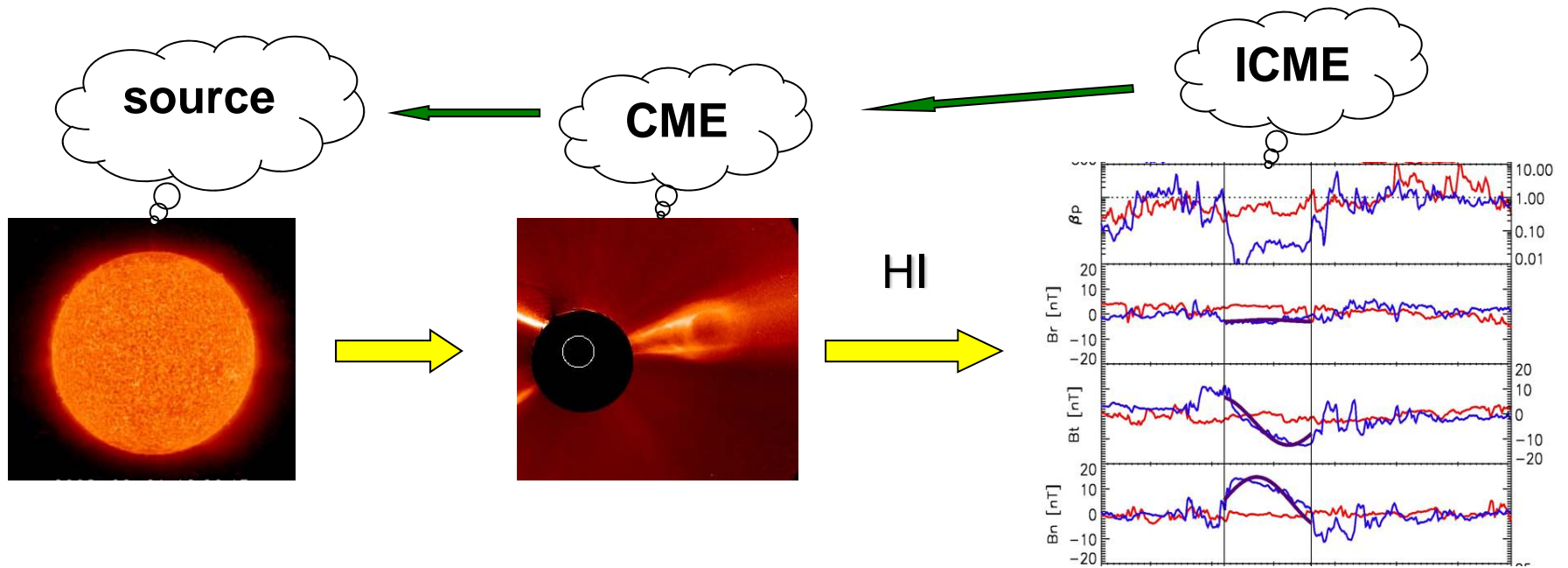


Origins of Solar Minimum CMEs with ICMEs

*Yan Li*¹

*B. J. Lynch*¹, *J. G. Luhmann*¹,
*A. Thernisien*², *A. Vourlidas*²,
*E. Kilpua*³, *L. Jian*⁴, *A. B. Gavin*⁵

1. *Space Sciences Laboratory, UC Berkeley, 7 Gauss Way, Berkeley, CA, 94720*
2. *Space Science Division, Naval Research Laboratory, Washington, DC 20375*
3. *Department of Physics, Theoretical Physics Division, University of Helsinki, Finland*
4. *Institute of Geophysics & Planetary Physics, UC Los Angeles, Los Angeles, CA 90095*
5. *Space Science Center, University of New Hampshire, Durham, NH 03824*



Where did a CME arise?

- source

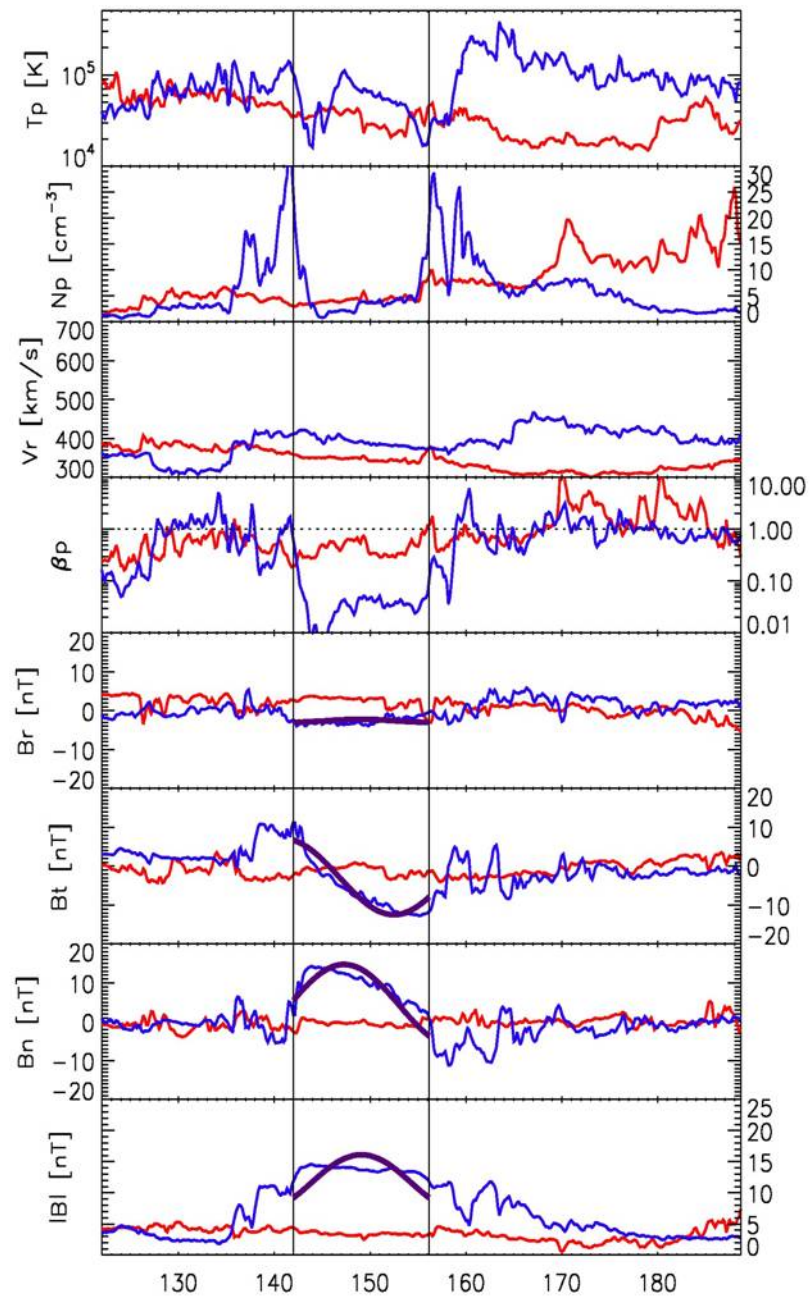
How did a CME arise?

- initiation

Where does a CME go?

How does a CME go?

- propagation



An update of ICME events at ~1AU

Number of ICMEs at each observing point				
Year	A&B angle	STB	ACE / Wind	STA
2007	0.052° – 44.018°	7	4	6
2008	44.018° – 88.494°	7	6	6
2009	88.494° – 132.322°	15	5	6
Number of ICMEs				
2007	0.052° – 44.018°	8		
2008	44.018° – 88.494°	17		
2009	88.494° – 132.322°	24		
total	0.052° - 132.322°	48		

ICME (shock and ejecta) dates, times and duration 2007

	A&B	STB (7)	ACE / Wind (4)	STA (6)
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
07Jan14	0.252	no data	11:48 17:10 14h0m	no data
07May21	8.995	no +4:45 17h20m	no 22:45 17h10m	no 22:08 02h56m
07May23	9.167			no 00:55 11h30m
07Jun08	11.821	no 5:10 4h10m	no 05:35 23h35m	no 18:30 20h50m
07Aug25	27.217			20:30 23:40 16h5m
07Oct23	37.440	no 16:50 6h45m		
07Nov19	40.768	13:49 22:34 8h28m	17:20 +0:40 8h46m	no 22:50 25h10m
07Dec30	43.927	no 06:05 45h55m		

ICME (shock and ejecta) dates, times and duration 2008 January - June

	A&B	STB (3)	ACE / Wind (3)	STA (2)
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
08Mar06	46.305	no 12:12 04h44m		
08Mar08			no 19:00 6h	
08Mar21				no 06:00 16h00m
08Apr04			-- 11:50 5h	
08Apr29	49.804	14:15 23:25 8h35m		
08May11	51.080			DG 11:00 6h54m
08Jun06	54.591	15:30 22:05 13h5m	DG 23:59 2h30m	

ICME (shock and ejecta) dates, times and duration 2008 July - December

	A&B	STB (4)	ACE / Wind (3)	STA (4)
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
08Jul10	60.2	11:00 14:00 19h		
08Jul30				-- 3:00 7h
08Aug15		-- 12:00 13h		
08Sep04			-- -17:00 7h	-- 10:00 14h
08Sep17			-- 02:30 26h	
08Sep28		-- 3:00 10h		
08Oct31	81.3			5:20 12:10 4h10
08Nov07				-- 2:20 25h
08Dec17	87.2		DG 04:00 9h30m	
08Dec31	88.4	-- 3:55 ~20h		

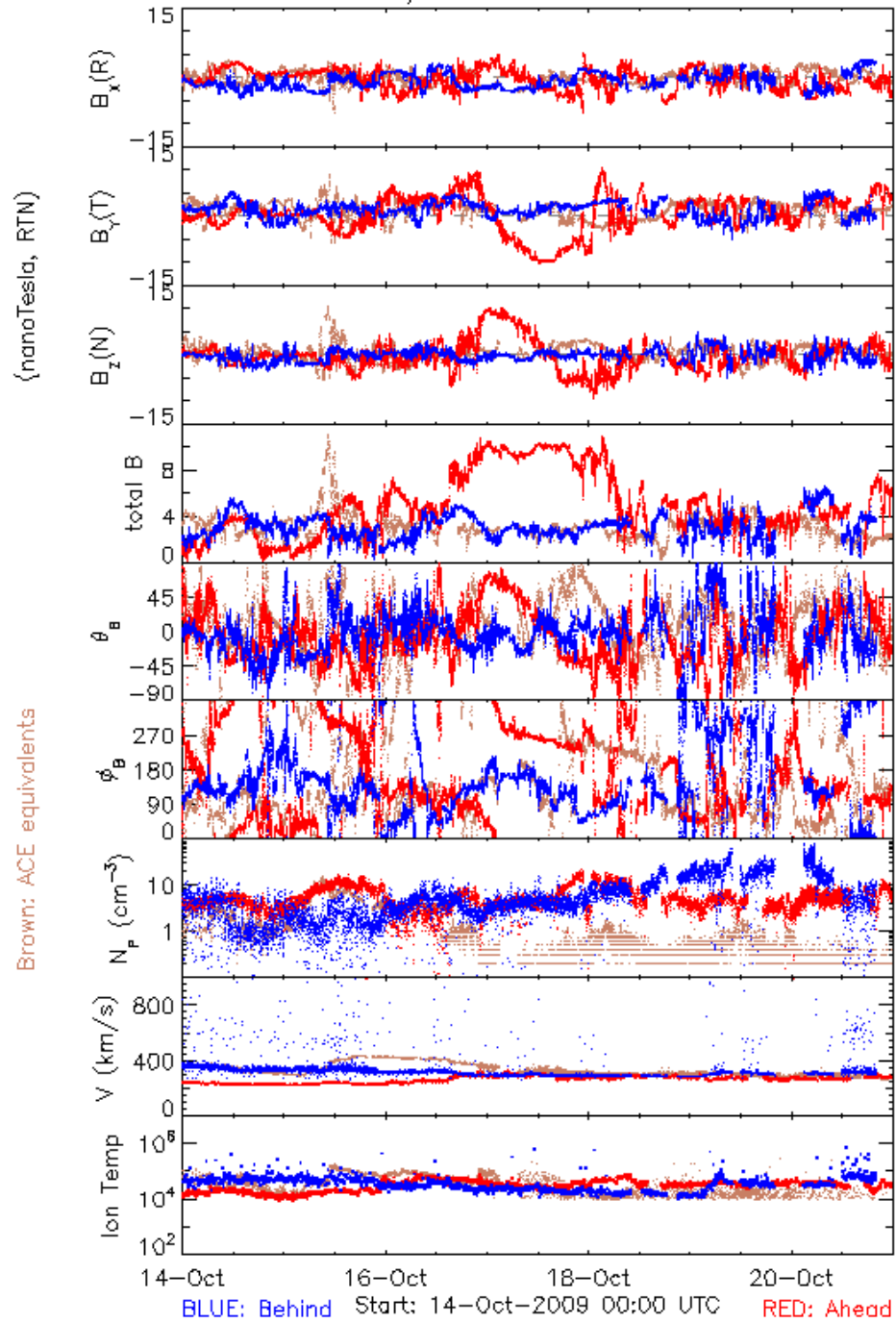
ICME (shock and ejecta) dates, times and duration 2009 January - July

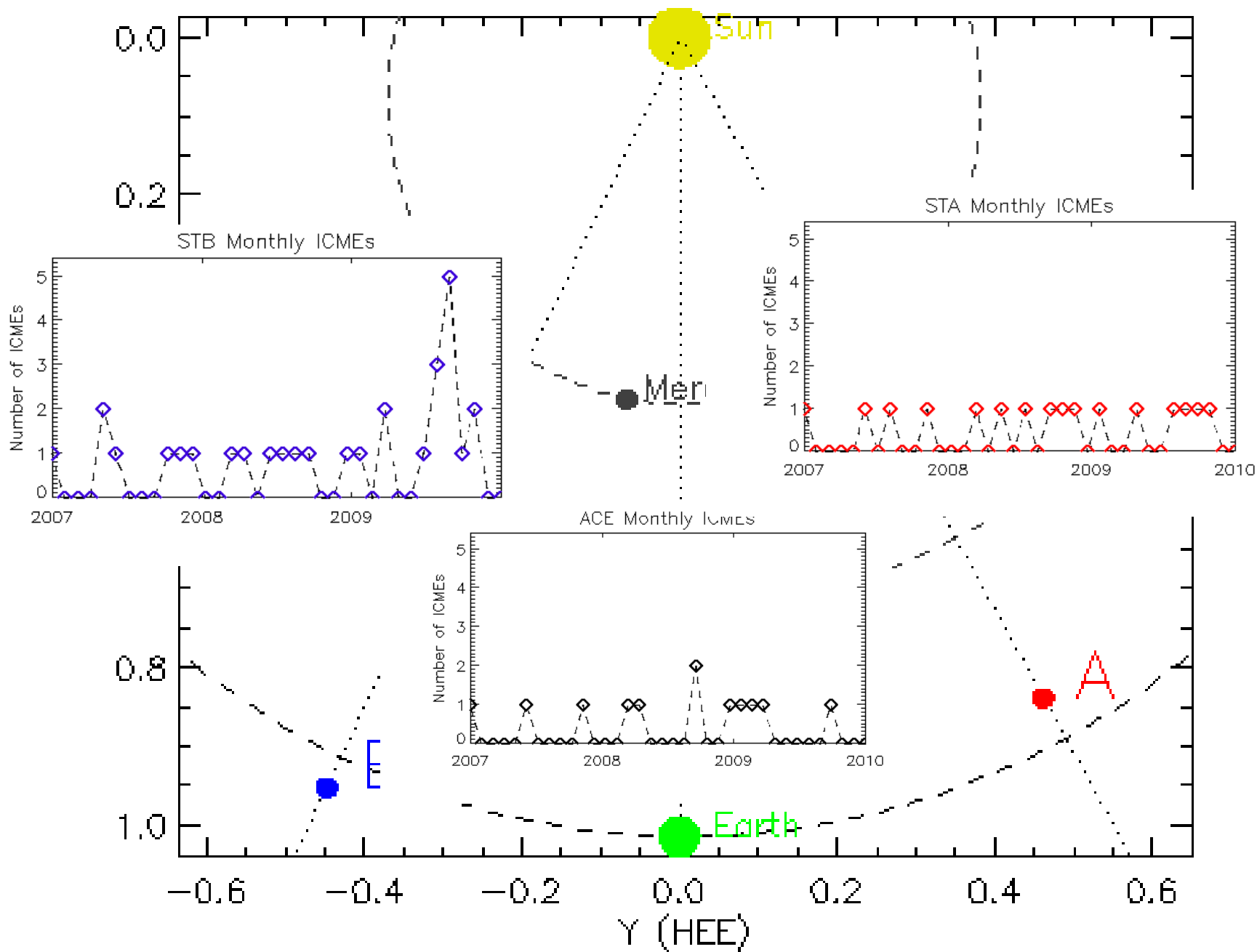
	A&B	STB (7)	ACE / Wind (3)	STA (3)
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
09Jan13	89.3	(-)6:10 5:40 20h10m	-- 5:35 3h	
09Jan26	90.1			-- 00:05 ~7h
09Feb03			-- 23:55 18h	
09Mar11			-- 22:00 ~26h	
09Mar14		12:00 20:00 13h		
09Mar30		6:00 12:00 ~10		
09Apr30				17:30 22:00 6h
09Jun19		00:30 8:00 4h		
09Jul05		23:00 12:10 14h30m		
09Jul11	103.2			-- 23:00 31h
09Jul16	104.0	-- 13:30 29h		
09Jul30		18:00 2:30 6h		

ICME (shock and ejecta) dates, times and duration 2009 August - October

	A&B	STB (8)	ACE / Wind (2)	STA (3)
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
09Aug01				-- 17:00 11h
09Aug06		-- 4:30 21h30m		
09Aug13		19:30 2:00 9h30m		
09Aug25	111.2	-- 10:00 27h		
09Aug30	112.1	?3:00 20:00 8h	?-- 8:00 7h	
09Sep08	113.8			7:00 10:00 12h?
09Sep09		-- 14:00 18h		
09Sep28		-- 3:00 9h		
09Sep30			-- 5:00 14h	
09Oct02	118.3	16:00 6:00 24h		
09Oct06		-- 19:00 8h		
09Oct16				7:30 23:00 24h

IMPACT/PLASTIC 17-Oct-2009





Identify the Sources of CMEs with ICMEs

1. Begin with ICMEs and identify the corresponding coronagraph CMEs.
2. Identify low-corona-activity / initiation-sites of this group of CMEs (a small fraction of CME population).

ICMEs and CMEs						
Year	A&B angle	ICMEs	CMEs	none		
2007	0.052° – 44.018°	8	5	3		
2008	44.018° – 88.494°	17	13	4		
2009	88.494° – 132.322°	24	22	2		
total	0.052° - 132.322°	49	40	9		
CMEs and sources						
Yeas	A&B angle	CMEs	flares	filaments	dimm	none
2007	0.052° – 44.018°	5	2	2	2	3
2008	44.018° – 88.494°	13	2	3	4	6
2009	88.494° – 132.322°	22	0	9+		4
total	0.052° - 132.322°	40	4	14+	6+	13

CMEs with ICMEs in 2007

No.	CME				ICME		A&B sprt°
	Date	Flare	other	speed	Date	Speed	
1	May19	B9.5	Filament Dimming wave	950	May21	481	8.995
2	May20	B6.7	Dimming wave	275 (500)	May23	535	9.167
3	Aug21	-	304ft?	357	Aug25	339	27.217
4	Nov15 18:50	-	-	125	Nov19	391	40.768
5	Dec24 19:30	-	-	132	Dec30	365	43.927

CMEs with ICMEs in 2008

No.	CME				ICME		A&B sprt°
	Date	Flare	Other	Speed	Date	Speed	
6	Mar17 7:54	-	double Dimming	211 (221)	Mar21 6:40	480	46.737
7	Apr26 14:30	B3.8	dimming	515 (741)	Apr29 14:10	453	49.804
8	May06 16:54	-	-	141	May11 6:31	-	51.080
9	Jun02 4:17	-	-	192 (265)	Jun06 15:36	412	54.591

CMEs with ICMEs in 2008

No.	CME				ICME		A&B sprt°
	Date	Flare	Other	Speed	Date	Speed	
10	Jul07 09:54	-	-	235 (292)	08Jul10 23:00	570	60.415
11	Aug10 14:24	-	-	294	08Aug15 12:00	365	66.195
12	Aug30 17:30	-	-	190	08Sep04 5:25	360	70.154
13	Oct26 15:06	-	-	172	08Oct31		
14	Nov03 00:54	-	filament dimming	370	08Nov07		
15	Dec12 08:54	A9.5	filament	203	08Dec17		87.2
16	Dec27 05:30	-	filament	468	08Dec31		

CMEs with ICMEs in 2009

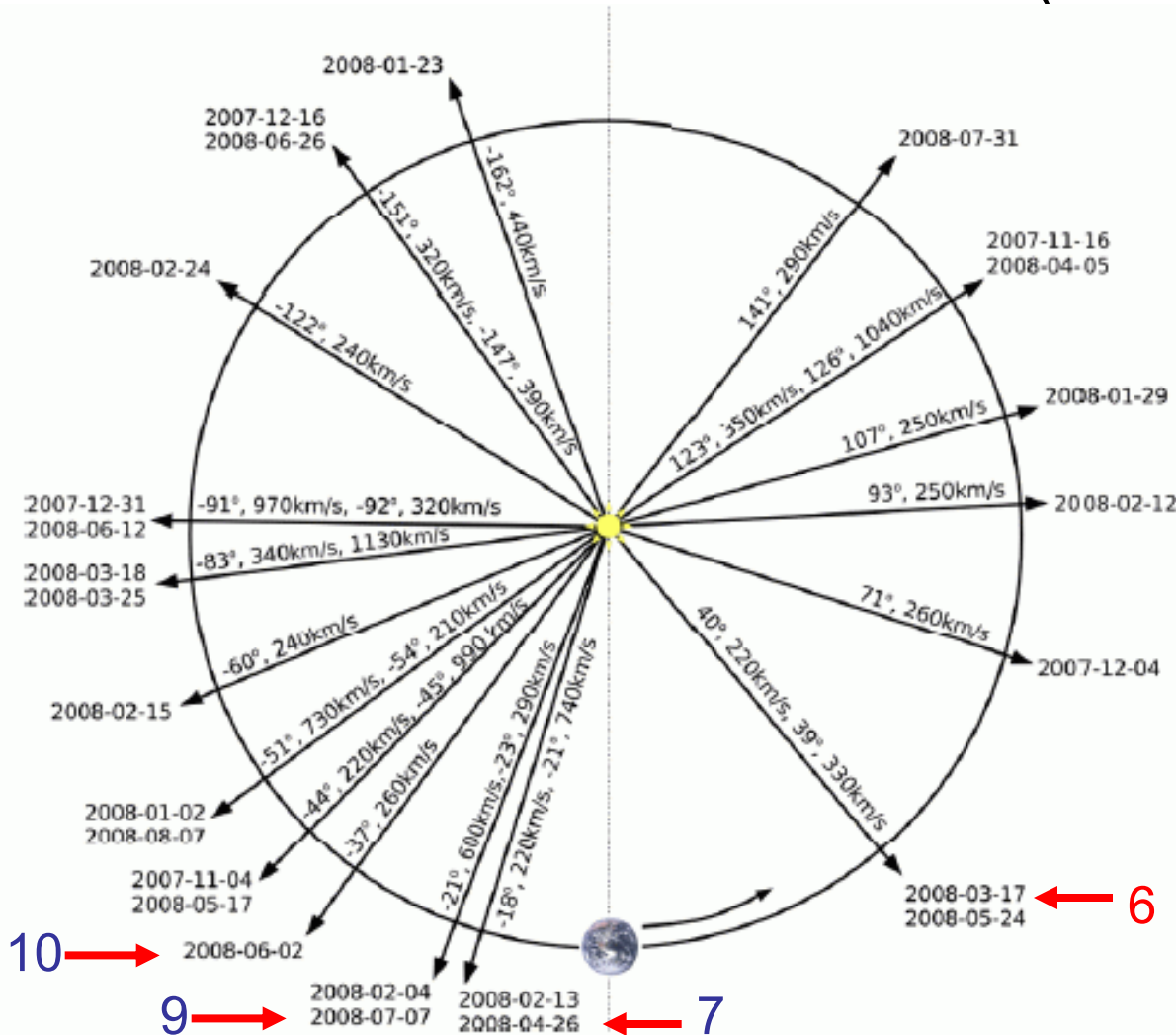
No.	CME				ICME		A&B sprt°
	Date	Flare	Other	Speed	Date	Speed	
	09Jan08 22:30	-	-	146	09Jan13		89.3
	09Jan21 18:54	-	Filament?	220	09Jan26		90.1
	09Jan31	-	Filament?		09Feb03		
	09Mar05		filament		09Mar11		
	09Mar10	-	-		09Mar15		
	09Mar24	-	filament		09Mar30		
	09Apr24	-	filament		09Apr30		
	09Jun16	-	Filament		09Jun19		
	09Jun30	-	Filament?		09Jul05		
	09Jul06	-	Filament?		09Jul11		103.2
	09Jul10	-	-		09Jul16		104.0
	09Jul26	-	-		09Jul30		

CMEs with ICMEs (MCs) in 2009

No.	CME				ICME		A&B sprt°
	Date	Flare	Other	Speed	Date	Speed	
	-				09Aug01		
	Jul31	-	-		09Aug06		
	Aug08	-	-		09Aug13		
	Aug19	-	-		09Aug25		111.2
	Aug25	-	filament		09Aug30		112.1
	Sep04	-	filament		09Sep08		113.8
	Sep04		filament		09Sep09		
	Sep22?	-	flt?		09Sep28		
	?	-	flt?		09Sep30		
	09Sep27	-	filament		09Oct02		118.3
	09Oct01	-	-		09Oct06		
	09Oct12	-	filament		09Oct16		

Forward Modeling Results of STEREO CMEs

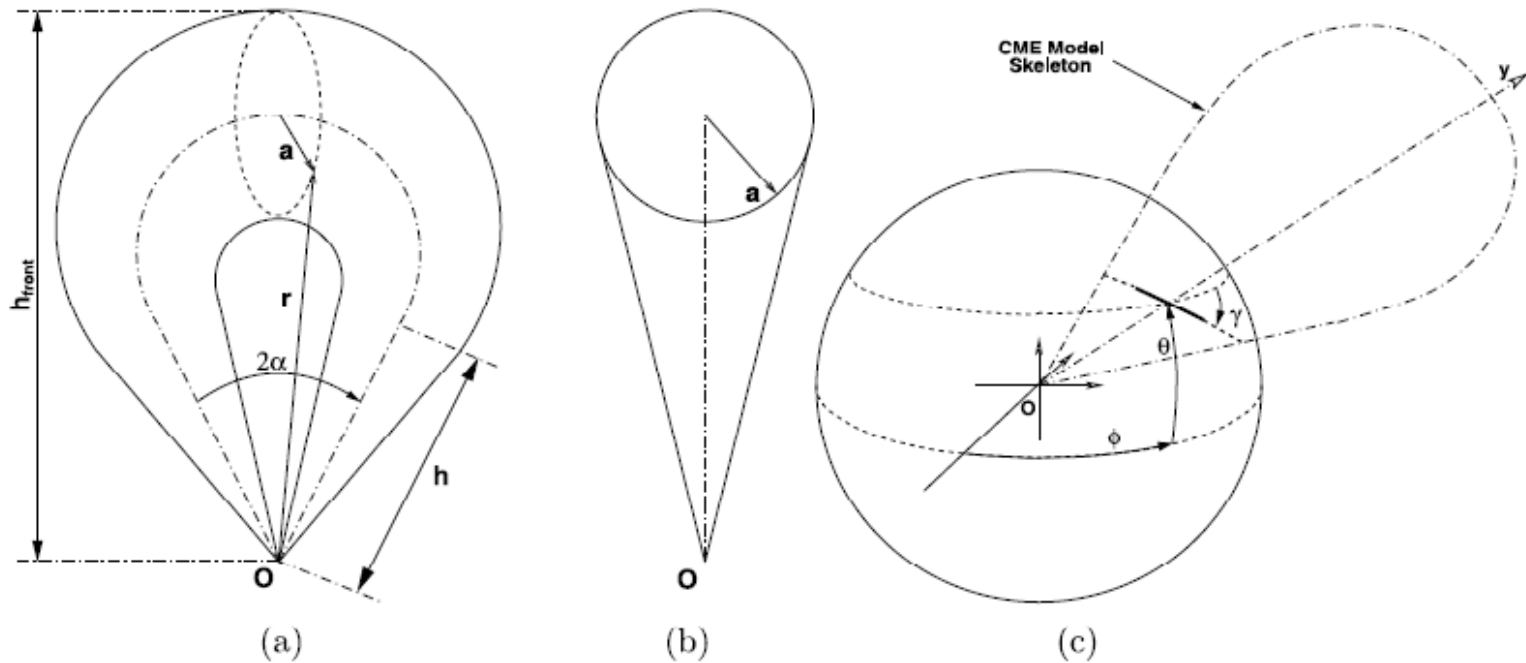
Thernisien et al. (2009)



- 26 bright STEREO CMEs (Nov07 to Aug08) were fitted with Forward Modeling;
- Three CMEs encountered STB;
- One CME encountered STA.

Parameters in Forward modeling

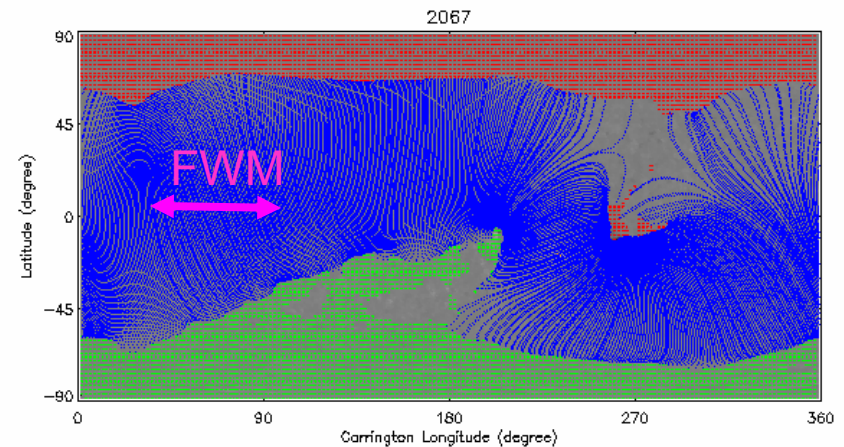
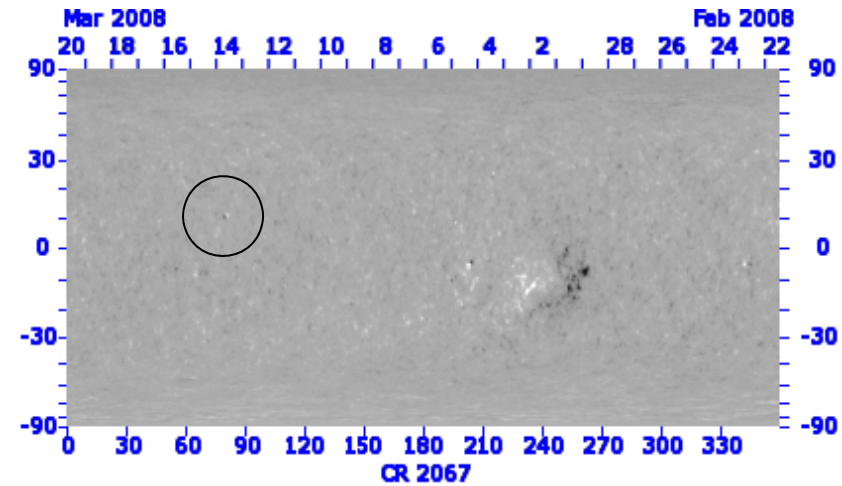
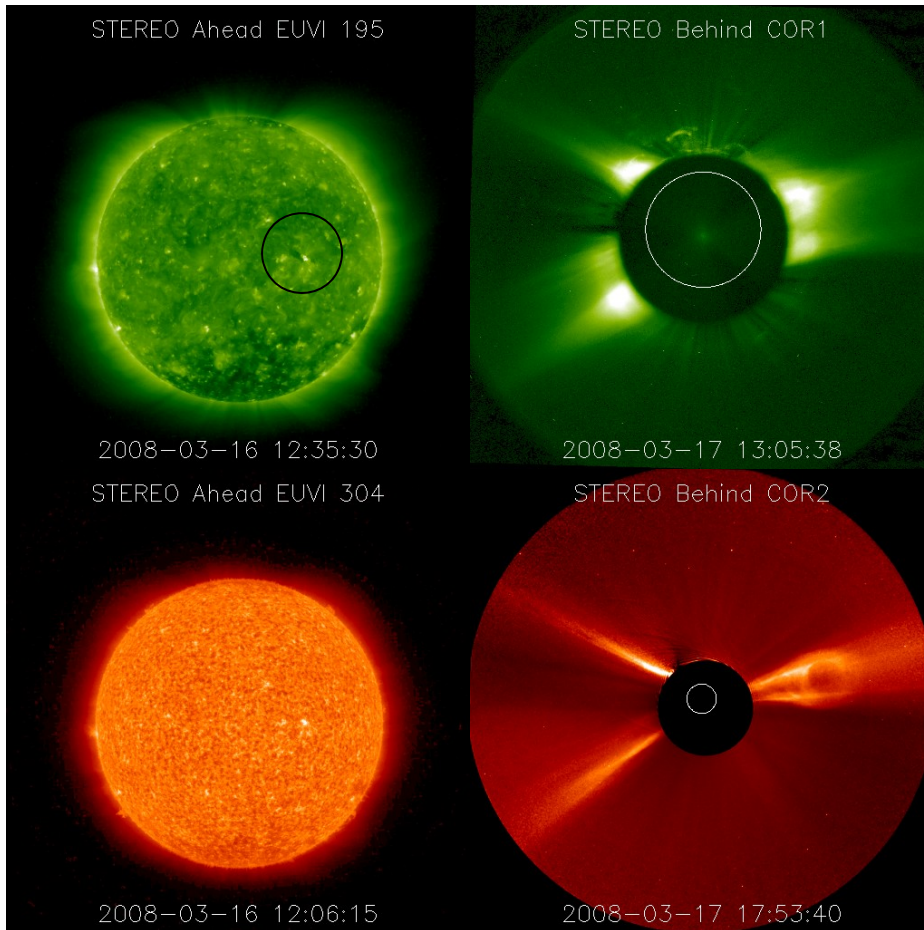
Thirnisien et al. (2006, 2009)



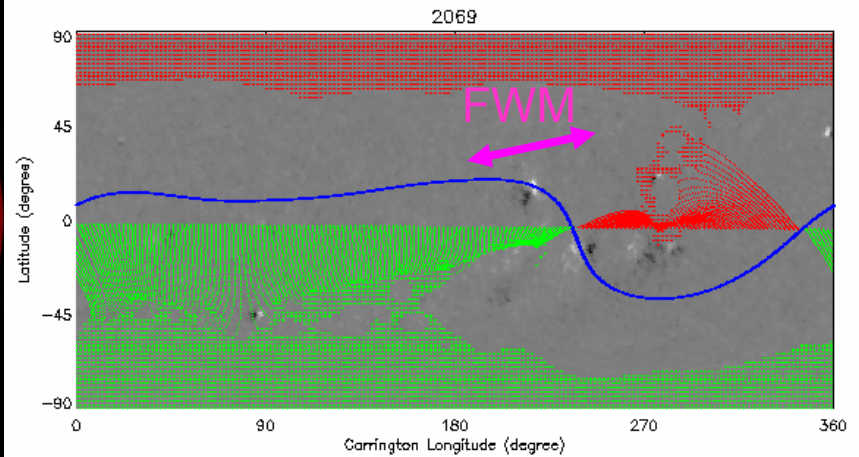
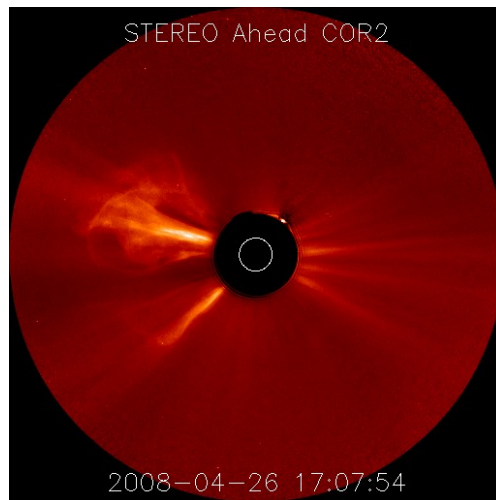
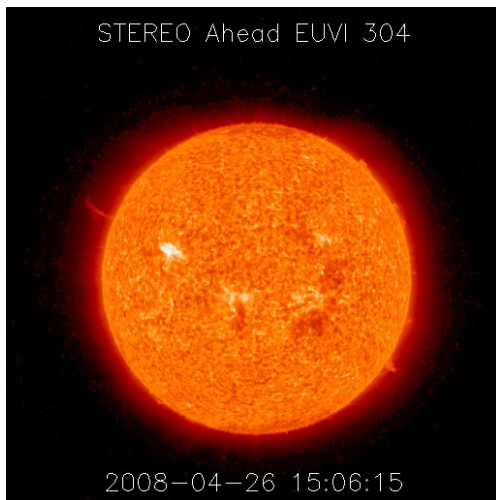
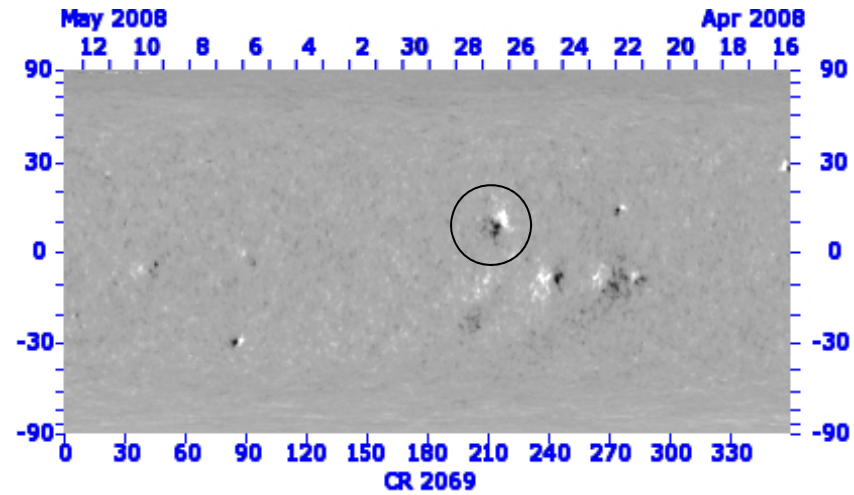
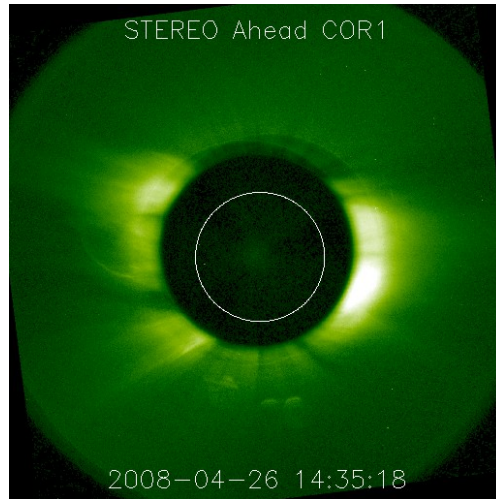
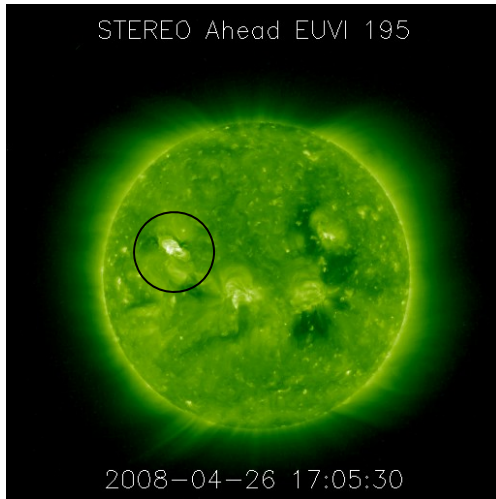
FWM 3D Parameters for Four Source CMEs of ICMEs in 2008

		FWM 3D Parameters							Observations	
Event No.	Date 2008	ϕ°	θ°	γ°	α°	κ	V Km s ⁻¹	A Km s ⁻²	V _{CDAW} Km s ⁻¹	V _{ICME} Km s ⁻¹
6	Mar17 17:52	40	4	2	6	0.20	221	6.9	211	480
7	Apr26 17:52	-21	6	13	8.4	0.22	741	1.4	515	453
9	Jun02 08:52	-37	-3	2	8	0.35	265	5.0	192	412
10	Jul 07 20:22	-23	-18	1	16	0.28	292	15	235	570

2008-March-17 small magnetic region and double dimming CME

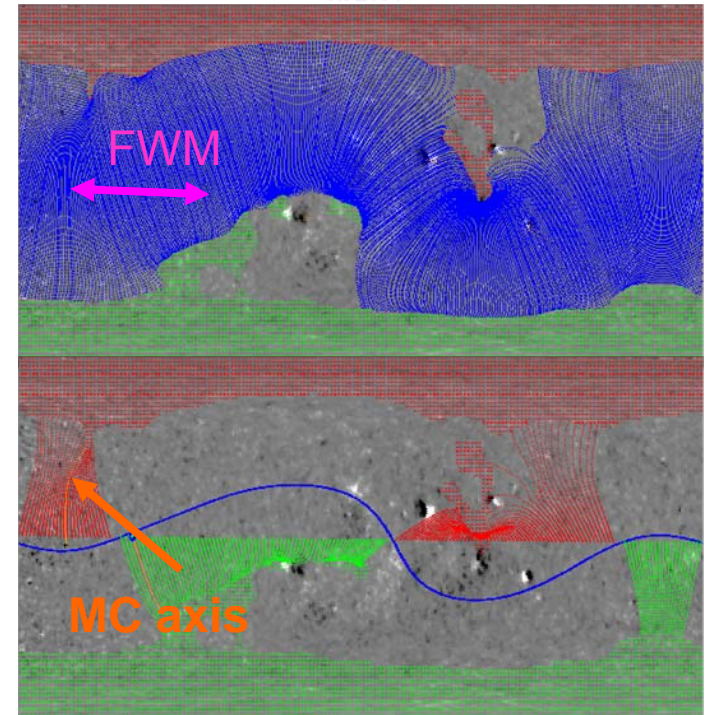
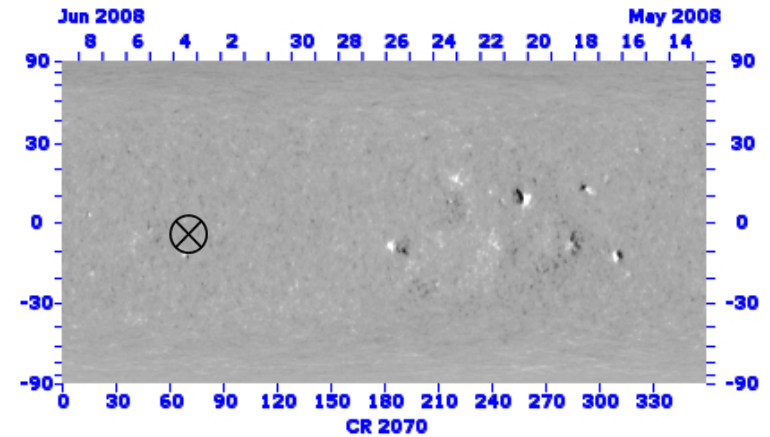
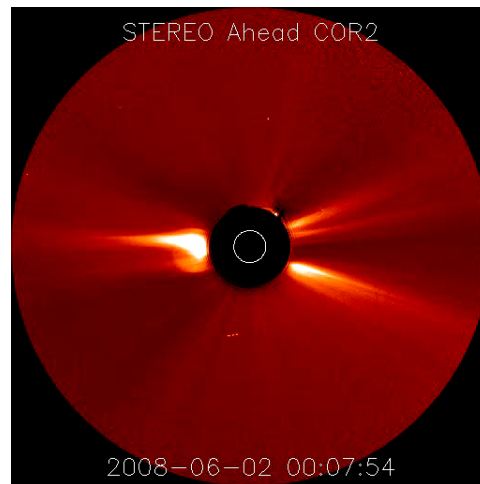
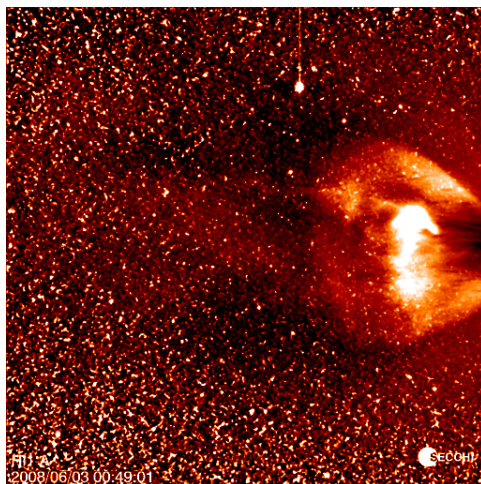
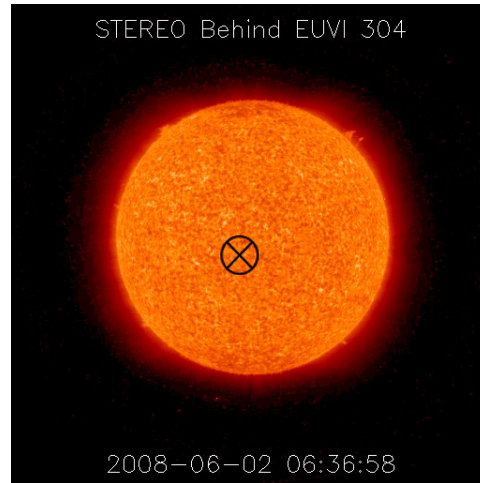
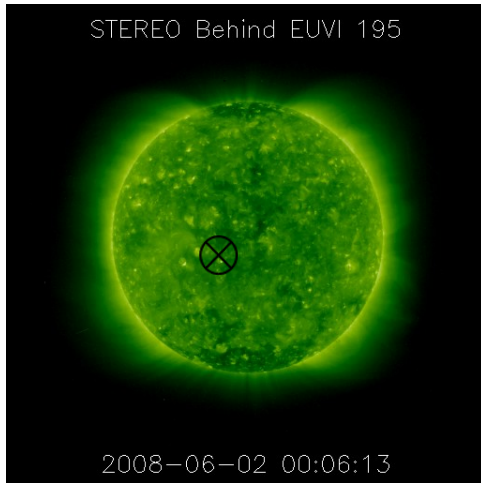


2008-April-26 flare related CME



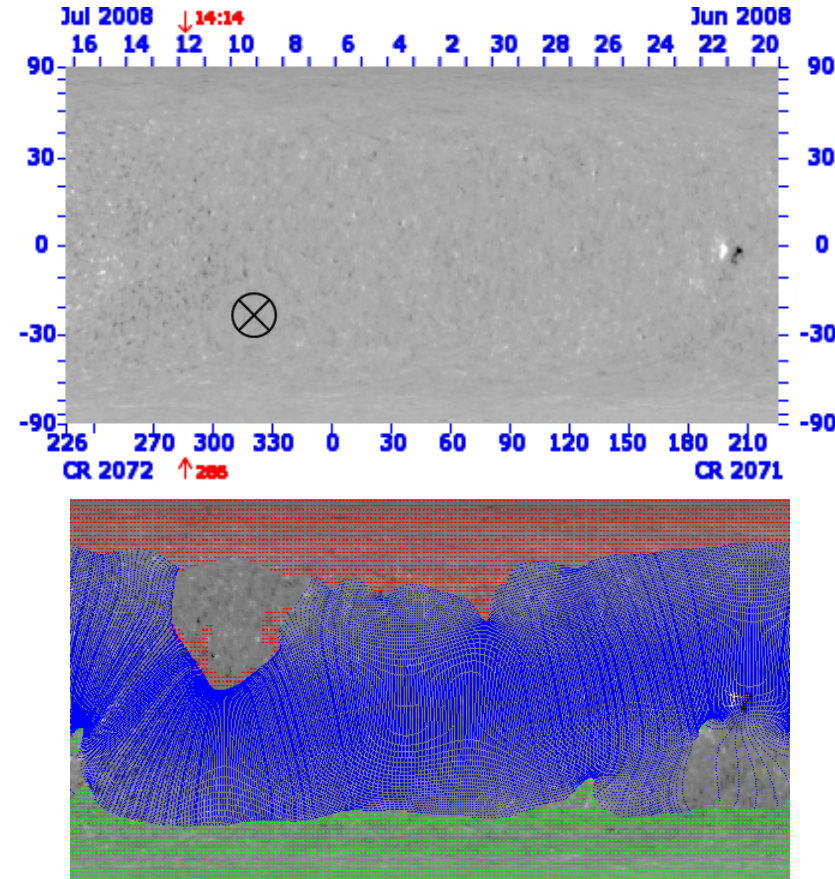
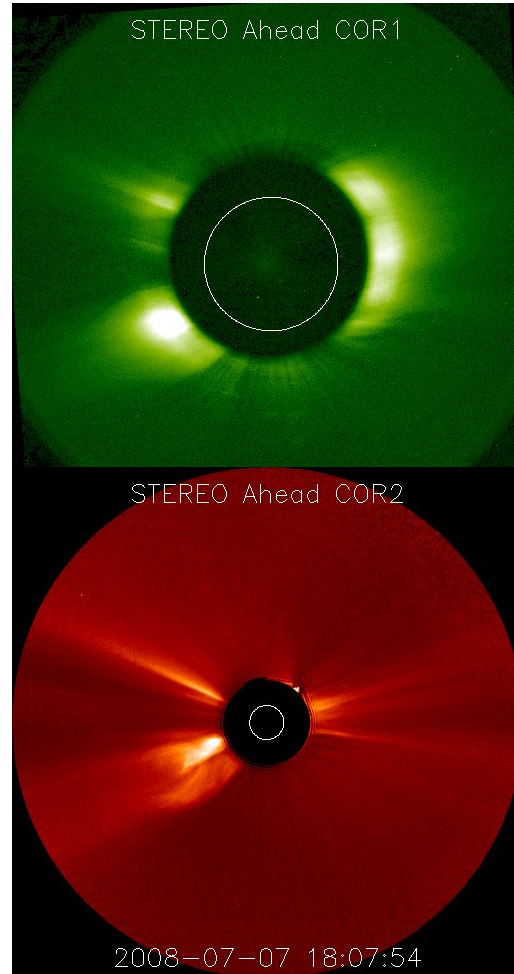
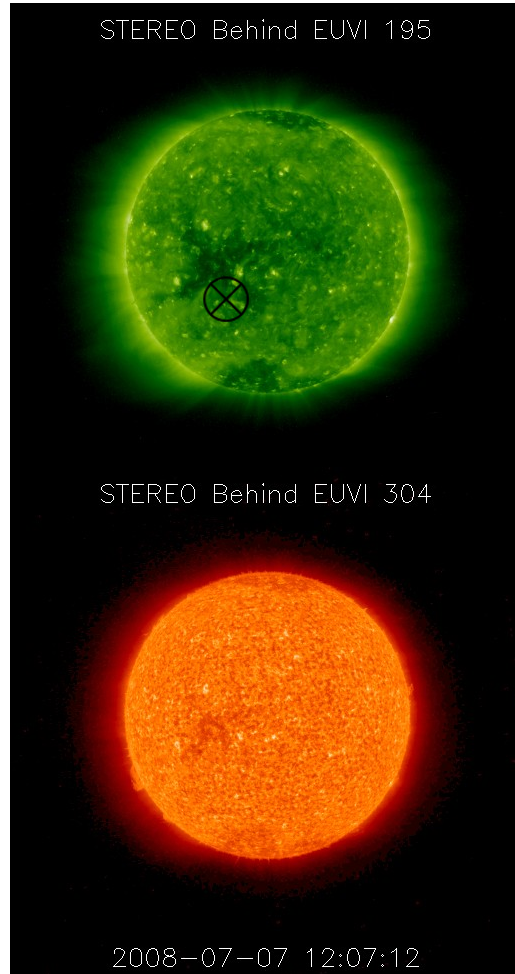
2008-June-02 quiet Sun streamer blow-out CME

⊗ - CME source location by FWM

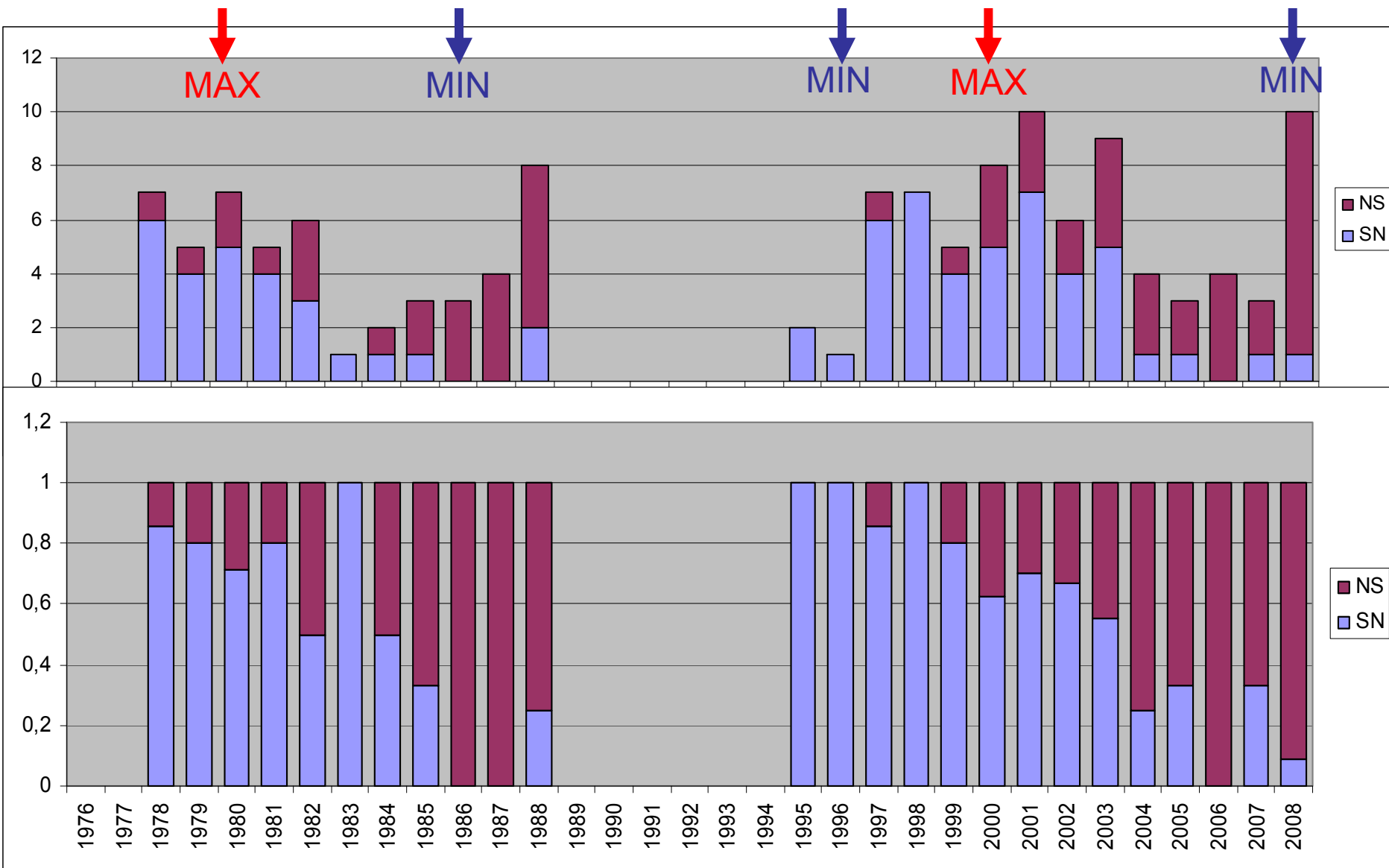


2008-Jul-07 CME with unclear source near a coronal hole boundary

⊗ - CME source location by FWM



Long term variation of Bz polarity within Magnetic Cloud



Summary

- The small group of CMEs with ICMEs during STEREO time had variety of solar sources, including small magnetic regions, weak flares, small EUV dimmings and quiet Sun, and lack of large active regions and large flares.
- Almost all of these CMEs are slow and so as to the resulted ICMEs.
- We have worked on detailed case studies for a few cases (not shown today), and are carrying on these studies further by other case studies and statistical studies.