ON THE ERUPTION OF PROMINENCES AND DISAPPEARANCE OF QUIESCENT FILAMENTS

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Abstract. We suggest the following heuristic model for the evolution of a quiescent filament. The middle part of the filament rises due to heating, while its ends remain anchored in the chromosphere; and a kink appears in the Hα filament due to projection and line-of-sight effects. Further, the top segment of the filament rises rapidly above the solar surface 1–2 days before the disappearance of a filament or eruption of a prominence. The top of the filament attains a high temperature due to further heating, thereby becoming invisible in Hα, giving the impression that the filament has split into two parts. It is expected that this gap between the Hα filament can be seen in the observations in high-temperature lines and soft X-rays.

1. Introduction

A number of attempts have been made in the past to understand the physical and dynamic characteristics of prominences and disappearing filaments (cf., D'Azambuja and D'Azambuja, 1948; Tandberg-Hanssen 1974; Priest, 1988; Hirayama, 1985; Zirker and Koutchmy, 1990; Rausaria *et al.*, 1993). The suddenly disappearing dark filaments are called disparition brusques (DB) when seen on the disc, and eruptive prominences when they occur at the limb (Kubota *et al.*, 1992). The prominences associated with activity generally erupt due to reorganisation of magnetic field structure in the active region and are short-lived as compared to quiescent prominences. In the quiescent phase, the cold prominence plasma forms a slab below the cylinder axis (Vršnak, 1992) where it is confined due to a small scale height of only 200–300 km (Priest, 1990). The detailed observations of quiescent prominences over a long period can provide a clue to conditions for the onset and growth of the eruptive instability, as well as its development (Vršnak, 1990a, b). Moreover, such observations could provide a clue for the comprehension of related violent processes such as flares, coronal transients, emission of blast waves, etc. (Harrison *et al.*, 1985). In this paper, we discuss the development of the gross structure of the filament with time and the role of shear in the disappearance of filaments and eruption of prominences.

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2. Observations and Data Analysis

Kodaikanal Observatory has been obtaining full-disc photoheliograms since 1904, pictures of prominences since 1907, and spectroheliograms in calcium K since 1907 and in Hα since 1912. In the case of flares and prominence eruptions, observations are made every 4–5 min. Using these data we have sketched the positions of sunspots, Hα filaments, calcium K-line plages and prominences on the Sun charts.

To detect changes in the filament orientation with time, the rotation axis of the Sun was chosen as a reference for measurement of angles due to non-availability of sunspots or plages near the quiescent filament. In case the extent of the filament appreciably differed from a straight-line fit, the filament was divided into two or three portions, each nearly a straight line. The angle made by the filament or each portion of the filament with the rotation axis of the Sun was measured from the north towards the east direction after correcting for the foreshortening effect. The shear angle for a non-straight-line filament has been defined and measured by the following procedure. Let us consider a filament XYZ as shown in Figure 1 which can be represented by two straight lines XY and YZ. θ_1 and θ_2 are the angles made by these two portions with the rotation axis of the solar image, respectively. The angle between these two portions of filaments, θ, is given by the relation

$$\theta = \theta_1 - \theta_2 + 180^\circ .$$

We have defined the shear angle $\gamma = 180^\circ - \theta$ as the amount by which the filament differs from a straight line.

3. Results

Here we discuss the specific cases of an eruptive prominence and a disappearing filament with a view to follow their evolution.

3.1. Eruptive Prominence of February 3, 1950

A filament was seen from December 27, 1949 to January 6, 1950 and from January 22 to February 2, 1950 on the disc during its first and second transit (Figures 2(a) and 2(b)). On February 3, 1950 the eruption of the prominence was recorded on the west limb. The height of the quiescent prominence was measured to be about 30 arc sec on January 6, and 40 arc sec on January 7, as well as on January 22. The filament can be represented by a straight line during its initial life of about one month. Due to the development of a kink at location 'A' in the filament on January 25, one needs two straight lines to represent this filament. The shear angle went on increasing gradually up to January 31 and then rapidly on February 1 and 2. A small kink developed at point 'B' of this filament on January 28, and

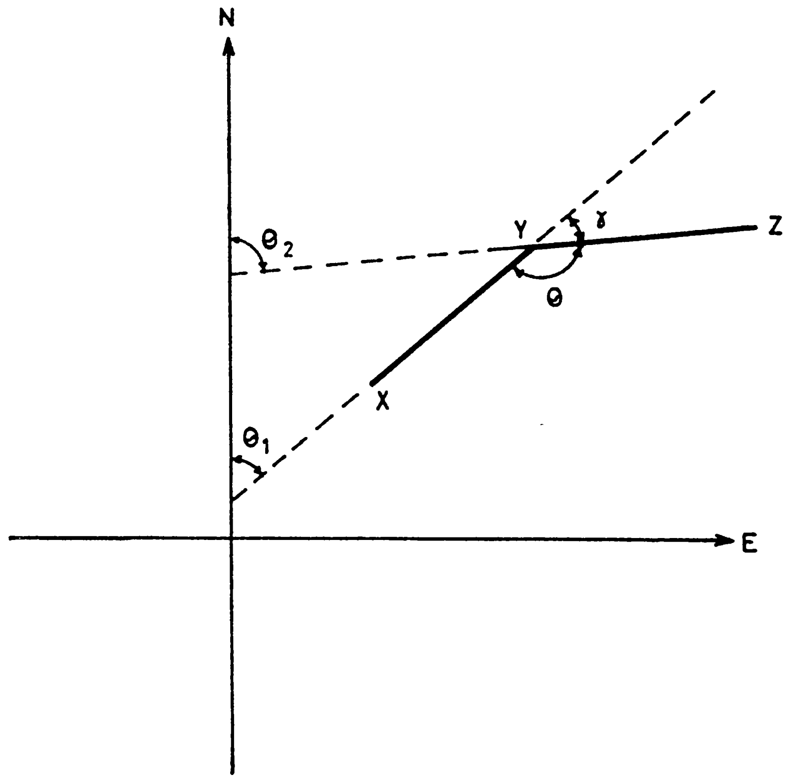

Fig. 1. Details of the technique used to measure the shear angle in Hα filaments.

increased with time. A part of the filament seen as a prominence at the west limb on February 2, 1950, had a height of about 100 arc sec above the limb, that is 2.5 times the height on January 22.

The initial eruptive phase of the prominence is shown in Figure 3. The third frame indicates that the material did not gain altitude, but knots of material started moving in the northern direction almost parallel to the solar surface. The fourth and fifth frames of this figure show the knots heading towards the solar surface from the southern to the northern hemisphere, covering large distances. Finally, the eruptive phase of the prominence was over, with a part of the material falling back at the location of the event, a part going into the solar atmosphere and a part falling at a far-away location in the vicinity of the sunspot group at 10 deg north.

3.2. Disappearing Filament of April 15, 1950

This quiescent filament lived for more than 5 solar rotations and was not associated with sunspot activity during its lifetime as seen in Figures 4(a) and 4(b). The associated quiescent prominence on December 15, 1949 had a height of 40 arc sec above the solar limb. A small kink developed at the point 'A' on January 16. The shear angle in the filament due to this kink remained at $13 \pm 7°$ for more than a month till February 19, 1950. The prominences seen on the west and east limb

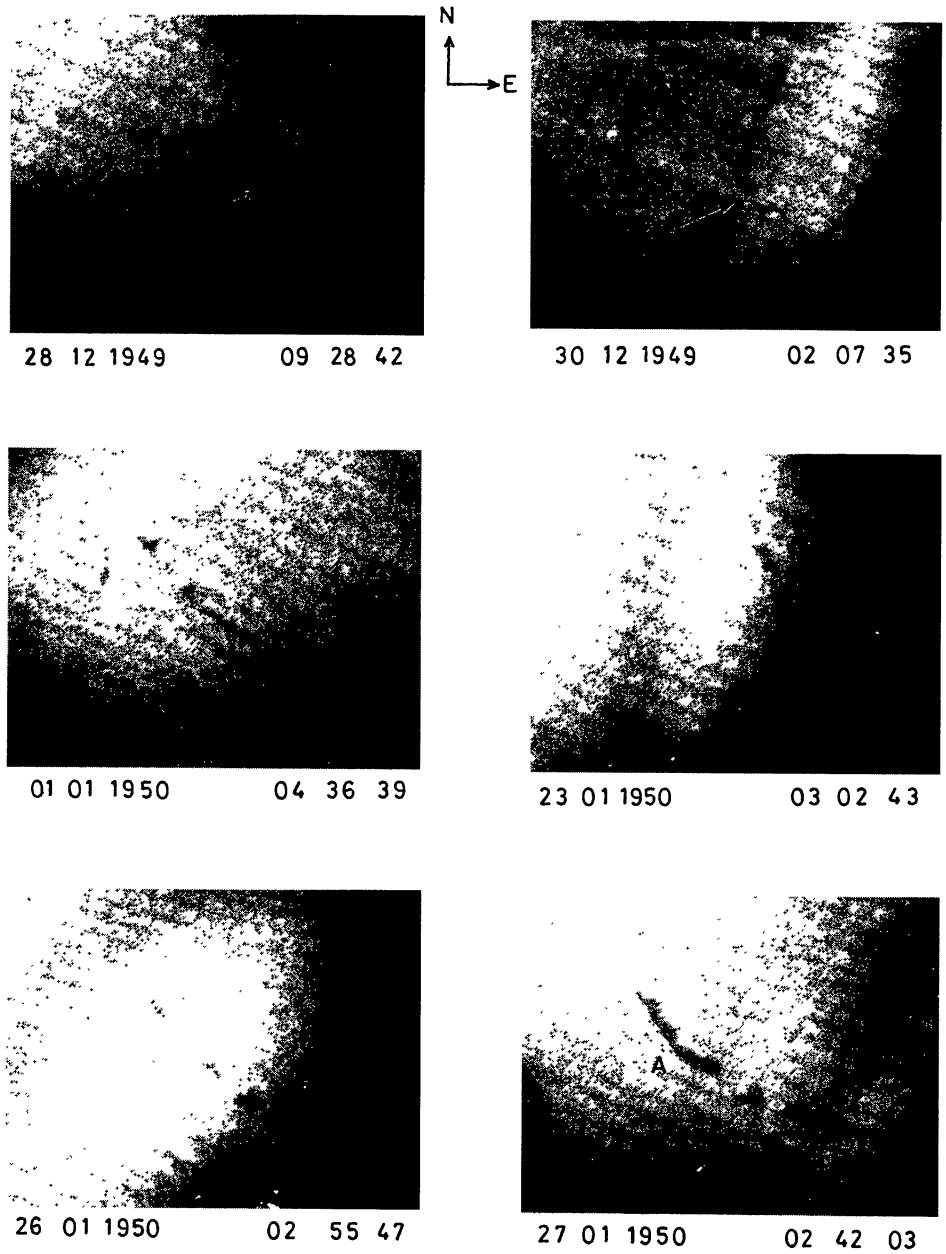

Fig. 2a. Hα spectroheliograms showing the evolution of the filament which erupted as a prominence on the west limb on February 3, 1950. Date and time in UT are given below each picture. Arrows in the first two frames indicate the filament under study.

corresponding to this filament also show a small increase in height during January and February. The kink further developed during the fourth transit from March 14 to March 18, with the shear angle increasing to 42 ± 2 deg. The prominences observed on the east limb before this epoch and on the west limb afterwards also showed an increase in height. The filament, seen near the east limb on April 12 at

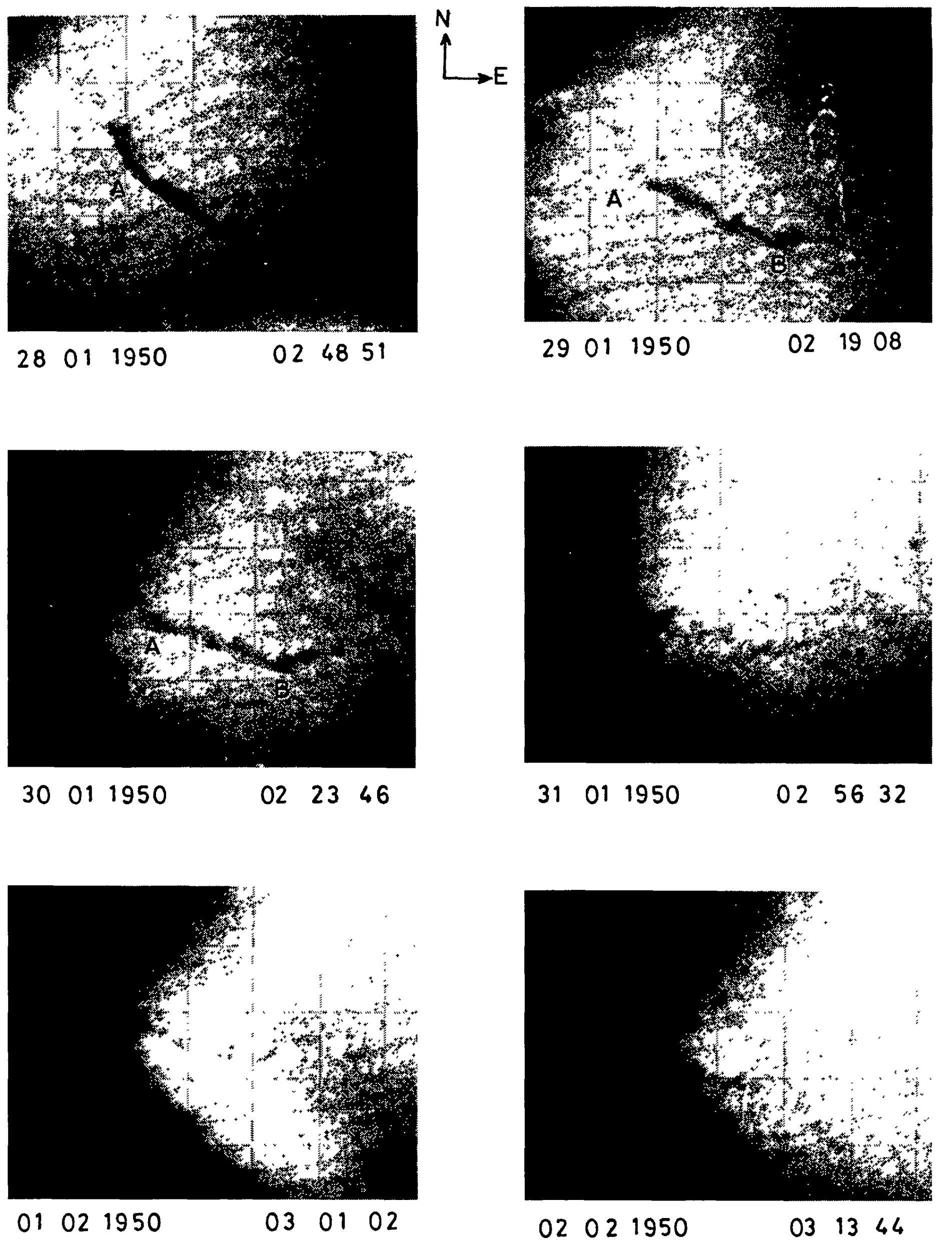

Fig. 2b. Same as Figure 2(a) except for the arrow marking.

the time of its fifth transit, was highly sheared with a gap of about 5 deg. Within a day the shape changed to an inverted U, with the gap increasing to 12 deg. The gap further increased to 17 deg on April 14, 1950 and the shear angle became 74 deg. Finally both portions of this filament disappeared between the afternoon of April 14 and the morning of April 15.

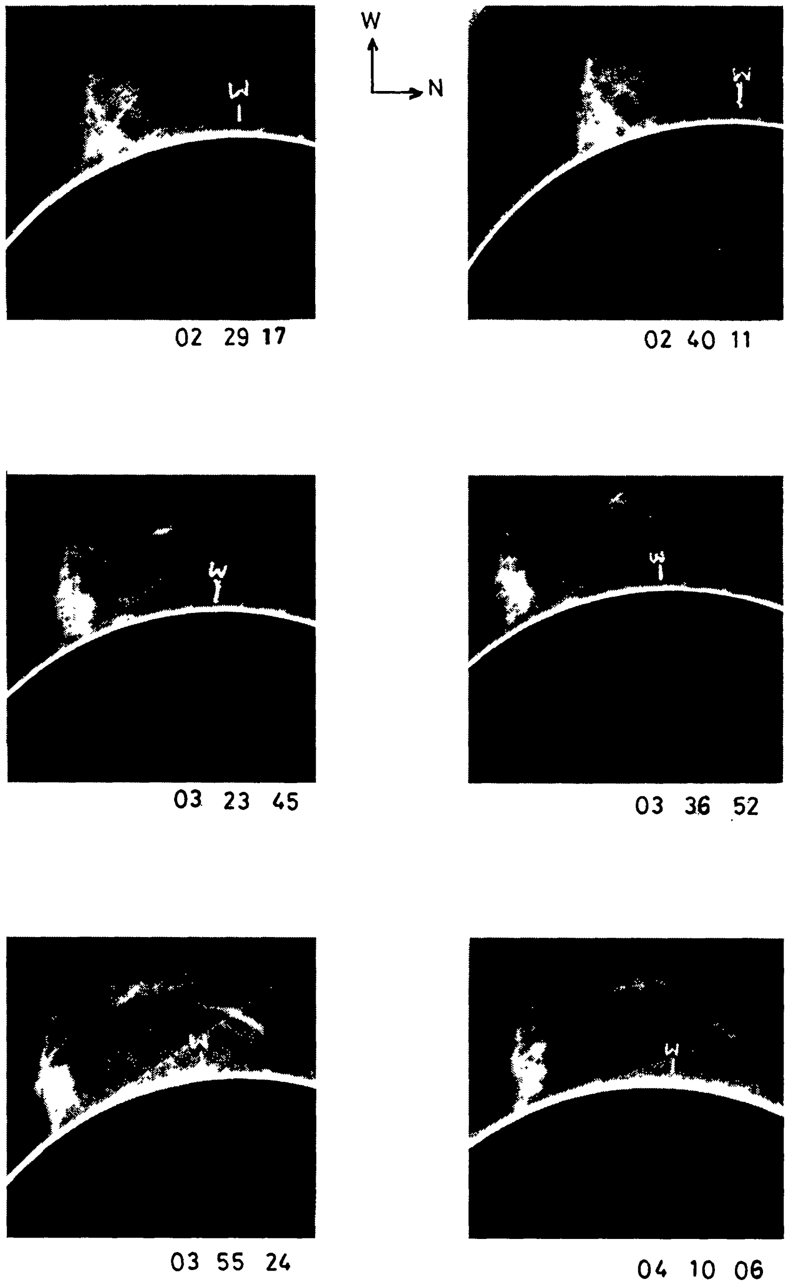

Fig. 3. Time sequence of prominence pictures obtained during the eruptive phase on February 3, 1950. Time in UT is given below each frame.

4. Discussion

We see that the most notable features of these observations are that (i) the shear angle of the Hα filament increases at a slow rate in the beginning and rapidly during the last stages of its life; (ii) the height of the prominence associated with the filament increases with time; and (iii) the Hα filament splits into two portions, followed by the disappearance of filament or eruption of the prominence. The

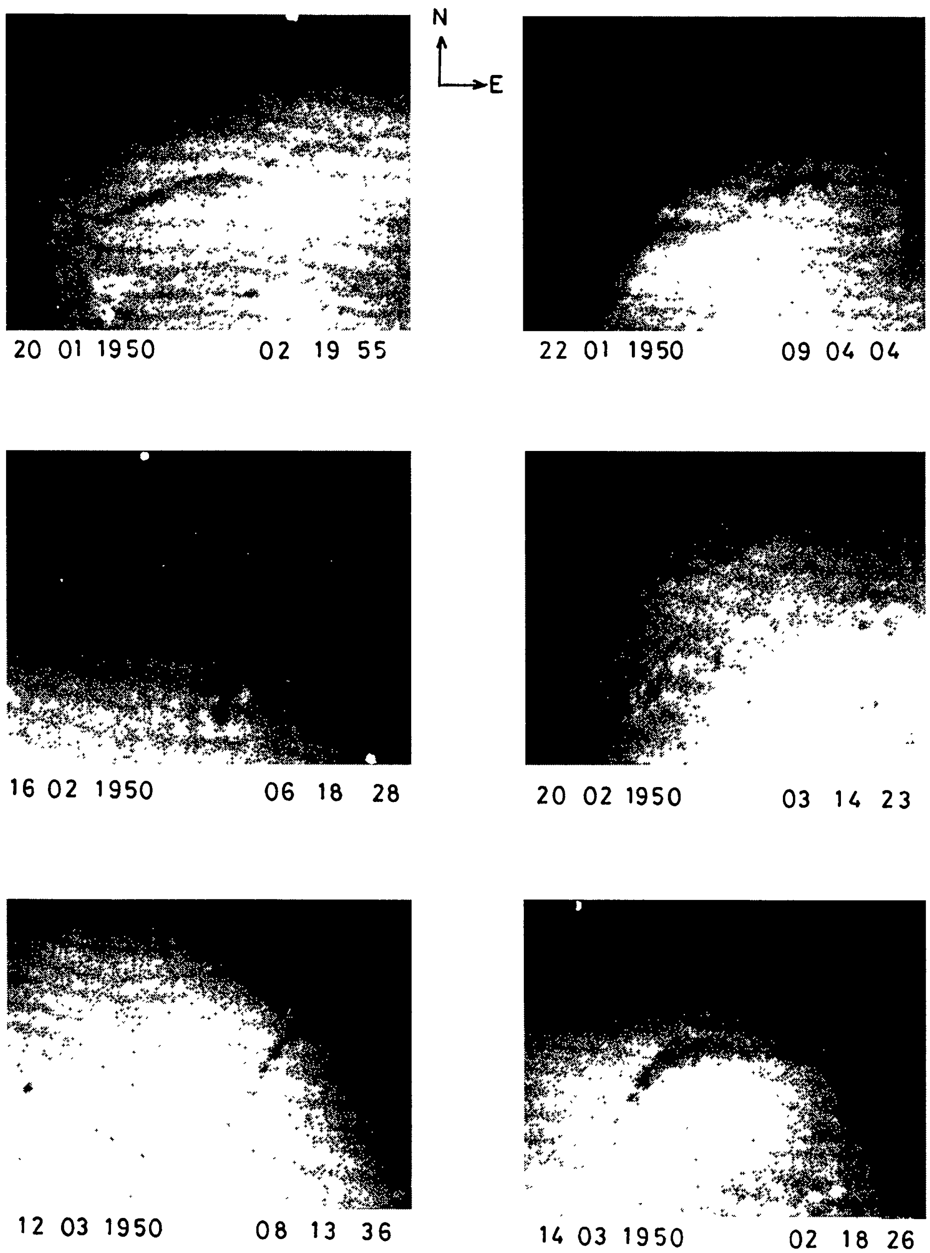

Fig. 4a. Hα pictures showing the growth and development of shear in the long-lived quiescent filament which disappeared between the afternoon of April 14 and the morning of April 15, 1950. Date and time in UT are given below each frame.

change in the shear angle is often explained in terms of changes in the magnetic field configuration and neutral line at the photospheric level. It is rather difficult to visualize the rapid movement in the Hα filament at the chromospheric level entailed by sharp changes in the shear angle.

In the following, we present an alternative mechanism which can consistently explain observed features of quiescent filaments and prominences. The starting

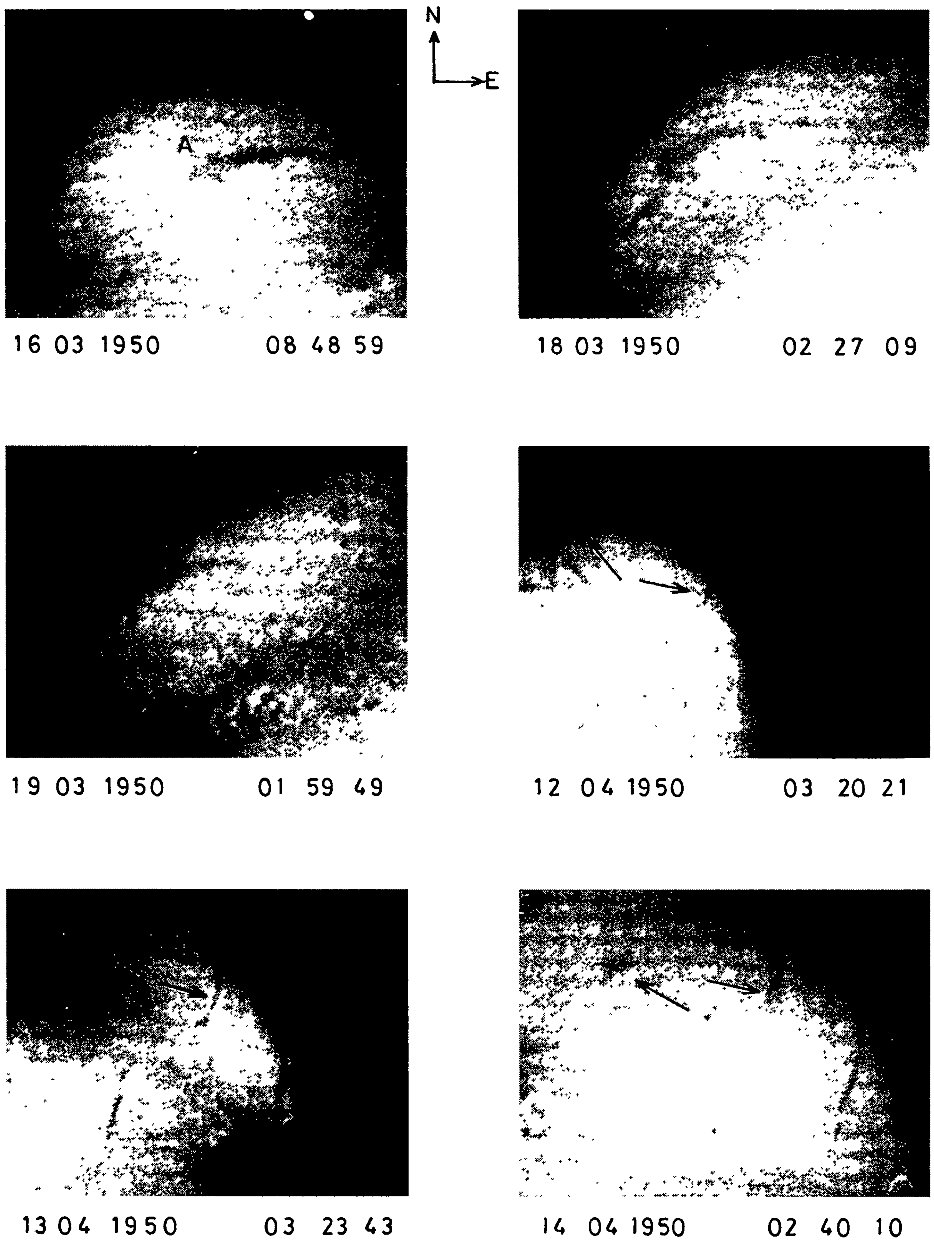

Fig. 4b. Same as that of Figure 4(a). In addition, arrows have been marked in the last three frames to indicate the filament of interest.

point is a quiescent filament seen as a straight line on the solar disc, which when on the limb is seen as prominence. It is postulated that the filament receives energy from the chromosphere and undergoes slow and steady heating. As a result, its middle portion rises to form a large loop-like structure, while its ends remain anchored in the chromosphere. As the heating of the looped structure continues, thermal pressure increases to such an extent that it cannot be balanced by the weak magnetic field of the filament. The filament or the prominence therefore expands rapidly and finally disappears or erupts, respectively.

The observational manifestations of the above assumption are the following. Owing to the projection and line-of-sight effects, the expanding loop-like structure will be seen as a filament with a kink with slowly increasing shear angle. When on the limb, the structure would be seen as a prominence with increasing height. As the structure progressively increases in temperature, the filament appears less dark in Hα pictures. With further heating, the loop structure expands rapidly. This is seen as a relatively rapid change in the shear angle. The top segment of the loop becomes so hot that it is no longer seen in Hα. Consequently, the Hα filament splits into two and the gap in the two parts of the filament increases with time. Eventually, 2–3 days after the beginning of this rapid phase, the filament disappears or the prominence erupts. It is also seen that both portions of the filament disappear at the same time. In this model, the gap in the filament is not a physical discontinuity but a manifestation of differential temperature. We expect to see the continuity in the filament in high-temperature lines and soft X-rays. Rust (1984) and Tang (1986) have already indicated that filament disappearance may be caused by heating or by dynamic processes. Considering the above-mentioned facts, we believe that heating plays an important role in the disappearance of quiescent filaments and eruption of prominences. Finally, we suggest that simultaneous observations with good photometric accuracy in different temperature-sensitive lines will help to understand the circumstances leading to the eruption of quiescent prominences and filament disappearances.

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