EFFECTS OF MAGNETIC SHEAR, SPOT, AND PLAGE ROTATION ON PROMINENCE EVOLUTION

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Abstract. We have studied the evolution of two dark Hα filaments as prominences during their disk passage from 12 to 19 February, 1992 and 6 to 17 March, 1992, using Kodaikanal Observatory Hα and Ca II K spectroheliograms. Both the filaments were well outside the spot regions. However, they were connected to sunspots by small threads. Outside the spot regions, the filaments were also anchored between opposite polarity plage regions. Both the filaments were almost straight in the beginning. However, they acquired a curved shape (inverted U-shape) as the spot and plages underwent rotation. It is shown that rotation of the plage and spot plays an important role in the evolution of prominences, one serving as the anchor and the other imparting necessary shear. Once the shear reaches a critical value it starts unwinding the filaments, resulting in the fine structure of the two prominences studied.

1. Introduction

Prominences are the exotic objects in the corona. The details of their formation, magnetic structure and support still are not clearly understood (Priest, 1988). Recently it has been shown observationally that the prominences possess fine structures and consist of a large number of threads (Zirker, 1989). Various attempts have been made in the past to understand prominence characteristics (Tandberg-Hanssen, 1974; Priest, 1988; Hirayama, 1985; Zirker and Koutchmy, 1990). In this paper we have addressed the problem of thread formation in the prominences, involving plage and sunspot rotations as the cause for the same.

Prominences are Hα filaments in projection. However, there is no one to one correlation between Hα filaments and the subsequent formation of prominences observed. In this paper, therefore, we have investigated the cause which results in twisting the Hα filament to acquire its inverted U-shape, using Kodaikanal Observatory Hα, Ca II K spectroheliograms and white-light spectroheliogram data for two events from 12 to 19 February, 1992 and 6 to 17 March, 1992. The analyses of the data show that rotations of plage and spots bring in non-potentiality in the magnetic structure of the filament. This in turn develops a shear and kink in the filament at a point where rotation of the plage is significant. This shear/kink keeps developing with the evolution of the plage and spot thereby imparting a curved structure to the filament. When the twist or shear reaches a critical stage it becomes untenable, and makes a quiescent prominence active and the fine structure threads in the filament becomes more easily observable. The Hα thread linking the main

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filament to the spot probably works as a channel for the supply of materials to the prominence.

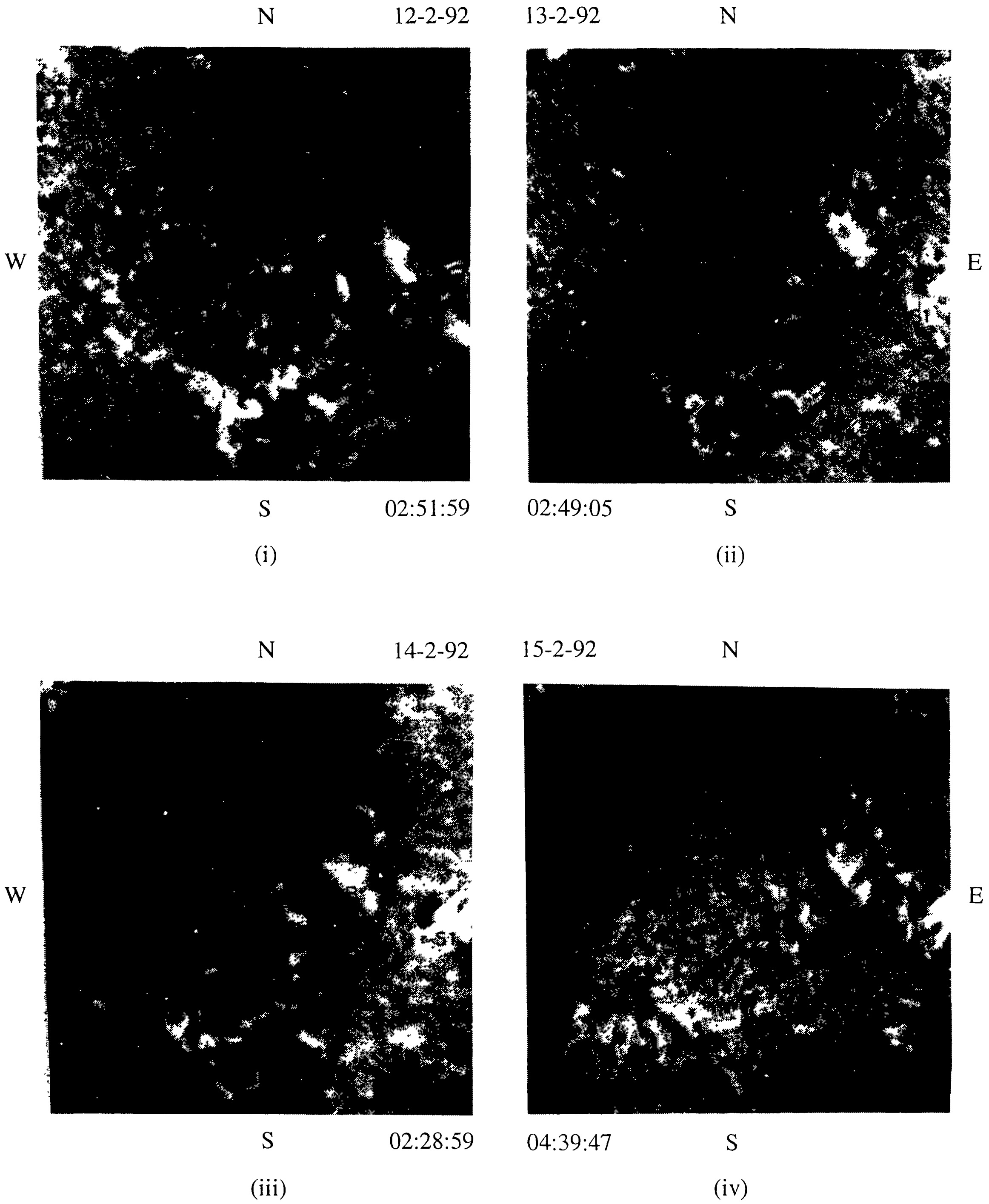
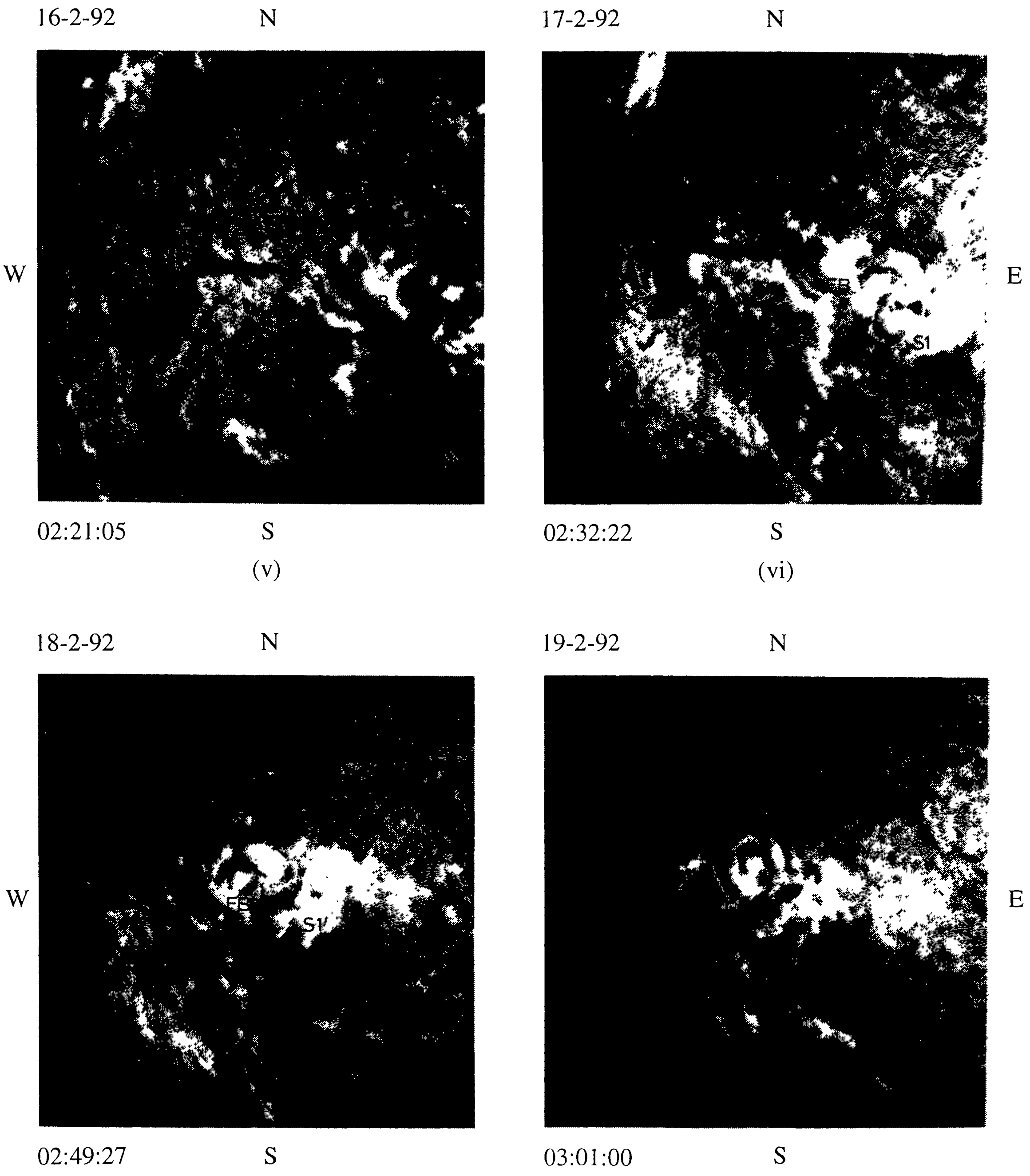


Fig. 1a. Hα spectroheliograms from 12 to 19 February, 1992 showing the variations in the orientations of the filament and associated plage region marked by arrows. The evolution of the fibril structure indicated by FB can also be seen.



(v) (vi) (vii) (viii)

Fig. 1a (continued).

2. Observational Data

A daily white-light photograph of the Sun of diameter 8″ is being taken regularly, using a 6″ refractor at Kodaikanal. Spectroheliograms in Hα are also recorded daily using a Littrow mount with a solar image of diameter 60 mm. Ca II K spectroheliograms of the same diameter, 60 mm, are also recorded daily using two prisms (60° angle, 100 mm height and 150 mm base) and two lenses of 175 cm focal length, producing 7 Å mm^{-1} dispersion around 3930 Å.

The Hα and Ca II K spectroheliograms showing the development of filament and plage orientations on various days for the event 12 to 19 February, 1992 are given in Figures 1(a) and 1(b), respectively, whereas the photoheliograms for the same event are given in Figure 1(c). The details of the Hα, Ca II K spectroheliograms

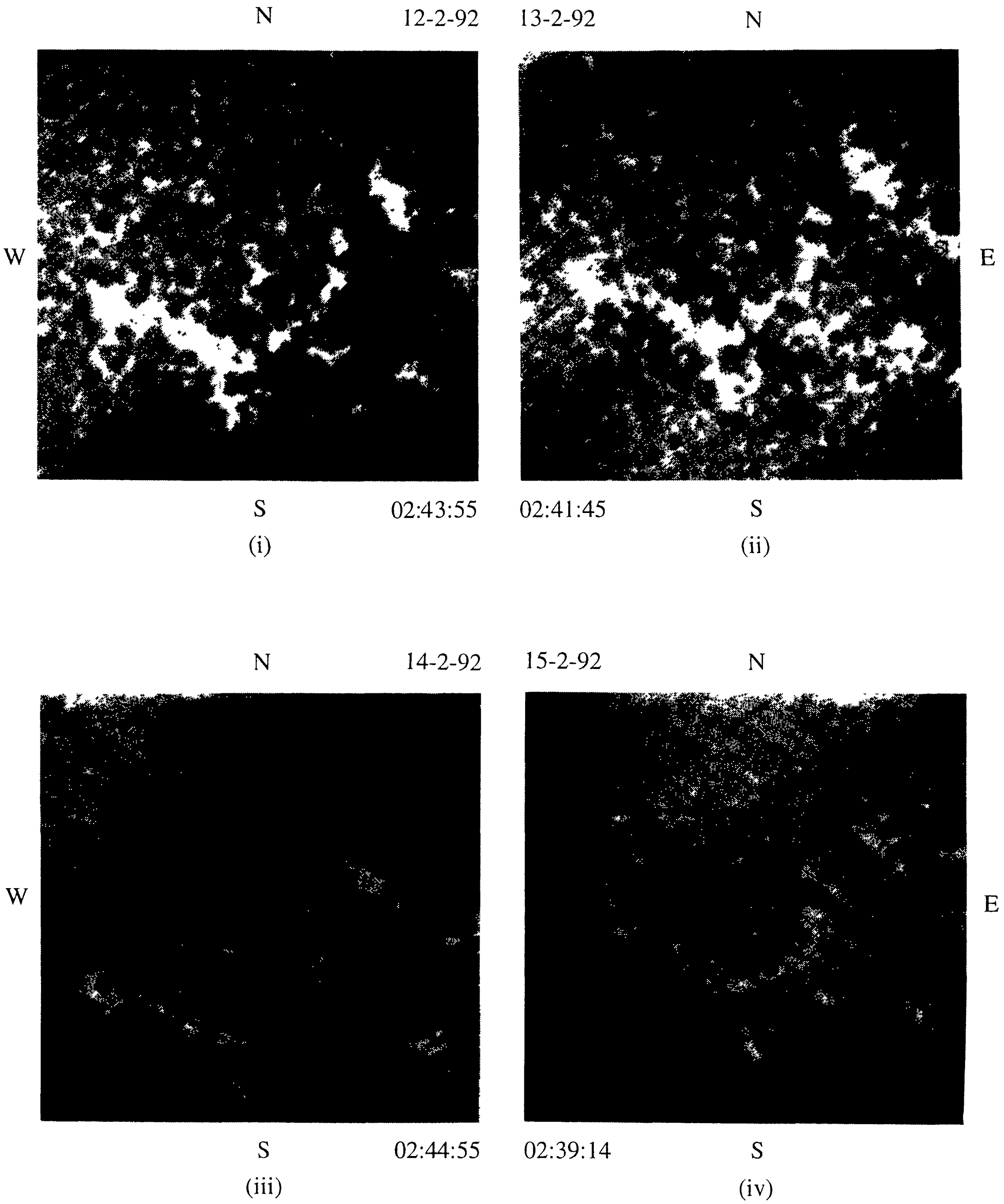
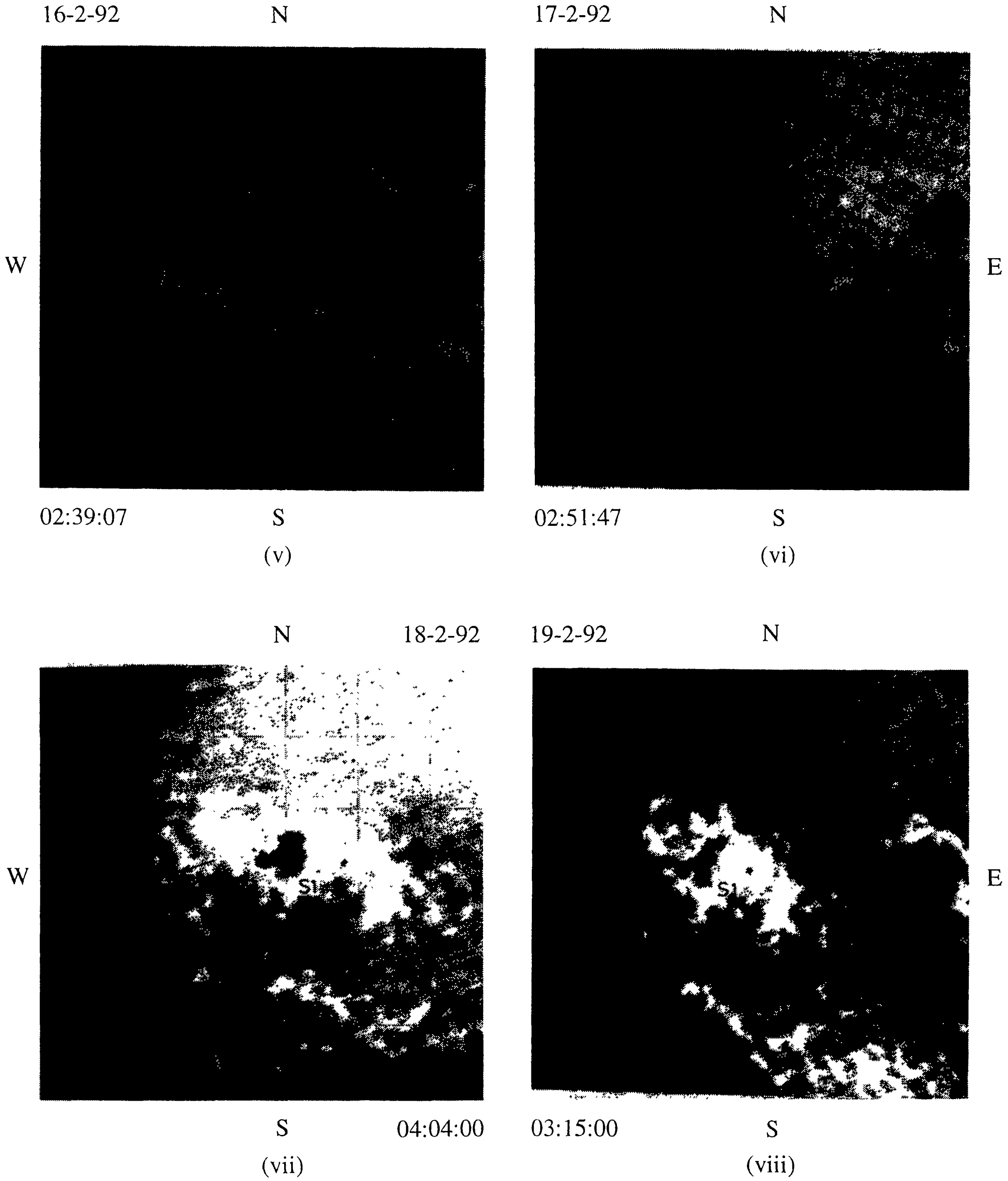


Fig. 1b. Ca II K spectroheliograms corresponding to the days in Figure 1(a). The main plage is marked as P1 whereas the portion of the plage undergoing change is marked by an arrow.



(v) (vi)

(vii) (viii)

Fig. 1b (continued).

and white-light photoheliograms for the event 6 to 17 March, 1992 are given in Figures 2(a), 2(b), and 2(c), respectively.

3. Results and Discussions

3.1. EVENT 12 TO 19 FEBRUARY, 1992

The dark Hα filament appeared at the location S20 E55 on 11 February, 1992.

The filament was well outside the sunspot region. The filament was thick and curved on 12 February, 1992 (Figure 1(a), frame i). It became thin and straight on 13 February, 1992. On 15 February, 1992 fibril structures appeared to be connecting the filament with a nearby sunspot region. On 16 February, 1992, fibrils took the form of small Hα threads, and the connecting link between the filament and the sunspot became visible and prominent. The plage regions surrounding the

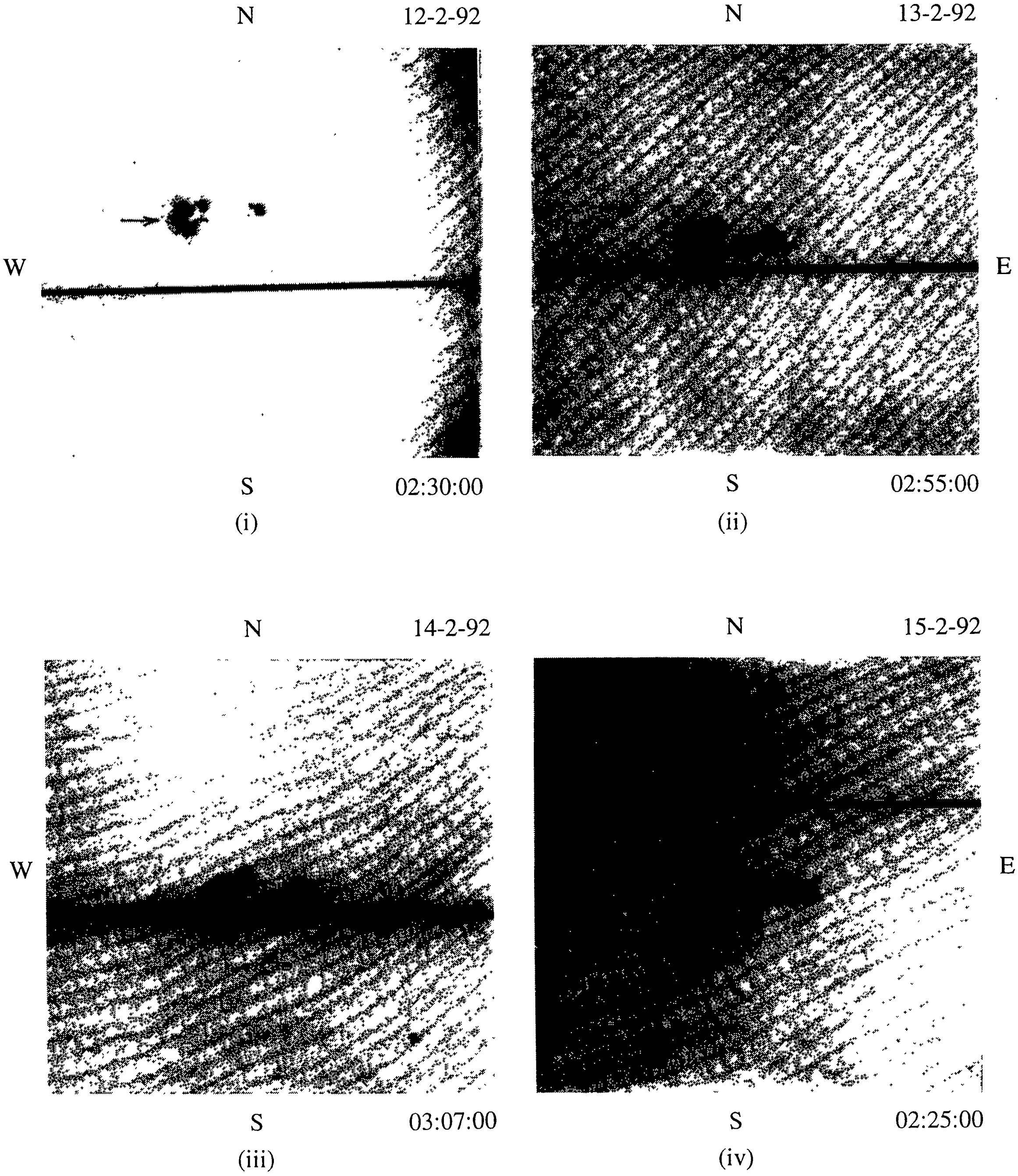


Fig. 1c. White-light photoheliograms showing the changes in the rotation of the sunspots umbrae corresponding to the days in Figure 1(a).

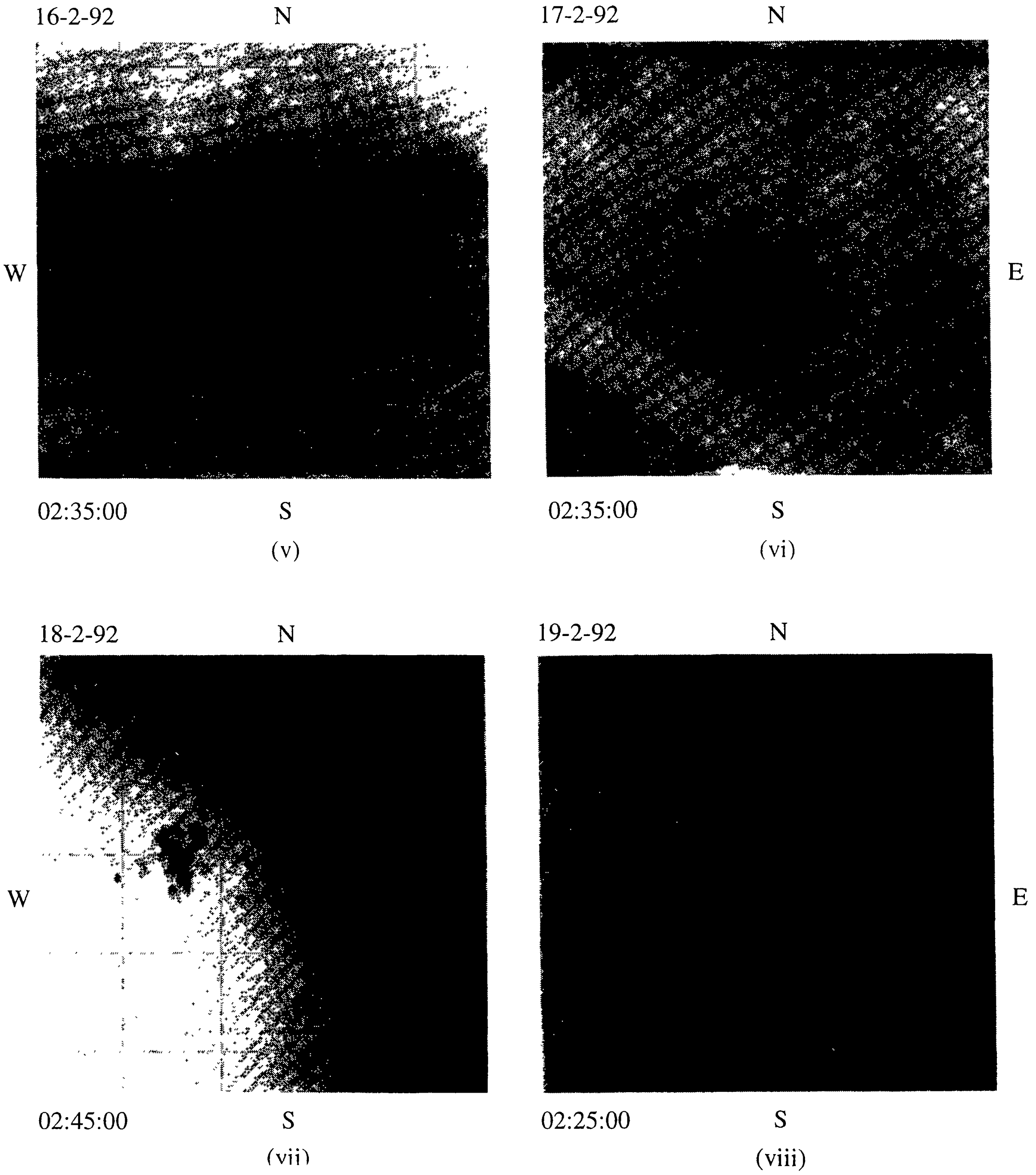


Fig. 1c (continued).

filament underwent rotation producing a noticeable, well developed, inverted U-type kink in the filament (Figure 1(a), frame iv). The sunspot connected to the filament through a small thread also underwent rotation (Figure 1(c), frames iii and iv). On 17 February, 1992 the plage and spot orientations changed further and the curved shape became much more prominent. The front position of the filament became very thick in appearance with a further change in the orientation of the plage on 18 February, 1992, and the inverted U-shape nature became much more discernible. At the same time the thick portion started breaking into strands (Figure 1(a), frame vii) and on 19 February, 1992 the prominence appearance is visible on the disk.

3.2. EVENT 6 TO 17 MARCH, 1992

The dark Hα filament first appeared on 6 March, 1992 at location N05 E75. On 6 March, 1992 the filament was broken into parts. However, the parts were connected with fibrils (Figure 2(a), frame i). The plage intensity associated with

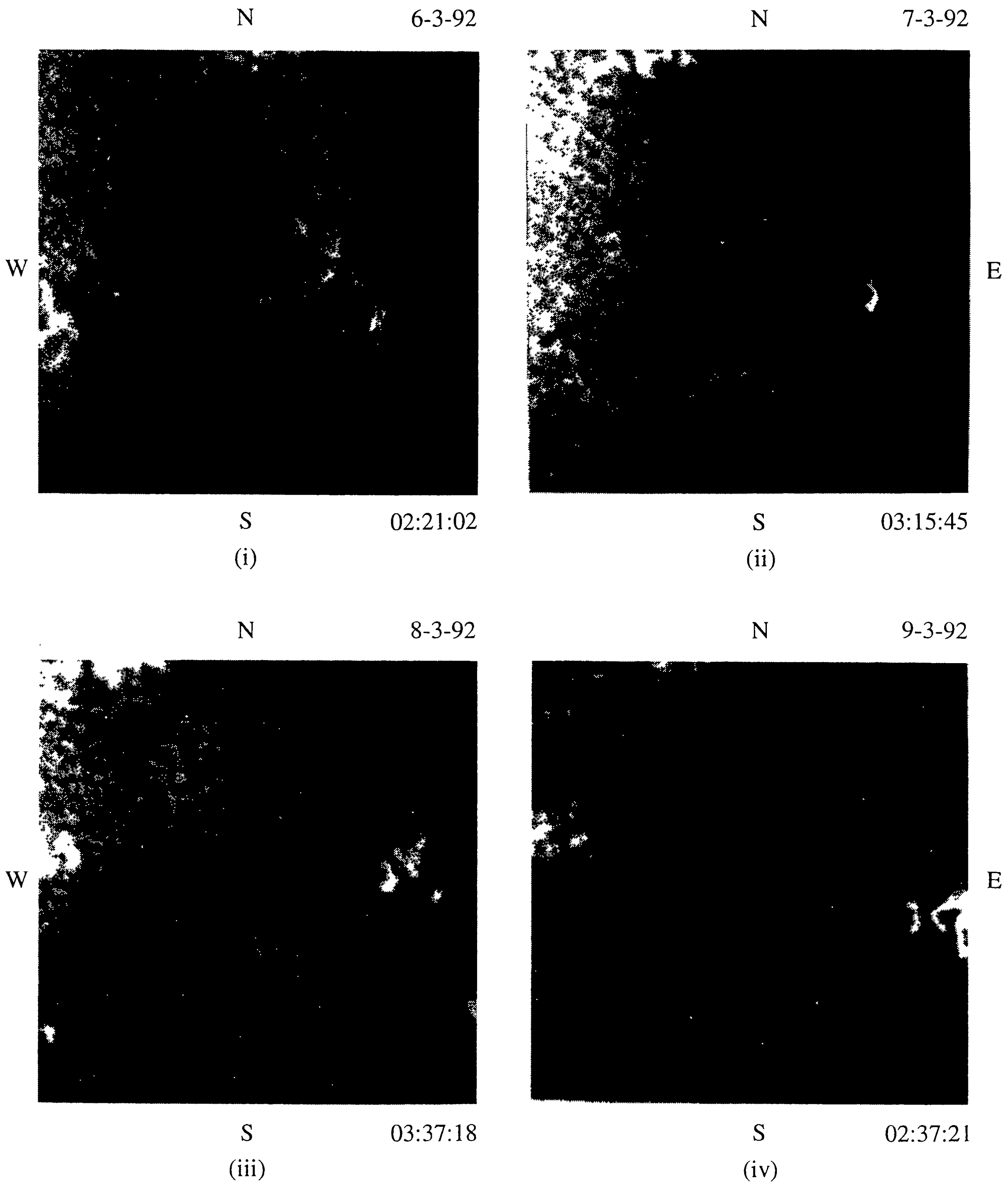
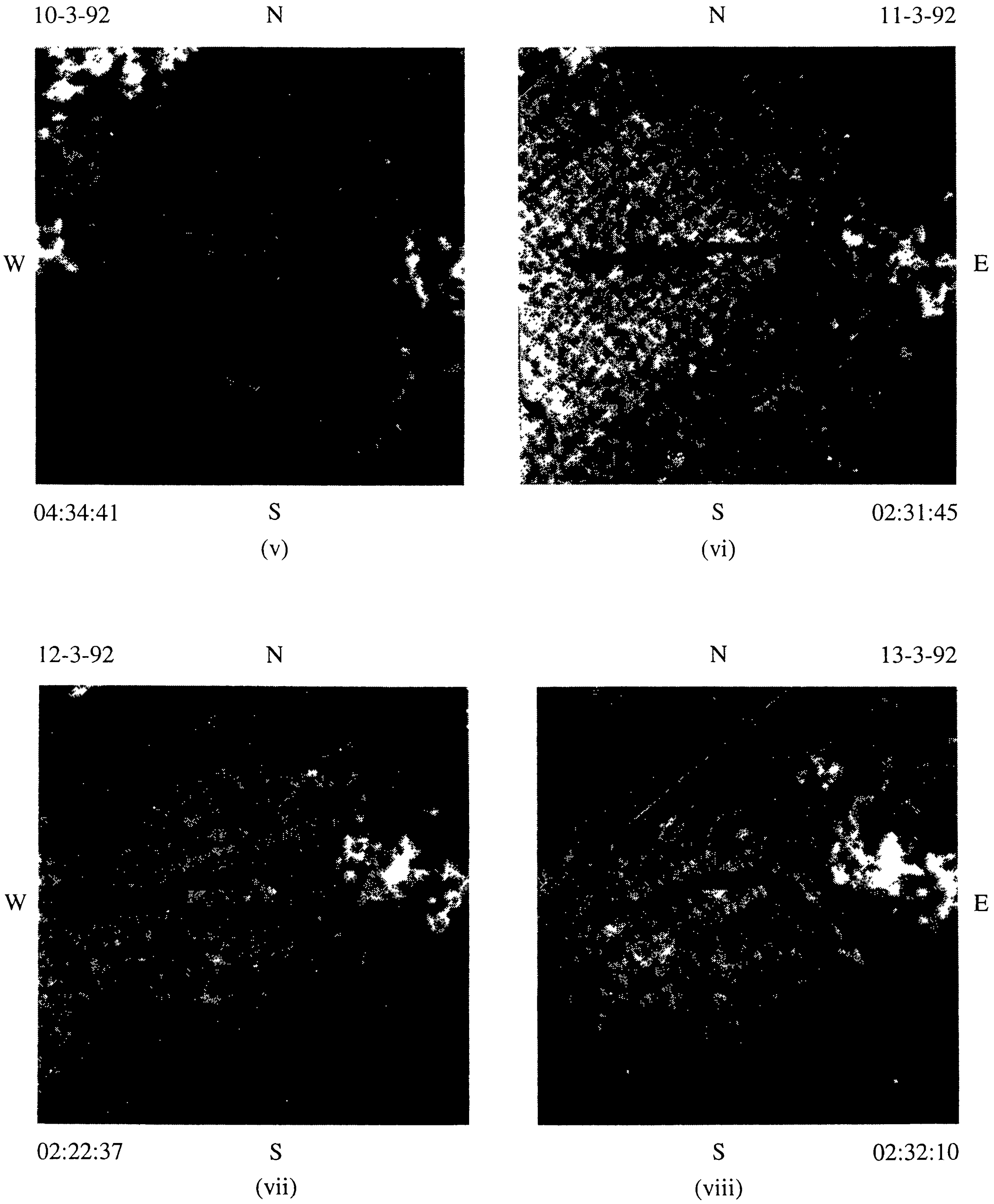


Fig. 2a. Hα spectroheliograms from 6 to 17 March, 1992 showing the variations in the orientations of the filament and associated plage region marked by arrows. The evolution of the fibril structure indicated by FB2 can also be seen.



(v) (vi)

(vii) (viii)

Fig. 2a (continued).

the filament was very feeble. On 8 March, 1992 the filament became thick and all the parts of the filament seemed interconnected (Figure 2(a), frame iii). The plage area grew, and the intensity of the plage also increased. On 10 March, 1992 a portion of the filament became more compressed and almost straight with 2–3 small kinks. The connected plage area grew further and broke into smaller parts. The filament also appeared to be linked to a nearby spot with fibrils. On 11 March,

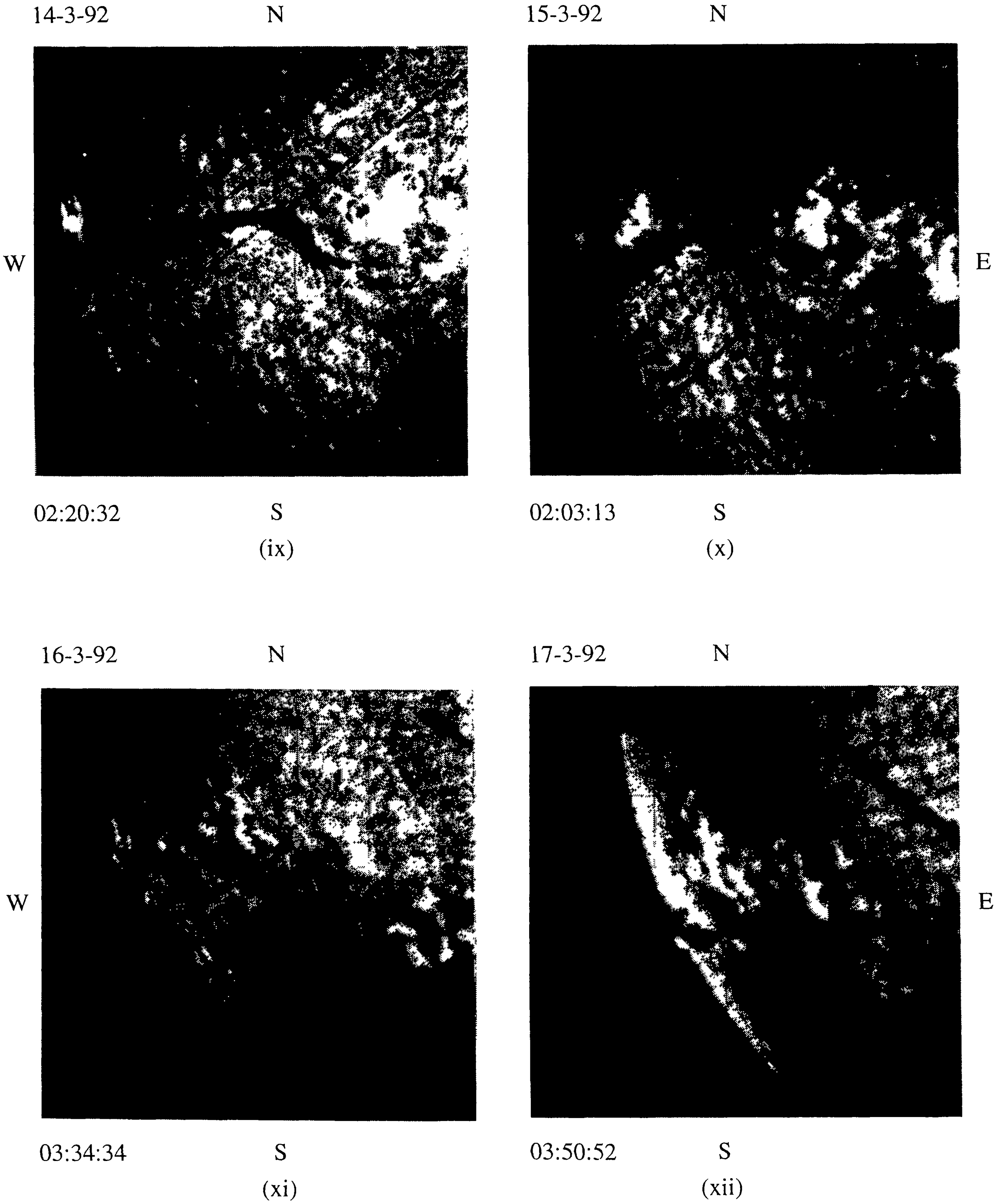


Fig. 2a (continued).

1992 the connection of the filament with the spot became more pronounced and the fibril structures took the form of the Hα thread (Figure 2(a), frame vi). The elongation underwent significant change in the orientation (Figure 2(b), frame vii marked by arrow). This produced a kink in the Hα filament away from the position of the kinks already present (Figure 2(a), frame vii marked by a double arrow). On 13 and 14 March, 1992 the plage and the spot underwent further rotation, as a result the kink became more pronounced, resembling an inverted U-shape on 14 March, 1992 (Figure 2(a), frame ix). With further increase in the rotation of plage on 15 and 16 March, 1992, the prominence appearance became more pronounced and visible. On 15 March, 1992 the orientation of the filament had undergone significant

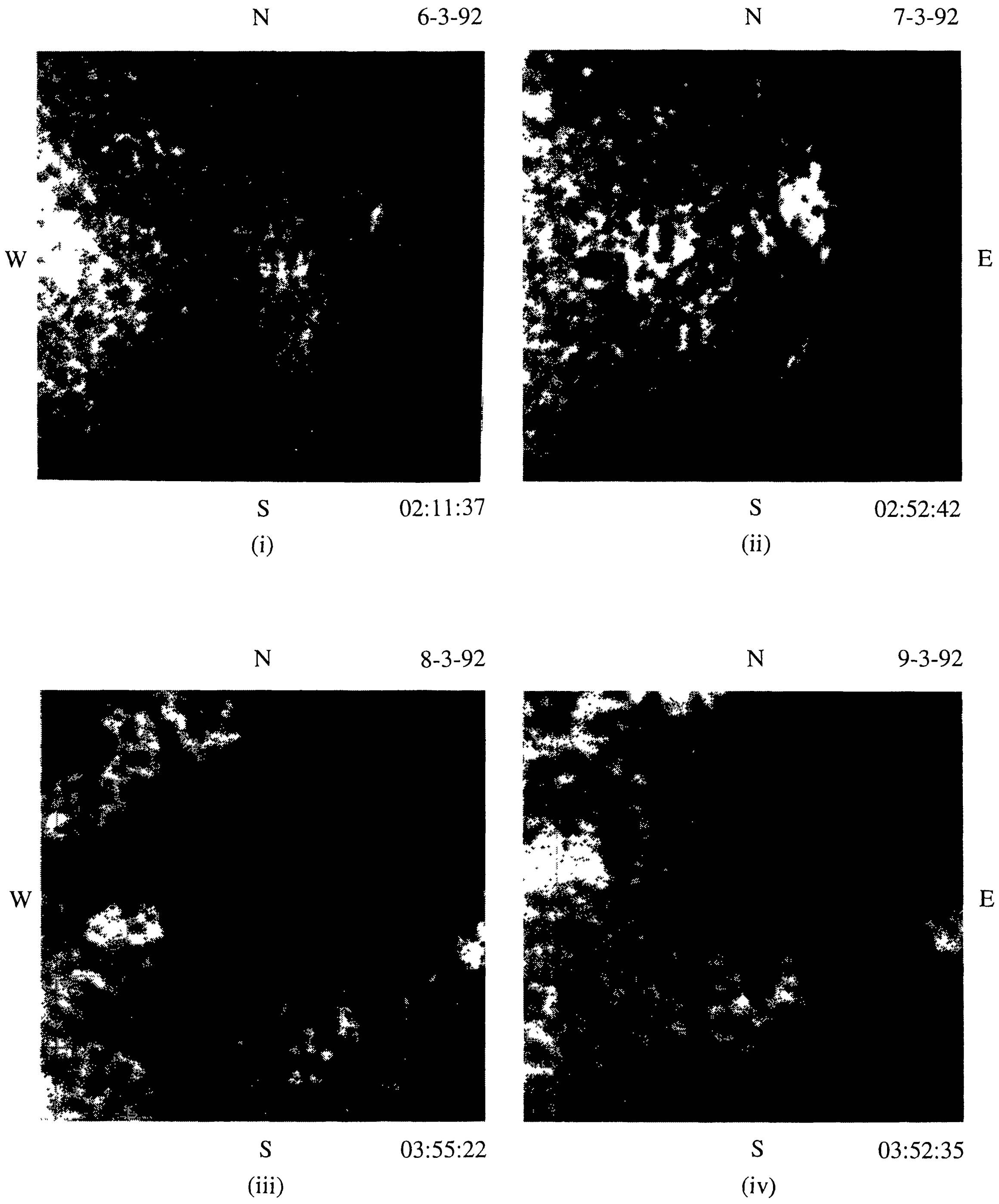
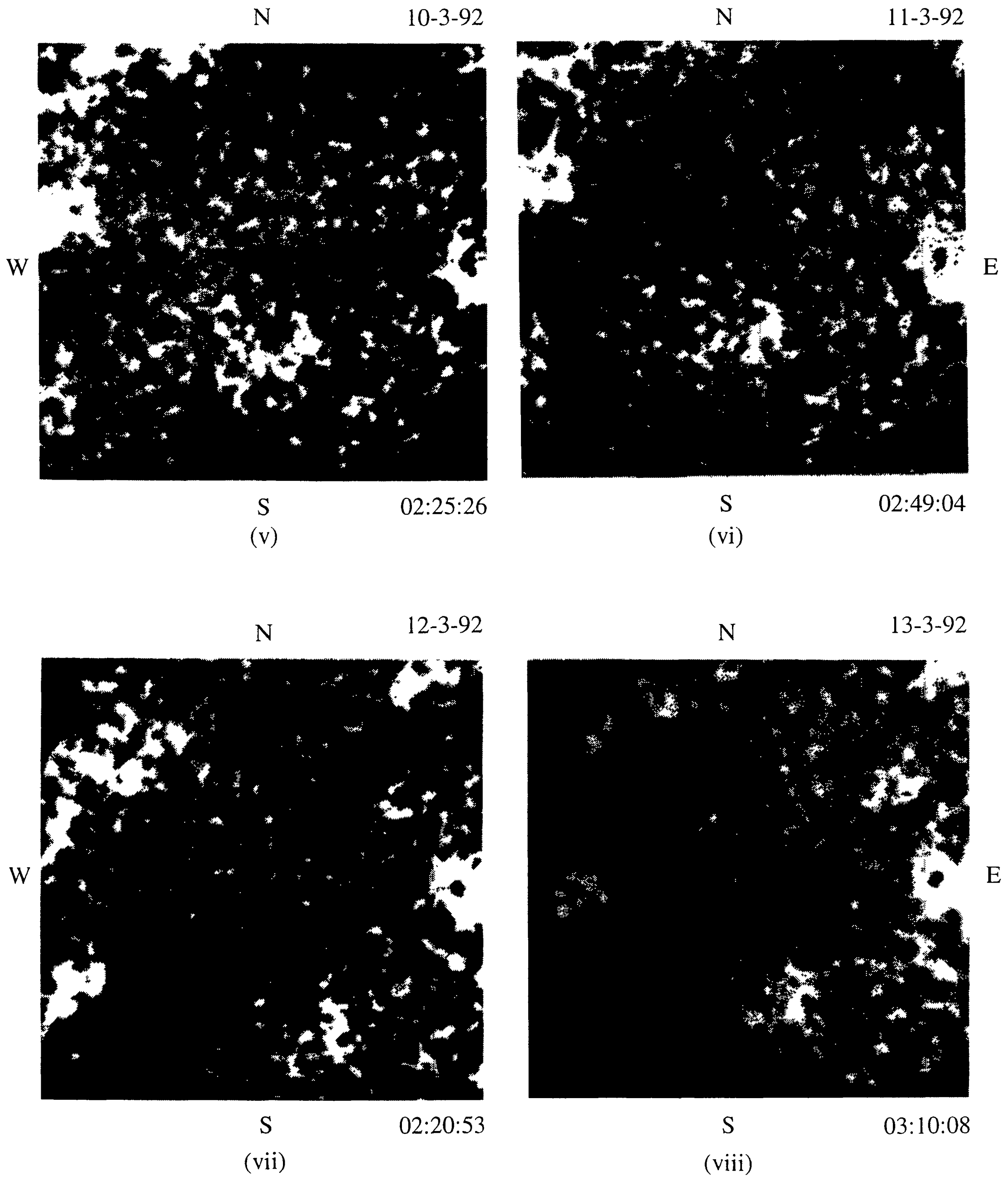


Fig. 2b. Ca II K spectroheliograms corresponding to the days in Figure 2(a). The main plage is marked as P2 whereas the portion of the plage undergoing change is marked by an arrow.



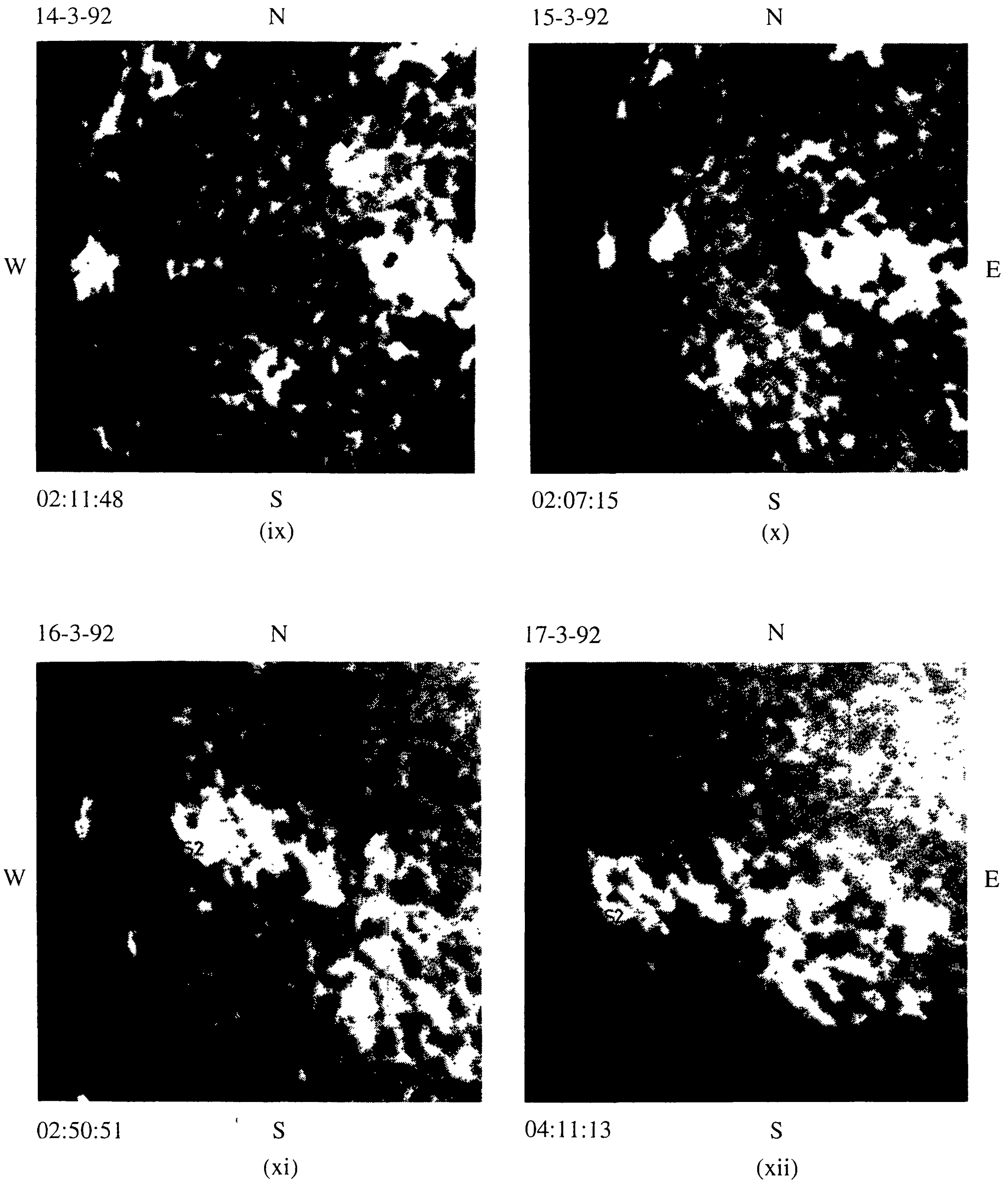
(v) (vi) (vii) (viii)

Fig. 2b (continued).

change. This change in the orientation of the filament brings in non-potentiality in the field lines, which in turn develops shear and activates the filament.

3.3. SUMMARY

To quantify the role of shear we have evaluated it on various days for the two events. We have used the argument that the value of the shear can be derived using dark Hα filaments as a proxy for the magnetic neutral line (Sivaraman, Rausaria, and

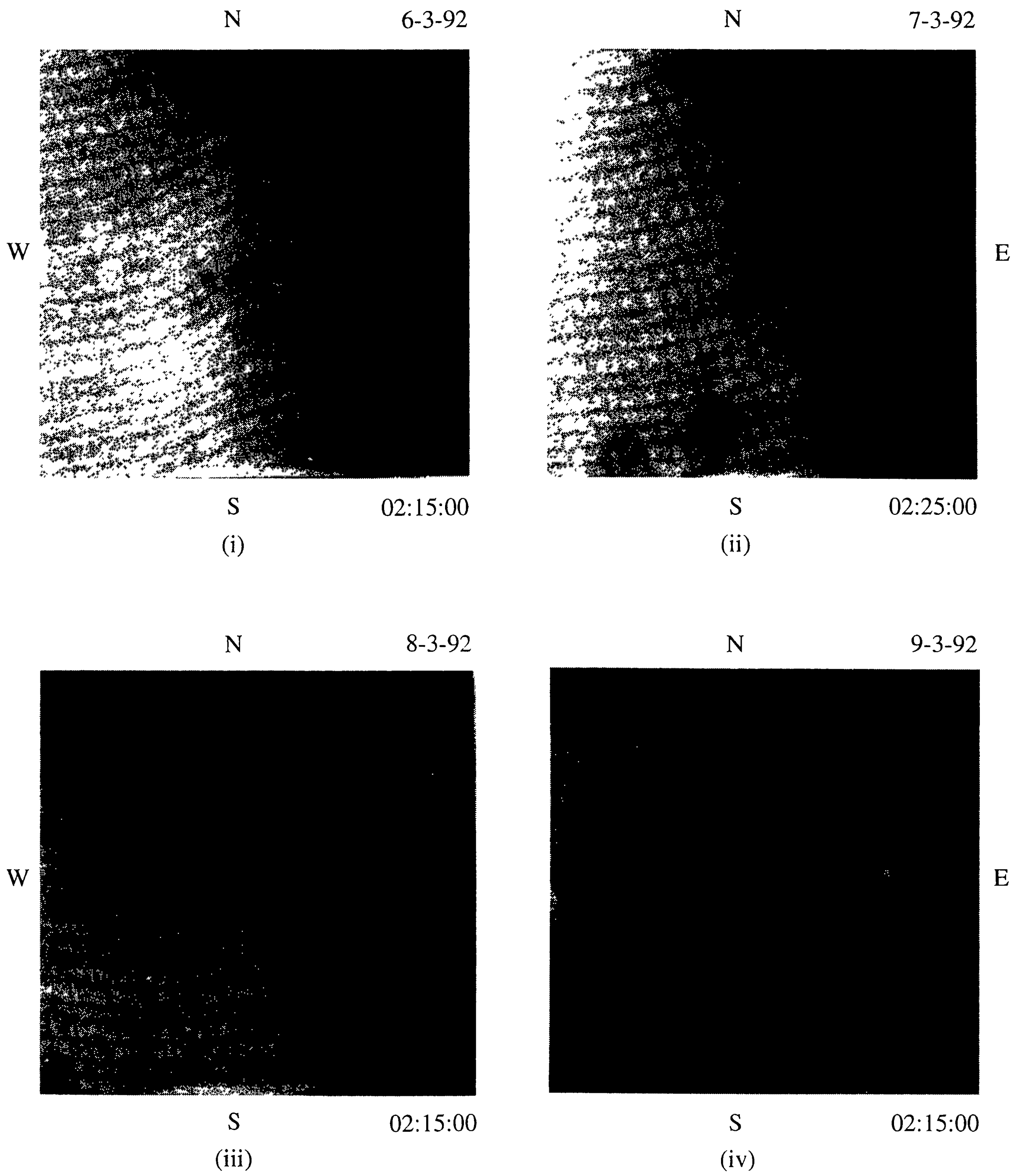


(ix) (x) (xi) (xii)

Fig. 2b (continued).

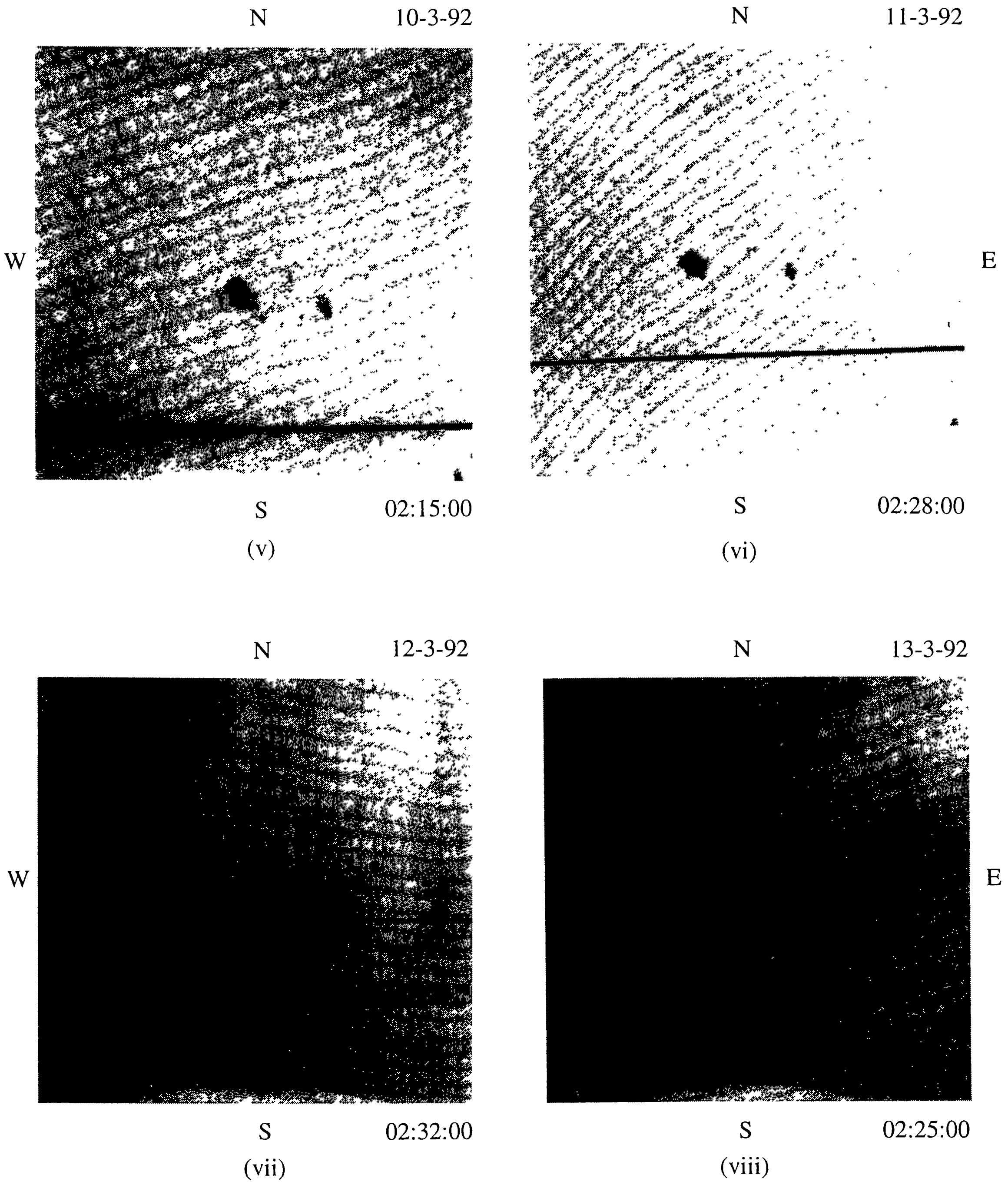
Aleem, 1992). The filaments are situated well outside the spot regions and anchored between two opposite polarity plages (Figures 1(a) and 2(a)). We proceed as follows to measure the shear angle of the filaments. Following Gibson (1973, p. 51), in the absence of magnetogram data, we have taken the opposite polarity plage regions as the reference point and have studied the variation of shear angle using dark Hα filaments, from one day to the next with respect to the centre of gravity of the plage regions. The values of shear angle derived in this way on various days for the two events are given in Table I.

A look at Table I shows that initially the change in the orientations of the two filaments are small. However, they keep increasing regularly and become very significant on the day when the curved structure of the filament becomes pronounced. In the first event this happened on 15 and 16 February, 1992 (Figure 1(a),



(i) (ii) (iii) (iv)

Fig. 2c. White-light photoheliograms showing the changes in the rotation of the sunspots umbrae corresponding to the days in Figure 2(a).



(v) (vi) (vii) (viii)

Fig. 2c (continued).

frames iv and v) and the corresponding changes in the shear angles are 15° and 30°, respectively, while in the second event, the variations in shear angles became pronounced on 14 and 16 March, 1992 (Figure 2(a), frames ix and xi) having the values 27° and 70°, respectively. The change in the shear angle for the second event on 16 March, 1992 is very high (70°). However, the filament is on the limb and even after applying the secant correction, the value still remains large. The total changes in the shear angles for the two events, from the day of their appearance

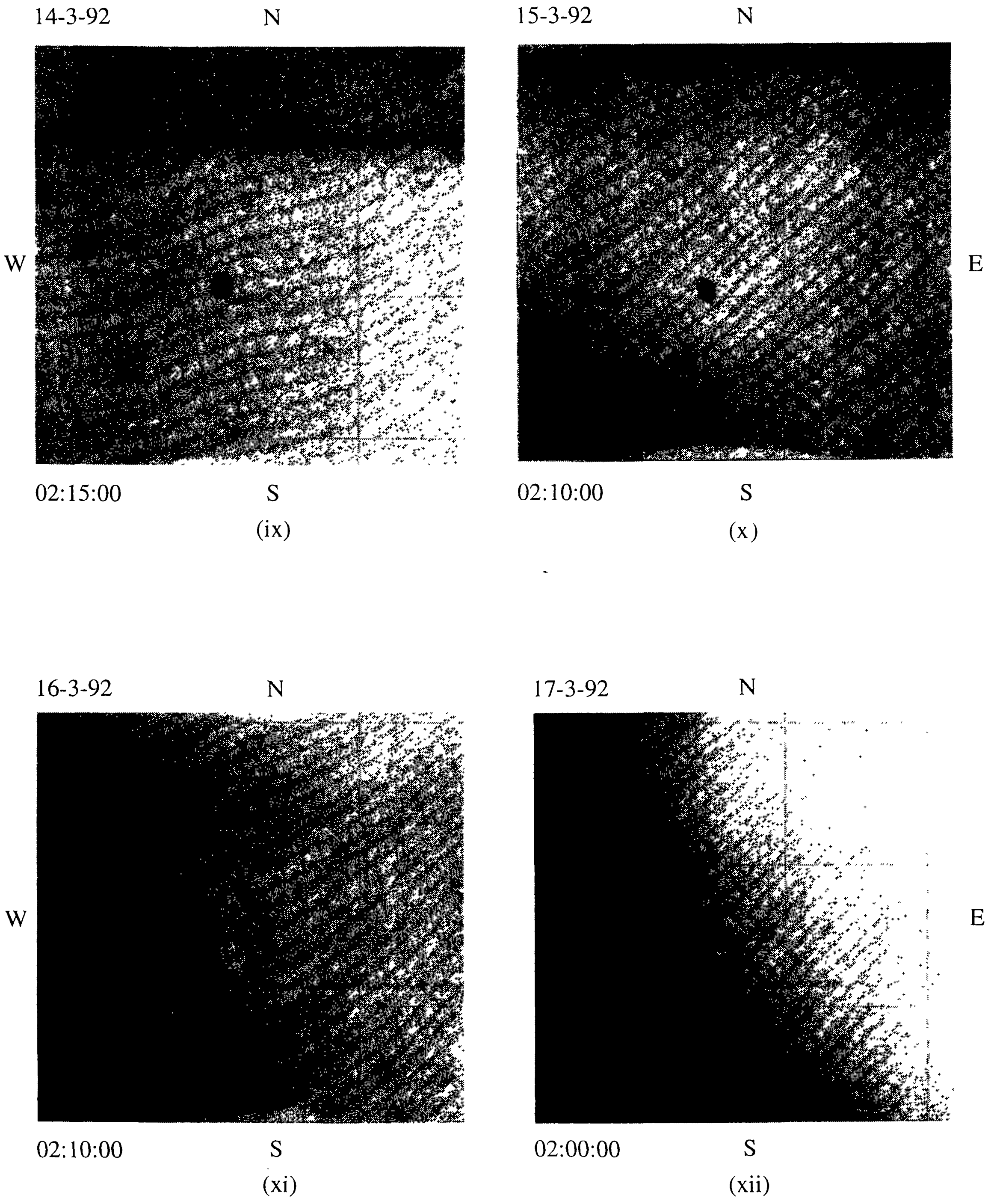


Fig. 2c (continued).

close to the eastern limb and between their passage to the western limb, are 80° and 60°, respectively. Thus we see that a cumulative change in the filament orientation coupled with the variations in spot and plage rotations on specific days play an important role on the evolution of a filament as a prominence. The shear angle, after reaching the critical value, makes the appearance of fine structure in the filament more discernible (Figure 1(a), frame vii marked TH and Figure 2(a), frame xi).

TABLE I

Changes in the orientations (shear angle) of the Hα filament on various days leading to prominence appearance

Event I				Event II			
S. No.	Date	Value of the shear angle	Change in the shear angle	S. No.	Date	Value of the shear angle	Change in the shear angle
1	12 Feb., 1992	40°	Initial value of the shear angle	1	6 March, 1992	Filament at the limb	
2	13 Feb., 1992	30°	5°	2	7 March, 1992	40°	Initial value of the shear angle
3	14 Feb., 1992	35°	5°	3	8 March, 1992	45°	5°
4	15 Feb., 1992	20°	15°	4	9 March, 1992	40°	5°
5	16 Feb., 1992	10° in opposite direction	30°	5	10 March, 1992	35°	5°
				6	11 March, 1992	42°	7°
6	17 Feb., 1992	2° in opposite direction	8° [a]	7	12 March, 1992	50°	8°
				8	13 Feb., 1992	42°	8°
7	18 Feb., 1992	20° in opposite direction	18°	9	14 March, 1992	15°	27°
				10	15 March, 1992	30°	15°
8	19 Feb., 1992	Appearance of the prominence		11	16 March, 1992	40° in opposite direction	70°
				12	17 March, 1992	Filament at the limb and the prominence appearance	

[a] The change in the shear angle looks small after reaching the maximum change, but the variations are in the opposite direction.

Working with some more events may evoke a better insight and probably confirm this result. More detailed studies concerning quiet and active prominences and the role of shear is in progress and will be reported elsewhere.

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