Solar Phys (2013) 285:269–280
DOI 10.1007/s11207-012-0217-0

OBSERVATIONS AND MODELLING OF THE INNER HELIOSPHERE

Stealth Coronal Mass Ejections: A Perspective

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Received: 27 January 2012 / Accepted: 12 December 2012 / Published online: 9 January 2013

Abstract "Stealth CME" has become a commonly used term in recent studies of solar activity. It refers to a coronal mass ejection (CME) with no apparent solar surface association, and therefore has no easily identifiable signature to locate the region on the Sun from which the CME erupted. We review the literature and express caution in categorising CMEs in this way. CMEs were discovered some 40 years ago and there have been numerous statistical studies of associations with phenomena in the solar atmosphere which clearly identify a range of associations, from bright flares and large prominence eruptions to small flares, and even a lack of flares or any identifiable surface activity at all. In this sense the stealth CME concept is not new. One major question relates to whether the range of associations reveal different CME classes, *i.e.* different CME launch processes, or are indicative of a spectrum of coronal responses to one common process. We favour the latter and stress that this spectrum must be considered in the description of the CME launch, meaning that the physics of a so-called stealth CME must not be fundamentally different from a CME associated with major surface events. On the other hand we also stress that the use of a stealth CME category implies that all surface activity could indeed be detected using modern instrumentation. We argue that this may not be the case, and that even in the SDO era of full-Sun, high resolution imaging, we are restricted by instrument sensitivity and bandwidth issues. Thus, having reviewed the case for stealth CMEs as a distinct category, we stress the need to keep the concept in perspective.

Keywords Corona · Coronal mass ejection · Solar physics history

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1. Introduction

An apparently newly recognised category of coronal mass ejection (CME) has begun making its appearance in a number of recent publications. The definition of this category is somewhat vague and varied between publications, but the commonly used term is the "stealth CME". In general, it appears to refer to a type of CME that does not have an easily identifiable solar surface association. In particular, recent observations utilising the stereoscopic viewpoints of the NASA STEREO spacecraft (Kaiser *et al.*, 2008) allow triangulation methods using coronagraphs to estimate the location of CMEs, thus providing more solid evidence to determine the 'front-side' or 'back-side' source of a CME. The two STEREO spacecraft, combined with other near-Earth solar imaging spacecraft (such as SDO and SOHO), currently allow us to image the entire solar globe. Thus, in principle, the source regions of all CMEs ought to be imaged and identified at all times. Given that observational capability, it is argued that we can now clearly reveal a class of CME that is front-sided and still cannot be associated with an eruptive or kinematic feature on the Sun. Studies of stealth CMEs have been conducted since the original paper by Robbrecht, Patsourakos, and Vourlidas (2009) (though they did not coin the phrase, instead referring to "problem CMEs"), including Ma *et al.* (2010) and Vourlidas *et al.* (2011), and the term has begun to appear in other publications (*e.g.* Wang *et al.*, 2011) and online CME catalogues (see *e.g.* http://umbra.nascom.nasa.gov/lasco/observations/halo/soho-haloalerts/halo-message.20110303).

It is the purpose of this paper to put the stealth CME idea into perspective; not to criticise the 'discovery' but rather to assess the nature of these events in the larger CME picture and to explore the statement that there is no physical, rather than observed, surface signature. We argue that the classification is an observational one only, and has little or no bearing on the underlying physics describing the behaviour of this phenomenon.

Indeed, the concept of a CME with no solar surface counterpart is not new. There are a number of reported observations of CMEs with no surface activity dating back to the early CME observations of the 1970s and 1980s, and such events have been described in the models of the time. Plunkett *et al.* (2002) make the statement that "Some CMEs have no EUV (extreme UV) signature, even when there is good reason to believe the source region is on the visible side of the solar disk, and other EUV signatures do not correspond well with white-light CMEs", based on observations from the SOHO spacecraft from the 1990s.

We explore these observations and reports, but the issue at hand is clear. We find evidence for CMEs associated with dramatic surface events in the form of flares and prominence eruptions at one extreme, and we witness CMEs associated with weak coronal activity towards the other. Our premiss is that the 'stealth' CME is nothing more than one end of this activity spectrum. We argue that there is a great danger in categorising the events as though they are fundamentally different from other CMEs, as this implies that the physics of the stealth CME eruption is different from other CMEs. In reality we are most likely simply looking at a spectrum of events physically defined by the magnetic complexity of the source region, the available energy, and the nature of its early development. In simple-minded terms, a complex source region is more likely to exhibit clear surface activity and a simpler configuration is more likely to display weaker activity. Indeed, this picture is precisely the view discussed by Harrison (1991). To further illustrate this point, we also briefly discuss a class of CME that is so weak it is not even observable in a coronagraph. The eruption process itself need not be, and probably is not, manifestly different for a stealth CME than for other CMEs.

Furthermore, we feel that the stealth CME category carries the implication that we are fully equipped to identify any associated surface activity. From past observations we know that there is a large range of active phenomena associated with CMEs, from the weakest brightening to the largest prominence eruptions and brightest flares. However, to categorise a class of CME with no surface activity suggests that i) the limitations of our instrument sensitivities are not inhibiting our ability to identify relevant activity, and ii) we have all of the observational tools that we require to observe all transient phenomena at the Sun. The first point is illustrated by the fact that even in the 1980's there were many CME onsets associated with extremely weak X-ray events, which were subflare in nature (*e.g.* Hildner *et al.*, 1986; Harrison *et al.*, 1990). However, the second point can be well illustrated by spectroscopic observations of coronal dimming. Whilst we observe coronal dimming using EUV instrumentation, and such events are well associated with CME onsets (Harrison *et al.*, 2003; Howard and Harrison, 2004), our prime tools are the EUV imagers such as those aboard SOHO (EIT, Delaboudinière *et al.*, 1995), STEREO (EUVI, Howard *et al.*, 2008) and SDO (AIA, Lemen *et al.*, 2012). Such devices are effectively broadband EUV imagers in the sense that their observations are made using wavelength bandwidths that are wide compared to the solar emission line widths, and they are necessarily restricted to a pre-selected set of emission line or wavelength bands. Such instruments have observed many dimming events and the associations with CMEs are well documented. However, a few coronal dimming papers have utilised spectroscopic observations (Harrison and Lyons, 2000; Harrison *et al.*, 2003; Howard and Harrison, 2004; Bewsher, Harrison, and Brown, 2008), *i.e.* examining a range of specific emission line intensities relating to specific plasma temperatures in the CME source regions. Bewsher, Harrison, and Brown (2008) demonstrate that different dimming events can be revealed at different temperatures so it is conceivable that the EUV imager instruments, with limited pre-set wavelength bands could miss some events that are not well suited to their range of sensitivity. In other words, we would not see a dimming event because the instrument is not sensitive to the temperature at which the dimming plasma is being evacuated. In this way, some CMEs will not have clear associated surface phenomena, but this does not mean that those phenomena are non-existent.

Our message in this paper is therefore one of caution: in reviewing the stealth CME phenomenon, mainly to avoid the implications of different physical processes to 'regular' CMEs; and to recognise that the instrumental limitations must not be overlooked.

2. Stealth CMEs

Robbrecht, Patsourakos, and Vourlidas (2009) describe a slow, accelerating CME, triangulate the likely location of its source to the south-eastern quadrant on the front side of the solar disc relative to the STEREO-B spacecraft, and identify no solar disc feature in this region (observed in EUV and Hα) corresponding to its launch. Closer inspection did reveal some signatures of evolution in the low corona, but nothing particularly noteworthy. Their paper describes a sound study and does present a review of previous work investigating CMEs without a solar disc association, albeit only referring to relatively recent publications.

This work was followed by a number of papers. Ma *et al.* (2010) make the statement that "before the launch of the STEREO spacecraft, it was generally accepted that a CME must be associated with at least one kind of low coronal signature (LCS)". Wang *et al.* (2011) state that the stealth CME concept has only recently been proposed. It is the opinion of the authors that the former statement is in error and the latter might be true in the sense that the term 'stealth CME' is new, but such events have been recognised for a very long time. The availability of X-ray disc imaging and coronagraph observations from the same platform, namely the NASA *Solar Maximum Mission*, was utilised by the so-called Coronal Mass

Ejection Onset campaign which was run in the mid-1980s. In various reports of that work, (*e.g.* Harrison *et al.*, 1990), it was clear that one regularly observed CME onsets associated with minor coronal signatures or, in some cases, no identifiable X-ray eruption at all.

Ma *et al.* (2010) classify a stealth CME as one without an LCS, where an LCS is defined as a filament eruption, flare, post-eruptive arcade, coronal wave, coronal dimming, or jet (these and other phenomena known to be associated with CMEs are reviewed by Howard (2011)). Their study of 11 such events found them to be slow ($< 300\ \mathrm{km\,s^{-1}}$) without any obvious difference to other slow CMEs with LCSs. Vourlidas *et al.* (2011), provide a different definition of a stealth CME as one with a weak coronal signature although their single event was associated with a filament in EUV data. Wang *et al.* (2011) describe "a kind of CME that does not leave any eruptive signatures in EUV pass-bands and sometimes may not even be visible in coronagraphs facing on them". We take the final portion of that sentence to mean that in some cases we cannot even identify a halo (Earth-directed) CME, though it could be detected from other sites (away from the Sun–Earth line). There is no reference in these papers to radio observations. In any case, the spread of definitions is confusing and, on the face of it, appears to be a weak basis for the identification of a new, major category of a solar phenomenon.

3. Historical Observations

The CME discovery paper is one from the 1972 COSPAR Proceedings by Tousey (1973). He describes an outward-moving cloud observed by the OSO-7 coronagraph accompanied by a prominence eruption. Another perhaps lesser-known paper published in the same year involves ground-based coronagraph data of "green line transients" or "coronal transients" observed from 1956 to 1972. DeMastus, Wagner, and Robinson (1973) attempted to find an Hα counterpart for their observed transients and were unable to do so for seven of their 30 events. They attribute the absence of activity to occurrence on the far side of the solar disk, but note that for a number of events where there was associated Hα activity it was very minor.

Similar observations were made using the Skylab coronagraph which was the first instrument to provide regular observations of CMEs. Gosling *et al.* (1976) recorded speeds of 38 "coronal mass ejections" (this is the first publication that used that term to describe white-light coronal transients) and categorised them into those events that are associated with Hα flares and those with eruptive prominences. While they were not discussed in the paper, 11 of these events were not associated with either flares or prominences. This was a follow-on study from even earlier work by Gosling *et al.* (1974), who noted 30 mass ejections observed by Skylab and found nine events that were not associated with a filament eruption or flare. Munro *et al.* (1979) reported on a total of 77 "mass ejection coronal transients" during 227 days of Skylab observations. They associated Hα and X-ray solar phenomena with these transients and found that 43 of them had no solar surface association. Like DeMastus, Wagner, and Robinson (1973) they attribute the absence of activity to events occurring from behind the solar limb, but unlike DeMastus, Wagner, and Robinson and Gosling *et al.* the number of events with an absence of solar activity was greater than the statistical expectation of 38 (50 %) of the transients. This is the first paper that calls out as noteworthy the fact that more than half of the observed CMEs did not have a solar surface association.

It is important for the reader to keep in mind that until the SOHO era, Earth-directed CMEs (the so-called halo CMEs) were almost never observed. For example, only 20 halos out of 998 CMEs were identified using Solwind observations from 1979 to 1981 (Howard

Table 1 Percentage of 65 geomagnetic storms related to solar sources and *vice versa* (reproduced from Joselyn and McIntosh, 1981)

Event	Storms related to source (%)	Sources related to storms (%)
M or X class X-ray flares	40	7
X class flares	17	30
Coronal holes	52	15
Disappearing filaments	65	23
Unknown	8	–

et al., 1985). However, solar surface associations for Earth-directed CMEs could still be broadly sought by investigating their geoeffectiveness. Such an attempt was made by Joselyn and McIntosh (1981), who sought solar surface signatures of 65 geomagnetic storms during the rising phase of Solar Cycle 21 (June 1976 to June 1979). They examined Hα, X-ray and radio solar observations along with He 10830 Å coronal hole maps (in order to accommodate for the geoeffectiveness of solar wind streams such as corotating interaction regions). They identified five (8 %) geomagnetic storms that could not be associated with solar surface activity. They list them as "Unknown" in their Table 1 (reproduced in Table 1), and comment that four of the five may have arisen from an active region beyond the western solar limb. They did not provide an explanation of the remaining event.

By early 1980 the coronagraphs on board OSO-7 and Skylab had been replaced by Solwind and the SMM C/P coronagraphs. A statistical survey of SMM observations by Webb and Hundhausen (1987) compared early results of CME solar associations with the Skylab results of Munro *et al.* (1979). They compared soft X-ray, Hα and radio burst observations with 58 SMM-observed CMEs and found 30 events without an X-ray flare or erupting filament. This is a ratio of slightly over 50 % and they were explained as being back-sided events.

The 1980s also witnessed detailed studies of coronagraph and X-ray flare features that made a major contribution to the solar flare myth debate (*e.g.* Harrison and Simnett, 1984; Harrison *et al.*, 1985, 1990; Sime and Hundhausen, 1987; Simnett and Harrison, 1984, 1985; Hundhausen, 1999). Most of these studies focused only on the flare aspect, and some found CMEs without a flare counterpart. One report, however, expanded the study to include all observable features. In their short list of 11 CMEs, Simnett and Harrison (1985) identified one that was associated with a Type III radio burst (suggesting that a solar eruption may have occurred on the near-side of the Sun) that could not be associated with an X-ray or Hα flare, or a filament or prominence.

By the SOHO and STEREO era in the 1990s and 2000s, papers were discussing CMEs without a solar surface association as though they were commonplace (as indeed they were). Along with those modelling onset mechanisms (*e.g.* Low, 1994; Forbes *et al.*, 2006), observational results include Plunkett *et al.* (2002) who made the comment quoted in Section 1; Howard and Tappin (2005a) who surveyed 938 foreshock-producing (*i.e.* Earth-directed) halo CMEs observed by SOHO/LASCO, and found that 260 did not have an X-ray flare of class C or higher; and Howard, Nandy, and Koepke (2008) who examined the catalog of 10512 CMEs from 1996 – 2005, and found only 1961 events that could be associated with an X-ray or Hα flare or disappearing Hα filament. One particular Earth-directed event, the first involving SOHO data to become a major ISTP collaborative study (Webb *et al.*, 1998), had a very weak coronal signature provoking the comment that "[t]he associated solar surface activity was so weak and unimpressive that, had the CME not been observed, the [geomagnetic] storm would not have been forecast." Finally, some CMEs observed in the early years of STEREO, such as the three in mid-November 2007 (Howard and Tappin, 2008, 2009) or the one in mid-December 2008 (Davis *et al.*, 2009; Lugaz, 2010; Liu *et al.*, 2010; Byrne *et al.*, 2010; Howard and DeForest, 2012) did not have a solar surface association. In their paper on triangulation of two CMEs using STEREO, Howard and Tappin (2008) make the comment that "These events were chosen because there is no significant solar surface activity of any kind associated with these events, and so this triangulation method is the only way in which the direction of these CMEs could be even estimated."

4. Onset Signatures

When one identifies associations between CMEs and flare events or prominence eruptions, the occurrence of such an event is clear. Studies such as those described for the CME Onset Campaign were tuned to the identification of bright flares through to weak X-ray signatures. Weak X-ray brightenings were identified and, in some cases, no associations were found. Given such a spectrum of associations one must always be aware that a null association may be a function of instrument sensitivity rather than a physical absence of such activity.

However, this issue is not just one of sensitivity in intensity where we may simply miss faint events. We must also take into account the wavelength sensitivity of the associated activity, and this is particularly so for so-called coronal dimming. Here we expand our discussion of that particular phenomenon because of its clear association with CME onsets and because of the weakness of the relative intensities involved.

There is no strict definition of coronal dimming, though it has become a well established and frequently reported phenomenon in solar physics. Most workers think of coronal dimming as an EUV or X-ray intensity depletion of a large region of the corona (although it has been observed in Hα (Jiang *et al.*, 2003; McIntosh *et al.*, 2007)), but there are no generally accepted parameters for the degree of depletion, the size of the area showing the intensity depletion, or the EUV/X-ray wavelengths displaying depletion. Howard and Harrison (2004) reviewed dimming observations, which date back to the mid-1970s and in particular discussed observations utilising the SOHO observatory in the late 1990s. It is beyond the scope of this paper to discuss the details of the observations, but it is important to stress that most observations have been made using EUV and X-ray imaging instruments. Spectral studies of dimming have been essential to provide plasma diagnostic information of dimming regions (see *e.g.* Harrison *et al.*, 2003; Howard and Harrison, 2004) and such studies are few and far between.

In a large spectroscopic study of CME-associated dimming, Bewsher, Harrison, and Brown (2008) identified 155 dimming events in the spectral line Mg IX at 368 Å, which is emitted by an ion whose abundance peaks at 1×10^6 K. They also identified 146 dimming events in the spectral line Fe XVI at 360 Å, which is emitted at 2×10^6 K. In only 96 cases was the dimming registered in both emission lines. Figure 1 shows the results from one dimming event reported by Harrison (2006), which was observed in the Mg IX 368 Å emission line but was much more prevalent in the Fe XVI line at 360 Å. These results demonstrate that dimming, which is a largely a coronal phenomenon, may have different signatures at different temperatures. Therefore it is highly likely that an imager tuned to a specific temperature may miss a dimming event whose prime signature is at a different temperature. Even a multi-band imager system may have sufficient insensitivity at certain temperatures to allow dimming events to be missed. The point of relevance to this paper is clear: we most likely do not have the tools to categorically state that there was no coronal signature; we can only state that we did not observe one.

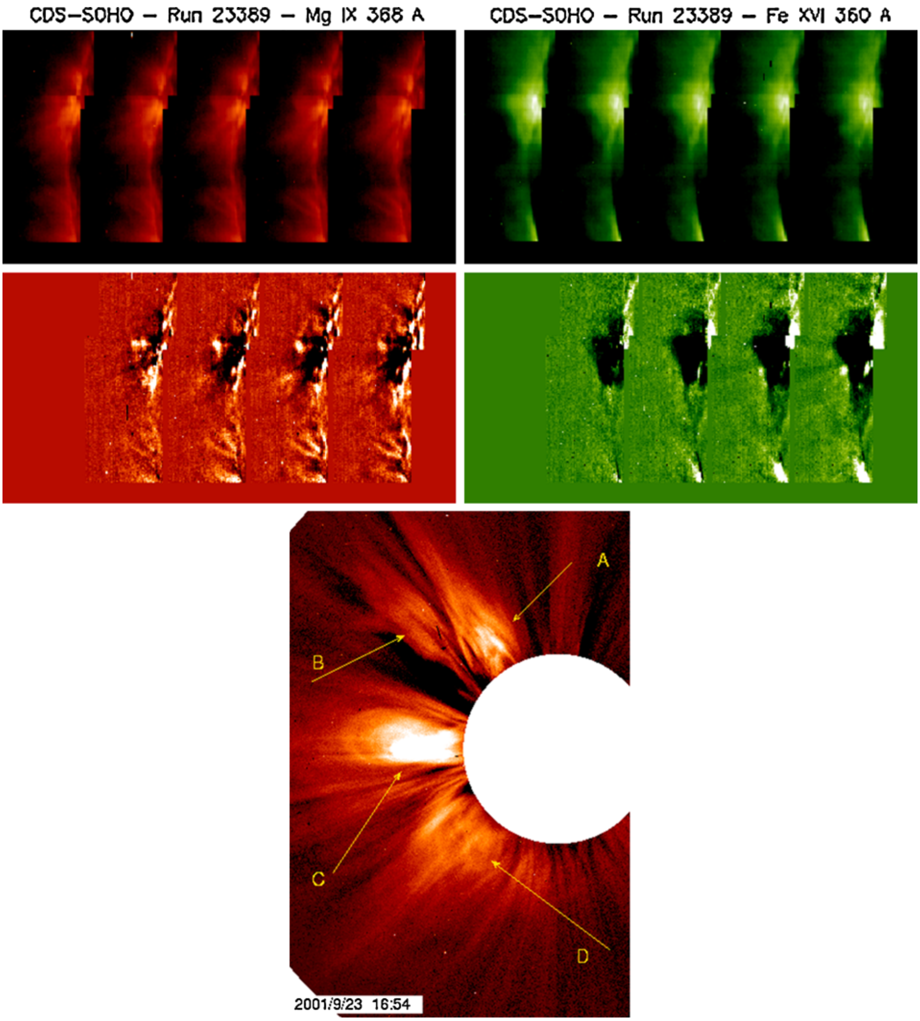


Figure 1 The CME events of 23 September 2001 imaged by SOHO/LASCO (bottom panel) and the SOHO/CDS (top left and right panels). The LASCO frame shows the principal CME, identified as "C", with associated coronal features (labelled A, B and D). The CDS instrument was scanning a 4×4 arcminute region on the eastern solar limb, recording a range of emission lines. Data from the two lines are shown: namely the Mg IX line at 368 Å (left panel), characteristic of a 1×10^6 K plasma; and the Fe XVI line at 360 Å (middle panel), at 2×10^6 K. Significant dimming was observed in both lines, although it is much more evident at 2×10^6 K in this case. For each of the Mg IX and Fe XVI displays we show five of the limb images in raw line intensity (top), recorded at 12:13, 13:03, 13:53, 14:43 and 15:33 UT, respectively, and the difference images (bottom) with the first image subtracted from those following. This is shown for both emission lines at the same times, and the difference images reveal the dimming. Images are modified from Harrison (2006).

This argument applies to the observation of weak EUV or X-ray bursts, or subflare brightening which seem to be associated with CMEs, or for prominence eruptions that are on the threshold of detection. All of these suggest that we are required to consider CME onset models that can cater for the full range of event associations, but we must take care not to call upon these apparent weak or non-event associations to define a distinct new class of CME.

Further to the limitations of the observational spectrum, it is known that CMEs themselves can erupt with an invisible or almost invisible signature in coronagraphs as well. Given that CMEs are primarily magnetic field eruptions it is conceivable that some eruptions may take place without containing sufficient excess plasma to be observed by coronagraphs. The reader is reminded that a coronagraph simply detects photospheric light that has been Thomson scattered off free electrons in the corona, and it is the concentrations (larger densities) that are detected due to enhancements trapped in the magnetic structures. However, weaker events (those of lower density) will be more difficult to identify even though the underlying physics driving their magnetic fields may be identical to those of regular CMEs. These "Erupting Magnetic Structures" are invisible to coronagraphs, but have signatures of foreshocks observed *in situ* (Howard and Tappin, 2005b), or are manifest in heliospheric imager datasets (Simnett, 2005; Howard and Simnett, 2008), which are wide-angle imaging systems viewing the heliosphere over large elongations from the Sun.

5. Speed Distribution

As shown in the results of Ma *et al.* (2010), stealth CMEs are generally very slow, *i.e.* have a relatively low kinetic energy. Attempts have been made to describe the onset and evolution of CMEs since they were first identified as separate phenomena in their own right (and not blast waves from solar flares). This realisation was made very early on by some workers (*e.g.* Gosling *et al.*, 1974). CMEs have always been categorised as fast or slow but it is generally believed that the physics responsible for each category is largely the same. The physical description is well established, as we explore in the next section. This section discusses observation of the distribution of CME speeds, and establishes that this is a continuum rather than groups of separate classes.

Figure 2 shows speeds measured for 38 CMEs observed by Skylab (Gosling *et al.*, 1976). The top panel shows the distribution of the events, showing a continuum for all speeds and a larger number of slower CMEs. Gosling *et al.* primarily associated the slow CMEs with eruptive prominences and the faster events with flares and Type II and IV radio bursts. They then make the cases that flares and eruptive filaments are different physical phenomena, and that the fast CMEs are responsible for the Type II and IV bursts. The physics of these cases are now well understood.

CME distribution with speed was investigated in greater detail by, amongst others, Yashiro *et al.* (2004) (shown in Figure 3). We show results from near solar minimum (1996, 1997, and 1998), which corresponds to the near-minimum measurements of Gosling *et al.* (1976). Note that Gosling *et al.* used observations from the declining phase of Solar Cycle 20 while the observations of Yashiro *et al.* were from the rising phase of Cycle 23. As with the results of Gosling *et al.*, Yashiro *et al.* show a continuum of CMEs across the range of speeds, with a large majority being slower CMEs.

The continuum of CME activity across the range of speeds implies that there is no physical distinction between slower and faster CMEs. The occurrence of slower CMEs is much more common, and the vast majority are not associated with solar flares or erupting filaments (Howard, Nandy, and Koepke, 2008).

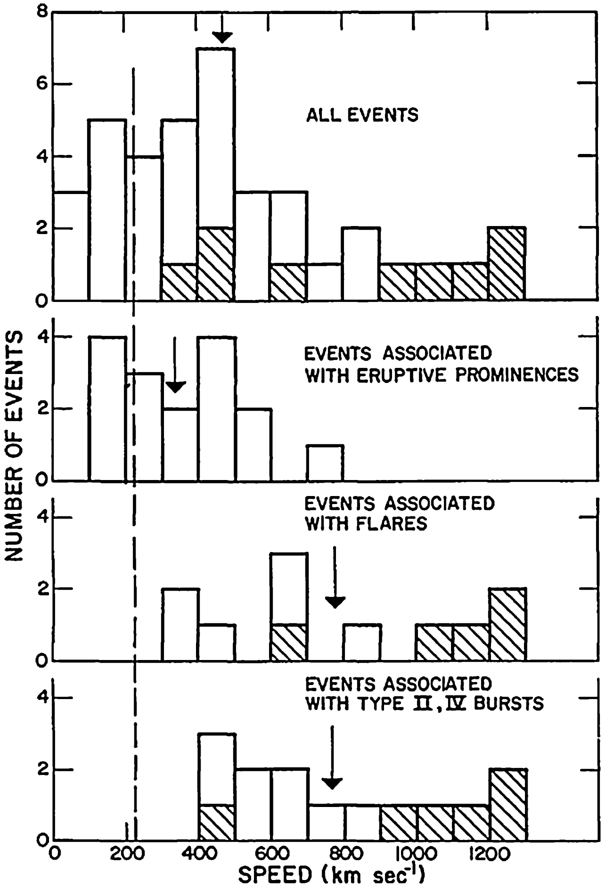


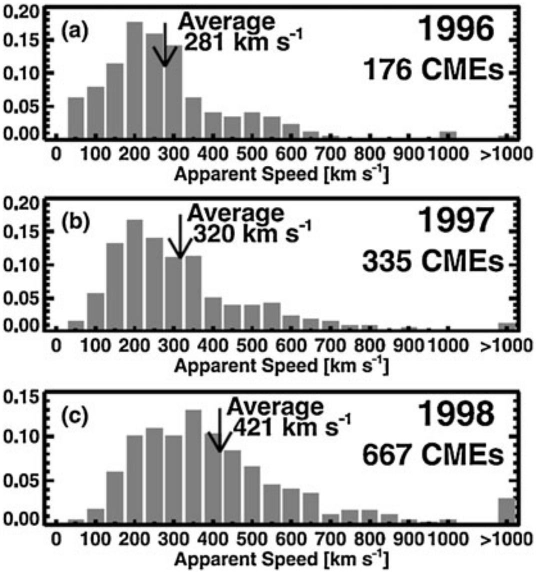
Figure 2 Distribution of measured Skylab CME speeds and their associations with Hα flares and filaments, and Types II and IV radio bursts. The arrows indicate the average speed in each case and the vertical dashed line is the gravitational escape velocity for material at 6 $R_\odot$ from the Sun. Those with a hatched pattern are those when the assigned speed is only a lower limit estimate (*i.e.* those speeds could be greater). Reproduced from Gosling *et al.* (1976) (their Figure 2).

6. Physical Description

Given that stealth CMEs are likely to be at the low end of the kinetic energy spectrum, and given also that CMEs derive their energy from the onset mechanism and the surrounding solar wind and coronal fields, it seems reasonable to deduce that slow CMEs arise from an environment that does not provide great amounts of energy. We can further deduce that the lack of associated activity at the Sun also arises from the sparsity of available energy from the same environment. In this section we discuss what these observations reveal to us about the physics involved.

Contemporary workers developing theoretical descriptions of CME onset and evolution have focused primarily on the faster energetic CME range. This is partly because energetic CMEs are of greater interest to the scientific, technological and public communities, and partly because they are a more interesting physical problem (how do you provide such vast quantities of energy over such a short time frame, and how do you accommodate for field line stretching during CME eruption?). However, the physics describing the eruption of fast CMEs can describe equally well the eruption of slower CMEs, where the slower eruptions arise from a less complex magnetic configuration, the available energy is small, and/or the quantity of accumulated material prior to the eruption is also small. Since the same physical

Figure 3 Statistical results for three years of SOHO/LASCO observations of CMEs. We have chosen three panels from Figure 5 of Yashiro *et al.* (2004) that correspond to the near-solar-minimum measurements of Gosling *et al.* (1976).



mechanism can be used to describe fast and slow CMEs, there is no requirement for different mechanisms for each.

While specific CME launch models vary in their details, a general physical picture emerges of a gradual build-up of coronal material within a magnetic configuration comprising of closed loop structures extending up to the mid-corona (from around $1.2-3.0\ R_{\odot}$). A new or existing magnetic structure emerges from the lower solar atmosphere beneath this magnetic structure and expands outwards, destabilising the equilibrium held between the restraining tension on the closed loops and the expansion of the corona. The loops are therefore free to expand into the corona deriving their kinetic energy from the solar wind, from the tension release and, according to some models, from magnetic reconnection with the overlying restraining (*i.e.* strapping) field. This process can be sudden, over the course of hours, or gradual, lasting over a day. The nature of the eruption therefore is entirely dependent on the amount of energy available to the erupting structure from the three sources. The result is a continuum of available energies and therefore of CMEs, ranging from the very fast arising from a highly complex pre-launch field and high interaction with the strapping field; to the very slow, arising from a simpler field configuration and a "more casual" drifting into the solar wind. Towards the innermost extreme, as stated in the CME model review paper by Forbes *et al.* (2006), "The possibility also remains that very slow ($<150\ \mathrm{km\,s^{-1}}$) CMEs which undergo weak acceleration over a period lasting as long as a day… may not involve a release of stored magnetic energy at all." The initial ejection process responsible for this entire range of associated observations, however, was ultimately the same process.

7. Conclusions

The purpose of this paper is to put into perspective the classification of the stealth CME. Our argument is that the classification is an observational one only (*i.e.* has no physical basis), and is limited by the observational thresholds of the observing instruments. We show that such events have been investigated since CMEs were first discovered and demonstrate, using coronal dimming as an example, how associated phenomena can be rendered invisible simply by observing the Sun with different passbands.

While it is doubtless helpful for observational (and perhaps forecasting) purposes to describe CMEs that are difficult to associate with auxiliary observations, we must be careful not to categorise them as a phenomenon that is physically different from other types of CME. We have presented the case that the stealth CME is a case that is simply towards the lower-energy end of a continuum of CME activity.

Acknowledgements Support for this work is provided in part by the NSF/SHINE Competition, Award 0849916 and the NASA Heliophysics program through grant NNX10AC05G. The authors thank C.E. DeForest for reviewing this work prior to submission.

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