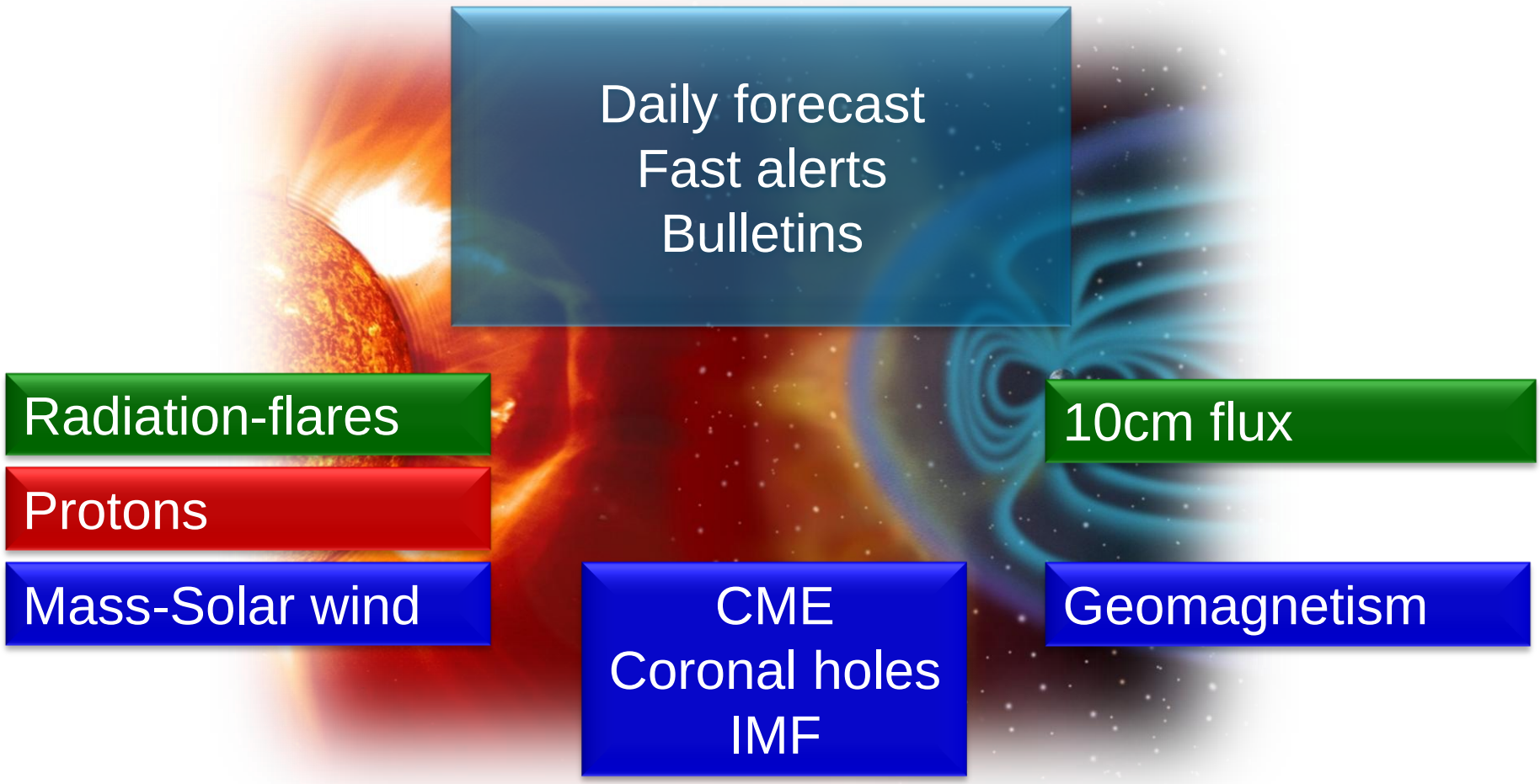
Space Weather Prediction

Become a forecaster in less than 3 hours

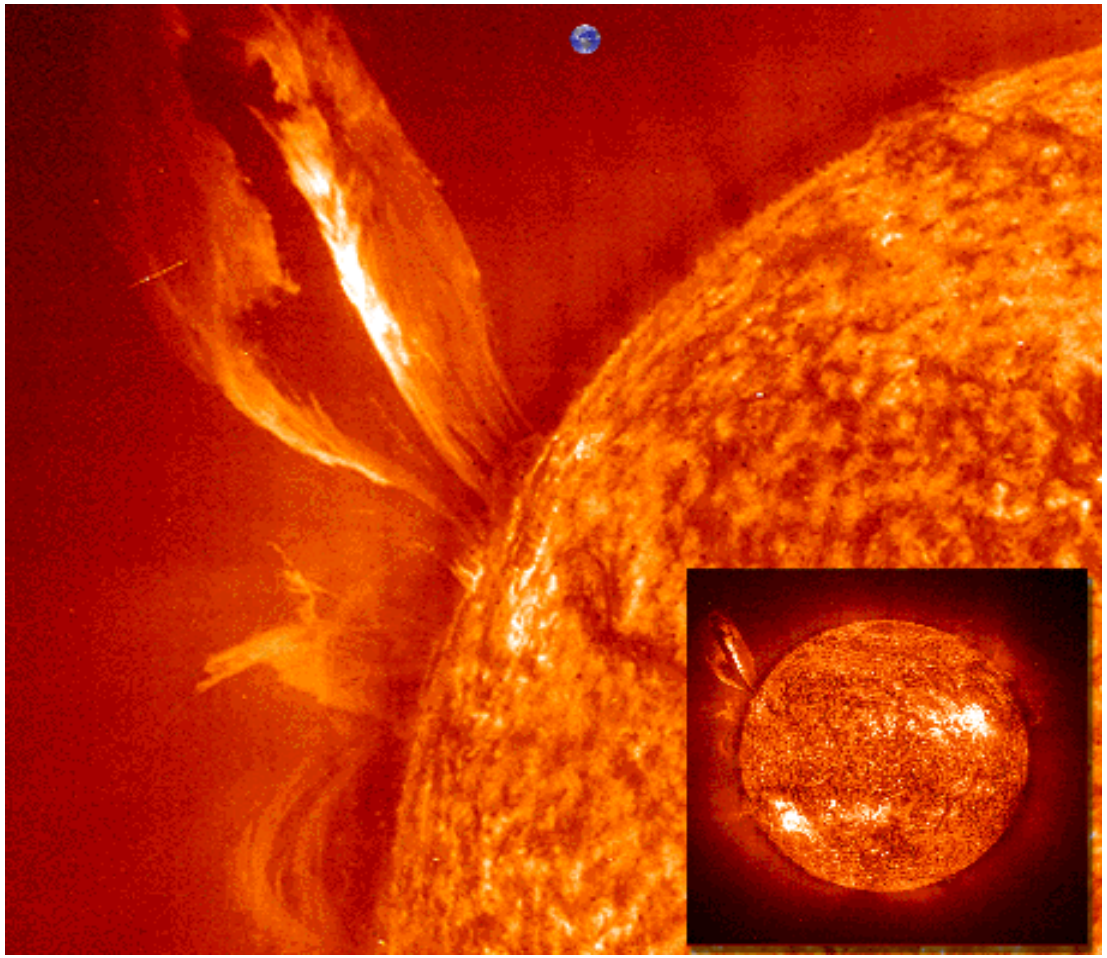
Petra Vanlommel
Solar-Terrestrial Centre of Excellence

From Sun to Earth



The daily forecast

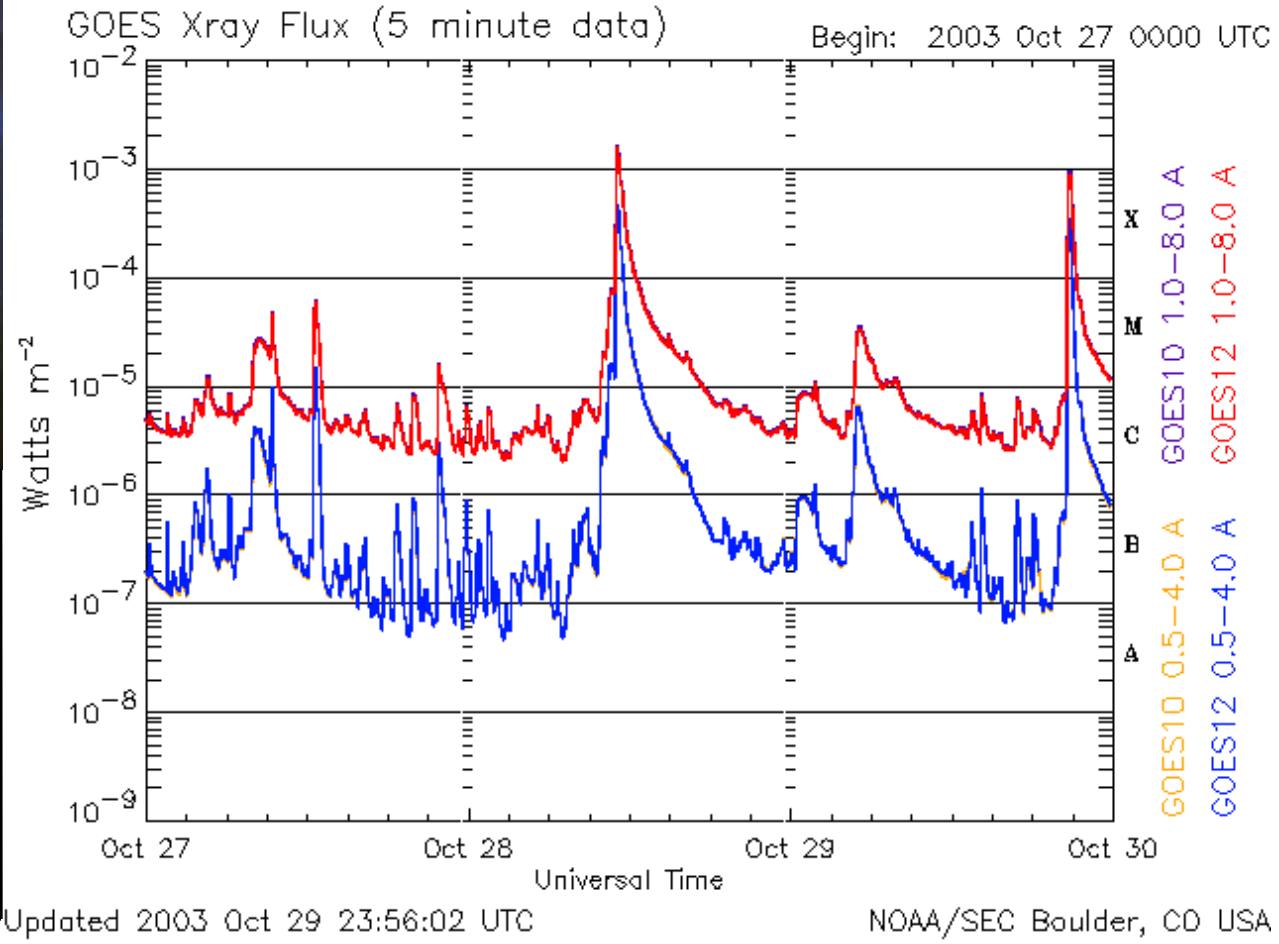
- Email
- Internet



Solar Flares

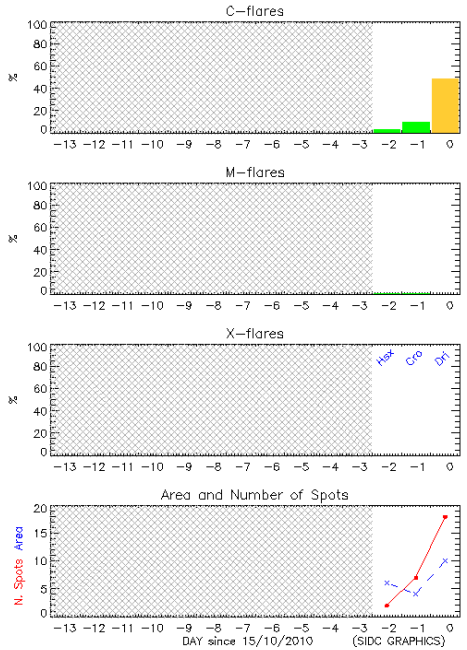
Light Flashes

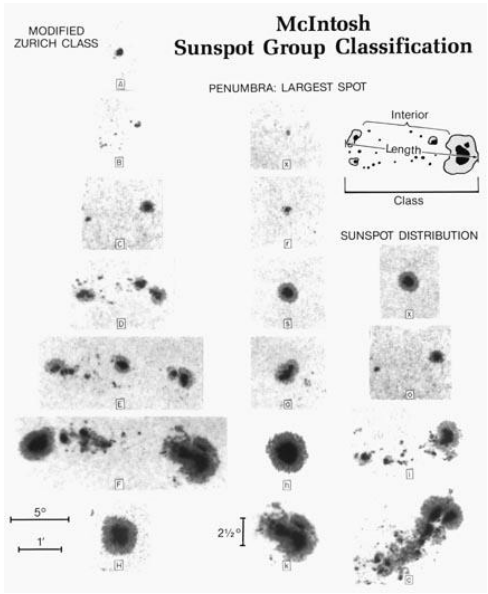
Klasse	Maximum Flux $\log_{10}(P)$ in Wm^{-2}
A	-8
B	-7
C	-6
M	-5
X	-4

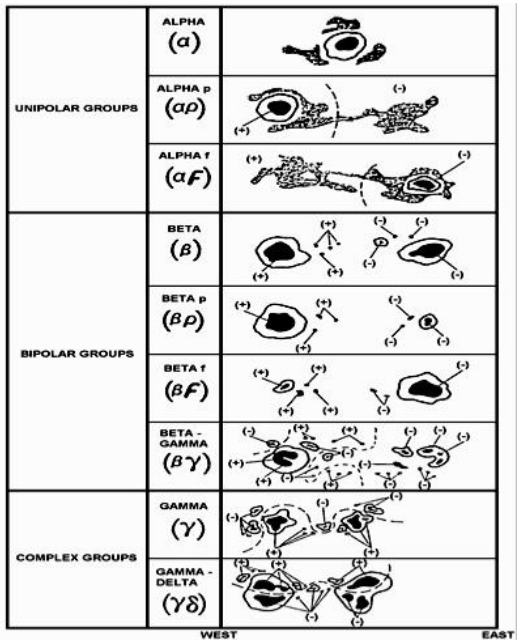


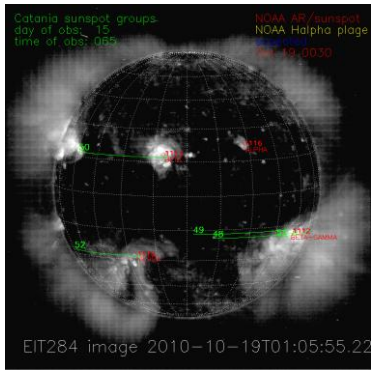
- Space Weather predictions - Flares

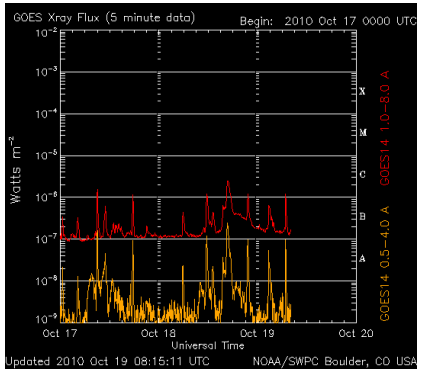
Flare prediction

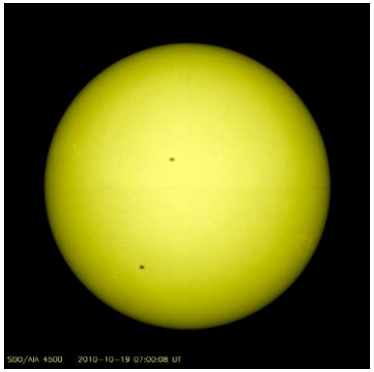


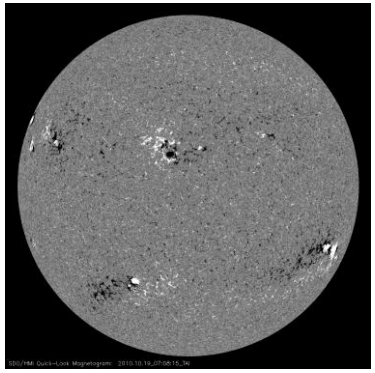






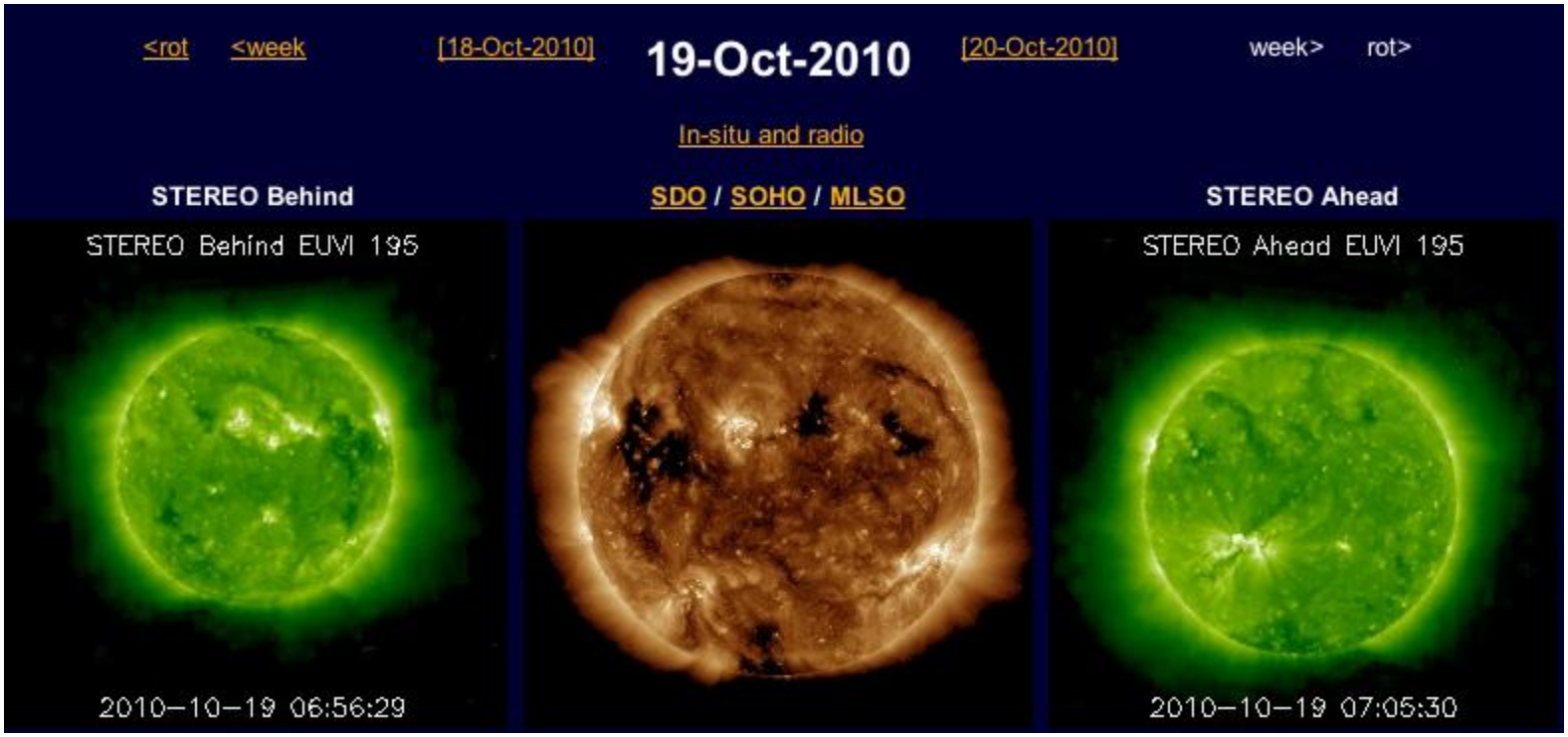






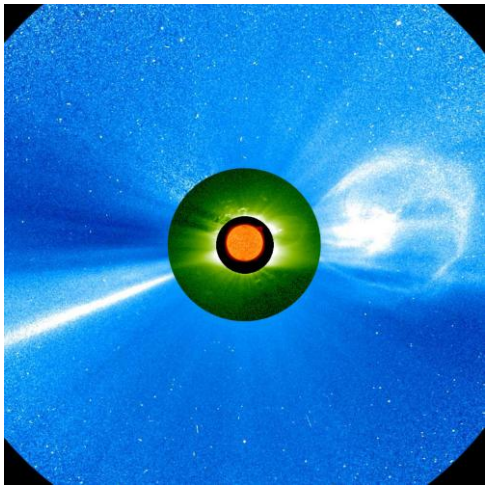
- Space Weather predictions - Flares

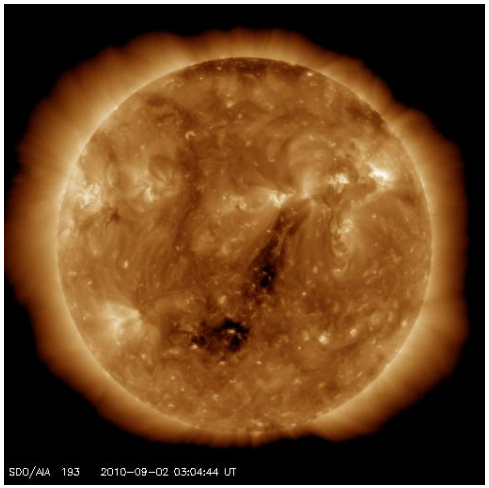
STEREO Behind as appetizer

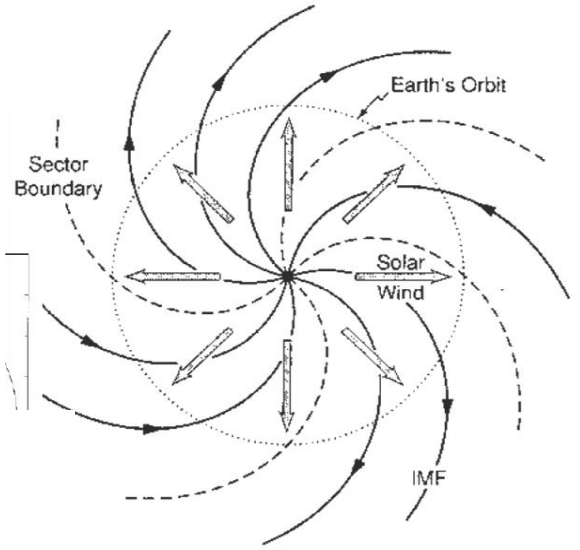


Geomagnetic Conditions

- Solar Wind data - ACE
- CME
- Coronal hole
- Boundary sector crossing

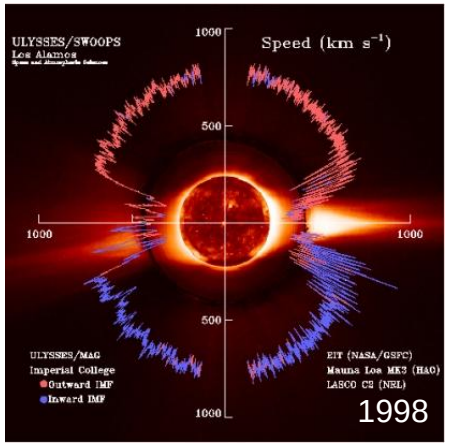






SLOW versus FAST

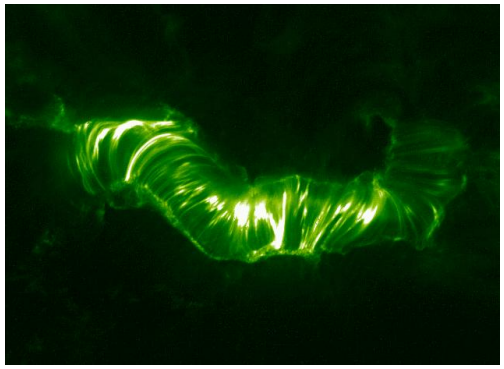
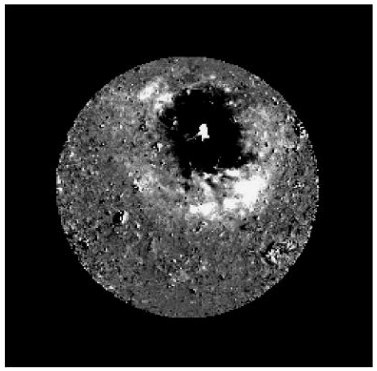
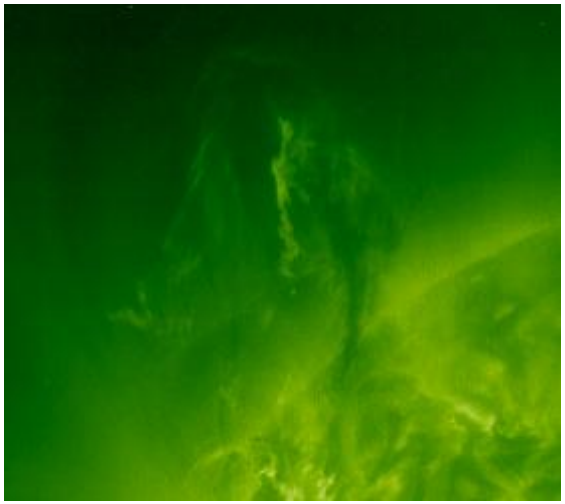
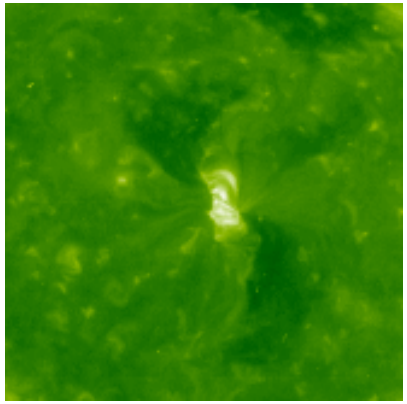
- 250-400 km/s
- High density: ~ 10 cm^{-3}
- Low temperature: ~ 10^4 K ~ 1 eV
- Very variable



- 400 - 800 km/s
- Low density: ~ 3 cm^{-3}
- High temperature: ~ 10^5 K ~ 10 eV
- Stationary for long times

Signatures of a CME in EUV

- Post-eruption loops
- EUV waves
- Prominence eruptions
- Dimming

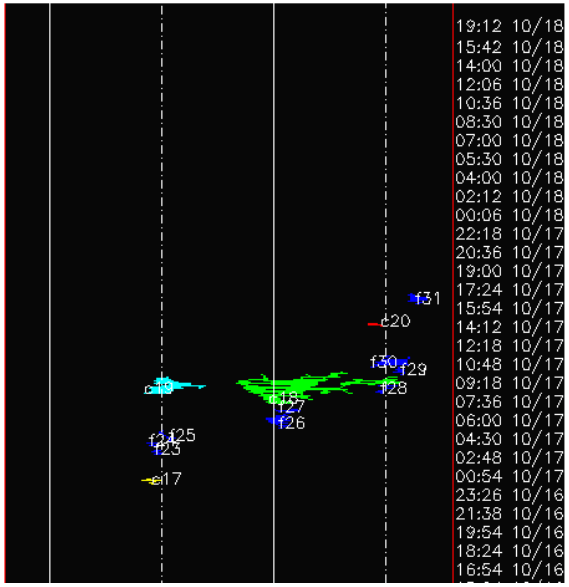





CACTus

```
  first c2: 2010/09/30  00:00:05.532 23364600.fts
  last  c2: 2010/10/18  19:12:05.641 23367213.fts
  first c3: 2010/09/30  00:06:05.829 33247001.fts
  last  c3: 2010/10/18  19:06:05.445 33249386.fts
#
#-------------------------------------------------------------------------
# Output: Detected cmemap with the following characteristics:
#
#    CME: CME number
#   Flow: Flow number. Flows are suspicious detections, their color in the detectionmap is dark blue
#     t0: onset time, earliest indication of liftoff
#    dt0: duration of liftoff (hours)
#     pa: principal angle, counterclockwise from North (degrees)
#     da: angular width (degrees),
#      v: median velocity (km/s)
#     dv: variation (1 sigma) of velocity over the width of the CME
#  mindv: lowest velocity detected within the CME
#  maxdv: highest velocity detected within the CME
#  halo?: II if da>90, III if da>180, IV if da>270, indicating potential halo/partial halo CME
#
```

# CME	t0	dt0	pa	da	v	dv	minv	maxv	halo?
0020	2010/10/17 14:36	00	082	010	1735	0112	1602	1894	
0019	2010/10/17 09:36	02	281	048	0299	0088	0139	0428	
0018	2010/10/17 09:24	03	037	132	0260	0083	0140	0425	II
0017	2010/10/17 01:36	01	262	014	0138	0003	0133	0146	
0016	2010/10/16 04:13	01	306	014	0309	0109	0122	0364	
0015	2010/10/15 16:12	01	250	010	0144	0282	0141	0771	
0014	2010/10/14 23:16	01	335	016	1350	0316	0715	1876	
0013	2010/10/14 17:36	00	051	016	0561	0174	0263	0880	
0012	2010/10/14 16:36	03	278	026	0139	0001	0139	0141	
0011	2010/10/13 23:37	01	074	006	0416	0010	0401	0425	
0010	2010/10/13 16:36	03	068	034	0513	0224	0137	1041	
0009	2010/10/10 21:38	04	102	078	0195	0062	0139	0323	
0008	2010/10/10 19:00	01	040	026	0367	0005	0361	0380	
0007	2010/10/10 18:48	02	044	026	0477	0080	0332	0637	
0006	2010/10/08 13:25	04	249	088	0139	0042	0134	0232	
0005	2010/10/07 09:12	05	307	072	0475	0079	0301	0624	
0004	2010/10/06 07:36	03	046	070	0205	0004	0195	0211	
0003	2010/10/03 22:00	00	305	024	1182	0319	0637	1689	
0002	2010/10/01 10:12	02	058	078	0141	0840	0133	1894	
0001	2010/10/01 08:48	00	258	010	1391	0285	1179	1785	

# Flow	t0	dt0	pa	da	v	dv	minv	maxv	halo?
0031	2010/10/17 16:42	01	116	014	0357	0036	0347	0419	
0030	2010/10/17 11:00	01	094	030	0141	0033	0136	0231	
0029	2010/10/17 10:24	01	101	008	0140	0001	0137	0142	
0028	2010/10/17 08:42	01	091	016	0213	0049	0140	0268	
0027	2010/10/17 07:12	00	011	020	0139	0000	0139	0139	
0026	2010/10/17 05:48	01	004	018	0139	0001	0136	0142	
0025	2010/10/17 04:48	01	275	012	0411	0000	0411	0411	

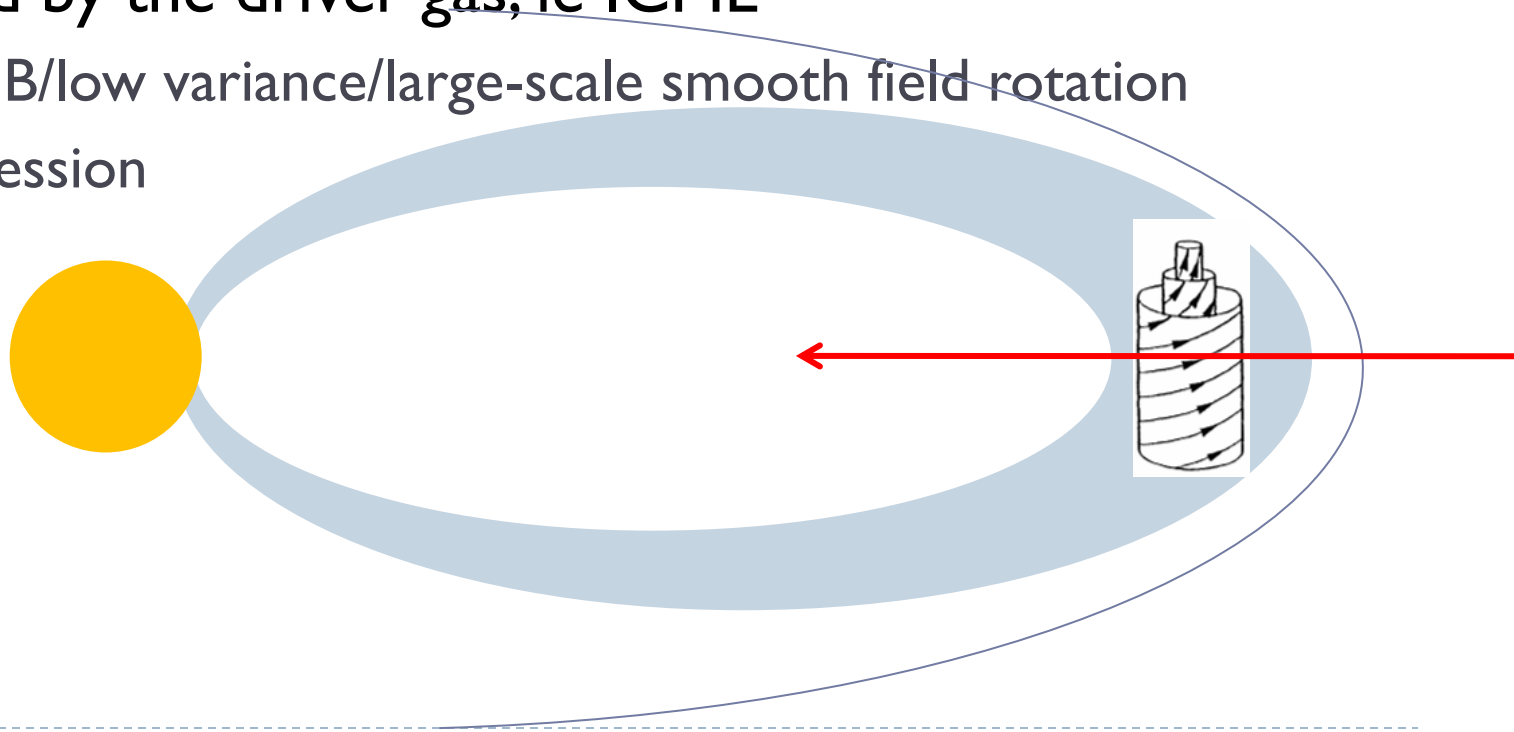


SOHO/LASCO – near real time
STEREO A/B COR2 – 3 days delay

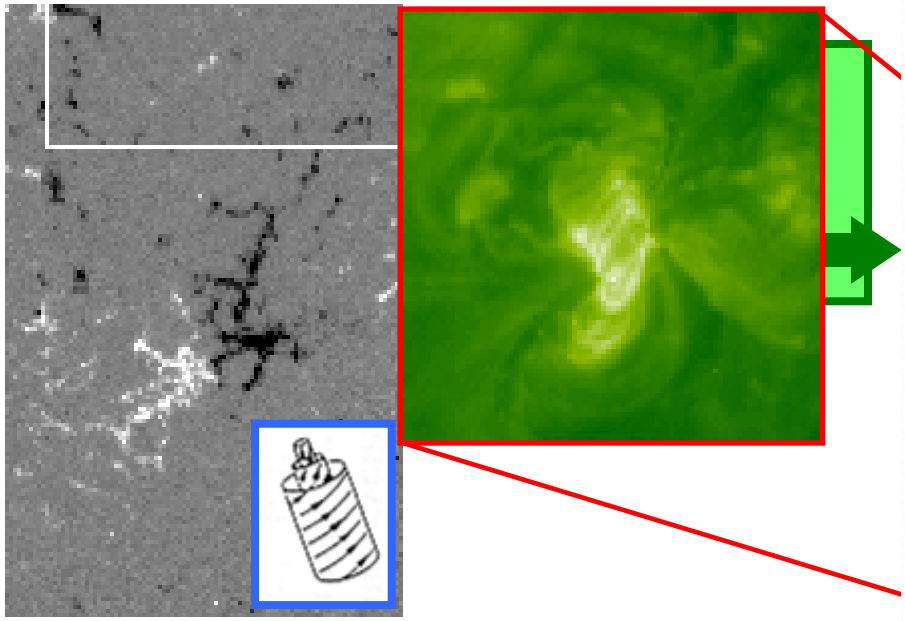
- Geomagnetic conditions -CME

Structure of a CME

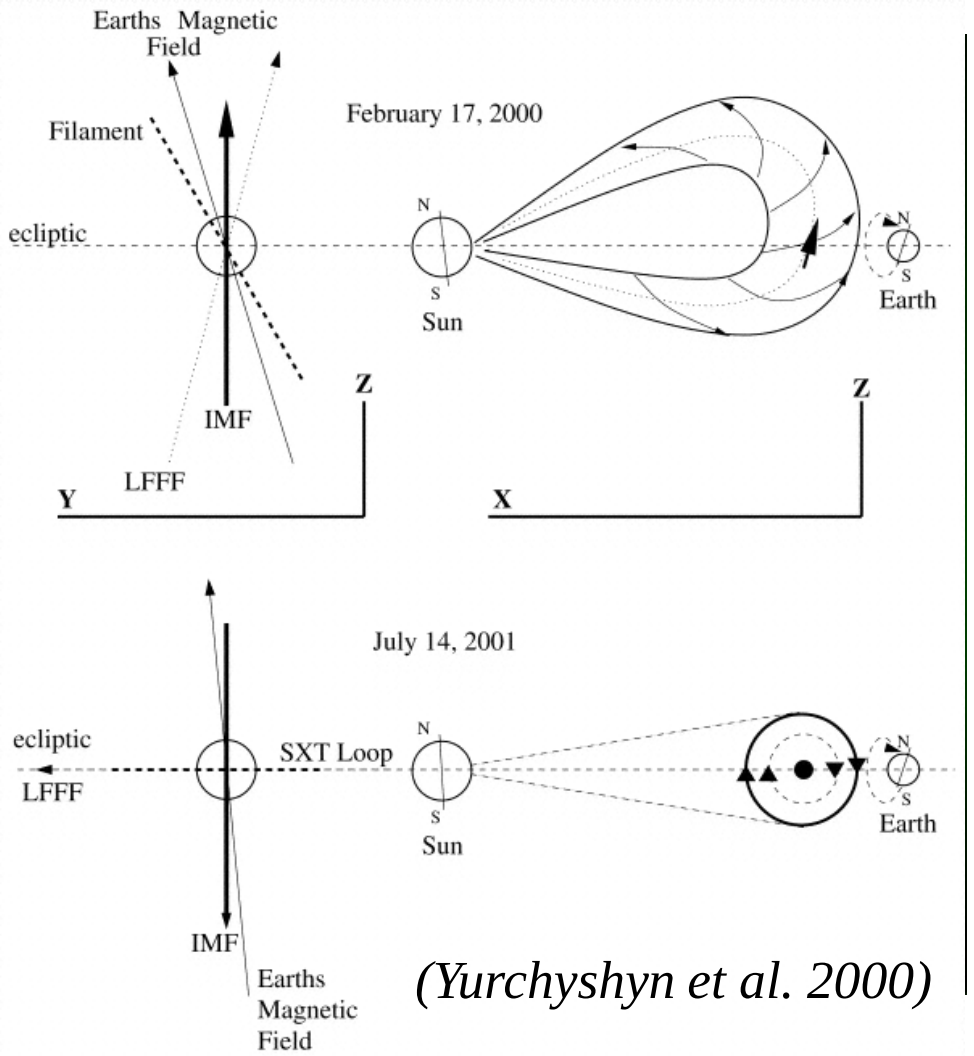
- Shock, if the ICME is fast enough
- Followed by shocked sheath plasma
  - Compressed – heated - oscillating magnetic field
- Followed by the driver gas, ie ICME
  - Strong B/low variance/large-scale smooth field rotation
  - T depression



Flux rope orientatie



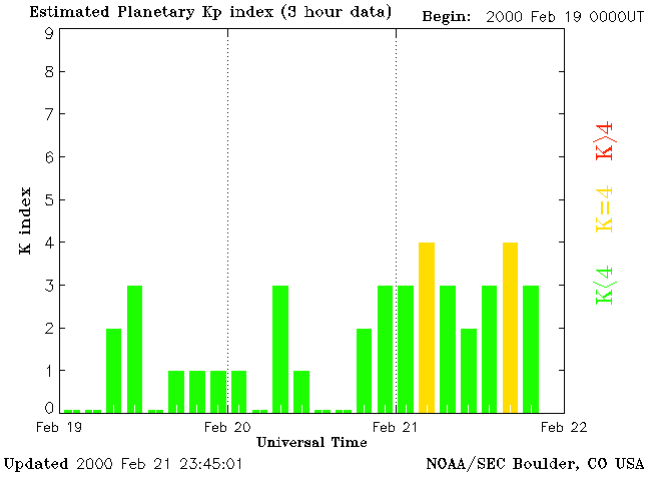
SOHO/MDI

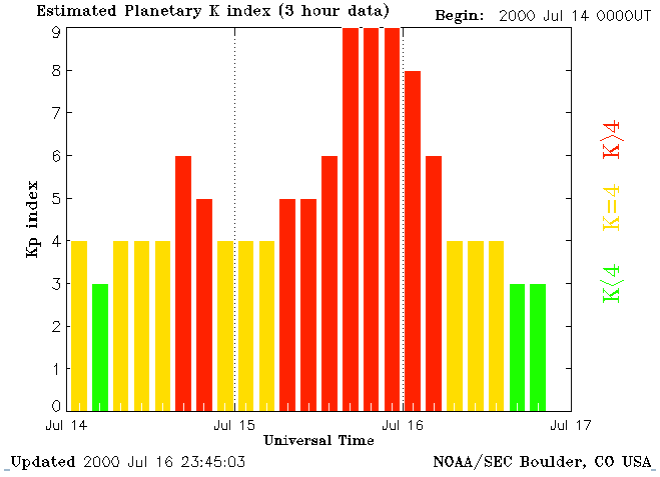


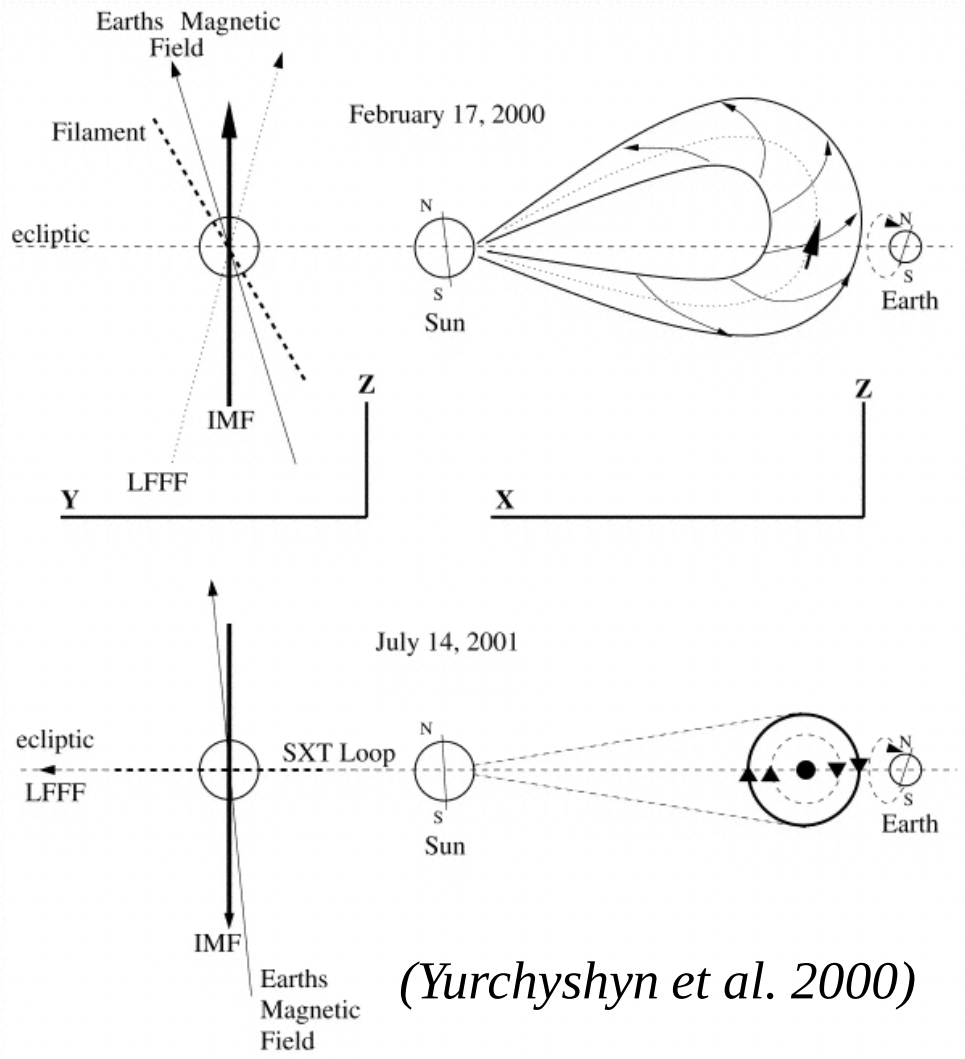
(Yurchyshyn et al. 2000)

- Geomagnetic conditions -CME

Geomagnetic result



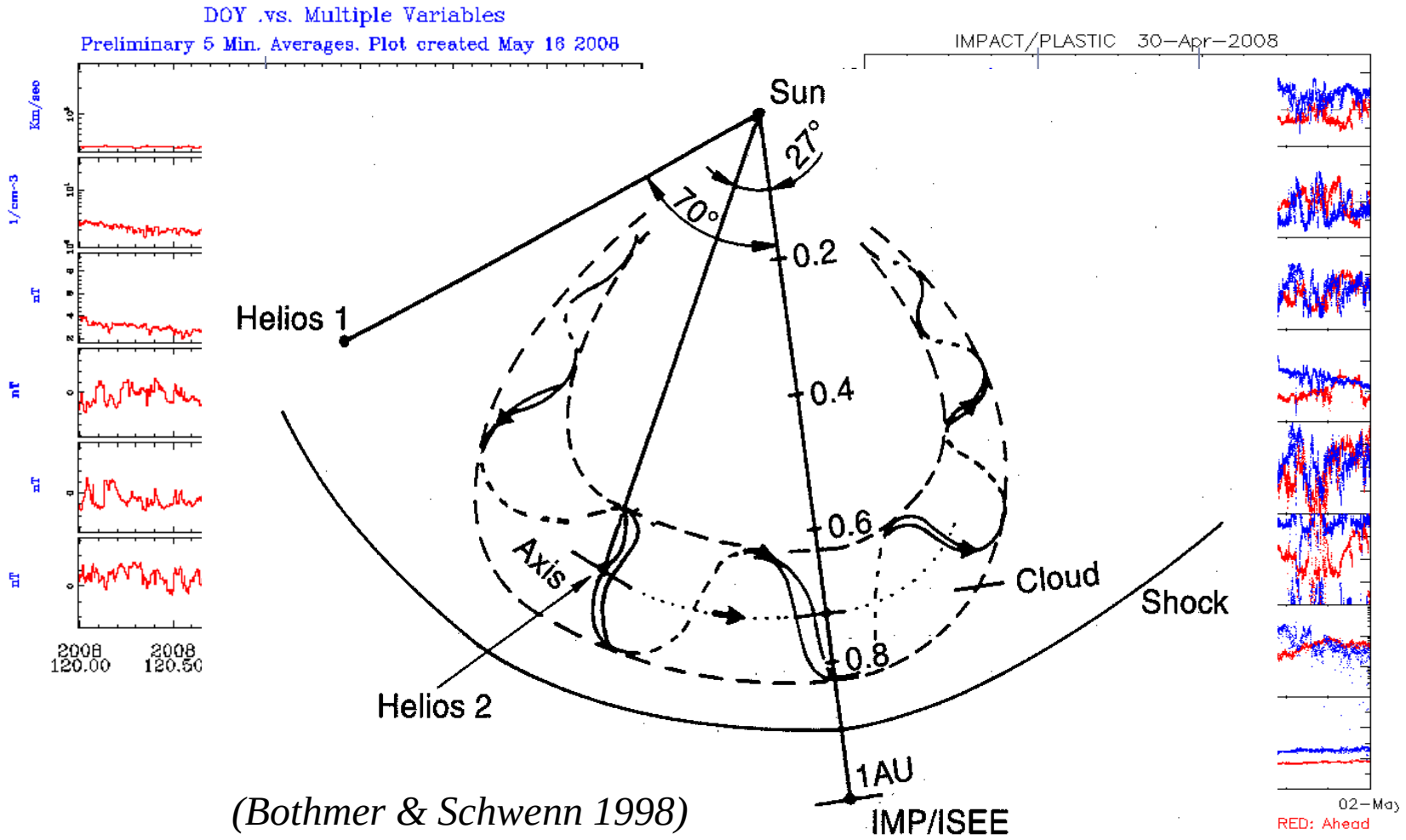




(Yurchyshyn et al. 2000)

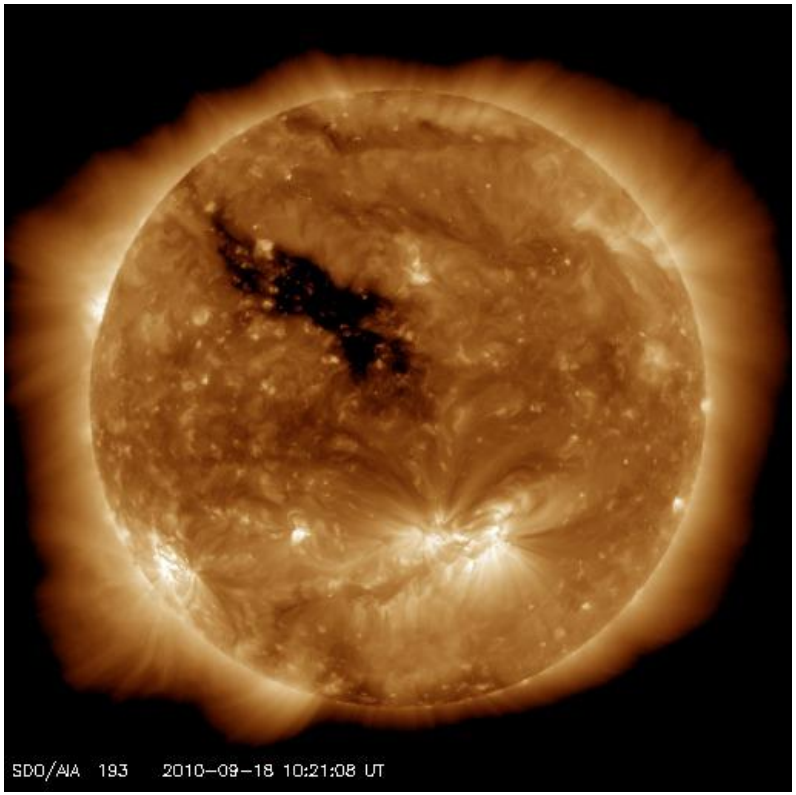
- Geomagnetic conditions -CME

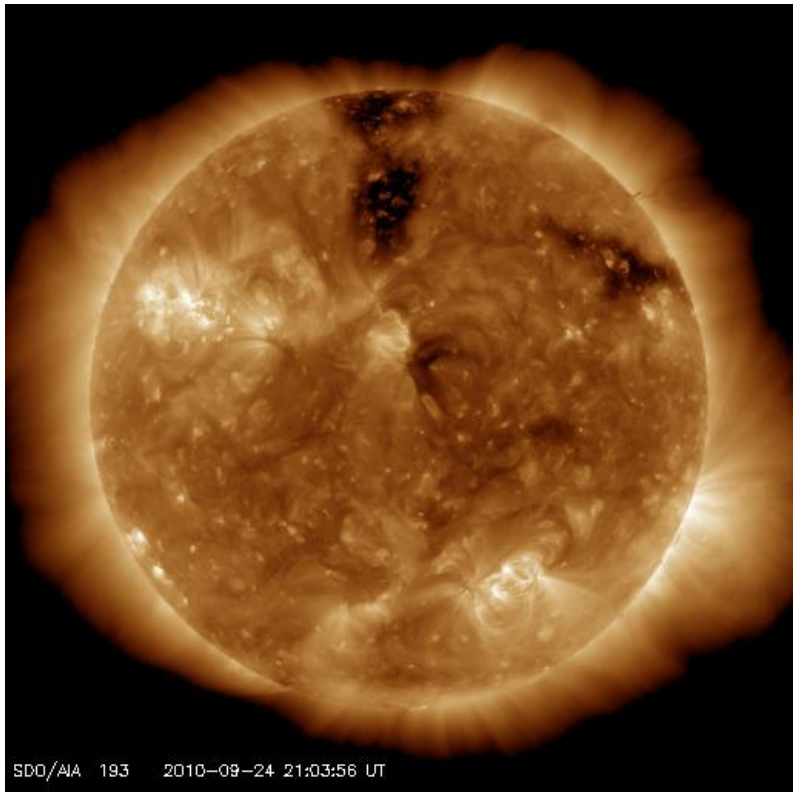
STEREO in situ data



(Bothmer & Schwenn 1998)

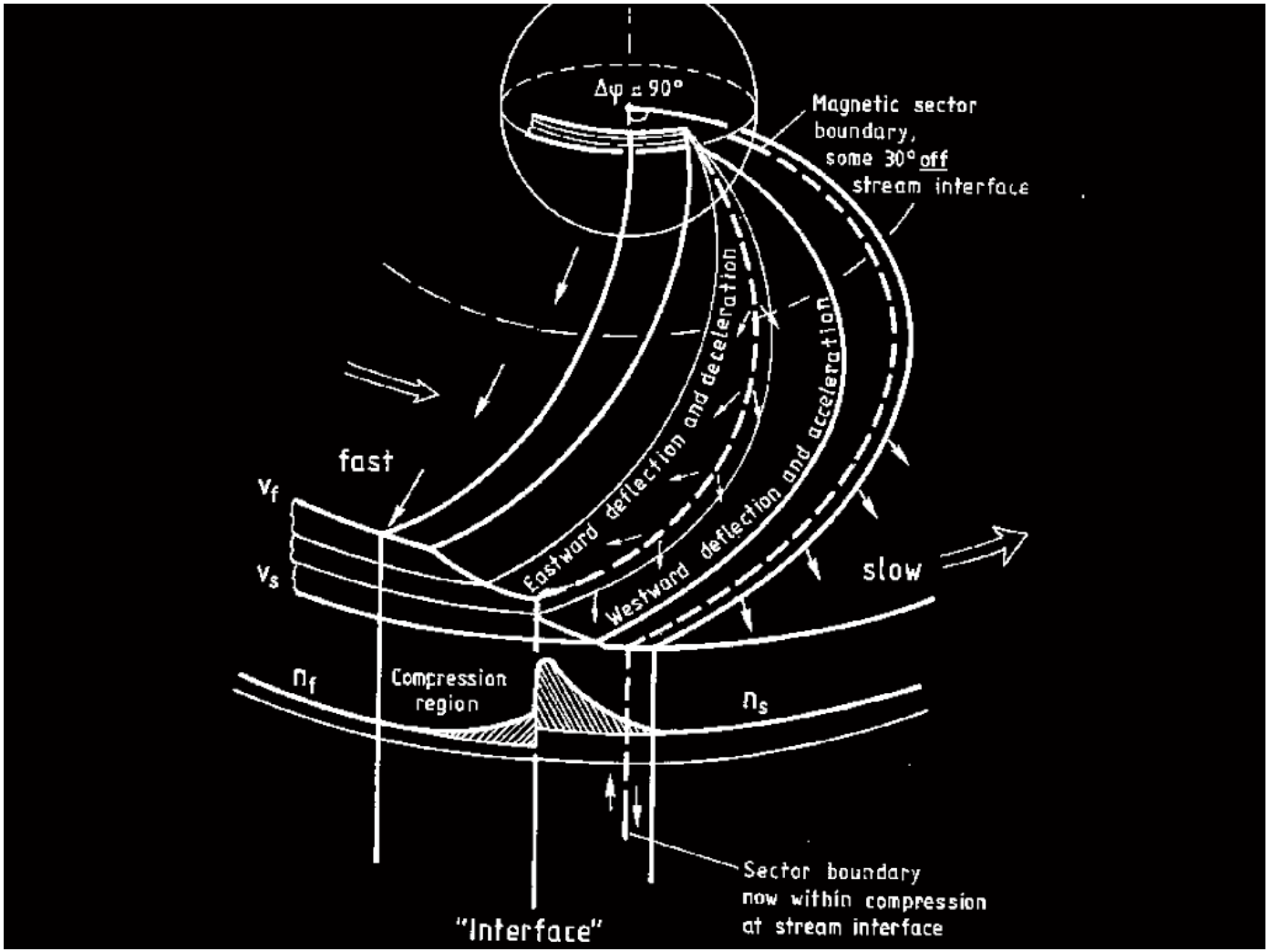
Coronal Holes





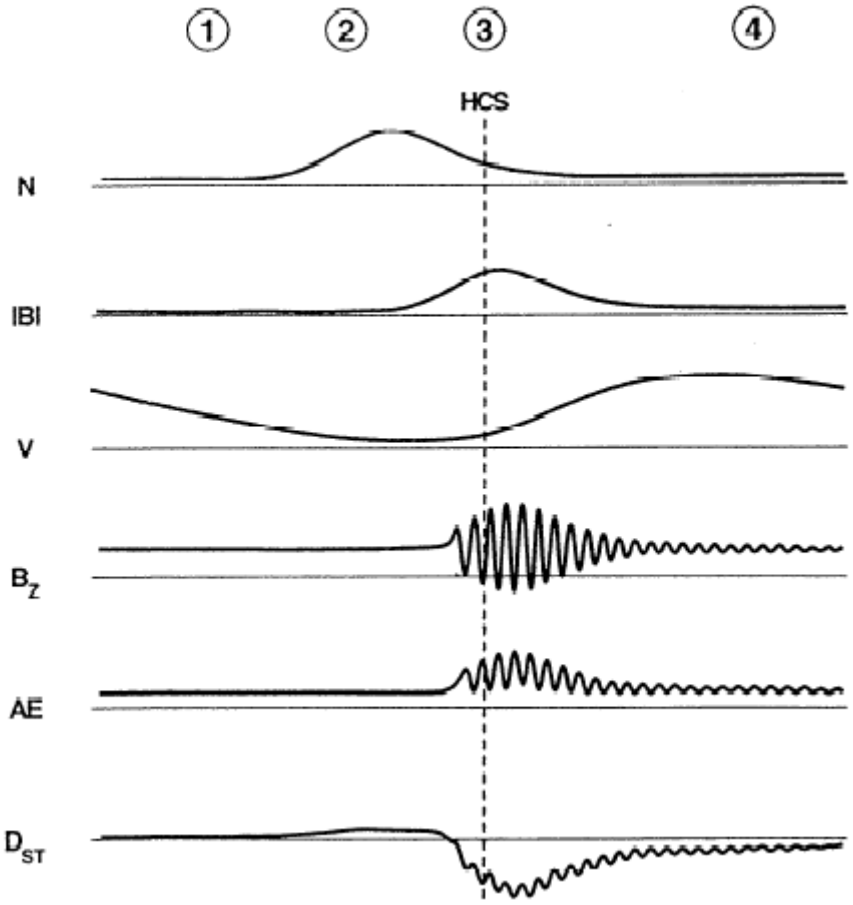
- Geomagnetic conditions –Coronal Holes

The IMF according to a Coronal Hole



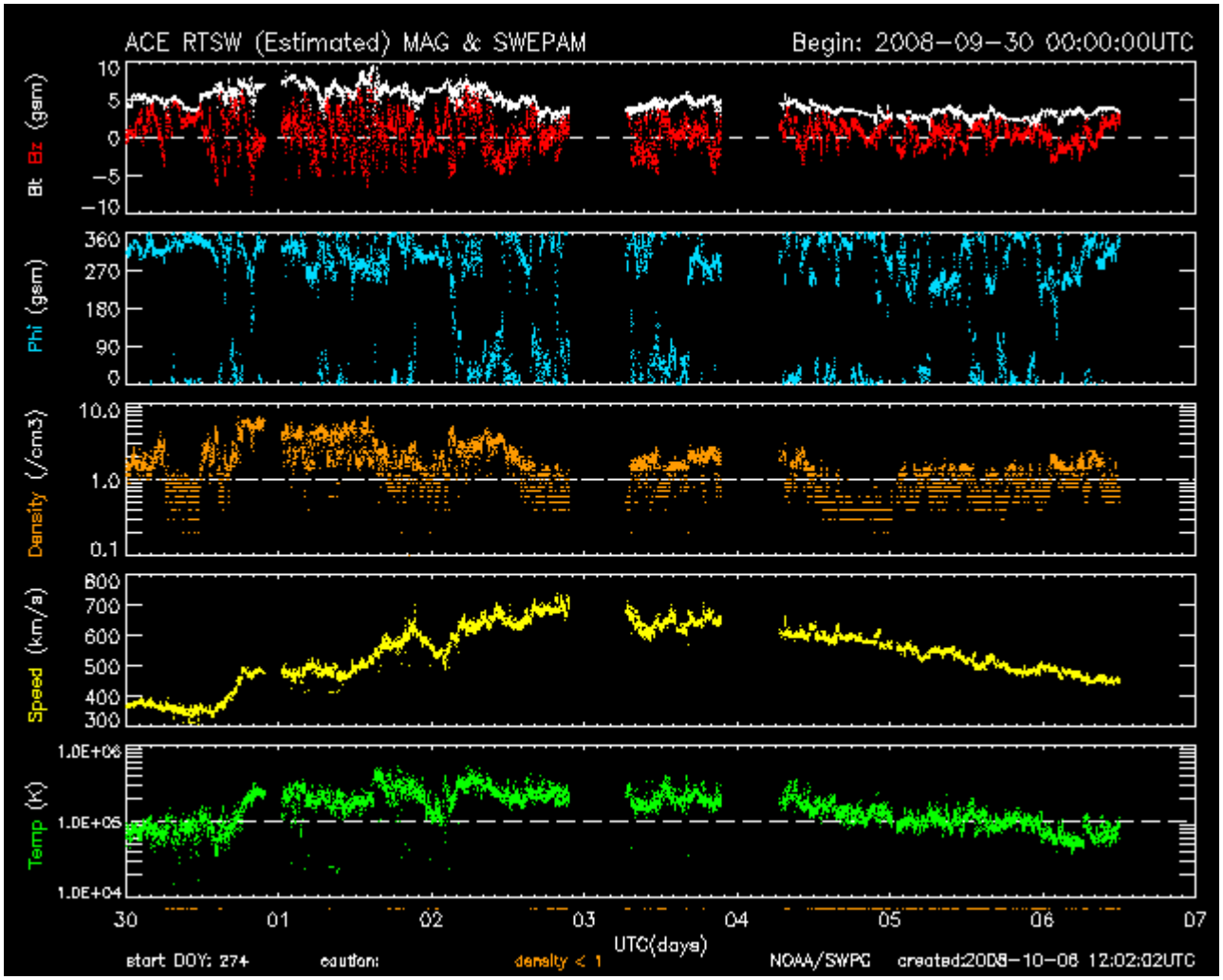
- Geomagnetic conditions –Coronal Holes

Scheme of a CIR



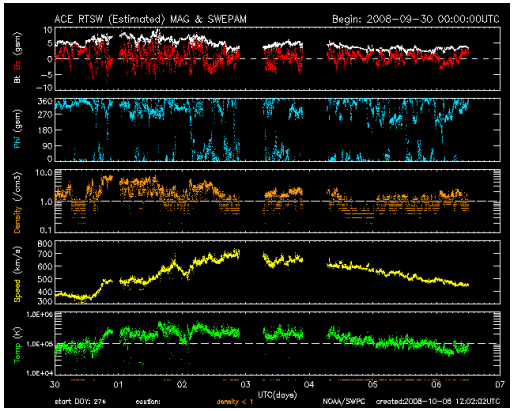
- Geomagnetic conditions –Coronal Holes

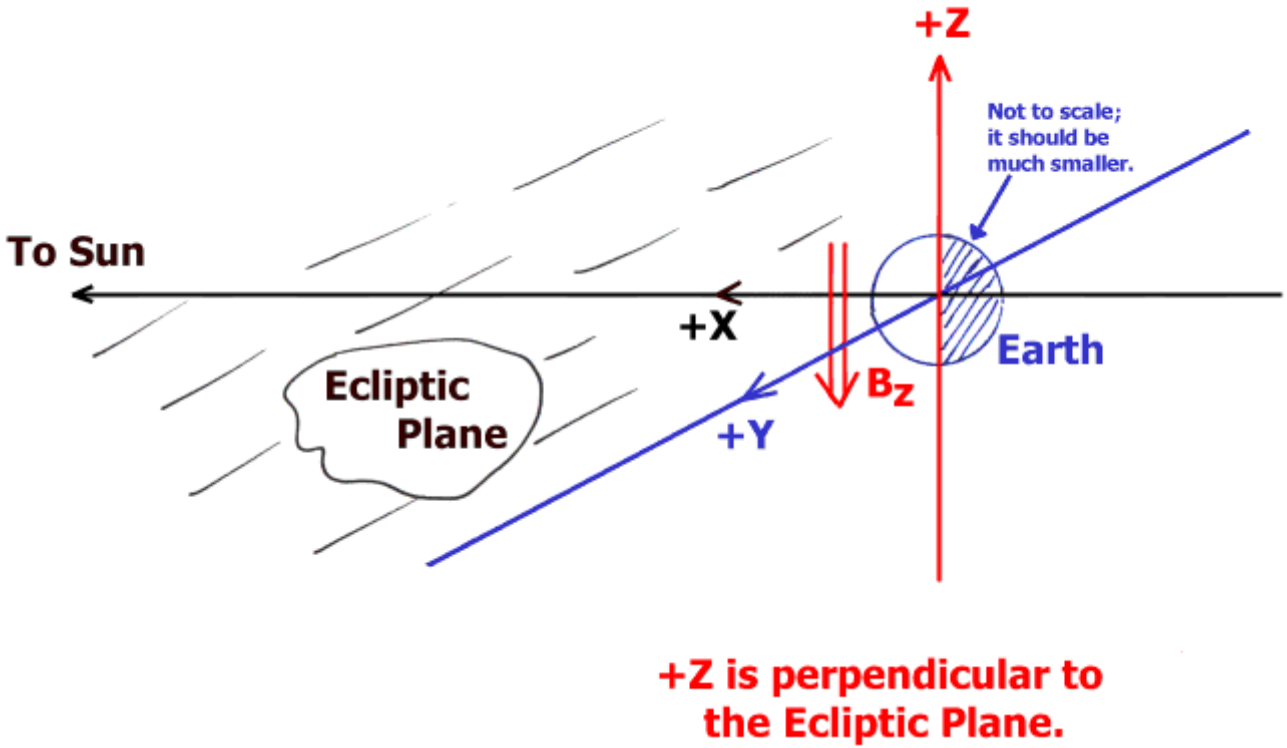
In Situ



- Geomagnetic conditions –Solar wind parameters

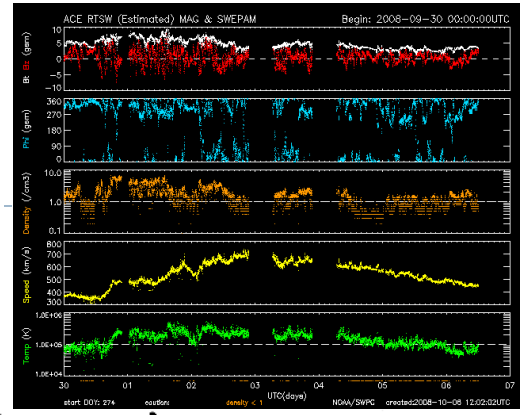
Coordinate system

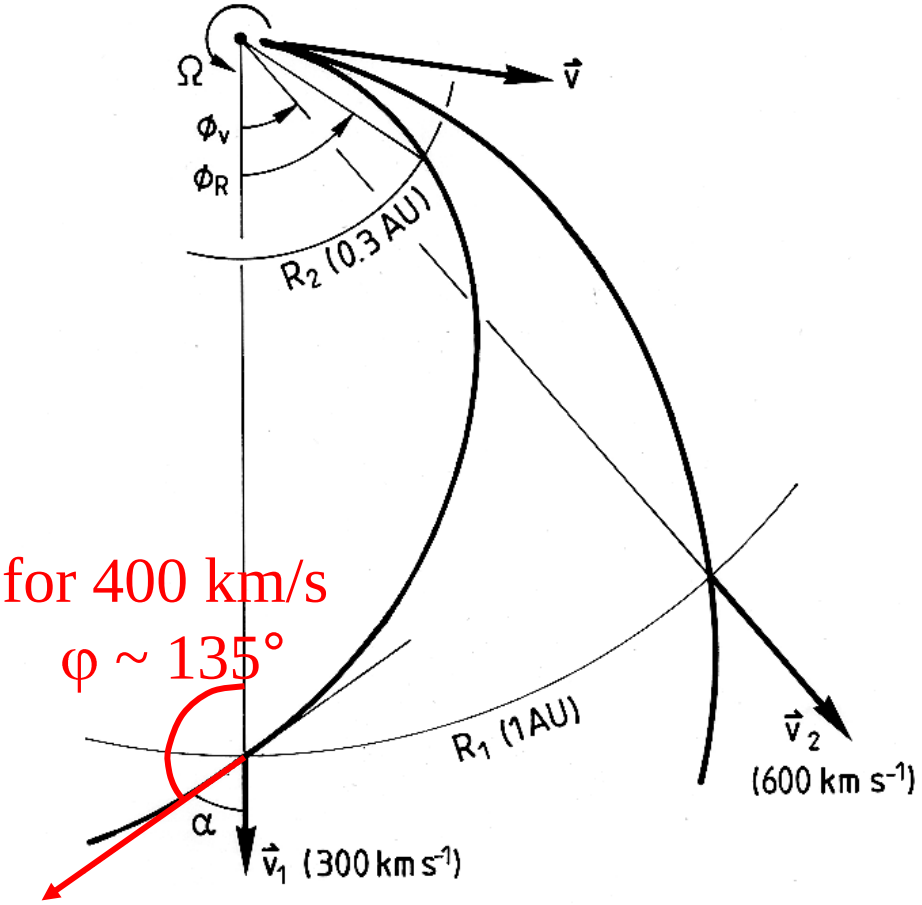




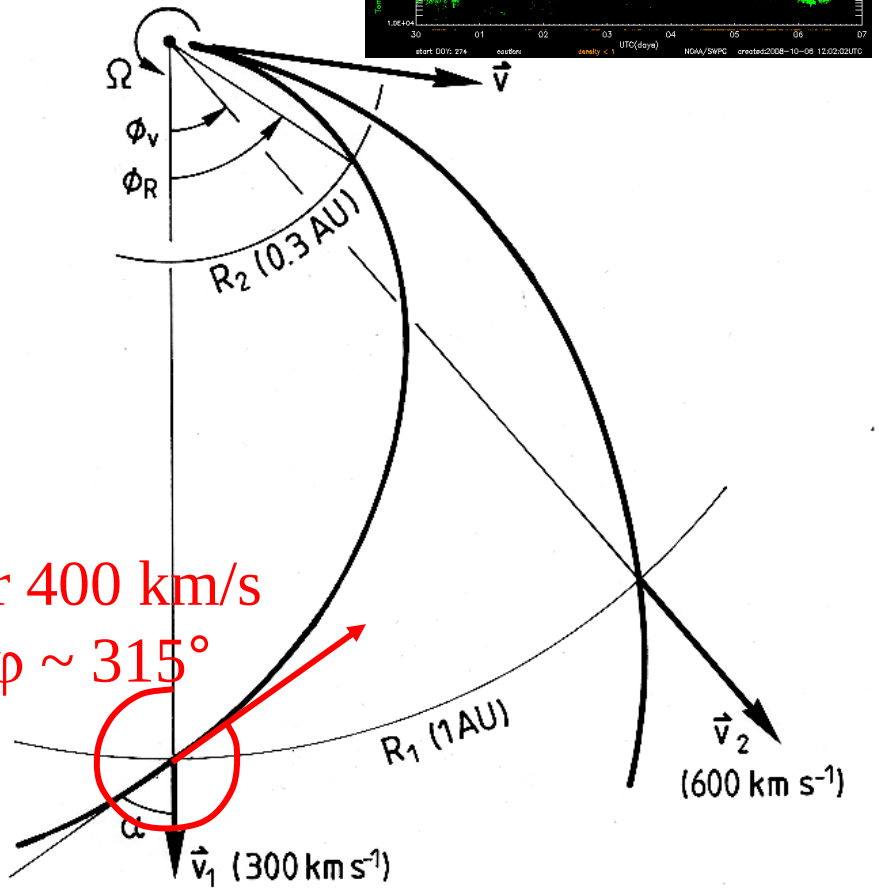
- Geomagnetic conditions –Solar wind parameters

IMF polarity





for 400 km/s
φ ~ 135°



for 400 km/s
φ ~ 315°

- Geomagnetic conditions –Solar wind parameters

When did the plasma leave the Sun

Distance

150 10^6 km

Speed

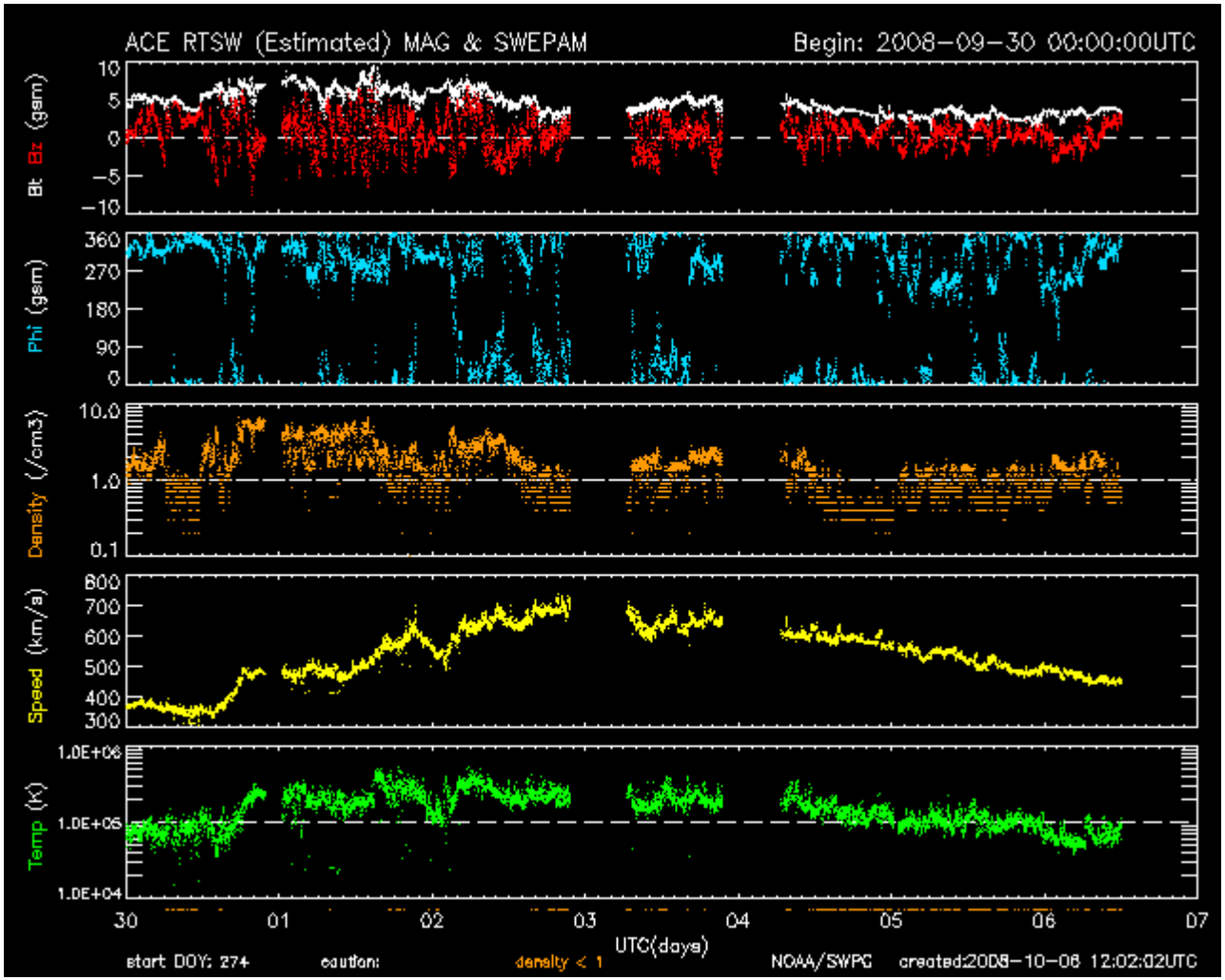
700 km/s

Time needed

214 285 s

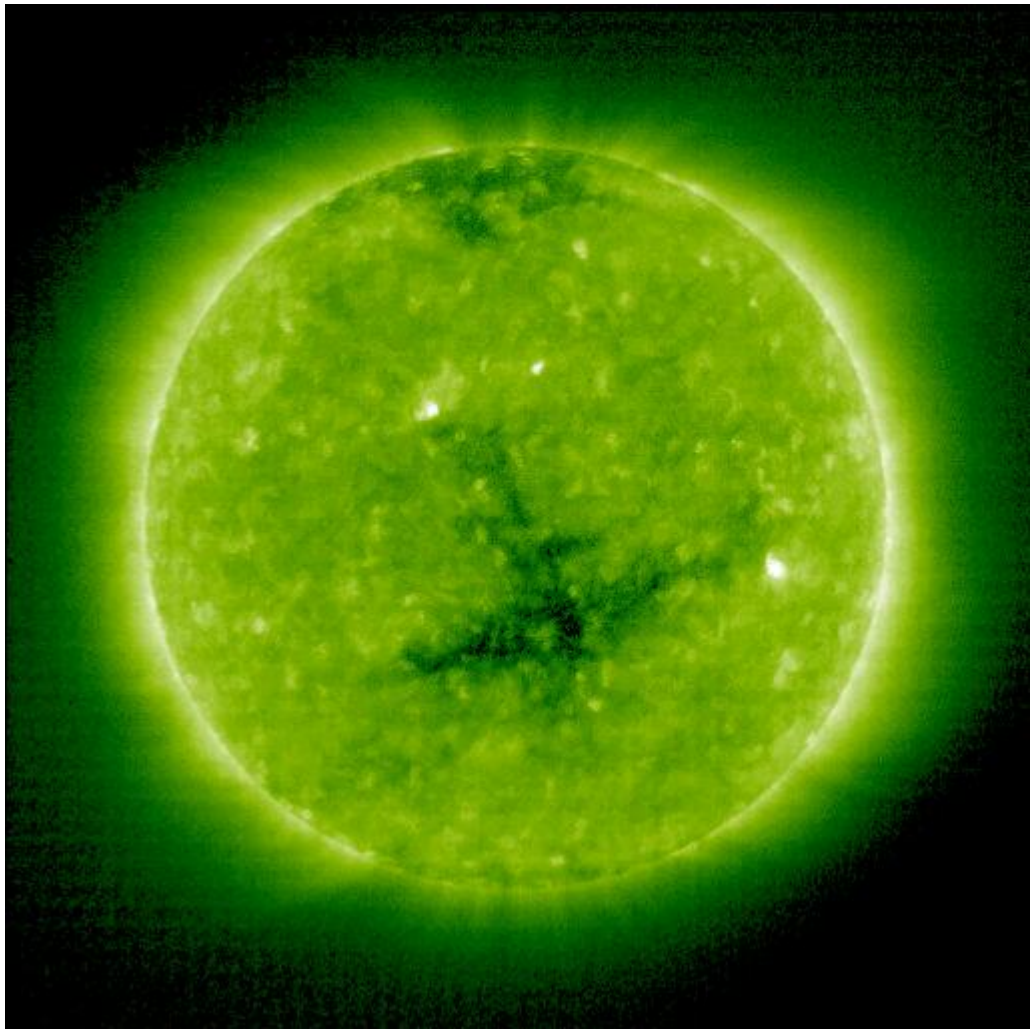
=2.48 days

=> 30 Sept



- Geomagnetic conditions –Solar wind parameters

At time of leaving



STEREO B as an appetizer