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SUNSPOT MOTIONS ASSOCIATED WITH THE 3B/X1.5 SOLAR FLARE OF 13 MAY 1981

WANG, JIA LONG , ZHANG, GUIQING AND MA, GUANYI
Beijing Astronomical Observatory, Beijing 100080, China
AND
YUN, HONG SIK
Department of Astronomy, Seoul National University, Seoul 151-742, Korea
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ABSTRACT

We have examined morphological change and movements of individual sunspots within a sunspot group in association with a large solar flare activity (3B/X1.5) appeared on 13 May 1981. For this purpose we measured distance among spots during the period before and after the flare activity and estimated the average velocity of their movement. Our main results are as follows: (1) The longitudinal displacement among sunspots are generally greater than the latitudinal displacement. (2) During the period the spots moved with an average velocity of 1.2 km/s in longitude and 0.86 km/s in latitude. (3) The most notable change took place in the central part placed between the two ribbons of the flare.

Key Words : Sunspot morphology, Sunspot group, Flare

I. INTRODUCTION

The 3B/X1.5 flare (3B/X1.5) of May 13, 1981 was one of the major flares occurred during the maximum of Solar Cycle 21. A number of papers have been devoted to this event (e.g., Loughhead *et al.* 1983; Kahler 1984; Morishita *et al.* 1984). Intense X-ray and radio bursts displayed a typical gradual time profile, even in the hard X-ray range of 152-340 KeV (Tsuneta,1984). It was also reported that the X-ray source of the burst was located on the top of the flare loops about 60000 km high and a dou ble ribbon H_α flare was formed at the foot points of the loop system (Loughhead *et al.* 1985). During the peak of the flare no Fe XXVI soft X-ray lines were observed and in the late phase a type IV burst in metric band was reported. Thus, this flare should be classified as type C burst in Tanaka-Tsuneta's classification and NNC in Wang's classification (Wang,1993). The peak proton flux of this event was only 130 pfu according to SGD. This might be attributed to the disk location of this fl are at E56.

Most of earlier works on this event were focused on temporal variation of the energy output in different energy band and spatial relationship with respect to energy source. The movement of sunspots renders another interesting problem for flare studies, because it is directly associated with magnetic energy releasing mechanism. Anwer *et al.* (1993) noted a striking disturbance in position and shape of sunspots during the major flare appeared on 15 November 1991. During the impulsive phase the sunspot located nearest to the site of the white light emission was displaced wit h a velocity greater than 2km s^{-1}. In the present work, a similar study is made to examine morphological change of the sunspot group and the movement of individual sunspots in the group.

II. OBSERVATION AND ANALYSIS

We observed a 3B/X1.5 flare on May 13, 1981 with H_α filter of 1/8Å attached to the Culgoora 30 cm high resolution telescope, which has a field of view of $4' \times 6'$. The H_α filter was set at $H_\alpha \pm$ 0Å, $H_\alpha \pm$ 0.25Å, $H_\alpha \pm$ 0.6Å and $H_\alpha \pm$ 1.0Å respectively. The H_α flare started at 0336UT, peaked at 0423UT and ended at 0612UT. It lasted for about 156

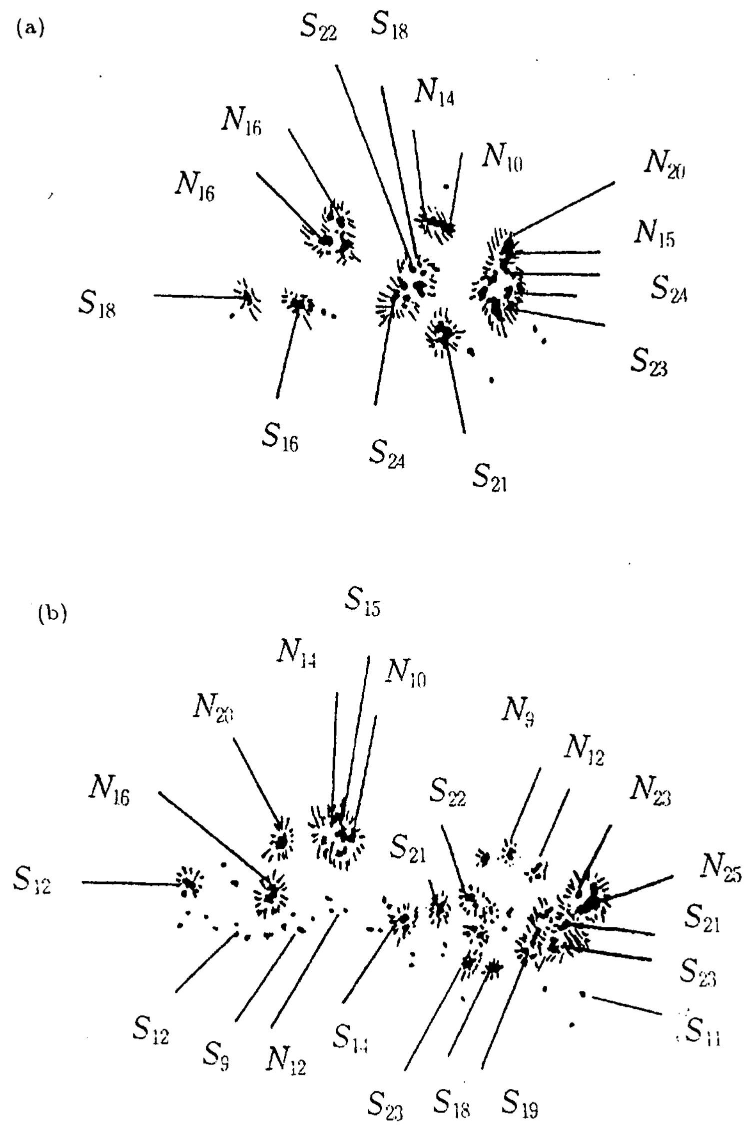

Fig. 1. Magnetic fields of AR3106 and AR 3112 for May 13 (a) and May 14 (b), 1981 (taken from Monthly Solar Activity, Yunnan Observatory, Vol. 1, No. 5).

minutes, and was located at N10E56 in Active Region 3106 (N11E58). There was another sunspot group numbered with AR3112 in the north-east side to AR3016. Figure 1 shows the magnetic field strength of sunspots in AR3016 and AR3112 appeared on May 13 and May 14, where N and S indicate the positive and negative polarity with field strength expressed in units of 100 Gauss.

As can be seen from Figure 1, AR3106 and AR3112 formed a magnetic complex. Two 3B major flares were produced in this complex on 14 and 16 May. To examine the impact of flare activity on sunspots, first we measure the longitudinal and latitudinal distance among individual sunspots undergone during the period before and after the flare. To do this, we numbered these sunspots as shown in Figure 2.

We measure the position (X,Y) of each spot referenced to a Cartesian reference frame, in which OX points to the geocentric west, OY to the geocentric north and O is located at a solar disk at $t_S = 00^h 28^m 03^s$UT before the flare, and at $t_e = 05^h 32^m 11^s$UT in the very late phase of the flare. Thus $X(t_s), X(t_e), Y(t_s)$ and $Y(t_e)$ are obtained from the filtergrams taken at $H_\alpha + 1$Å at 002803UT and 053211UT, respectively.

Next, we transform X and Y to a reference frame in which OX' points to the heliocentric west and OY' to the heliocentric north by means of

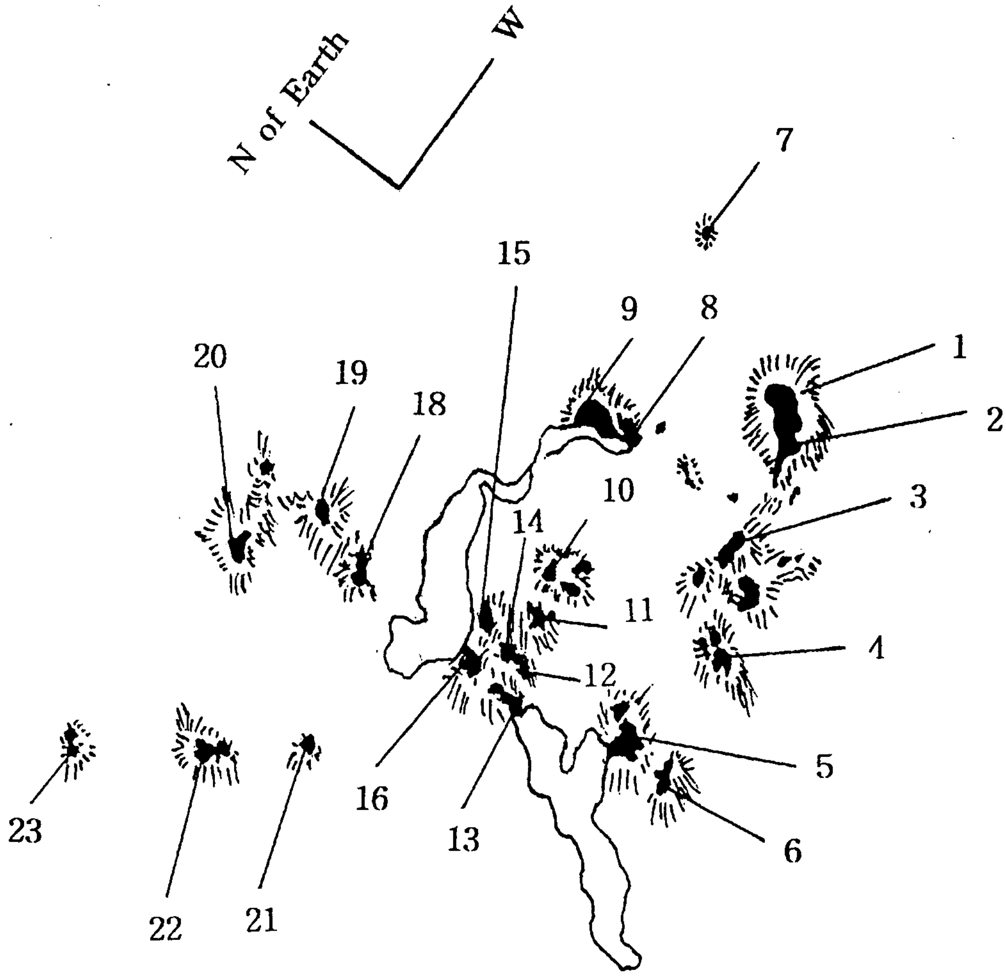

Fig. 2. Distributions of sunspots in the 3B/X1.5 flare region at 042321UT. The solid line outlines the H_α bright areas. The numerical numbers are assigned to the sunspots for identification.

$$X' = X\cos p + Y\sin p, \tag{1}$$

$$Y' = Y\cos p - X\sin p, \tag{2}$$

where p is the position angle of the sun's pole. Then, the distance between a pair of spots, m and n in OX' and OY' axes are obtained as $\Delta X'(t_s, m, n)$ and $\Delta Y'(t_s, m, n)$ at t_s (002803UT) and $\Delta X'(t_e, m, n)$ and $\Delta Y'(t_e, m, n)$ at t_e (053211UT) from

$$\Delta X'(t_s, m, n) = X'(t_s, m) - X'(t_s, n) \tag{3}$$

$$\Delta Y'(t_s, m, n) = Y'(t_s, m) - Y'(t_s, n) \tag{4}$$

$$\Delta X'(t_e, m, n) = X'(t_e, m) - X'(t_e, n) \tag{5}$$

$$\Delta Y'(t_e, m, n) = Y'(t_e, m) - Y'(t_e, n). \tag{6}$$

After correcting the longitudinal projection effect for $\Delta Y'$ (measured in unit of millimeter on filtergrams), it is converted in unit of arcseconds as

$$\Delta Y''(t_s, m, n) = \Delta Y'(t_s, m, n)/cos11°/0.08772 \tag{7}$$

and

$$\Delta Y''(t_e, m, n) = \Delta Y'(t_e, m, n)/cos11°/0.08772 \tag{8}$$

where 0.08772 is the distance in mm per 1 arcsec on filtergram, and 11° is the latitude of the active region. For $\Delta X'$ we also correct the longitudinal projection effect at t_s and t_e to obtain

$$\Delta X''(t_s, m, n) = \Delta X'/cos58.^\circ 3/0.08772 \tag{9}$$

$$\Delta X''(t_e, m, n) = \Delta X'/cos55.^\circ 3/0.08772 \tag{10}$$

where 58.°3 and 55.°3 are the heliolongitude of the region at t_s and at t_e, respectively. Actually, $\Delta X''$ and $\Delta Y''$ are longitudinal and latitudinal lines in units of arcseconds. Then the displacement between sunspot m and sunspot n from time t_s to time t_e are given by

$$\Delta\Delta X''(t_e - t_s, m, n) = \Delta X''(t_e, m, n) - \Delta X''(t_s, m, n) \tag{11}$$

$$\Delta\Delta Y''(t_e - t_s, m, n) = \Delta Y''(t_e, m, n) - \Delta Y''(t_s, m, n). \tag{12}$$

III. RESULT AND DISCUSSION

The movement of individual spots before and after the flare activity and the resulting displacement of these spots is listed in Table 1. Since the measuring error is estimated to be about 8″ for $\Delta\Delta X''(t_e - t_s, m, n)$ and 6″ for $\Delta\Delta Y''(t_e - t_s, m, n)$, we have listed only $\Delta\Delta X''$ which is greater than 8″ and $\Delta\Delta Y''$ which is greater than 6″ in the table. In the table the negative(positive) sign refers to a shortening(lengthening) of the i nterspot distance.

As can be seen from Table 1, morphologically the flare did not make any considerable change of the sunspot group as a whole, but a fairly distinct change took place in the central part of the active region, particularly the region surrounded by a roughly circled bright double ribbons. Here, we note that No. 1 and No. 2 spot are displaced southeastwards, No. 3 through No. 6 and No. 8 spot are moved southwards, No. 9 spot northwestwards, No. 10 through No. 16 spot eastwards except for No. 11 spot which is displaced northeastwards. No. 19 and No. 20 spot are displaced eastwards and No. 21 and No. 22 spot are moved northwestwards. It may be summed up to say that the sunspot motion during the flare is very complicated, because their related magnetic field has to be reconstructed after the flare.

To demonstrate the degree of movement each individual sunspots made we group $\Delta\Delta X$" (longitudinal) and $\Delta\Delta Y$" (latitudinal) into four, as seen in Table 2. Here we note that over two-thirds of the spots have displaced less than 8" in longitude and 6" in latitude. None of the spots has moved over 25" in longitude and 15" in latitude. The spots displaced by more than 8" in longitude and 6" in latitude are located in an area roughly encircled by the bright two ribbons, demonstrating once again its close tie to the sunspot movement, namely the *flare-sunspot connection.*

The weighed average of $\Delta\Delta X$" and $\Delta\Delta Y$" are found to be 11.9 and 8.3 arcseconds, which correspond to 8568 km and 6018 km on the sun, respectively. The average velocity of the movement then becomes 1.23 km/s and 0.47 km/s. These are smaller than the one (i.e., 2 km/s) obtained by Anwer *et al.* (1993) for the flare appeared on November 15, 1991, but greater than the one(i.e., 0.1 ~ 0.7 km/s) found by Dezsö *et al.* (1980).

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Table 1. Change in longitudinal and latitudinal interspot distance in units of arcseconds undergone from time t_s to time t_e.

Assigned Sunspot Number	Assigned Sunspot Number								Assigned Sunspot Number							
	1	3	4	5	6	9	18	20	1	3	4	5	6	9	18	20
	Longitudinal Distance ($\geq 8''$)								Latitudinal Distance ($\geq 6''$)							
1		-11	-10	-10	-13						-6		6		9	9
2		-8			-10										7	7
3								10							8	8
4								9								
5																
6						9										
8															6	6
9																
10					-8				8	7						
11	17					12			12	11	6	7	6	7		
12	8								8	7						
13	24	13	14	15	11	20	17	23	14	13	8	9	8	10		
14	9								6							
15	8								6							
16					-10				14	13	8	9	8	10		
18																
19					-10				8							
21		-8			-10				7	6						
22		-8			-10				10	9				6		

Table 2. Distribution of $\Delta\Delta X$" (longitudinal) and $\Delta\Delta Y$" (latitudinal).

Number of changes	Range of $\Delta\Delta X$" (arcseconds)	Number of changes	Range of $\Delta\Delta Y$" (arcseconds)
95 (77%)	< 8	84 (68%)	< 6
24 (19%)	8~15	31 (25%)	6~10
5 (4%)	15~ 24	9 (%)	10~15
0	≥25	0	≥15
Total 124 (100%)		124(%)	

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