Stealth Coronal Mass Ejections and properties of its associated ICME

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June 30, 2023, 12:00 to 12:20 pm

Coronal Mass Ejections

Coronal mass ejections (CMEs) are large eruptions of solar plasma, embedded with the solar magnetic field. Upon occurrence, typically one or more signatures are observed in the lower solar atmosphere, such as filament eruptions, solar flares, post-eruptive arcades, EUV dimmings, and EUV waves that enable the CME source region to be identified. (Webb & Howard 2012)

Back sided CME events

We used to attribute CMEs without observable low coronal signatures to be a back-sided event.

This lack of association makes it difficult to determine their solar source region.

CME - not backside - but without low coronal signatures

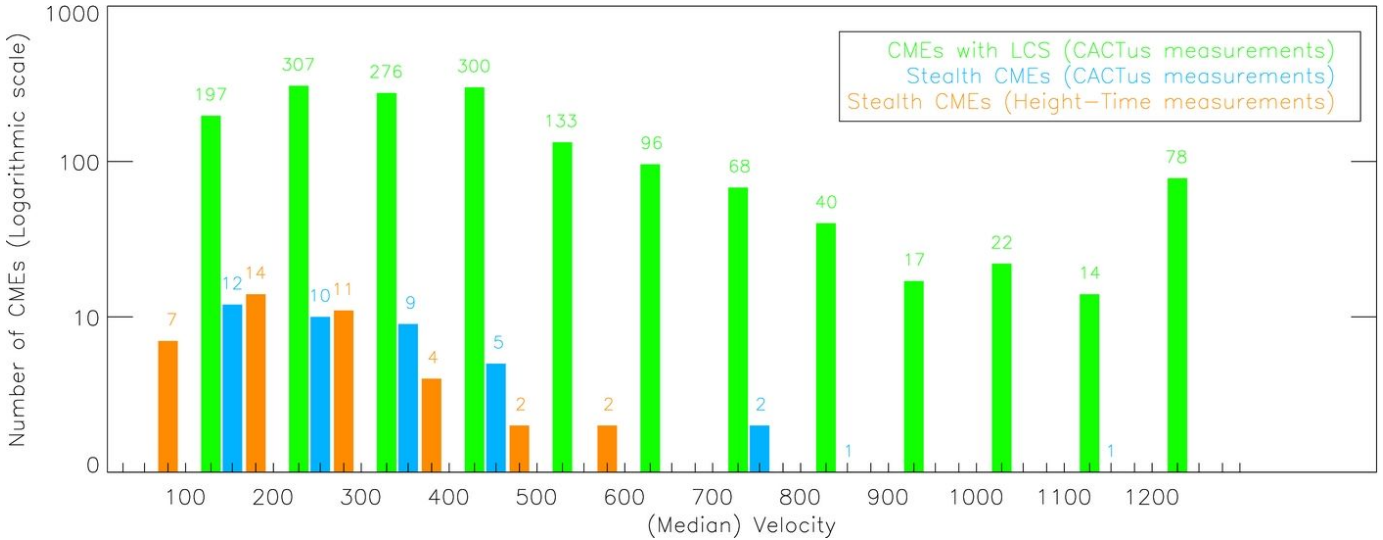
The launch of the twin Solar Terrestrial Relations Observatory (STEREO) spacecraft (Kaiser et al. 2008) enabled the CME propagation direction to be determined, and therefore the identification of which side of the Sun the CME originated from, using geometric triangulation techniques.

Stealth CME

CMEs without associated eruptive or dynamical phenomena low in the solar atmosphere: solar flares, flows, magnetic reconfiguration, EUV waves, jets, coronal dimmings or brightenings, filament eruptions, or the formation of post-flare loop arcades but not back sided are identified.

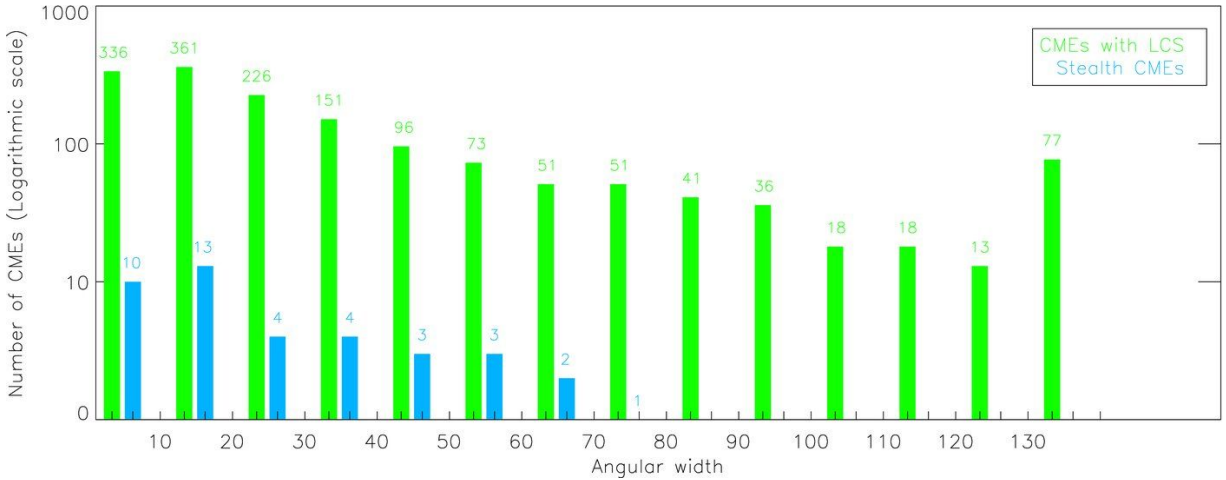
Lack of association makes it difficult to determine their solar source region - Robbrecht et al. (2009) named those eruptions that are seen in coronagraph data but that leave no observable signatures in the low corona as "stealth" CMEs.

Velocity Distribution of Stealth CMEs



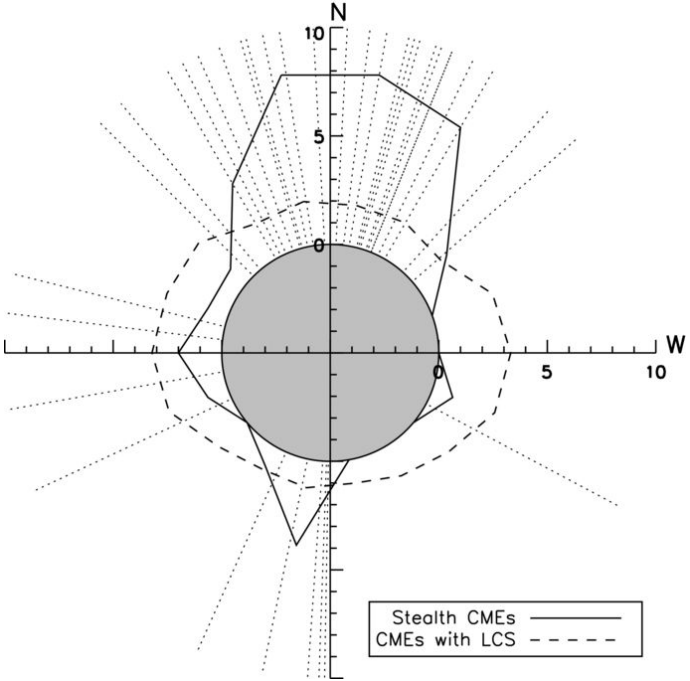
Median velocity for coronal mass ejections with and without low-coronal signatures as measured by the CACTus algorithm and plotted on a logarithmic scale (E. D'Huys *et al* 2014)

Angular Width of Stealth CMEs



Angular width for coronal mass ejections with and without low-coronal signatures (E. D'Huys *et al* 2014).

Position Angle of Stealth CMEs



Principal angle of propagation of coronal mass ejections with (dashed line) and without (full line) low-coronal signatures (E. D'Huys *et al* 2014).

Present Work

The purpose was to study the Stealth CMEs and associated ICMEs derived from the available online catalog i.e. LASCO SOHO CME catalog, CACTus catalog, STEREO data, ACE data, Wind data and OMNIWEB data.

Data are selected from the online catalog for various parameters from STEREO spacecraft and ACE and Wind spacecraft. All the magnetic and plasma parameters are plotted for the date of ICME 2-4 days after and before.

Parameters which are considered for studying the ICMEs associated with Stealth CMEs are as follows:

Magnetic Parameters (1 AU)

Total magnetic field component and Bx, By, Bz components

Plasma Parameters (1 AU)

Solar wind speed, Proton density, Proton temperature, Plasma Beta, Theta, Phi

Selected Stealth CMEs are classified in two types one consist of earth directed Stealth CMEs and another consist of not earth directed. 5 cases of Stealth CMEs are studied. ICME parameters for three of these Stealth CMEs are presented here.

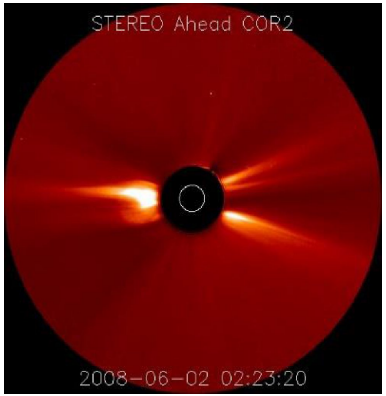
Stealth CMEs under study and its ICME characteristics

Sr No.	CME Date	CME Time (UT)	CME PA (deg)	Width (deg)	CME Speed (km/s)	ICME at L1 point Date	ICME	Location
1.	Jun 2nd, 2008	04:46	95	120	192	June 6th	15:50	STB
2.	Mar 3rd, 2011	06:12	169	206	263	Not Seen	Not Seen	Not Seen
3.	Feb 23rd, 2012	19:36	27	29	381	Not Seen	Not Seen	Not Seen
4.	Jan 3rd, 2015	03:12	118	153	163	Jan 7th	06:20	L1
5.	Oct 9th, 2016	02:12	329	Partial Halo	128	Oct 12th	21:22	L1

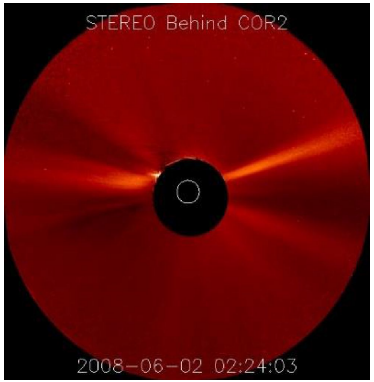
Stealth CME of 3rd June 2008

First case of stealth CME is of June 2nd 2008. This CME reached at L1 point on 6th June 2008 at 15:50 UT. In this case the PA was 95 so the CME was not Earth directed. But in the year 2008 the position of STEREO spacecraft was as shown in figure. The CME was observed by both the twin spacecraft.

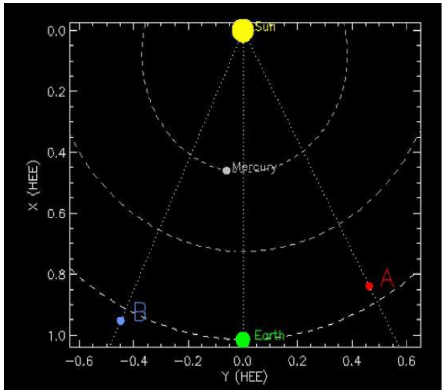
(a) STA COR2



(b) STB COR2



(c) STEREO location on June 2008



It was seen faint in STB as compared to STA. The coronagraph images taken from STA and STB. It can be seen in figure. The CME was observed by both the twin spacecraft. From the coronagraph images taken by STA and STB are shown in figure, the faint structure of CME can be seen in STB and clear structure can be seen in STA.

ICME Parameters *June 06, 2008*

Shock Time	*15:52 UT*
Bz	*-10 nT*
B Tot	*14.50 nT*
Proton Density	*34.55 n/cc*
Temp	*2.8E5 K*
Flow Speed	*430km/s*

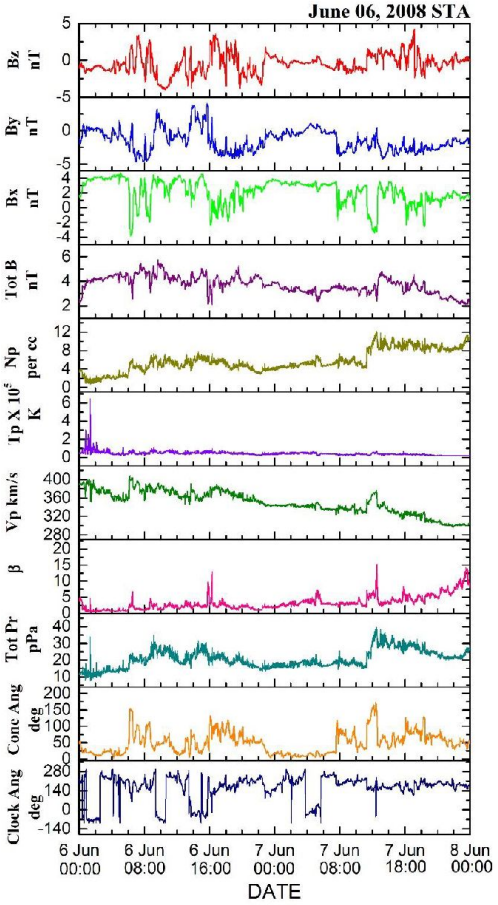
ICME Parameters

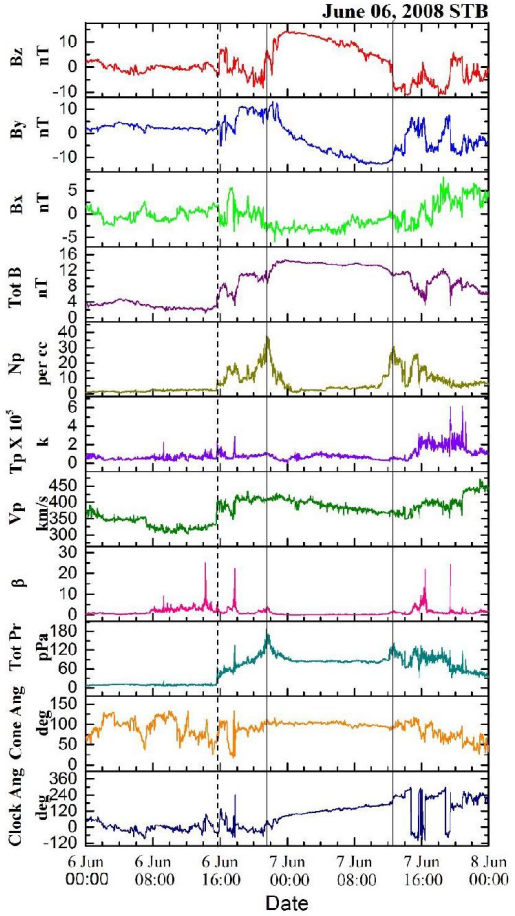
ICME parameters for plasma as well as magnetic parameters are plotted for the ICME at STB. As ICME has only reached to STB not to STA because the direction of the ICME was towards STB. This storm was not Earth directed. Here one thing is to be mentioned that Bz for this storm was ~ -8.6 nT and there was a mild shock can be seen from figure.

ICME Parameters

The ICME did not arrive at STA or at L1. But, from the ICME parameters at STB seeing that it would have produced a strong storm if it would be Earth directed. ICME parameters for this ICME are as shown in table. The shock arrival time at STB was 15:52 UT.

ICME parameters for June 6, 2008 in STA and STB





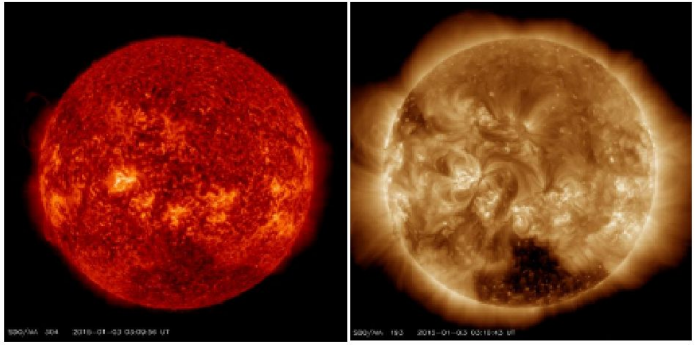
This implies that although there are no coronal signatures of Stealth CME, the IP CME signatures are strong enough to produce a geomagnetic storm if directed towards the Earth.

Stealth CME of January 03, 2015

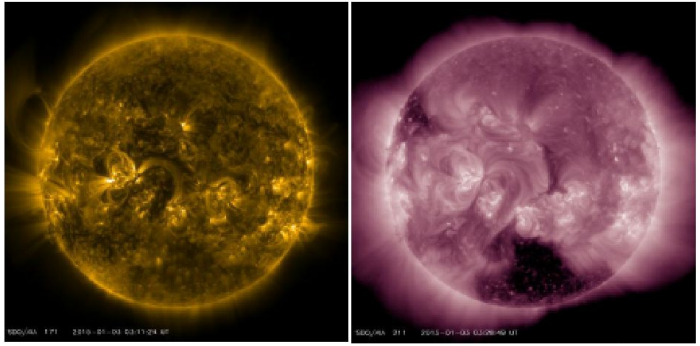
This stealth CME the event occurred on 3rd January 2015. It reached at L1 point on 7th January 2015 at 06:20 UT. In this case, the CME occurred near a southern coronal hole of the Sun. There was not any LCS seen as shown in figure.

Images of the Sun taken from

SDO/AIA for Jan 03, 2015



(a) SDO/AIA 304A^{O} (c) SDO/AIA 193 A^{O}

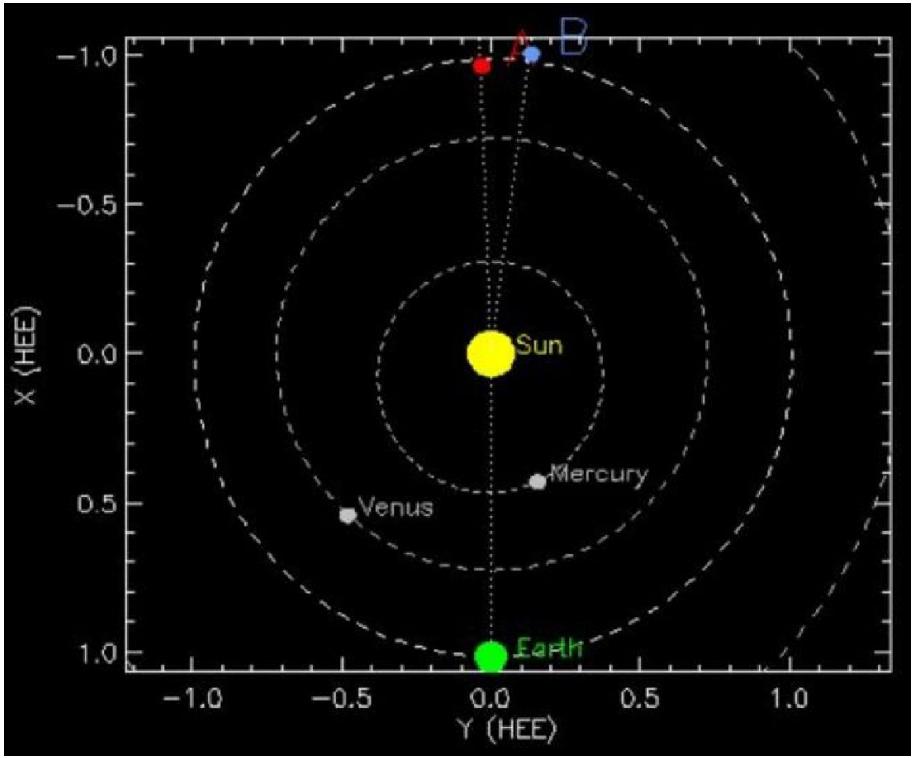


(b) SDO/AIA 171 A^{O} (d) SDO/AIA 211 A^{O}

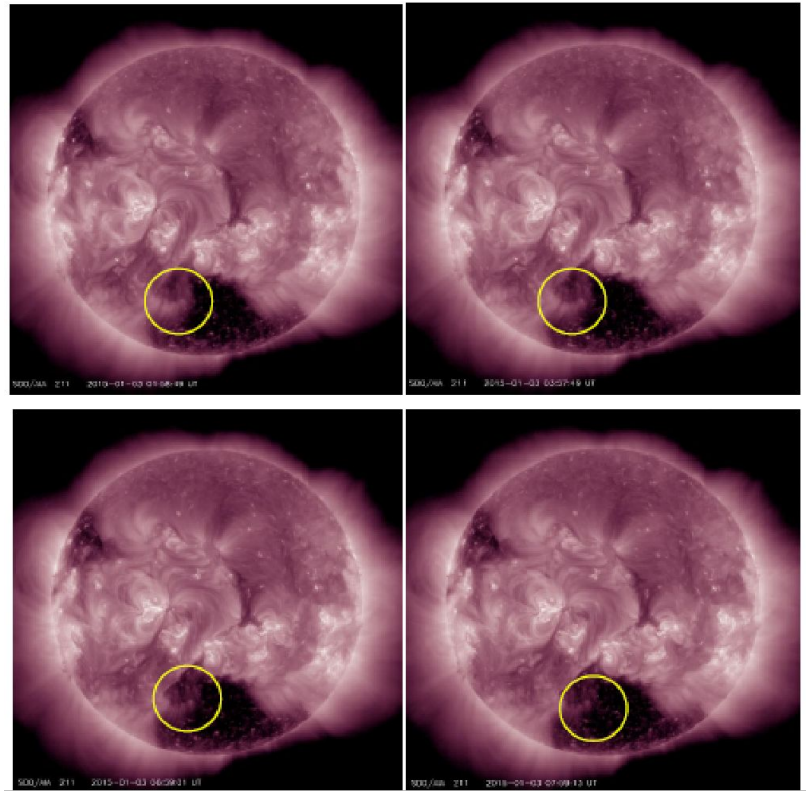
Images taken from *https://sdo.gsfc.nasa.gov/assets/img/browse/*

No storm was forecasted, however Dst value was less than 100 nT so it produced a strong storm. ICME parameters for plasma as well as for magnetic parameters are plotted in the figure by using ACE/Wind data.

At this time the STEREO location was as shown in figure and can be seen that location was unfavorable so CME was not observed by STEREO.



211 A Images showing plasma amount disappearing gradually from a Southern coronal hole.



Images taken from *Images taken from SDO/AIA for Jan 03, 2015*

ICME parameters for Jan 07, 2015

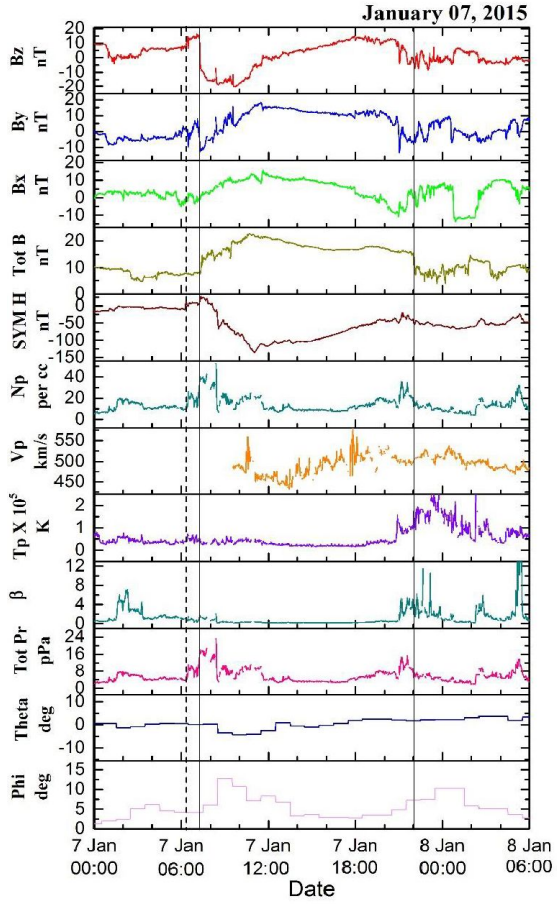
Shock Time	06:10 UT
Bz	-20 nT
B Tot	9.65nT
Proton Density	34 n/cc
Temp	4.1E5 K
Flow Speed	480 km/s
SYM H	-135 nT

The ICME parameters are shows the properties of ICME.

The Bz component was -20 nT for several hours leading to a strong storm of Dst under -150 nT.

The proton density was of the order of 40/cc and total B was 20 nT.

ICME parameters for Jan 07, 2015 recorded at L1 by ACE/WIND spacecraft



Images taken from *https://cdaweb.sci.gsfc.nasa.gov/index.html/*

The storm was strong but a mild shock can be seen in ICME plot in figure.

The shock arrival time at L1 point was at ~ 06:10 UT.

A mild shock at 6:10 UT and solid line shows the boundaries of the ICME.

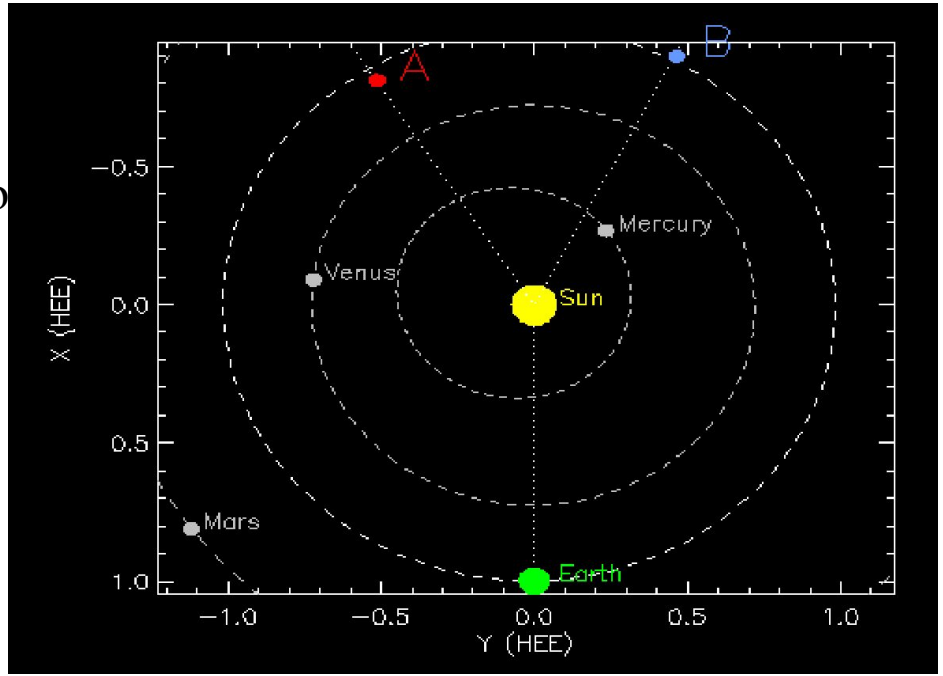
Stealth CME of October 09, 2016

This Stealth event was also Earth directed and had produced strong geomagnetic storm of Dst < -100 nT.

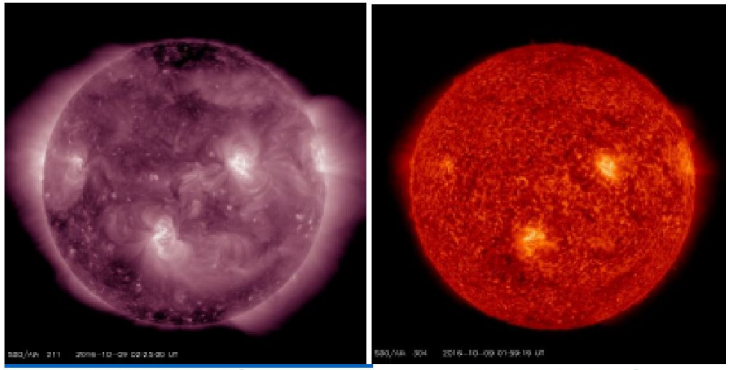
The source location of this event was unknown.

The STEREO location fo

Oct 2016.



Images of the Sun taken from SDO/AIA on Oct 09, 2016



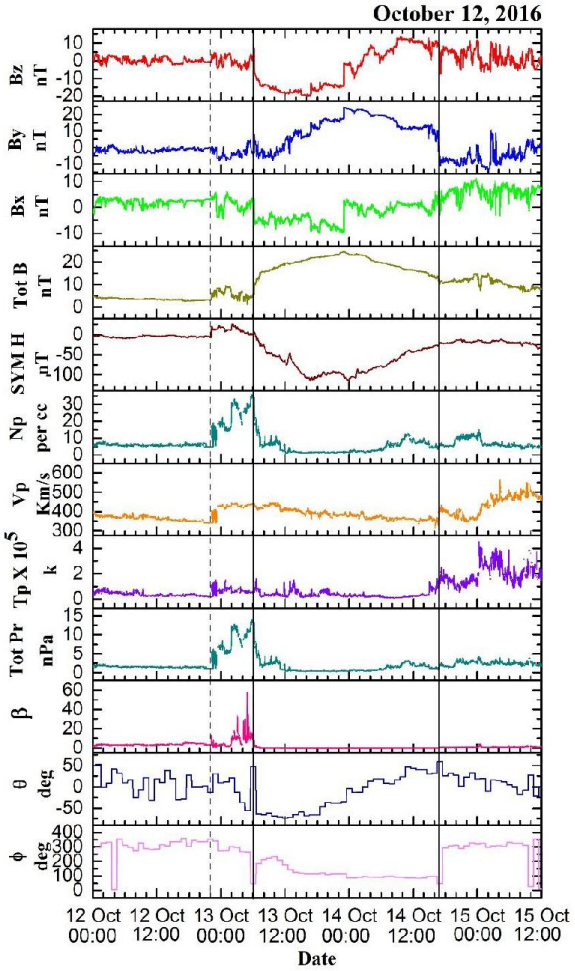
(a) SDO/AIA 211 A^O (c) SDO/AIA 304 A^O

(b) SDO/AIA 193 A^O (d) SDO/AIA 171 A^O

Images taken from *https://sdo.gsfc.nasa.gov/assets/img/browse/*

There is no particular LCS seen in the different wavelength in SDO figures. Another noticeable thing was its initial speed was low and the CME was forecasted to arrive at earth by Oct 13th but has arrived on Oct 12th itself.

ICME parameters for October 12, 2016 recorded at L1 by ACE/WIND spacecraft



It can be seen from the figure that temperature goes down and along with that magnetic field value also varies and plasma beta also decreasing which shows the characteristics of Magnetic Cloud.

Though this event came out to be a Stealth CME but it led to strong geoeffective storm. This event was not seen in any of the STEREO spacecraft.

The shock denoted by dotted line can be seen for this ICME.

Storm is denoted by solid line.

Shock arrival time was at 21:22 UT on Oct 12th, 2016.

Summary

From the study of these Stealth CMEs and their associated ICMEs as recorded by ACE/WIND spacecraft and STEREO spacecraft we found as follow:

Summary

All the Stealth CMEs studied here have low initial speed (300 km/s) and small angular width and originated from Polar Regions.

Summary

ICMEs associated with Stealth CMEs have minor shocks as compare to regular ICMEs.

Summary

In the June 2008 event the shock and ICME structure arrived at STEREO B but did not arrive at the Earth.

Summary

For the event of January 2015 and October 2016 the shock is minor and it reached the Earth and led to a Geomagnetic storm (-120 nT & -100 nT).

Discussion

E. D'Huys *et al* 2014 suggested that based on their low velocities, gradual acceleration, limited angular width, and, most importantly, the absence of LCS of eruption, it is likely that stealth CMEs are not very energetic events.

Discussion

Presumably, all available energy goes into expelling the CME, and little is left to leave observable eruption signatures on the solar disk.

If in fact the initiation of CMEs without LCS occurs at larger heights, this might explain why we observe stealth CMEs to be predominantly narrow and slow.

Thank You.