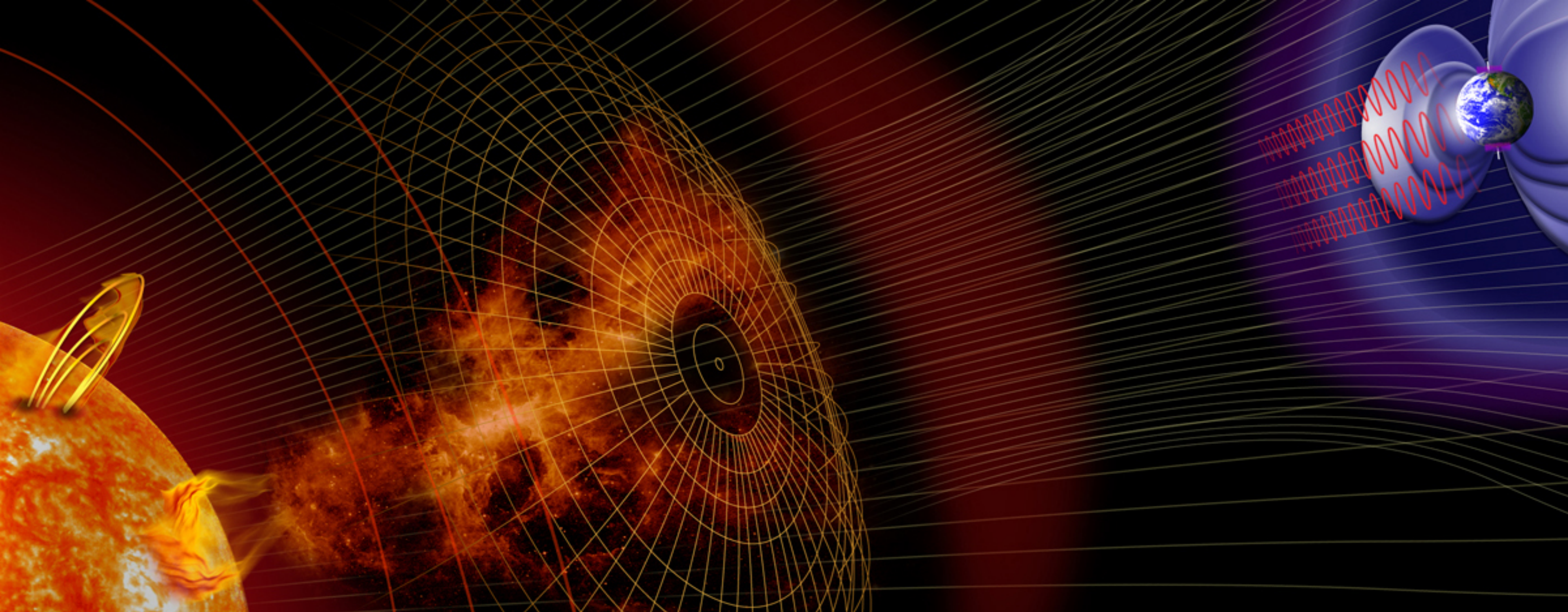

Key Problems in the forecasting of the geoeffectiveness of CMEs

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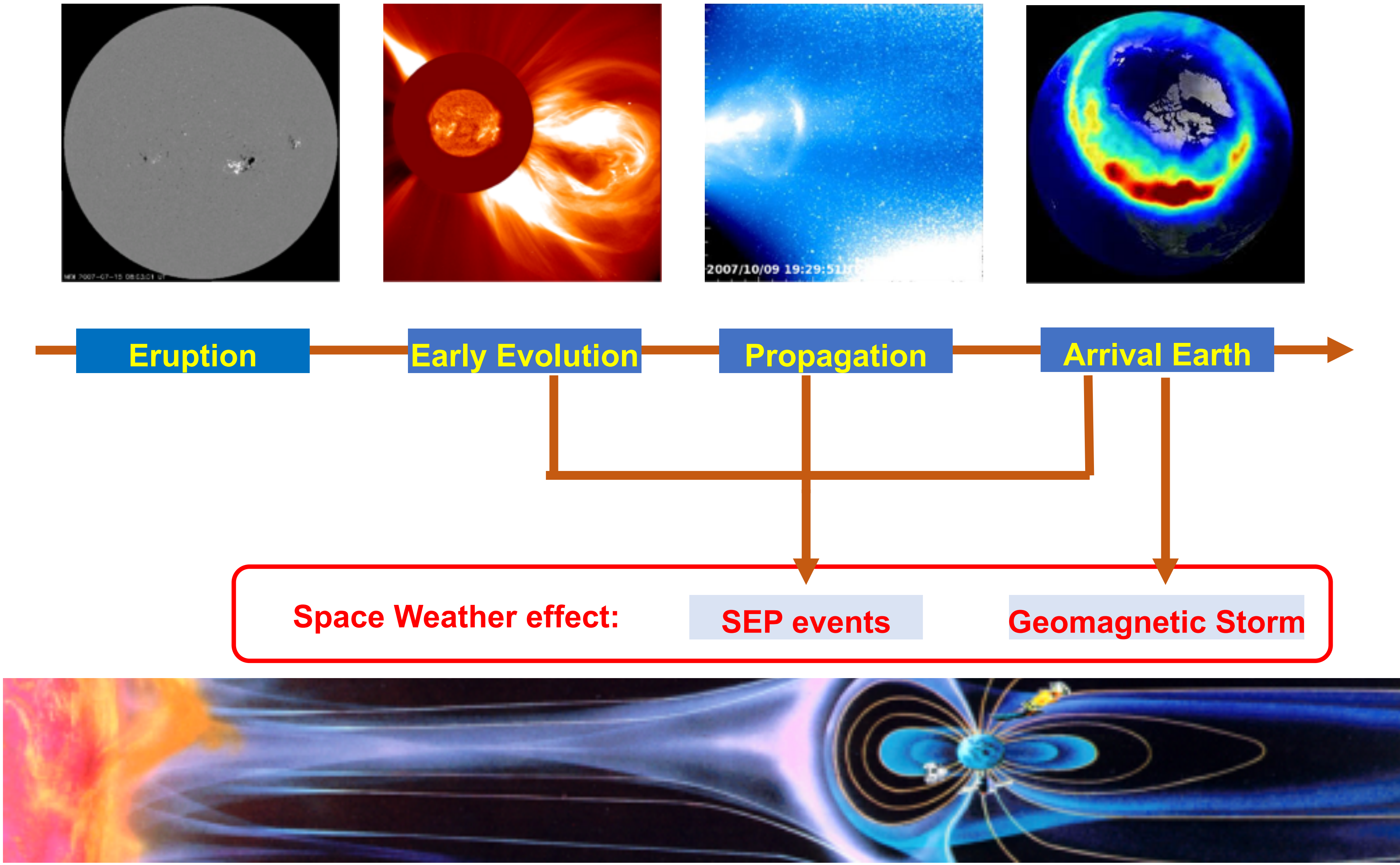
Sun-Earth connection of a CME event



Key Problems

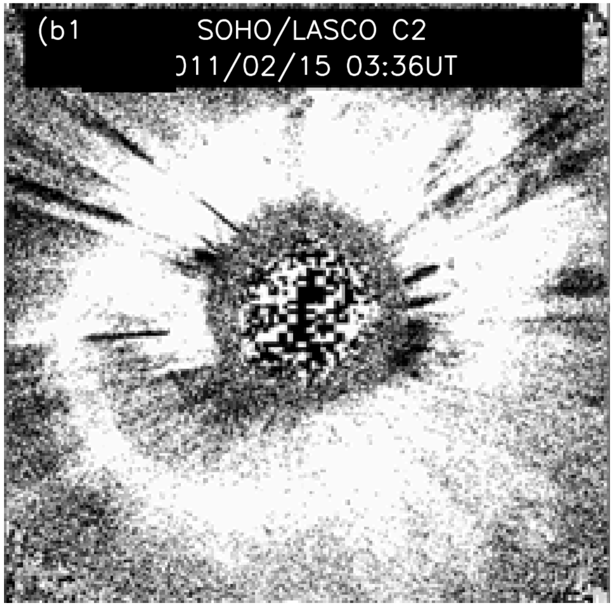
Main questions:

- **Whether the CME will arrival at the Earth?**
- **When the CME arrival at the Earth?**
- **What is the intensity of the geomagnetic storm?**

Have to know first:

- **The 3 dimensional kinematic and geometrical parameters of CMEs → Whether and When?**
- **The south component of the magnetic field when the CME arrival at 1AU → What?**

1. How to obtain the 3D parameters of CMEs?



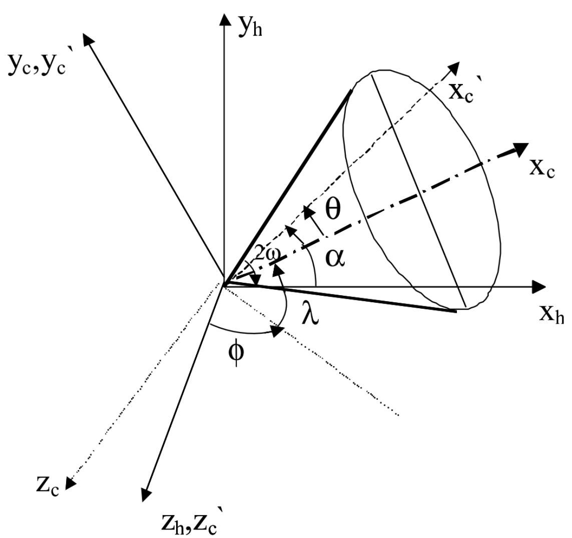
Projected Observations

- **Projection Effect?** [e.g. Vršnak et al., 2007; Howard et al., 2008; Temmer et al., 2009; Shen et al., 2013; Jang et al., 2016]
- **Useful models**? [e.g. Zhao, 2002; Michanek et al., 2003 ;Xie et al., 2004; Xue et al., 2005; Na et al., 2017]

3 Dimensional Parameters

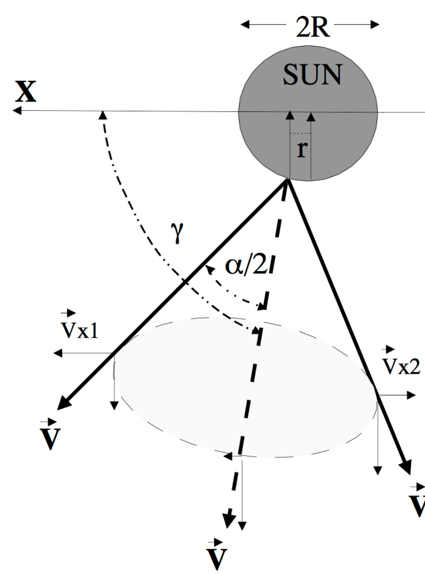
Cone Models

Different cone models have been developed by different authors!



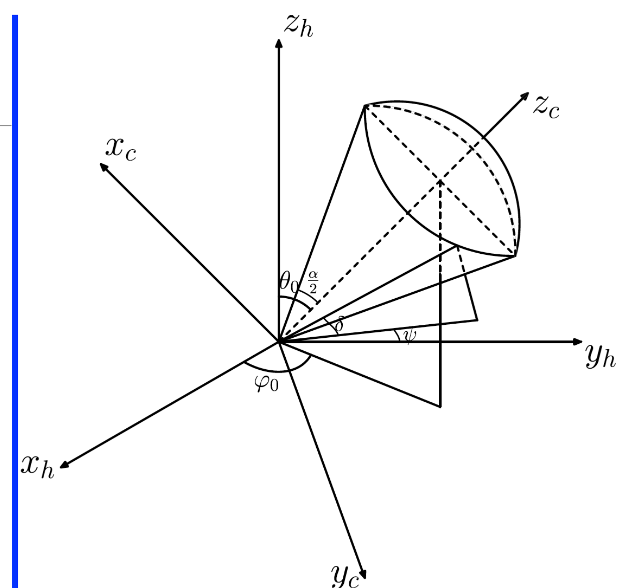
Cone Model (Circle)

[Zhao, 2002; Xie et al., 2004]



Cone Model (Ellipse)

[Michalek et al., 2003]



Ice Cream Cone Model

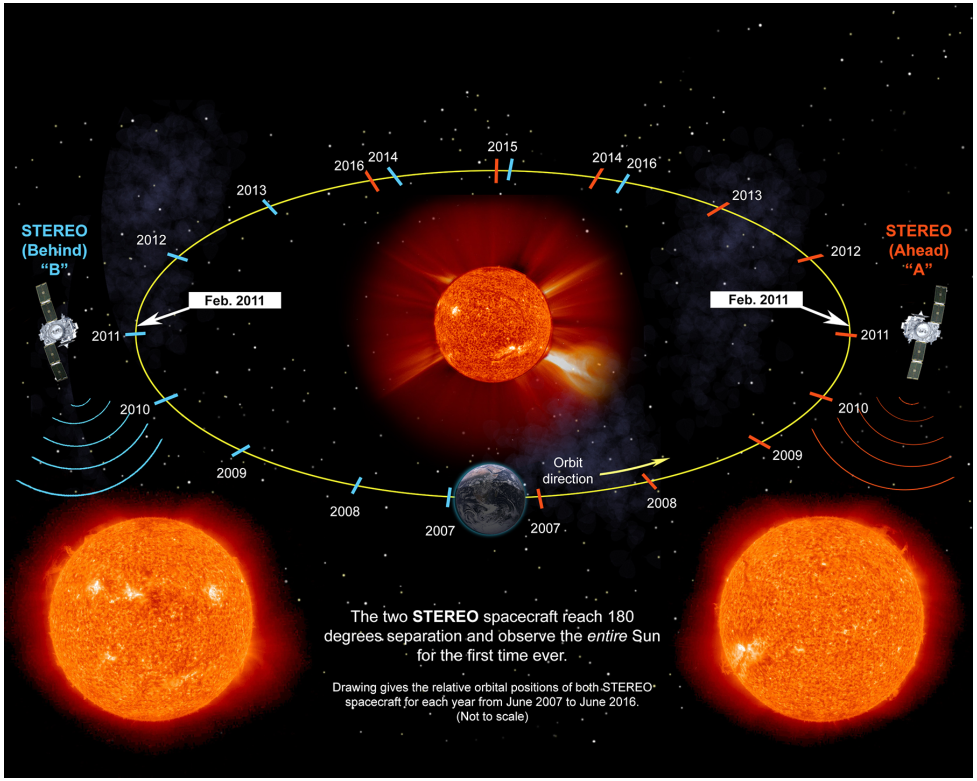
[Xue et al., 2005; Na et al., 2017]

STEREO Period

CMEs can be seen from multiples points!

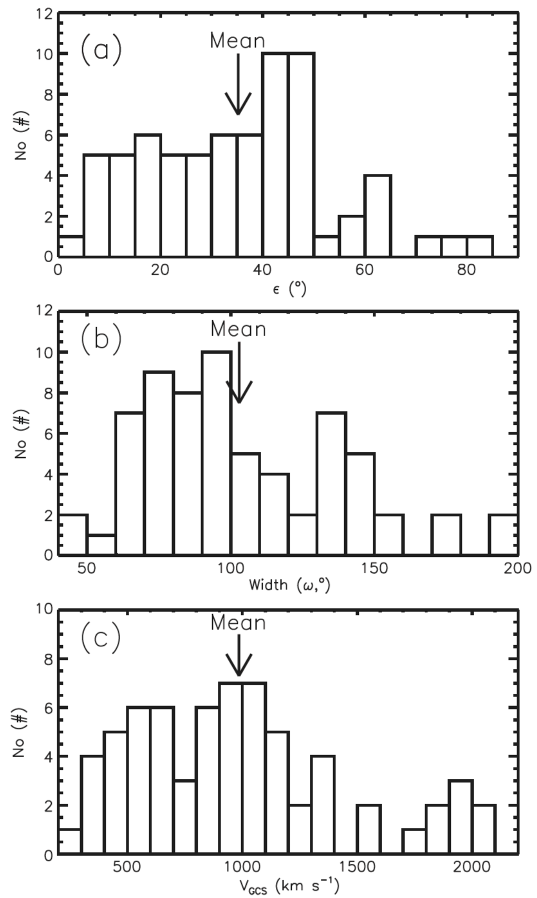
Different models have been developed:

- **Harmonic Mean(H-M) method** [Lugaz et al., 2009; 2010]
- **Triangulation method** [Liu et al., 2010]
- **GCS model** [Thernisien et al., 2009; Thernisien, 2011]
- **Polarization method** [Moran and Davila, 2004]
- **Mask fitting method** [Feng et al., 2012]
- ...

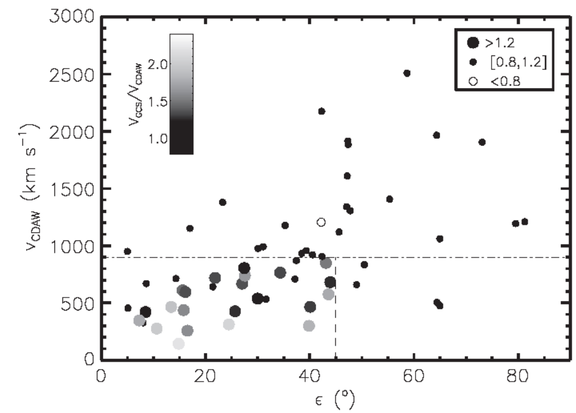


But, STEREO is not always there!

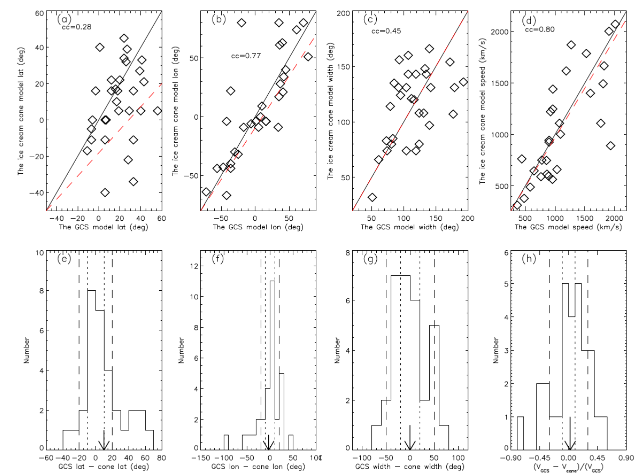
STEREO Period



Three dimensional parameters obtained from multiple points observations



Discuss the projection effect



Evaluate the Models

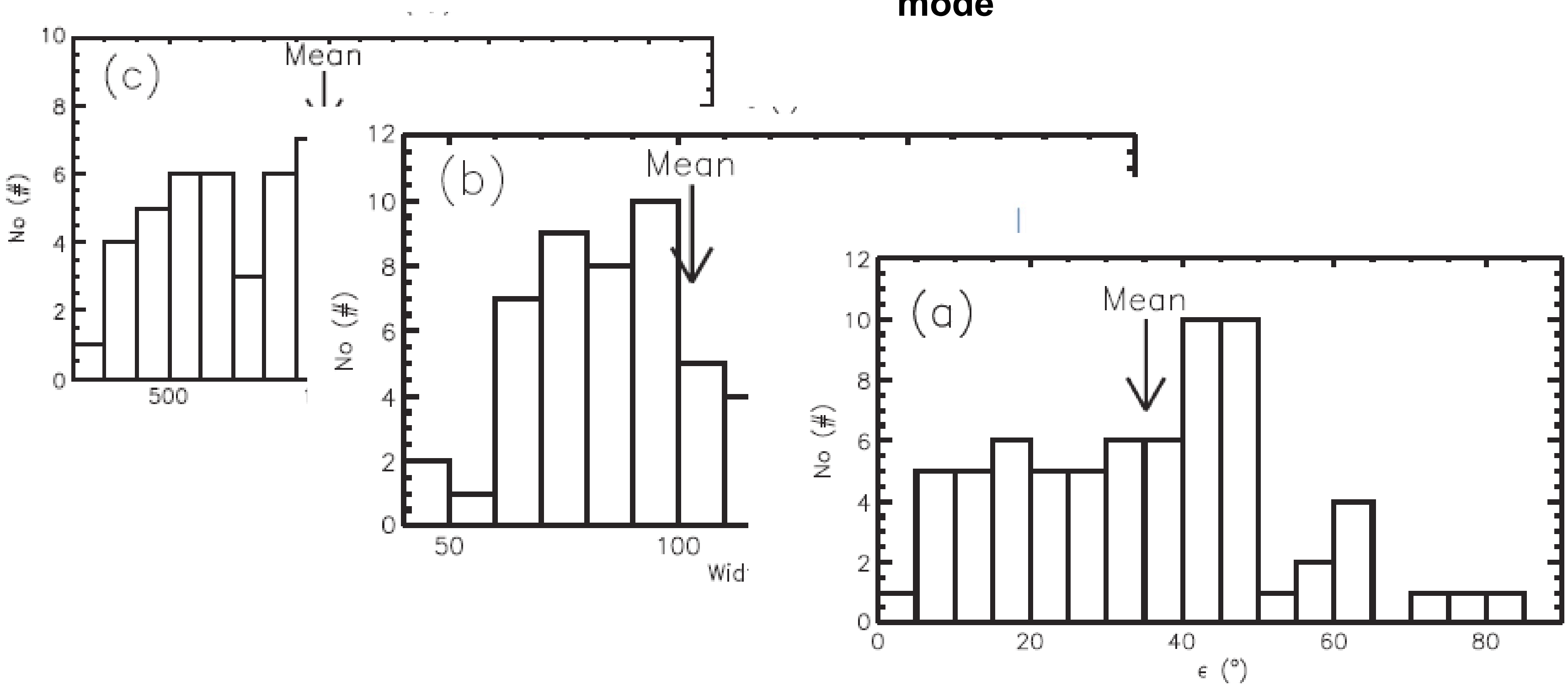
3-Dimensional Parameters of Full Halo CMEs [Shen et al., 2013]

	Group I	Group I	Group III	Total
Frontside	37	2	9	48
Backside	29	1	8	38
Total	66	3	17	86

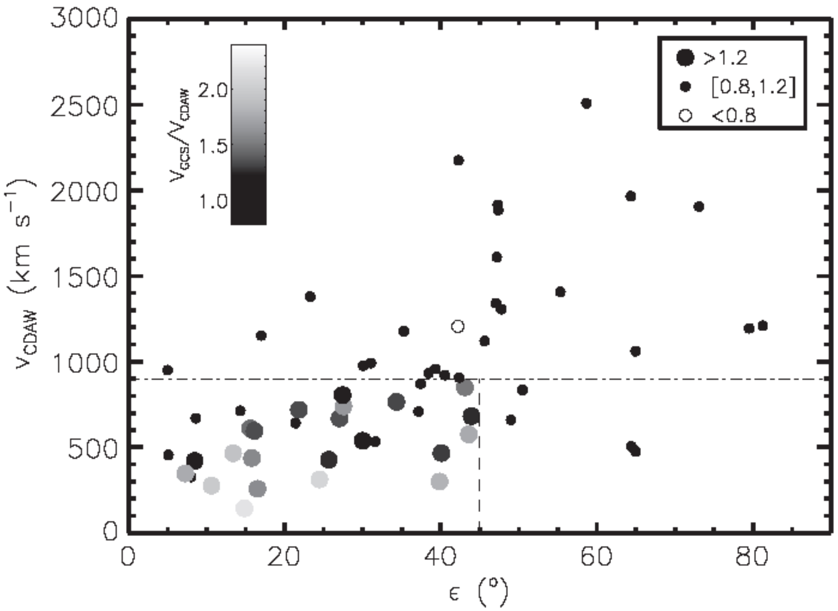
Group I: Can be fitted by the GCS model.

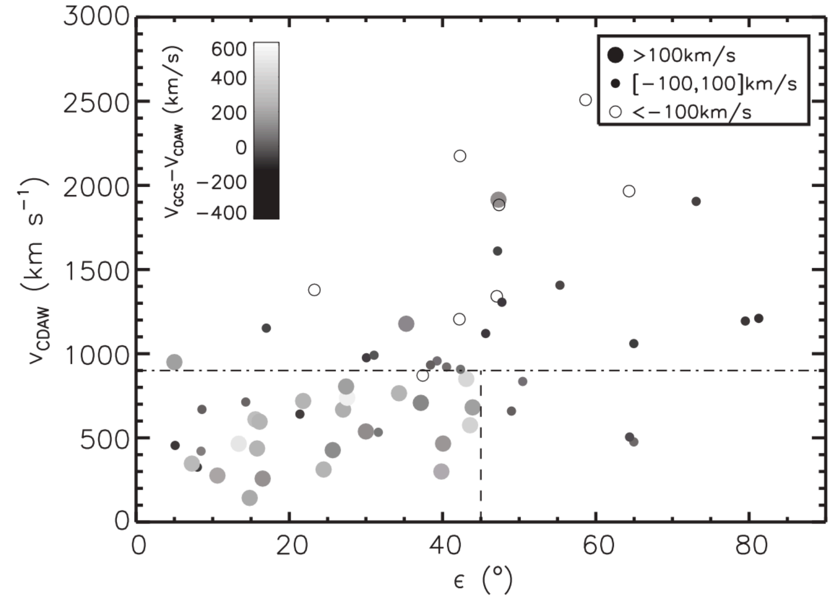
Group II: Can be fitted by the GCS model. But, No v_{CDAW} is obtained due to points less than 3.

Group III: Cannot be fitted by the GCS mode



Projection Effect of Full Halo CMEs

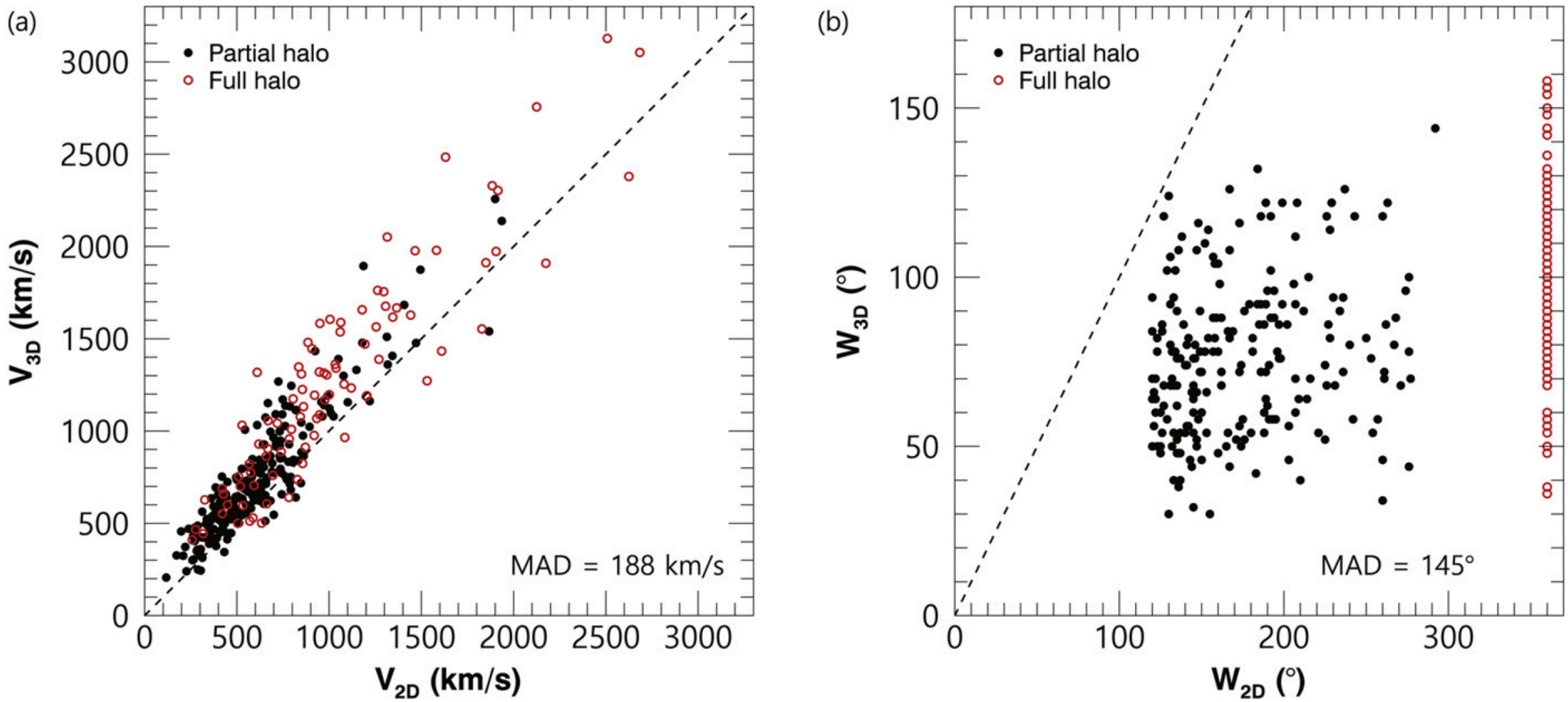




The projection effect is not obvious for [Shen et al., 2013]:

- **Fast CMEs (V > 900km/s)**
- **Limb CMEs with ε > 45°**

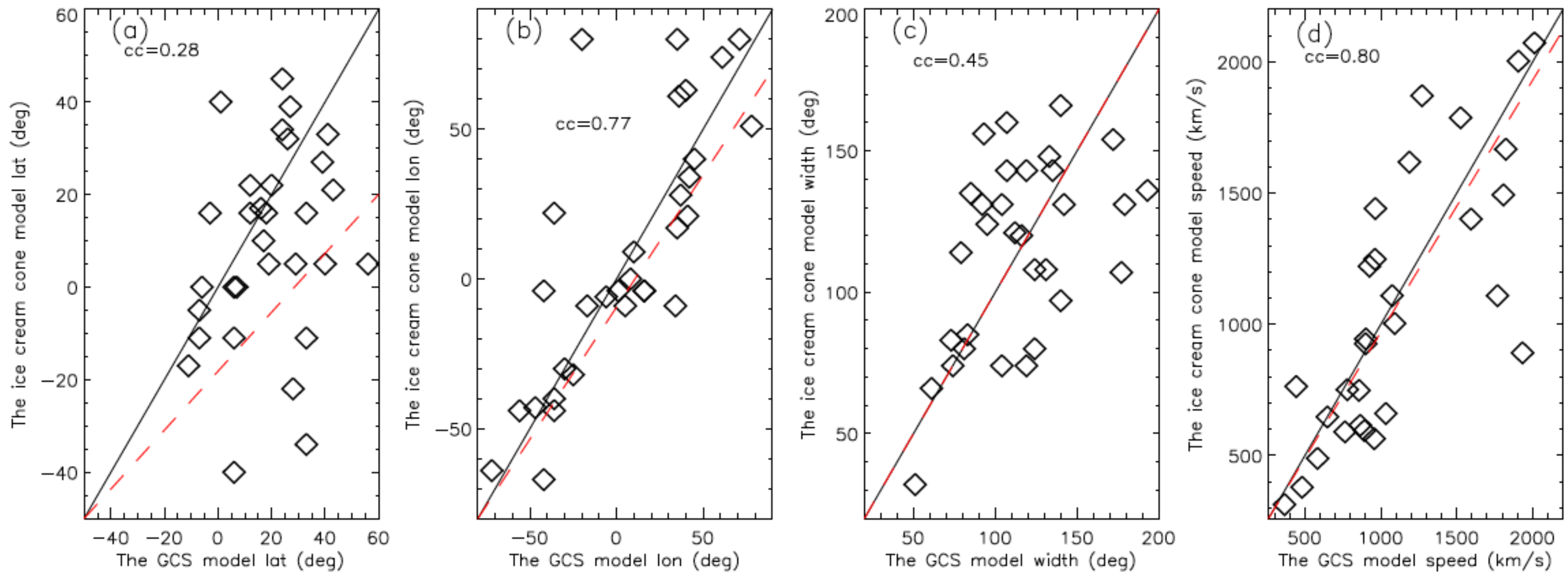
Projection Effect of Front side Halo CMEs [Jang et al., 2016]



2D speeds underestimate the 3D speed by about 20%

How can we believe the Cone model?

Comparison of the parameter obtained by GCS model and Cone model (Automatic analysis) [Zhuang et al., 2017]



- **Velocities and longitude are consistent well**
- **Latitude and angular width show some different**

2. Which CMEs can hit the Earth?

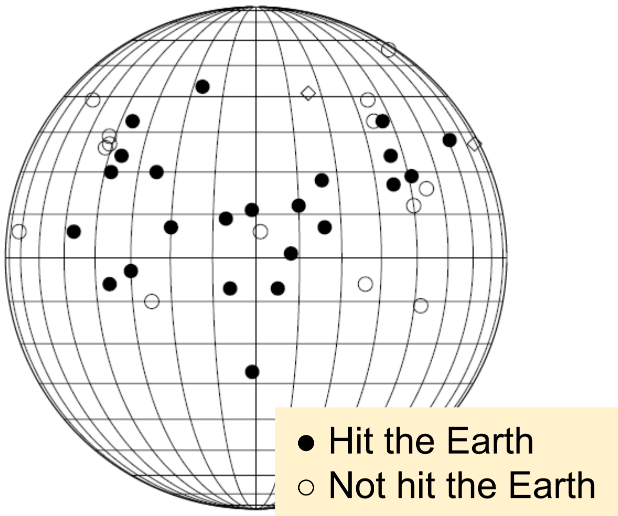
Halo CMEs are thought to propagate along the Sun-Earth Line

+

Front side CMEs are face to the Earth

→

Front side halo CMEs can hit the Earth

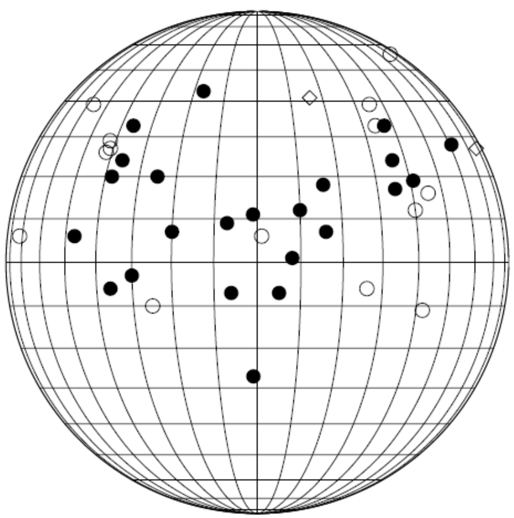


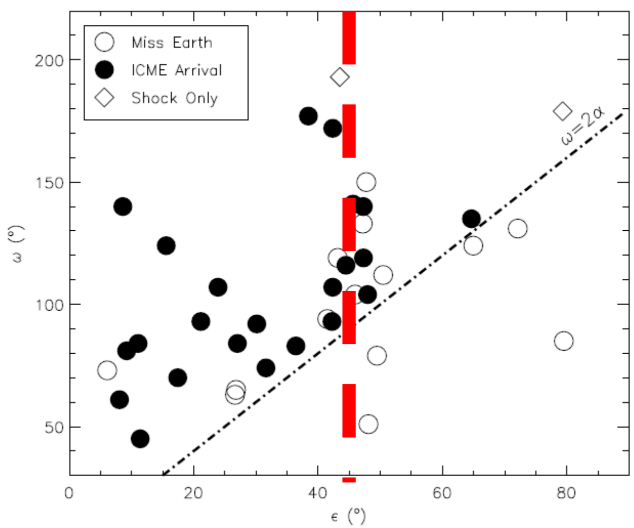
Ratios of the front side halo CMEs with geoeffectiveness varied from 45% to 71%.

[e.g.,Webb, 2002;Wang et al., 2002; Zhao and Webb, 2003; Zhang et al., 2007; Gopalswamy et al., 2007; Shen et al., 2014;Hess and Zhang, 2017]

Possible Criteria

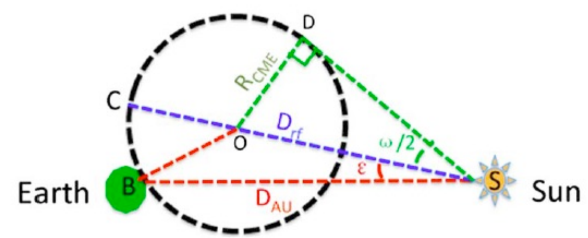
27 (56%) front side full halo CMEs hit the Earth





Self similar expansion models

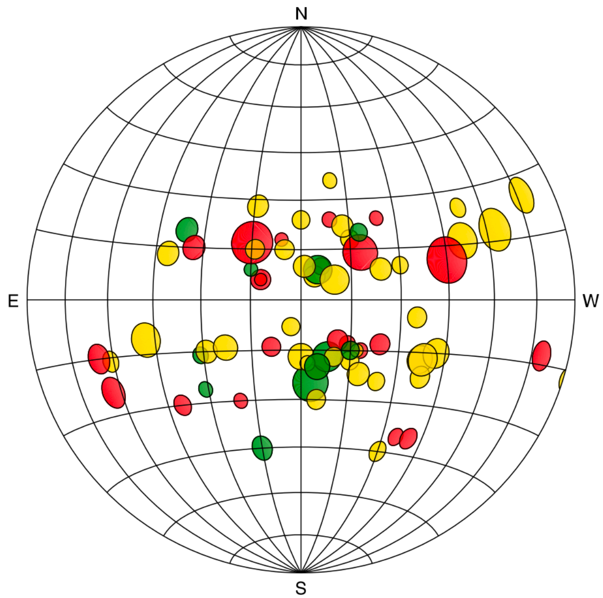
[Davies et al., 2012, Mostl and Davies,2012]



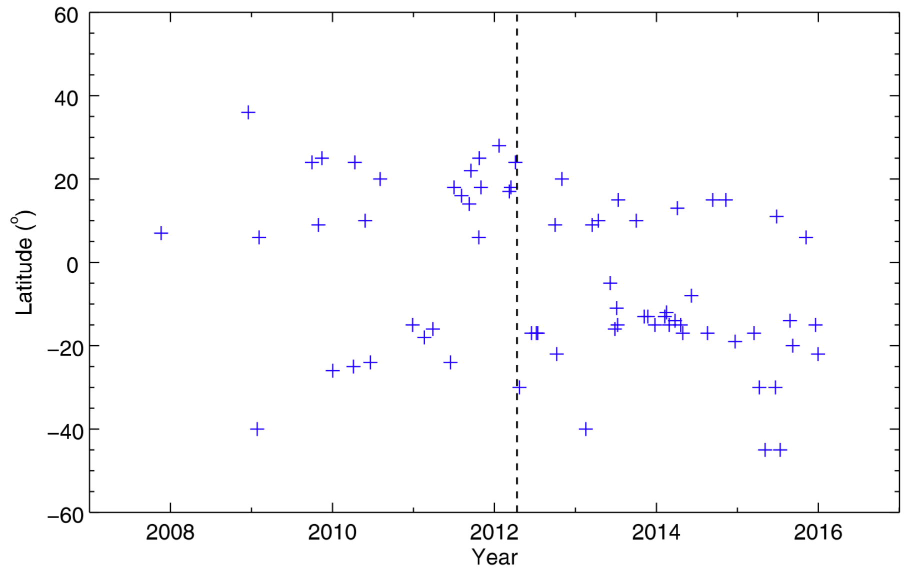
- ❑ **Central events**
  - ➢ **[E40, W40] (72%)**
  - ➢ **ε < 45° (75%)**
- ❑ **Large events**
  - ➢ **ω>2ε (74%)**

[e.g. Shen et al., 2014]

CMEs from which hemisphere can easy hit the Earth?



Hess & Zhang et al., 2017



CMEs from west hemisphere can hit the Earth with higher possibility

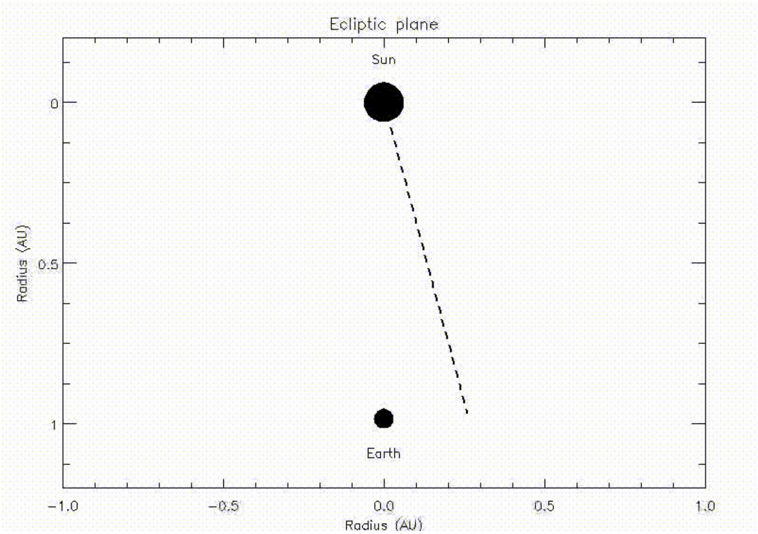
[e.g. Wang et al., 2002; Zhang et al., 2003; Shen et al., 2014; Hess & Zhang et al., 2017]

- **Before April 2012, 71.4% of events come from the northern hemisphere**
- **After April 2012, 73.8% of the events come from the southern hemisphere**

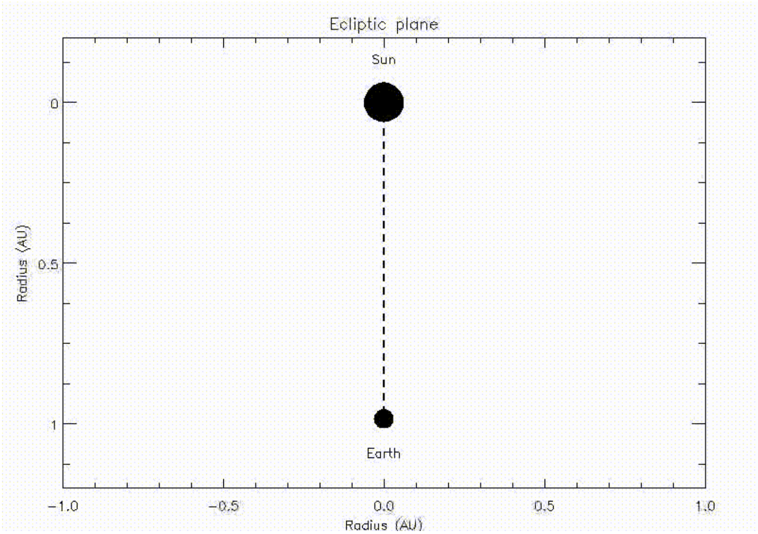
[Hess & Zhang, 2017]

An Influence Factor: CME Deflection

Deflection make a Not-Earth direct CME hit the Earth



Deflection make a Earth direct CME miss the Earth

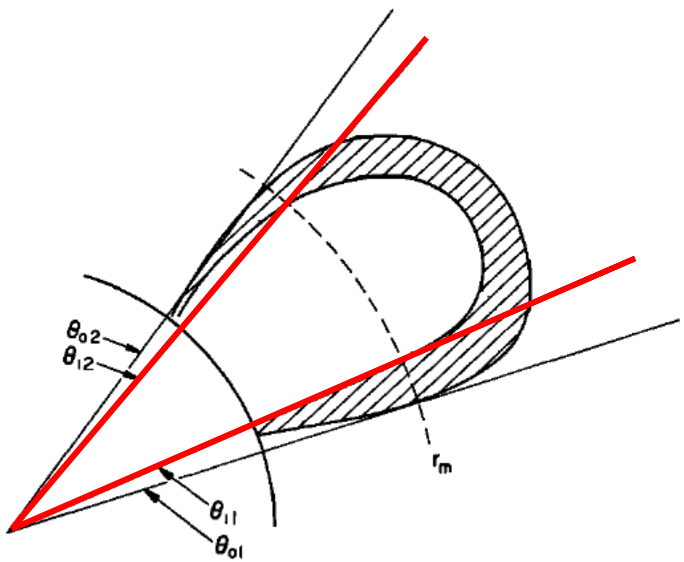


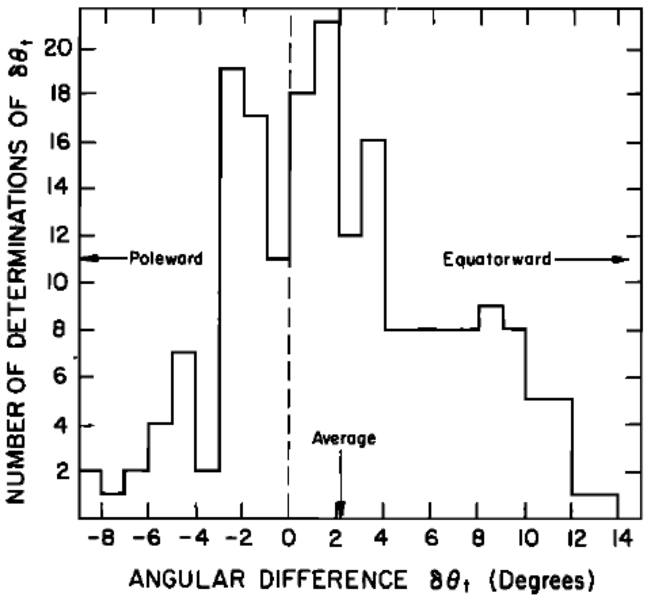
Three types of deflection:

- **Deflection near the Sun** [MacQueen et al. 1986; Gopalswamy et al., 2003, 2004, 2009; Cremades and Bothmer, 2004; Cremades et al., 2006; Kilpua et al. 2009; Shen et al. 2011; Wang et al., 2011; Kay et al., 2013, 2015a,b;2016;2017a.b]
- **Deflection in the interplanetary Space** [e.g. Wang et al. 2004; 2006; 2014; Zhang et al., 2017]
- **Deflection caused by CME interaction** [e.g. Lugaz et al. 2012;Shen et al. 2012; Temmer et al., 2012; Liu et al. 2012, 2014a; Mishra et al.,2015,2016,2017]

Deflection Near the Sun

First reported by MacQueen et al. (1986)





$$\delta\theta = 0.5(\theta_{i1} + \theta_{i2}) - 0.5\ (\theta_{01} + \theta_{02})$$

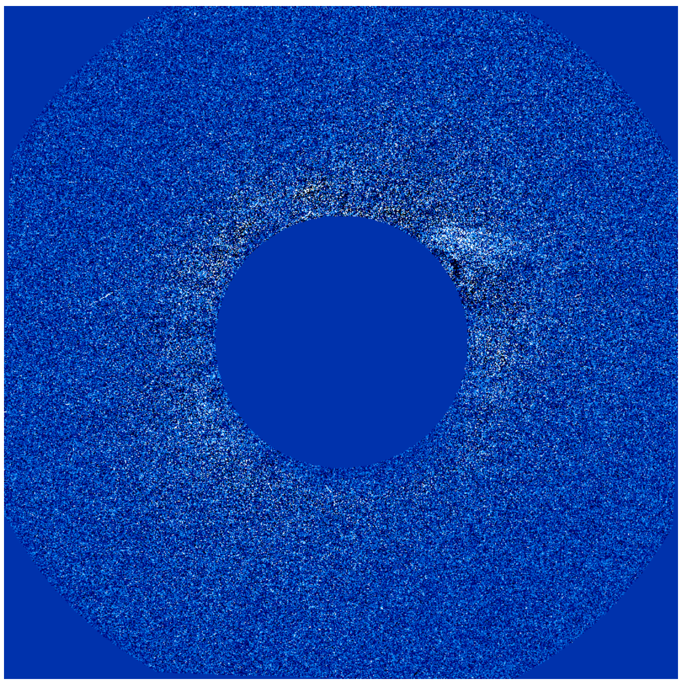
$\delta\theta$ >0: Deflect to Equator

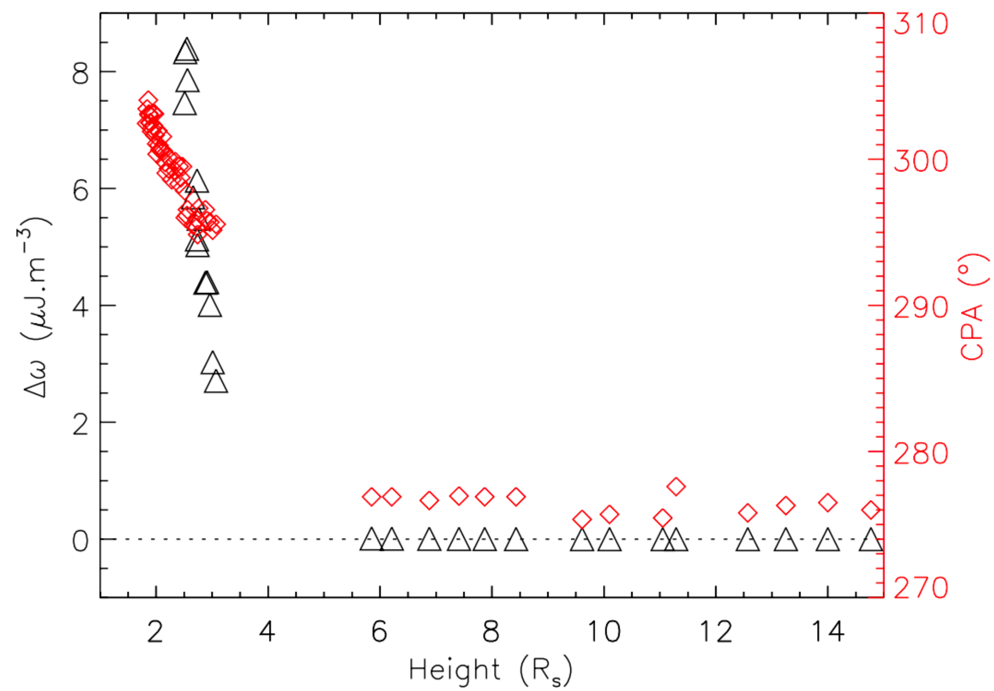
$\delta\theta$ <0: Deflect to Polar

CMEs are likely to deflect to Equator!

Magnetic Energy Density Models

Deflection of 2007 October 8 CMEs [Shen et al., 2011]

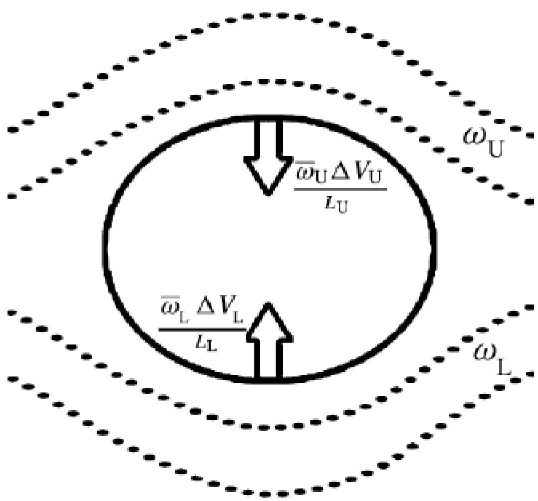




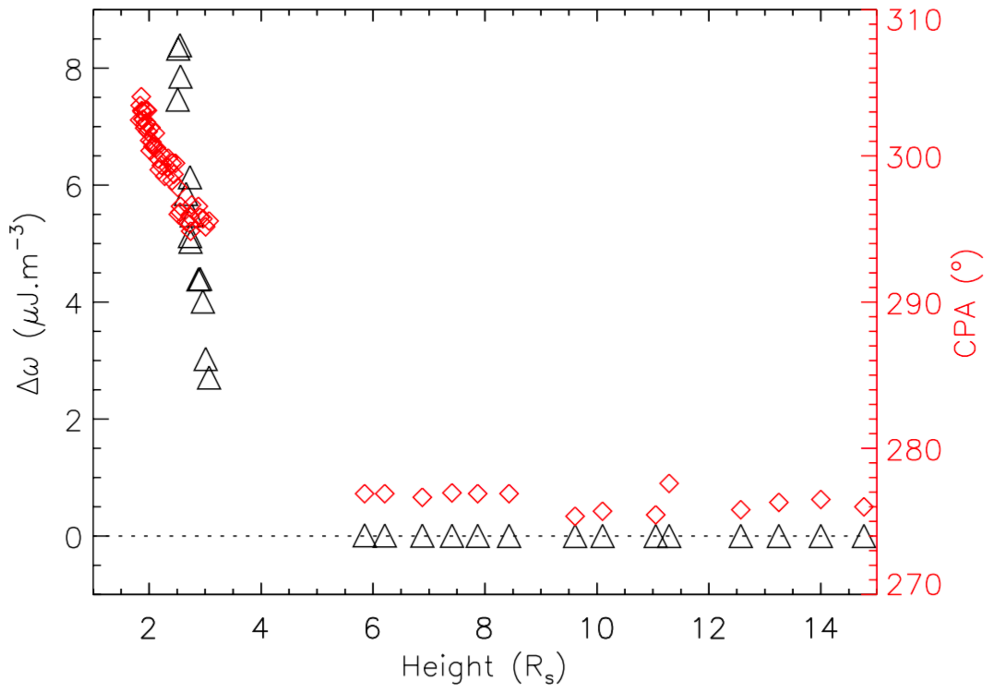
This CME deflected to the Equator obviously!

Magnetic Energy Density Models

Physical model to describe such deflection [Shen et al., 2011]



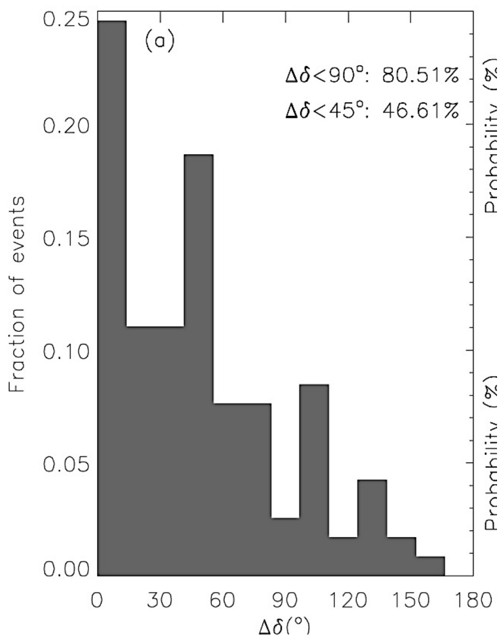
Sketch of magnetic energy density models

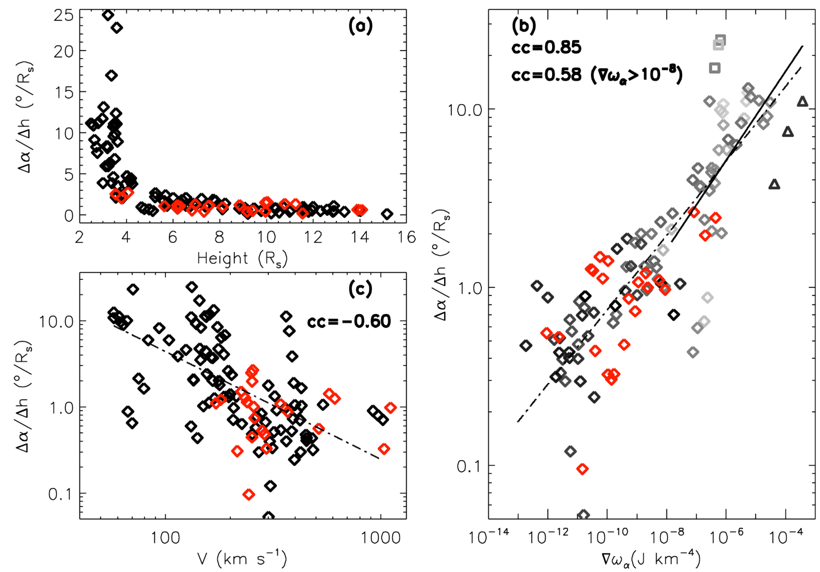


CME may deflect to the region with lower magnetic energy density!

Magnetic Energy Density Gradient Models

Statistical analysis [Gui et al., 2011]

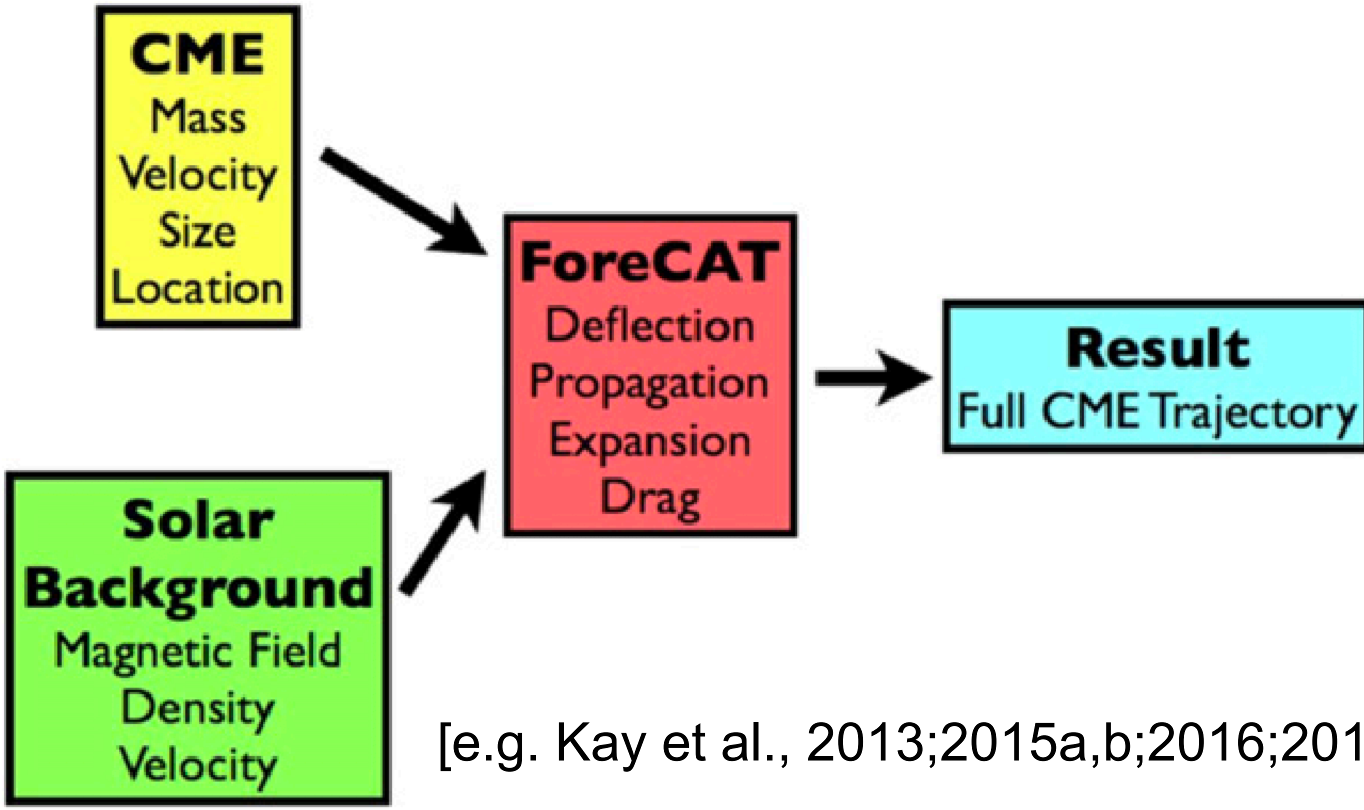




Observed deflection directions are well consistent with the model.

Observed deflection rates are consistent with the intensity of magnetic energy density gradient.

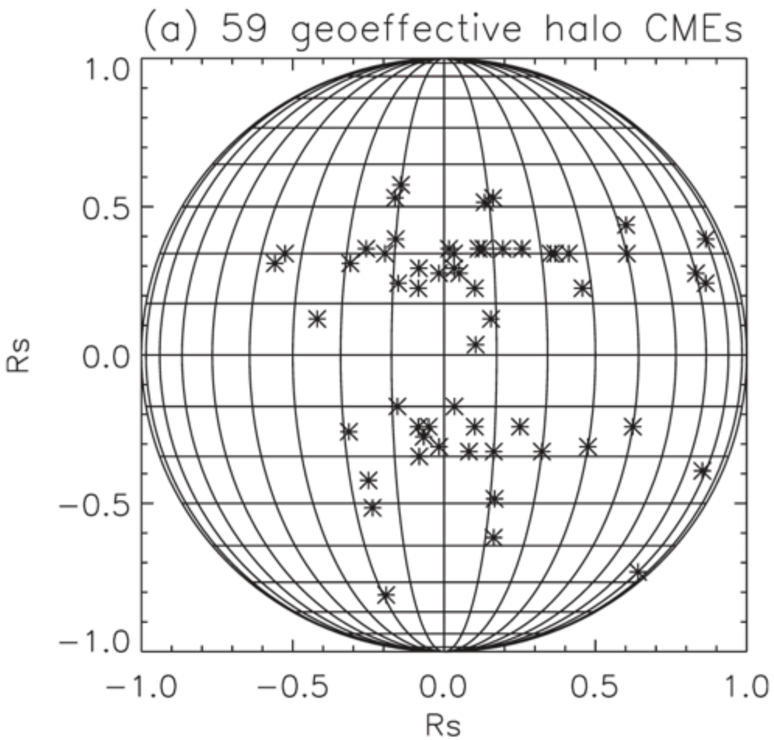
Forecasting a CME's Altered Trajectory (ForeCAT)



[e.g. Kay et al., 2013;2015a,b;2016;2017a]

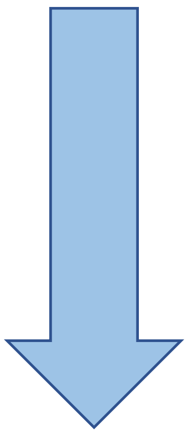
Now, it is ForeCAT In situ Data Observer (FIDO) model [Kay et al., 2017b] **which can predicting the in situ magnetic field of CMEs.**

Deflection in Interplanetary Space



Wang et al, 2002

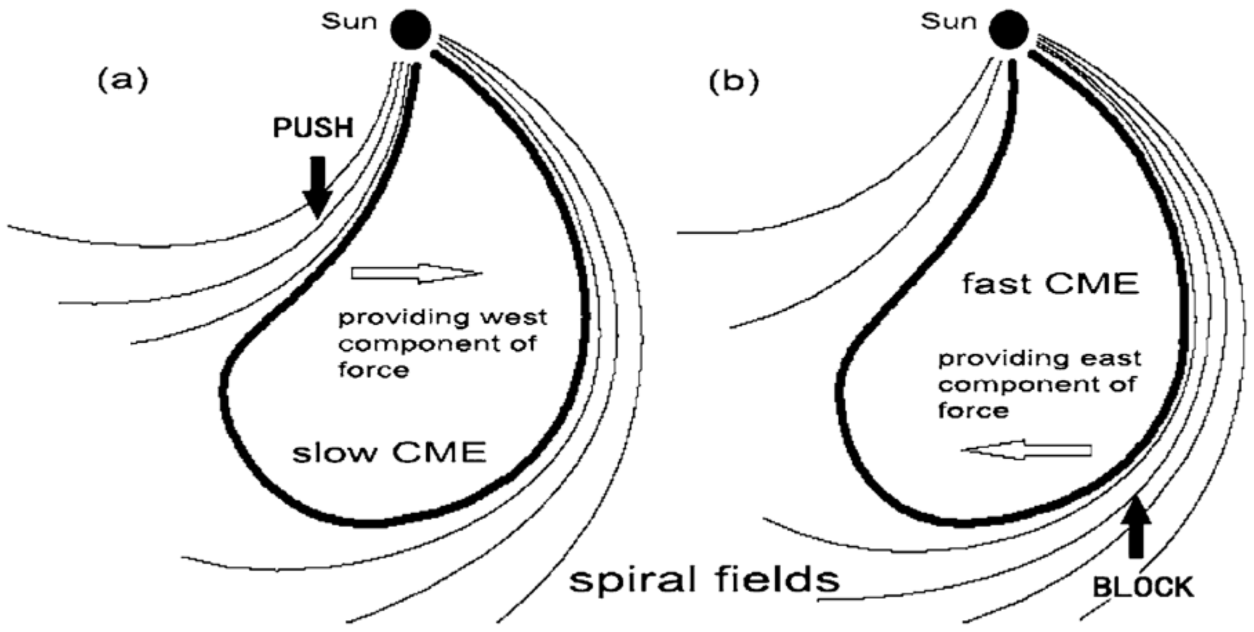
The source region of Earth-Arrived CMEs show obvious East-West asymmetry
[e.g. Wang et al., 2002; Zhang et al., 2003; Shen et al., 2014; Hess & Zhang 2017]



CME may deflect during its propagation in interplanetary space [e.g. Wang et al, 2004]

Deflection in interplanetary space (DIPS)

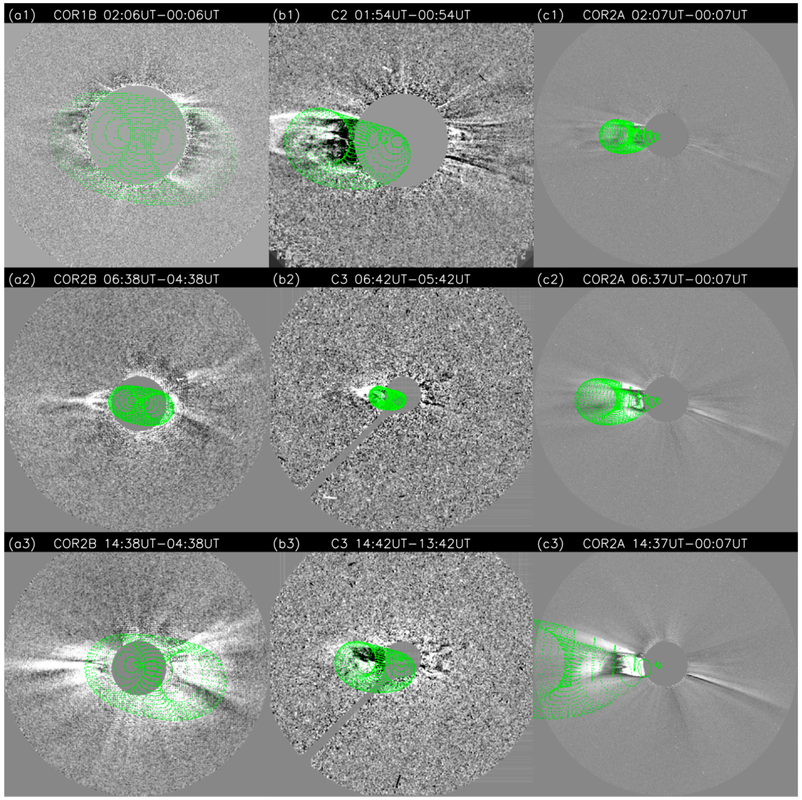
Deflection of CME in interplanetary space might bes controlled by the background solar wind [Wang et al. 2004].

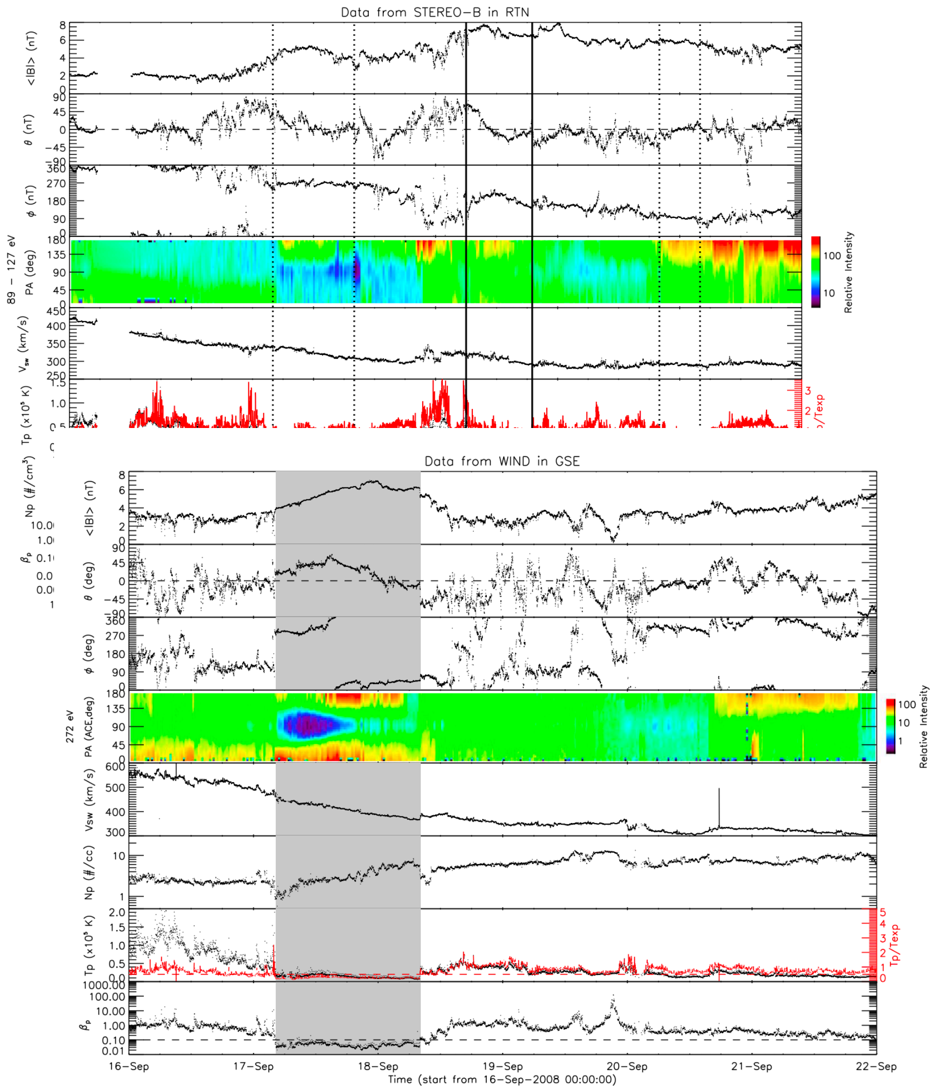


Fast CME ($v>v_{sw}$) → East

Slow CME ($v<v_{sw}$) ← West

Direct evidence of CME's deflection [Wang et al., 2014]



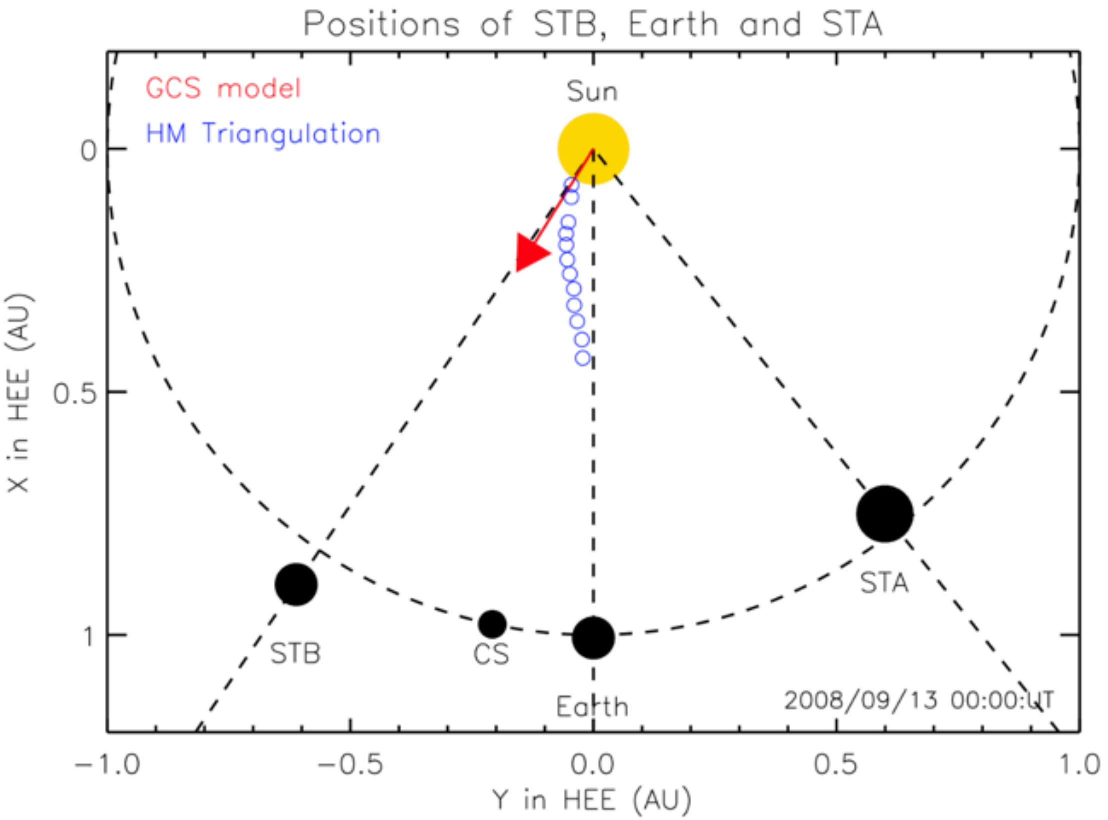


Propagation Direction: N00E32

Longitudinal extent of the CME

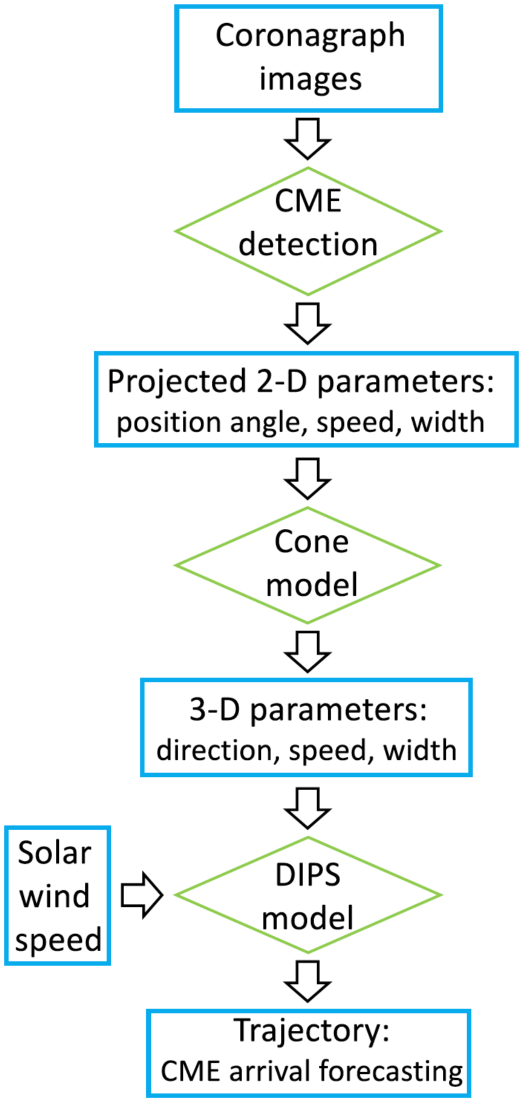
in the ecliptic plane: 60^o

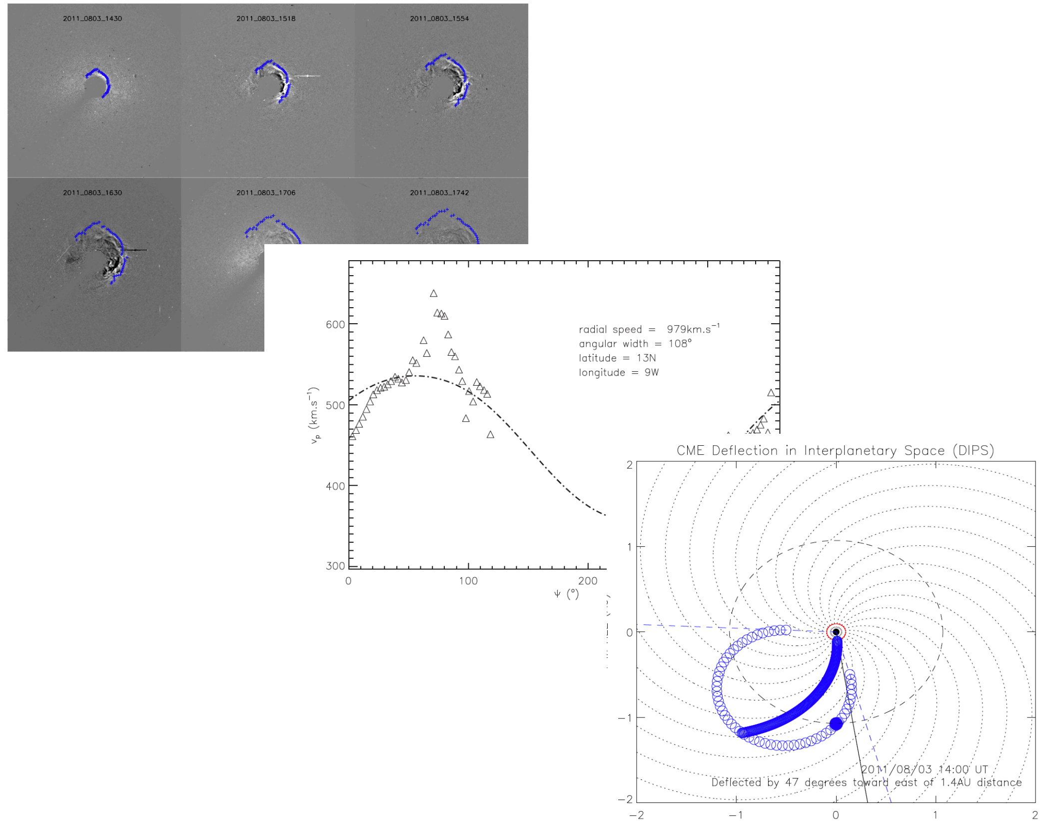
Direct evidence of CME's deflection [Wang et al., 2014]



The deflection of this CME make this STB-direct CME hit the Earth [Wang et al., 2014]!

Integrated CME-arrival forecasting (iCAF) [Zhuang et al., 2017]

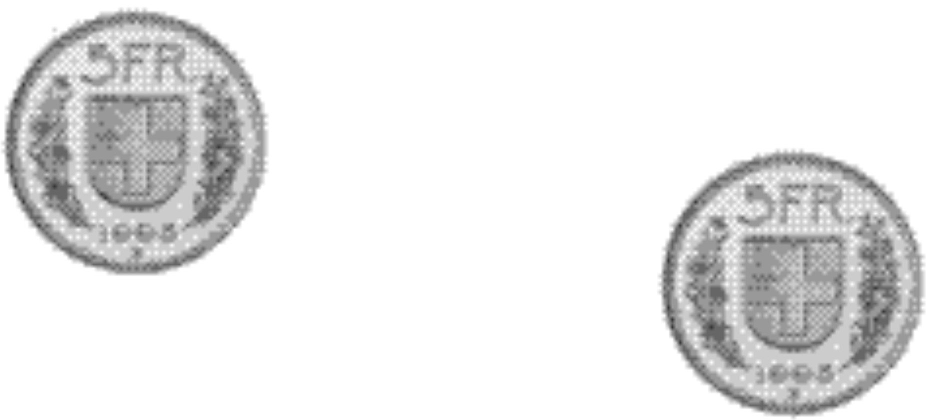




Success rate of the CME-arrival predictions

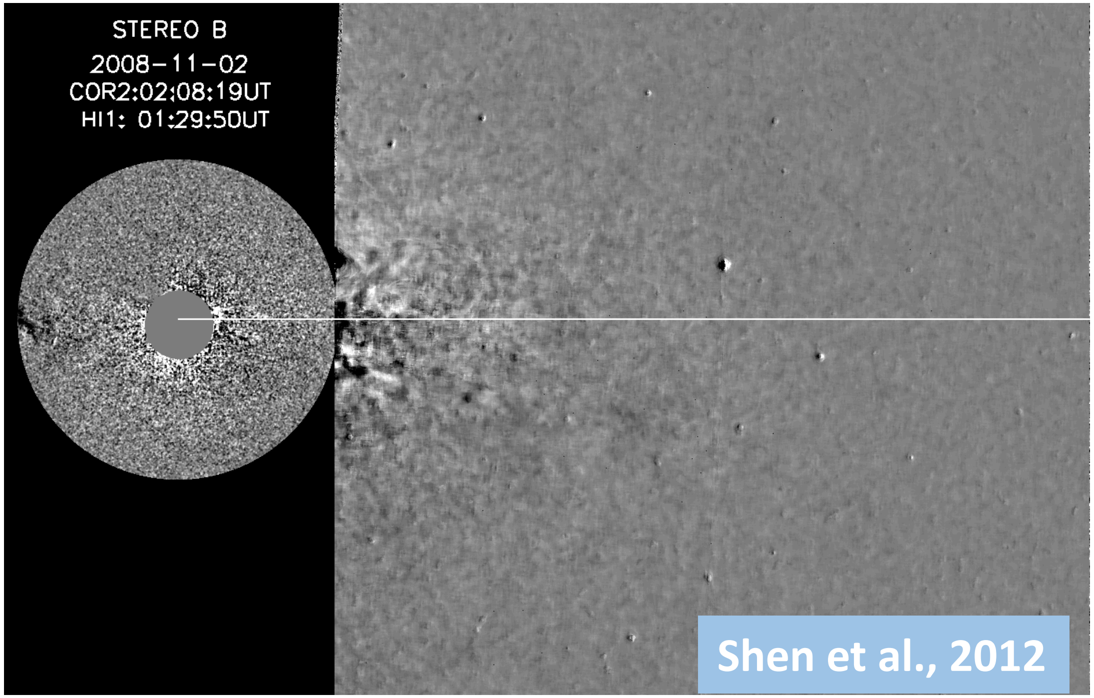
- **Include Deflection: 82%**
- **Not Include Deflection: 63%**

Deflection caused by CME interaction



Interaction between two objects can change their propagation direction.

Deflection caused by CME interaction



CME interaction will change their propagation direction [e.g., Lugaz et al. 2012; Shen et al. 2012; Temmer et al., 2012; Liu et al. 2012, 2014a; Mishira et al., 2015,2017 and Some review papers: Manchester et al., 2017; Shen F. et al., 2017; Lugaz et al., 2017]

Table 1 | The parameters of the two CMEs before and after the collision.

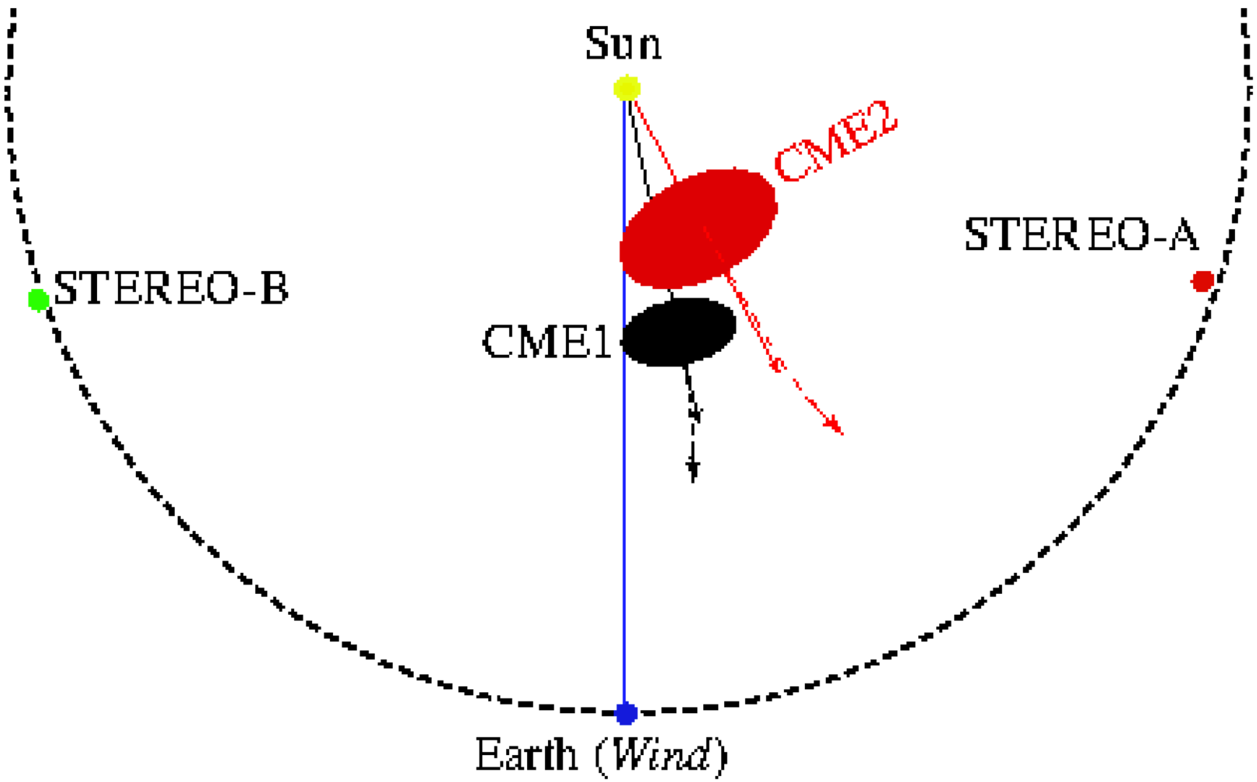
Parameters derived from observations

	θ	φ	v_c	v_e
CME1	6±2	28±10	243^{+25}_{-16}	43^{+16}_{-15}
CME2	16±2	8±10	407^{+102}_{-74}	74^{+65}_{-51}

Second-level derived parameters

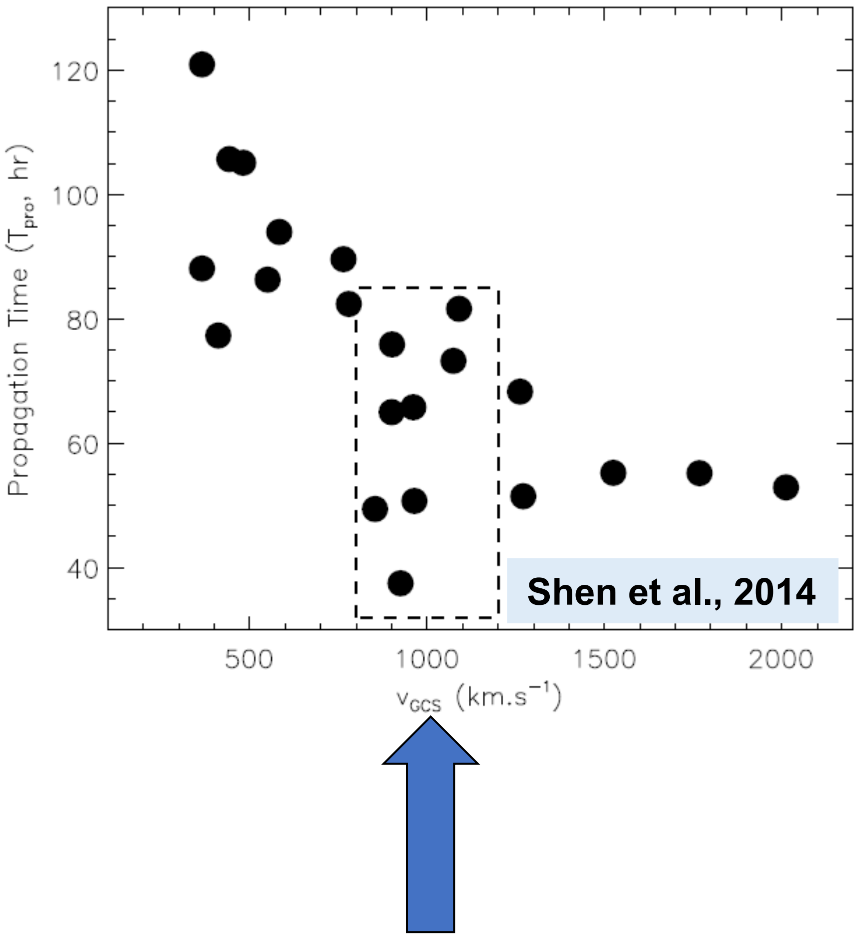
	v_p	v_{ep}	θ_C	φ_C	$v_\perp$	$v_\parallel$	$v'_\parallel$	v'_c	v'_p	v'_{ep}	$\Delta\theta_v$	$\Delta\varphi_v$	$\Delta E/E$	$\Delta E_t/E_t$	e
CME1	241	36			130	205	288	316	316	41	−4	7	68%		
			−10	57										6.6%	5.4
CME2	392	26			332	237	116	351	325	N/A*	6	−16	−25%		

Deflection caused by CME interaction



Deflection caused by CME interaction make CME1 fact to Earth and the hit the Earth [Lugaz et al., 2012]

3. When the CME arrival at the Earth?



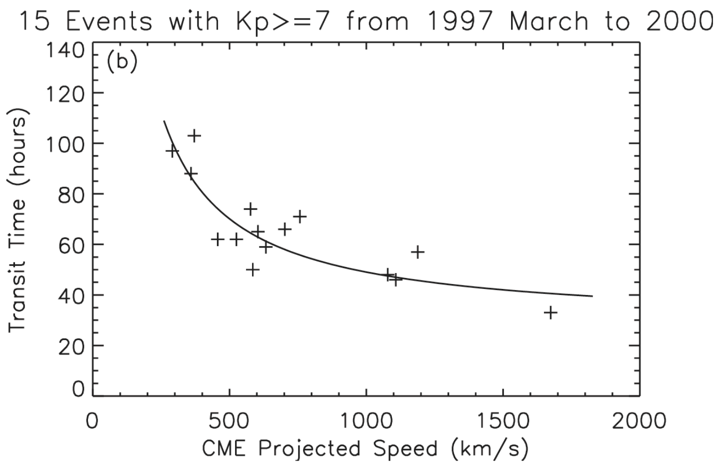
Similar Velocities, different propagation time!

Possible Influence Parameters:

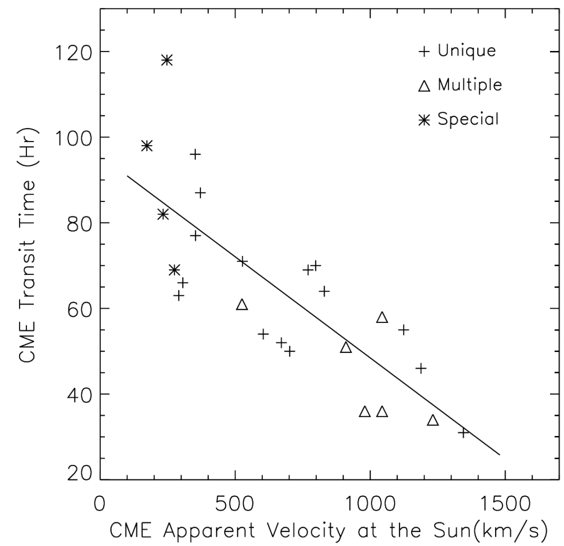
- **Initial velocity → Empirical models**
- **Acceleration or deceleration influenced by background solar wind** [e.g. Gopalswamy et al., 2000; Lugaz et al., 2012; Vrsnak et al., 2013;Zhao et al., 2016] **→ Drag models**
- **CME interaction** [e.g. Gopalswamy et al., 2001; Shen et al., 2012; Temmer et al., 2012, Lugaz et al., 2013; Mishra et al., 2016]

Any other factors?

Empirical models

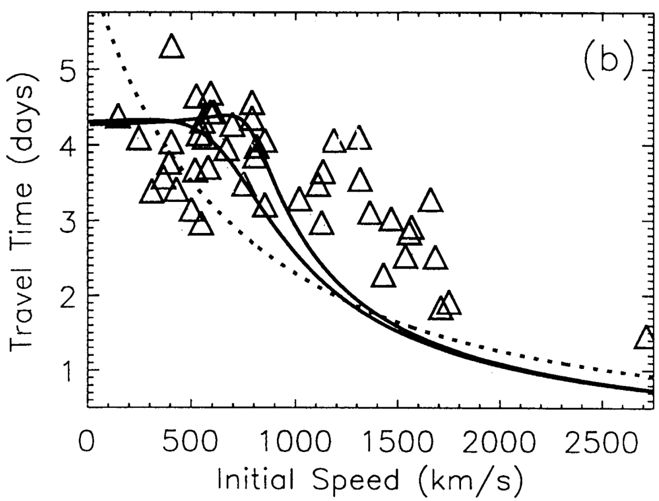


$$T = 27.98 + \frac{2.11\times10^4}{v_P}$$ [Wang et al., 2002]



$$T = 96 + \frac{v}{21}$$

[Zhang et al., 2003]



The ECA model: consistent acceleration model [Gopalswamy et al. 2000; 2001]

$$a = 1.41 - 0.0035u$$

$$S = ut - 1/2at^2$$

u: initial velocity

S=1AU

Drag-based model (DBM)

Drag-based model (DBM) is based on the assumption that the dynamics of CMEs is dominated by the MHD 'aerodynamic' drag

Drag acceleration:

$$a = -\gamma(v - v_{sw})|v - v_{sw}|$$

$$\gamma = \frac{c_d A \rho_w}{V(\rho + \frac{\rho_w}{2})} = \frac{c_d}{L(\frac{\rho}{\rho_w} + \frac{1}{2})}$$

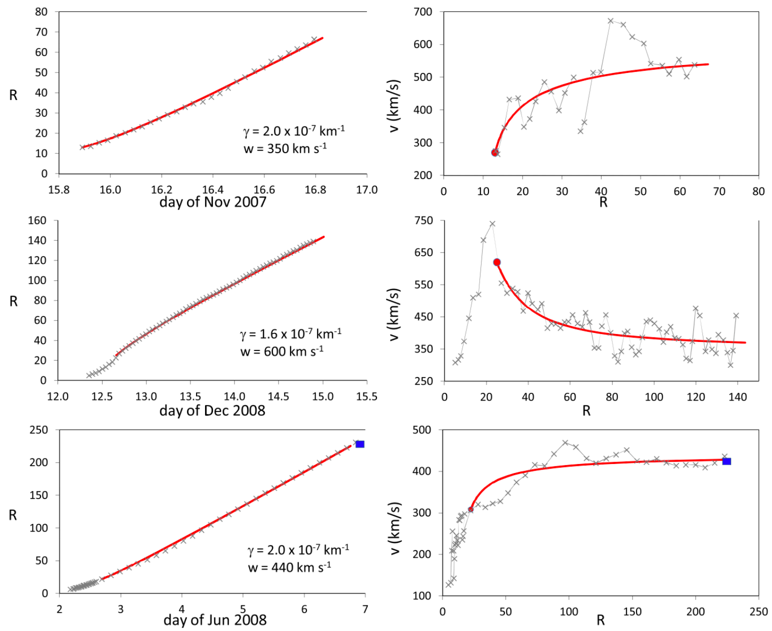
e.g. Cargill, 1996, 2004; Vršnak et al. 2013; Hess & Zhang, 2014, 2015

Simple form:

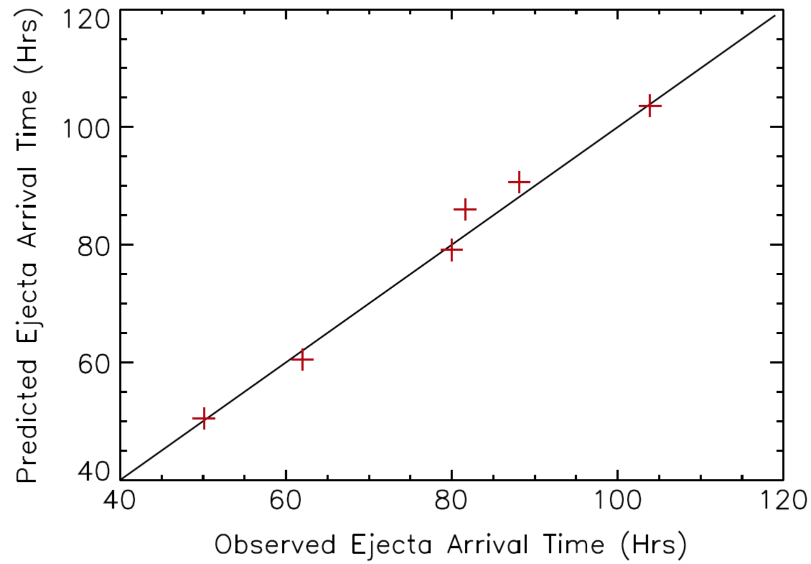
$$a = -Cr^{-\frac{1}{2}}(v - v_{sw})|v - v_{sw}|$$

Maloney & Gallagher, 2010; Vršnak & Gopalswamy, 2002

Drag-based model (DBM)



Vršnak et al., 2013

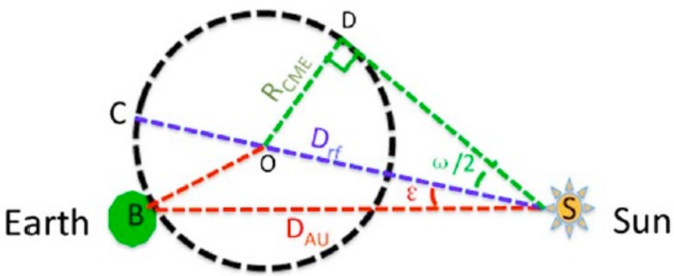


Hess & Zhang, 2015

What is the value of c_d (or C in simple form)?

c_d: 1 to 1.5 [e.g. Poomvises 2010 ; Subramanian et al. 2012]

Influence of the propagation direction and angular width

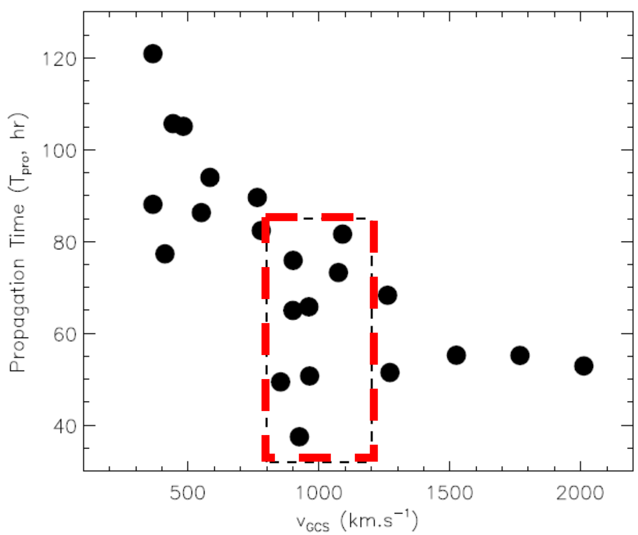


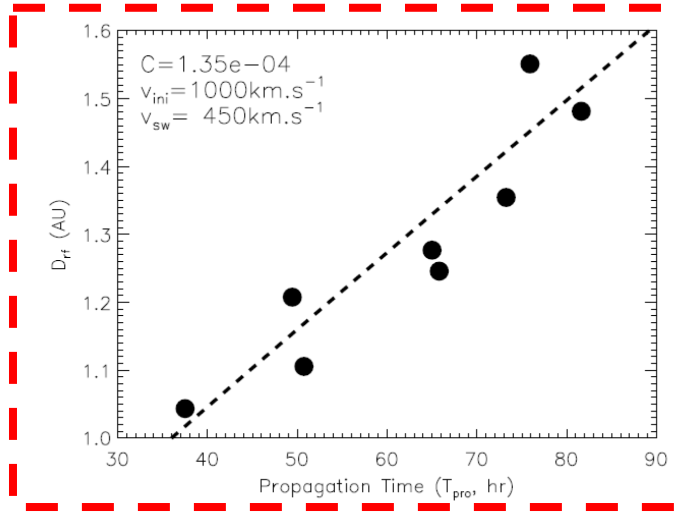
Propagation direction

+

Angular width

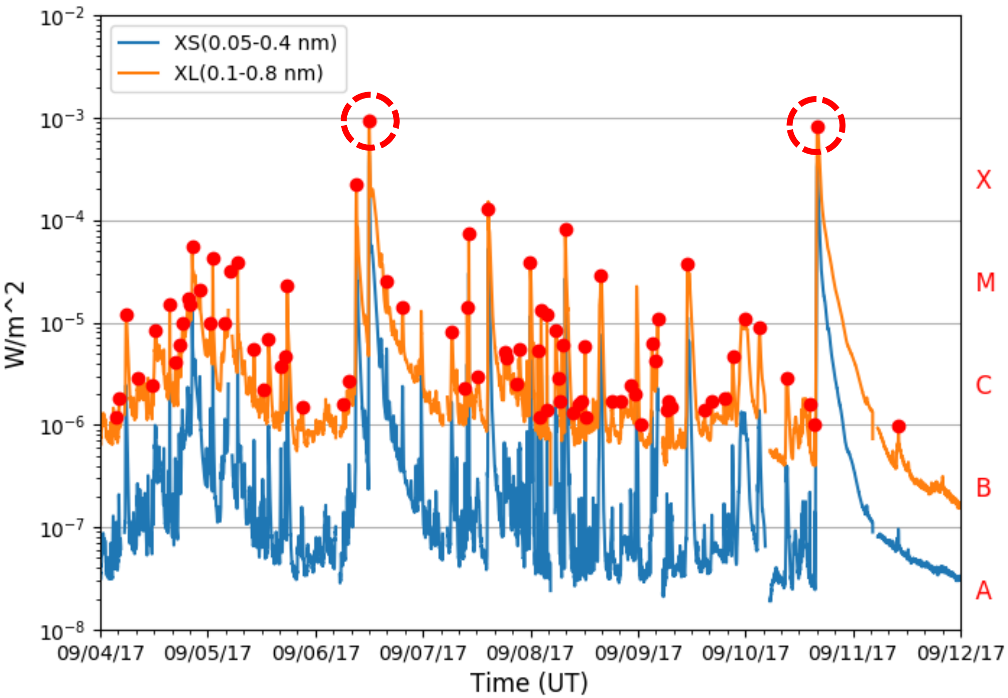
Front Propagation Distance





True angular width and the propagation direction are all important parameters in the CME arrival time forecasting **[e.g. Möstl el et.2013; Shen et al., 2014]**

4. The 2017 September events : Active region 12673



Produced the top 2 flares of solar cycle 24

Top 50 solar flares

On this page you will find an overview of the strongest solar flares since June 1996 together with links to more information in our ar
and a video (if available) of the event. This page is updated daily.

Solar Cycle ▾ year ▾

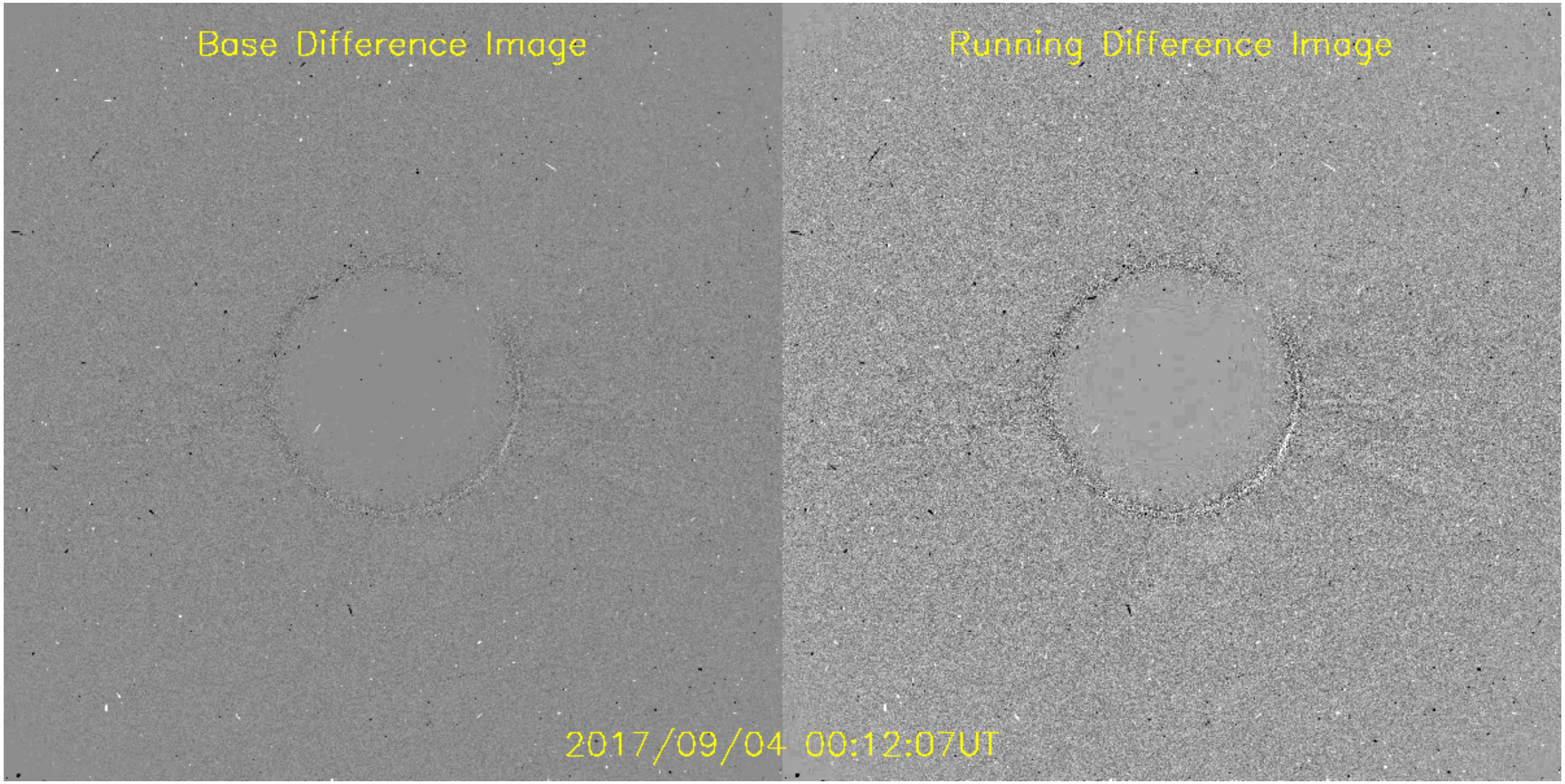
			Region	Start	Maximum	End	
1	X28.0	2003/11/04	0486	19:29	19:53	20:06	Movie View archive
2	X20.0	2001/04/02	9393	21:32	21:51	22:03	Movie View archive
3	X17.2	2003/10/28	0486	09:51	11:10	11:24	Movie View archive
4	X17.0	2005/09/07	0808	17:17	17:40	18:03	Movie View archive
5	X14.4	2001/04/15	9415	13:19	13:50	13:55	Movie View archive
6	X10.0	2003/10/29	0486	20:37	20:49	21:01	Movie View archive
7	X9.4	1997/11/06	8100	11:49	11:55	12:01	Movie View archive
8	X9.3	2017/09/06	2673	11:53	12:02	12:10	View archive
9	X9.0	2006/12/05	0930	10:18	10:35	10:45	Movie View archive
10	X8.3	2003/11/02	0486	17:03	17:25	17:39	Movie View archive
11	X8.2	2017/09/10	-	15:35	16:06	16:31	View archive
12	X7.1	2005/01/20	0720	06:36	07:01	07:26	Movie View archive
13	X6.9	2011/08/09	1263	07:48	08:05	08:08	Movie View archive
14	X6.5	2006/12/06	0930	18:29	18:47	19:00	Movie View archive
15	X6.2	2005/09/09	0808	19:13	20:04	20:36	Movie View archive

Produced 83 flares during its pass through the front of the Sun

B	C	M	X
1	54	24	4

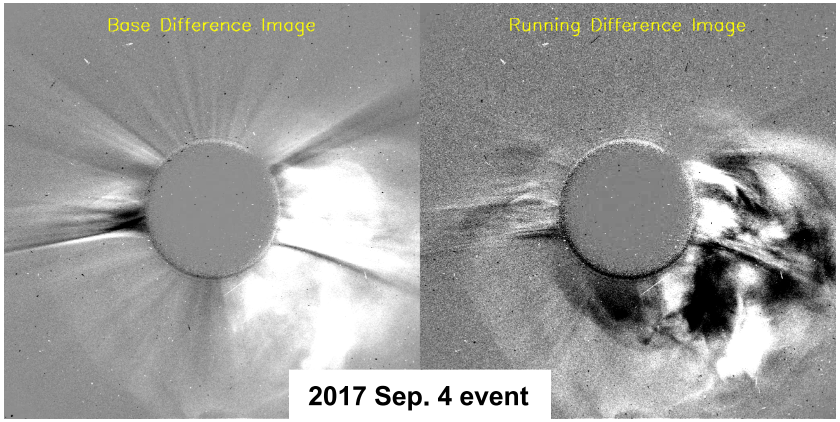
Coronagraph observations

At least 20 CMEs erupted from this active region.

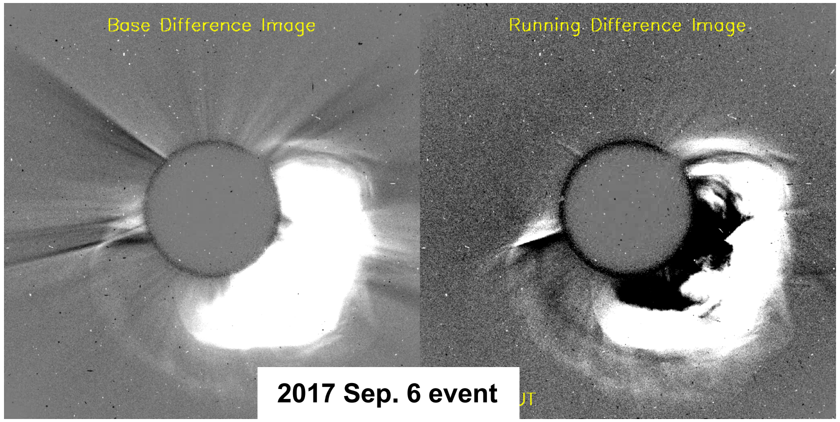


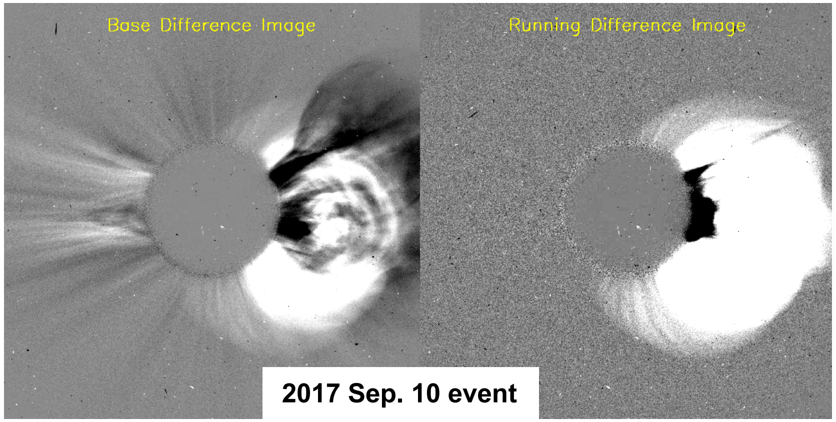
What is the geoeffectiveness of these CMEs?

Three major halo CMEs during this period



No	CME Time
1	Sep. 4 20:36
2	Sep. 6 12:24
3	Sep. 10 16:00



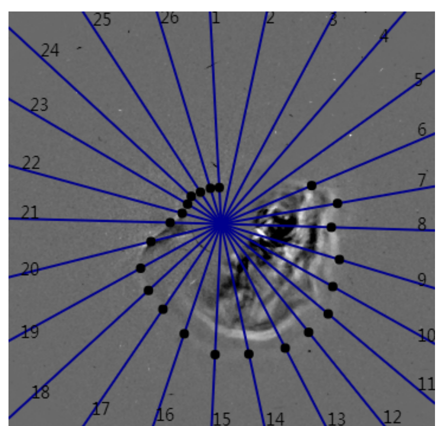


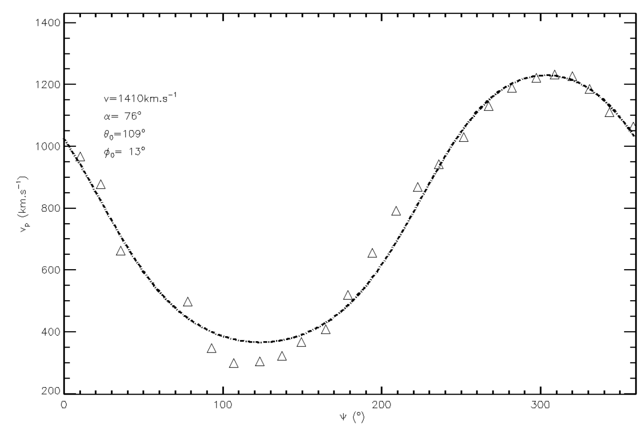
Cone model Parameters of CMEs

No		Projected	Cone Model			
	CME Time	Velocity(km/s)*	Velocity(km/s)	ω (°)	Direction	ε (°)
1	Sep. 4 20:36	1758	1250	63	W04S13	14
2	Sep. 6 12:24	1429	1410	76	W13S19	23
3	Sep. 10 16:00	3288	2150	87	W36N04	36

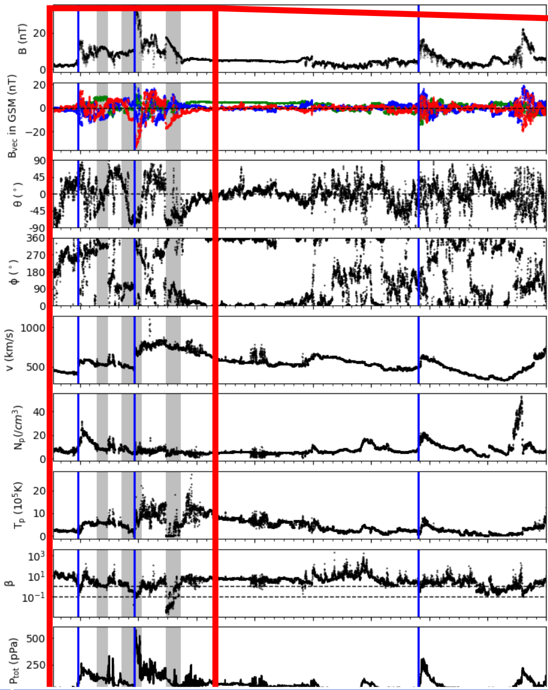
*Projected velocities are from SOHO/Halo CME alert

Fitting result of the Sep. 6 CME

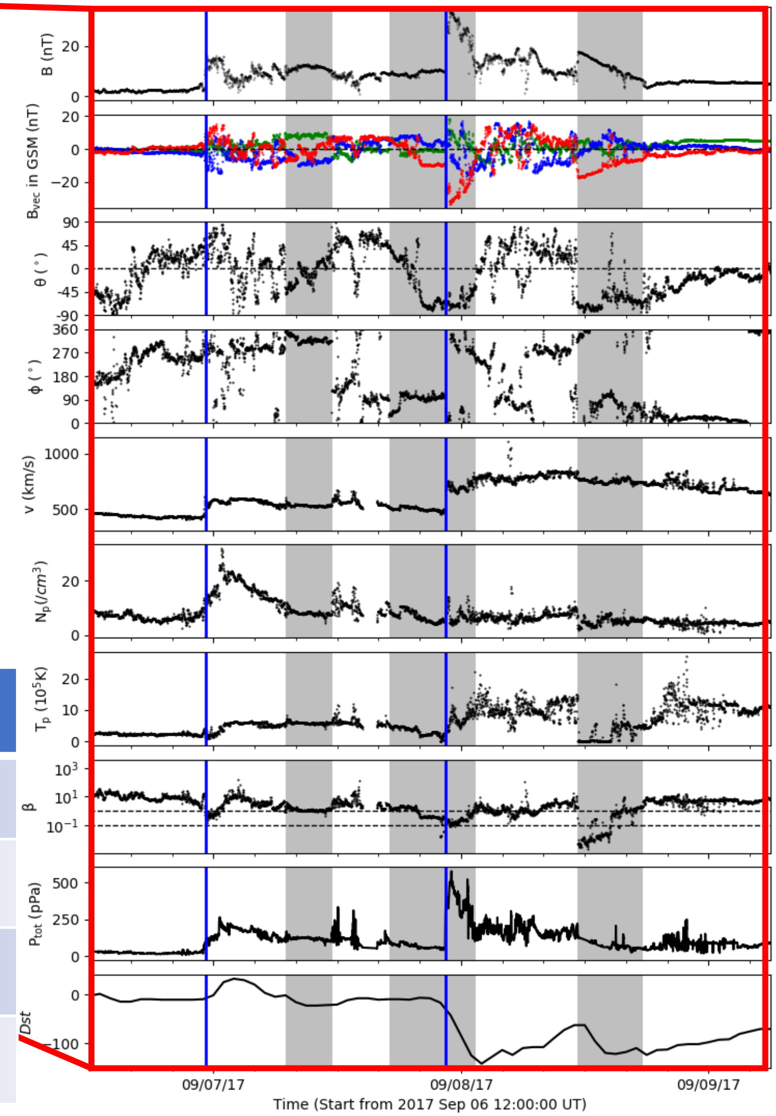




In-situ observations

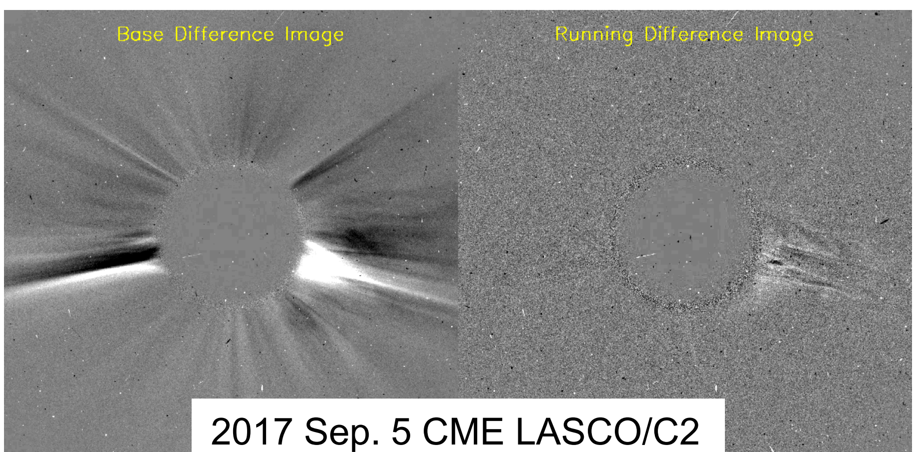


No	Time (UT)		
1	Sep. 6 23:14	Sep. 7 07:00	Sep. 07 11:30
2	---	Sep. 7 17:05	Sep.8 01:28
3	Sep. 7 22:29	Sep. 8 11:20	Sep. 8 17:38
4	Sep. 12 19:26	---	---

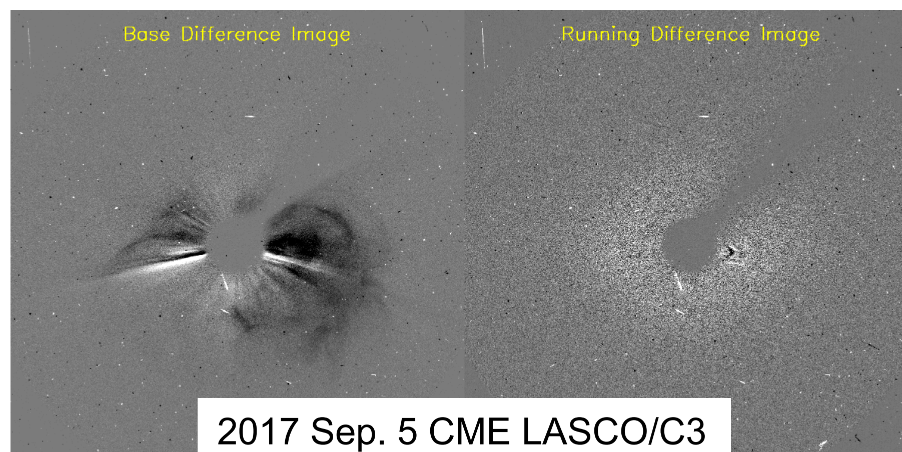


Sun-Earth connection

No	CMEs					ICMEs		
	Time	Velocity(km/s)	ω (°)	Direction	ε (°)	Shock Time	Begin Time	End Time
1	Sep. 4 20:36	1250	63	W04S13	14	Sep. 6 23:14	Sep. 7 07:00	Sep. 07 11:30
	Sep. 5 18:00	?	?	?	?		Sep. 7 17:05	Sep.8 01:28
2	Sep. 6 12:24	1190	107	W13S18	22	Sep. 7 22:29	Sep. 8 11:20	Sep. 8 17:38
3	Sep. 10 16:00	2190	86	W37N04	37	Sep. 12 19:26	---	---

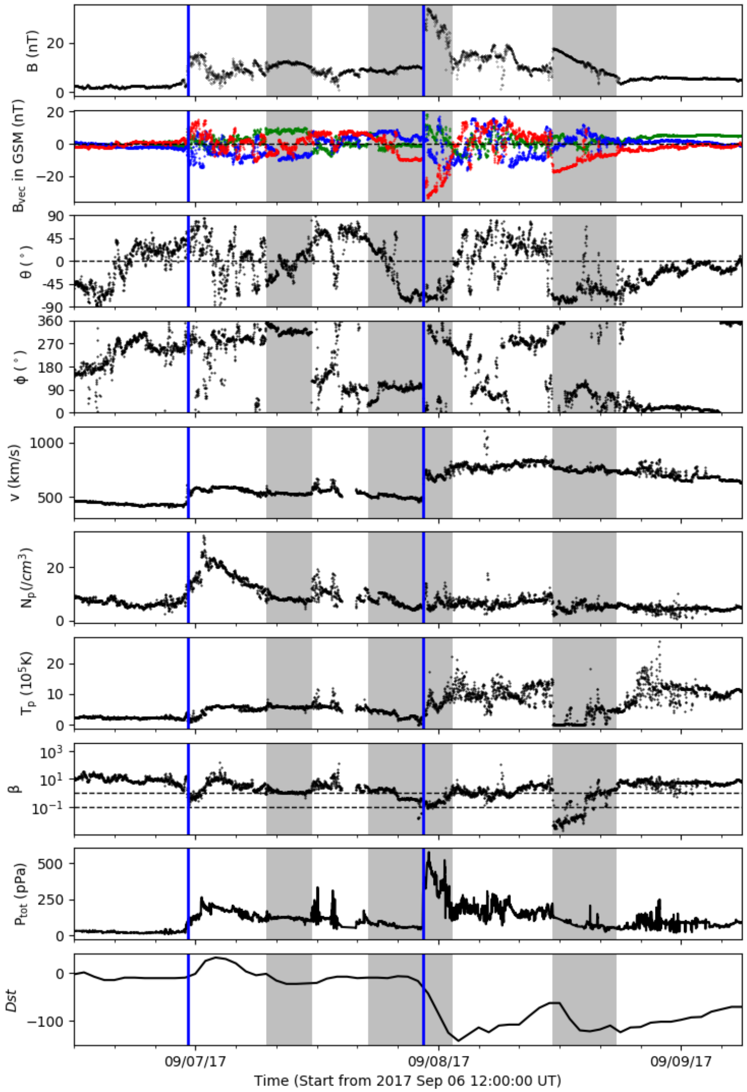


2017 Sep. 5 CME LASCO/C2

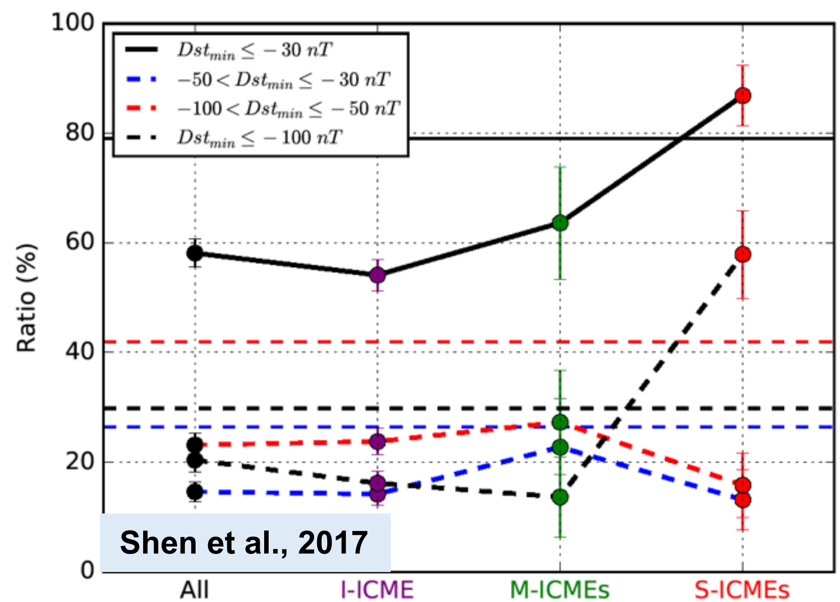


2017 Sep. 5 CME LASCO/C3

The interplanetary source of the geomagnetic storm

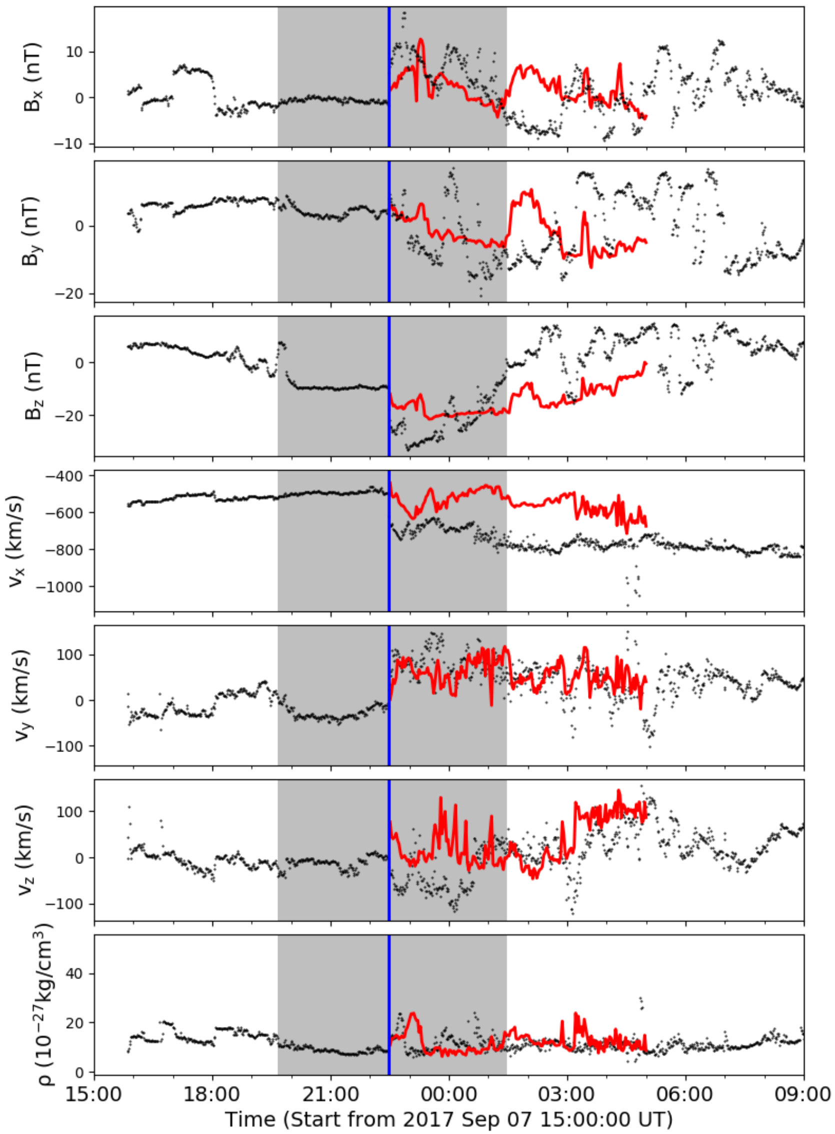


A geomagnetic storm with Dst_{min}=-142 nT is caused by the Shock-ICME complex structure

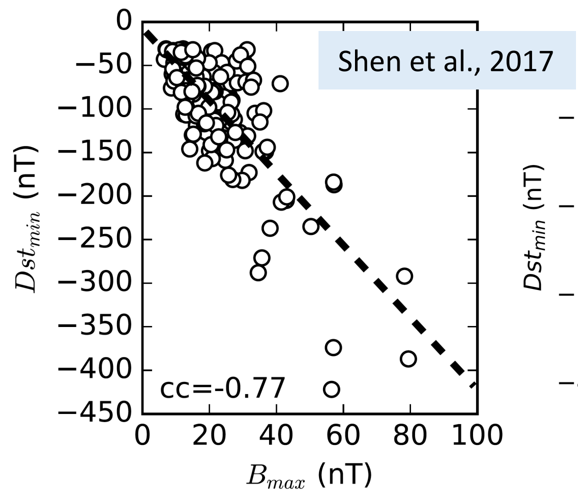


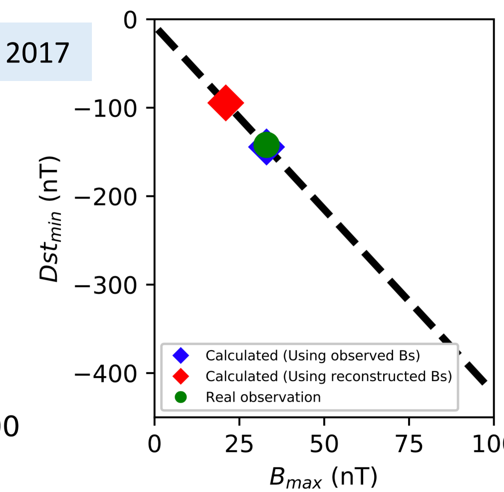
Shock-ICME complex structure can produce the geomagnetic storm especially the intense geomagnetic storm with higher probability [e.g. Wang et al., 2003a,b; Lugaz et al., 2015; Shen et al., 2017].

If without shock compression ICME?



A method based on the R-H relation has been developed to get the possible parameters of CMEs without shock compression [Wang et al., 2017, Under Review]

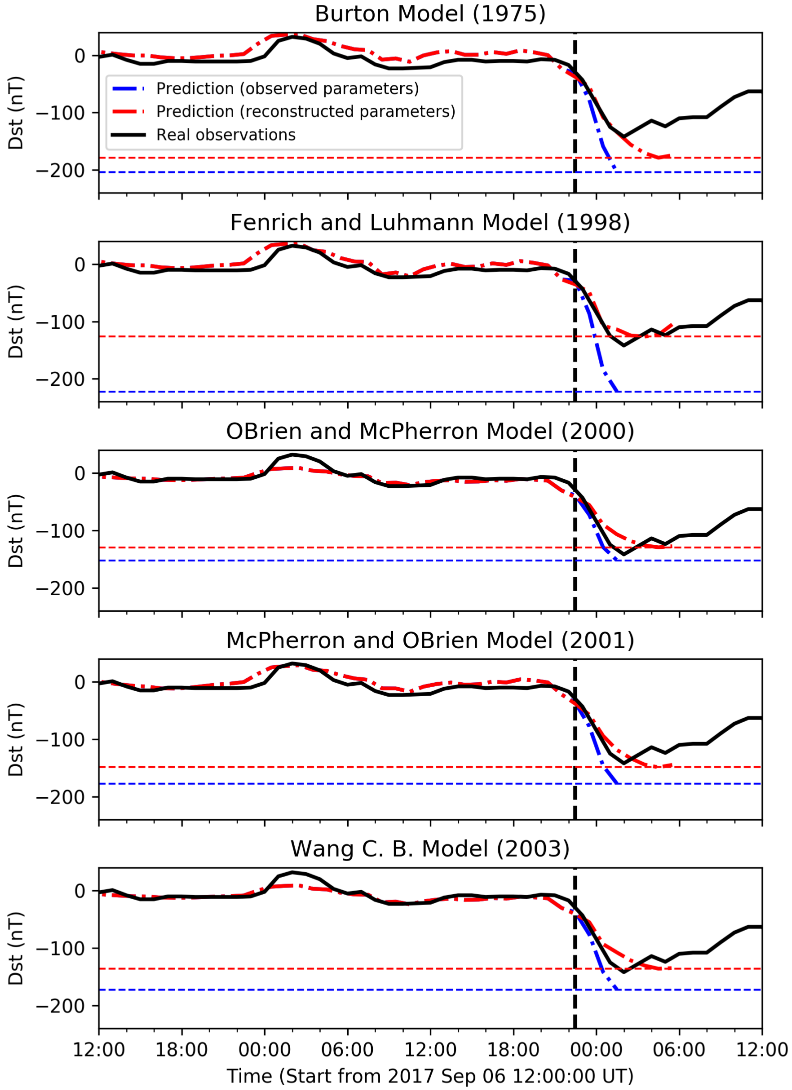




Observed $B_{z,min}$ in this CME: -33 nT (Dst=-142 nT)

Reconstructed $B_{z,min}$ with out compression in this CME : -21 nT (Dst = -95 nT)

Forecasting Model Calculation

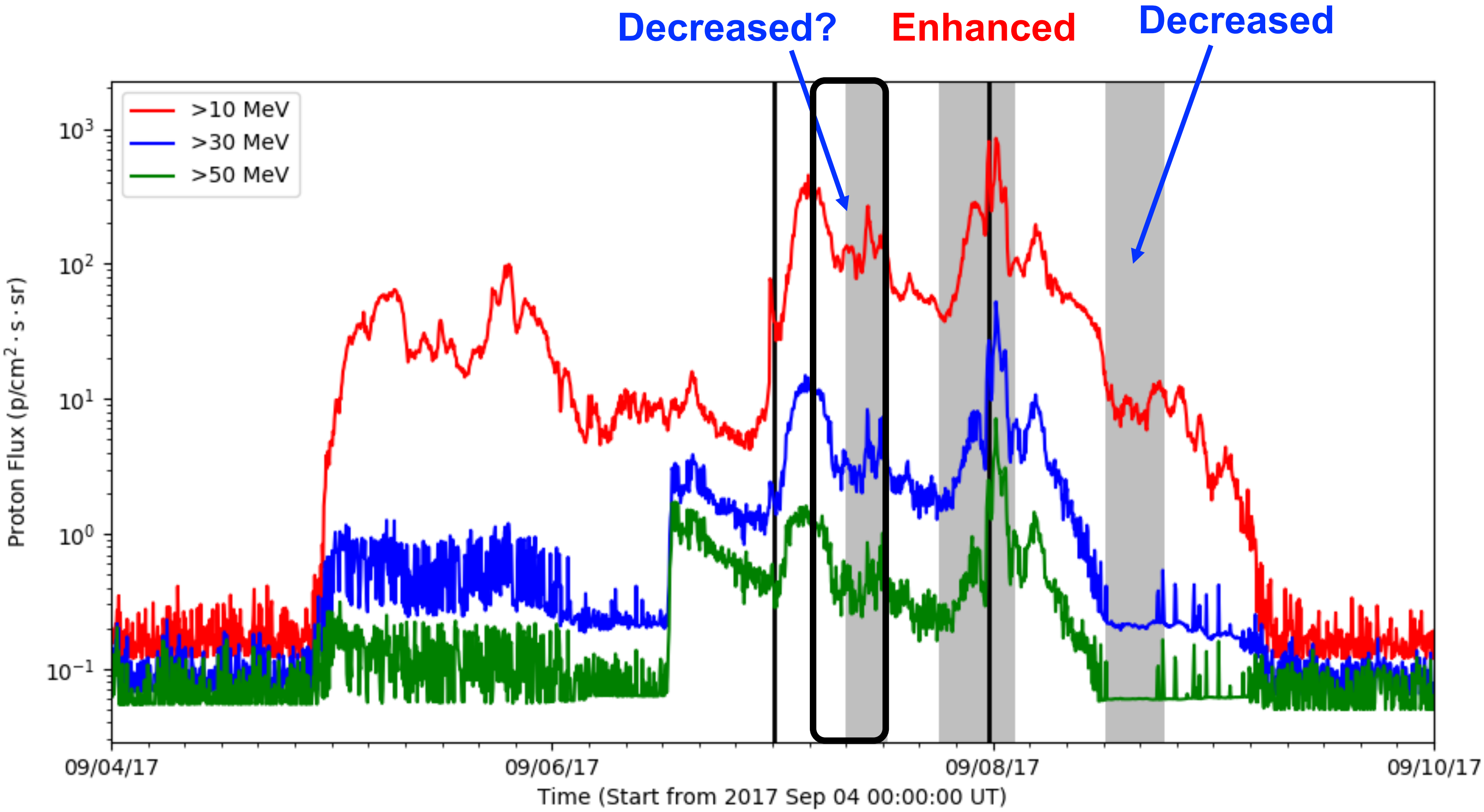


Different Dst forecasting models are applied.

- **Forecasting value of Dst_{min} based on real time solar wind observation is lower than the observed of Dst_{min} .**
- **Without comparison, the of Dst_{min} would be larger and the peak time would be later(comparison between blue and red lines)**

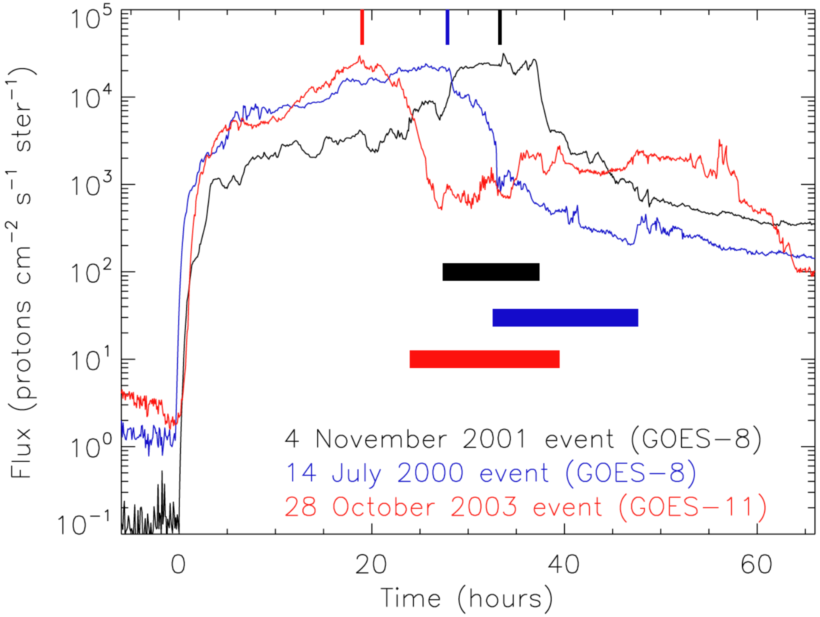
Shock-compression is very important. It should be taken in to account in the forecasting of geomagnetic storm caused by CME.

Enhancement of the proton flux in Shock-ICME



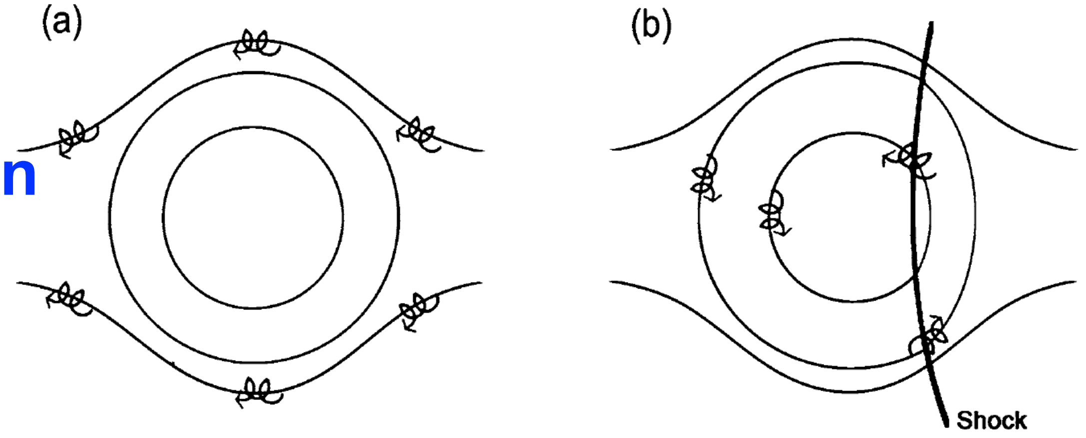
The proton flux enhanced obviously in the Shock-ICME complex structure!

Enhancement of the proton flux in Shock-ICME



Proton flux enhancement in Shock-ICME structure is an important factor in causing the largest SEP event in solar cycle 23 [Shen et al., 2008].

Possible Explanation



5. Summary

Following key problems are discussed:

1. How to get 3 Dimensional parameters of CMEs?
2. Whether the CME will hit the Earth? What are the influence parameters?
3. When the CME will hit the Earth? What are the influence parameters?

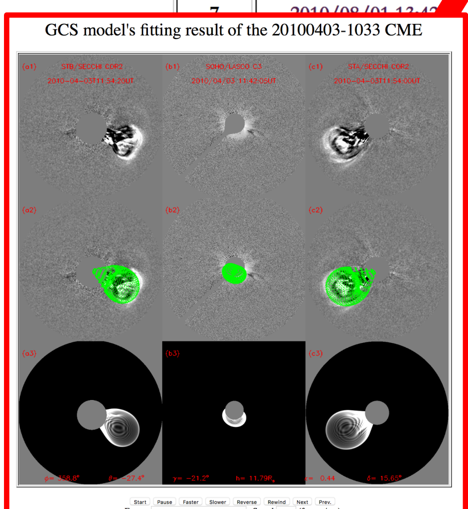
The Sun-Earth connection of 2017 September events are discussed.

Full halo CME catalogue with GCS model parameters and in-situ observations in USTC

http://space.ustc.edu.cn/dreams/fhcmes/

Table B: The list of all the frontside full halo CMEs(back to top)

No	CME date	Direction	ϵ	Width	v_{GCS}	v_{CDAW}	T_{Shock}	$T_{ICME\ Begin}$	$T_{ICME\ End}$
1	2009/12/16 04:30:03	E6,N9	10	45	411(14)	208	---	2009/12/19 09:49	2009/12/20 09:22
2	2010/02/07 03:54:03	E6,S7	9	81	481(25)	398	2010/02/11 00:00	2010/02/11 13:00	2010/02/11 22:00
3	2010/02/12 13:42:04	E1,N11	11	84	550(42)	-2	2010/02/15 17:40	2010/02/16 04:00	2010/02/16 12:00
4	2010/04/03 10:33:58	E1,S27	27	84	853(40)	629	2010/04/05 07:56	2010/04/05 12:00	2010/04/06 16:00
5	2010/05/23 18:06:05	W16,N7	17	70	365(28)	228	2010/05/28 01:58	2010/05/28 19:00	2010/05/29 17:00
6	2010/05/24 14:06:05	W26,S6	26	63	552(18)	436	---	---	---
7	[illegible]	E38,N20	42	93	1262(78)	838	2010/08/03 17:00	2010/08/04 10:00	2010/08/05 02:00
[illegible]	[illegible]	E36,S6	36	83	779(71)	880	---	2010/08/11 05:00	2010/08/12 17:00
[illegible]	[illegible]	W42,S11	43	119	864(10)	1108	---	---	---



Time Coverage: 2007 to 2012 May (will update to the end of 2016 this year)

Related papers: Shen et al., 2013; 2014

ICME catalogue in USTC

http://space.ustc.edu.cn/dreams/wind_icmes/

List of Interplanetary Coronal Mass Ejections (ICMEs) [Last updated on 2016 June 16]

No	Shock Time	Start of the Ejecta	End of the Ejecta	MC	Mean Values in the Ejecta							Mean Values in the Sheath Region							Figures	Group Number	Type[2]	Dst Peak Time	Dst_{min}	Group Figures
					B (nT)	B_s (nT)	Duration of Bs (hours)	v (km/s)	v_xB_s (mV/m)	T_p (10^5K)	N_p (cm^{-3})	B (nT)	B_s (nT)	Duration of Bs (hours)	v (km/s)	v_xB_s (mV/m)	T_p (10^5K)	N_p (cm^{-3})						
1	------	1995-02-08T03:34:17	1995-02-08T21:00:00	Y	11.75	-6.74	10.83	411.58	2873.65	0.33	7.68	------	------	------	------	------	------	------	MAGSWE;EPF	1	I	1995-02-08T10:00:00	-80	MAGSWE;EPF
2	------	1995-02-09T07:16:30	1995-02-10T03:59:59	N	7.31	0.00	0.00	363.37	0.00	0.24	7.36	------	------	------	------	------	------	------	MAGSWE;EPF	2	I	----------	------	MAGSWE;EPF
3	1995-03-04T00:38:34	1995-03-04T11:42:51	1995-03-05T00:08:34	Y	11.41	-6.88	11.95	446.85	3067.96	0.22	9.45	6.92	-0.98	3.97	434.59	419.26	0.77	16.13	MAGSWE;EPF	3	I	1995-03-04T22:00:00	-90	MAGSWE;EPF
4	1995-03-23T09:45:00	1995-03-23T22:10:42	1995-03-24T16:10:42	N	8.96	-0.99	1.68	332.55	343.34	0.27	16.81	8.71	-3.53	4.43	337.69	1188.92	0.51	20.92	MAGSWE;EPF	4	I	----------	------	MAGSWE;EPF
5	------	1995-04-01T16:34:17	1995-04-02T05:42:51	N	8.94	-6.61	10.80	382.95	2562.98	0.21	7.56	------	------	------	------	------	------	------	MAGSWE;EPF	5	I	1995-04-02T06:00:00	-67	MAGSWE;EPF
6	------	1995-04-03T13:00:00	1995-04-04T12:51:25	Y	8.92	-1.70	7.40	293.93	456.66	0.26	3.36	------	------	------	------	------	------	------	MAGSWE;EPF	6	I	----------	------	MAGSWE;EPF

Data Usage: WIND observations

Time Coverage: 1995 -2015 (Updating to the end of 2016 now)

Related Papers: Chi et al., 2016; Shen et al., 2017

CIR catalogue in USTC

http://space.ustc.edu.cn/dreams/cir/ (coming soon)

Dst Peak Time	Dst Peak	CIR Begin Time	CIR End Time	CIR Mid Time	If rope	Rope Begin Time	Rope End Time
2010-01-21T04:00:00.000	-35	2010-01-20T08:53:34.287	2010-01-21T08:40:42.862	2010-01-20T16:42:51.431	N		
2010-02-17T23:00:00.000	-22	2010-02-17T10:45:00.019	2010-02-19T15:14:59.995	2010-02-18T12:45:00.019	N		
2010-03-01T16:00:00.000	-3	2010-03-01T06:27:51.432	2010-03-02T01:23:34.272	2010-03-01T17:10:42.855	Y	2010-03-01T10:04:17.146	2010-03-01T12:25:42.859
2010-03-07T07:00:00.000	-18	2010-03-06T18:32:08.574	2010-03-07T15:25:42.864	2010-03-07T02:47:08.574	N		
2010-03-11T06:00:00.000	-30	2010-03-08T06:51:25.722	2010-03-12T19:17:08.587	2010-03-10T03:51:25.738	N		
2010-03-18T03:00:00.000	-26	2010-03-15T14:15:00.008	2010-03-18T01:29:59.983	2010-03-16T07:15:00.016	N		
2010-03-26T12:00:00.000	-10	2010-03-24T17:04:17.144	2010-03-26T20:51:25.712	2010-03-25T16:49:17.142	N		
2010-04-15T00:00:00.000	-36	2010-04-14T08:34:17.145	2010-04-15T12:25:42.865	2010-04-14T22:51:25.718	N		
2010-05-02T19:00:00.000	-71	2010-05-02T05:15:00.004	2010-05-03T10:17:08.562	2010-05-02T10:17:08.577	N		
2010-05-18T11:00:00.000	-34	2010-05-18T05:00:00.011	2010-05-20T18:15:00.001	2010-05-19T12:30:00.014	N		
2010-05-30T21:00:00.000	-58	2010-05-29T21:21:25.717	2010-06-01T19:42:51.443	2010-05-30T15:34:17.162	N		
2010-06-10T11:00:00.000	-9	2010-06-09T18:00:00.005	2010-06-10T09:57:51.435	2010-06-10T03:19:17.144	N		
2010-06-13T22:00:00.000	-12	2010-06-12T18:25:42.860	2010-06-14T00:25:42.862	2010-06-13T03:32:08.572	N		
2010-06-16T04:00:00.000	-36	2010-06-15T03:08:34.284	2010-06-16T23:25:42.859	2010-06-15T09:51:25.715	N		
2010-06-26T10:00:00.000	-31	2010-06-24T05:45:00.008	2010-06-27T10:59:59.988	2010-06-26T03:15:00.008	Y	2010-06-25T10:51:25.721	2010-06-25T18:08:34.293
2010-06-29T23:00:00.000	-24	2010-06-29T19:21:25.717	2010-06-30T03:00:00.002	2010-06-30T00:04:17.149	N		
2010-07-15T06:00:00.000	-25	2010-07-14T09:38:34.288	2010-07-15T08:53:34.287	2010-07-14T20:21:25.720	Y	2010-07-14T21:47:08.573	2010-07-14T23:30:00.008
2010-07-28T01:00:00.000	-31	2010-07-26T21:32:08.573	2010-07-28T21:44:59.998	2010-07-27T01:55:42.863	N		
2010-08-24T13:00:00.000	-34	2010-08-23T12:51:25.718	2010-08-25T04:49:17.142	2010-08-24T06:12:51.429	N		
2010-09-03T02:00:00.000	-15	2010-09-01T18:57:51.430	2010-09-03T02:34:17.140	2010-09-02T07:04:17.150	N		
2010-09-06T01:00:00.000	-16	2010-09-05T13:25:42.868	2010-09-06T07:59:59.998	2010-09-05T21:42:51.436	Y	2010-09-05T21:35:00.000	2010-09-06T04:11:15.001
2010-09-09T13:00:00.000	-11	2010-09-09T08:27:51.431	2010-09-09T22:55:42.848	2010-09-09T15:32:08.569	Y	2010-09-09T13:34:17.147	2010-09-09T16:30:00.000
2010-09-16T20:00:00.000	-22	2010-09-16T00:34:17.150	2010-09-17T05:29:59.988	2010-09-16T14:40:42.864	N		
2010-09-21T07:00:00.000	-16	2010-09-20T18:08:34.299	2010-09-21T15:12:51.449	2010-09-21T01:06:25.720	Y	2010-09-20T19:38:34.288	2010-09-20T21:12:51.432
2010-09-24T10:00:00.000	-32	2010-09-22T23:34:17.150	2010-09-25T12:51:25.702	2010-09-23T16:34:17.155	N		
2010-10-11T20:00:00.000	-75	2010-10-10T09:42:51.430	2010-10-12T08:34:17.163	2010-10-11T17:42:51.437	Y	2010-10-11T10:04:17.146	2010-10-11T11:55:42.854
2010-10-18T22:00:00.000	-22	2010-10-18T15:49:17.149	2010-10-19T23:57:51.419	2010-10-19T07:32:08.586	Y	2010-10-19T17:59:59.998	2010-10-19T23:47:08.578
2010-10-23T23:00:00.000	-41	2010-10-22T08:00:00.001	2010-10-25T12:59:59.981	2010-10-22T19:30:00.006	N		
2010-11-05T19:00:00.000	-12	2010-11-05T06:25:42.866	2010-11-05T18:12:51.426	2010-11-05T14:27:51.430	N		
2010-11-09T05:00:00.000	-11	2010-11-08T06:34:17.152	2010-11-09T07:51:25.725	2010-11-08T11:51:25.718	Y	2010-11-08T11:42:51.433	2010-11-09T03:42:51.428
2010-11-12T00:00:00.000	-45	2010-11-10T16:17:08.573	2010-11-12T09:57:51.429	2010-11-11T01:10:42.865	N		
2010-11-15T00:00:00.000	-28	2010-11-14T01:45:00.006	2010-11-16T01:45:00.019	2010-11-14T13:00:00.012	N		
2010-11-19T02:00:00.000	-17	2010-11-18T03:38:34.295	2010-11-18T22:23:34.288	2010-11-18T11:40:42.867	Y	2010-11-18T04:34:17.145	2010-11-18T06:51:25.715

Data Usage: WIND observations

Time coverage： 2010 – 2016 (to combine with Lan Jian's catalogue from 1995 to 2009)

Related Papers

Chi, Y., Shen, C., Wang, Y., Ye, P., Xu, M., Ye, P., & Wang, S. (2016). Statistical Study of the Interplanetary Coronal Mass Ejections from 1995 to 2015. *Solar Physics*, *291*(8), 2419–2439. https://doi.org/10.1007/s11207-016-0971-5

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Shen, C., Wang, Y., Pan, Z., Miao, B., Ye, P., & Wang, S. (2014). Full-halo coronal mass ejections : Arrival at the Earth. *Journal of Geophysical Research : Space Physics*, DOI:10.1002/2014JA020001. https://doi.org/10.1002/2014JA020001.Received

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Related Papers

Shen, C., Wang, Y., Ye, P., & Wang, S. (2008). Enhancement of Solar Energetic Particles During a Shock – Magnetic Cloud Interacting Complex Structure. *Solar Physics*, *252*(2), 409–418.

Wang, Y., Chen, C., Gui, B., Shen, C., Ye, P., & Wang, S. (2011). Statistical study of coronal mass ejection source locations: Understanding CMEs viewed in coronagraphs. *Journal of Geophysical Research*, *116*(A4), A04104.

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Online Models

- CME Deflection in Interplanetary Space (DIPS)
  Predict the CME trajectory in the ecliptic plane from the Sun to 1 AU. (launched on October 31, 2015)
- Fitting Magnetic Clouds
  Velocity-modified cylindrical flux rope models for magnetic clouds observed in-situ. (launched on Aug 5, 2014)

Data Products

- Interplanetary Causes of Geomagnetic Storms Since 2007 (GeoStorms)
  Interplanetary causes of moderate to intense geomagnetic storms since 2007 are identified. (launched on May 4, 2014)
- ICMEs recorded by WIND spacecraft Since 1996 (WindICMEs)
  Interplanetary coronal mass ejections (ICMEs) are identified based on the Wind observations since 1996. The Dst peaks of the associated geomagnetic storms are also listed. (launched on Apr 16, 2015)
- Full Halo CMEs (FHCMEs)
  A list of full halo CMEs viewed by SOHO/LASCO since 2007 March 1. (launched on Mar 13, 2013)
- Quasi-Homologous CMEs (QHCMEs)
  A list of quasi-homologous CMEs originating from the same super active regions during solar cycle 23. (launched on Nov 6, 2012)
- CME Source Locations (CMELOC)
  CME's source locations on the visible solar disk manually identified based on SOHO/EIT and LASCO images. (launched on Apr 6, 2011)
- Solar LImb Prominence CAtcher & Tracker (SLIPCAT)
  Movies and catalogs of auto-detected solar limb prominences based on EUV observations at the wavelength of 30.4 nm. (launched on Mar 1, 2010)
- Events
  Events of interest. (launched on Mar 22, 2013)

Data Mirrored

- Solar & Heliospheric Monitor (SHM)
  Javamovies displaying the solar and heliospheric data observed by past and current spacecraft, including SOHO, STEREO, SDO, etc.