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Filaments disappearances in relation to solar flares during the solar cycle 23

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Abstract

We studied the association between the filament disappearances and solar flares during 1996–2010; we listed 639 associated filament disappearances with solar flares under temporal and spatial condition, those particular 639 filament disappearance were associated with 1676 solar flares during the period 1996–2010. The best angular distance between filament disappearances and associated solar flares ranged between 30° and 60°. The number of the associated events increased with increasing solar activity and decreased with quiet sun. The location of filament disappearances ranges between latitude ±50° and longitude ±70°. We found that longer filament disappearances have activity and ability of contemporary association with flares more than shorter filament disappearance, filament disappearance powers the associated flares more than non-associated flares events. The associated flares have higher solar flux, longer duration, and higher importance compared to non-associated flares with filament disappearance. In addition the associated filament disappearance with flares have two types depending on their duration, short-lived (<9 h), and long-lived (>9 h).

Keywords: Filament; Filament disappearance; Solar flare

1. Introduction

A review of filament disappearance relationship which is given by Smith and Ramsey (1964) extracts from this review is given below:

Newton (1934) recognized 2 types of flare associated filament disappearances: (1) filament disappearances associated with sunspot groups, (2) filament disappearances not associated with sunspot groups. Newton (1935) also reported cases of filaments exhibiting high radial velocities and complete or partial disappearances after flare start. In a study of flares observed during the period from March to December 1988, Giovanelli (1940) found that approximately one fifth of the flares gave rise to eruptive prominences (filaments), and that there is a statistical increase in the velocity of the ejected prominence with an increase in the intensity of the flare. A more complete description of flare-associated filament motions was published by Newton (1942). Bruzek (1951, 1958) noted events in which strengthening of a filament, combined with ascending motion, occurred before the start of a flare and prior to the dissolution of the filament. Martres (1956) pointed out that for disparitions brusques (sudden filament

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disappearances) associated with flares, the flare assumes almost the exact position where the filament previously existed. Observers at the Royal Observatory in Greenwich (1930) described a filament which showed a negative radial velocity of 450 km/s before it disappeared during the occurrence of a flare. Smith and Ramsey (1964) considered that the term "disappearance of a filament" could be appropriately applied to 4 different kinds of filament changes. These 4 types may be distinguished by their relationship to the occurrence of flares as: (1) Flare effected, (2) Flare associated, (3) Associated with flare-like brightenings, (4) Not flare-associated.

Smith et al. (1964) surveyed all of the Lockheed flares of importance 2 or greater for association with sudden filament disappearances. This survey included 71 flares recorded during the period January 1959 to January 1963. With respect to the occurrence of disappearing filaments, the flares were divided into four groups: (1) *Definitely associated*: A filament disappearance clearly occurred above or adjacent to the flare and before flare maximum. (2) *Indeterminate*: Absence of adequate observations before flare start. (3) *Ambiguous*: Except for the absence of a clearly defined, pre-existing filament. This type of event has been referred to as "flare filament" by Bruzek (1951). (4) *Not associated*: No filament disappearance adjacent to or above the flare.

Smith et al. (1964) found that the filaments which disappear before or during a solar flare frequently display a consistent pattern of changes beginning many minutes before flare start. This pattern of filament changes may be summarized in seven overlapping phases: (1) Widening and darkening; (2) Arch-like expansion; (3) Break-up; (4) Transition to emission; (5) Ejection of matter; (6) Complete disappearance; (7) Appearance of absorption during flare.

The visibility of the phases is a function of the part of the Hα line profile being observed, and appears to be a function of the observed position on the solar disk. Dodson et al. (1971) studied the 'disparitions brusques' in solar cycles 19 and 20 (to 1969) indicate that such events occur frequently. Approximately 30% of all large filaments in these cycles disintegrated in the course of their transit across the solar disk. Major flares occurred with above average frequency on the last day on which 141 large disappearing filaments were observed (1958–1960; 1966–1969). Relationships between a disintegrating filament on July 10–11, 1959, a prior major flare, a newly formed spot, and concomitant growth of Hα plage are presented. Observation of prior descending prominence material apparently directed towards the location of the flare of 1959 July 15^{d} 19^{h} 23^{m} is reported. The development of the filament-associated flare of February 13, 1967 is described.

Dodson et al. (1971) Studies of prominence in the course of their transit as filaments across the solar disk can add significantly to information relating to the life histories of prominences and to their possible connection with other solar phenomena. The relatively sudden disintegrations of filaments, the 'disparitions brusques', are the disk counterparts of at least some of the phenomena called eruptive or ascending prominences when such events occur at the limb of the sun.

Statistics for 'disparitions brusques' appear in the tables of the *Cortes Synoptiques* published at Meudon Observatory. From these statistics, and from daily observations at the McMath–Hulbert Observatory, it is clear that the disintegration of a filament, even a great one, is a common event. In solar cycles I9 and 20 (to 1969) at least 252 large filaments 'disappeared' during the course of transit across the solar disk. These filaments represented approximately 30% of all filaments evaluated as importance 5 or greater on the Meudon scale. 'Disparitions brusques' were frequent during the years of high solar activity and few in the years near solar minimum. These findings are in general accord with the results of study of 'disparitions brusques' in earlier years by d'Azambuja (1948). In cycle l9, the greatest number of large filaments and major 'disparitions brusques' occurred in 1959, two years after sunspot maximum.

Kahler (1980) studied a flare event involved with the disappearance of a filament near central meridian on 29 August 1973. The event was well observed in X-rays with the AS & E telescope on Skylab and in Hα at BBSO. It was a four-ribbon flare involving both new and old magnetic inversion lines which were roughly parallel. The Hα, X-ray, and magnetic field data are used to deduce the magnetic polarities of the Hα brightenings at the footpoints of the brightest X-ray loops. These magnetic structures and the preflare history of the region are then used to argue that the event involved a reconnection of magnetic field lines rather than a brightening in place of pre-existing loops. The simultaneity of the Hα brightening onsets in the four ribbons and the apparent lack of an eruption of the filament are consistent with this interpretation. These observations are compared to other studies of filament disappearances. The preflare structures and the alignment of the early X-ray flare loops with the Hα filament are consistent with the schematic picture of a filament presented first by Canfield and Athay (1974).

Haimin et al. (2002) found that the thermal type of sudden filament disappearances in the filament disappeared during a time interval between 17:59 UT and 19:47 UT on 22 October 2001 immediately after the onset of a major flare, which occurred in the active region NOAA 9672. At about 23:23 UT of the same day, the filament began to reappear in Hα and, after about 15 h, the filament recovered to its steady state with its size being slightly smaller than that before its disappearance. This filament disappearance event belongs to the thermal type of sudden filament disappearances, which is caused by an input of additional heat.

In general, the heating mechanism that leads to sudden thermal disappearances of quiescent filaments is still not well understood.

2. Data sets

We selected the filament disappearance observed at Meudon and tabulated by National Geophysical Data Center (NOAA), from URL:

ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FILAMENTS/

And selected solar X-ray flare data from NOAA:

ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_FLARES/

We have 24933 solar X-ray flares events observed by GOES satellite, and 2018 filament disappearance events observed from NOAA, during the period 1996–2010.

3. Approach

We will study the flares which are occurred contemporary during filament disappearance lifetime, where start time of flare must occurred between the start and end time of filament disappearances, and the flares must occur near to the filament disappearance location. The condition of the location between flares and filament disappearance is a problem where both have different shapes and the flare has one location, but filament has up to three locations.

The angular distance between filament disappearance and solar flare must be less than the total length of associated filament disappearance has been taken as a *first assumption*. The *alternative assumption* is that the angular distance must be less than specified angular distance between the both events (like 60°). According to our statistical study, we found no difference between both assumptions approximately. We selected the second assumption (specify max angular distance), we found that the popular of events have angular distance between filament disappearance and solar flare less than 60° (Fig. 1). We choose the location condition <30° for better accuracy.

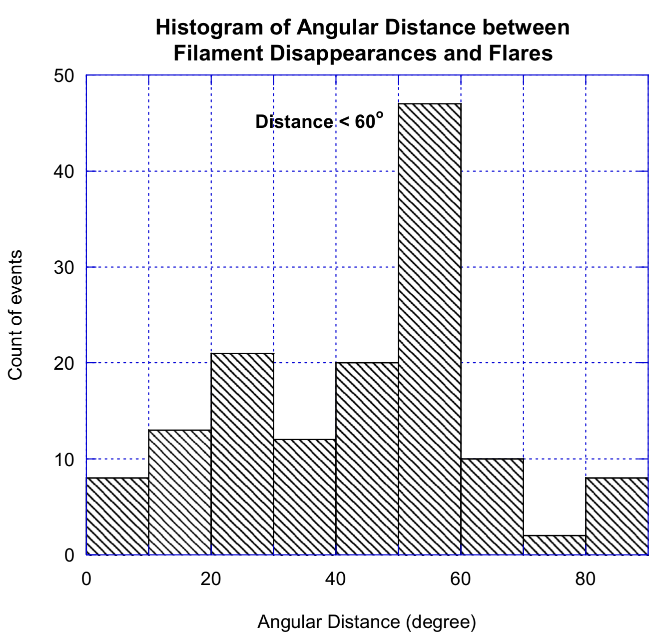

Fig. 1. Histogram of angular distance between filament disappearances and flares.

Filament disappearance may be associated with many flares, it is the second problem, but we assumed the flux of flares is the total flux of all flares which occurred during filament disappearance duration. The flare start time is the first flare start time, and end time is the last flare end time, and flare duration is all flares durations.

4. Results

We listed 639 filament disappearance events contemporary associated with 1676 solar flare events during 1996–2010 grouped yearly in Table 1.

We plot the result of Table 1 in Fig. 2 for the two cases: count of all filament disappearances and solar X-ray flares events which are contemporary associated. From Fig. 2, we showed that the associated events have the same curve behavior of all filament disappearances. The number of the associated events increased with the increasing of solar activity and decreased with quiet sun. This result gives us an indication that there is a strong correlation between solar flares and filament disappearances for the events selected based on our conditions.

From Fig. 3 we found significant dependence between the associated filament disappearances and associated flares (plot from Table 1).

$$Y = -5.2688 + 2.7465X, \qquad R = 0.99449 \tag{4.1}$$

where X is the annual count of the associated filament disappearances, and Y is the annual count of the associated flares.

The empirical equation (4.1) can be used to predict the annual number of the X-ray flares if we know the annual number of the filament disappearances and vice versa within 30° angular distance between disappearing filaments and flares.

We studied the characteristics of the filament disappearances and flares which are contemporary associated, and the results are in the following sections:

4.1. Duration time of filament disappearances

From Fig. 4 we found that there are two distinct groups of the filament disappearances which are contemporary associated with flares. The first group has a duration time of filament disappearance less than 8 h and few events belong to this category. The second category of filament disappearances has long duration more than 8 h.

It is easily to notice from this figure that the count of the short duration group decayed as the duration of filament disappearance increase. On the other hand, the second long duration category shows a normal distribution with a maximum at 15 h.

The duration of filament disappearance which is associated with solar X-ray flares can be classified into two groups:

(a) Short-lived < 9 h.
(b) Long-lived > 9 h.

Table 1
Counts of filament disappearances.

	All disappearances	Associated disappearance	Associated flares
1996	107	11	29
1997	112	16	23
1998	237	83	233
1999	204	67	160
2000	318	118	292
2001	296	120	342
2002	207	74	207
2003	247	87	245
2004	92	28	78
2005	65	15	23
2006	70	11	22
2007	7	2	3
2008	9	1	2
2009	6	0	0
2010	41	6	17
Total	2018	639	1676
Ratio	23% of all filaments	32% of disappearances	~7% of all flares

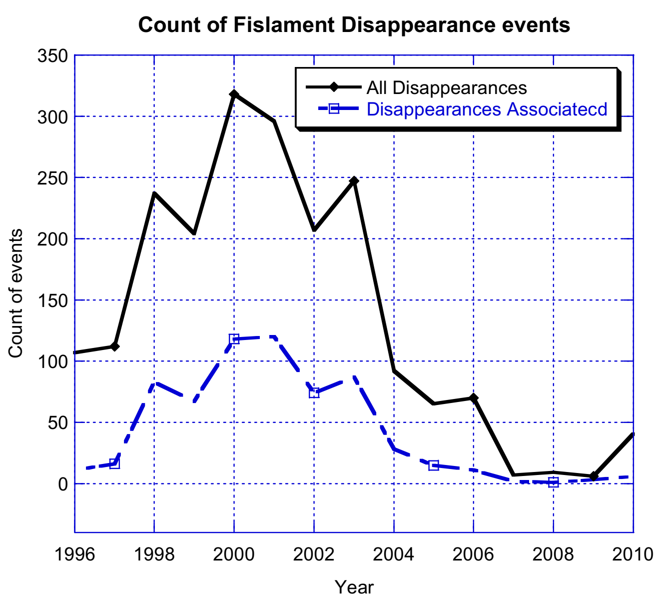

Fig. 2. Count of associated and non-associated filament disappearances with solar X-ray flares during 1996–2010.

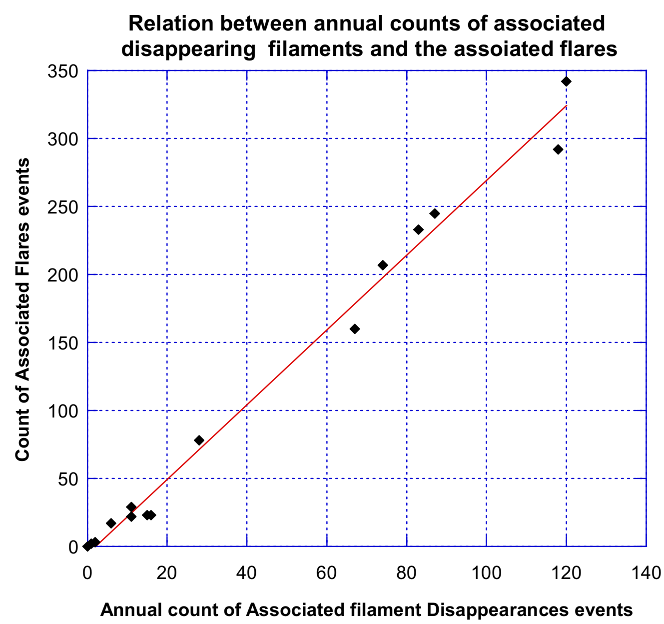

Fig. 3. Annual count of associated filament disappearance events and count of associated flare events during 1996–2010.

Most of the associated filament disappearance events have long time duration.

The mean value of duration of associated and non-associated X-ray flares with filament disappearance is 0.31 and 13.64 h respectively. This indicates that the filament disappearance lead to flare short duration.

4.2. Count of associated solar flares

We found that only 38% of the filament disappearances can cause one flare event during the filament disappearance duration. On the other hand the one disappearance event may cause up to 15 solar flare events (Fig. 5).

4.3. Intensity of solar flares

Most of the solar flares which occurred during duration time of filament disappearances have weak intensity 20 and the count of events decrease with intensity increase, Total intensity in data numbers/sec, as determined from SXI imagery (Fig. 6).

4.4. Flux of solar flares

It is found that most of solar X-ray flares which are associated with filament disappearance are of type C (Fig. 7). The mean values for solar X-ray flare flux for the associated and non-associated events are 6.6×10^{-3}

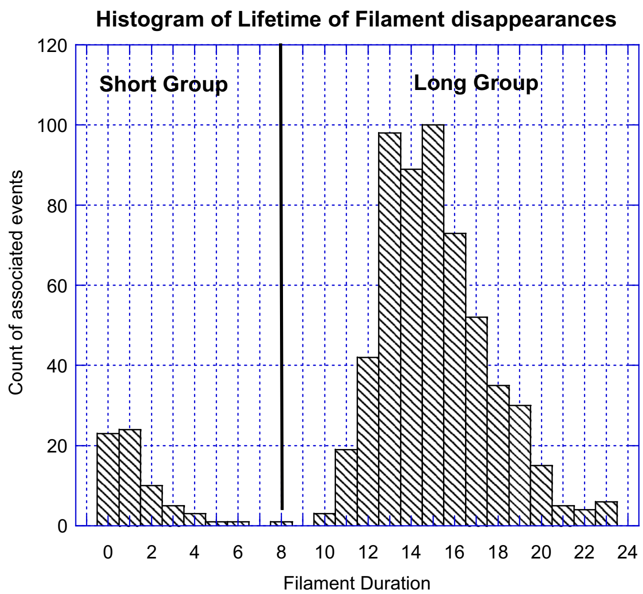

Fig. 4. Histogram of duration of filament disappearance events which are associated to solar flare during 1996–2010.

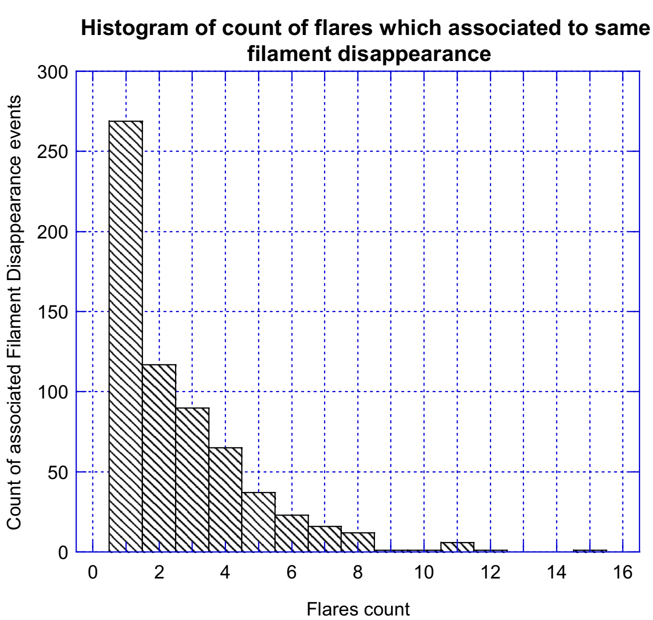

Fig. 5. Histogram of count of solar flares which are occurred during one filament disappearance event during 1996–2010.

and 4.8×10^{-3} ergs cm^{-2} s^{-1} (Type C) respectively (Flare classifications mentioned in Table 2). This indicate that the filament disappearance enhance the solar flare energy.

4.5. Relation between importance and solar flux

From Fig. 8, only long filaments of level 3 have the potential of producing most energetic M and X classes of X-ray flares.

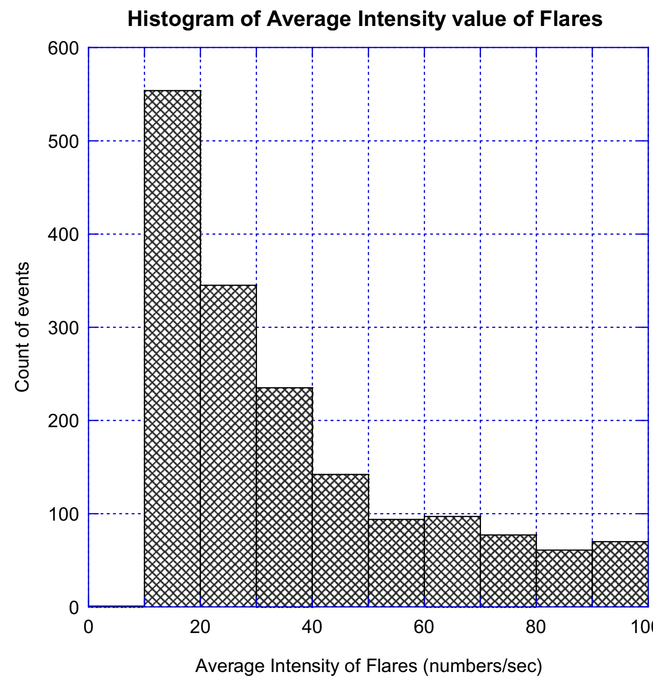

Fig. 6. Histogram of intensity of solar flares which are occurred during duration time of filament disappearance event during 1996–2010.

4.6. Flare optical importance & filament importance relationship

From Fig. 9, it is found that sub flares are associated with all filament disappearances importance. On the other hand, high optical importance 3 are only associated with filament disappearance of importance 3. Filament of importance 2 can be associated with sub flares & flares of optical importance 1 and 2. Filament of importance 3 can be associated with sub flares & flares of optical importance 1 to 3.

4.7. Interval time between disappearance and solar flare

Solar X-ray flares may occur within 15 h from start time of filament disappearances. Note that filament disappearance can take up to 15 h, we found that most association occurred in first three hours of filament disappearances (Fig. 10).

4.8. Importance of filament disappearances

Fig. 11 showed that most of the filament disappearance events which are associated with solar X-ray flares have medium and high importance.

4.9. Filament disappearance location

Fig. 12 indicates that the location of filament disappearances ranges between latitude ±50° and longitude ±70°. The latitude and central meridian are both symmetric

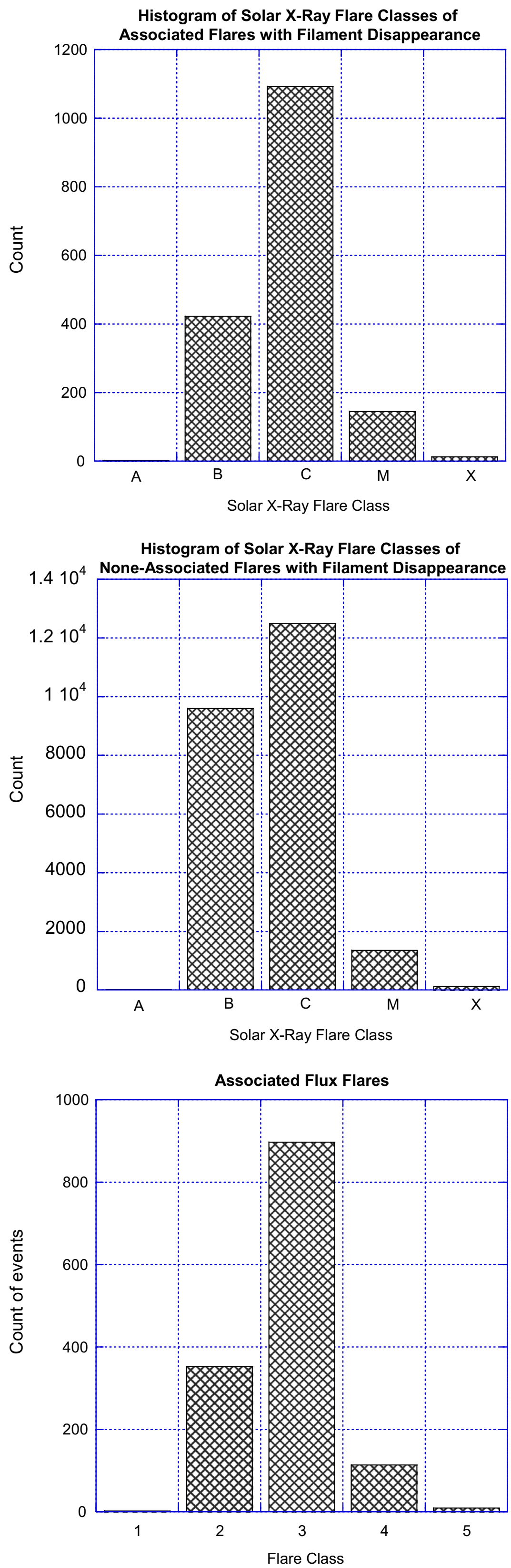

Fig. 7. Histogram of solar X-ray flares flux associated with filament disappearance during 1996–2010.

(Figs. 13 and 14) Most filament disappearances associated with solar X-ray flares have latitude ±20° and longitude ±20°. This makes filament disappearances a potential hazard for the earth.

From Fig. 14 we showed that the most of the filament disappearances have two locations.

Table 2
Flare classification.

Class	W/m * 2	Ergs cm^{-2} s^{-1}
B	$I < 10^{-6}$	$I < 10^{-3}$
C	$10^{-6} \leqslant I < 10^{-5}$	$10^{-3} \leqslant I < 10^{-2}$
M	$10^{-5} \leqslant I < 10^{-4}$	$10^{-2} \leqslant I < 10^{-1}$
X	$I \geqslant 10^{-4}$	$I \geqslant 10^{-1}$

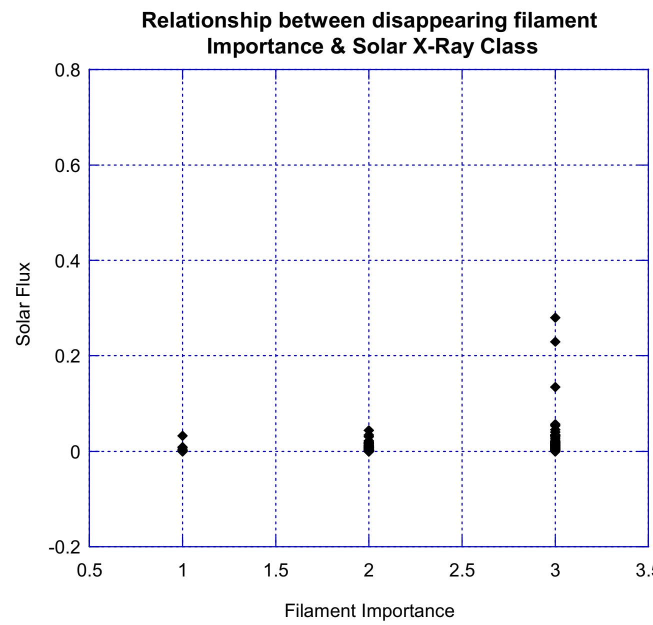

Fig. 8. The relationship between disappearing filament importance and solar X-ray flux during 1996–2010.

5. Conclusions

We studied the association between the filament disappearances and solar flares during 1996–2010; we concluded that the solar flares may occur during filament disappearance duration and near the location of the filament disappearances, the best angular distance between filament disappearances and associated solar flares ranged between 30° and 60°. We listed 639 associated filament disappearances, those particular 639 filament disappearance were associated with 1676 solar flares during the period 1996–2010. Only 32% of all filament disappearances were associated with flares. A single filament disappearance can produce as many as 15 solar flares. About 62% of filament disappearance events were associated with many solar flares, while 38% were associated only with a single flare. The number of the associated events increased with increasing solar activity and decreased with quiet sun. This result gives us an indication that there is a strong correlation between solar flares and filament disappearances

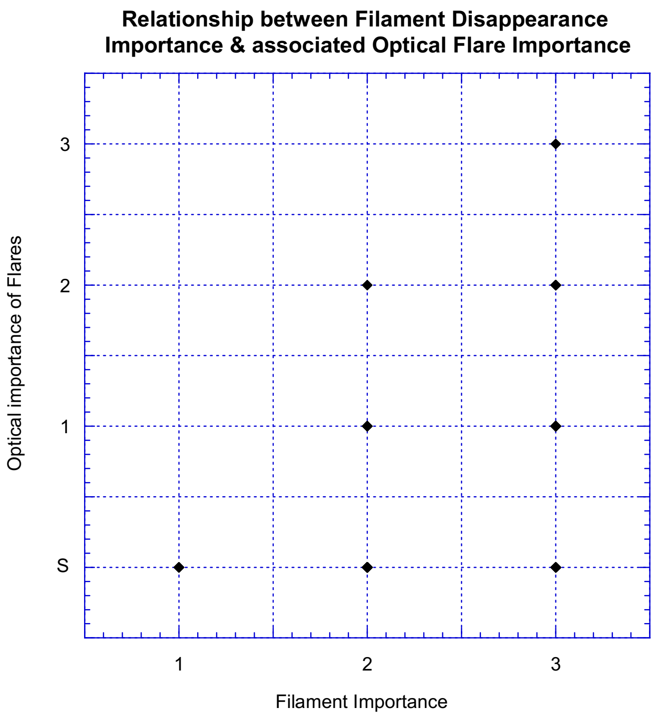

Fig. 9. The relationship between filament disappearance importance and the associated optical flares importance for 216 associated events during 1996–2010.

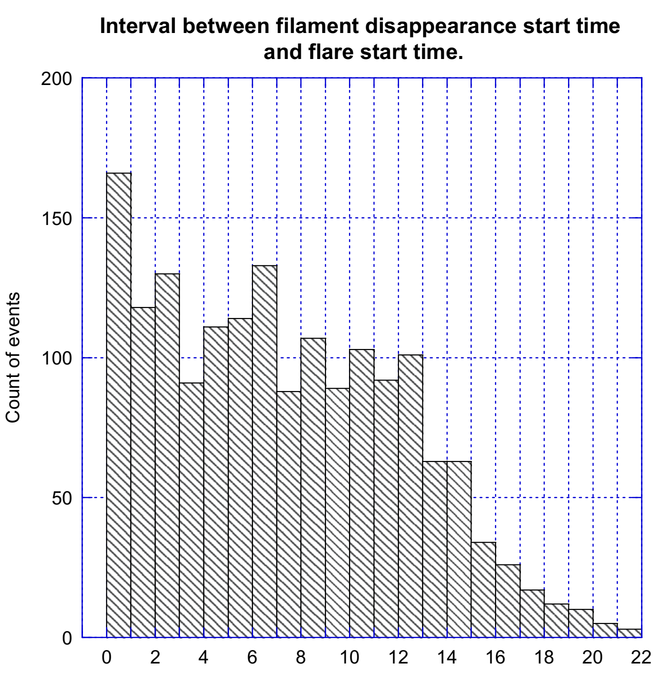

Fig. 10. Histogram of interval time between start time of filament disappearance and start time of associated solar flares during 1996–2010.

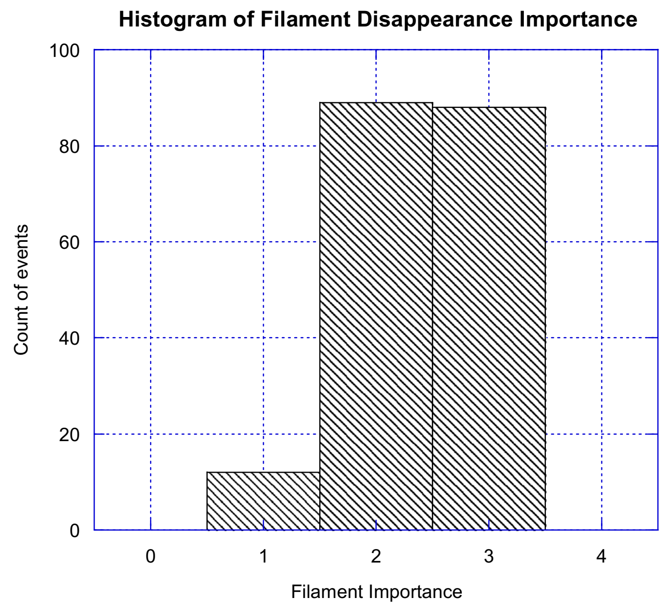

Fig. 11. Histogram of filament disappearance importance which is associated with solar flares during 1996–2010.

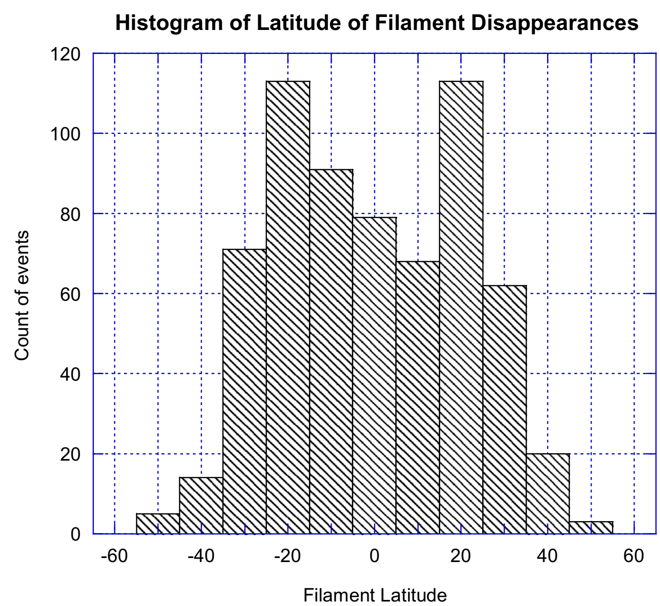

Fig. 12. Histogram of X-ray solar flares latitude which are associated with filament disappearance during 1996–2010.

which have been selected using our spatial and temporal conditions, we found significant dependence between the associated filament disappearances and associated X-ray flares is found,

$$Y = -5.2688 + 2.7465X, \qquad R = 0.99449$$

where X is the annual count of the associated filament disappearances, and Y is the annual count of the associated X-ray flares, R is the correlation coefficient.

We can thus predict the annual number of the X-ray flares if we know the annual number of filament disappearances and vice versa within 30° angular distance between disappearing filaments and flares.

The duration of those filament disappearances are classified into two groups:

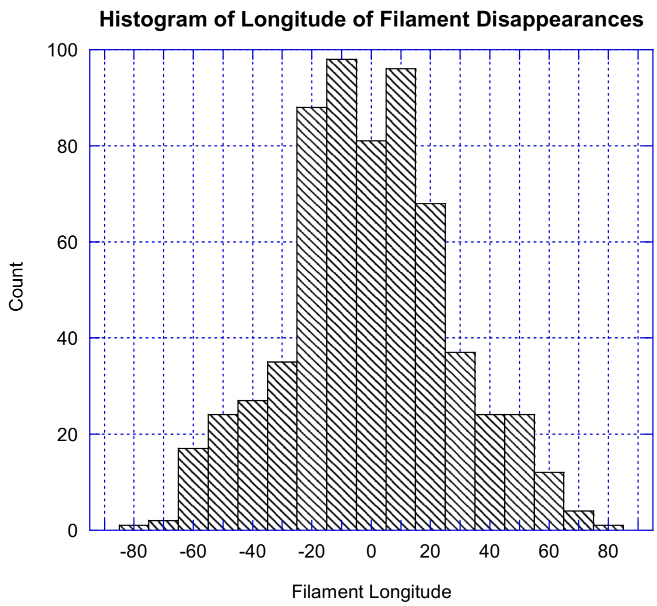

Fig. 13. Histogram of longitude of filament disappearances which are associated to solar flares during 1996–2010.

Fig. 14. Histogram of filament disappearance locations which is associated to solar flares during 1996–2010.

(a) Short-lived < 9 h.
(b) Long-lived > 9 h.

Most of those contemporary flare-filament disappearance events have long duration. The mean value of X-ray flare duration of associated and non-associated filament disappearance is 13.64 and 0.31 h respectively. It is found that most of solar X-ray flares which are associated with filament disappearance are of type C. The mean values for solar X-ray flare flux for the associated and non-associated events are 6.6×10^{-3} and 4.8×10^{-3} ergs cm^{-2} s^{-1} respectively (Type C). This indicates that the filament disappearance enhance the solar X-ray flare energy. Only long filaments disappearances of importance 3 have the potential of producing most energetic M and X classes of X-ray flares, most of the filament disappearance events which are associated with solar X-ray flares have medium and high importance. The location of filament disappearances ranges between latitude ±50° and longitude ±70°. The latitude and central meridian are both symmetric. Most filament disappearances associated with solar X-ray flares have latitude ±20° and longitude ±20°. This makes filament disappearances a potential hazard for the earth. Disintegration by rapid outflow of matter is not found in all filament disappearances which are associated with X-ray flares during all period 1996–2010. The filament disappearances which have long duration and long length are contemporary associated with solar X-ray flares. The associated solar X-ray flares have long duration and high solar flux relative to non-associated solar X-ray flares.

Table 3
Summarize non-associated flares.

Flares	Non-associated	Associated
Duration (h)	0.31160229	13.648565
Flux mean (J/m^2)	0.0048615797	0.0066830369
Intensity	35.257325	35.650655

Table 4
Summarize associated flares.

Filament	Non-associated	Associated
Importance	2.3705357 ~2	2.4021164 ~2
Blue shift	0.66059723 ~1	0.4153605 ~0
Red shift	0.66715222 ~1	0.4200627 ~0
Duration (h)	11.096827	13.648565

Tables 3 and 4 summarizes our conclusions.

Finally, we show that the longer filament disappearances have activity and ability of contemporary association with flares more than shorter filament disappearance. Filament disappearance powers the associated flares more than non-associated flares events. The associated flares have higher solar flux, longer duration, and higher importance compared to non-associated flares with filament disappearance. In addition the associated filament disappearance with flares have two types depending on their duration, short-lived (<9 h), and long-lived (>9 h).

The list of contemporized flare-filament disappearance events provided in the link: http://astro.azhar.edu.eg/ramy.mawad/flare-filament-disappearance.html.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.asr.2014.11.003.

References

Bruzek, A., 1951. Beobachtungen über das Verhalten von Filamenten während chromosphärischer Eruptionen. Mit 7 Textabbildungen. Zeitschrift für Astrophysik 28, 277.

Bruzek, A., 1958. Die Filamente und Eruptionen eines Aktivitätszentrums. Mit 6 Textabbildungen. Zeitschrift für Astrophysik 44, 183.

Canfield, Richard C., Athay, R. Grant, 1974. Theoretical chromospheric flare spectra. I: hydrogen equilibrium for the kinematic flare-shock models of Nakagawa et al. (1973). Sol. Phys. 34 (1), 193–206, 01/1974.

D'Azambuja, L., 1948. Thesis at the Observatory of Paris.

Dodson, Helen W., Hedeman, E. Ruth, Marta Rovira, Miceli, 1971. Comments on filament-disintegration and its relation to other aspects of solar activity. Sol. Phys. 23 (2), 360–368. http://dx.doi.org/10.1007/BF00148100.

Giovanelli, R.G., 1940. The motion of eruptive prominences. Astrophys. J. 91, 83, 01/1940.

Haimin, Haisheng, Edward, Jiong, Chang, Na, 2002. Sudden disappearance of a small sunspot associated with the 2002 February 20 M2.4 flare. Astrophys. J. 580 (2), L177–L180, 12/2002.

Kahler, S.W., 1980. X-ray structures associated with disappearing H-alpha filaments in active regions. In: Solar and Interplanetary Dynamics; Proceedings of the Symposium, Cambridge, Mass., August 27–31, 1979. (A81–27626 11–92) Dordrecht, D. Reidel Publishing Co., 1980, p. 61–64; Discussion, p. 65.

Martres, M.-J., 1956. Disparition brusque d'une protubérance observée à l'héliographe monochromatique, le 9 août 1956. L'Astronomie 70, 401, 11/1956.

Newton, H.W., 1942. A solar eruption and the magnetic storm of 1942 March 1–2. The Observatory 64, 260–264, 06/1942.

Newton, H.W., 1935. Note on two allied types of chromospheric eruption. Mon. Not. R. Astron. Soc. 95, 650, 06/1935.

Newton, H.W., 1934a. The distribution of radial velocities of dark $H\alpha$ markings near sunspots. Mon. Not. R. Astron. Soc. 94, 472, 03/1934.

Newton, H.W., 1934b. The Sun's rotation period derived from recurrent sunspots, 1924–1933. Mon. Not. R. Astron. Soc. 95, 60, 11/1934.

Smith, S.F., Ramsey, H.E., 1964. The flare-associated filament disappearance. With 9 figures in the text. Zeitschrift für Astrophysik 60, 1.