

Low Mass Coronal Mass Ejections Missed by STEREO A/B or LASCO and Associated ICMEs

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DATA

- COR1 CME preliminary list :
<http://cor1.gsfc.nasa.gov/catalog/>
- LASCO CME Catalogue:
http://cdaw.gsfc.nasa.gov/CME_list/index.html
- STEREO image search tool / movie maker :
<http://stereo-ssc.nascom.nasa.gov/cgi-bin/images>
- UCLA ICME list:
http://www-ssc.igpp.ucla.edu/forms/stereo/stereo_level_3.html
- STEREO level2 IMPACT magnetic and PLASTIC solar wind Data at UCLA
aten.igpp.ucla.edu/forms/stereo/level2_plasma_and_magnetic_field.html
- NSSDC OMNI 2 data
<http://omniweb.gsfc.nasa.gov/form/dx1.html>

OUTLINE

1. Scientific Background:

Thomson scattering; brightness vs. CME longitude

2. Case study: faint CMEs missed by either STA or B (/LASCO) and associated ICMEs.
3. Properties and propagation of faint CMEs.
4. Statistics: CME missing rate of STA/B.

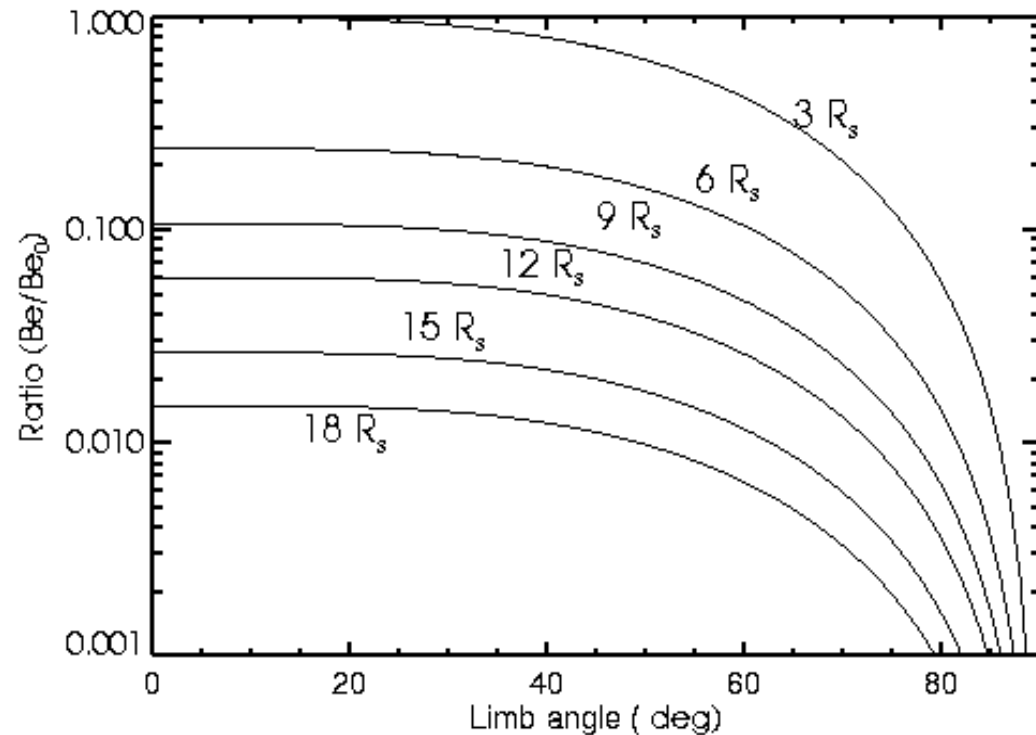
CME Brightness

White-light brightness are from Thomson scattering of electrons in the corona (Billing, 1960):

$B_{\text{tot}} = N_e \times B_e(R_{\text{in}}, \phi)$, where $B_e(R_{\text{in}}, \phi)$ is the scattering function for a single electron.

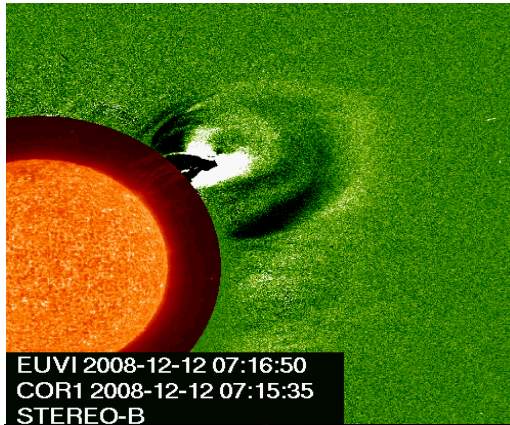
B_e/B_0 vs ϕ at various R_{in}

where, $B_0 = B_e(R_{\text{in}}, \phi)$ at $R_{\text{in}} = 3 R_s$ & $\phi = 0$.



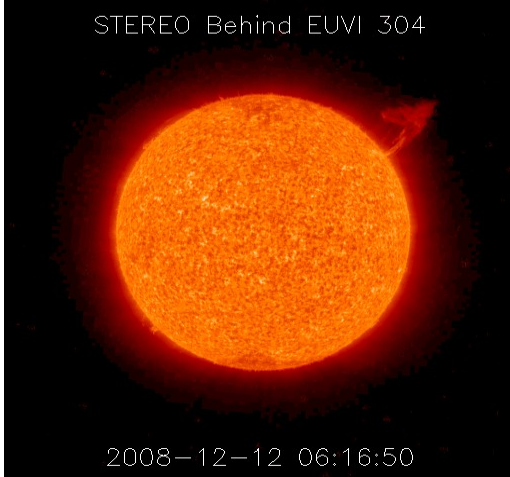


B (W52)



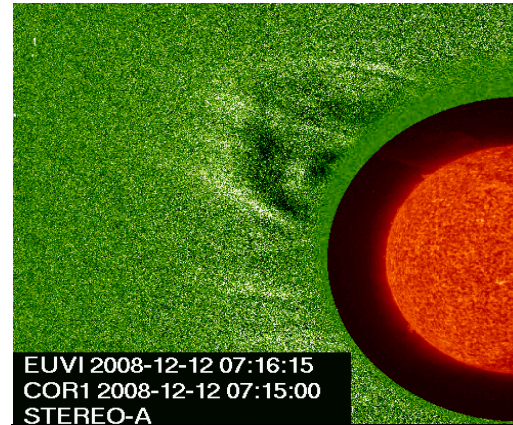
EUVI 2008-12-12 07:16:50
COR1 2008-12-12 07:15:35
STEREO-B

STEREO Behind EUVI 304



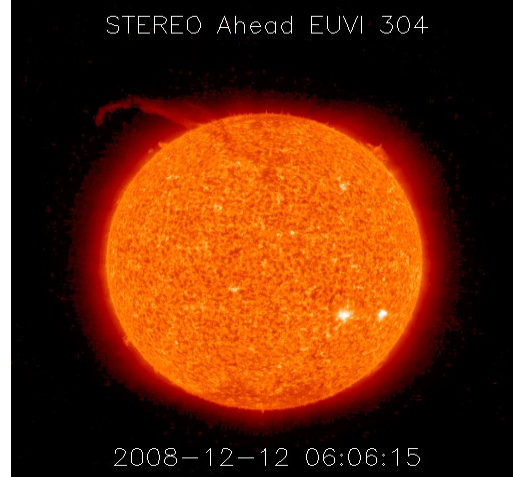
2008-12-12 06:16:50

A (E34)



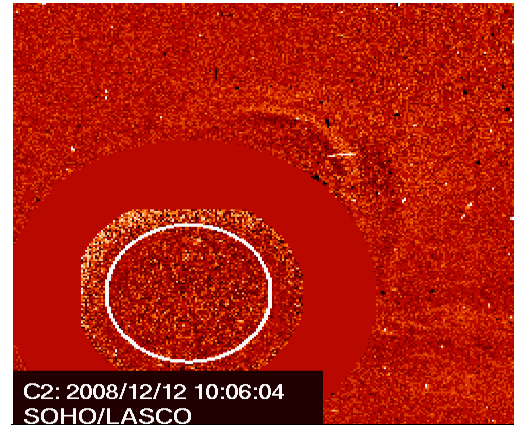
EUVI 2008-12-12 07:16:15
COR1 2008-12-12 07:15:00
STEREO-A

STEREO Ahead EUVI 304



2008-12-12 06:06:15

LASCO (W08)



C2: 2008/12/12 10:06:04
SOHO/LASCO



MLSO PICS
HALPHA
2008-12-10
20:07:31 UT
DOY: 345

Scaling: 800 to 1200

CME: 2008/12/12 04:35; Speed: 252 km/s; A-B sep ang: 86.7

STB: Bright nice FR, nice EUVI 304 EP, N21W52

STA: Wider & fainter, nice EUVI 304 EP, N21E34

LASCO: Faint partial halo, MLSO H α DSP, ~DC N21W08

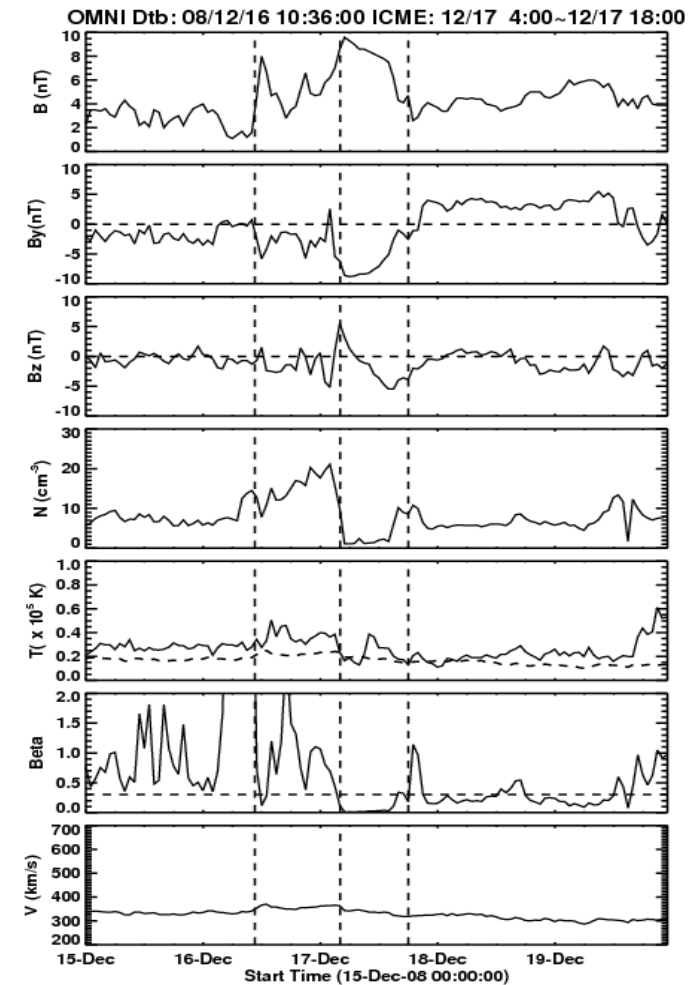
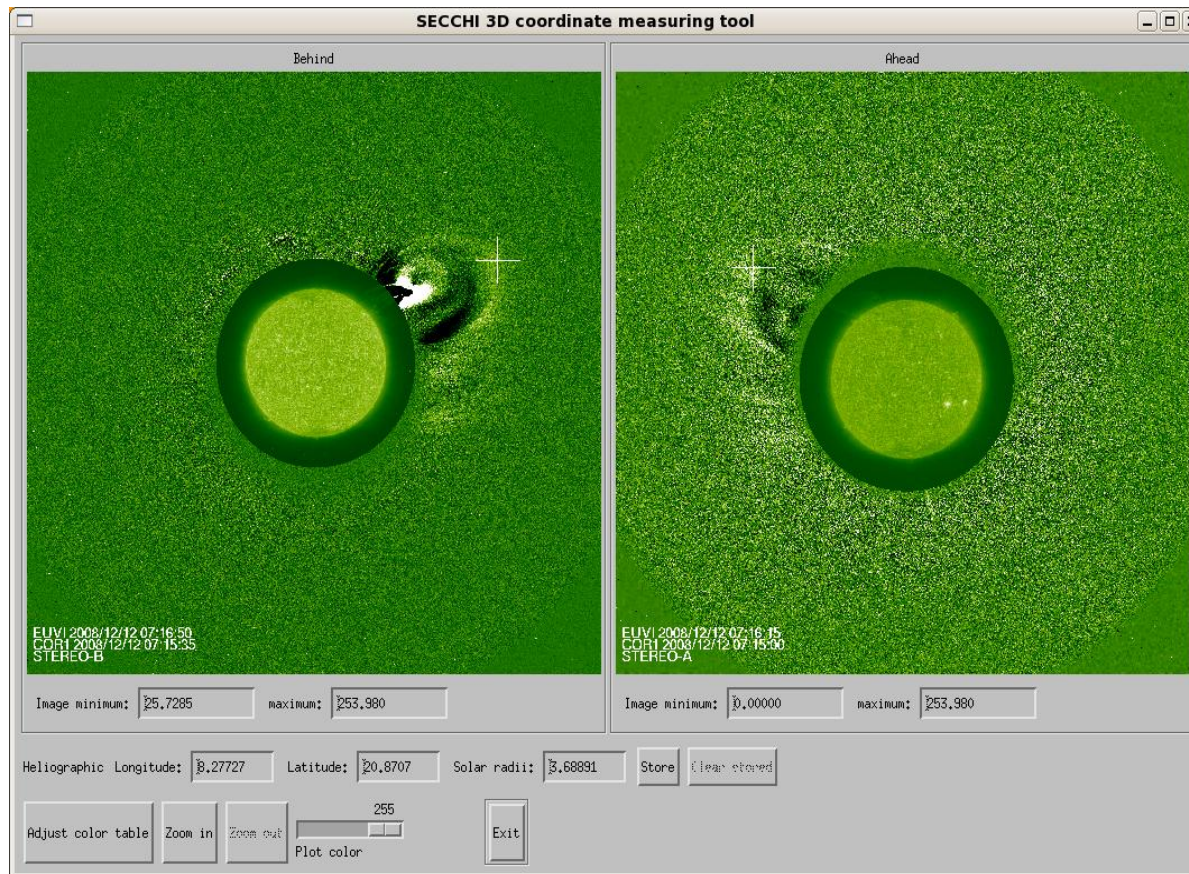
3D triangulation (solarsoft: scc-measure)

CME heliographic loc: N21W08

Dtb: 12/16 10:36 UT

ICME: 12/17 04:00-18:00UT

Bmax = 9.8 nT, Vmax = 340 km/s



CASE 1: a CME missed by STB

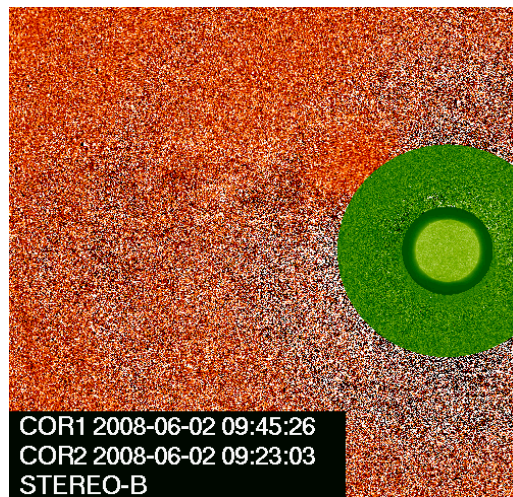
CME: 2008/06/01 not seen in B (E13)

LASCO(E38), A(E67)

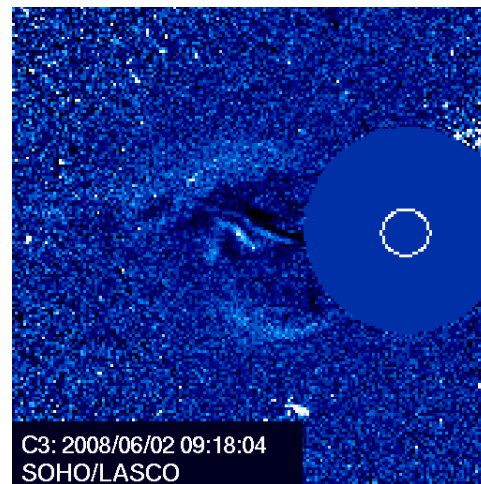
Speed: 222 km/s

Nice MC : $B_{\max} = 14.8$ nT, $V_{\max} = 430$ km/s

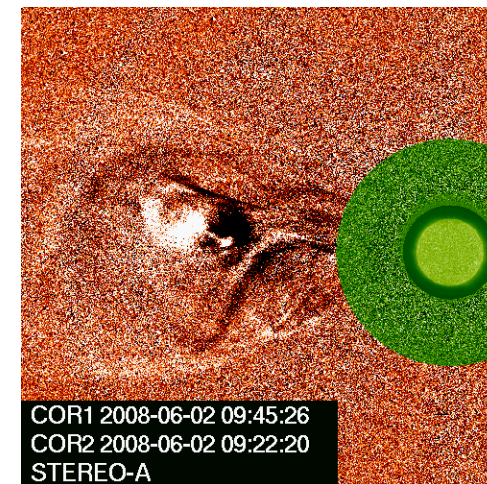
B (E13)



LASCO (E38)



A (E67)



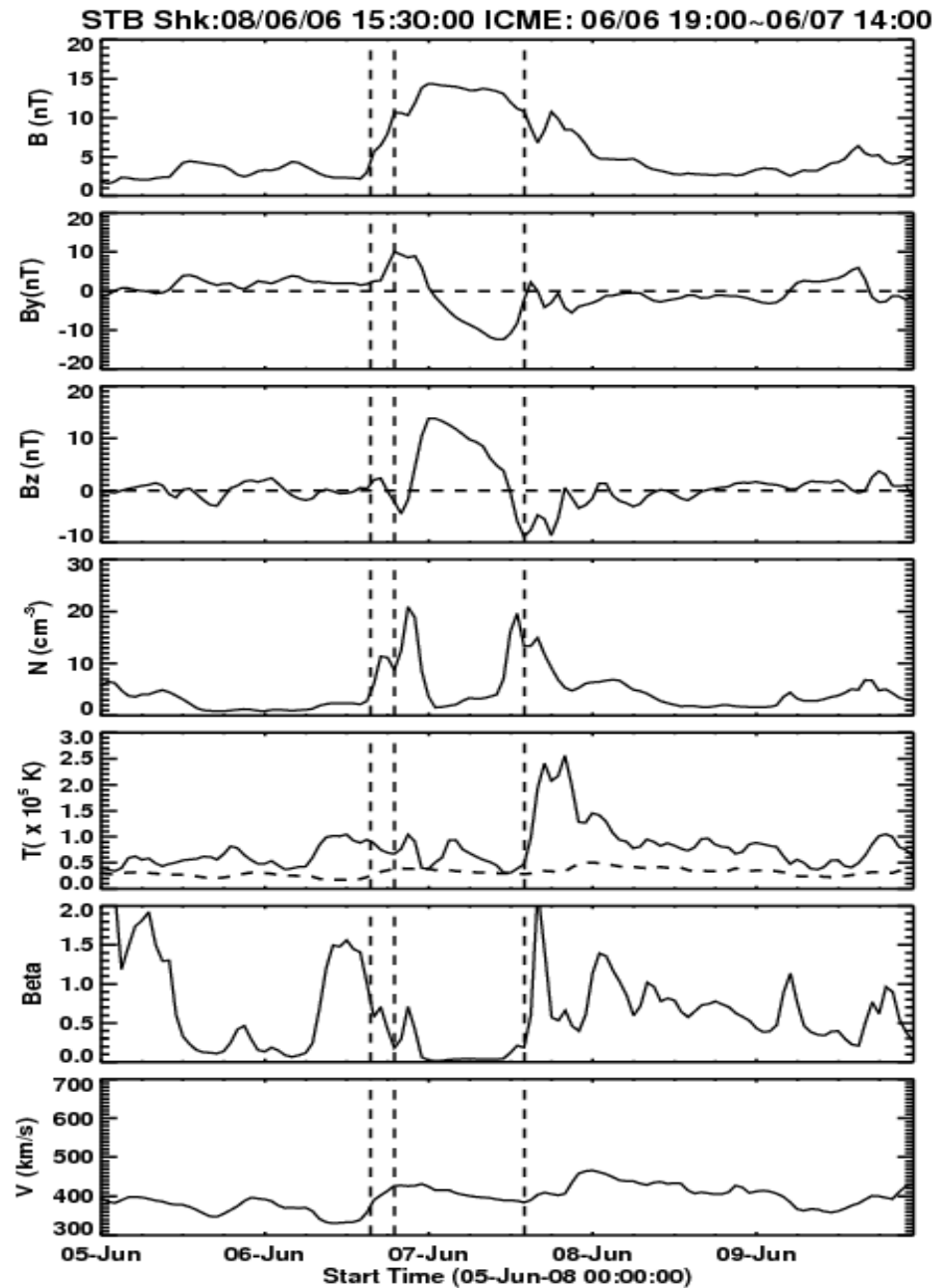
STB/COR
LASCO/C3
STA /COR1

Not seen
2008/06/02 04:16
2008/06/01 09:05

N03E13
N03E38
N03E67

In situ STB (IMPACT & PLASTIC)
Shock: 2008/06/06 15:36
ICME: 06/06 19:00 ~ 06/07 14:00
DT: 19 hr
Bmax: 14.8 nT
Vmax: 430 km/s

Comment:
Nice B-rotation, low Beta



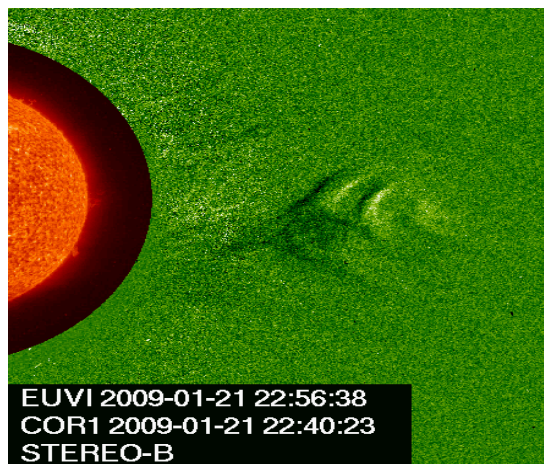
CASE 2: a CME missed by STA

CME: 2009/01/21 not seen in STA (E14)

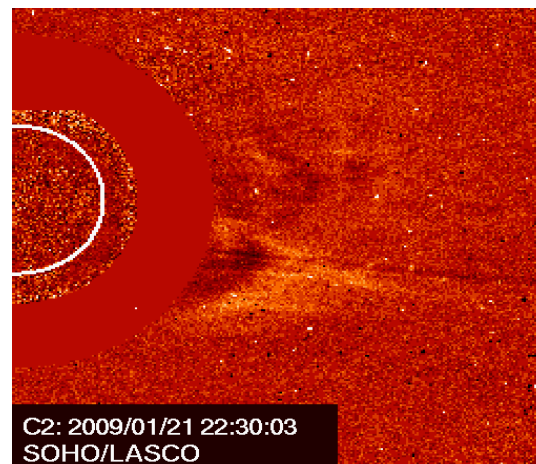
LASCO(W29), B(W76)

Speed: 227 km/s

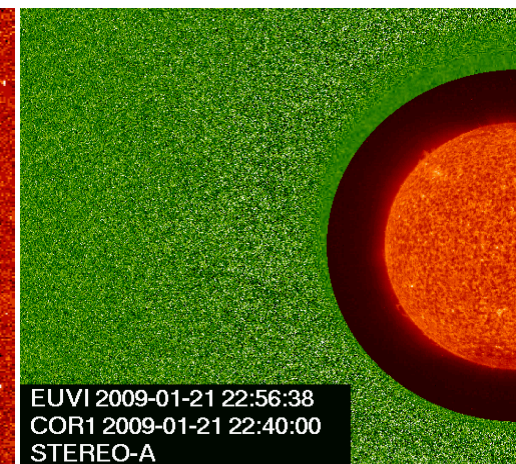
B (W76)



LASCO (W29)



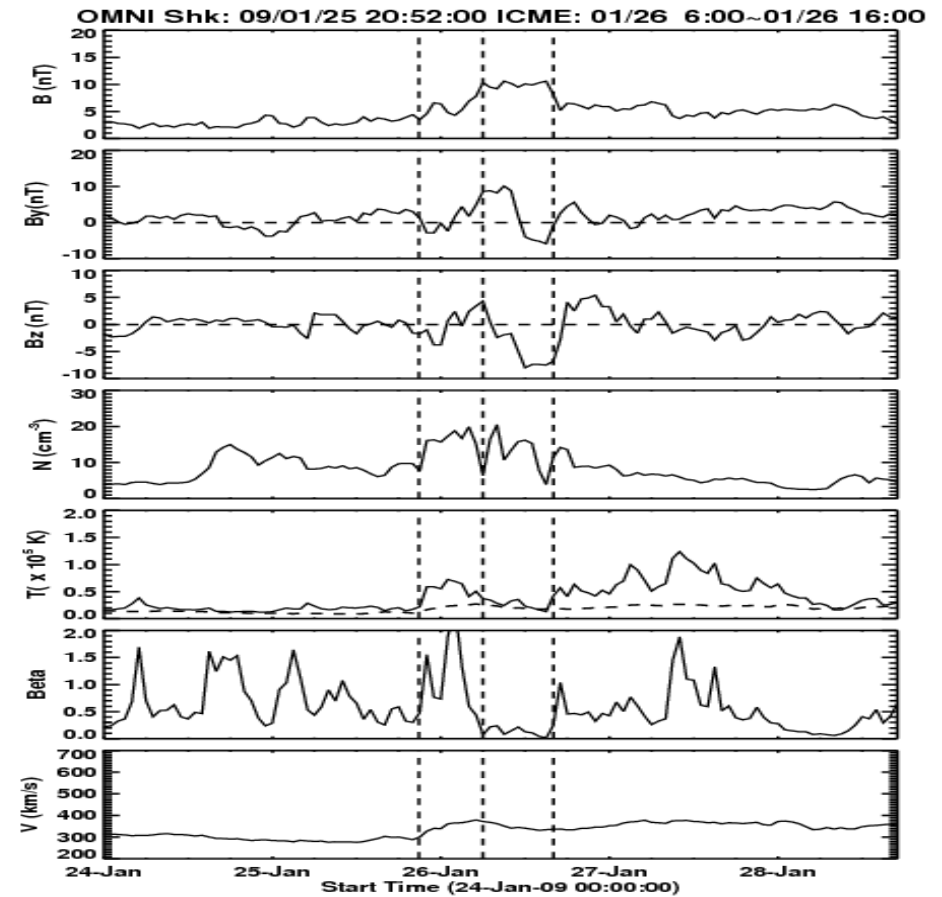
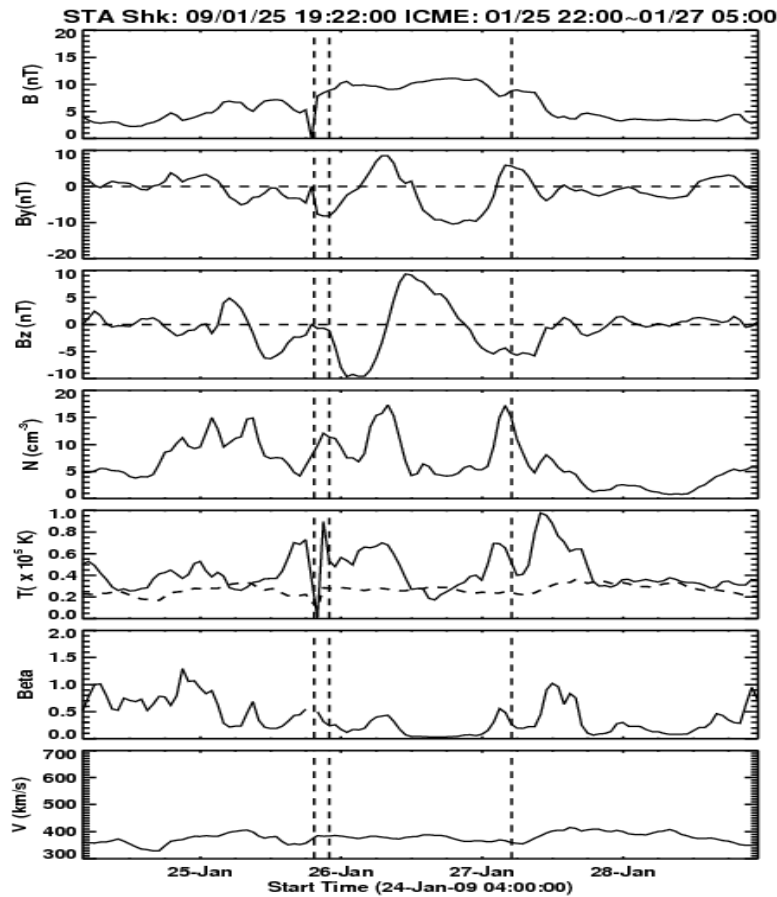
A (E14)



STA	Not seen	S09E14
LASCO/C2	2009/01/21 18:54	S09W29
STB /COR1	2009/01/21 16:45	S09E76

In situ STA (PLASTIC)
 Shock: 2009/01/25 19:22
 ICME: 01/25 22:00 ~ 01/27 05:00
 DT: 31 hr Bmax: 11.5 nT
 Vmax: 400 km/s
 Nice B-rotation, low Beta

In situ L1 sc (OMNI)
 Shock: 2009/01/25 20:52
 ICME: 01/26 06:00 ~ 01/26 16:00
 DT: 31 hr Bmax: 9.5 nT
 Vmax: 400 km/s
 Nice B-rotation, low Beta



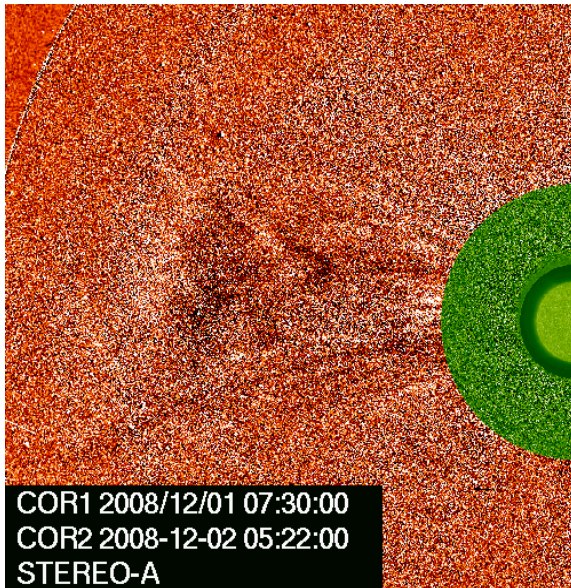
CASE 3: a CME missed by COR1 and COR2-B

CME: 2008/12/01 not seen by B (W02)

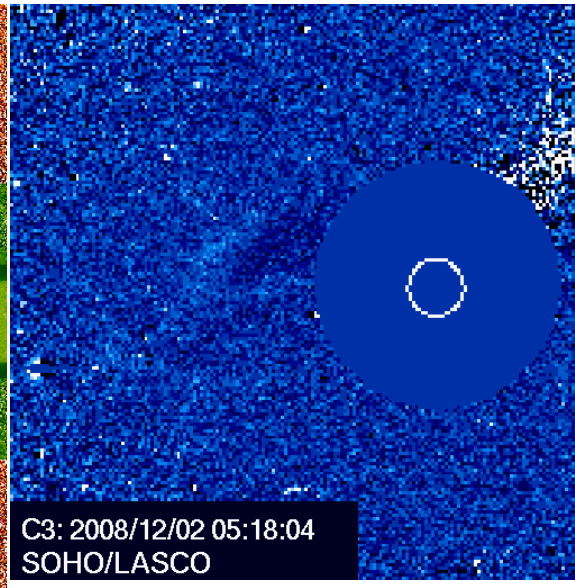
LASCO(E41), A(E83) COR2 only

Speed: 227 km/s

A (E83)



LASCO (E41)



In situ STB (PLASTIC)

Shock: 2008/12/07 ~03:46

ICME: 12/07 17:00 ~ 12/08 22:00

DT: 29 hr Bmax: 19 nT

Vmax: 350 km/s

Nice B rotation; compressed by a HSS at the rear of ICME

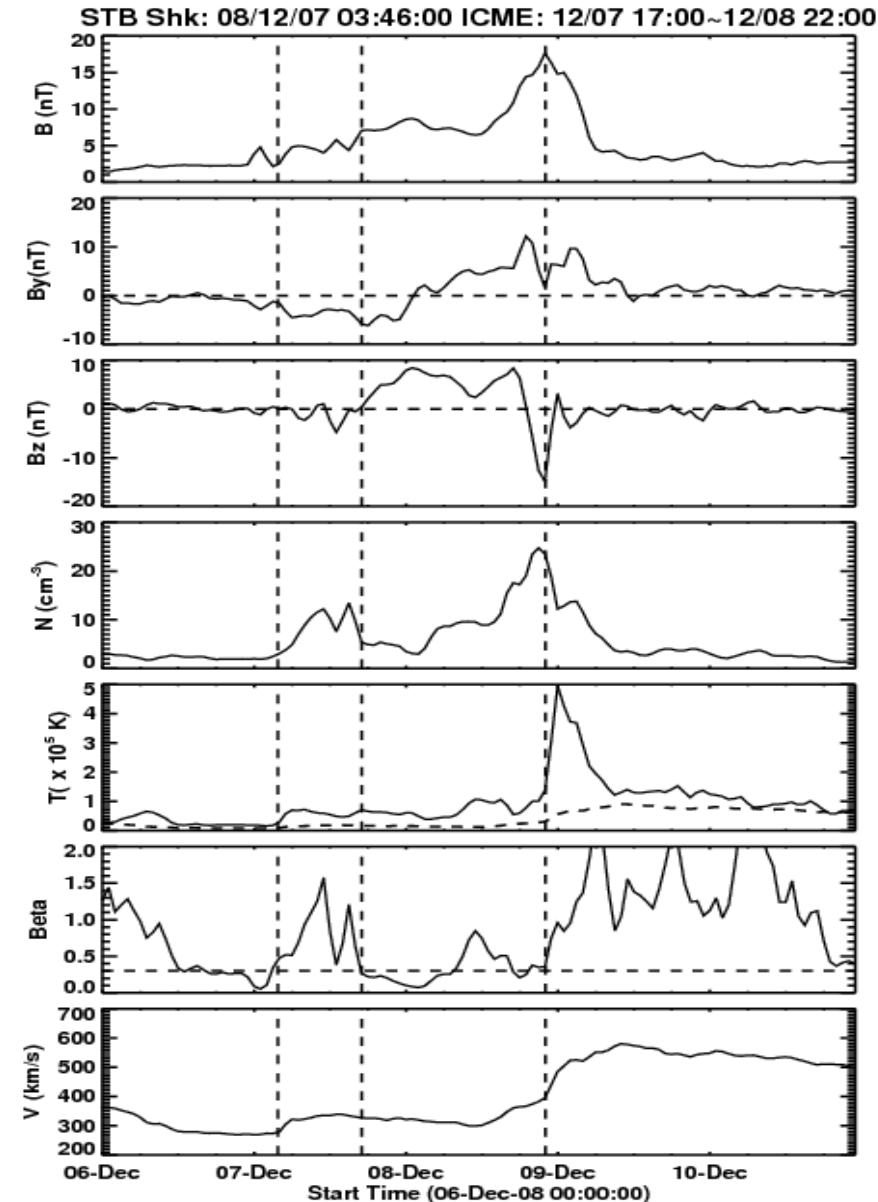


Table 1: ICME disturbance date & time; CME date, time and location; and shock (dtb) travel time

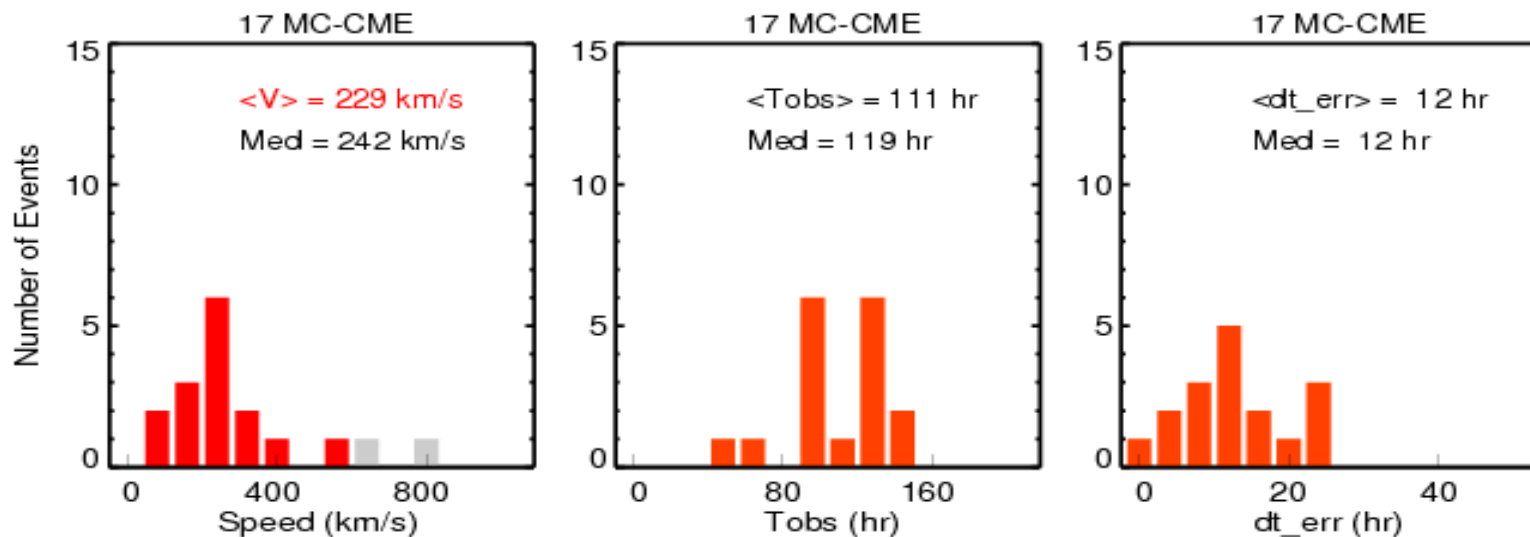
SC	ICME Disturbance		STB (COR1)		STA (COR1)		LASCO (CME)				DT (hour)
	Date	Time	Date	Time	Date	Time	Date	Time	Loc	V(km/s)	
A	11/19/2007	22:00	11/15	18:22	NA		11/15	18:50	W20?	226	100
A	03/21/2008	06:40	03/17	00:25	NA		03/17	07:54	N02W55	276	102
A	05/11/2008	06:31	05/07	07:23	NA		05/06	16:54	N10W55	241	95
A	09/04/2008	05:25	08/29	14:06	NA		08/30	01:30	~W55	196	135
A	10/31/2008	12:10	10/26	00:41	NA		10/26	12:54	S15W74	178	131
A	11/28/2008	21:49	11/23	11:25	NA		11/23	17:06	S09W72	114	130
A	01/25/2009	18:22	01/21	16:45	NA		01/21	18:54	S09W29	427	97
B	12/30/2007	02:00	NA		12/24	11:25	12/25	21:26	N08E49	242	135
B	02/05/2008	20:37	NA		01/31	00:15	01/31	13:31	S09E42	49	140
B	06/06/2008	15:36	NA		06/01	09:05	06/02	04:16	N03E38	222	127
B	08/12/2008	16:00	NA		08/06	18:06	08/06	22:30	S19E50	154	142
B	08/15/2008	12:00	NA		08/10	08:46	08/10	14:24	N03E59	309	123
B	10/16/2008	04:00	NA		10/12	04:25	10/12	07:31	N06E43	256	96
B	10/19/2008	01:02	NA		10/16	20:50	10/16	20:58	N09E56	678	52
B	01/13/2009	05:22	NA		01/08	05:35	01/08	22:30	S06E29	322	120
B	04/29/2008	14:10	04/26	14:26	04/26	14:15	04/26	14:30	N08E07	770	72
B	12/31/2008	02:00	12/27	04:10	12/27	02:25	12/27	05:30	N20E52	595	95

Ref: UCLA ICME list (2007/09 ~ 2009/01):

http://www-ssc.igpp.ucla.edu/forms/stereo/stereo_level_3.html

Statistical results

- Most ICMEs are associated with faint CMEs missed either by STA or B (15 out of 17), red bars in left panel, 7 missed by A and 8 missed by B; 2 CMEs (grey bars in left panel) are bright.
- 12 of 17 ICMEs are preceded by shocks
- Average speed of 15 faint CMEs: 229 km/s (left)
- Average CME-driven shock or disturbance travel time: 111 hrs (middle)
- The predicted travel time error by ESA: 12 hr (right)

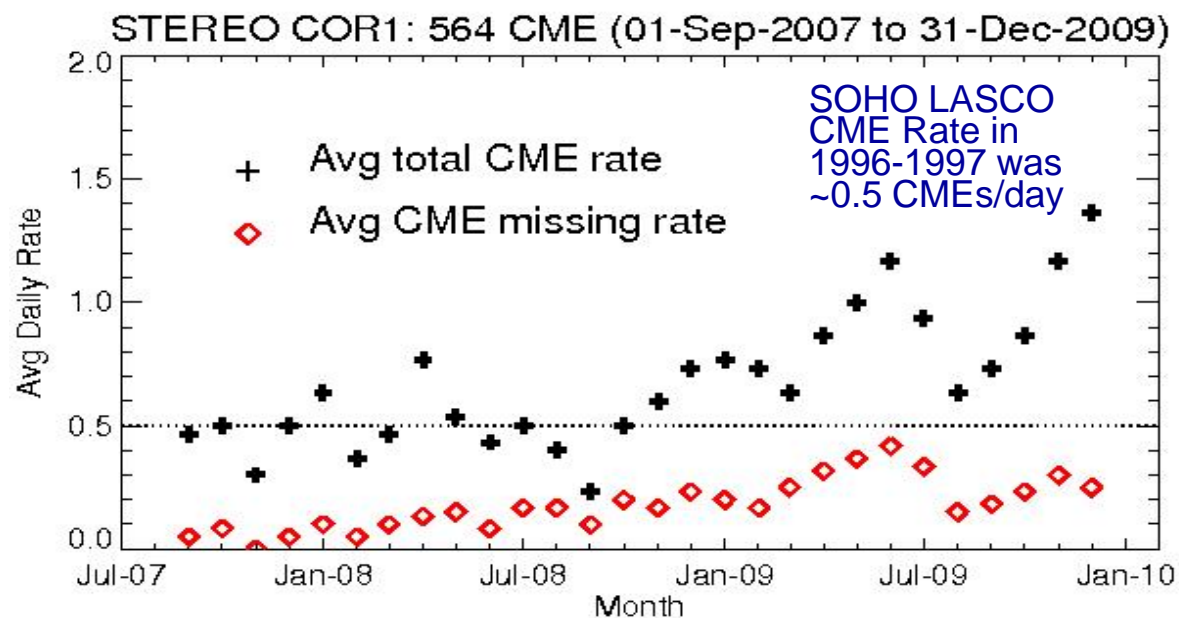


Ref: ESA--Empirical Shock Arrival model(Gopalswamy et al., 2005)

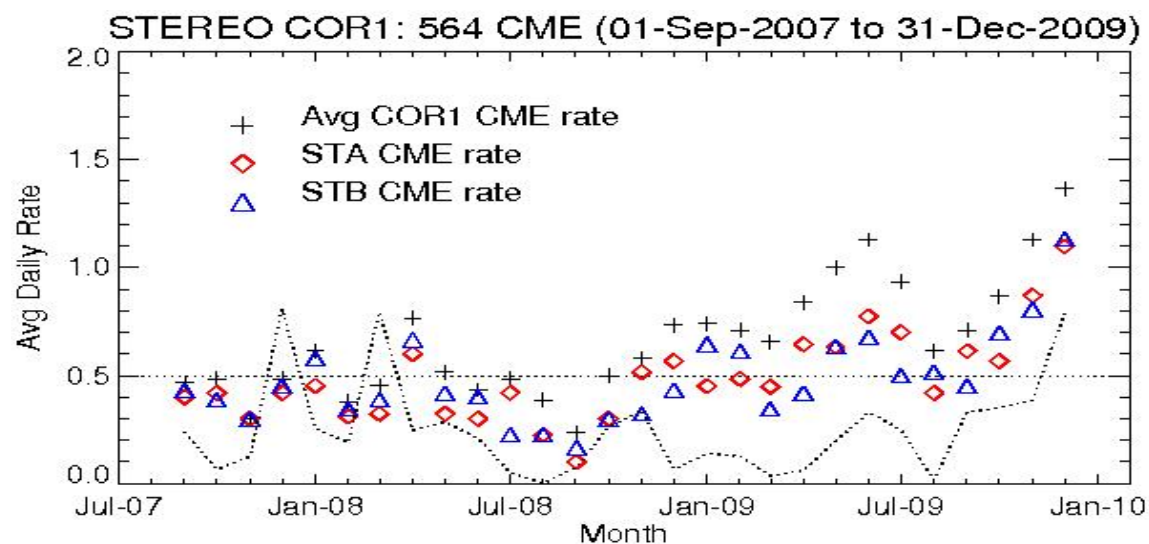
Statistics: CME missing rate & CME total rate

- The missing rate reaches maximum of ~ 0.4 CMEs/day when A-B separation angle is ~ 100 degrees on Jun-2009.
- CME total rate around Jun-09 is overrated due to A & B has larger possibilities seeing different events
- CME separation rate of A & B rose starting on Oct-2009, consistent with SSN curve (dash line in bottom panel).

CME total rate vs. Missing rate



CME total rate vs. STA (B) rate



Conclusions

- Faint CMEs are important sources for the shocks and ICMEs detected at 1 AU during solar minimum.
- CME monthly averaged daily rate has started to pick up since Oct-2009.

CME missing rate

Table 2: CME (STA/B, LASCO) first appearance time and location

DATE	A-B Ang Sep [deg]	TIME			LOC			Comments
		STB	STA	LASCO	STB	STA	LASCO	
12/01/2008	85.5	NA	07:05	23:30	NOOW02	N00E83	N00E41	very faint FR in COR1 (brighter in COR2)
12/02/2008	85.6	NA	01:35	NA	F_dc	NElimb	NE45?	likely merged w/previous CME
12/02/2008	85.6	16:35	NA	18:30	N20W91	N20W05	N20W47	NW, narrow eruption
12/03/2008	85.7	NA	04:15	12:54	F_dc	NElimb	NE45?	NE, narrow jet
12/06/2008	86.1	03:45	NA	07:31	Wlimb	F_dc	W45?	W, narrow jet
12/06/2008	86.1	NA	14:35	18:54	B_dc	SWlimb?	SW135?	SW, narrow blob-like jet
12/06/2008	86.1	17:45	NA	22:06	N06E77	B_NE163	B_NE121	Nice FR w/304 EP in STB
12/07/2008	86.2	NA	08:25	NA	F_dc	SElimb	SE45?	faint loop w/c rising slowly, SE, CME?
12/08/2008	86.3	14:45	10:45	15:30	N09W78	B_NW164	B_NW120	Nice FR in STA & LASCO
12/11/2008	86.6	05:45	NA	06:06	S19W109	S19W23	S19W65	Flare: AR1009 S26W63/B2.6
12/12/2008	86.7	NA	early	NA	Back_dc	Wlimb	W135?	very very faint, wide loop w/core?
12/12/2008	86.7	04:35	04:55	08:54	S22W51	S22E36	S22W06	omni Nice FR w/304 EP in STA, STB
12/13/2008	86.8	early	NA	NA	Elimb	Back_dc	E135?	small cavity rising, very slow, E, CME?
12/13/2008	86.8	NA	15:05	15:54	SWlimb	Bck	Bck	narrow eruption, failed?(hardly seen in COR2)
12/15/2008	87	14:25	18:25	19:31	S24E57	SE144	SE102	FR w/c and 304 EP
12/18/2008	87.3	NA	17:05	21:30	F_dc	NElimb	NE45?	very faint & narrow eruption
12/20/2008	87.5	04:25	09:25	NA	S14E128	S14E145	S14E173	very narrow FR
12/20/2008	87.5	19:45	19:45	20:30	N05E133	N05W140	N05E178	nice FR w/304 EP
12/27/2008	88.1	03:45	02:25	05:30	N20S06	N20S94	N20S52	0 STB nice FR w/core
12/29/2008	88.3	NA	17:05	17:54	F_dc	NElimb	NE45?	Very faint FR?
12/31/2008	88.4	NA	12:45	NA	Back_dc	NWlimb	NW135?	Narrow eruption
12/31/2008	88.4	NA	12:25	14:30	Back_dc	NWlimb	NW135?	Narrow eruption

ref. <http://cor1.gsfc.nasa.gov/catalog/>
http://cdaw.gsfc.nasa.gov/CME_list/index.html