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On the disappearance of H-alpha filaments and soft X-ray enhancements as seen from Yohkoh SXT

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Abstract. We have studied H-alpha images of the sun taken at Kodaikanal and Mitaka observatories and soft X-ray images obtained by SXT onboard *Yohkoh* for the years 1993 and 94. From events of disappearing quiescent H-alpha filaments and associated soft X-ray brightenings we find that in some cases H-alpha filament appears broken and diffused about a day earlier than beginning of the soft X-ray transient brightening which lasted for 7 - 10 hours. Further, enhancements began along filament channels and then moved along arches which were inclined to the filament direction. From these observations we postulate that heating of plasma in the filament begins when it appears broken and less dark and continues till it triggers some physical process, responsible to begin soft X-ray enhancement. It is not possible to say that if the H-alpha filament disappears earlier than the beginning of soft X-ray enhancement or vice versa as there is time difference between H-alpha and soft X-ray observations.

Key words : solar activity - disappearing H-alpha filaments - soft X-ray enhancements - heating of plasma.

1. Introduction

The disappearing dark filaments usually correspond to eruptive prominences when seen at solar limb (Tandberg-Hanssen, 1974). The physical and dynamical characteristics of prominences have been best described in the review articles D'Azambuja and D'Azambuja, 1948; Tandberg-Hanssen, 1974; Martin, 1980 and Hirayama, 1985. Results of various studies to investigate the association between disappearing filaments and X-ray enhancements, changes in overlying corona and magnetic flux tubes have been reviewed in Priest, 1988 and 1990 and Kahler, 1992. Sheeley et al. (1975) using the Skylab/ATM data in XUV and X-rays and ground base spectroheliograms in H-alpha and magnetograms obtained at KPNO found that long duration X-ray enhancements and active events seen in H-alpha images of the sun are related. They found that as the filament disappears, the nearby coronal plasma was heated to temperature in excess of 6×10^6K and formed a loop like structure which remained visible for days.

Rust and Webb (1977) and Kahler (1977) used H-alpha pictures and X-ray Skylab/ATM data to study mainly active region structures whereas Webb, Kreiger and Rust (1976) studied disappearing quiescent filaments using same data. They all found that filament disappearance, prominence eruption, flare and coronal mass ejection gave rise to long duration large scale transient X-ray enhancement. In case of filament disappearance they found that X-ray emitting coronal structure appeared at or near the filament with the shape and size resembling with the filament. The duration of X-ray structures were considerably longer than associated H-alpha filament disappearance. Webb and Zirin (1981) have intercompared synopitic H-alpha, CaII K and magnetograms and Skylab soft X-ray and EUV data of a typical active region to identify the basic coronal magnetic structure of loops and found that typically a loop brightens in response to magnetic field activity at its feet, which heats the plasma. From the simultaneous observations of a prominence eruption on July 30/31, 1992 in radio, soft X-ray and H-alpha wavelengths Hanaoka et al. (1994) show temporal and spatial relationship between erupting prominence and coronal arcade formation which puts restrictions on the magnetic field configuration of such events. McAllister et al. have analysed in detail data of an H-alpha filament eruption on November 5, 1992 obtained at Hida Observatory and pre- and post-eruption evolution of coronal magnetic fields observed through soft X-ray images of the sun taken by SXT onboard *Yohkoh*. They find that it is not necessary to have a complete opening of coronal fields in order for a filament to erupt.

Smith and Ramsey (1964) and Martin (1980) have reported that H-alpha filaments break up and become activated before filament eruption or disappearance. By analysing data of H-alpha quiescent filaments Singh and Gupta (1995) found that some of the quiescent filaments show rapid changes 1-2 days before their disappearance. They suggested that rise in the middle part and diffused and broken appearance of H-alpha filament may be due to heating of plasma in the filament before its disappearance. We have compared images of the Sun in H-alpha and soft X-rays obtained by SXT onboard *Yohkoh* to confirm their findings. Here we discuss the changes in H-alpha quiescent filament. It may be noted that soft X-ray images obtained on board *Yohkoh* represent plasma at very high temperature of about $3 \times 10^6\,^{\circ}K$ whereas H-alpha images represent cooler plasma at a temperature of the order of $10^4\,^{\circ}K$. There is a large gap between these two temperatures. The aim of this work is, therefore, to study the morphological changes in H-alpha filaments before their disappearance and related soft X-ray enhancements and to investigate role of changes in filaments, triggering some physical process which may cause beginning of soft X-ray enhancement.

2. Observations

By examining H-alpha spectroheliograms obtained at Kodaikanal observatory we made a list of quiescent filaments which disappeared on visible disc of the sun during the period 1993-94. Then we scanned soft X-ray images obtained by SXT onboard *Yohkoh* to see corresponding emission at the locations of disappearing filaments. The details of SXT and soft X-ray images obtained using *Yohkoh* may be seen in Tsuneta et al. (1991) and Ogawara et al. (1991). In all cases seen by us soft X-ray brightening followed the disappearance of filament in agreement with the findings of Sheeley et al. (1975) and Webb, Krieger and Rust (1976). We have selected three cases of soft X-ray brightening for detailed investigation. Enlarged prints of full disc soft

X-ray images obtained using Al/Mg filter were made to compare the locations of soft X-ray enhancements with those of disappearing H-alpha filaments. H-alpha images obtained at Mitaka and others published in the prompt report of Solar Geophysical Data (1993, 1994) were also used to fill in gaps between the observations at Kodaikanal.

3. Results

The active regions on the sun always show brightening in soft X-rays and probably it appears with the birth of an active region on the solar surface. Apart from these active and soft X-ray emitting regions there happen to be transient soft X-ray brightenings seen away from the active regions. Some of these brightenings occur in the regions of disappearing H-alpha quiescent filaments. Here we discuss three such events which occurred during 1993-94.

Event of May 13, 1993

We have measured co-ordinates of H-alpha filaments on various days to see their development and those of soft X-ray enhancements to compare the regions of filament disappearance and X-ray enhancements. In Table 1 we list co-ordinates of H-alpha filament for the period May 9-13, 1993 and in Figure 1 we show the various stages of development of this filament. Up to May 11, 1993 the H-alpha filament remained intact without much changes in shape and appearance except that it grew in size slowly but steadily. On May 12 it underwent a major change and appeared broken at many places and was seen only at few scattered locations at the filament site as apparent in the H-alpha spectroheliograms taken at 02:37 UT on that day. It continued to be visible in similar way until 02:49 UT of May 13 and finally disappeared as seen in the H-alpha image of May 13 at 15:06 UT. Mean while brightening in soft X-rays began in this region at 05:28 UT on May 13 as indicated by the image of the sun taken by SXT onboard *Yohkoh*. Table 1 shows that coordinates of soft X-ray transient brightening over lap that of the H-alpha filament and Figures 1 and 2 show shape of both of these is similar in nature. The small difference in shapes are because of soft X-ray emission arches crossing the filament channels. The enhancement in soft X-rays appears to be initially centred around three different locations along the filament channel and then spread to join together to be seen as a single enhancement along the filament channel. Figure 2 shows the different stages of this brightening in soft X-rays. The emission first began along the filament channel and appeared to move along arches which were inclined to the direction of filament channel. These arches appear to become wider with time which can be due to one of the following two reasons. This can happen either because of the outward movement of the foot points of arches or due to the reason that temperature or density of high temperature plasma or both first increase at the top of arches and then this increase travels downward along the arches. The brightness of the emitting region became maximum after about one and half hour from the beginning at about 07:03 UT and covered a much larger area (30-58 S; East limb - 50 W) than that of H-alpha filament. This increase in area is because of emission in arches which cross the filament channel.

Finally the emission became negligible at about 12:15 UT after lasting for about 7 hours. One may note that the soft X-ray enhancement did not start as soon as H-alpha filament appeared broken at number of places. It began only after a gap of at least 26 hours.

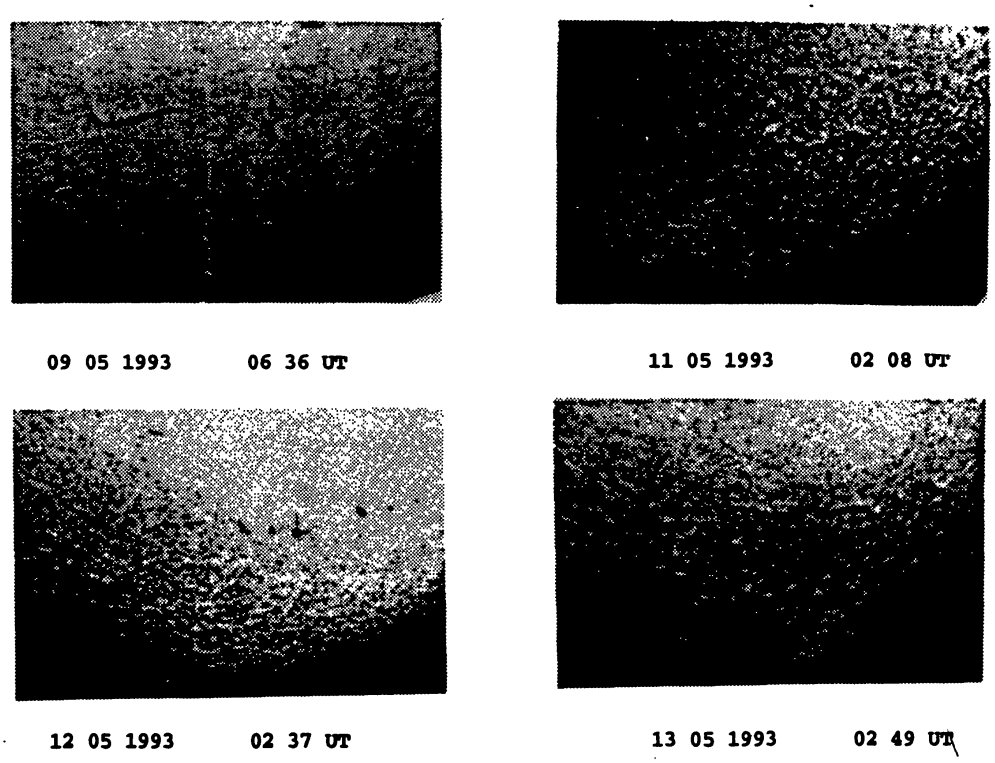
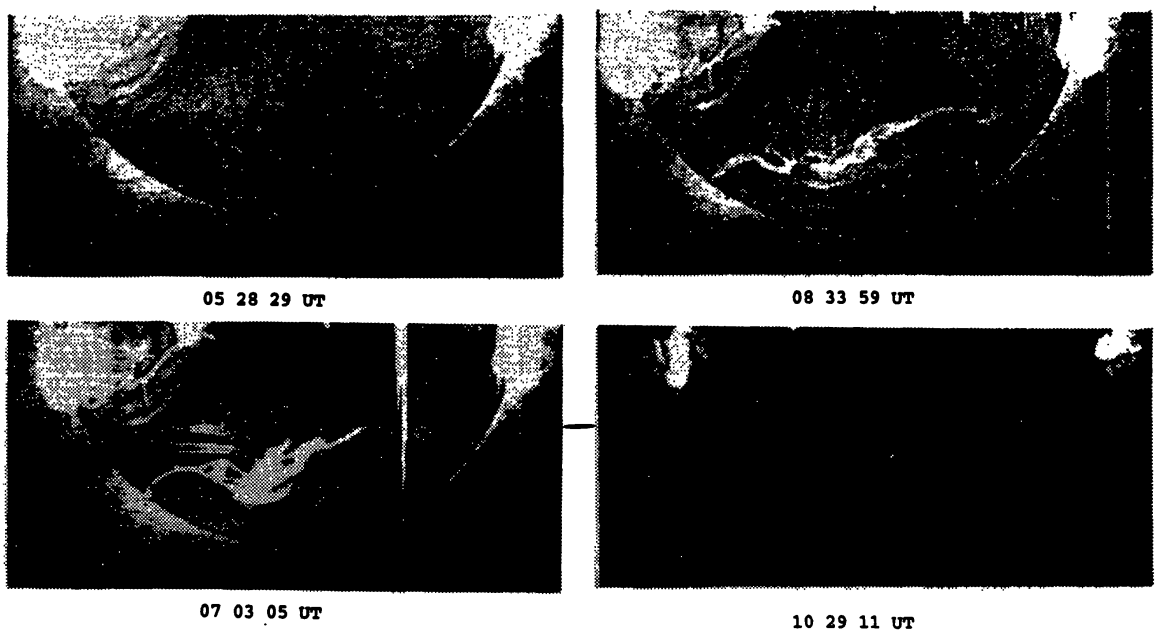


Figure 1. The development of H alpha filament. Date and time of observation are written below each image North is up and east towards left.



Fogure 2. Soft X-ray images of the sun taken by SXT onboard YOHKOH on May 13, 1993 of the enhancement associated with H-alpha filament shown in figure 1. Time of observation is written below each image. The solar regions shown in figures 1 and 2 are same but not identical in size.

Event of December 15, 1993

The coordinates of the H-alpha filament observed between Dec. 10-15, 1993 are given in Table 1. The crucial phases of development of this filament are shown in Figure 3. On Dec. 13 we saw a well formed H-alpha filament which appeared broken on Dec. 14 in H-alpha image of the sun obtained at 04:22 UT. Further, on Dec. 15 at 02:40 UT north-west part of the filament was not seen and we saw only south-east part. After a gap of about seven hours at 09:40 UT, enhancement in soft X-rays began in this region as seen in figure 4. Figures 3 and 4 and Table 1 indicate that the shape and region of enhancement are the same as those of full H-alpha filament seen on Dec. 13. The intensity of emission became maximum at about 12:45 UT covering a region (02N-28S; 08W-61W) on the sun. The intensity of emission became very less at 16:05 UT and negligible at about 22:35 UT and thus enhancement lasted for about 10 hours. The enhancement appeared to begin along the filament channel and then move along the arches which crossed the filament channel. The direction of arches changed as direction of the filament channel changed. It may be noted that soft X-ray enhancement began at about 10 UT on Dec. 15 whereas visible changes in H-alpha filament had began about 30 hours earlier at about 04 UT on Dec. 14.

Table 1. Details of H-alpha filaments

Date D M Y	Time (UT)	Lati. Extent (Degrees)	Long. Extent (Degrees)	Comments about X-ray enhancement
Example No. 1				
09 05 93	06 36	39-43 S	22-04 E	The enhancement began
10 05 93	04 35	40-44 S	15E-05 W	at 05:28 UT on May
11 05 93	02 08	39-44 S	12E-17 W	13, 1993. Became maximum
12 05 93	02 37	38-48 S	30E-38 W	at 07:03 UT in region
13 05 93	02 49	36-48 S	14W-47 W	30 - 58 S in Lati. and
13 05 93	15 06	Not visible		east limb - 50W in Long.
Example No. 2				
10 12 93	17 45	01-13 S	40-20 E	Soft X-ray enhancement
12 12 93	02 19	03-14 S	22E-02 W	from 09:40 to 16:05 UT.
13 12 93	02 36	02-15 S	06E-16 W	Maximum at 12:45 UT in
14 12 93	04 22	06-15 S	02-28 W	02N-28 S; 08-61 W
15 12 93	02 40	02-10 S	28-42 W	region on the sun.
15 12 93	16 42	Not visible		

Event of June 19, 1994

In above mentioned cases of H-alpha filament disappearance, we have seen that H-alpha filaments begin to break, get less dark and become broader before their disappearance and related soft X-ray enhancements. We refer this state of filament as diffused state of the filament. Figure 5 shows the state of a quiescent filament in southern hemisphere of the sun on June 17 and 19, 1994 as seen in the H-alpha pictures taken by Mauna Loa Solar Observatory. The filament which is well seen on June 17 appeared less dark and broad on June 19 at 18:48 UT. The diffusion of filament might have started earlier but we do not have data in this gap. The

development of soft X-ray brightening in the region of H-alpha filament shown in Figure 6 indicates beginning of emission around 22:56 UT at least 4 hours later than the diffusion of H-alpha filament was seen. As in earlier cases emission began along the filament channel and then moved along the arches which appear to lie below the filament channel. In this case the emision continued to be more at the top of arches crossing the filament channel. The reason for this may be line of sight effect and angle of arches makes the emission overlap at the top of arches and thus appearing brighter or the filament channel and the top of arches lie in the same direction with respect to the observer. We have determined mean latitude of the channel of soft X-ray enhancement as a function of time. The values listed in Table 2 indicate that mean latitude of soft X-ray enhancement increases from 35.5° S to 39.5° S in a period of about 6.5 hours. The enhancement appers to lie above the solar surface in the corona. We see the projections of the enhancement on the solar disc. Therefore, the increase in latitude of the enhancement may indicate further rise of this above the solar surface. There is also, a possibility that this enhancements moves parallel to the solar surface towards higher latitude. Also the arches appeared to get higher rather tan becoming wider which happened in other two cases. It appears that the filament channel moved up slowly and continuously above the solar surface throughout its existence. It took short time for the brightening to become maximum and then its intensity decreased slowly and steadily. The brightening lasted for about 10 hours.

Table 2. Mean latitude of the soft X-ray enhancement observed on June 19-20, 1994

Time (UT) H M	Mean Latitude South (degrees)
22 56	35.5
23 57	36.2
01 37	38.0
03 41	38.7
05 30	39.5

4. Discussions

In Figure 7, we sketch the filaments by dark markings and the soft X-ray enhancements by dots. The figure shows the spatial coincidence of these events. All these events are similar in nature but the first two are more similar. Both show that a part of the H-alpha filament became invisible about a day prior to its complete disappearance and beginning of soft X-ray enhancement. In some cases disintegration of H-alpha filament may start only some hours before the soft X-ray event. It may be noted that there is a difference in the parts of filament becoming less dark and invisible (disintegration) than the disappearence of filament. The disintegration starts earlier and disappearance of quiescent filaments begins latter. It is not possible to say if the H-alpha filament disappears earlier than the beginning of soft X-ray enhancement or vice versa as these observations are not simultaneous. In all the cases the emitting region had the shape and location of respective H-alpha filament seen in full. Also the soft X-ray enhancement began along filament channel and travelled along the arches which crossed the filament.

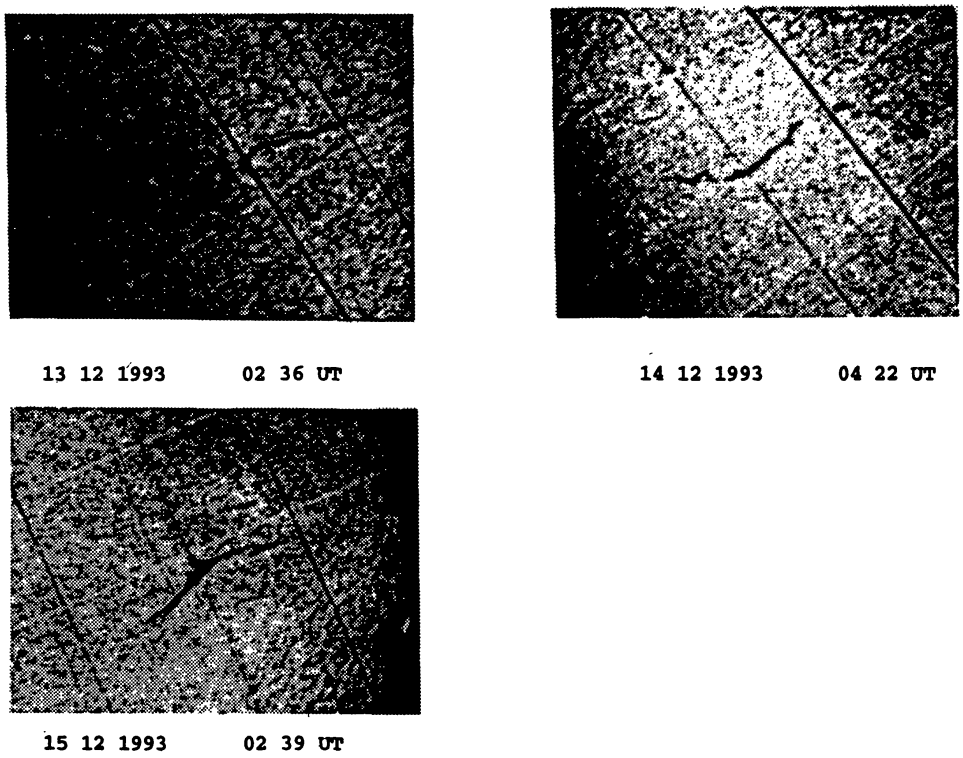


Figure 3. H-alpha filament as seen on different days. Date and time are wirtten below each image.

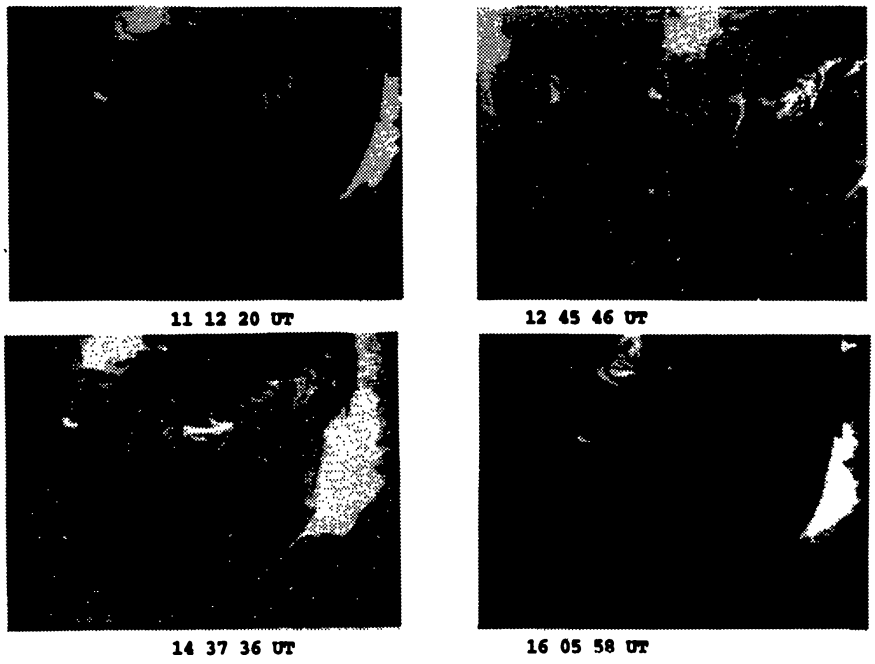


Figure 4. Soft X-ray picture of the sun showing different phases of an enhancemnt which occurred on Dec. 15, 1993. Time of observation is indicated below each image. The regions shown in figures 3 and 4 are same but not identical in size.

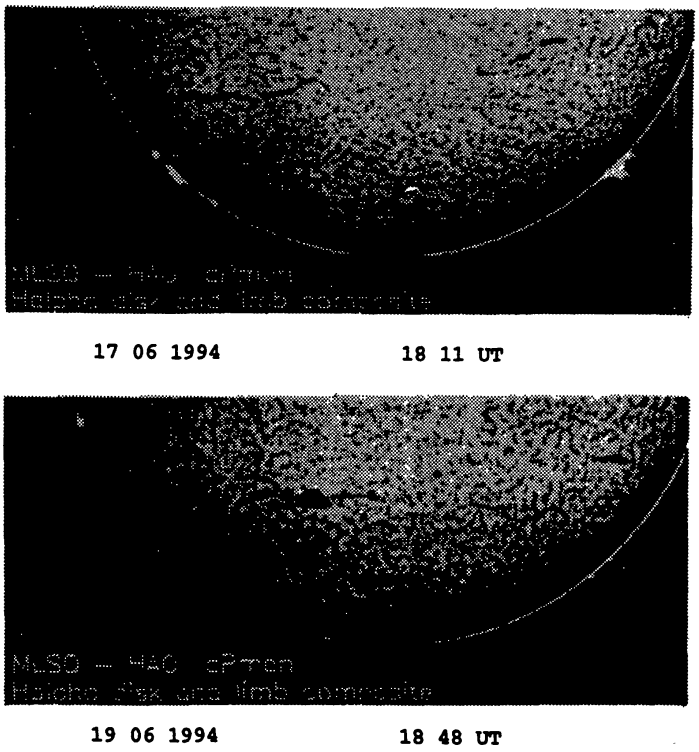


Figure 5. H-alpha filament as seen on two different days observed at MLSO. Date and time are indicated below each image.

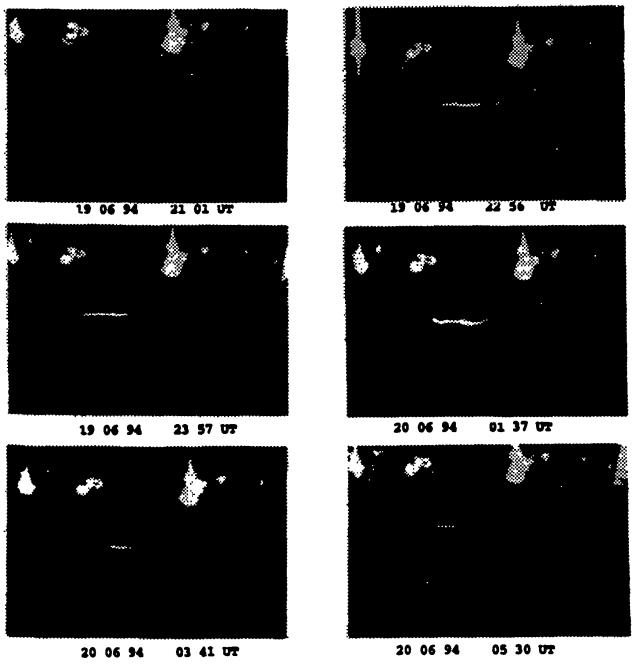


Figure 6. Soft X-ray pictures obtained by SXT onboard YOHKOH showing different phases of a brightening on June 19, 1994. Date and time of observation are written below each image. The regions shown in figures 5 and 6 are same but not identical in size.

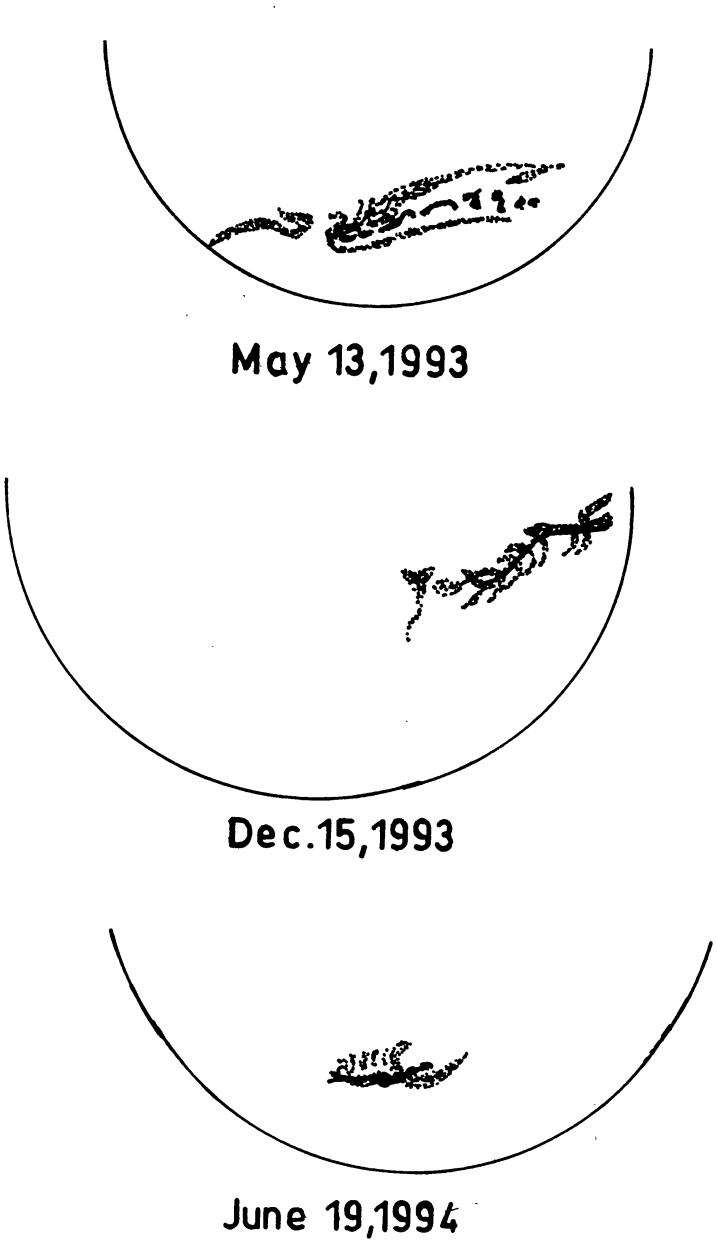


Figure 7. The sketches of filaments represented by dark marking and soft X-ray enhancements shown by dots for all the three events.

These arches appeared to become wider with time which might be due to movement of foot-points of these arches or time taken for the effect to reach from the arch top to the foot-points.

From these observations we may conclude that heating of the plasma in the H-alpha filament starts about a day and in some cases only 4-5 hours before the event of soft X-ray brightening. The H-alpha plasma may get heated upto a moderate temperature of the order of $10^4\,^{\circ}K$ or above, may not reach to a value of soft X-rays emitting plasma at $3 \times 10^6\,^{\circ}K$ at this stage. The

heated plasma at temperature 10^4 will show very faint H-alpha features. The behaviour of solar plasma in the temperature range of 10^4 to $10^6\,^{\circ}K$ is dominated by thermal instability. Thus, when the heating even slightly exceeds the threshold of $10^4\,^{\circ}K$, there is a "thermal catastrope" that changes the temperature directly to $10^6\,^{\circ}$K. This may trigger some physical process (may be reconnection) which may be responsible to heat the plasma further to a temperature in the range of 2 - 5 x $10^6\,^{\circ}K$ and to begin soft X-ray enhancement along the filament channel. Also the soft X-ray enhancement occurs along the whole length of fully developed H-alpha filament even though part of the filament becomes invisible about a day earlier than the beginning of enhancement. Therefore, we may say that the small scale magnetic structure of the region does not get disturbed as soon as part of the H-alpha quiescent filament becomes invisible but may reorganise or disappear during and after the enhancement in soft X-rays. The reason for part of H-alpha filament not to be visible may be high temperature of the plasma in that part of the filament. We, therefore, postulate that heating continues till it triggers some physical process which leads to the beginning of soft X-ray enhancement and subsequently H-alpha filament disappears.

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