limb on the following day.)

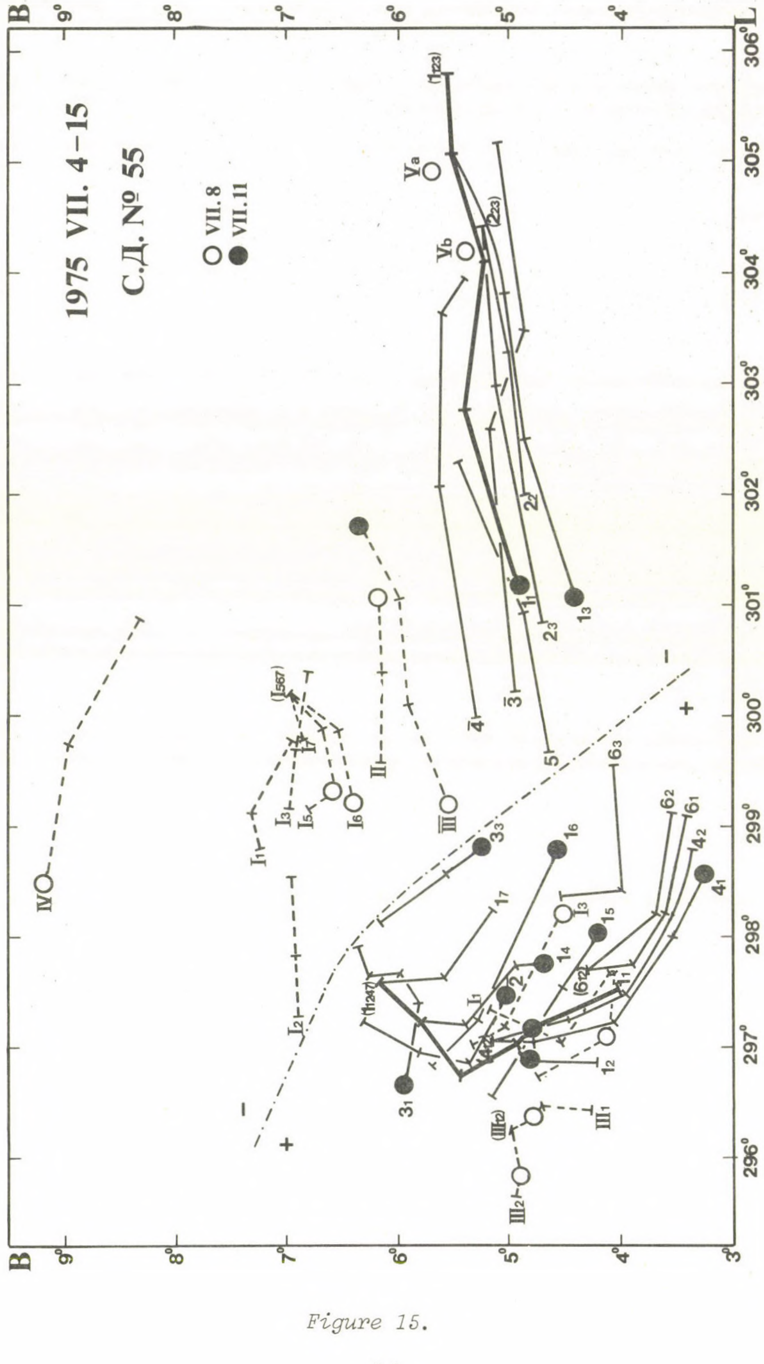


Figure 15.

Figure 15. Trajectories of umbrae

measured on at least three consecutive days. Broken lines mark trajectories of the "first" spot group, solid lines those of the "second".

The open and filled circles mark the daily mean positions on July 8 and 11, respectively, while the short bars on the trajectories show similar mean coordinates for the other days.

The designations of the spots are marked by their first mean position, but in some cases a designation in brackets marks the last point of a trajectory and indicates the coalescence of two or more spots. The dates of first point of trajectories not marked by open or filled circles are as follows:

July 4: I_1

5: I_2, I_3

12: 2_2, 2_3, $\overline{3}$, $\overline{4}$, 5, 6_1

13: 6_2, 6_3

The negative magnetic polarity region is approximately marked off from the positive polarity region by a broken line in the Figure.

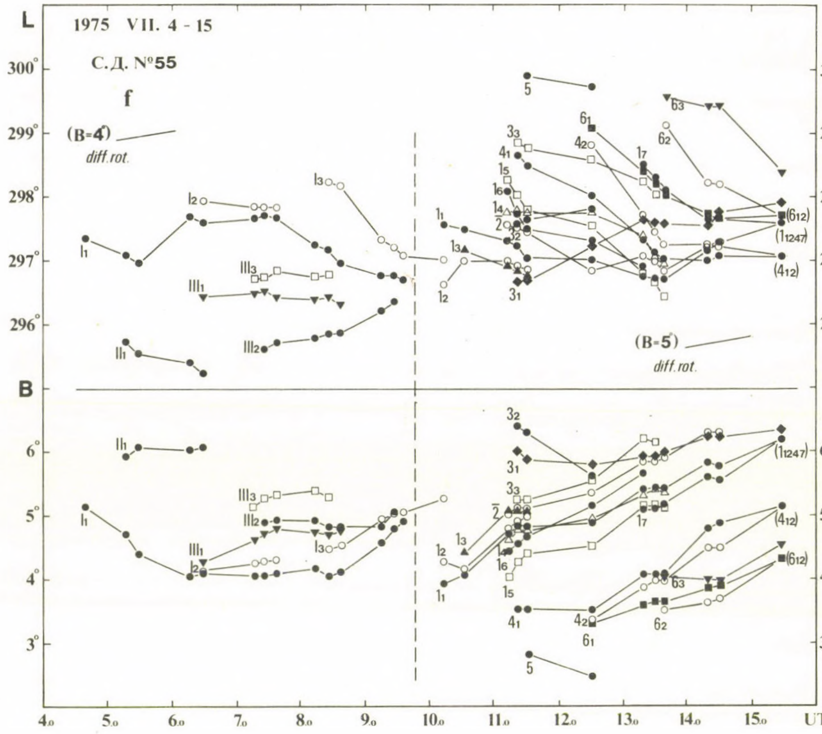


Figure 16. Heliographic (Carrington) longitudes (L) and latitudes (B) versus time of spots of *f* polarity, observed on at least two consecutive days. Each dot shows a mean coordinate over one of the periods given in Table 1.

The broken line in the middle gives attention to two distinct evolutional phases of the region which are considered as a "first" and "second" spot group.

The relevant rate of the solar differential rotation is also indicated.

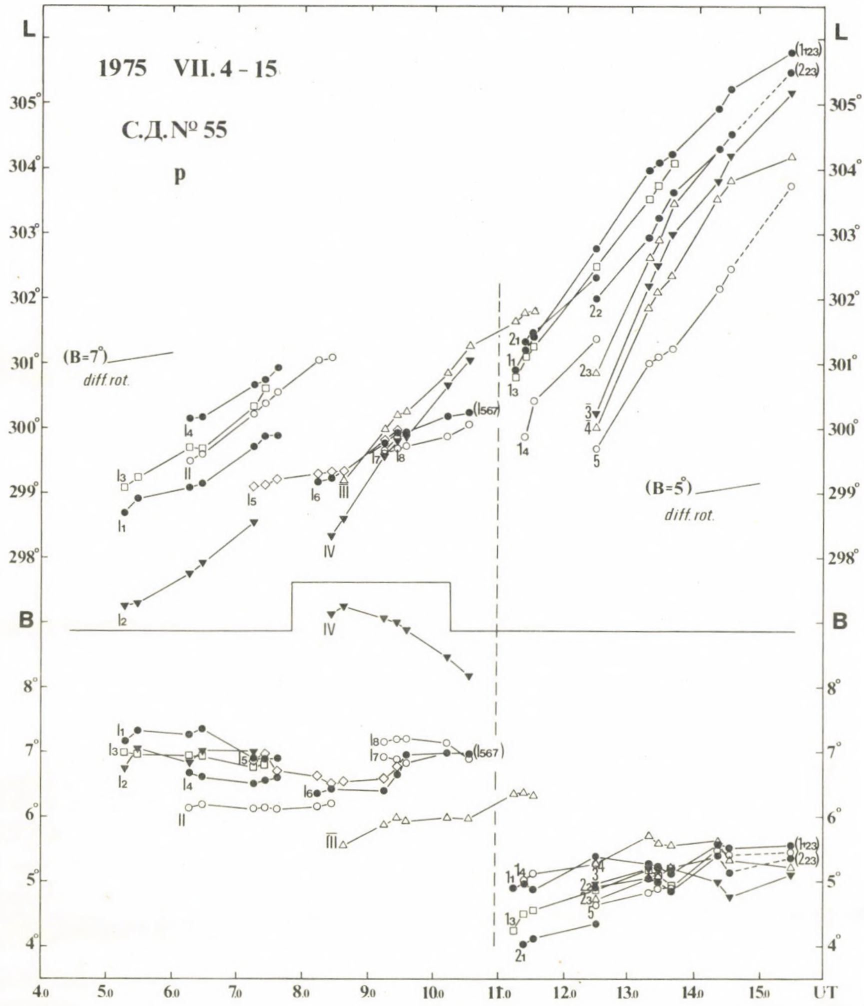


Figure 17. The caption of Fig.16 also applies to this Figure, concerning the spots of *p* polarity.

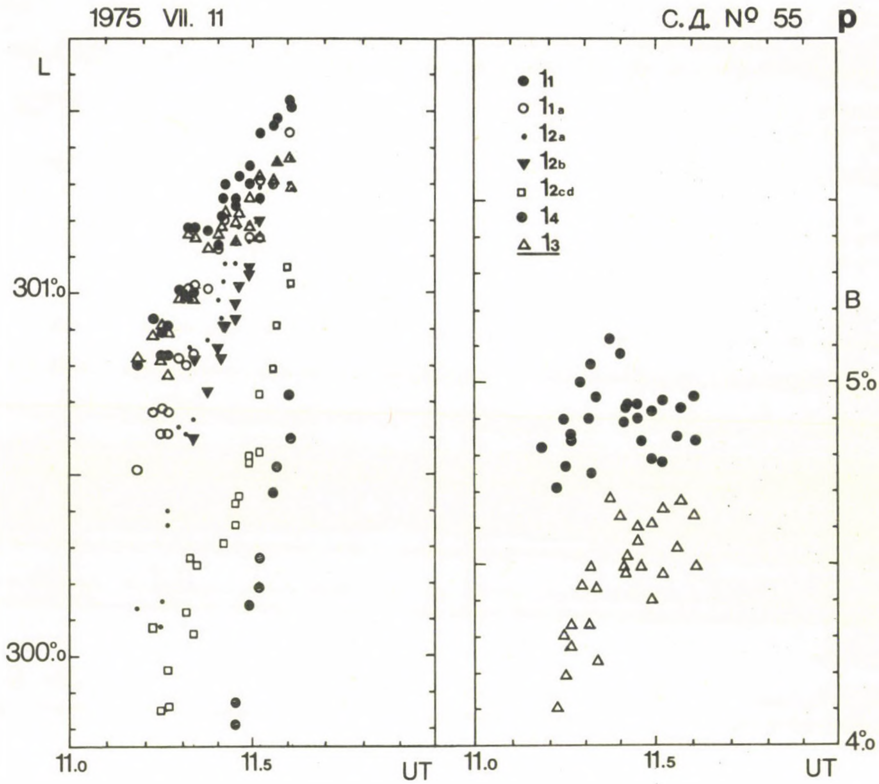


Figure 18. Heliographic (Carrington) longitudes (L) and latitudes (B) versus time relating to the *p* spots of rapid movements on July 11. These spots merge through motion by July 14 forming spot 1_{123} (cf. also Table 5.)

Each dot shows the result of measurement of a single observation. The B coordinates of five spots are not plotted since they did not show any real change during July 11.

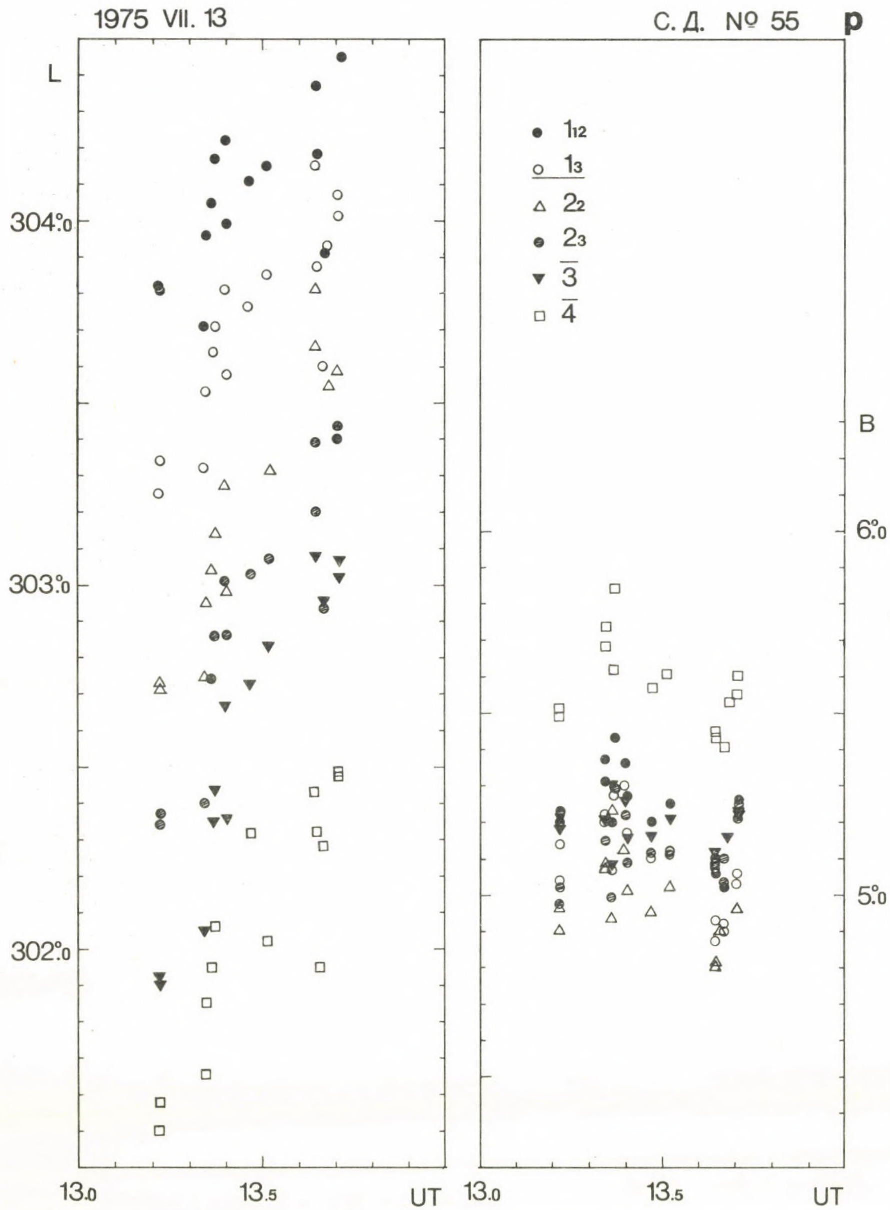


Figure 19. Heliographic coordinates (L,B) versus time for almost all *p* spots on July 13.

Each dot shows the result of measurement of a single observation. The concerning velocities parallel to the solar equator are given in Table 5.

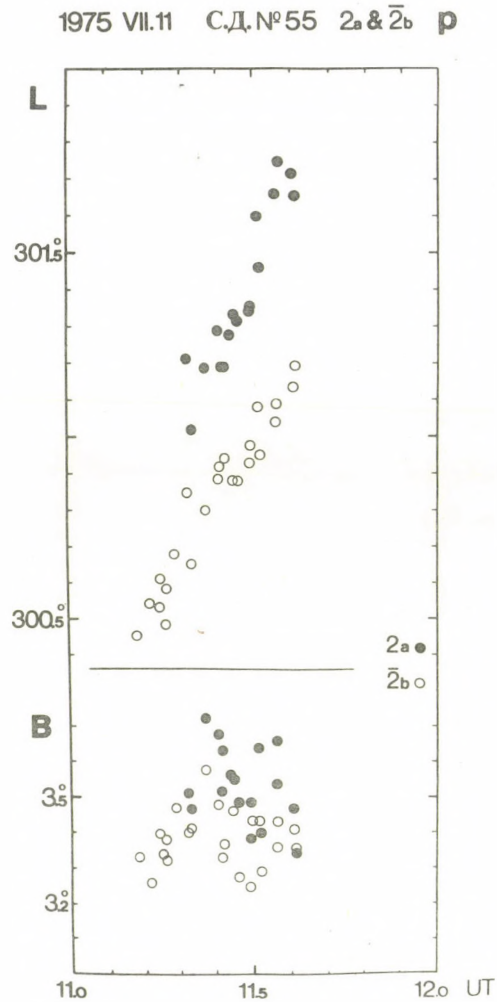


Figure 20. Heliographic coordinates (L,B) versus time for the *p* polarity spots 2a and $\overline{2b}$ on July 11.
The velocities of spot motion parallel to the solar equator are given in Table 5.
Each dot shows the result of measurement of a single observation.

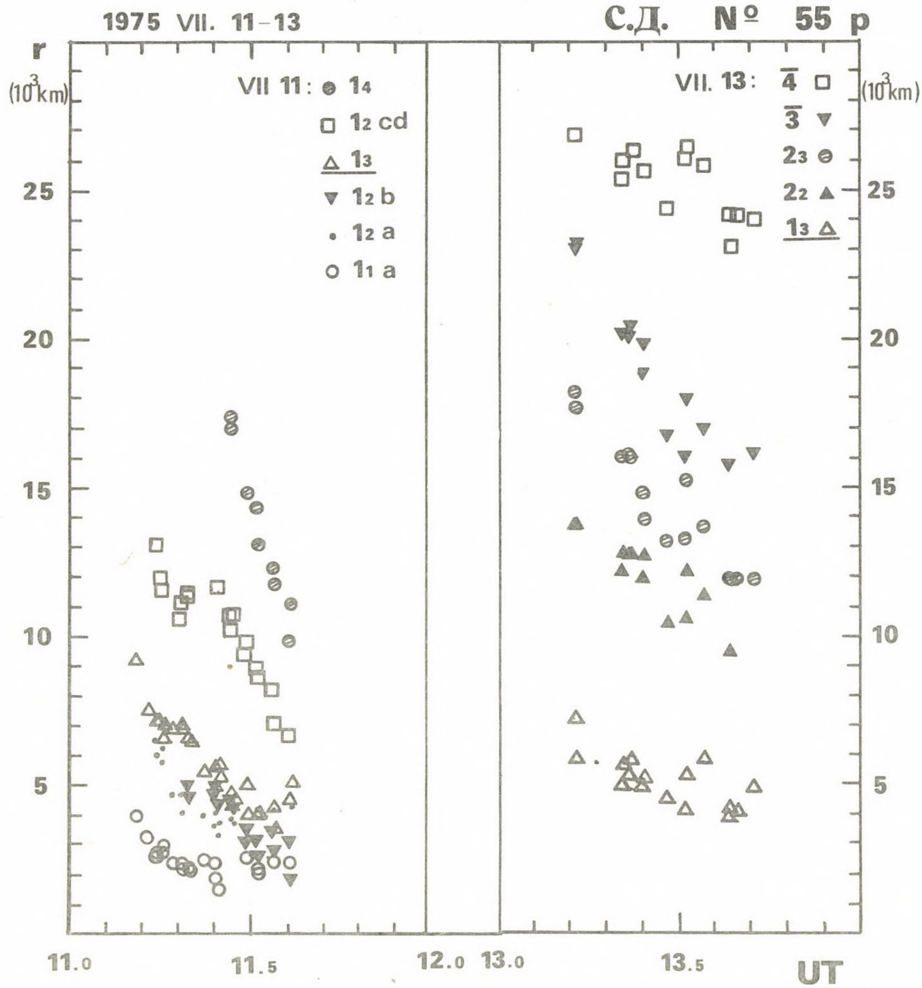


Figure 21. Relative distances (r) between the principal *p* spot (11 on July 11; 112 on July 13) and other *p* spots approaching it.

Each data plotted is related to a single observation.

Hozott anyagról sokszorosítva

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A NOTE ON SUNSPOT GROUP DEVELOPMENT, SPOT MOTIONS AND SOLAR ROTATION

L.DEZSŐ and Á.KOVÁCS

Abstract: *On the basis of long daily series of accurate photographic sunspot positions over some consecutive days it is shown through a few examples that there is the possibility of distinguishing between two kinds of apparent spot motions, i.e. motions relative to the surrounding photosphere and those due to solar rotation. It could also be seen from these limited instances that the development of a sunspot group and flare occurrences are closely associated with spot motions and the rate of solar rotation can already be determined from a few days observations.*

ЗАМЕЧАНИЕ О РАЗВИТИИ ГРУПП ПЯТЕН, ДВИЖЕНИЯХ ПЯТЕН И ВРАЩЕНИИ СОЛНЦА

Л.Дежё и А.Ковач

Абстракт: *На основе длинных ежедневных серий точных фотографических положений солнечных пятен наблюденных в течение нескольких последовательных дней, на некоторых примеров показано, что имеется возможность различать два сорта видимых движений пятен, то есть движения относительно окружающей фотосферы и движения вследствие вращения Солнца. Из этих нескольких примеров также видно, что развитие группы солнечных пятен и возникновения вспышек тесно связаны с движениями пятен и скорость вращения Солнца можно определить из наблюдений нескольких дней.*

ADALÉK NAPFOLTCSOPORT FEJLŐDÉSE, FOLTMOZGÁS ÉS NAPROTÁCIÓ KAPCSOLATÁHOZ

Dezső Loránt és Kovács Ágnes

Összefoglalás: *Néhány napon át végzett hosszu fotografikus észlelés-sorozatokból nyert pontos napfolt poziciók révén néhány példát mutatunk arra, hogy különbséget lehet tenni a napfoltok látszólagos mozgásának két fajtája, azaz a környező fotoszférához viszonyitott mozgás és a naprotáció-tól eredő mozgás között. A kevés példa ellenére az is látható, hogy a napfoltcsoport fejlődése és a fler-gyakoriság szoros kapcsolatban áll a foltok mozgásával, és hogy a naprotáció sebessége már néhány napi megfigyelésből is meghatározható.*

INTRODUCTION

We have chosen to study one complex sunspot group and two pairs of almost isolated old sunspots. The two pairs of spots are the still important and very likely the only remnants of four bipolar groups, the occasionally appearing small spots or pores in their surroundings, which were most likely only separated tiny fragments of the decaying large spots, were disregarded. From both pairs of spots one spot was on the north the other on the south hemisphere of the sun and they could be observed simultaneously for nearly a two-week period, one pair of spots in June, the other in September 1979.

Each of the four single spots formed in itself practically a whole sunspot group during its passage over the sun's disc. At Mt.Wilson the groups received, in order of appearance as they rotated onto the solar disc, the serial nos. *20 646*, *20658*, *20 878* and *20 883* (*Figs.1-3*). All four groups were born on the far side of the sun and with the exception of group *20 878*, they also died out there. Only group *20 883* was recurrent. In September it crossed the disc for the second but last time. In addition it may be interesting to note that this recurrent sunspot group was a rare extreme case in so far as its large preceding (*p*) spot has shown north (N) magnetic polarity, i.e. it failed to obey Hale's law of sunspot polarities.

The complex sunspot group in question was denoted at Mt.Wilson as sunspot group *20 882* and belonged to the same solar active region as group *20 878* (*Fig.2*). Strictly speaking the complex group *20 882* forms two bipolar sunspot groups, both born on the solar disc and not seen again after they passed the western limb. We shall often mention them simply as Part *I* and Part *II* of the double group *20 882*. Part *I* developed rapidly for a regular bipolar group by the early morning on 9 September. We only noticed the first few tiny spots of Part *II* after two days. See in *Figure 2* the rapid development of Part *II* and the slow decay in the *f* polarity region of Part *I* of the group during 12-15 September.

The heliographic positions of the four old spots and a number of spot positions relating to a young spot group, mentioned above, were determined. Making use of these data there will be some ground for comparing two quite different kinds of spot motion (i.e. "real" proper motion, for example relative to other spots, and motion due to solar rotation).

* * *

For the time being, we believe the less uncertain determinations regarding the law of the sun's rotation, i.e. the variation of its rotation rate with heliographic latitude, are those which use the apparent motion of sunspots. Sunspots, however, could be reliable tracers of solar rotation only if they had no intrinsic proper motions. Since in general this requirement is not fulfilled it presents an obstacle which is difficult to eliminate entirely.

Spot positions should only be used for solar rotation studies when the spot has no motion relative to its surrounding solar region or if that is presumed to be the case. In practice, therefore, spots should be chosen when their proper motions both along solar meridians and along parallels are zero or very small. When picking out the likely small proper motions along parallels the relevant rate of the differential rotation, in so far as it is known, should obviously be taken into account according to one of the generally applicable formulae.

Using Greenwich measures over six solar cycles, consistent values for the sun's rotation have been given in turn by Greenwich authors (1925), H.W.Newton (1934), and H.W.Newton and M.L.Nunn (1951), for the years 1880-1923, 1924-1933 and 1934-1944 respectively. Their results, also summarized in algebraical expressions of slightly different numerical parameters, were derived from long-lived, recurrent sunspots. (They found something over 700 spots available to calculate the mean daily sidereal rotation for 5° zones of latitude.) The very fact that each spot used was unobservable for at least two weeks may raise objections about the accuracy because over such a relatively long time any intrinsic spot motion could pass unnoticed.

Consequently it is worth trying to determine the solar rotation from tracer lines of spots of single disc passage. Such work is already in progress by means of a computer-controlled direct observational method, as has lately been reported by A.Koch *et al.* (1981). This report gave us the idea of taking some initial steps in making use of our daily series of white light photoheliograms for solar rotation studies as well. Moreover, since Dr.H.Wöhl called upon us to give some additional information on four sunspots, mentioned above, which seemed to be suitable as a check on the rate of solar rotation, we took the opportunity at the same time to indicate to what extent our observations on this point are adequate on the basis of a handful of examples.

THE MATERIAL OF OBSERVATION

The photographic observations used were obtained at our Observing Station in Gyula, on the top of a water tower 44 m high. The objective of the heliograph was stopped down to 9 cm. For the orientation two spider-wires are fixed at the principal focus of the heliograph (f= 2 m) and, for the sake of high accuracy, their directions are permanently controlled. At the secondary focus the diameter of the solar disc was 10.4 cm. Exclusively full-disc heliograms were photographed through yellow filters. Mostly a metal interference filter was used (maximal transparency at 554 nm, passband about 7 nm), and the photographs were taken on Kodalith film of estar base. (In the June period the majority of the observations were obtained by S.Rostás, in September by L.Győri, the rest mostly by Zsuzsa Kiss.)

The sunspot positions were determined on the photographs by means of an Ascorecord coordinate measuring instrument and from the measurements the heliographic coordinates calculated. In the calculations we used, as usual, the parameters given in the Ephemeris (1979): the position angle of the sun's rotational pole (P_0) and the heliographic latitude (B_0) and longitude (L_0) of the central point of the solar disc.

The determined heliographic Carrington coordinates are given one by one in *Figures 4* and *5*. Their accuracy is well shown by the scatter of the plots. But this scatter should be mainly attributed to seeing conditions in the moments of exposure of the photoheliograms. However its secondary source may sometimes have solar origin which can also arise from a real change of form of the objects measured. Still, mention must be made that repeated measurements usually result in values within the limit of the circle plotted.

The sunspot positions we measured are, in principle,always umbra positions. However in the case of our two pairs of large, rather symmetric sunspots each position measurement in *Figure 5* applies, in practice, to the "whole" spot (umbra+penumbra) as well,i.e. when a penumbra contained more than one umbra their center of gravity were determined. On the other hand, in the Mt.Wilson group *20 882* we sometimes followed umbrae within a common penumbra one by one by position measurements, and also measured such "pores" which earlier or later revealed themself as umbrae; furthermore for two or more close objects often only the mean positions were determined (a dash above the symbol of designation draws attention to this fact).

TWO TYPES OF APPARENT SPOT MOTIONS

In *Figures 4-5* the trends of plots show spot motions in respect of the Carrington coordinate network. The slope of the dotted straight line extended over a one-day long interval roughly indicates the rate of the differential rotation for the solar parallel where the spot was. By means of these marks it can be seen at a glance when and where the apparent spot motions in longitude can probably be attributed only to the sun's rotation.

When comparing the trends of spot positions in *Figures 4* and *5* a considerable difference is immediately obvious. In *Figure 5*, showing the motion of the four old spots, the solar rotation dominates, while this is not true in the case of

Figure 4, where the young spots of group *20 882* reveal quite another kind of motion, perhaps with the only exception of spot $\overline{1}_{123}$ in *Figure 4b*. It is clearly seen in *Figure 2b* and *TABLE 1* also indicates that $\overline{1}_{123}$ became the principal spot of group *20 882 II* by 15 September. For those spots which show more or less the solar rotation some examples of spot areas are given in *TABLE 2*. (O.Gerlei determined all spot areas with our area measuring instrument using video facilities.)

From the heliographic coordinates by least squares estimation where appropriate for linear fit we determined spot velocities for the four old sunspots, as well as for the principal and other interesting young spots of the double group *20 882*. The results of calculations are given in *TABLES 3-4* and *Figure 6*.

DISCUSSION ON SPOT MOTIONS

In several cases it has been shown that the course of general development of sunspot groups, particularly both the growth and decrease of umbra areas, proceeds above all through motions; anyhow the dominance of motion seems to be an important feature of evolution of sunspot groups (see the references in Dezső's observatory report,1981). It is precisely the double group *20 882*, which offers an additional strikingly good example of this characteristic.(Cf. *Figs.2* and *4*, and *TABLE 1*.) On the other hand, it has been known for a long time that the probability of a flare occurrence is associated with the rate of change of spot area (Waldmeier,1938; Giovanelli,1939).

Consequently in relation to sunspot motions we should also consider flare activity since the relative motions of umbrae, within a sunspot group, mostly imply changes in the magnetic configuration and flare occurrences are somehow connected with magnetic field variations. On account of this we looked through the Hα solar flare data, as published by NOAA (1980-1981), in respect of the spot groups in question. Ignoring subflares and considering only the "group reports", the results of our search are as follows.

TABLE 1

Brief account and genealogical table which outlines the main evolution of the double sunspot group *20 882*, indicating the most important coalescences and separations of spots. (Cf.*Figs.2* and *4*.)

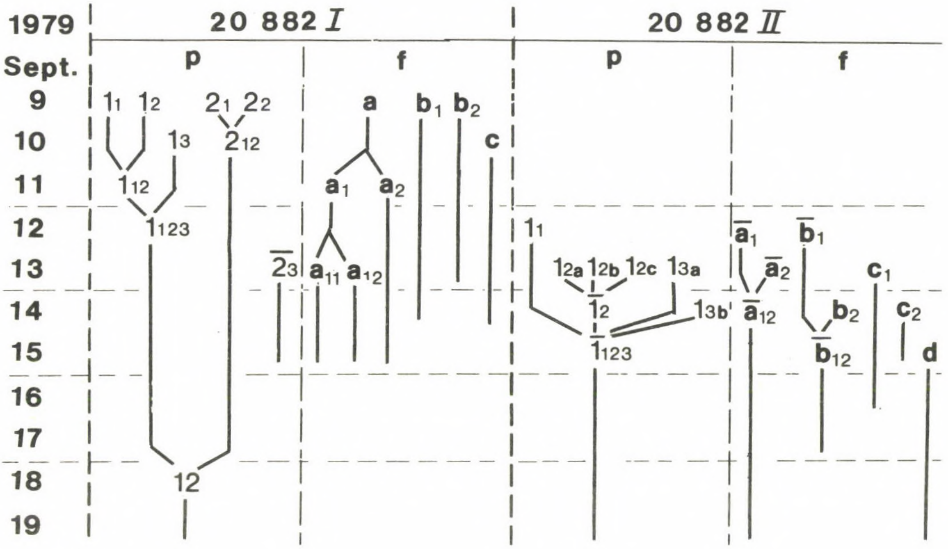

TABLE 2

Some umbra (U) and umbra+penumbra (U+P) area data in millionth of the solar hemisphere, concerning the principal spots of five sunspot groups in their final phase of slow decay. (Cf.*Figs.1-3*.)

June 1979	*20658 p*		*20646 p*		Sept. 1979	*20878 p*		*20883 p*		*20882 II* $\bar{1}_{123}$	
d UT	U	U+P	U	U+P	d UT	U	U+P	U	U+P	U	U+P
7.360	28	178	30	181	11.317	26	172				
8.420	27	169	26	168	12.248			73	339		
9.379	26	161	24	152	15.369	15	75			63	247
10.486	23	149	24	124	16.515			52	330	50	235
11.417	28	139	23	124	21.436			44	275		

T A B L E 3

Velocities of the most important motions of umbrae of the double sunspot group *20 882*. (Cf. *Figs. 2* and *4*.) The velocities were calculated by linear fits over some series of spot positions. Additional explanations are given on page 44.

SPOT	1979 Sept. UT	n	$\bar{B}$	$\frac{dB}{dt}$		$\frac{dL}{dt}$		SID.ROT. ξ_*		$\Delta\xi_*$
			°	°/d	km s^{-1}	°/d	km s^{-1}	°/d	km s^{-1}	°/d
20 882 I										
1_{123}	13.3-16.3	18	+9.1 ±0.2			-0.36 ±0.07	0.050 ±0.010	13.82	1.918	-0.49
2_{12}	13.3-16.3	18	+8.9 ±0.2			-0.42 ±0.06	0.058 ±0.009	13.73	1.908	-0.58
$1_{123}+2_{12}$	16.2-18.6	10	+9.1 ±0.2			0.00 ±0.08	0.000 ±0.011	14.19	1.970	-0.12
1_3	10.3-11.5	8	+8.8 ±0.2			+0.68 ±0.04	0.095 ±0.006			
$\bar{2}_3$	13.5-15.4	14	+8.6 ±0.4	+0.27 ±0.08	0.038 ±0.012	-0.73 ±0.09	0.101 ±0.012			
20 882 II										
$\bar{1}_{123}$	16.5-18.6	8	+9.2 ±0.2			-0.05 ±0.04	0.007 ±0.006	14.14	1.962	-0.16
1_{3a}	13.3-14.6	12	+8.4 ±0.4	+0.51 ±0.07	0.071 ±0.010	+1.85 ±0.09	0.257 ±0.013			
$\bar{a}_{12}$	14.3-16.5	14	+7.2 ±0.7	+0.46 ±0.13	0.065 ±0.019	-0.24 ±0.08	0.033 ±0.011	13.93	1.943	-0.40
$\bar{b}_{12}$	15.4-17.5	10	+8.1 ±0.5	+0.40 ±0.07	0.057 ±0.010	-0.24 ±0.07	0.034 ±0.009	13.91	1.935	-0.41

TABLE 4

Velocities of four isolated old sunspots calculated by linear fits over spot positions of at least three consecutive days, indicated by the horizontal heavy lines in *Figures 5a* and *5b*. (Cf. *Figs. 1-3.*) Additional explanations are given on page 44.

SPOT	1979	n	$\overline{B}$	$\frac{dB}{dt}$		$\frac{dL}{dt}$		SID.ROT. ξ_*		$\Delta\xi_*$
			°	°/d	km s^{-1}	°/d	km s^{-1}	°/d	km s^{-1}	°/d
	June									
20 658 p	5- 7	30		+0.15 ±0.06	0.021 ±0.008					
	7- 9	26	+17.7 ±0.1			-0.16 ±0.06	0.022 ±0.009	14.07	1.885	-0.05
	9-11	26	+17.9 ±0.2	+0.12 ±0.05	0.017 ±0.007	-0.22 ±0.05	0.029 ±0.007	14.00	1.873	-0.12
	11-13	23	+18.0 ±0.1			-0.37 ±0.06	0.049 ±0.008	13.81	1.847	-0.31
20 646 p	7- 9	26	-15.0 ±0.1			-0.08 ±0.08	0.011 ±0.011	14.18	1.926	-0.01
	9-11	26	-15.1 ±0.1			-0.11 ±0.07	0.015 ±0.010	14.10	1.914	-0.09
	Sept.									
20 878 p	10-12	14	+12.4 ±0.2			-0.24 ±0.06	0.033 ±0.008	13.94	1.914	-0.31
	12-14	18	+12.5 ±0.2			+0.02 ±0.06	0.003 ±0.008	14.22	1.952	-0.03
	10-13	20		+0.07 ±0.07	0.010 ±0.009					
20 883 p	12-16	26	-25.4 ±0.5			-0.50 ±0.09	0.063 ±0.011	13.65	1.734	-0.22
	12-14	18	-25.3 ±0.2			-0.51 ±0.09	0.065 ±0.011	13.64	1.734	-0.23
	14-16	14	-25.5 ±0.4	-0.19 ±0.10	0.026 ±0.014	-0.51 ±0.08	0.064 ±0.010	13.64	1.731	-0.23
	16-18	10	-25.9 ±0.3	-0.18 ±0.10	0.025 ±0.014	-0.53 ±0.05	0.067 ±0.006	13.64	1.725	-0.21
	18-21	22		-0.25 ±0.07	0.034 ±0.009					

ADDITIONAL EXPLANATIONS TO *T A B L E S 3* AND *4*

All velocities were determined by least square estimations and their standard deviations (σ) were also calculated. The data used for the temporal variation in heliographic latitude (B) and Carrington longitude (L) are plotted in *Figures 4* and *5*, but longitudes from central meridian (L_{CM}) were used to calculate first the angle of the daily synodic rotation rates (ξ_{δ} ; cf. *Fig.6*) and then from these those of the sideric (ξ_*). The standard deviations for the sideric rotation rates are not indicated since these never exceed the relevant values shown in column dL/dt.

In columns n and $\overline{B}$ the number of observations and the average latitudes are given respectively.

$\Delta\xi_*$ is the difference between the observed and calculated angle of daily sideric rotation rate, i.e.

$\Delta\xi_* \equiv \xi_* - \xi_*(NN)$, where

ξ_* is our result of observation, shown in the *TABLE*, and

$\xi_*(NN)$ is calculated using:

$$\xi_* = 14.38° - 2.77° \sin^2 \overline{B},$$

the formula given by Newton and Nunn (1951) on the basis of more than 700 recurrent sunspot groups, observed between the years 1880 and 1944.

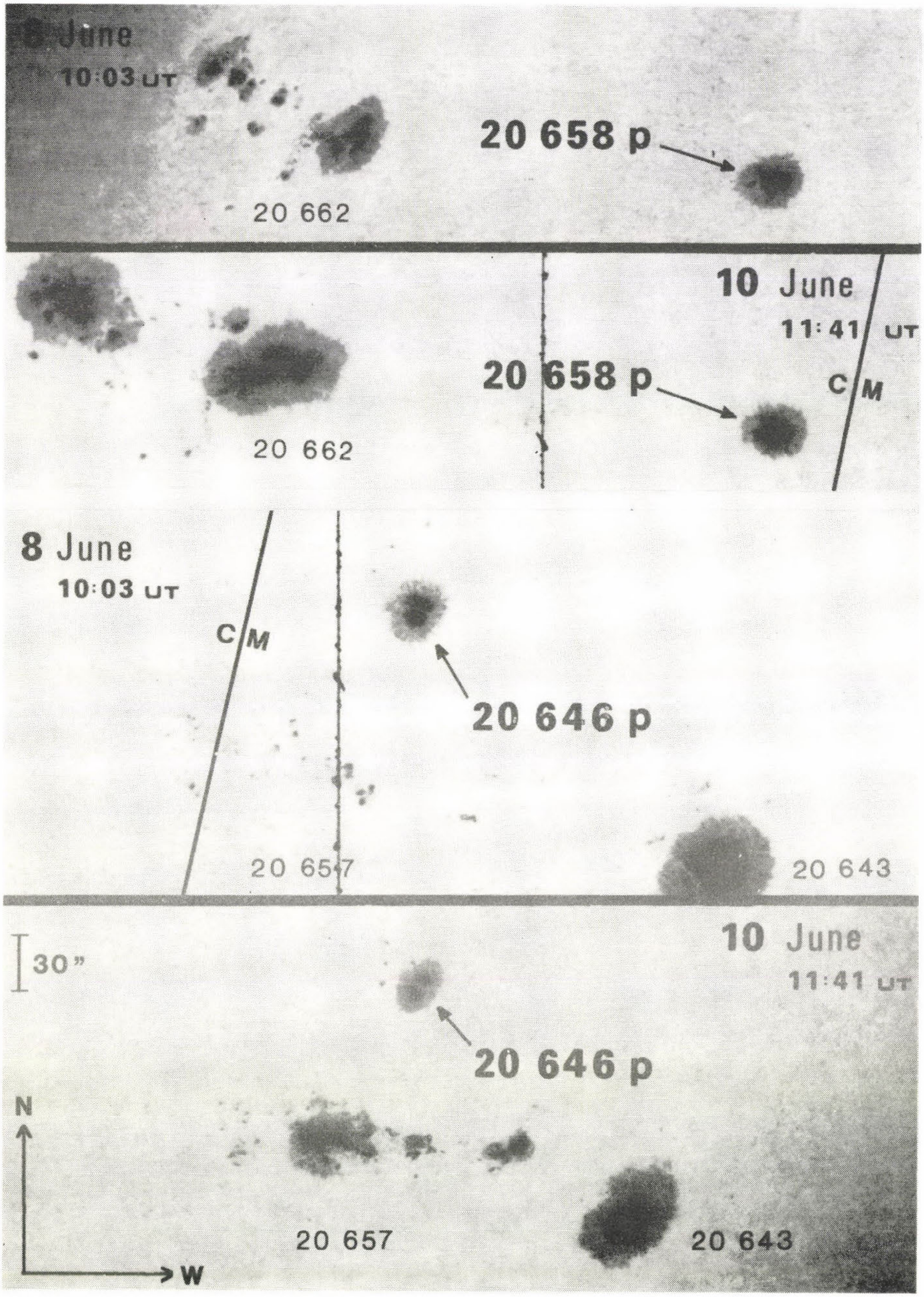

Figure 1. Two sections of the solar disc, June 8 and 10, 1979.

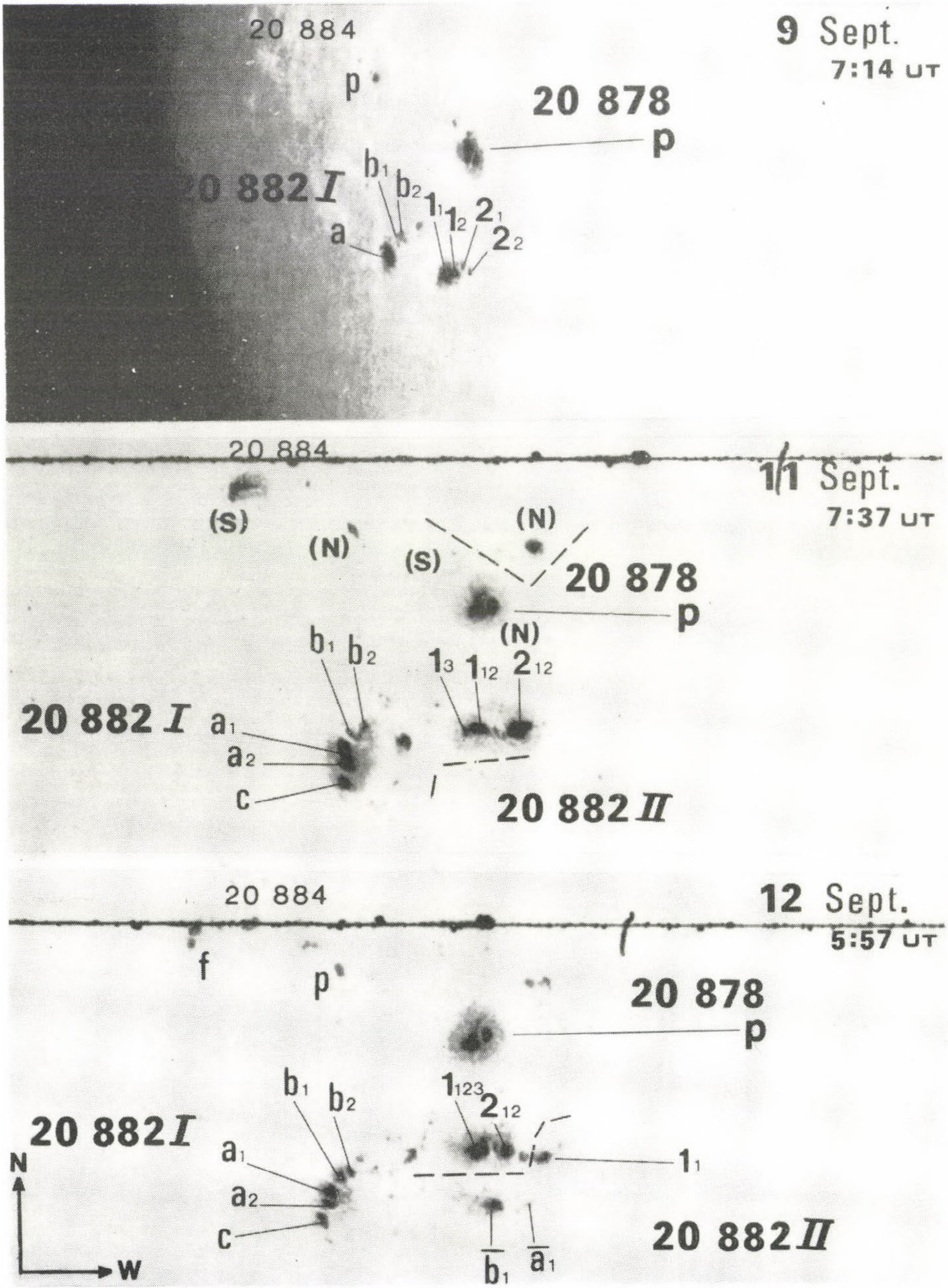

Figure 2a. Sunspots in McMath region 16279, 9,11 and 12 September 1979.

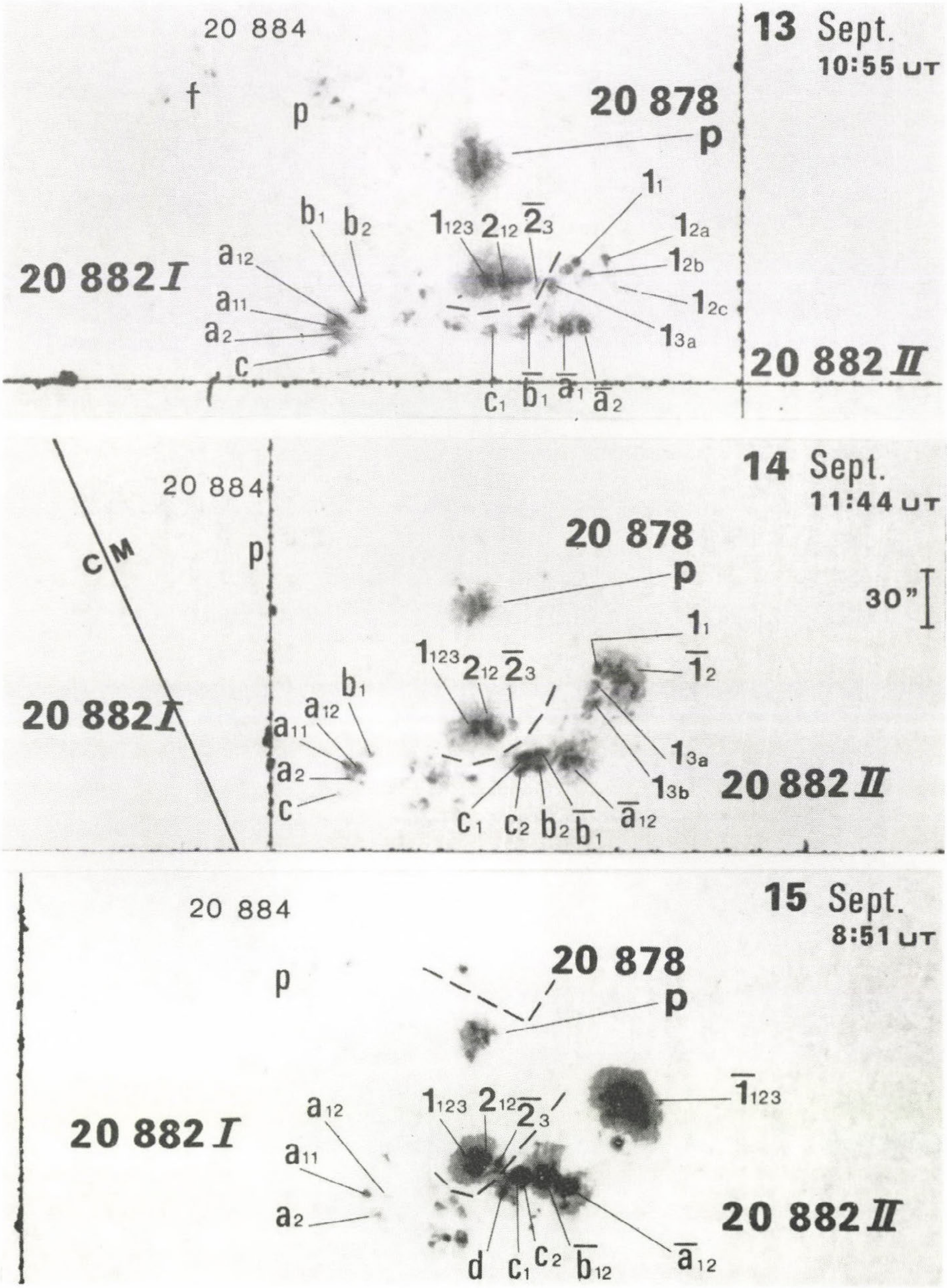

Figure 2b. Sunspots in McMath region 16279, 13,14 and 15 September 1979.

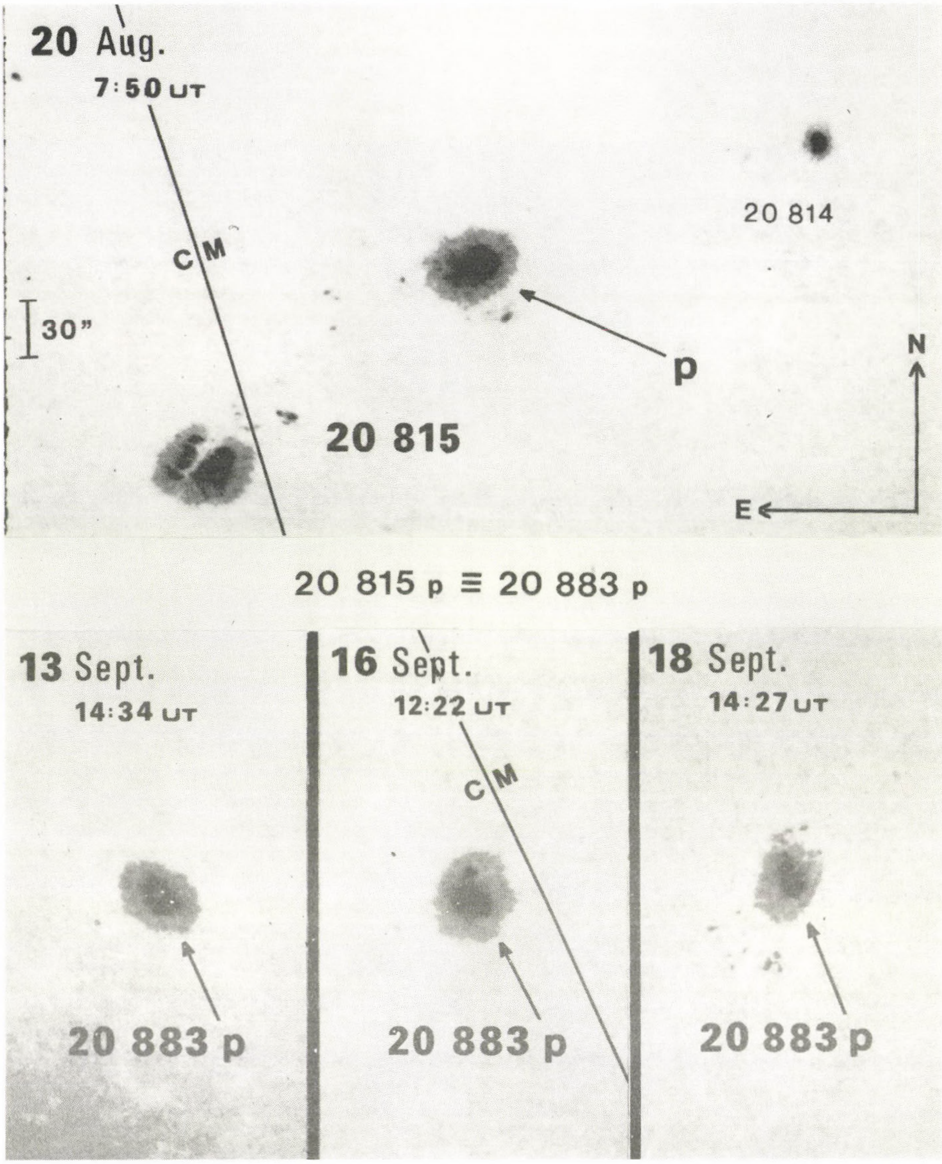

Figure 3. A large sunspot group (*20 815*), 20 August 1979, and its remnant, one solar rotation later, 13, 16 and 18 September 1979.

ADDITIONAL NOTES TO *Figures 1-3*

Fig.1.

Group *20 658* (in McMath region 16058) consisted mainly of a fairly large umbra of a single *p* polarity spot,but from 7 to 12 June some small fragments of disintegrated umbrae within the penumbra were also always seen. (E of the spot the large bipolar group belongs to another solar active region, McMath no. 16067.)

Group *20 646:* The umbra of the group of mainly a single spot of *p* polarity broke up in two approximately equal parts on 5 June, but later the spot did not show any other significant change at least until it passed the west solar limb. (All three spot groups shown in the *Fig.* are in the same McMath region 16052.)

Fig.2.

Group *20 882:* The designations are shown for the most important umbrae (and pores) for which there are position measurements. The denotations also indicate the magnetic polarities, the *p* polarity is marked with numbers, the *f* polarity with letters.

Group *20 878:* Its main *p* spot already consisted of at least two umbrae within its penumbra when first seen on the east solar limb on 7 Sept. On the following days the umbra and penumbra areas of the slowly disintegrating spot continue to grow a little until 10 and 11 Sept., respectively. The spot of several umbrae decreased considerably only by the 15th, the next day it broke up,and died out probably on 17 Sept.
NW of group *20 878* the unnumbered bipolar-looking group could be seen from 10 Sept. for about six days, while group *20 884* appeared two days earlier and its scattered small spots lived a little bit longer. (Moreover the *Fig.* shows all spot groups in McMath region 16279. The polarities of some spots, according to Crimean observations, are shown in the 11 Sept. photograph.)

Fig.3.

Group *20 883:* It was the only group in McMath region 16285. The great umbra had an area decrease of 40% in the period 12-21 Sept., but consisted only of one piece until 15 Sept. By the next day the umbra, as well as the whole spot, definitely began to show a slow disintegration. In the former rotation the region of this group got the McMath no. 16224. (The isolated spot, i.e. the group *20 814*, belonged to another McMath region, no. 16225.)

Figs.1-3.

Both scale and orientation are the same in all photographs, as indicated once in each *Fig.* and also the position of the central meridian (CM) is marked once in relation to each spot group.

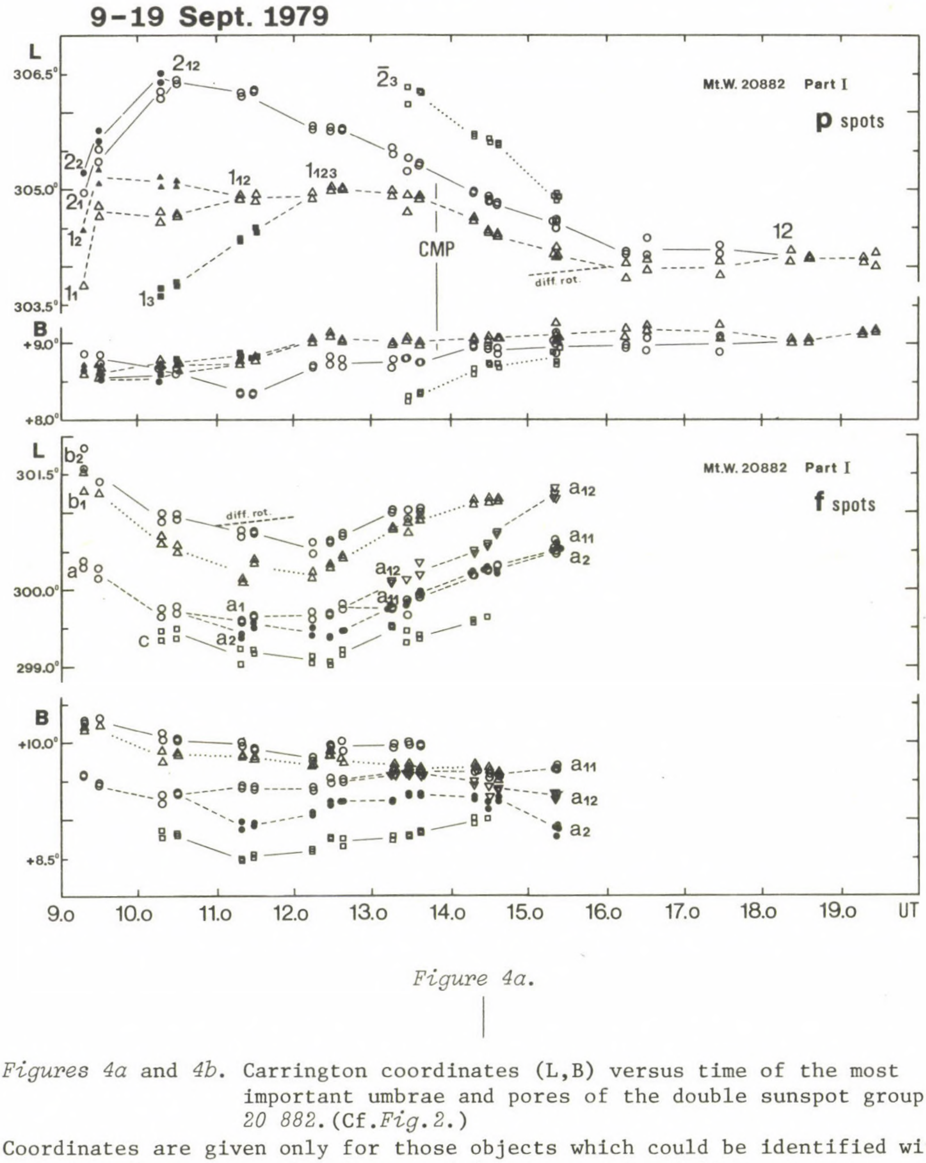

Figure 4a.

Figures 4a and *4b*. Carrington coordinates (L,B) versus time of the most important umbrae and pores of the double sunspot group *20 882*.(Cf.*Fig.2.*)

Coordinates are given only for those objects which could be identified with certainty for a reasonable long period on successive heliograms.
The time of central meridian passage (CMP) is marked for spots *I* 1_{123} and *II* 1_1.
(Where in the *Figures* the coalescence or separation of some objects are not clearly visible compare *TABLE 1.*)

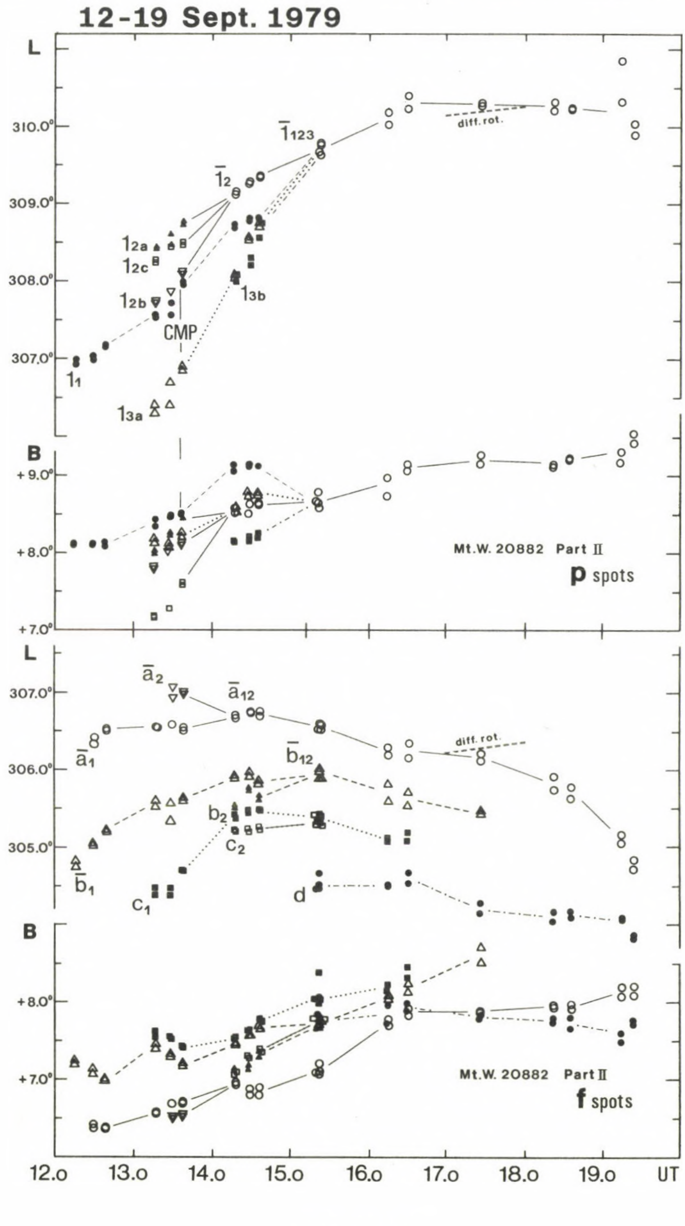
12-19 Sept. 1979
L
310.0°
309.0°
308.0°
307.0°
diff. rot.
CMP
B
+9.0°
+8.0°
+7.0°
Mt.W. 20882 Part II
p spots
L
307.0°
306.0°
305.0°
diff. rot.
B
+8.0°
+7.0°
Mt.W. 20882 Part II
f spots
12.o
13.o
14.o
15.o
16.o
17.o
18.o
19.o
UT

Figure 4b.

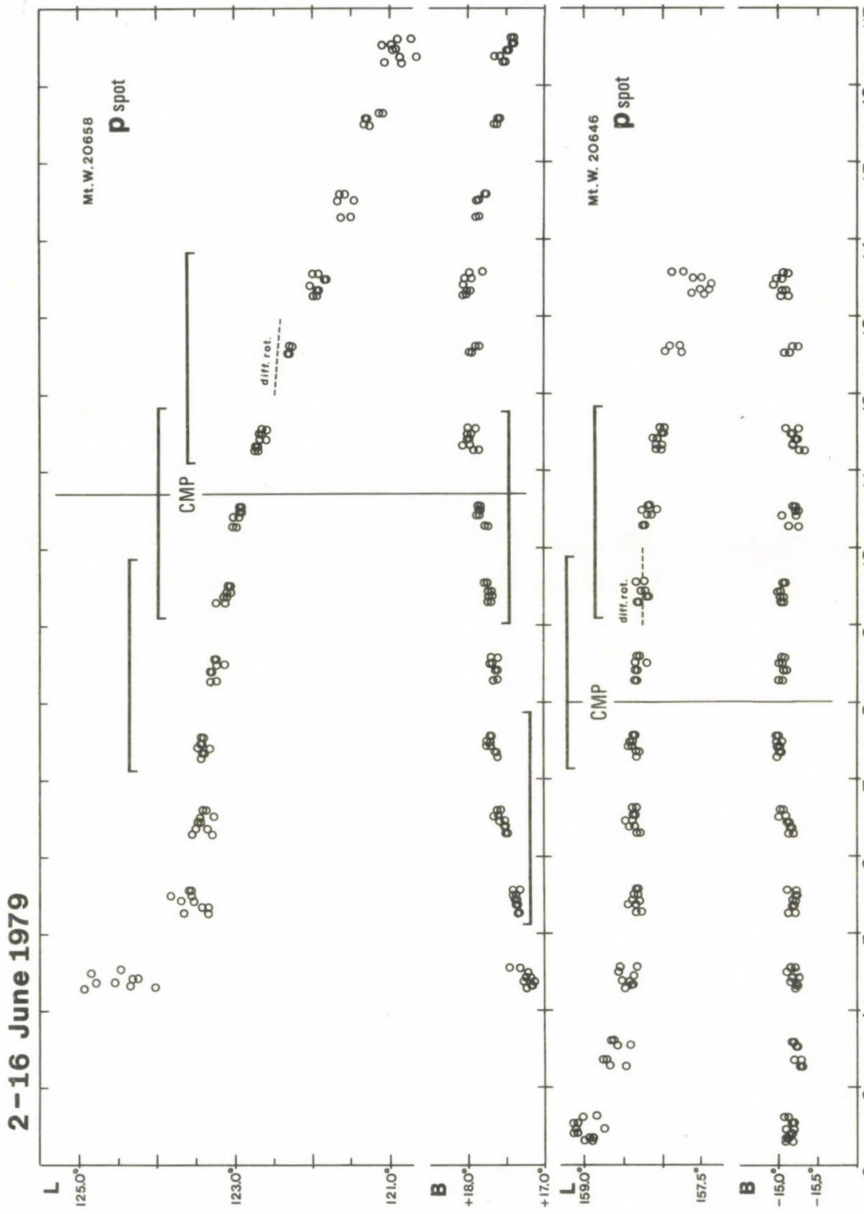

Figure 5a.

Figure 5a and *5b*. Carrington coordinates (L,B) versus time concerning two pairs of fairly large old sunspots during their disc passage. Spot velocities given in *TABLE 4* were determined by linear fits in relation to the periods of observation indicated by the horizontal heavy lines. The time of central meridian passage (CMP) is marked.

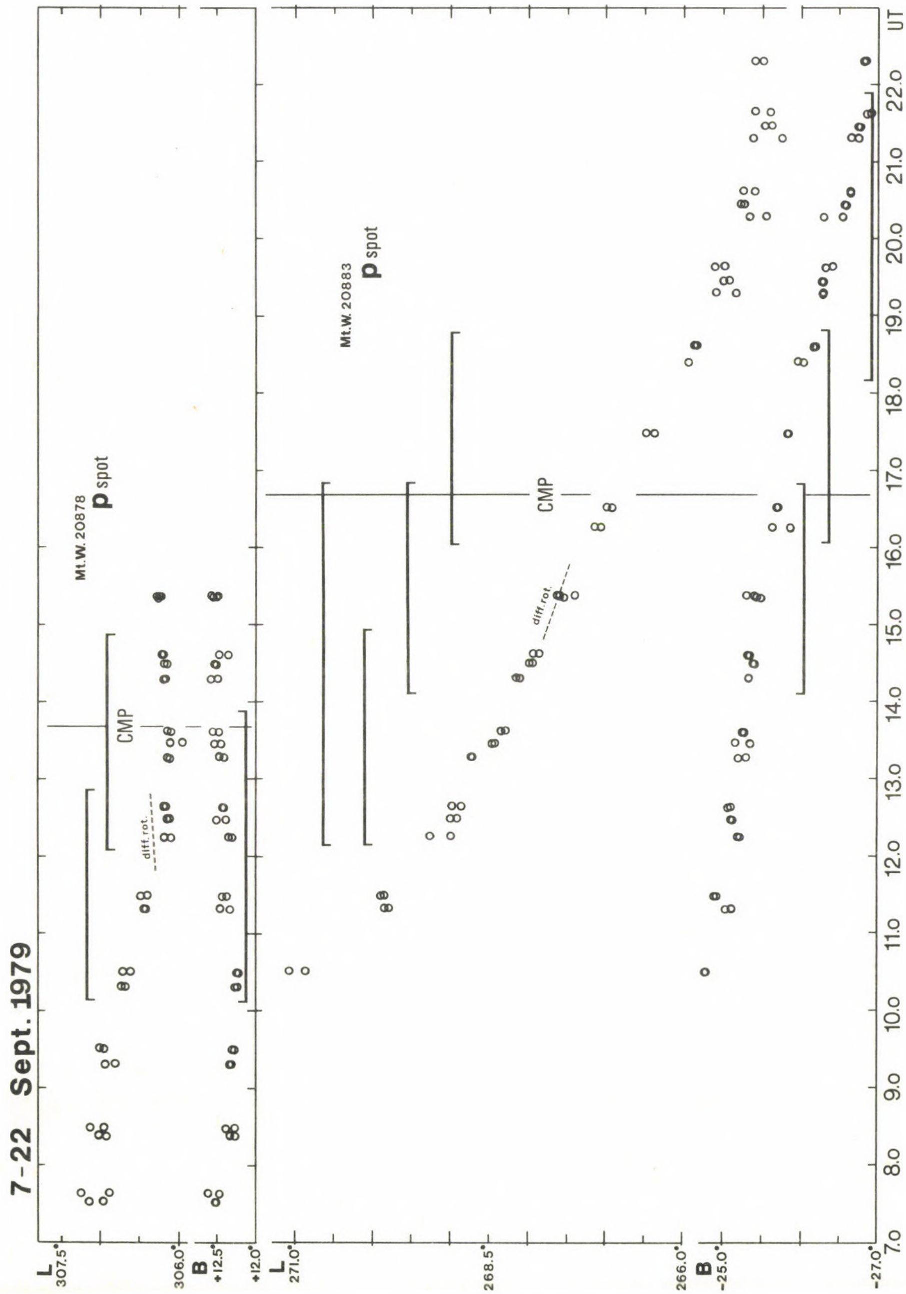
7-22 Sept. 1979
Mt.W. 20878
p spot
Mt.W. 20883
p spot
CMP
diff. rot.
L
B
307.5°
306.0°
+12.5°
+12.0°
271.0°
268.5°
266.0°
-25.0°
-27.0°
UT
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
19.0
20.0
21.0
22.0

Figure 5b.

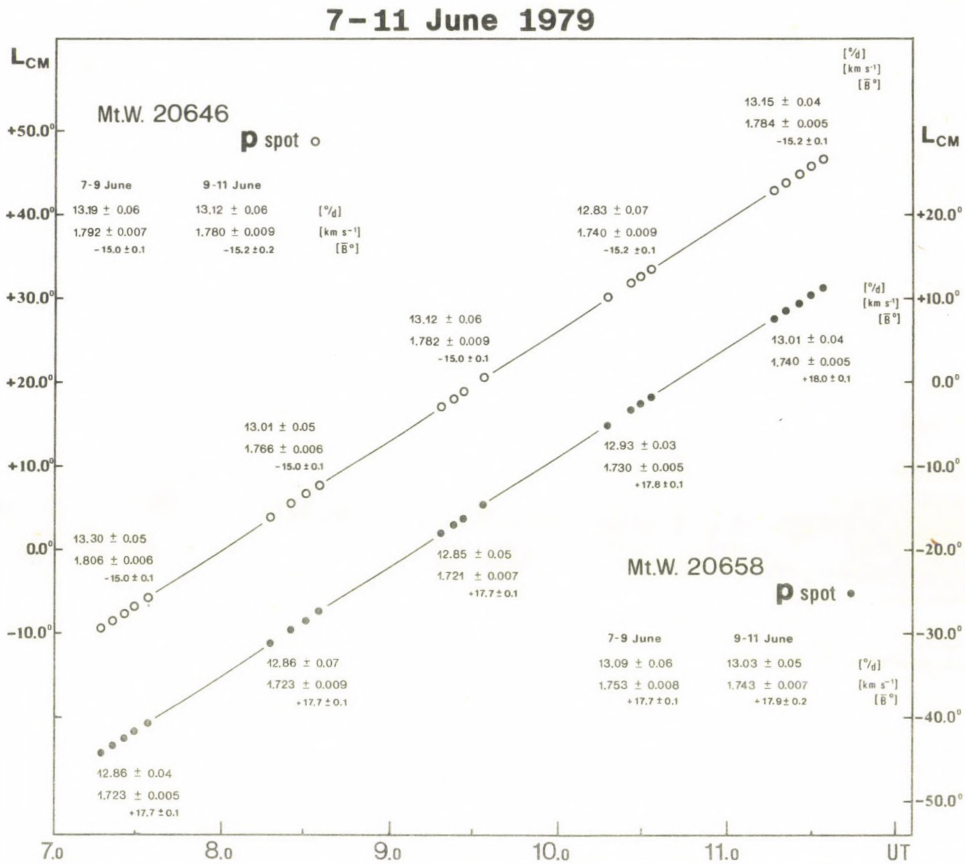

Figure 6. Heliographic longitudes measured from central meridian (L_{CM}) versus time. (Every open and filled dot shows the coincident results of a pair of measurements on two nearly simultaneous heliograms.)

Synodic rotation rates ($\xi_{\odot}$) over five days of the two large isolated old sunspots of *Figure 1.* Data used are the same as for the upper part of *TABLE 4.* Besides the calculated angular velocities and linear velocities their standard deviations (σ) are also given.

According to the reasonable limitations not a single flare remained on the list related to our four old sunspot groups which consisted almost always of one large spot in June and September 1979. In contrast to this, in the double group *20 882* and during the former disc passage of group *20 883*, i.e. in group *20 815*, several flares occurred.

There are 13 flares reported concerning group *20 815*, observed during its phase of development, between 13-18 August. One was a 2n flare, all others only reached "importance 1", but eight of them occurred in a one-day period beginning in the morning of 14 August.

In the double group *20 882* 8 flares were observed, all between Parts *I* and *II*, i.e. no doubt, close to the zero line of the longitudinal magnetic field(approximately indicated with broken lines in *Fig.2*). Of these flares the first (1n) occurred on 11 September when the first spots of bipolar group *II* appeared, while the last three (two 1n and one 1b) were already observed near the solar limb in a one and a half day interval on 18-19 September. The other four flares (1n, 2n, 1b, 1f) occurred within 24 hours on 14 September and were observed between the *p* spots of group *I* and the main *f* spots of group *II*. They deserve particular attention.

Between 13 and 15 September bipolar group *II* had well--marked abrupt development by motions, prominently seen in *Figure 2b*. So it is understandable why an enhanced flare activity in this group took place just on 14 September. All the important *f* spots of N magnetic polarity of group *II* were moving north, approaching the *p* spots of S magnetic polarity of group *I*. Two small *p* spots moved on 14 September in the photosphere with a speed of about 0.1 km s^{-1}, one ($I\ \overline{2}_3$) to NE, the other ($II\ 1_{3a}$) to NW, but one day earlier they were still close together on different sides of the dividing line of group *I* and *II*. (Cf. *Figs.2b, 4* and *TABLE 3*.) At the same time, within bipolar group *I* the umbrae of the main *p* spot and the decaying *f* spots made a rapid approach to one another. (Cf. *Fig.4a*.) We found these relative velocities to be about 0.10-0.15 km s^{-1}. (For example, the lower limit applies to the spot pair 1_{123} - a_{11}, for the period 13-15 September.)

On the following days the principal *f* polarity part of group *II* (i.e. its *a-b-c* conglomerate) continued to drift northward, thus toward the whole *p* polarity part of group *I*. From 15 to 16 September the mean velocity of approach between the spots *I* $1_{123}+2_{12}$ and *II* $\overline{a}_{12}$ was 0.055 ± 0.008 km s^{-1}. Over some days the groups of umbrae *II* $\overline{a}_{12}$ and *II* $\overline{b}_{12}$ had a northward average velocity of at least 0.05 km s^{-1} (which should already be regarded as a considerable high spot velocity). By means of all these motions a large complex spot of δ configuration developed. So, the revival of flare activity on 18-19 September can be understood well.

In addition we wish to mention that there were no more flares reported related to the whole solar active region to which double group *20 882* belonged than those we have mentioned above.

* * *

It can be seen in *TABLE 4* that out of our four old spots the first three followed the suspected rate of rotation "perfectly",i.e. $|\Delta\xi_*| \leq 0.05$ °/d $< |\sigma|$, at least for one three-day period. Also, both June spots between 9-11 June and even the spot of group *20 646* in three one-day periods of observations (on 7,9 and 11 June not exhibited in *TABLE 4*, but cf. *Fig.6*) still show the solar rotation fairly well, their $\Delta\xi_*$ data being small. Among these five $\Delta\xi_*$ values there is only a single one slightly greater than twice the relevant standard deviation.

The comparison is more discordant in the case of the fourth old spot, notwithstanding we find the most consistent data there (cf. the bottom of *TABLE 4*). Therefore we may suspect that this spot still had a considerable intrinsic proper motion too, in our judgement the relatively high dL/dt > 0.05 km s^{-1} (and some dB/dt $\approx$ 0.03 km s^{-1}) values strengthen our supposition. On the other hand, since this was a recurrent spot, an opportunity presented itself to check up on the rotation in the same way as Greenwich authors (1926) used to do.The result is:

$$\xi_* = 13.80 \text{ °/day} = 1.756 \text{ km s}^{-1} \quad (\overline{B} = -25.2°).$$

The value has been derived from two pairs of heliograms taken on 20 August and 16 September, each pair within four minutes, on the days of central meridian passage. For each day the two measurements in both heliographic coordinates yielded only a difference of 0.1°, if that. Accordingly, over one complete solar rotation we have a correct *average* daily sidereal rotation rate, which agrees better with the corresponding value of Newton and Nunn than with the result of our observation for 12-14 September; the relevant differences are about +7 m s^{-1} and -22 m s^{-1}, respectively.

Our four spots, which more or less revealed the sun's rotation in their apparent motions, were all in the phase of slow decay. Some examples of areal data given in *TABLES 2* also indicate this clearly and the brief descriptions in the notes to *Figures 1-3* also point to a steady decline. However, both kinds of spot areas of the large spot of group *20 883*, i.e. in its former disc passage the leader of group *20 815*, were nearly equal on 20 August and on 16 September. But since the bipolar group *20 815* reached its maximal development, according to observations, around 20 August, we think that it could have had a sort of secondary evolution later, on the sun's far side. In consequence it is not impossible that the leader spot of the group was moving during its invisible period. This is the reason why we underlined that by utilizing the recurrency an *average* rotation is determined.

Coming back to the young double group *20 882* we note that the leader spots of Part *I* ($1_{123}+2_{12}$) and Part *II* ($\overline{1}_{123}$) became fully developed by 13 and 15 September respectively and only after these days, when both spots entered upon their phase of decay, were the velocities of apparent spot motions found approaching the "true" ξ_* (cf. *TABLE 3*).

Still it should be mentioned that although not only the growth but also the shrinking of a large spot often clearly takes place through motion, the separated and rather slowly receding small fragments of umbrae usually do not alter the position of the spot centre for quite a few days and therefore such spots are not dubious objects for solar rotation studies.

CONCLUSION ON DETERMINATION OF SOLAR ROTATION

From the data of observations given it can clearly be seen that,by using a series of adequate full-disc photoheliograms taken in a three-day period, it is possible to determine consistent heliographic sunspot positions which are accurate enough to allow for the calculation of the daily rate of solar rotation with the appropriate requirements of accuracy.

The preliminary conditions for reliable results are evidently that the spots should not move in relation to the photosphere, i.e. in practice, to their surroundings. Because of the intrinsic proper motions of sunspots we think observations over periods of 3 days have been found suitable. Moreover, because of the physical foreshortening effect (cf. Dezső,1964, p.44), sunspots within the limit of 40° heliocentric angle should be used if possible for the sake of accuracy of the measurements of spot positions. This is a severe limitation especially in the case of spots of high latitude, which are rare objects anyway.

Maybe we succeeded in demonstrating with a few limited examples of apparent motions of sunspots that there does indeed also exist the possibility of determining the rate of solar rotation by means of tracers of photographic spot positions over not more than a couple of days.

However we should add a concluding remark. Among the final results of rotational data those which apply to a longer daily period of observation are obviously more often considered more reliable. On the other hand, observations obtained early and late in the day are inadequate for the exact determinations of the heliographic coordinates, since, if the sun's altitude (h) above the horizon is not high enough, there is a great problem in finding the right corrections to cancel the effects of differential refraction. Therefore, here we used the June observations only if $h > 30°$, and neglected forty of $16° \leq h < 30°$, (as well as eighteen of $7° < h < 16°$, which may still be useful for the determination of relative positions, etc.). But for the September period, seeing that we have far fewer observations, we used all of $h \geq 16°$. Perhaps it is due to this fact that we found less conformity to solar rotation for the September spots than that of those for June. (At any rate two thirds of our September material also consisted of $h \geq 30°$ observations.)

R e f e r e n c e s:

Dezső,L.: 1964, *Publ.Debrecen Obs.* 1, No.1.

Dezső,L.: 1981, *Solar Phys.* (in press)

Ephemeris: The American ... for the year 1979. (U.S. Govern.Printing Office,Washington,1977)

Giovanelli,R.G.: 1939, *Astrophys.J.* 89, *555*.

Greenwich authors: 1925, *Monthly Notices Roy.Astron.Soc.* 85, *548* and 1926, *Results of Measures R.Obs.Greenwich, 66.* (Publ.H.M.Stationary Office,London)

Koch,A.,Wöhl,H. and Schröter,E.H.: 1981, *Solar Phys.* 71, *395*.

Newton,H.W.: 1934, *Monthly Notices Roy.Astron.Soc.* 95, *62*.

Newton,H.W. and Nunn,M.L.: 1951, *Monthly Notices Roy.Astron.Soc.* 111, *413*.

NOAA: 1980-1981, *Solar-Geophysical Data*, Part II, Nos.431,436 and 439. (Boulder)

Waldmeier,M.: 1938, *Z.Astrophys.* 16, *276*.

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