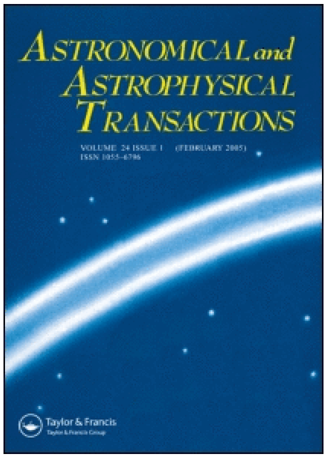

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A LARGE FLARE-ASSOCIATED FILAMENT IN SEPTEMBER 1989

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The behaviour of a long-lived extended filament in active region NOAA 5669 with a complex magnetic structure has been followed. The relation between the filament behaviour and flare activity in September 1989 has been investigated. The filament was quiet when flares were generated in the inner parts of the active region. Some matter layers were separated from the parent filament and erupted when flares occurred near the rooted end of the filament.

KEY WORDS Sun, flare, filament eruption, magnetic reconstruction

1 INTRODUCTION

A close relation is known to exist between flares and filament eruptions (Smith and Ramsey, 1964; Hirayama, 1974; Rust *et al.*, 1975). The last Yohkoh soft X-ray data provide observational evidence that for some cases magnetic reconnection of a X-type neutral sheet associated with a rising destabilized filament is involved in flare energy release (Tsuneta, 1993). Many flares have been observed to be associated with preflare activization of neutral line filaments and their subsequent disappearance or exhaustion. In other cases, filament eruptions occur simultaneously with flares or during the flares. Sometimes a filament is revealed to remain without a change throughout the flare and activizes in consequence of the flare development. The behaviour of the flare-associated filament might be complex. Investigations of the behaviour of the filament features and its evolution help us to understand magnetic field topology in the vicinity of the filament and its role in flare processes.

Up to now some morphological schemes describing the relationship between filament eruption and flares have been proposed. Theoretical evaluations concerning processes connected with filament eruption have been made. However, many details in the flare scenario are still not clear and additional information about flare-associated filament eruptions is useful.

In this paper we try to investigate the fate of a large longlived filament, one end of which was anchored in the tail part of the active region (AR) NOAA 5669 of

September 1989. The filament behaviour was analysed and compared with the flare situation in the AR during the September 1989 period of the disk passage, when many flares occurred. Some of them were accompanied by X-rays.

2 OBSERVATIONS AND DESCRIPTION OF THE AR

Observations were obtained at High Altitude expedition of the Sternberg Astronomical Institute on the coude-refractor Opton using a Hα-filter with a passband of 0.25Å. Sequences of filtergrams in the Hα line centre and wings up to ± 3Å were considered.

The investigated AR appeared in March 1989 and existed during 10 solar rotations or more. Events in the AR 5669 SGD have been investigated during its disk passage from August 29 to September 11 1989.

During the previous rotation this AR (5629) was very active and produced 48 X-ray flares and 131 Hα flares. Arch structures, surges, and filaments activization were observed. On August 15, 16 and 17 well-developed loop structures were seen at the west limb.

On August 29, 1989 the AR appeared from the east limb having more complex spot and magnetic field structures, stretching for about 30° along the east–west direction. The leading spot had negative polarity, the next and subsequent ones had mainly positive polarity with an inclusion of N polarity spots. In this period the AR gave 61 X-ray flares and 176 Hα flares. A special feature consisted of many emission knots of Ellermann bombs around the spots. They were located along all the AR area and observed in the wavelength range from Hα–2Å to Hα+2Å.

During all the time of the observations a long active filament behind the AR existed. On September 8 its length was more than 200 000 km (Figure 1). One end of the filament was anchored in the tail spots of the AR. Another end seemed to be placed in several floculae brightenings. On the best photos a twisted structure of the filament can be seen distinctly. Its channel was wide and consisted of several streams. Two or three separate streams were often observed. The filament fate was closely connected with active processes in the AR. Its appearance and behaviour were changeable. Sometimes it seemed to be almost quiet but usually it had Doppler shifts.

3 RESULTS AND DISCUSSION

We analysed the filament behaviour and compared it with the flare situation in the AR during a dozen cases on September 2, 3, 7 and 8, 1989, when several subflares occurred, four of them accompanied by X-ray flares. A connection between the filament behaviour and flare activity has been found. The filament has been revealed to be almost quiet when flares or flare-like brightenings occurred near the middle of the AR area and active when flares occurred near the rooted filament end.

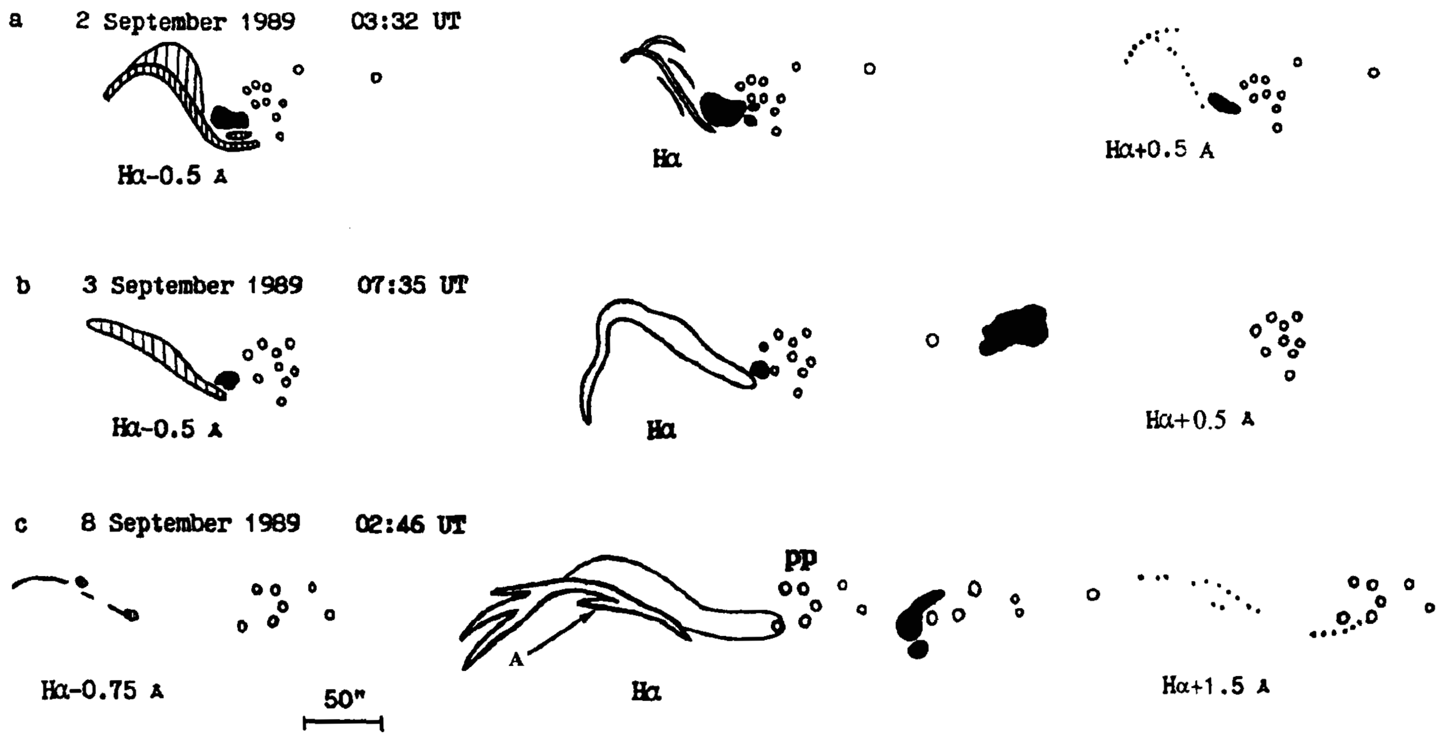

Figure 1 The events observed in NOAA 5669 in September 1989. The filament has been revealed to be almost quiet when flares or flare-like brigtenings were situated near the middle of the area (*b*, *c*, *d*) and active when flares occurred near the rooted filament end (*a*, *e*, *f*). The arrows indicate separated and elevated segments of the filament. PP is pivot-point. North is at the top, west is at the right. *1*, spots; *2*, flare; *3*, Hα-filament; *4*, blue filament; *5*, red filament.

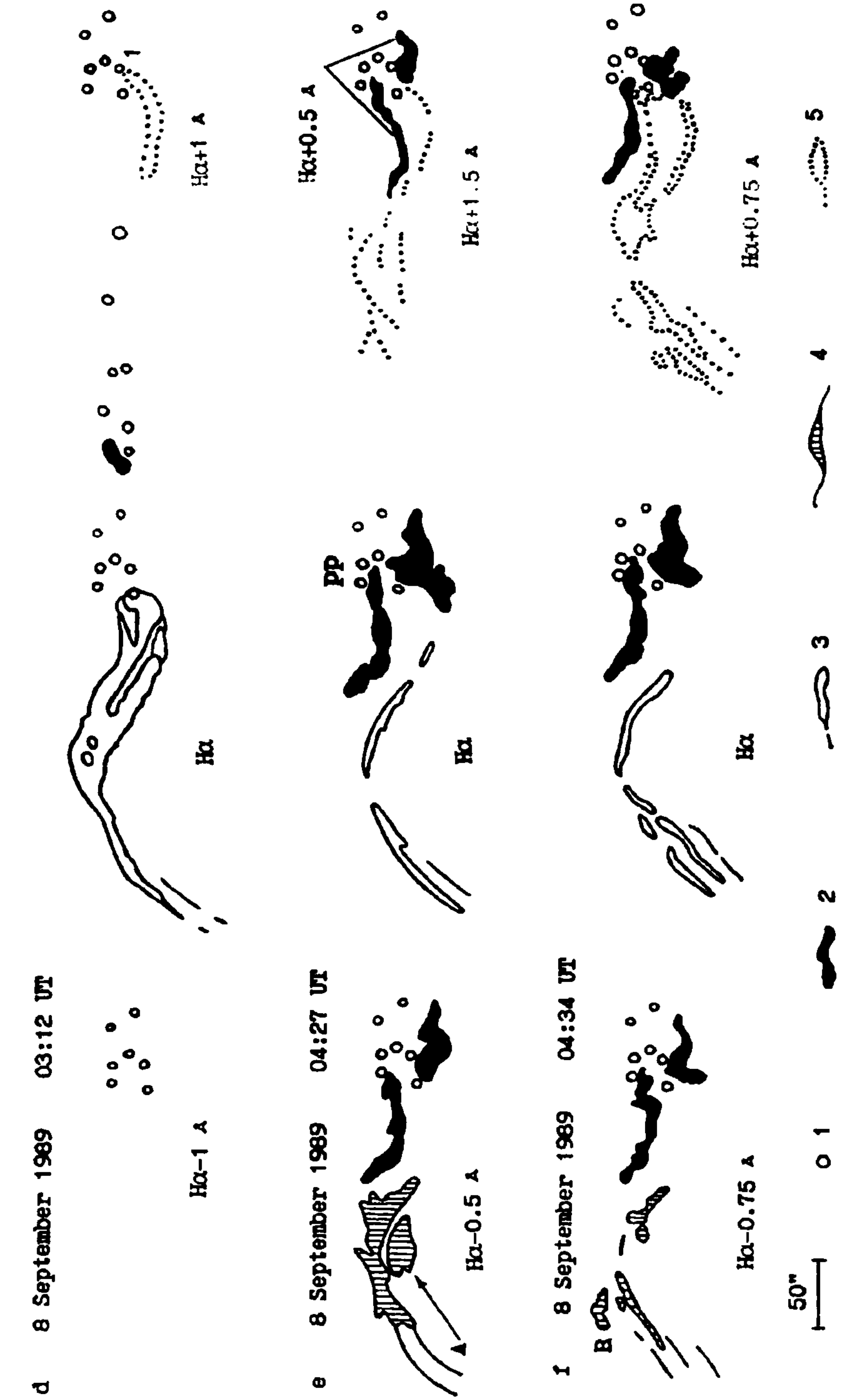

Figure 1 Continued.

Table 1. Events in AR 5669 in September 1989

Date 1989	*Time of observations (UT)*	*Data about flare*	*Characteristics of filament* λ*(Å)*	*Description and localization of flare*
2/09	03:09–03:15	Hα-brightening	Hα–0.75Å	Emission kernels in AR back part
	03:30–03:36	03:30–03:34–03:45 SN, 21°S,54°E	Up to Hα–2Å, in Hα not visible	
	05:34–05:36	05:22–05:24–05:46 SF, 18°S,48°E	Up to Hα–1Å, in Hα not visible	
3/09	07:08–07:09	Hα-brightening	Hα	Emission kernels inside AR
	07:34–07:36	07:25–07:30–07:40 SN/C3, 16°S,22°E	Hα	
	10:49–10:58	10:35–10:40–10:52 1B/M5, 21°S,54°E	Hα + 0.5Å, Vestiges in Hα	Emission kernels in AR back part
4/09 [3]	09:04	08:57-09:04–09:45 1B/X1, 18°S,20°E	Surges up to Hα–1Å	Emission ribbons in AR back part
7/09	02:11–02:18	01:45-01:48–02:13 SN, 18°S,10°W	Vestiges in Hα	Emission kernels in AR back part
	10:10–10:14	10:08–10:11–10:36 SN, 18°S,16°W	Surge in Hα–1.75Å	Two-ribbon flare in AR back part
8/09	01:42–01:46	Hα-brigtening	Surge in Hα–1	Emission kernels in AR back part
	02:35–02:54	02:32–02:34–02:44 SF/C5, 19°S,32°W	Vestiges in Hα, Hα+0.5Å	Emission kernels inside AR
	03:05–03:17	03:02-03:04–03:14 SN, 18°S,34°W	Hα, vestiges in Hα+1Å	
	04:22–04:37	04:07-04:08–04:59 1B/M1, 19°S,39°W	Surges up to Hα-3Å Vestiges in Hα	Two-ribbon flare in AR back part

The main results are given in Table 1, where observational results for September 4, obtained by Mouradian and Soru-Escaut (1991), are shown too. In Figure 1 schematic drawings of events are given for separate moments. Day, universal time and wavelength of observations are indicated.

In four cases (September 3, 07:08 UT, 07:35 UT; September 8, 02:35 UT, 03:10 UT) the filament was relatively quiet and flares took place in the middle of the AR. In nine cases (September 2, 03:10 UT, 03:30 UT, 05:35 UT; September 3, 10:50 UT; September 4, 09:04 UT; September 7, 02:11 UT, 10:10 UT; September 8, 01:45 UT, 04:30 UT) the filament had Doppler shifts and flares or flare-like brightenings were generated in the back part of the AR.

Let us examine some more details.

On September 2 three intervals from 03:09 to 05:36 UT were considered when two subflare and one Hα-brigtening occurred. In all cases the parts of the filament that were nearest to the following spot group in the AR, were seen in blue Hα wing to Hα–2Å and were not seen at all in the Hα line centre and its red wing (see Figure 1*a*). Near this place, parallel to the filament channel flare emission or flare-like brightenings were seen. The central and eastern parts of the filament channel were distinctly seen in the blue wing, hardly in the Hα line centre and scarcely in the red Hα line wing.

On September 3 three cases were considered. At 07:08 and 07:35 UT the Hα-brightening and subflare, respectively, were located near the middle of the AR area. At these moments the filament seemed to be almost quiet and was seen only weakly in the blue wing (Figure 1*b*). At 07:35 UT one large flare seat was situated in the AR middle and another faint flare kernel occurred behind the trailer spot group. The last seems to explain the existence of the blue shifted filament. The third case at 10:50 UT was similar to those on September 2 described above. However, the flare was situated not behind, but above the trailer spot group.

On September 8 events at four moments from 01:43 to 04:40 UT were analysed, when three subflares and one flare-like brightening occurred. Two Hα-flares were accompanied by X-ray irradiance. At 01:42 UT an ejection along the filament was seen in λ = Hα−1Å. Hα-brightening occurred in the vicinity of the trailer spots.

In two other cases (02:35 and 03:10 UT) only the central and eastern parts of the filament were hardly seen in the blue wing and the very western part near the following spots was not seen at all. On the contrary the whole filament was well seen in the centre of the Hα line and weakly in the red wing. The flare kernels were situated in the inner places of the region (Figure 1*c* and *d*).

The situation during the flare on September 8 1B/M1.4 (04:07–04:08–04:59 UT, S19, W29, SGD) was investigated in more detail. A two-ribbon flare near the following spots (Figure 1*e*) was observed. One ribbon was located parallel to the filament channel. The southern ribbon was more compact. In the Hα line centre the eastern and central parts of the filament were weakly seen. The very western pieces were not visible at all. In the red wings thin threads and isolated clusters were observed up to Hα+2Å. Mass motions to spot 1 with velocities of 50–60 km s^{-1} could be seen. In the blue wing there were seen matter clouds and separate condensations ejected along the filament channel with velocities of about 60–190 km s^{-1}. Their dimensions were more than 100 arcsec in length and 18–40 arcsec in cross-section (Figure 1*c*). At 04:27 UT on September 8, 1989 a dark massive formation of ellipsoidal shape was observed in the blue wing of the Hα line up to λ = Hα − 3Å. It is indicated by an arrow in Figure 1*e*. During the 1B/M1.4 class flare (04:07-04:59 UT) the large cold plasma segment seemed to detach from the parent filament and elevate upward. That is why in projection on the solar disk we see this severed layer beneath the filament. A similar layer is likely to be visible on September 8 at 02:46 UT (Figure 1*c*) in the Hα line, it is indicated by an arrow. Between 04:22 and 04:29 UT the central part of the filament thickened, then some layers separated and rose up. The whole filament and detached pieces were generally seen in the blue wings and weakly seen in the centre and red wing of the Hα line. Later, the filament became visible mainly in the red wing. Some ejected material appears to fall down and inflowed in the spots (Figure 1*f*).

So during many days in spite of numerous flares occurring in the AR the filament remained in place along the magnetic inversion line. The large filament connected with the AR flares did not erupt and did not disappear. Activating the filament began to thicken, separate segments and levels of it became detached and lifted up with velocities of 50–150 km s^{-1}. Some time later possibly a part of, or all, the severed material descended down and merged with the parent filament. Ejections along the filament channel were observed on September 4 and 7 (see Table 1).

Velocity structures in flare-associated dark filaments are discussed, for example, by Martin (1989), Zhang (1993) and Zhang *et al.* (1993). Zhang *et al.* investigated a dark filament in the same AR on September 1 and 2, 1989. The filament was situated under the AR in the eastern part. They found that the vicinity structures of the filament were not stable during the few hours after the major 2N/M5.8 flare at 23:50 UT on September 1, 1989, but the large-scale magnetic structures were relatively stable in the vicinity of the filament. Relative stability of the filament investigated by us appears to be an evidence of relative stability of the large-scale magnetic structure in the back of the AR.

So about 12 events in NOAA 5669 in September 1989 have been investigated and the behaviour of the active filament was compared with the situation. In four cases the filament was relatively quiet and the observed subflares were located in inner parts of the AR area. In nine cases the filament changed its shape and had Doppler shifts and there were flares along the filament channel or near it. During the Hα flare on September 8 which was accompanied by X-ray flare (1B/M1.4) large mass clouds were observed to separate from the filament channel. At definite moments the filament was not seen in the blue wing at all. Hence there was a close correlation between the filament behaviour and flare situation. The shape and location of the filament channel were revealed to be changed during flares. A similar filament flare connection in this AR on September 4, 1989 was investigated by Mouradian and Soru–Escout (1991). They established that the starting point of the observed cool moving structures and of flare emission were rooted in a pivot-point PP (Figure 1*c* and *e*), that is a singularity point with which the position of the maximum concentration of flares in AR coincides.

As magnetograms (Mouradian and Soru–Escout, 1991; Zhang *et al.*, 1993) show there were two places of the emergent magnetic flux in the AR: in the middle of the AR and near the pivot-point PP at the back of the AR. In most cases flares occurred in these two places (Table 1). The flares seem to be caused by the interaction between new emergent magnetic flux and pre-existing large-scale magnetic structures, the latter remaining relatively stable.

In conclusion we should like to underline that real filament events were often difficult to see because of flare ribbon obstruction. Besides, different filament pieces along the channel had different Doppler velocities and the observation picture became complicated. At first it seemed to us that the filament erupted and its reformation occurred. But a more detailed and thorough analysis has shown that only layers peeled off the filament and segments separated from it and then lifted at a higher altitude. The separated layers were hanging above the filament channel for minutes or tens of minutes. The elevated matter pieces (like A and B in Figure 1*c*, *e* and *f*) were sometimes not lying directly above the photosphere magnetic inversion line. The filament below remained in place during the flares. It was not a classical type of eruption when the filament expanded, broke and disappeared. Such an uncommon type of large filament eruption was likely to be observed during the September 1989 disk passage of the AR.

It seems that magnetic field instabilities existed inside the filament which triggered separations and eruptions of the superficial layers of the filament. We hope that detailed analysis of the observations is useful for understanding and theoretical consideration of the magnetic field reconstruction inside and in the vicinity of the filament and its connection with the flare process.

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