STEREO ICMEs and Solar Origins

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Some of the goals of STEREO as a solar minimum mission

- To have observations of isolated and less distorted CME events to identify the association between the in-situ signature and the source region activity on the solar disk and lower corona;
- Such that an eruption can be traced and analyzed and characterized from the initiation at the source and lower corona;
- Propagation/evolution through the heliosphere and finally the magnetic field and plasma properties ambient and internal to the ICME near 1AU can be studied.

This study

- Began by searching the in-situ solar wind disturbances and select ICME events using:

  - STEREO level 2 data: 2007-Apr-01 to 2008-Sept-30;

  - ACE level 2 data from 2007-Jan-01 to 2008-Jun-30;
- Attempt to identify associated CMEs and activity on solar disk;
- Study the magnetic property of the CMEs/ICMEs and the corona.

ICME (shock and ejecta) dates, times and duration

2007

	A&B	STB	ACE / Wind	STA
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

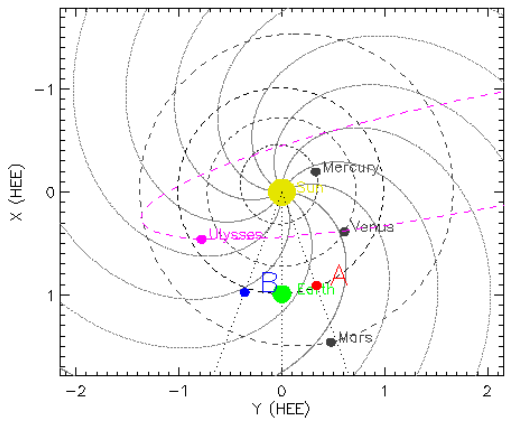
	A&B	STB	ACE	STA
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
08Mar06	46.305	no 12:12 04h44m		
08Mar08			? 19:00 6h	
08Mar21				no 06:00 16h00m
08Apr29	49.804	14:15 23:25 8h35m		
08May11	51.080			nd 11:00 6h54m
08Jun06	54.591	15:30 22:05 13h5m		
08Jul10		11:00 14:00 19h	No level2	
08Jul30			No level2	no 3:00 7h
08Aug15		No 12:00 13h	No level2	
08Sep04			No level2	No 10:00 14h
08Sep28		? 3:00 10h	No level2	

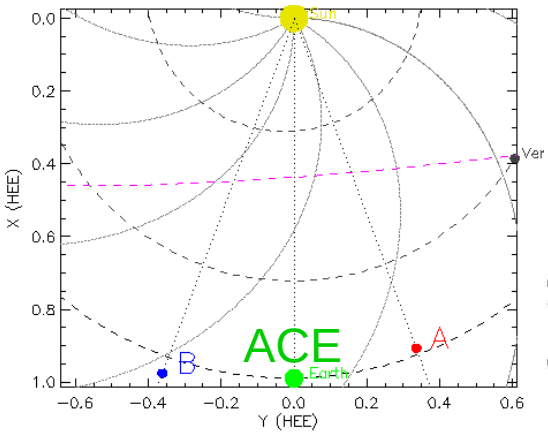
Work in progress …

Analysis of two Magnetic Clouds

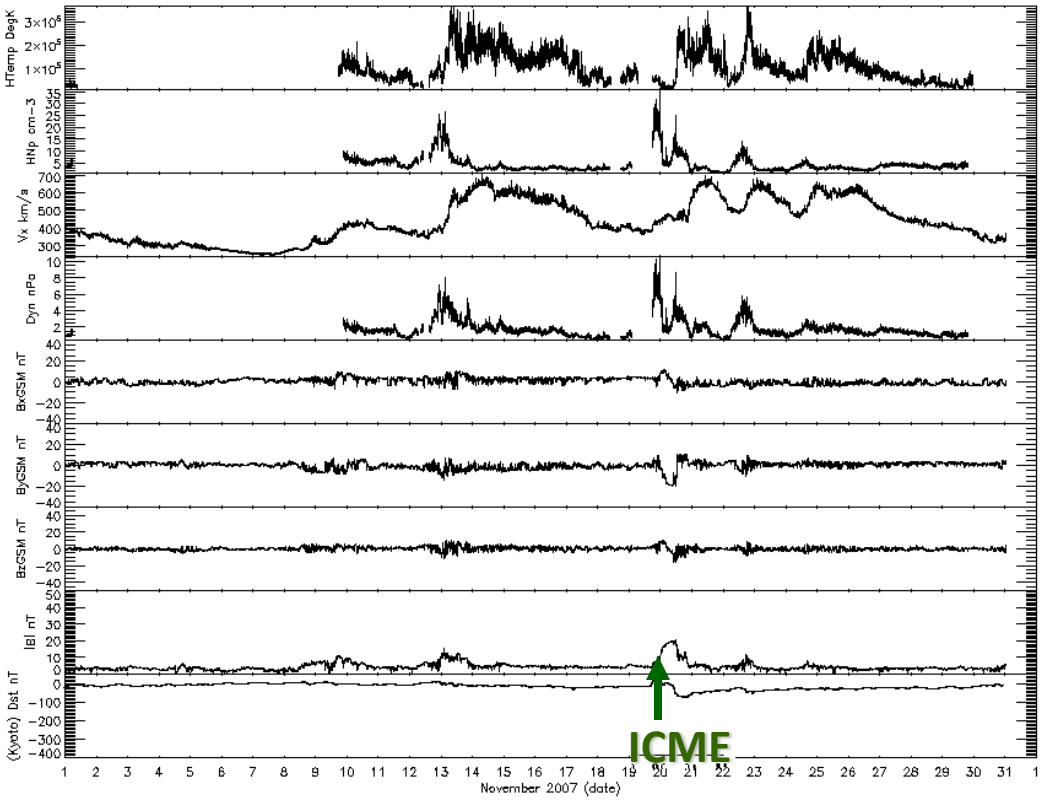
- 2007 November 17: ACE, STA and STB;
- 2008 June 06: STB, possible ACE;

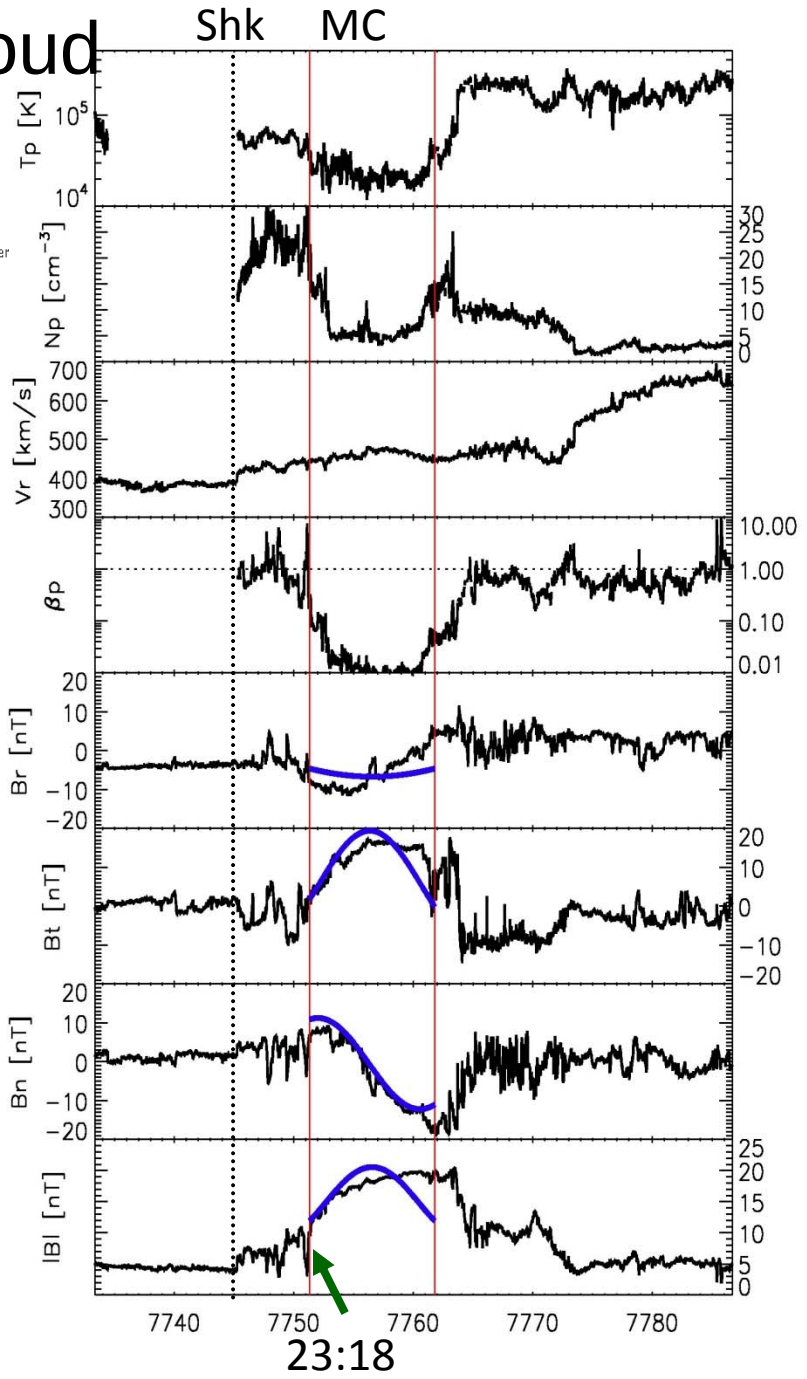
2007 November 19 Magnetic Cloud



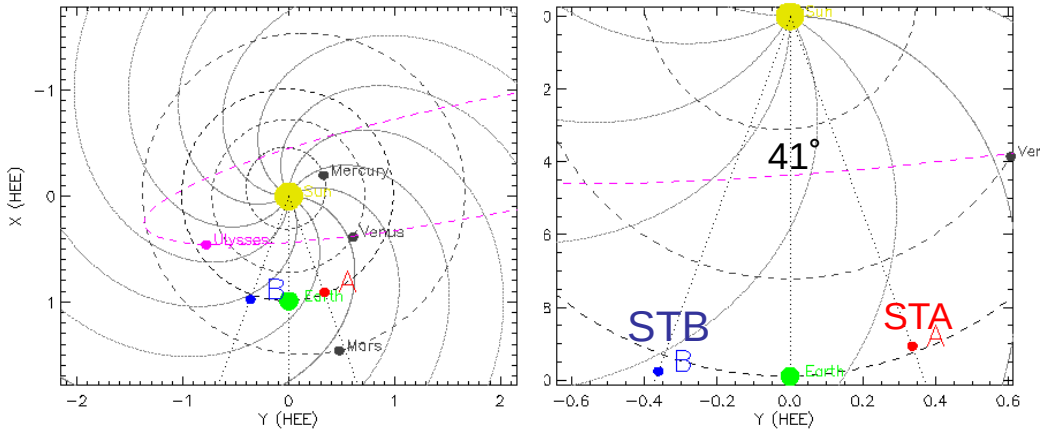


ACE data of November 2007

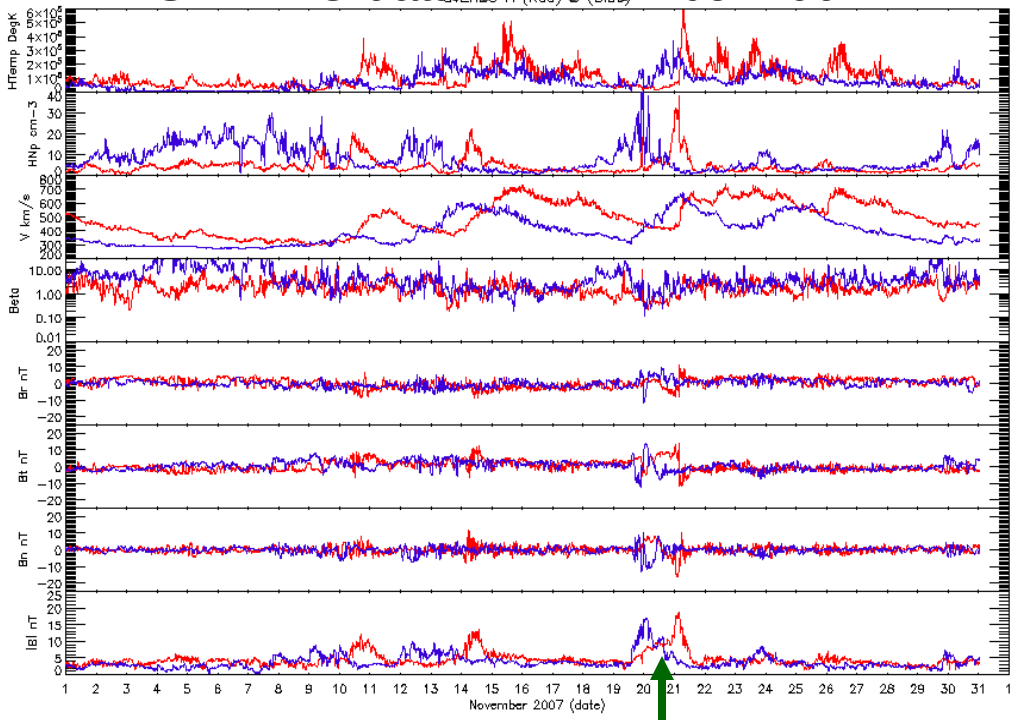




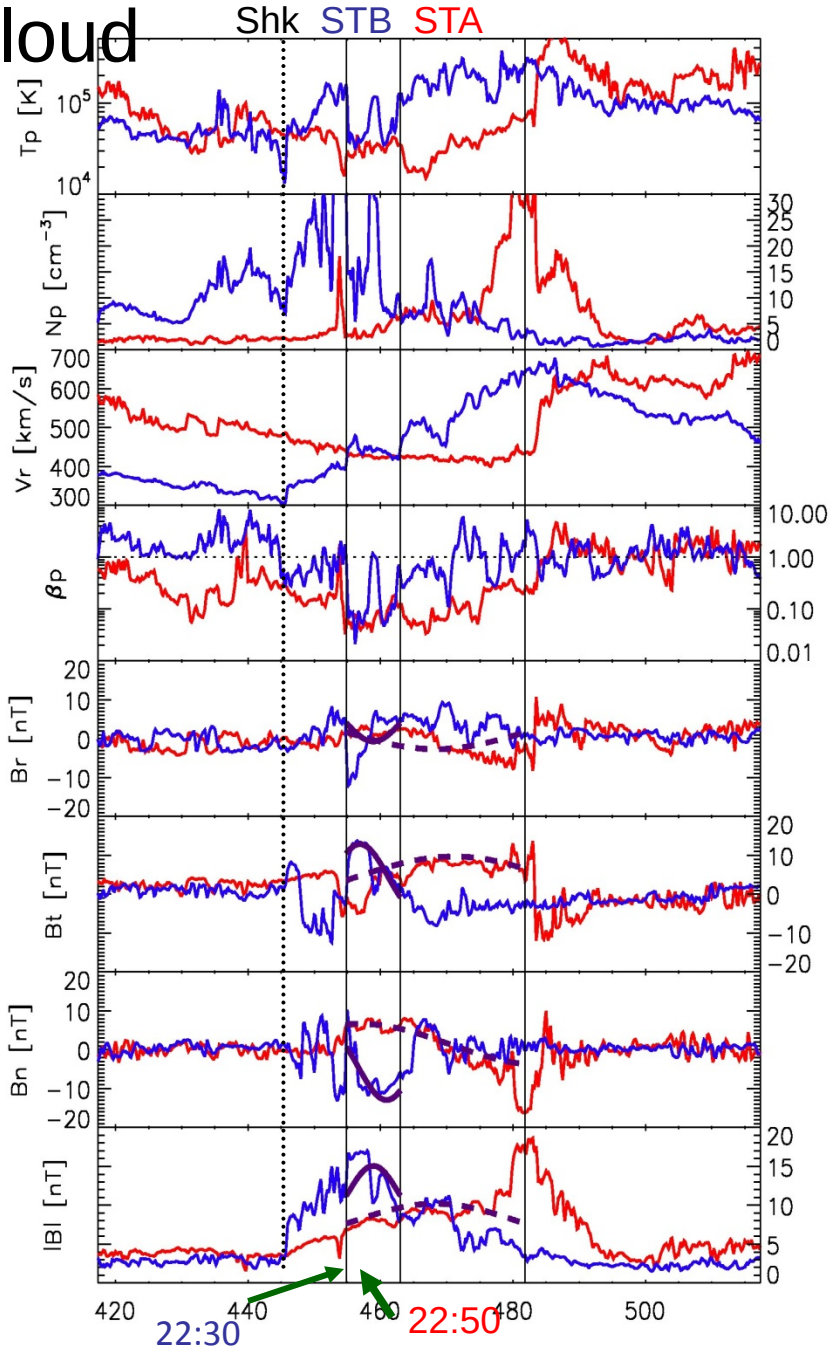
2007 November 19 Magnetic Cloud



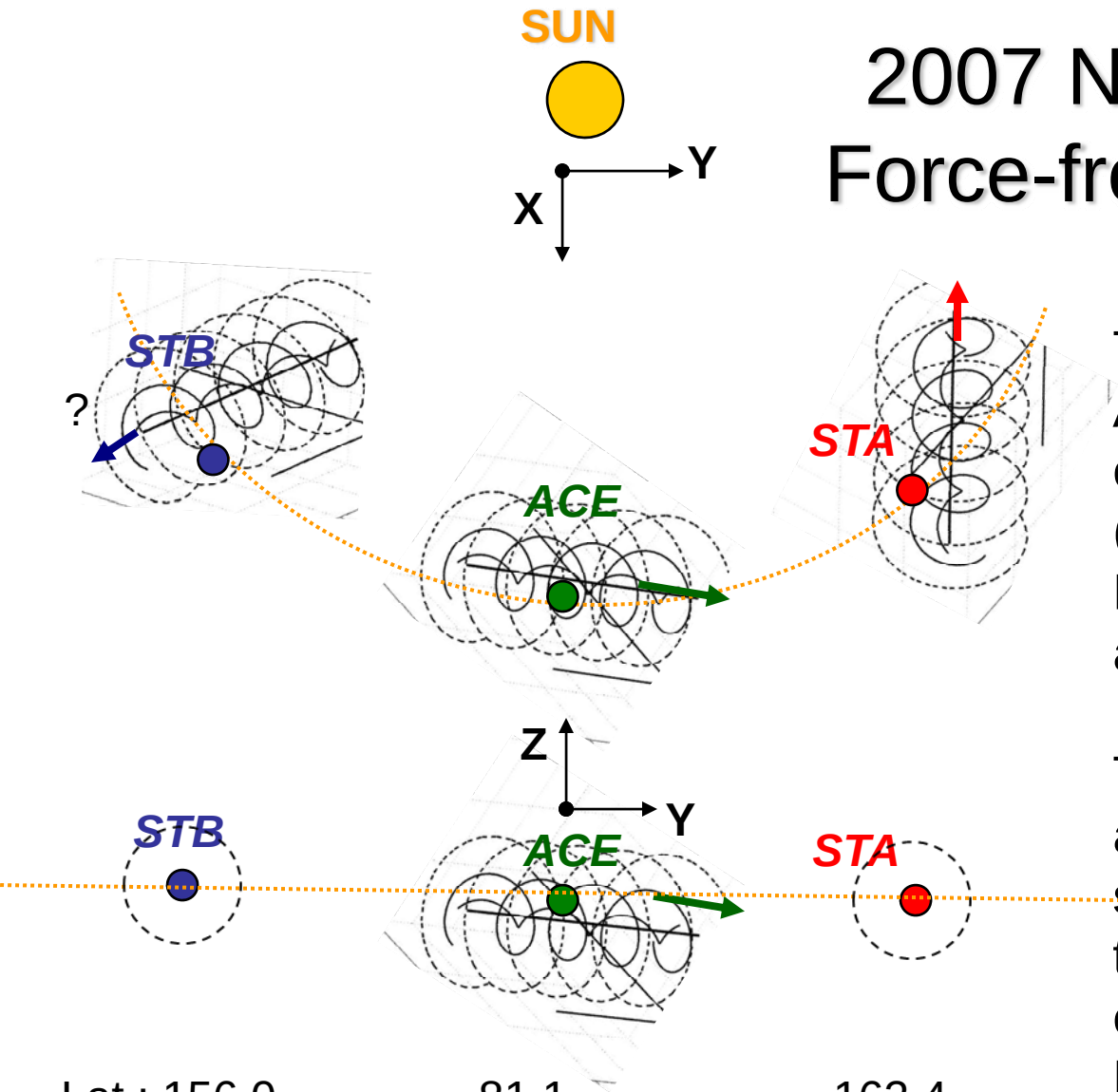
STEREO data of November 2007



ICME



2007 November 19
Force-free fluxrope fit

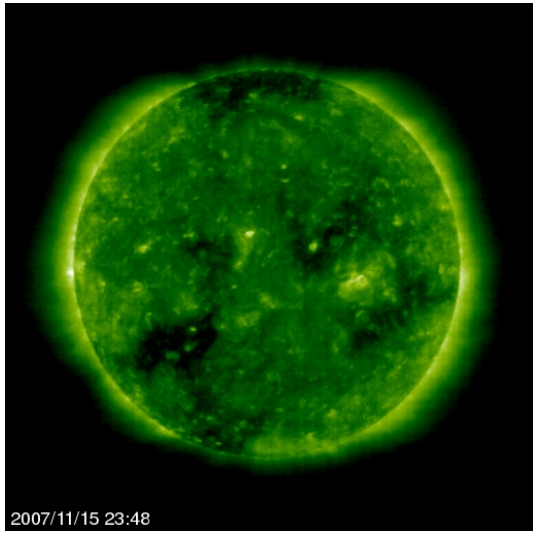


Lat.: 156.0	81.1	162.4
Lon.: -22.2	-4.7	4.9
Rho -0.70	0.39	-0.72
left-handed	left-handed	left-handed

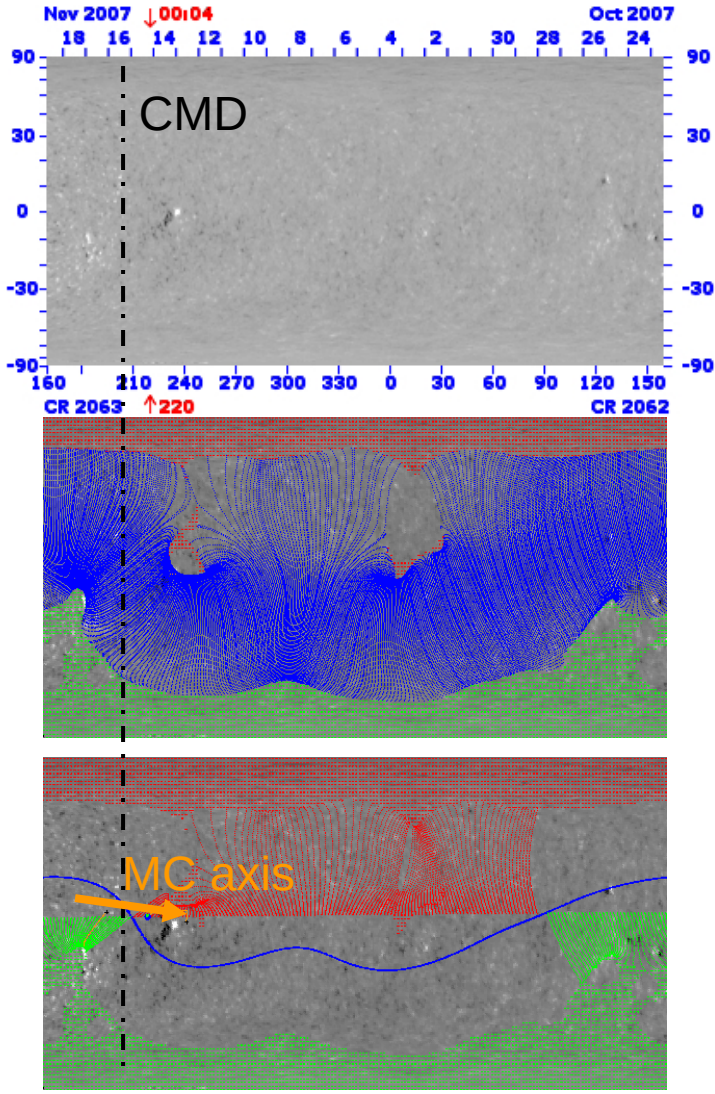
Two views show the Approximate orientations of the the force-free fluxrope (Lynch et al., 2003) Magnetic Cloud (MC) at STB, ACE, and STA.

The fluxrope (all left-handed) are consistent with a CME structure/fluxrope having the axis parallel with the ecliptic plane with a Longitudinal extend at the same scale with the STEREO separation ~41˚.

2007/11/15 CME and solar and coronal field

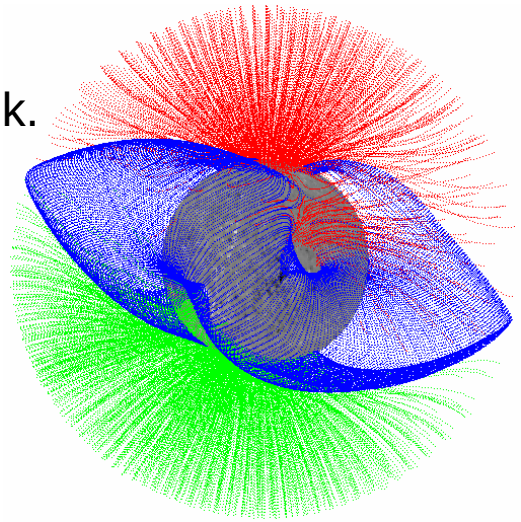


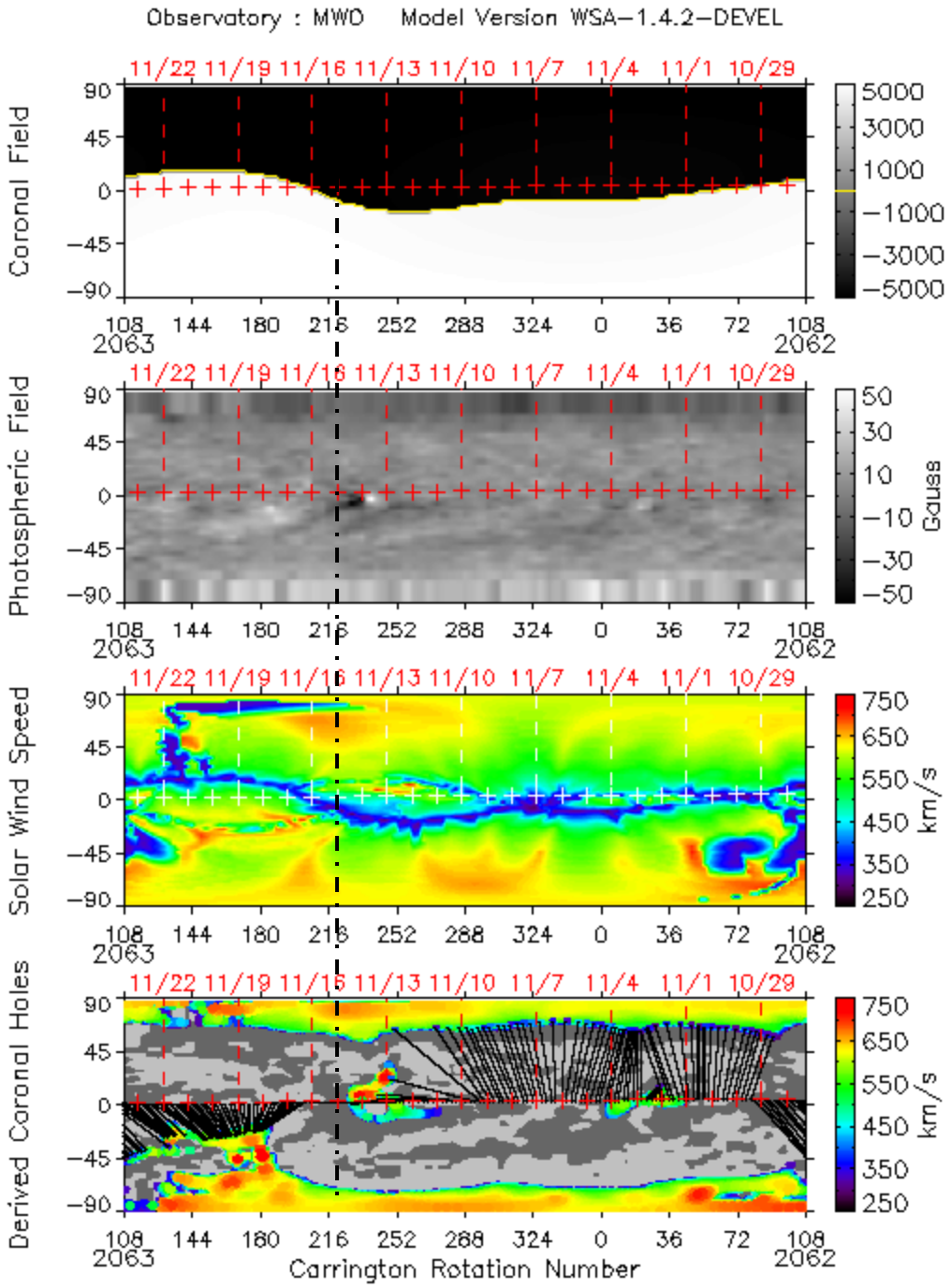
GONG map and PFSS



No obvious solar activity
at low corona, no significant
Magnetic region on solar disk.

Global PFSS coronal field
Shows a tilted dipole.
Moderately warped HSC.





WSA model

- 2007-Nov-19 was within a quiet global solar magnetic field, and moderately warped heliospheric current sheet;
- Trace to positive IMF sector, and close to a sector boundary;
- Traces to southern coronal hole extension with fairly high solar wind speed.

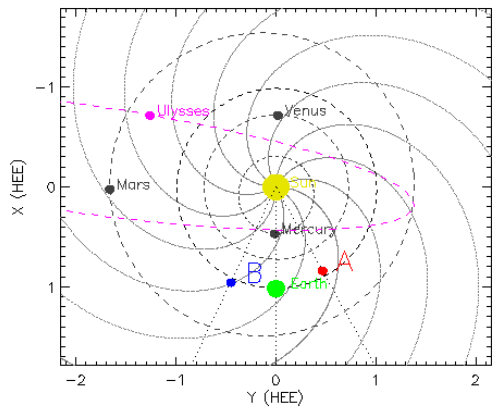
2007 November 19 ICME

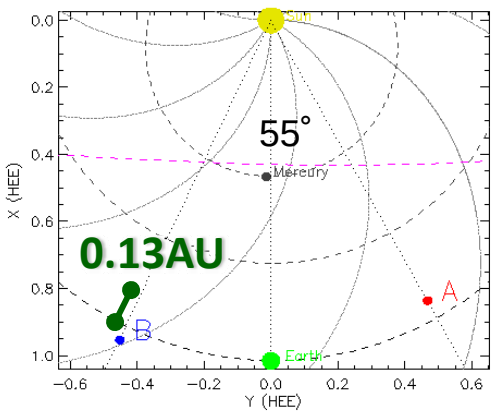
- A Magnetic Cloud (MC) was observed on 2007-Nov-19 ~23UT at three points by ACE and STEREO A&B of separation ~41˚(~0.7AU).
- Local MC at ACE showed best classic fluxrope signature. The fluxrope diameter was ~0.1AU. Force-free-fluxrope fitting showed the fluxrope axis was almost parallel to ecliptic plane and perpendicular to Earth-Sun line, and the crossing was ~0.3Rrp from the center of the fluxrope.
- Local MCs at STEREO A and B are identifiable. Model fits show STA crossed ~0.7Rrp from the central axis and the diameter of the rope was ~0.12AU; and STB crossed ~0.7Rrp and the rope diameter was ~0.064AU.
- The longitudinal dimension of the ICME structure (> ~0.7AU) was much larger than the diameter of any local MC fluxropes (0.06 ~ 0.1 AU) for this event, when the ICME fluxrope structure was parallel to the ecliptic plane.
- The MC internal B field was strongest at ACE peaked at ~16nT, STA at ~10nT and STB ~14nT. ACE and STA MC showed similar rotation, size and orientation, STB MC was much shorter and slightly more inclined. Both STA and STB field rotations are less smooth.
- The fluxrope was left-handed at all three spacecraft.

2007 Nov 15-19 CME
ambient solar wind, magnetic field

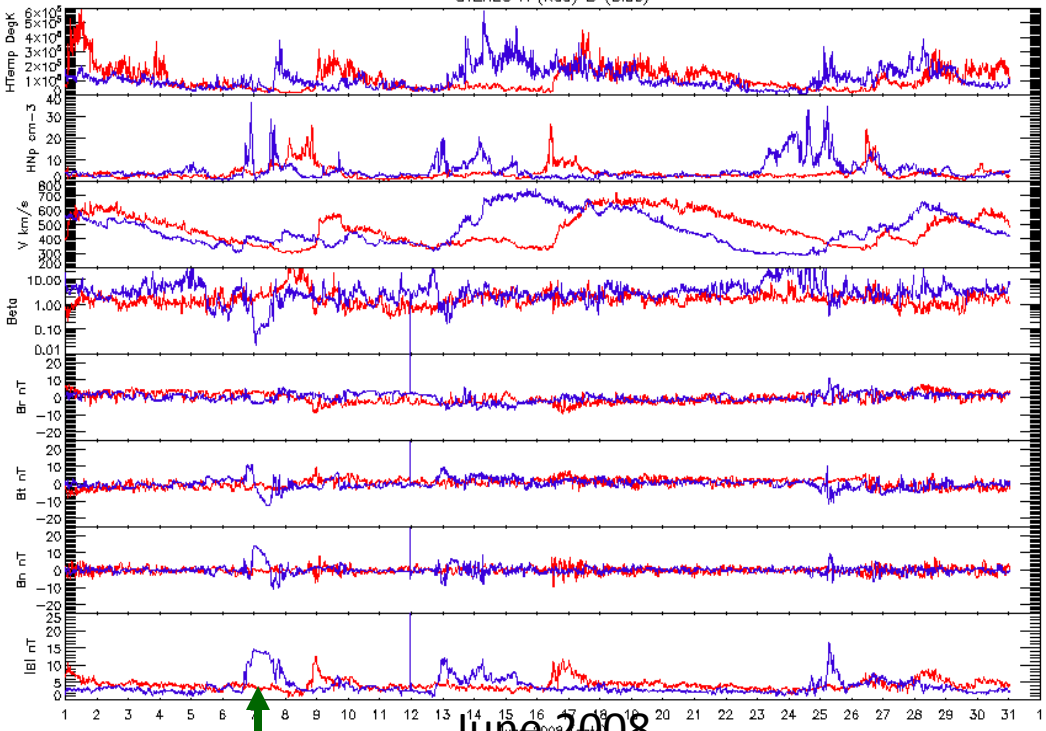
- High speed solar wind stream compressed the rear boundary of the MC.
- From WSA model based on MWO daily updated synoptic map, the ambient solar wind during the few days around the ICME interval is from the southern coronal hole extension within positive B field on the photosphere, and the predicted solar wind speed should be around ~600km/s.
- The most likely parental CME was a slow partial Halo on Nov 15 of speed 125km/s with angular width of 199˚.
- No activity (flare, dimming, etc) at the low corona in association with the slow CME. No significant magnetic region on photosphere.

2008 June 06

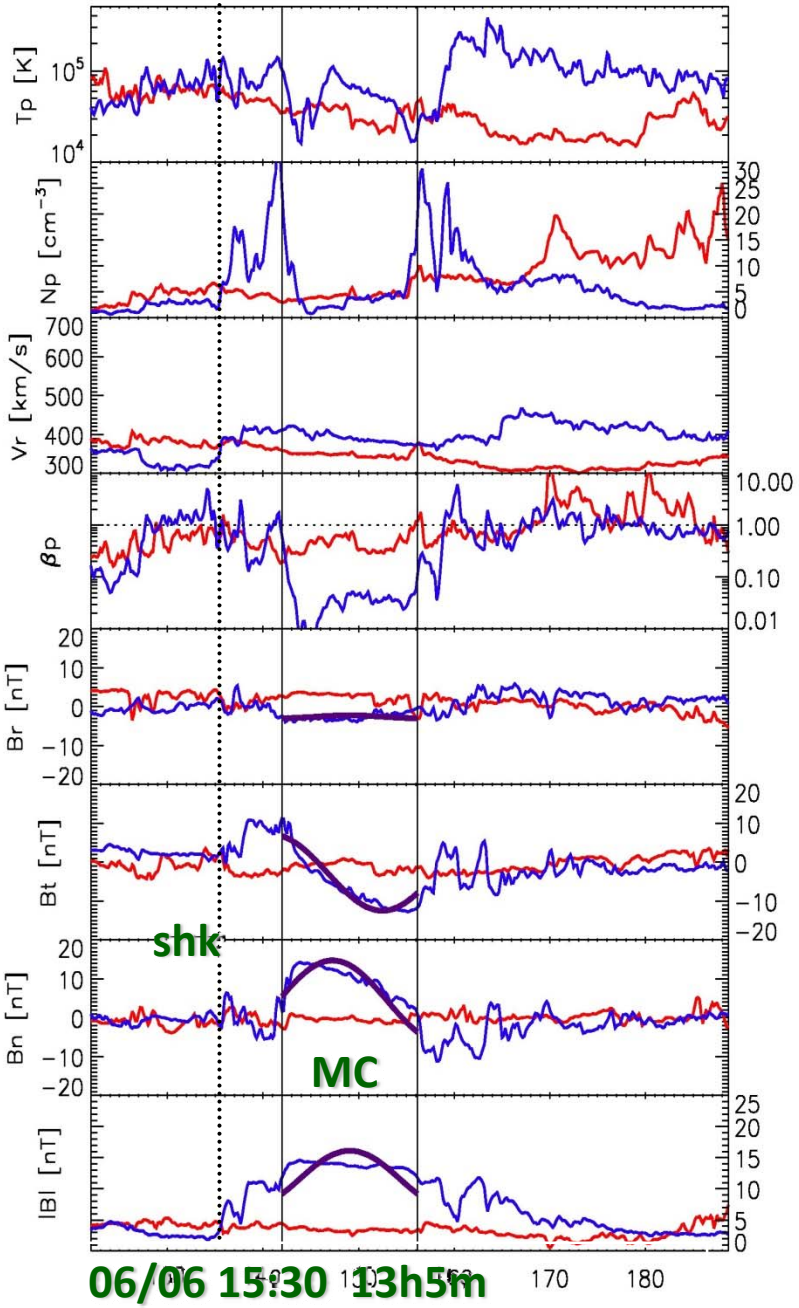




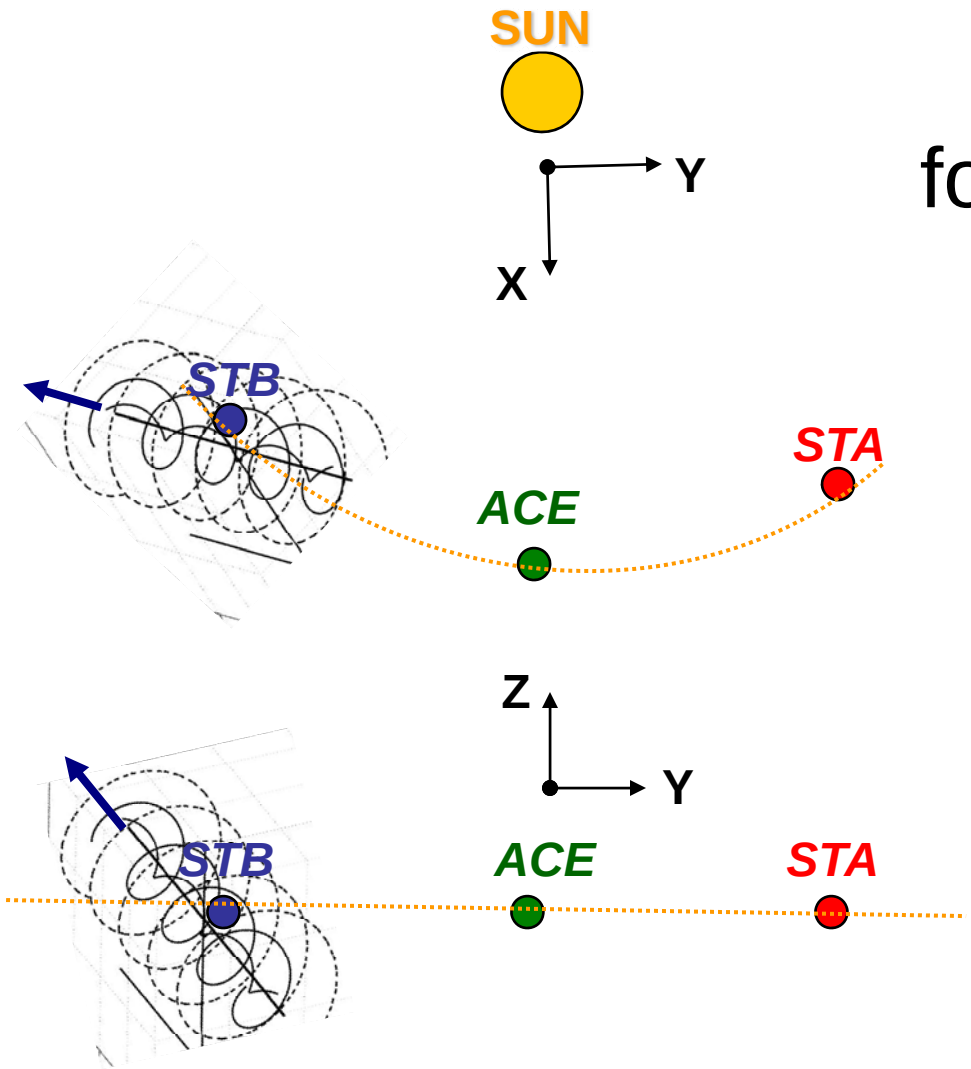
STEREO data of JUNE 2008



MC



2008 June 06 force-free fluxrope fit



Two views show the Approximate orientations of the the force-free fluxrope (Lynch et al., 2003) Magnetic Cloud (MC) at STB.

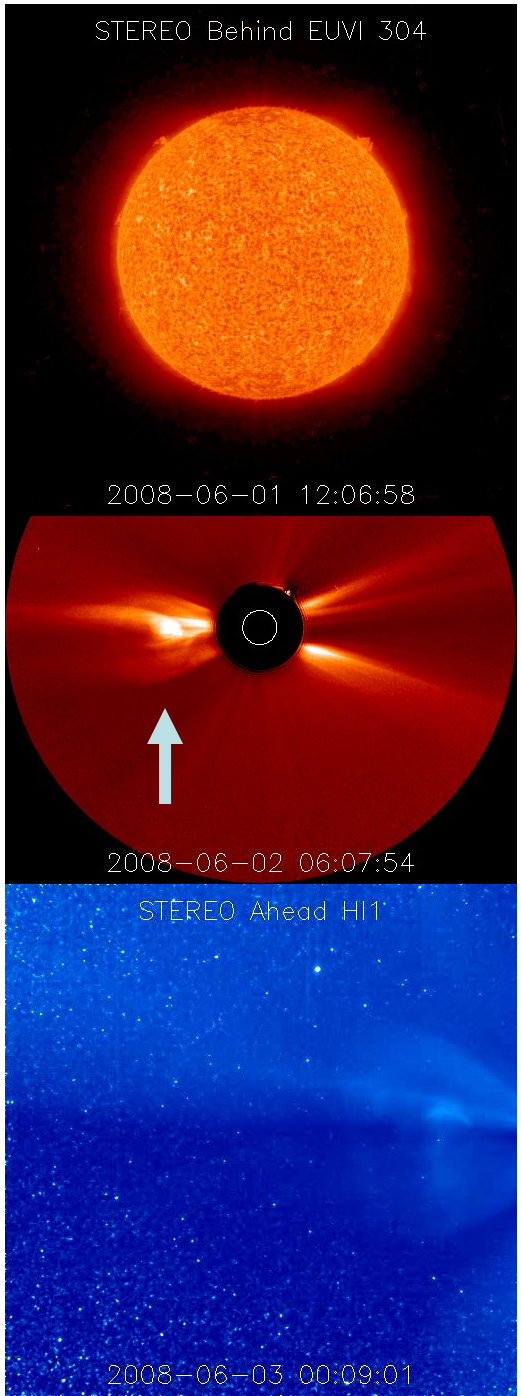
The fluxrope based on STB data is right handed, and has its axis highly inclined to the ecliptic plane.

ACE likely crossed the edge Of the MC, level 2 data not yet online.

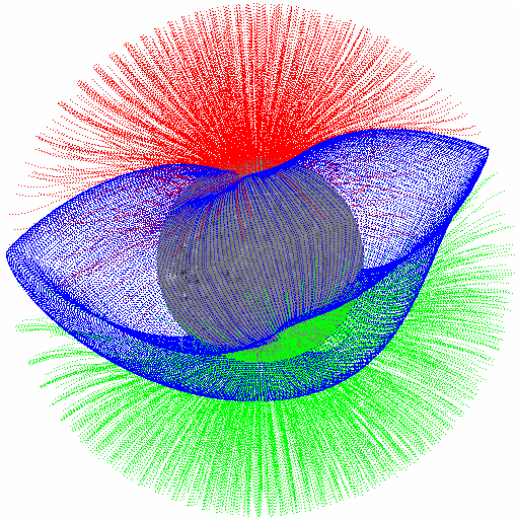
Lat.: 298.4
Lon.: 54.3
Rho: -0.34
Righthanded

likely encounter
Waiting for
Level 2 data

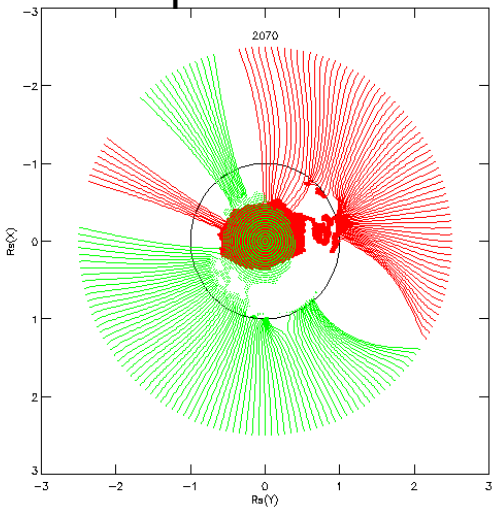
2008Jun01-03



Earth view

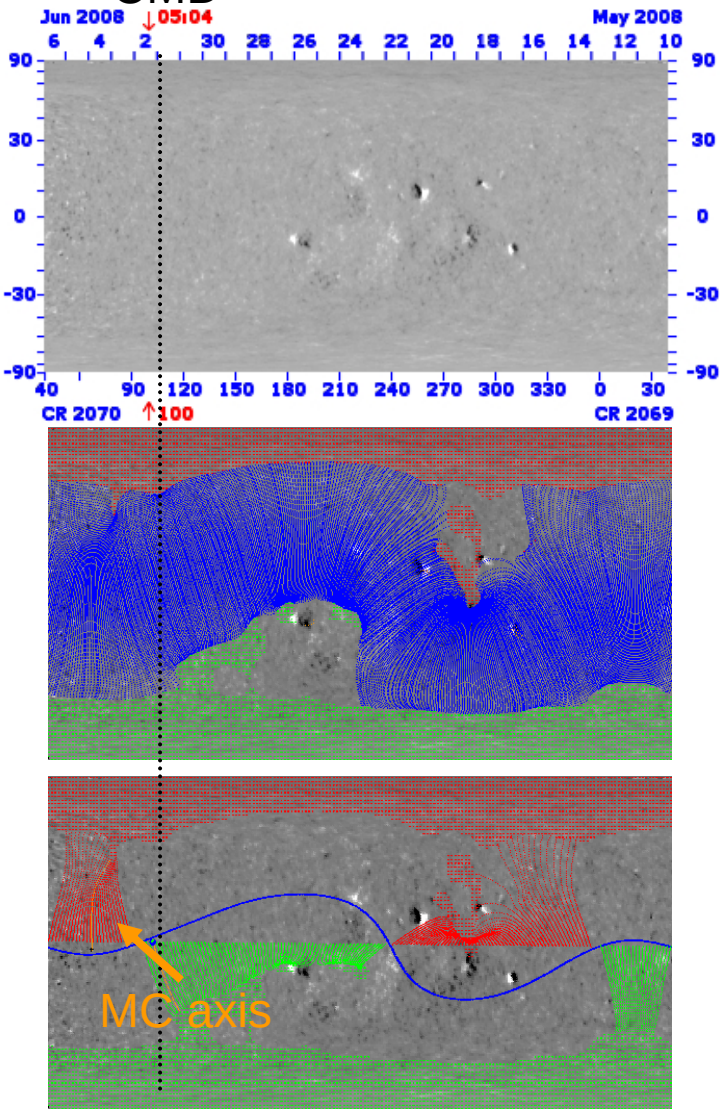


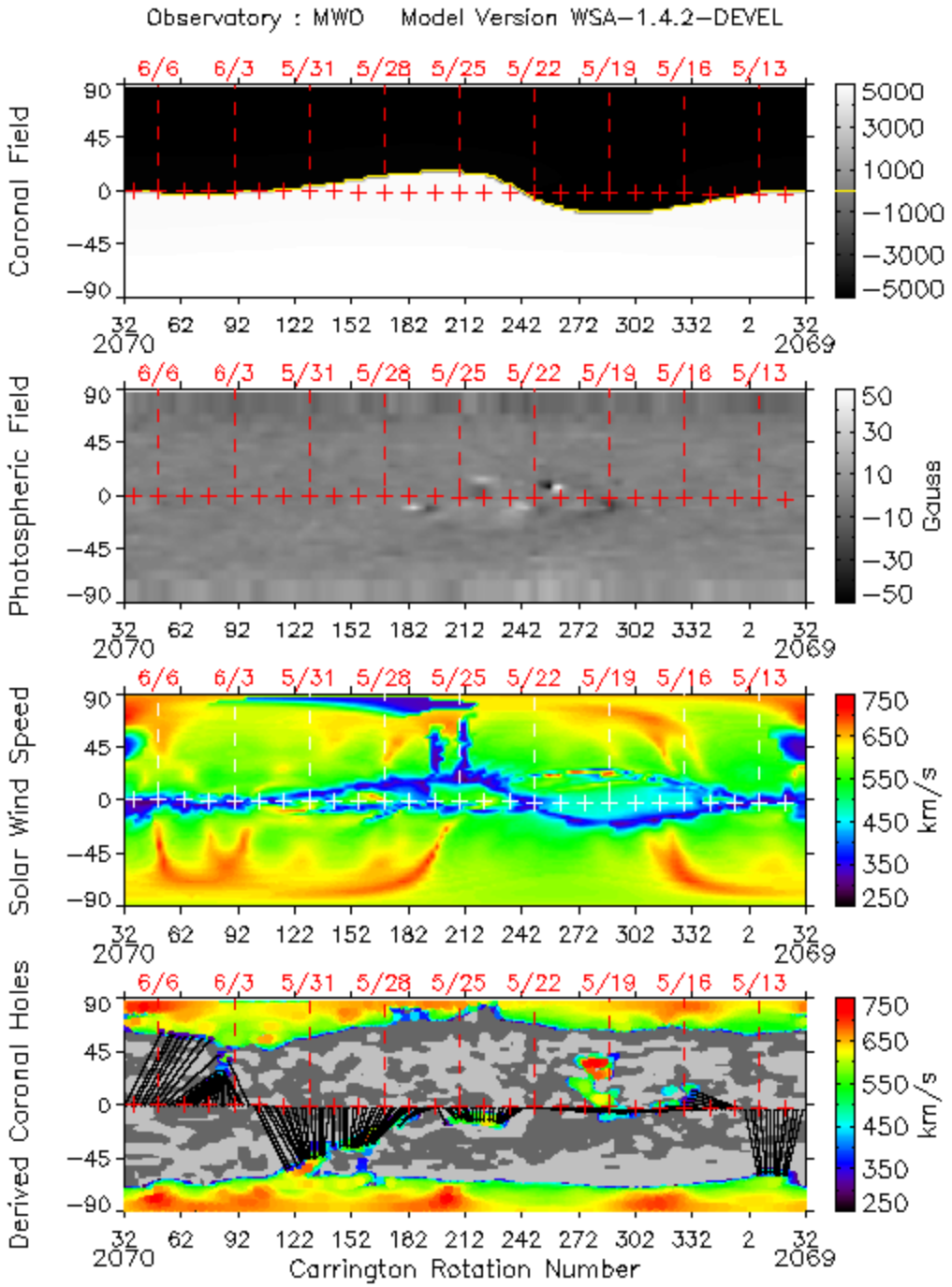
polar view



GONG map and PFSS

CMD

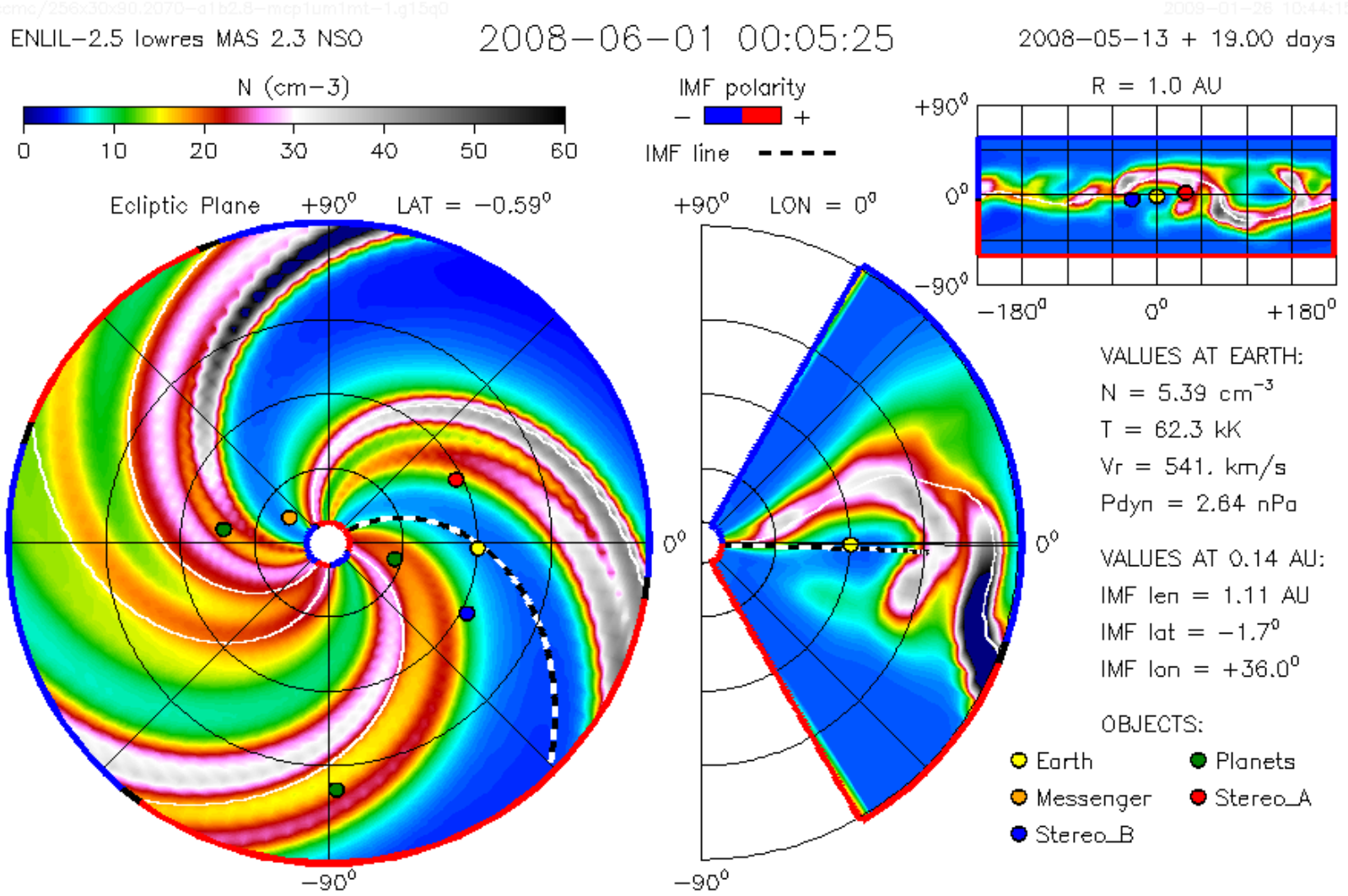




WSA model

- 2007-Jun-06 was within a quiet global solar magnetic field, and moderately warped heliospheric current sheet;
- Trace to negative IMF sector;
- Traces to northern coronal hole boundary with low solar wind speed.

CCMC:
NSO-synoptic-map + MAS spherical ejecta + ENLIL



2008 June 06 STB Magnetic Cloud

- A MC was observed by STB only on 2008-Jun-06 ~15:30UT with a duration of ~13 hours, when the separation between STA&STB was ~55˚.
- The MC showed classic fluxrope signatures. The peak magnitude of B was ~14nT.
- The fluxrope diameter was ~0.13AU, and STB crossed at ~0.3Rrp from the axis.
- The fluxrope was highly inclined to the ecliptic plane at ~54˚, and right-handed.

2008 June 02-06 CME
ambient solar wind, magnetic field

- The ambient solar wind around the MC on 2008-Jun-06 was slightly above 400km/s, no high speed stream encounters.
- GONG PFSS model shows the coronal field with a section of highly inclined coronal streamer belt and HSC.
- The parental CME was seen by the imaging instruments on STA as a east-limb three-part CME, a Halo CME by STB and east-limb CME by SOHO. It was a slow CME less than 300km/s. A three-part CME was also seen in STA HI (helispheric imager) images.
- No obvious activity (flare, dimming, etc) at the low corona associated with the CME. Photospheric full disk magnetograms show a very quiet disk with no active region on the visible side.

ICME (shock and ejecta) dates, times and duration

2007

	A&B	STB	ACE / Wind	STA
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
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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

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08Mar08			? 19:00 6h	
08Mar21				no 06:00 16h00m
08Apr29	49.804	14:15 23:25 8h35m		
08May11	51.080			nd 11:00 6h54m
08Jun06	54.591	15:30 22:05 13h5m		
08Jul10		11:00 14:00 19h	No level2	
08Jul30			No level2	no 3:00 7h
08Aug15		No 12:00 13h	No level2	
08Sep04			No level2	No 10:00 14h
08Sep28		? 3:00 10h	No level2	

Summary of ICME events

- 8 ICMEs identified in year 2007 (STA and STB between ~0.05˚ to ~44˚) .
- 11 ICMEs 2008-Jan-01 to 2008-Sept-30 (STA and STB between 44˚ to ~77˚).
- Before separated further than ~40.8˚ (~0.7AU) on 2007 Nov 19, STA and STB intersected a few same ICMEs, but beyond that distance, no ICMEs were encountered by both.
- Magnetic fields and other paremeters can behave very differently at each spacecraft within some of the same ICMEs.
- Most of these ICMEs were followed with or compressed by a high speed solar wind stream. There are also some entirely in slow solar wind.

Summary of ICME parameters

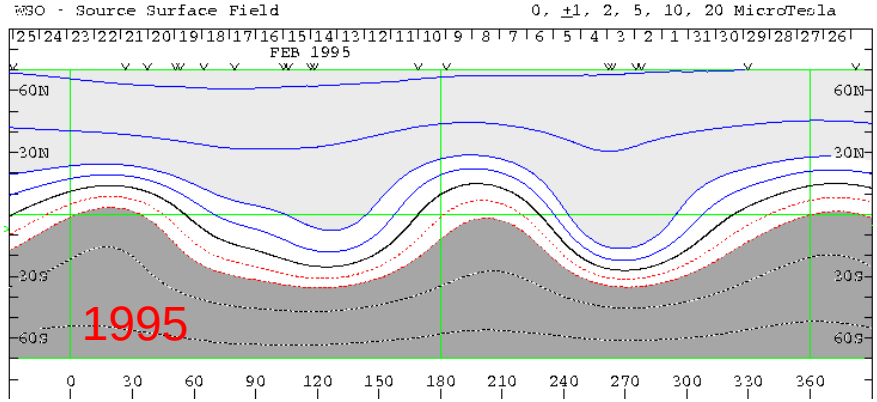
- These solar minimum ICMEs had slow to moderate speed between ~300 km/s and ~500 km/s.
- CME driven shocks were weak or unidentifiable.
- The transit times of these ICMEs range from as short as ~4hrs to as long as ~46hrs.
- The peak magnitude of the enhanced magnetic field within the transients ranges from ~8 nT to ~18 nT.
- Orientation of fluxrope axis varies in large range, not ordered.

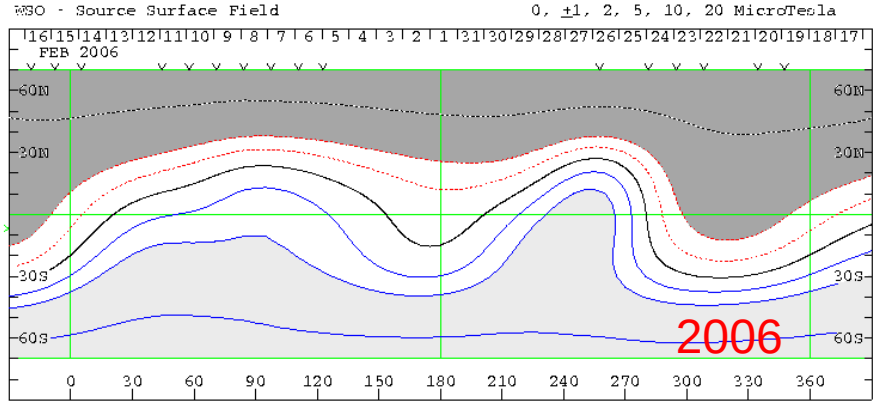
Solar origins and coronal context

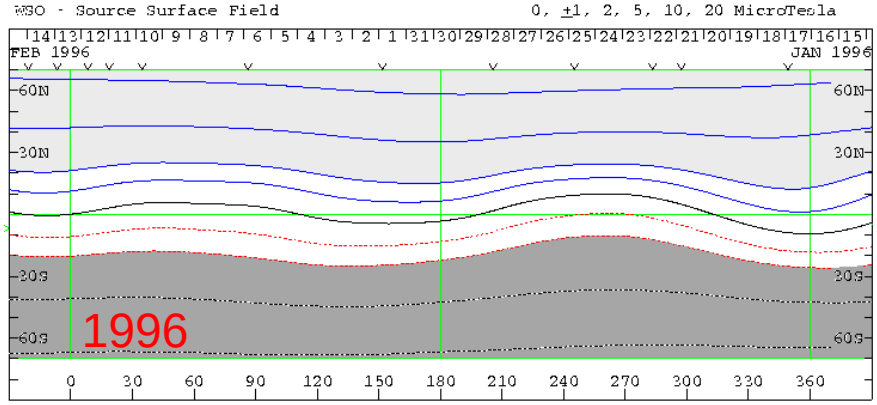
- In contrary to expectations for solar minimum time, it is difficult to determine the solar origins of these ICMEs, partly because most CMEs during this period are faint in coronagraph images, and have no association with intense flares and other obvious on-disk activity.
- We search for possible source CMEs in a time window prior to the ICMEs.
- The coronal structure of the current solar minimum is quite far from dipolar structure as at the previous solar minimum, but had low latitude coronal holes and highly warped coronal streamer arcades. We discuss coronal and solar wind context for and the likely influence of the coronal structure on solar minimum time ICMEs.
- The ICME characteristics are discussed in comparison with events at the previous solar minimum.

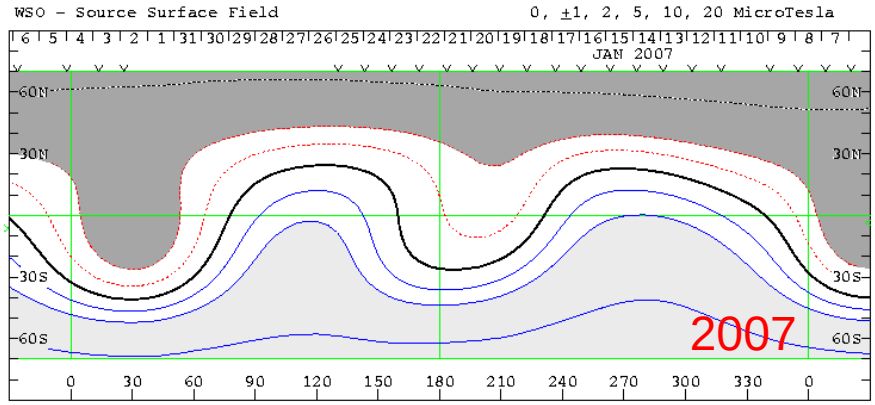
Previous Solar Minimum

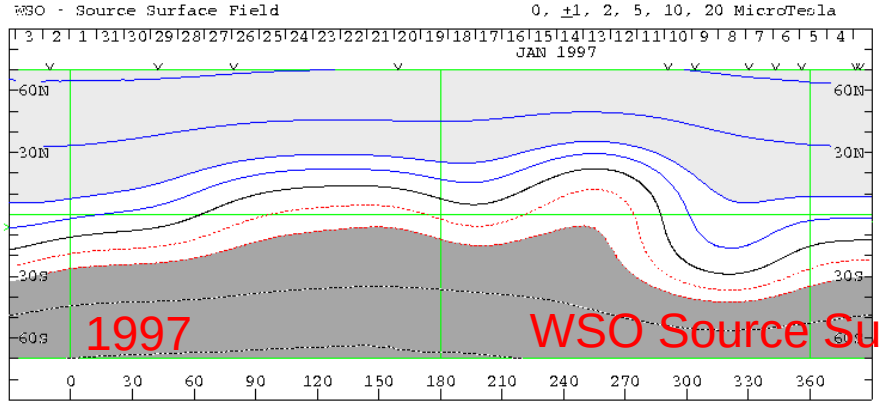
Current Solar Minimum

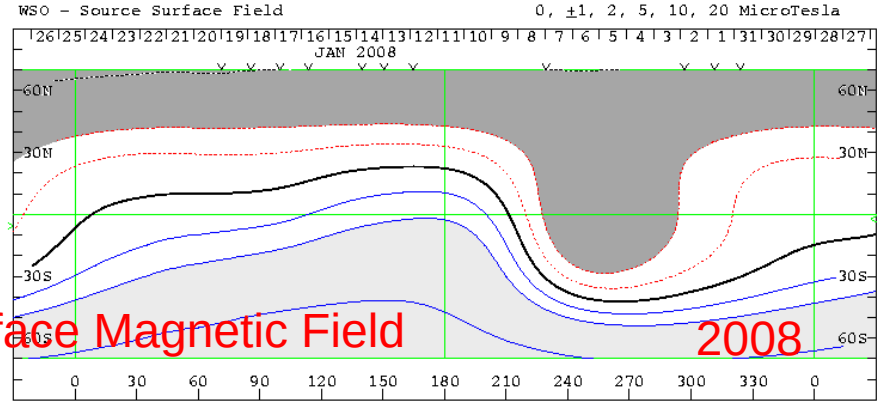








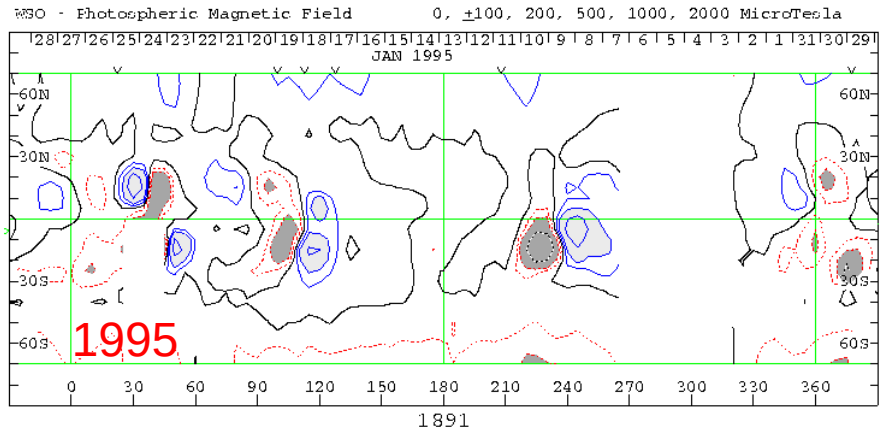


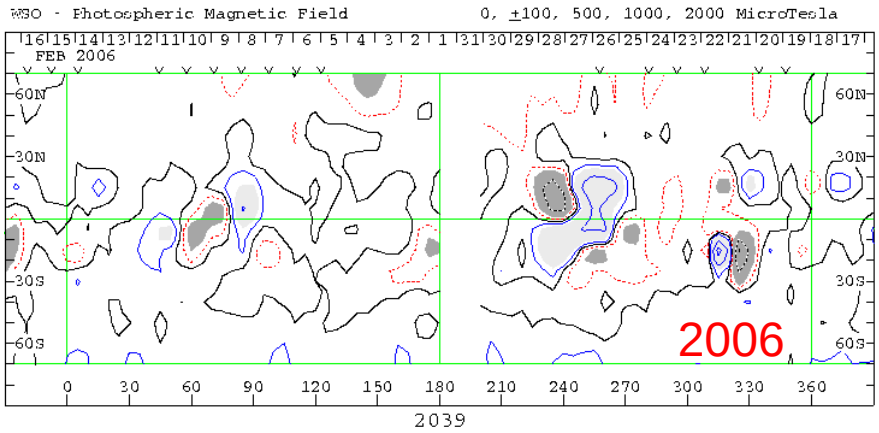


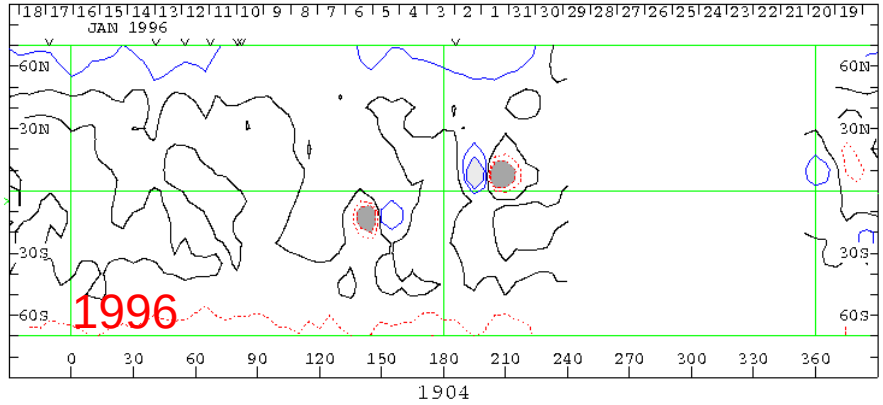
WSO Source Surface Magnetic Field

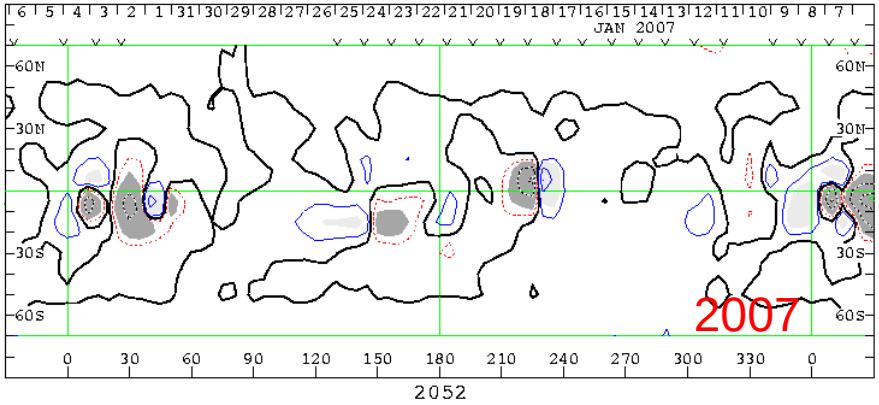
Previous Solar Minimum

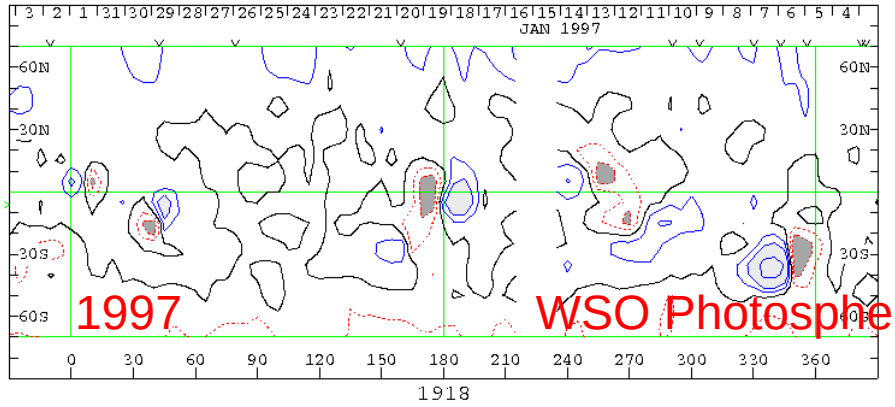
Current Solar Minimum

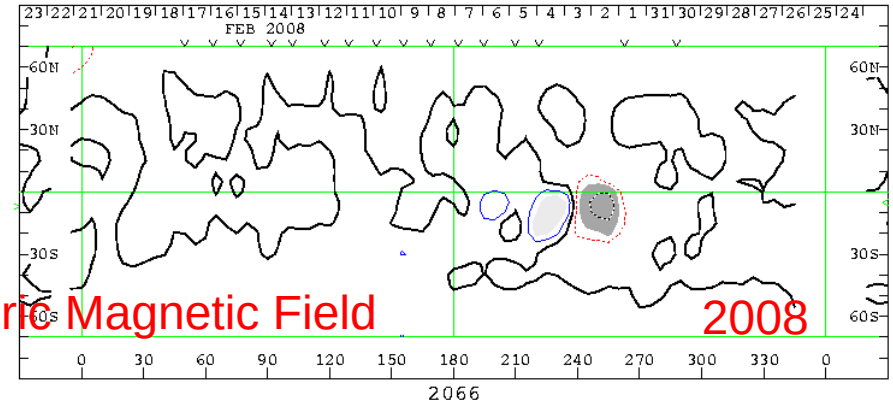










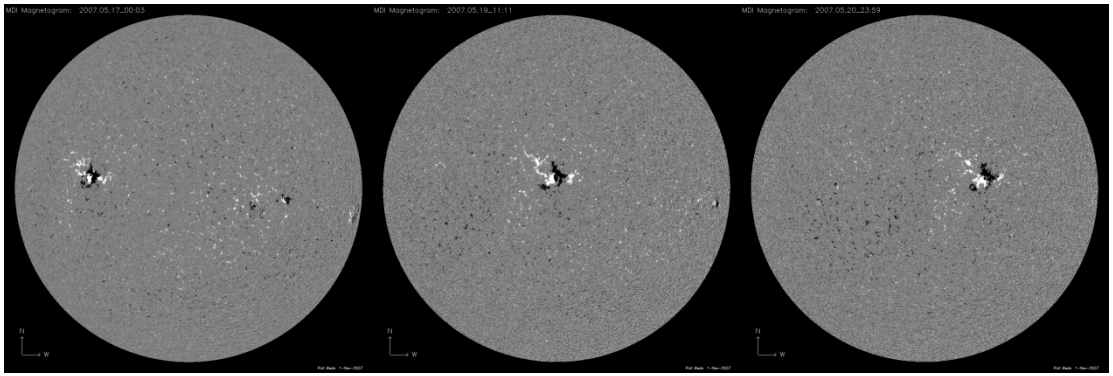


WSO Photospheric Magnetic Field

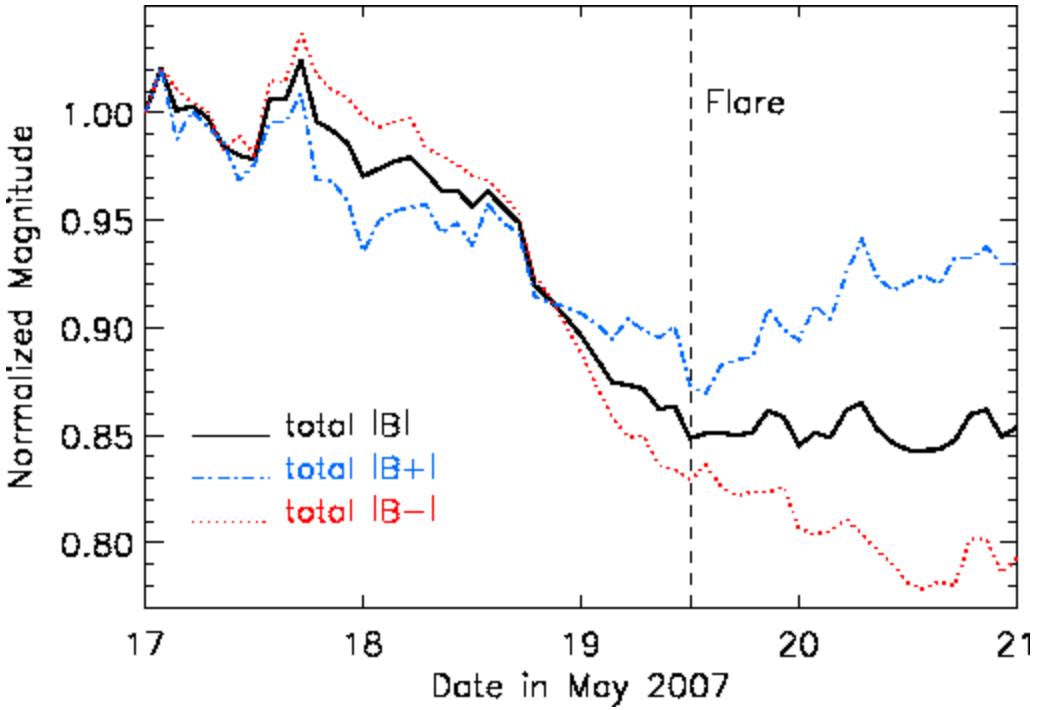
Summary

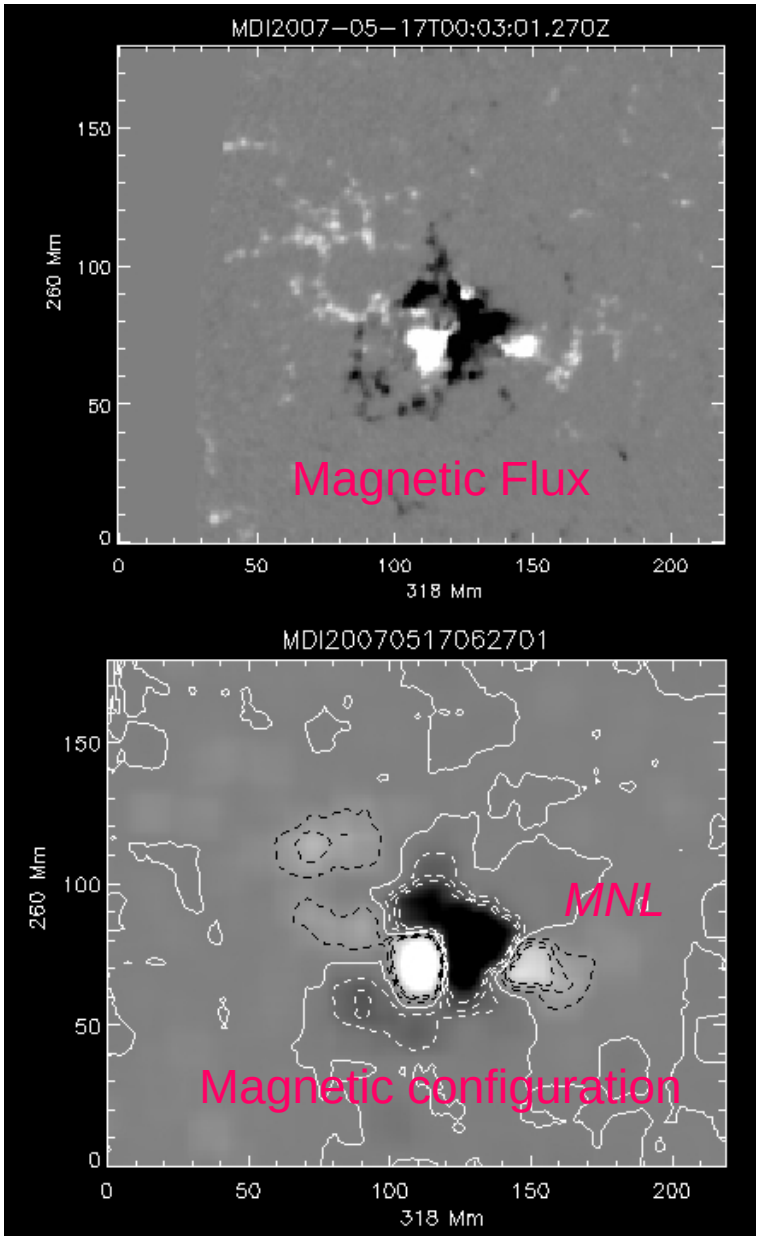
- We presented analyses of two MCs on 2007-Nov-19 and 2008-Jun-06.
- First MC was nearly parallel to the ecliptic plane from force-free fluxrope fit (Lynch et al, 2003) and was crossed by three spacecraft ACE, STA and STB separated by ~41˚. The MC was best at ACE passed near the rope axis, and the local fluxrope Magnetic field at STA showed much weaker magnitude but similar rotation, orientation and size. But STB MC had smaller size and somewhat more inclined to ecliptic plane. But all three local fluxrope were left-handed.
- Second was a classic MC only seen by STB, and fluxrope was highly inclined to the ecliptic plane and right-handed.

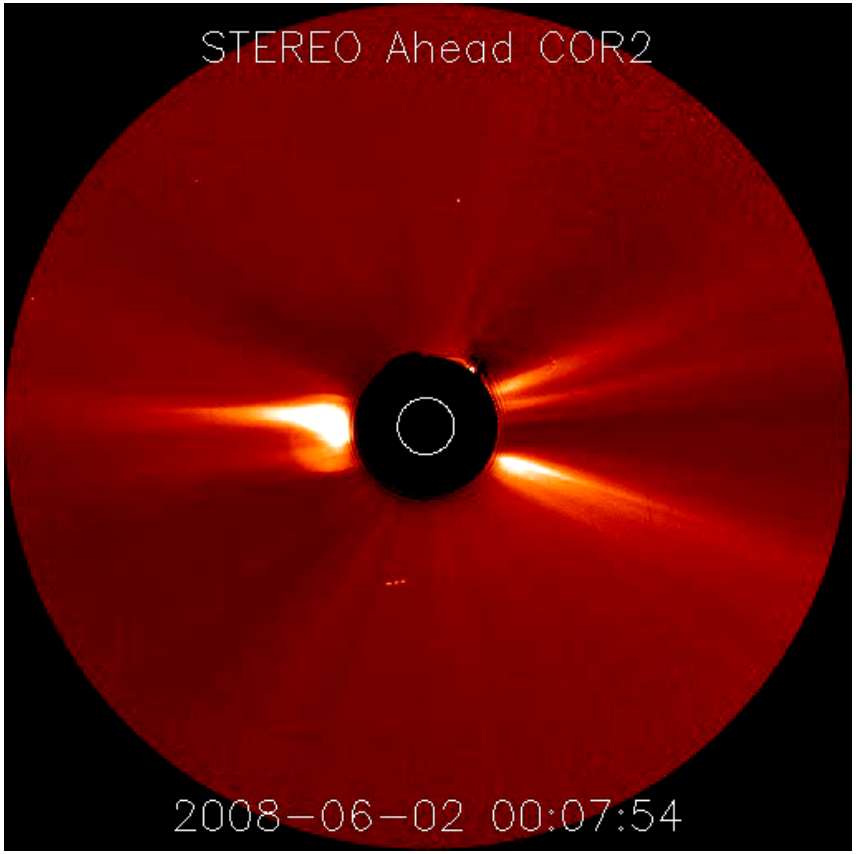
Magnetic flux and configuration of AR 10956 (2007 May)

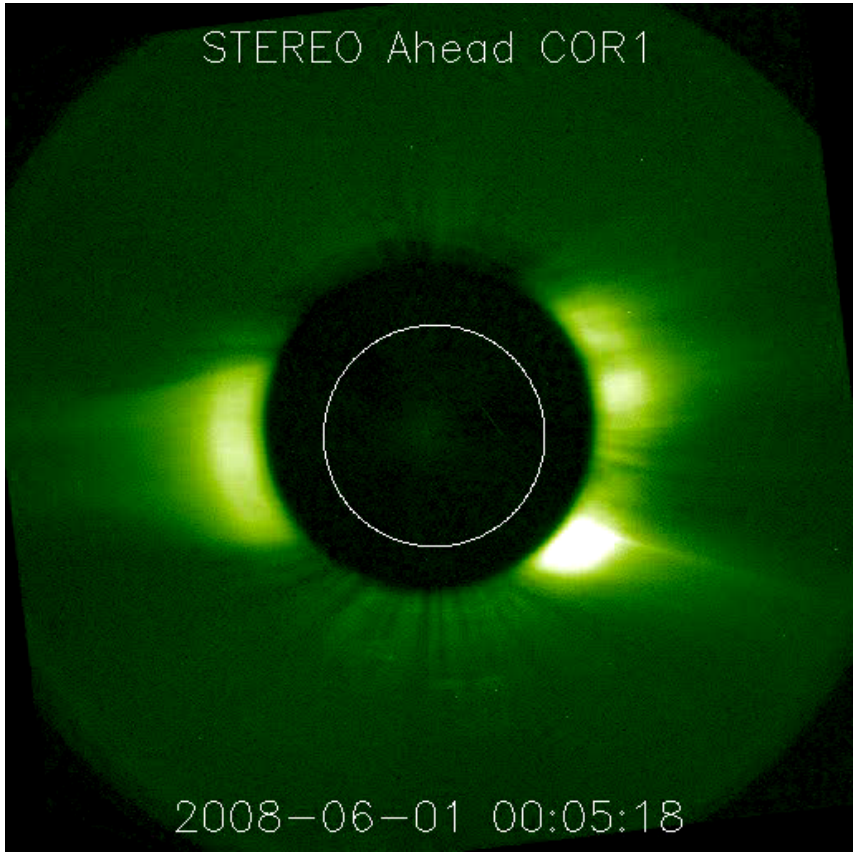


Total magnetic flux in the region decreased by ~17% in ~48hrs before the B9.5 flare.






STEREO Ahead COR2
2008-06-02 00:07:54


STEREO Ahead COR1
2008-06-01 00:05:18

ICME list 2007 January to 2008 June

1. 2007Jan14-15 (ACE): ~12 UT, ICME, low beta, possibly MC, compressed(?) by a high speed stream, electron? Shock:
2. 2007May21-22 (all craft): ~23 UT, ICME, low beta, MC, complex, between high speed streams, bi-directional electron flux at WIND and STB, no shock.
3. 2007May23 (STA): 00:56UT, ICME, low beta, MC, between high speed streams, uni-directional electron flux, no shock.
4. 2007Jun8-9 (all craft): ~2 UT, ICME, complex, low beta, MC(?), no high speed stream involved, electron flux? shock:
5. 2007Aug25-26 (STA): ~23 UT ?
6. 2007Oct23-24 (STB): ~12 UT, ICME, low beta, MC, followed by a high speed stream, electron flux? Shock:
7. 2007Nov19-20 (all craft): ICME, Good MC at ACE: 19th ~23:30UT, low beta, compressed by a high speed stream, shock. Good MC at WIND: 00:40UT, shock 19th 17:20UT, unidirectional electron flux. STB: 19th 23:34UT, possible MC, low beta, unidirectional electron, shock19th, 13:49UT. STA(?): 19th ~22UT, low beta, bi-directional electron flux.
8. 2007 Dec 30 (STB): 6:05UT, ICME, MC, longest B rotation (47 hrs), but short low beta period, high density later half, unidirectional electron, no shock.
9. 2008 Mar 6 (STB): ~12UT, ICME, MC, shortest (4hrs only), low beta, no counter-streaming electrons, followed by a high speed stream.
10. 2008 Apr 29 (STB): ~16UT, ICME, MC? Not so good, but there was supposed to be a coronal CME source and Dave Webb thinks it's a good ICME or MC, WHI people are looking into it.
11. 2008 May 11 (STA): 10:58UT, Good MC, PLASTIC data problem.
12. 2008 Jun 06 (STB): 21:55UT, Best MC, low beta, no high speed stream involved, electron? Shock 15:35UT.

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

	A&B	STB	ACE / Wind	STA
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	none	none	no 00:55 11h30m
07Jun08	11.821	no 5:10 4h10m	no 05:35 23h35m	no 18:30 20h50m
07Aug25	27.217	none	none	20:30 23:40 16h5m
07Oct23	37.440	no 16:50 6h45m	none	none
07Nov19	40.768	13:49 22:34 8h28m	17:20 +0:40 8h46m	no 22:50 25h10m
07Dec30	43.927	no 06:05 45h55m	none	none

ICME (shock and ejecta) dates, times and duration 2008

	A&B	STB	ACE / Wind	STA
Date	sprt°	shk MC_start drt	shk MC_start drt	shk MC_start drt
08Mar06	46.305	no 12:12 04h44m	none	none
08Mar08		none	? 19:00 6h	none
08Mar21		none	none	no 06:00 16h00m
08Apr29	49.804	14:15 23:25 8h35m	none	none
08May11	51.080	none	none	nd 11:00 6h54m
08Jun06	54.591	15:30 22:05 13h5m	none	none
08Jul10		11:00 14:00 19h	No level2	none
08Jul30		None	No level2	no 3:00 7h
08Aug15		No 12:00 13h	No level2	none
08Sep04		None	No level2	No 10:00 14h
08Sep28		? 3:00 10h	No level2	none

ICME (shock and ejecta) dates, times and duration

	A&B	STB	ACE / Wind	STA
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	none	none	no 00:55 11h30m
07Jun08	11.821	no 5:10 4h10m	no 05:35 23h35m	no 18:30 20h50m
07Aug25	27.217	none	none	20:30 23:40 16h5m
07Oct23	37.440	no 16:50 6h45m	none	none
07Nov19	40.768	13:49 22:34 8h28m	17:20 +0:40 8h46m	TBD
07Dec30	43.927	no 06:05 45h55m	none	none
08Mar06	46.305	no 12:12 4h44m	-check ACE data?	none
08Apr29	49.804	14:15 23:25 8h35m	-?	none
08May11	51.080	none	-?	nd 11:00 6h54m
08Jun06	54.591	15:30 22:05 13h5m	-?	none

ICME ejecta |B|max (nT), orientation, eHeatFlux

	A&B	STB	ACE / Wind	STA
Date	sprt°	B(nT) lat lon ehf	B(nT) lat lon ehf	B(nT) lat lon ehf
07Jan14	0.252	no data	14.5 3.1 86.0 U/hfd	no data
07May21	8.995	17.6 46.7 77.6 CS	14.8 --- --- CS	9.9 --- --- ---
07May23	9.167	none	none	11.8 41.1 44.3 U
07Jun08	11.821	11.5 --- --- U	10.1 --- --- U	9.2 --- --- U
07Aug25	27.217	none	none	14.8 11.6 51.7 U
07Oct23	37.440	10.3 45.7 43.7 U	none	none
07Nov19	40.768	17.6 38.1 272.0 U	14.6 0.53 283.7 U	---TBD--- CS
07Dec30	43.927	11.9 19.9 68.9 U	none	none
08Mar06	46.305	16.5 24.2 270.6 U	-	none
08Apr29	49.804	8.8 --- --- CS/hfd	-	none
08May11	51.080	None	-	14.5 10.5 295.5 ---
08Jun06	54.591	14.9 ---TBD---	-	none

ICME radial distance (RD), speed

	A&B	STB	ACE / Wind	STA
Date	sprt°	RD(AU) Vl Va dV	RD(AU) Vl Va dV	RD(AU) Vl Va dV
07Jan14	0.252	no data	.12 368.2 352.8 -50.0	no data
07May21	8.995	.19 481.1 447.4 -46.4	.19 482.6 456.3 -27.3	.035 492.6 492.1 -10.6
07May23	9.167	none	none	.14 535.0 497.2 -72.4
07Jun08	11.821	.24 338.3 358.5 54.5	.21 353.1 363.8 16.2	.18 372.5 356.4 -13.9
07Aug25	27.217	none	none	.14 339.2 356.7 11.0
07Oct23	37.440	.06 383.9 377.4 -15.2	none	none
07Nov19	40.768	.09 391.2 440.3 57.9	.1 478.7 478.7 5.8	TBD
07Dec30	43.927	.35 364.9 313.5 -81.5	none	none
08Mar06	46.305	.04 382.8 389.9 6.8	-	none
08Apr29	49.804	.11 453.1 465.3 16.7	-	none
08May11	51.080	none	-	no data
08Jun06	54.591	.13 412.8 392.7 -39.6	-	none