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The peculiar solar flare of 1981 May 13

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Abstract. Time-lapse photographic observations with 0.7 Å passband H-alpha filter and the morphological-cum-temporal behaviour of a large double solar flare which occurred on 1981 May 13 have been described. The two strands, constituting the flare, which initially appeared to cross each other, with a bright region at the location of crossing, later separated out, ultimately becoming roughly parallel. The mean separation between the two strands at various intervals of time have been measured. It is concluded that apart from the oscillating behaviour of the strands, there is shearing in them probably due to rotation of the footpoints.

Key words : solar flare—helical structure—magnetic shearing—ionospheric effects

1. Introduction

As a part of the solar maximum year program for observing solar activity, the sun was regularly monitored through a 10 cm f/15 refractor fed through a coelostat and a 0.7 Å passband H-alpha Halle filter. On 1981 May 13 at about 3^h30^m UT the solar disk showed a number of sunspots surrounded by plages and also by an extended plage and a filament ring. At this moment, the first signs of brightening associated with the flare were noticed. However, this brightening may have started somewhat earlier. A quick changeover was made to a 15 cm, f/15 refractor to obtain a bigger image size of 22 mm.

2. Observations

The observations comprised of time-lapse photographs, recorded on Kodak SO-115 film using a Robot recorder camera having an automatic arrangement to register the event. The exposure time used was 1/250 s, with the filter centered on H-alpha.

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The pictures were taken at intervals of less than 3 min. On the day of the observation the seeing fluctuated much. This is reflected in some of the filtergrams taken. The negatives were enlarged suitably for making the prints. Outlines of the flare strands were traced for the study and the measurements of the separation and the temporal behaviour of the two flare strands.

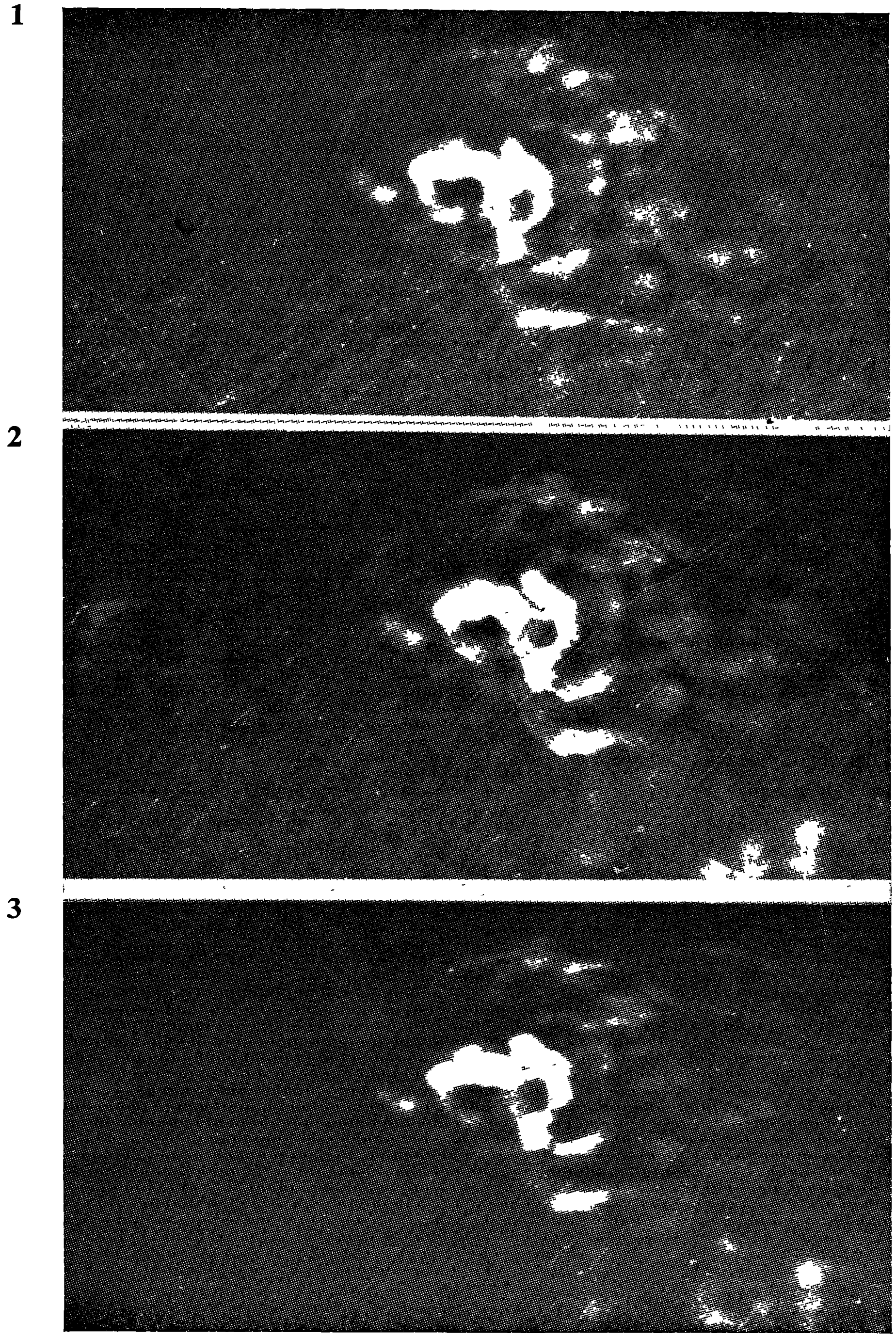
3. Analysis of filtergrams

The flare occurred near Hale plage region 17644 at location N13 E54 and has been classified as 3B (Solar Geophysical Data 1981). We measured the area and found it to be 740 millionths of the visible solar disk at the flare's brightest phase at 4^h50^m UT (figure 5) which also corroborates the above classification. In all we took about 80 frames, out of which 20 were selected for making the prints. Six of these are reproduced here.

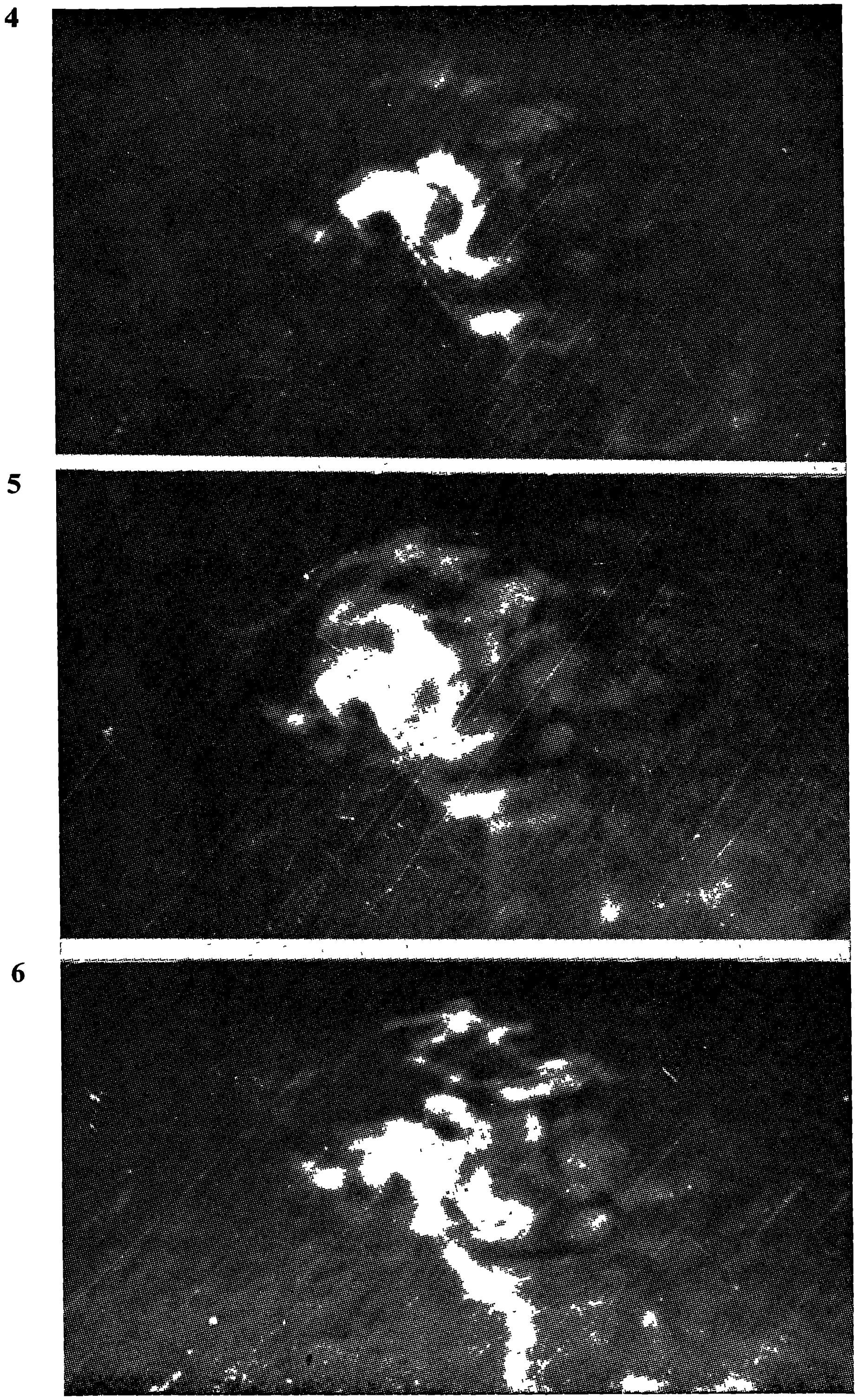
Initially, the flare strands seemed to cross each other, with a bright region at the location of crossing. The entire configuration resembled the *Swastik* symbol with the strands showing appreciable curvature (figure 1). A number of sunspots with a large one could be seen below the flare configuration. The brighter parts of the strands were on the same side towards the limb, and the fainter extensions or tails of the strands on the other, with a bright region at the crossing point. It is here that a noticeable increase in the brightening started. This increase in brightening was not only of the flare, but also of the surrounding region. One can see the plage ring surrounding the flare strands and also by contrast a dark long channel filament. The thickness of the flare strands and of their tails increased.

In figure 2, taken at 4^h10^m UT, the C-shaped strand shows splitting into a fine canal-like structure. The possibility of a loose connection between the strands indicating a flow of matter is not ruled out at this stage. The point of crossing thickens and brightens at 4^h15^m UT (figure 3). From here onwards, the curvature of the strands changes to lesser degree and the helical structure in one of the strands is clearly discernible at 4^h39^m UT (figure 4). The brightening also seems to fluctuate and the strands appear more diffuse. But this could also be attributed to a fluctuation in seeing conditions. Later sequences show a clear separation and unbending of the strands coupled with rotation. This configuration assumes a parallel shape and closely resembles the flares described by Tanaka & Nakagawa (1973). These frames show that both the brightness and the shape of the configuration of the flare strands become steady.

Analysing the filtergrams frame by frame, we found a peculiar and complex type of motion, namely, separation of the strands coupled with rotation of the same. The general charateristics common to two-ribbon flares, *viz.* expanding motion and separation in distance as reported by Svéstka (1968) have also been observed by us. This is important from theoretical point of view also, as this rotation has to be explained in terms of the motion of the footpoints. Figure 7 is a plot showing the separation at different times as the flare progresses. To arrive at this, we traced out the flare configuration after suitable enlargement of the negatives. For measuring the separation between the two flare strands on each frame, median lines were drawn on each strand. Then, dividing the full length of the strand in equal intervals, the



Figures 1–3. (1) Flare shape resembling Swastik symbol with strands having appreciable curvature. (2) Appearance of fine canal-like structure. (3) The phase of thickening and brightening at the crossing point.



Figures 4–6. (4) Appearance of the helical structure. (5) Brightest phase of the flare. (6) The final phase in which the strands become parallel and cover the sunspot umbrae.

least distance from each point on the first strand's to the second strand's median line was measured. The mean of all such least distances was obtained as the average separation between the two strands for a particular frame (and so at a particular time). This was repeated for some selected frames to get the dependence of separation on time.

Figure 7 shows that the separation increases with time, finally becoming stationary. The variation shows that the curve can be explained by the parabolic relation $S = A + BT^{1/2} + CT + DT^{3/2}$, where T is the time in UT, and S the mean separation between the flare strands at time T. A, B, C and D are constants determined by a least-squares solution: $A = -2.30 \times 10^3$, $B = 2.87 \times 10^3$, $C = -1.18 \times 10^3$ and $D = 1.62 \times 10^2$. The error in the measurement of S was found to lie within the 3σ value, where σ is the standard deviation. This shows that the scatter of the points is real, arising purely from the error in the measurement of separation.

The velocity of separation persistently decreases with time. This persistent decrease in the velocity, together with the presence of a strong spot group below the region where the flare was formed, strongly indicates the flare to be of a proton type (Svéstka 1968).

Further, the flare strands became roughly parallel, receded from one another and also covered the umbrae of the sunspots ultimately (figure 6). The recession significantly slowed down and almost stopped as can be seen from the graph.

4. Ionospheric effects of the flare

The phases of two standard very low frequency (VLF) transmissions (i) at 16 kHz, GBR Rugby (UK) and (ii) 13.6 kHz Omega (La Reunion) were also monitored continuously. A notable feature in the phase of the received VLF signals was the simultaneous occurrence of a sudden phase anomaly (SPA) at 3^h30^m UT on 1981 May 13, for these two VLF signals. Although the commencement of the SPA was simultaneous for both signals, the maximum phase deviations of $31 \mu s$ could be detected clearly only in the monitored phase of 16 kHz VLF signal at 4^h45^m UT. One microsecond corresponds to a change of 5.76 degrees in the phase of the 16 kHz VLF signal. This SPA effect on the VLF signal could have been caused by an enhancement of the solar x-ray flux along the signal propagation path during the solar flare. However, further evidence is needed to support this point.

5. Possible explanation of morphological changes

The shear and rotation of the flare can be understood on the basis of the mechanism suggested by Piddington (1979), since our figures also show the strands to have an S shape, which changes with time. The overall morphological behaviour of the flare can also be understood on the basis of the energy stored in the force-free magnetic fields above sunspots, due to magnetic shear produced by the proper motions of sunspots as shown by Tanaka & Nakagawa (1973) for flares of 1972 August. However, in some of the photographs we have noticed a distinct appearance of a helical structure, presumably of the magnetic field, in each of the strands. It is significant that the degree of twist in these helically braided structures

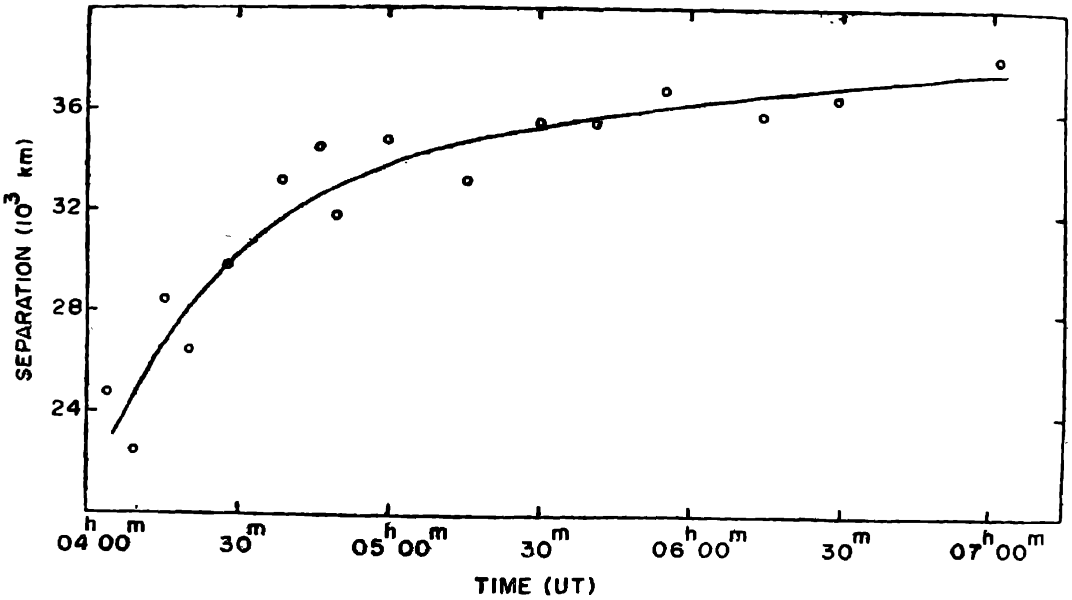


Figure 7. Curve showing increase in separation of the flare strands with time.

waxes and wanes. In the mechanism given by Tanaka & Nakagawa (1973) and Piddington (1979) an additional sub-mechanism is needed to explain this phenomenon.

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