Properties and Initiation Mechanisms for CMEs without distinct coronal signatures

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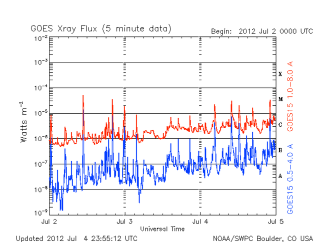
Abstract

We study the properties and initiation mechanisms for CMEs without distinct coronal signatures. Though easily visible in coronagraph observations, these so-called stealth CMEs do not obviously exhibit any of the low-coronal signatures typically associated with solar eruptions (changes in magnetic configuration, flows, solar flares, the formation of post-flare loop arcades, EUV waves, erupting filaments, or coronal dimmings). We focus on what the presence or absence of these signatures can tell us concerning the mechanisms by which these stealth CMEs are initiated and driven.

CMEs without low coronal signatures (LCS) can have important implications on space weather, since many early warning signs for significant space weather activity are not present in these events. A better understanding of their characteristics and initiation mechanism will significantly improve our ability to asses their potential geo-effectiveness.

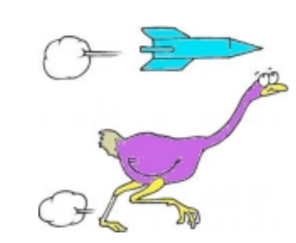
Characteristics of CMEs without low coronal signatures

CACTus LASCO CME Detections →



GOES event lists →

CACTus COR2 A & B CME Detections →



SoFAST Detections (EUV variability) →

Candidate Stealth CMEs

We identified CMEs without LCS from the CACTus LASCO CME detections for 2012 by excluding CMEs associated with flares or other EUV variability, as well as back-sided events. Visual inspection revealed weak coronal signatures for many of the remaining candidate stealth CMEs and allowed to confirm 40 stealth CME detections.

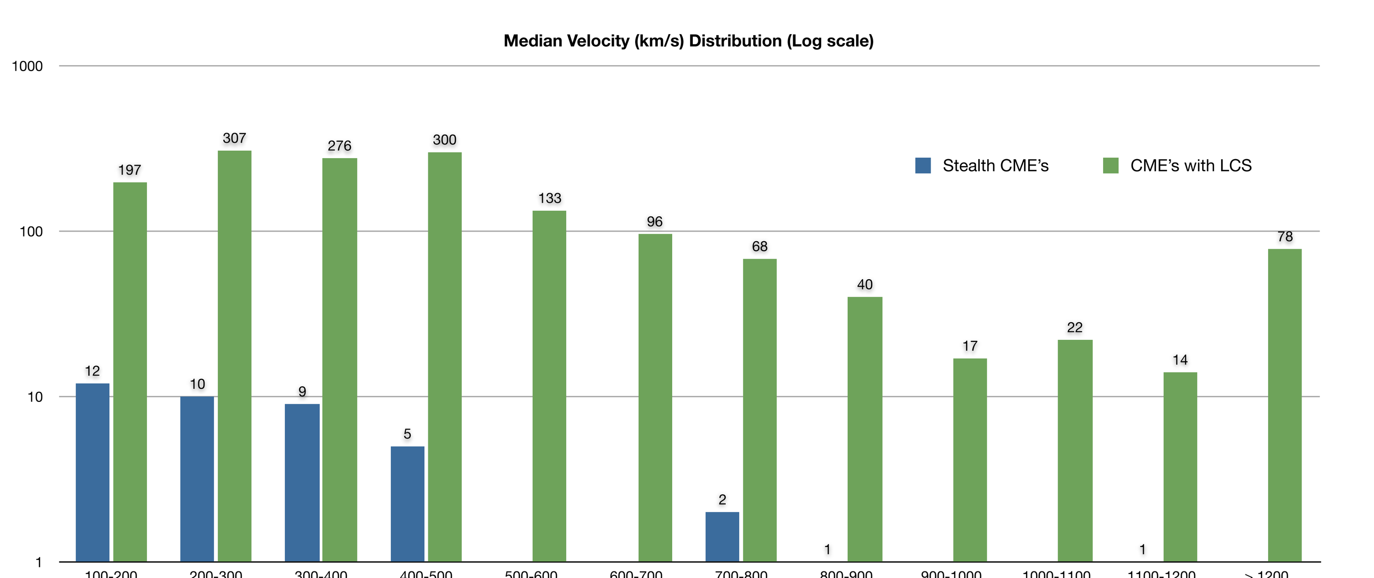


Fig 2. Median velocity distribution for stealth CMEs (blue) compared to CMEs with LCS (green) observed by CACTus in 2012. Stealth CMEs are generally slow events.

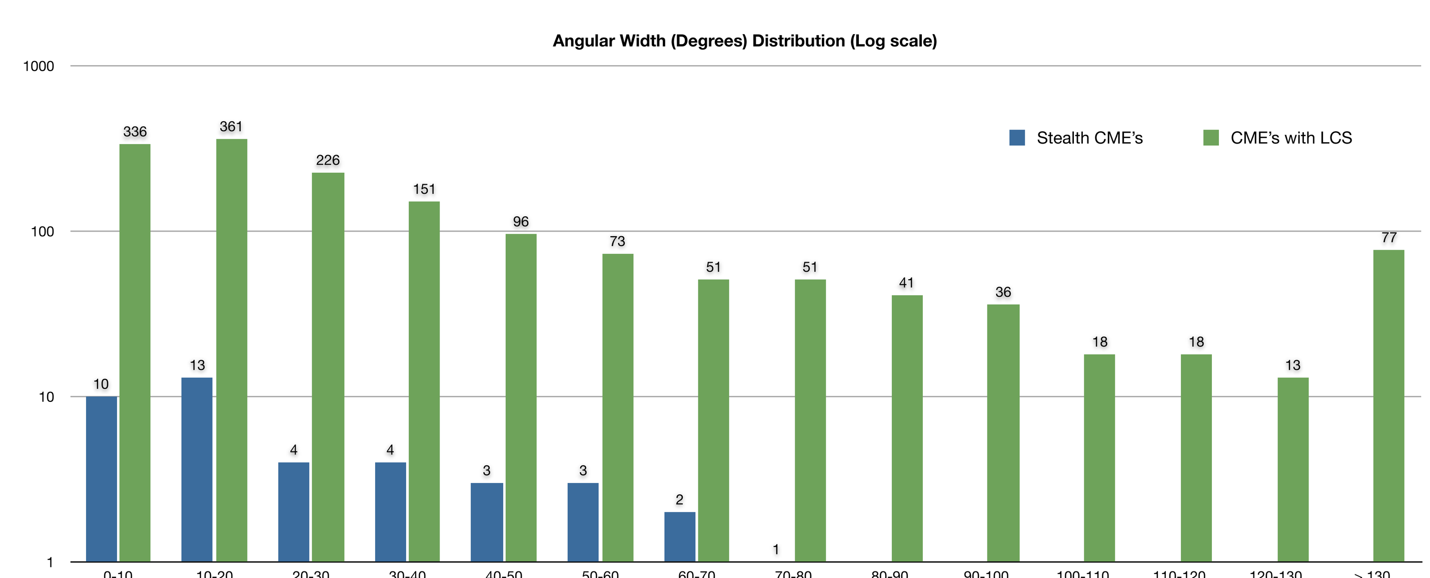


Fig 3. Angular width distribution for stealth CMEs (blue) compared to CMEs with LCS (green) observed by CACTus in 2012. All detected CMEs with a width larger than 80 degrees were associated with low coronal signs of an eruption.

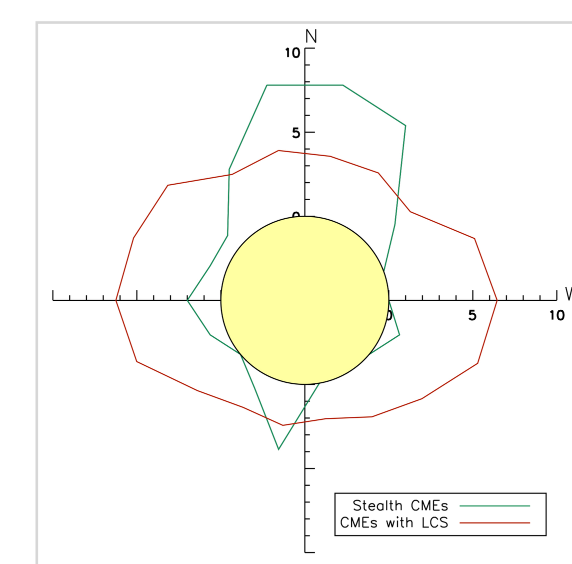
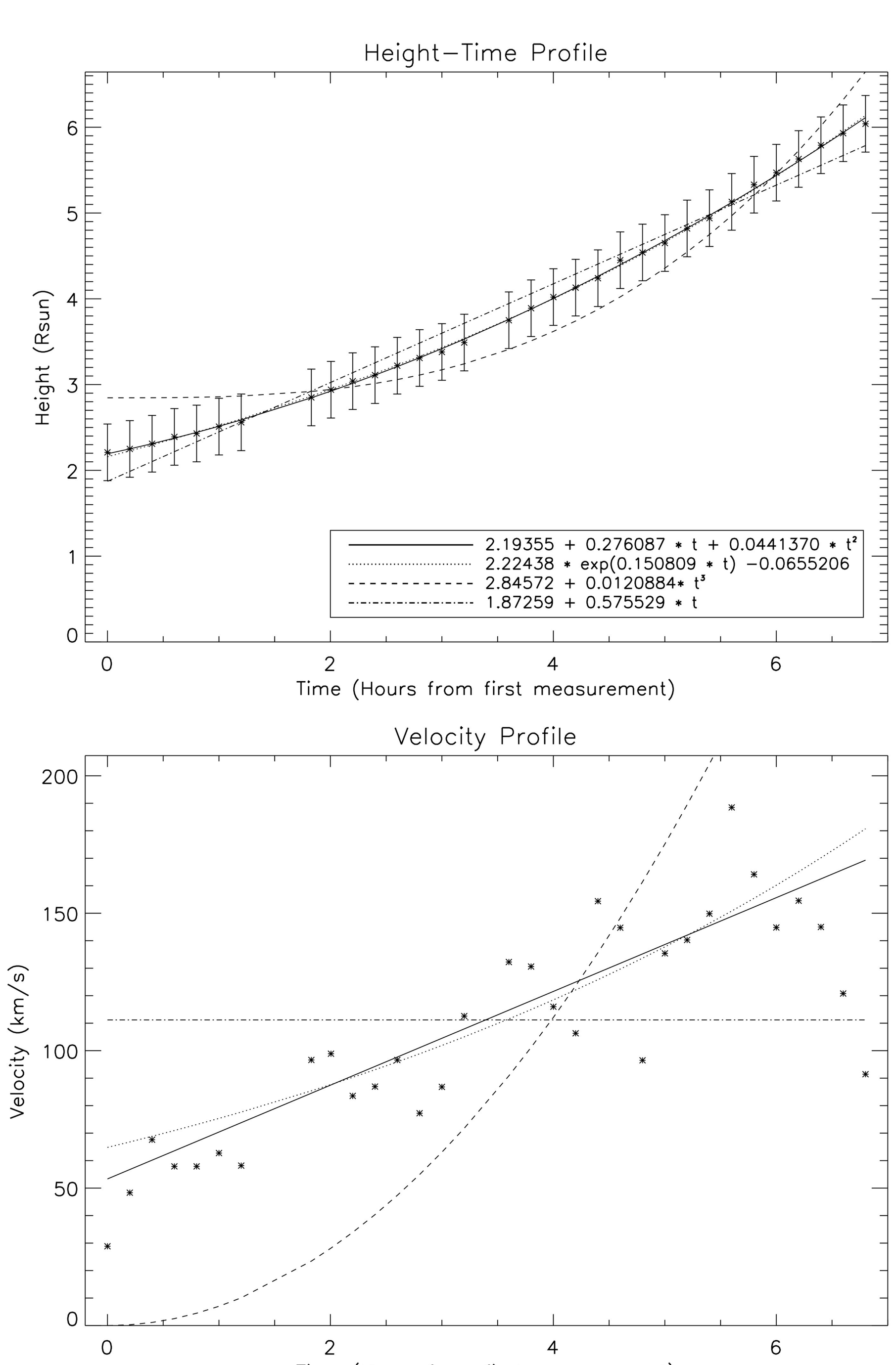


Fig 4. Position Angle distribution for stealth CMEs (green) compared to CMEs with LCS (red, number of occurrences divided by 20). Most stealth CMEs occurred near the north pole. For CMEs with LCS the position angle is more evenly spread across the solar disk.

Kinematics



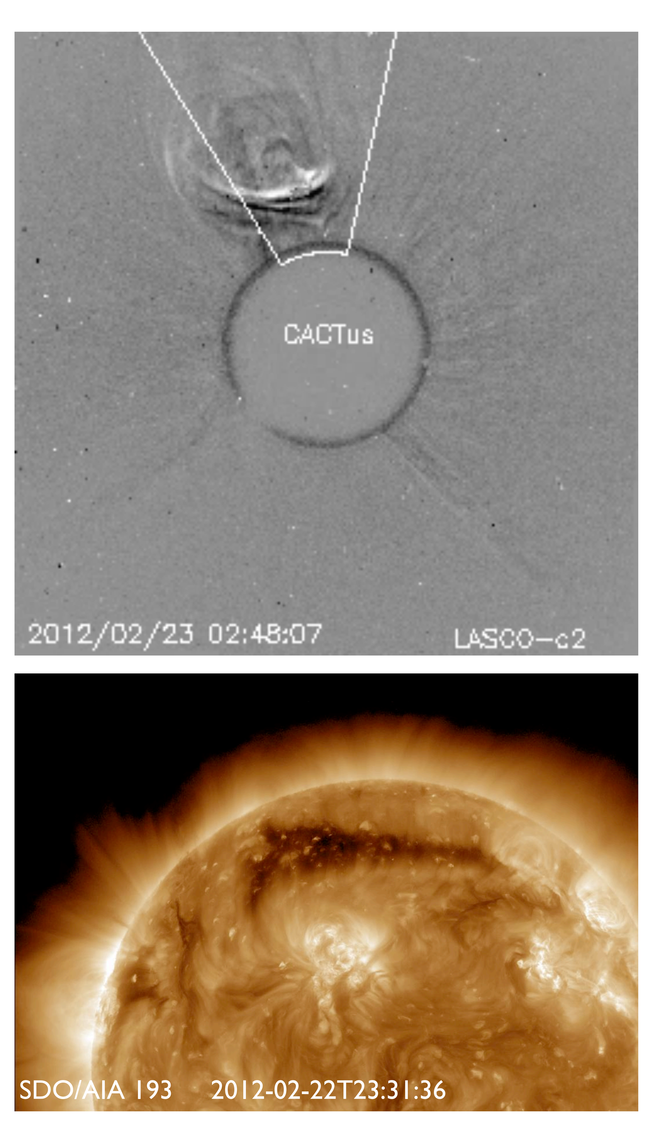


Fig. 5 Right panel: Stealth CME on February 22, 2012 detected by CACTus in LASCO data (top). The SDO/AIA 193 images show no coronal signatures related to this event (bottom). Left panel: Height-time and velocity measurements for this event, fitted with different rise profiles.

We compared the height-time evolution of stealth CMEs to published results for different eruption mechanisms (Schrijver et al., 2008). The best fits to our measurements are exponential and parabolic profiles, corresponding to ideal MHD instabilities and breakout, respectively (Fig. 5). The lack of LCS suggests that these eruptions are not driven by impulsive reconnection near the solar surface, which is consistent with the evidence from our height-time profiles.

Scale Invariance

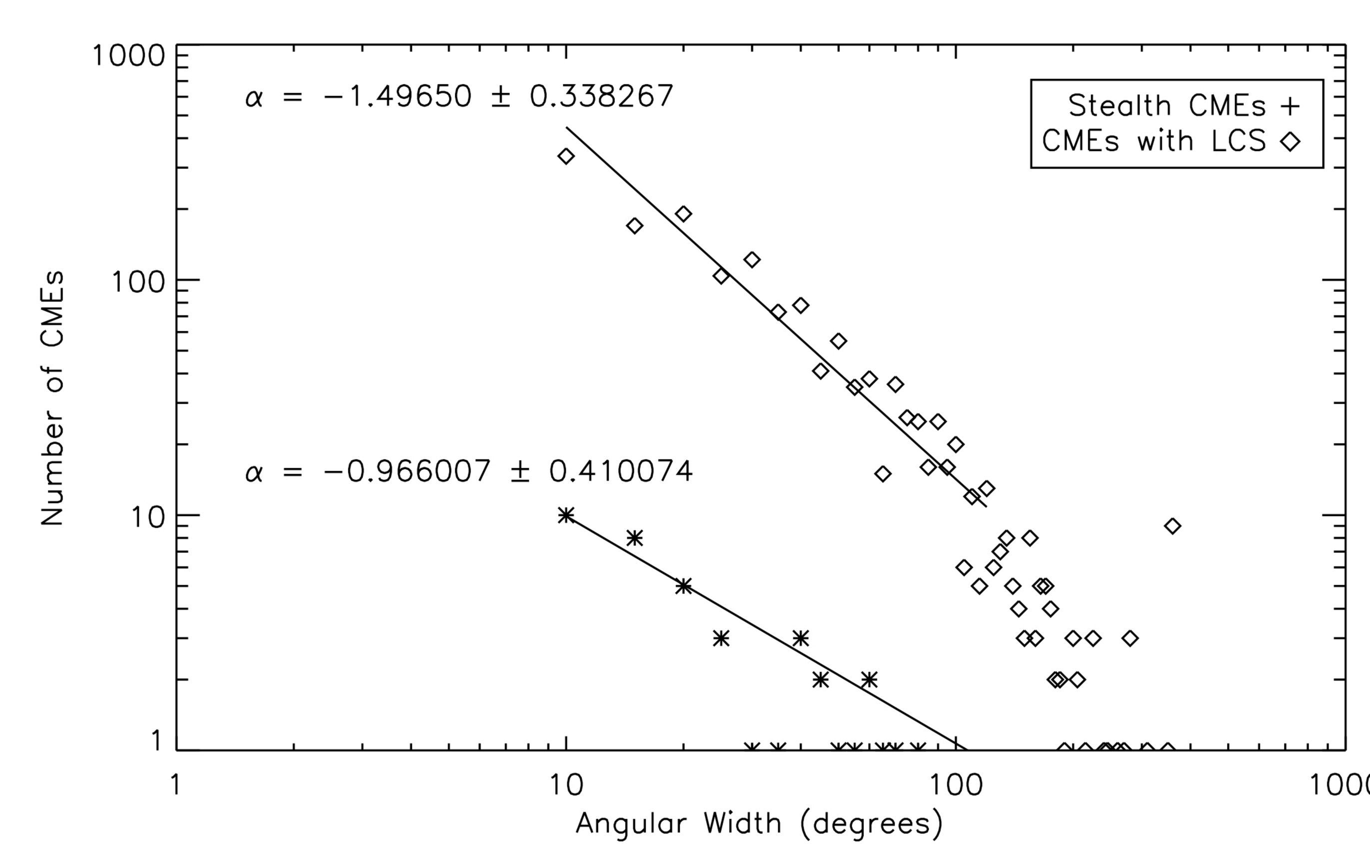


Fig. 6 CME angular width distributions for CMEs with and without low coronal signatures. The linear fits for CME widths, using the values between 5° and 120°, indicate a scale invariance for stealth CMEs and CMEs with LCS, however with a clearly different slope.

We investigated the frequency distributions of CMEs with and without LCS as a function of width. These distributions show a linear behavior over a large range of angular widths, indicating scale invariance (Robbrecht et al., 2009). This implies that there is no typical size for a CME. We find that the distributions for stealth CMEs and CMEs with LCS have a different slope, suggesting a different initiation mechanism may be at work for each class of events.

Conclusions and Outlook

Although CMEs without LCS are rare events (only 40 out of 1596 CACTus detections in 2012 were stealth CMEs), they are important to space weather. The lack of coronal signatures makes them difficult to identify and analyze. Stealth CMEs are generally slow and narrow compared to CMEs with LCS. A majority of the stealth CMEs in our study were observed near the northern pole.

The angular width distributions of CMEs with and without LCS suggest that both classes of events may have a different initiation mechanism. Height-time profiles for stealth CMEs are compatible with models for ideal MHD instabilities and breakout. Through numerical simulations of selected events, we will test if these models can explain the lack of coronal signatures observed with stealth CMEs.