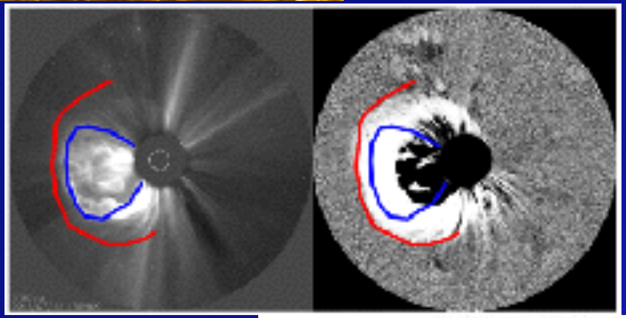
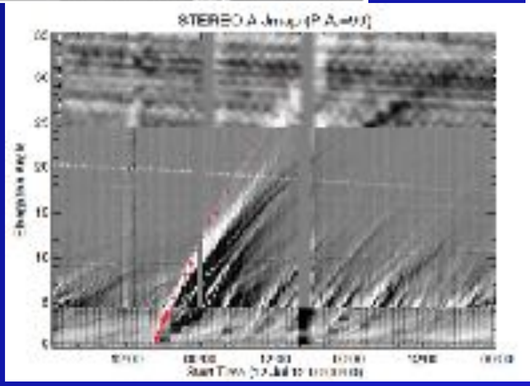
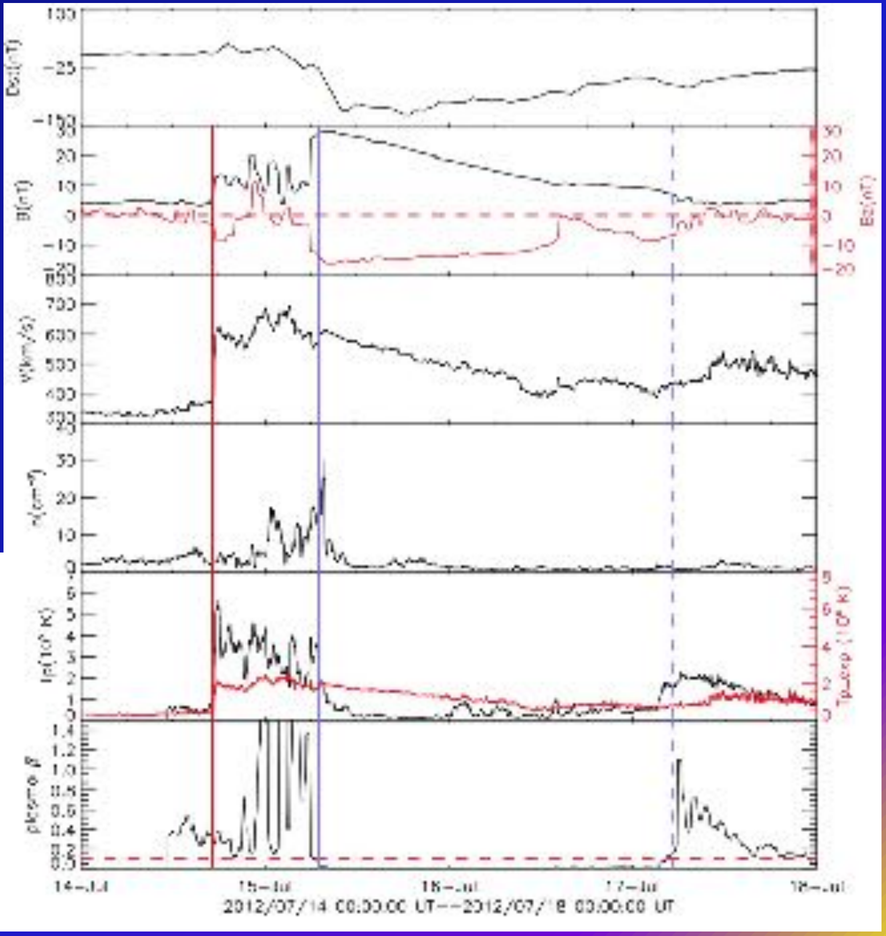

International Study of Earth-affecting Solar Transients
ISEST 2017 WORKSHOP
18-22 September 2017, ICC JEJU, Jeju, Rep. of Korea




ISEST WG1 Summary: Data Group







Scientific Objectives

1. Understanding Sun-to-Earth Evolution of Ejecta and Shocks.

2. Predictions
    - On Predicting HIT/MISS
    - On Predicting TOA (Time of Arrival)
    - On Predicting Intensity (Dst) or Category (Kp) of Geomagnetic Storm

WG Tasks

1. Create event catalogs. This is to identify all Earth-Affecting solar transient events, CMEs and CIRs, during the STEREO era (2007 - 2017)

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

Summary of Talks

- Theme-setting talks by Chenglong Shen on "Key problems in the forecasting of the geoeffective CMEs"
- Eleven other talks on various issues, including prediction and limits on prediction, different types of flares and/or CMEs, nature of CME collision, PC index, and filament eruption

5. Summary

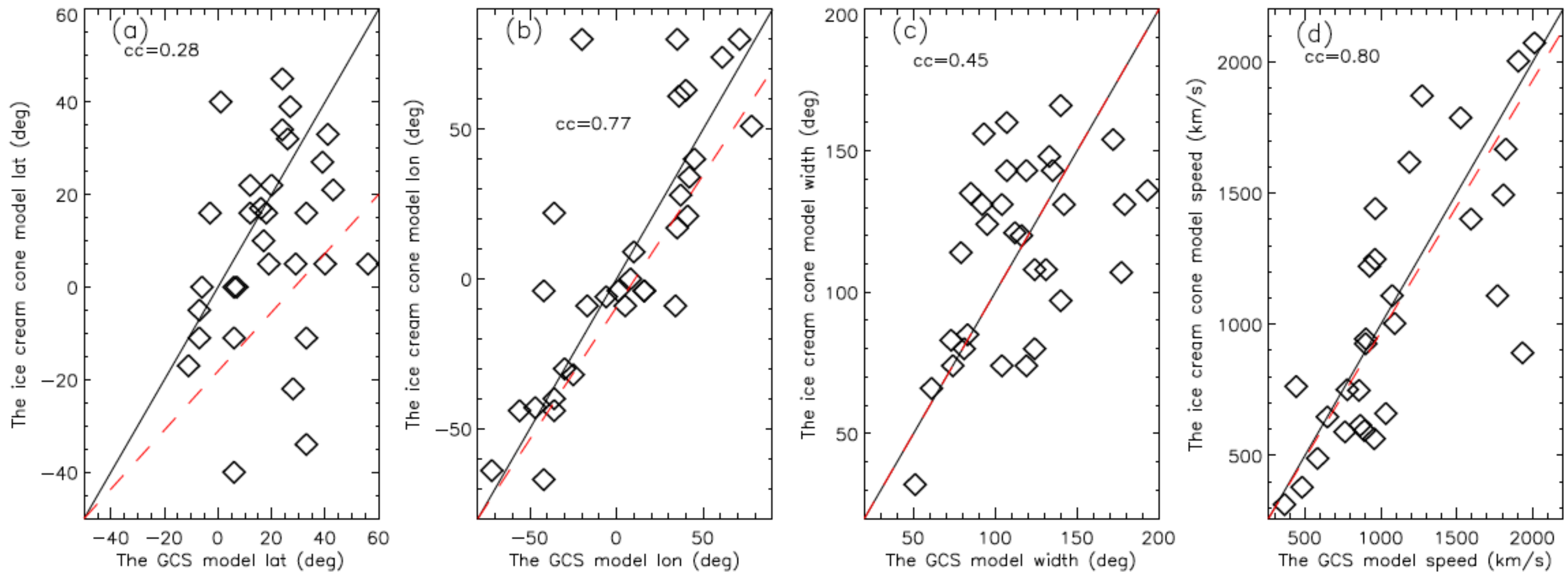
Following key problems are discussed:

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.

How can we believe the Cone model?

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

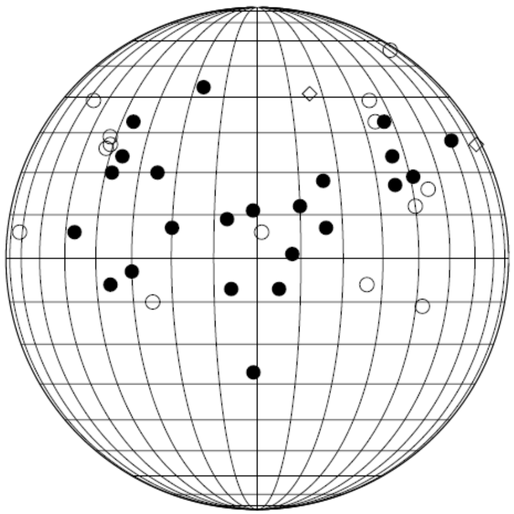


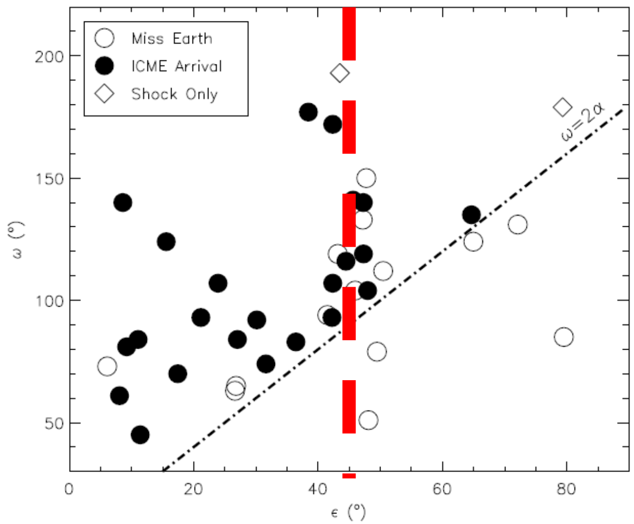
- **Velocities and longitude are consistent well**
- **Latitude and angular width show some different**

Sheng, Chenglong —Talk

Possible Criteria

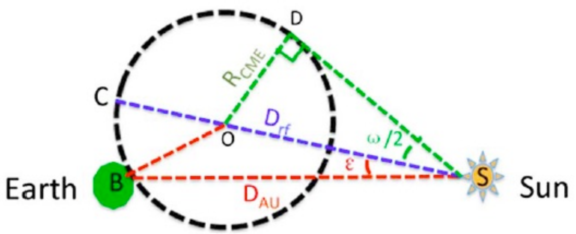
27 (56%) front side full halo CMEs hit the Earth





Self similar expansion models

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

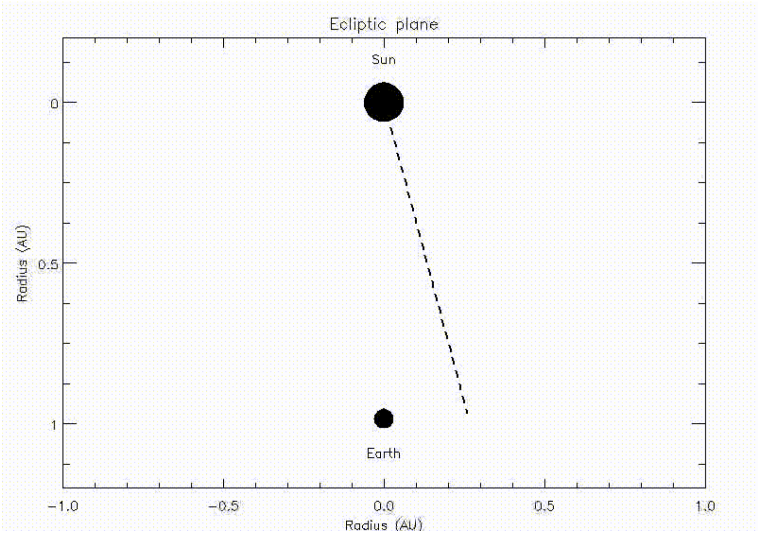


- **Central events**
  - **[E40, W40] (72%)**
  - **ε < 45° (75%)**
- **Large events**
  - **ω>2ε (74%)**

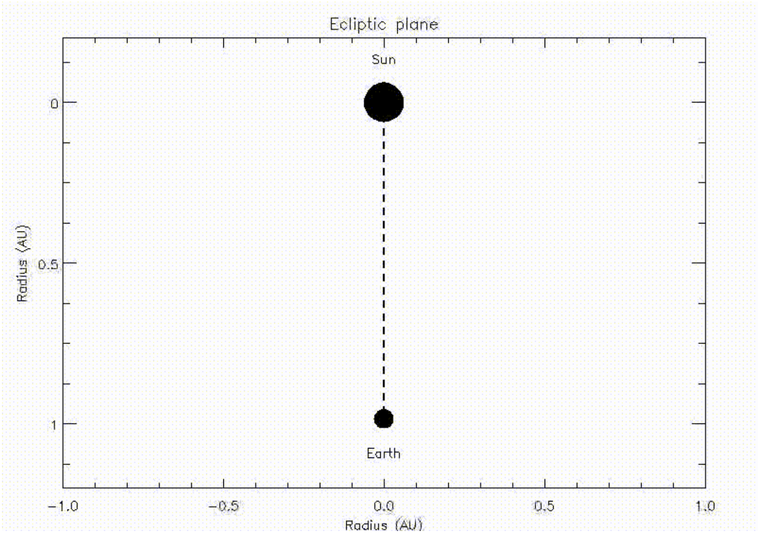
[e.g. Shen et al., 2014]

An Influence Factor: CME Deflection

Deflection make a Not-Earth direct CME hit the Earth



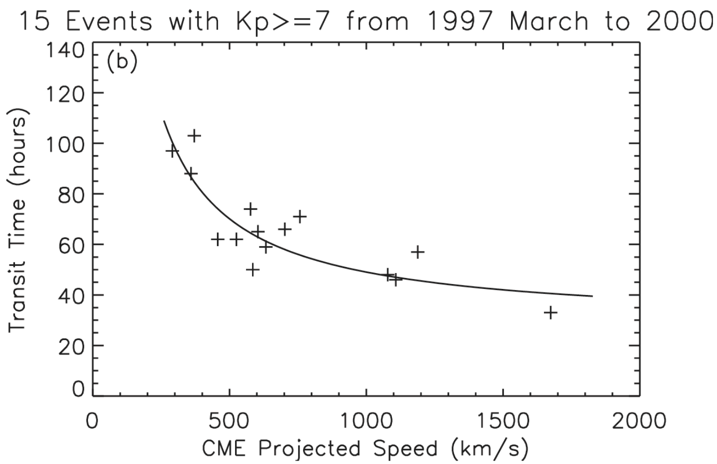
Deflection make a Earth direct CME miss the Earth



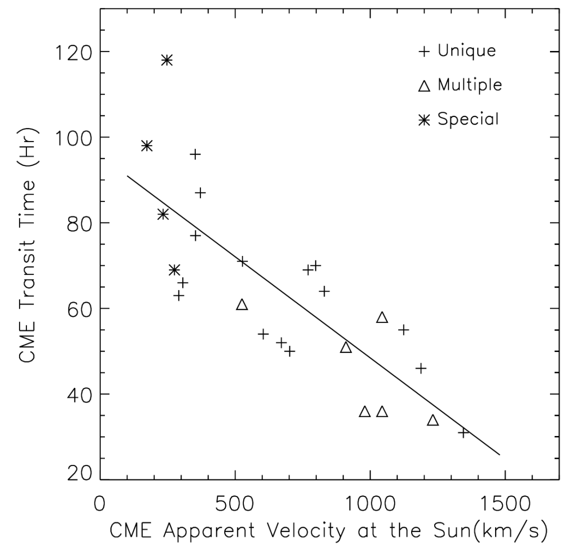
Three types of deflection:

- **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]

Empirical models

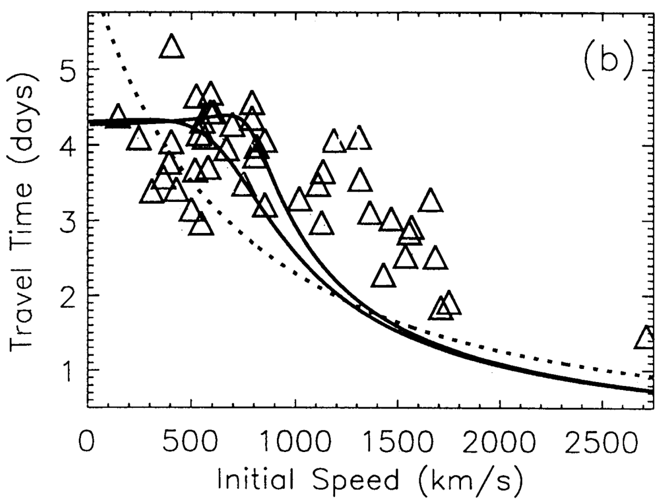


$$T = 27.98 + \frac{2.11 \times 10^4}{v_P}$$ [Wang et al., 2002]



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

[Zhang et al., 2003]



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

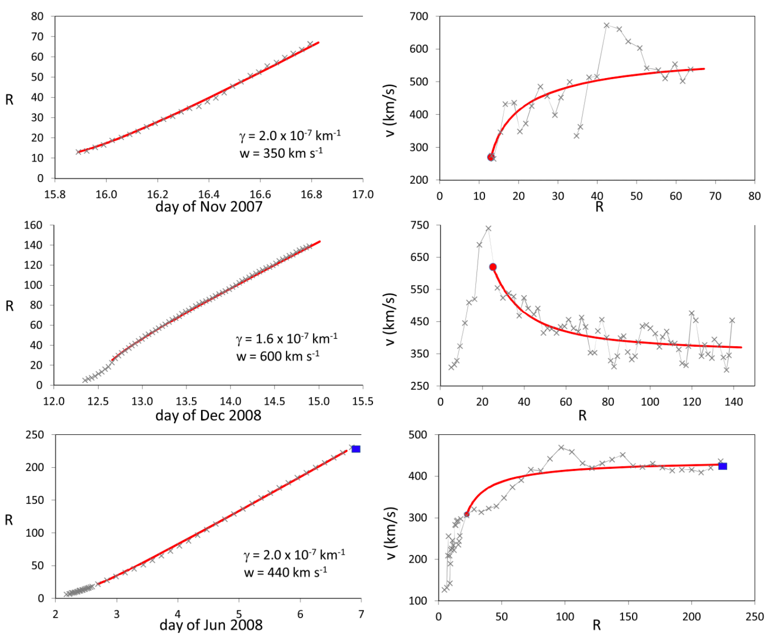
$$a = 1.41 - 0.0035u$$

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

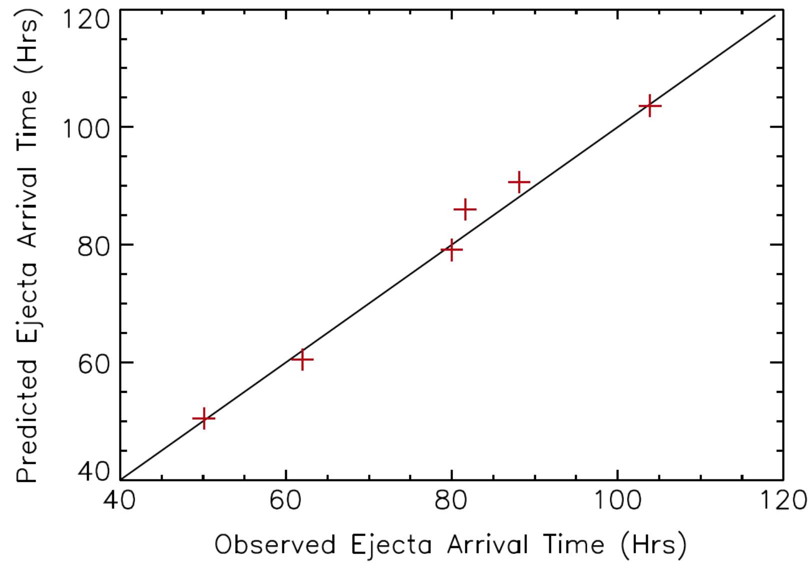
u: initial velocity

S=1AU

Drag-based model (DBM)



Vršnak et al., 2013



Hess & Zhang, 2015

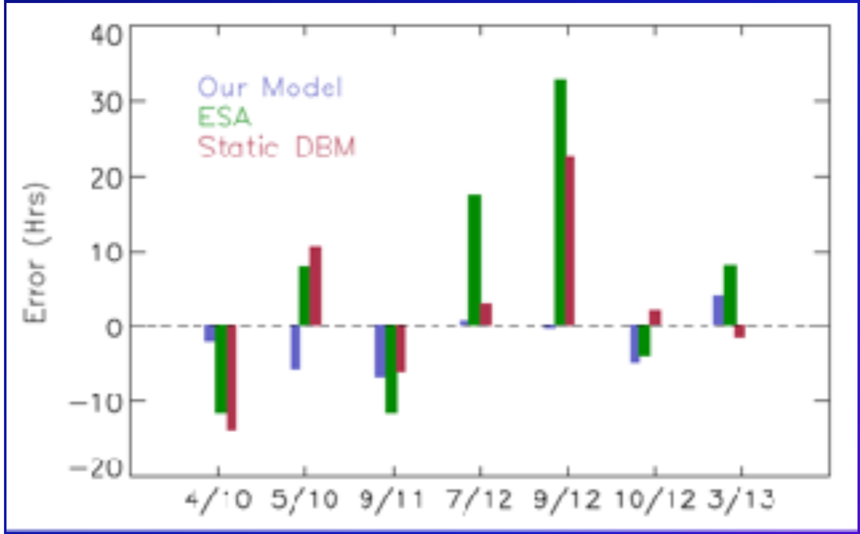
What is the value of c_d (or C in simple form)?

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

A "Fair" Comparison

Table 3
A Comparison of the Error in Hours between Our Method and the ESA and DBM Models for Each Event

ICME Date	Constrained Drag Model	ESA	Static DBM
04/05/2010	−1.89	−11.6	−14.0
05/24/2010	−5.69	7.91	10.6
09/14/2011	−6.68	−11.5	−6.00
07/12/2012	0.84	17.4	2.88
09/28/2012	−0.34	32.9	22.5
10/27/2012	−4.99	−3.70	2.11
03/15/2013	3.91	8.00	−1.45
Average	3.47	13.27	8.5
rms	1.58	6.04	4.20



TOA error
(Hess & Zhang 2015)

- In blue: our improved DBM model (Hess & Zhang 2015)
- In green: Empirical Shock Arrival model (ESA) (Gopalswamy et al. 2013)
- In red: Static Drag-based Model (DMB) (Vrsnak et al. 2014)

Zhukov, Andrei — Talk on constraining CME models

Raise the problem of fitting magnetic cloud at 1 AU. The fitting results depend on the method adopted, thus make it difficult to connect to the geometric property near the Sun, e.g., tilt angle of flux rope.

True Skill Statistic (TSS) Comparison

Reference		Data	Forecast	Method	Period	Training/Test	TSS
Bloomfield *et al.* (2012)		McIntosh Classification	Probability	Historical Poisson Statistic	Dec 1988 ~ Dec 2010	Chronological Selection	0.54
Bobra and Couvidat (2015)		SDO/HMI	Yes/No	Support Vector Machine	May 2010 ~ May 2014	Random Selection	0.76
Nishizuka *et al.* (2017)		SDO/HMI	Yes/No	K-Nearest Neighbor + UV Emission + Flare History	June 2010 ~ December 2015	Random Selection	0.91
Liu *et al.* (2017)		SDO/HMI	Multi class	Random Forest	May 2010 ~ December 2016	Random Selection	0.53
This work	TOTUSJH	SDO/HMI	Probability	Empirical Relationship	May 2010 ~ April 2017	Chronological Selection	0.81
This work	TOTUSJZ	SDO/HMI	Probability	Empirical Relationship	May 2010 ~ April 2017	Chronological Selection	0.8
This work	USFLUX	SDO/HMI	Probability	Empirical Relationship	May 2010 ~ April 2017	Chronological Selection	0.79

Results

Occurrence (M+X) Scores

	Convolutional Neural Networks Occurrence After Performing Classification		Multi-layer Perceptron Shin et al. (2016)		Statistics Bloomfield et al. (2012)	
	AlexNet	ResNet50	ANN1	ANN2	Optimum TSS	Optimum HSS
POD	0.78	0.66	0.51	0.40	0.70	0.30
TSS	0.48	0.66	0.32	0.31	0.54	0.27
CSI	0.60	0.66	0.24	0.21	-	-
FAR	0.28	0.00	0.39	0.67	0.85	0.68
HSS	0.46	0.57	0.32	0.29	0.19	0.28

Our results show a great possibility that convolutional neural network can be applied to flare forecasts, as well as similar types of problems.

Park, Jinhye — Talk on SEP flux

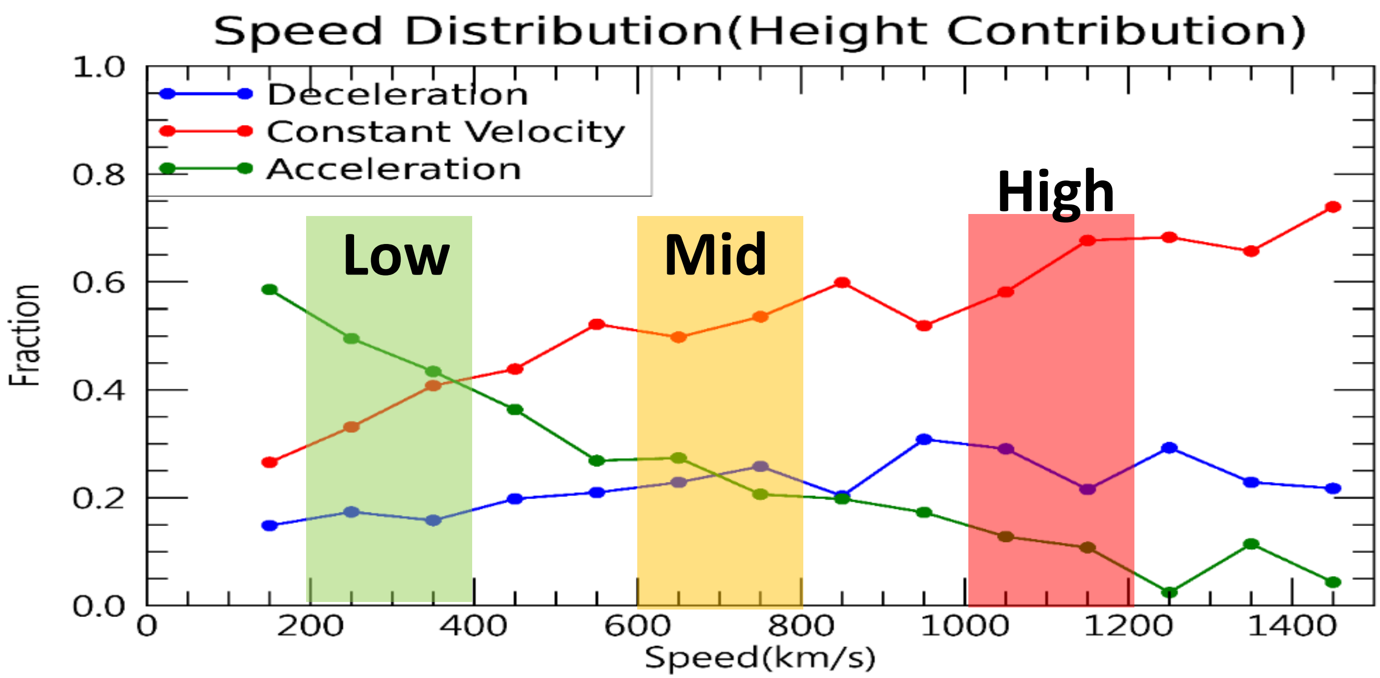
1) We find the dependence of the SEP peak fluxes on CME 3D speed and 3D angular width from multi-spacecraft.

2) There is a noticeable anti-correlation (r=-0.62) between SEP peak flux and separation angle.

3) We predict the SEP peak fluxes using a multiple regression method considering longitudinal separation angle, CME 3D speed and 3D angular width. It shows that the separation angle is the most important parameter, and the CME 3D speed is secondary on SEP peak flux.

4. Result

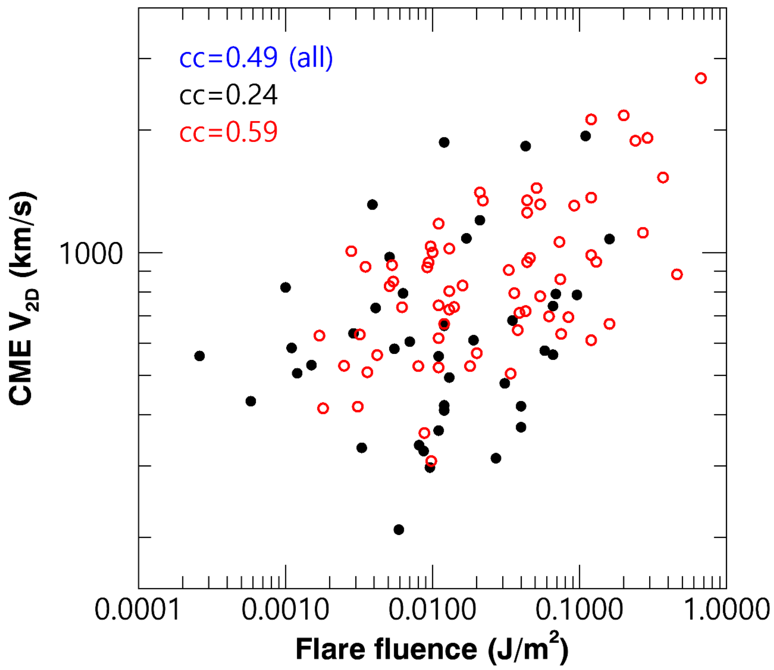
Jeon, Seong-Gyeong —Talk

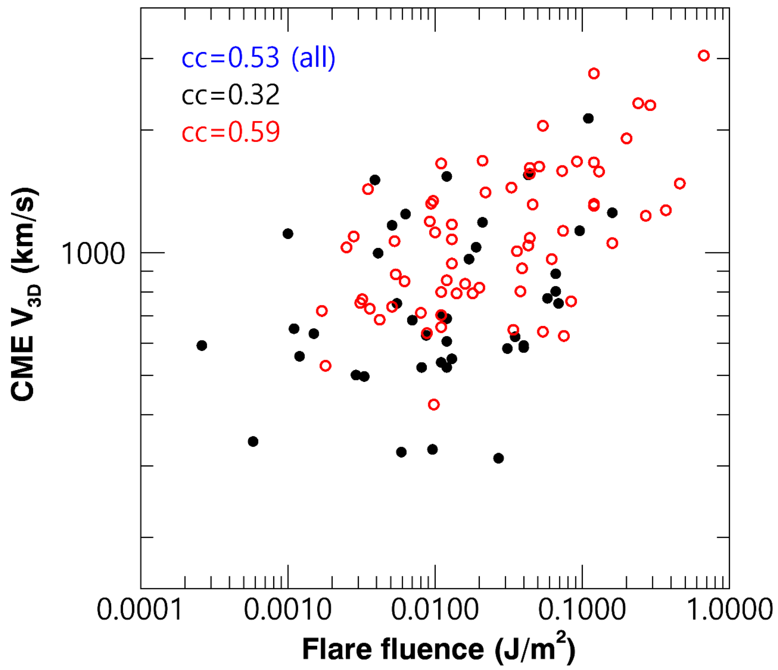


	Low(200~400km/s)	Mid(600~800km/s)	High(1000~1200km/s)
Deceleration	16%	25%	26%
Constant velocity	38%	**51%**	**62%**
Acceleration	**46%**	24%	12%

Jang, Soojeong —Talk on CME-flare relationship of two types

1 CME speed vs Flare fluence





The linear relationship between the 3D (and 2D) speed and the flare fluence for group B is much clearer than that for group A.

Mishra, Wageesh—Talk on CME interaction

- The crucial pre-collision parameters of the CMEs responsible for increasing the probability of a super-elastic collision are, in descending order of priority, their lower approaching speed, expansion speed of the following CME higher than the preceding one, and a longer duration of the collision phase.

- The expansion speed of the CMEs plays a greater role than any other parameters.

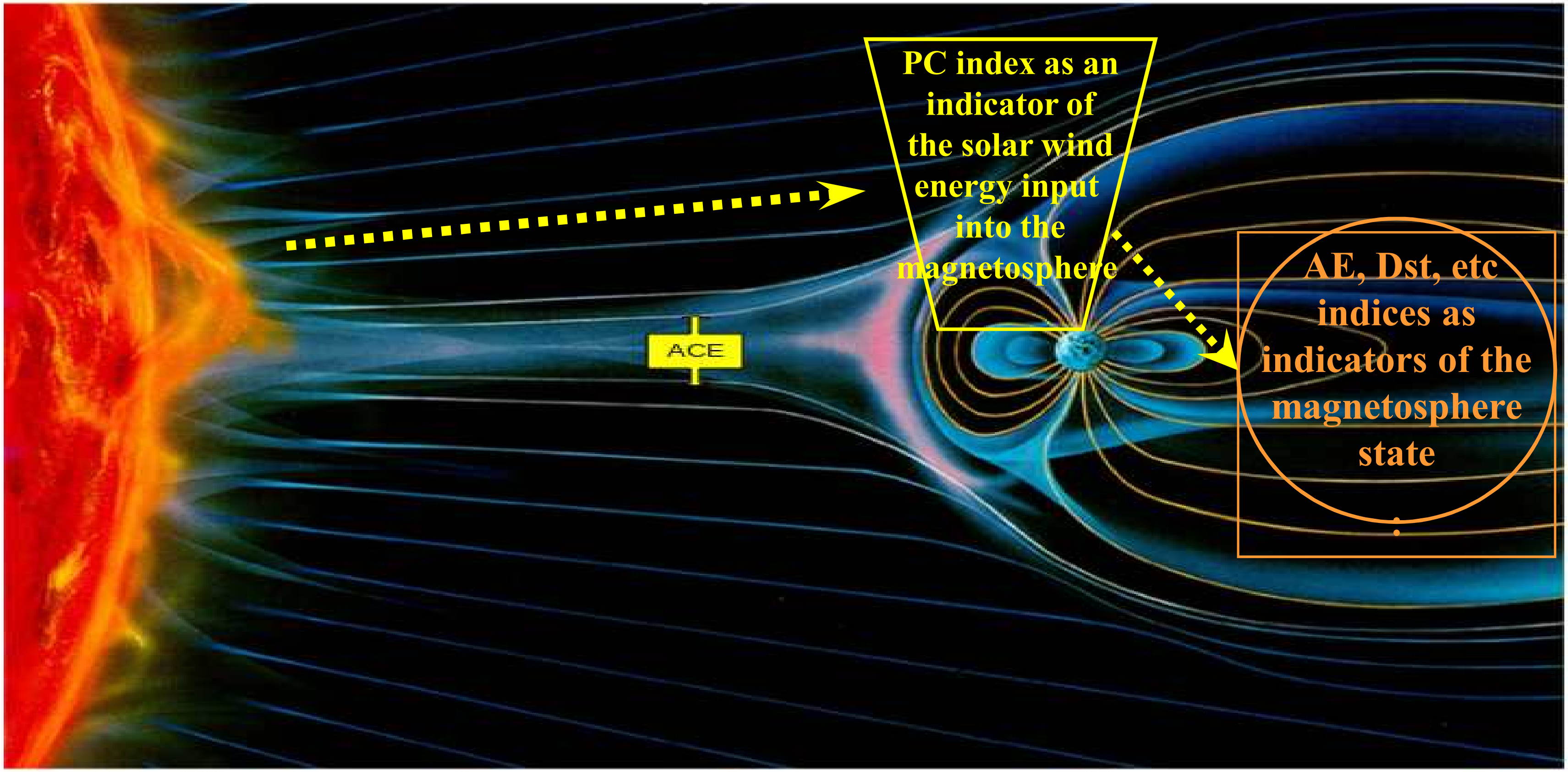
- The change in direction indirectly may alter the relative contributions of expansion speeds in the approaching speeds of the CMEs centroids.

- The direction of impact, distance of a collision site from the Sun, and mass ratio of the CMEs do not favor for a particular nature of collision.

- In head-on (1D) collision assumption, the value of "e" is underestimated.

- Nature of collision of the CMEs should only be determined with a finite probability for a specific nature.

Troshichev, Oleg —Talk on PC Index



The experimental facts are strongly indicative of the *PC* index as an adequate indicator of the solar wind energy input into the magnetosphere.

The *PC* index might be useful for monitoring the space weather, nowcasting the actual state of the magnetosphere, fitting the solar wind-magnetosphere coupling function, and checking whether or not the solar wind fixed in Lagrange point L1 actually encounters the magnetosphere.

The sets of data on PC index for 1997-2015and current *PCN* and *PCS* indices calculated on-line by magnetic data from stations Thule and Vostok are presented at web site: http://pcindex.org

:

Discussion and Conclusion

- The neutral column density as seen absorption features is constrained about $4x10^{18}$ - $9x10^{19}$ cm^{-2} with the covering factor of 0.33-0.48, while ion column density is hard to constrain.
  - This is because 304 Å and 335 Å are not absorbed by He+, but we don't use 304, and 335 has significant response at short wavelengths and relatively poor signal-to-noise.
- The prominence as seen emission has a peak at about LogT=6.3-6.4, while the DEMs of overlying erupting loops show evidence of a higher peak at around LogT=7.0.
  - **The reconstructions for 94 Å and 335 Å are hard to fit the observations. The choice of abundances does little to solve the discrepancy between AIA and XRT.**
- **The thermal energies are comparable to the heating energies at the earlier time, and the heating rates are larger than any other cooling terms.**
- **This event shows a writhing motion of the erupting prominence, which may indicate a hot flux rope heated by thermal energy release during magnetic reconnection.**

Lee et al. ApJ 2017 844,3

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Lee et al. ApJ 2017 844,3

Chandra, Ramesh —Talk on two-step filament eruption

- **The initiation of the filament eruption on 14 March 2015 and its full eruption on 15 March 2015 are associated with the jets in the active region.**

- **The decay index calculation suggests that on 14 March 2015 the filament first enters into the instability zone and after reaching some height it finds itself in the stability zone. Again on 15 March 2015 the filament enters into the instability zone and finally it erupts.**

- **The major part of filament which had not been destroyed on 14 March 2015 was activated on March 15 but could not erupt. Therefore it was a failed eruption. The coronal magnetic field calculation shows evidence that the decay index at the filament location is below the threshold of the torus instability and hence the filament fails to erupt.**

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?

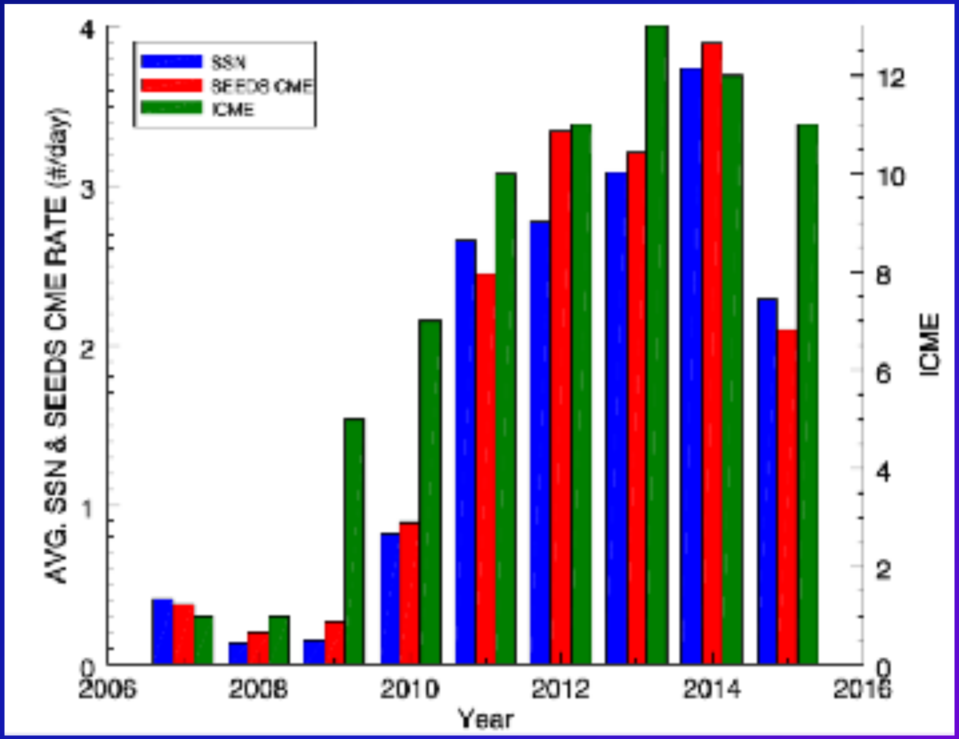
Scientific Questions

How can we predict the potential geoeffectiveness of an arriving ICME?

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

Event Catalog

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

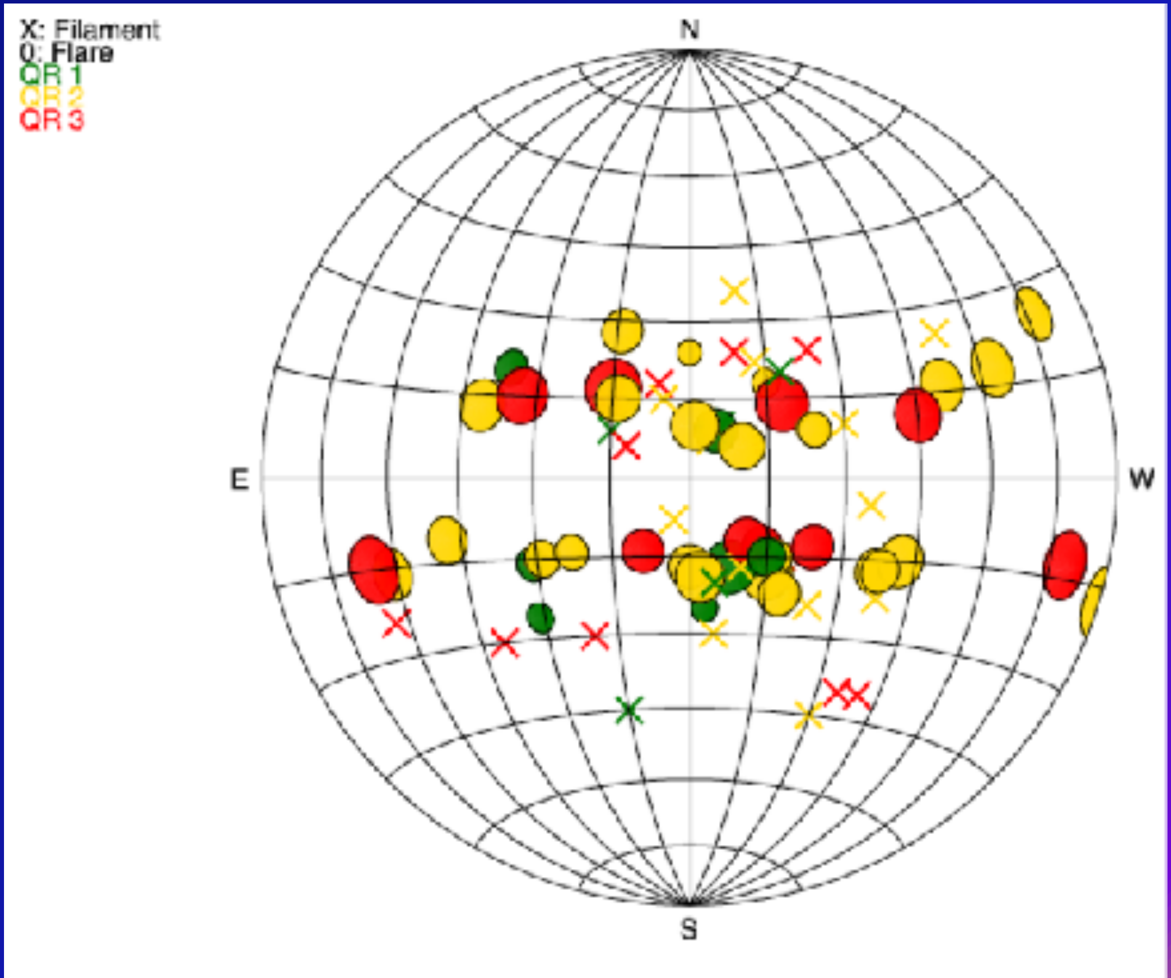


(Hess & Zhang, 2017 in Solar Physics Topical Issue)

Event Catalog

- **Hess & Zhang CME-ICME 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 ("stealth" events)**

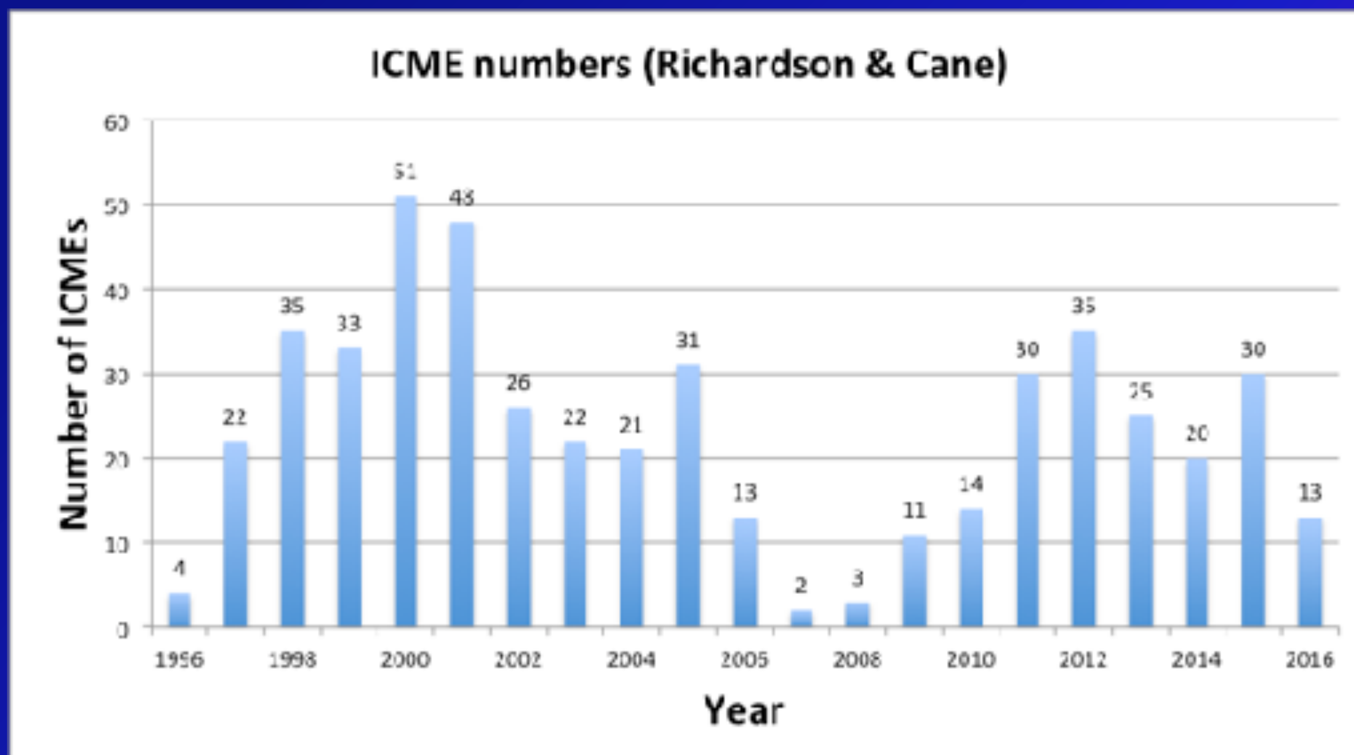


1. **34 (49%) full halo**
2. **20(29%) partial halo**
3. **11 (15%) non halo**
4. **5 (7%) can not be identified**

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

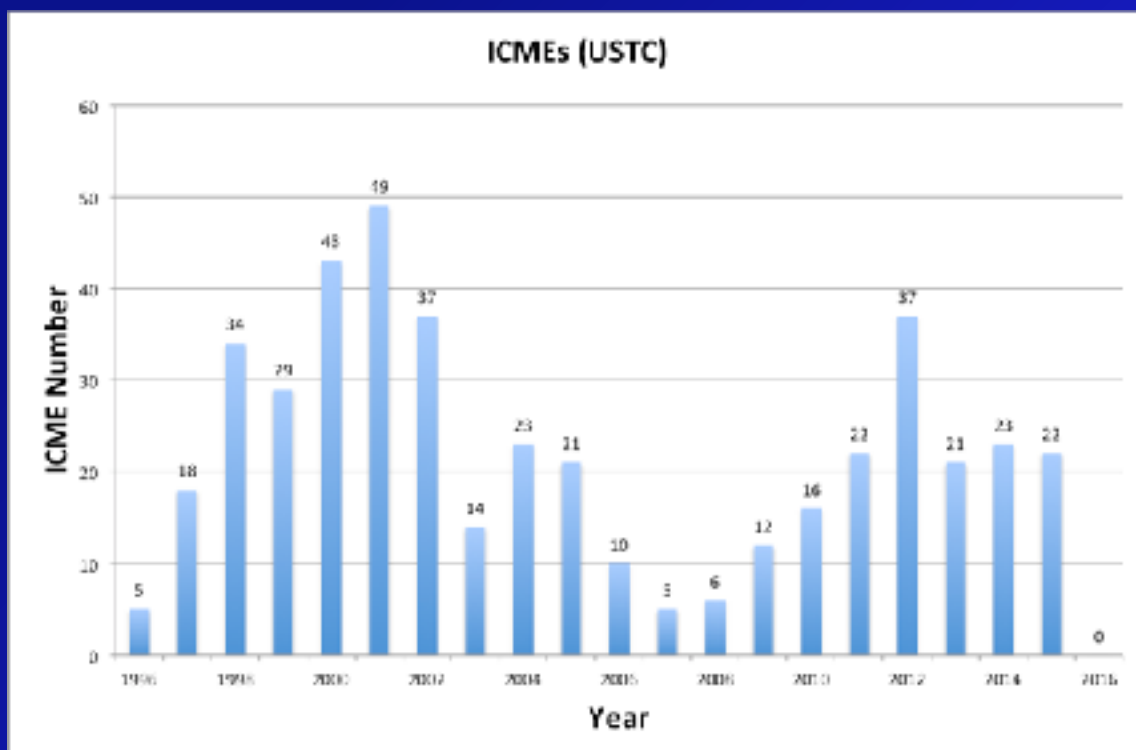
Event Catalog

- 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.



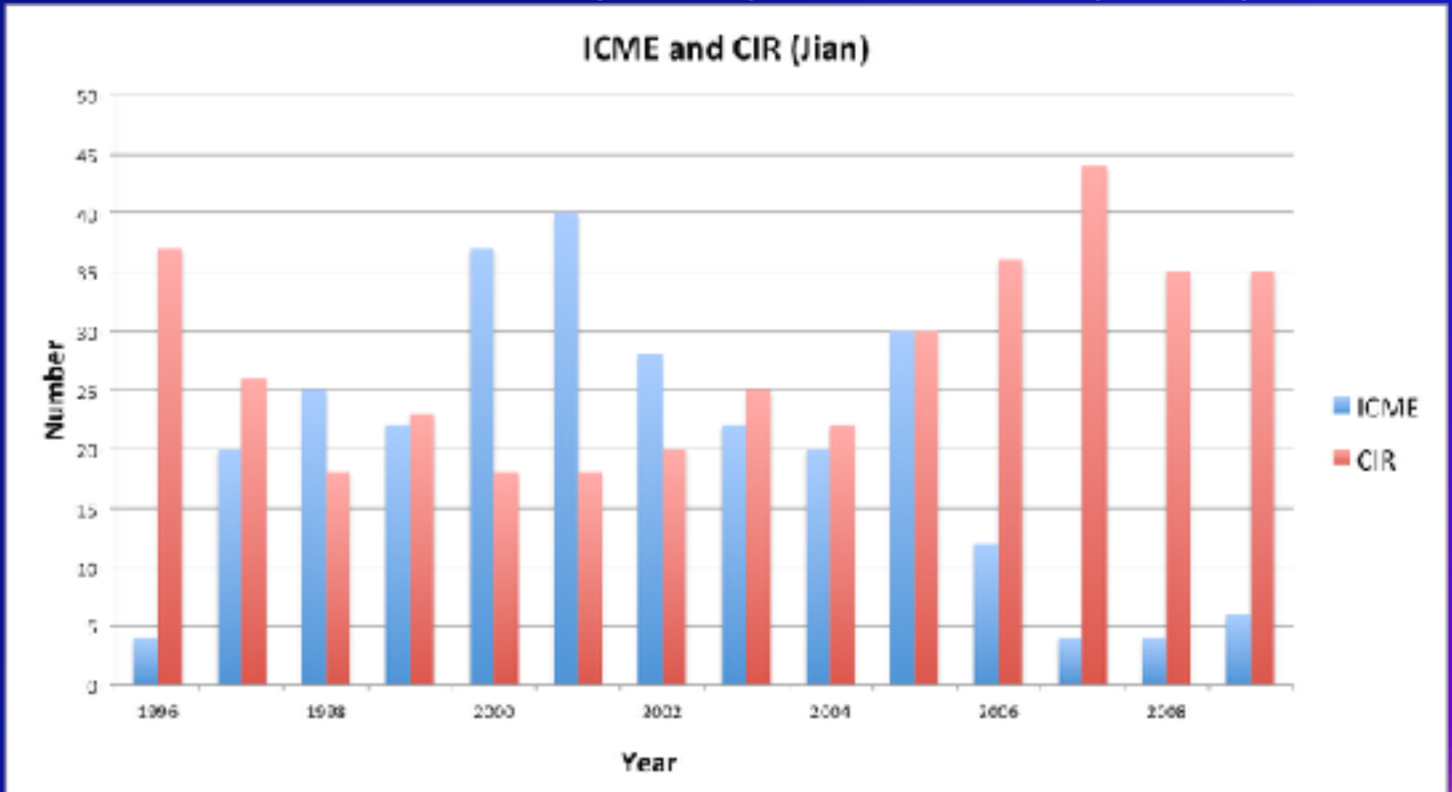
Event Catalog

- 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)



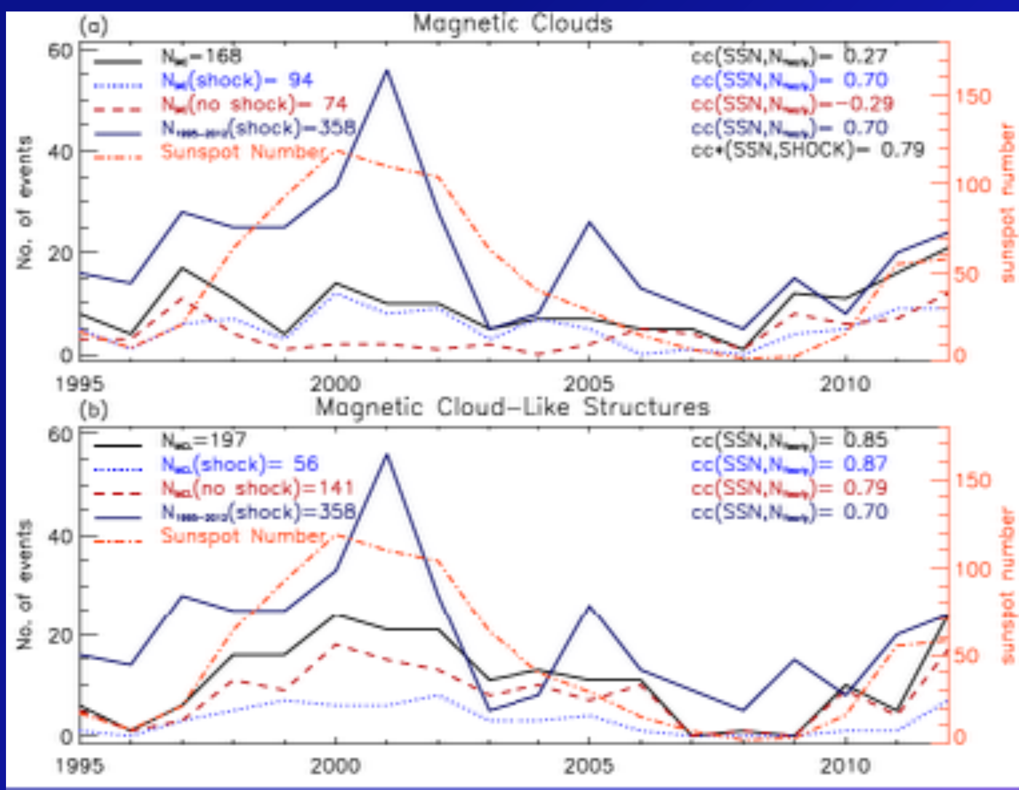
Event Catalog

- Jian's ICME and CIR Catalogs
  - Available at http://www-ssc.igpp.ucla.edu/~jIan/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)

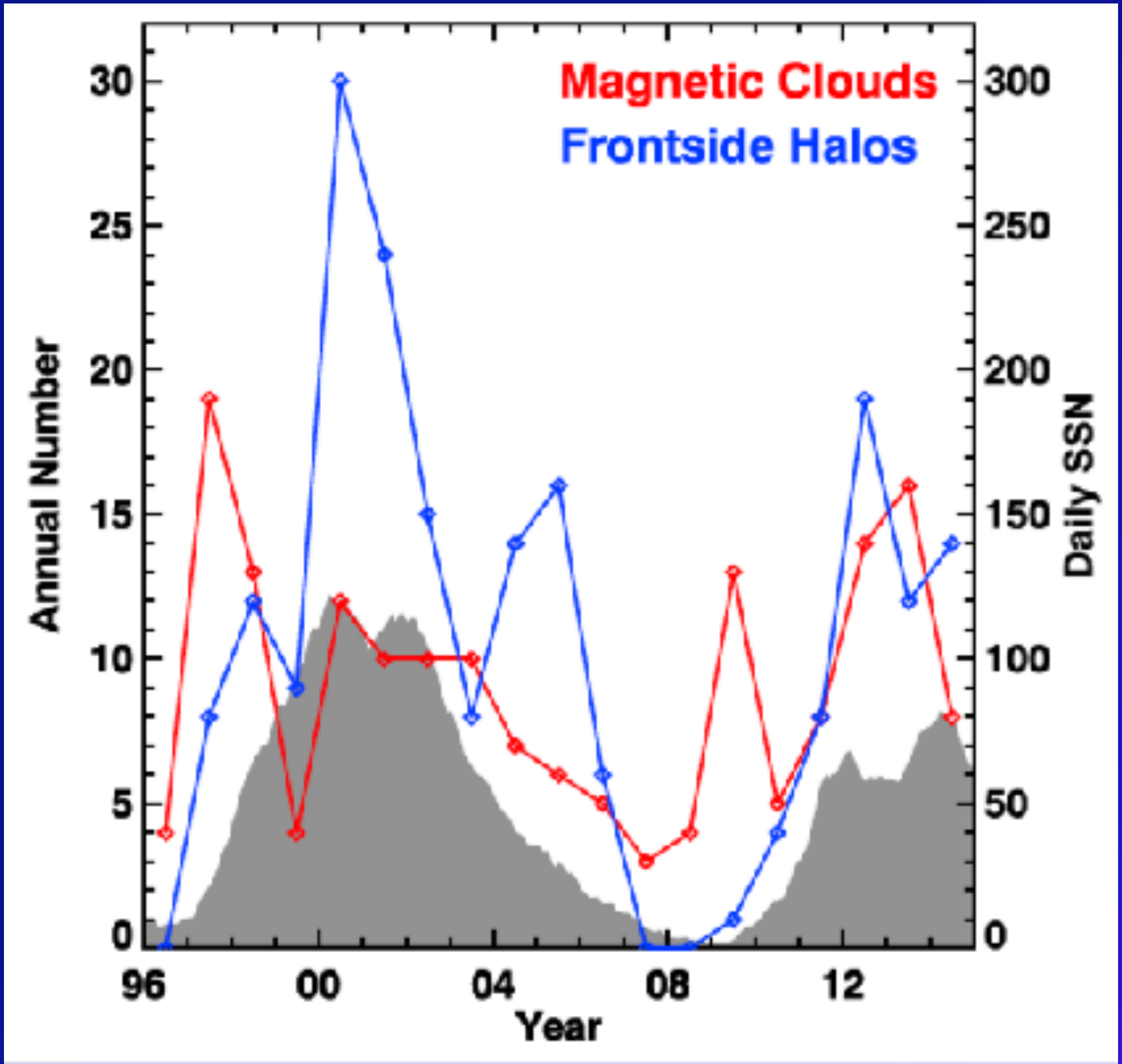


Wu & Lepping 2016

MC: 168
MCL: 197

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**

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

CME Sun-to-Earth Tracking

- Track 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

Tracking Methods

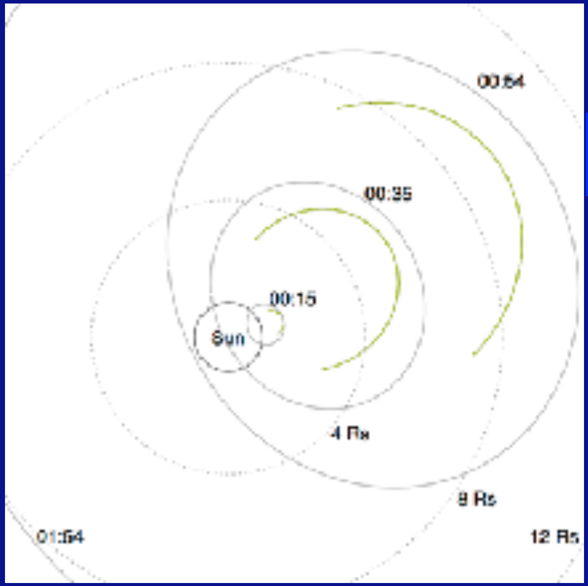
- For ejecta and shock near the Sun (COR2, C3, HI-1)
  - GCS model (Thernisien et al. 2006)
  - GCS + spherical model (Hess et al. 2014)
  - GCS + spheroid/ellipse model (Kwon et al, 2014, Mostle 2015)
  - Mask fitting method (Feng et al. 2012)
- For shock in the interplanetary space (HI-2) (single versus double)
  - J-map: fixed-ϕ (Rouillard et al. 2008)
  - J-map: harmonic mean (Lugaz et al. 2010)
  - J-map: Self-similar expansion (SSE) (Davies et al. 2012)
  - J-map: fixed-ϕ and triangulation (Liu et al. 2010) for using double HI-2 images

Tracking Methods

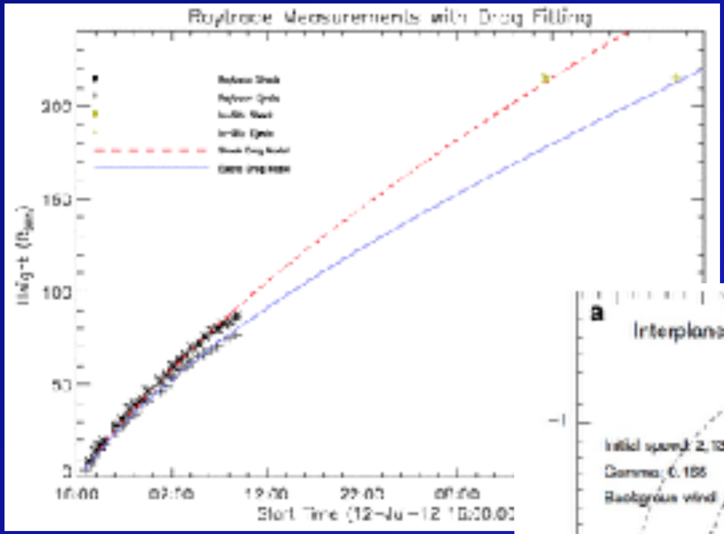
Prior to STEREO

- Cone Model (Zhao 2002)
- Ellipse Cone Model (Michalek et al. 2003)
- Ice Cream Cone model (Xue et al. 2005)
- Polarization method (Moran & Davila 2004)

Tracking Example

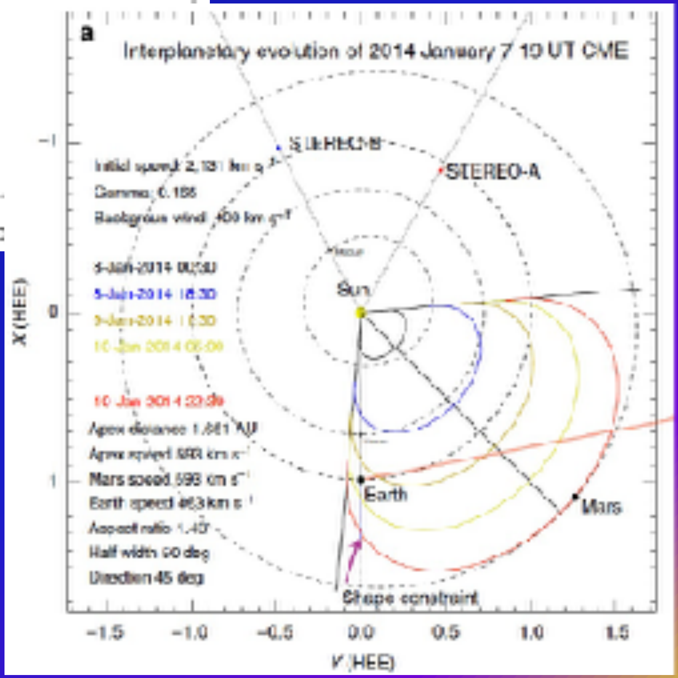


Ejecta and Shock (Kwon et al. 2014)



Ejecta and Shock (Hess & Zhang, 2014)

Ellipse evolution model (Most et al. 2015)



Action Items on Catalogs

- GMU group will finalize the CME-ICME event list with solar source regions for all Earth-affecting CMEs from 2006-2017
- USTC group finish the near-Sun measurement of all full halo CMEs using cone model and GCS model for events till 2017
- Reconcile the differences of multiple ICME catalogs
- Look into why a large number of ICMEs have no solar CME counterparts. Is this the visibility effect? Is this of different origin?

Action Item on Tracking

cross-comparison between different observers for a selected number of events

- Height and Velocity at a series of time of measurement
- Time and velocity at 5 Rs, 10 Rs, 20 Rs, 40 Rs, 80 Rs, 160 Rs, 1 AU and Earth
- Used to evaluate different methodology of measurement
- Used to evaluate human error in measurement when the same methodology is used

Action Item on MC fitting

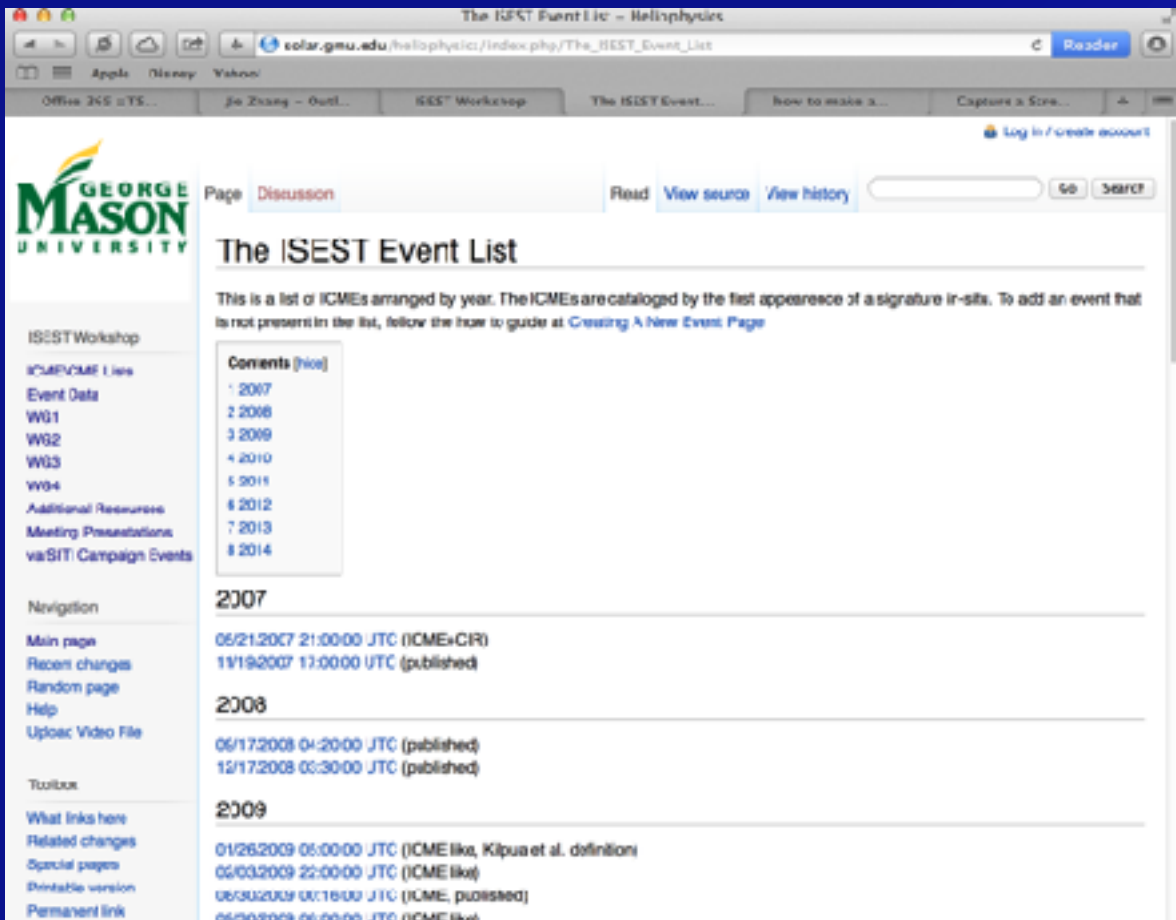
cross-comparison between different observers for a selected number of events

- the selection of MC front and rear boundary
- the fitted MC parameters: axis orientation, impact parameters etc
- Comparison between fitted MC and the flux rope inferred from solar observations

Use the ISEST WiKi

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

Access data/information and provide your contribution



Without your input, it won't work

Thanks