ON THE SUDDEN DISAPPEARANCES OF SOLAR FILAMENTS AND THEIR RELATIONSHIP WITH CORONAL MASS EJECTIONS

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ABSTRACT

Sudden disappearances of prominences/filaments were identified from the Prairie View Solar Observatory Hα images and Meudon Observatory spectroheliograms for the period January 1, 2000 to March 31, 2000. Three classes of disappearances were considered for the purpose of this study: eruptive, quasi-eruptive and vanishing filaments. The Hα events were compared with CME data from LASCO C2 and C3 coronographs aboard SOHO. Our study shows that the eruptive events are strongly associated with CMEs while the other types are not.

INTRODUCTION

During the lifetime of prominences/filaments, incidents may occur that lead to the sudden disappearance of the prominence, a phenomenon also called ”disparition brusque” (DB). This sometimes violent event results from an instability of the prominence structure, and takes place on a very short time-scale (from a few minutes to several hours). In some cases, it is followed by a reappearance of the prominence at the same location. Many studies show that the disappearances of prominences/filaments are often associated with Coronal Mass Ejections (CMEs) (Webb and Hundhausen, 1987). However, although the connection between DBs and CMEs is clearly demonstrated in individual cases (e.g. Schmieder et al., 2000), conflicting overall conclusions are obtained for the correspondence between these two phenomena: from a nearly one-to-one (Gilbert et al., 2000) to a poor correlation (Yang and Wang, 2000).

There are at least two factors, which we consider in this paper, that may lead to such results. The first is that there are different types of prominence activity that are often referred to as disappearances, and these types may have a different relationship with CMEs. Detailed studies of individual events (Pettit 1943, Mouradian and Soru-Escaut 1989, Tonooka et al. 2000) clearly indicate that there are different scenarios that lead to the same result: the disappearance of the prominence or filament. In many cases, the actual eruption of the prominence takes place, while in other situations the prominence vanishes with no portion of it appearing to escape from the Sun. The events may be roughly classified as eruptive (entire prominence ascends with uniform velocity) and active (material seems to be streaming into nearby active centers) according to Petit (1943), or as dynamic (expansion and ejection of the prominence plasma following a major reorganization of the magnetic field) and thermal (disappearance only in the Hα line due to the heating of the prominence) according to Mouradian et al. (1995). While few studies that investigate the DB-CME correspondence take into account the specific type of disappearance (often for a limited number of well-observed events), many other broader studies do not consider such differentiation (Yang and Wang, 2000).

The second factor possibly accountable for such discrepancies relates to the difficulties encountered by investigators when associating events that come from different data sources, while also being best observed in different conditions. On one hand, the filament disappearances near the disk center are easier to detect but more difficult to categorize than those at or near the limb. Furthermore, the available data on sudden disappearances are usually compiled from observations of filaments taken from one day to the next, which does not clearly differentiate the events. In contrast, CME data has a bias in favor of events occurring at or near the limb. Moreover, identification of surface phenomena related to CMEs is a difficult process because of the uncertain location of the CME origin. In many cases the corresponding surface event may be situated on the back side of the Sun. These biases are not uniform and apply less to large and bright events, while smaller and less bright events are strongly affected.

The paper herein concentrates on identifying different types of disappearances of prominences and filaments, while also performing a separate correlation analysis with the CMEs from the catalog compiled from LASCO coronograph data. We here show our first results from our ongoing investigation concerning the disappearances and their relation with CMEs. Unlike most of other studies on this topic, which identify the disappearances associated with the CMEs, our investigation begins with the filaments and finds the corresponding CMEs.

OBSERVATIONS AND ANALYSIS PROCEDURE

The main instrument of the Prairie View Solar Observatory (PVSO) is a 35-cm Gregorian Vacuum Telescope equipped with a Daystar 0.5A Hα filter and a SBIG ST-7 camera. As part of our daily observing program, several images of the most important filaments are taken during the day. The images are 382x255 pixels in size, with a resolution of 0.91 arcseconds per pixel on the sky. In addition to our data, we used the spectroheliograms and the synoptic maps from Meudon Observatory. We also examined the EIT 195Å images for filament activity as well as CME-related phenomena in the lower corona. The overall timeframe considered for this study was Jan 1st - Mar 31st, 2000.

For this study, we have investigated both filaments on the disk and prominences at the solar limb. In this analysis, cases considered as disappearances were those where a minimum of 30% of the overall length of the prominence/filament had vanished over a maximum of 36 hours. Though certain events were visible within minutes/hours of observational time, most were recorded the following day. In addition, prominence eruptions and activations were occasionally seen in EIT 195Å data and included in our sample. A minimum of 10 degrees was set for the maximum observed length of the filaments in order to minimize the bias related to their detection.

From all the recorded DBs only a small fraction allowed us a identification of the disappearance type. Most of the rest of the events were incomplete observations or were recorded the following day. Three classes of events were considered for the purpose of this study: eruptive, quasi-eruptive and ”vanishing” prominences. Eruptive events are characterized by all or some prominence plasma escaping the solar surface. The second type show important plasma motions (either a rise or tangential motion parallel to the surface) but with no portion of the prominence appearing to escape the solar gravitational field. The last prominence type includes those that vanished in place, with minor motions or configuration changes. In the paper herein, we term this last class of prominences as ”vanishing” - though this is not an established term throughout the literature. This denomination does not refer to, nor does it imply a known mechanism, as it is only descriptive of the observable behavior of the prominence within the observing time frame. The events in this class may correspond to the thermal disappearances described by Mouradian et al. (1995) or to very rapid erupting events seen against the disk. Many events belonging to the first two types were observed in the EIT 195Å movies, while no change in the configuration of the coronal structure surrounding the prominences was distinguished for the third type.

CMEs were taken primarily from the catalog compiled by Seiji Yashiro from the LASCO C2/C3 observations and made available by the LASCO team. C2/C3 movies were also studied in order to estimate the possible surface origin of CMEs and search for additional CMEs not included in the list. A CME was defined as a discrete brightening propagating away from the Sun. Several data gaps were present in the LASCO data during our overall timeframe; disappearances occurring during these gaps were not included in our analysis.

In order to identify the surface events associated with the CMEs, EIT 195Å images were inspected for signatures that could correspond to the CME initiation in the lower corona. These signatures include plasma motions, coronal dimmings, EIT waves and eruptive prominences. An association between a disappearing prominence and a CME was established if the following requirements were fulfilled: such a EIT surface manifestation occurred at the position of the prominence; the apparent position angle of the disappearing event was located within 30 degrees of the position angle of the CME; and the disappearing event occurred in an interval of 180 minutes centered on the onset of the CME. The temporal and spatial criteria were chosen in the same way as in the previous association studies (Webb and Hundhausen 1987, Gilbert et al. 2000).

In addition to the correlations strictly satisfying the above criteria we also included two other lower levels of confidence, only in the case of gaps in the Hα observations: DBs recorded 3 hours and 6 hours after the CME,

Table 1. Association between DBs and CMEs

	Eruptive	Quasi-eruptive	Vanishing	All DBs
Number of DBs	47	27	7	426
DBs with CME association				
High confidence level	33 (70%)	5 (19%)	0	57 (13%)
High + Moderate confidence level	39 (83%)	13 (48%)	0	120 (28%)
All confidence levels	40 (85%)	18 (67%)	0	168 (39%)

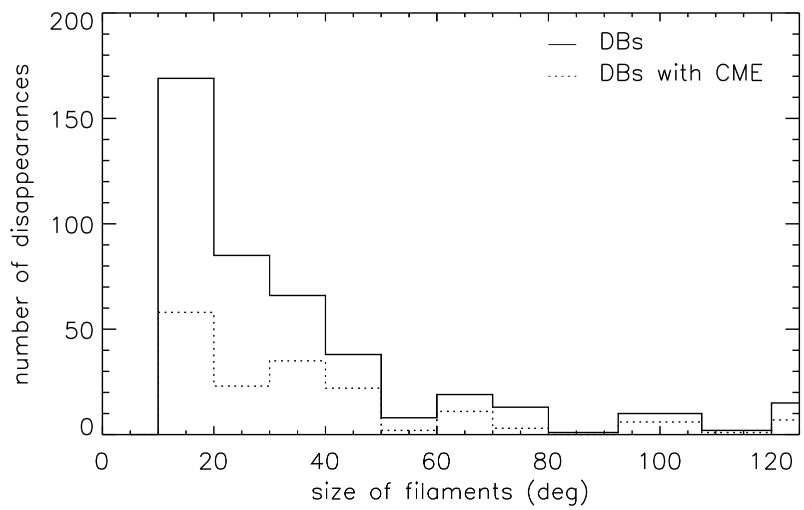

Fig. 1. Size distribution of filaments.

respectively. For both cases we required that a change of the coronal structures in the vicinity of the filament be detected in the EIT images. Associations were searched for the whole data set with emphasis on the disappearances with identified type.

DISCUSSION

During the studied period, that was also covered by LASCO observations, 426 disappearing filaments were documented. From those, 81 were identified as eruptive, quasi-eruptive, or vanishing events. The associations for the specific types of events as well as for the whole data set are shown in Table 1.

As seen from Table 1, 70% of the eruptive events are associated with CMEs (considering only the CMEs from the LASCO catalog); this percentage increases to 85% if the data includes the events with all the confidence levels. Meanwhile, the correlation is weaker for the quasi-eruptive events and none of the vanishing filaments are related to CMEs. These results show that eruptive prominences are extremely violent phenomena that are strongly related to CMEs. Observations of DBs at radio frequencies also support this conclusion (Gopalswamy et al., 2002). However, many of the observed disappearances are local phenomena that do not involve the destabilization of the large-scale coronal structures or they may be associated with minor CMEs that are more difficult to detect. When the entire set of data is being considered, a low correlation level with CMEs is obtained (13% to 39%). This may be due to the mixing of different types of prominence activity as well as to associations with small scale coronal events not included in the data set. From all the CMEs recorded during this period, 42% were associated with disappearing prominences.

It is noteworthy that the above results are subject to the biases described in the first section (introduction), regarding the size and position of events. Figure 1 shows the size distribution of the observed filaments. We see that the percentage of associations increases for filament lengths greater than 30 degrees as compared to smaller ones. The center

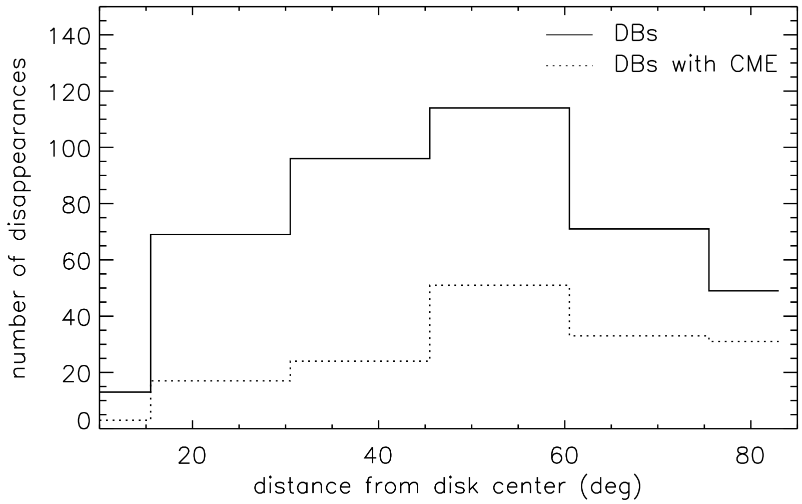

Fig. 2. Center to limb distribution of filaments.

to limb distribution of the events is given in Figure 2; while the number of disappearing prominences decreases towards the limb, the percentage of associations with CMEs increases. For instance, from the total of 63 disappearances occurring at or near the limb, 40 (63%) were correlated with CMEs.

In order to show the DB-CME connection during the solar cycle, we plotted the position of each disappearing event and CME in a time-latitude diagram for a longer interval, from 12/26/1997 to 01/7/2002 (Figures 3 and 4). All disappearances observed at Meudon and all CMEs from the LASCO CME catalog were included in this study. No CME data was available for rotations 1937-1941 and 1944-1945, as well as for other much smaller intervals. Figure 5 shows the equivalent diagram for all the optical flares recorded during the same period (provided by NGDC). Figures 3 - 5 show that, while the flares are concentrated in the active belts, the DBs and CMEs are spreading to higher latitudes as the cycle progresses towards its maximum. The rather high latitude of CMEs is also given by the fact that it is inferred from the position angle of the CMEs, the latitude of the point of origin being lower for the events occurring far from the limb. However, many of the highest latitude CMEs are clearly related to the disappearances undergone by the polar filaments (see also Pojoga and Huang, 2002). Therefore, as for the previous solar cycle (Hundhausen, 1993), the current cycle exhibits a similar latitude-time distribution of CMEs, which is closer to the behavior of DBs than to the one of solar flares.

CONCLUSIONS

From the analysis of the prominence/filament activity and the CMEs recorded during this period (LASCO CME catalog), we have found that different types of disappearances exhibit a different correlation with CMEs. While the eruptive events are, as expected, strongly associated with CMEs, the other types are not. This analysis suggests that many of the disappearing prominences are local phenomena, that do not involve the destabilization of the large-scale coronal structures, or are associated with other coronal events that are difficult to detect. A low correlation level is obtained when considering all available data, probably due to the mixing of different types of events, as well as to the difficulties related to the event detectability. The latitude-time distribution of CMEs and DBs shows some correspondence between the two phenomena and a clear association for high latitude events. More comprehensive observations of prominences/filaments are needed in order to identify the specific types of disappearance.

ACKNOWLEDGEMENTS

This research was supported under NASA grant NAG8-1338. Spectroheliograms and synoptic maps are produced by Observatoire de Paris-Meudon. SOHO is a project of international cooperation between NASA and ESA. The CME catalog is generated and maintained by the Center for Solar Physics and Space Weather, the Catholic University of America in cooperation with NRL and NASA. Flare catalogs are compiled by NGDC.

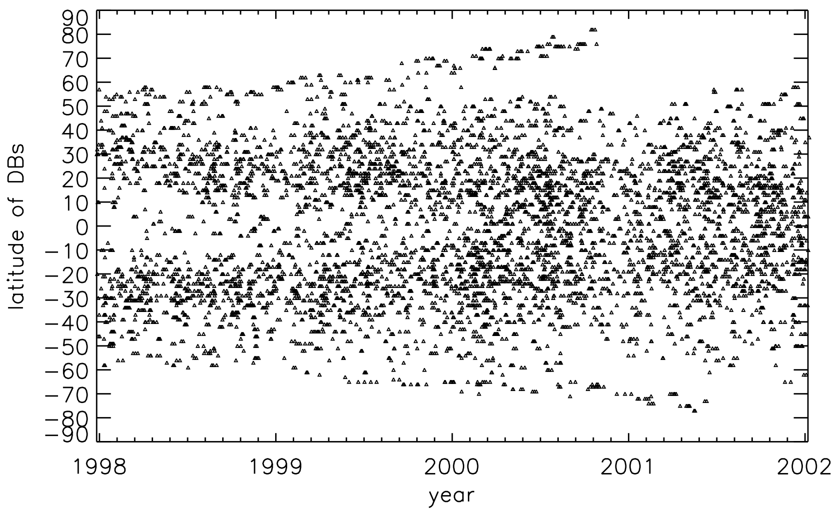

Fig. 3. Time-latitude distribution of DBs.

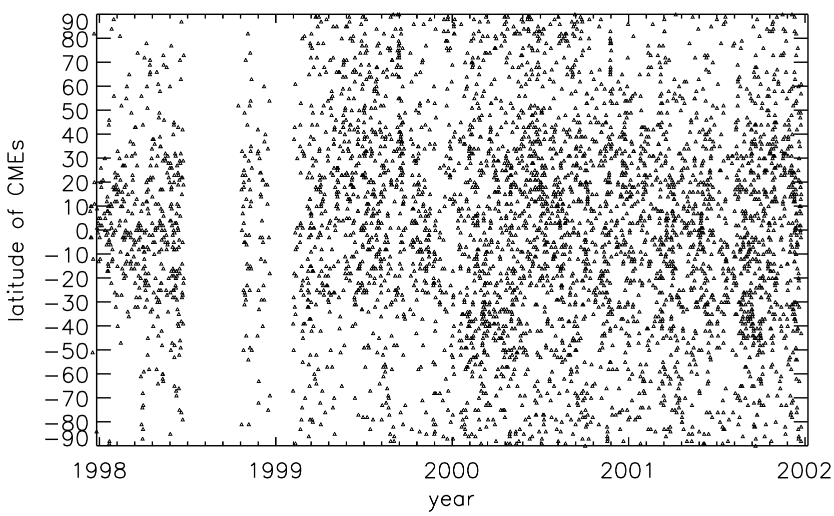

Fig. 4. Time-latitude distribution of CMEs.

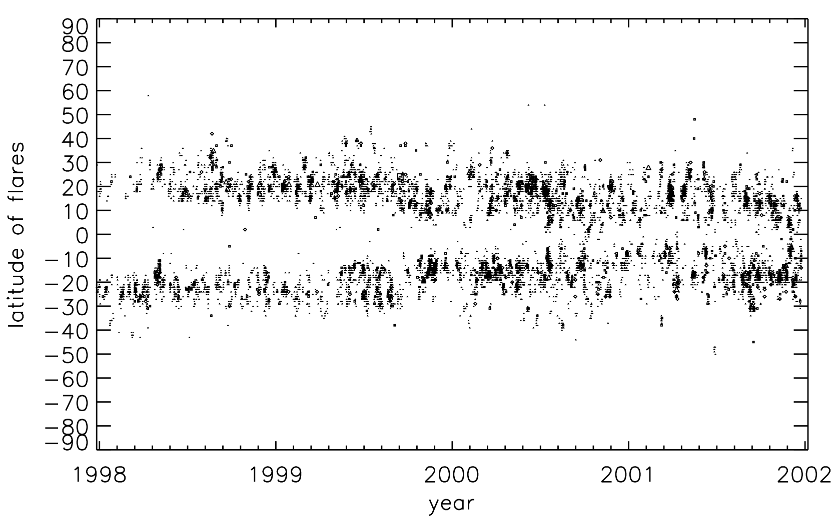

Fig. 5. Time-latitude distribution of flares.

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Manuscript received 27 November, 2002; revised 21 May, 2003; accepted 7 July, 2003.