ISEST WG4 Report: Campaign Events Summary and Future Plans

Wednesday, 20 Sep 2017
Session 5: WG4

09:00 - 10:00 Marubashi
10:00 - 10:20 Schmieder
10:20 - 10:40 Wang
10:40 - 11:10 Coffee Break
11:10 - 11:30 Nitta
11:30 – 11:50 Srivastava

Nariaki Nitta (LMSAL)

ISEST 2017 Workshop Jeju, Korea

22 September 2017

WG 4 Goals

- **Integrate observations, theory and simulations to understand chain of cause-effect dynamics from Sun to Earth/1 AU for carefully selected events.**
- **Develop/improve the prediction capability for these transients' arrival and their potential impacts at Earth.**
- **Textbook cases are provided for the community, but a focus is on less well understood events, such as stealth & problem CMEs.**
  - WG 4 wiki: *http://solar.gmu.edu/heliophysics/index.php/Working_Group_4*

• Textbook cases: Complete chain of a well-observed event from solar source, through IP propagation, to geoeffects.
• Not Textbook but Understood cases: Something is missing in the chain of a well-observed event but, *in retrospect,* we understand why.
• Problem cases: The chain is not complete and we do *not* understand why.

- ICME and storm but source is faint or missing (a "stealth" CME) or multiple sources
OR
- Source is expected to be geoeffective but is not.

Dave Webb slide at ISEST 2015 Meeting, Mexico

ISEST 2017 Workshop, 18-22 September 2017

What we can learn from the ISEST WG4 Campaign Study of Sun-Earth events?

K. Marubashi (NICT), K.-S. (KASI)
And H. Ishibashi (NICT)

Introduction

WG 4 (Campaign Events)

Objectives:

- ♦ To understand cause-effect chain of Sun-Earth activity
- ♦ To develop space weather prediction capability

Task: To study selected events (T, U, P categories)

Present report

- ♦ Analysis of possible flux rope structure in the 11 events
- ♦ Consideration on key factors in the cause-effect chain (CME initiation, ICME propagation, geoeffectiveness, etc.)
- ♦ Report for 4 (5) selected events (Marubashi et al., 2017)

Final comments

- ♦ Difficulties in REAL predictions (cf. retrospective study)

ISEST/MiniMax WG4 Event List

ID	Dates	Solar Events	Solar Wind	Dst	Type
1	2012 July 12-14	X1 flare, CME	Shock, MC	-127	T
2	2012 Oct. 4-8	CME (stealth?)	Shock, MC	-105	P/U (solar source?)
3	2013 Mar. 15-17	M1 flare, CME	Shock, MC?	-132	T
4	2013 June 1	CME?	Shock, CIR?	-119	P (strong storm?)
5	2015 Mar. 15-17	C9 flare, CME	Shock, MC	-223	P/U (super storm?)
6	2015 June 21-24	2 M fls, CMEs	Shock, MC	-204	T?
7	2012 Mar. 7-9	X5 flare, CME	Shock, MC	-131	T
8	2012 July 23-24	2 fls, EPs	STEREO-A (Carrington-type) , T?		
9	2012 Jan. 6	CME, West-Limb	No storm, GLE at Earth		P/U
10	2014 Jan. 7-9	X1 flare, CME	Shock, No MC	-----	P/U (MC deflection)
11	2014 Sep. 10-13	X2 flare, CME	Shock, MC	-75	P/U

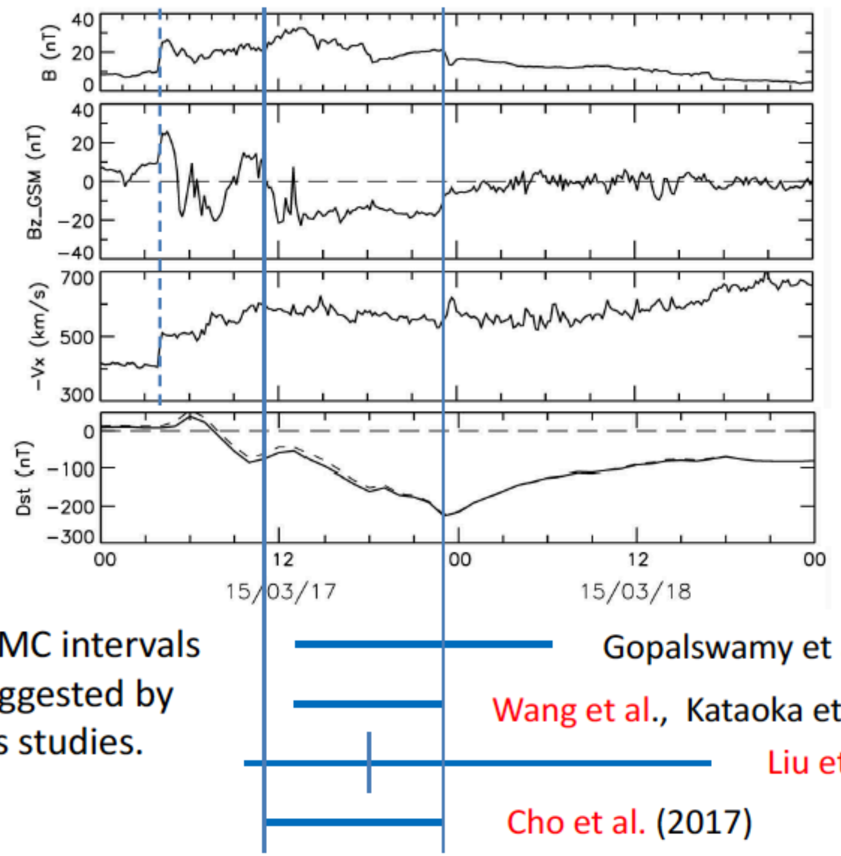
Type: T = Textbook, P = Problem, U = Understood

Only yellow-highlighted events are reported

Event 5: 2015 March: What caused such an intense storm?

Cylinder vs torus: Torus model provides better interpretation.
Dst analysis: The prolonged southward IMF caused the strong storm.

Solar wind features and corresponding Dst variation, March 17-18

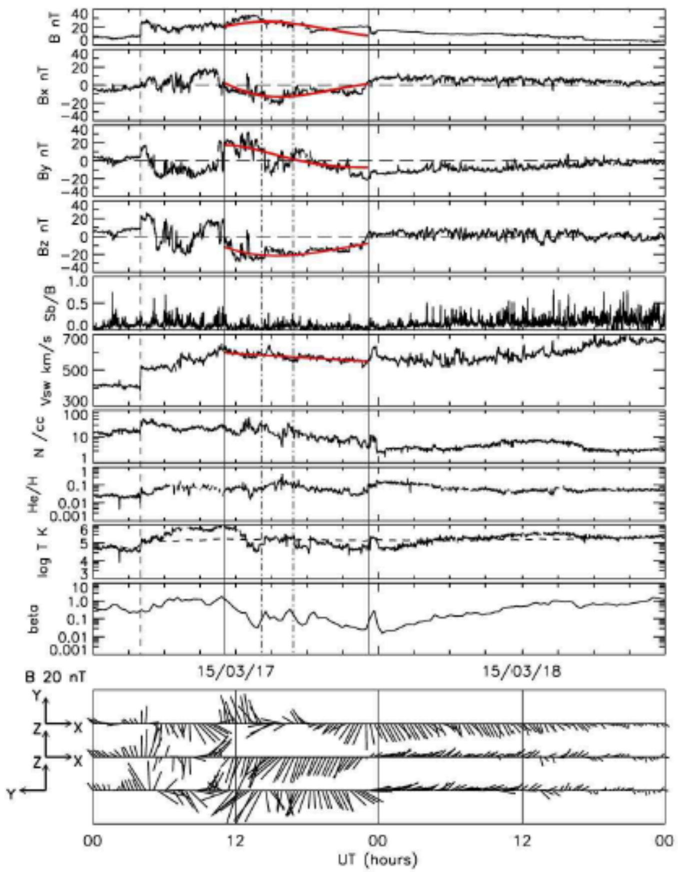


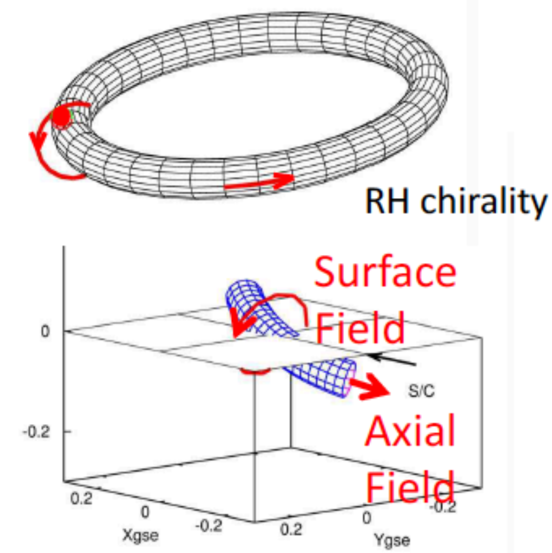
Different MC intervals were suggested by previous studies.

Gopalswamy et al.
Wang et al., Kataoka et al.
Liu et al. (2 MCs)
Cho et al. (2017)

Event 5: 2015 March

Geometry of interplanetary flux rope (torus-fit)



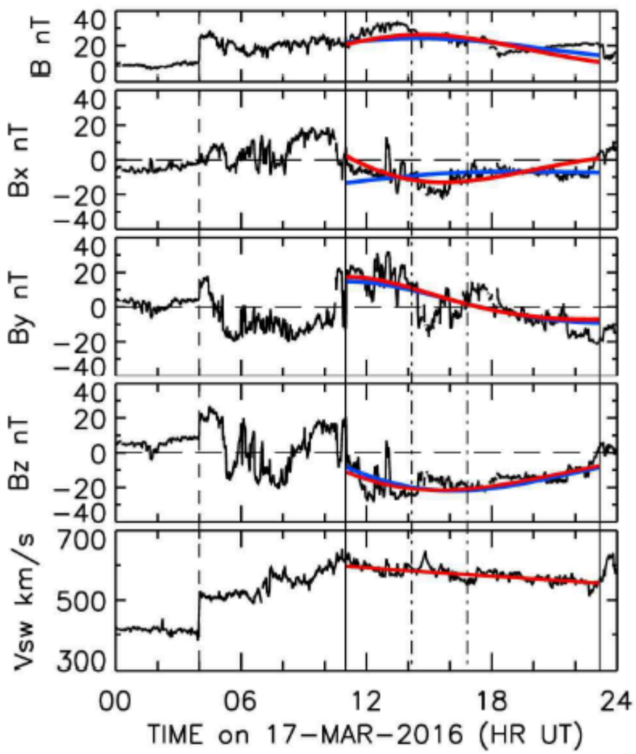


Spacecraft crossed near the eastern flank (consistent with the eruption in the western hemisphere),where the magnetic field is southward throughout passage.

Thus, prolonged southward field attacked the Earth!

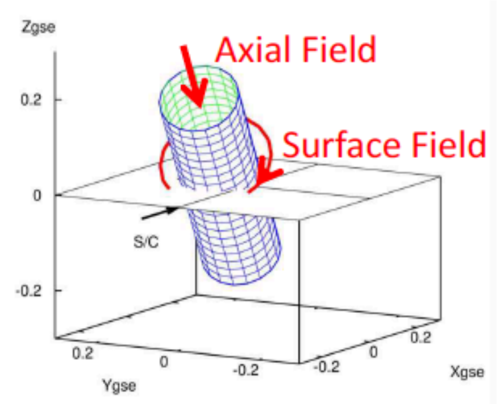
Event 5: 2015 March

Comparison: cylinder vs torus model



red: torus-fit

blue: cylinder-fit



cylinder model

Fit is not so good as torus-fit.

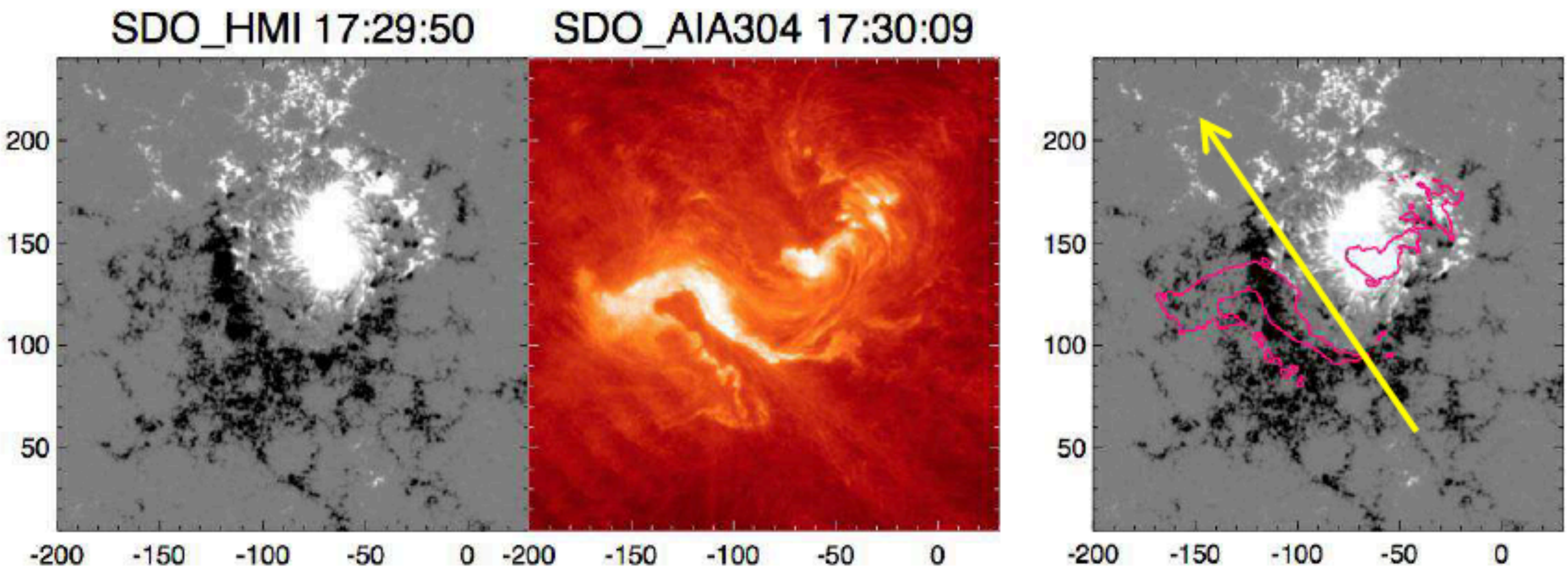
Axis orientation (280) is largely different from PIL orientation.

Spacecraft passes near the western edge of flux rope.

Thus, cylinder-fit is unacceptable.

Event 11: 2014 September: Why was the storm so weak?

Causative solar eruption (originally suspected)



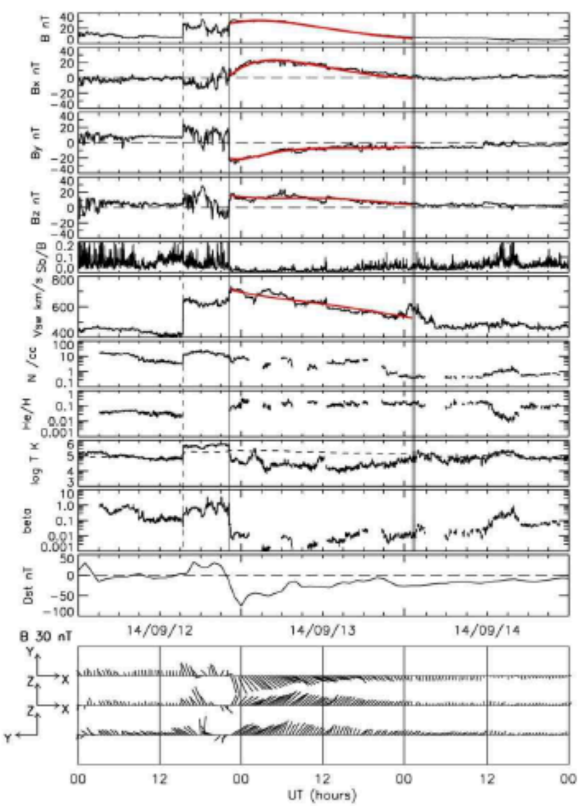
10 September, X1.6 flare, Sep 10/17:21 (start)

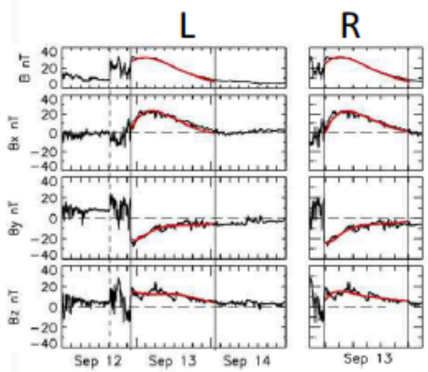
in AR 12158 (N11E05), start: 17:21 UT

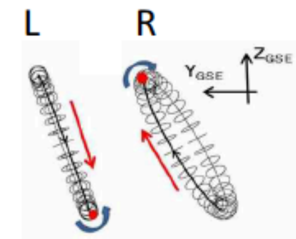
A full halo CME : 18:21 UT first appearance in LASCO C2 FOV

Event 11: 2014 September:

Two flux rope geometries: from Torus-fit







Required polarity change
in the solar source
(if parallelism assumed)

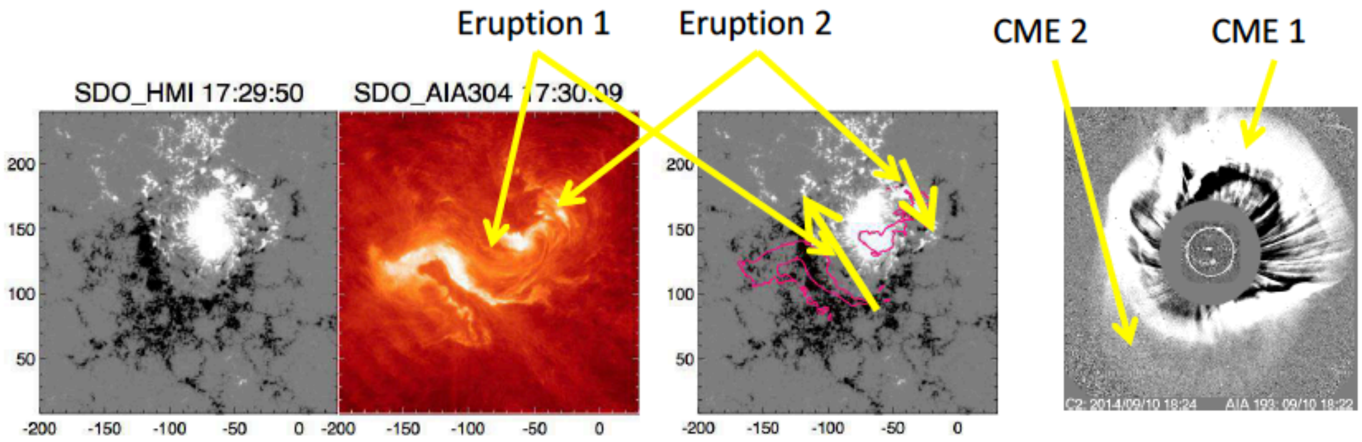
- Both right-handed (R) and left-handed (L) models reproduce the observation.
- Spacecraft passage: southern edge (L)
  northern edge (R)

Bz > 0 throughout the S/C passage

Event 11: 2014 September:

Eruption details (Cho et al., 2017)

- FACT: a multi-onset event of two separate eruptions:
  - Eruption 1 at N15 E07 , CME 2 (18:00 UT): faint one
  - Eruption 2 at N17 E03 , CME 1 (18:12 UT): prominent one



- CME 1 did not hit the Earth.
- CME 2 is the origin of the September 10 flux rope.
  (Required polarity change is satisfied, and axis parallel to PIL.)

Marubashi

Summary

We have seen the flux rope structures and their solar origins for the WG 4 campaign events.

It seems possible (at least in principle) to predict magnetic structures of ICMEs from solar observations.

We recognize many problems that need further studies.
- CME-source eruption correspondence: still unclear
- ICME propagation: strongly affects IMF at Earth

We strongly recognize the difficulty of prediction:
- we may "correctly" predict the shape of ICMEs,
- but what we need is "precise" geometry

Tracing an Interplanetary Magnetic Cloud from Mercury to Venus, Earth and beyond

Yuming Wang[1]

C. Shen[1]、R. Liu[1]、J. Liu[2]、J. Guo[3]、X. Li[1]、M. Xu[1]、Q. Hu[4]、T. Zhang[1]

[1]School of Earth and Space Sciences, University of Science and Technology of China, China
[2]School of Mathematics and Statistics, University of Sheffield, UK
[3]Institute of Experimental and Applied Physics, University of Kiel, Germany
[4]Department of Space Science and CSPAR, The University of Alabama in Huntsville, USA

ISEST Workshop, Jeju 2017.09.20

Motivation

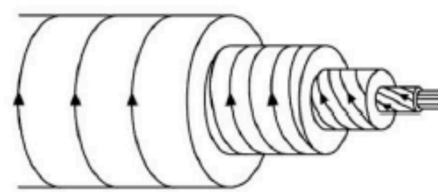
How does the twist distribute in the cross-section of a magnetic flux rope?

Twist: $T = \frac{B_\varphi}{rB_z}$, Total twist angle: $\Phi_T = \int_0^l T dz$, Number of turns: $\tau = \frac{T}{2\pi}$, or $n = \frac{\Phi_T}{2\pi}$

Two competing scenarios:

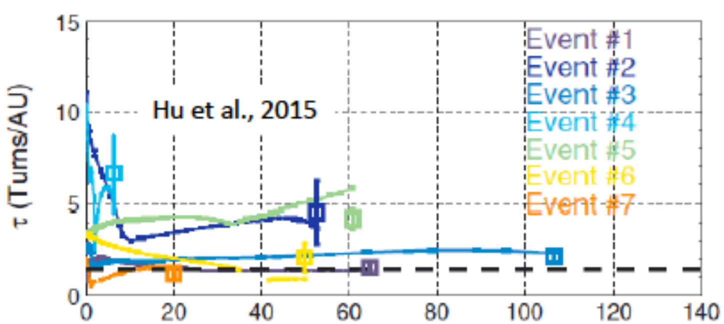
1. **Less-twist at the axis and increasing to periphery:**

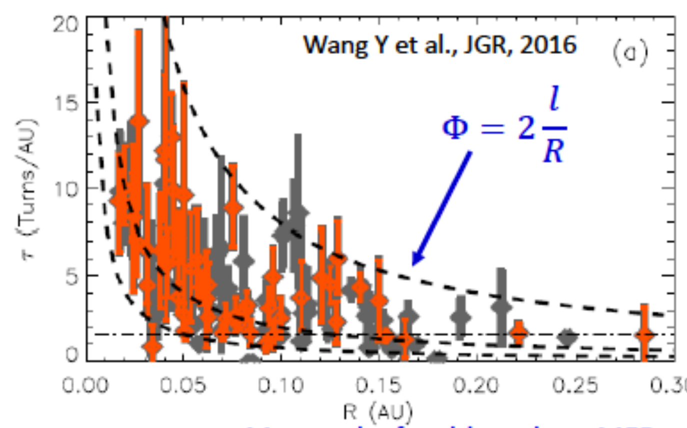
   → Linear force-free field has minimum magnetic energy (Lundquist solution), MCs have sufficient time to relax



Linear force-free (Lundquist, 1950)

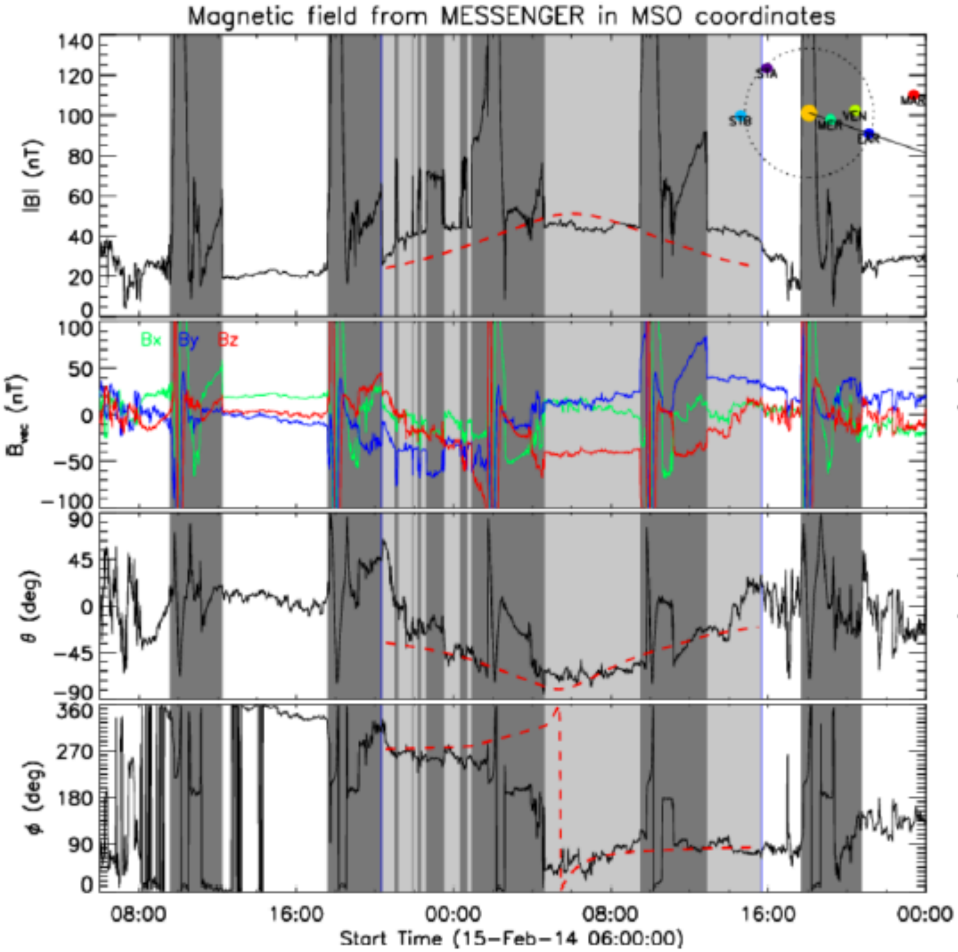
2. **High-twist core enveloped with a weak-twist shell**

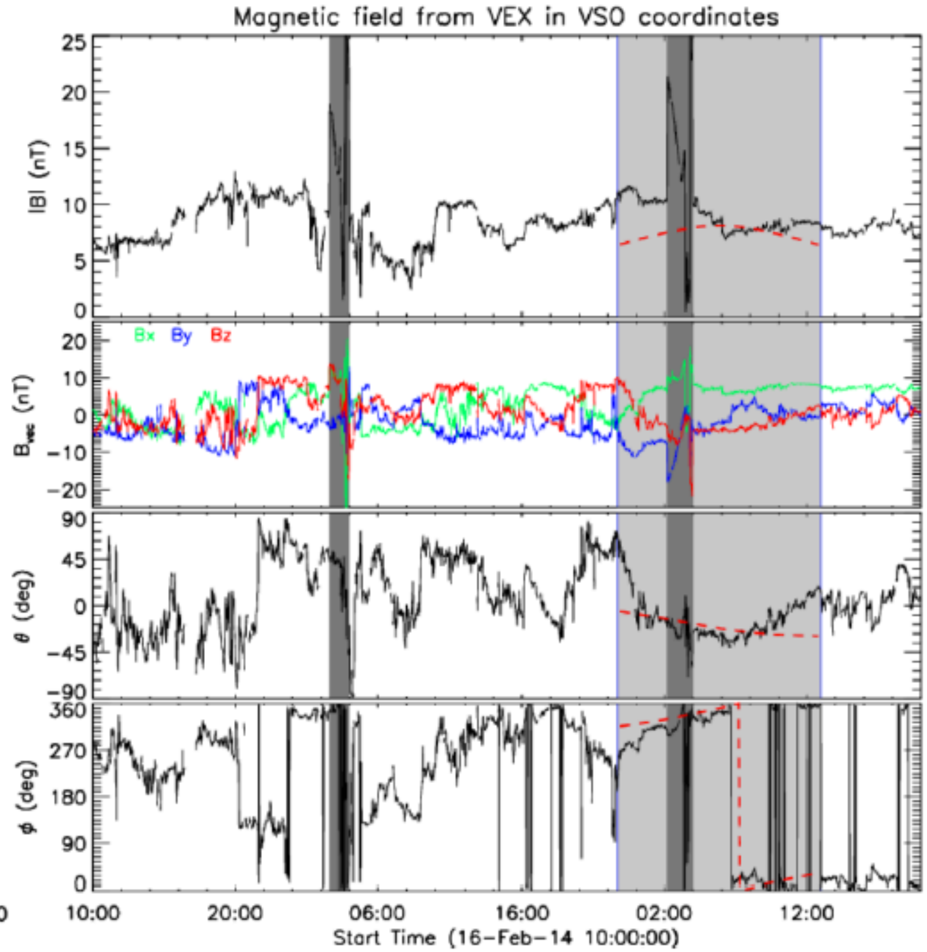




More twist for thin or long MFRs

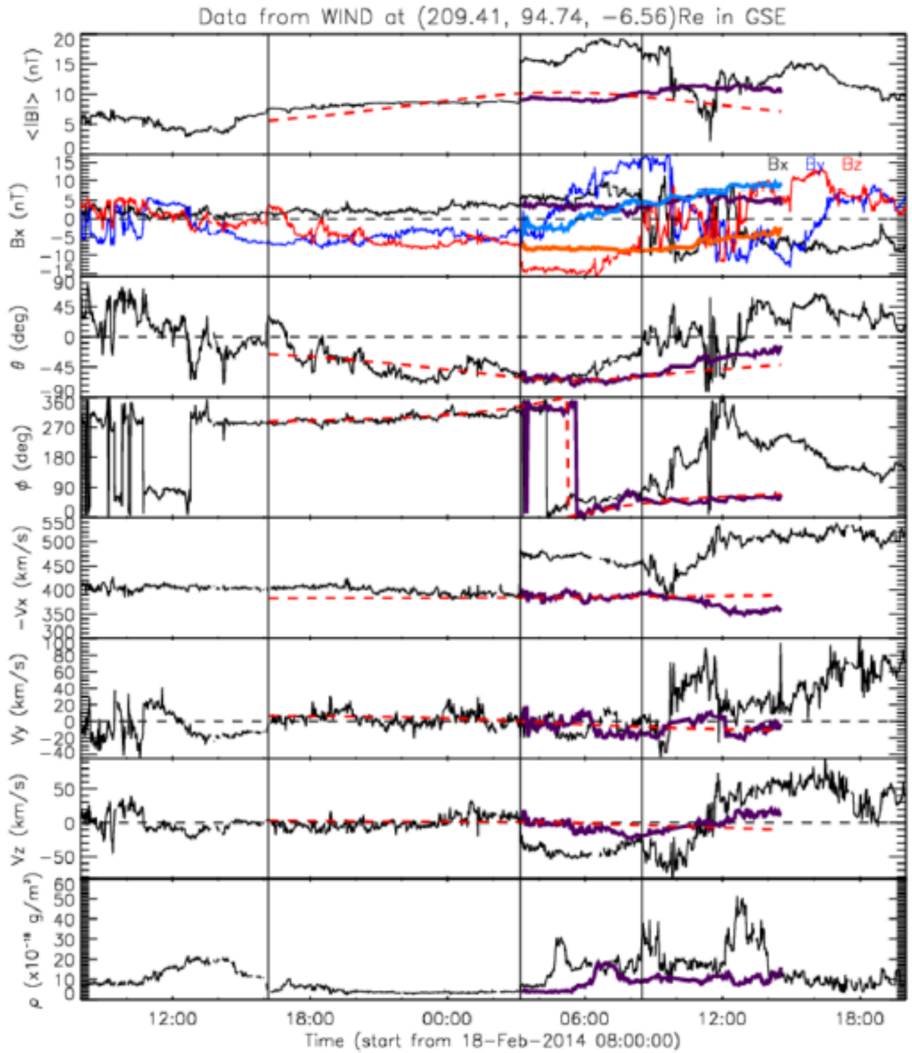
Fitting the MC at Mercury and Venus





Recover the shocked structure

- Based on shock relations, calculate
  - → shock normal: (-0.93, -0.01, -0.37), θ_{Bn}=87 deg
  - → shock speed: 585 km/s
  - → compression ratio: 1.69
- convert the shocked (downstream) ***B*** and ***v*** to un-shocked (upstream) ***B*** and v, with assumptions:
  - → the sheath plasma follows the shock relation and
  - → the same compression and normal direction in the sheath region



Results

- Helicity per AU, h_m, and turns per AU, τ, have been normalized to the distance at 1 AU, $h_{m,AU}$ and τ_{AU}
- Axial flux, F_z, and $-h_{m,AU}$ decreased significantly from Mercury to Earth

  F_z: 19% - 54% at Venus

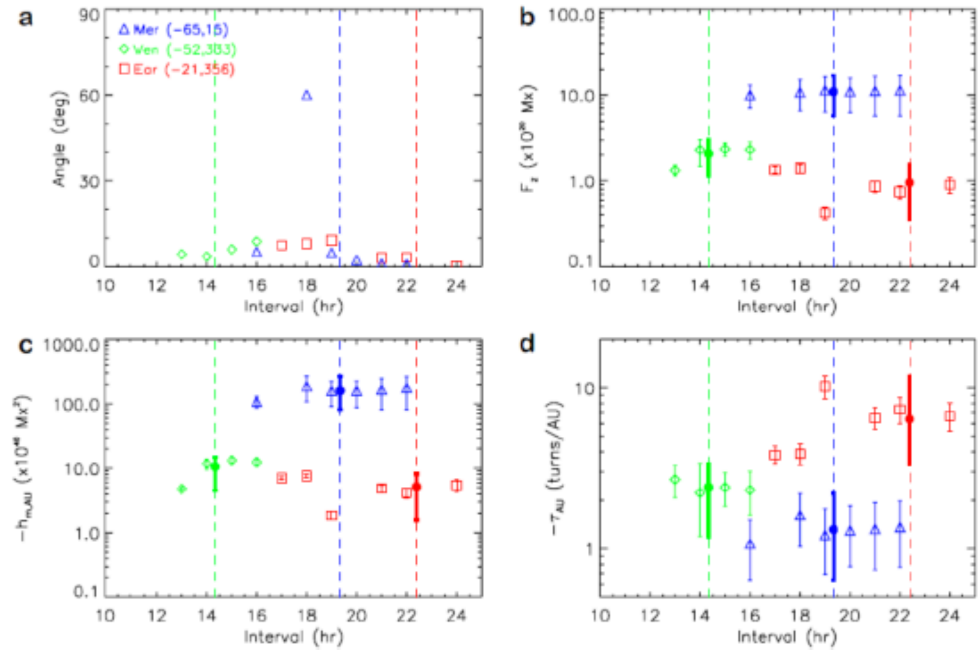
  9% - 28% at Earth

  $-h_{m,AU}$: 7% - 19% at Venus

  3% - 10% at Earth

  → Eroded greatly, expose inner core in sw at 1 AU
- $-\tau_{AU}$ increased from Mercury to Earth

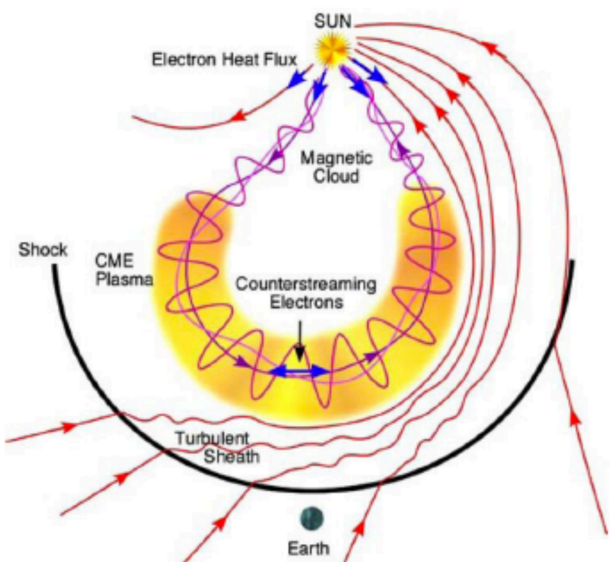
  → High-twist core



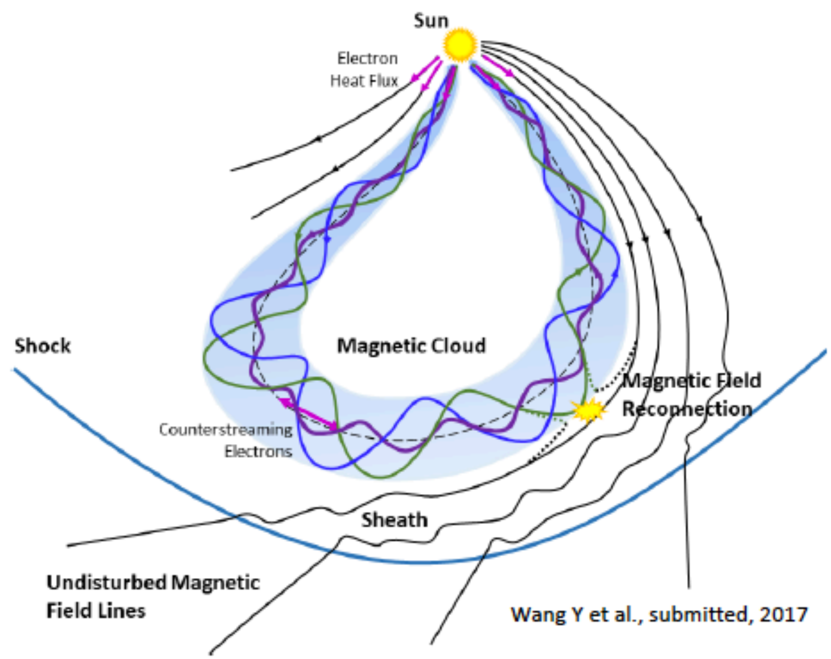
	r	(θ, ϕ)	F_z	τ	τ_{AU}	$h_{m,AU}$
	AU	deg	$\times 10^{20}$ Mx	turns/AU	turns/AU	$\times 10^{40}$ Mx^2
Mercury	0.35	(−65, 15)	$11.0^{+5.8}_{-5.3}$	$-3.8^{+1.9}_{-2.5}$	$-1.3^{+0.7}_{-0.9}$	-160^{+79}_{-108}
Venus	0.72(0.84)	(−52, 333)	$2.1^{+1.0}_{-0.9}$	$-6.9^{+3.5}_{-2.8}$	$-2.4^{+1.2}_{-1.0}$	$-10.6^{+6.1}_{-4.4}$
Earth	1.0	(−21, 356)	$1.0^{+0.6}_{-0.6}$	$-6.4^{+3.1}_{-5.4}$	$-6.4^{+3.1}_{-5.4}$	$-5.1^{+3.6}_{-3.0}$

Conclusions

- A stage-like distribution of twist for a post-eruption magnetic flux rope, consisting of a high-twist core and weak-twist outer shell
- Fine structures may exist because we have only three points



Zurbuchen & Richardson, 2006



Wang Y et al., submitted, 2017

Solar Events Associated With SSCs in 2002: propagation and effects from the Sun to the Earth

B. Schmieder

K. Bocchialini, M. Menvielle, A. Chambodut, N. Cornilleau-Wehrlin, D. Fontaine, B. Grison, C. Lathuillère, A. Marchaudon, M. Pick, F. Pitout, S. Régnier, B. Schmieder, Y. Zouganelis

Bocchialini et al 2017, just accepted
Solar Physics in a special issue "Earth-affecting Solar Transients"

Korea September 2017

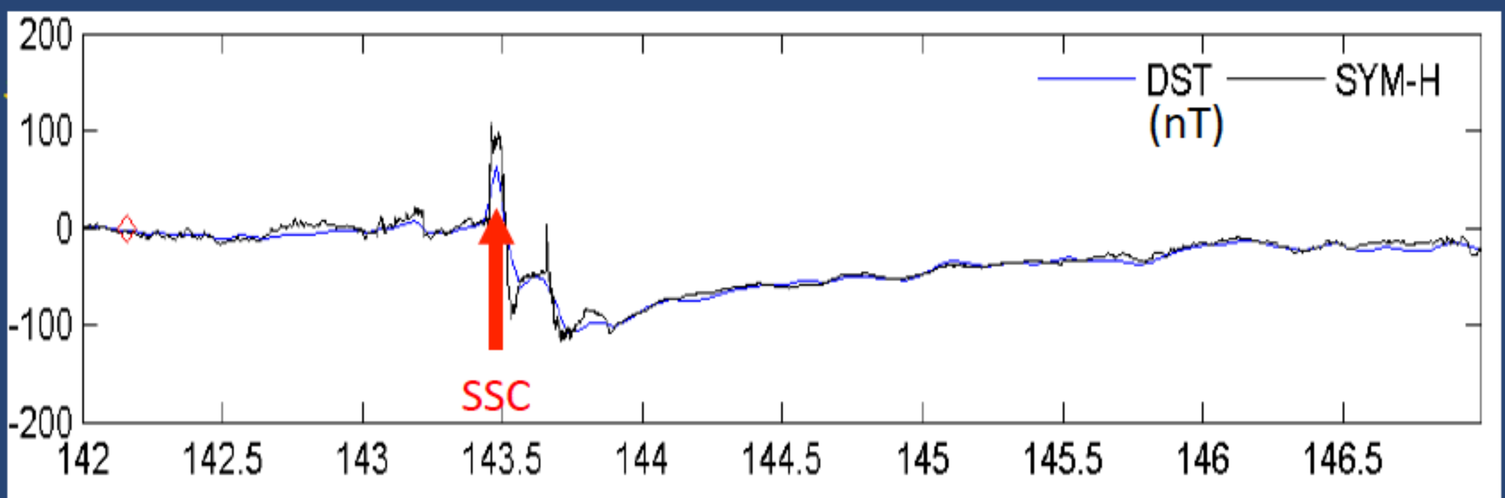
Introduction - Motivation

The aim: to investigate the link between Coronal Mass Ejections (CME) and the geomagnetic storms, related by the occurrence of a Sudden Storm Commencement (SSC),

SSC : sudden growth of the magnetic field strength at the Earth's surface, signature of the impinging of a shock on the magnetopause.

Starting point: the 32 SSCs of year 2002 listed by the observatory de l'Ebre /ISGI.
Identification of the nature of the perturbation at L1, relying on existing catalogues, and characterize it.
Association to a solar source we perform a multi-criteria analysis (velocities, drag coefficient, radio waves, helicity).
---- impact of the solar event studied on the whole chain from Sun to Earth (magnetosphere, ionosphere, thermosphere), as a function of the Dst index value.

Dst (Disturbance
to the equator).

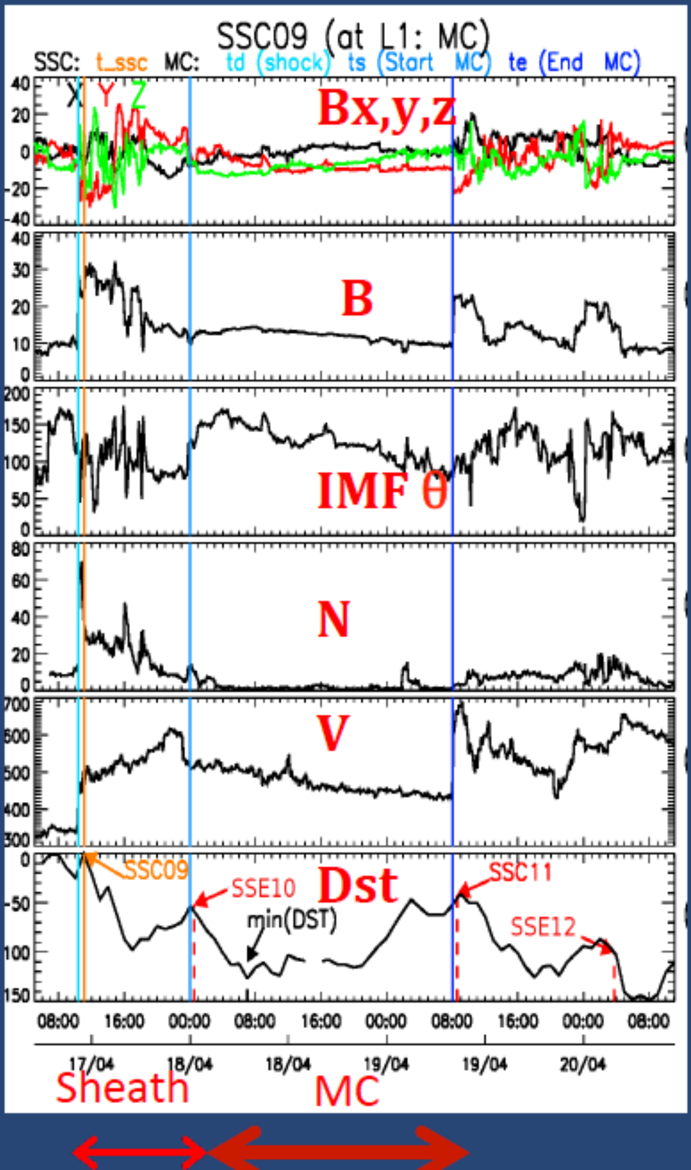


Example of one event: characterization of a MC

Magnetic Cloud (MC) at L1 (17 april – 19 april 2002):

The shock and the sheath causes
-- a SSC: increase of B,N,V
-- followed by a geomagnetic storm and a first decrease of the Dst (min Dst=-100 nT).

The MC causes also
-- a rotation of IMF, a decrease of N and V
-- a fast increase of Dst (-125 nT)
followed by a second decrease of the Dst, that we called Sudden Secondary Event (SSE)



Conclusions

44 CME (including 20 halo CME) are at the origin of 28 of the 32 year 2002 SSCs;

Despite multicriteria for SSC-CME association, including radio wave diagnosis (type IV and type II waves), some cases remain ambiguous.

100% of the well defined Magnetic Clouds induce an SSC

Magnetic Clouds (MC) and ICME (non MC) are the most geoeffective at magnetospheric, ionospheric and thermospheric level.

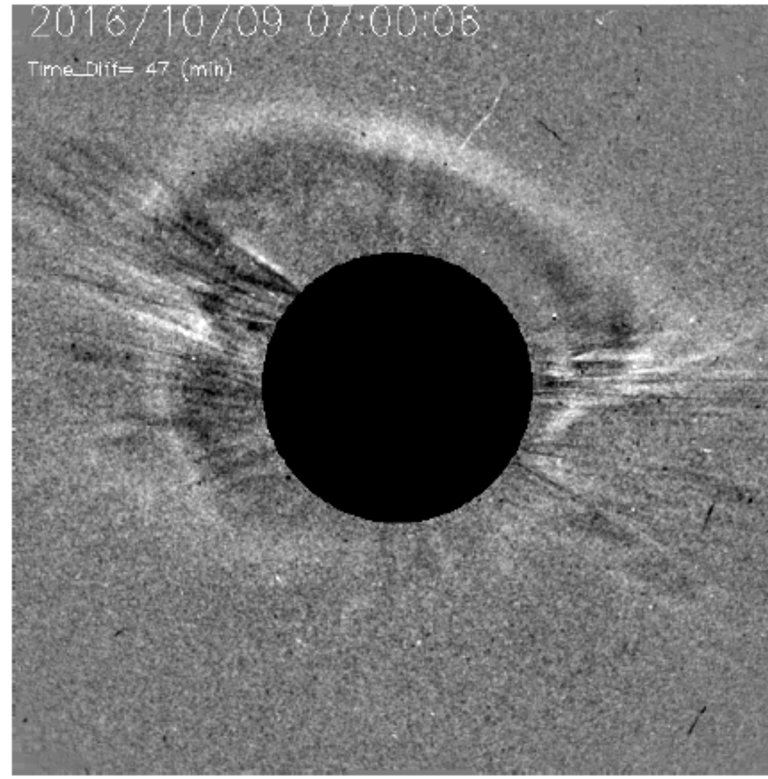
About the geoeffectivity index SSC:

75% of the year 2002 intense storms (Dst <-100nT) are associated with a SSC

40% of the moderate ones (-100nT< Dst < -50nT) are associated with a SSC.

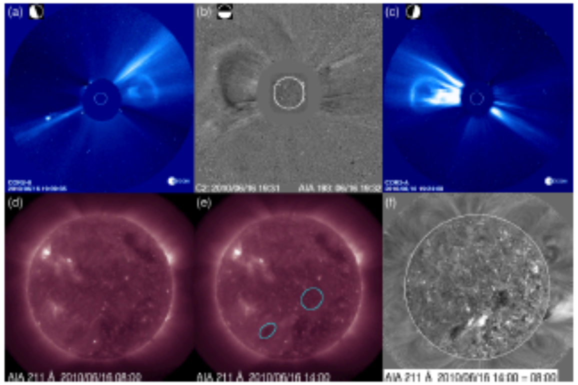
www.ias.u-psud.fr/gmi (login: gmi, password: cme).

Stealthy but Earth-Affecting CMEs

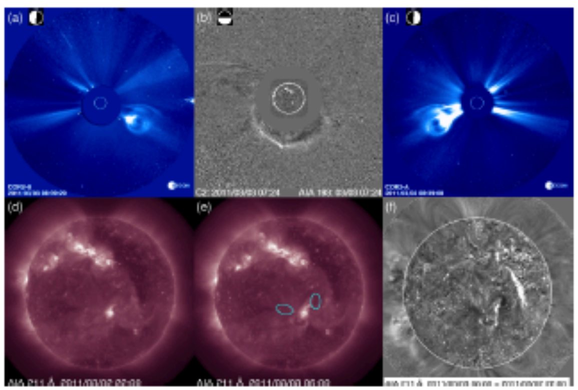


Nariaki Nitta (LMSAL), Tamitha Mulligan (Aerospace Corporation)

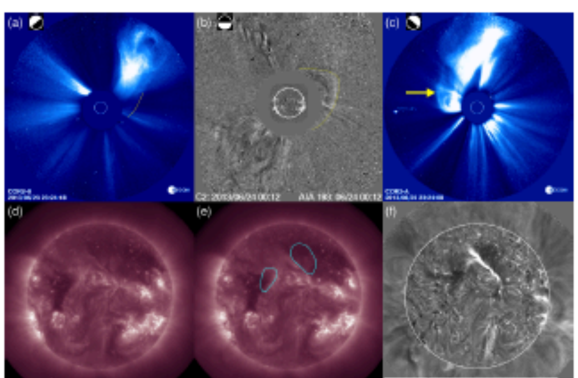
Origins of Somewhat Stealthier Events



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

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

Nitta and Mulligan 2017

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 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/).

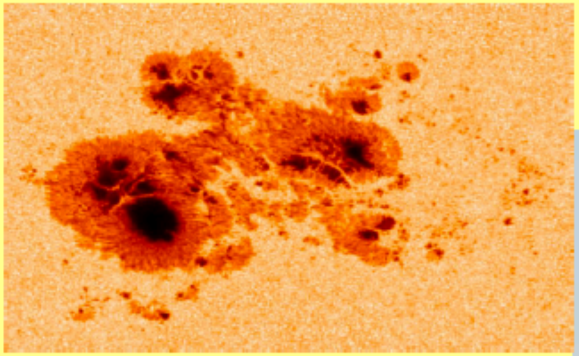
There should be much more, especially since 2014, on the basis of monitoring data in near real time. We will discuss these events at two ISSI team meetings.

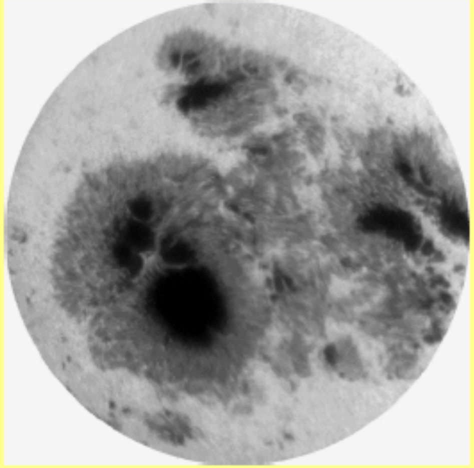
Nitta

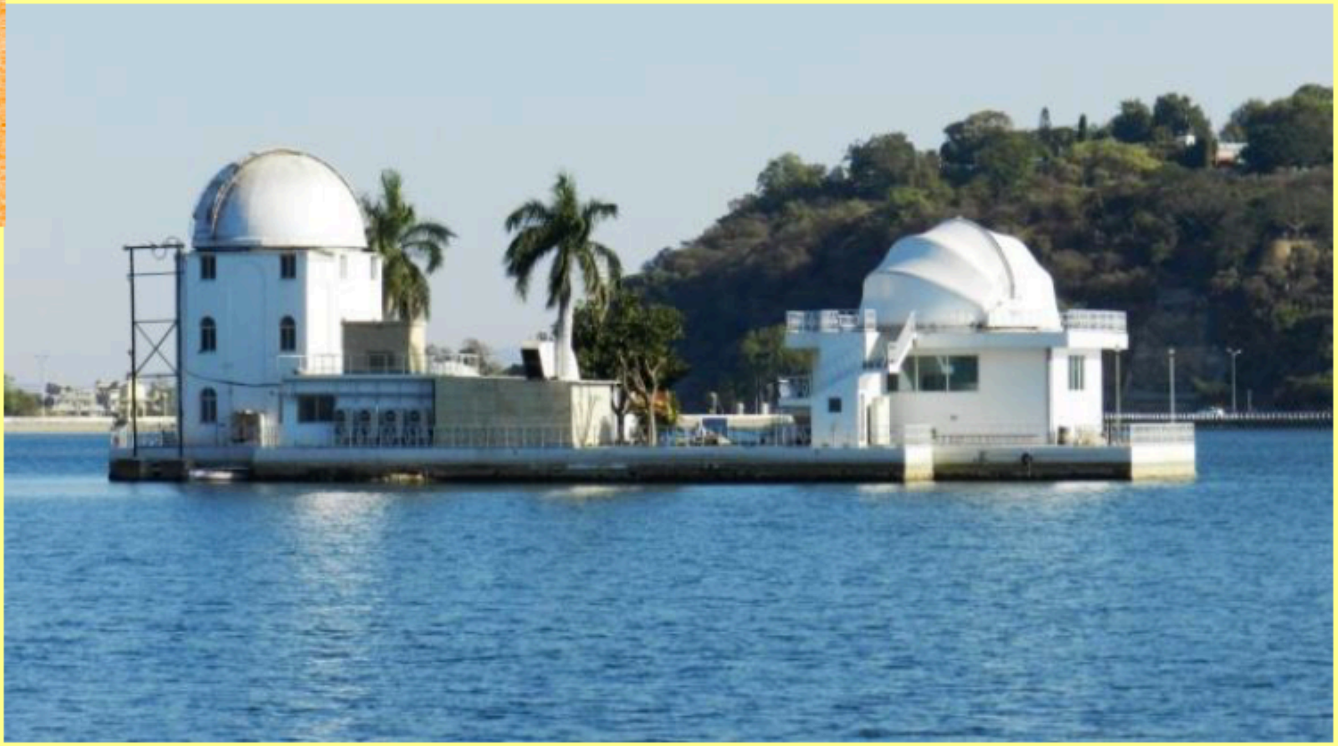
Summary

- 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.

On the dynamics of the largest active region of the SC24



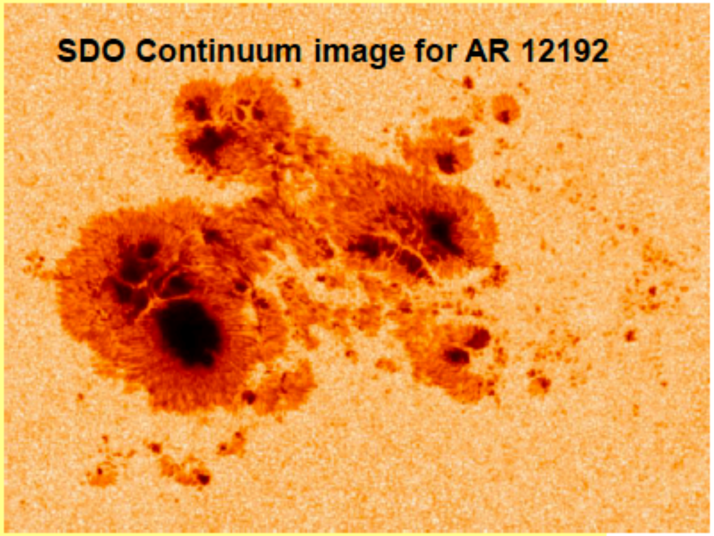


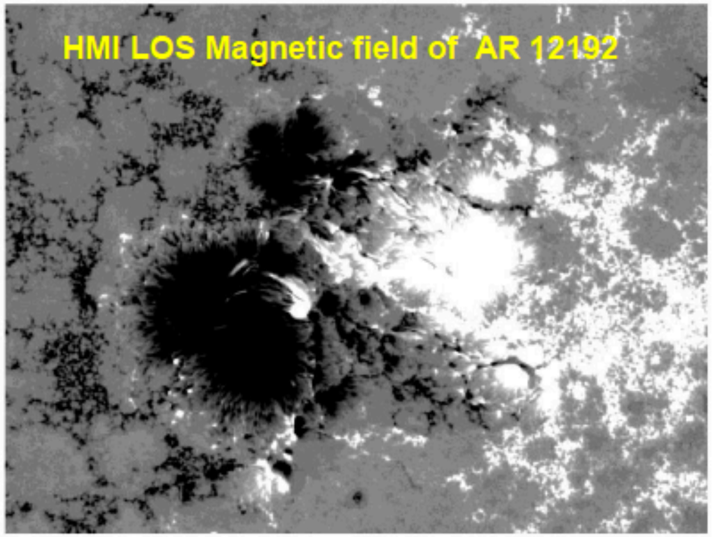


Nandita Srivastava & Ranadeep Sarkar
Udaipur Solar Observatory, Physical Research Laboratory, Udaipur, India

ISEST Workshop 2017

NOAA Active Region 12192





Date (UT)	GOES Start Time (UT)	GOES Peak Time (UT)	GOES End Time (UT)	GOES Class	Location	Nature of Eruption
22/10/2014	01:16	01:59	02:28	M8.7	S13E21	Non Eruptive
22/10/2014	14:02	14:06	22:30	X1.6	S14E13	Non Eruptive
24/10/2014	07:37	07:48	07:53	M4.0	S19W05	Eruptive
24/10/2014	20:50	21:15	00:14	X3.1	S22W21	Non Eruptive
25/10/2014	16:55	17:08	18:11	X1.0	S10W22	Non Eruptive

Magnetic field changes in Eruptive & Non-Eruptive flares

AR12192

Date	GOES Peak time (UT)	GOES flare class	Nature of eruption	Change in mean B_h (Gauss)	% change in B_h	Change in Lorentz force / unit area ($dyne/cm^2$)	Flux cancellation/emergence	Morph-ological change	Overlying magnetic field strength
22 Oct	01:59	M8.7	Non-eruptive	≈15	≈2%	≈1390	-	Not significant	Strong
22 Oct	14:06	X1.6	Non-eruptive	≈15	≈2.5 %	≈390	-	Not significant	Strong
24 Oct	07:48	M4.0	Eruptive	≈135	≈30%	≈4040	Flux cancellation	Significant	Weak
24 Oct	21:15	X3.1	Non-eruptive	≈25	≈5%	≈890	-	Not significant	Strong
25 Oct	17:08	X1.0	Non-eruptive	≈30	≈10%	≈960	-	Not significant	Strong

Srivastava

AR 12192: Summary

A comparison of magnetic characteristics of non-eruptive and eruptive flares of AR 12192 reveals:

- Confined flares occur in the core of the AR while the eruptive flare away from the PIL.

- Abrupt and permanent changes in photospheric magnetic field observed for all flares.

- Confined flares exhibit smaller changes in the horizontal component of the magnetic field and Lorentz force/area as compared to the eruptive flares.

- Distinct morphological changes related to the eruptive flare were observed. Rapid penumbral area decay due to strong Lorentz force changes.

- Gradient of magnetic field strength decayed faster in the eruptive region as compared to that in non-eruptive region, suggesting that overlying fields are stronger in non-eruptive case.

- The height at which the decay index (for Torus instability) 1.5 is attained is lower (32 Mm) for eruptive while for the non-eruptive it is higher (55 Mm) .

ISEST / MiniMax WG 4 Event List

Dates	Source	Geo-response*	Dst	Kp/G Level	Forecast Success
VarSITI-wide Campaign Study Events					
1) 2012 July 12-14	X1 flare, wave, fast CME	Shock, MC, Strong storm	-127	7/G3	Under-predicted
2) 2012 Oct. 4-8	CME; weak surface signs.	Shock, MC, HSS, Moderate stm	-105	6+/G2	Under-predicted
3) 2013 March 15-17	M1 fl, wave, EF, IV, fast halo	Shock, MC? SEP, Strong storm	-132	6+/G2	
4) 2013 June 1	Slow CME on 27 May? CH influence?	Cause of Strong stm unclear;CIR?	-119	7/G3	Failed-not pred.
5) 2015 March 15-17	C9;C2 fl, wave, EF, fast CME	Shock, sheath, MC, Severe storm	-223	8+/G4	Under-predicted
6) 2015 June 22-24	2 M-fls, waves, fast halo CMEs	Shock, sheath, MC, SEP, Severe storm	-204	8+/G4	Mostly successful
Other ISEST/MiniMax Study Events					
7) 2012 March 7-9	X5 flare, wave, fast CME	Shock, MC, Strong storm	-131	8/G4	
8) 2012 July 23-24	2 flares? Wave, EFs	Extreme ST-A event; "Strong storm" (Carr.-type)	---		
9) 2012 January 6	CME <2000 km/s, over WL	GLE at Earth	No	---	
10) 2014 January 7-9	X1 fl, wave, fast asym halo	Shock, SEP. No storm- CH deflection; AR channeling?	No	≤3	
11) 2014 Sept. 10-13	X2 flare, wave, sym halo	Shock, MC, Moderate storm	-75	7/G3	Over-predicted
12) 2015 January 3-7	Slow CME	Brief ICME, MC, HSS, Mod. stm	-99	6+/G2	
13) 2016 October 8-12	Slow CME	Shock, MC, HSS, Moderate stm	-104	6+/G2	
14) 2017 Sept 4-10	Act. series; M5,X9,X8, etc	Shocks, MCs, Strong storm(s), FD	-142	8/G4	

CME = coronal mass ejection; AR = active region; EF = erupting filament; CH = coronal hole; MC = magnetic cloud; SEP = solar energetic particle event; CIR = corotating interaction region; GLE = ground-level event; HSS = high speed stream

xx) Events featured in Webb & Nitta (2017)

xx) Problem events featured in Nitta & Mulligan (2017)

Possible Interactions with Other Groups

Event	Storm	WG2, 3, 5	SPeCIMEN Magnetosp	ROSMIC Ionosp	SEE/WG6 Climate/SEPs
<u>VarSITI Events</u>					
1) 2012 July12	Strong	X	X		
2) 2012 Oct.4-8	Mod	X	X		
3) 2013 March 15	Strong	X-3	X		SEP
4) 2013 June1	Strong			X	
5) 2015 March 15	Super	X-3	X	X	2-step, CIR, deflection
6) 2015 June 22	Super	X-3	X	X	SEP 2-step, FD, hi dens.
<u>Other ISEST Events</u>					
7) 2012 March 7	Strong	X	X		
8) 2012 July 23	“Strong“	X	----	----	SEP
9) 2014 Jan. 6	None	?			GLE
10) 2014 Jan. 7	None	X			SEP
11) 2014 Sep. 10	Mod.	X	X		FD
12) 2015 Jan 3-7	Mod.	X	X		HSS
13) 2016 Oct. 8-12	Mod.	X	X		HSS
14) 2017 Sept 4-10	Strong	X	X	X	SEP, GLE, FD

Future Plans?

- Continue discussion/analysis of events and interpretations:
  - Add comments, data, simulations, etc. to wiki event page - for all WG pages.
  - Update references (do we have a master reference list?)

- Keep writing papers on analyses:
  - Solar Physics Special ISEST Issue – 20-30 papers
  - More WG4-related papers

- Next/final ISEST Workshop in 2018?