NASA's STEREO Mission

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The STEREO Mission

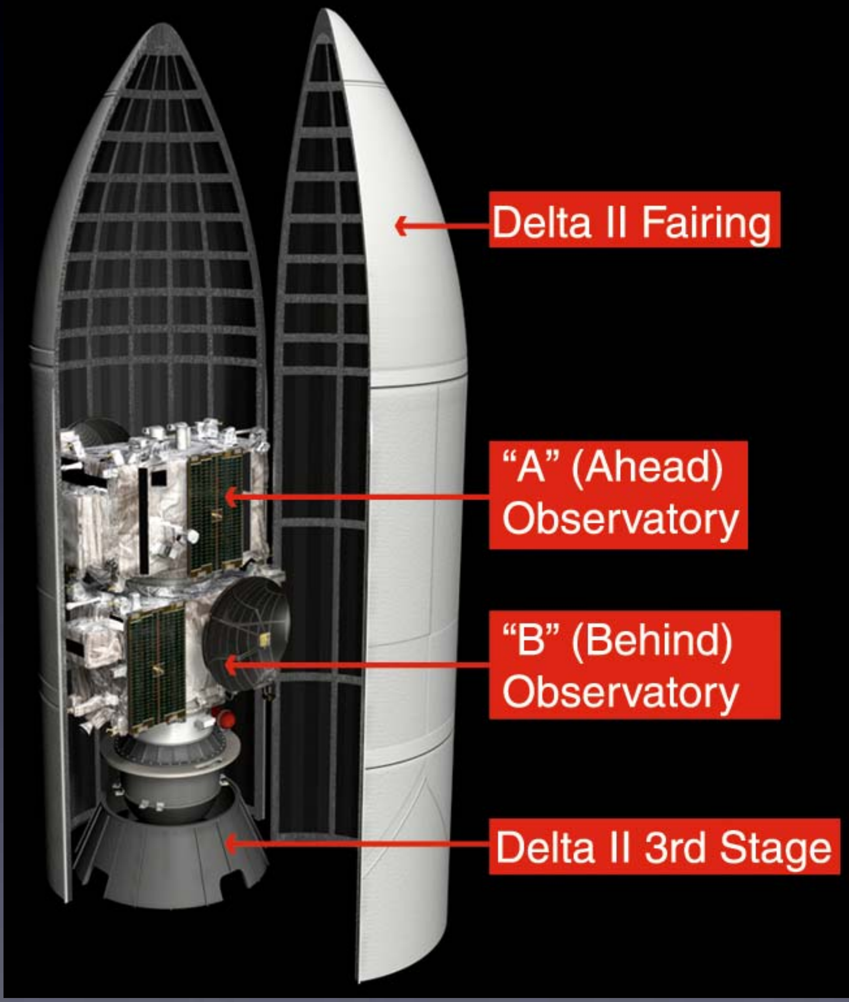
- Science and technology definition team report, 1997 December:
  - Understand the origin and consequences of coronal mass ejections (CMEs)
  - Two spacecraft in earth-leading and -lagging orbits near 1 AU (Solar Terrestrial Probe line)
  - “Beacon” mode for near-realtime warning of potentially geoeffective events

Level 1 Requirements

- Understand the causes and mechanisms of CME initiation
- Characterize the propagation of CMEs through the heliosphere
- Discover the mechanisms and sites of energetic particle acceleration in the low corona and the interplanetary medium
- Develop a 3D, time-dependent model of the magnetic topology, temperature, density, and velocity structure of the ambient solar wind

Implementation

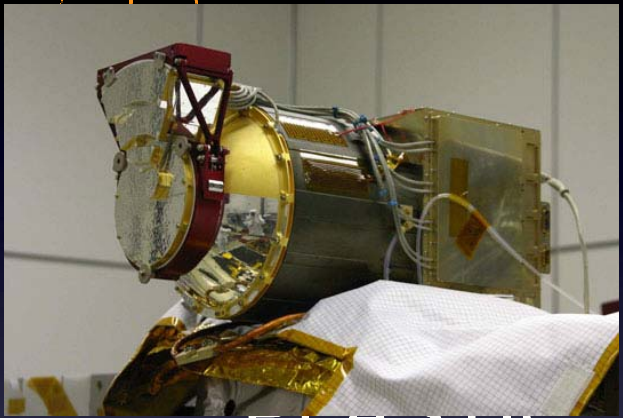
- Two nearly identical spacecraft launched by a single ELV
  - Bottom spacecraft in stack has adapter ring, some strengthening
  - Spacecraft built at Johns Hopkins University APL
- Four science investigations



Scientific Instruments

- S/WAVES - broad frequency response RF detection of Type II, III bursts
- PLASTIC - solar wind plasma and suprathermal ion composition measurements
- IMPACT - energetic electrons and ions, magnetic field
- SECCHI - EUV, coronagraphs and heliospheric imagers (surface to 1.5 AU)

Instrument Hardware



PLASTIC

IMPACT boom

IMPACT boom

SECCHI SCIP

SECCHI HI

S/WAVES

Orbit Design

- Science team selected a separation rate of 22° $year^{-1}$ from the Sun-earth line
- Implemented by launching the spacecraft into slightly different phasing orbits with apogees beyond the moon's orbit
  - Use moon for gravity assist to achieve heliocentric orbits with desired separation rate

Launch and Transfer

- Spacecraft launched 2006 October 25 (26 UT)
  - Delta II 7925-10L from CCAFS
- Ahead spacecraft transferred to heliocentric orbit 2006 December 22
- Behind in heliocentric orbit 2007 January 21
- To see where STEREO A and B are today, use:
  - http://stereo-ssc.nascom.nasa.gov/where.shtml

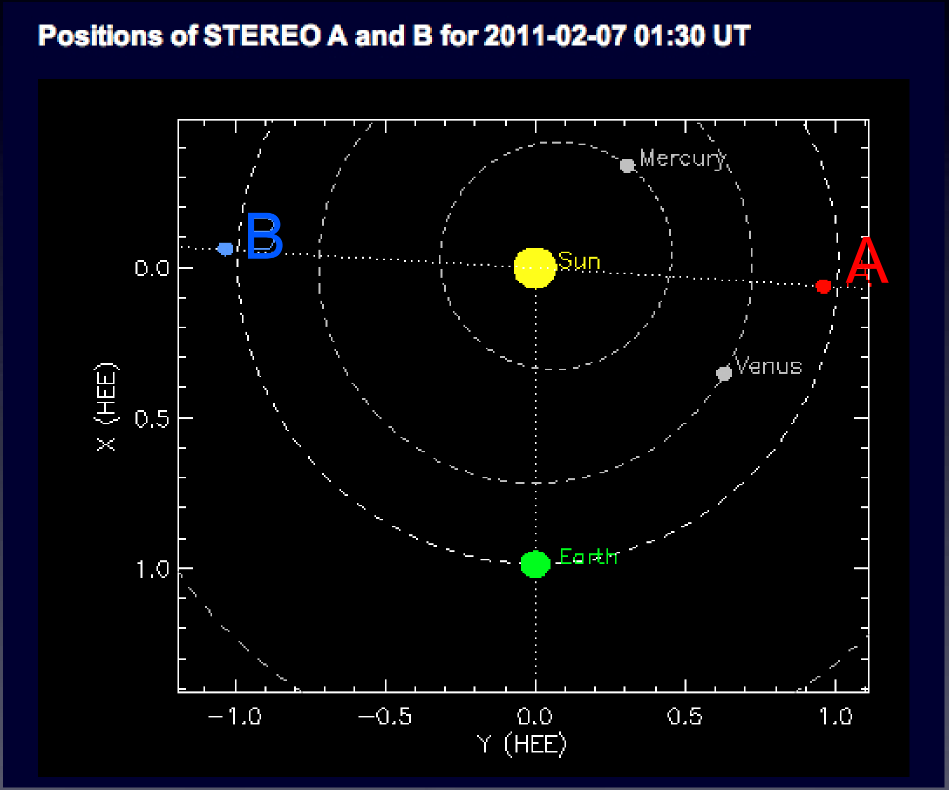
A unique view (during early heliocentric ops)

- Lunar transit of the Sun, 2007 February 25

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

An Aside

- Question: What will happen on 2011 February 6 at 7:30 PM CST?
    - Super Bowl XLV
    - STEREO spacecraft will be in opposition



Space Weather Information from STEREO (I)

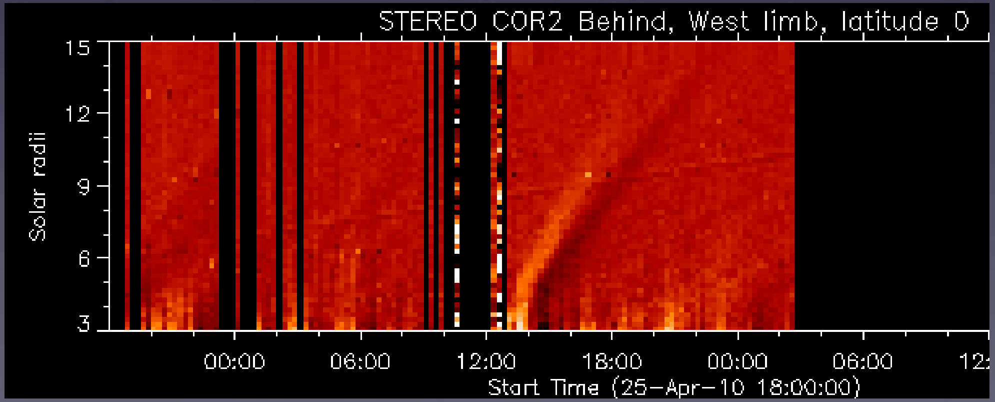
- Beacon mode
  - Low rate (633 bps)
  - Informal antenna partners
    - Arranged in partnership with NOAA SWPC
    - Currently: Bochum and Kiel (radio *amateurs* in Germany), Toulouse, France (CNES), Koganei, Japan (NIISC)
    - Don’t quite span the globe: need more!
      - Large gap between 139°E and 7°E
      - Need site(s) in Pacific, mainland US

Beacon mode data availability

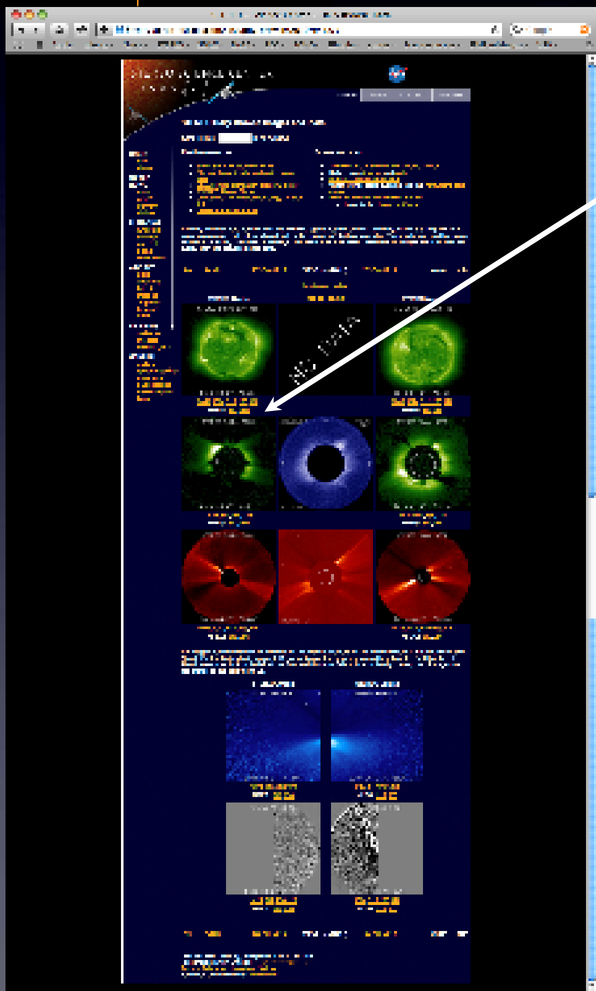
- Like all STEREO data, under the NASA Heliophysics Data Management Policy, the beacon mode data are publicly available as soon as they hit the ground and are reformatted (< 5 min.)
  - from the STEREO Science Center (SSC)
  - Images
    - http://stereo-ssc.nascom.nasa.gov/browse/
  - *In situ* and radio
    - http://stereo-ssc.nascom.nasa.gov/browse/insitu.shtml

What do we get in beacon mode?

- SECCHI images reduced to 256 x 256 pixels and mercilessly compressed
- Subsampled solar wind and energetic particle data (PLASTIC, IMPACT)
- Subsampled RF data from S/WAVES
- Links to higher level beacon-mode products, such as "J-plots"



Beacon mode data

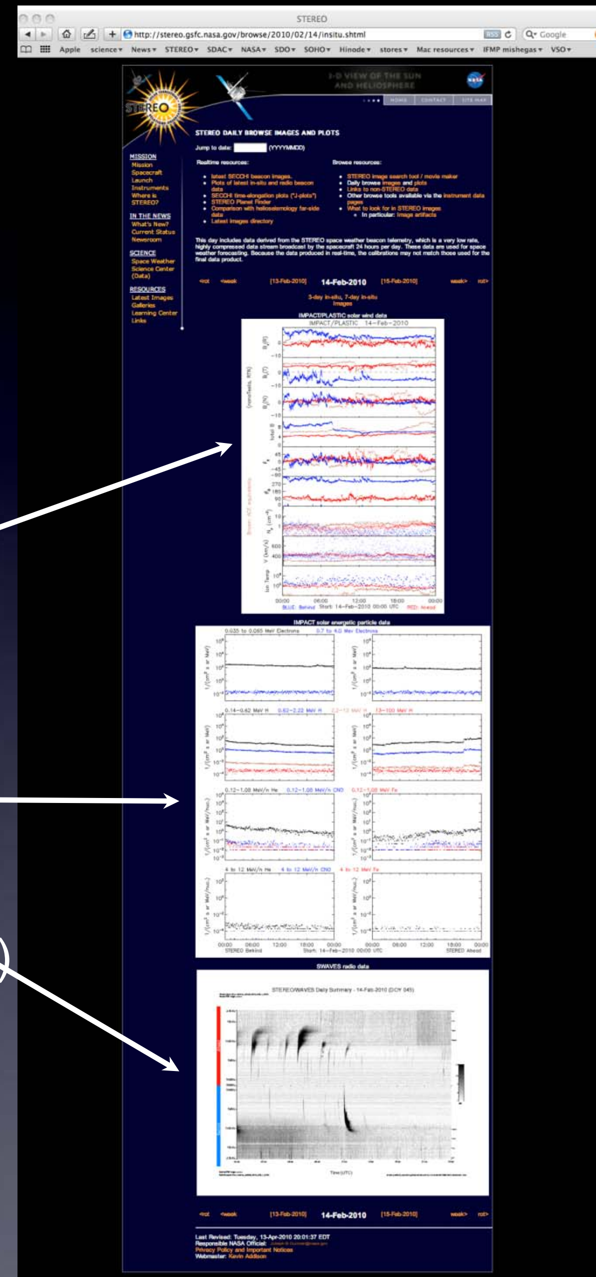


Images, links to movies

Solar wind plasma and magnetic field data

Energetic particles

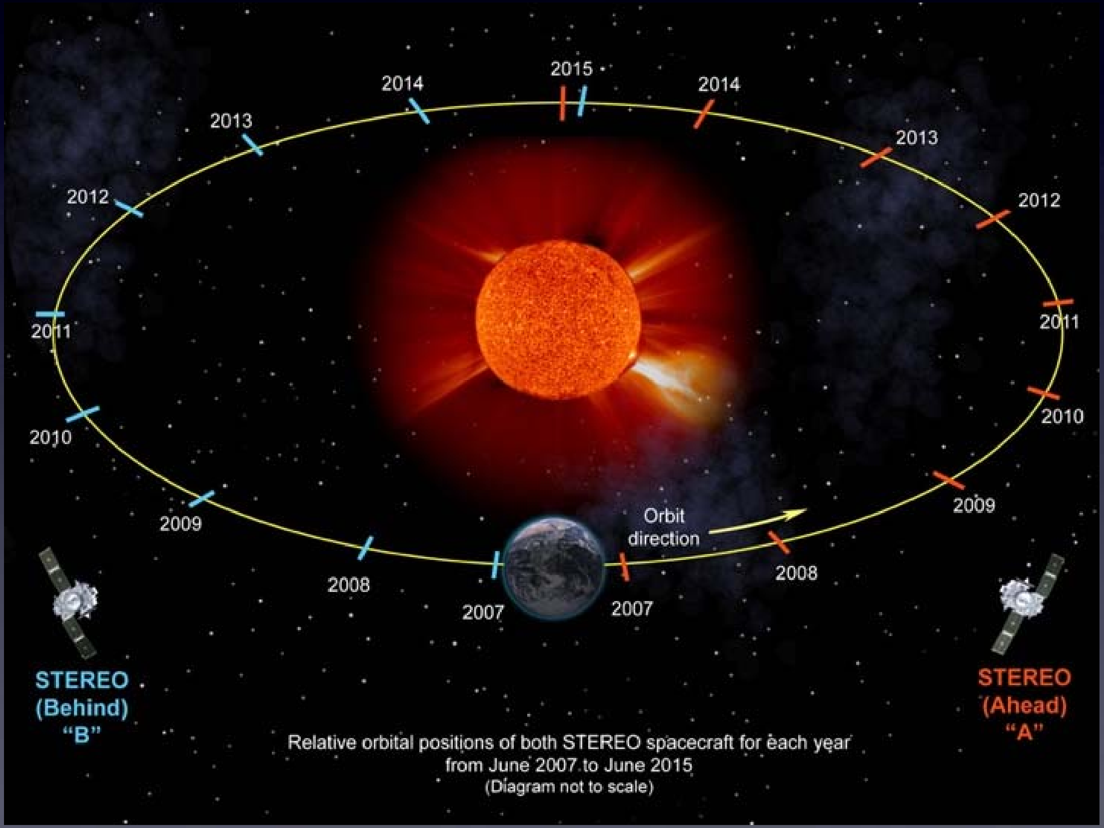
RF data (2.5 kHz - 16 MHz)



How long can we keep this up?

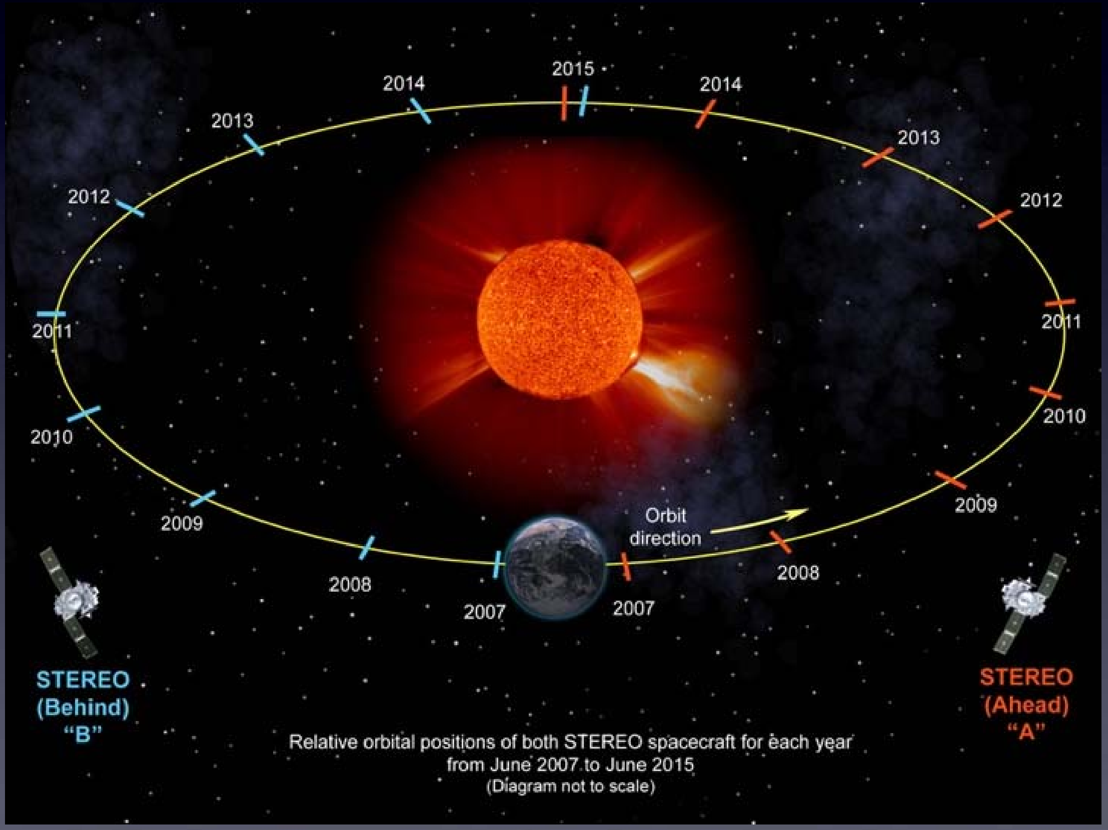
Spacecraft will pass one another on the far side of the Sun in 2015

- Will need to rename them Abaft and Before, or something like that



How long can we keep this up?

Telemetry rate (kbps)	Date (Behind)	Date (Ahead)
720	2007/01/22	207/01/22
480	2008/09/15	2008/10/13
360	2009/09/08	2009/08/17
240	2009/12/07	2010/04/26
120	2010/11/15	2011/04/11
96	2011/09/19	2011/09/26
30 (?)	TBD	TBD



Beacon mode?

- Beacon mode will need to switch to a different encoding scheme to maintain data rate with increasing distance
  - Will create issues with some receiving sites
  - Will work with NOAA SWPC to resolve
- Some receiving sites may not have sufficient link margin to obtain data from ~ 2 AU

What have we learned?

- We can model CME propagation
  - in 2 dimensions, geometrically
  - in 3 dimensions, using a forward model

Geometric triangulation using J-maps

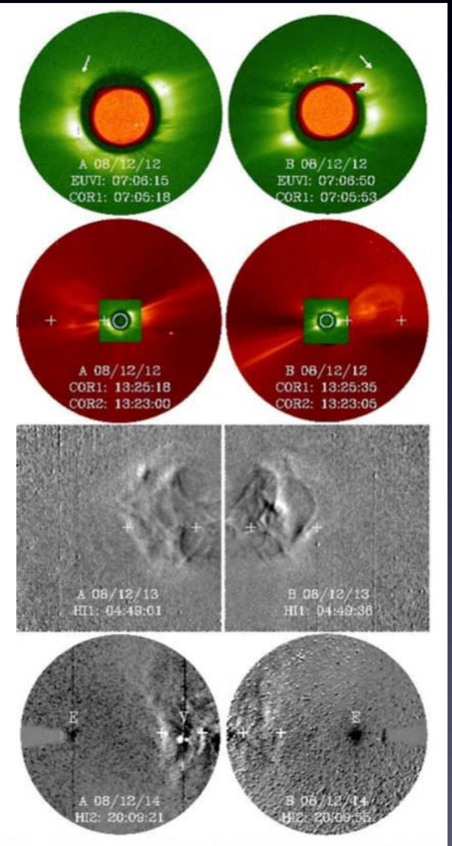


Figure 2. CME evolution observed by STEREO A (left) and B (right) near simultaneously. From top to bottom, the panels display the composite images of EUVI at 304 Å and COR1 showing the nascent CME (indicated by the arrow), combined COR1 and COR2 images of the fully developed CME, and running difference images from HI1 and HI2 when the CME is far away from the Sun. The crosses mark the locations of the two features obtained from Figure 3. The positions of the Earth and Venus are labeled as E and V.

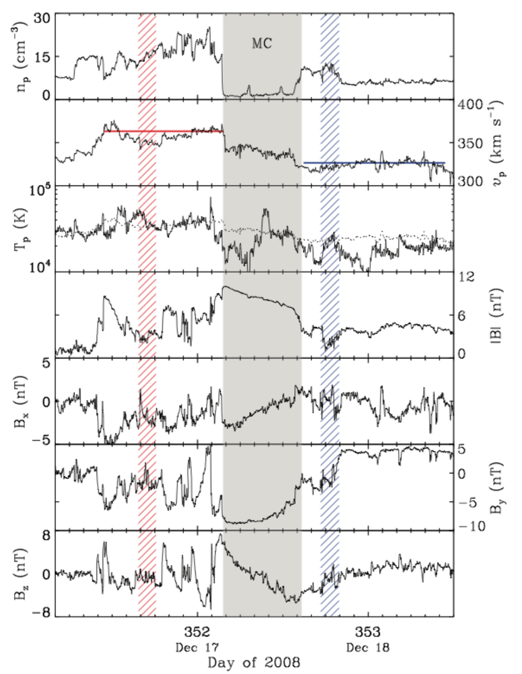
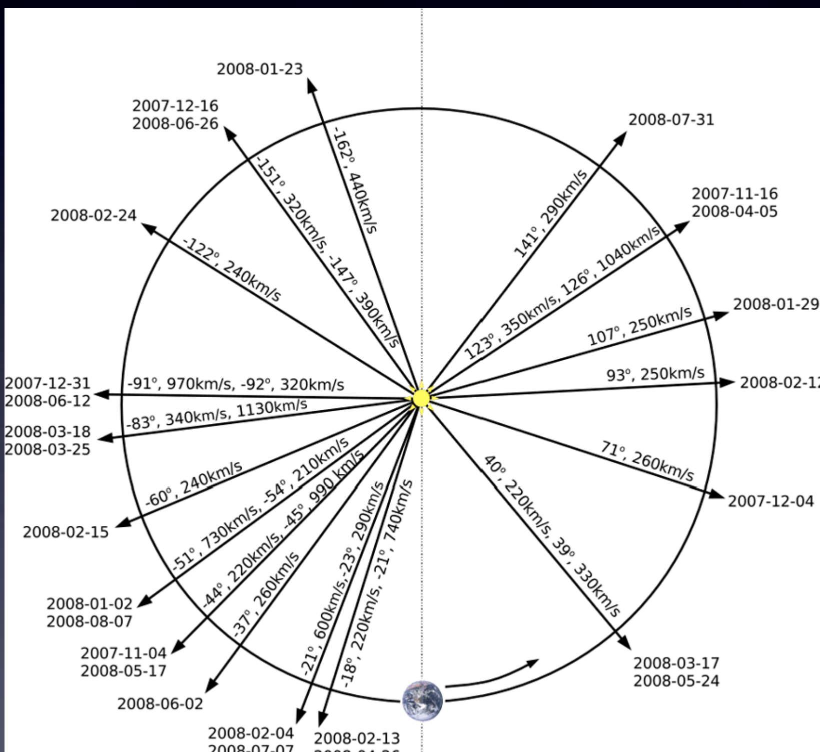


Figure 5. Solar wind plasma and magnetic field parameters across the MC observed at WIND. From top to bottom, the panels show the proton density, bulk speed, proton temperature, and magnetic field strength and components, respectively. The shaded region indicates the MC interval, and the hatched area shows the predicted arrival times (with uncertainties) of features 1 (red) and 2 (blue). The horizontal lines mark the corresponding predicted velocities at 1 AU. The dotted line denotes the expected proton temperature from the observed speed.

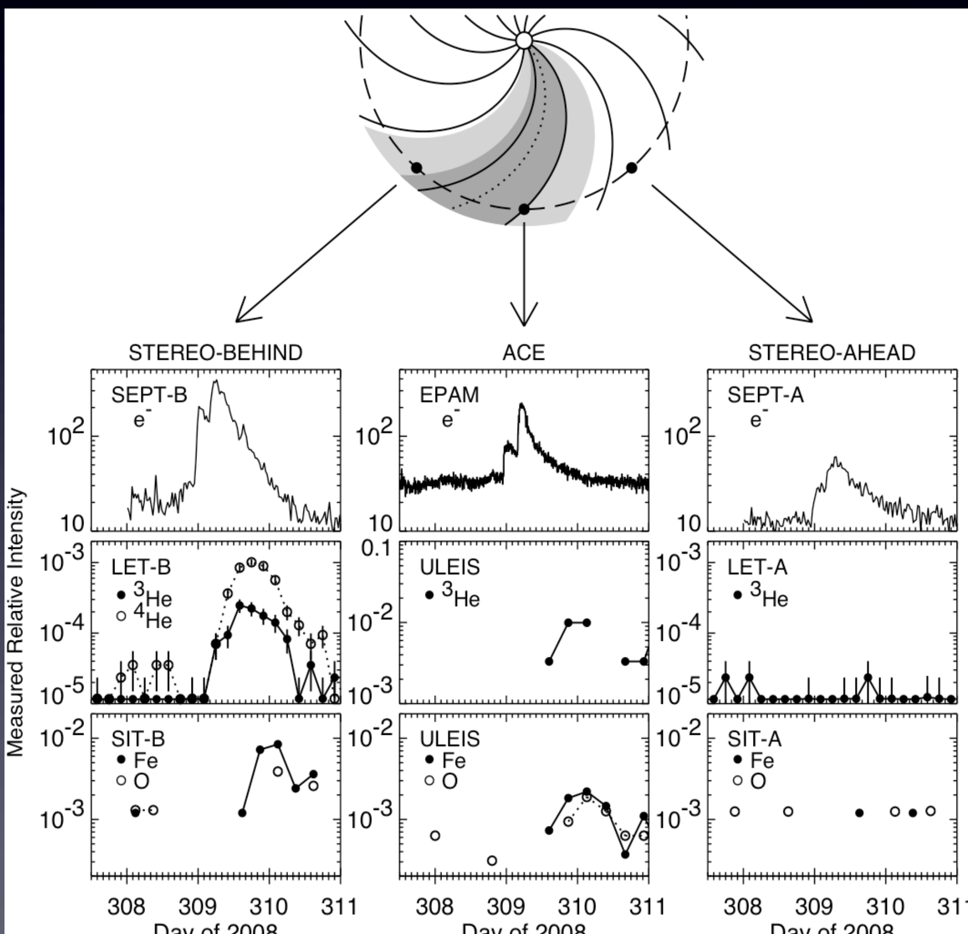
- *Liu et al. 2010, ApJ, 710, L82*
- *Able to predict speed, arrival time of at least two features in a CME*

Forward modeling

- Thernisien *et al.* 2009, Solar Phys., 256, 111
- Assume flux-rope geometry
- Works well for 17 events considered
- Implies that nearly all CMEs are flux ropes
- Can predict flux rope orientation → geoeffectiveness



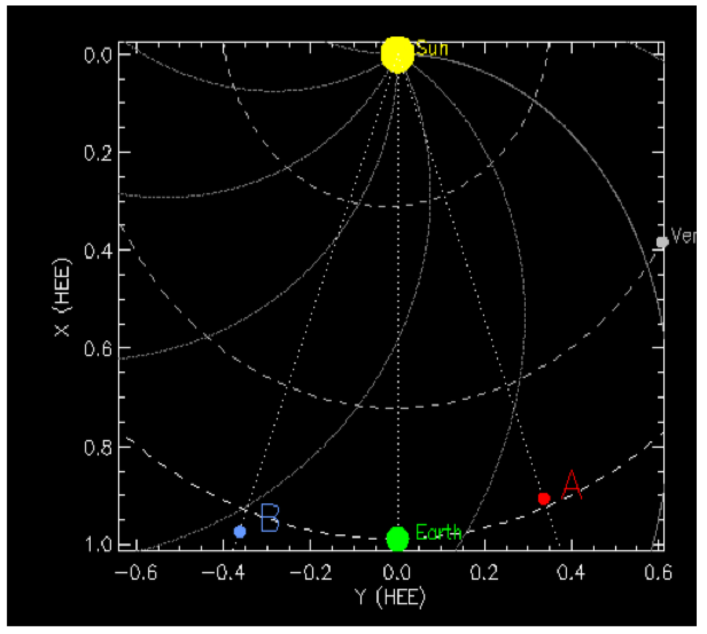
Angular extent of energetic particle events (I)



- Wiedenbeck *et al.* 2010, Proc. 12th Solar Wind Conf.
- STEREO A, B; ACE measurements show impulsive electron profile over > 80° in heliolongitude
- 2010/02/12 event was visible when

Complexity of Magnetic Cloud field (CIR interaction)

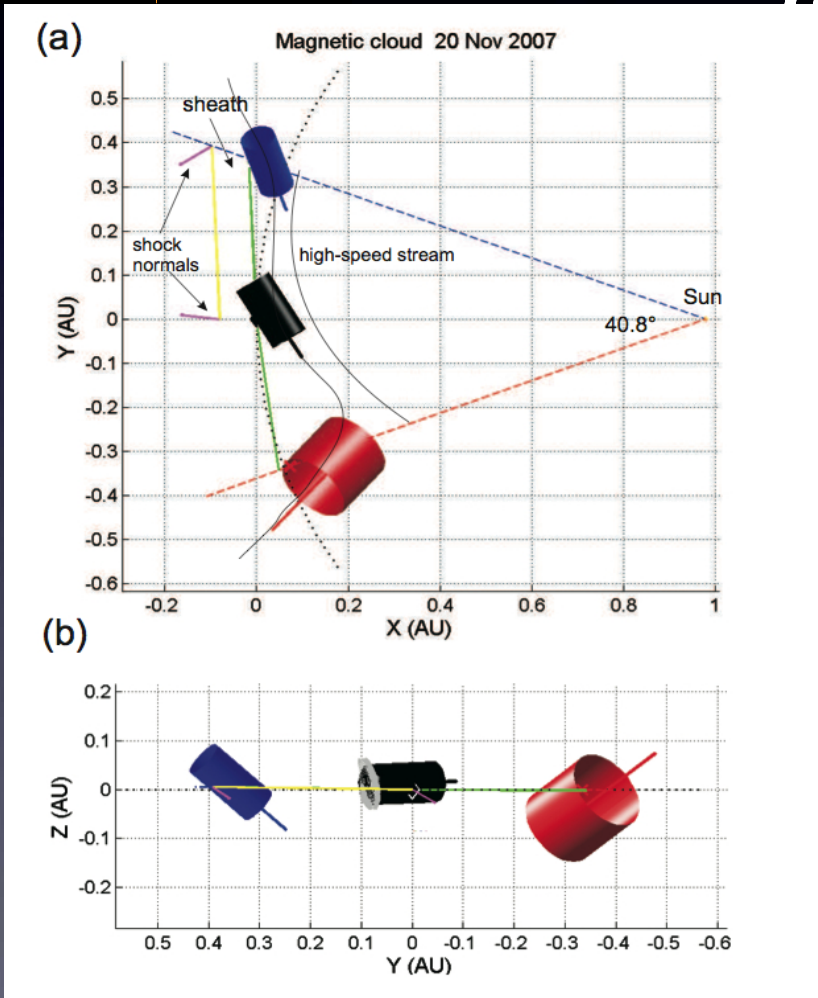
- 2007 November 19 - 21



- Interaction of a CIR and a magnetic cloud near the heliospheric current sheet

- Farrugia *et al.* 2010, submitted to JASTP (special CME/ICME issue)
- "Double-dip" event in Dst (peak of -100 nT)

Complexity of Magnetic Cloud field (CIR interaction)



- Reconstructions from three measurements (B, WIND, A) appear to show, from E to W, magnetic cloud:
  - after interaction with CIR
  - interacting with CIR, and
  - before interacting with CIR

And I’m leaving out....

- Dust impacts
- High-amplitude whistler waves in solar wind halo electrons
- and about 300 other refereed journal articles

A Unique Set of Viewpoints on Solar and Heliospheric Activity

Movie sequence from all four SECCHI telescopes
on both STEREO spacecraft
2010 April 3 - 12

A Unique Set of Viewpoints on Solar and Heliospheric Activity

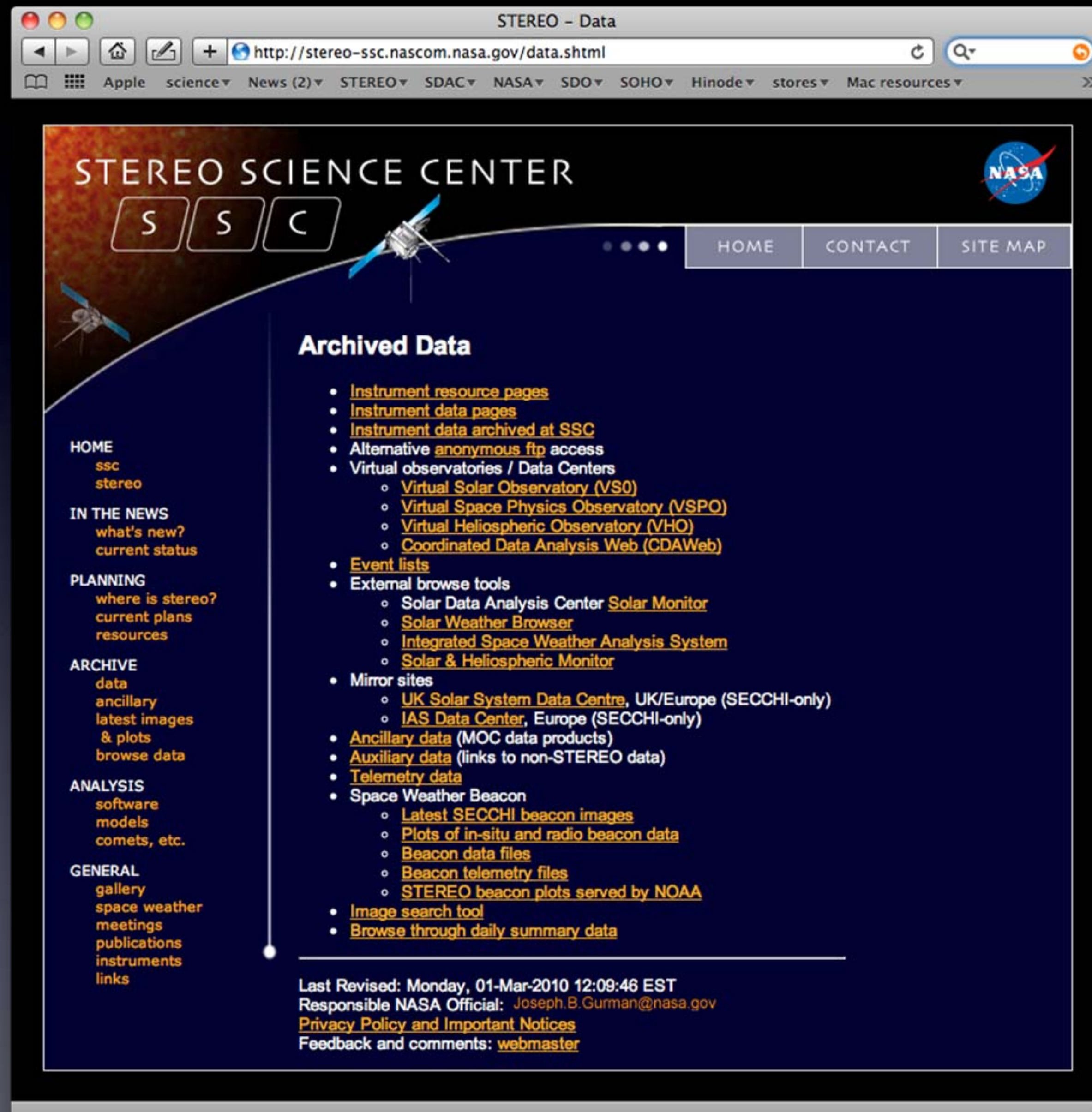
QuickTime™ and a
YUV420 codec decompressor
are needed to see this picture.

Full-resolution telemetry

- Acquired through Deep Space Network sites only
- Reformatted and available online in ~ 2 days
  - Longer for some higher level data products
- Available from the STEREO Science Center:
  - http://stereo-ssc.nascom.nasa.gov/data.shtml
  - Includes “instrument resource pages” link

STEREO data

- Instrument resource pages
- Anonymous ftp access
- Data at PI institutions and elsewhere
- Access *via* virtual observatories
- Ancillary data



A sample “instrument resource” page (SECCHI)

- File contents description
- User’s guide
- Contact info