ON THE TWO CLASSES OF FILAMENT-PROMINENCE DISAPPEARANCE AND THEIR RELATION TO CORONAL MASS EJECTIONS

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Abstract. We analyze the phenomenon of sudden disappearance (DB) of quiescent filaments and prominences, with examples of the two classes (dynamic and thermal DB) observed on the solar disk and at the limb. The differences between their dynamics are discussed, and it is shown that only dynamic DBs are associated with coronal mass ejections (CME), whereas thermal DBs are only local disturbances of the lower corona. We finish with a discussion of DBs detected on the disk and limb, to explain the statistical differences between the disappearance of filaments and the production of CME.

1. Introduction

In this article, we wish to add a few comments concerning the phenomenon of 'disparition brusque' (DB) of filaments (prominences). We have previously shown (Mouradian, Martres, and Soru-Escaut, 1981; Mouradian and Soru-Escaut, 1989a) that there exist two categories of DB: dynamic (DBd) and thermal (DBt).

The DBd process consists of an expansion and ejection of prominence plasma into the corona due to changes in the underlying magnetic field structure, for example with the emergence of new magnetic flux. Generally, this process leads to complete and final disappearance.

DBt is the disappearance of a prominence in Hα due to an increase in energy input which, as it heats the plasma, ionizes the hydrogen. In this case, the gas pressure and the magnetic field of the prominence becomes stronger, but the shape remains essentially unaltered (see Mouradian, Martres, and Soru-Escaut, 1981, Figure 2). Once cooled, the prominence reappears.

Although several aspects of the latter process have already been studied in the above references, here we bring out the observational differences between the two phenomena, on the disk and at the limb, mainly in the Hα line, and discuss the relation with the coronal mass ejections (CME) that represent the higher-altitude response to these events.

To truly isolate the DB phenomenon, we will be looking at the activation of the quiescent filaments (prominences), although DBs also occur in plage filaments, in which case they are usually DBd followed by a double ribbon flare. Malherbe *et al.*

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(1983) have described a case of DBt at the time of a flare (see Section 6 below, (v)).

Schmieder (1989), Forbes (1990), Démoulin and Vial (1992), and Ballester (1994) have published review papers on DBs. Harrison (1991) and Webb *et al.* (1994) have reviewed the sources of CME. But let us note that, while there currently exist theoretical models of dynamic instability leading to DBd, there is no such equivalent for the heating of prominences. That is, the prominence may, by heating, reach a new stable stage for a few days, at a higher temperature (Eddy, 1979). If the heating is of short duration due to a thermal instability (Mouradian, Martres, and Soru-Escaut, 1981), the disappearance lasts only a few hours.

To begin with, we will present DBs observed at the limb and then those observed on the disk, where the difference between the two classes is more difficult to grasp. Then we will show the relation between the DB and CME, as well as the problems in detecting the DB process.

2. DBd and DBt at the Solar Limb

Recently, Rompolt put forward the idea of two types of DB: one symmetrical and the other asymmetrical (Figures 55 and 63, respectively, in Rompolt (1990)). Close examination shows that symmetrical and asymmetrical DBs do indeed exist initially, but that all become asymmetrical in a later phase. Two typical cases of this are illustrated in Figures 1(a) and 1(b) (Mouradian and Soru-Escaut, 1989a). That is, it seems that the asymmetry of the DBd process is a general and characteristic phenomenon, even if the undisturbed prominence exhibits a high level of symmetry before or at the beginning of the disappearance as, for example, the well-known DB observed by Roberts in 1946 (Tandberg-Hanssen, 1974, Figure II.2). Generally, the DBd process begins with one of the two legs of the prominence 'lifting off', and continues with the structure piling up in a 'column' on the foot of the other leg. This suggests a complete upset in the magnetic field organization of the prominence, as for example by the appearance of new magnetic flux (Martin *et al.*, 1984; Mouradian and Soru-Escaut, 1989a, Figure 3) near the lifted foot, and followed by magnetic reconnection. Vršnak (1990) and Vršnak *et al.* (1993) have studied in depth the unwinding of the prominence structure into a spiral during the DBd process. Note that the Hα images show only the cool plasma morphology structured by the magnetic field and not the magnetic field itself.

Comparing Figures 1(a) and 1(b) with Figure 1(c), a basic difference can be seen between the two disappearance processes. The example of Figure 1(c) (Mouradian and Soru-Escaut, 1989a) is a thermal sudden disappearance (DBt) where the prominence is seen to fade while stationary, and where its magnetic field is affected by only minor alterations, with the general shape remaining the same. The structure vanishes slowly in the Hα line because of the ionization of the hydrogen due to the input of energy. This type of phenomenon is accompanied by the appearance of

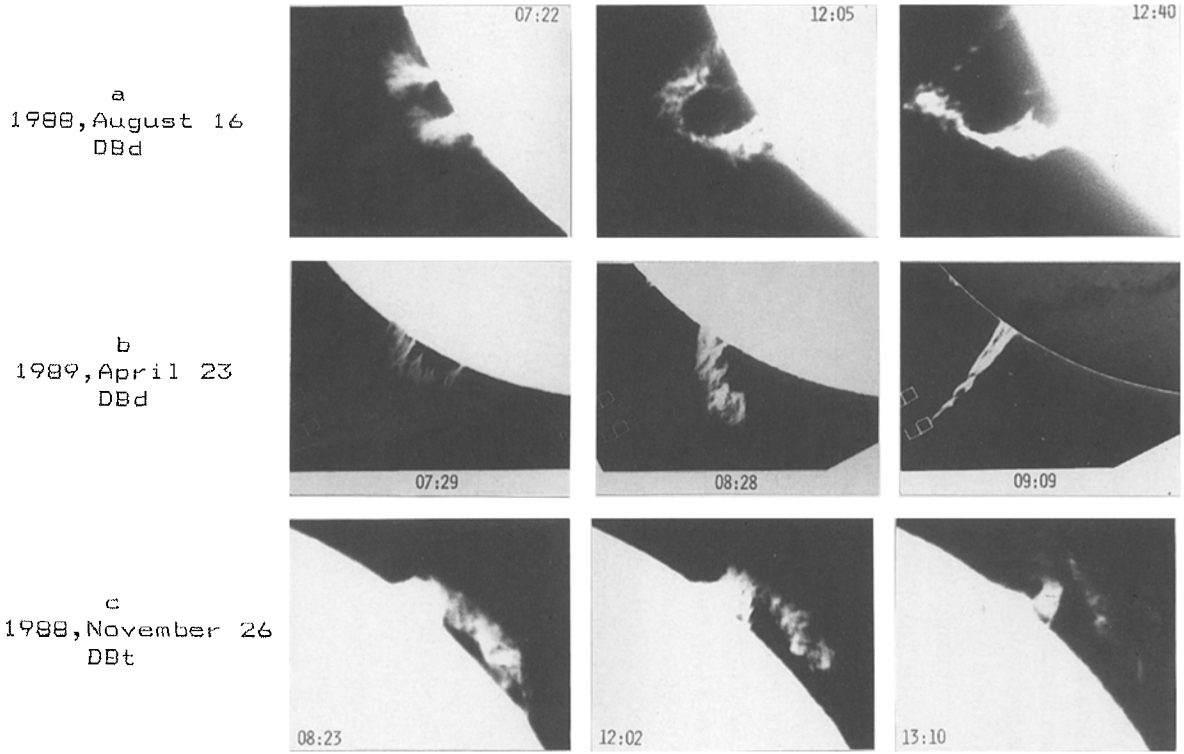

Fig. 1. Examples of prominence DBs observed in Hα with the 3λ heliograph at the Paris-Meudon Observatory. Dynamic DB (a) and (b) compared with thermal DB (c). The three examples are taken from Mouradian and Soru-Escaut (1989a), which gives the full variation of the phenomena.

emissions in the far ultraviolet (Mouradian, Martres, and Soru-Escaut, 1981; 1986) or X-ray wavelengths (Eddy, 1979; McAllister *et al.*, 1992; Watanabe *et al.*, 1992). As DBt is not very spectacular at the limb, it does not easily attract the attention of observers, and it is because of this that the the DBt is often overlooked (see Section 5).

Figure 2 shows the DBt of a prominence subject to successive disappearances and reappearances during the seven hours it was observed. This phenomenon appears as a fluctuation in Hα light, which is in fact due to ionization rate variations within the prominence. This is a borderline case, as the heating is not great enough to achieve a total disappearance.

The above examples show us that the most important feature of DBs is the time variation of the prominence height. Figure 3 shows the maximum height variation of four DBs observed in Hα with the '3λ heliograph' instrument at the Paris-Meudon Observatory. The difference between the two types of DB can be seen clearly: DBt phenomena (1988, November 26 and 1989, April 15) have little or no ascending velocities; while DBd (1988, August 16 and 1989, April 23), after starting out at a low and approximately constant velocity V_{I}, go through an acceleration phase to another phase of almost constant but much higher velocity, V_{II}. Table I gives the characteristics of a few, but well observed, cases we have studied. Columns 4 to 11 give the measured parameters in Hα observations. Columns 6 to 8 give the position angle, the distance from the disk center, and the DB class. The last columns (9 to 11) give the dynamic parameters and maximum visible altitude in Hα.

To increase the DBd sample of Table I, we added those in Rompolt's graph (Rompolt, 1990, Figure 49) and determined the average V_{I} and V_{II} velocities as well as the acceleration at the beginning of V_{II}. Table II, which includes Table I and Rompolt's data, gives the means of the velocities V_{I} and V_{II} and of the acceleration γ, along with the standard deviations and their extrema, in those cases where DBs occurred in the plane of the sky, which is a reasonable hypothesis. Considering that there is an approximately uniform distribution around the sky plane, we can determine a coefficient of 1.1 to correct for the measured heights. Consequently, if we want to find the correct values of V_{I}, V_{II}, and γ, the measured values must be multiplied by 1.1 . This coefficient is $1/\cos\theta$ in which θ is the average angle of the DBd around the sky plane. The value $\theta = 25^\circ$ is found from the ratio between the average apparent heights and the average maximum height of the DBd.

Several authors have indicated that, as the plasma rises through the corona, Hα plasmoids detach from it and fall back to the surface. This phenomenon is responsible for the last two points in the graph of the 1988 November 26 event in Figure 3.

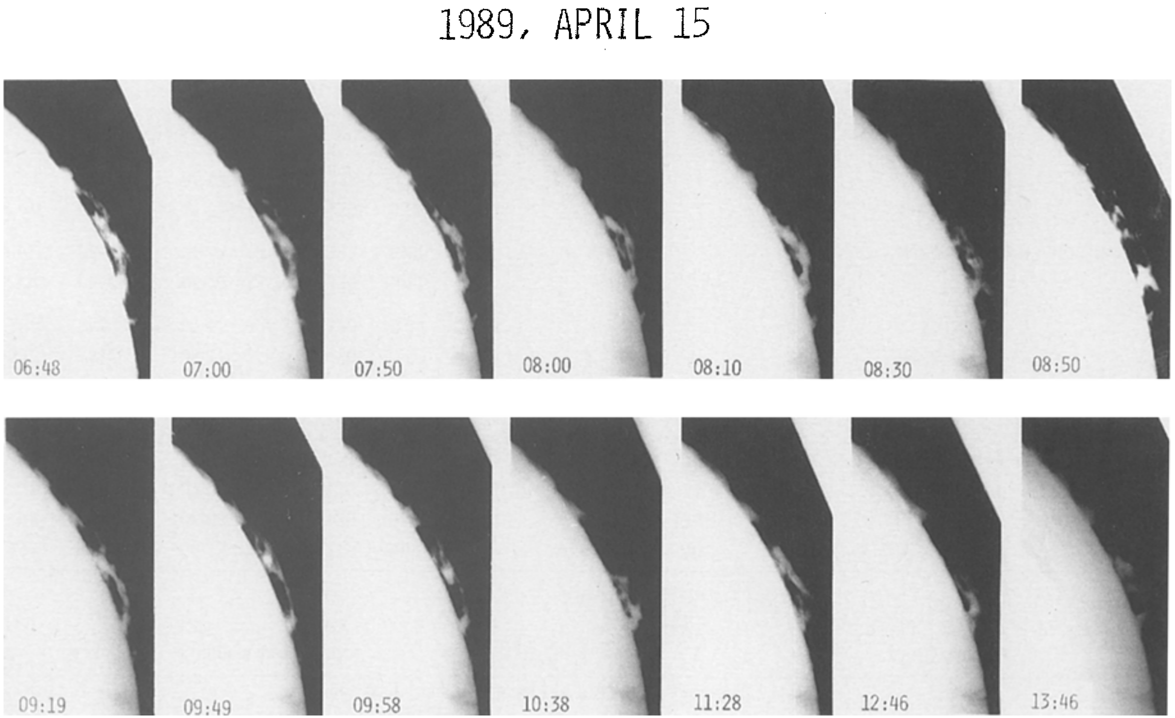

Fig. 2. Time variation of Hα visibility in an arch-type prominence, due to ionization of H as a consequence of the energy input variation. North up, east left (Paris-Meudon Observatory's 3λ heliograph).

TABLE I

Dynamic properties of filament-prominences and CME

Date	Rot.	Coord.	Obs.[a]	*Filament-prominence*							CME (SMM)			Feature
				UT	PA (°)	r/R	Type	$V_{\rm I}$ (km s^{-1})	$V_{\rm II}$ (km s^{-1})	$H_{\max}$ (km)	UT	PA (°)	V (km s^{-1})	
1979, May 8	1681	55S, 295	Romp.	06:53–11:20	215	limb	DBb	9	40	3.1E5	10:59–15:38	225	350	bubble[d]
1980, Aug. 18	1698	30S, 68	Romp.	08:03–12:14	120	limb	DBd	4	138	6.1E5	11:43–13:10	116	∼650	loop cavity
1988, Aug. 16	1805	37S, 26	PMO	07:22–13:20	120	limb	DBd	1.5	31	2.1E5	13:02–20:11	120		cavity
1989, Apr. 23	1814	50S, 29	PMO	06:30–09:09	151	limb	DBd	1.6	45	2.4E5	08:15–12:48	143	477	loop cavity
1946, June 4	1240	53S, 180	Rob.	16:04–20:08	180	0.71	DBd	/	130	8E5	no SMM			
1983, July 12	1737	32S, 246	PMO	13:10–15:31	210	0.53	DBd			/	no SMM[b]			
1989, Aug. 18	1819	39S, 320	PMO	06:15–15:50	180	0.79	DBd	7	/	2.7E5	16:46–18:19	200	/	loop cavity
1990, June 15	1830	15S, 280	PMO	07:55–09:41	120	0.47	DBd			/	no SMM			
1988, Nov. 26	1809	55N, 330	PMO	08:23–13:30	320	limb	DBt	2		0.95E5				no CME
1989, Apr. 15	1814	18N, 261	PMO	06:48–13:46	297	limb	DBt	0		0.36E5	data gap < 18:43, no CME later			
1983, May 5	1734	26S, 10	PMO	11:30–15:00	130	0.61	DBt			/	no SMM[c]			
1988, Aug. 8	1805	30S, 271	PMO	06:51–08:48	228	0.88	DBt	∼15		/				no CME

[a] Romp.=Rompolt, 1990; Rob.=Roberts in Tandberg-Hanssen, 1974; PMO=Paris-Meudon Observatory.

[b] No event observed on *Solwind*.

[c] Data gap for *Solwind*.

[d] No SMM data, see Rompolt.

/ cannot be measured.

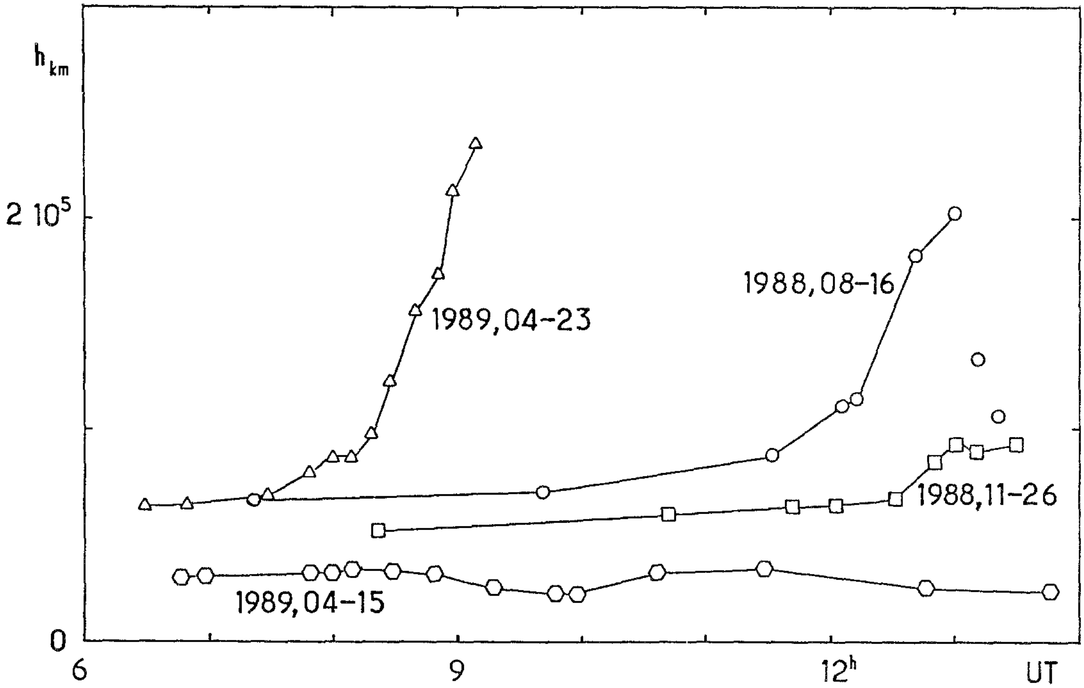

Fig. 3. Variation of the maximum height of Hα prominences subject to dynamic DB (1988, August 16 and 1989, April 23) and thermal DB (1988, November 26 and 1989, April 15).

TABLE II

Prominence expansion measured in Hα

		Mean	Stand. dev.	Extrema	Number
Velocity	V_I km s^{-1}	9	6	2–22	12
Acceleration	γ km s^{-2}	0.045	0.052	0.004–0.2	19
Velocity	V_{II} km s^{-1}	195	157	25–635	22

3. DBd and DBt on the Disk

Though it may be more difficult to distinguish between the two types of DB inside the disk, it is still possible if we use simultaneous observations in the center and on the wings of the Hα line. Figure 4 shows an example of DBt on the disk (Mouradian and Soru-Escaut, 1990). The filament vanishes while moving slowly upward, as seen in the blue wing of the Hα line, similar to the 1988, November 26 event in Figure 3. This upward motion is driven by the increasing gas pressure, due to the heating. As concerns the way DBt is manifested on the disk, the filament becomes more and more transparent over its entire length, exhibiting a little or no evidence

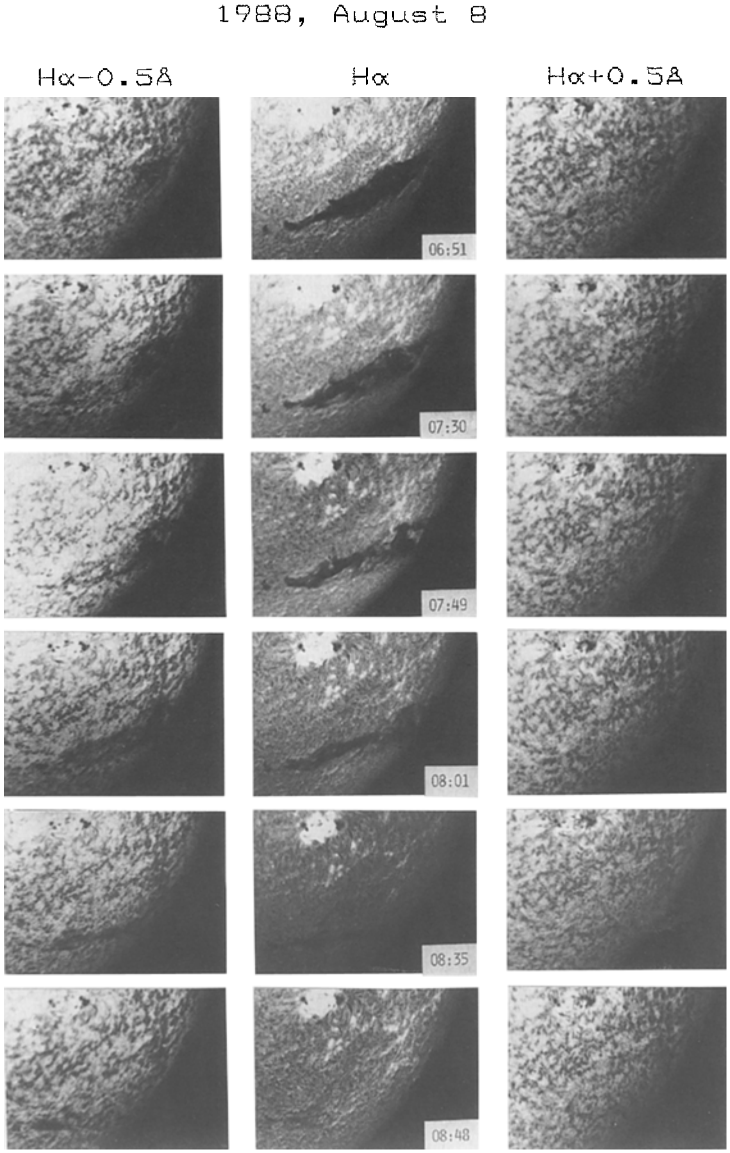

Fig. 4. Thermal sudden disappearance (DBt) observed on the disk in Hα with the Paris-Meudon Observatory's 3λ heliograph (Mouradian and Soru-Escaut, 1990). North up, east left.

of radial velocity, before it vanishes totally. It should be recalled that the DBt is preceded by densification – higher absorption – and by settling – downward motions (Mouradian and Soru-Escaut, 1990).

If a filament undergoes DBd while it is located on the disk, then the displacements in height are detectable only by making use of the Doppler effect. So we should expect that the filament will have ascending velocities to begin with, espe-

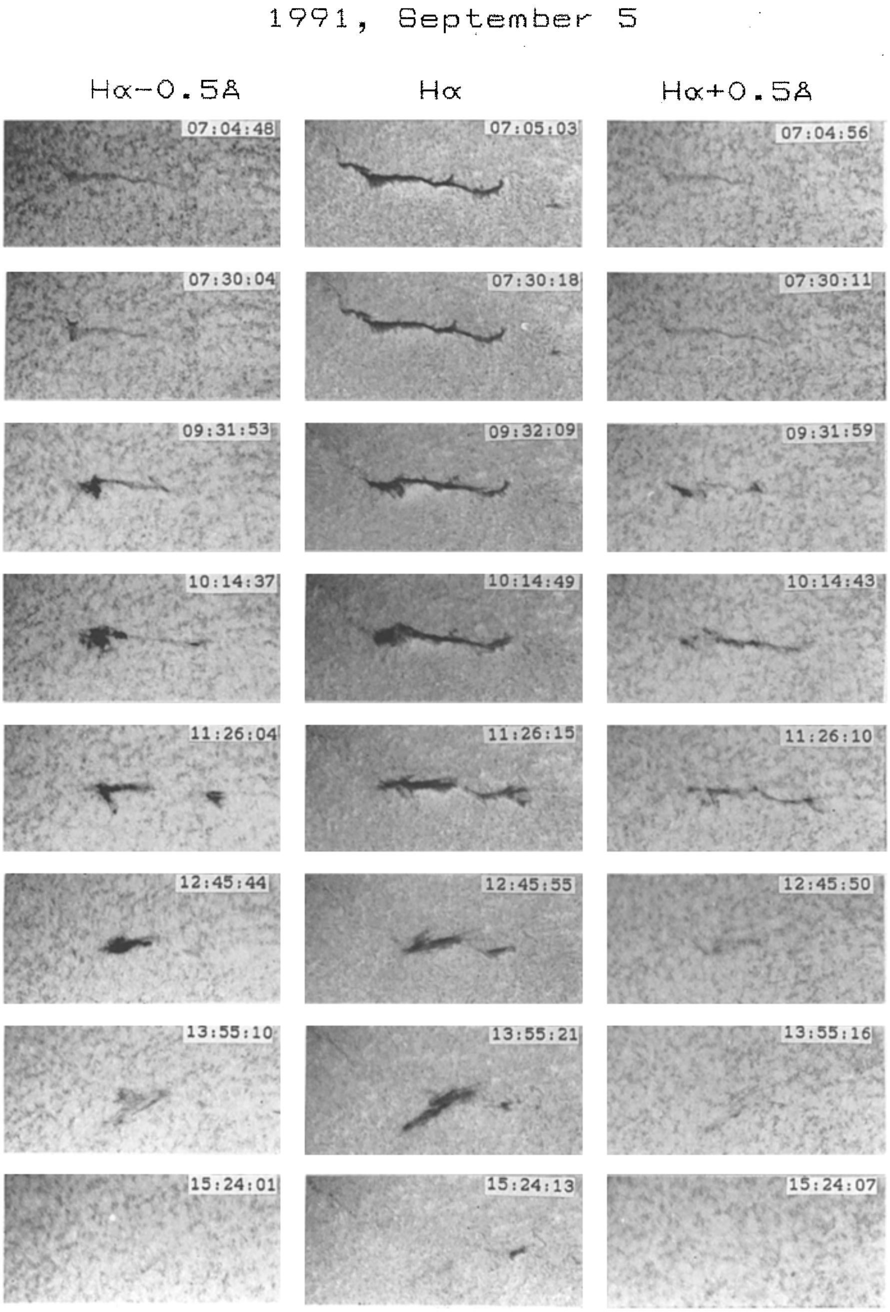

Fig. 5. Dynamic sudden disappearance observed on the disk in the Hα line with the Paris-Meudon Observatory's 3λ heliograph. North up, east left.

cially at one of its feet, with stronger absorption at the other foot. This case is illustrated by the example of 1991, September 5 (Figure 5), where a quiescent filament at 37° N, between 15° and 50° E, undergoes DB starting at 07:05. This DB is evidenced by the appearance of ascending velocities at the eastern foot (tip) of the filament. Later, at about 10:15, this velocity is stepped up by an amount of the order of 10 km s^{-1}, with the rising plasma approaching the center of the filament up to about 12:45, increasing its speed all the time. At 15:24 the disappearance is complete. The west side disappears similarly, with the anchoring point being at the west foot this time. After three days, the west part of the filament forms again, which is not the same process as the cooling of filaments after a DBt.

The dynamic DB phenomenon as seen on the disk (Figure 5) can be compared with the phenomenon as observed at the limb (Figure 1(a)), i.e.:

- 1991 September 5 at 07:05 is equivalent to 1988 June 16 at 07:22;
- 1991 September 5 at 10:15 is equivalent to 1988 June 16 at 12:05;
- 1991 September 5 at 12:46 is equivalent to 1988 June 16 at 12:40.

4. DB and CME

Having distinguished between these two classes of DB – one static and the other dynamic – we are prompted to look at the consequences they have on the upper corona.

Columns 12 to 15 in Table I give some data concerning the cases we have studied, along with any CMEs occurring during the period of coronagraph operation on the Solar Maximum Mission, taken from the catalogue of Burkepile and St. Cyr (1993). The corresponding CME, of the 1989, April 23 event, is given in Figure 16 of the catalogue. We see in Table I, as might have been expected, that only DBd produces any CME in the corona. DBt therefore remains a local temperature disturbance that will lead to a variation in Hα detectability. This explains why no direct correlation is observed between all DBs taken together (DBd+DBt) and CME. The DB–CME relation that we have found is based on only a few examples; but it should be emphasized that, while this has no statistical value, there are no contrary examples either.

As far as the DBd ejection velocities are concerned, we can compare those of Table II with the CME measurements published by MacQueen and Fisher (1983) and conclude that the agreement is good between the V_{II} velocities of 195 ± 157 km s^{-1} and the mean of the CME initial phase velocities of 127 ± 98 km s^{-1}, due to the prominences.

5. DB Detectability

The problem of DB detectability is very important because it conditions the prominence-filament DB statistics and their correlation with CME. The detectability of a structure in Hα depends on how sharply the structure contrasts with its background, whether that be disk or sky, and on whether the structure is a filament or a prominence. The contrast of a filament (C_F) and of a prominence (C_P) are defined with respect to their background intensities I_d and I_s, respectively. Using standard 'Cloud Model' notation, we can evaluate the filament intensity I_F and that of the prominence I_p and compute the contrast of the same volume of plasma under both conditions, i.e., at the disk and limb:

$$C_F = \frac{I_D - I_F}{I_d} = (1 - e^{-\tau})\left(1 - \frac{S}{I_d}\right)$$

and

$$C_P = \frac{I_P - I_s}{I_s} = \frac{S}{I_s}(1 - e^{-\tau}) - 1 \,.$$

We will be analyzing the filament (prominence) heating using the model of Gouttebroze, Heinzel, and Vial (1993), which gives us the source function S and the optical thickness τ for temperatures from 4300 to 15 000 K. We find that $(\Delta\tau/\Delta T) > (\Delta S/\Delta T)$, so to get a qualitative estimate of the contrast, we will assume that only τ varies with the increase in temperature. Because of the ionization of hydrogen, $\tau \to 0$, and so C_F and C_P both tend toward zero. Considering the fact that $(S/I_s) \gg (1 - (S/I_d))$ then $\Delta C_F < C_P$ at all times. This simple calculation shows that the filament contrasts less than the prominence; and for this reason, any small variation in the optical depth due to an input energy variation can produce a DBt on the disk, but only an intensity variation at the limb. This explains why more DBt are detected on the disk (Mouradian and Soru-Escaut, 1989b), and more DBd on the limb. So it is difficult to compare the total number of observed DBs with the number of CMEs, as the basic mechanisms driving each of them are different.

6. Discussion

(i) The two classes of DB are initially due to magnetic or thermal instabilities. In DBd, the magnetic equilibrium of the structure is first destroyed, followed by ionization of plasma ejected into the corona. In the case of DBt, the increase in gas pressure due to the heating may be balanced by a strengthening of the magnetic field. We suggest that an increased twisting of the magnetic tubes making up the prominence could compensate such a magnetic field increase without changing the general shape of the prominence.

(ii) In the initial phase of DBd, the velocities V_{I} are quite similar to any ascending velocities of DBt. This suggest that DB might begin with an increase in the gas pressure and that, once the other forces come into play, such as magnetic reconnections, an acceleration γ would occur that would impart the V_{II} velocities to the plasma. Note that velocity V_{II} is the measure of the upward speed of the top of the Hα plasma. But if we remember that the plasma is ionized in contact with the hot corona, it might then be that the speed measured is less than the actual velocity of the plasma, which is measured by the CME speed. So by comparing V_{II} with the CME speed, we can deduce something about the ionization effect in the corona (Table I).

(iii) Dermendjiev *et al.* (1994) have recently studied the cold coronal emissions that are sometimes attached to prominences. Some of these structures might be prominences which undergo a DBt and whose temperatures are close to the ionization limit of H ($T \approx 2 \times 10^4$ K). This would support low Hα emission, as most emission is in the far ultraviolet lines.

(iv) Concerning the reappearance of the filament after DB, it should be noted that, subsequent to a DBt, the reappearance is due quite simply to the weakening and final canceling of the excess input energy that produced the ionization (Mouradian and Soru-Escaut, 1990). That is, since the cooling time by radiative loss is too short to explain the observed cooling time, we think that the cooling is due to the weakening of the energy input. In the case of DBd, reappearance is possible by a new formation of the filament, often with other anchor points (feet).

(v) In the present article, we have not addressed the problem of plage filament DBs, which might exhibit other forms of disappearance, considering that the energies involved in these cases are much greater. In active regions, filament disappearance is very often accompanied by a flare and surge. While these three events are physically different, and may be dynamically different too, it is difficult to distinguish between them for instance when they are seen on the limb. This is why we have eliminated this type of DB from our study.

(vi) The consequence of DBt is the appearance of coronal structures that correspond to no visible chromospheric structure, i.e., that the filament now visible in EUV lines disappears when viewed in Hα.

(vii) We note that the existing DBs lists are generally compiled by observing the disappearance of a filament from one day to the next, which makes it difficult to break them all down into DBt and DBd types. Furthermore if a filament disappears and reappears or re-forms between two observations, the phenomenon cannot be listed. Indeed, DBs on the limb are generally DBds, since the listings are usually made from events actually seen to erupt.

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