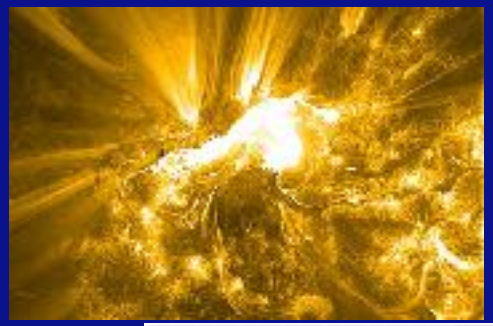
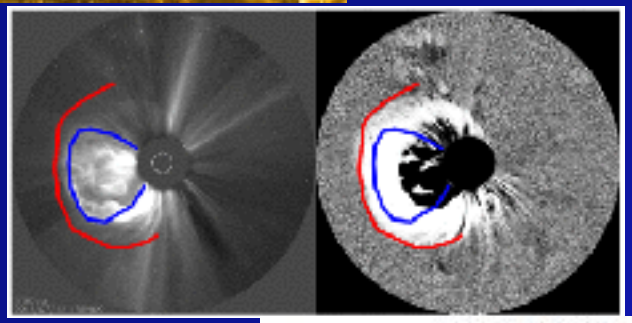
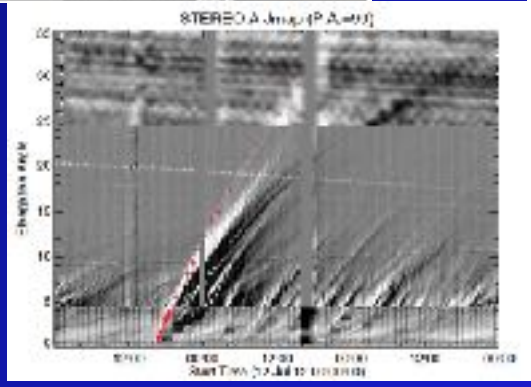
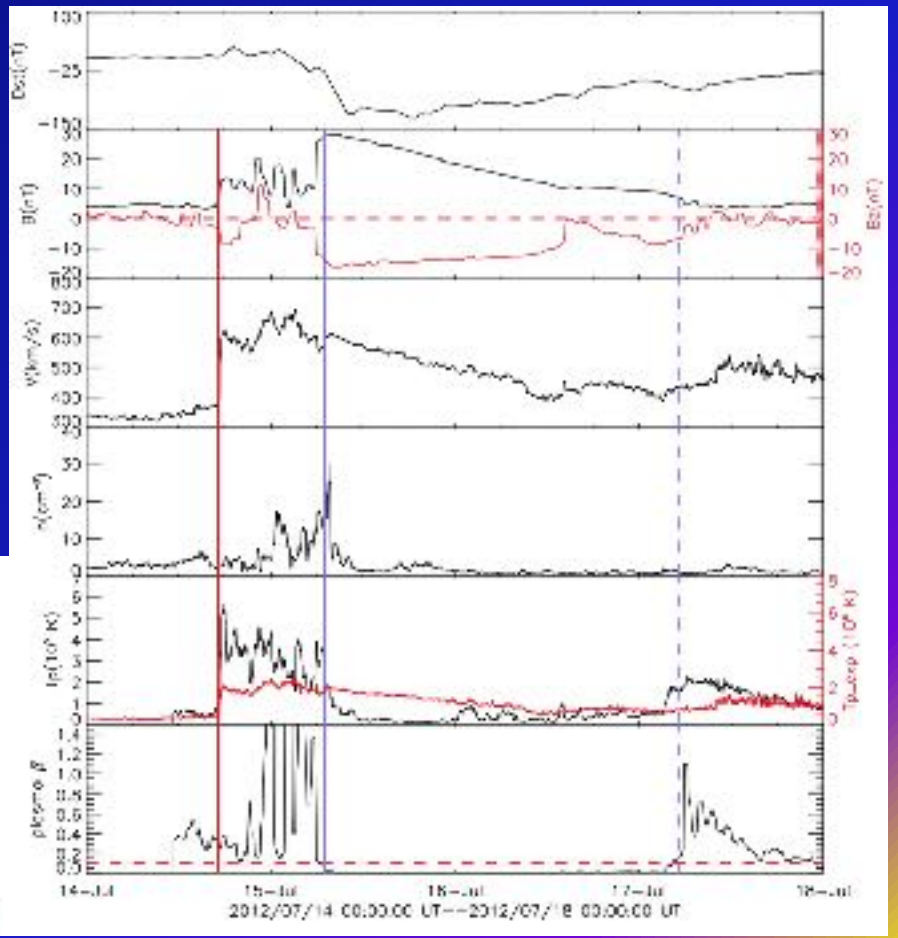
ISEST WG1 Report: Data Group (Jie Zhang)









WG1 Tasks

1. Identify all Earth-affecting solar transient events, CMEs and CIRs, during the STEREO era (2007 - 2017)

2. For selected events, fully measure, characterize and quantify their evolutional properties from the Sun to the Earth

Serving the Community

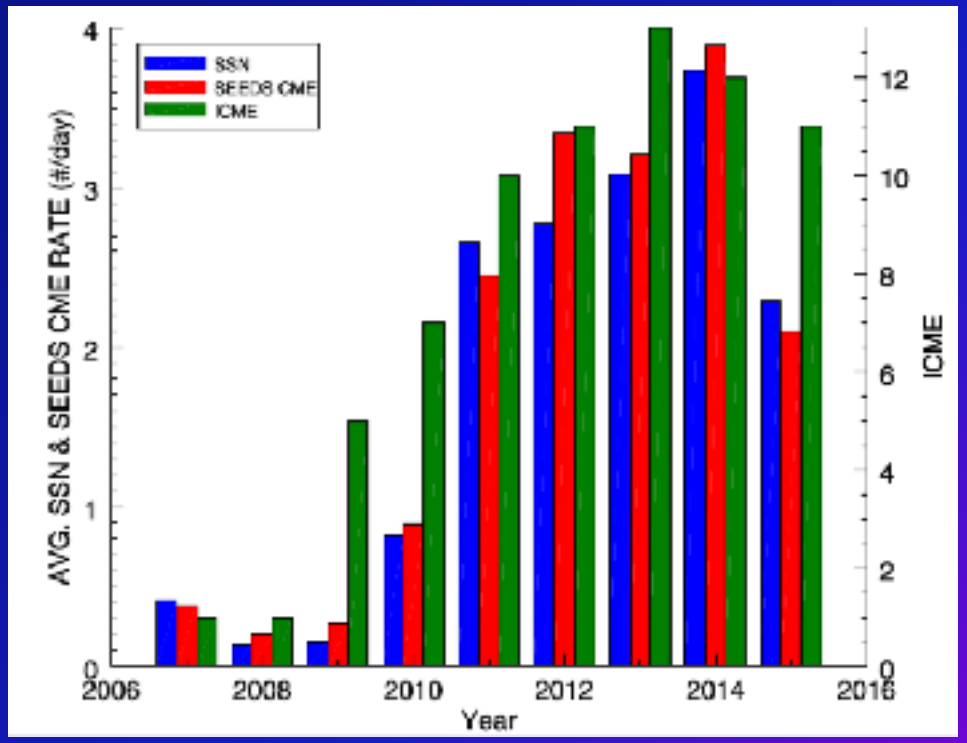
Provide a comprehensive event **database** which are valuable and necessary for a variety of scientific studies:

- Statistical studies of events and new findings
- Create empirical evolution models
- Create prediction models
- Improve theoretical understanding and models
- Constrain and validate numerical models

— an invaluable data asset for the community for studying Sun-Earth Connection and predicting space weather—

Event Catalog

- **Hess & Zhang ICME-CME catalog**
  - Available at http://solar.gmu.edu/heliophysics/index.php/GMU_CME/ICME_List/
  - 72 ICME events between 2006 and 2016 based on in-situ observations of ACE
  - Their solar sources are mostly identified, thanks to STEREO



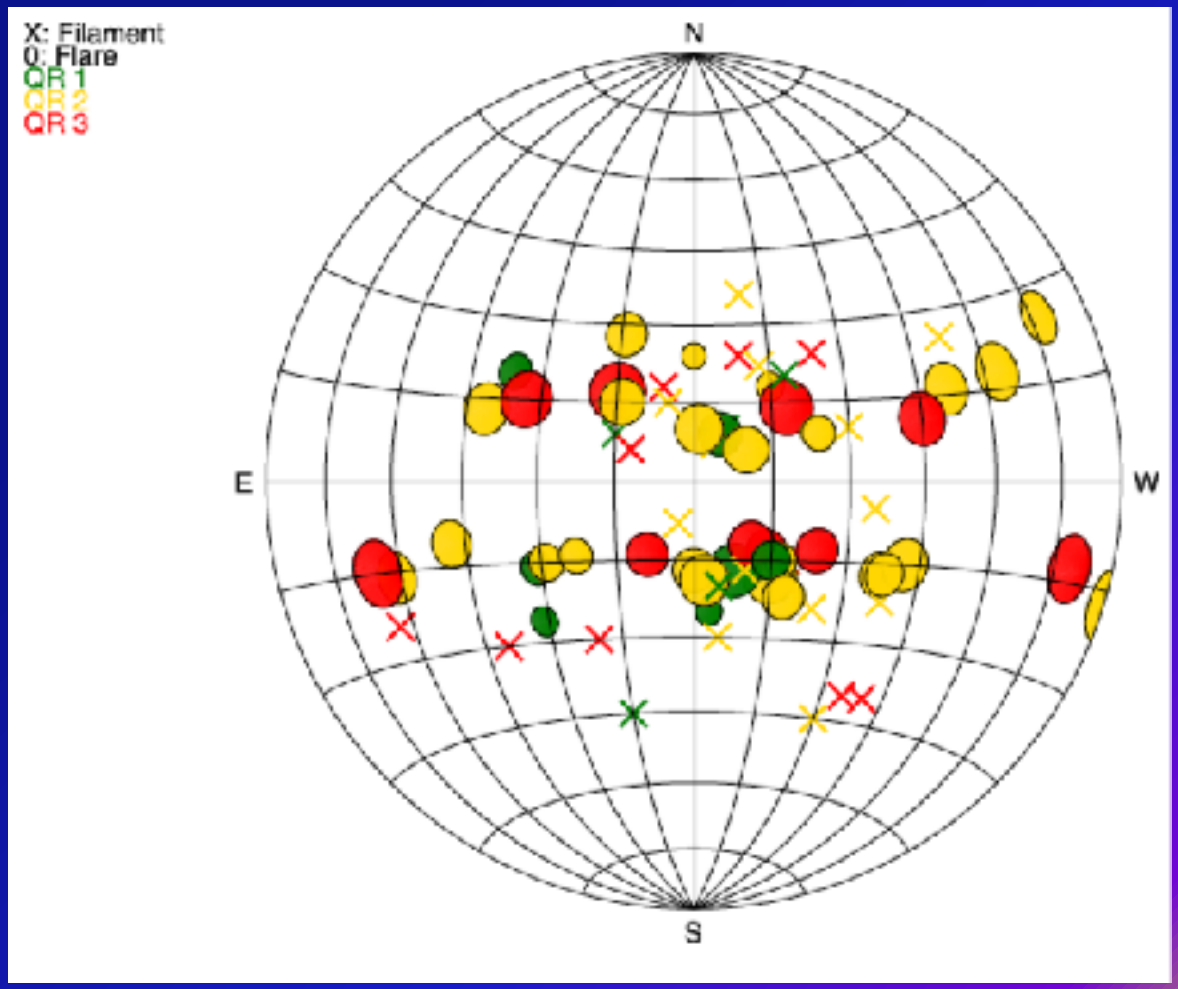
(Hess & Zhang, 2017 in Solar Physics Topical Issue)

Event Catalog

- **Hess & Zhang ICME-CME catalog**

1. **28 (40%) major flares (M & X)**
2. **13 (19%) minor flares (B & C)**
3. **29 (41%) quiet Sun region filament or filament channel**

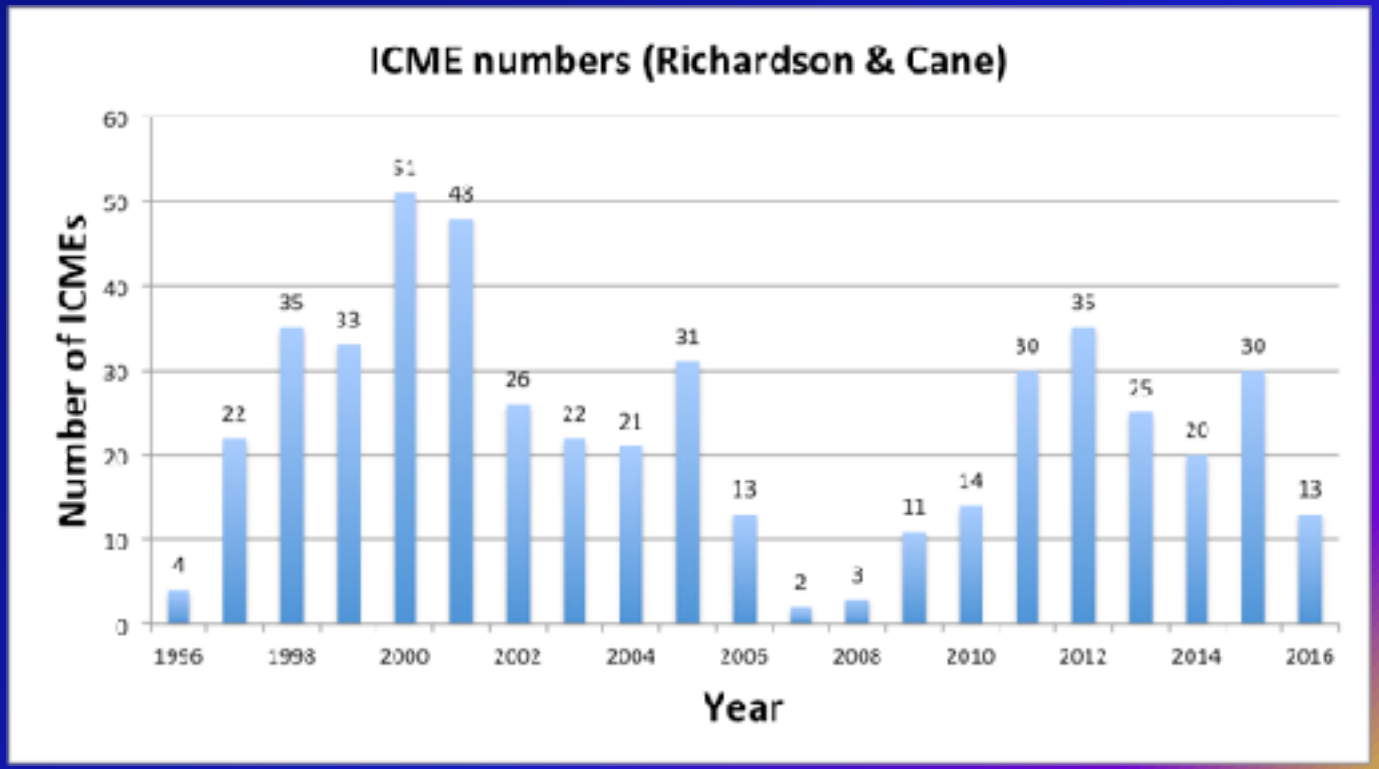
1. **34 (49%) full halo**
2. **20(29%) partial halo**
3. **11 (15%) non halo**
4. **5 (7%) can not be identified**



(Hess & Zhang, 2017 in Solar Physics Topical Issue)

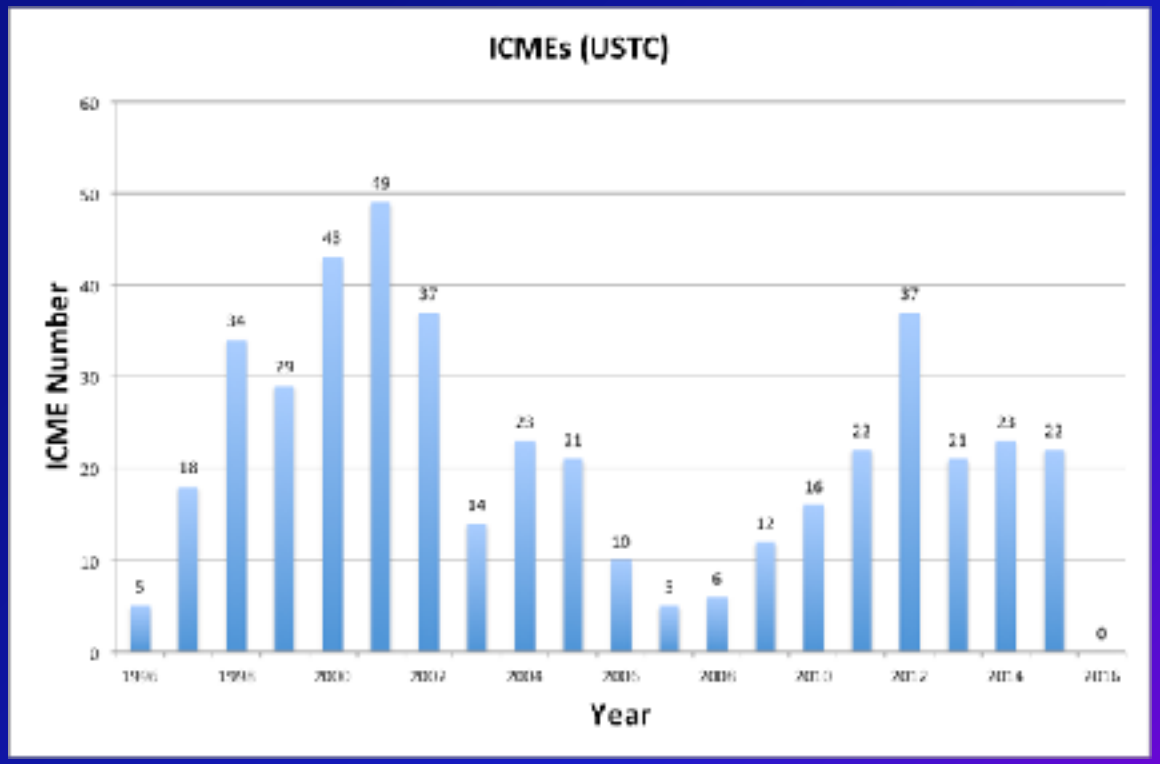
Event Catalog

- Richardson & Cane ICME Catalog
  - Available at http://www.srl.caltech.edu/ACE/ASC/DATA/level3/icmetable2.htm
  - **196 ICMEs from 2006 to 2016** based on ACE and WIND
  - 306 ICMEs from 1996 to 2006 in solar cycle 23rd
  - Refer to Cane & Richardson 2003; Richardson & Cane 2010.



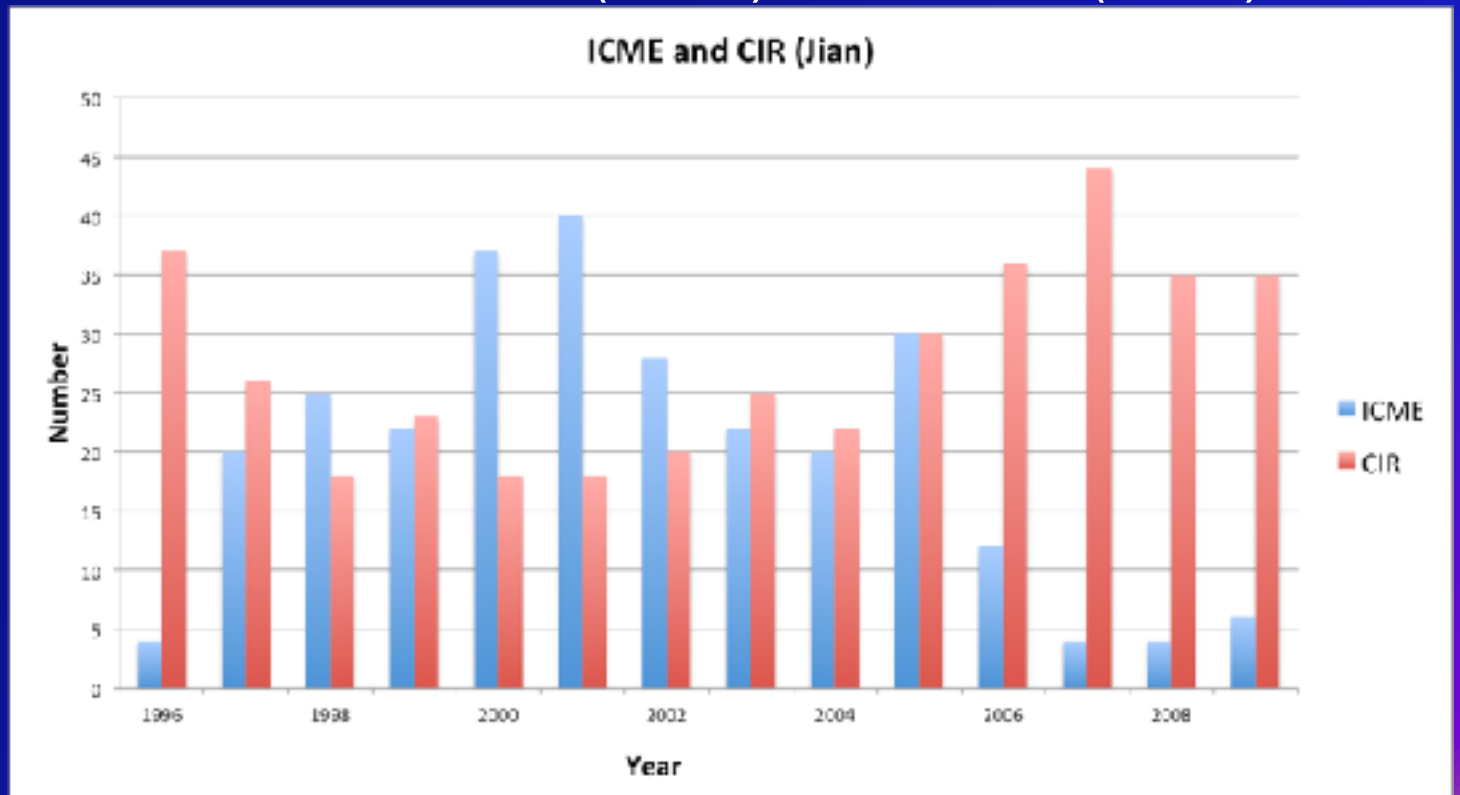
Event Catalog

- USTC ICME Catalog
  - Available at http://space.ustc.edu.cn/dreams/wind_icmes/
  - **174 ICMEs from 2006 to 2016** based on ACE and WIND
  - 283 ICMEs from 1996 to 2006 in solar cycle 23rd
  - Refer to Chi, Shen, Wang etc (2016)



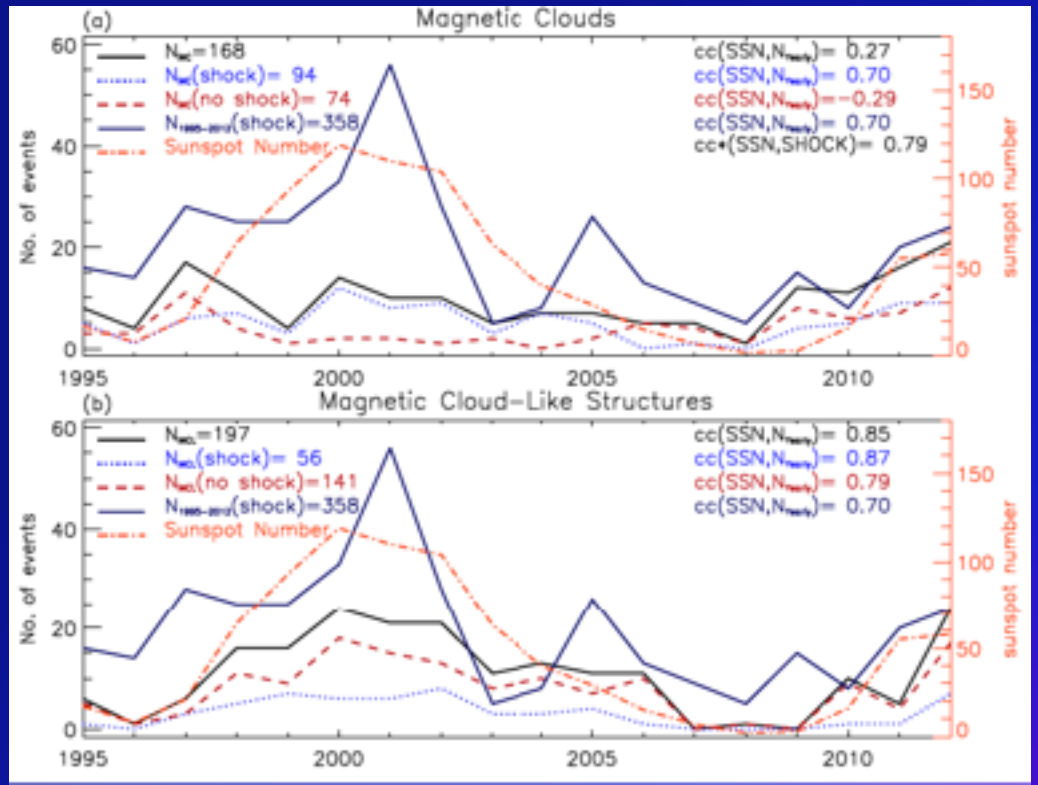
Event Catalog

- Jian's ICME and CIR Catalogs
  - Available at http://www-ssc.igpp.ucla.edu/~jlan/ACE/Level3/
  - Only up to 2009 based on WIND and ACE
  - 260 **ICMEs from 1996 to 2006**
  - **273 CIRs from 1996 to 2006**
  - Refer to Jian et al. (2009); Jan et al. (2011)



Event Catalog

- Lepping & Wu MC and MCL lists
  - MC from 1995-2007 at https://wind.nasa.gov/mfi/mag_cloud_pub1.html
  - MC from 2007-2010 (Lepping et al. 2011)
  - MC from 2010-2012 (Lepping et al. 2015)
  - MC-like events from 1995-2012 (Wu & Lepping 2015; 2016)

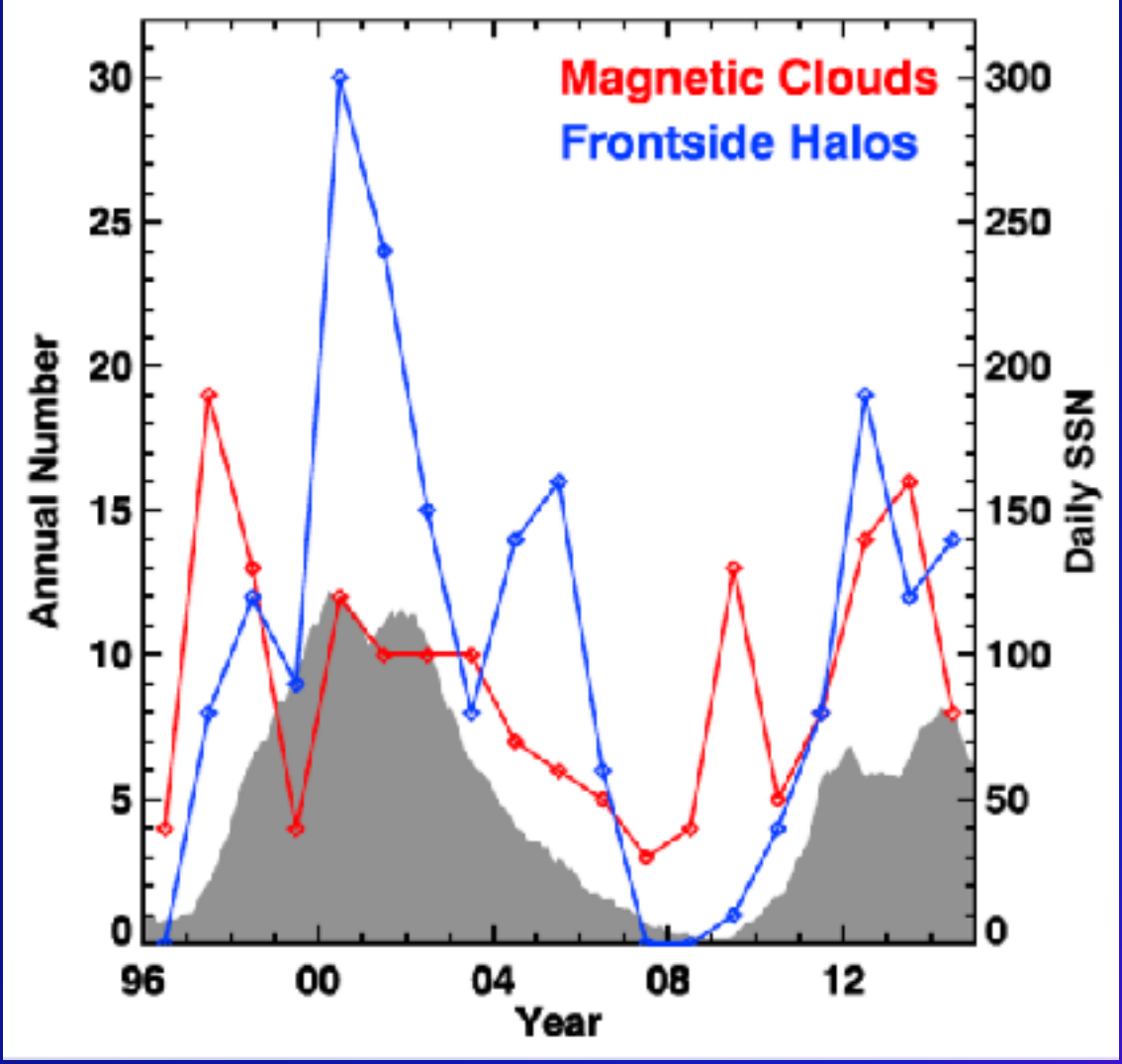


Wu & Lepping 2016
MC: 168
MCL: 197

Also see Nieves-Chinchilla et al. 2017
Magnetic Obstacle (MO): 298

Event Catalog

- MC study in solar cycle 23 and 24 (Gopalswamy et al. 2015)



Rise 1996-1998: 36
Max 1999-2002: 32
Total: 68

Rise 2008- 2010: 27
Max 2010-2014: 33
Total: 61

Event Catalog

Yermolaev's large scale solar wind phenomena catalog

- include HCS, SLOW, FAST, CIR, EJECTA, MC, RARE, IS, ISA
- from 1976 to 2016 based on OMNI database
- Available at ftp://www.iki.rssi.ru/pub/omni/
- Refer to Yermolaev et al. (2009) in Cosmic Research

Type of event	Total number	Minimum number per year	Maximum number	Average number	Standard deviation
HCS	1449	17	219	57.96	46.12
CIR	884	21	55	35.4	9.04
SHEATH	740	10	51	29.6	13.9
EJECTA	1567	36	123	62.68	23.45
MC	136	0	15	5.44	4.19
RARE	18	0	8	0.72	1.8
IS	319	2	43	12.8	10.2
ISA	14	0	5	0.56	1.3

solar wind phenomena from 1976 to 2000 (Yermolaev et al. 2009)

Event Catalog

- **Y.-Liu List (NSSC, China) for highly selected events (2006-2010)**
  - **Available at http://sprg.ssl.berkeley.edu/~liuxying/CME_catalog.htm**

- **MostI ICME List**
  - Available at http://www.uni-graz.at/~moestlc/events/chris_list_v1.htm
  - 24 events from 2008 to 2012-July

An Issue on Catalogs

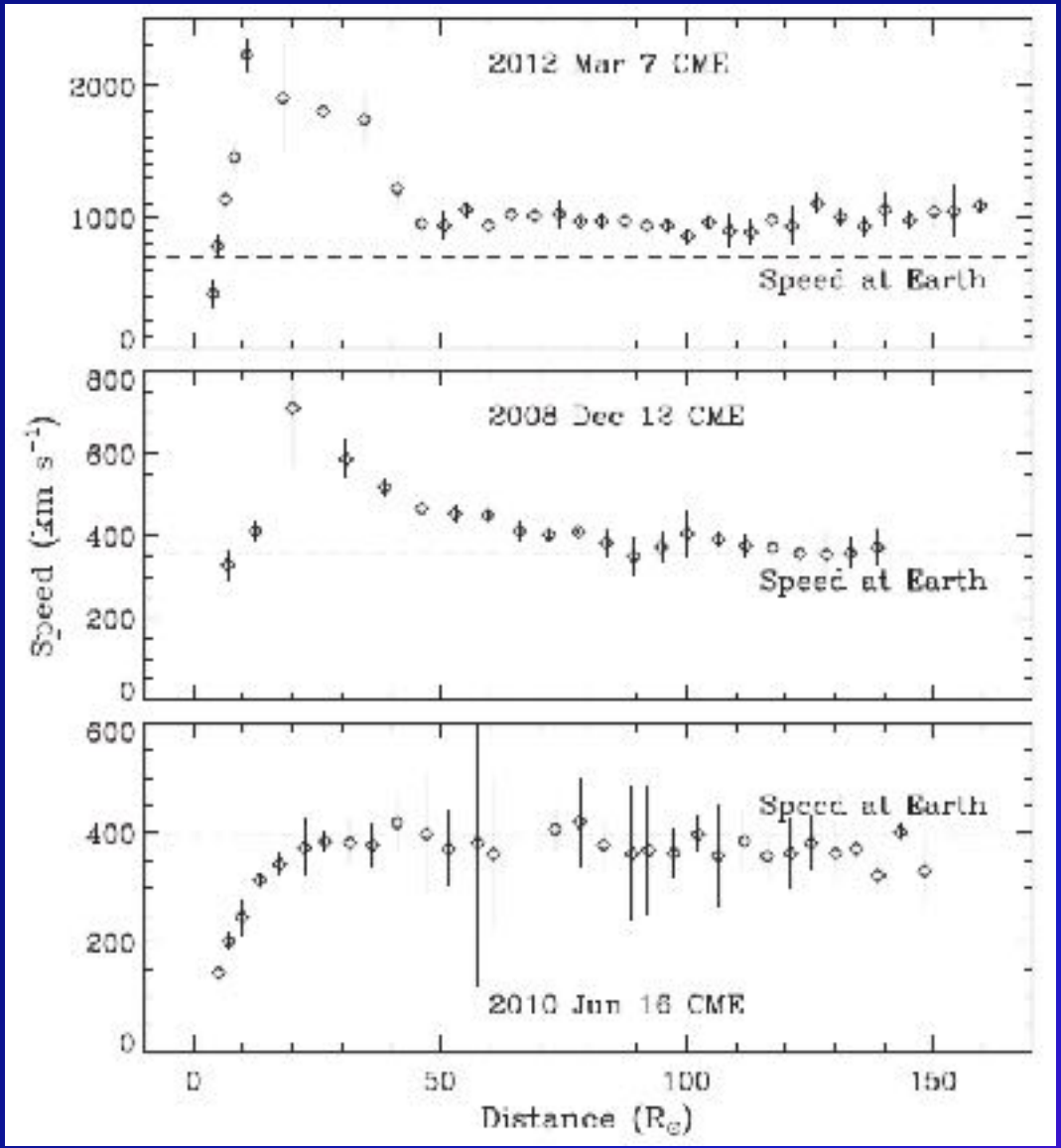
- Merge and clean the catalogs to make a unified ISEST ICME-CME catalog
  - ICME events at the Earth
  - Solar sources of these ICMEs

- Did a united ISEST catalog for events from 2006 to 2013 as a group in the 2013 Workshop
- Probably not applicable to have an ISEST endorsed catalog
- GMU group has populated this ICME-CME catalog from 2006 to 2016
- GMU group welcomes other groups to provide comments/inputs

CME Sun-to-Earth Measurement

- Measure the evolution from the Sun to Earth in 3D for as many events as possible (but will be a small number)
  - Kinematic evolution in 3D (free of projection effect): distance-time profile, velocity-time profile, acceleration time profile
  - Morphological evolution of ejecta: angular width and 3D shape
  - Morphological evolution of shock: angular width and 3D shape, and the standoff distance

CME Sun-to-Earth Measurement

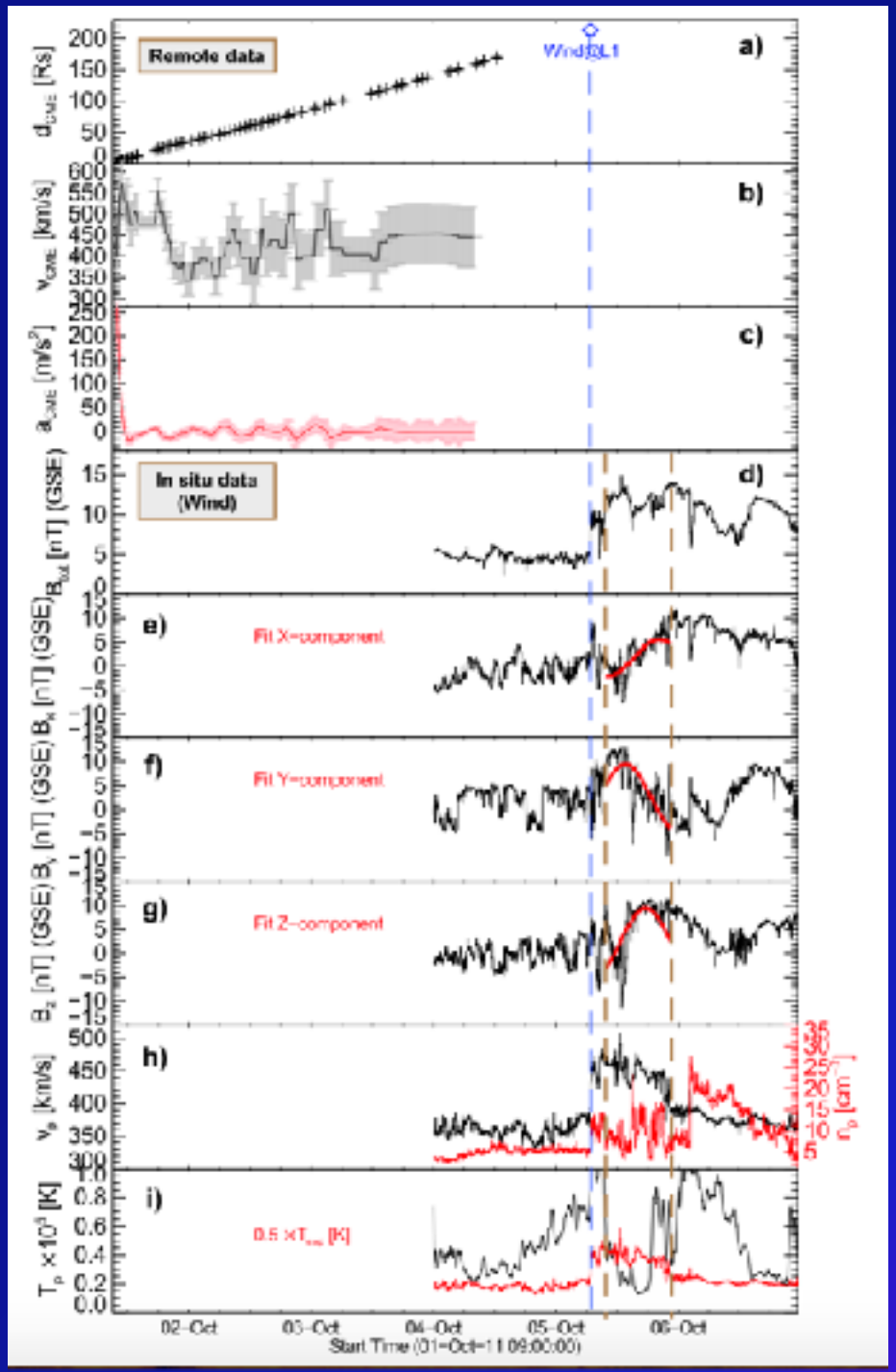


2012 Mar. 7 CME

2008 Dec.12 CME

2010 Jun. 18 CME

Liu et al (2016)



Temmer et al (2017)

2011 Oct. 01 CME

CME Sun-to-Earth Measurement

Table 2
The Predictions for Each Front in Time, Velocity, and Density as Derived from the Model, Compared to In Situ Observations from ACE

ICME Date[a]	ΔT_{SF}[b]	ΔT_{EJ}[b]	ΔV_{SF}[c]	ΔV_{EJ}[c]	$\rho_{ratio}(R(0))$[d]	$\rho_{ratio}(L1)$[d]	$\rho_{ratio}(ACE)$[e]
04/05/2010	1.89	0.38	23.3	26.4	32.17	0.91	0.41
05/24/2010	5.69	2.52	96.3	38.1	6.70	0.15	1.21
09/14/2011	6.68	4.39	15.8	13.0	3.24	0.09	0.71
07/12/2012	0.84	1.51	24.8	22.4	18.61	0.41	0.61
09/28/2012	0.34	0.9	61.6	45.6	10.31	0.31	0.97
10/27/2012	4.99	0.28	24.5	19.0	14.78	0.47	0.67
03/15/2013	3.91	0.26	22.9	7.2	5.98	0.21	0.38
Average	3.47	1.46	38.5	24.5	13.11	0.36	0.80
rms	1.58	0.76	17.9	12.9	…	…	…

Hess & Zhang (2015)

CME Sun-to-Earth Measurement

Table 1
CMEs Associated with *Wind* MCs

ID	CME Start	ICME Arrival	ϕ_f[a] (deg)	θ_f[a] (deg)	Q_f[a]	ϕ_s[b] (deg)	θ_s[b] (deg)	Q_s[b]	Surface Activity Type[c]	Surface Activity Time	Surface Activity λ_p[d] (deg)	Surface Activity β_p[e] (deg)
1	2008 Dec 12T05:25	2008 Dec 16T08:00	65	1	2	68	−10	2	FE	3:00	24	41
2	2009 Jun 22T04:15	2009 Jun 27T12:00	52	42	3	257	65	3	none	...	...	...
3	2009 Jul 15T04:30	2009 Jul 21T00:00	297	−17	2	335	4	3	none	...	...	...
4	2009 Sep 03T01:00	2009 Sep 10T08:00	247	57	2	226	27	2	none	...	...	...
5	2009 Sep 25T12:00	2009 Sep 30T02:00	78	51	2	110	18	1	none	...	...	...
6	2009 Oct 27T09:00	2009 Nov 01T04:00	352	58	2	42	18	3	none	...	...	...
7	2009 Dec 06T02:30	2009 Dec 12T06:00	233	−35	3	217	−3	3	none	...	...	...
8	2010 Apr 03T09:10	2010 Apr 05T09:00	173	57	2	219	−1	3	FL(B7.4), FE	9:04	2	−21
9	2010 May 23T16:35	2010 May 28T03:00	125	−81	1	78	−70	2	FL(B1.3), FE	16:52	12	19
10	2010 Jun 16T06:35	2010 Jun 21T07:00	260	−4	2	266	32	3	FE	4:30	12	−5
11	2010 Aug 01T08:45	2010 Aug 03T18:00	119	−55	3	144	−29	1	FE	6:30	17	29
12	2010 Sep 11T01:10	2010 Sep 14T15:00	282	64	3	52	74	3	FE	1:30	−25	20
13	2010 Oct 26T02:00	2010 Oct 30T10:00	153	60	3	169	73	1	FE	0:30	1	−55
14	2010 Dec 14T05:00	2010 Dec 19T20:00	319	24	3	285	−19	3	none	...		
15	2011 Feb 15T01:55	2011 Feb 18T02:00	11	−4	3	53	−72	3	FL(X2.2), FE	1:44	12	−7
16	2011 Mar 24T19:00	2011 Mar 29T16:00	294	7	2	276	22	2	none	...		
17	2011 May 25T04:20	2011 May 28T07:00	112	−29	1	114	−25	2	FL(B1.9)	3:41	12	−16
18	2011 Jun 02T07:45	2011 Jun 04T21:00	317	20	3	274	−17	2	FL(C3.7), FE	7:22	−24	−15
19	2011 Jun 14T06:10	2011 Jun 17T03:00	18	66	3	208	17	3	FE	3:00	−54	−13
20	2011 Sep 13T22:10	2011 Sep 17T04:00	272	−27	3	208	9	2	FL	22:00	3	10
21	2011 Sep 13T22:10	2011 Sep 17T04:00	335	−12	3	184	5	3	FL	22:00	3	10
22	2011 Oct 02T01:00	2011 Oct 05T08:00	137	38	3	172	80	2	FL(M3.9)	0:37	14	−3
23	2011 Oct 22T00:05	2011 Oct 24T19:00	291	40	2	286	45	2	FE	1:30	28	25
24	2012 Feb 24T02:25	2012 Feb 26T22:00	295	5	3	308	46	1	FE	2:00	−32	28
25	2012 Jun 08T03:20	2012 Jun 11T15:00	90	−35	3	73	−66	1	FL(C7.7)	2:54	18	−23
26	2012 Jun 14T13:30	2012 Jun 16T10:00	284	−15	2	267	−9	1	FL(M1.9)	12:52	−9	−20
27	2012 Jul 03T20:45	2012 Jul 08T03:00	161	36	3	185	76	3	FL(C9.3)	20:36	23	6
28	2012 Jul 04T16:45	2012 Jul 08T03:00	160	−40	2	160	−51	1	FL(M1.8)	16:33	33	6

Wood et al. 2017
28 events from 2008 to 2012 when STEREO A/B are in favorable position.

CME Measurement Methods

- For ejecta and shock near the Sun (COR2, C2/C3, HI-1)
  - GCS model (Thernisien et al. 2006)
  - GCS + spherical model (Hess et al. 2014)
  - GCS + spheroid/ellipse model (Kwon et al, 2014)
  - Flux rope 3D Geometry and Density model (Wood et al. 2009)
- For shock in the interplanetary space (HI-2) (single versus double)
  - J-map: fixed-ϕ (Rouillard et al. 2008)
  - J-map: harmonic mean (Lugaz et al. 2010)
  - J-map: Self-similar expansion Fitting (SSEF) (Davies et al. 2012)
  - J-map: fixed-ϕ and triangulation (Liu et al. 2010) for using double HI-2 images

Scientific Questions?

How do CMEs propagate from the Sun to Earth?

- **How do CMEs accelerate or decelerate in the interplanetary space through interaction with the ambient solar wind?**
- **How does the CME morphology change, e.g., pancaking?**
- **How does the shock front separate from the ejecta front, i.e., the evolution of the standoff distance with time?**
- **Effects of CME interaction with preceding CME?**
- **Effects of CME interaction with preceding and trailing CIRs?**
- **CME erosion due to magnetic reconnection**

Scientific Questions?

What kind of CMEs would reach the Earth?
i.e., predicting HIT/MISS from near-Sun observations?

- **Source location distribution on the solar disk?**
- **Why so many halo CMEs missed the Earth?**
- **What is the true nature of halo CMEs? Is merely a projection effect?**
- **How significant is the CME deflection?**
- **What are the causes of CME deflection?**
- **What about the effect of CME rotation?**
- **Stealth CMEs?**
- **Problem ICMEs?**

Scientific Questions?

How well could we predict the time of arrival (TOA) of CME ejecta and driven shocks?

- **How accurately can we predict the TOA of an ICME?**
- **How accurately can we predict the TOA for shocks and ejecta separately ?**
- **How can we further improve the prediction of TOA?**

Scientific Questions

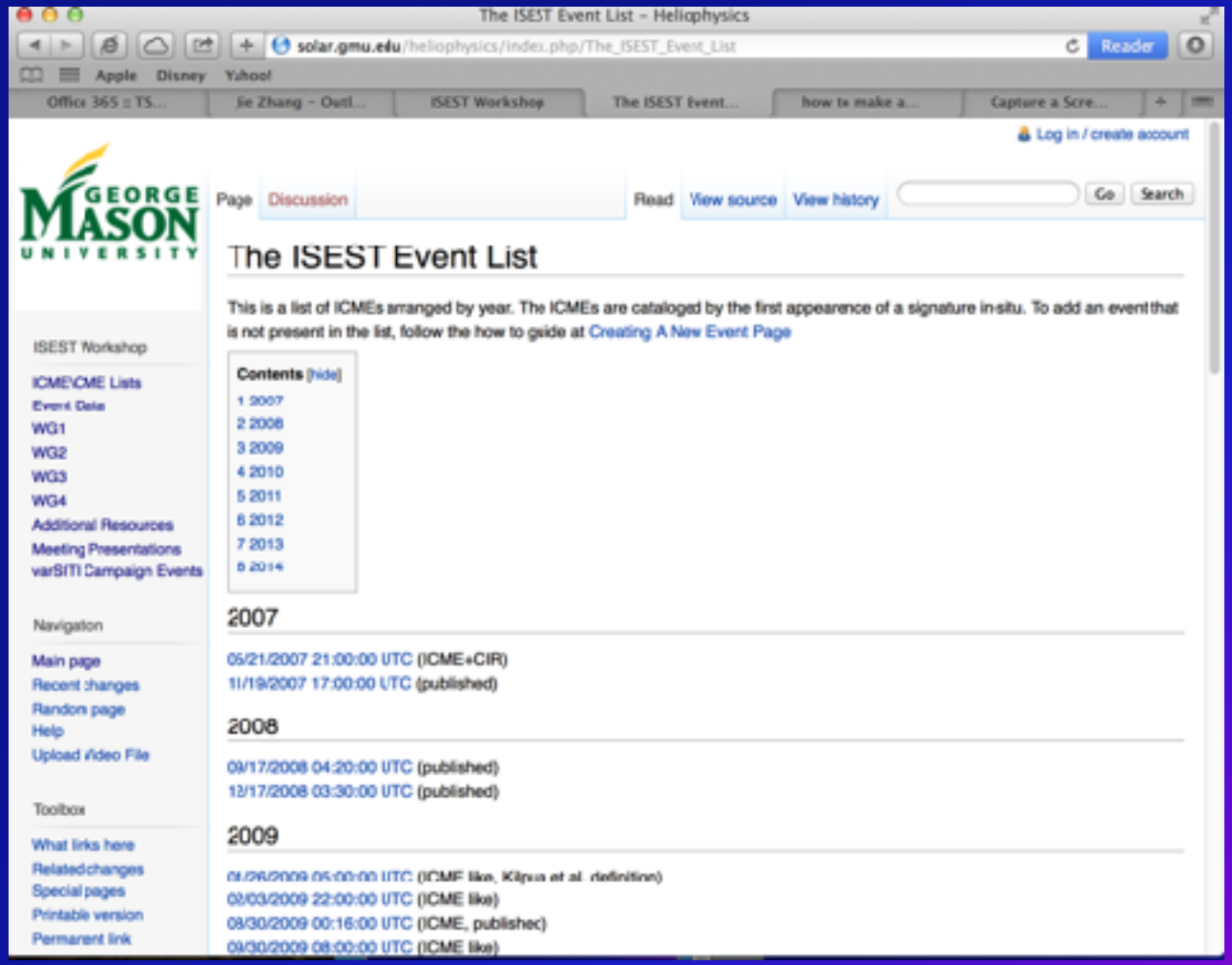
How can we predict the potential geo-effectiveness of an arriving ICME?

- **The big problem is the Bz issue, or the magnetic field topology in magnetic flux ropes (WG5).**

Use the ISEST WiKi

http://solar.gmu.edu/heliophysics/

Access data/information and provide your contribution



The End