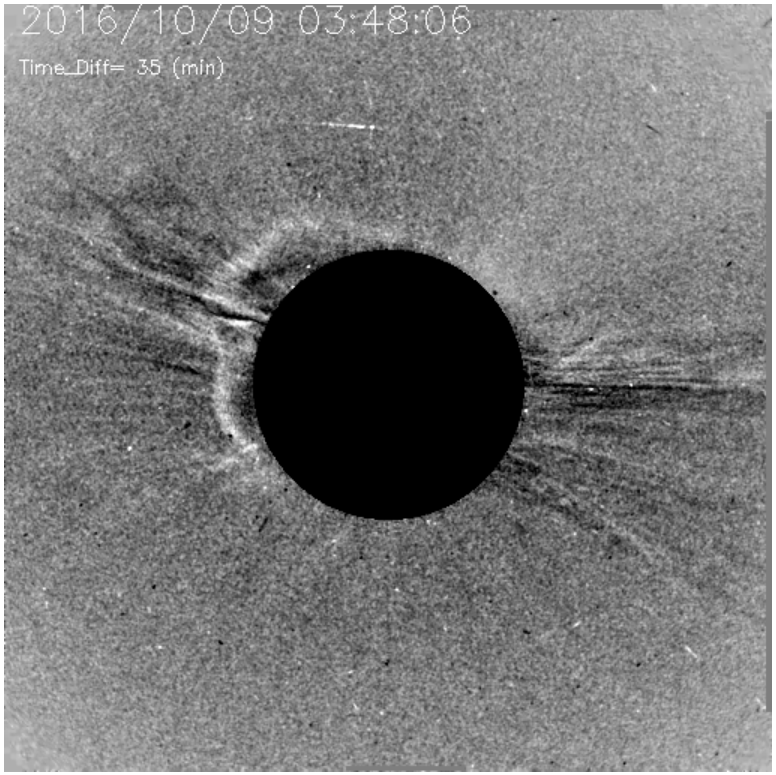
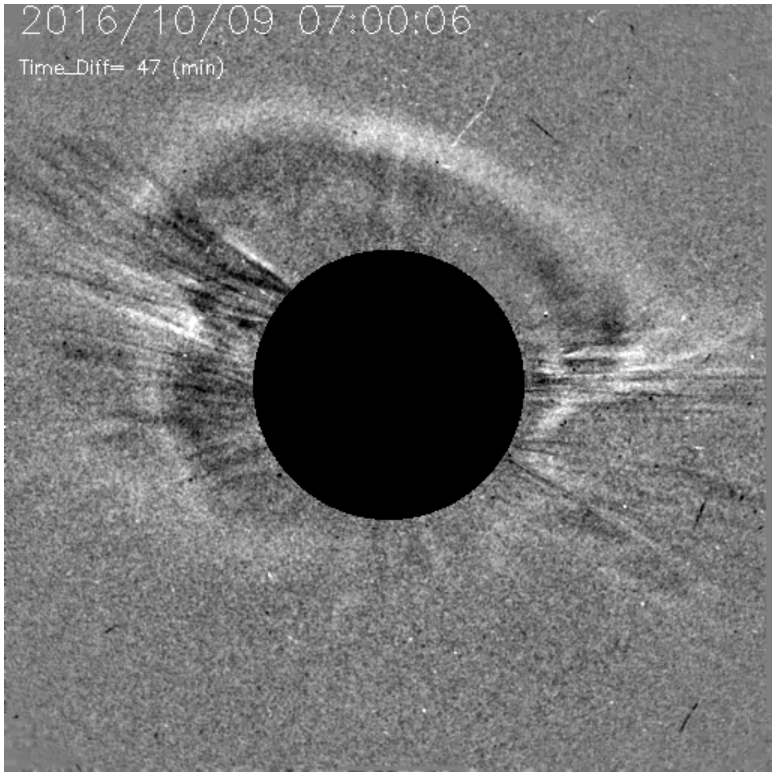
Stealthy but Earth-Affecting CMEs





Nariaki Nitta (LMSAL), Tamitha Mulligan (Aerospace Corporation)

Difficulty of Linking Solar Eruptions and ICMEs at 1 AU

1. A CME occurs and the source region is clearly identified on the front side, but no ICME follows at 1 AU. *The CME does not survive 1 AU? Deflection?*

2. An ICME is observed at 1 AU, but there is no CME near the Sun. *The CME too diffuse? It forms many solar radii away from the Sun?*

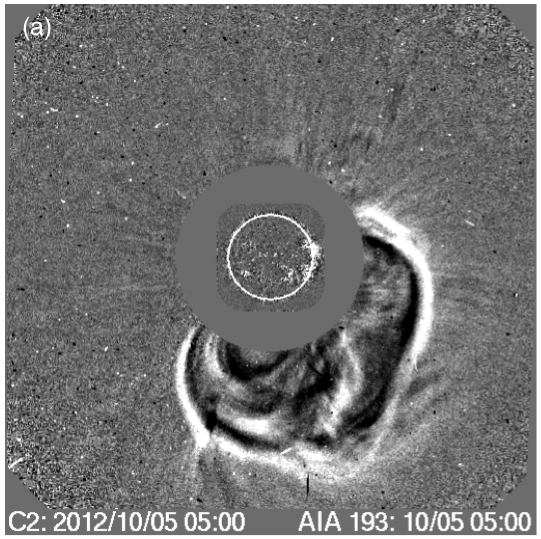
3. Multiple CMEs precede a simple or complex ICME, and it is not clear which CME is (or CMEs are) responsible for the ICME. *One CME or interacting CMEs?*

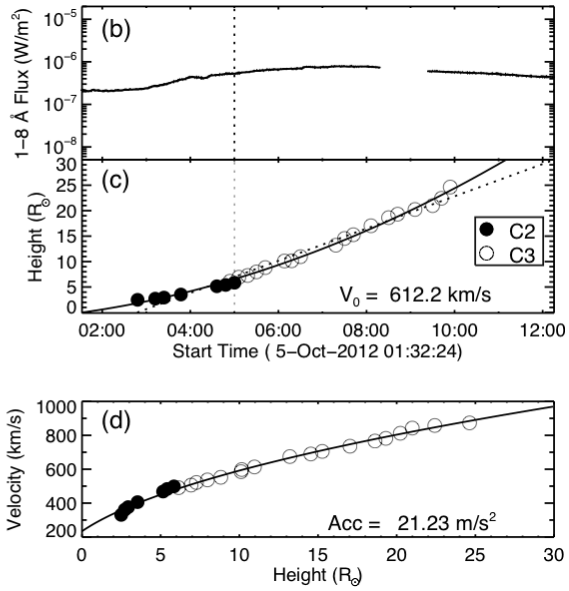
4. The ICME is traced back to a CME, but its low coronal signatures (LCSs) are not found (stealth CME). *Another category not explained by the "standard" model, or reflecting instrumental effects (T.A. Howard & Harrison 2013)?*

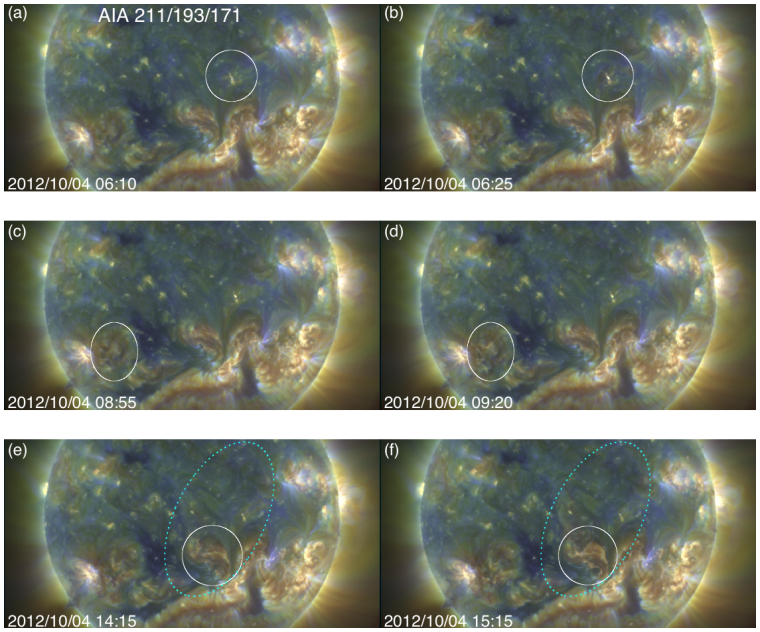
5 October 2012 Event

This was somehow selected as a problem event or even a stealth CME by scientists on VarSITI/ISEST.

Changes were looked for in a 20 hour window.



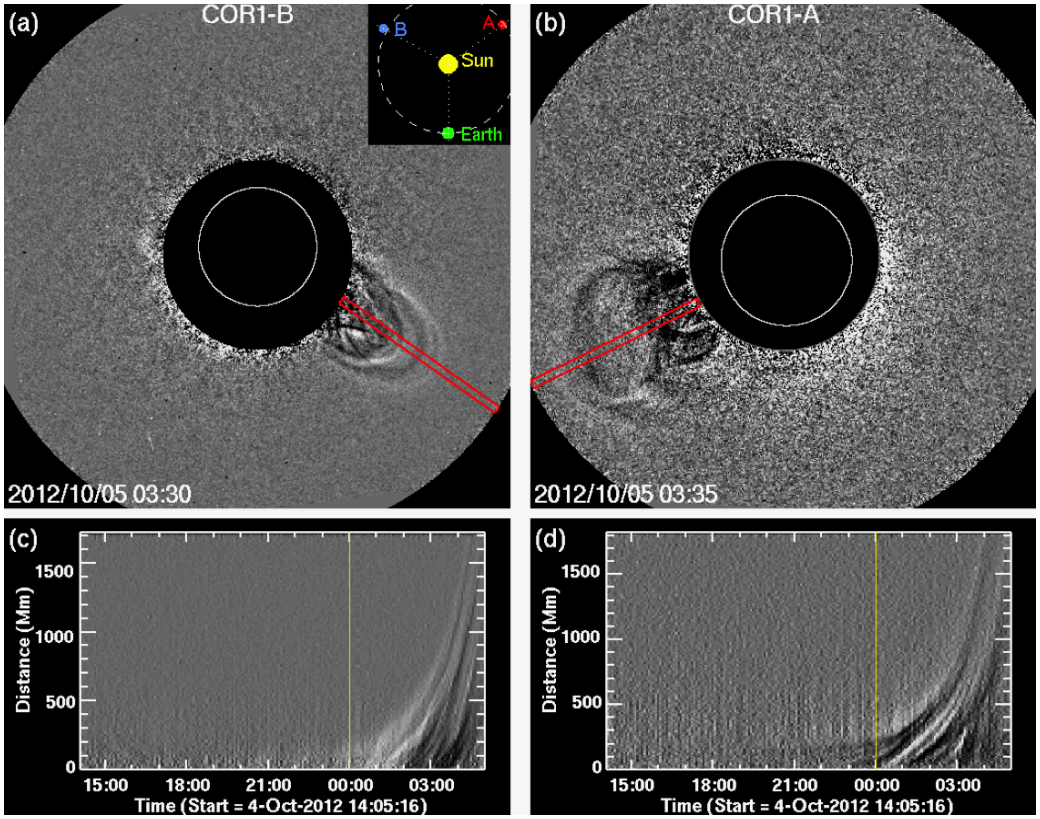


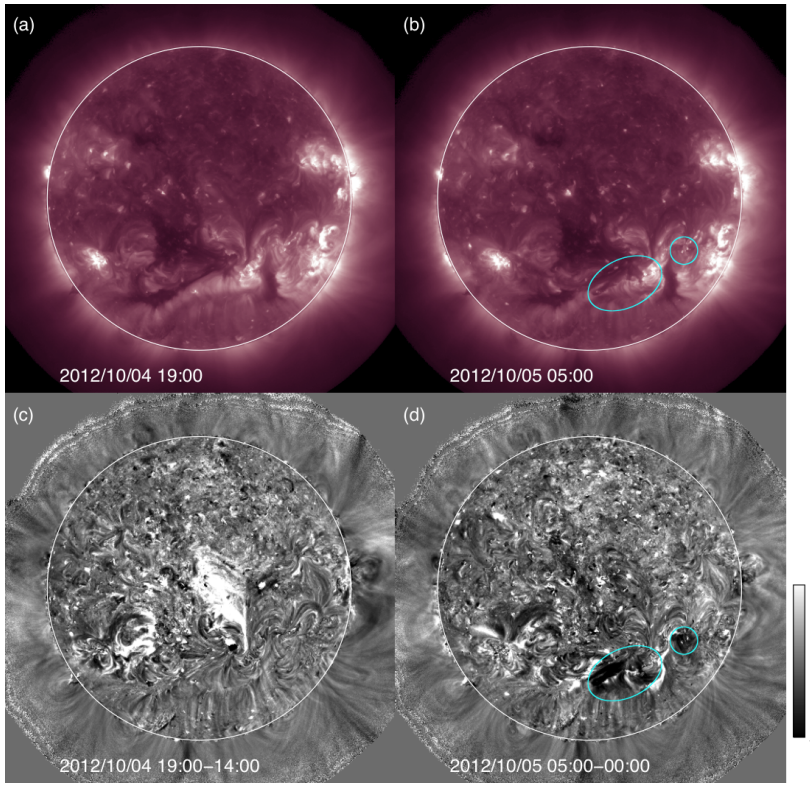


Slow start, actual onset may have been earlier than the linear extrapolation of h-t curve to 1 $R_\odot$.

5 October 2012 Event

COR-1 data indicate that the CME started and accelerated only around 5 Oct 2012 00 UT.



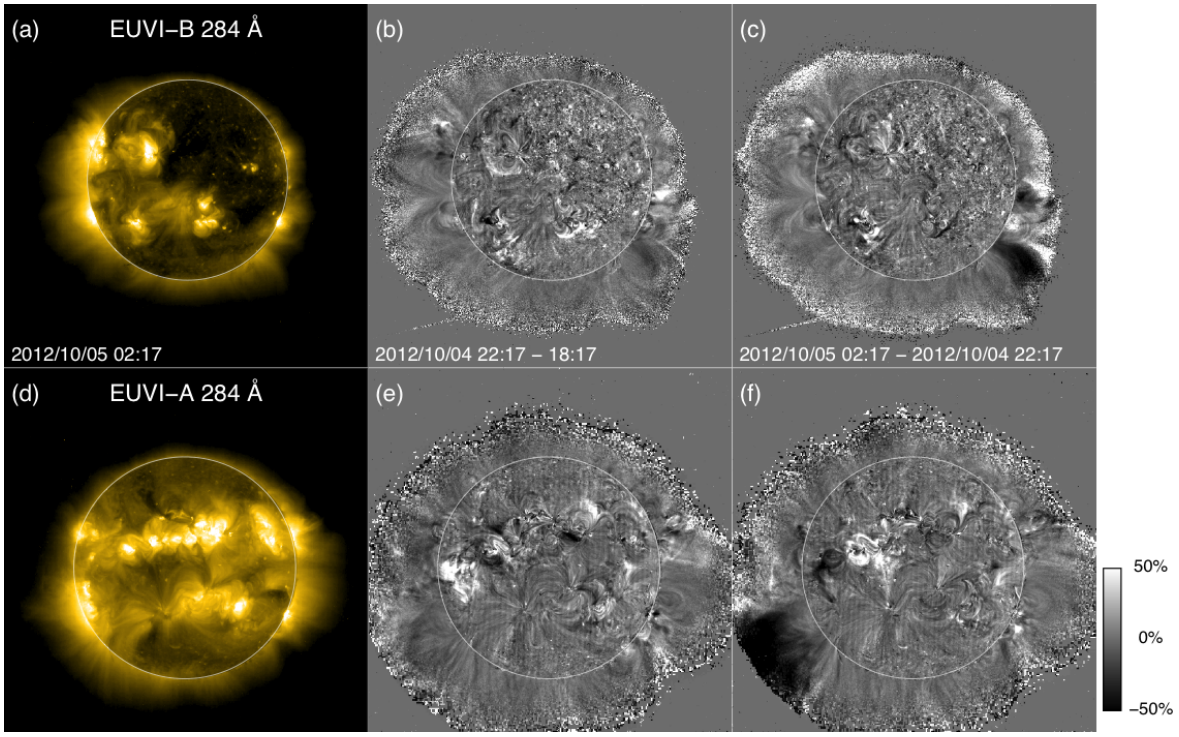


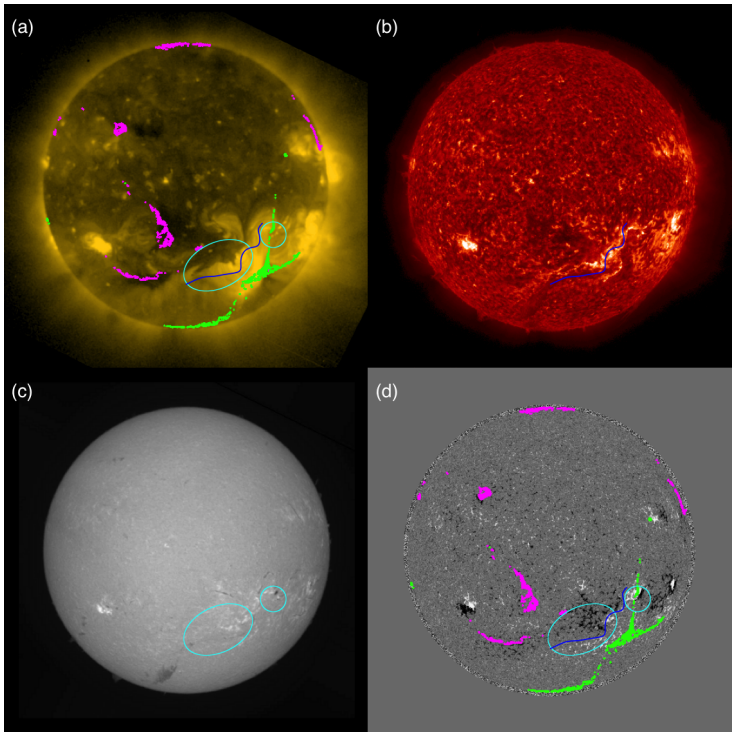
Dimming and a PEA grew in the southwestern quadrant, consistent with the USTC-China discussions.

5 October 2012 Event

Dimming is more easily seen in side views provided by STEREO. In this view dimming is noted even before the main CME acceleration takes place.

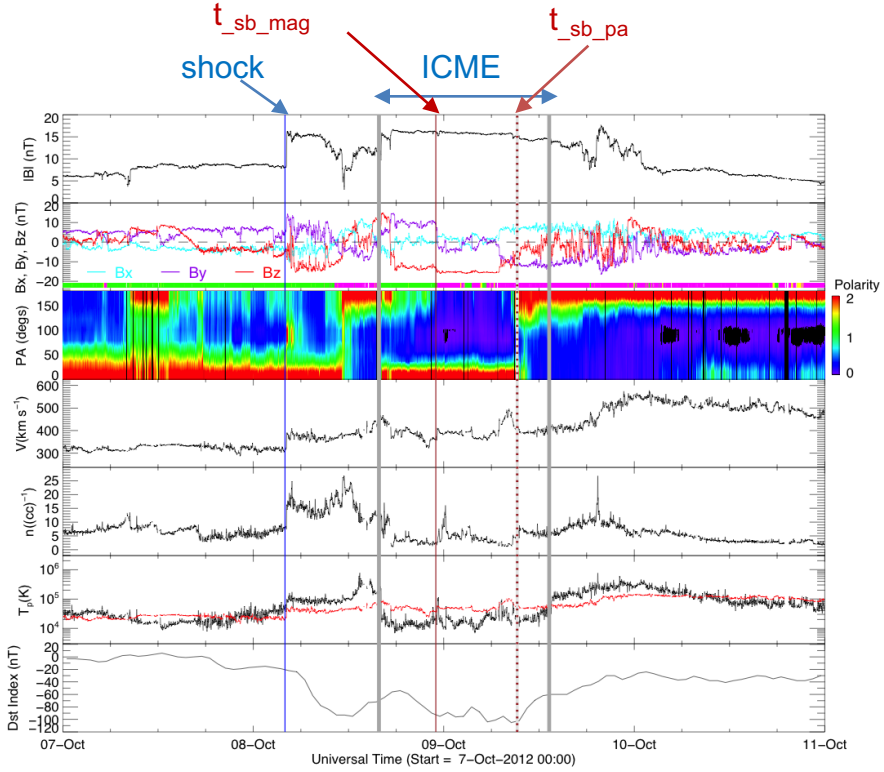
Dimming regions overlapping with a filament channel and active region. Close to open field regions.



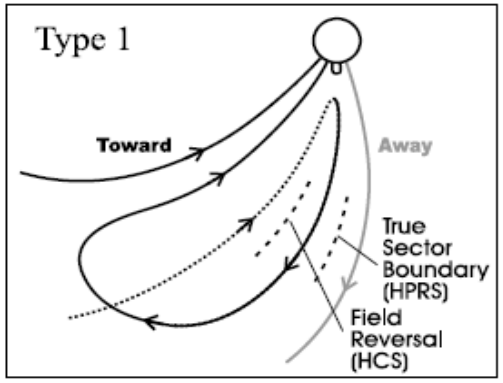


Consequences of the 5 October 2012 Event at 1 AU

The CME was the only one to account for the geomagnetic storm (Dst = -105 nT) starting on 8 October.



- The ICME was preceded by a shock.
- It contains a sector boundary crossing.
- It is followed by a high-speed stream (HSS) from a coronal hole.
- Mismatch of sector boundary crossing time (Crooker et al. 2004)?



This suggests interchange reconnection. But beware of the dominance of Bz.

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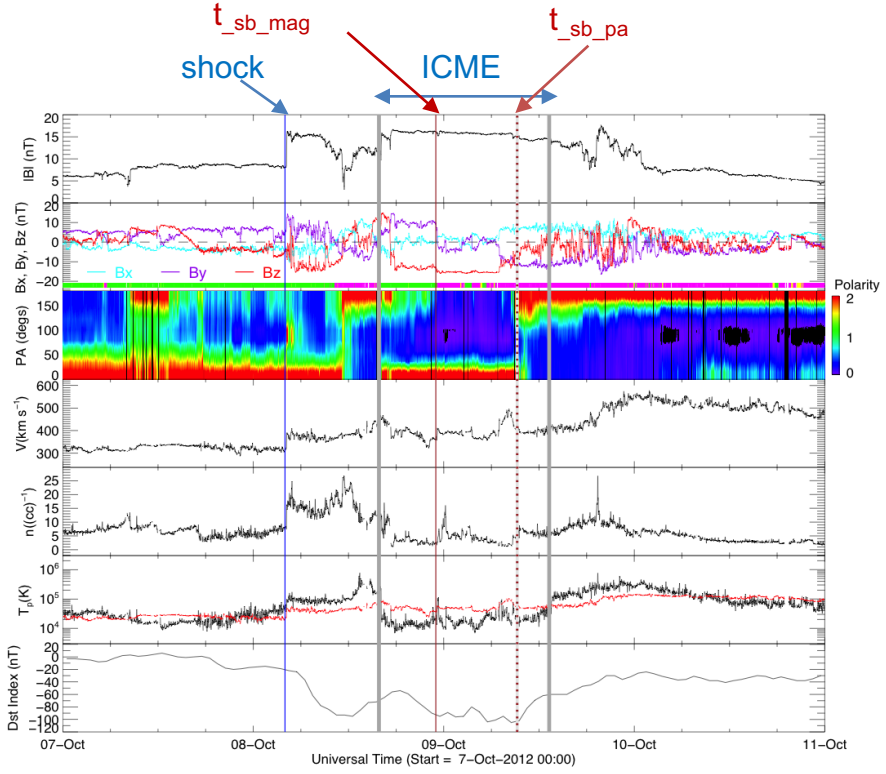

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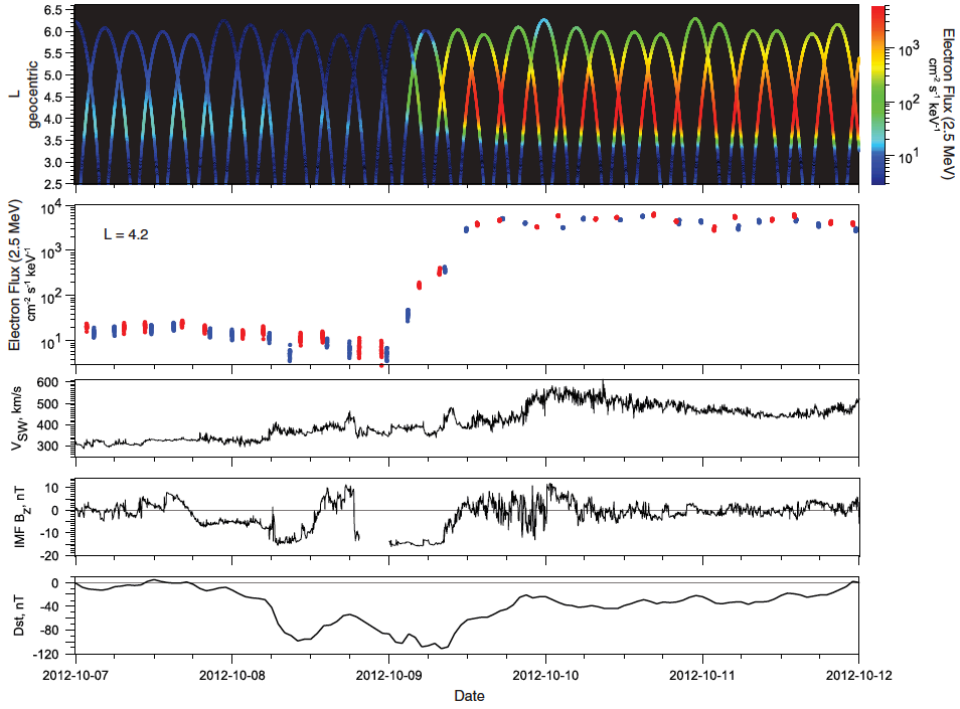
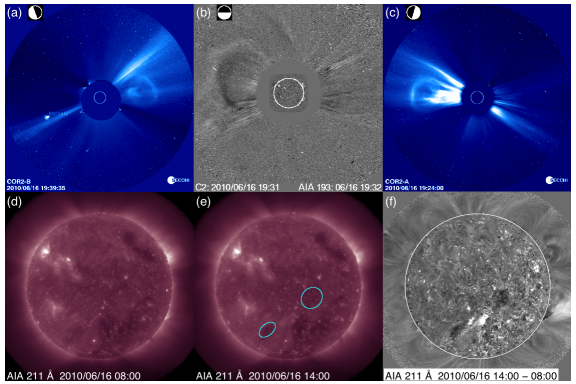
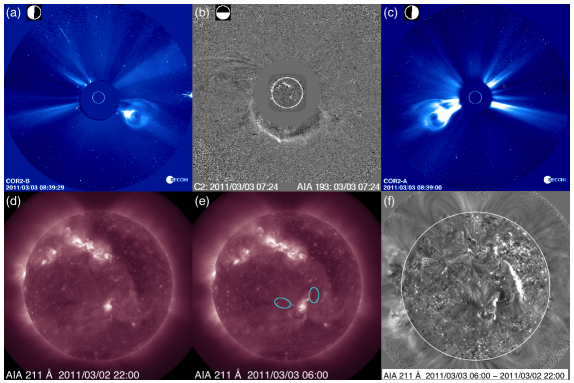


First electron event observed by the van Allen Probes (Reeves et al. 2013)

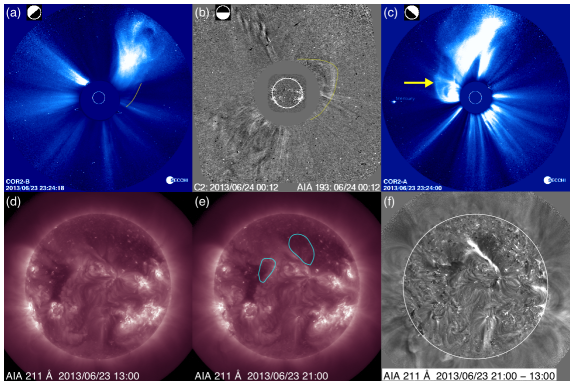
Origins of Somewhat Stealthier Events



Event studied by Vourlidas et al. 2011



Event studied by Pevtsov et al. 2013



The 5 October 2012 CME turned out to be not very stealthy. It was bright, not slow, and associated with a B-class flare. However, the LCSs were very weak. We learned:

- STEREO COR-1 data limit the time range to look at AIA images for disk signatures.
- Difference of images (193, 211, 335 Å) with long separation is needed to isolate dimming and a PEA. These may grow even after the CME is seen by LASCO.
- It is important to distinguish the region that erupted and those that destabilized it.

We can use this knowledge to find the solar sources of stealth CMEs as previously labeled (See pictures on the left).

More Stealthy Earth-Affecting Events

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Table 2. Partial list of stealthy events (1 AU)

1 ID	2 Dist. start time	3 Dur.	4 v_{max}	5 Shock	6 B_{max}	7 FR	8 Pol.	9 HSS	10 Dst	11 Kp
1	2010/06/20 20	1.8	410	N	7.7	WNE, R	+	N	-11	2+
2	2010/12/28 03	0.5	360	N	14.0	NES, R?	+	N	-43	4o
3	2011/01/24 07	1.2	400	N	8.2	NES, R	+	N	-14	3o
4	2011/02/04 13	0.3	470	N	23.3	NES, R?	–	Y	-63	6-
5	2011/03/06 03	2.1	530	N	7.3	–	–	N	-27	4-
6	2011/03/29 16	1.5	390	N	14.6	–	+	N	-4	3+
7	2011/05/28 01	0.8	540	N	13.3	SWN, R	–	Y	-80	6+
8	2012/10/08 04	1.5	420	Y	16.7	ESW, R	+–	Y	-105P	6+
9	2013/05/31 15	1.5	410	Y	24.5	–	–+	Y	-119P	7o
10	2013/06/06 03	1.9	510	N	13.5	WSE, L	+	N	-73P	6-
11	2013/06/27 14	2.0	450	Y	13.6	WSE, L	–+	Y	-98P	6+
12	2013/07/05 01	2.6	370	N	13.0	ESW, R	+	N	-77P	5-
13	2015/01/07 06	0.5	470	N	22.6	SEN, L	–+	N	-99Q	6+
14	2016/10/12 21	1.6	370	Y	24.8	SEN, L	–	Y	-104Q	6+

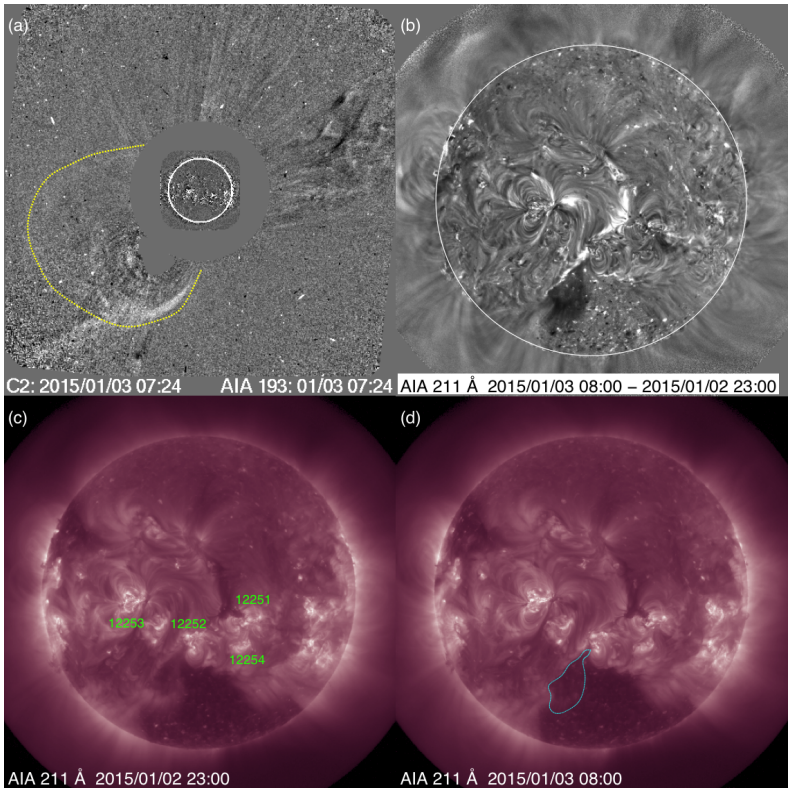
1: Event ID. 2: The disturbance start time in the closest hour, taken from the *Wind* or Richardson-Cane Catalog. The only exception is event 7, where the observed shock arrival time is entered. 3: Duration in days of the event from the start time in 2 to the ICME end time. 4: Observed maximum solar wind speed in $\mathrm{km\,s^{-1}}$. 5: If a shock is observed (Yes or No). 6: Observed maximum magnetic field strength in nT. 7: Flux rope type if observed. 8: IMF polarity from a day before the start time (in column 2) to a day after the end of the ICME. 9: If the ICME is followed by a solar wind high speed stream (HSS) within 12 hours (Yes or No). 10: Minimum Dst index (nT), taken from the official Dst index page at the World Data Center for Geomagnetism, Kyoto (http://wdc.kugi.kyoto-u.ac.jp/dstdir/). P stands for "Preliminary" and Q "Quicklook". 11: Maximum Kp index, as found in the official Kp index page at the German Research Centre for Geosciences (GFZ) (http://www.gfz-potsdam.de/en/section/earths-magnetic-field/data-products-services/kp-index/).

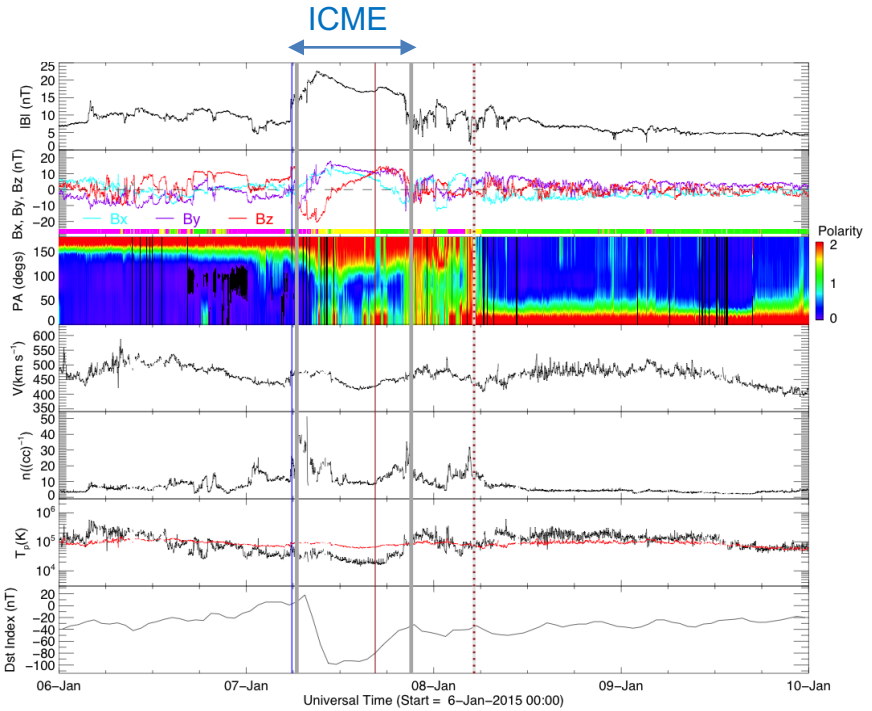
There should be much more, especially since 2014, on the basis of monitoring data in near real time. We will discuss these events at two ISSI team meetings.

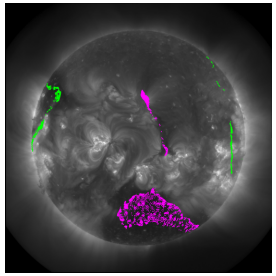
Challenging Event: 3 January 2015

Out of the 14 stealthy events studied, 4 have been problematic in identifying LCSs. Nevertheless, they resulted in Dst ~-100 nT storms.

CME on 3 January 2015

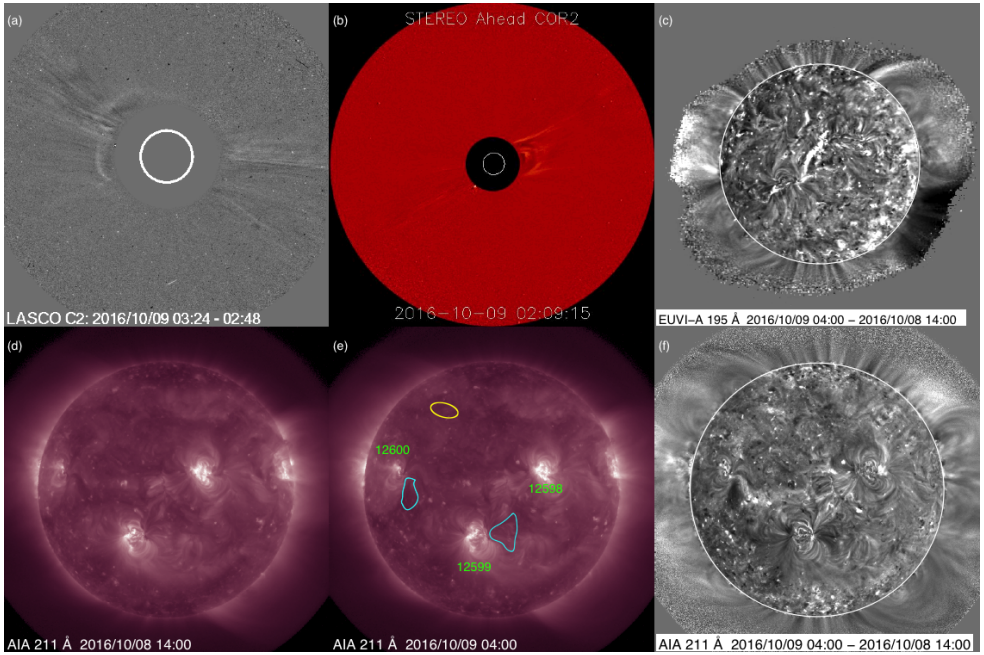


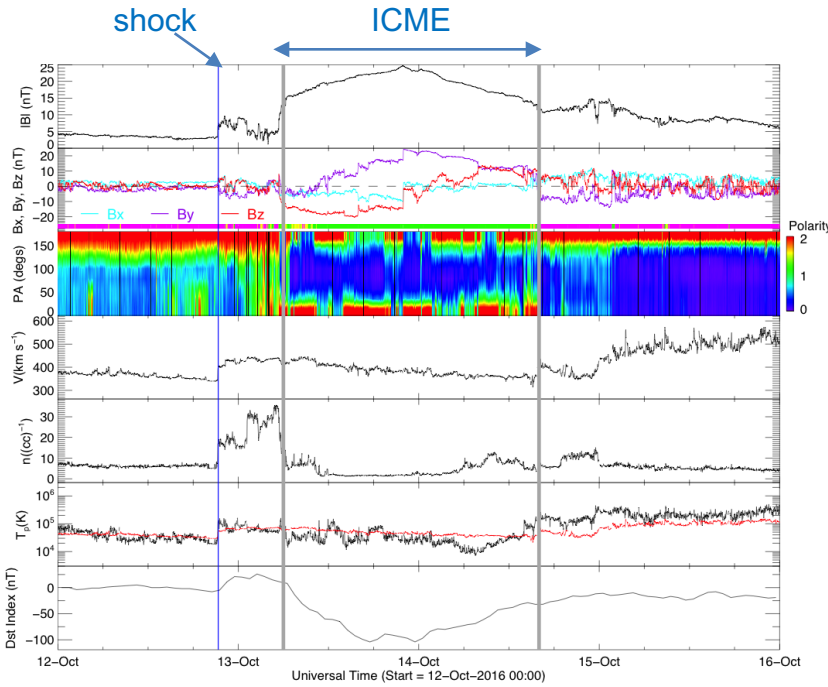


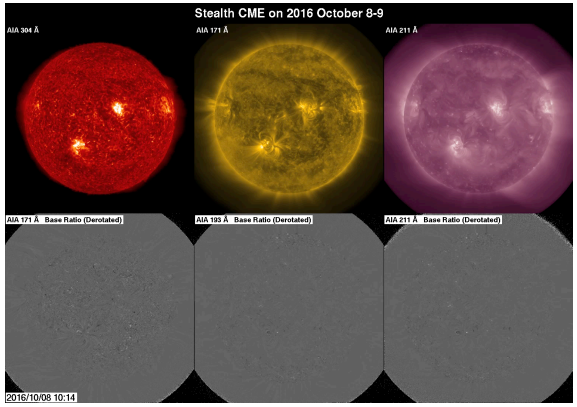


Challenging Event: 8 – 9 October 2016

CME on 8 – 9 October 2016





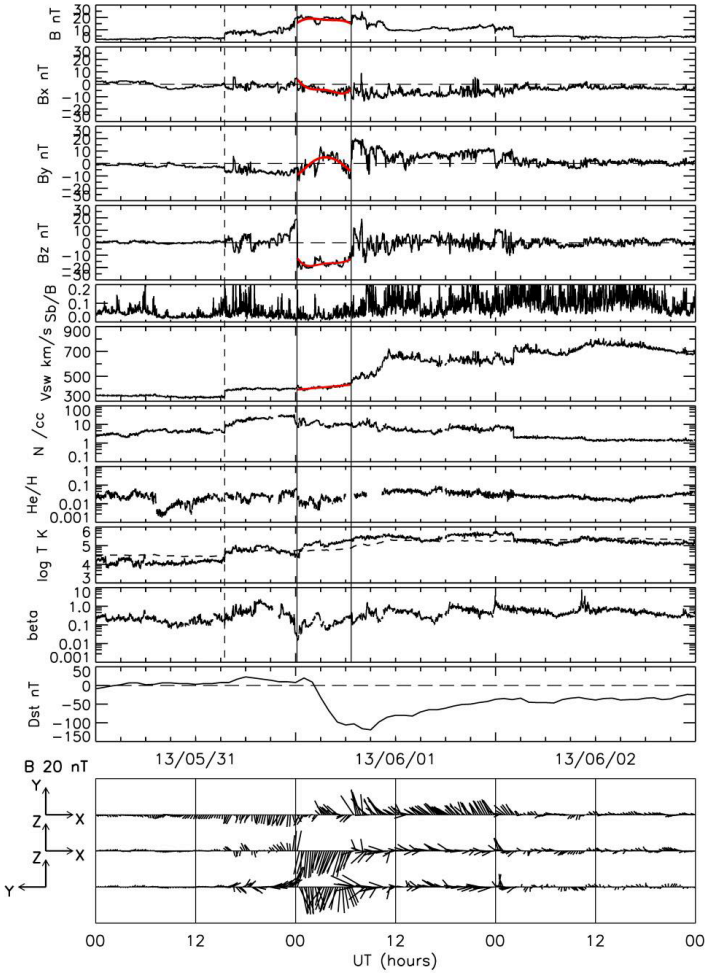


The CME was very diffuse. Without STEREO-A data, it could have been identified as a backside event.

A small filament eruption was seen in NE but it was too localized and early for the CME.

Coronal Hole Dominant – Need for a CME?

Did the slow CME heading to northeast contribute?



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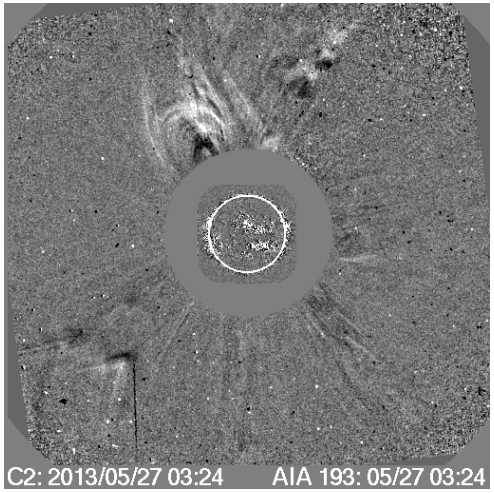

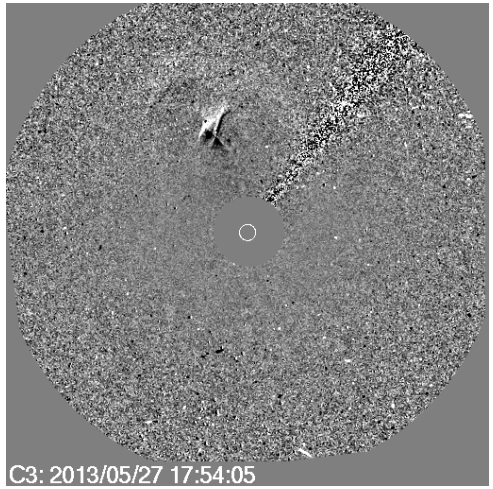

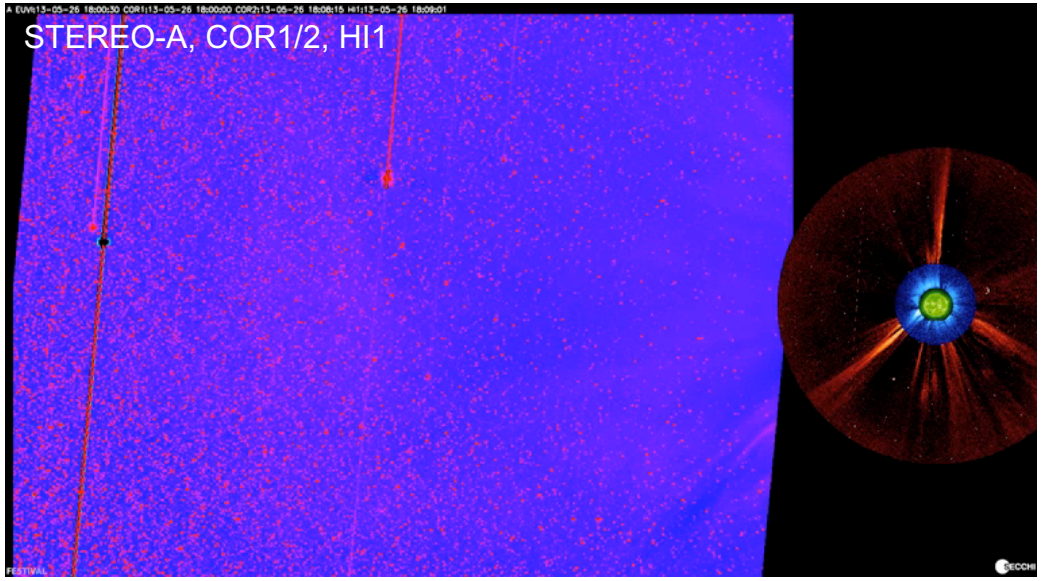

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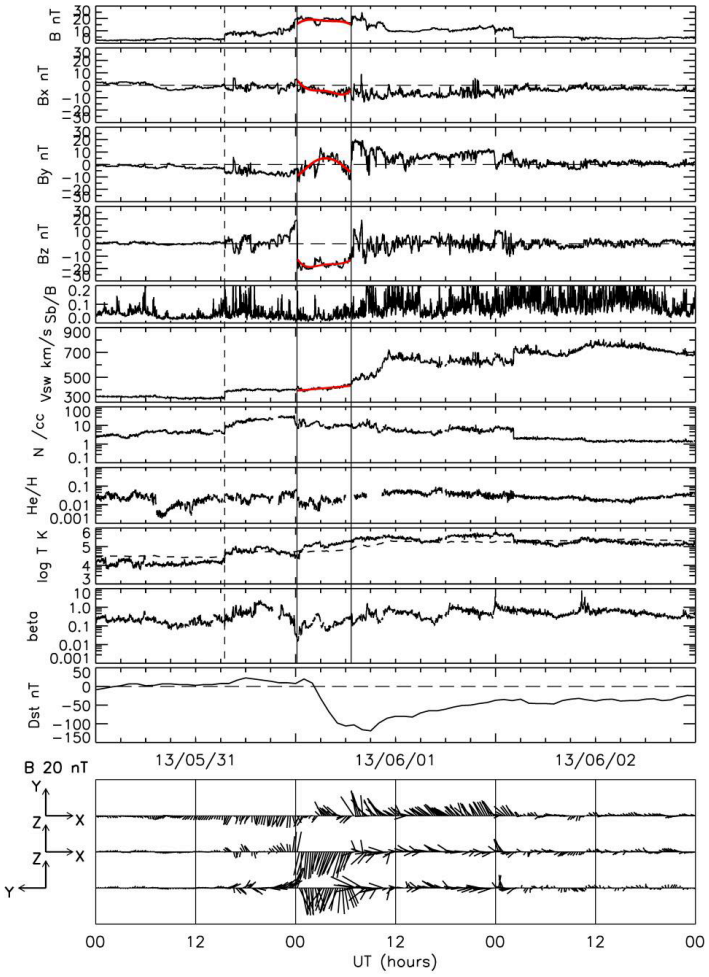

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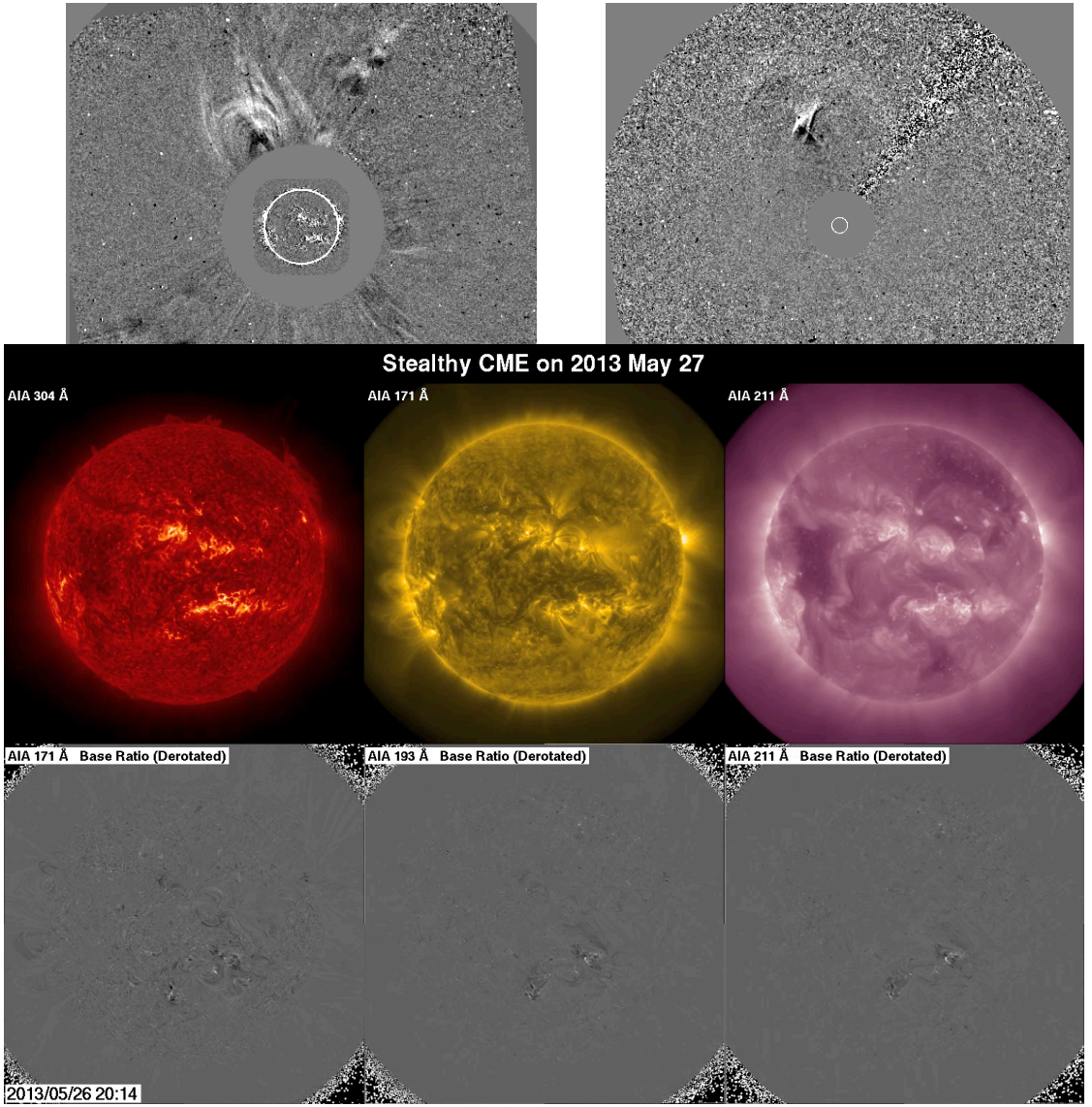

Summary

- There are different levels of difficulty to find the LCSs and source regions of stealthy CMEs, partially supporting the view of Howard and Harrison (2013).
- Helped by STEREO observations, SDO/AIA has revealed dimming and PEAs for several stealthy events, even though there are still unclear events. Some of them may have clear flux rope structures and result in Dst $\lesssim$ -100 nt storms.
- Stealthy CMEs do not recur, representing once-in-life energy build-up.
- Proximity of stealthy CMEs to coronal holes has consequences in the way the eruption is driven (e.g. interchange reconnection) and how it eventually disturbs the heliosphere (interaction with HSS and CIR).
- Possible ICME signatures from stealthy CMEs may be often buried in solar wind data, when they are dominated by those of high-speed streams.
- Need to study these ICMEs in more detail, especially their evolution with time and how the magnetosphere responded.
- Need to investigate the relation of stealthy events with small flux ropes which may be of interplanetary origin.