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On the relation between large scale solar magnetic fields and filament positions

Rajendra N. Shelke and M. C. Pande
Uttar Pradesh State Observatory, Manora Peak, Naini Tal 263 129

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Abstract. Interrelationships of filament positions and large scale solar magnetic field structures are examined here. The broad neutral bands seem to be suitable locations for the formation and development of filaments. Filaments generally break into fragments as soon as narrow neutral bands are formed.

Key words : solar magnetic field—filaments

1. Introduction

It is now well established that the quiescent filaments appear along the boundary, the so called neutral line, between regions of opposite polarities, as seen on magnetograms. This was first pointed out by Babcock & Babcock (1955) and subsequently confirmed by Howard & Harvey (1964) and Smith & Ramsey (1967). Further, Martin (1973) showed that the filaments can appear along neutral lines which occur (i) in the active regions between the p- and f-polarities of the bipolar field, (ii) on the border between two adjacent active regions, and (iii) in the weak field regions between f-parts of decaying active regions and the polar magnetic field. Using high resolution Hα-filtergrams and Leighton magnetograms (spatial resolution < 2 arcsec, magnetic field $\geqslant 50$ Gauss), Frazier (1972) also pointed that the filaments appear along broad neutral lanes or zones rather than along lines of quasi-zero longitudinal field.

To the authors' knowledge, however, no work has been done on the relation between the filament positions and large scale solar magnetic field structures, except for the work by Duvall *et al.* (1977), where they have compared the positions of the neutral lines as inferred from Hα observations and the direct observations of the photospheric fields using the Stanford magnetograph.

In the present study, an attempt has been made to investigate some crucial relationships between the large scale solar magnetic fields as seen in the Stanford magnetograms and the relative positions of Hα filaments.

2. Observational data

The observations used are the Hα- and the large scale solar magnetic field synoptic charts, which are from Solar-Geophysical data. The large scale magnetic field synoptic charts consist of daily full disc Stanford magnetograms, with spatial resolution of 3 arcmin and only crudely show regions of strong or complex fields. The large scale organization of the net field can usually be clearly seen in the Stanford magnetograms. The Hα synoptic charts show filaments. The Hα- and the large scale magnetic field synoptic charts of Carrington rotations 1683–1687 are used in this study. Each Hα synoptic chart is superposed on the corresponding large scale magnetic field synoptic chart and the positions of filaments (cross-hatched) are drawn on it. In figures 1–5, the superpositions of the corresponding two types of synoptic charts are shown.

3. Results and discussion

The positions of filaments are critically examined in view of large scale organization of solar magnetic field. Filaments are classified, according to their locations, into four characteristic classes : (i) filaments which run along the magnetically neutral band, (ii) filaments which appear across the neutral band and appear to connect the regions of opposite polarities, (iii) filaments which lie partially along and partially across the neutral band, and (iv) filaments which do not conform to any of the above classes.

For each Carrington rotation, only about 62% of the filaments are found to belong to class 1. This class of filaments seems to satisfy the first necessary condition for the existence of a filament, as mentioned by Martin (1973), that the vertical component of the local magnetic field be oppositely directed on either side of the filaments.

About 11.5% filaments are found to belong to class 2. Filament no. 11 (lat. S 35, long. 355) of figure 2 is an example of a class 2 filament. This class of filaments seems to have common properties of 'threads'. Threads presumably connect the magnetic clumps of opposite polarities as seen in high resolution magnetograms; and there are threads which look very much like classic filaments (Frazier 1972).

Our study shows that about 7.5% filaments belong to class 3. These are essentially intermediate cases between threads and filaments (Frazier 1972). Filament no. 12 (lat. S 30, long. 170; figure 4) is the best example of an intermediate case. This filament appears to lie partially along and partially across the neutral band.

About 18.5% filaments of a Carrington rotation are found to belong to class 4. These filaments appear to exist in the regions of either polarity and seem to have no connection with the neutral bands. Filament no. 1 (lat. N 25, long. 20; figure 1) and filament no. 13 (lat. S 25, long. 220; figure 4) are examples of this class.

3.1. The formation of filaments

Broad neutral bands seem to be the favourable locations for formation and development of filaments. As soon as a narrow neutral band gets transformed into a broad neutral band, a new filament becomes apparent. The classic example is the position '2' (lat. N 30, long. 80) in figure 1 (Carrington rotation 1683). Here the neutral band

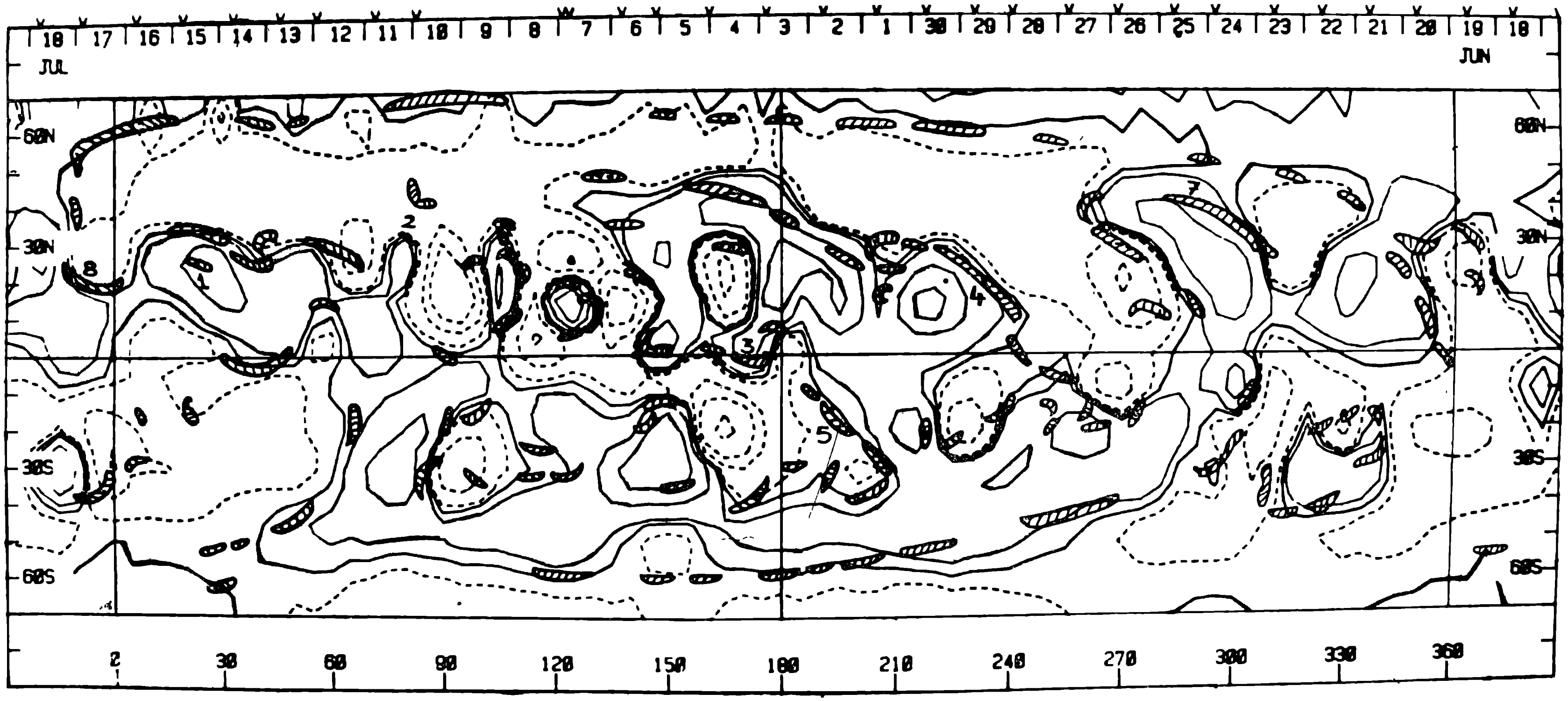

Figure 1. A comparison of the Hα- and the large scale solar magnetic field synoptic charts for Carrington rotation 1983. For the Hα synoptic chart, the hatched region corresponds to the filaments. The positive and the negative magnetic contours are indicated by solid and dashed lines respectively.

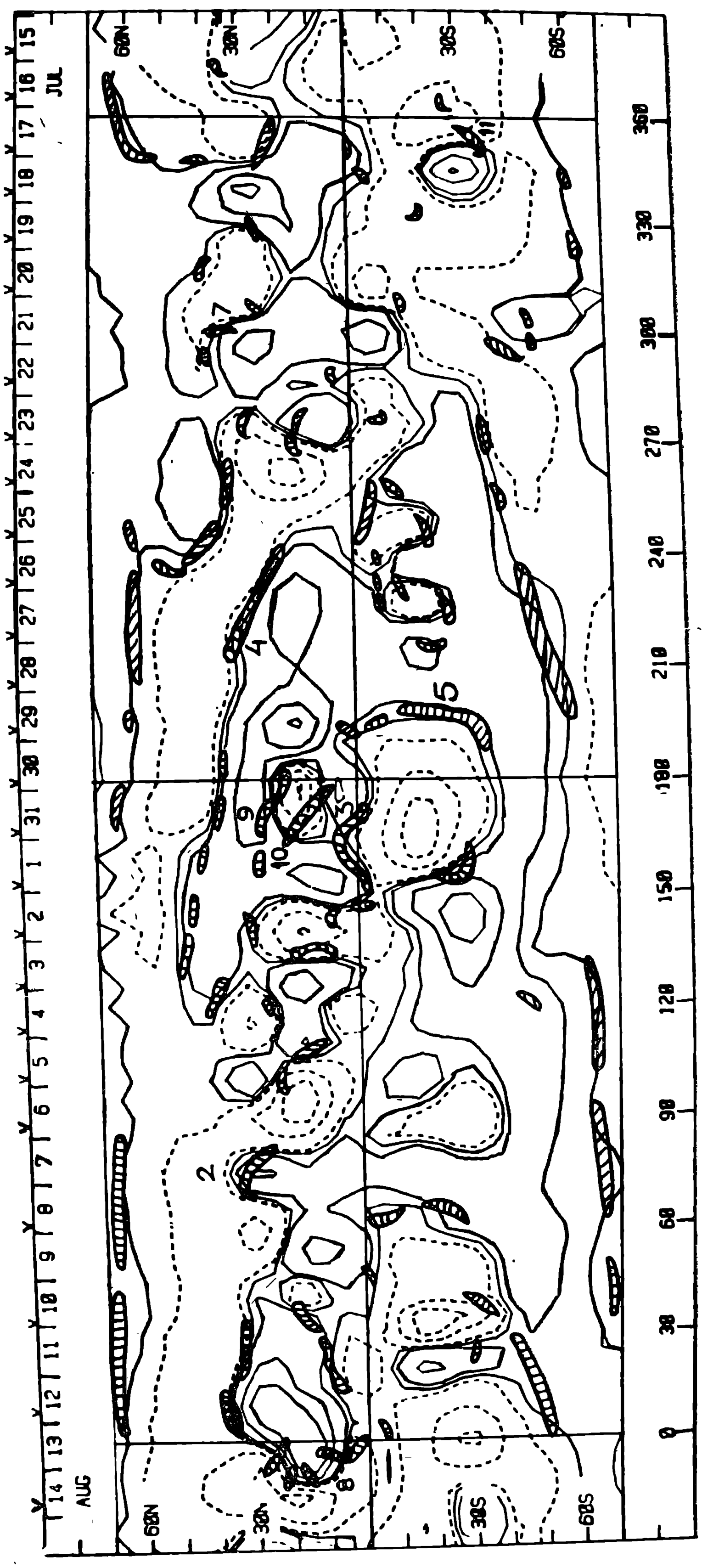

Figure 2. A comparison of the H α- and the Stanford magnetogram synoptic charts for Carrington rotation 1684.

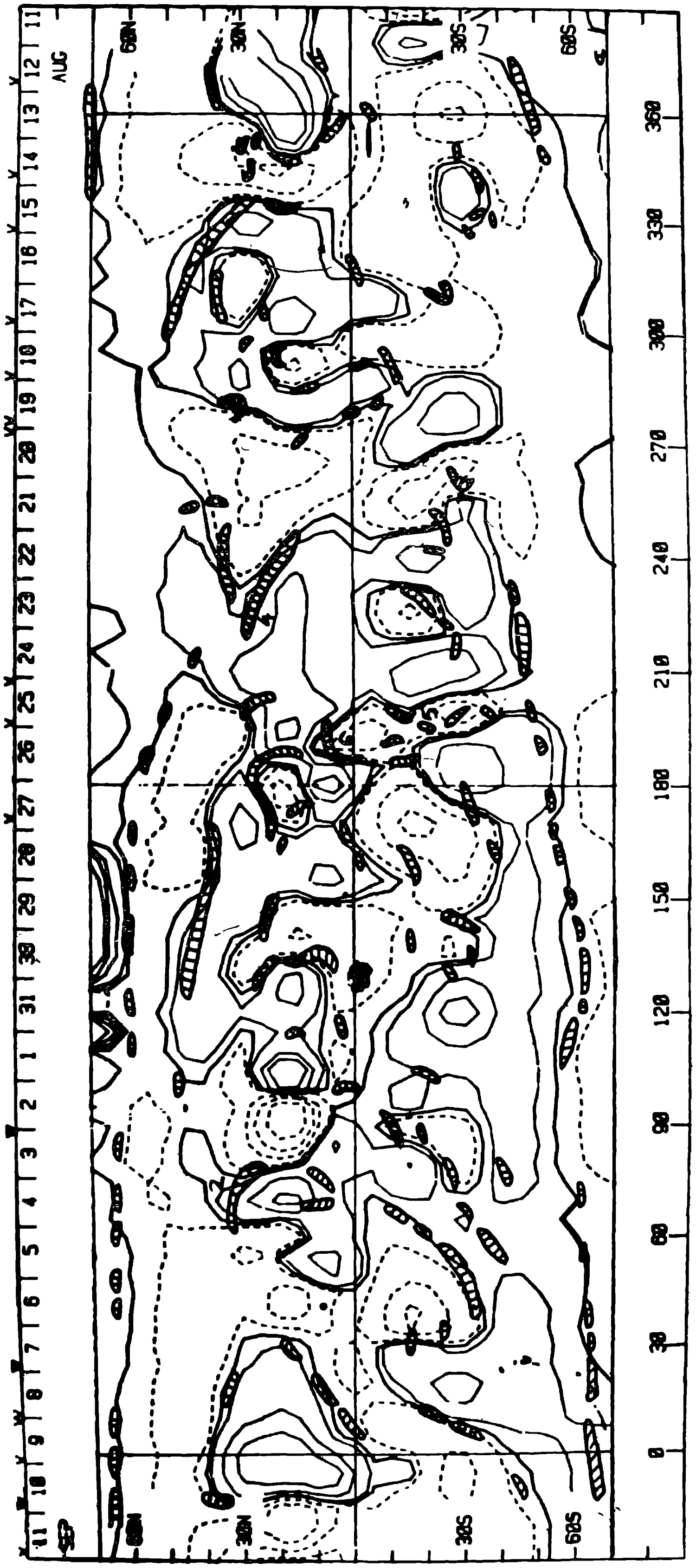

Figure 3. A comparison of the Hα- and the Stanford magnetogram synoptic charts for Carrington rotation 1685.

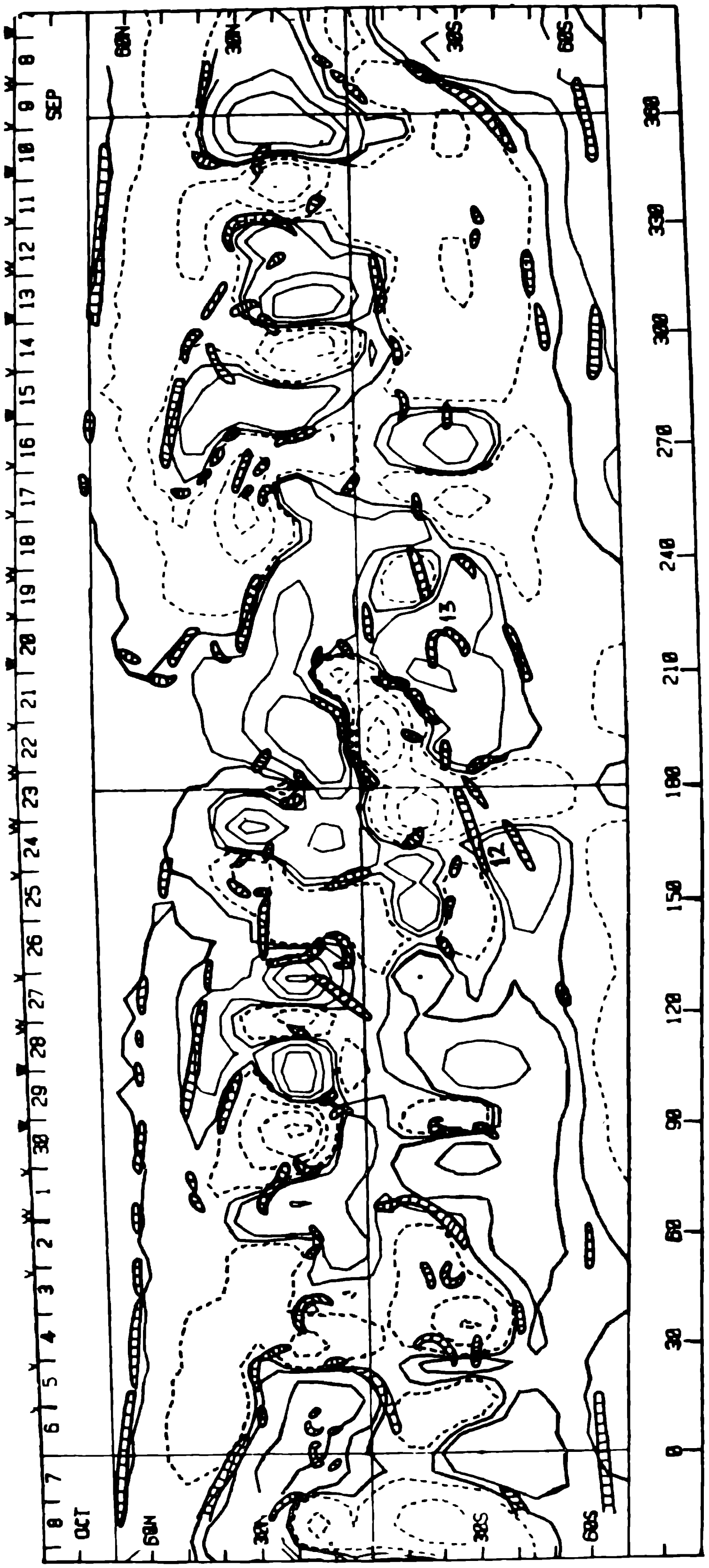

Figure 4. A comparison of the Hα- and the Stanford magnetogram synoptic charts for Carrington rotation 1686.

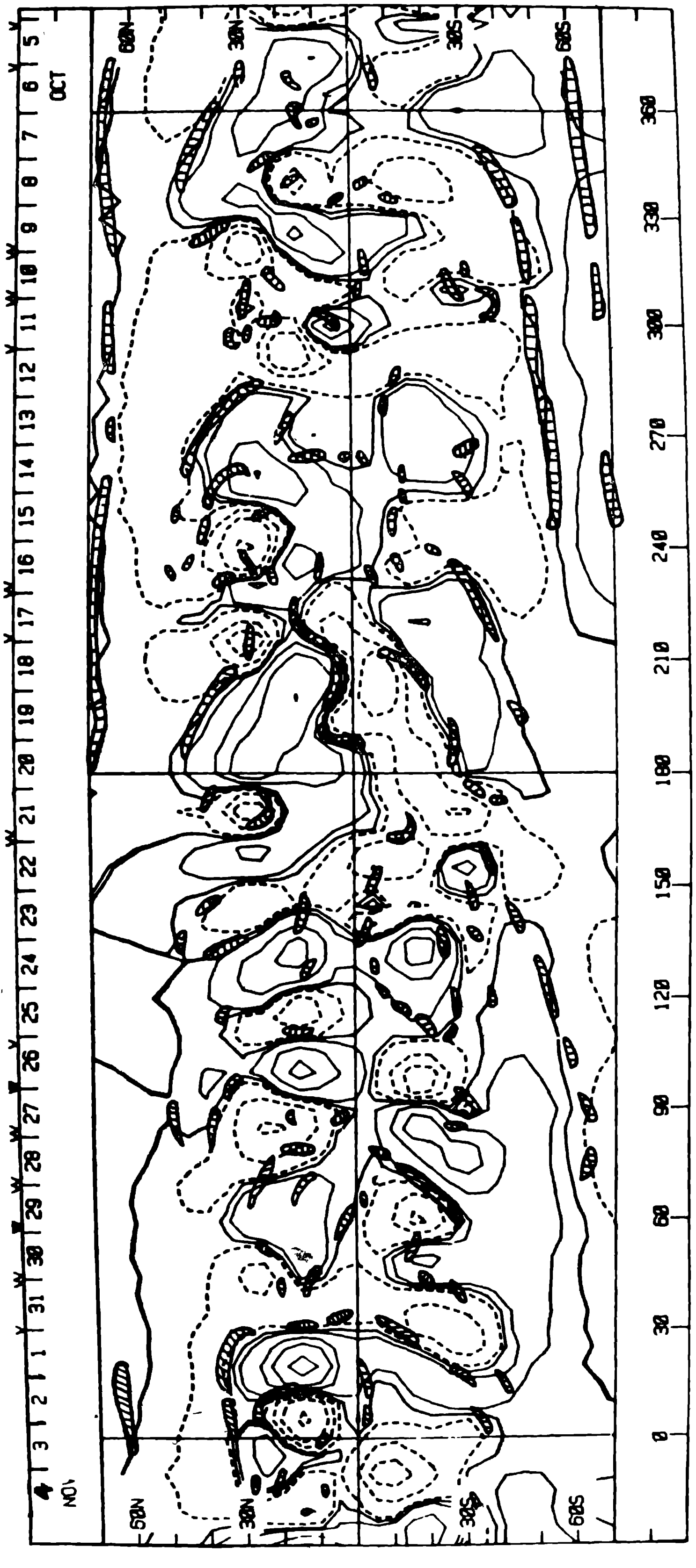

Figure 5. A comparison of the Hα- and the Stanford magnetogram synoptic charts for Carrington rotation 1687.

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is narrow due to steep magnetic field gradient, and no filament is seen at position '2'. However, during the next rotation (Carrington rotation 1684; figure 2) a broad neutral band appears to have developed and a new filament is seen at position '2'. The neutral band has got broadened still further during the third rotation (Carrington rotation 1685; figure 3) and filament no. 2 is seen to have developed into a long filament. This shows that a new filament forms and develops in the region of broad neutral band rather than in the region of a narrow neutral band. Frazier (1972) has called this broad neutral line as the "zone of avoidance".

Filament no. 3 (lat. N 02, long. 160; Carrington rotation 1683) and filament no. 6 (lat. N 10, long. 190; Carrington rotation 1685) go to show that a long filament develops out of the aligned filament fragments. Three fragments of filament no. 3 appear to be located in the narrow neutral band during Carrington rotation 1683. This narrow neutral band seems to have broadened and the filament fragments seem to have got connected resulting in a single long filament in Carrington rotation 1684. Another filament, no. 6 of Carrington rotation 1685, also appears to have developed into a long filament during Carrington rotation 1687 (figure 5) out of the filament fragments seen in the preceding Carrington rotation 1686 (figure 4).

These examples demonstrate that whenever the narrow neutral band region gets transformed into a region of broad neutral band, a new filament forms or a long filament develops out of the aligned filament fragments.

3.2. *Dissolution of filaments*

Only three forms of prominence dissolution have been recognized by Kiepenheuer (1953) and further discussed by Martin (1973). These are (i) the slow dissolution, (ii) the quasi-eruptive, and (iii) the eruptive dissolutions. Bruzek (1952) studied the nature and cause of eruptions. He found that a velocity of expansion of 1 km s^{-1} for the centre of activity would eventually result in the eruption of filaments up to a distance of about 25 heliographic degrees.

Our study shows that the expansion of the border of either polarity region in the vicinity of the filament leads to a developement of the narrow neutral band along the path of the filament which in turn breaks the filament into fragments. This can be seen in the case of filament no. 5 (lat. S 30, long. 200; Carrington rotation 1684) which developed out of the four filament fragments seen in the Carrington rotation 1683. In Carrington rotation 1685, the narrow neutral band is seen to have developed along the path of the filament no. 5 and the filament is seen to have fragmented into pieces (figure 3). This is a classic example to demonstrate that the fragmentation of long filament is a consequence of the formation of narrow neutral bands along the path of a filament. Other examples can be found at latitude N 20, longitude 240 (filament no. 4), and at lat. N 35, long. 280–310 (filament no. 7) in figure 1.

It is also found that a filament or its fragments have a general tendency to avoid the locations with steep magnetic field gradients. In figure 3, one can note that the pieces of filament no. 5 are aligned away from the neutral band, indicating this tendency.

3.3. *Class 3 filaments*

Consider filament no. 8 (lat. N 20, long. 00) of Carrington rotation 1683. This filament seems to have fragmented into pieces (figure 2) which are aligned across the neutral band. This illustrates how a filament breaks up into fragments, which in turn, are pushed sideways when they encounter locations with steep field gradients. Although, the filament fragments prefer to run along the neutral band, this pushing away aligns the filament or its fragments across the neutral band or partially along and partially across it. Other examples of this class are the filament at latitude N 20, longitude 80 (figure 4) and the filament at lat. N 20. long. 130 of Carrington rotation 1685.

4. Conclusions

The formation, development and dissolution of filaments depend on the geometry of the neutral band. A broad neutral band is suitable and necessary for the formation of the filaments. There are many cases which indicate that new filaments develop out of the aligned filament fragments in broad neutral zones. As soon as narrow neutral band broadens, the filament pieces join together, forming a single long stable filament. Foukal (1971) also pointed out that the filament develops out of aligned chromospheric elements.

According to Frazier (1972), no stable filament exists on a true, very narrow neutral line, probably because the magnetic field gradient across it is too steep to provide a suitable support to the prominence. Rust (1970) also points out that around local field concentrations filaments detour or thin down enough to be squeezed out. The present study also indicates that the filaments get fragmented into pieces when a steep field gradient is encountered. It is also seen that the filaments have a general tendency to avoid locations with steep field gradients. This leads to an alignment of the filaments either sideways or into the paths of low-gradient neutral band. In the former case, the filament is aligned across the neutral band characterising class 2 or class 3 filaments. The latter appears as the migration of filament depending upon the geometry of the neutral band.

The class 4 filaments do not run along the neutral band and exhibit horizontal displacement from the neutral band. This displacement is larger than can be explained by projection effects. Malville (*cf.* Anzer 1978) also reported the observations of one quiescent filament which was positioned slightly off (a few second of arc) from the neutral line of the photospheric field and has a strong vertical field component in the same direction as the adjacent photospheric field. Such horizontal displacements would contradict both the Kippenhahn-Schluter and the Kuperus-Raadu model (*cf.* Anzer 1978). However, the strong vertical fields reported by Malville and inferred in this paper can only be explained by the Kuperus-Raadu and the Malville models. Briefly, at present no prominence model seems to explain class 4 filaments.

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