

Eruption of twisted filament, associated flare and transient phenomena

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Abstract. In this paper we present CCD observations between 14th to 20th Feb. 1994 and analysis of the giant twisted filament evolved in the active region NOAA 7671. The dynamic eruption of the filament accompanied by major flare (3B/M4), CME long duration type II, type IV radio bursts, great microwave bursts, long duration soft X-ray burst, SIDs, strong geomagnetic storms and most energetic proton flare. We analysed and estimated the twist, length, volume, mass and energy associated with filament system between 14th to 20th Feb. 1994. We also give the explanation of the event in the light of existing theories.

Key words: twisted filament - energy storage - solar flare - filament eruption

1. Observations, data analysis, results and discussions

The observations of the filament evolution in $H\alpha$ emissions between 14th - 20th Feb. 1994 have been recorded with 15cm f/15 Coudé refractor and peltier cooled (-25°C) CCD camera system. The CCD camera system used for the observations has the chip size 385×578 pixels, pixel size 22×22 microns and A/D 16 bit.

The shape of the filament kept on changing from 14th to 19th Feb. 1994 and ultimately the filament twisting, shearing and energy buildup reached a critical stage which led to eruption of the filament system on 20th Feb. 1994. The eruption of the filament was not recorded at UPSO because it took place before sunrise at Naini Tal. The filament eruption and flare was recorded at Hida Observatory, Japan (Kurakawa and Shinkawa, 1995). We could record the decay phase of the filament/flare eruption.

In Fig. 1 we have shown the composite figure of filament evolution with spot group from 16th to 19th Feb. 1994. As is clear from Fig. 1 that twisting and shearing of the filament was continuously increased from 16th to 19th Feb. 1994. The twisting of the filament started on 14th Feb. which is not shown here due to shortage of space. The filament erupted out ultimately on 20th Feb. 1994 and the decay phase of the filament/flare eruption is shown in Fig. 2. From the observations of filament evolution from 14th to 19th Feb. we estimated twist of the filament, length of the filament, mass, volume and energy of the filament which are

shown in Table 1. The spot group associated with the filament under study between 14th to 20th Feb. was found to be rotating which enhanced the twist in the filament. The emerging flux regions also increase the complexity of the magnetic field. The rotation of the sunspot group measured by us is shown in Table 1.

Table 1.

| Date Feb 1994 | Twist of filament (total) π | Measured rotation of sunspot group (in degree) | Total filament length (in km) $\times 10^5$ | Twisted filament length (in km) $\times 10^5$ | Energy in ergs $\times 10^{31}$ | Volume cm^3 $\times 10^{28}$ | Mass gm $\times 10^{16}$ |
|------------------|--|---|---|---|---------------------------------------|---|--------------------------------|
| 14 | – | 0 | 1.677 | – | 0.387 | 0.95 | 1.63 |
| 15 | 2 | 5 | 2.924 | 1.161 | 1.05 | 2.65 | 2.52 |
| 16 | 2.5 | 15 | 3.268 | 2.064 | 1.69 | 4.27 | 3.46 |
| 17 | 3.0 | 22 | 3.354 | 2.279 | 3.10 | 5.15 | 4.43 |
| 18 | 3.5 | 32 | 3.440 | 2.365 | 4.35 | 6.10 | 5.14 |
| 19 | 4.0 | 65 | 3.569 | 3.354 | 5.10 | 6.34 | 7.15 |

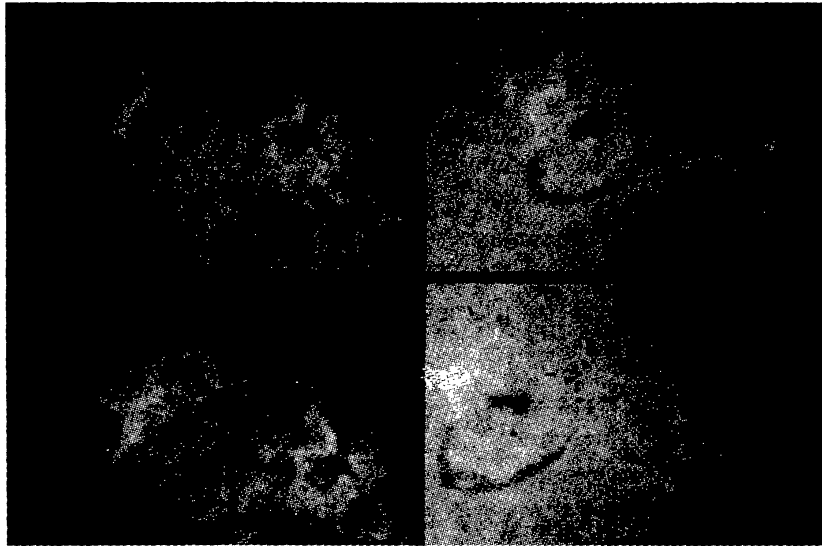


Figure 1. Evolution of the twisted filament from 16th to 19th Feb. 1994.

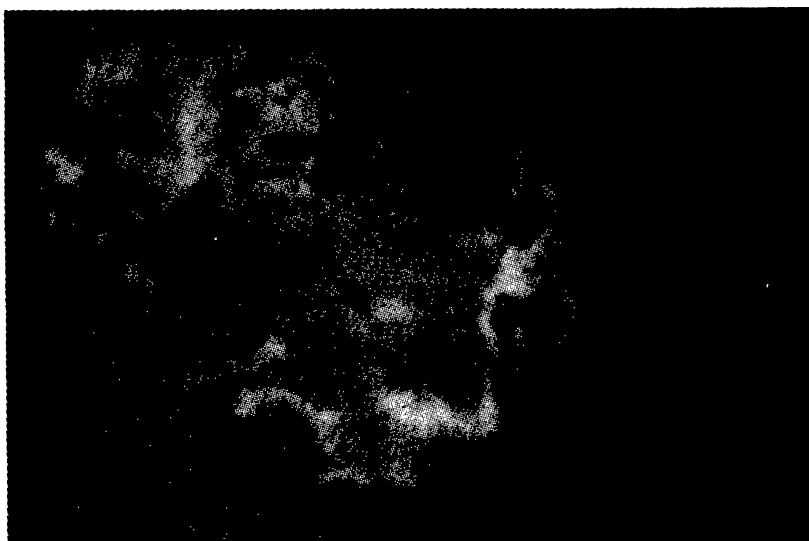


Figure 2. The disappearance of filament system and the decay phase of the 3B $H\alpha$ flare.

The magnetic energy storage took place due to enhancement of twisting and shearing in the filament (Moore, 1988; Hagyard et al., 1990).

This is a very dynamic long duration event which occurred as a result of twisted giant filament eruption. We can say that this is the most energetic event in the decay phase of solar cycle 22, because the event associated with major flare 3B/M4, third largest proton flare (10,000 pfu) of solar cycle 21 and 22, great MW bursts, long duration type II, (1400 km/s), type IV radio bursts, SIDs, strong geomagnetic storms, CME and other related phenomena (SGD, 1994, 1996). This is a best example of dynamic disparition brusque. It is also the observational manifestation of flare models proposed by Carmichael (1964), Sturrock (1968), Hirayama (1974 and Koop and Pneuman (1976) (CSHKP model). Most recently Rust and Kumar (1996) explained the eruption of helically twisted S-shaped $H\alpha$ filament on the basis of MHD helical kink instability. The filament system reported here has also the S-shaped twisted helical structure.

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