LOCKHEED CALIFORNIA COMPANY
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FINAL REPORT

SOLAR FILAMENT STRUCTURE

Harry E. Ramsey Sara F. Smith

Contract No. N00014-66-C0059
ARPA Order 215, Amend. No. 21

Prepared For: OFFICE OF NAVAL RESEARCH
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LR-20444 December 1966

PHYSICAL AND LIFE SCIENCES LABORATORY

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Period Covered: 29 Nov. 1965 - 28 Nov. 1966

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Lockheed Solar Observatory

The work described herein was performed with funds provided by ARPA through Contract No. N00014-66-C0059 with the Office of Naval Research.

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FOREWORD

This report describes results obtained under Contract N00014-66-C0059, "Solar Filament Structure" between 21 March 1966 and 30 November 1966. The funds for this study were supplied by the Advanced Research Projects Agency through the contract with the Office of Naval Research.

The purpose of this project was to search for and study any type of preflare phenomena which could be found in the Lockheed H-alpha solar films. Particular emphasis was placed on the correlation of flares with changes in filaments preceding the flares. This project was an extension of a previous contractual study entitled "Flare-Associated Filament Phenomena". The previous work was concentrated on a study of preflare changes in filaments occurring within 2 hours of the onset of a flare. The present report describes preflare changes occurring several hours to several days before the onset of a flare. A few aspects of shorter period preflare changes are included which were not previously described ("Flare-Associated Filament Phenomena" Ramsey and Smith, 1965).

Other reports submitted under this contract were:

Quarterly Letter Reports	Number - 1	4 May 1966
	Number - 2	8 July 1966
	Number - 3	12 Oct 1966
Quarterly Technical Reports		
	Number - 1	18 May 1966
	Number - 2	28 July 1966
	Number - 3	31 Oct 1966

Part of the results obtained under this contract were presented at the Special Meeting on Solar Astronomy sponsored by the American

Astronomical Society in Boulder, Colorado, 3-5 October 1966. The presentation was titled "A Flare-Associated Event Observed on 21 March 1966, 2215 U.T.". The first cases that we have observed of preflare changes in fibrils were described.

ACKNOWLEDGEMENTS

The work of Mr. Barry Nolan in the preparation of the illustrations is greatly appreciated.

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TABLE OF CONTENTS

ILLUSTRATIONS

Section 1

INTRODUCTION

A survey of the films of the Lockheed Solar Observatory was made for the purpose of looking for parameters which might be related to the occurrence of major solar flares. The survey was conducted only to search for parameters of possible interest without any attempt to prove or disprove, at that time, whether or not the parameters were in fact related to flare occurrences. The parameters sought were ones which would precede major flares by 2 hours up to 5 or 6 days. Pre-flare phenomena occurring within 2 hours prior to a flare were given little attention unless different from the parameters analyzed under a previous contractual study entitled "Flare-associated Filament Phenomena", (Ramsey and Smith, 1965).

Rather than yielding single parameters, which suggest a possible relation to flares, this survey has yielded groups of parameters better described as situations. These possible flare-productive situations are:

1. A pronounced increase in the sporadic changes in a filament one or more days prior to a major flare.

2. A new region forming near or in the midst of an old one or the slow interaction of two regions closely adjacent.

3. Two sunspots close together or multiple umbra in a single penumbra adjacent to or obscured by plage; notable absence of a clearly defined filament but evidence of a magnetic neutral line

provided by the existence of a dark lane, surges, or subflares.

4. The appearance of rapidly changing short-lived absorption features prior to or associated with flares.

The following sections of this report describe the information that we have collected to date about each of these flare productive situations. Examples of each are illustrated from recent high resolution observations obtained during 1965 and 1966.

Section 2

CHANGES IN FILAMENTS PRECEDING MAJOR FLARES

2.1 Long Period Changes

Figure 1 is an excellent example of a characteristic long period (hours-days) filament change preceding the production of several major flares in an active center.

The east limb passage of this region (12 Sept. 1966, Figure 1) displays the characteristics common to a moderately active region. The plage appears as an area of raised and brightened chromosphere from which frequent small surges emanate; some of flare intensity. This plage frequently displays a low, bright, anvil-shaped prominence, varying rapidly in shape and intensity, with surges and surge-like ejecta occurring in the direction of a higher prominence. Frequently down-flowing streamers (half-loops) are visible, probably descending into sunspot umbrae.

Solar rotation brings the region onto the visible disk by 13 Sept. The high prominence seen on the limb on the previous day now appears as a large dark filament extending outward from the active center. In the brightest plage area near the visible spot there is a narrow crescent-shaped filament. This feature has no permanent visible limb counter-part as does the other filament. Apparently it is predominently chromospheric in height. Its crescent shape is analogous to an eyebrow partially encircling the sunspot with a preference for the north and west side.

In successive frames of Figure 1 both extremities of the crescent are seen leading into a larger, less sharply defined filament away from the active center. The crescent displays frequent changes in visibility and continuity, associated with small flares. Although no observations in the wings of H-alpha were obtained for this event, crescent changes of this type are typically more readily observable in either wing of H-alpha. Most flares occur on the concave side of the crescent. The larger sub-flares produce transient moving emission which travels the length of the large filament and return along the same path. In a period of four days, sub-flare activity increases, and the crescent-shaped filament progressively becomes more sharply defined, increases in darkness, and more completely encircles the visible spot.

The first major flare in this region on 16 Sept. (Figure 1) is typically preceded by a pronounced darkening, transition to emission, and short-lived disappearance of the crescent preceeding and accompanying the flare. The initial proximity of the crescent to the visible sunspot and its narrow, sharp boundaries indicate high longitudinal magnetic field gradients. As subsequent major flares occur (17-20 Sept.) the dark crescent migrates away from the sunspot, becoming less visible, less sharply defined, more serated. The early major flares are generally more energetic, than those following. As the major flares decrease and become less energetic, the subflares continue but decrease in size and frequency. Before the region reaches the west limb, the visible dark crescent-shaped filament is completely gone, and there is almost no flare activity. Only the visible sunspot and diffuse residual plage remain.

Figure 2 illustrates an example of the formation of a filament which is later associated with at least one major flare and several sub-flares. On 23 Aug. 1966 (Figure 2) two distinct active centers are

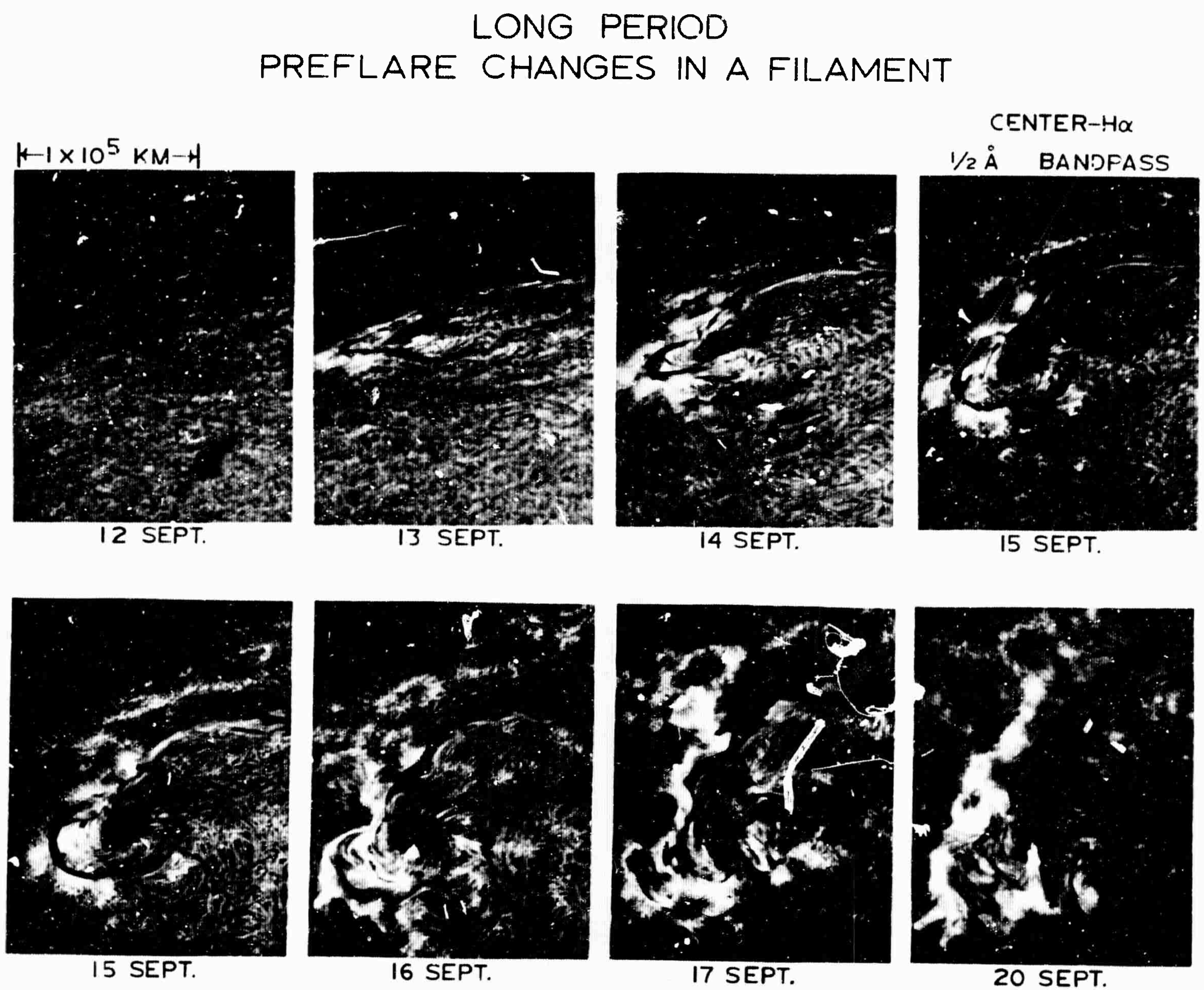


Figure 1. Prior to the Major Flares on 16 and 20 Sept. 1966, the Crescent-shaped Filament is Observed to Increase in Darkness, Become More Sharply Defined, and More Completely Encircle the Visible Sunspot.

seen near the east limb. On 24 Aug. and 25 Aug, these two active centers are seen to have appreciably increased in area. Apparently the boundaries between the regions meet on the 24th of August at which time faint, flowing emission is occasionally observed between the regions along the mutual boundary. Strands of absorption also form, change, and disappear along the boundary. Visually, there appears to be very little difference between the flowing emission and the changing strands of absorption. A flow of emission is usually accompanied by a short-lived protrusion of absorption. Similarly a strand of absorption frequently appears to make a transition to emission and occasionally returns to the absorption state again without completely losing its identity as a feature. By the morning of 26 August (Frame 3, Figure 2) a definite filament has formed from the strands of absorption. Faint emission is still frequently observed flowing along the path of the filament. At this stage, however, the flow of emission is initiated by subflares occurring near the end of the filament. This subflaring and consequent flow of emission sporadically occurs up to and after the first major flare in this location at approximately 1800 U.T. on the 26 of August. By 1615 on the morning of 26 Aug., the filament has already reached the intense darkened active stage indicative of a flare at least within several hours to several days. Around 17:45 U.T. the filament begins to exhibit the classic short period pattern of changes leading up to the disappearance of the filament during the flare.

2.2 Short Period Changes

Figure 3 illustrates in relatively high resolution pictures ($<$ 1 sec of arc) the pattern of short period preflare changes in a filament as seen in center H-alpha observations prior to some flares. We have previously described these changes as:

1. Increased darkening of a filament . . . . .Frame 1
2. Occurrence of a subflare or preflare . . . . .Frame 2

FORMATION AND DISSOLUTION OF A FILAMENT

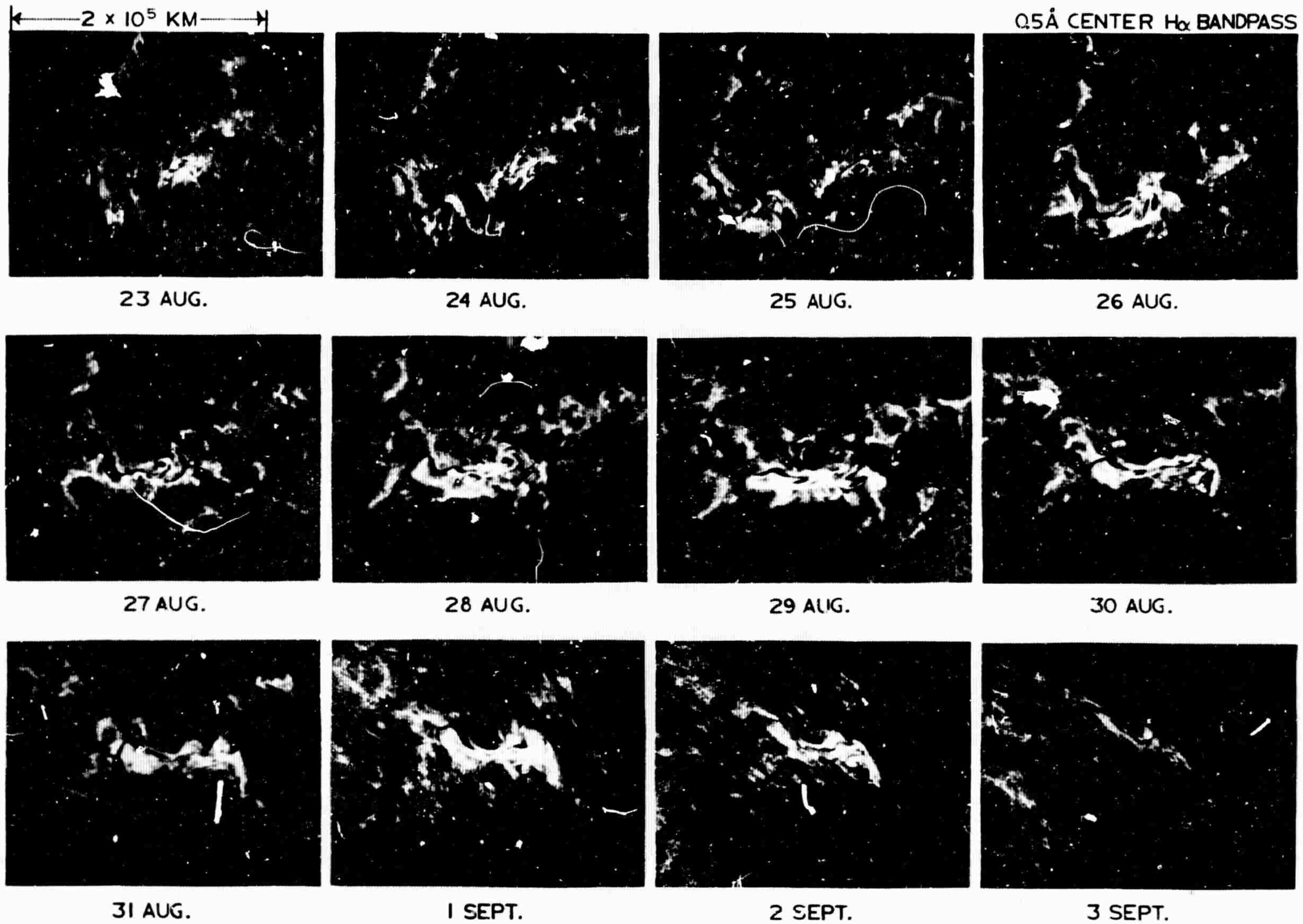


Figure 2. A Filament is Observed in the Process of Formation on 24 and 25 Aug. 1966 Between the Two Active Centers Initially Observed on 23 Aug. Accompanying a Major Flare (Figure 3 - Each Frame Rotated 180°) The Filament Disappears and a New Filament Forms. With the Subsequent Decay of the Active Region on the Right, the New Filament Gradually Dissipates Until it is no Longer Visible on 31 Aug.

3. Expansion of the filament (barely detectable) . . . . . Frame 2
4. Break-up of the filament . . . . Between Frames 2 and 3
5. Transition to emission . . . . Frame 4
6. Ejecta from the filament (in emission) . . . . Frame 4
7. Complete dissolution of the filament . Between Frames 4 and 5
8. Appearance of absorption at a new location . . . . . . Frame 5
9. Formation of a new filament . . . . Frames 5 and 6

While time lapse films of increased resolution reveal the detailed structure of the flare-associated filament disappearance much more clearly, the overall pattern for center H-alpha observations is essentially the same as for observations of lower resolution (Ramsey and Smith, 1965). Center H-alpha observations offer little or no warning of the exact time of occurrence of a flare. Even with moderately high resolution observations, the red and blue wings, as well as center H-alpha are essential if these short period changes in filaments are to be useful factors in the prediction of some flares.

Flare prediction has two facets: the prediction in time and the prediction in space.

The utility of center H-alpha high resolution observations in flare prediction is in enabling one to locate the positions where flares can be anticipated in the active centers. Section 4 of this report summarizes some information essential to the prediction of the location of flares from H-alpha observations.

A FLARE-ASSOCIATED FILAMENT DISAPPEARANCE

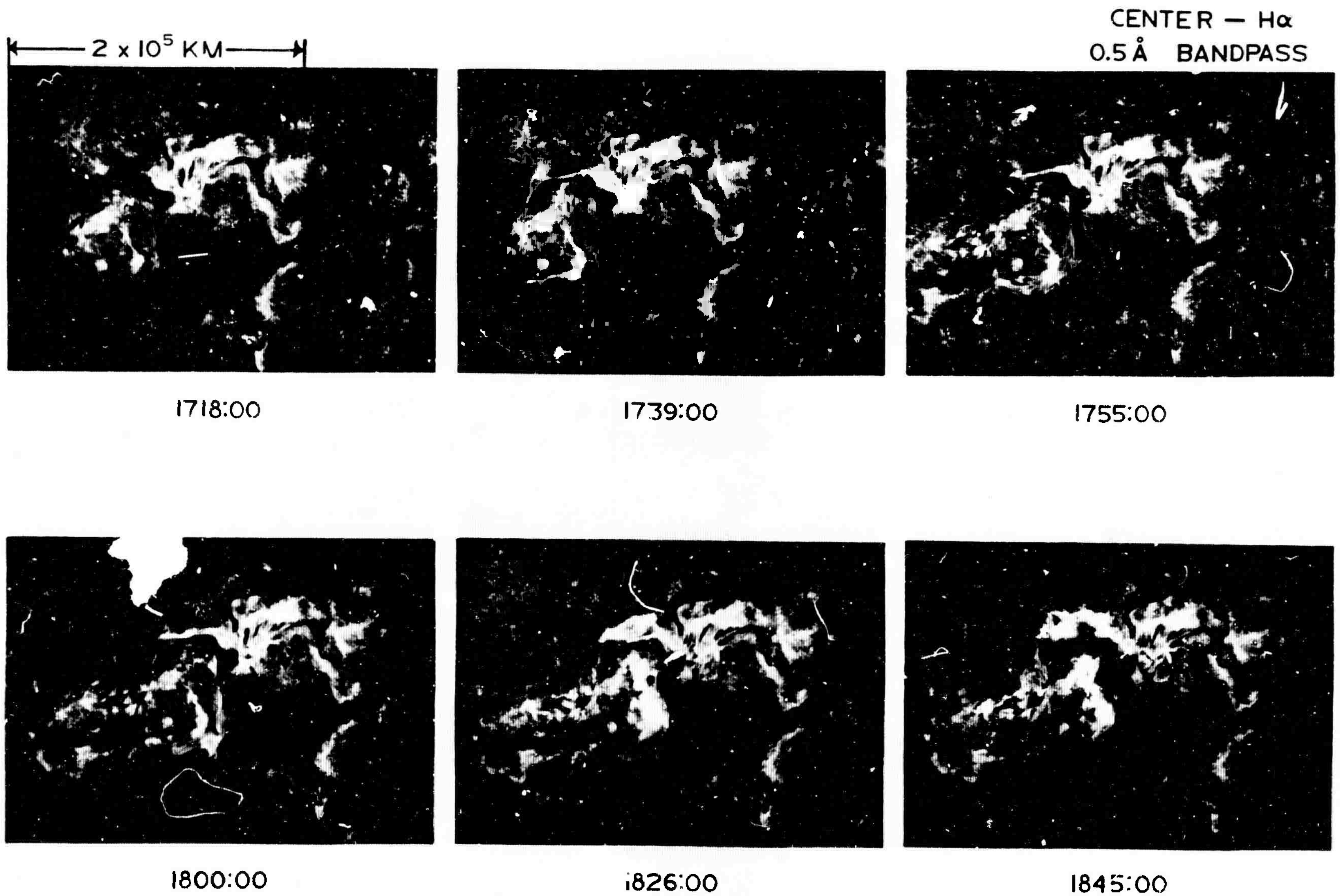


Figure 3. A Classic Example of the Disappearance of a Filament Accompanying a Flare Observed in the Center of H-alpha.

Section 3

A RELATIONSHIP OF PLAGE COMPLEXITY TO MAJOR FLARES

One of the possible flare-productive situations being studied involves the interaction of two or more plages. This situation may occur either when a new plage forms near or in the midst of an older plage or when two adjacent regions expand toward each other as a normal result of the development of each plage. Figures 2 and 3 present an example of the latter situation.

As an aid in studying these situations, simple charts were constructed showing the evolution of the plages listing the McMath-Hulbert plage numbers assigned to each disk passage of the plages. These numbers were extracted from Solar-Geophysical Data published by the National Bureau of Standards. Two of these plage evolution charts are shown in Diagram 1 to illustrate the difference between a simple plage and a complex plage system. Such charts were constructed for all plages first appearing on the sun between August 1959 and December 1962 and which had identifiable lifetimes of at least three solar rotations. Each asterisk on the charts in Diagram 1 symbolizes a major flare which occurred in the plage during the disk passage denoted by the adjacent number. Underlining indicates that the plage was new or partly new. Arrows show that two or more plages were identified in approximately the same location where only one was identified on the previous solar rotation.

The plage charts were divided into two groups: those in which major flares occurred between 15 and 05 hours U.T. and those in which no major flares ($\geq$ importance 2) occurred during these hours. Each of these groups were then subdivided into three categories: complex plage systems, moderately complex plage systems and simple plages. A count of the number of major flares (15 - 05 hours U.T.) is shown for each sub group in Table 1 below. Plages with major flares reported only between 05 and 15 hours U.T. are omitted because of the inhomogeneity of flare reports during these hours as compared to the reports between 15 and 05 hours U.T. (Dodson and Hedeman, 1960).

TABLE 1

PLAGES WITH LIFETIMES $\gtrsim$ 3 SOLAR ROTATIONS, NEW AFTER AUG. 1959 AND BEFORE JAN. 1963, AND HAVING MAJOR FLARES OR NO MAJOR FLARES BETWEEN 15 AND 05 HOURS U. T.

Plage Category	No Major Flares 15-05 Hr.U.T.	Major Flares 15-05 Hr.U.T.	
	No. of Plage Systems	No. of Plage Systems	No. of Flares
Simple	17	22	79
Mod. Complex	2	6	9
Complex	2	19	66

For the group associated with major flares the number of simple and complex plage systems are approximately equal. For the group with no major flares, however, there is a striking absence of complex or even moderately complex systems.

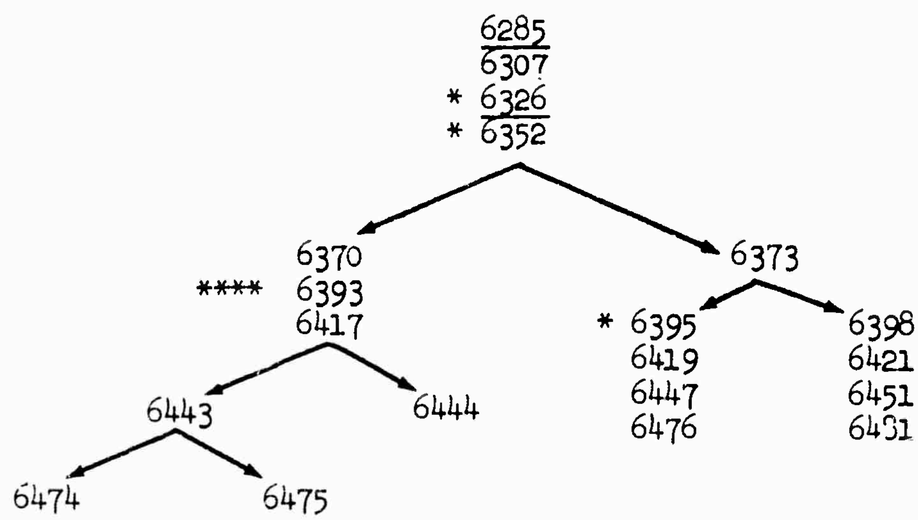
Considering only plages which are major flare producers, it is also evident in Table 1 that the complex systems produce about the same number of flares per plage system as do the simple plages. Thus, the frequency of flaring per plage system is not significantly greater for the complex systems defined here.

DIAGRAM 1

SIMPLE PLAGE

6062
6082
* 6104
6133
6156

COMPLEX PLAGE SYSTEM



KEY: 1111(4 digits) McMath-Hulbert plage numbers from Solar-Geophysical Data published by N.B.S.(new numbers assigned each solar rotation).

* (asterisks) Number of major flares in plage during each rotation.

_____(underline) With no number directly above, plage is new
With a number directly above, plage is partly new.

(arrows) Two plages identified in approximately the same location where only one was identified on the previous rotation.

NOTE: As stated in Solar-Geophysical Data, the plage identifications are considered tentative - subject to re-identification upon further study of the data.

It is clear that the complex plage systems almost invariably result in one or ore major flares, the average being greater than 3 major flares per complex plage system. Complex systems are mostly due to the development of new plage in the midst of older plage. Since this is a difficult parameter to record, especially near plage which has not weakened appreciably, the data cannot be expected to be completely consistent. However, the data do suggest the possibility that the occurrence of major flares may be related to the relative growth or merging of new and old plage. Further evidence of this flare-plage relationship is presented in the Lockheed final report "Solar Magnetic Fields", Smith and Ramsey (1967). 15 of the 24 largest major flare producing active centers observed since Aug. 1959 were cases in which 2 or more plages appeared to interact because of their close proximity.

Section 4

H-ALPHA EVIDENCE FOR LOCATIONS OF POLARITY CHANGE IN ACTIVE CENTERS

It was first shown by Babcock and Babcock (1955) that filaments outside of active centers coincide with lines where the longitudinal component of the photospheric magnetic field is 0. These locations are often referred to as neutral lines, defining the change from positive to negative polarity in a magnetic field. That this relationship between filaments and neutral lines in photospheric fields also exists in active centers was shown by Howard (1959), Howard and Harvey (1964), and further corraborated by Smith and Howard (1965).

Because of the frequent occurrence of flares developing in segments on either side of an activated filament, it was obvious to many solar observers that at least some flares occurred in segments centered around lines marking the change in polarity in active centers. However, since only a fraction of flares are associated with filaments, it was not known definitely that major flares almost invariably occur immediately adjacent to the line of polarity change until a study of flare positions relative to photospheric magnetic fields was reported by Smith and Howard (1965).

More precise relationships between H-alpha structures, flares, and magnetic field configurations were demonstrated from higher quality observations by Howard and Harvey (1964) and Smith and Ramsey (1967). Since these papers describe only a few observations, a lot of work remains to be done in the detailed correlation of magnetic fields with flares and other chromospheric features. Progress in this area largely awaits technical developments which will permit obtaining magnetograms of higher time and spatial resolution.

Based on the studies mentioned, however, it is possible to derive some day to day information about the configuration of the magnetic field of an active center from H-alpha observations alone. Using Figures 4, 5, and 6, we suggest how this can be done with high resolution observations, assuming the following statements to be true:

1. The path of a filament marks the division between an area of positive and negative polarity.

2. A series of fibrils sometimes bridge a division between polarities in the center of a strong plage.

3. Bright plage generally does not cross the division between polarities.

4. The initial position of the segments of a flare tend to occur adjacent to but not coincident with the polarity division.

5. The region has a normal basic bipolar configuration, for the hemisphere and solar cycle in which it appears. For example in normal regions in the northern hemisphere in solar cycle 20, the leading or western polarity will be negative and the following or eastern polarity will be positive. Regions having a reversed polarity configuration are relatively rare (Smith and Ramsey, 196,

In Figure 4, an active center observed on the 19th, 20th, and 21st of July 1966 is presented as an example of what appears to be a simple bipolar region is the southern hemisphere. In a simple bipolar region there is only one line running in approximately a north-south direction which separates the opposite polarities. The dark lane in this region separating the two areas of bright plage in between the two sunspots marks the division between the western or positive polarity and the eastern or negative polarity. The dark lane is partially resolved into a series of dark fibrils each of which extends from the western to the eastern area of bright plage. The division between polarities is marked at the south of the region by segments of a filament which appear to terminate in the dark lane.

As the region develops between the 19th and 21st of July, the separation between the two halves of the bright plage increases due to the effect of projection and the aging of the plage. As the region ages, the sunspot on the left is replaced by an increased area of bright plage.

Figure 5 shows an active center observed on 6 July 1965 which is also basically a simple bipolar region. However, this active center appeared in the midst of older plage and in this case the division between polarities is approximately horseshoe-shap with the ends pointing to the right of the region. The fibrils in the center of the region cross the line of polarity change. The filaments extending to the right above and below these fibrils follow the remainder of the line of polarity change out of the region. All plage left of the fibrils is negative in polarity and the plage to the right of the fibrils and in between the filaments is positive in polarity. In Frame 2 of Figure 5 the flare is seen adjacent to the described line of polarity change but not crossing it. By comparing the sunspots in this active center (Frame 3, Figure 5) with the H-alpha images, it is easy to determine the polarity of almost every spot without having access to magnetic field measurments. However, in this case, magnetic field measurements were available. The magnetograms corresponding to this plage appear in "Solar Magnetic Fields," Smith and Ramsey, 1967.

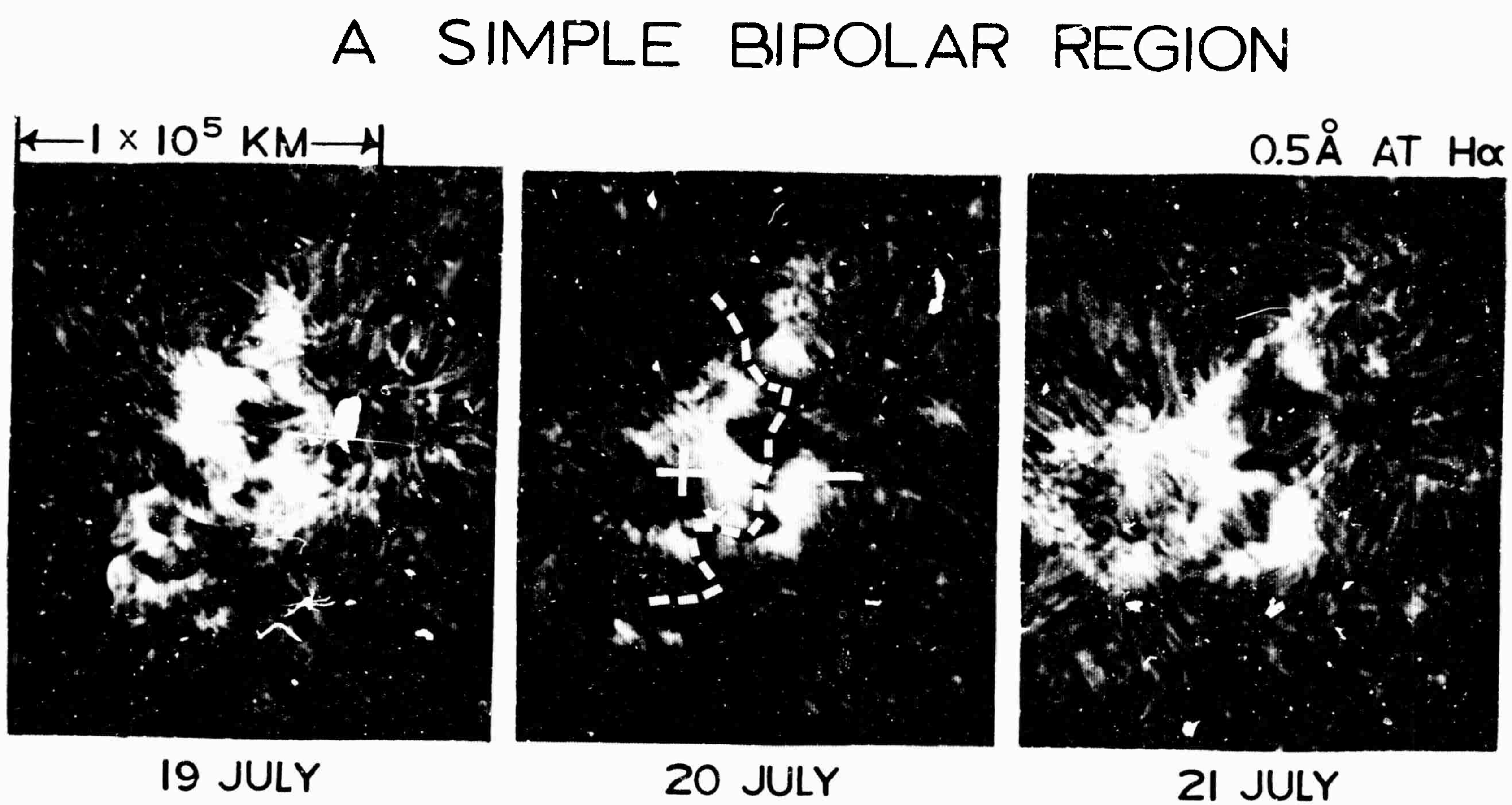


Figure 4. The Fibrils Between the Two Areas of Bright Plage are Assumed to Bisect the Imaginary Line Dividing the Polarities in this Region. Since this is a Southern Hemisphere Region, the Areas of Plage Left and Right of these Fibrils are Thought to be Negative and Positive Respectively.

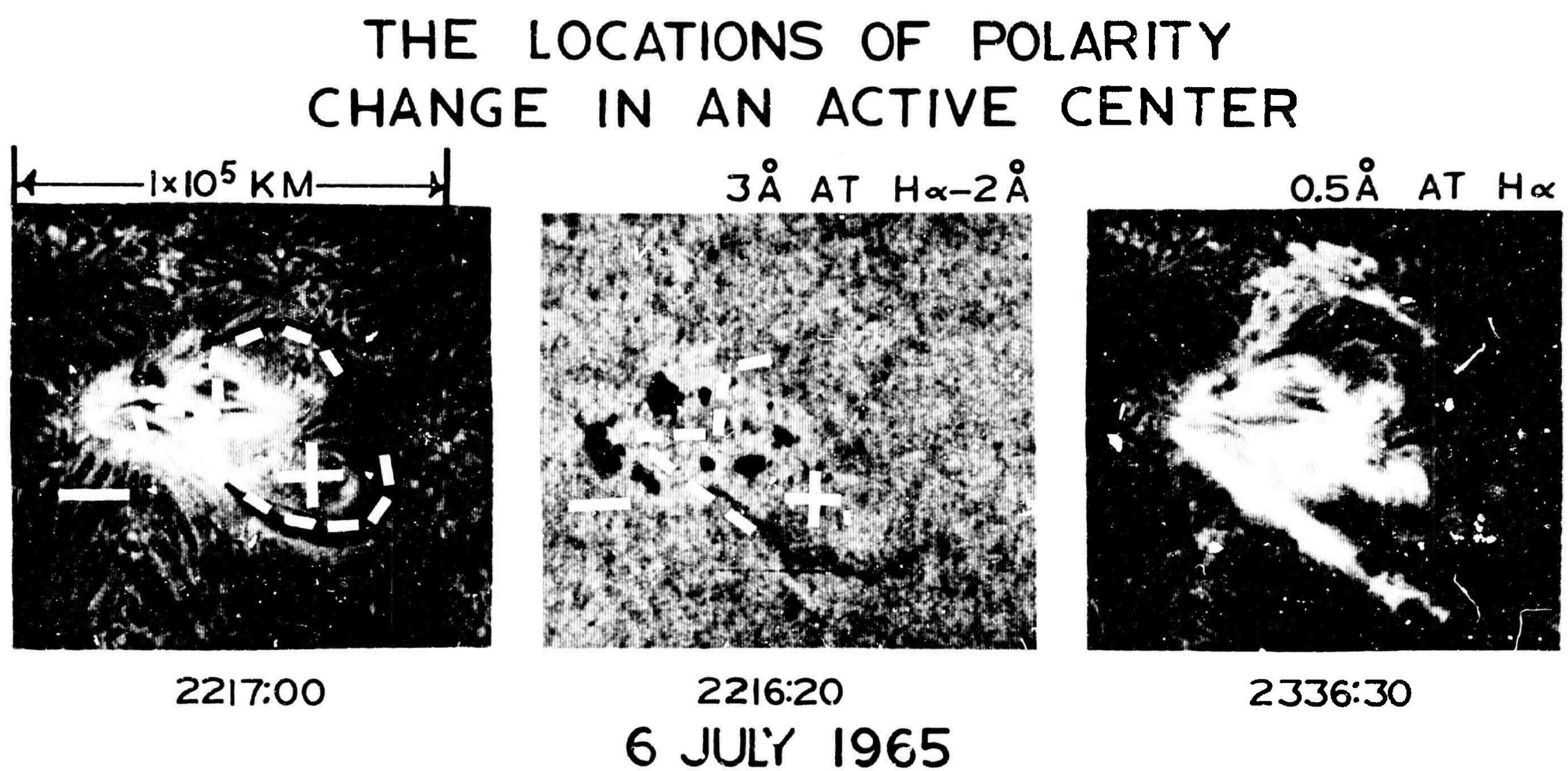


Figure 5. An Active Center Observed on 6 July 1965 with the Configuration of its Largest Flare and its Sunspot Configuration Shown. The White Dashed Line Follows the Line of Polarity Changes Across Fibrils and Along Filaments. In This Case the Polarity of Every Sunspot Could be Determined From the H-alpha Observations.

The position of polarity change in an active center is not always as clearly defined by H-alpha structures as in these two examples. In Figure 2, two active centers are seen to have grown relatively close together. In this situation, there must be at least 3 lines separating areas of opposite polarity: one in each active center and one between the two active centers. An enlargement of this plage configuration on 25 August is shown in Figure 6. The estimated position of the division between polarities is shown with white dashed lines running along filaments, across fibrils and in between bright plage.

The flare shown in Figure 3 develops on both sides of the filament between the two active centers shown in Figures 2 and 6. Without the presence of two active centers, the polarity division represented by the filament would not have formed at precisely this location and it would have been highly improbable that this flare could have occurred. Thus, the adjacency of these two strong active centers was a necessary, if not sufficient, condition for the production of this flare.

Frames 8 and 9 of Figure 2 are an excellent example of a flare-productive situation where two sunspots are very closely spaced and partially obscured by plage. One of the subflares occurring at this location appears in the previous or 7th frame of Figure 2. The close spacing of the two sunspots and their obscuration by plage indicates that these spots are of opposite polarity. The polarity division is marked only by a very narrow filament-like structure. This is one of the few situations in which there is very little or no gap between plage areas of opposite polarity.

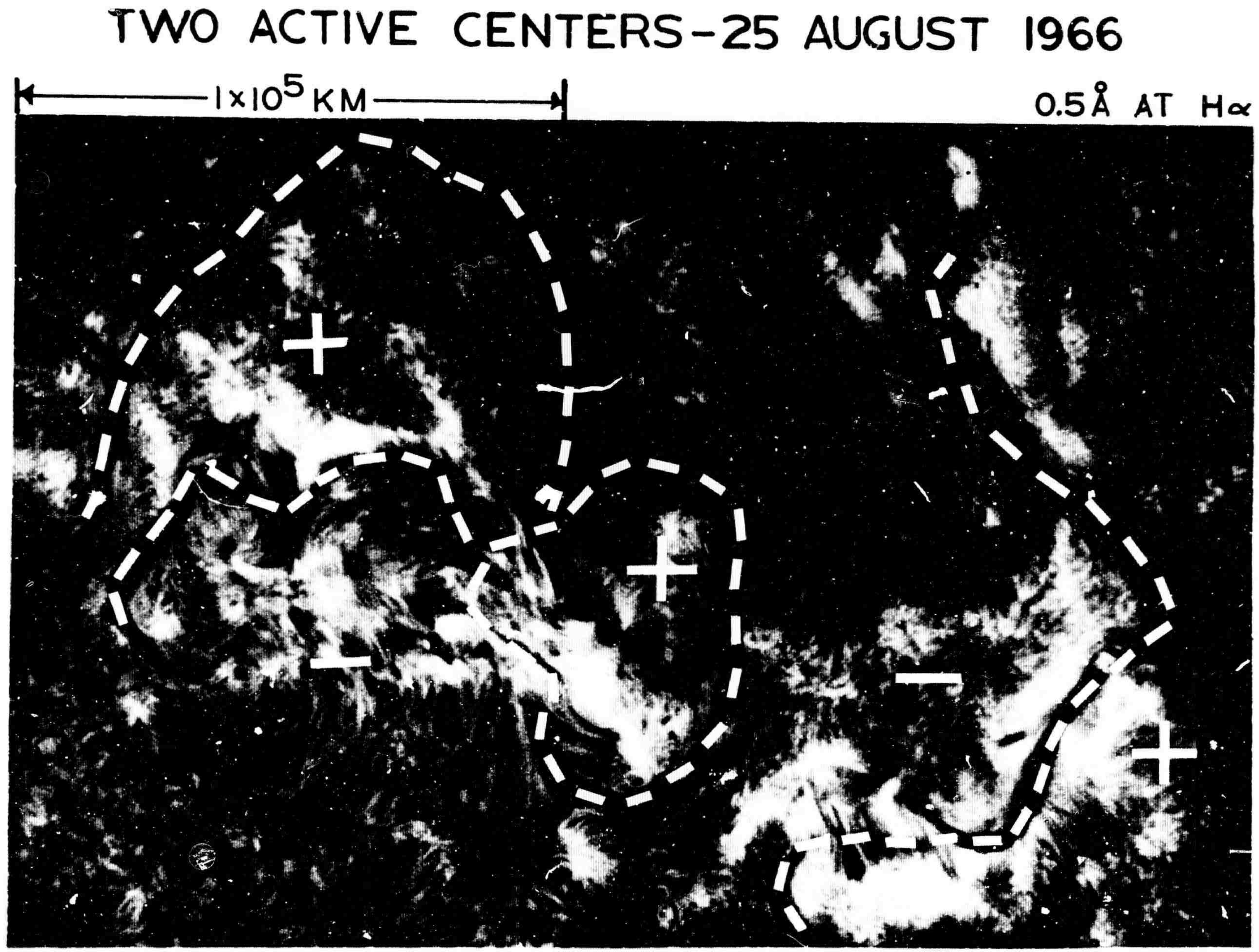


Figure 6. The Estimated Positions of Polarity Change for This Set of Two Active Centers is Shown by the White Dashed Lines Running Along Filaments, Across Fibrils and Between Bright Plage.

Section 5

A FLUTTERING ACTION ASSOCIATED WITH FLARES

On 21 March 1966 blue wing H-alpha time lapse observations revealed a type of flare-associated phenomenon which, as far as is known to us, has not been previously described in the literature.
It appeared to be a consecutive series of expanding arches, both in absorption and emission, rapidly appearing and disappearing above a flare. The rapidity of the event is apparent in Figure 7 although the faint emission is not visible in a frame to frame display. When the observations taken at 20 second intervals are projected at a rate of 16 frames per second or faster, the visual effect is a rapid fluttering of the arches between absorption and emission as the whole succession of arches expands slowly outward. The phenomena lasts for 35 minutes.

A survey of the Lockheed high resolution films obtained during irregular intervals in 1965 and 1966, has revealed 4 additional flare associated events which may be the same kind of fluttering action. Because of slight differences in appearance in each of the events and differences in the type of photographic observations, each event is described separately. The last part of this section discusses the possible interpretations and generalizations which can be made about this type of event from so few observations. Throughout this section the type of flare-associated event, which is the main subject of interest, will be referred to as the "flutter" or the "fluttering action".

The Observations

21 MARCH 1966 - 2212 U.T.

Types of Observations

1. Center H-alpha, 1/2 Å bandpass, 16mm image, 4 frames per min.

2. Blue wing H-alpha (H-alpha - 0.5Å), 1/2 Å bandpass, 16mm image, 3 frames per min.

3. Red wing H-alpha (H-alpha + 0.5 Å), 1/2 Å bandpass, flare patrol, images from the Sacramento Peak Observatory, 1 frame per min.

4. Blue and red wing H-alpha (H-alpha + ~ .75 Å and H-alpha - ~ .75 Å combined), ~ 3/4 Å bandpass each wing, 17mm flare patrol images from the Sacramento Peak Observatory, 1 frame per min.

1. Center H-alpha

A flare-surge event starts at 2212 U.T. At approximately 2232 faint waves of emission appear to be ejected into the corona from the area of the surge, but in a direction perpendicular to its trajectory. After the faint waves of emission have ceased, a flare is seen to be in progress in the chromosphere below the location of the faint emission. Extensive brightening of the chromosphere is seen west of the main bright segments of the flare from 2236 to about 2330.

2. Blue wing H-alpha

The surge in the flare-surge combination beginning at 2212 U.T. is both darker and larger than in the center H-alpha observations. At 2217 a consecutive series of dark and bright arches appear at the same location that the faint waves of emission are seen in center H-alpha. A slow outward expansion perpendicular to the trajectory of the surge is apparent. The fluttering arches cease at 2252 with the

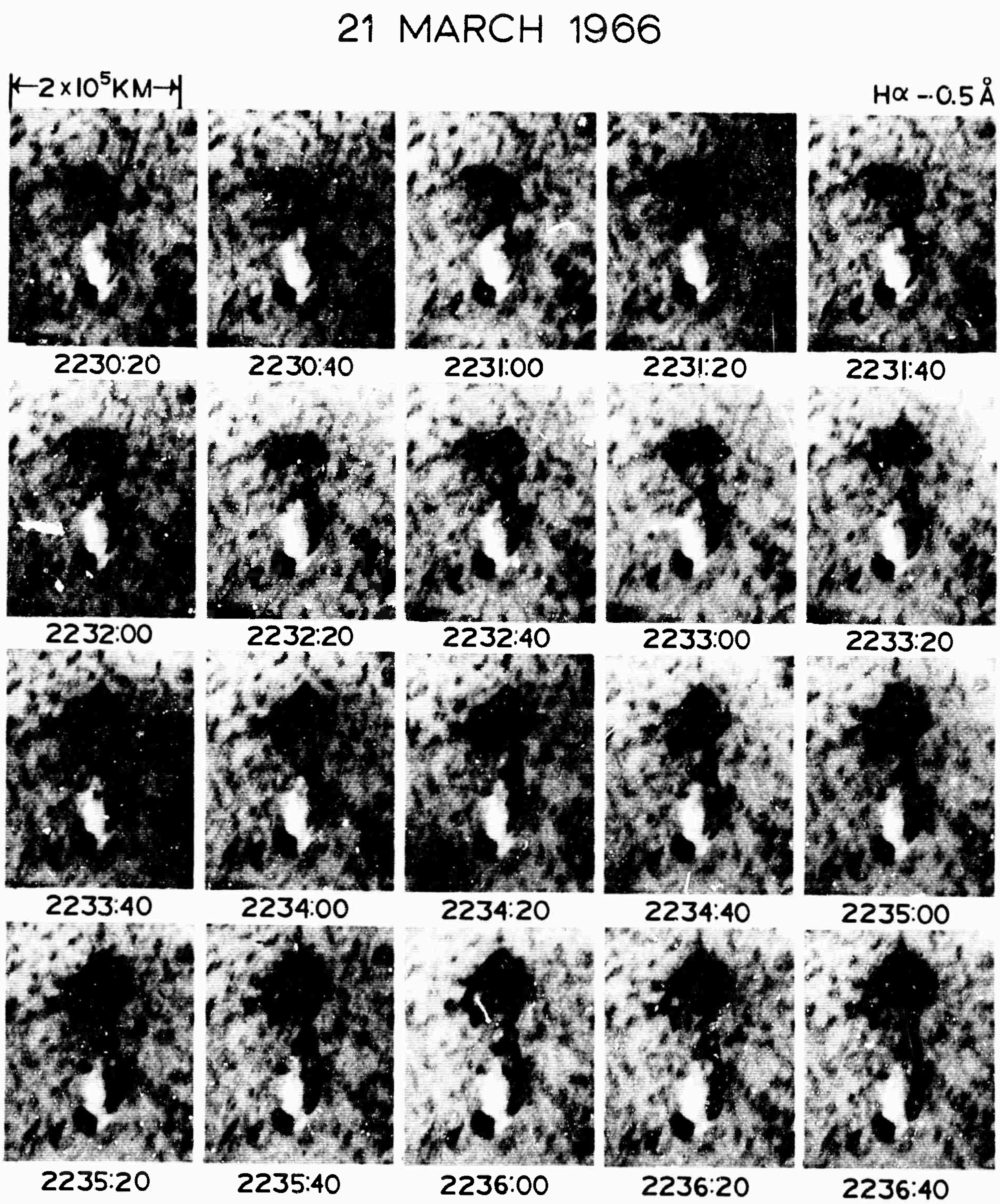


Figure 7. Extremely Rapid Changes Referred to as "Flutter" are Visible in the Short-lived Arcs of Absorption Close to the Sunspot. Less Rapid Changes Occur in the Absorption at the Top of Each Frame Which Later Evolves into a Complex Surge.

ejection of material faintly visible to the west of the flare. The extensive brightening of the chromosphere observed in center H-alpha is not seen. Only the bright main flare segments are visible.

3. Red wing H-alpha (Sacramento Peak Observatory Film)

Red wing observations were begun at 2230, 18 minutes after the start of the flare-surge combination. The arches of absorption material are present but not as visible as in the blue wing. The arches are most apparent at the ends close to a sunspot. These observations are suggestive of material pouring down into the sunspot. However, this point cannot be conclusively established. The action ceases at 2253 almost simultaneously with the end of the fluttering action seen in the blue wing.

4. Combination, red and blue wings of H-alpha (Sacremento Peak Observatory Film)

At a rate of 1 frame per minute, these observations were begun at 2246. The flare does not show until 2254 U.T. and lasts until at least 2330 when these observations were discontinued for the day. The flare is detectable only with difficulty. The nature of the blue wing fluttering action is not clear from this short sequence of observations.

<u>6 JULY 1965 - 2306 U. T.</u>

Types of Observations

1. Center H-alpha, 1/2 Å bandpass, ~ 75mm image, 2 frames per min.
2. Blue wing H-alpha, 3 Å bandpass, ~ 75mm image, 3 frames per min.
3. Center H-alpha, 1/2 Å bandpass, ~ 16mm image, 2 frames per min.

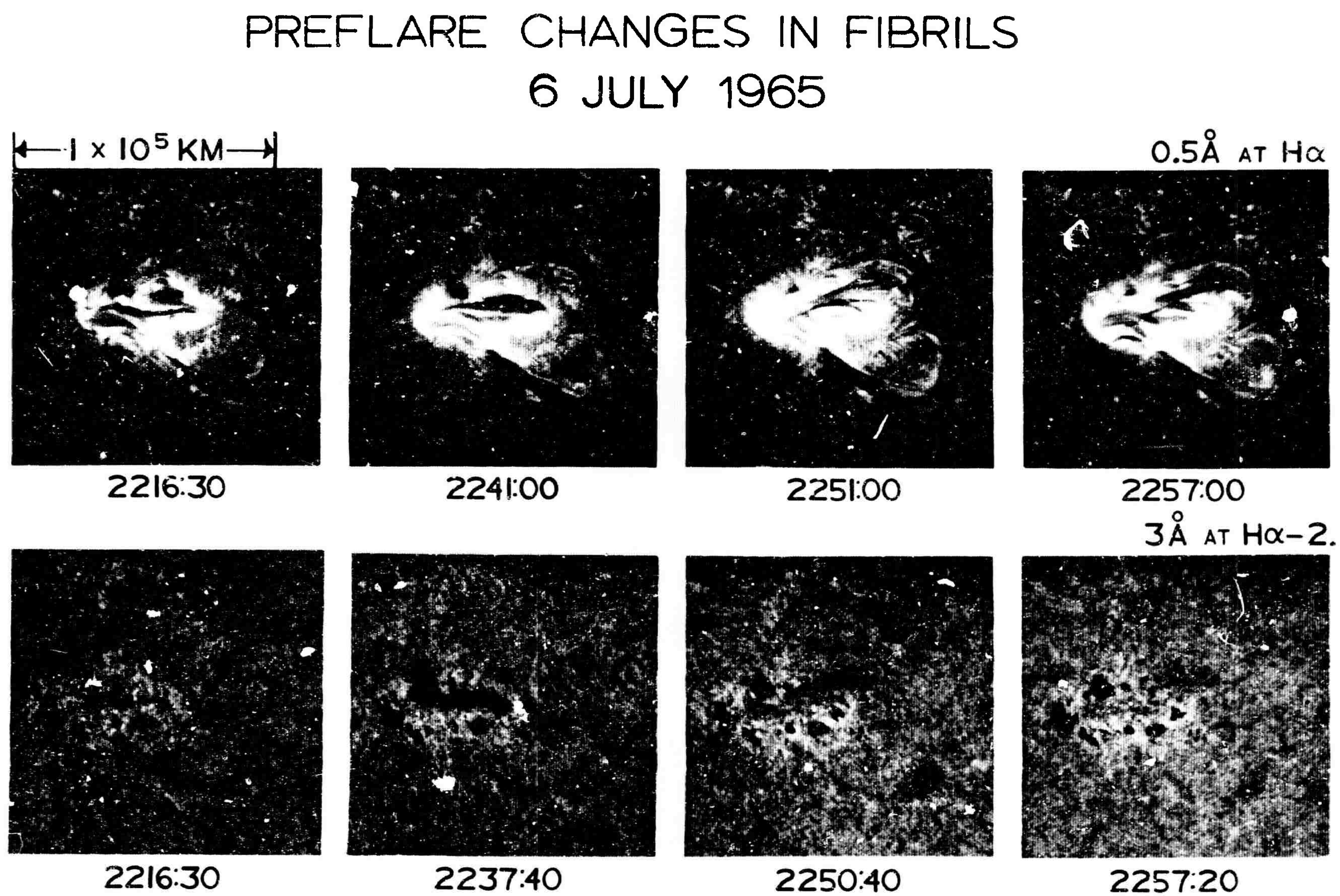


Figure 8. The Fibrils in the Center of the Bright Plage Exhibit Rapid Preflare Motion and Changes in Density Which are Visible in Both the Narrow Band (1/2 Å) and Broad Band (3 Å) H-alpha Pictures. The Fibrils Surrounding the Plage Remain Unaffected.

1. Center H-alpha, large-scale image

Twenty-eight minutes prior to the start of an importance 1 flare at 2306 U.T., several fibrils in the center of this active region show a definite increase in darkness and therefore visibility, (Frames 1-4, Figure 8). Each fibril remains visible after the darkening from less than one to seven minutes. Several new fibrils appear in succession and undergo the same darkening and diminishing to that the whole fluttering action takes place in twenty-four minutes. There was only a four minute delay between the end of this action of the fibrils and the onset of the flare. Fibril structures at this location remain visible during the flare (Figure 5).

2. Blue wing, broad-band H-alpha

Thirty-nine minutes before the start of the flare at 2306, a dark absorption feature appears, apparently due to Doppler shift. Several of these absorption features appear in succession (Frames 5-8, Figure 8). The position, appearance, and motion is similar to that of the fibrils observed in the center of H-alpha and is therefore assumed to be the same phenomena. A striking feature is that the earliest appearing fibril was observed before the fibrils appeared to darken in the center of H-alpha.

3. Center H-alpha, small-scale image

From 2230 to 2246 a faint dark surge appears to come out of the region. From 2238 to 2246, a second more visible dark surge comes out of the center of the region but in a different direction. Fibrils are not resolved in the observations. The surges are apparently the same fibrils which show the fluttering action in the higher resolution observations.

<u>1 JULY 1965 - 2030 U. T.</u>

Types of Observations

1. Center H-alpha, 1/2 Å bandpass, ~ 75mm image, 2 frames per min.

2. Blue wing H-alpha, 3 Å bandpass, ~ 75mm image, 3 frames per min.

3. Center H-alpha, 1/2 Å bandpass, ~ 16mm image, 2 frames per min.

1. Center H-alpha, large-scale image.

Eight minutes before a tiny subflare a few of the fibrils in a two day old region appear to rapidly flutter as if a disturbance passed through them. A temporary darkening of several almost parallel fibrils is seen. The action resembles that of the fluttering fibrils observed on 6 July except that the fibrils remain intact and visible. The tiny subflare appears before the fluttering action has terminated. While the subflare is still in progress the fibrils in an adjacent area appear to be disturbed and produce the same kind of fluttering action. Seventeen minutes after the start of the second fluttering action, another subflare appears close to the ends of the disturbed fibrils. The second fluttering action continues for thirty-five minutes.

2. Blue wing, broad band H-alpha

As in the 6 July 1965 event, little arches or lines of absorption successively appear and disappear at almost the same time and place as the fibril motion is seen in the center H-alpha, large-scale film. In this case also the flutter is clearly a preflare phenomena.

3. Center H-alpha

New regions characteristically show numerous subflares and shortlived absorption features. On these seventeen millimeter images the fibrils are not resolved and the fluttering action is not recognizable as a distinct event different from the normal activity of the region.

4 SEPTEMBER 1966 - 1745 U.T.

Types of Observations

1. Center H-alpha, 1/2 Å bandpass, ~ 75mm image, 4 frames per min.

2. Center H-alpha, 1/2 Å bandpass, ~ 16mm image, 2 frames per min.

1. Center H-alpha, larg -scale image

The region in which this fluttering action occurs is approximately thirty-six degrees from the west limb of the sun. A series of arches appear at 1657 with each successive arch having a slightly increased height relative to the previous ones. The action is complete twenty-two minutes later when all of the arches disappear. A small brightening along the base of the arches persists throughout the fluttering action. After a twenty-six minute delay, the area previously occupied by the arches and brightened chromosphere becomes a definite bright subflare with an arch of emission outlining the location previously occupied by the absorption arches. The flare ends at 1800.

2. Center H-alpha, small-scale image

A single small arch of absorption noticeably darkens at 1615, fluctuates slightly in intensity, and fades out of sight at 1705. A low intensity brightening is visible from 1658 to 1737. The first point of the bright subflare is visible at 1745. An arch of emission having the same shape as the previous arch of absorption appears at 1750.

22 JULY 1966 - 2043 U. T.

Types of Observations

1. Center H-alpha, 1/2 Å bandpass, ~ 75mm image, 4 frames per min.
2. Center H-alpha, 1/2 Å bandpass, ~ 16mm image, 2 frames per min.
3. H-alpha Limb System, 12 Å bandpass, ~ 18mm image, 2 frames per min.

1. Center H-alpha, large scale

At 2043 U.T. a bright event appears to rise above the east limb as seen in Figure 9. Pronounced changes are visible from frame to frame (15 sec) indicating unusually fast motion. There does not appear to be any organized pattern to the changes except that the event gradually extends further above the limb. The most rapid changes occur within 20,000 km of the limb. After a period of 15 minutes the event evolves into a bright surge. The rapid changes and the low height are the factors which place the early phase of this event in the same category as the flutter events observed on the disk.

2. Center H-alpha, small scale

Small but rapid changes are apparent followed by a small surge.

3. H-alpha limb system

The event appears as a common fast spray or complex surge as seen in the upper halves of the frames in Figure 9. Only two frames near the start of the event indicate any unusually rapid action in the form of a tiny ejecta.

FLUTTER EVENT ON THE LIMB
22 JULY 1966

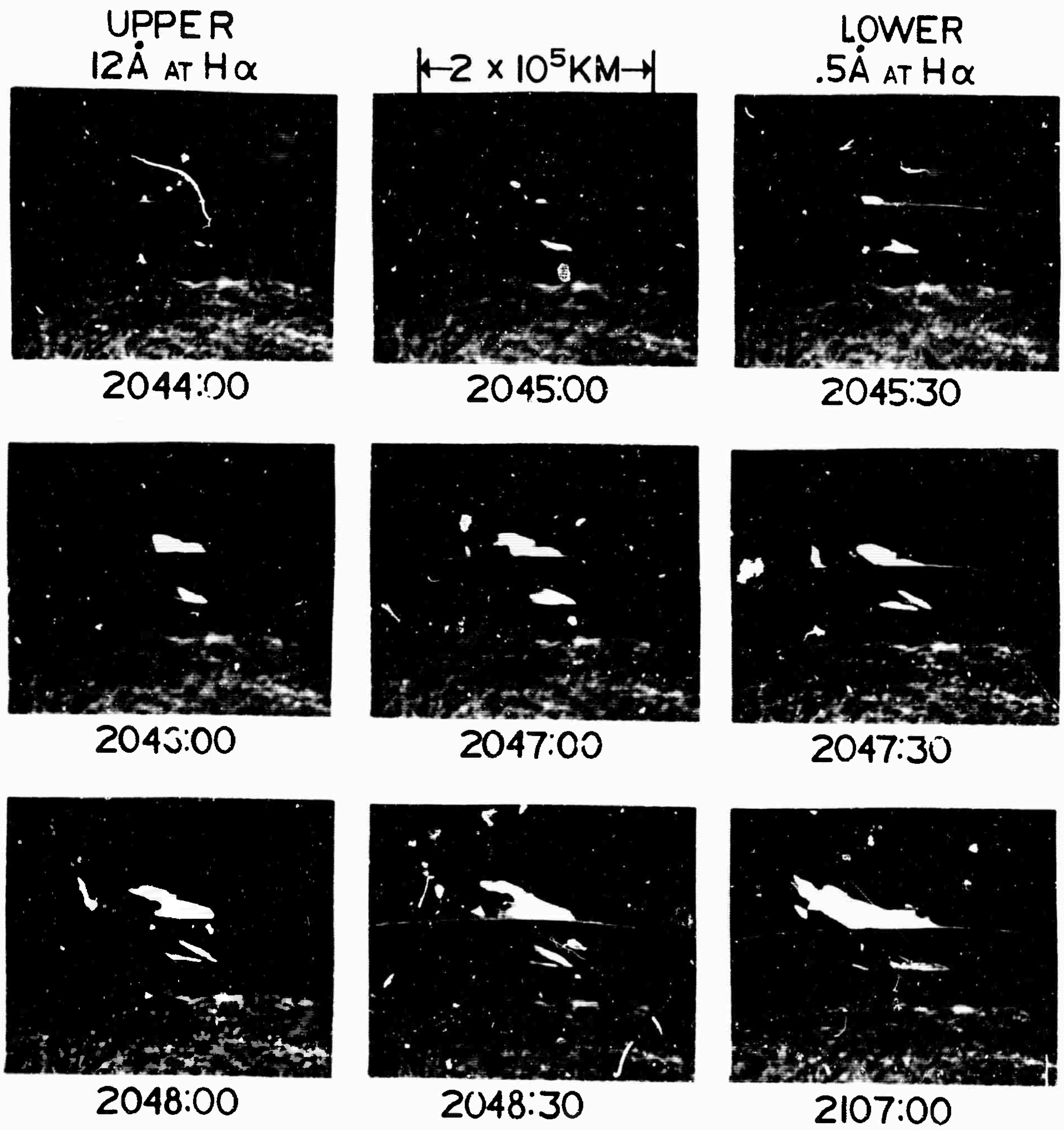


Figure 9. This Unusually Fast Event was Observed in a 1/2 Å H-alpha Disk System (Lower Presentation in Each Frame) and in a 12 Å H-alpha Prominence System (Upper Presentation). In the 1/2 Å Observations Material Appears to Simultaneously Move Toward and Away From the Disk and to One Side While Only a Complex Surge is Observed in the 12 Å System.

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Discussion

One of the most interesting characteristics of the flutter events is that in three out of the five cases described, the action is clearly a preflare phenomena beginning within one hour of the start of a flare at the same location. In another case (21 March 1966) the flutter can be interpreted as a preflare event if the flare-surge combination and the second chromospheric brightening are considered to be two separate flares. Using this interpretation, the flutter precedes the second flare by approximately nineteen minutes. In the fifth case (22 July 1966), the event occurs on the limb and is thought to be a preflare event because of the timing of the most rapid changes relative to the ensuing complex surge. This fast complex surge is a type typically associated with flares.

In the three events where blue wing observations were taken, the flutter is seen to begin before it is detectable in the center of H-alpha. The differences are appreciable - amounting to eleven minutes for the 6 July 1965 event, nine minutes for the 1 July 1965 event, and six minutes for the event on 21 March 1966.

In at least two of the events the flutter clearly appears to take place in fibril structures in the middle of an active region. The fibril structures of a region were found to follow the lines of force of the magnetic field of a region by Howard and Harvey (1964). The observed motion is perpendicular to the fibrils and therefore is assumed to amount to an expansion of the lines of force at a particular location in a region. The increased visibility of the fluttering action in the blue wing observations offers additional evidence that the process is at least partially one of outward expansion. The amounts of Doppler shift, however, cannot accurately be extracted from these observations.

In the one event on the limb, the rapid changes called "flutter" occurred during the first few minutes of a spray or complex surge. The flutter took place within 20,000 km of the limb. The rapid changes did not reveal any consistent pattern or directional characteristic and could not be adequately described as ejecta.

It is clear in these observations that no filaments were present in the vicinity of the fluttering action. However, there are several similarities between these preflare fluttering events and the well-known preflare changes in filaments. Both occur on the same time scale, occurring within an hour before a flare. Both phenomena represent a process having a component of motion radially outward from the sun. Both types of events can occur in approximately the same position with respect to flares.

There is one major observational difference between preflare changes in filaments and preflare changes in fibrils. Filaments initially appear to expand outward as a unit while fibrils rapidly appear and disappear requiring a succession of several fibrils to yield the appearance of outward expansion. We suggest that both of these phenomena may be early observational manifestations of the same type of physical process which results in flares.

Section 6

SUMMARY AND RECOMMENDATIONS

The results from two areas of this study should find immediate application is any attempt to predict flares. These areas are long period changes in filaments and the interaction of two or more plages. These types of changes do not by any means indicate precisely when a flare can be expected. They do, however, pinpoint locations in some active centers where a major flare might be anticipated.

Filaments should be monitored for increased darkening and sharpness at the edges. If a pronounced condition of increased darkening and sharpness persists over a period of one or more hours, it is likely that one or more flares will appear adjacent to the filament in a matter of several hours to several days. Additional study of long period changes in filaments, especially in the wings of H-alpha and with high resolution observations is essential if filament changes are to be used more effectively in attempts to predict the locations and approximate times of flares.

The growth of a new plage in the middle of a well-developed plage, or the interaction of two closely-spaced plages, are also indicators of the occurrence of flares. 15 of the 24 largest flare producing active centers observed since Aug. 1959 had the common characteristic of being cases in which two or more plages were interacting. In these cases the formation of new plage is synonomous with the formation of a new bipolar magnetic region (Ramsey and Smith "Final Report on Research on Solar Magnetic Fields", 1967). For a better assessment of the value of plage interaction as a tool for flare prediction, it is recommended that a statistical treatment of plage and flare data be made using original data available from the 19th and 20th solar cycles. It is not recommended that the currently available statistics on plages be used for this type of analysis. A new classification of plages needs to be made directly from the observations. Magnetic field observations should be used as an aid whenever possible.

Short period preflare changes in fibrils have been observed on recent high resolution time-lapse films of H-alpha filtergrams. In a small group of fibrils, individual member fibrils rapidly appear and disappear as seen a filter of 1/2 Å band width. Pronounced changes are visible from frame to frame (15 sec. or less) with some fibrils darkening and/or shifting slightly in position before disappearing. The changes are sufficiently small, low in intensity, and occur so close in time to the flares (within 60 minutes) that it would be extremely difficult to use these changes in any real time system for the prediction of flares. Nevertheless, these short period preflare changes in fibrils are essential ingrediants for theoretical models of flares. A large quantity of high resolution observations of these preflare changes in fibrils taken at a rate greater than 1 every 10 seconds are needed for a better understanding of the relationship of these phenomena to flares.

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13. ABSTRACT A survey was made of the Lockheed solar patrol films in search of any parameters which could possibly be linked with the occurrence of flares. Four flare-productive situations were observed frequently enough to warrant further study. These are increases in the sporadic changes in filaments, closely space sunspot umbrae, absorption features.

High resolution observations ($\lesssim$ 1 sec of arc) show that some filaments increase in darkness and become more sharply defined within several hours to several days before the onset of a flare. However, if obtained only in the center of H-alpha, high resolution observations do not allow one to predict the onset times of flares any better than with observations of lower resolution. Observations in the wings of the H-alpha line are needed. For flare prediction utility of high resolution observations in the center of H-alpha is in enabling one to locate the positions of polarity change around which flares occur in an active center.

Complex plage system were defined as a combination of two adjacent plages or the growth of new plage in the midst of older plage. It is shown that such complex systems rarely fail to produce at least one major flare. The frequency of flaring in a complex system, however, does not appear to be statistically greater than for plages which are not complex according to the above definition.

A few examples of preflare changes in fibrils have been analyzed. These changes are thought to be related to short period, preflare changes in filaments because of their similarity in time of occurrence, position with respect to the ensuing flares, and general outward motion.

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