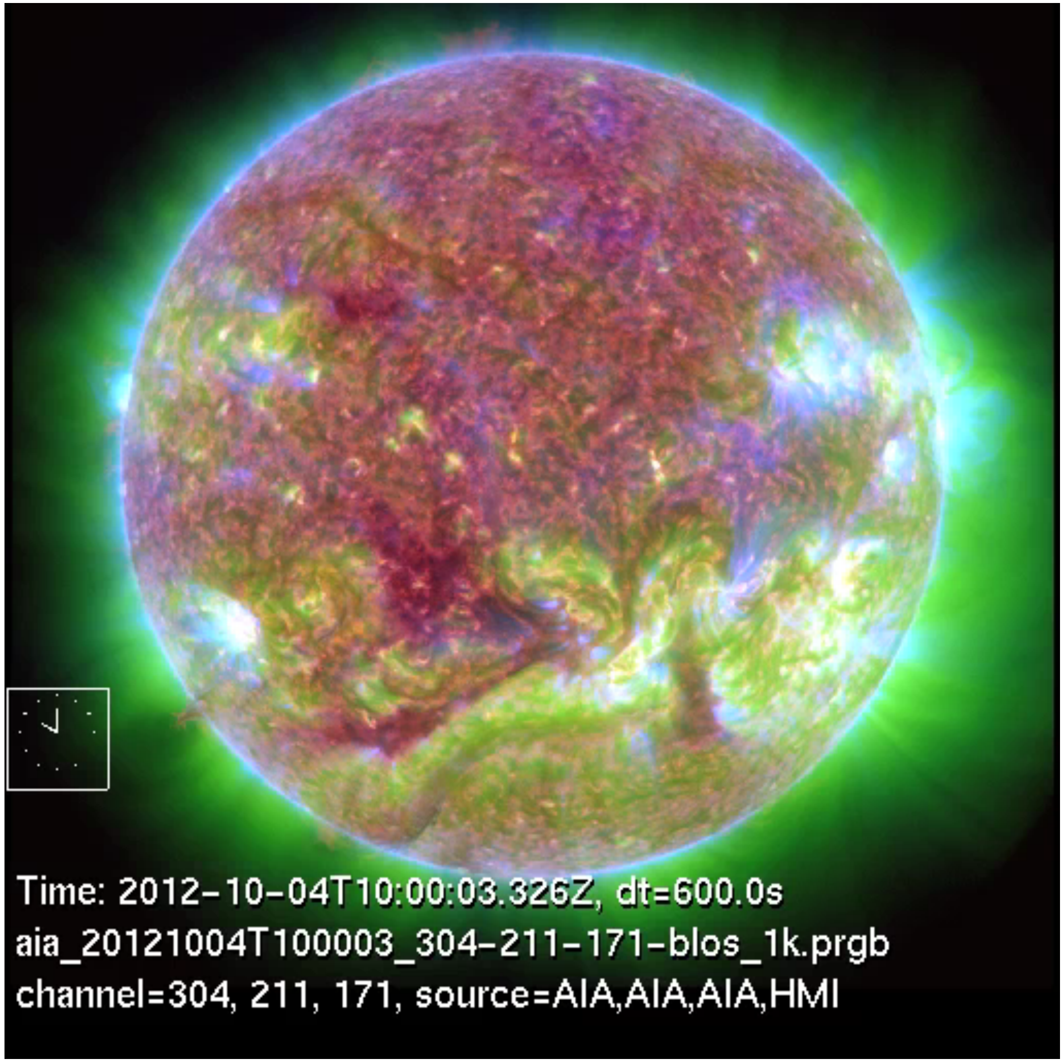
Stealthy Sun-Earth Events



Nariaki Nitta (LMSAL)

Sun-Earth Connection

Sun-Earth Disconnection

The connection between solar eruptions and heliospheric disturbances at 1 AU is still not well understood.

1. A CME occurs and the source region is clearly identified on the front side, but it does not arrive at Earth.
2. An ICME is observed at 1 AU, but there is no CME on the Sun within a reasonable time window.
3. A candidate or candidates of CME may be found for the ICME, and the timing seems to be OK, but the source location is unreasonable.
4. The ICME is traced back to a CME observed by a coronagraph, but its coronal manifestation is not found (stealth CME).

It is still important to establish the association or lack thereof of solar and in-situ signatures.

Two steps to trace an ICME to solar origin

ICME
In-situ (ACE, Wind)

Step-1 →

(Halo) CME
Coronagraph (LASCO)

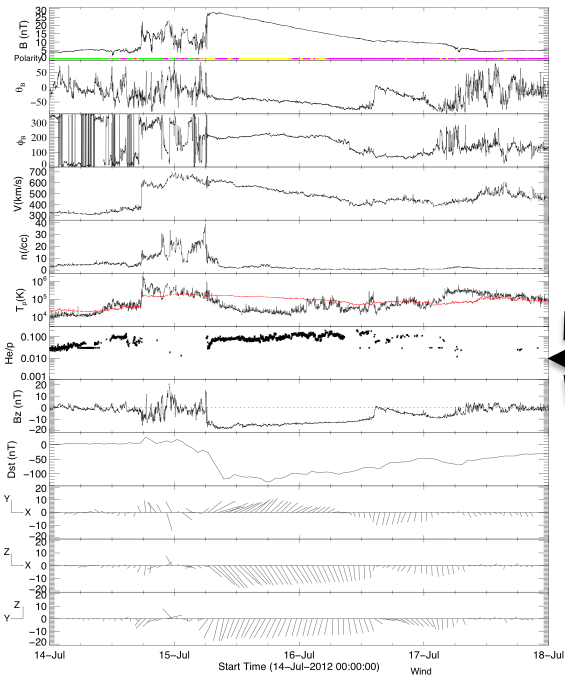
Step-2 →

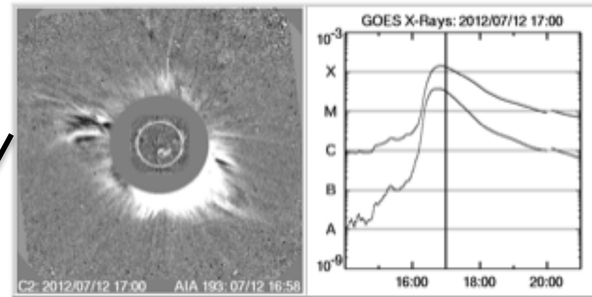
Low coronal signatures
EUV images (EIT, AIA)

P2

C2

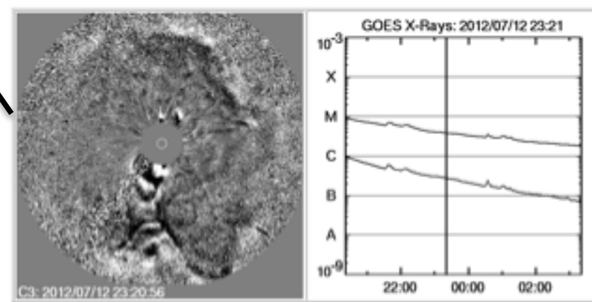
P3, P4

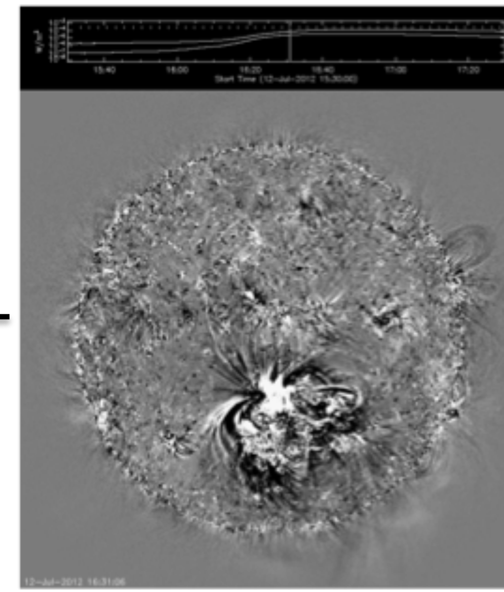




P1

C3





From ~200 $R_\odot$ to ~30 $R_\odot$

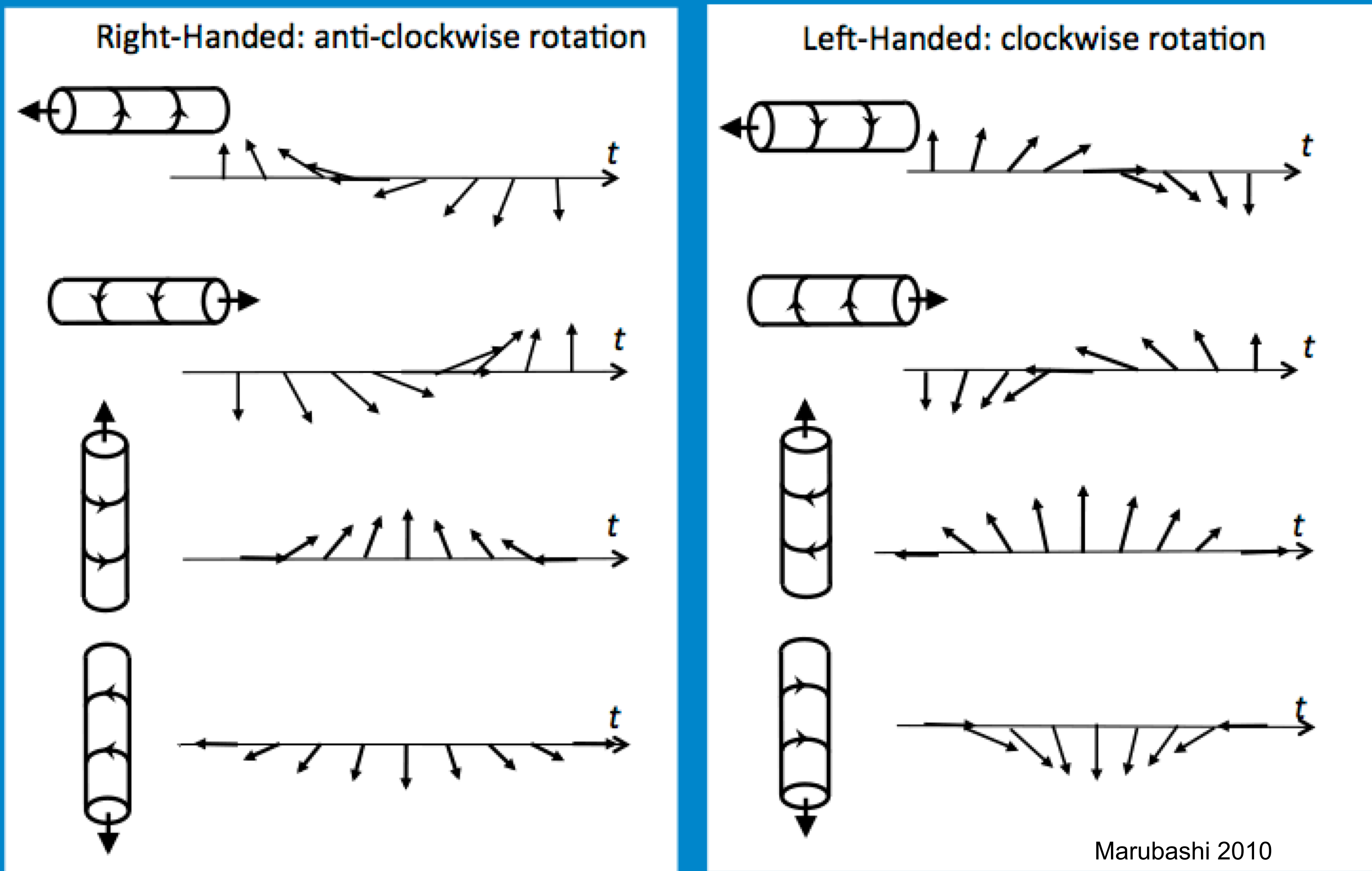
COR2 and HI1/2 of **STEREO** narrows the time range and provides side views

From ~2.2 $R_\odot$ to ~1.2 $R_\odot$

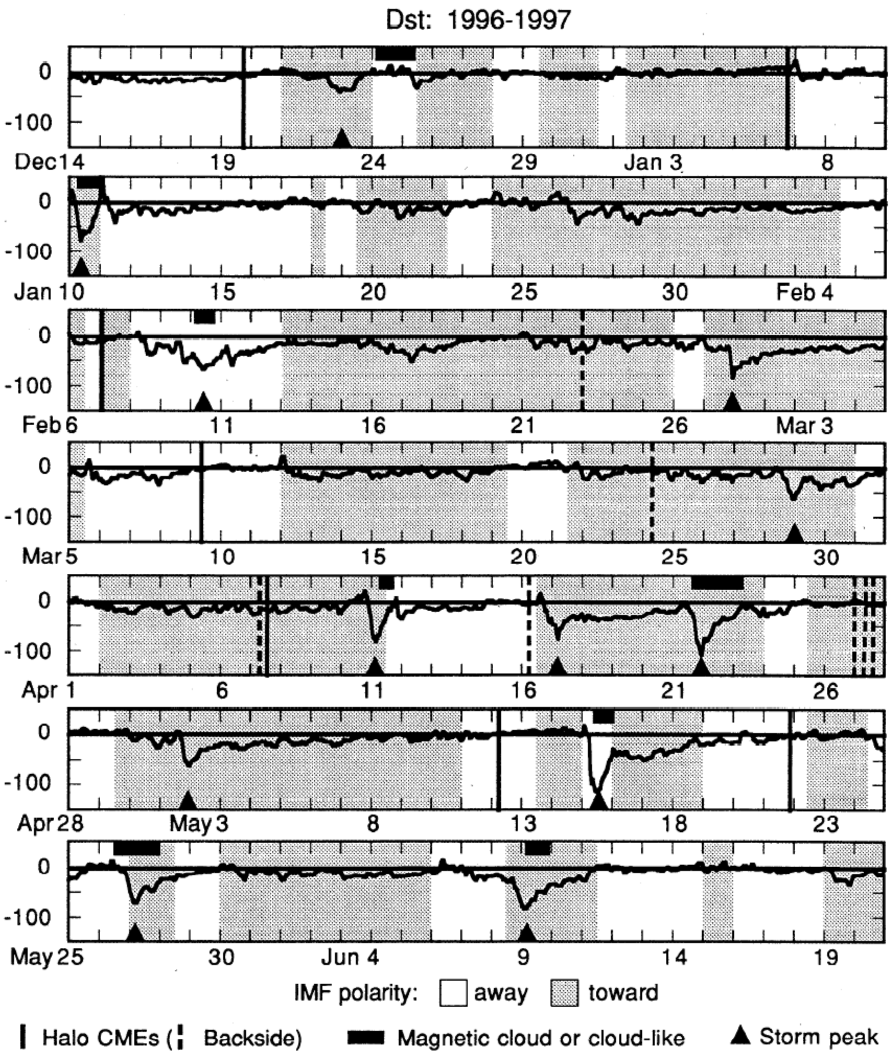
EUVI and COR1 of **STEREO** narrows the time range and provides side views

Flux rope type

Magnetic field rotation, when passed near axis



Halo CMEs – Reliable Indicator of geoeffectiveness



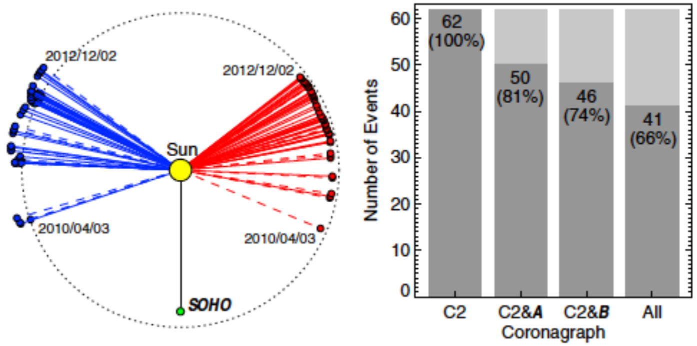
Would some events labeled "backsided" have actually been front-sided, had STEREO observed them?

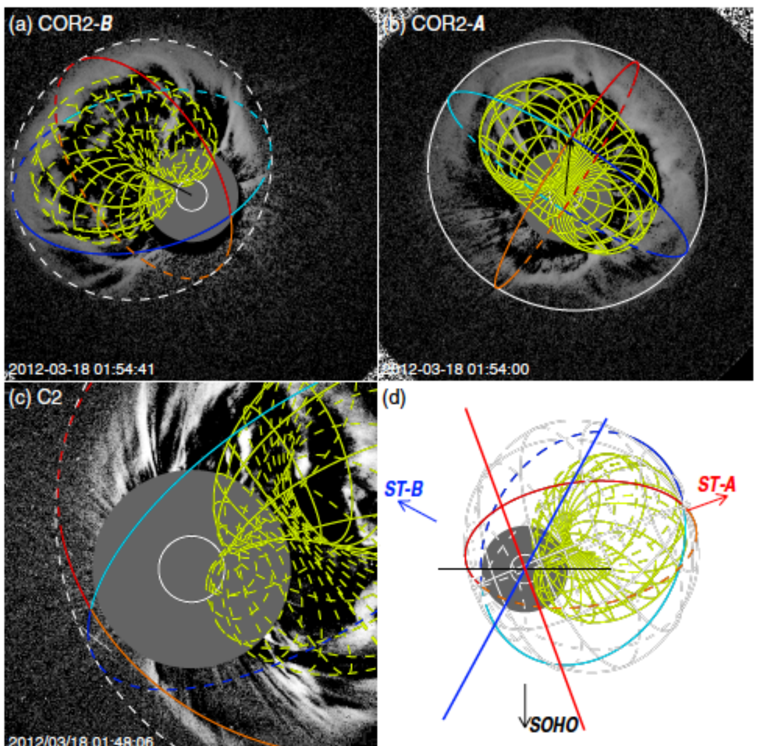
Many ICMEs in the Richardson & Cane list have no associated halo CME. There is a possibility that the associated CME may be too narrow or diffuse to be observed by LASCO.

Webb et al. (2000)

Halo CMEs – Just Projection Effect?

Many halo CMEs observed by LASCO are also halo CMEs in side views by STEREO.





They are likely to be MHD waves driven by the CME.

Asymmetric halo CMEs are often non-Earth-directed.

Kwon et al. (2015)

CMEs Without Surface (Coronal) Activity

42.18

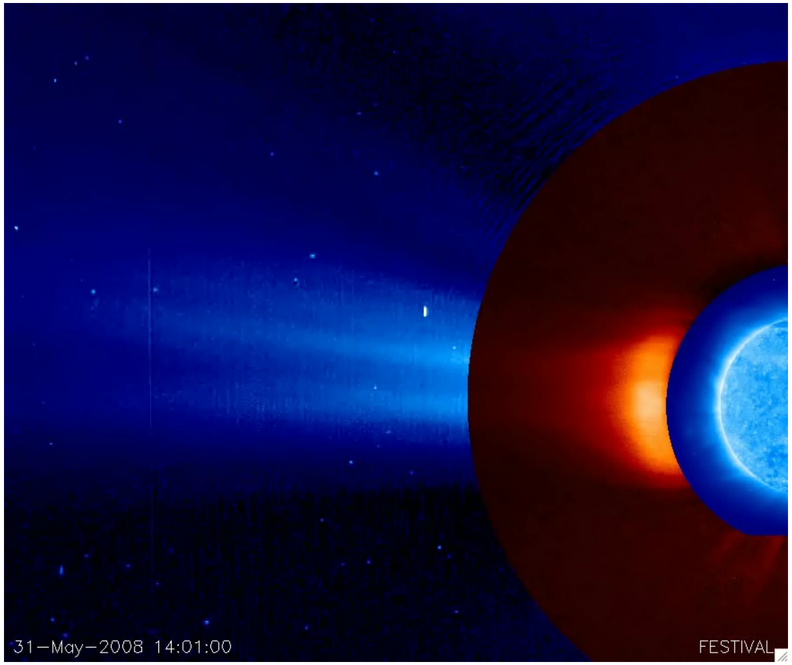
<u>Spontaneous Coronal Mass Ejections</u>

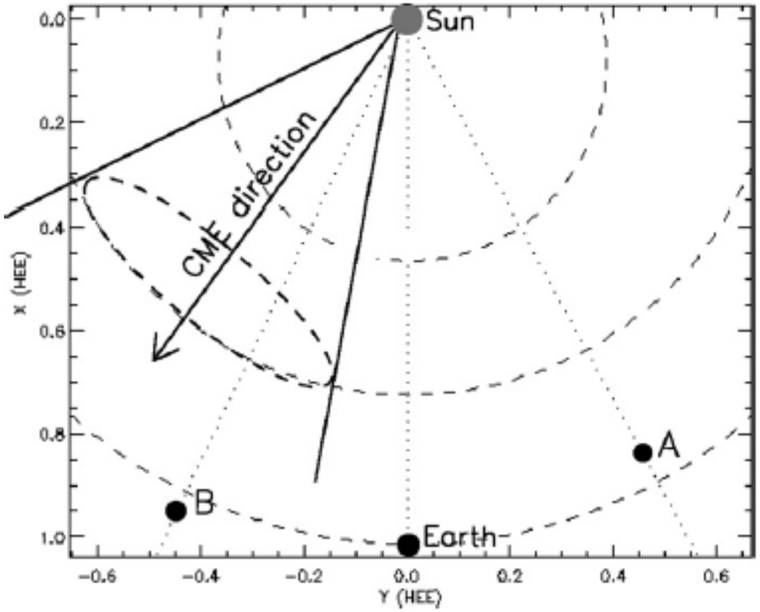
W. J. Wagner (High Altitude Observatory/NCAR)

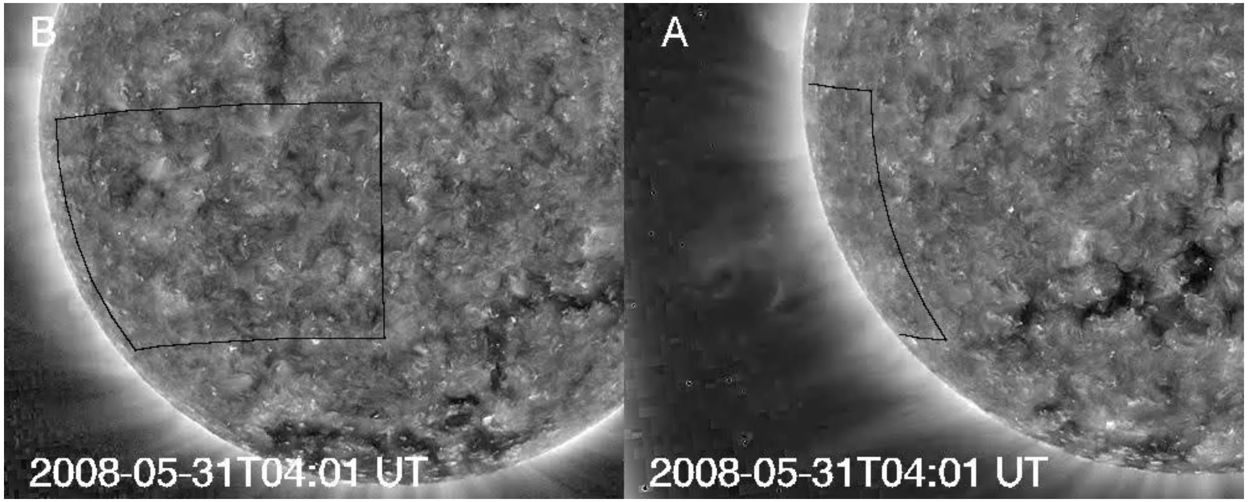
In the Skylab period, limb flares and eruptive prominences were usually accompanied by coronal mass ejections (CMEs). Nevertheless, only about 1/2 of the 1973 CMEs could be associated with such near-surface activity. A study, relying only on statistical probabilities, investigated both Skylab and Solar Maximum Mission mass ejections, comparing time and locations of CMEs to those of H-alpha flares, erupting prominences, long-duration X-ray emission, and metric type II and IV radio bursts. I find that a considerable number of mass ejections have no associated flare, erupting prominence, X-ray or radio burst. Corrections were made for estimated behind the limb activity. The study concluded that almost 1/2 the Skylab CMEs and almost 1/3 of the Solar Maximum Mission ejections needed no energetic impulsive initiation.

BAA, 16, 536 (1984)

Stealth CMEs (No Trace Left Behind)







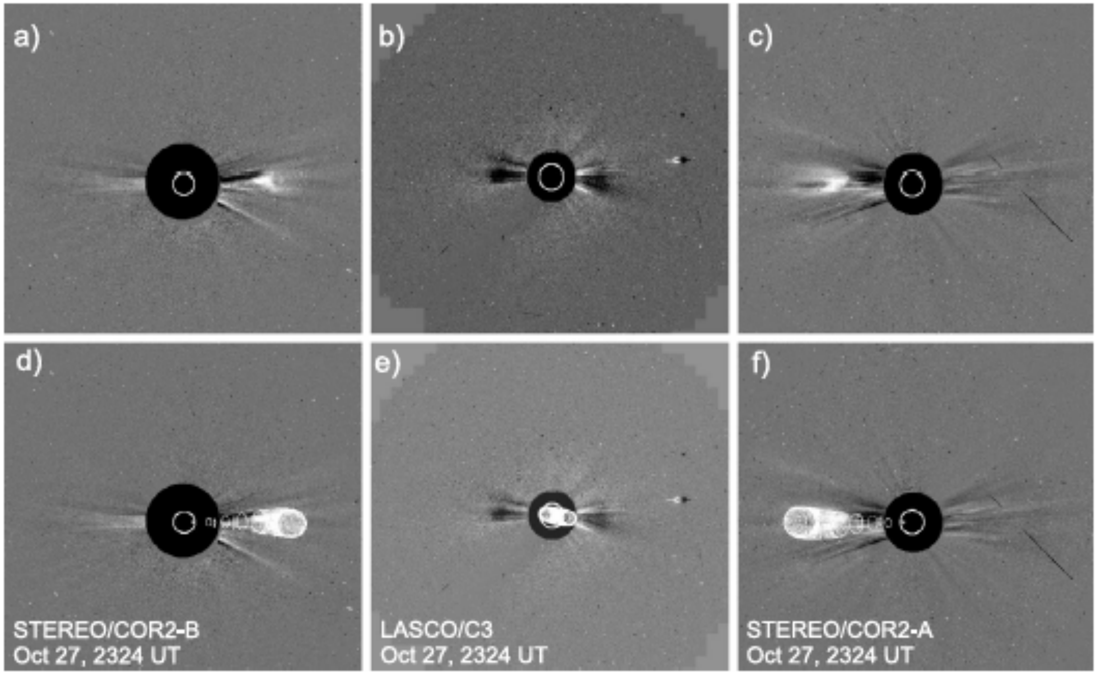
A slow eruption is seen in limb view (STA), but not in disk view (STB).

The event was initiated at a high altitude.

Robbrecht et al. 2009

Stealth CMEs

- Yum. Wang et al. (2011): ~16 % of front-side CMEs during 1997-1998 missed by EIT
- Ma et al. (2010): ~30 % of CMEs in 2009 had no low coronal signatures on the disk.
- Kilpua et al. (2014): 16 of 20 ICMEs in 2009 could be traced back to a CME. 60% of them were stealth CMEs.

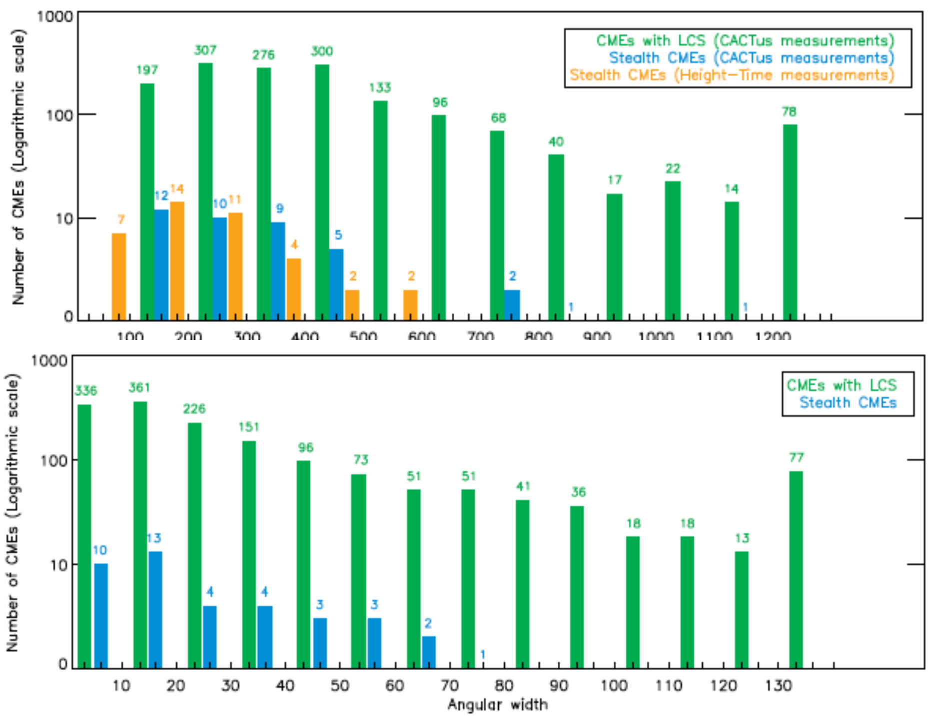


Kilpua et al. 2009

Stealth CMEs during the SDO (+STEREO) Era

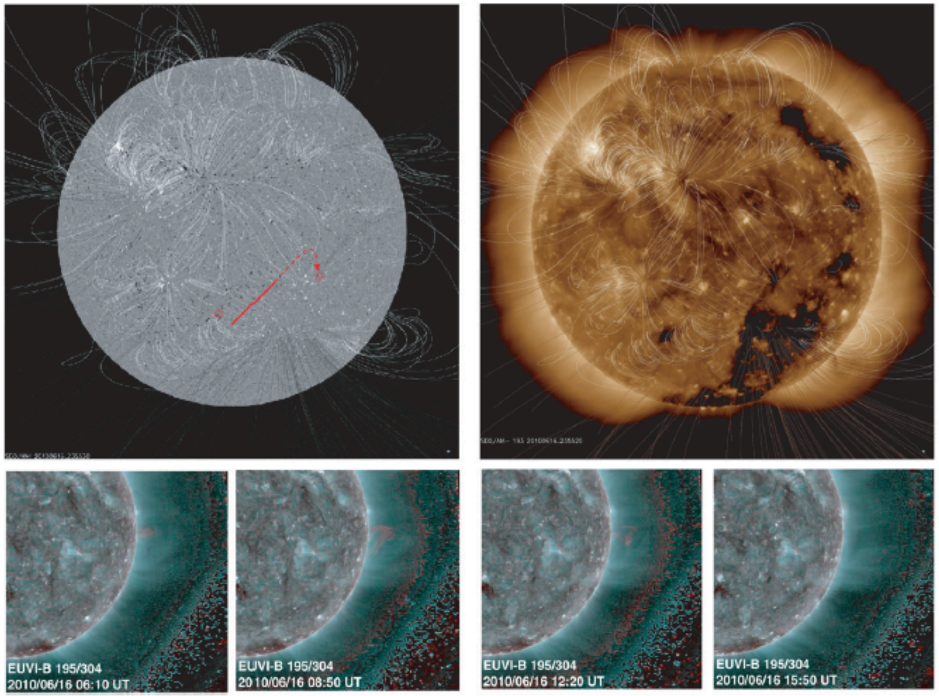
Do stealth CMEs still exist when the Sun is continuously observed by SDO and STEREO? Howard and Harrison (2013) suggested that stealth CMEs are nothing special, only because of instrument sensitivity.

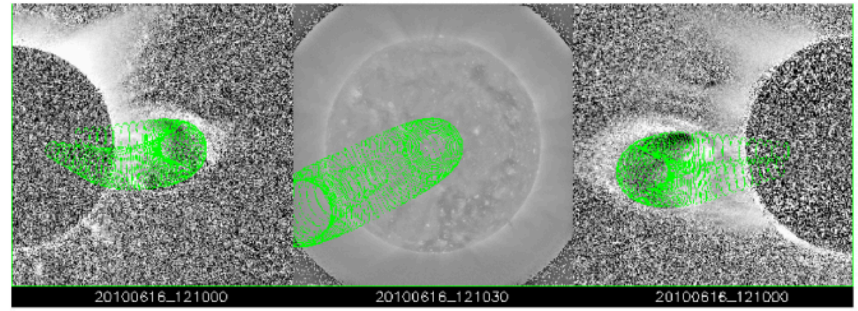
- Akiyama et al. (2013): ~4% of front-side wide CMEs in 2011 were stealth CMEs.
- D'Huys et al. (2014): 40 stealth CMEs in 2012 selected with strict criteria (no low coronal signatures in any views).

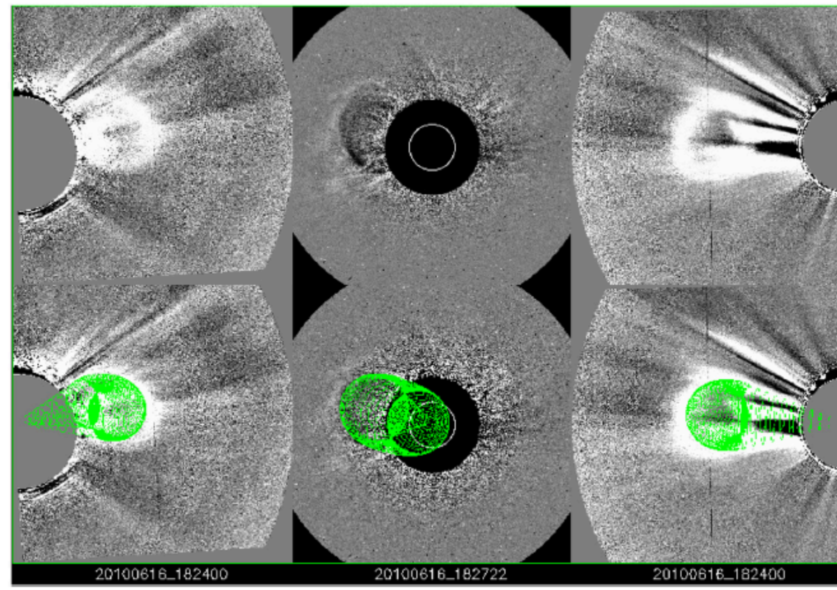


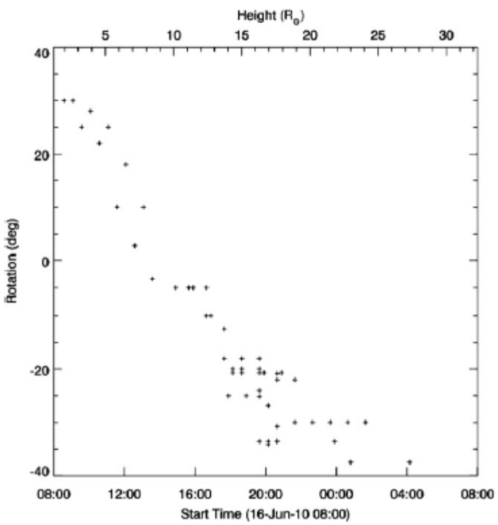
D'Huys et al. 2014

Stealth CME on 16 June 2010







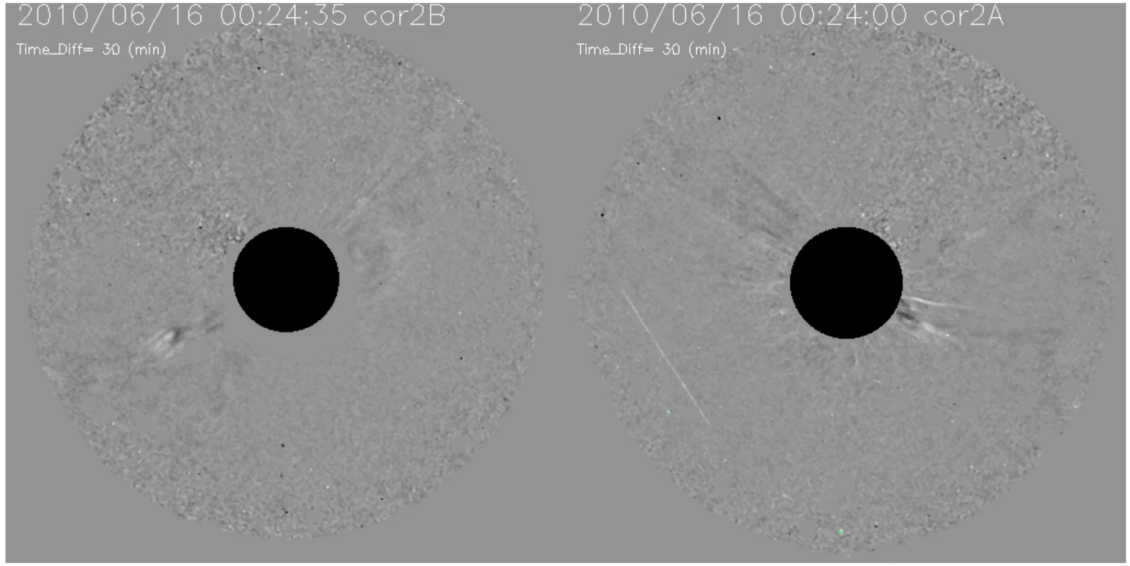


Big rotation near the Sun

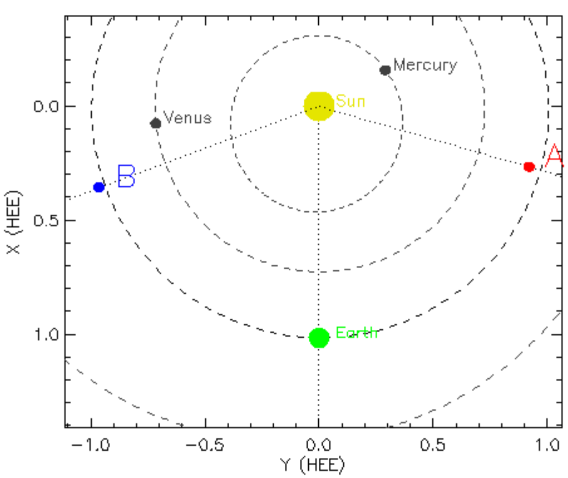
Vourlidas et al. 2011

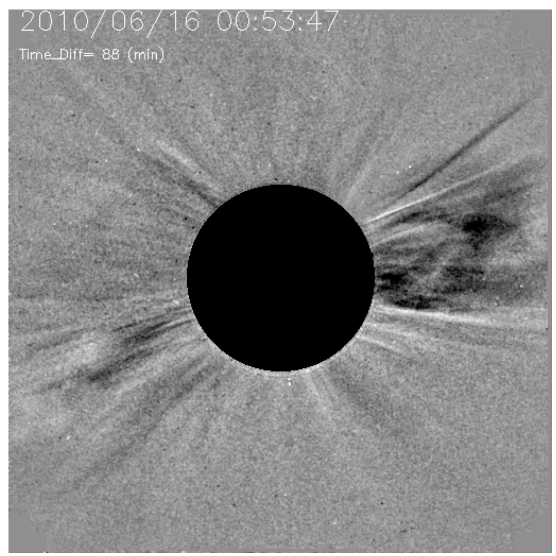
Stealth CME on 16 June 2010

SEEDS

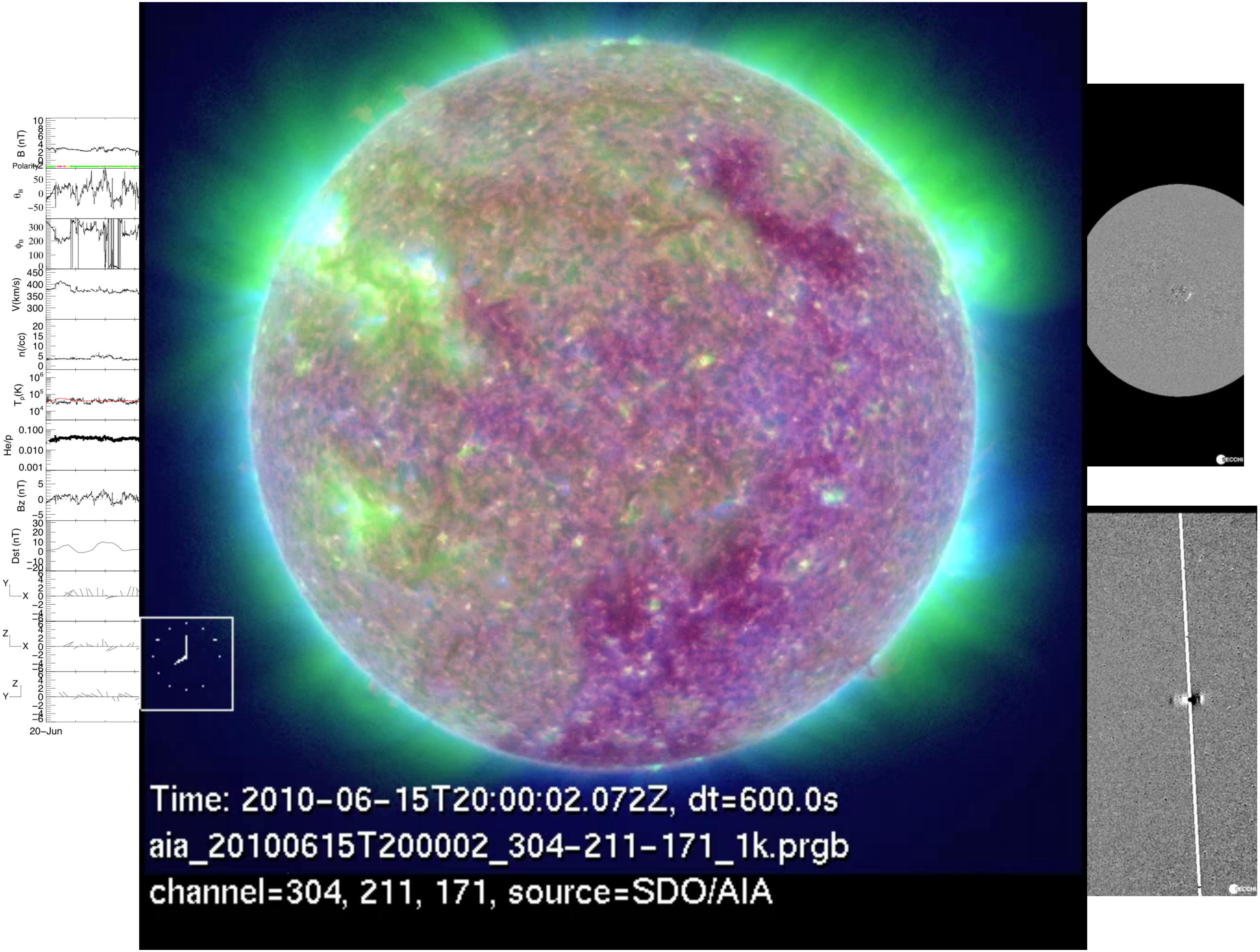


STEREO COR2

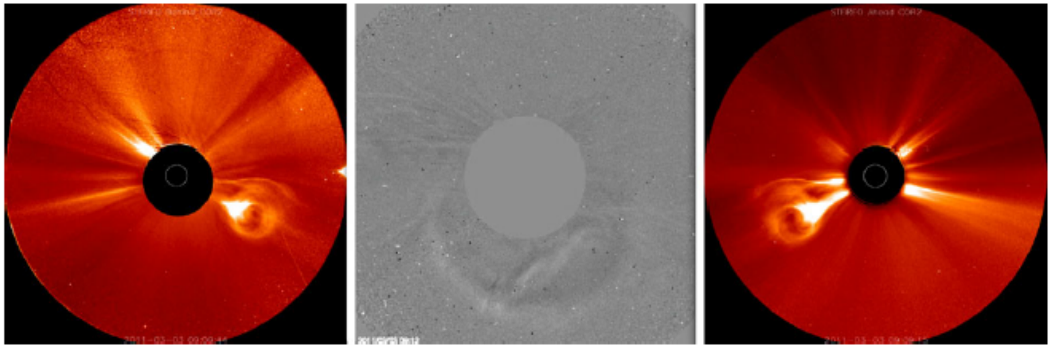


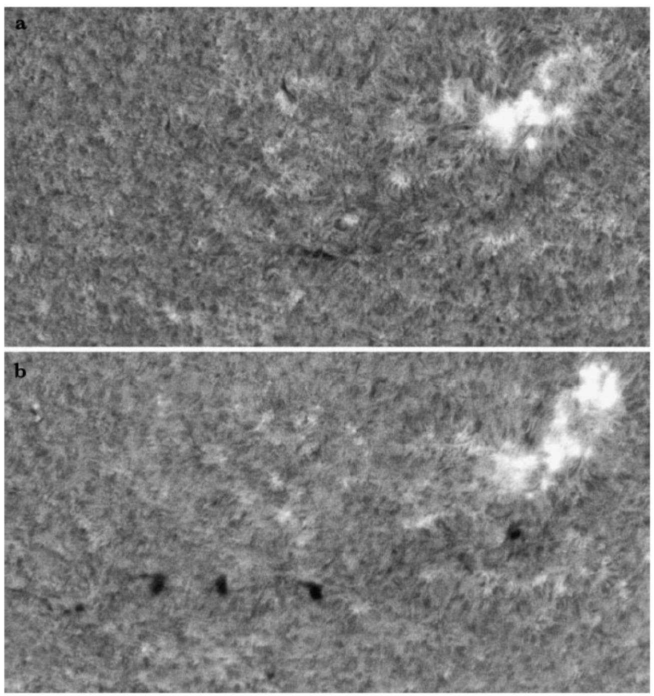


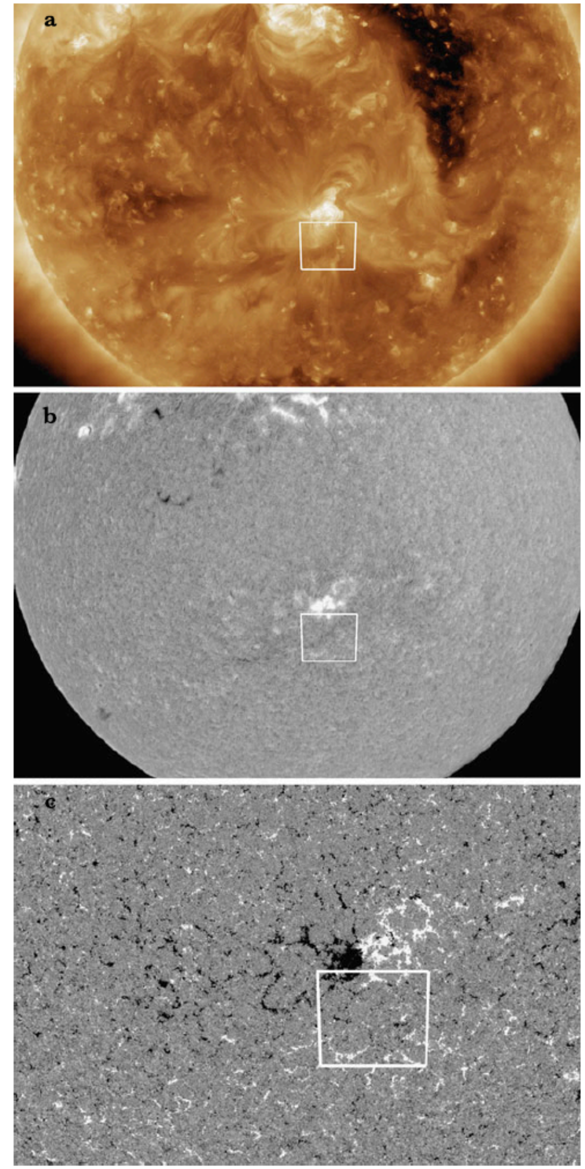
STEREO COR2


B (nT)
Polarity
θB
φB
V(km/s)
n(/cc)
Tp(K)
He/p
Bz (nT)
Dst (nT)
20–Jun
SECCHI
SECCHI
Time: 2010-06-15T20:00:02.072Z, dt=600.0s
aia_20100615T200002_304-211-171_1k.prgb
channel=304, 211, 171, source=SDO/AIA

Stealth CME on 3 March 2011



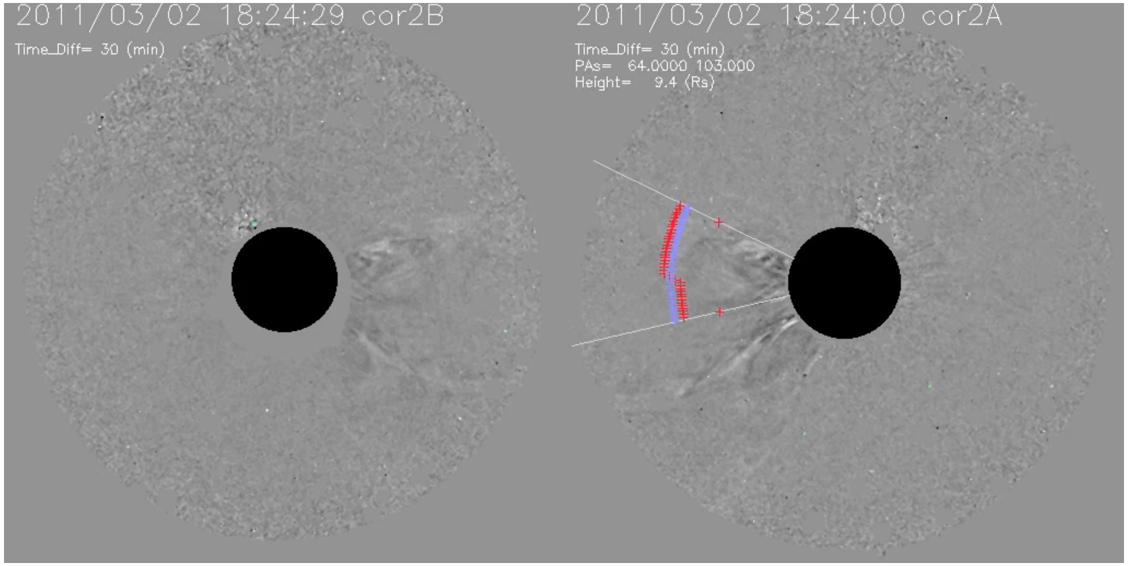




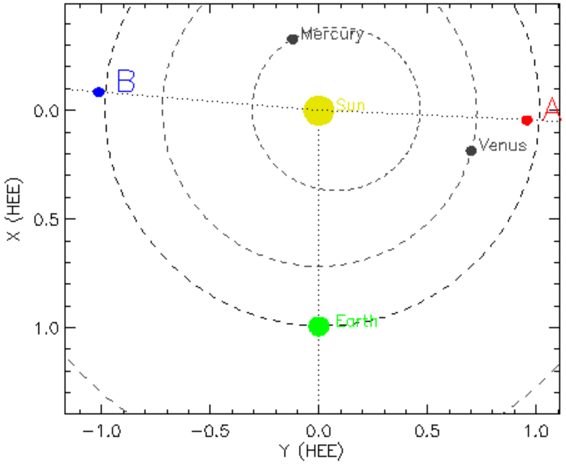
Pevtsov et al. 2012

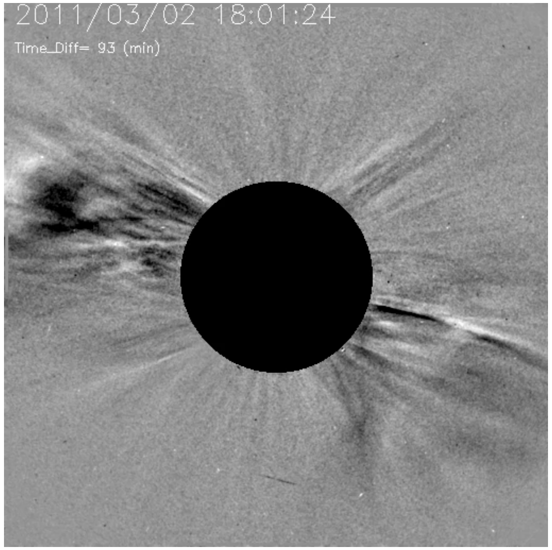
Stealth CME on 3 March 2011

SEEDS

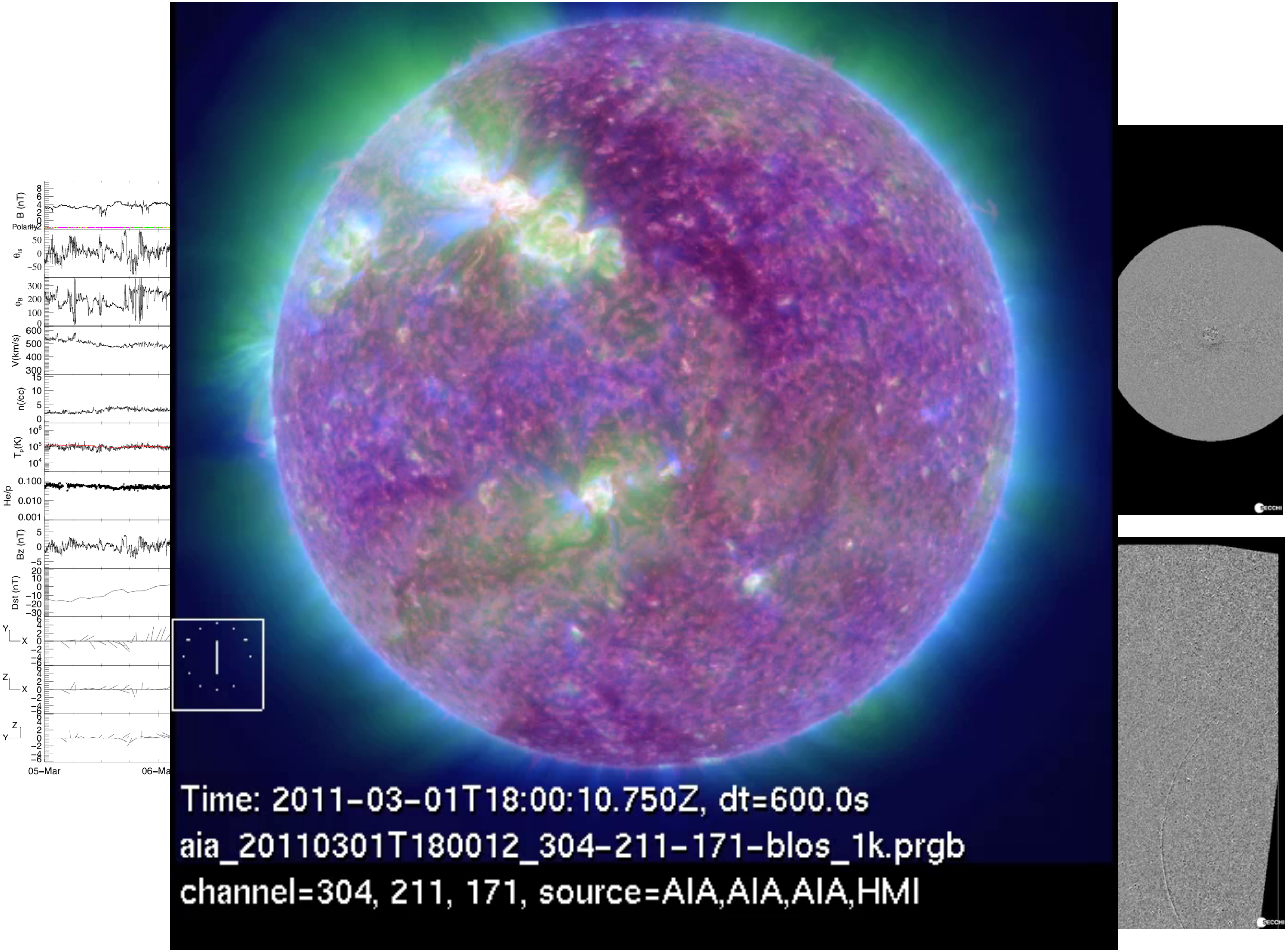


STEREO COR2





STEREO COR2



Time: 2011-03-01T18:00:10.750Z, dt=600.0s
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channel=304, 211, 171, source=AIA,AIA,AIA,HMI
B (nT)
Polarity
V(km/s)
n(/cc)
He/p
Bz (nT)
Dst (nT)
05–Mar
06–Ma
SECCHI
SECCHI

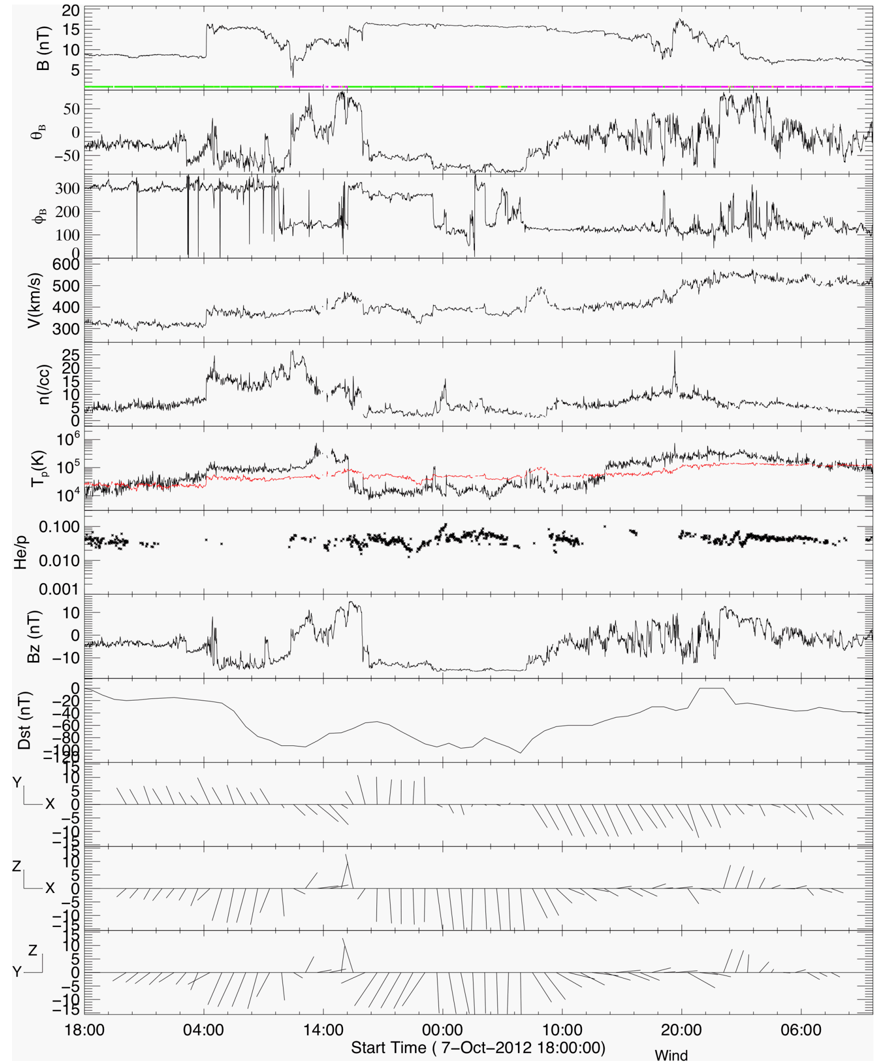
Stealth-like CME on 5 October 2012 (campaign event)

2012 October 4-8 (DW; KM) CME. This event has been recommended by ISEST and SPeCIMEN.

This is an excellent stealth CME, i.e., a strong CME in the inner corona and ICME, but the solar disk signatures are multiple and weak, and it had slow propagation to Earth.

At Earth a smaller storm, Dst=-105. Electron acceleration in the radiation belt has been studied by Reeves, G.D. et al (2013).

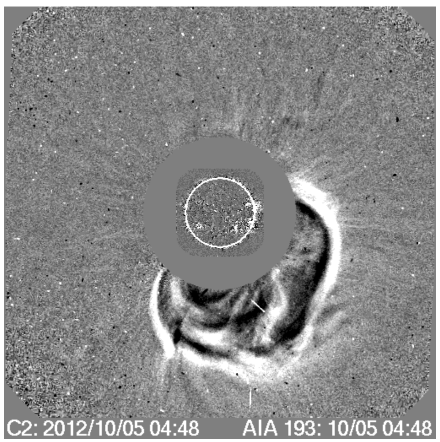
(P)roblem event.
URL: http://solar.gmu.edu/heliophysics/index.php/10/08/2012_05:00:00_UTC

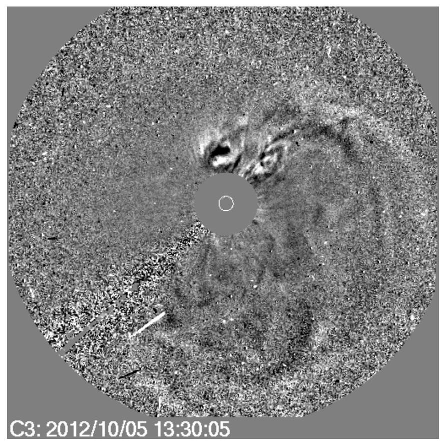


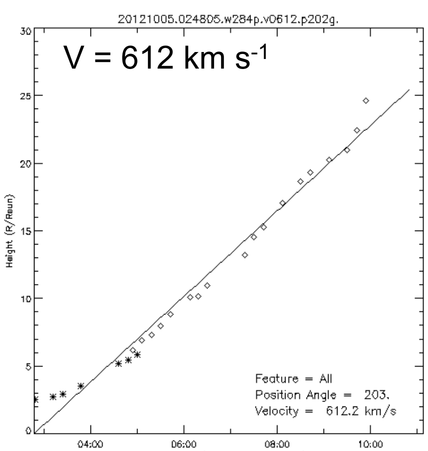
2012-10-08 ICME, 2012-10-05 CME

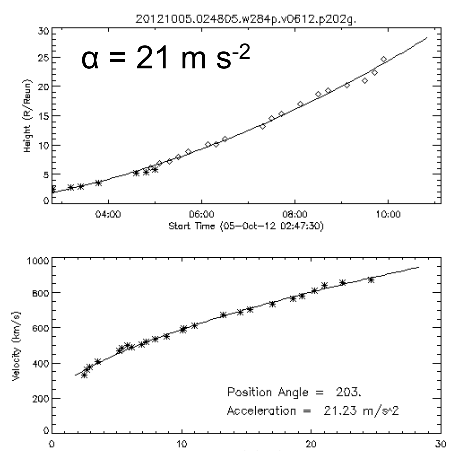
This was first selected by ISEST because of a possible stealth CME.

The only halo CME in the possible time window that may account for the ICME is:







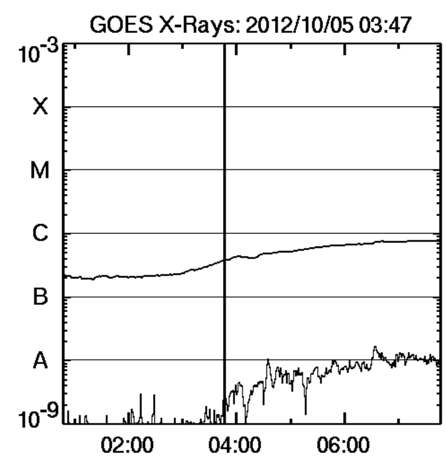


But How can this be a stealth CME?

The CME is quite bright.

It is not slow.

It is associated with a slow B8 flare.



2012-10-05 CME

Comment Section

- This is a varSITI campaign event
- A good ICME, strong CME source, however, "stealth" surface signature (J. Zhang)
  - A good example of "stealth" CME: bright CME, but no or very weak surface signature (in terms of no flare, dimming, filament eruption etc)
- This event has a very difficult to distinguish source region, if you look very closely at S22 W38 just before 00:00 UT on the 10/05 it is possible to see a very small disturbance on the Sun, especially in 304 Angstroms. (Hess)
- M. Temmer: clear on-disk signatures - movie from SDO - are visible. It is a "silent" CME, hard to catch for space weather forecasters, but not a "stealth" in sense of no solar surface signatures at all.

http://sdowww.lmsal.com/sdomedia/SunInTime/2012/10/04/daily_211-193-171.mov [October 4, 15UT, central south]

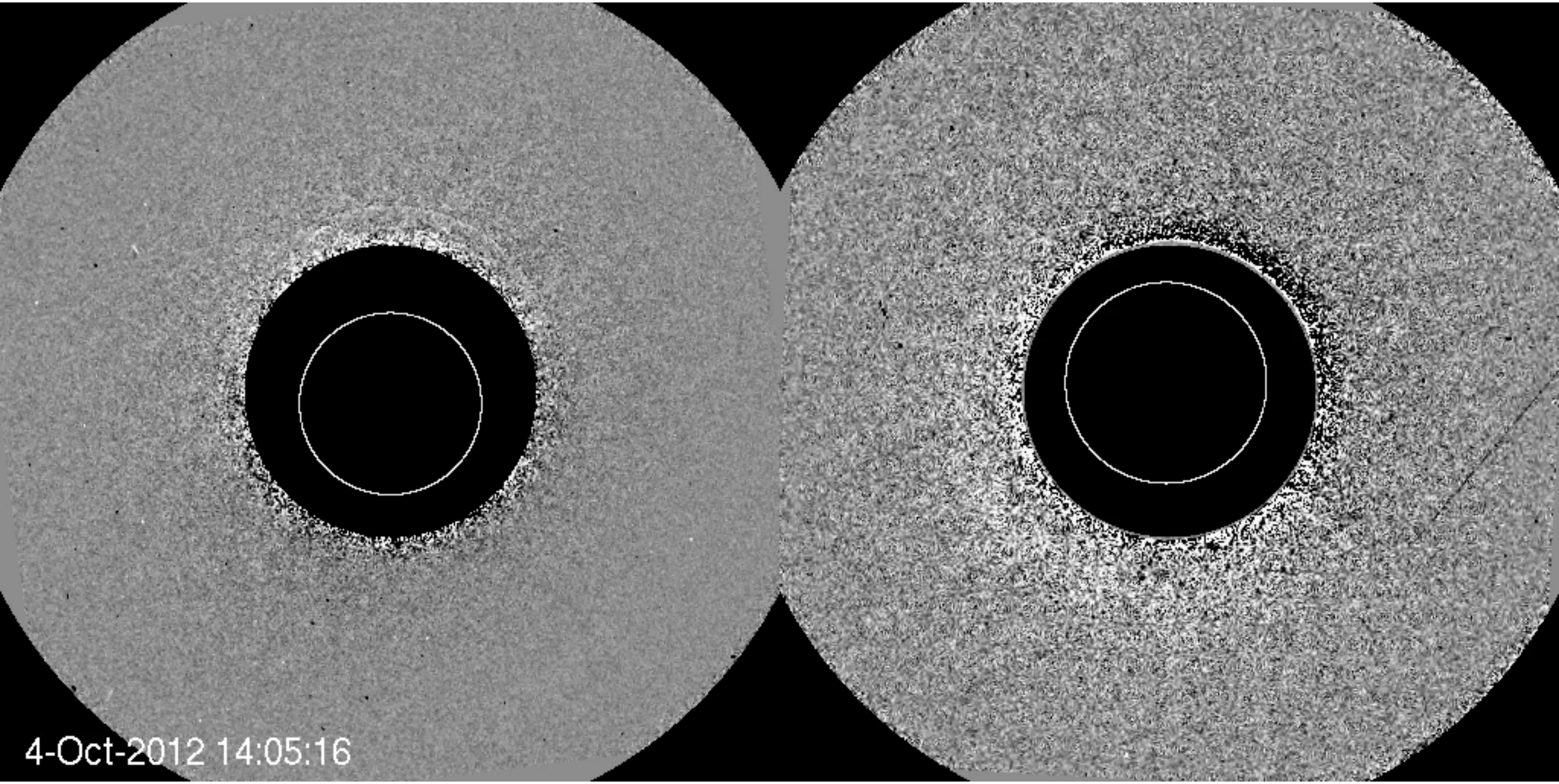
I put some images showing clear coronal restructuring and some discussion points under> http://www.uni-graz.at/~temmerma/download/varsiti/

- C. Moestl: looking at the whole October 4 SDO movie, there are also two other minor eruptions which I find very hard to distinguish from the 15 UT one (1. 7 UT, slightly west of disk center; 2. 0930 UT, south-east quadrant)
- timing - evolution from SDO FoV to coronagraph - is an issue and needs to be looked at in detail
- these eruptions are also visible in the SWAP data (http://proba2.oma.be/), including another minor one at 14h UT in the south-east quadrant (A. Devos)
- Discussion in USTC-China ISEST Workshop on April 19, 2014
  - Inferred from GCS model based on STEREO/A, STEREO/B and SOHO coronagraphs, longitude W11 deg, latitude S20 degree
  - Around this position, there was a minor activity from 14 to 15 UT on Oct. 14 seen in SDO AIA 193 images. The activity appeared as a weak dimming followed by a diffuse brightening.
  - In EUVI-A 195, from 22 UT on Oct. 14, there was a very faint eruption above the south-east limb. This beyond-limb faint eruption is consistent with the heliospheric position of W11S20.
  - The CME continued to accelerate to about 10 Rs with a peak speed of 800 km/s at 06 UT, Oct. 15.
  - If the eruption started at 14 UT, Oct. 14, it took a long time (10 hrs) for the eruption to reach the COR1 FOV. It indicates that the eruption has a long-lasting low-speed low-acceleration phase

2012-10-05 CME (STEREO COR-1)

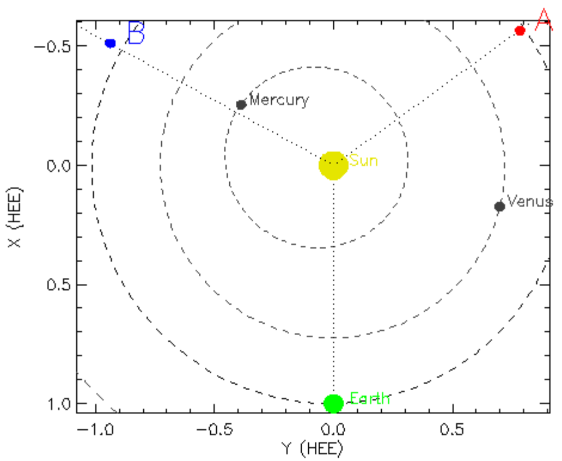
Indeed, it is extremely hard to find anything convincing in AIA intensity or running difference images.

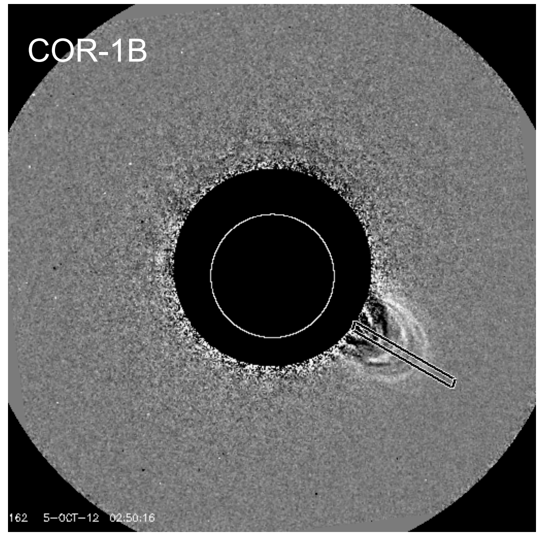
First study data from STEREO, which gives a limb view of the regions close to the central meridian from Earth.

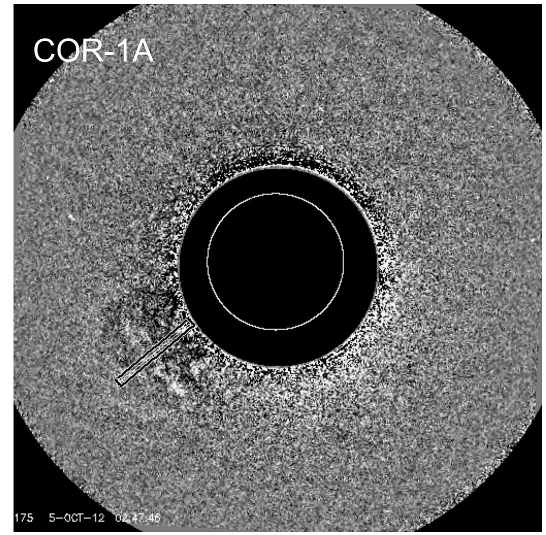


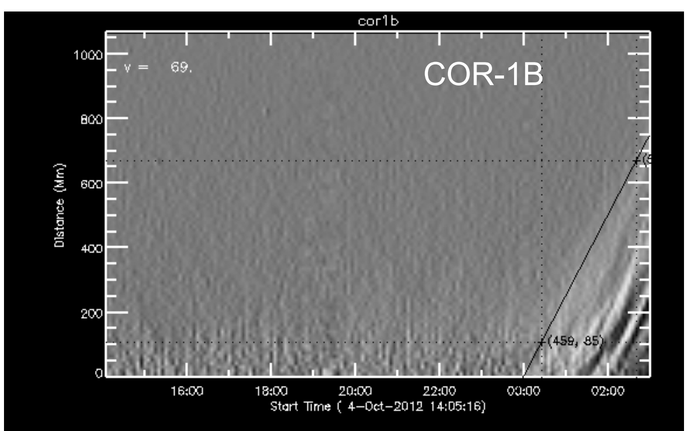
2012-10-05 CME (STEREO COR-1)

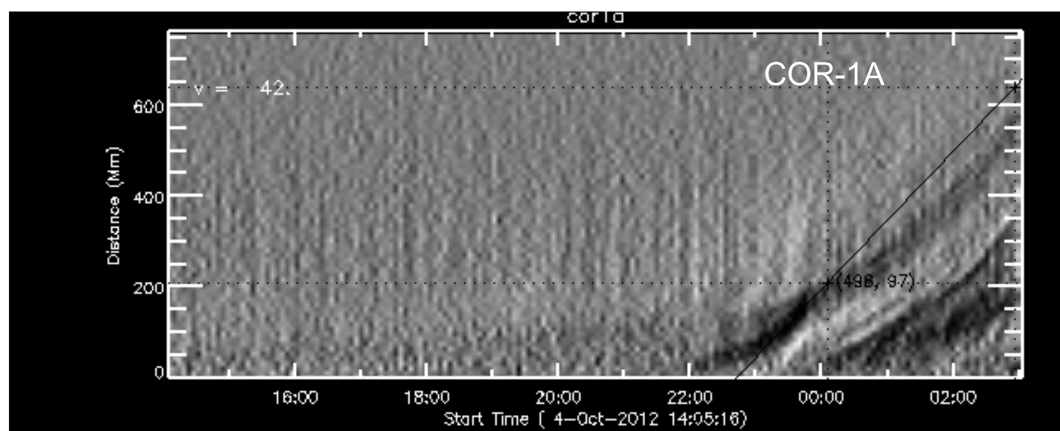
Time-distance profiles from COR-1 data, although not clean, indicate that the eruption reached ~1.5 Rs (heliocentric) only around 5 October 2012 00 UT.





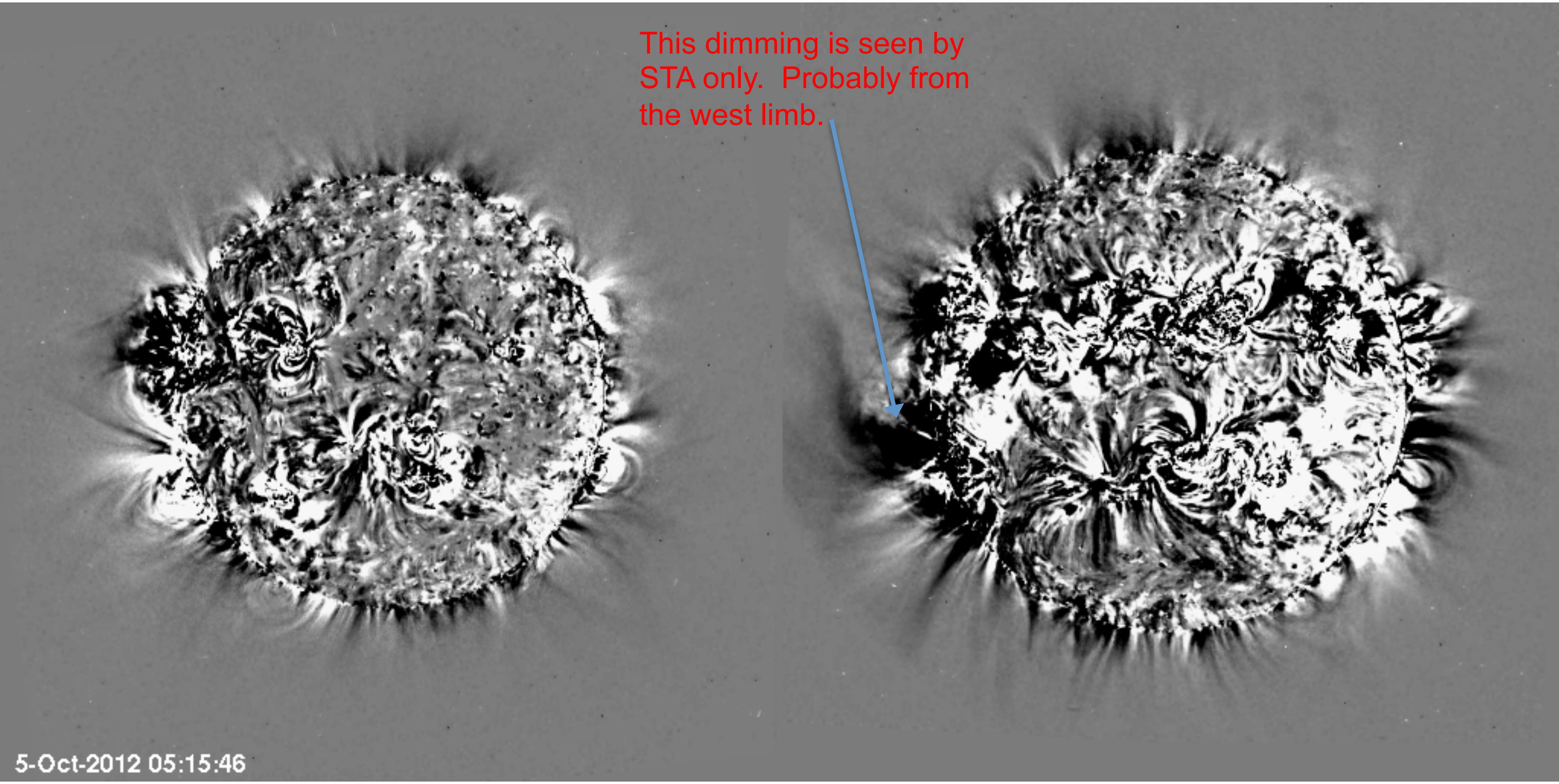






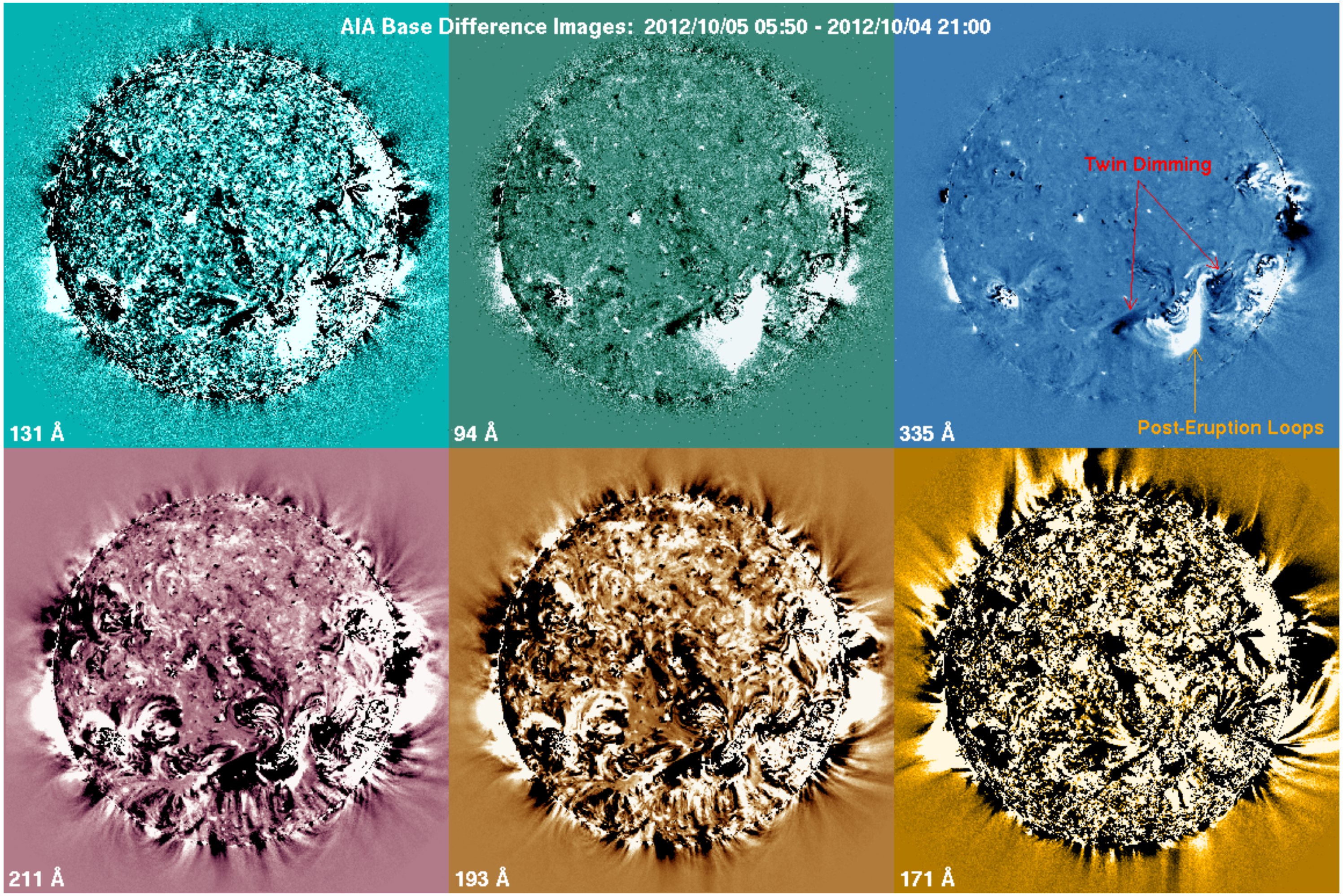
2012-10-05 CME (STEREO EUVI)

EUVI base difference images show that the outgoing motion got accelerated around 5 October 2012 00 UT. Dimming is marginal.



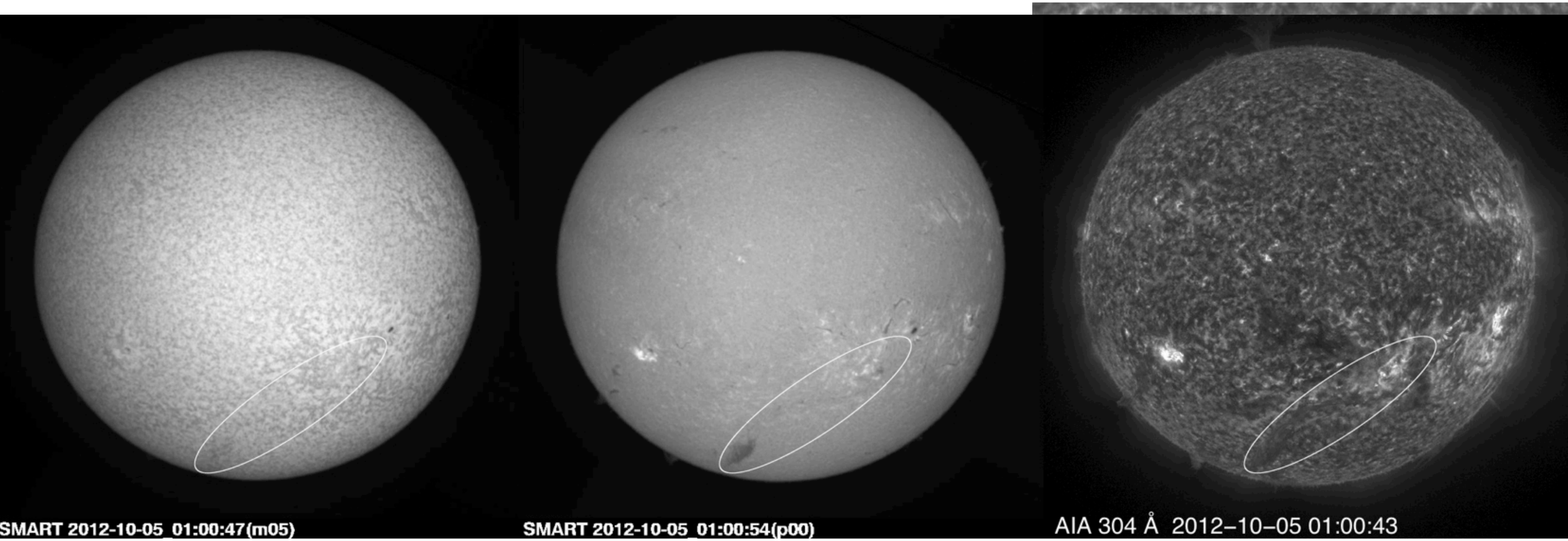
2012-10-05 CME (AIA)

Make AIA base difference images to find dimming. They clearly show post-eruption loops (at high temperatures) and twin dimming. The location is consistent with the UTSC-China finding of S20 W11 (see wiki). Note another dimming on the west limb, which was also seen by EUVI-A.



2012-10-05 CME (at low temperatures)

Hα and 304 Å images suggest that the elongated region to the southeast of the flare was involved in the CME. None of these images show a coherent filament eruption, but dynamic motions in the filament channel.



2012-10-05 CME (at low temperatures)

Hα and 304 Å images suggest that the elongated region to the southeast of the flare was involved in the CME. None of these images show a coherent filament eruption, but dynamic motions in the filament channel.

The AIA 304 Å movie shows the spreading flare ribbons.

We suggest that this was not a stealth CME. It was bright and fast, accompanying a B-class flare. Instead, this was a “stealth-like” CME. We just need to examine base difference (ratio) images over a long period that extends to several hours after the CME detection.

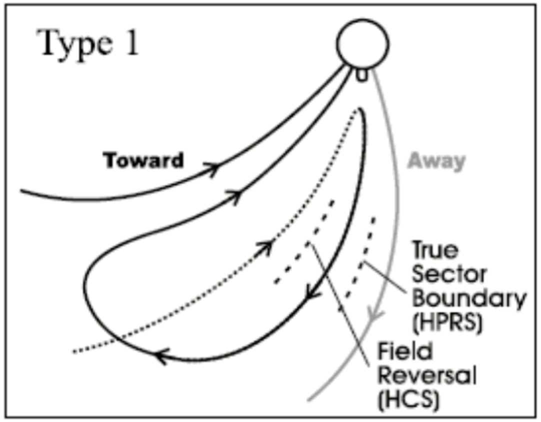
Stealth or Stealth-like CMEs

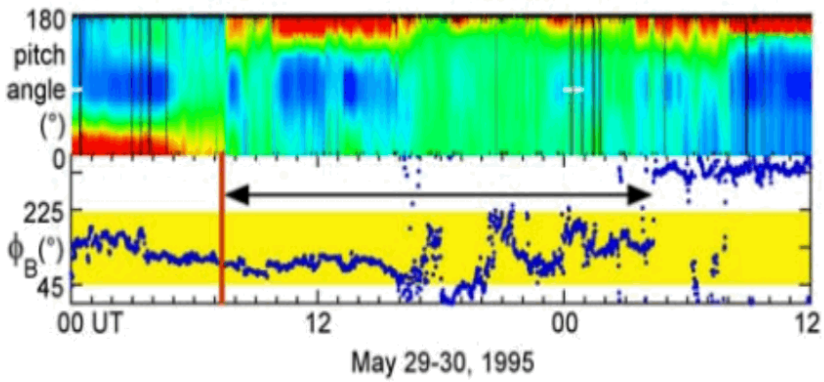
They seem to represent those ICMEs in the Richardson-Cane list without a candidate of halo CME.

They tend to occur close to a coronal hole, and we may spot the origin by closely monitoring the coronal hole boundaries.

They may be responsible for the field inversion at sector boundaries.

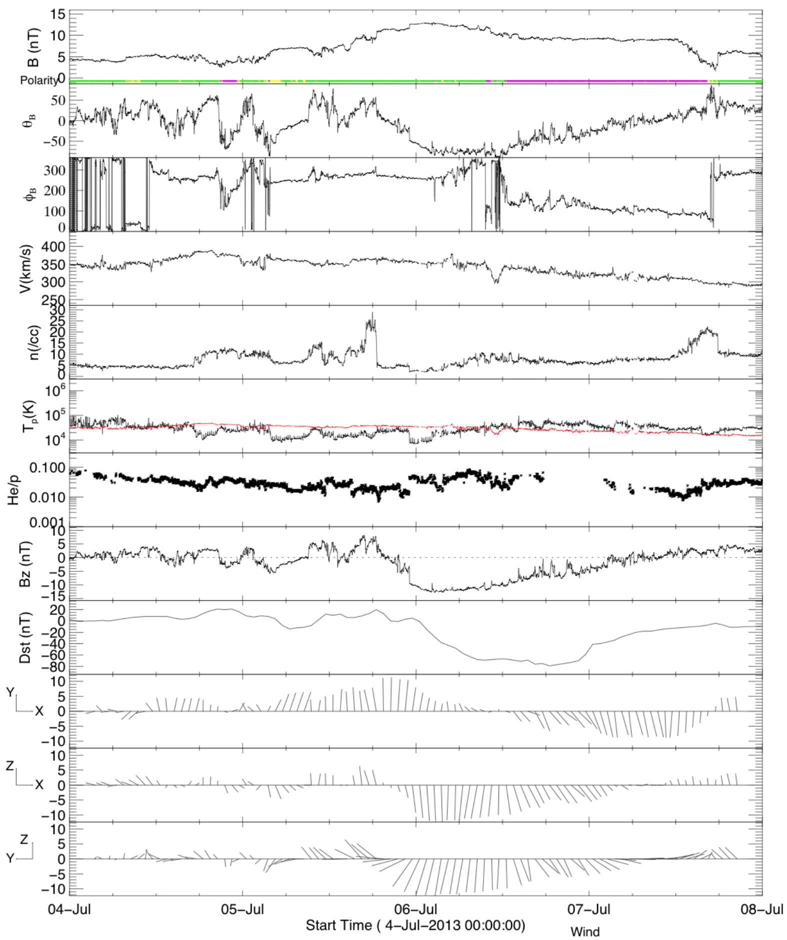
They may be a consequence of continuing loop expansions.



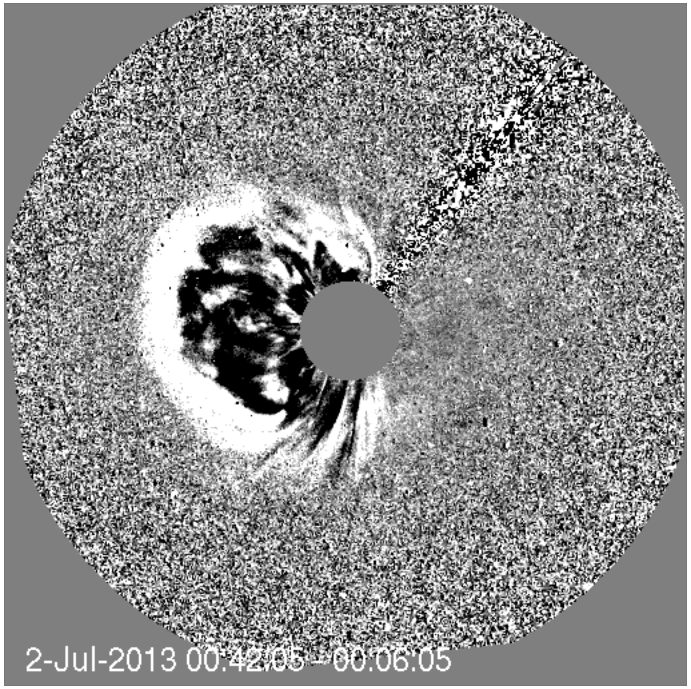


ICME on 5-6 July 2013

During June-July 2013, there were a few ICMEs whose origin is not well understood. One complication may be the presence of a CIR. But the one on 5 July 2013 may be a simpler ICME.



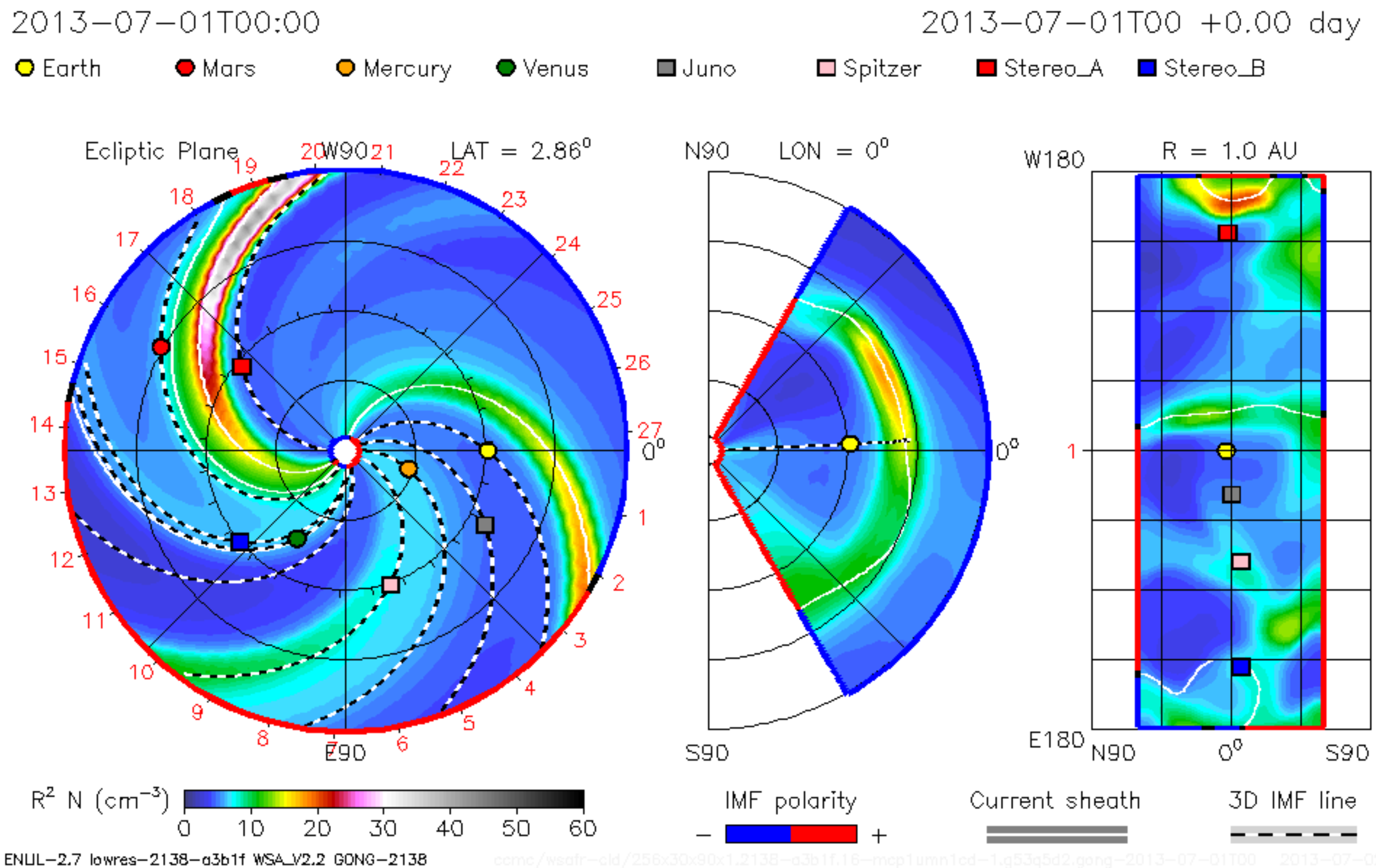
Following the usual procedure, the only clear halo CME during the interval of interest was considered to result in the ICME.



But the CME originated from the region close to the east limb.

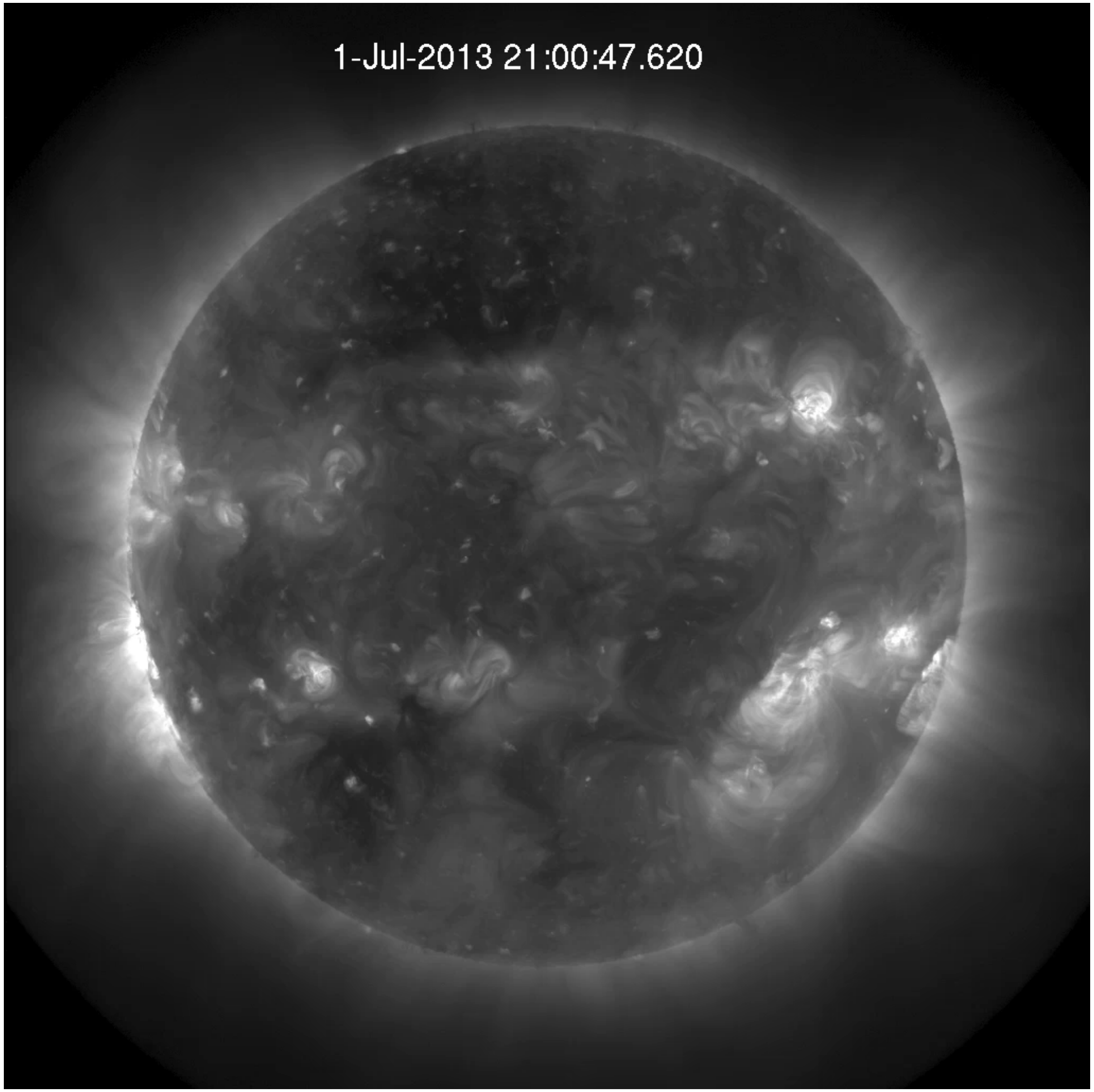
ICME on 5-6 July 2013

ENLIL at CCMC (predict arrival around 5-Jul-2013 but flank encounter)

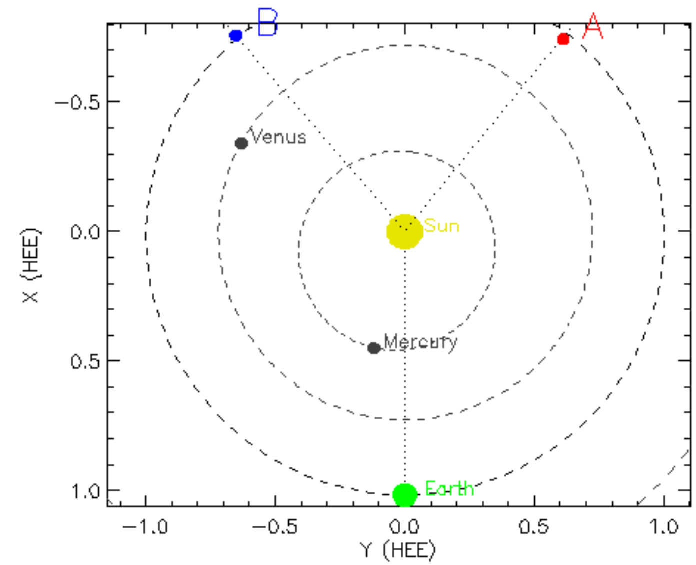


ICME on 5-6 July 2013

ENLIL at CCMC (predict arrival around 5-Jul-2013 but flank encounter)



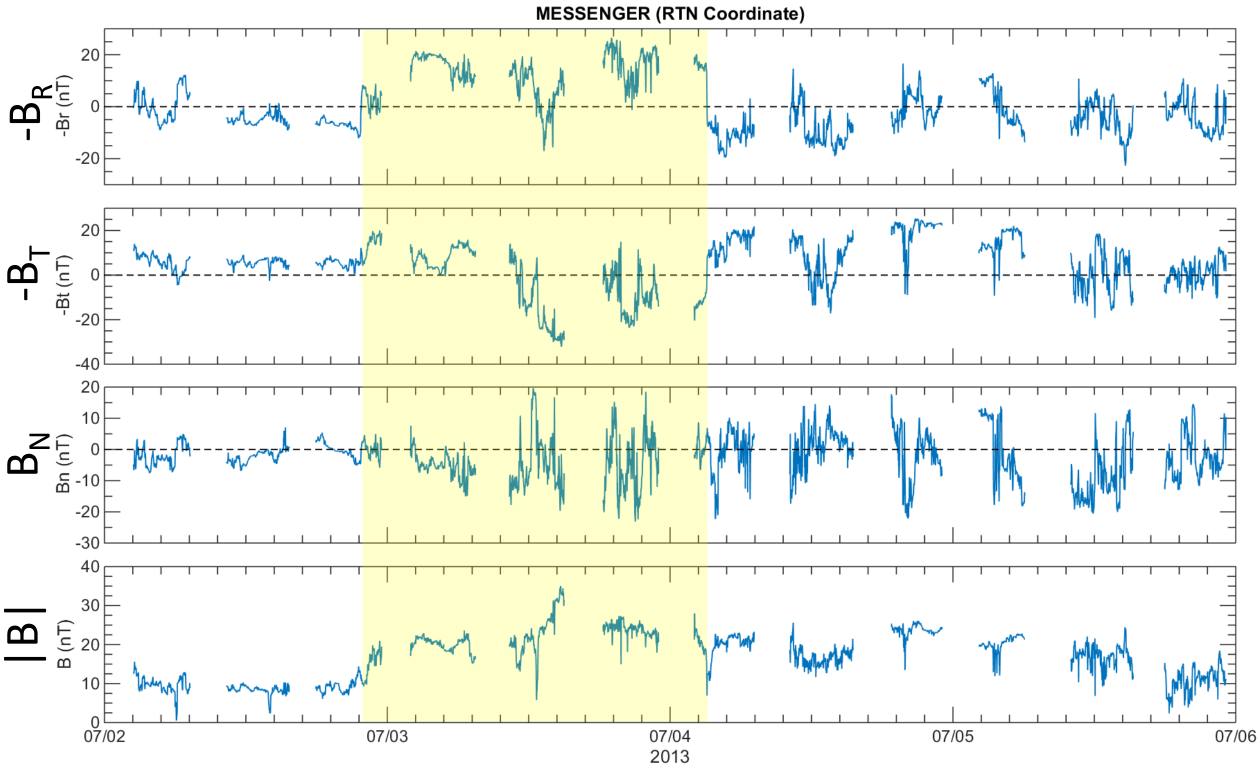
This is likely to be an eruption on a much smaller scale, and was not observed by STEREO.

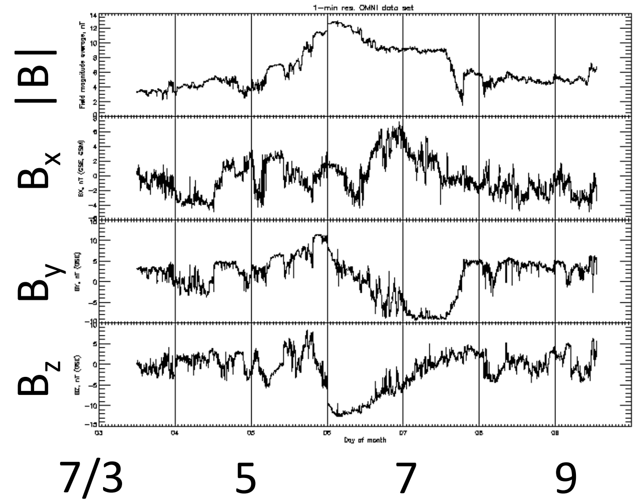


Before LASCO, people used filament eruptions like this for studying ICMEs.

ICME on 5-6 July 2013

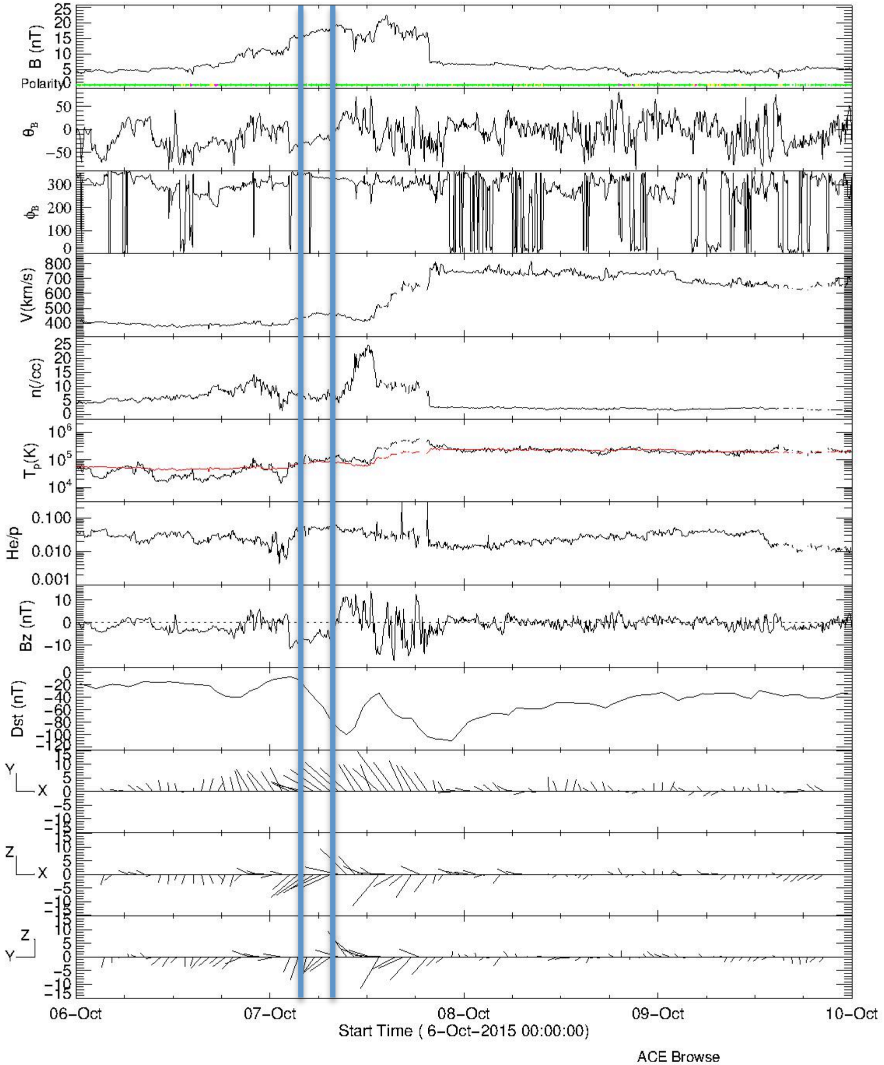
Messenger (0.46 AU) MAG data





The magnetic field observed at Mercury on 3 July was somewhat similar to that observed at 1 AU during 5-6 July.

Pure HSS (or CIR) or CME Embedded?



Summary

Helped by STEREO observations, especially during 2010−2012, SDO AIA can *in principle* observe the nascence of all CMEs from the visible side. In reality, however, there are still many CMEs, whose coronal signatures do not come out with standard analysis procedures.

Some of them could be found out by expanding the time ranges, changing the sampling, comparing different channels (temperatures) and using difference and ratio techniques.

These “stealth-like” CMEs tend to occur close to a coronal hole, and interchange reconnection may play a role in their initiation. They may also manifest in minor flux ropes sometimes seen embedded in CIRs, also partly account for the mismatched sector boundaries.

The origins of the remaining “real stealth CMEs” may be found out with particular attention to their possible proximity to a coronal hole. Eventually we will be able to address the question of whether the stealthiness depends largely on the CME’s initiation height or there are other important factors.

Stealth and stealth-like CMEs may contribute to the orphan ICMEs whose corresponding CME is not unambiguously found.