EVOLUTION OF FINE STRUCTURES IN A FILAMENT

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ABSTRACT

UDC 523.987-54
conference paper

A quiescent filament observed in June 1986 underwent a slow Disparition Brusque which lasted 4 days. Here, we focus our study on the dynamical behaviour of the fine structures (Full-Width Half-Max ~ 350 km) in this filament which were observed at Pic du Midi with the Multi-Channel Subtractive Double Pass spectrograph during a period of 30 minutes. We observed no changes in intensity during this period, but we did observe changes in the velocity field with no correlation from one minute to the next. High velocities were detected at the footpoints where the filament is anchored in the photosphere, of the same order than those observed at the boundaries of the supergranules (between ±10 km s⁻¹). To explain these observations we suggest a spicule-like model which supplies material to the prominence.

1 General evolution of the filament

The filament lies in a long corridor. Parts of the filament disappear during the 4 day interval from June 16 to June 20. After June 20 the filament is no longer visible in Hα spectroheliograms (Figure 1). The observations made with the Multi-Channel Subtractive Double Pass (MSDP) with a short time scale (1 min) during half a hour on June 17 show no evolution of the filament features, that would indicate that the process of filament disappearance is not continuous, no sudden disappearances were seen.

A relationship between the fine structures of the chromosphere and the filament is apparent. We recognize in the chromosphere the different absorbing features already described by Foukal (1971) and Bray and Loughhead (1984) such as mottles, fibrils, threads, bushes or rosettes (Figure 2 a,c). The MSDP spectrograph observations allow us to obtain the line profiles of each point, so we can understand the different aspects of the features generally observed with filtergrams. And with the line profiles, we can study quantitatively the Dopplershifts of the different structures.
Figure 1 Meudon Spectroheliograms.
2 Fine structures

The filament looks like sheared threads along the magnetic inversion line. In map (Figure 2 c), most of the filament regions which are dark correspond to footpoints (i.e. anchorages of the filament in the photosphere). These footpoints are clearly visible in the histogram of $I_{0.26}/I_{0.51}$ (Figure 3 a) and they are very stable over time.

The reduced velocity values observed in the filament corridor (Figure 2 b) may be due to the deflection of the fibrils at the proximity of the opposite polarity of the magnetic field, (c.f. Martin 1973) which was relatively strong because of the plages on both sides of the filament. The velocity cells seem to be orientated along the axis of the filament but there is little difference between the size and magnitude of velocity cells in the filament and the size and the magnitude of the whole cells in the corridor. Besides there is no correlation between intensity and velocity (Figure 3 b). The typical cell sizes are 1" by 10" and the Full Width Half Maximum (FWHM) is about 350 km (Figure 4).

Relatively strong Dopplershifts of up and down ± 5 km s⁻¹ are located at the edges of the filament, and these shifts have the same temporal behaviour as those in the supergranules boundaries i.e. the rosettes (Figure 2 b,d). Material moves up and down along the flux tubes which form the filament footpoints.

3 Analysis of the profiles

We have considered the filament as a moving cloud overlying the chromosphere. We use the “cloud model” first proposed by Beckers (1964), and extended recently by Mein and Mein (1988). This model was also used by Schmieder et al. (1988) for filament study. The line profile is full described.

Table 1 Line-profile characteristics of the filament observed at 6:43:24 UT.

<table>
<thead>
<tr>
<th>points</th>
<th>Source function</th>
<th>“Standard Method”</th>
<th>“Cloud-model method”</th>
</tr>
</thead>
<tbody>
<tr>
<td>unit</td>
<td>$I_{\text{min}}$</td>
<td>$V \pm 0.256 \text{ km s}^{-1}$</td>
<td>$\tau \pm 0.256 \text{ km s}^{-1}$</td>
</tr>
<tr>
<td>A</td>
<td>0.7</td>
<td>-4.65</td>
<td>0.296</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>0.486</td>
</tr>
<tr>
<td>B</td>
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<td>3.78</td>
<td>0.565</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>0.52</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td></td>
<td>0.35</td>
</tr>
<tr>
<td>C</td>
<td>0.5</td>
<td>0.24</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td>0.9</td>
<td></td>
<td>0.61</td>
</tr>
</tbody>
</table>

by four parameters; namely $S$, the source function in the cloud; $\tau$, the optical thickness of the cloud, $V_c$, the Dopplershift of the cloud, $\Delta \lambda$, the line broadening. We take a constant source
Figure 2 MSDP observations of a filament at Pic du Midi (200"x122" - 1" = 6 pixels). Maps (a) and (c) show the appearance of the chromospheric network: at the center of the line (panel a), the boundaries of the supergranules are mostly bright while the interior is overlain by dark threads and in the corridor of the filament the threads are elongated in the direction of the filament axis; in panel (c) large supergranules (30000 km) appear as bright features in Hα± 0.5 Å which are surrounded by dark mottles organized in rosette pattern.
Maps (b) and (d) both show velocity field, in panel (b), black regions correspond to redshifts, white regions to blueshifts, in panel (d) contours ±5 km s⁻¹ are represented with dashed lines corresponding to redshifts and continuous lines to blueshifts. Redshifts are mostly observed at the boundaries of supergranules with small blueshifted area in between. The Dopplershift magnitudes are reduced in and around the filament (corridor 3 times wider than the filament). excepted at the footpoints of the filament where up and downflows are detected. Points A, B, C in panel (d) correspond to the points indicated in Table 1.
Figure 2 Histograms $I_{\pm 0.256 \text{A}} / I_{\pm 0.52 \text{A}}$ and $I_{\pm 0.52 \text{A}} / V_{\pm 0.256 \text{A}}$.

Figure 3 Cuts through the filament with the vertical arrows indicating the position of the filament and the horizontal bar indicating a length of 1". Note the small scale structures.

Figure 4 Filament histograms showing good correlation between the intensities, and poor correlation between the velocities during an observation period of 180 s.

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function in the cloud and assumed to be between 0 and 1 in units of the minimum of $I(\Delta \lambda)$. Table 1 shows some examples of the computation of the cloud velocities, the corresponding optical thickness and the Doppler widths obtained for 3 points in the filament. The point C exhibits microturbulence equal to $30 \text{ km s}^{-1}$, which may indicate that different velocity structures are integrated along the line of sight.

4 modelization and conclusion

Fine structures are really puzzling. They appear to be stable as absorbing features, but really turbulent according to their velocity behaviour (Figure 5). Jensen (1986) has proposed Alfvén wave dissipation as a support mechanism for quiescent prominences. By contrast, Kuijpers (1989) proposed a model based on reconnection of twisted elementary flux tubes as the tubes are shortened by the observed converging and shearing flow in the underlying photosphere. Different states of heating, radiation and conduction may also be needed to explain the stability of these dynamical structures (e.g. Van Hoven et al. 1983).

At the footpoints, up or downward motions with high values (up to $10 \text{ km s}^{-1}$) are observed which strongly suggest a connection between the filament body and the chromospheric network. To explain this connection we propose a spicule-like model based on expulsion of gas in neutral lines by pressure or magnetic pulses (Suematsu 1985) which may be direct manifestation of hydromagneto- dynamic shock waves travelling along fibrils (Sterling and Hollweg 1988, 1989). If we follow a fluid element, it will receive an impulsive upward acceleration when each shock passes, and this acceleration should balance the deceleration due to the component of gravity along the flux tube. The shocks also heat the fluid element and this heating must be balanced by radiative cooling between the encounters with shocks. So far in these models there is a continual increase in the density since the models do not yet include a mechanism for returning material to the chromosphere. Hopefully, future models will include such a mechanism.

Acknowledgements: The authors want to thank Dr. Forbes and Dr. Raadu for fruitful discussions.
REFERENCES


Questions:

E.Wiehr: Are you sure that Hα observations of filaments on the disk exclusively refer to 
prominence body? At least at the Hα-wings (used for Doppler data) I would expect considerable 
contribution from the underlaying chromosphere. This statement certainly holds for the fibrils on 
both sides of the filament which are chromospheric and thus not necessarily physically related to 
the prominence body. Observations in the optically thick Ca+ K line might be more relevant.

B.Schmieder: You are right, the observations in Hα wings could concern more the chromo-
sphere than the filament itself if the filament is optically thin. The analysis of the line profile 
is useful to understand what structures is concerned. In our case, Doppler shifts measured at 
±0.256 Å refer to the filament while those at ± 0.512 Å concern the chromosphere except at the 
footpoints.

G.Simnett: You have shown areas around the ends of the prominence where there are upflows. 
Do you ever see simultaneous upflows from both ends of the prominence?

B.Schmieder: At the ends of the prominences up-and down-flows are observed. It is difficult 
with these observations to follow particular threads and to define their both ends, even with the 
good spatial resolution we have. The fine threads are better define in active region prominences 
than in quiescent ones.
RAZVOJ FINIH STRUKTURA U JEDNOM FILAMENTU

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UDK 523.987-54
Izlaganje

Sažetak: Mirni filament opažan u lipnju 1986. godine prolazio je kroz faze polaganog "Disparition Brusque" tijekom četiri dana. Naše istraživanje je usredotočeno na dinamičko ponašanje finih struktura (FWHM 350 km) u tom filamentu koji je opažan sa opservatorija Pic du Midi pomoću Multi-Channel Subtractive Double Pass spektrografa tijekom 30 minuta. U tom periodu nismo zamijetili promjene u sjaju, ali smo opazili promjenu polja brzina koje nije pokazalo korelaciju od jedne do duće minute. U nožištima gdje je filament uoktetljen u fotosferi ustanovljene su velike brzine, istog reda veličine kao brzine koje se opažaju na rubovima supergranula (između ± 10 km s⁻¹). Da bi objasnili naša opažanja, predlažemo model sličan onom razrađenom za spikule, a koji može objasniti opskrbljivanje prominencije materijom.