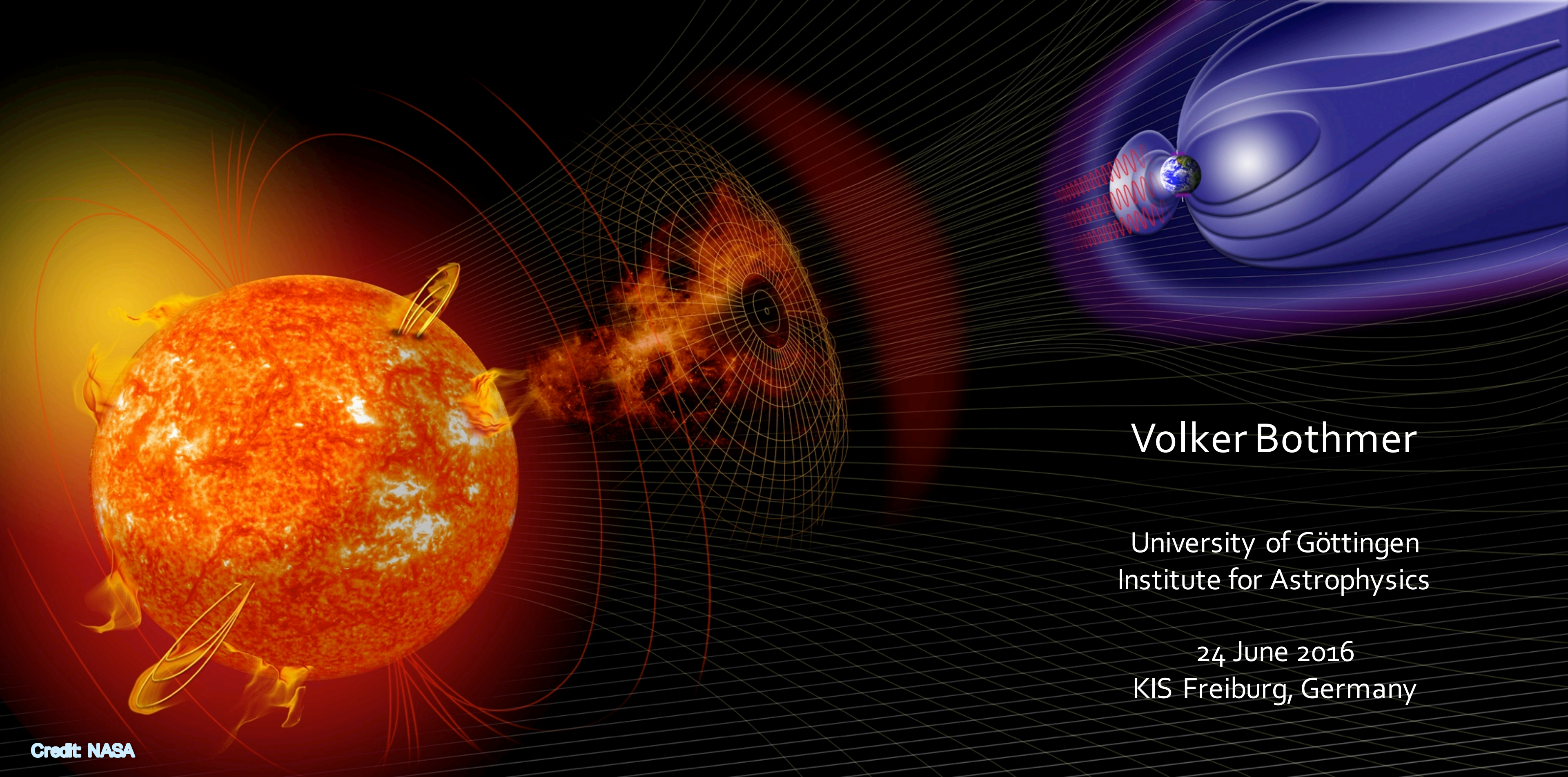


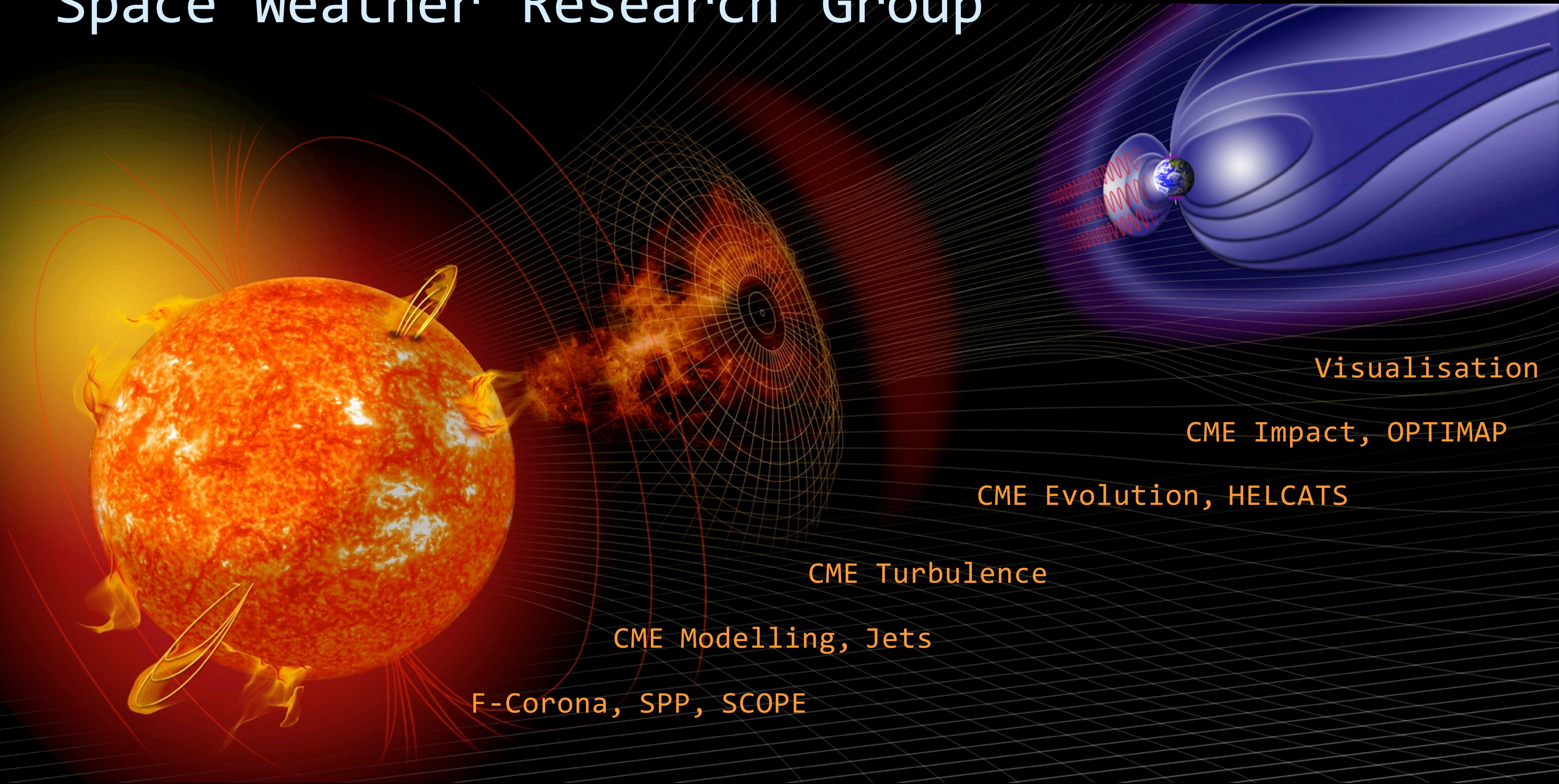
Volker Bothmer

University of Göttingen
Institute for Astrophysics

24 June 2016
KIS Freiburg, Germany

CORONAL MASS EJECTIONS IN THREE DIMENSIONS – PHYSICS AND SPACE WEATHER FORECAST

University Göttingen – Sun, Heliosphere and Space Weather Research Group

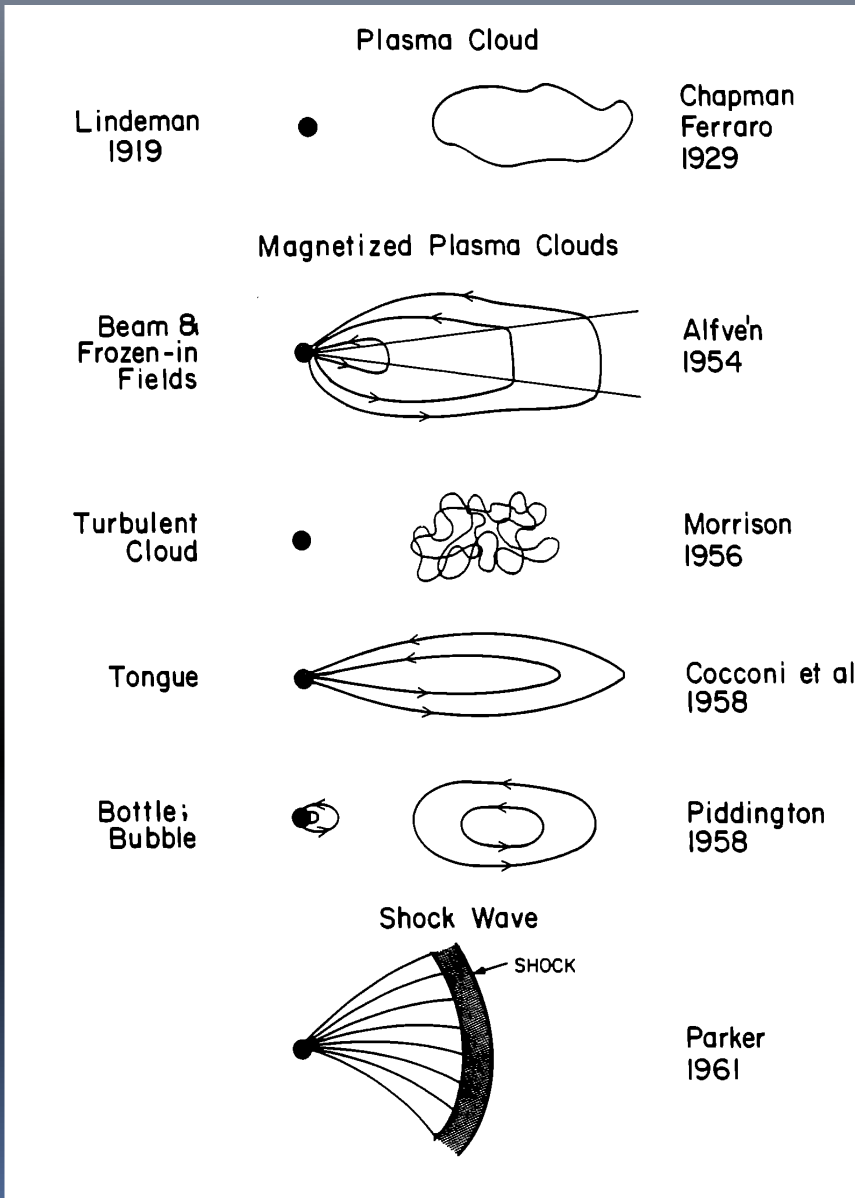


J. Rodmann J. Hinrichs N. Mrotzek E. Bosman A. Pluta M. Venzmer L. Volpes N. Sachdeva J. Florczak C. Schöpper J. Achenbach F. Schindler

Outline

1. Introduction – Coronal Mass Ejections in the Pre-STEREO Era (sensed remotely and in-situ)
2. STEREO Observations of CMEs
3. CME Origin and Evolution in 3D
4. Space Weather Forecast – The AFFECTS Project
5. Summary & Conclusions

Early Ideas about the Structure of Solar Ejecta



George Francis Fitzgerald (1892) proposed that "a sunspot is a source from which some emanation like a comet's tail is projected from the Sun…"and asked "is it possible then that matter starting from the Sun with the explosive velocities we know possible there, and subject to an acceleration of several times solar gravitation, could reach the Earth in a couple of days?".

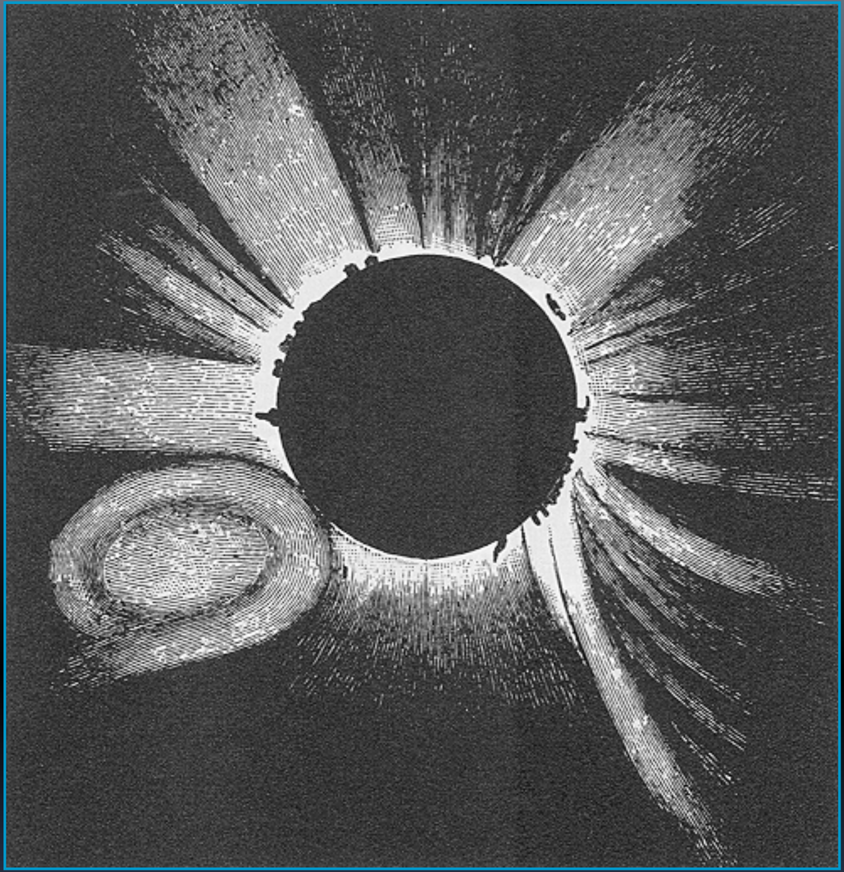
Oliver Lodge (1900) suggested that magnetic storms are caused by " . . . a torrent or flying cloud of charged atoms or ions".

A magnetized particle cloud was proposed in 1959 by Thomas Gold.

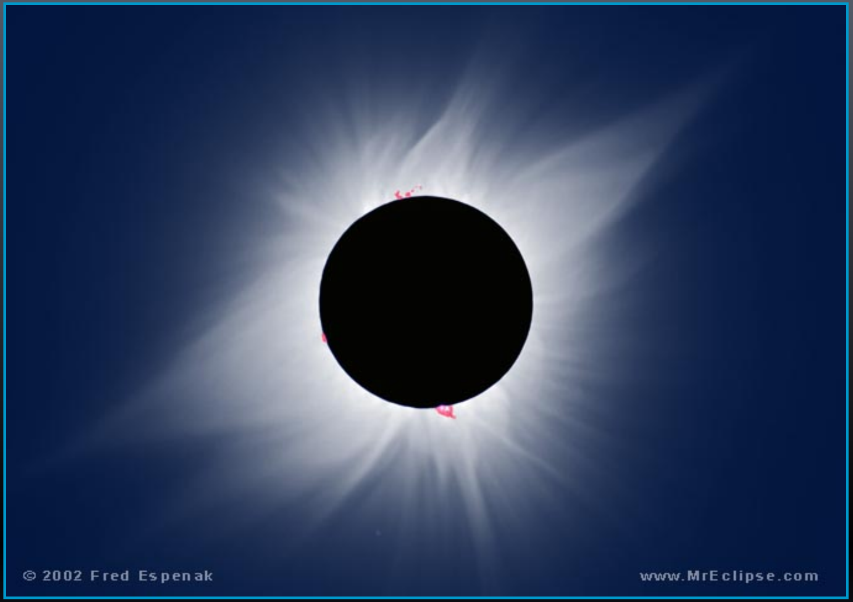
No Flux Rope has been Proposed !

Burlaga, 1991

Historical CME Observation?

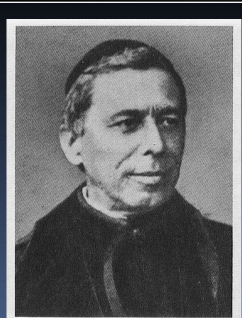


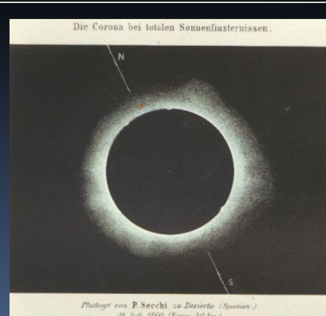
Eclipse Drawing by the German astronomer E. Tempel on 18 July 1860 (from Eddy 1974)



Total solar eclipse of 1991 July 11th courtesy F. Espenak

The corona as observed during the total solar eclipse in March 2006





Angelo Secchi (1818-1878)

Overall brightness from different components ($B_K \approx 10^{-6}$ B_0):

K(Kontinuum)-Korona (Photospheric Light scattered by free electrons (Thomson-Scattering), $I \sim N_e$, polarised)

+

F-(Fraunhofer)-Korona (Zodiakal-Light, Rayleigh-Scattering by dust particles, esentially unpolarised, continuum spectrum)

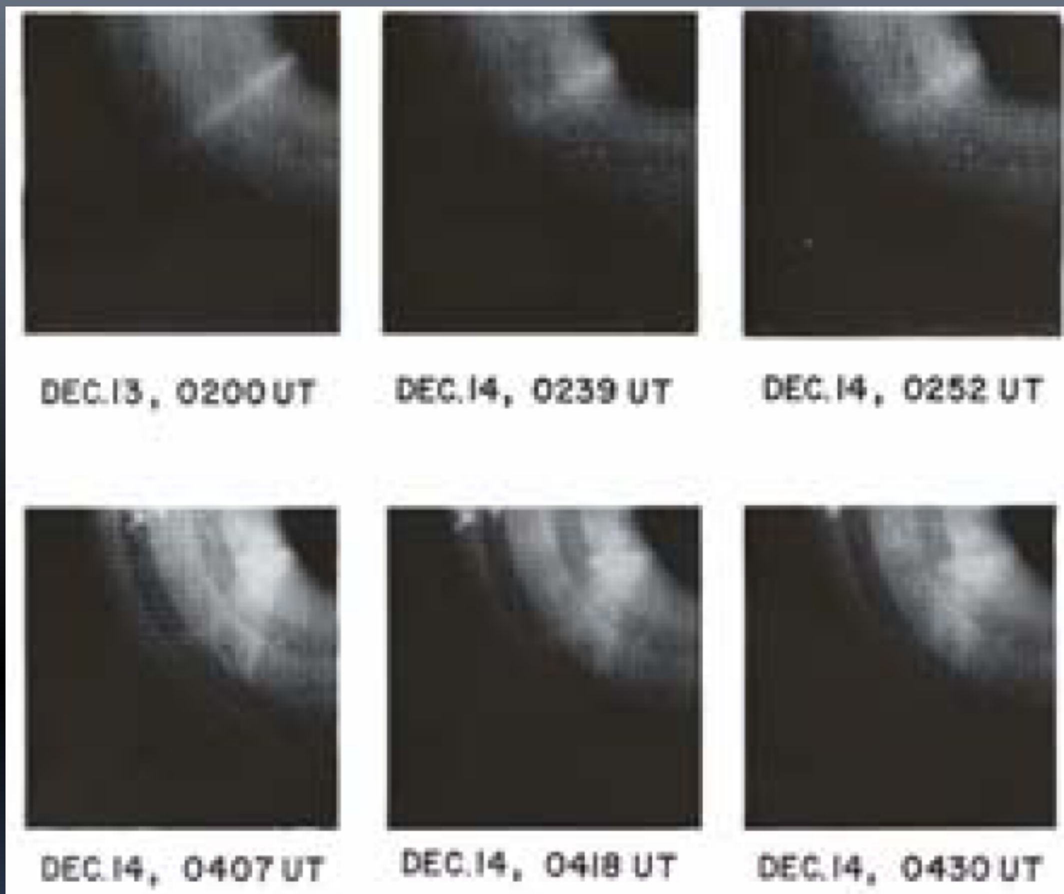
+

E(Emission Line)-Korona, e.g. 530.3 nm FeXIV, 28.4 nm Fe XV, polarised)

+

T-Korona (thermal emission from dust particles in IR)

On 14th December 1971: OSO 7 images of the first „good“ observed CME



On 13-14 Dec 1971, a bright streamer in the southeast participated in the “coronal transient” that traveled outward at over 1000 km/s (Tousey, 1973)

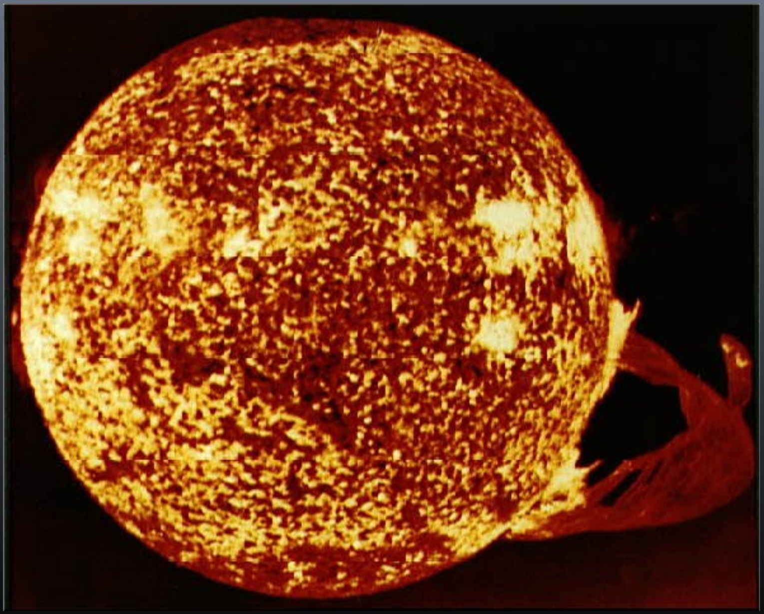
NASA Orbiting Solar Observatory 7 (1971-1973):

3.0 - 10 R_s; SEC Vidicon detector (3 arcmin resolution)

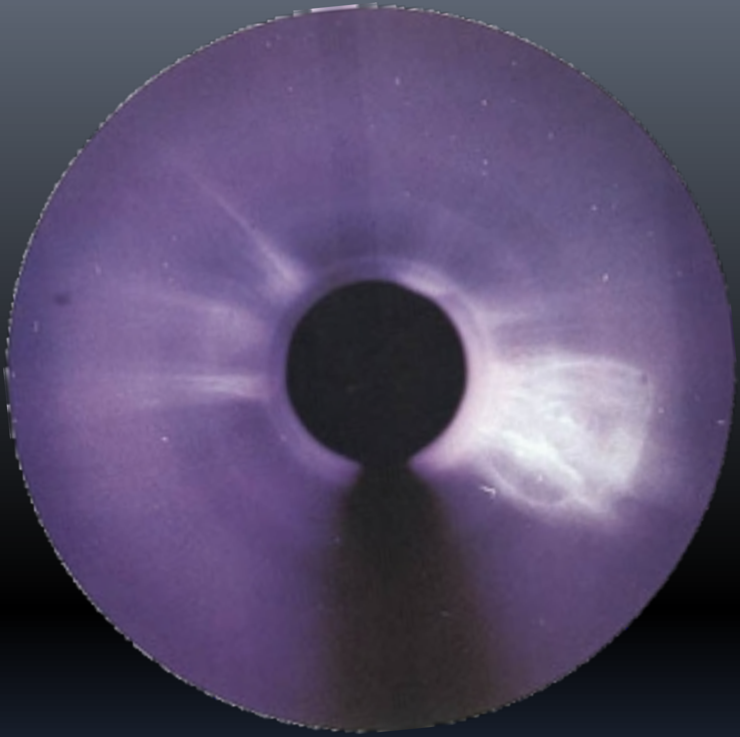
Weakness - 4 full images per day (~30 CMEs observed)

(from Howard, 2006)

1973-1974: Skylab Observations



A CME Observed with the Coronagraph on board Skylab in 1973

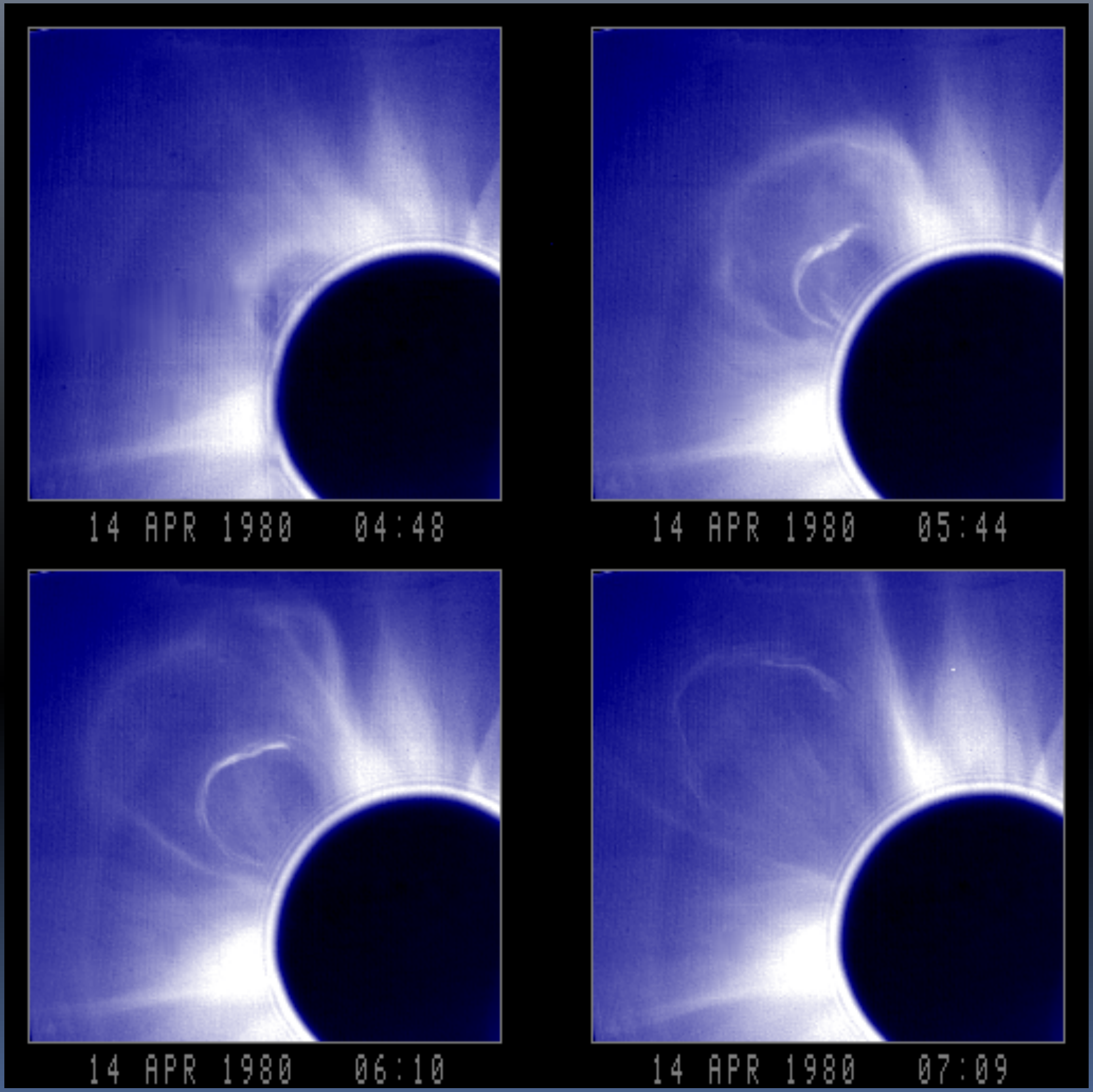


- 2.0 - 6 solar radii; Film detector (5" resolution)
- ~100 CMEs observed, established importance (and beauty); statistics; associations
- Weakness: limited film capacity, 3 short duration missions

What is a CME?

A new, discrete, bright feature appearing in the field of view of the coronagraph and moving outwards over a period of minutes to hours (Munro et al., 1979)

SMM Observations of Three Part Structured CMEs



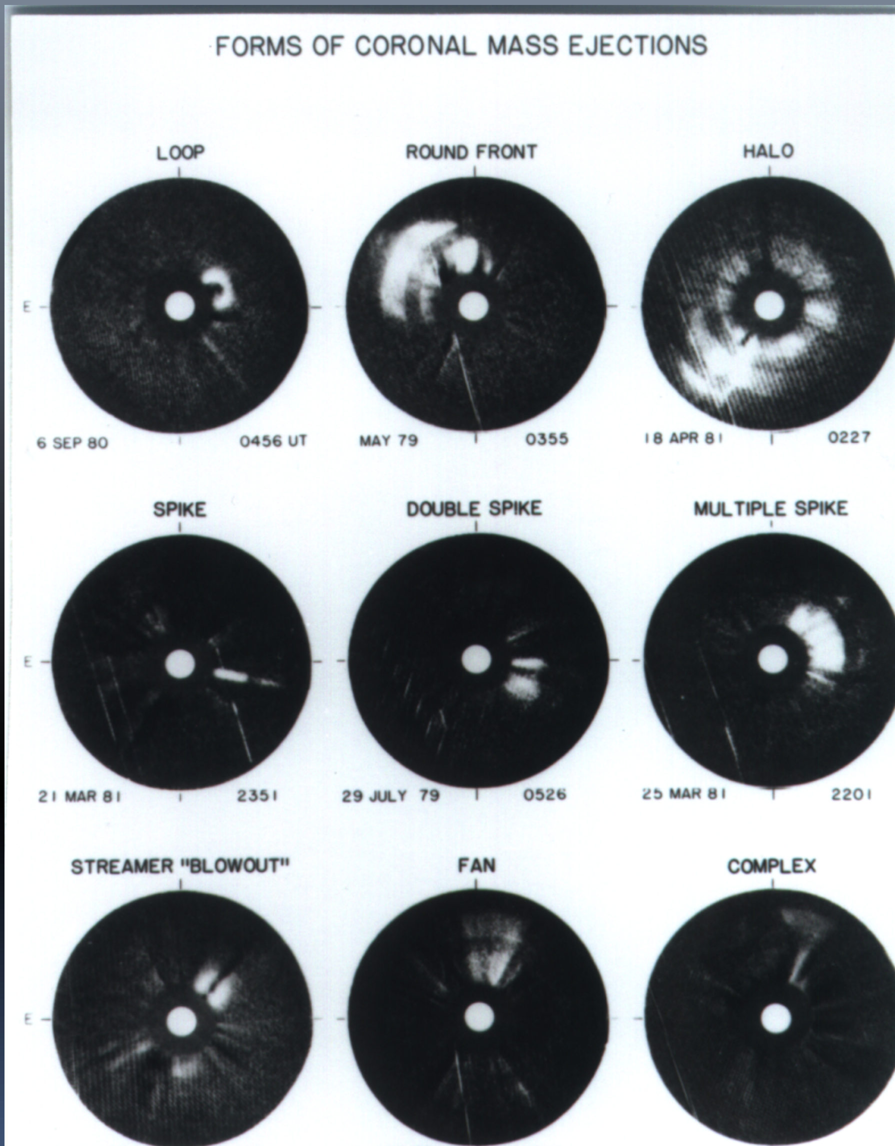
Hundhausen, 1980

NASA Solar Maximum Mission (SMM) (1980, 1984-1989)

- 1.6 - 6 solar radii
- 5 cm SEC Vidicon detector, (30 arc second resolution)
- CME statistics, 3-part structure to CMEs Weakness: quadrant field of view, cadence

(Howard, 2006)

1979-1985: Solwind Observations



Howard et al. 1984

USAF P78-1 (Solwind 1979-1985)

Same characteristics as OSO-7:

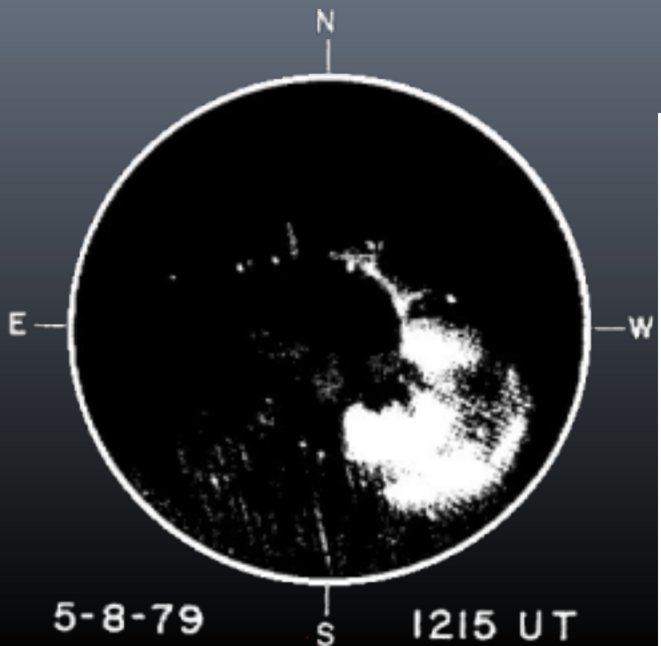
CME Statistics, solar cycle dependence, relation to shocks, first halo event

German Helios mission presented in-situ measurements of solar wind in quadrature to Sun-Earth line and had a zodiacal light photometer that provided the first detection of a CME in the inner heliosphere

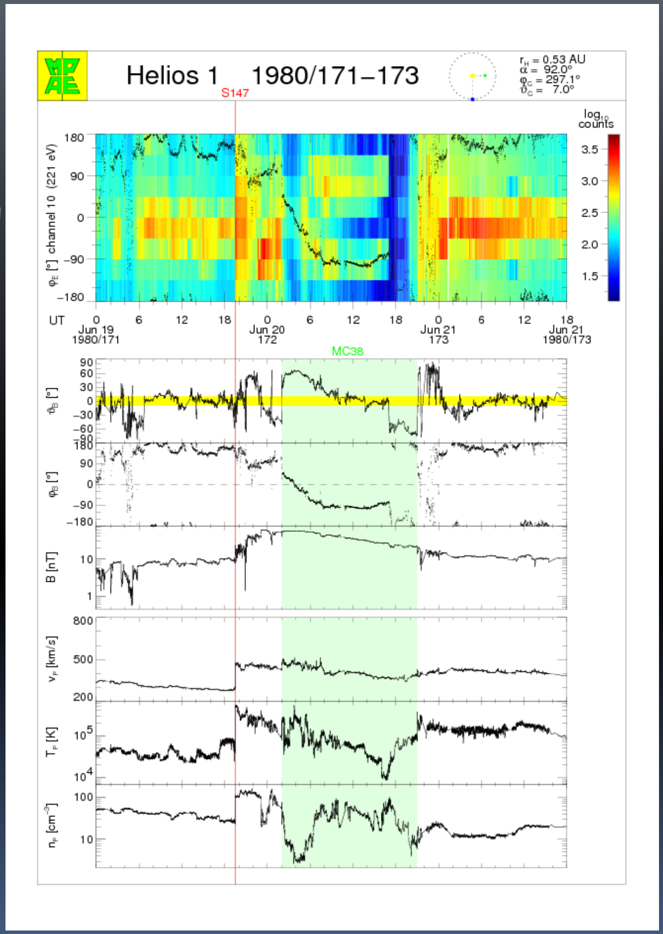
Weakness: limited spatial resolution, field of view

(Howard, 2006)

Correlated Analysis of Remote Sensing and In-Situ Observations with P78-1 and Helios 1 & 2

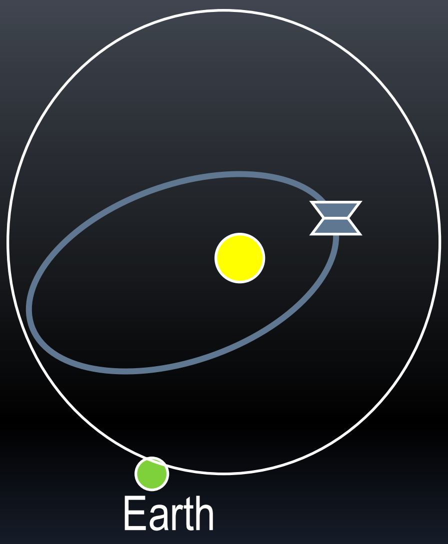


Solwind Coronagraph on board P78-1 (1979-1985)



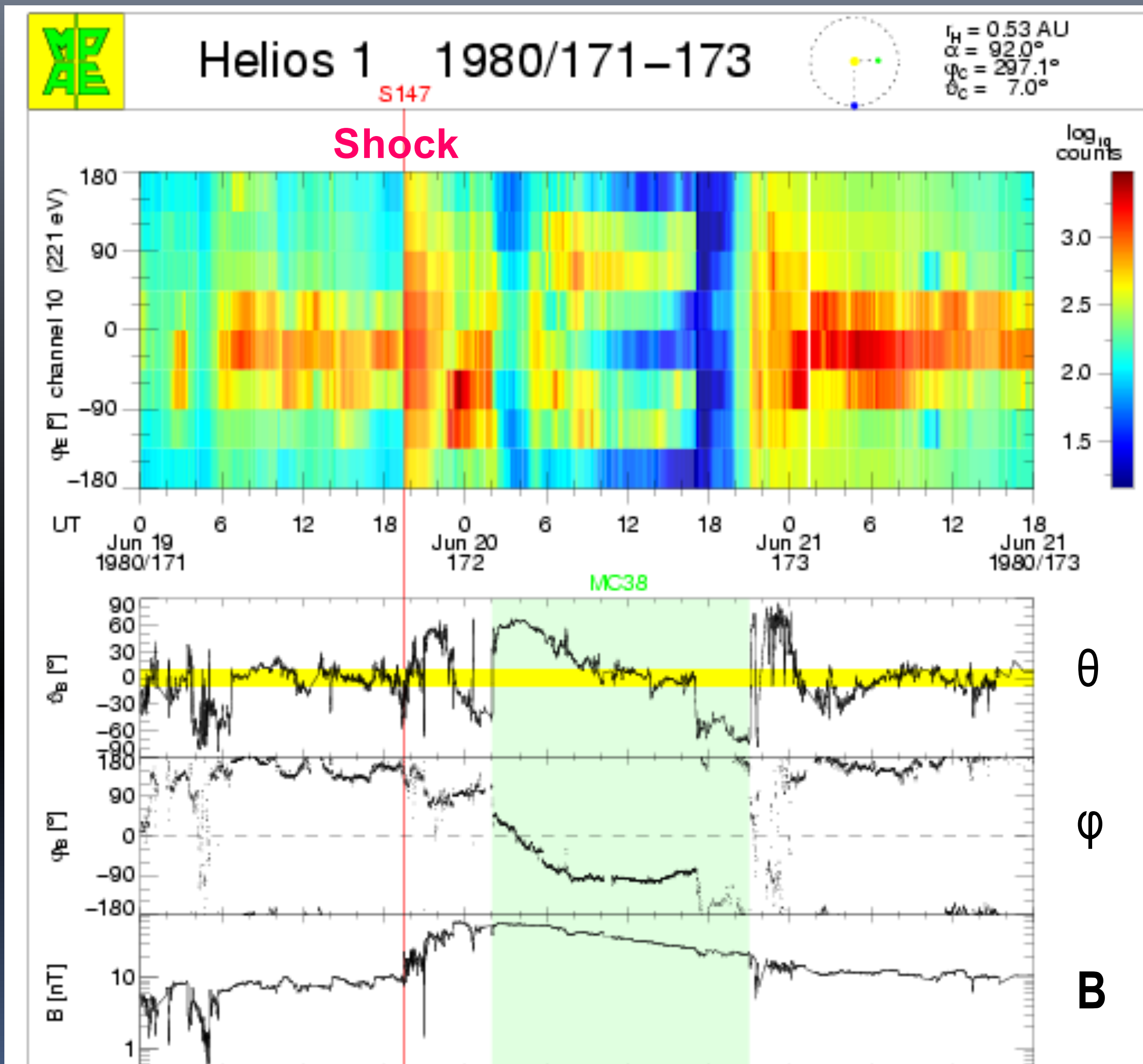
Burlaga: Magnetic Clouds

Helios-Orbit: 0.29 - 1 AU



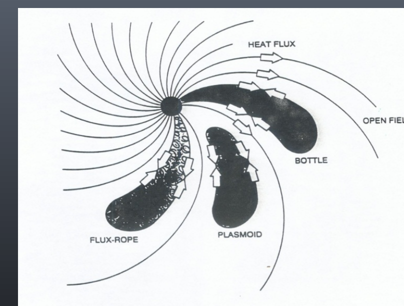
The Helios 1 & 2 Spacecraft (1974-1986)

A Magnetic Cloud (Helical Flux Rope CME in the Solar Wind) Measured by Helios 1 following a S/C Directed CME



1 Day

Suprathermal Electrons (E=221 keV)



Phillips et al., Solar Wind 7, 1992

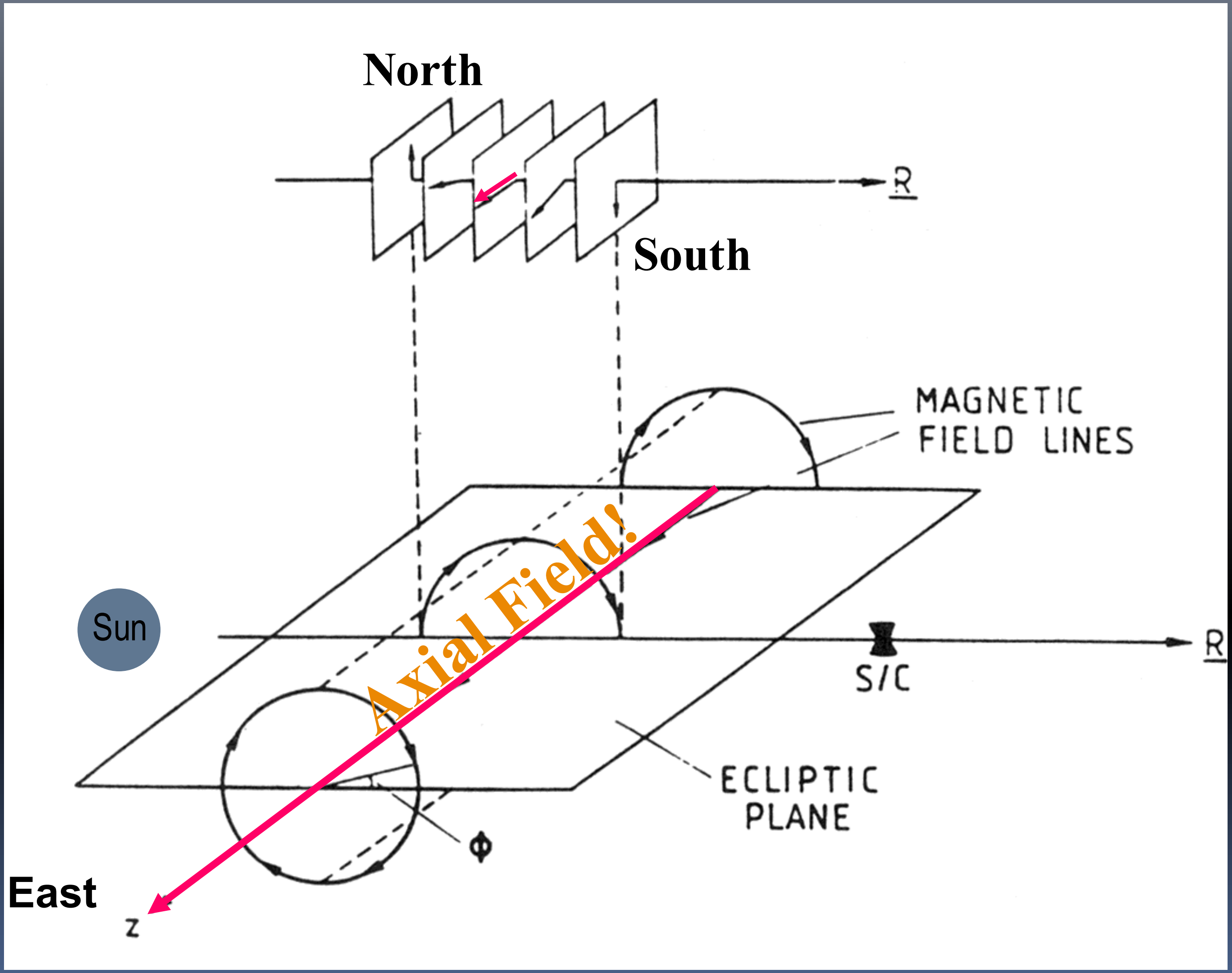
IMF Polar (NS) Direction

IMF Azimuthal (EW) Direction

IMF Strength

Bothmer, Solar Wind 9, 119-126, 1999

Explanation for the Magnetic Structure of a CME in the Solar Wind



In Principal,

the Cylinder can

be Arbitrarily

Inclined

with Respect

to the

Observer!

Helical
Structure!

Goldstein, 1983; Bothmer & Schwenn, Ann. Geophys., 16, 1-24, 1998

MHD-Equations for Magnetic Flux Ropes (CAFF)

A plasma in static equilibrium, without influence of external forces (e.g. Gravitation), can be described as follows:

$$-\text{grad } p + \underline{j} \times \underline{B} = 0$$

p = plasma pressure

$\underline{j}$ = current density

$\underline{B}$ = magnetic field

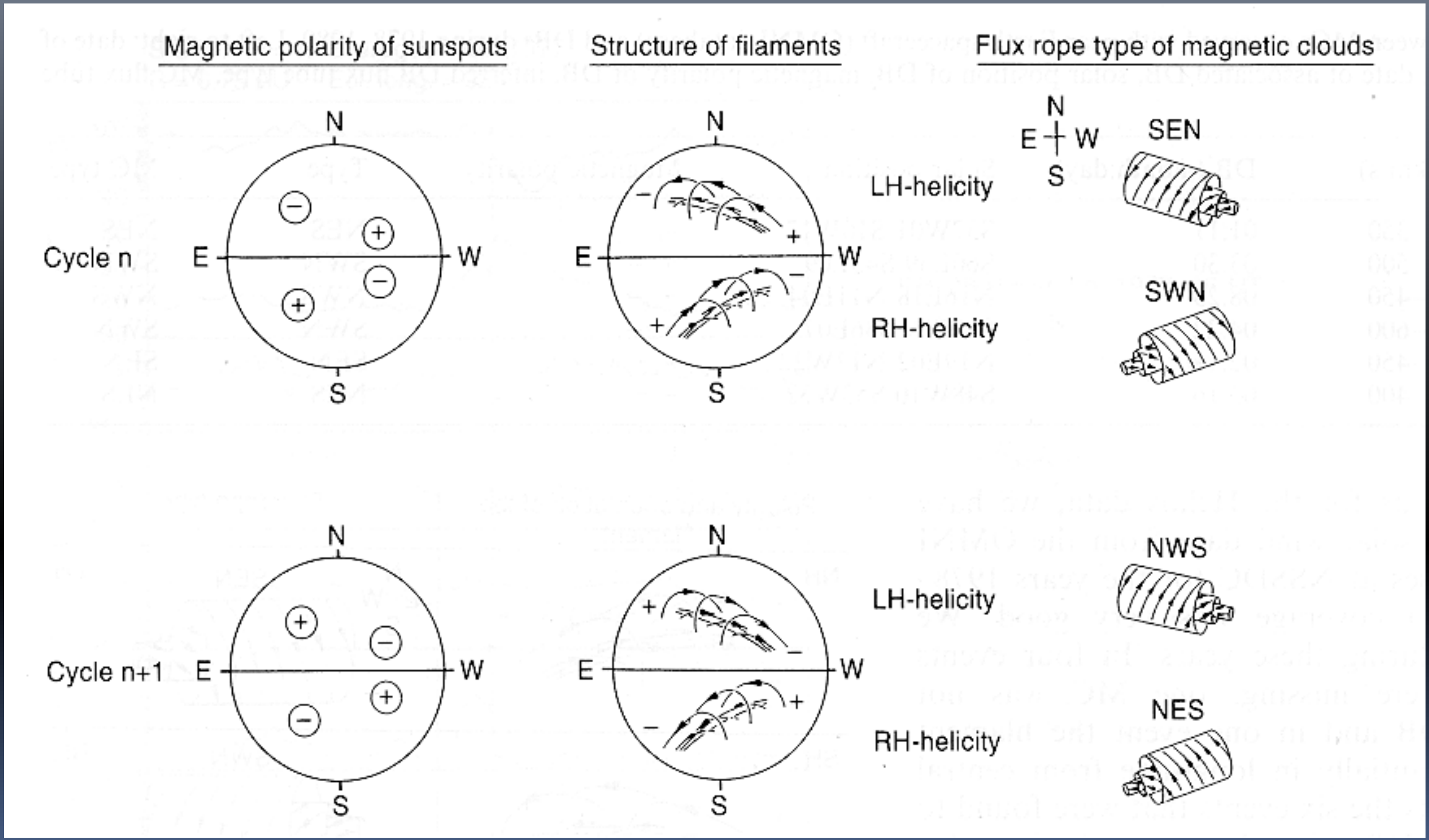
since $\beta \ll 1$, a force-free configuration can be considered:

$$\underline{j} \times \underline{B} = 0$$

The electric current is flowing everywhere parallel or antiparallel

with respect to $\underline{B}$

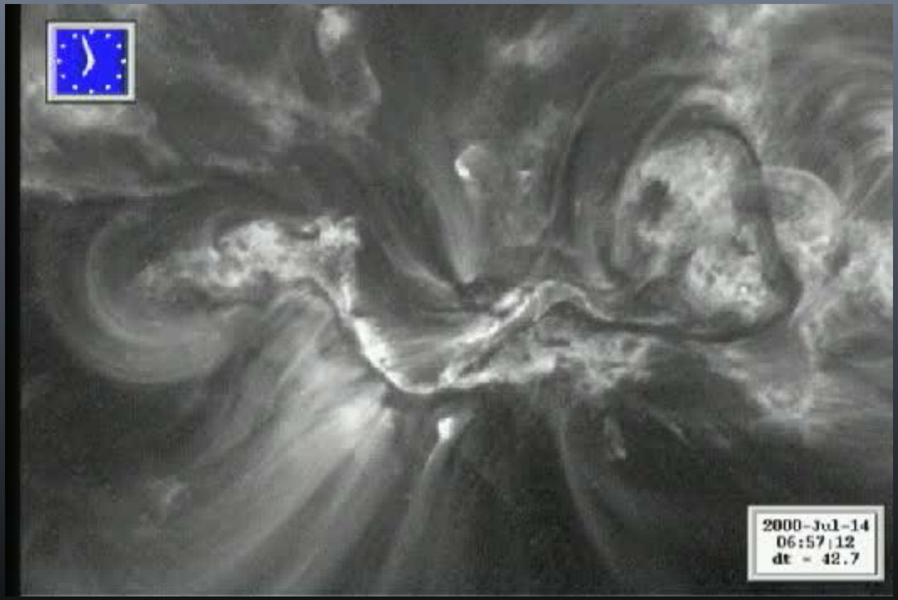
The B&S Scheme for FR CMEs

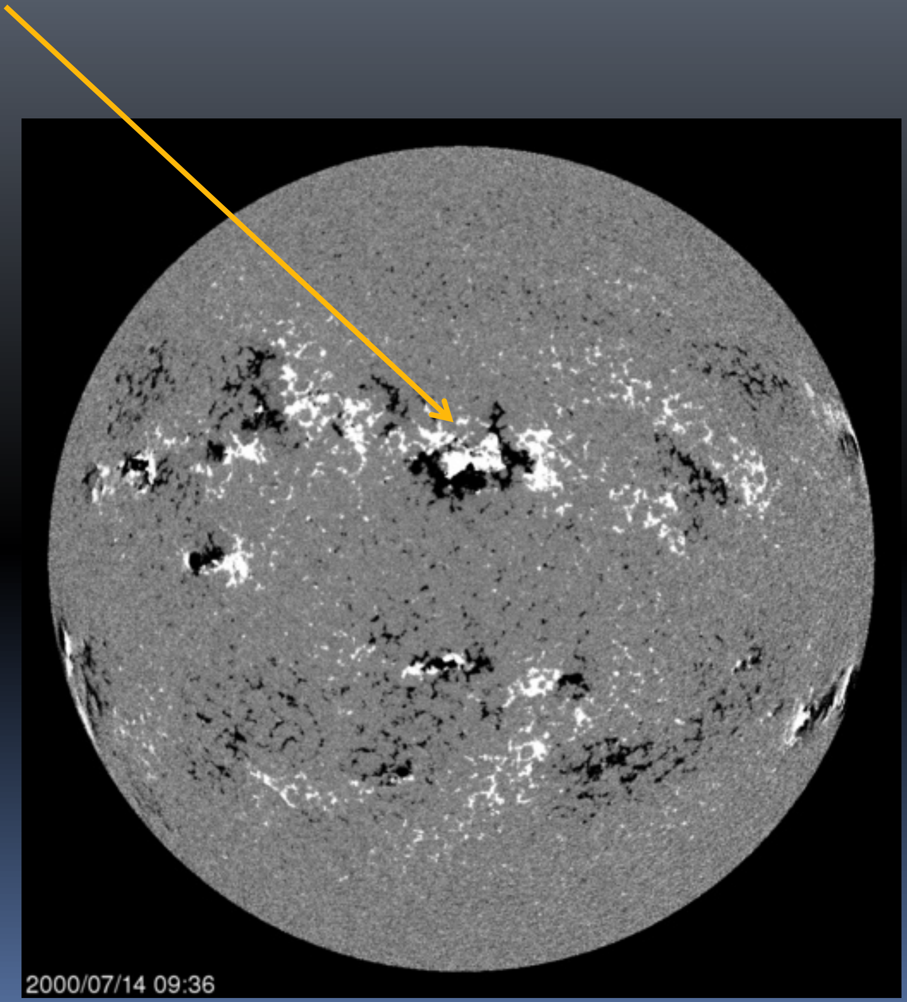


Quadrupolar Fields not Included

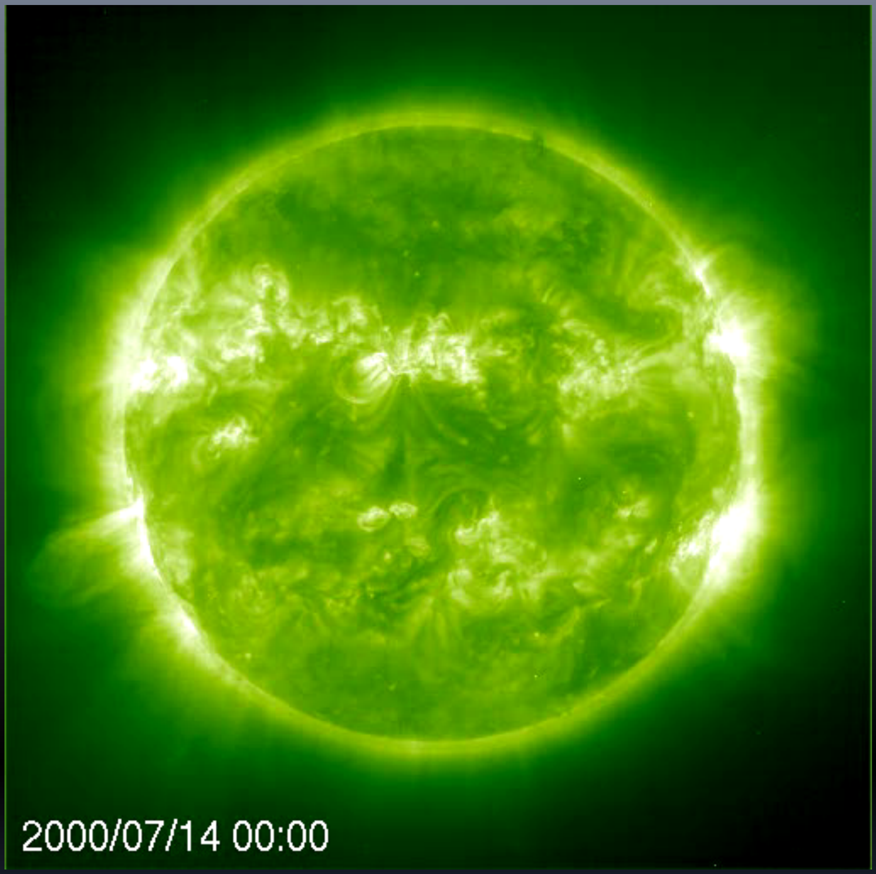
Bothmer & Schwenn, 1998

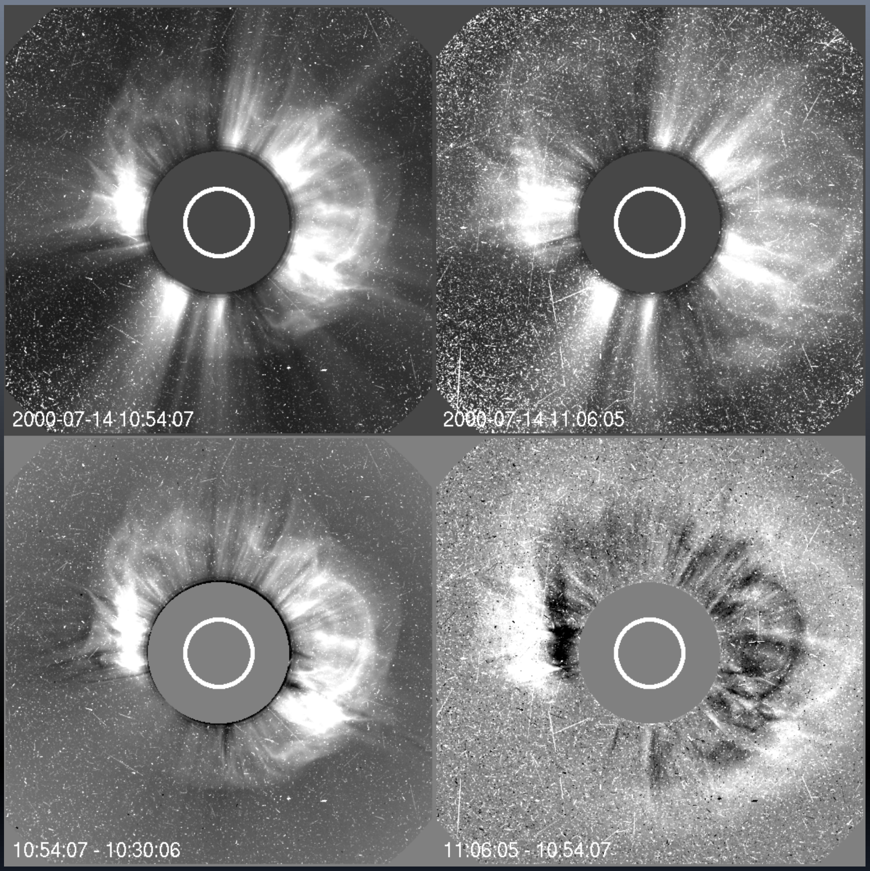
TRACE Observations and SOHO/MDI magnetogram

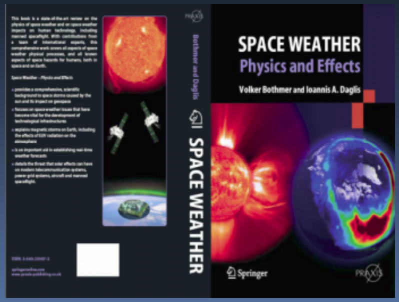




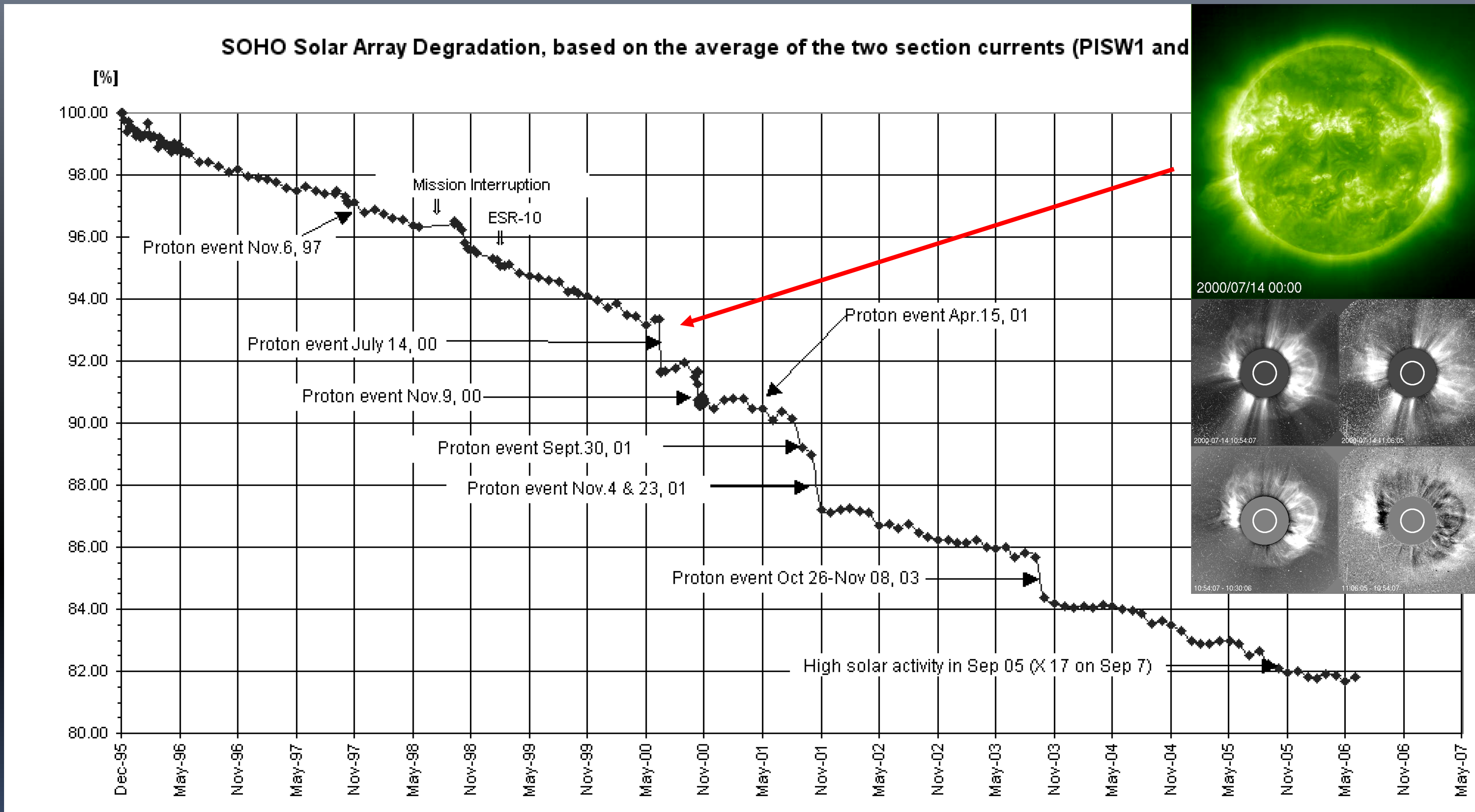
Sample CME: The July 14, 2000 event







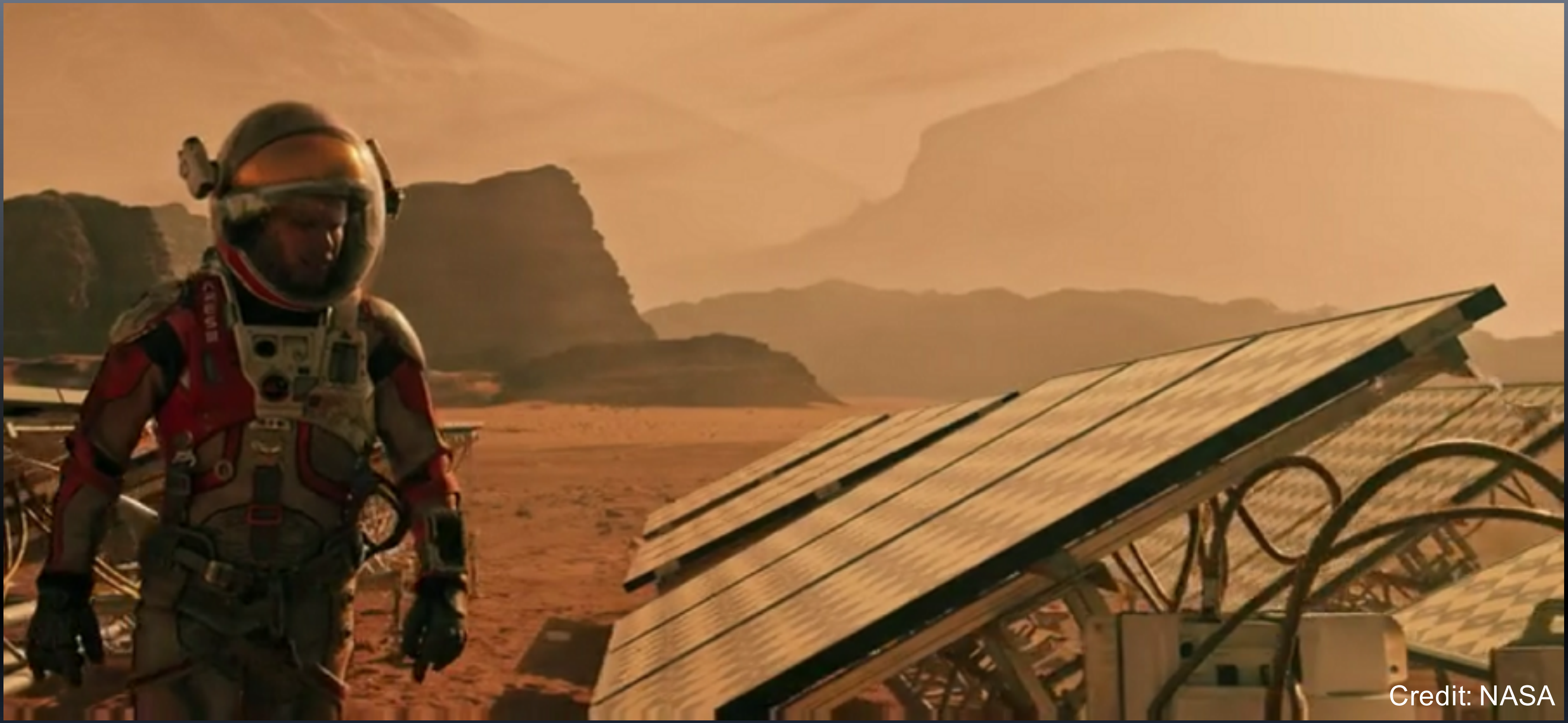
SEP effects on SOHO solar cells



Extreme SEP event occurred on August 7, 1972, i.e., between Apollo 16 and 17. SEPs cause problems for start trackers, electronic devices (e.g. Nozomi)

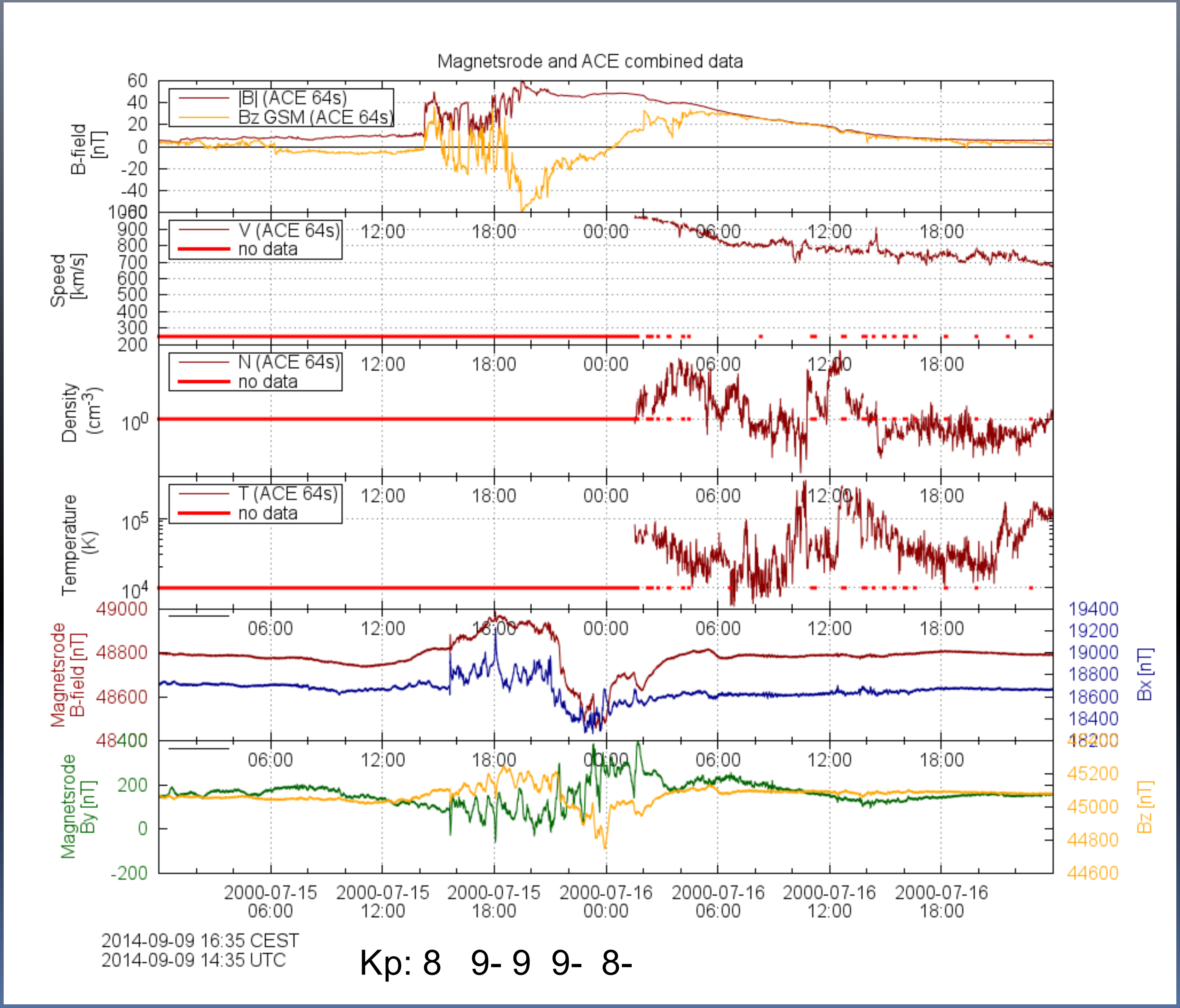
Brekke et al., 2006

Space Weather on Mars



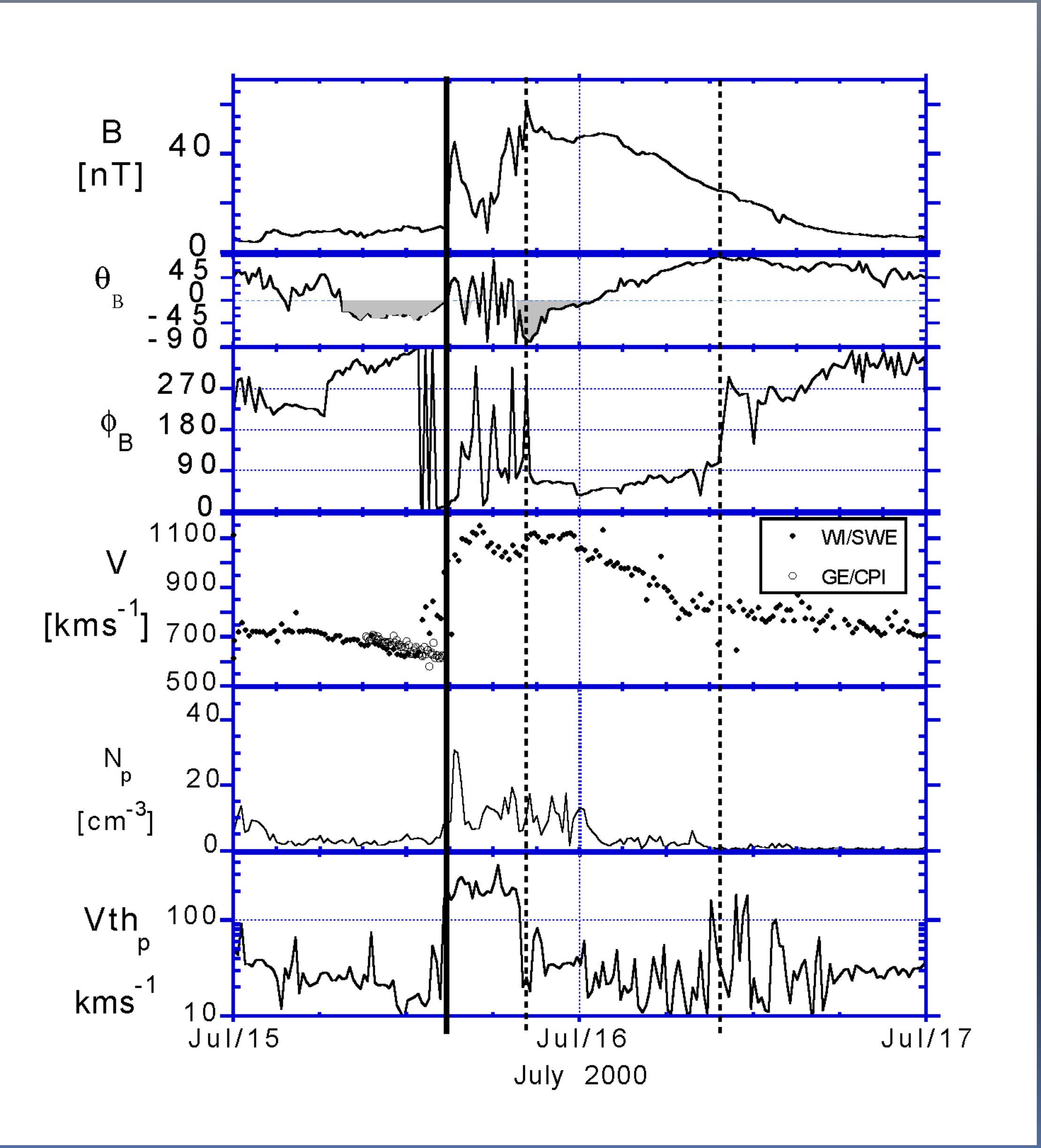
- Radiation hazards due to solar energetic particles (SEPS) and cosmic rays
- Effects of SEPs on solar cells and electronic devices
- Effects of dust particles on solar cells

Solar wind and ground-based magnetometer data



Credit: M. Venzmer, AFFECTS

The solar wind data from Wind



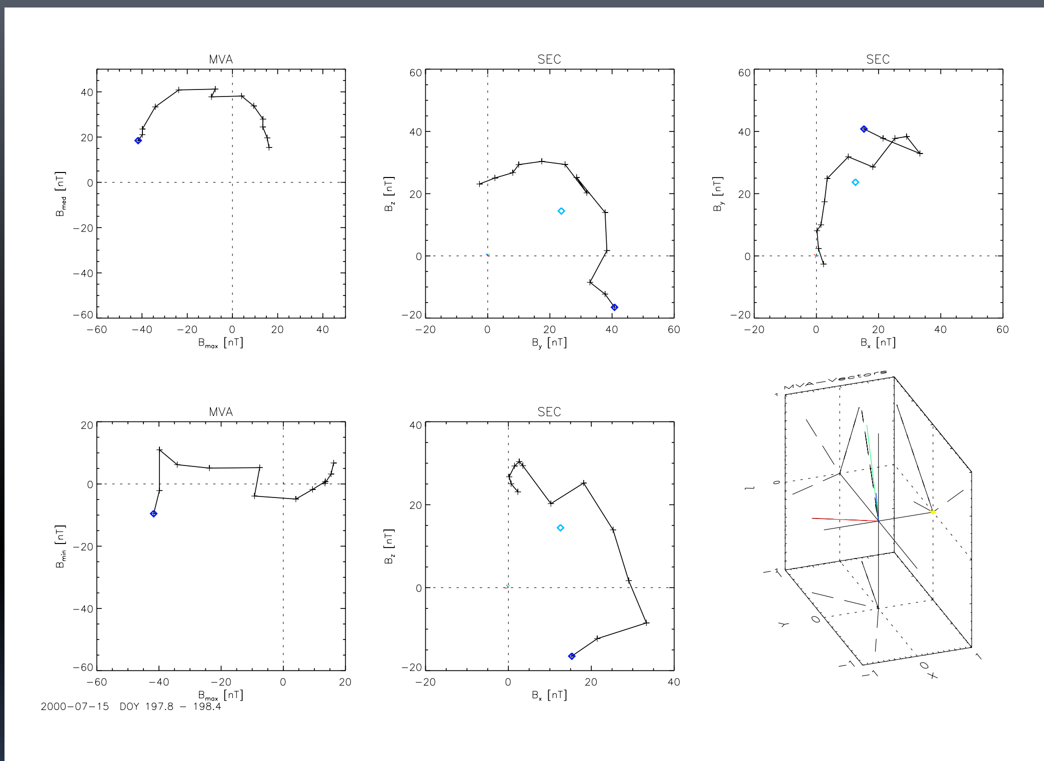
South

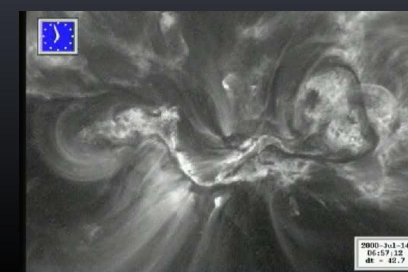
to East

to North

Credit: Bothmer & Daglis, 2006

CME MVA-Analysis





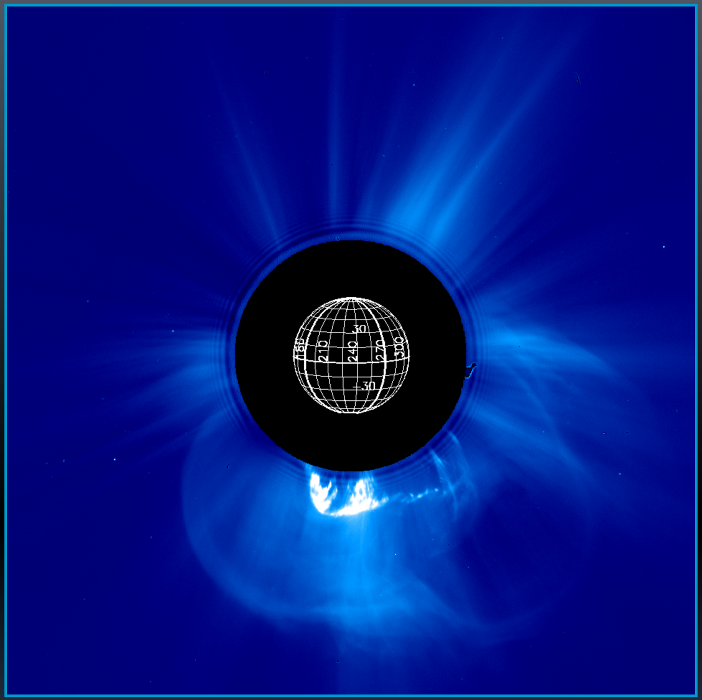
Axis orientation:

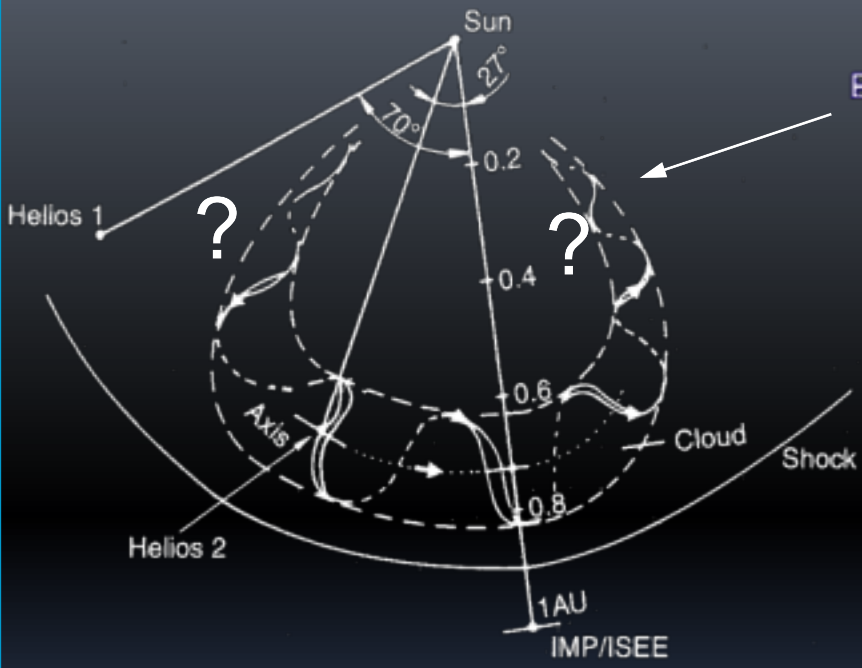
$\Phi = 69°$

$\vartheta = +45°$

M. Venzmer, OPTIMAP, HELCATS

Sketch of the Possible Origin of Interplanetary Magnetic Flux Ropes

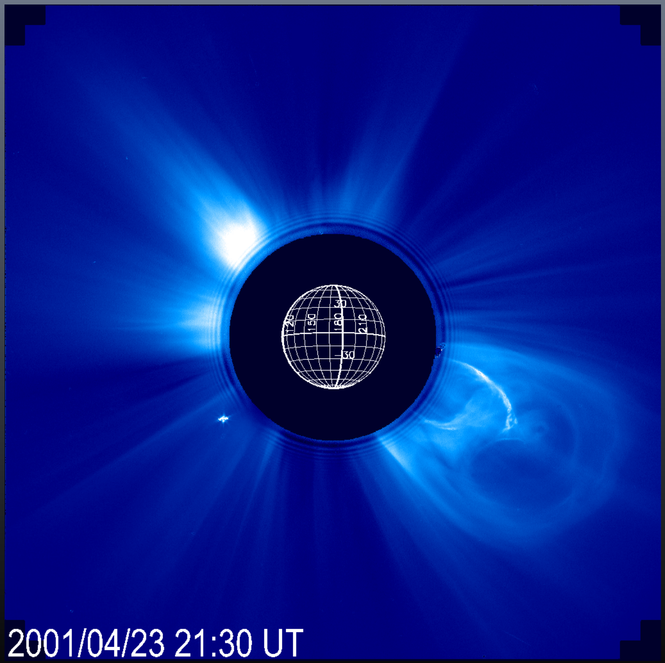


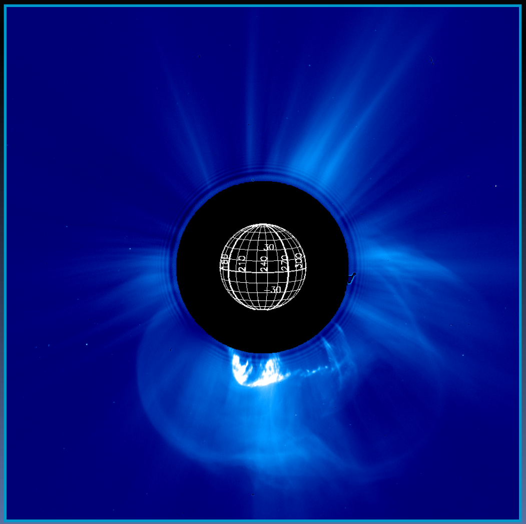


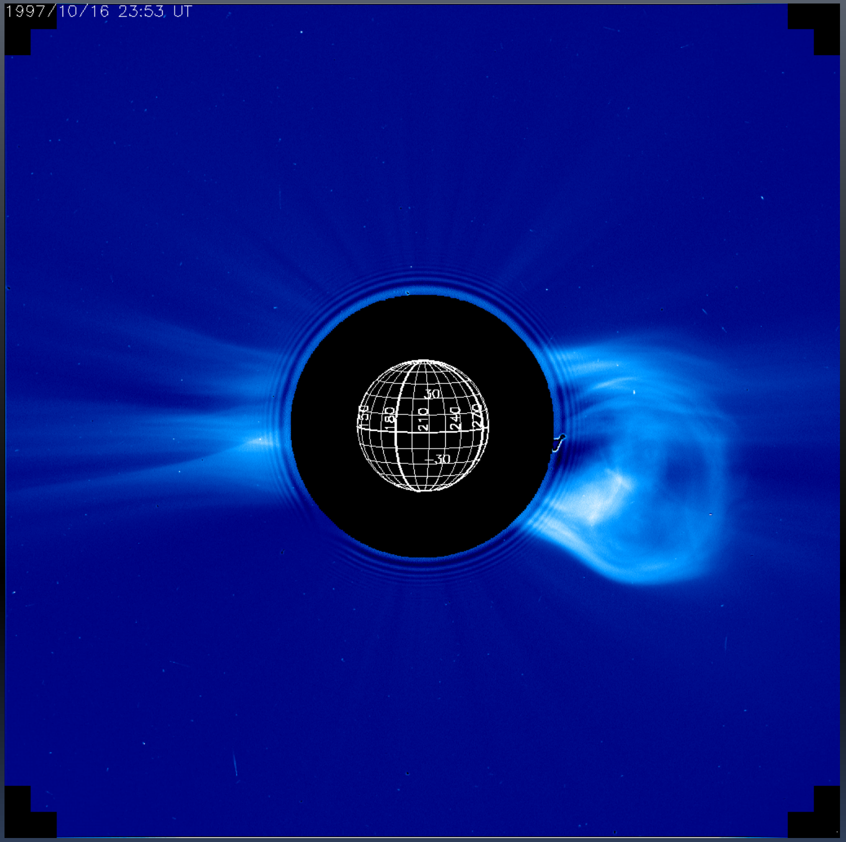
Only 1/3 of all ICMEs appear to be flux ropes (Gosling, 1993); 46% (Bothmer & Schwenn, 1996)

Adapted from Bothmer & Schwenn, Ann. Geophys., 16, 1-24, 1998

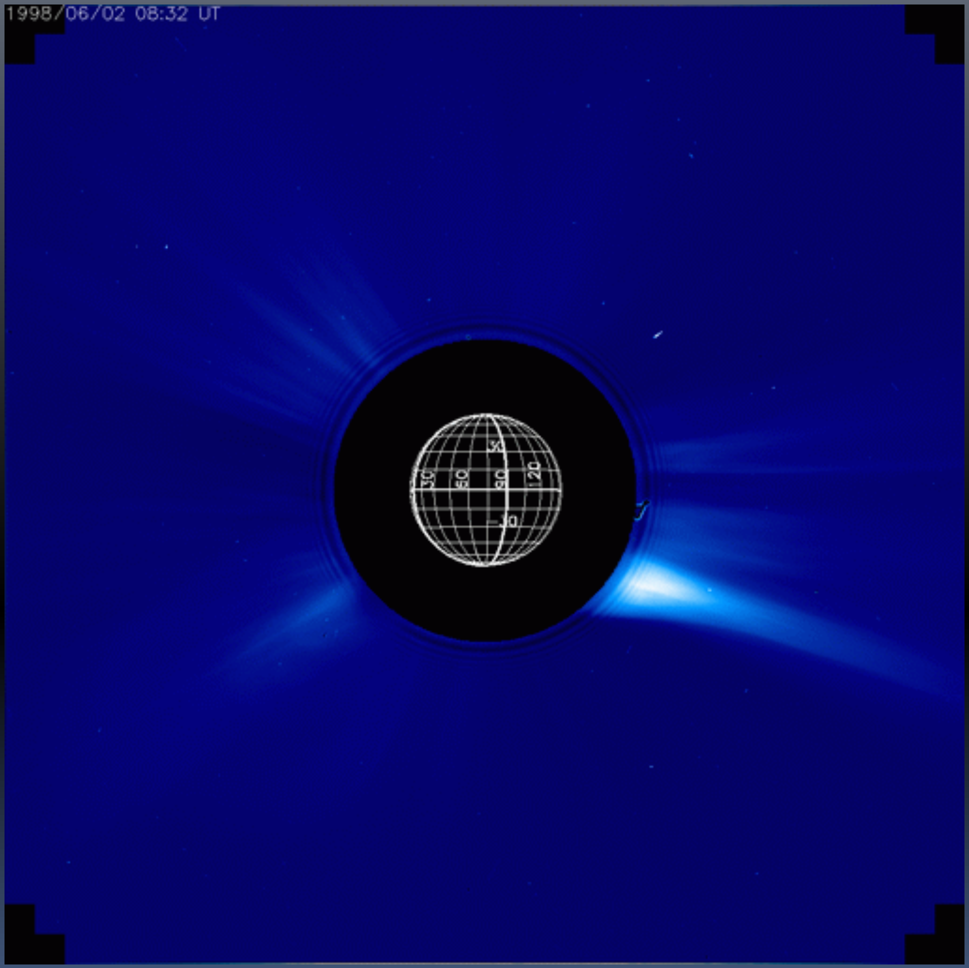
SOHO/LASCO Reveals Flux Rope Structure of CMEs







Unprecedented Observations of CMEs with SOHO

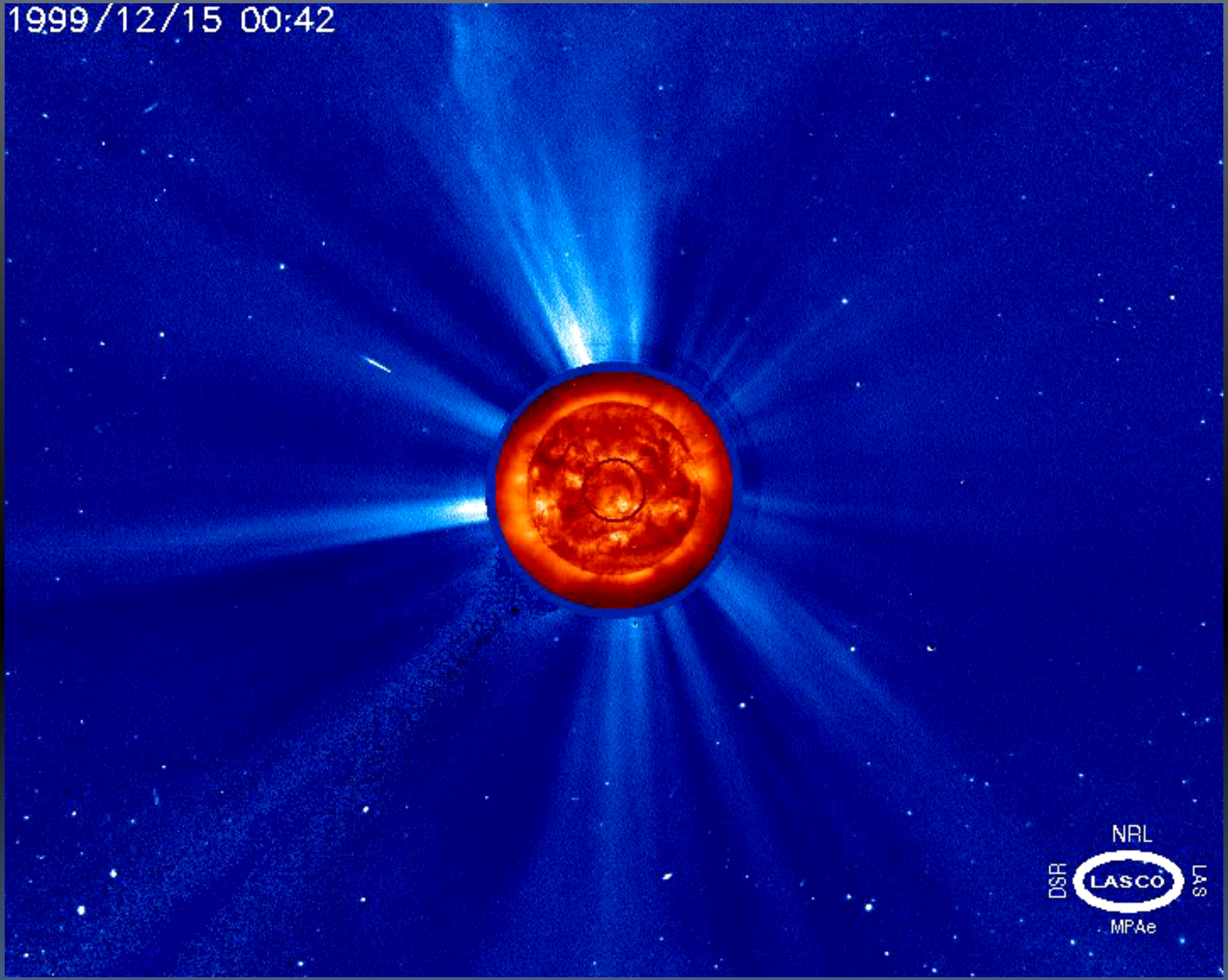


Note the CME's three part structure!

Basic Properties

- Frequency:
  - 3.5 Events per Day in Maximum
  - 0.2 Events per Day in Minimum
- Mass: $5x10^{12}$ bis $5x10^{13}$ kg
- Velocities:
- 20 km s^{-1} (sub-sonic) up to over 2500 km s^{-1} (sub-alfvénic)
- CMEs with V>400 km/s cause shocks

The Dynamic Corona Observed with SOHO/LASCO/EIT - December 1999 to January 2000

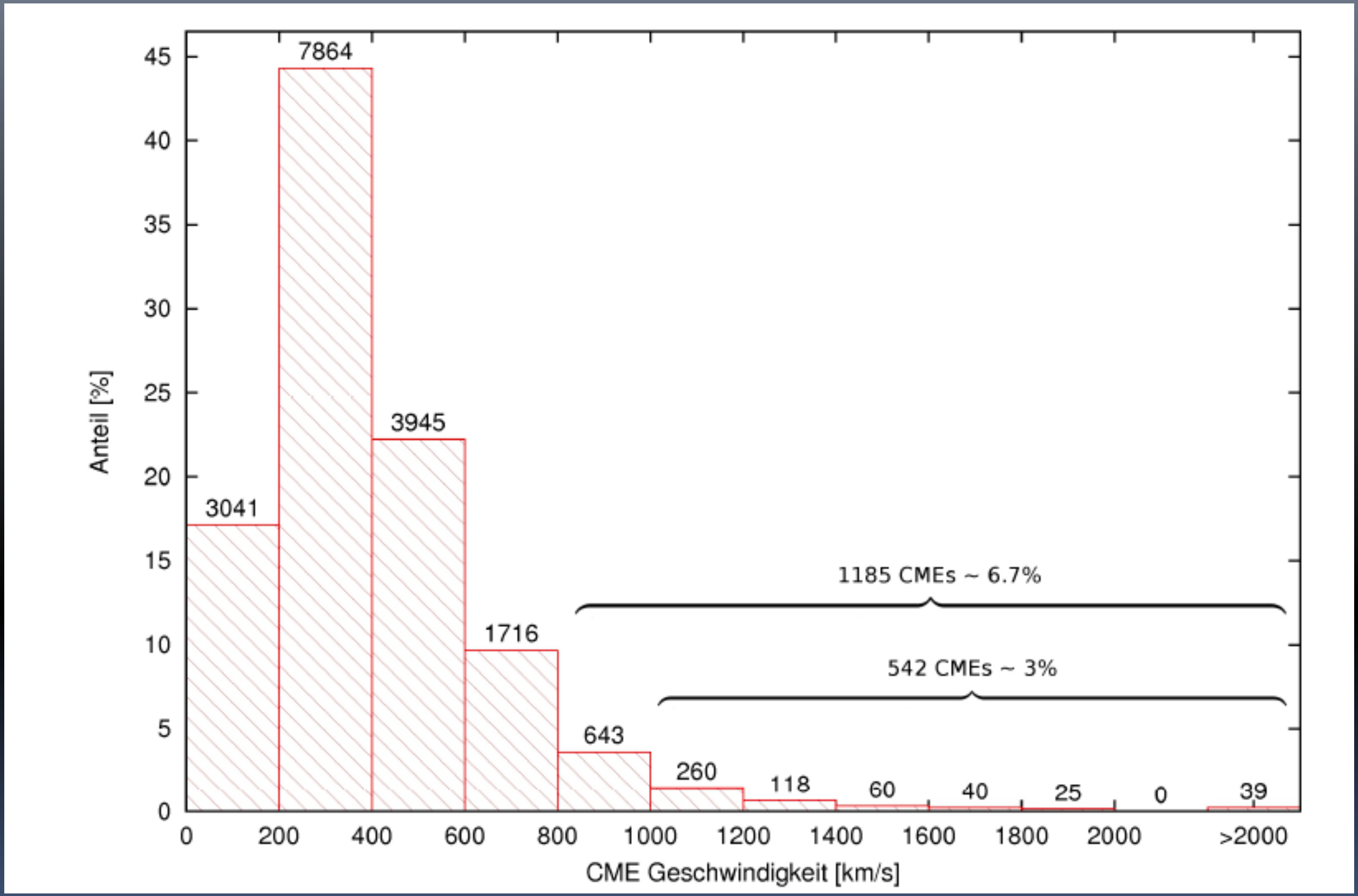


SOHO has observed >10.000 CMEs during 1996-2007.

Coronal Mass Ejections (CMEs) occur on variable spatial- and time-scales.

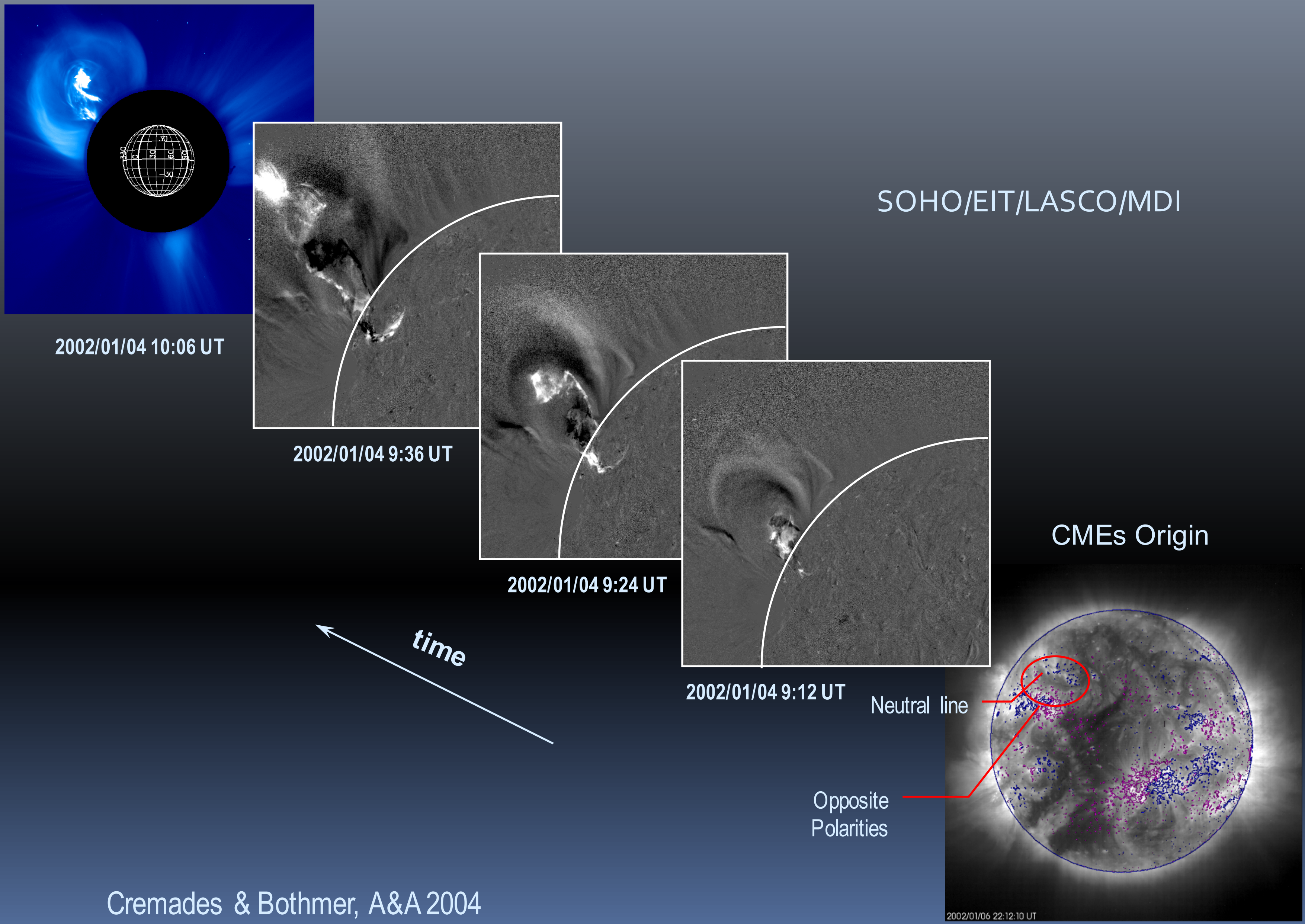
Courtesy: B. Podlipnik

Frequencies of CME velocities from January 1996 – March 2013, 20.635 CMEs (SOHO/LASCO)



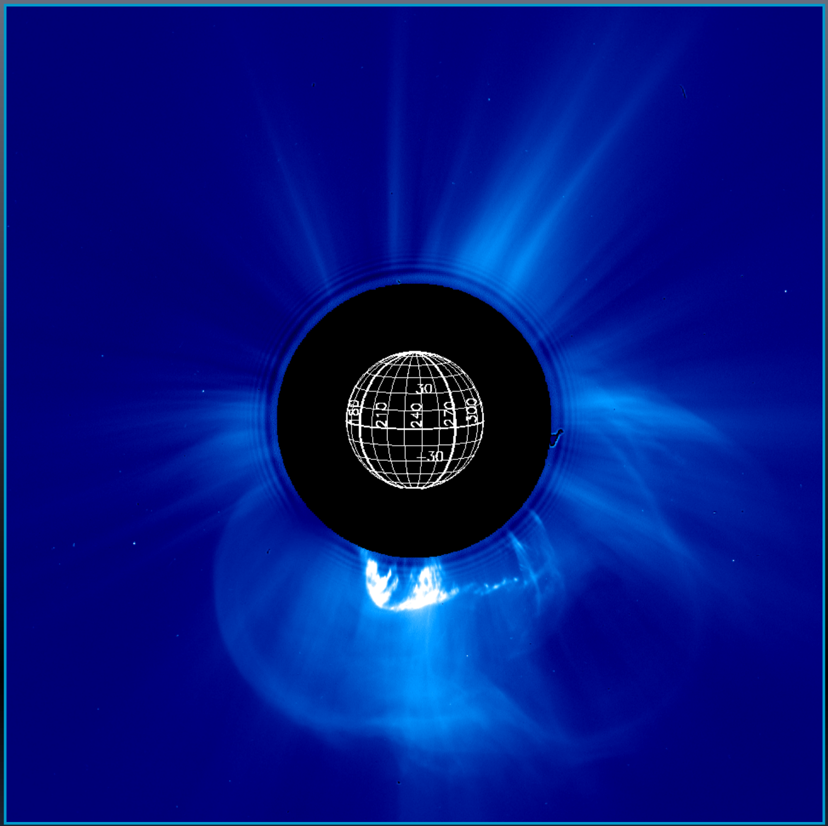
V. Bothmer, R. Kanzler, A. Pluta; eHEROES EU FP7 project

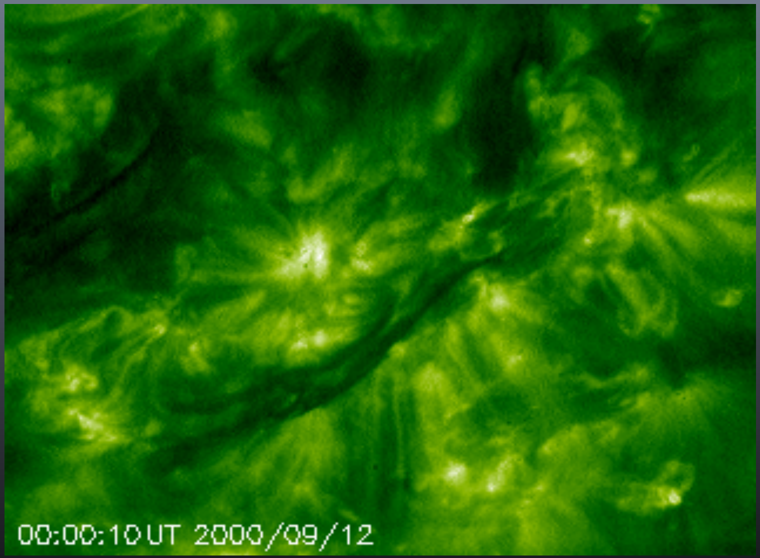
CMEs originate from bipolar photospheric fields regions



Cremades & Bothmer, A&A 2004

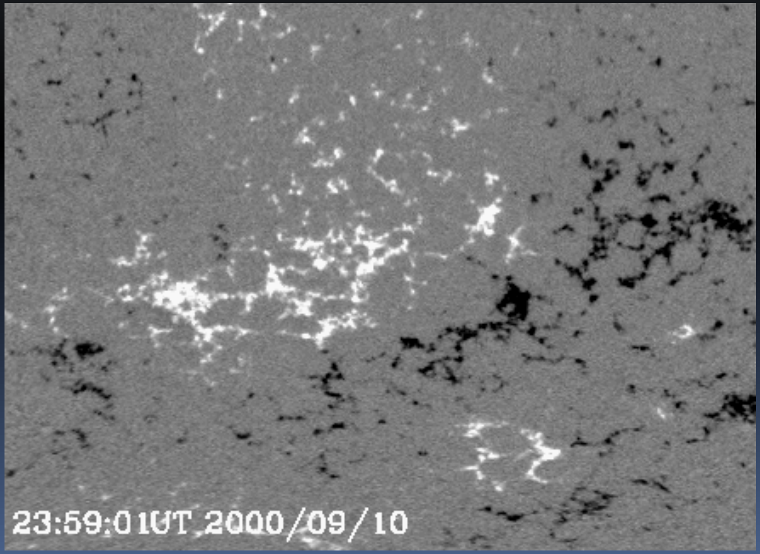
Filaments, Arcades, CMEs and Variation of the Photospheric Magnetic Flux in the Source Region





EIT

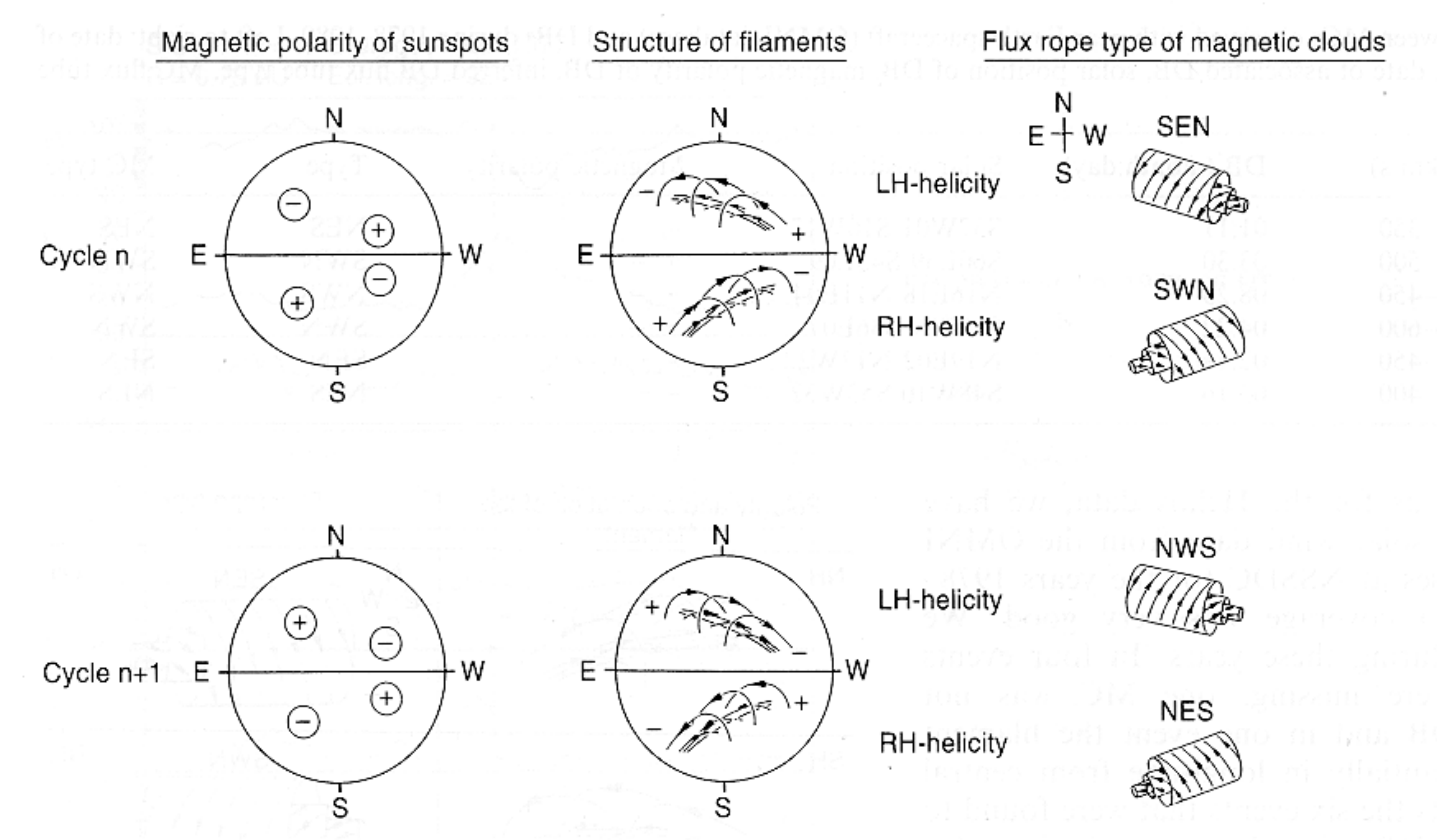
195 Å



MD
I

A detailed study has started to investigate the evolution of the photospheric flux in the source regions of CMEs *(Tripathi, Bothmer, Cremades, A&A, 422, 307-322, 2004).*

Scheme of the Dependence of CME Magnetic Cloud Configurations on the Solar Cycle



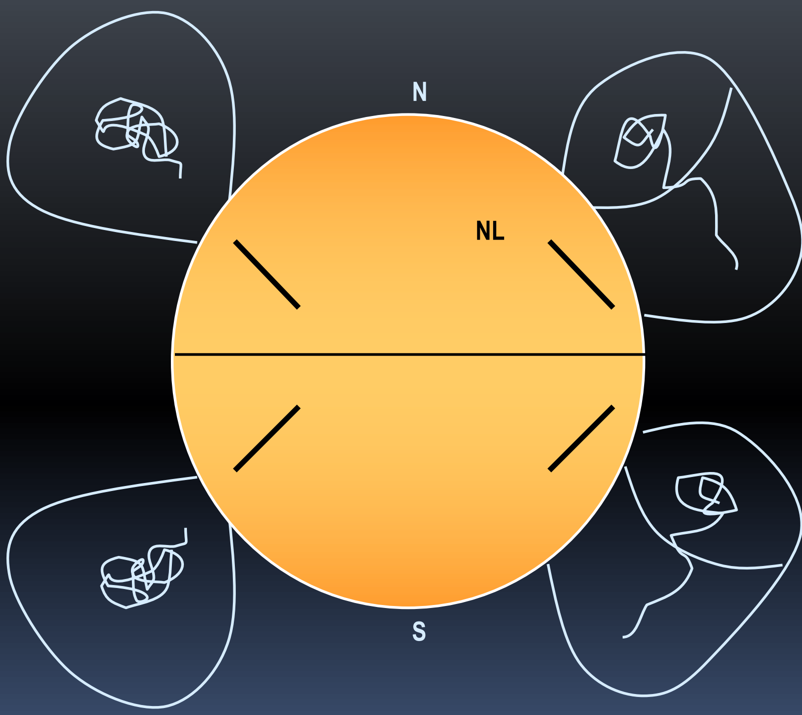
No consideration of quadrupolar fields

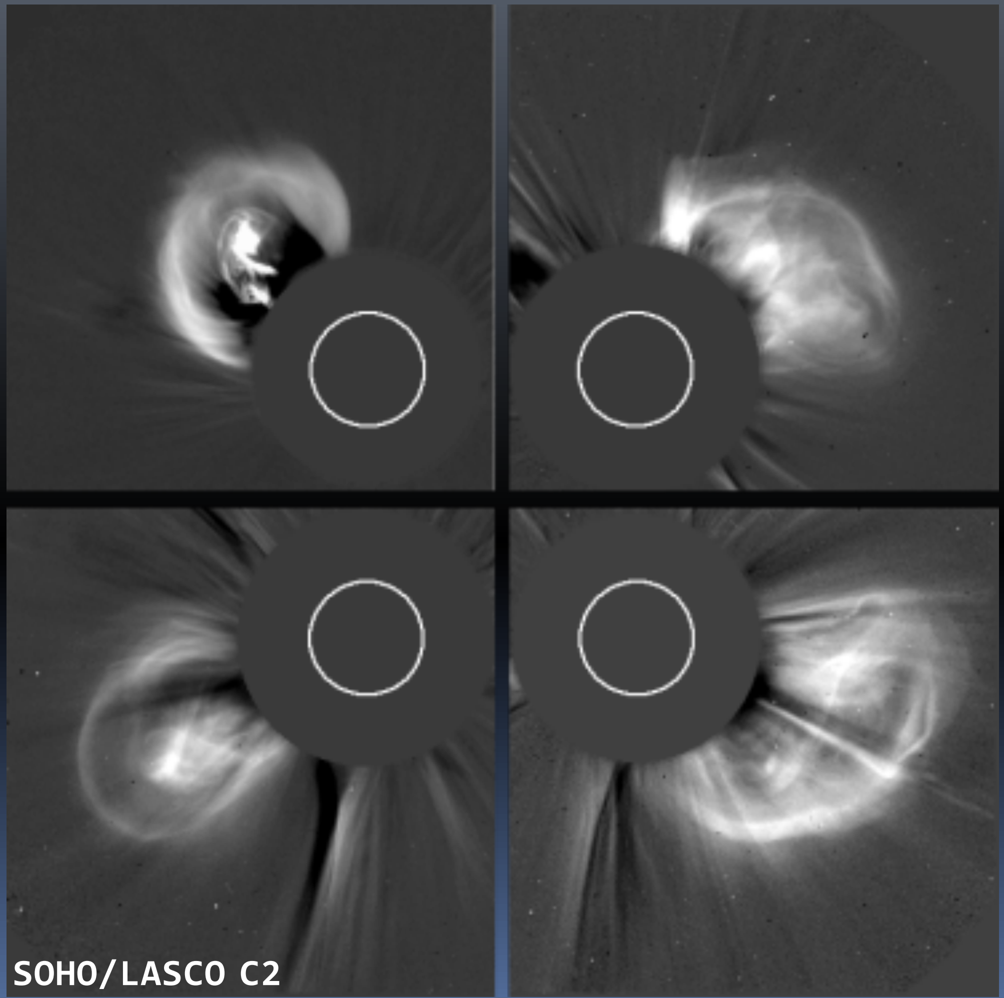
Bothmer & Schwenn, 1998

Basic Scheme Explaining the 3D Structure of CMEs

The WL coronagraph observations of CMEs can be modeled through large-scale magnetic flux ropes which properties depend on the magnetic source region characteristics.

Joy‘s & Hale‘s laws



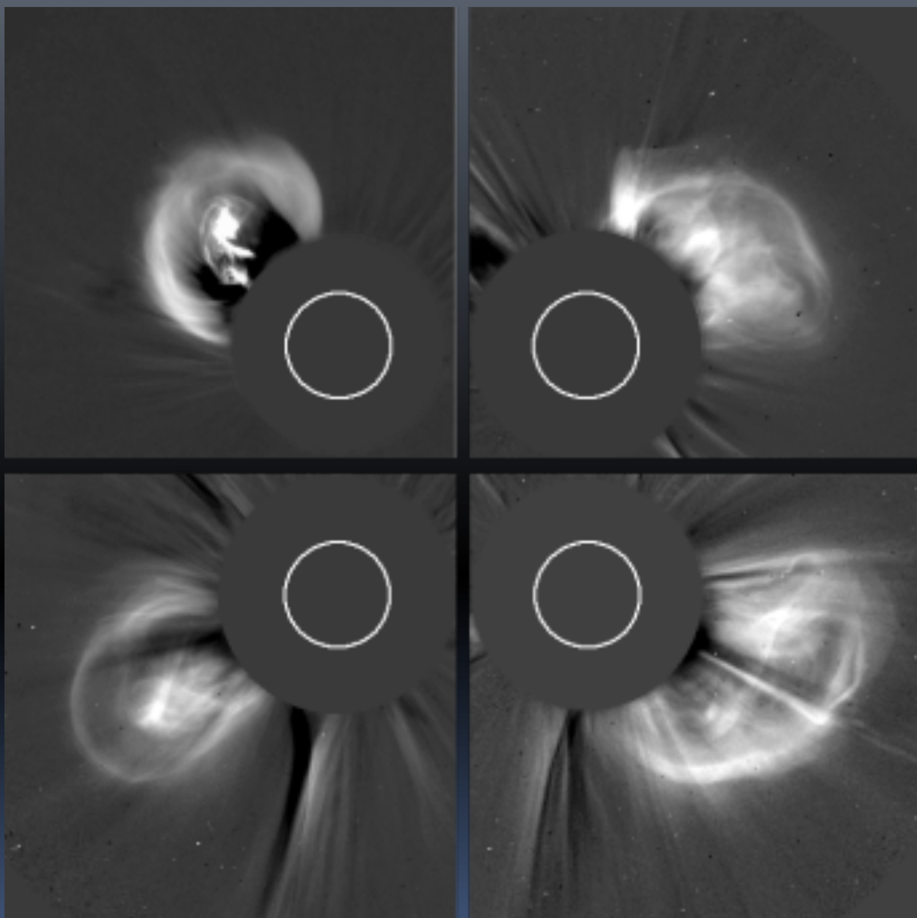


Scheme is simplification !

Cremades & Bothmer, A&A 2004

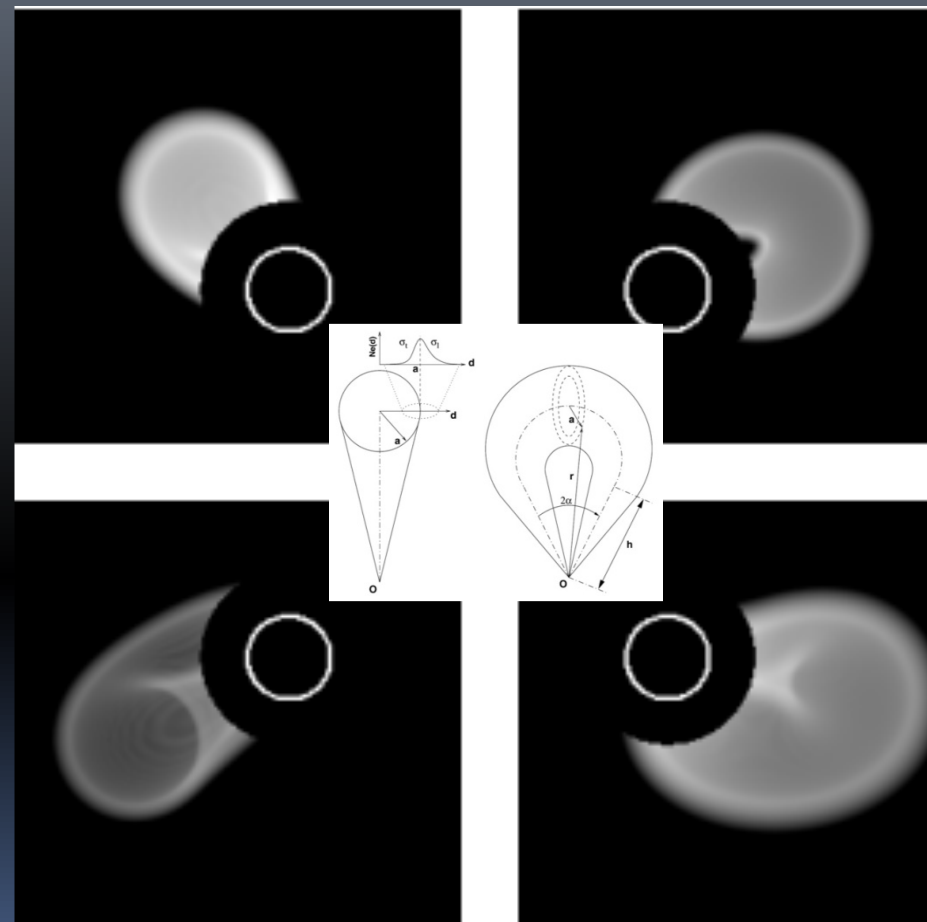
Modelling the Electron Density Distribution

LASCO Observations



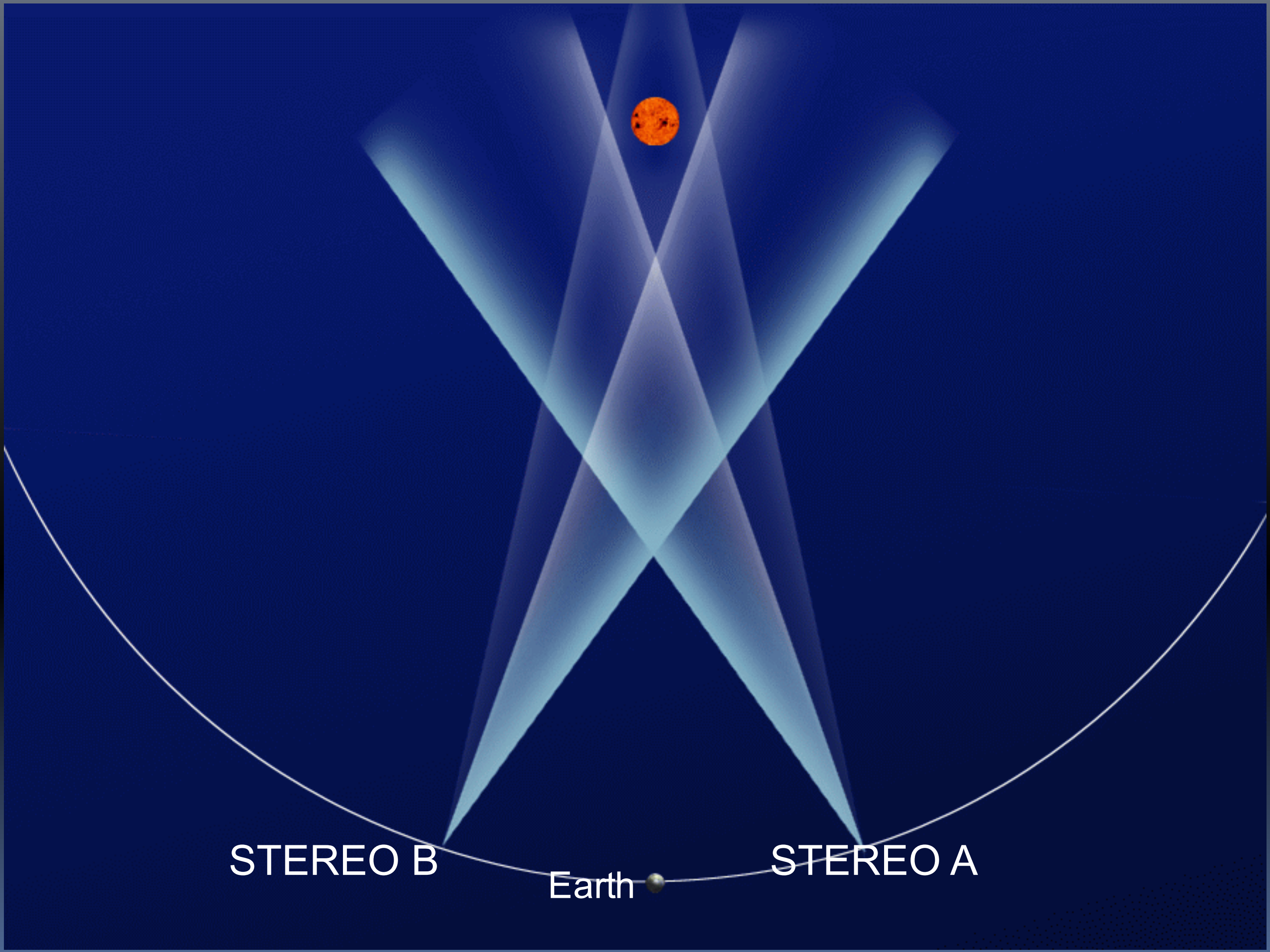
Cremades & Bothmer, A&A 2004

Simulations (GCS-Modell, $\int n_e dV$)

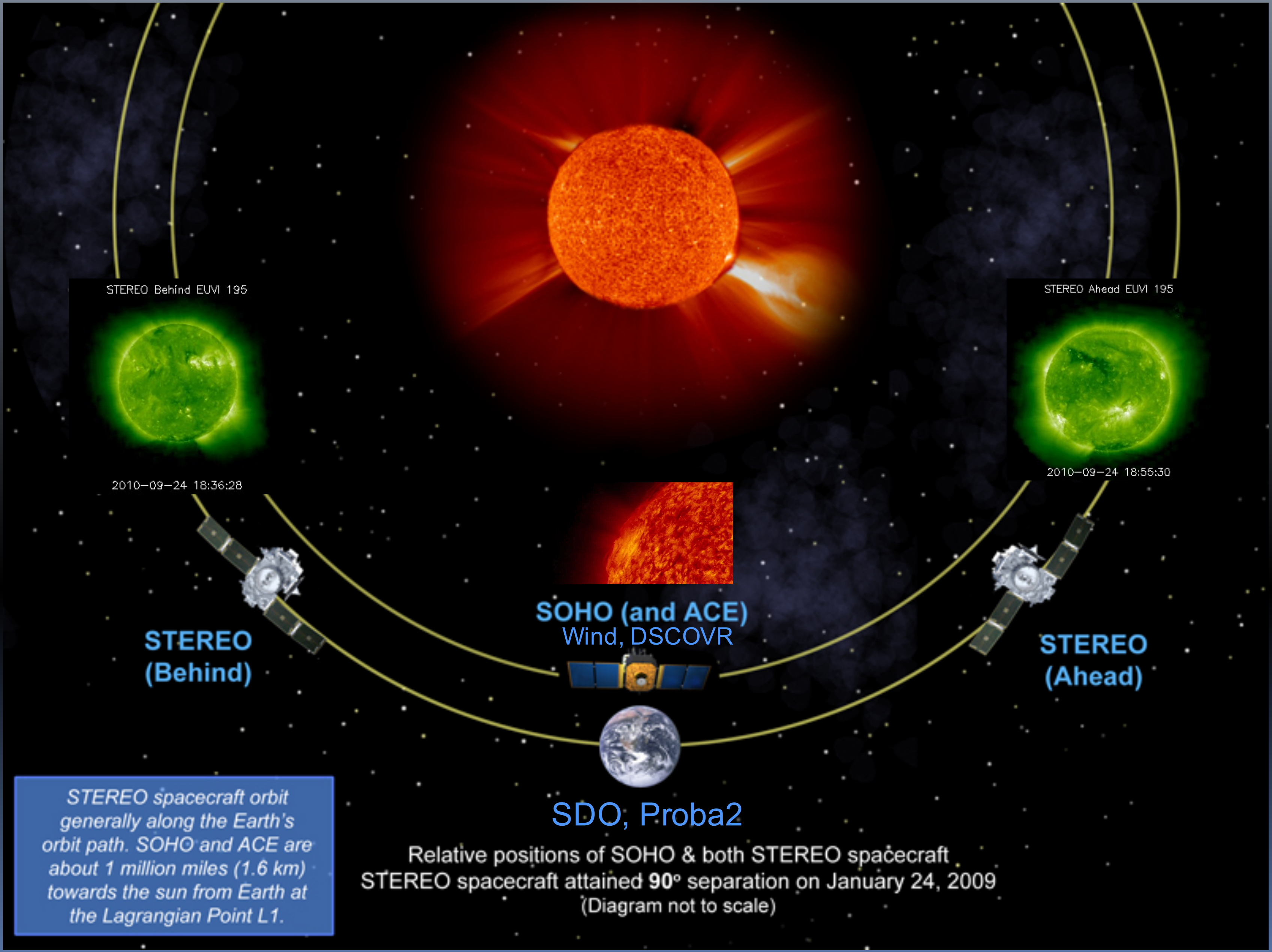


Howard, Thernissien and Vourlidas, ApJ 2006

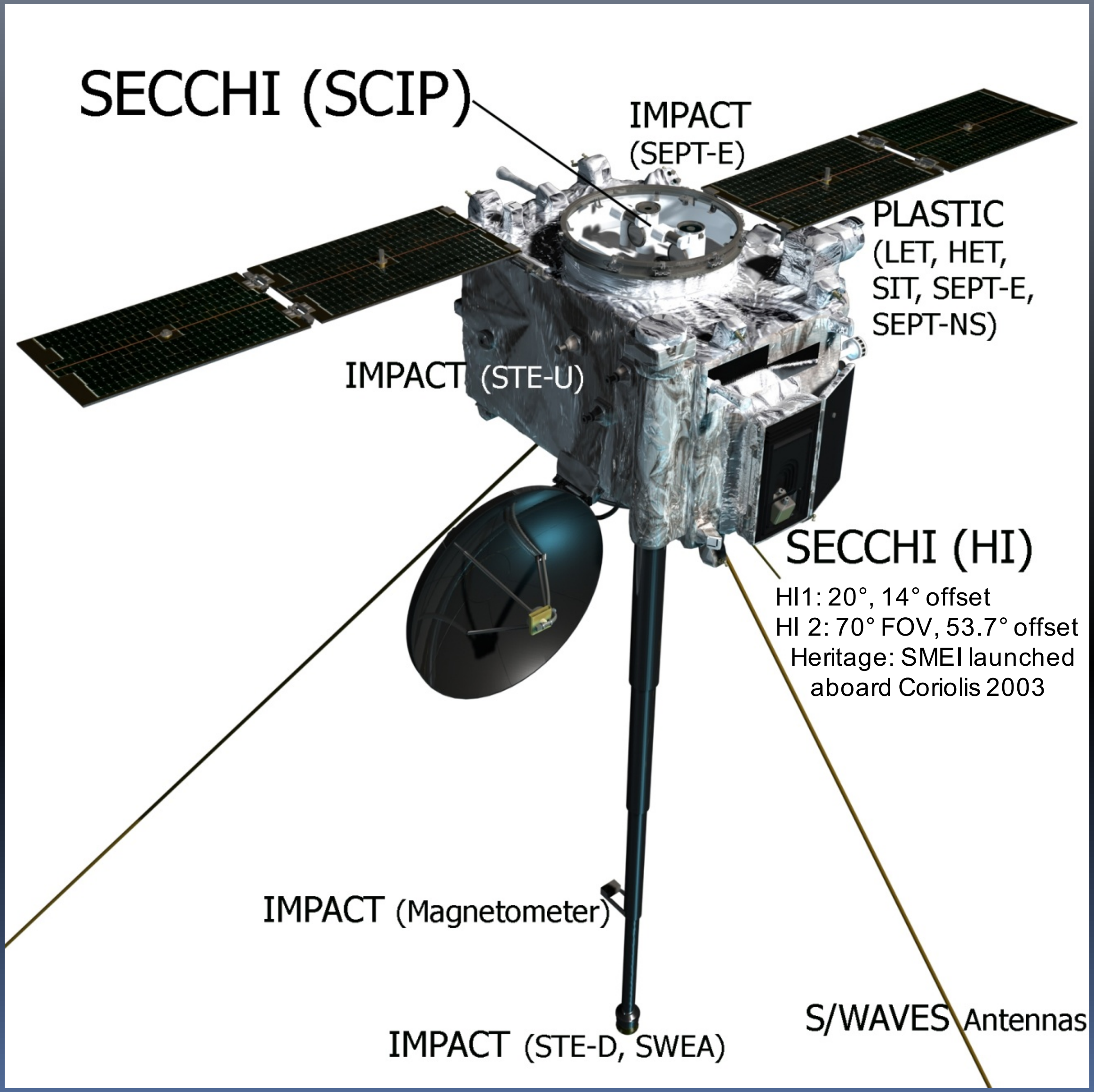
Stereoscopic Observations of the Sun-Earth System



Multi-point Space Observations



STEREO-B (BEHIND) Satellite and Payload



Scientific Payload

(~60% from Europe):

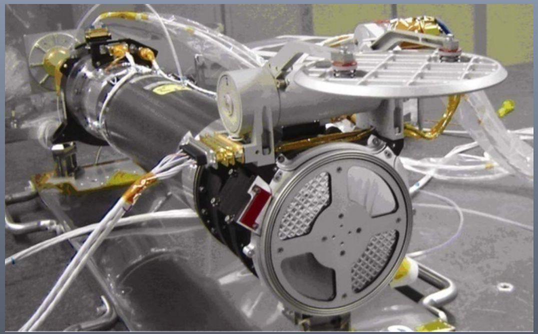
SECCHI

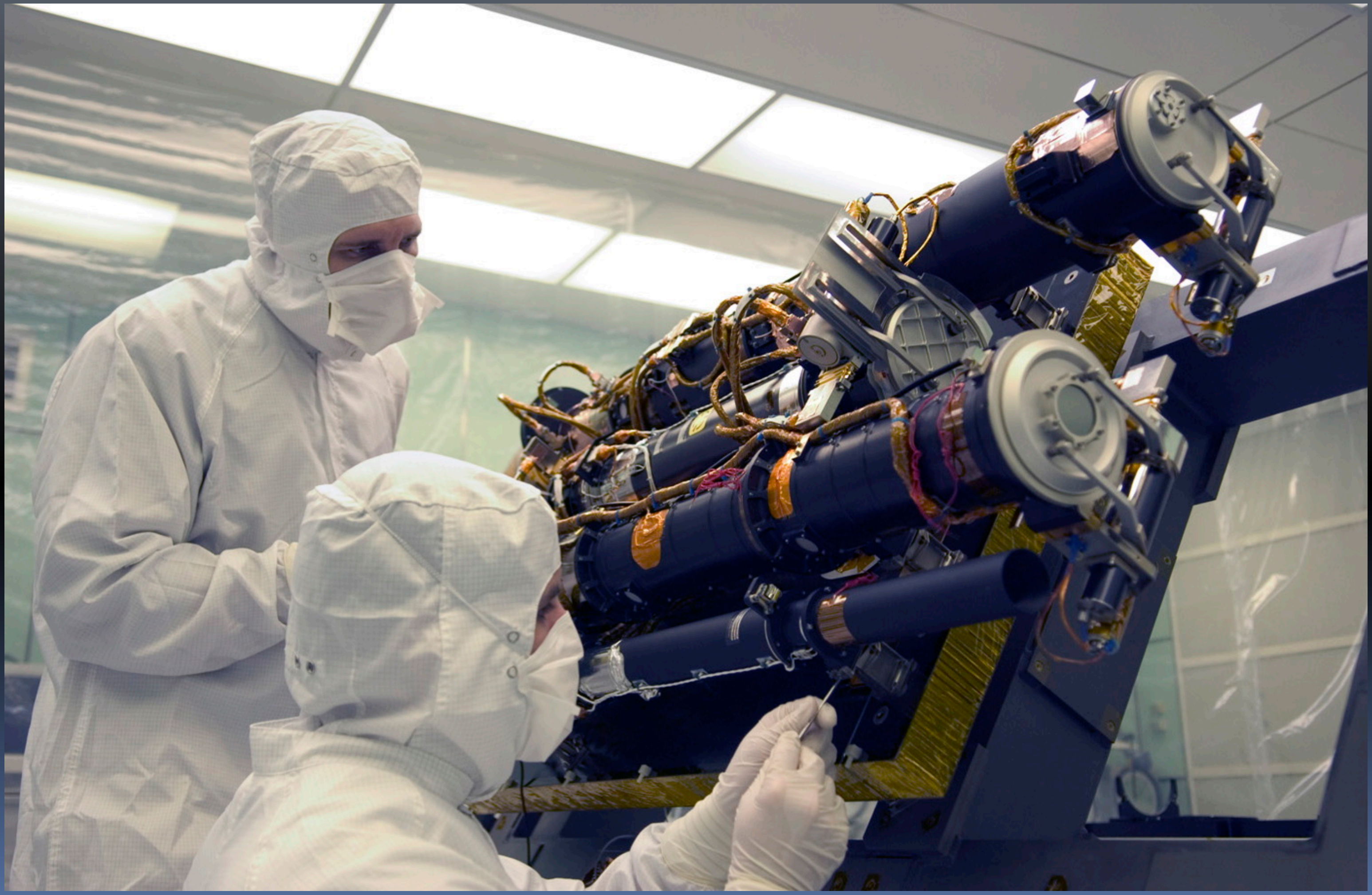
IMPACT

PLASTIC

SWAVES

Sun Centered Imaging Package (SCIP) und SESAMe

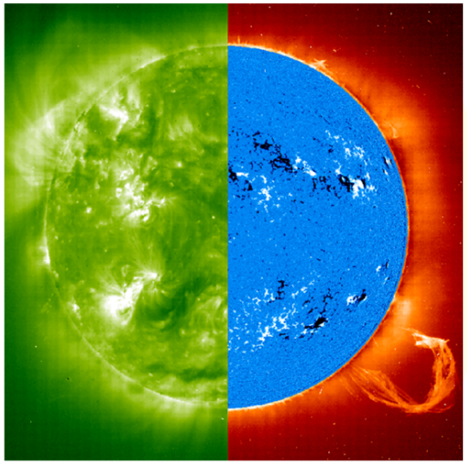




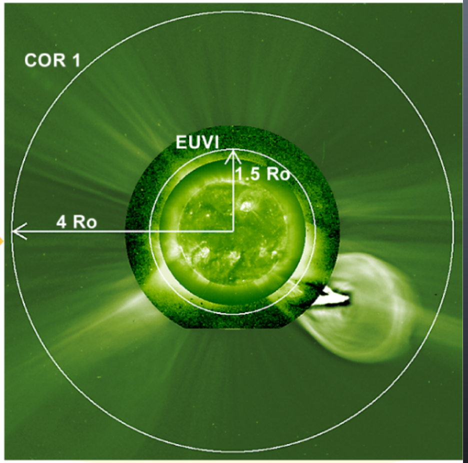
Fields of View of the Five SECCHI Telescopes

SECCHI Exploration of CMEs and the Heliosphere on STEREO

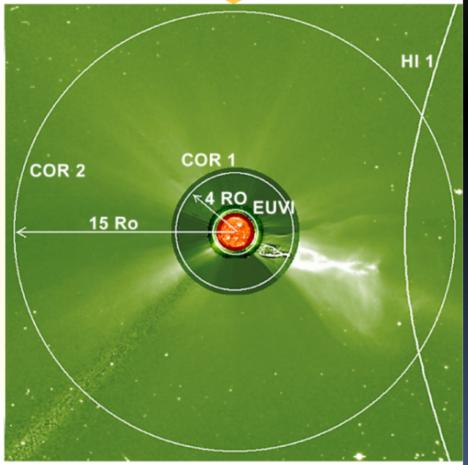
- *What Configurations of the Corona Lead to a CME?*
- *What Initiates a CME?*
- *What Accelerates CMEs?*
- *How Does a CME Interact With the Heliosphere?*
- *How do CMEs Cause Space Weather Disturbances?*



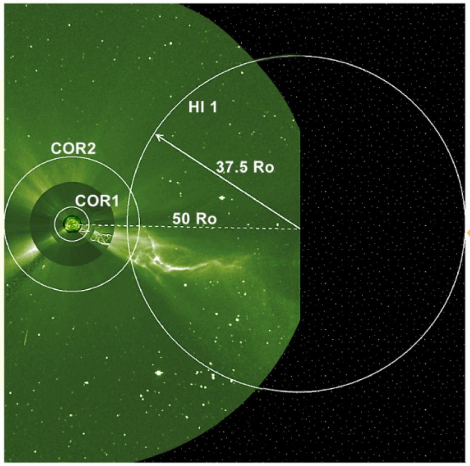
- Explore the Magnetic Origins of CMEs
  - Photospheric Shearing Motions
  - Magnetic Flux Emergence
  - Magnetic Flux Evolution and Decay



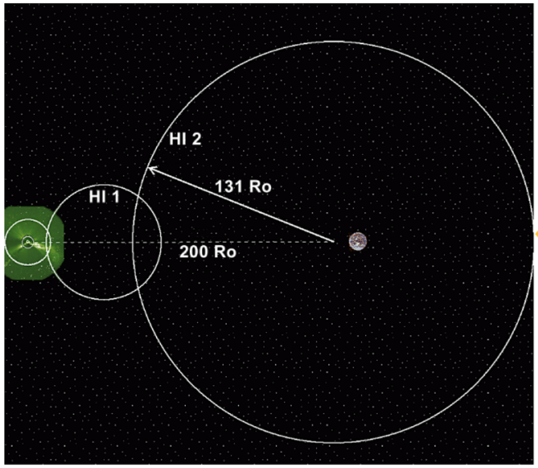
- Understand the Initiation of CMEs
  - Reconnection
  - The Role of Plasma vs. Magnetic Field Effects
  - Rapid vs. Slow Drivers



- Study the Physical Evolution of CMEs
  - Reconnection
  - Continued Energy Input and Mass Ejection
  - Effect on Helmet Streamers

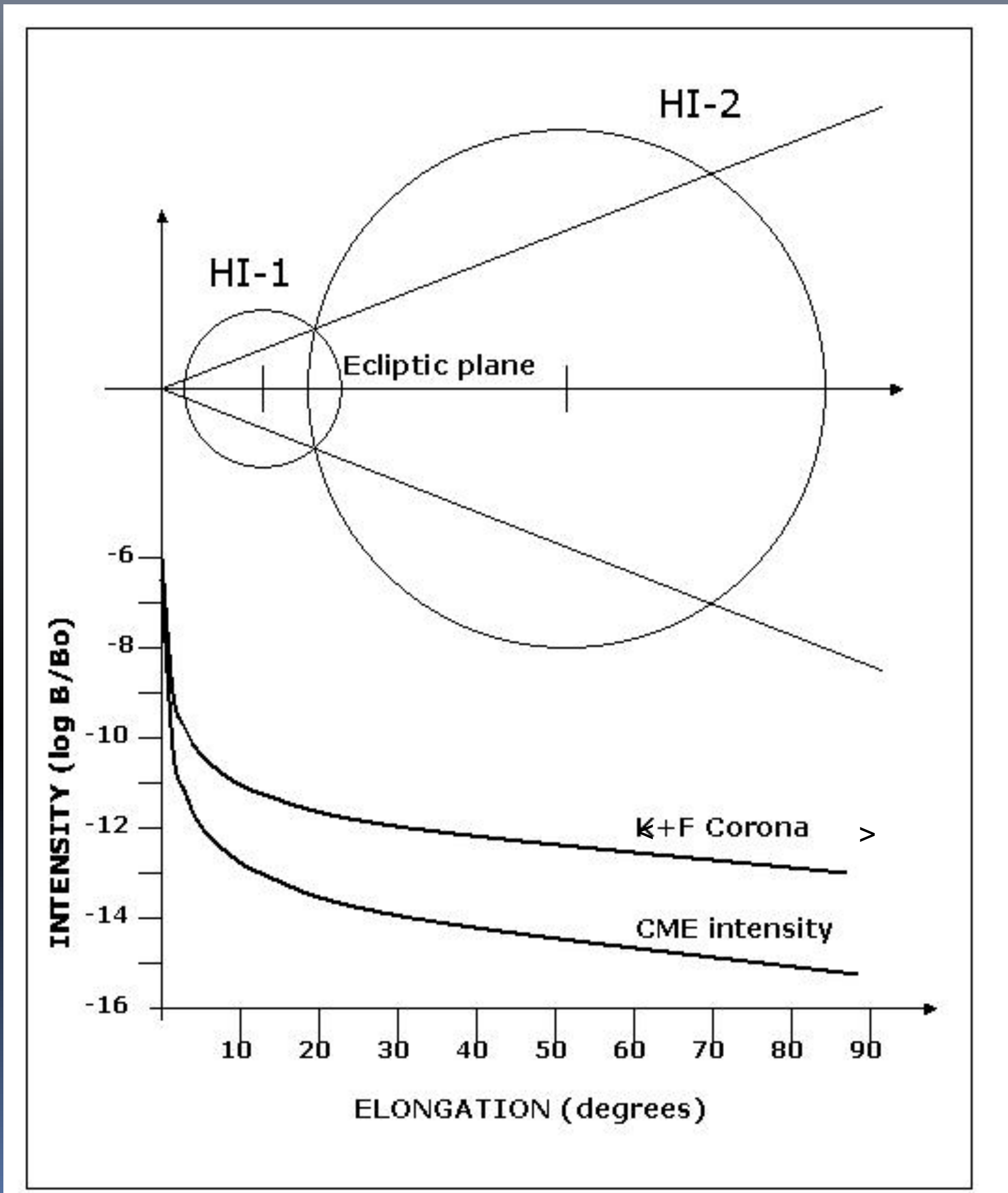


- Investigate the Interaction of CMEs With the Heliosphere
  - CME Physical Signatures at 1 AU
  - Generation of Shocks
  - Acceleration of Charged Particles
  - Interaction With Heliospheric Plasma Sheet & Co-Rotating Interaction Regions
  - Interaction With Other CMEs



- The Sun-Earth Connection: Understand the Role of CMEs in Space Weather
  - Observe Trajectory of Earth-Directed CMEs
  - Predict Arrival Time and Geo-Effectiveness of CMEs

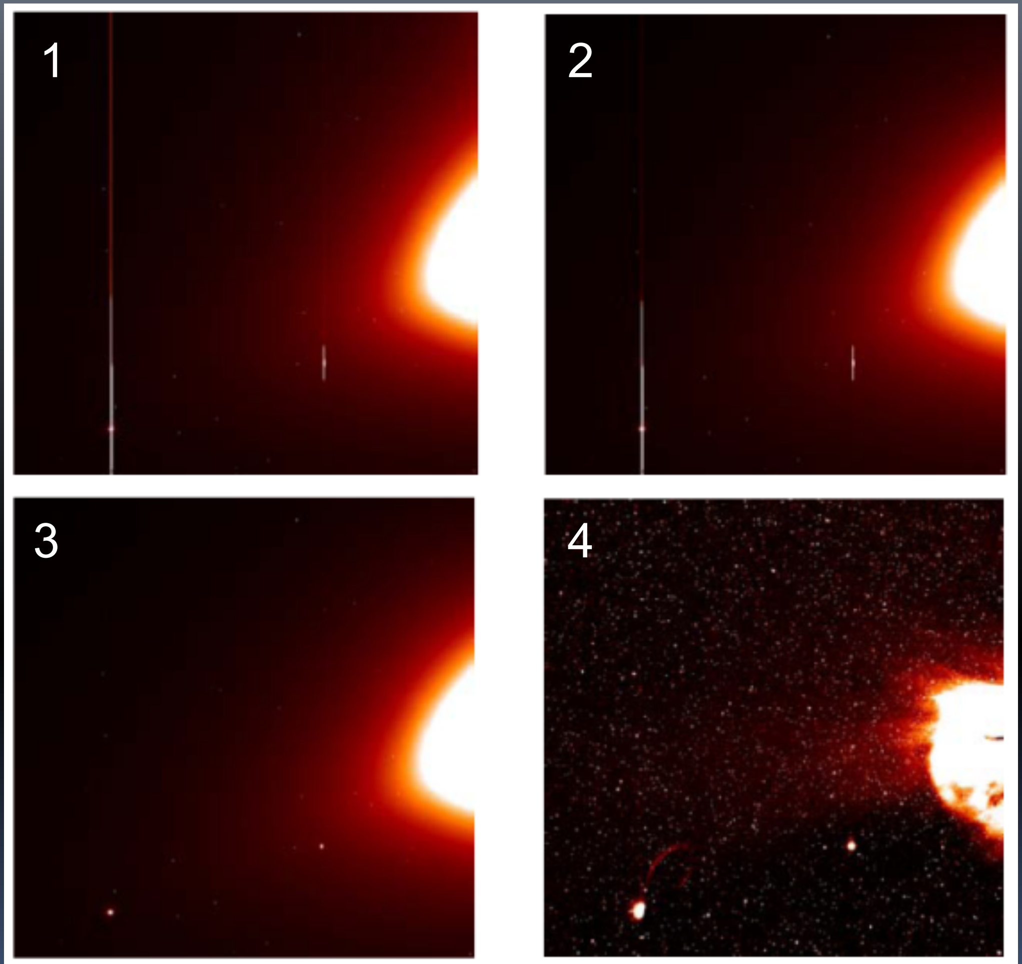
HI FOV Geometry and WL Sensitivity



Basic Parameters	HI-1	HI-2
Direction of Centre of FOV	14 degrees	53.7 degrees
Angular Field of View	20 degrees	70 degrees
Angular Range	4-24 degrees	18.7-88.7 degrees
Image Pixel Size	70 arcsec	4 arcmin
Spectral Bandpass	630-730 nm	400-1000 nm
Nominal Image Cadence	60 min	120 min
Brightness Sensitivity (B_o = solar disk)	3 $x10^{-15}$ B_o	$3x10^{-16}$ B_o

Harrison et al., Sol. Phys. 2008; from Socker et al. (2000)

HI Image Analysis

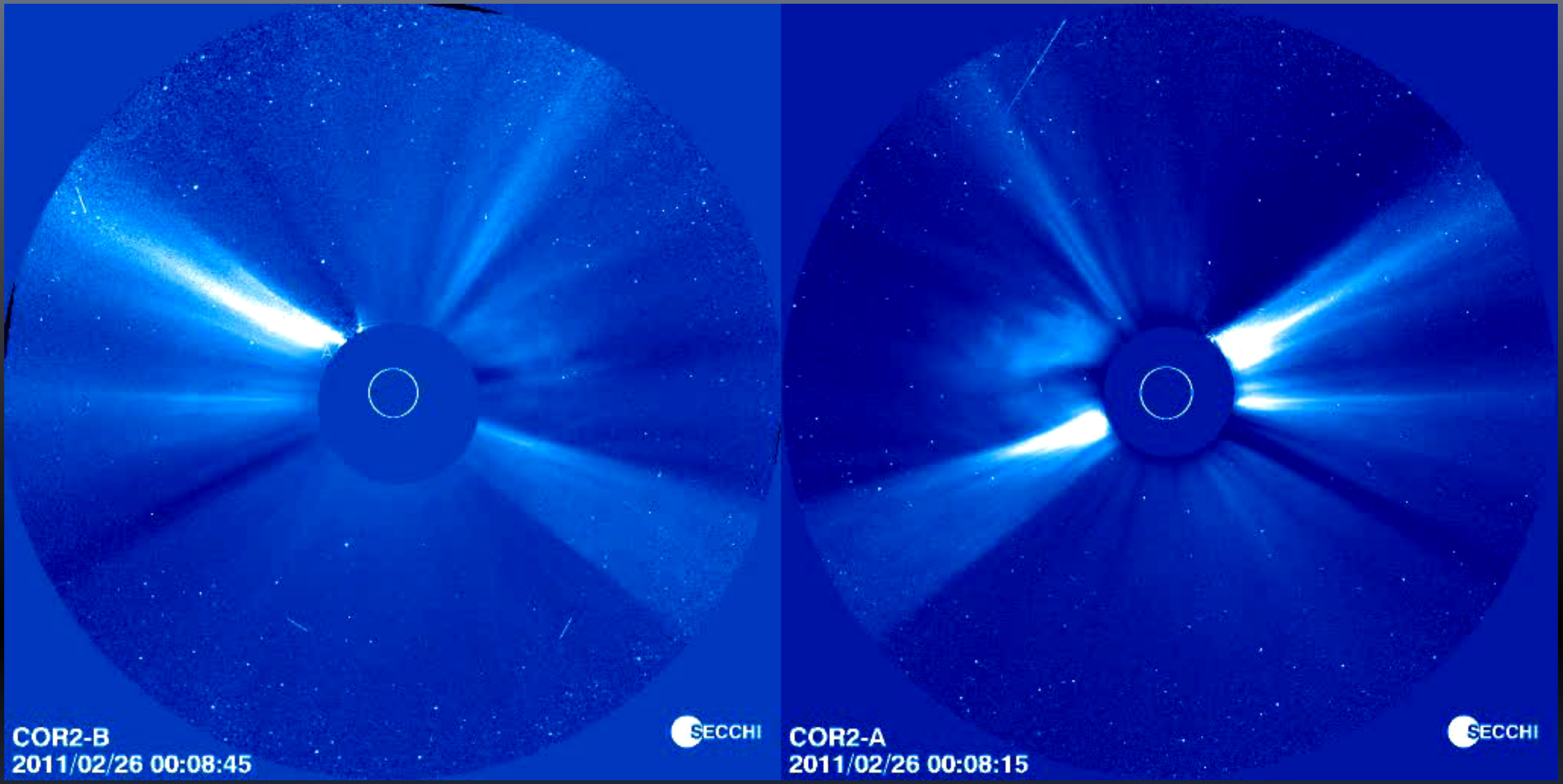


Venus (lower left) and Mercury

1) Correction for shutterless operation and flatfielding.
2) Blooming around Venus and Mercury (or stars) removed.
3) Background substracted:
   Light from K, F, corona, stars, milky way, planets, cosmic rays.
   Background selection: longer for stable structures like streamers, min. in each px over 1 day (CMEs), 3 days (streamers), 7 days, moving averages for movies.
4) CMEs become visible as 1.7×10^{-14} B_0 bright features.

- Running difference images ($I_{n+1} - I_n$)
- Star drift (~2.5 arcmin/hr=1px, star alignment GEI)
- Correction for dust impacts
- HI 2 image analysis most sensitive

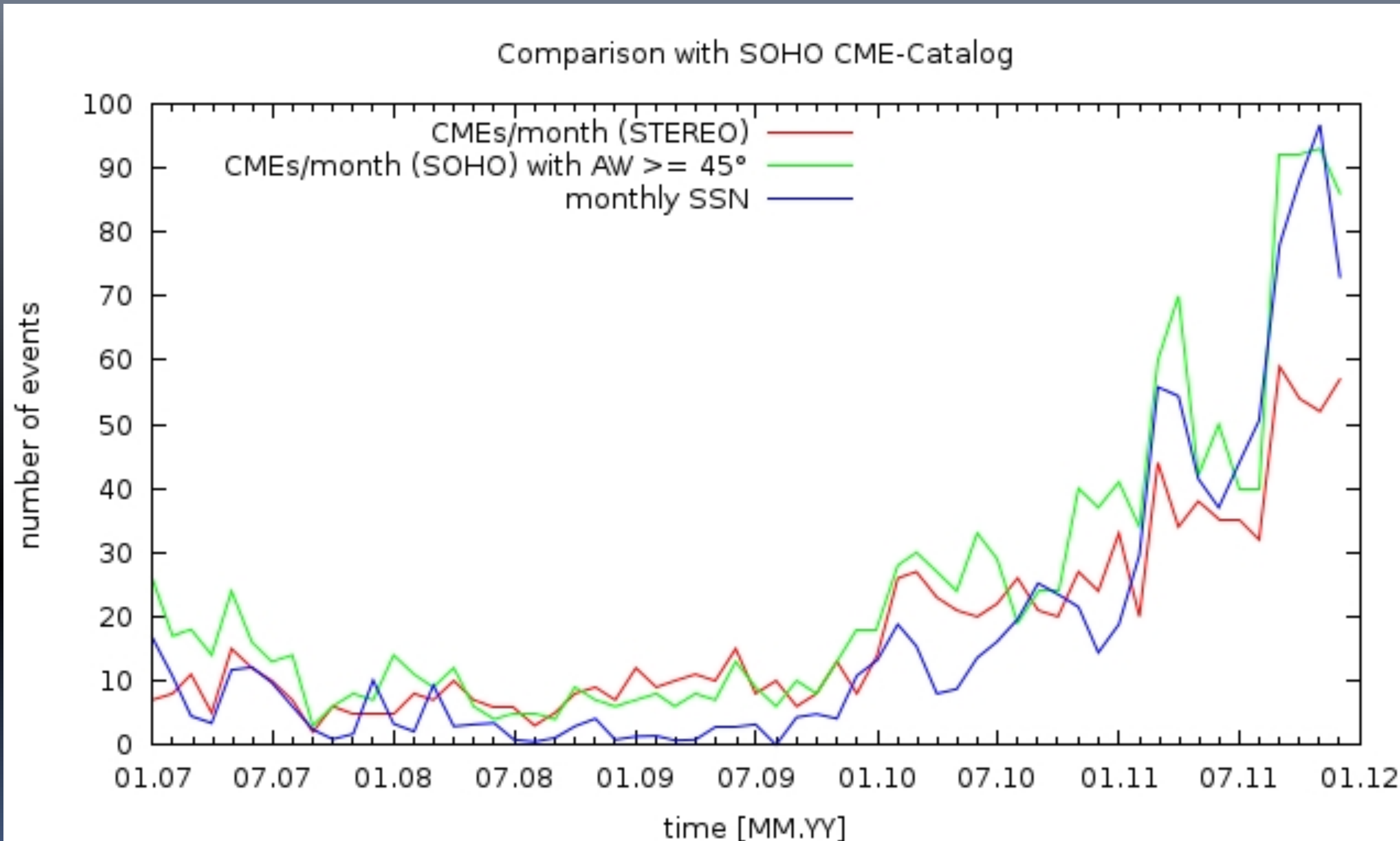
Examples of STEREO/SECCHI/COR2 CME Observations



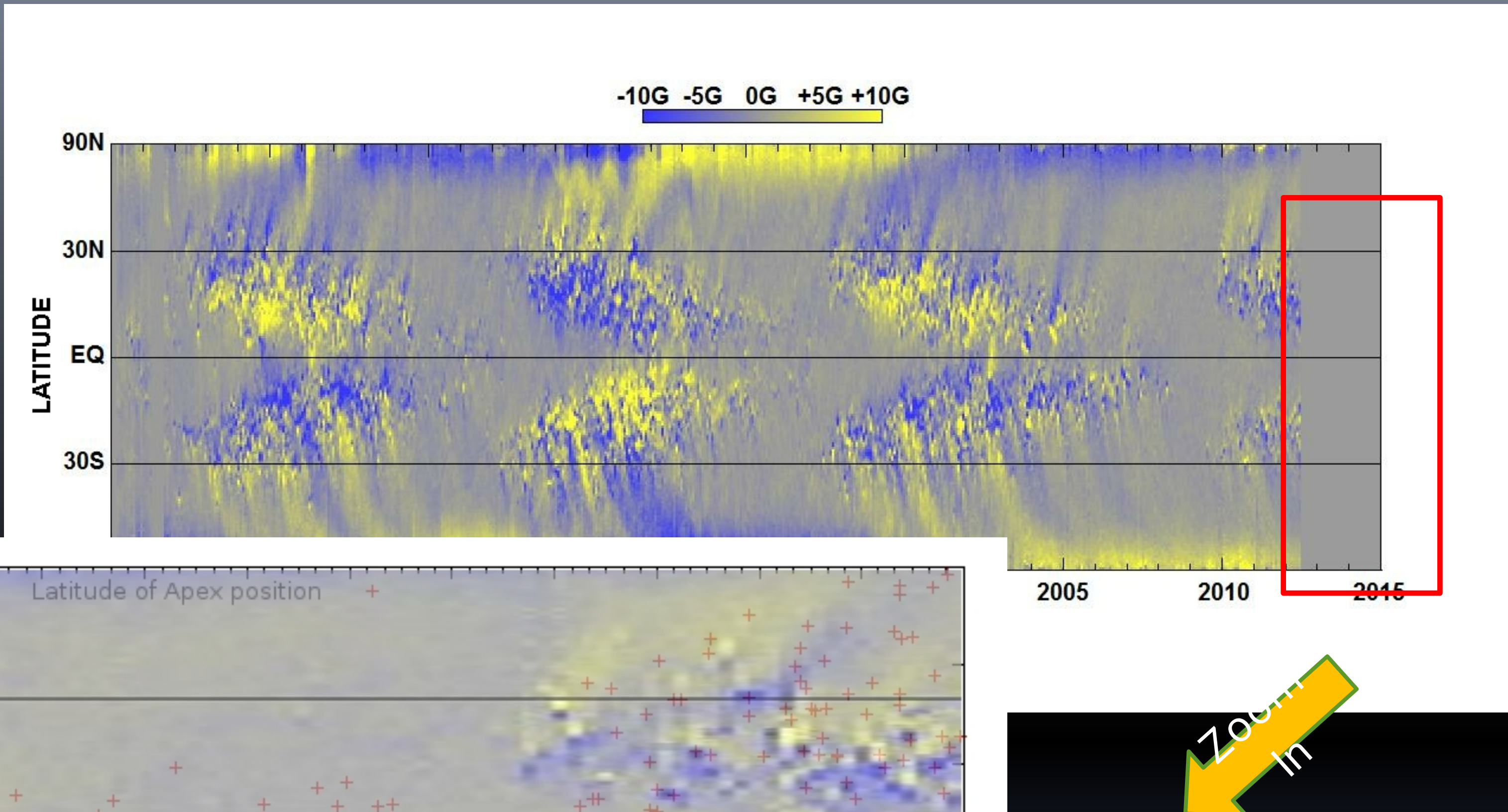
http://secchi.nrl.navy.mil/

STEREO/SECCHI/COR2 Synoptic Movie

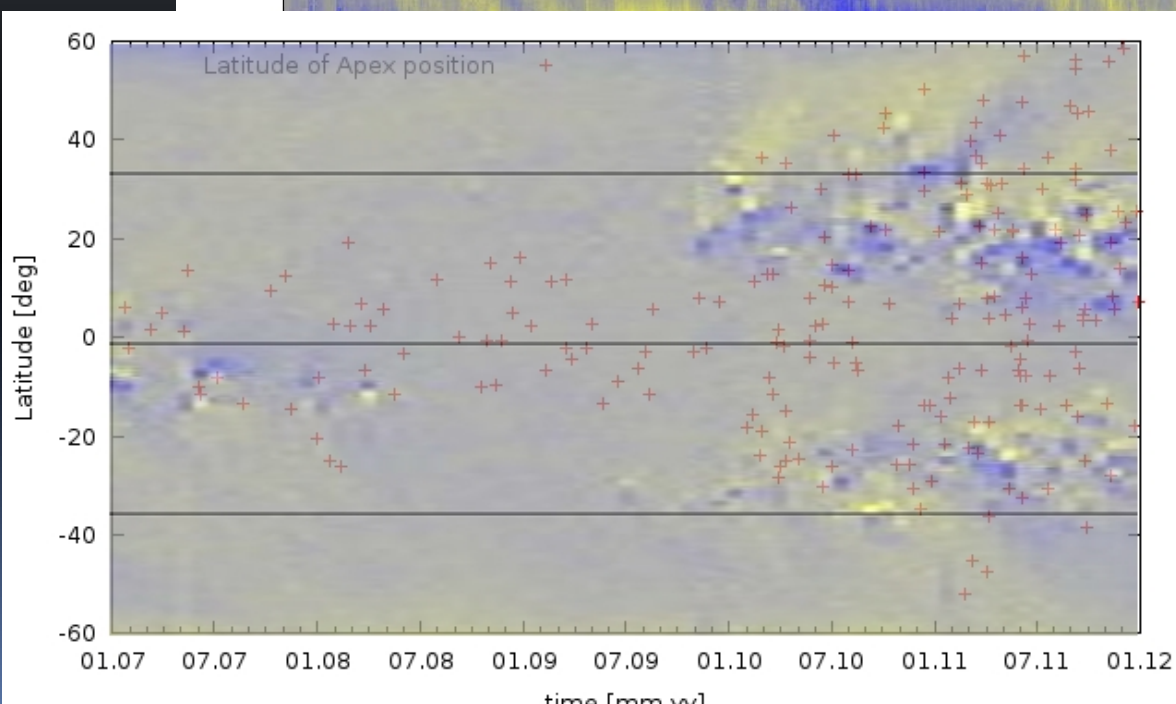
CME Frequencies and Sunspot Number



CMEs are intimately connected to the photospheric magnetic flux

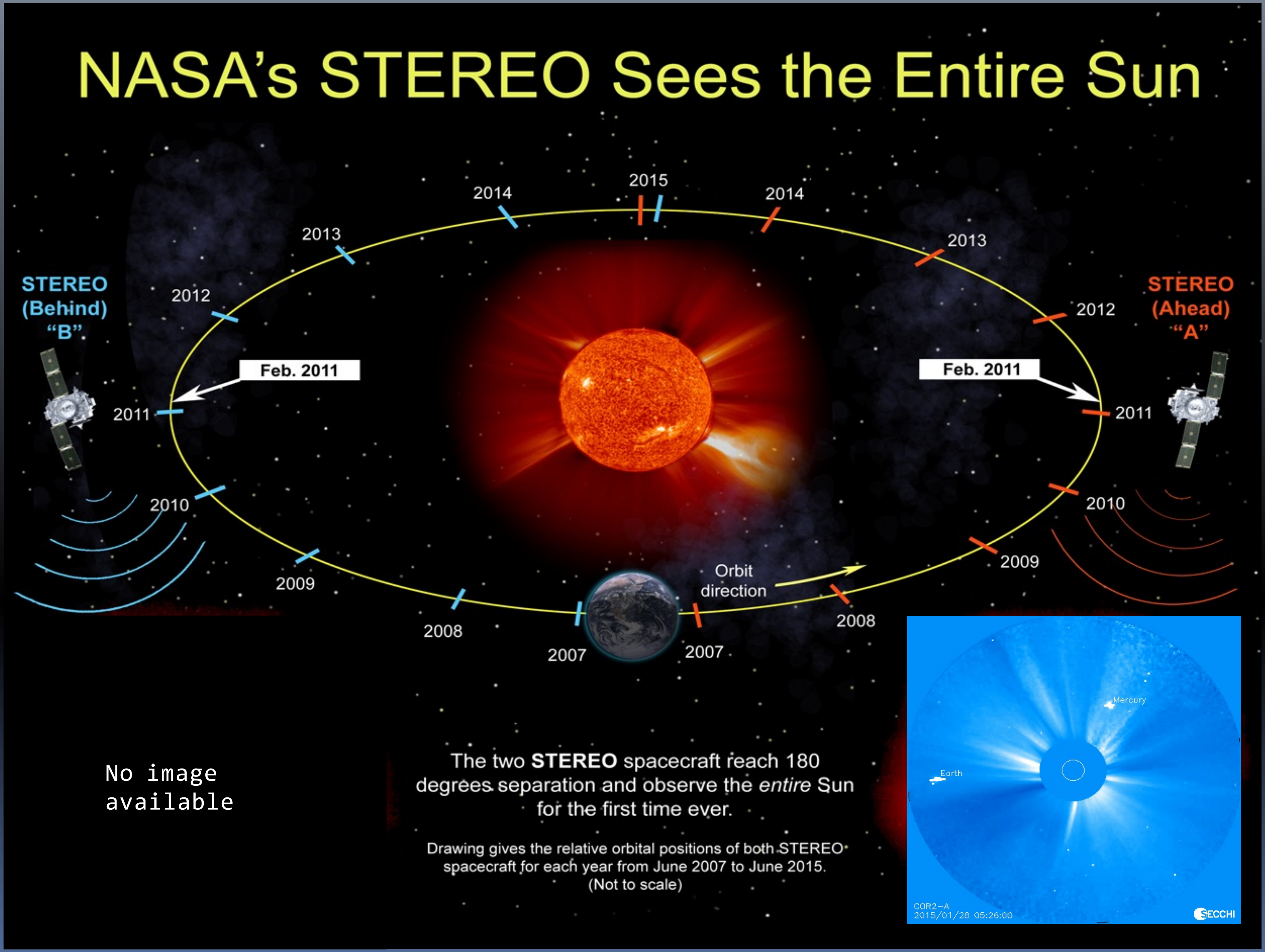


NASA, Marshall Space Flight Center



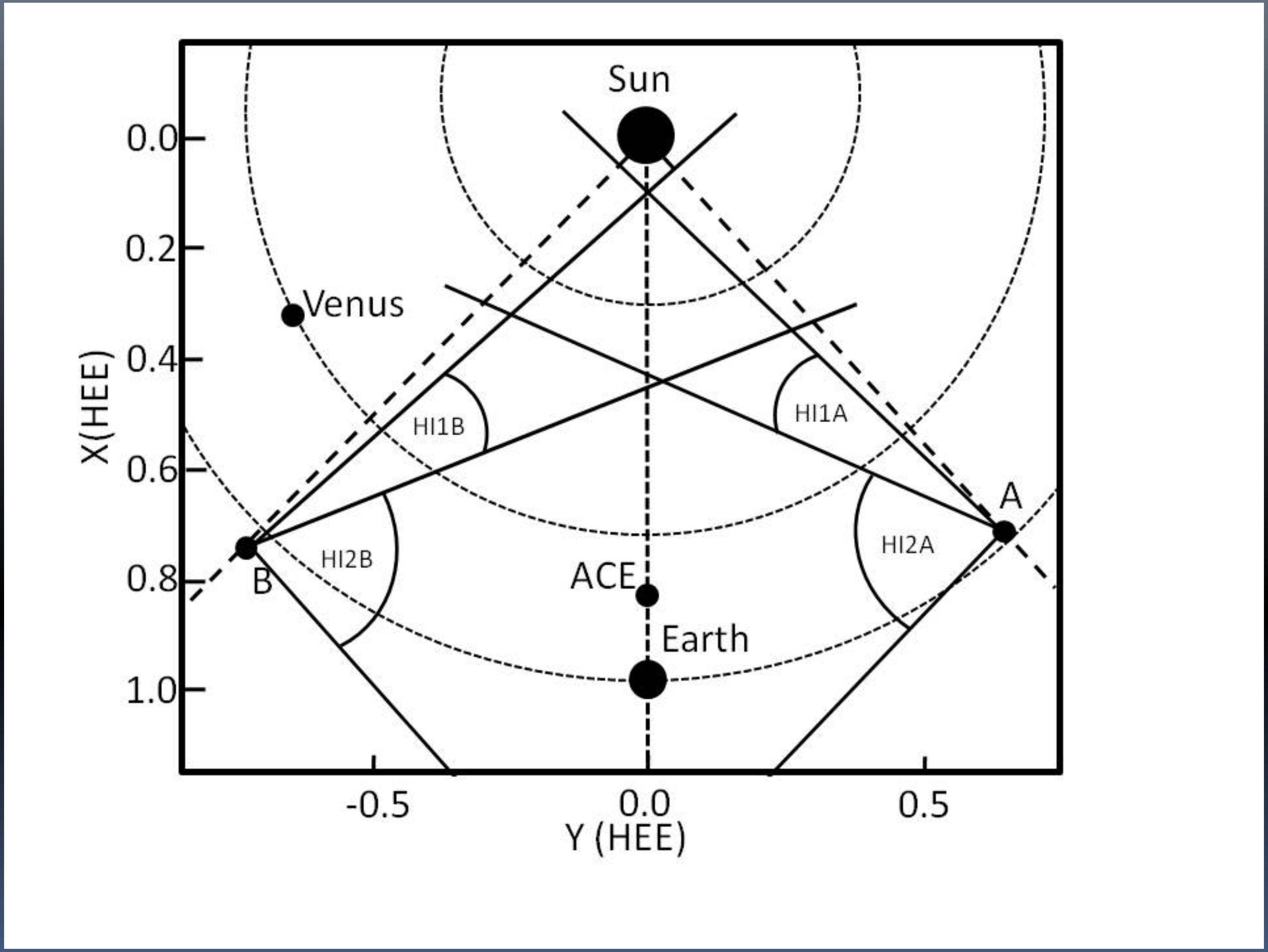
In Feb 2010 increasing solar activity and Jump of Apex to higher latitudes

Earth-Selfie from STEREO-A



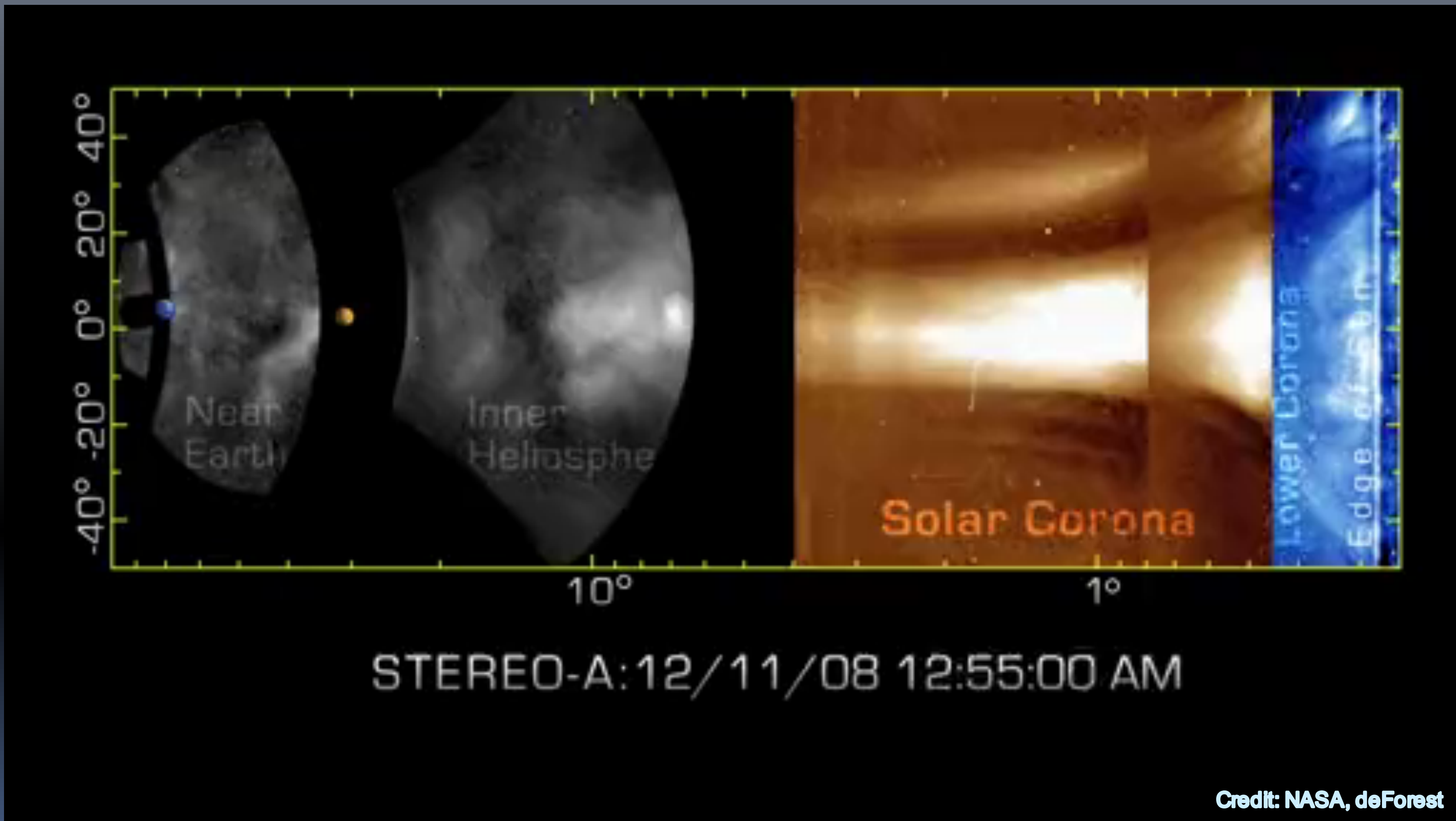
No image available

December 2008 – First CME Tracked All Away Along the Sun-Earth Line



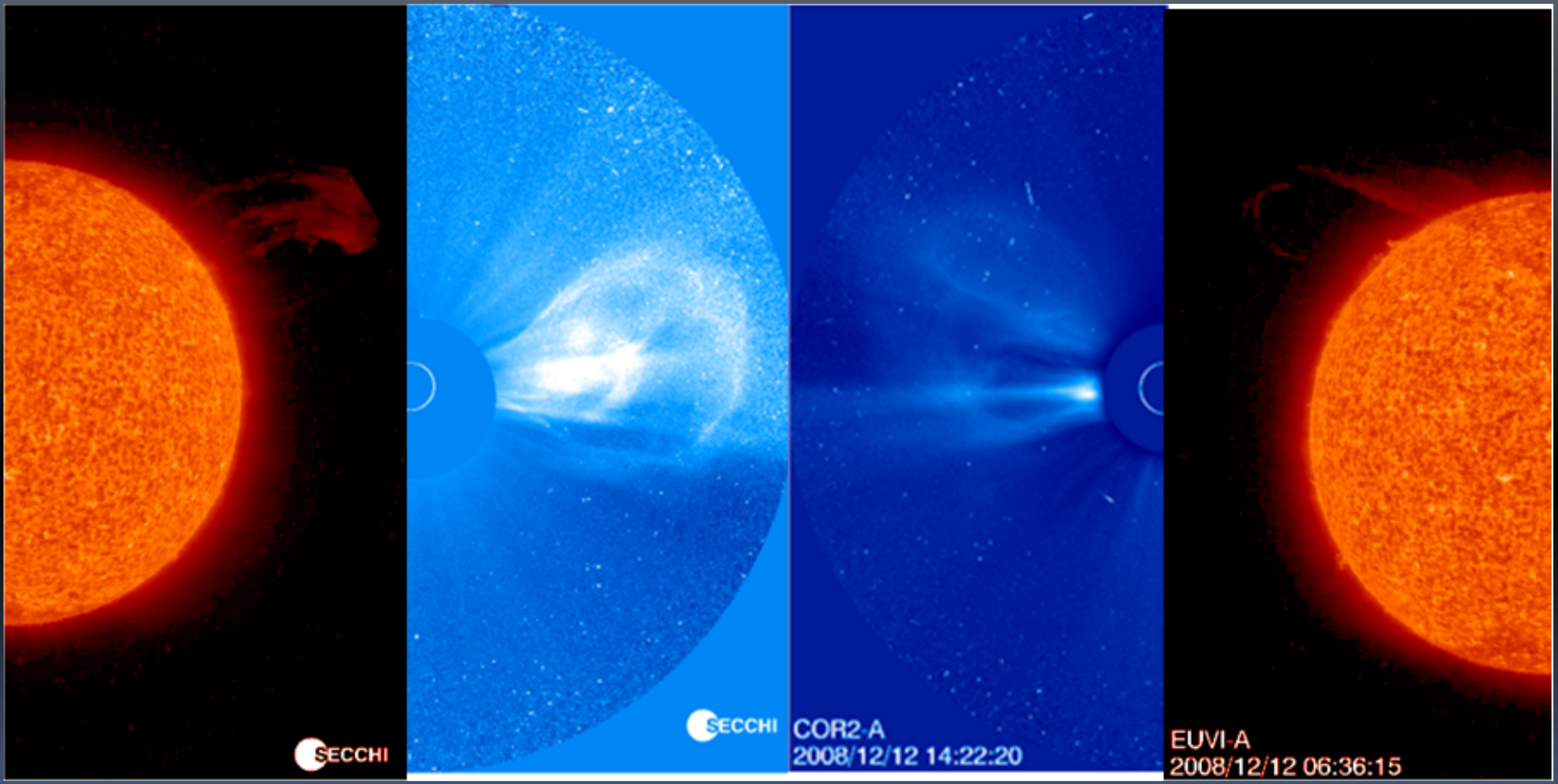
Davis et al., 2009

CME tracked Sun to Earth

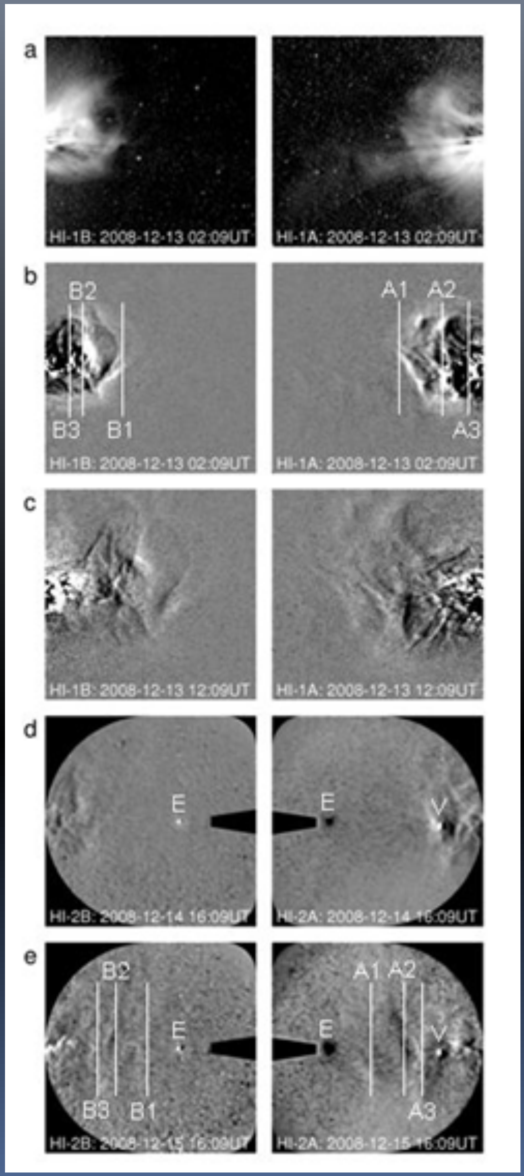


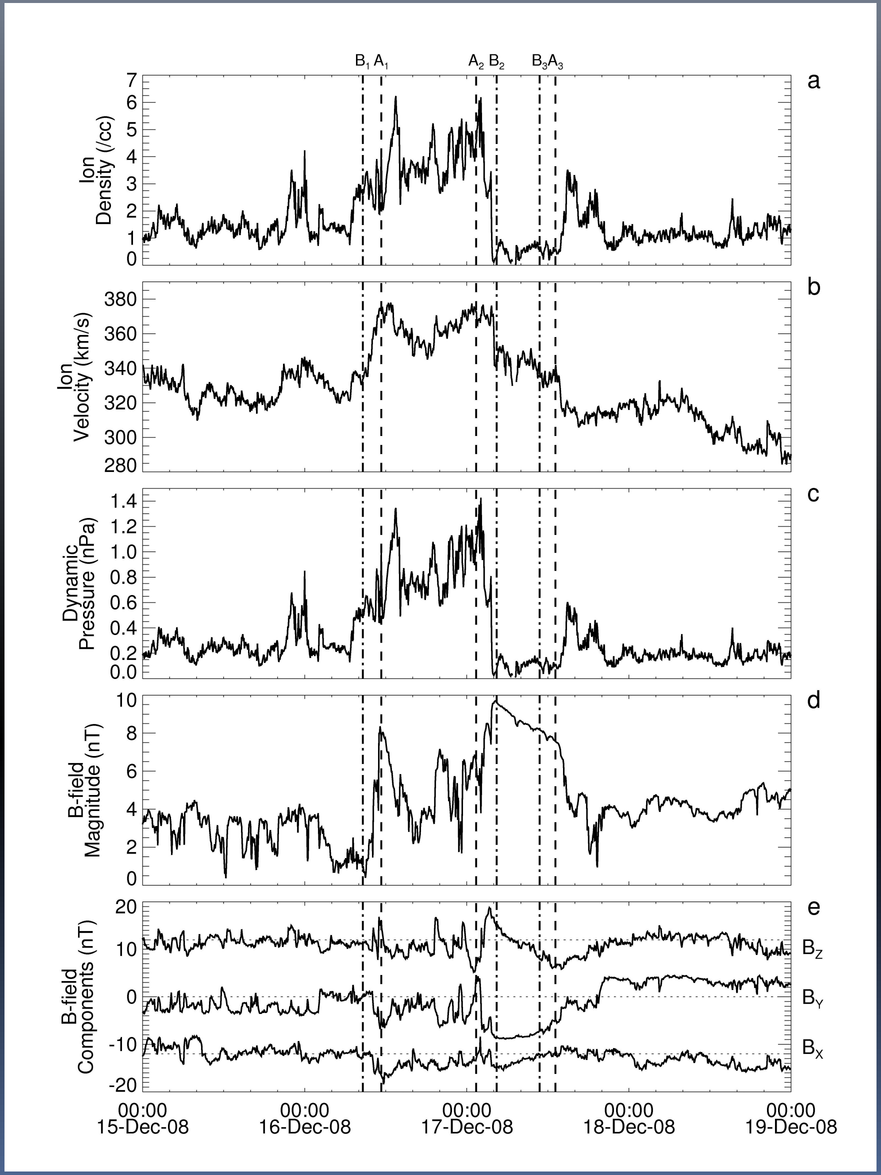
Credit: NASA, deForest

STEREO SECCHI/EUVI A, B 304 Å and COR 2 A, B Observations



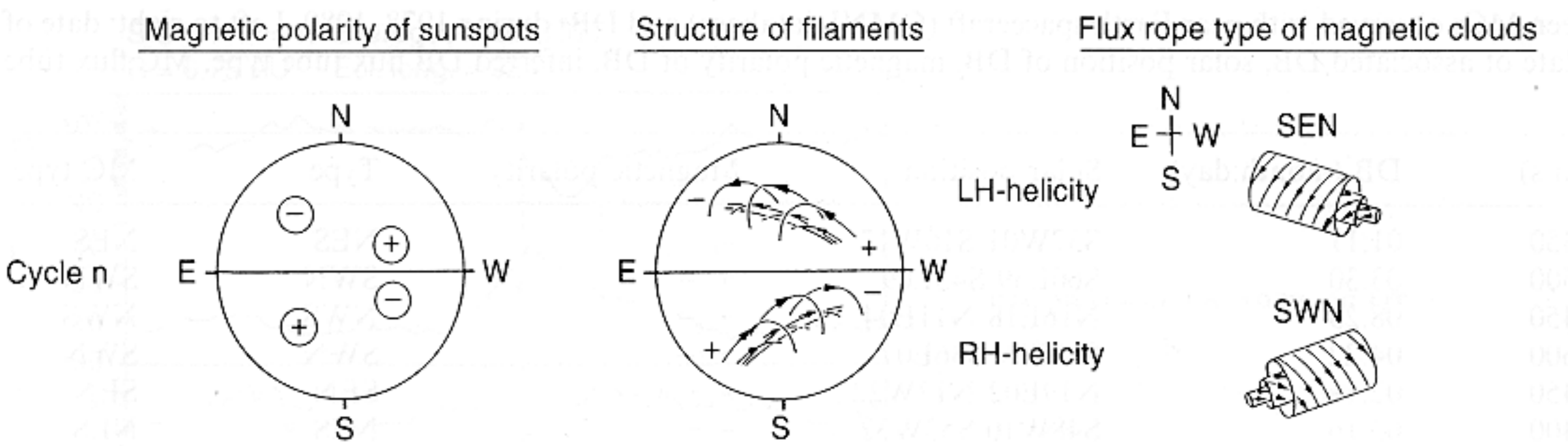
Correlated Analysis of STEREO/SECCHI/HI and ACE Data



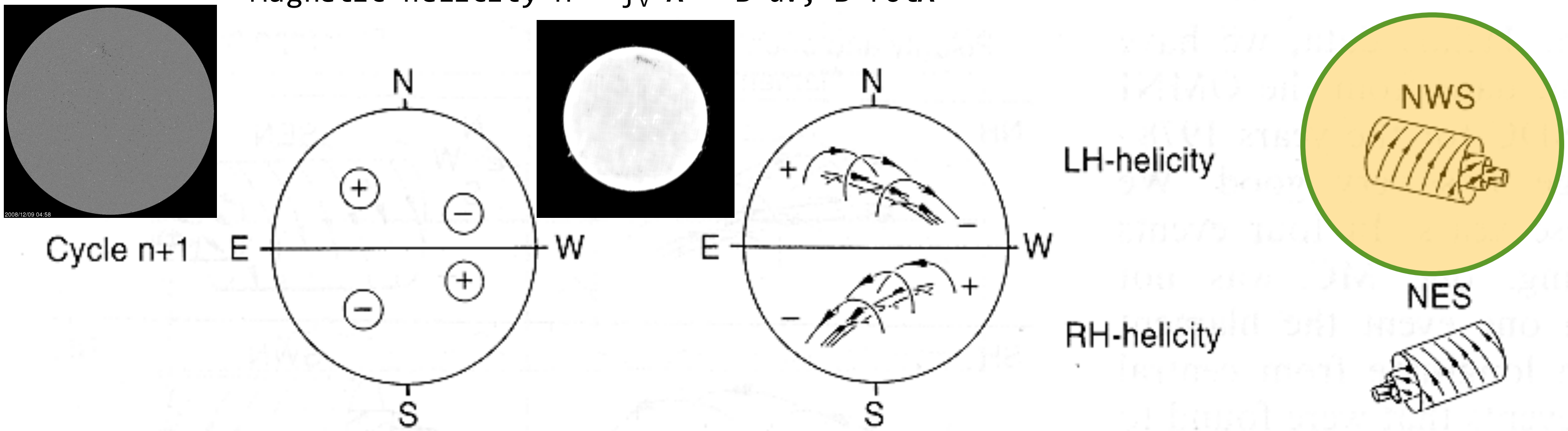


Davis et al., 2009

Consistent with the basic scheme introduced by Bothmer & Schwenn

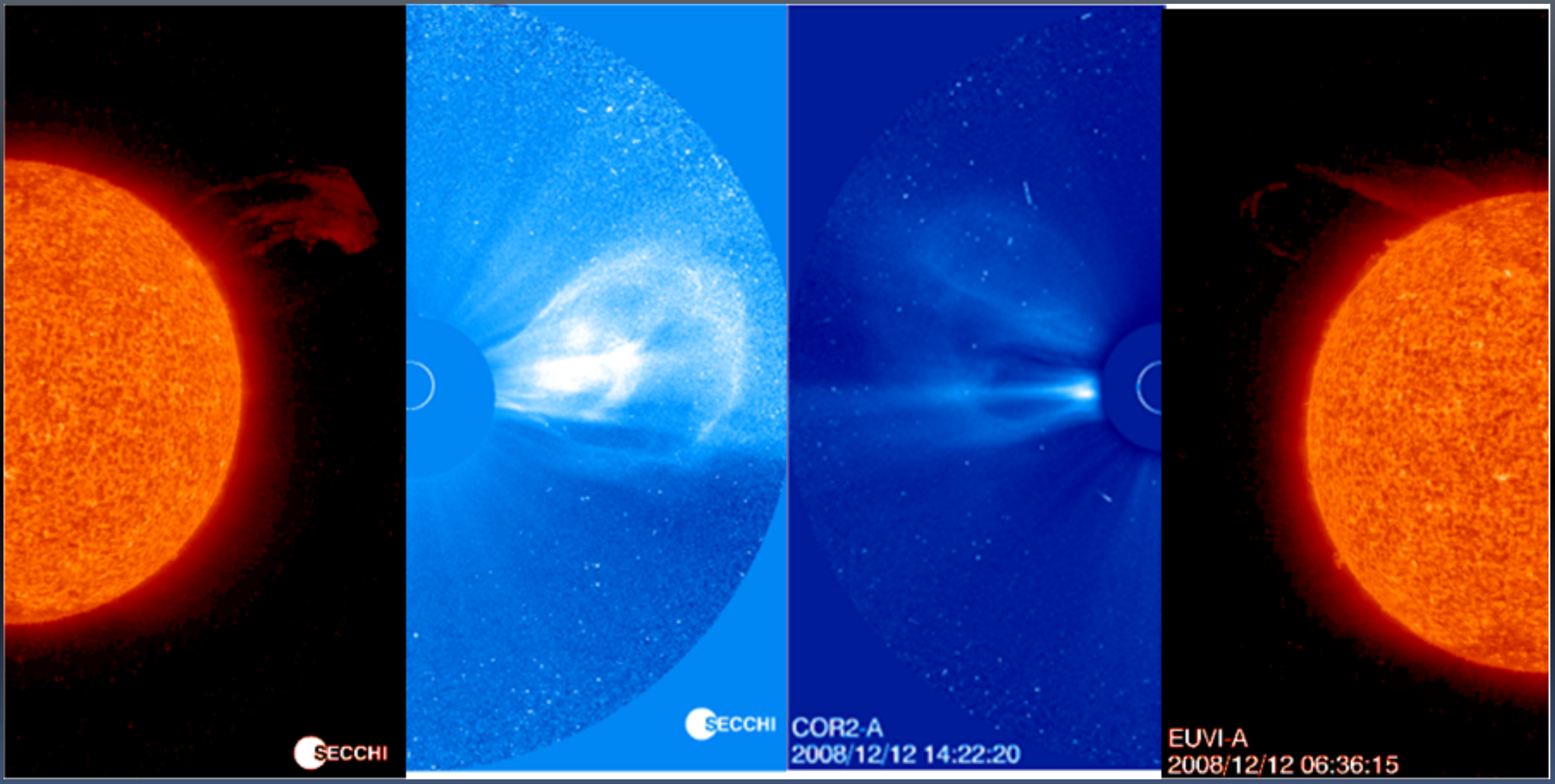


Magnetic helicity $H = \int_V \mathbf{A} \cdot \mathbf{B} \, dV$, $\mathbf{B} = \mathrm{rot}\mathbf{A}$

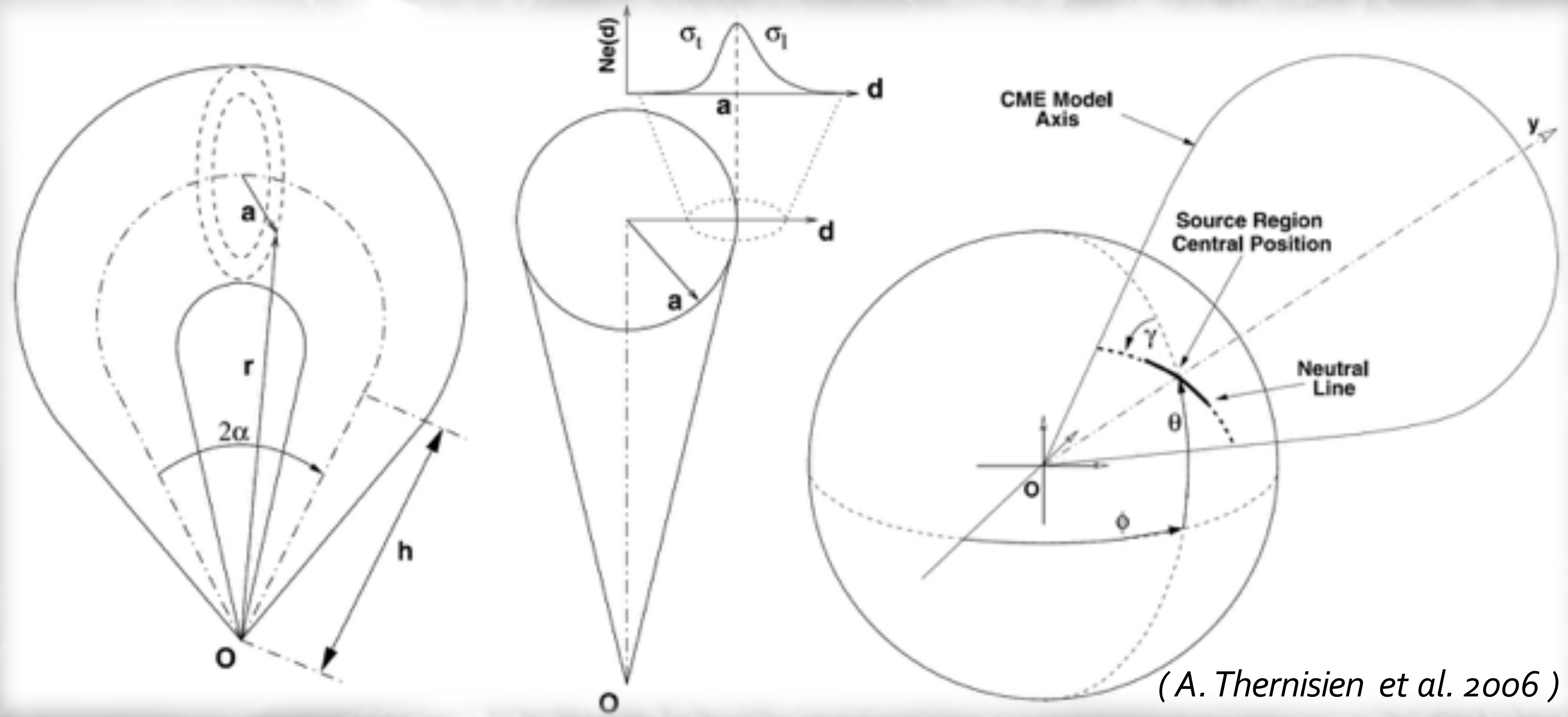


Complications not addressed, e.g. quadrupolar configurations, deviations from Joy's & Hale's lawa, effects from coronal interactions and ip compression

STEREO SECCHI/EUVI A, B 304 Å and COR 2 A, B Observations



The Graduated Cylindrical Shell Modell



(A. Thernisien et al. 2006)

Position on Sun:

Longitute: ϕ; *Latitude:* θ

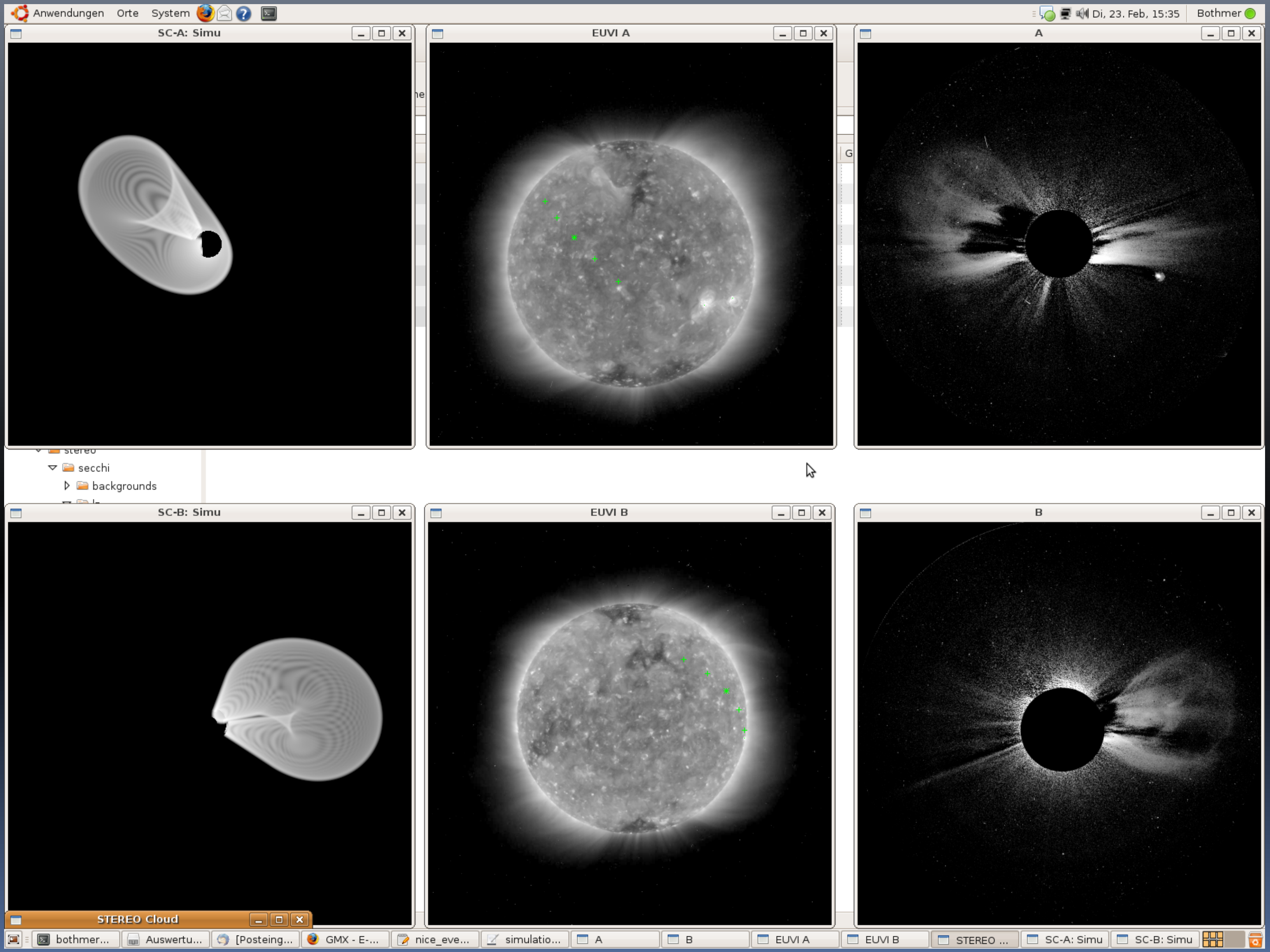
Electron model:

Gaussian width of density profile inside GCS: σ_t
Electron density: N_e
Gaussian width of density profile outside GCS: σ_l

Geometrical parameter:

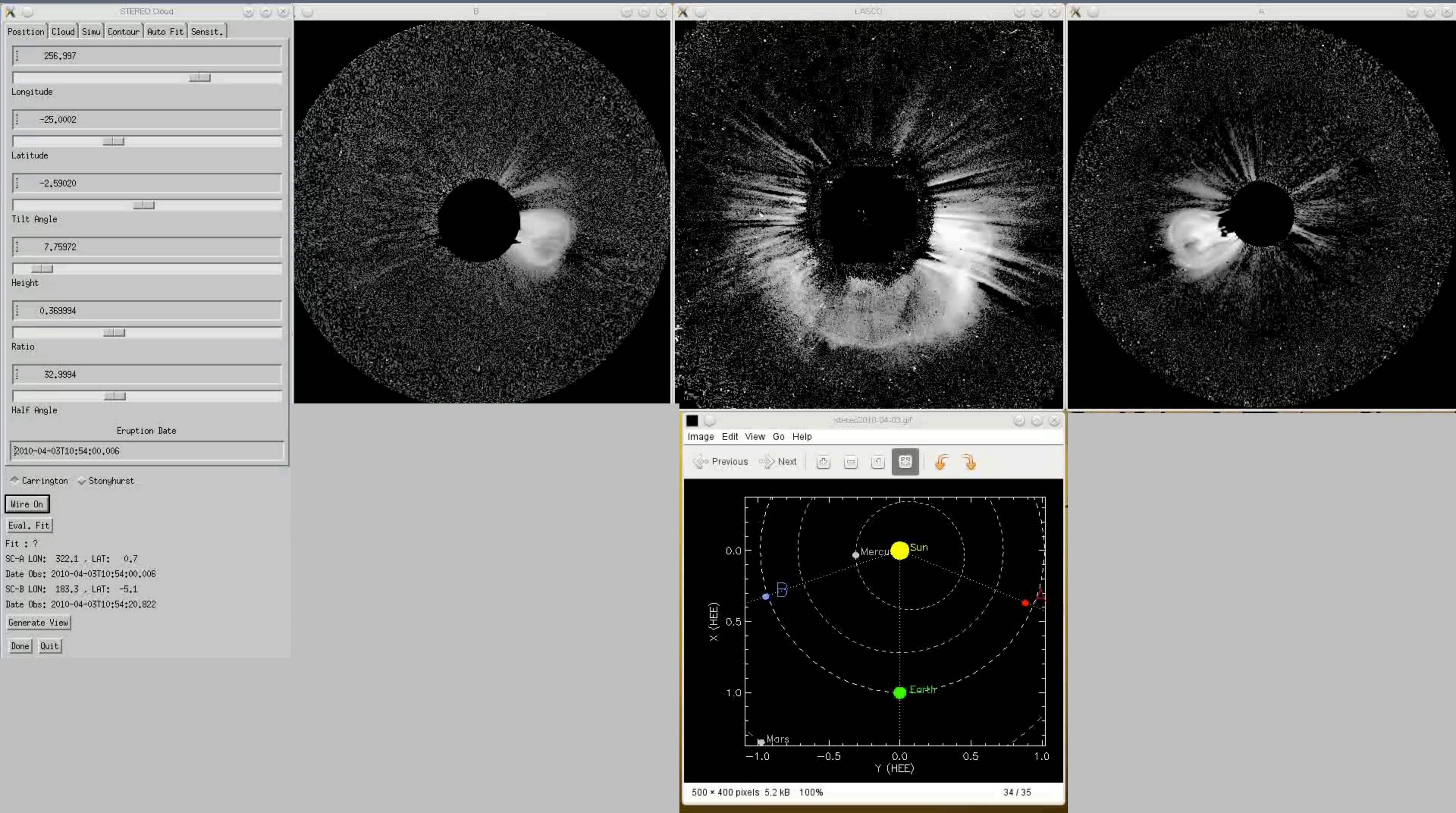
Angle between both legs: 2α
Radius of cross-section: a
Distance between sun center & boundary point of GCS: r
Height of the legs: h
Tilt angle: γ
Distance between O (sun center) & leading edge: h_{front}

CME Modelling: Dec. 12, 2008

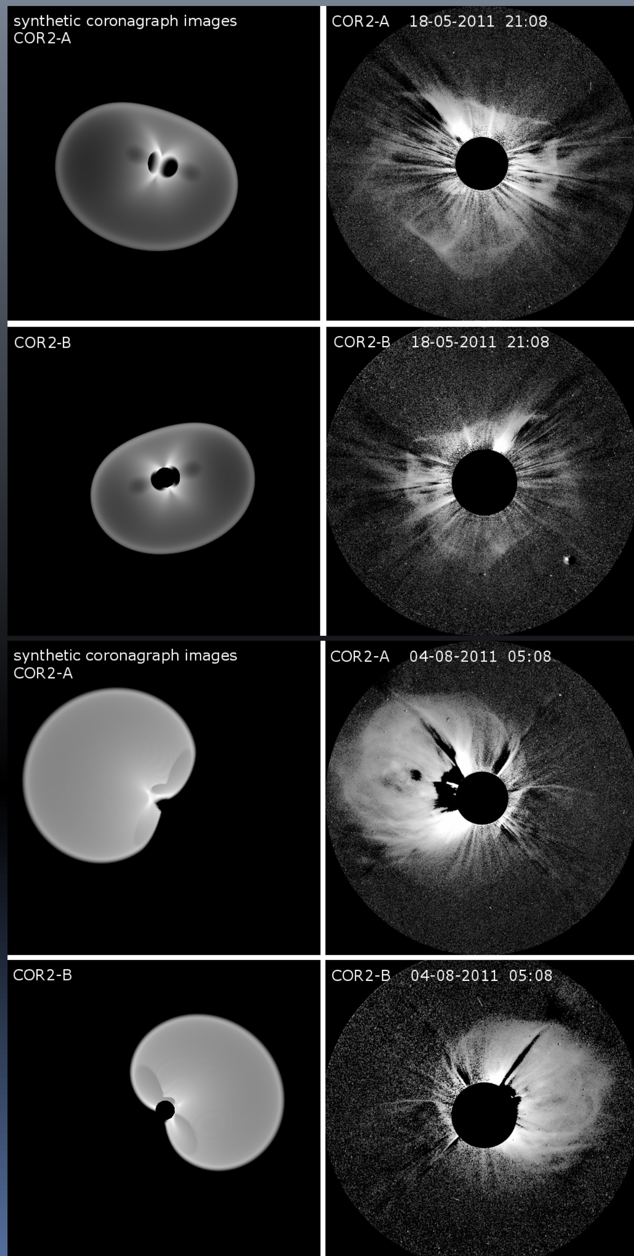


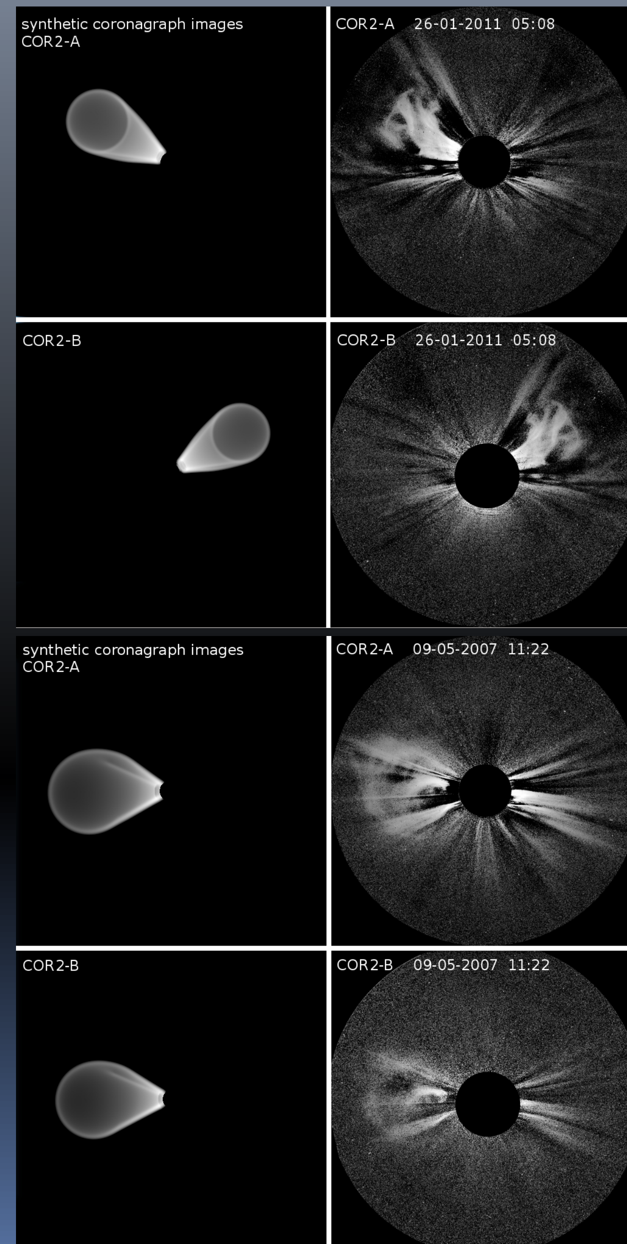
Credit: E. Bosman

Sample GCS Modelling



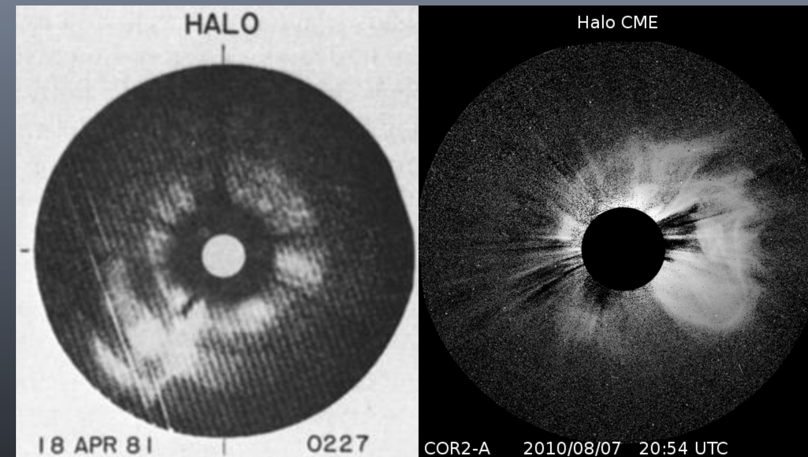
CME-Type WL-Reproductions

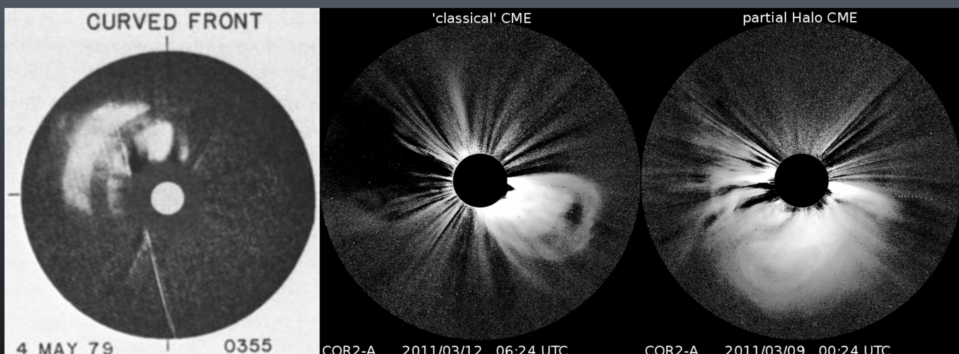


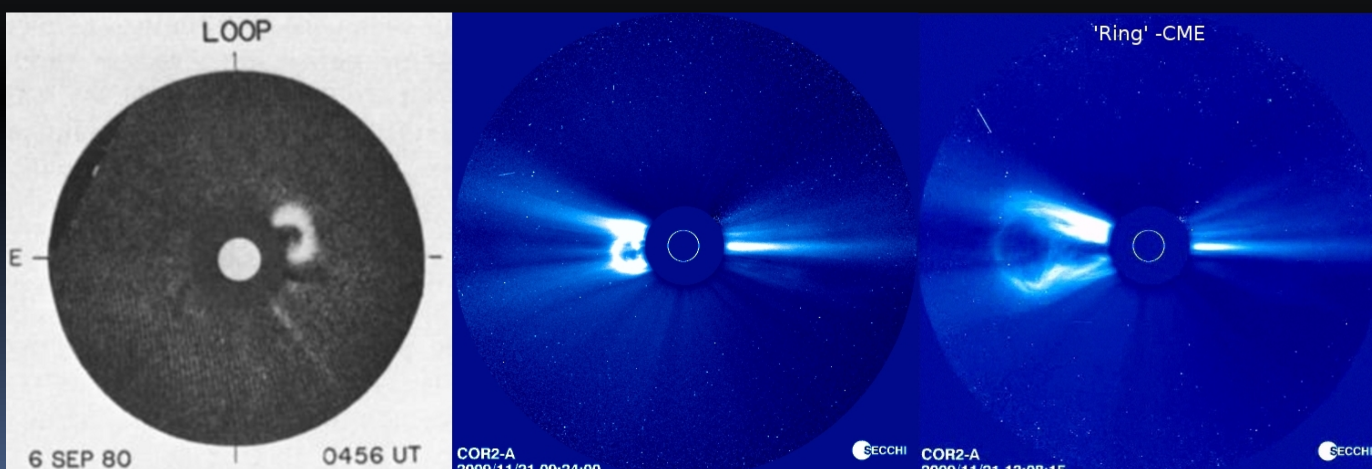


Credit: E. Bosman

CME-Types can be reproduced through FRs

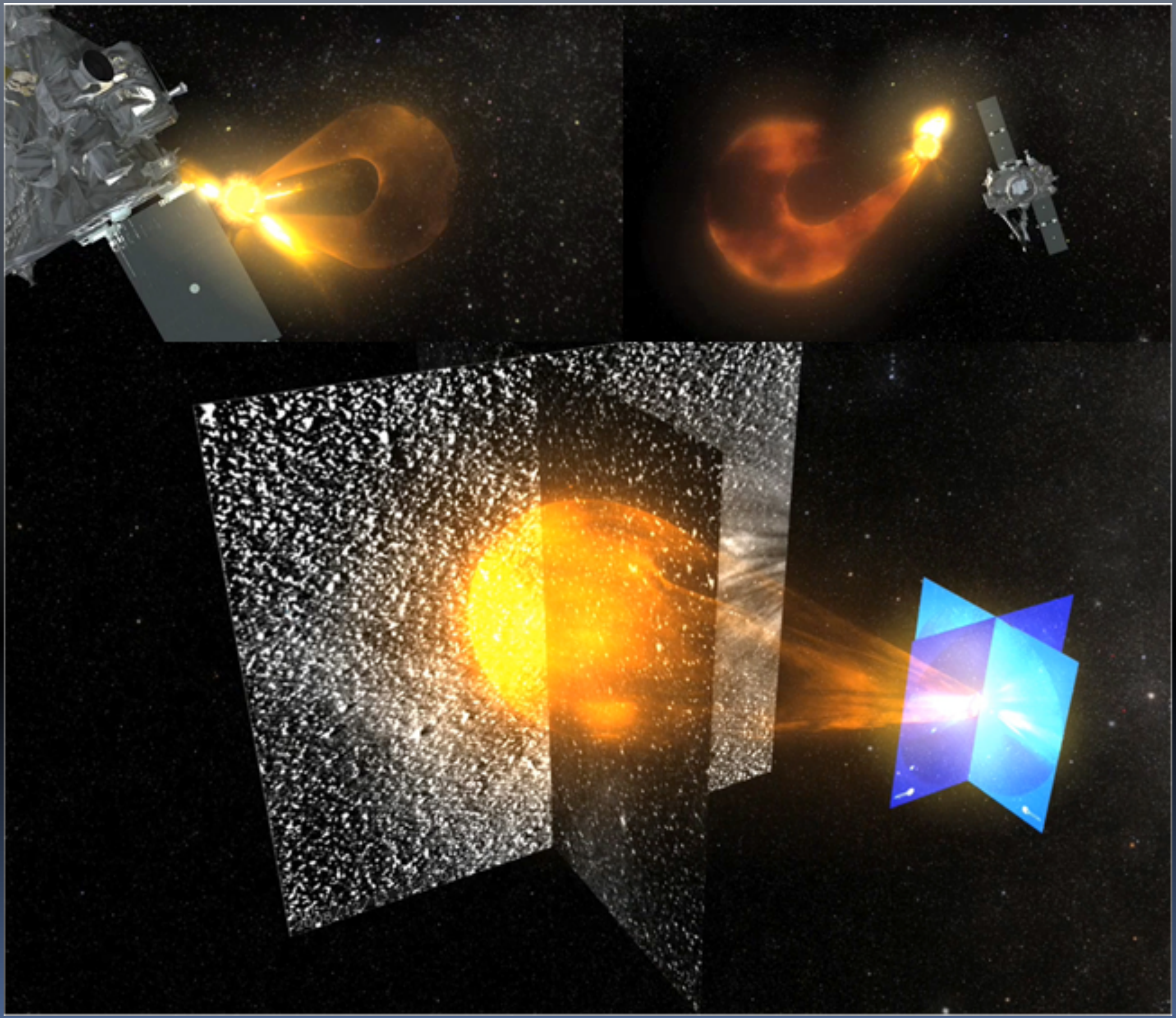






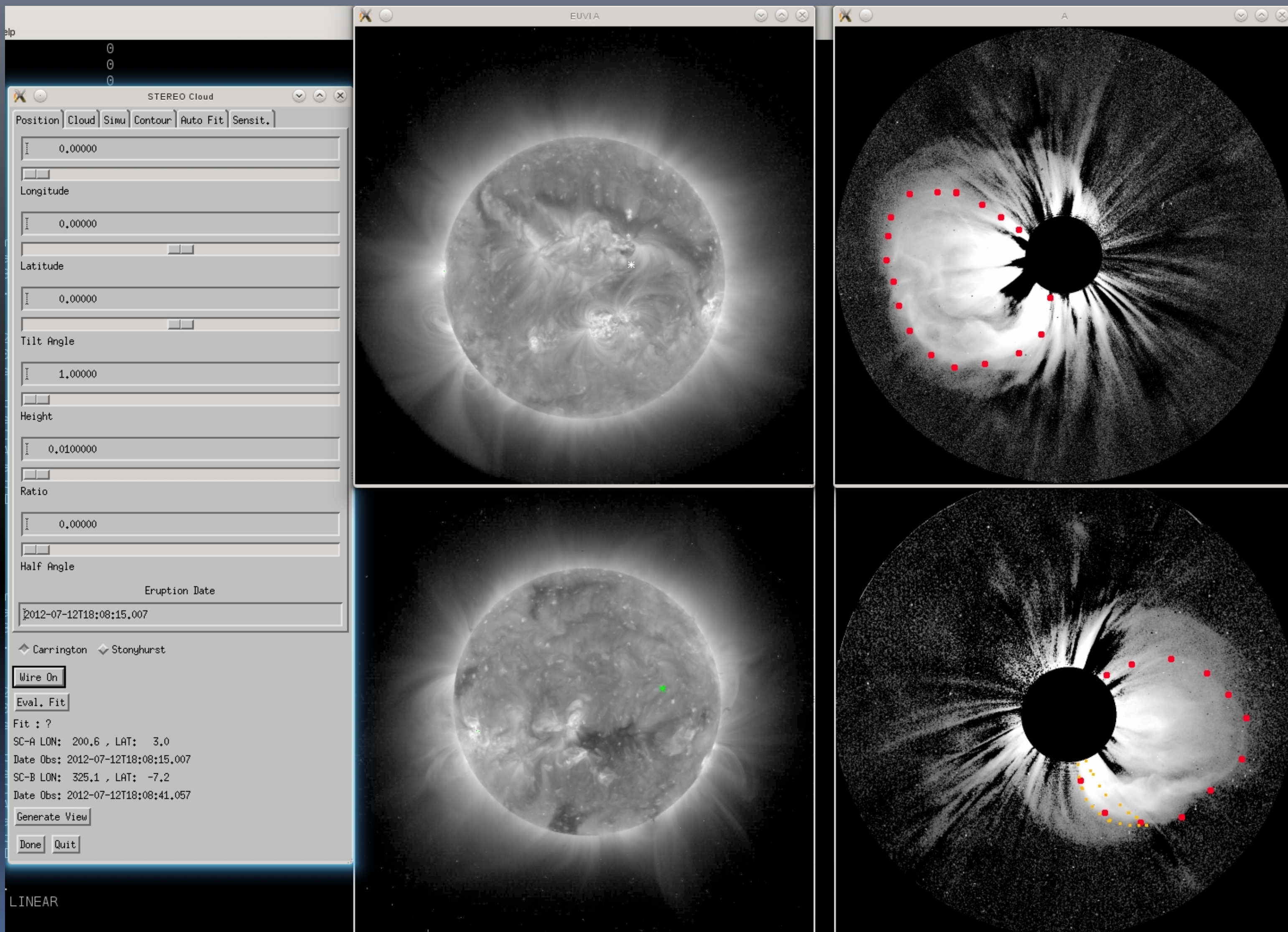
Credit: E. Bosman

CMEs are large-scale magnetic flux ropes

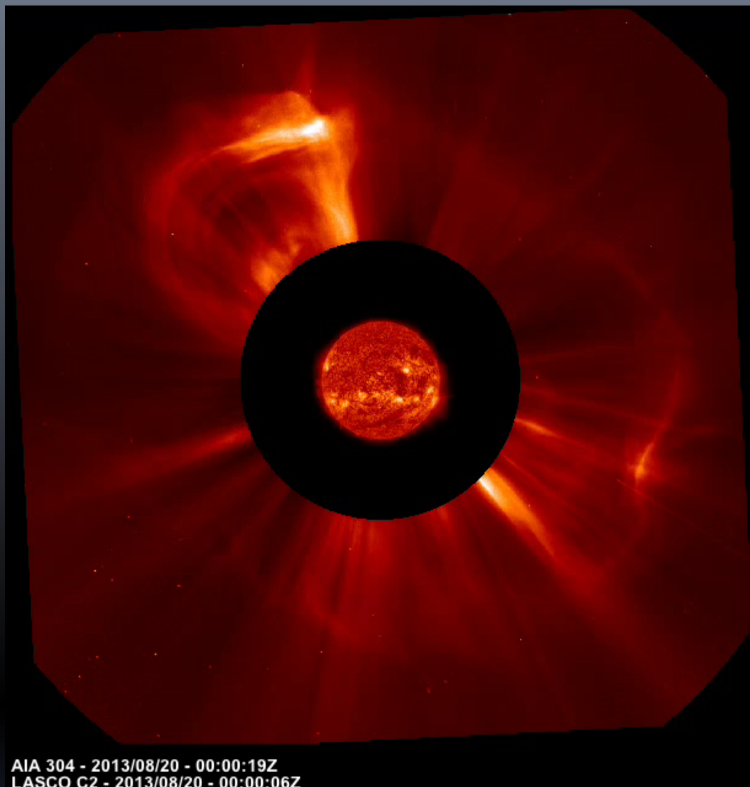


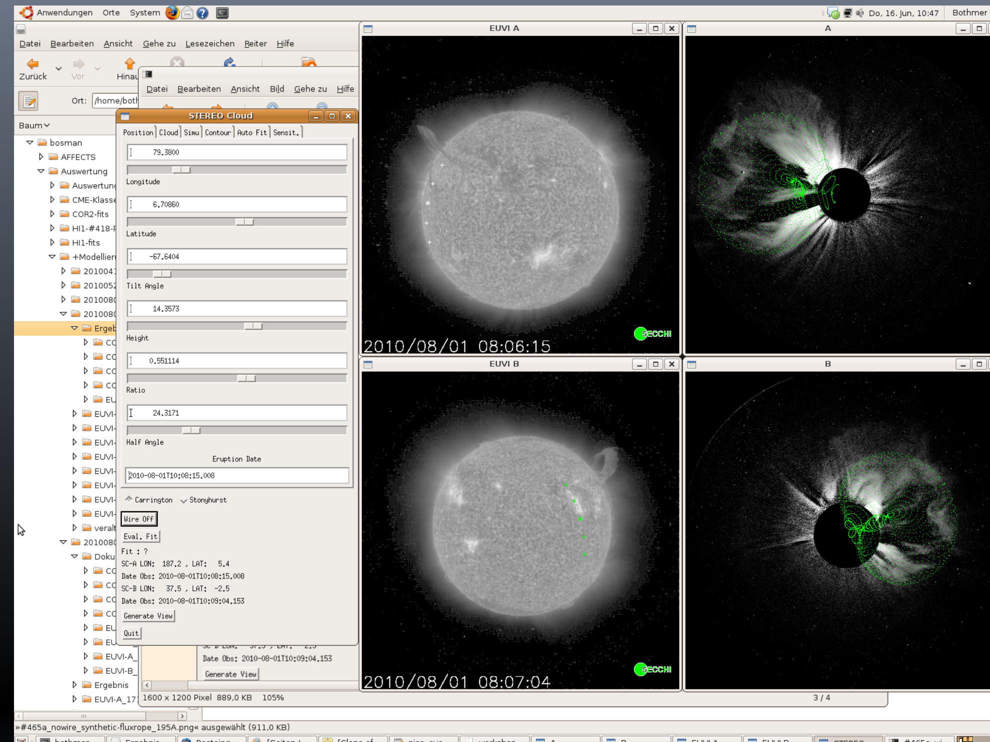
STEREO/SECCHI Consortium

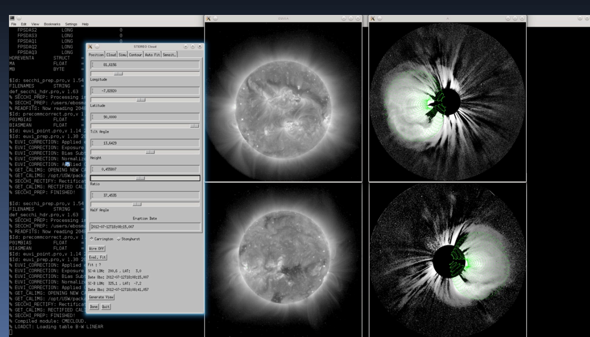
Complications: Shock fronts ahead of CMEs



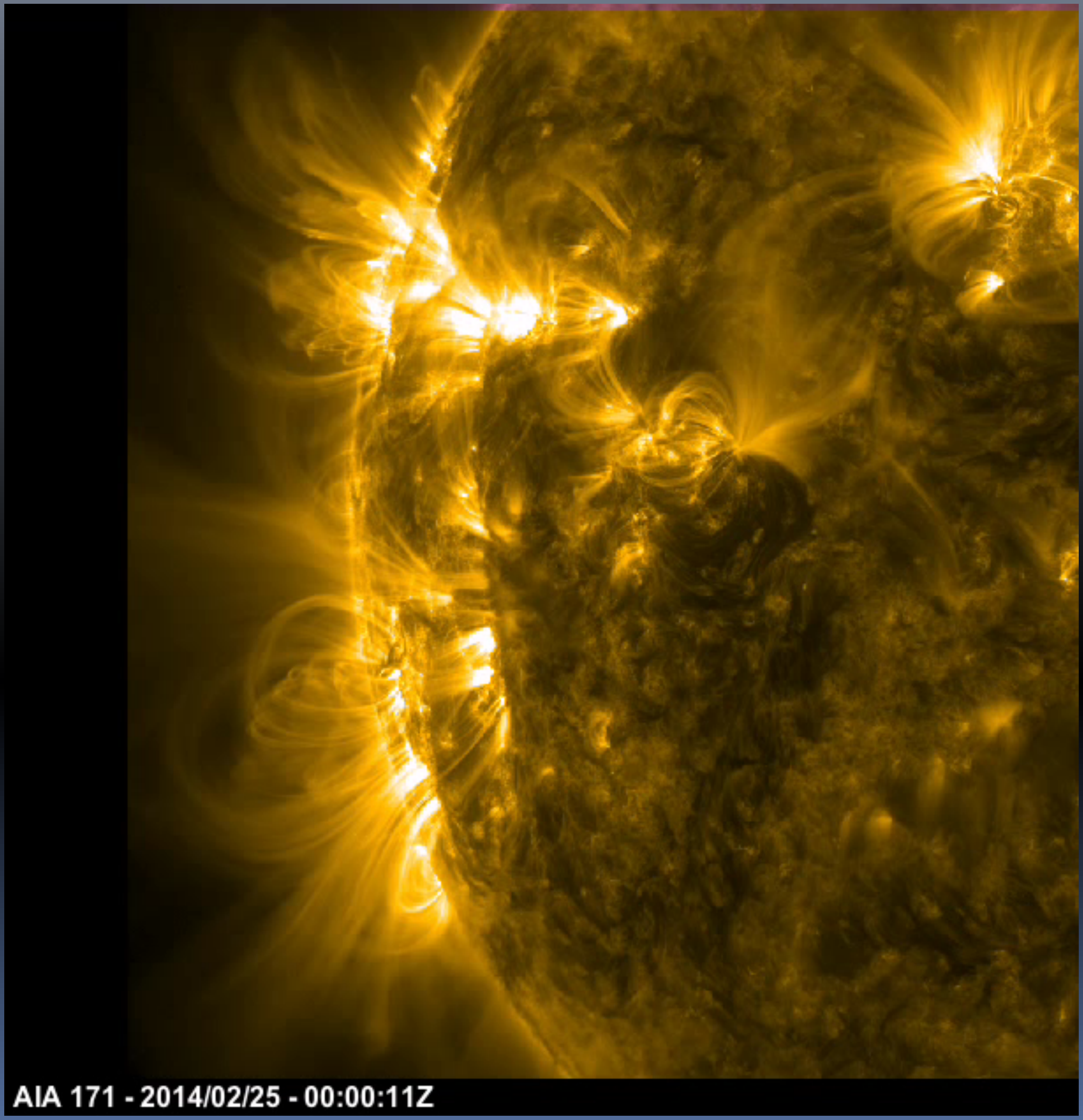
Distortion of CME fronts







Lateral expansion of CMEs – SDO/AIA 171



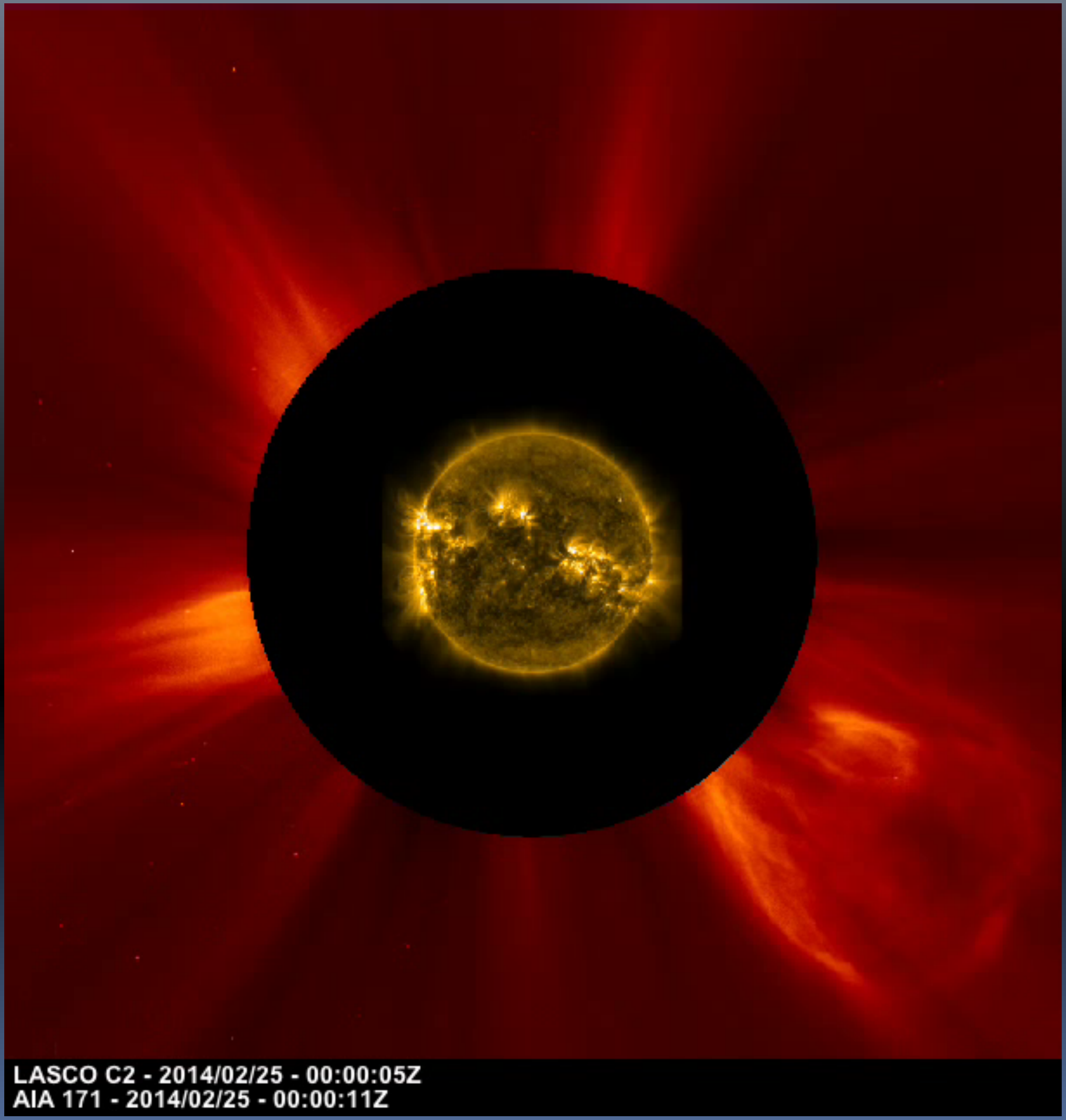
Credit: SDO/AIA

The associated low coronal wave

Can be studied with AFFECTS Solar Demon Tool in NRT

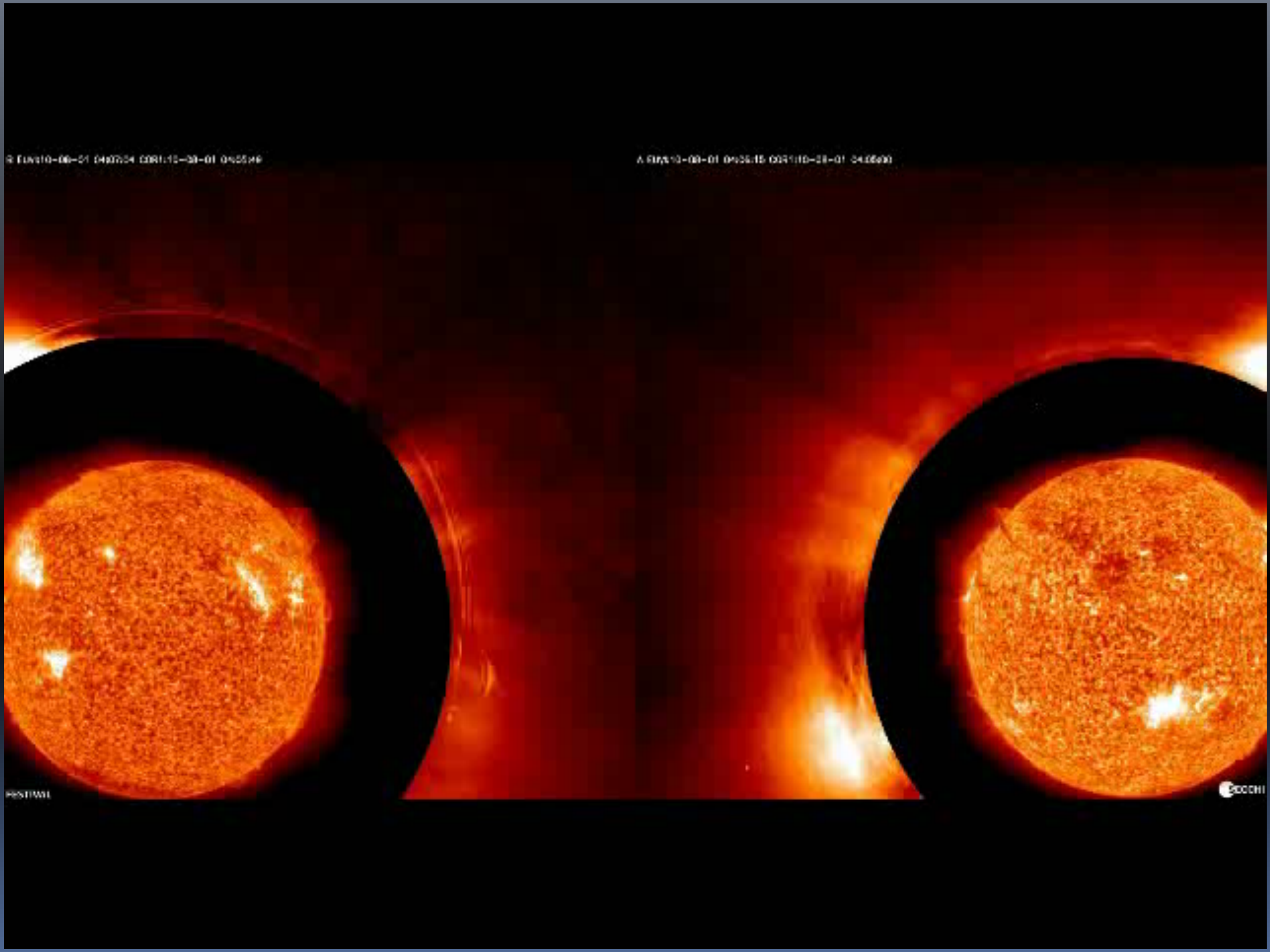
Credit: SDO/AIA, SIDC, AFFECTS

Near-Sun rapid CME-Evolution



Credit: SDO, SOHO

Multiple activity: STEREO/SECCHI A, B EUVI, COR 1 – August 01, 2010

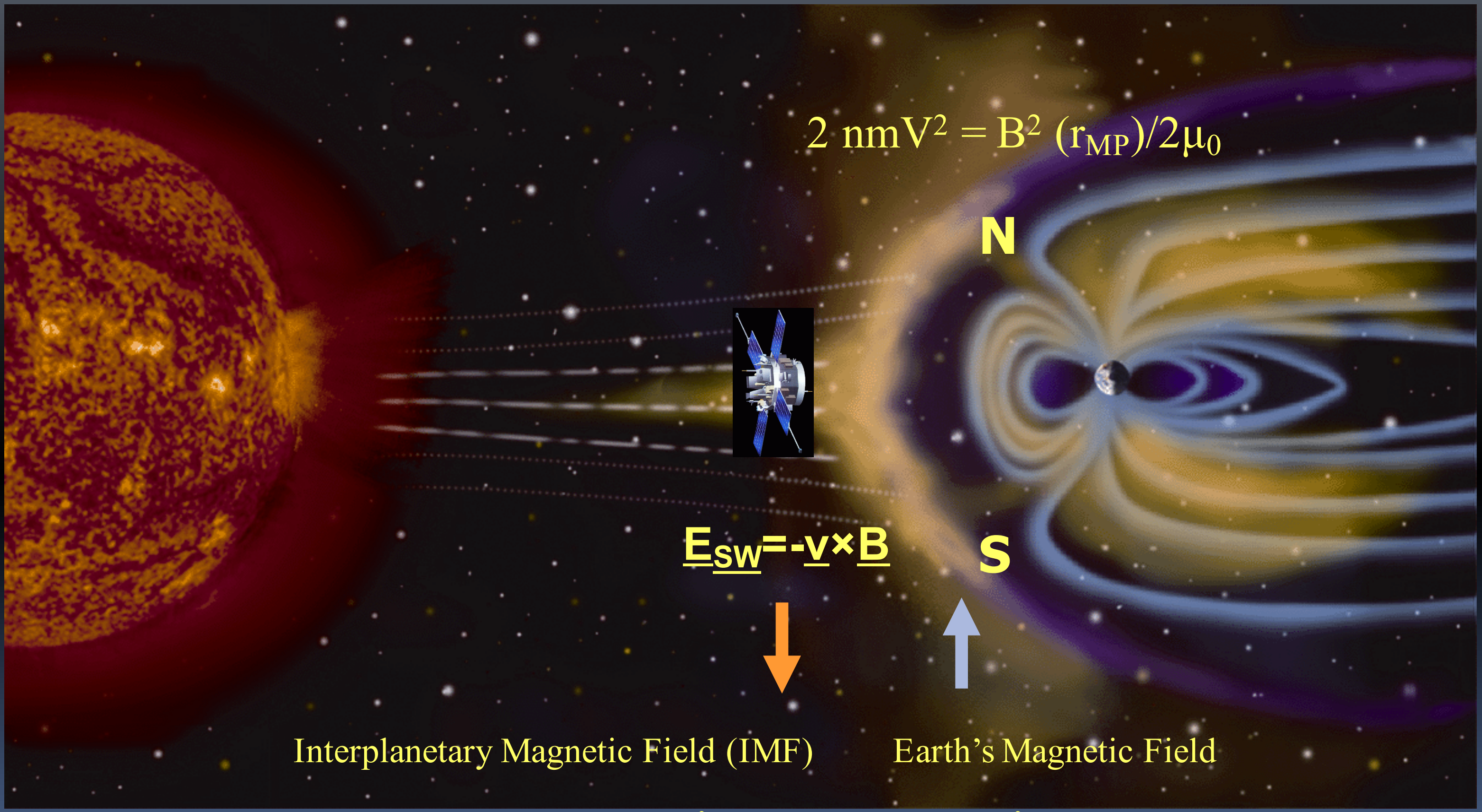


STEREO/SECCHI/HI1

STEREO/SECCHI A CME Tracking – August 01, 2010

Increased Geomagnetic Activity Requires Magnetic Reconnection Processes

Distance Sun – Earth = 1 AU ≈ 150 Million Kilometers

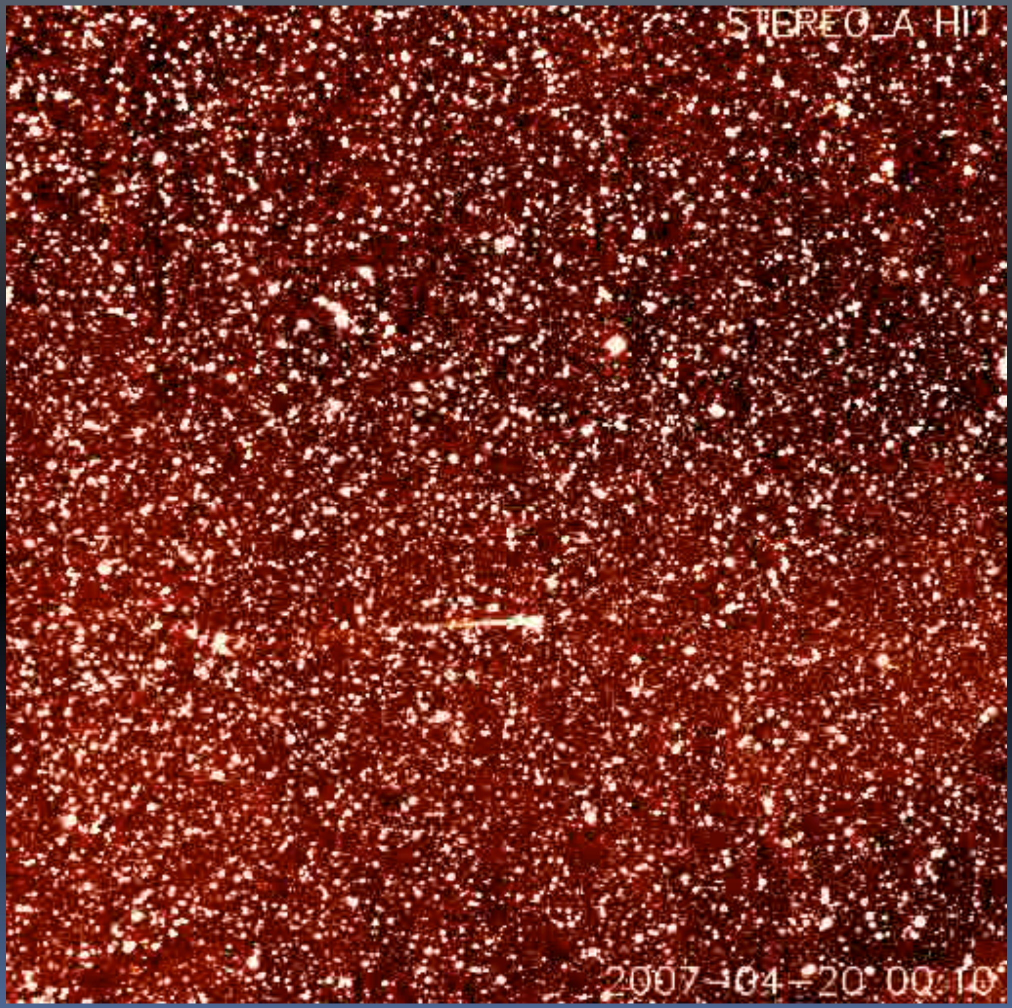


„Magnetic Reconnection“

Comet Encke – Tail disruption through CME impact - HI 1 A, 20th April 2007

Period: 3.3 Years; Perihel: 0.338 AU

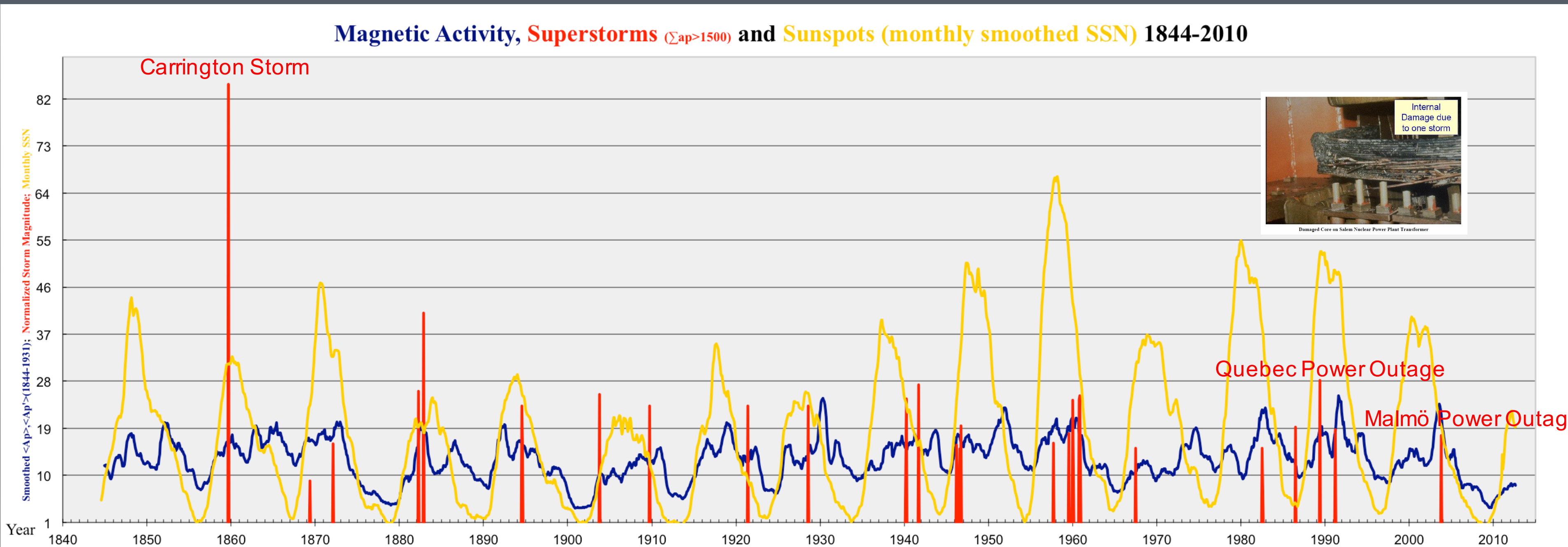
FOV ~ 42·10^6 km (0.28 AU)



Vourlidas et al., ApJ 2007

Magnetic activity, Superstorms (Kp=9, ∑ap>1500) and Sunspots 1844-2010

; Monthly Smoothed <Ap>, <Ap'>(1844-1931); Normalized Storm Magnitude;, 1/3 SSN



(Ap' reconstructed by Svalgaard)

Year

Some Statistics (1932-2010):

- 281 storms with Kp≥8-
- 44 storms with Kp≥9-
- 26 storms with Kp 9
- About 1-4 severe storms per cycle

A comparison of all storms with Kp-values of 9, with disturbances of the Swedish Power Grid since 1950 shows: ~1/3 of all events had effects – under study

UNITED NATIONS

J O U R N A L

COMMITTEE ON THE PEACEFUL USES OF OUTER SPACE

SCIENTIFIC AND TECHNICAL SUBCOMMITTEE
FORTY-EIGHTH SESSION
Vienna, 7-18 February 2011

THURSDAY, 10 FEBRUARY 2011 No. 5

Programme of Meetings and Agenda for Thursday, 10 February 2011

10.00 am - 1.00 pm — 744th meeting — Room M1

Agenda Item	*Item No.*
General exchange of views	[3]
Remote Sensing	[6]
Disaster management support	[8]
Nuclear power sources	[10]
International Space Weather Initiative	[12]

Special Presentations on Outer Space Activities

At the end of the morning session (744th) of the Scientific and Technical Subcommittee of the Committee on the Peaceful Uses of Outer Space, *today*, 10 February 2011, there will be four special presentations on "Extreme Space Weather" by Ms. Lika Guhathakurta of the United States of America, on "From Research to Operations – Ongoing and planned European and International Space Weather Projects" by Mr. Volker Bothmer of Germany, on "Reception, interpretation and utilization of satellite images received by UN-SPIDER during earthquake and tsunami which affected Chile on 27 February 2010" by Mr. Eugenio González of Chile, on "the 10th anniversary of the International Charter Space and Major Disasters" by Mr. Jean-Charles Bigot of the European Space Agency, in Room M1.

V.11-80698 (E)

Congress of the United States

Washington, DC

Invitation to the Electric Infrastructure Security Summit – Washington D.C. January 12, 2011

The 2nd annual world infrastructure security summit, April 11, 2011.

Based on extensive testimony to Congress and numerous recent reports from U.S. government commissions and agencies[1], the national electric grids of the U.S. and allied nations could be severely damaged or permanently burned out by natural or malicious electromagnetic threats.

Growing concerns over grid vulnerability to natural threats led NASA and the National Academy of Sciences to predict catastrophic, long-duration failures in unprotected electric grids, due to expected unusually severe solar flares and coronal mass ejections. They have advised the U.S. government that severe flares of this magnitude could occur in the near term: such flares recur around once per century, with the last two observed in 1859 and 1921. According to government reports an EMP strike – a nuclear detonation over a targeted nation or nearby international waters – would also damage or permanently destroy critical long-lead components in a national electric grid, causing a blackout that could last months or years. Non-nuclear electromagnetic devices could have a similar impact over smaller areas.

With the impact of severe space weather expected to be world-wide and the affected area from an EMP strike continental in scale, the effects of either would be serious societal disruption and destruction. Given the loss of vital infrastructures, these threats could involve loss of life on an unprecedented scale.

As the Organizing Co-Chairs, we wish to invite you to join us in a special multi-national government-only summit in the U.S. Congress on April 11, 2011. Senator Jon Kyl will also co-chair the event. The **Electric Infrastructure Security Summit (EISS) Washington D.C.**[2] will be the 2nd meeting of this new international security framework. **EISS London**[3] took place on September 20, 2010 with senior delegates from eighteen nations, including cabinet level representation from the U.K. and U.S. delegates from Congress, the White House, DOE, DOD, FERC and other agencies.

We are concerned with the unprecedented danger of this national infrastructure vulnerability, and hope you will be able to participate in this new security framework. **EISS Washington D.C.** will accelerate efforts to upgrade and protect the national electric grids of the U.S. and its allies through multi-national coordination and cooperation, and will include review and potential endorsement of the draft **International Infrastructure Protection Roadmap**.

We look forward to your participation in the summit.

Thank you.

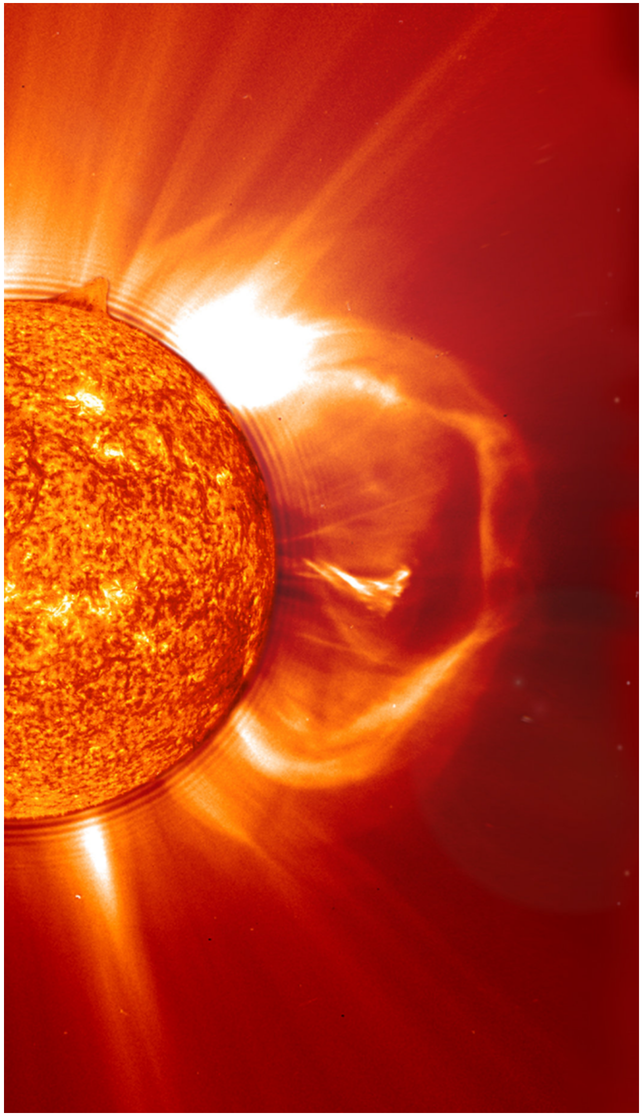
Congresswoman Yvette D. Clarke
Organizing Congressional Co-Chair

Congressman Trent Franks
Organizing Congressional Co-Chair

Rt. Hon. James Arbuthnot MP
Organizing UK Parliament Co-Chair
Chair, UK Defence Select Committee

[1] Please contact our offices for access to reports from Congress, DOE, FERC (with DOE and DHS), and NASA / NAS.
[2] The EISS Summit Series is a government / NGO partnership, co-hosted by the EIS Council and the Henry Jackson Society.
[3] To view EISS London, visit www.eissummit.com

Forecast requires knowledge on CME Magnetic Field and Evolution to Earth

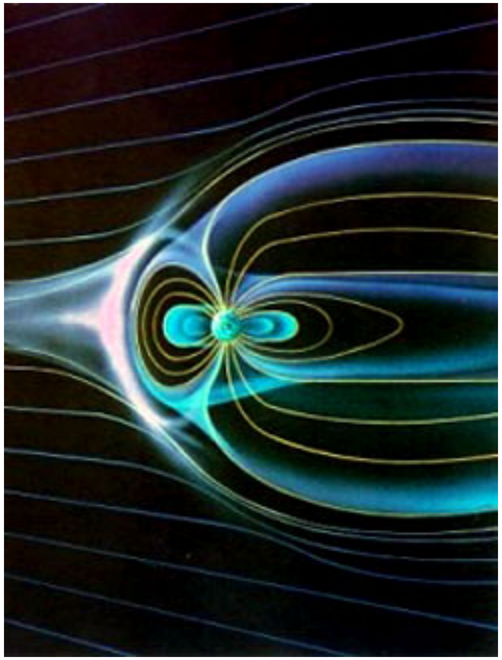


Images: NASA

Which direction does the CME take?

Will it hit or miss Earth?

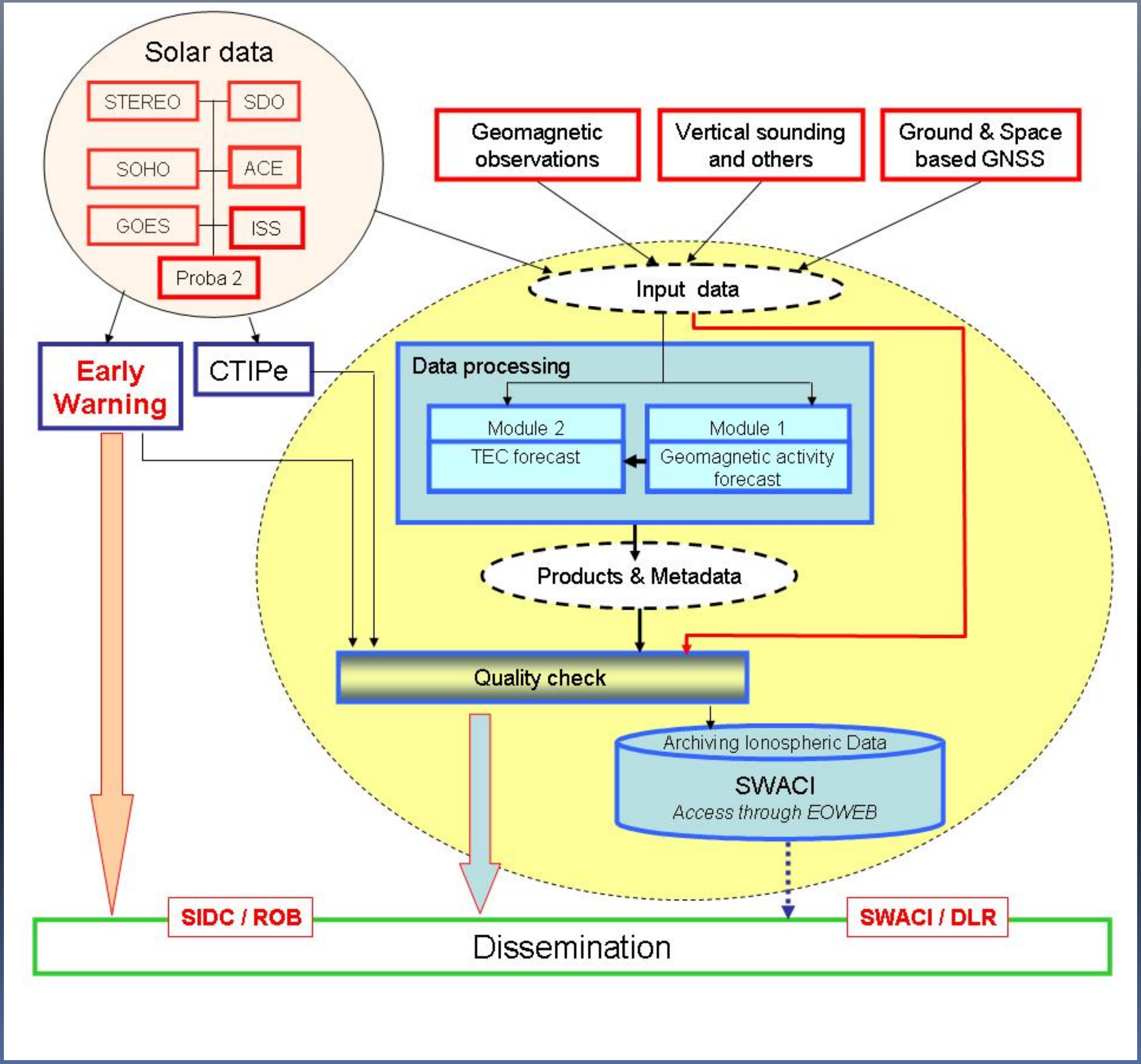
When will it arrive at Earth and with which V and B_z ?




STEREO A
ACE
SOHO
AFFECTS
Advanced Forecast For Ensuring Communications Through Space
Solar storms are a consequence of sudden eruptions of magnetised gas in the Sun's outer atmosphere. Commonly such storms start with a sudden release of electromagnetic radiation – a solar flare, and by an eruption of a giant cloud of magnetised plasma – a coronal mass ejection (CME). A fast CME also accelerates solar particles to high energies – a solar energetic particle event.
Solar storms affect the Earth environment from the magnetosphere down to the ionosphere, and even to the lower atmosphere climate system. The natural hazards of severe space weather have the potential to catastrophically disrupt the operations of technological systems, such as communication systems and power grids on Earth. Through the AFFECTS project funded by the European Union's 7th Framework Programme, European and US scientists develop an advanced prototype space weather warning system to safeguard the operation of telecommunication and navigation systems on Earth to the threat of solar storms. The project is led by the University of Göttingen's Institute for Astrophysics and comprises worldwide leading research and academic institutions and industrial enterprises from Germany, Belgium, Ukraine, Norway and the United States.
SDO
Proba-2
ISS
GEORG-AUGUST-UNIVERSITÄT GÖTTINGEN
Fraunhofer IPM
UNIVERSITY OF TROMSØ UiT
ASTRIUM AN EADS COMPANY
DLR
IKД
PLANETARIUM
www.affects-fp7.eu
Funded by the European Union
infoNetwork
Official Media Partner
Image Credits: University of Göttingen, NASA, ESA, Planetarium Hamburg

AFFECTS Trailer

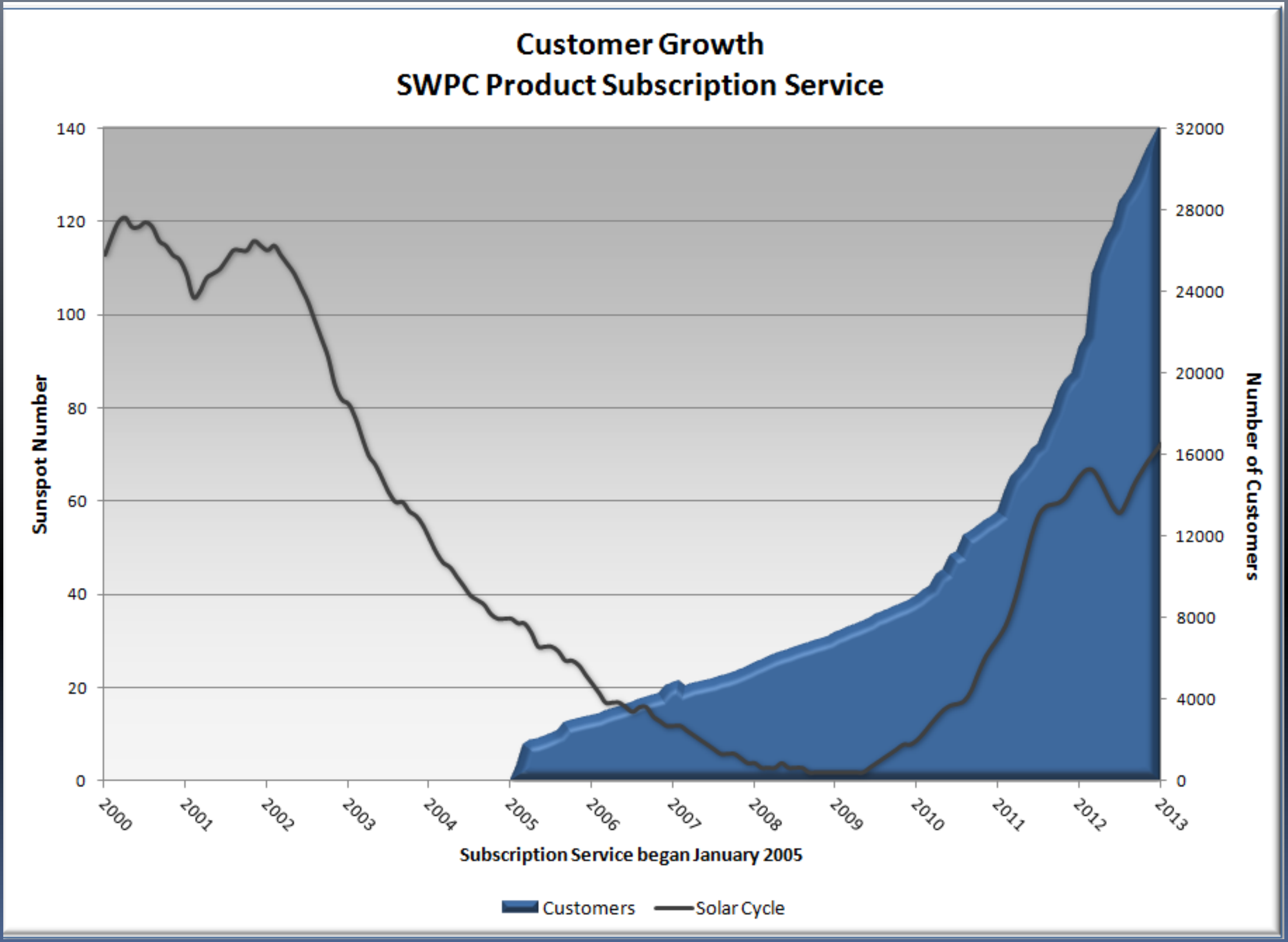
AFFECTS Workflow



AFFECTS Website - http://www.affects-fp7.eu/weather

- Space Weather Services (e.g., L1, Kp, aurorae RSS feeds)
- Weather reports and alerts based on solar activity analysis
- Links to partner sites and other useful resources
- Subscription Services (Flares, CMEs, SEPs)
- Service Brochure
- PR Material (Trailer, press releases, meeting reports)
- CME databases, modelling results
- Link to AFFECTS iOS App
- Official forecast for RTL and base for dedicated project for German Space Situational Awareness Center (OPTIMAP)

Growing Number of Users



Sample Users

Airlines	Surveying and Mapping	Electric Power	Satellites
Aer Lingus	AE & E Trucking, Etc., LLC	Allegheny Power	Lucent Technologies
Air Canada	AEI-CASE Engineering	Ameren Corporation	AeroMap U.S.
Air China	Airmag Surveys	Bechtel Nevada	Aerospace Corporation
Air Europa	Associated Engineers, Inc	Bonnevill Power Administration	Alcatel Space
Air Line Pilots Association	Athens Group (oil & gas)	Central Maine Power	American Space Culture Foundat
Air New Zealand	Baker Hughes (drilling)	Cleco Power LLC	AMSAT-France
AirMed Inc.	Banks		
Airservices Australia	Barr E		erospace
Alaska airlines	Benne		g
Allied Pilots Association	Black		dian Space Agency
ALPA Japan	Carver		a Space Surveillance Centre
American Airlines	Christo		Globe
American Eagle airlines	Clarida		tar
American Trans Air	Consu		n Reconnaissance Systems
Boeing / Flight Test	DGR (		ral Dynamics C4S
British Airways	Diamo		sat
Bushmail	Earth		at
Cathay Pacific Airway	Easter		pace Systems Division
Continental Airlines	Excel		Aerospace Exploration Agency
Emirates	Geoco		ommunications
FedEx	GeoLo		eed Martin
German ALPA	Global		Skynet
Icelandic ALPA	GRW A		hay Satellite Corporation
Irish Aviation Authority	Halcyo		Space Science Systems, Inc.
Jet Aviation Business Jets	J. D. B		AT Info
korean air	Johnso		Skies Satellites
Lufthansa	Jones		pace Technology
Lufthansa Cargo	marine R/D Survey	Puget Sound Energy	North Star Data
Northwest Airlines	NC Geodetic Survey	Soreq NRC	Northrop Grumman
Oslo Lufthavn AS	Nexen Inc. (oil)	Swedish Geological Survey	Oceaneering Space Systems
Qantas Airways	NOVA Engineering & Consulting, Int'l.	Texas-New Mexico Power	Omnistar, Inc.
Raytheon Aircraft Co.	NYS Professional Engineer	Transpower NZ Ltd	ORBCOMM
SCTA	Old Dominion Freight Lines	US NRC	Orbital Sciences Corp
SkyWest Airlines	Olson Trucking	We Energies	PT Asia Cellular Satelitte
Sun Country airlines	Oxy (oil & gas)	Western Area Power Admin.	Raytheon
Sundt air (Norway)	Pape-Dawson Engineering		Rockwell Collins, Inc.
Swales Aerospace	PGS Onshore		SES Americom
United Airlines	Planning Consultants, Inc.		SES ASTRA
APLA, Argentina	Portland Natural Gas Transmission		Sirius Satellite Radio
ATA Airlines	Raymac Surveys		Skyway, Inc.
NetJets	Schlumberger Drilling & Measurements		Space Engineering Development
North American Airlines	Seelye		Space Imaging

- **Every Major Airline (world wide)**
- **Every Major US Power Company**
- **Every Major Satellite Company (world wide)**
- **US Federal Agencies**
  - **Department of Defense.**
  - **NASA**
  - **Department of Energy**
  - **Department of Homeland Security**
  - **Federal Aviation Administration**

- **32,000 Specific Customers**
- **15 – 20 Million Web Hits a day**

ESA - Space Situational Awareness (SSA) Program

PROJECTS: ESC-H, ESC-I, SCOPE, AFFECTS

Image: ESA

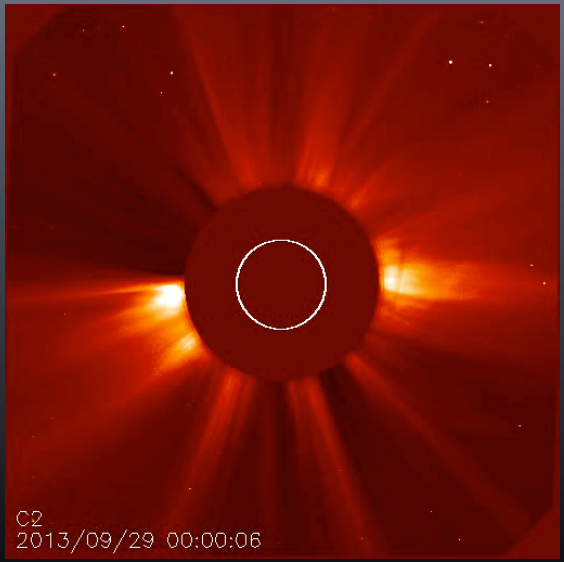
Event Awareness – Subscription Services

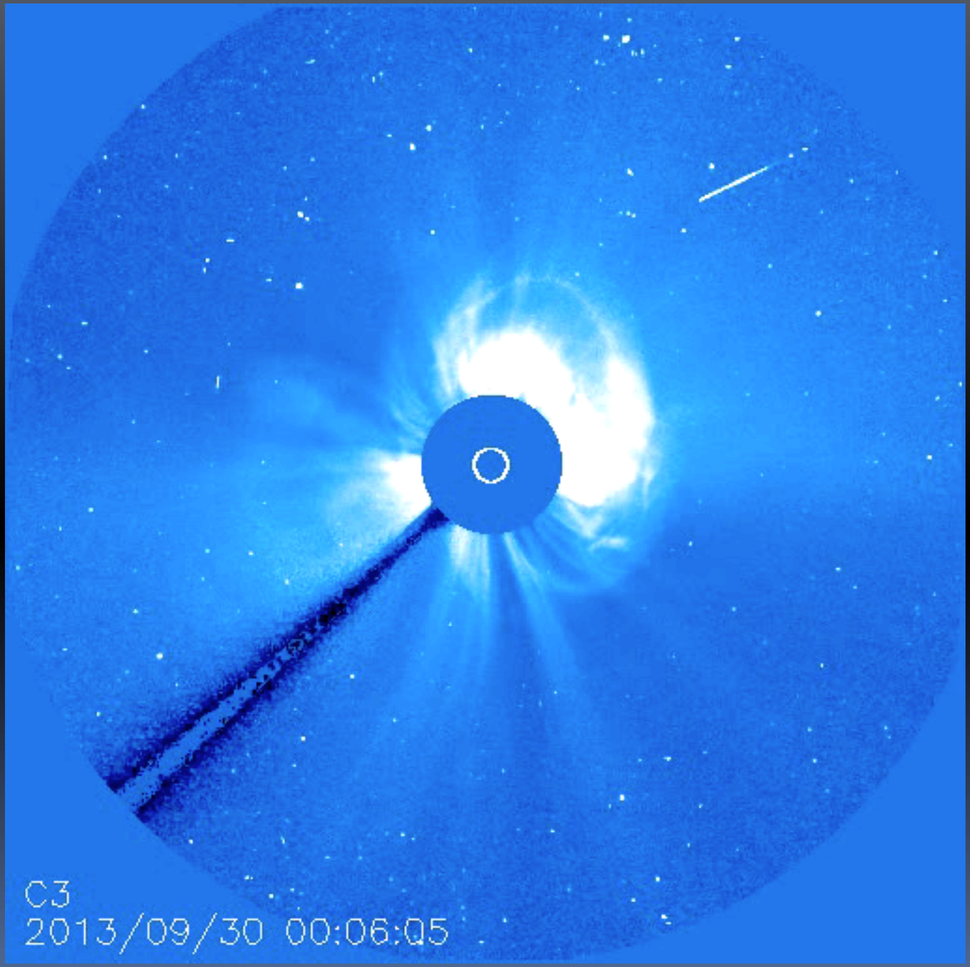
Von SWPC Product Subscription Service <SWPC.Products@noaa.gov>
Betreff **SUMMARY: X-Ray Event exceeded X1 (R3)**
An Volker Bothmer

```
Space Weather Message Code: SUMX01
Serial Number: 91
Issue Time: 2013 Oct 29 2221 UTC

SUMMARY: X-ray Event exceeded X1
Begin Time: 2013 Oct 29 2142 UTC
Maximum Time: 2013 Oct 29 2154 UTC
End Time: 2013 Oct 29 2201 UTC
X-ray Class: X2.3
Location: N05W90
NOAA Scale: R3 - Strong

NOAA Space Weather Scale descriptions can be found at
www.swpc.noaa.gov/NOAAscales

Potential Impacts: Area of impact consists of large
portions of the sunlit side of Earth, strongest at the
sub-solar point. Radio - Wide area blackout of HF
(high frequency) radio communication for about an hour.
```

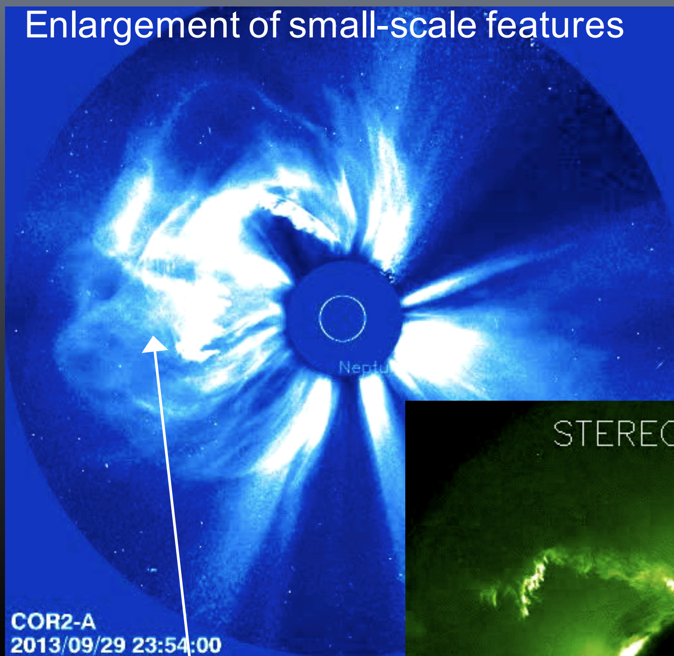
```
:Issued: 2013 Oct 29 2313 UTC
:Product: documentation at http://www.sidc.be/products/presto
#--------------------------------------------------------------------#
# FAST WARNING 'PRESTO' MESSAGE  from the SIDC (RWC-Belgium)         #
#--------------------------------------------------------------------#
NOAA active region (AR) 11875 produced an X2.3 flare peaking around
21:54 UT on
October 29. This flare is accompanied by a CME detected in LASCO/C2 at
22:12 which will be analyzed
as more data come in. More X flares are possible.
The warning for proton storms is maintained. Since AR 11875 is
currently located at the west limb, a proton event associated to this X
flare is very likely.
```

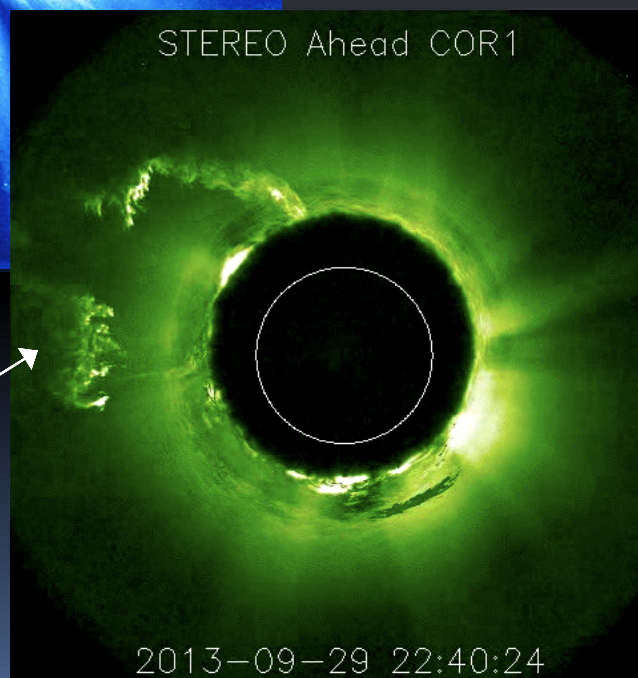
Sample Event - Halo CME on September 29, 2013

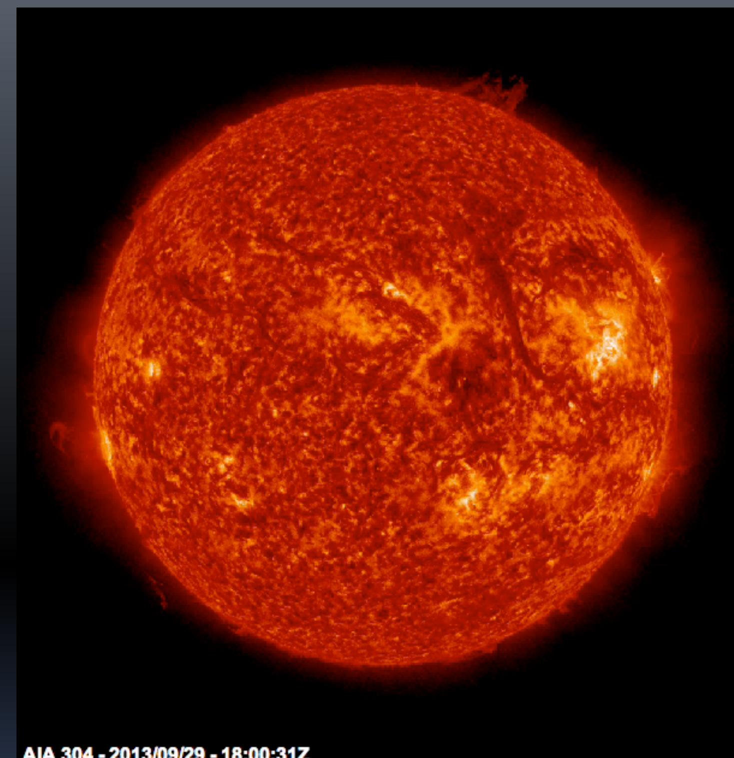




CME on 29 September 2013 - SDO, STEREO/SECCHI/COR2 & COR1 A observations

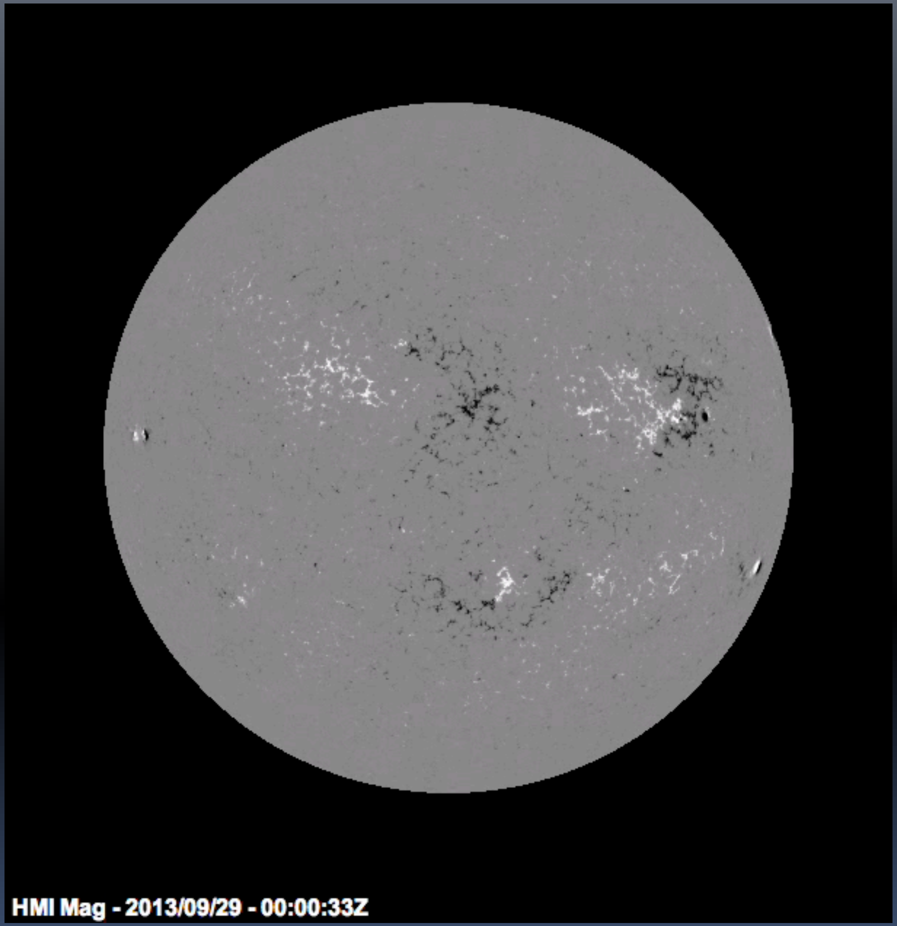


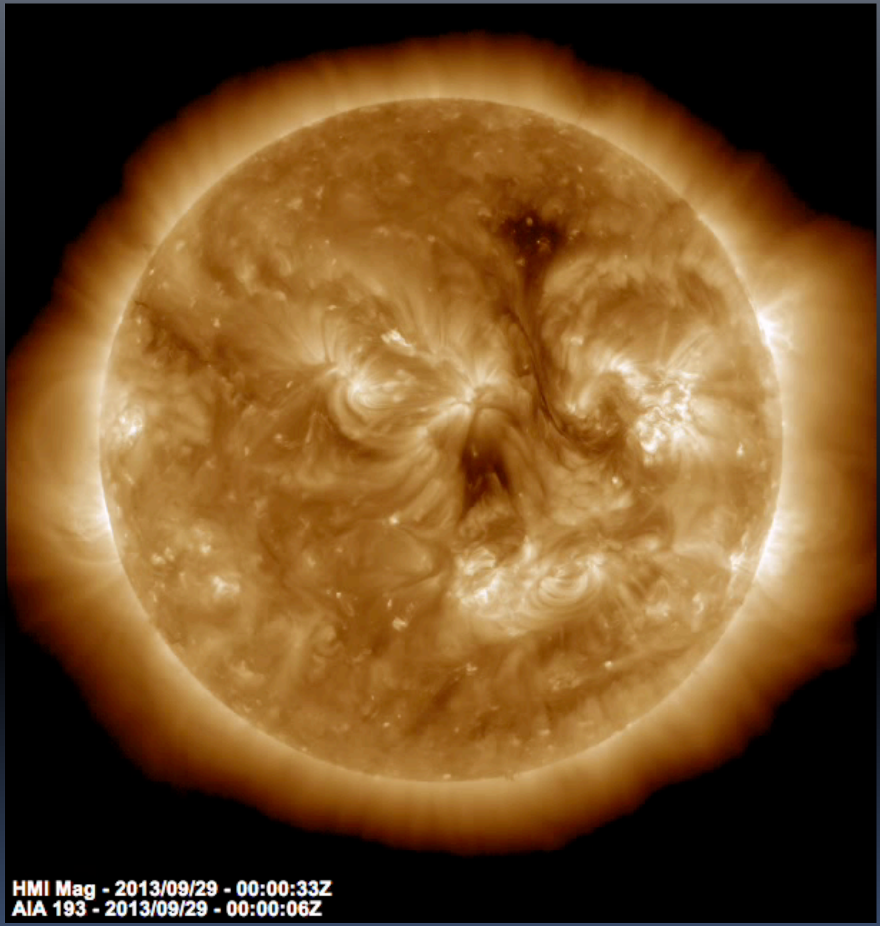




Expansion of fine-scale features
- Arrival times will depend on observer‘s position wrt CME SR

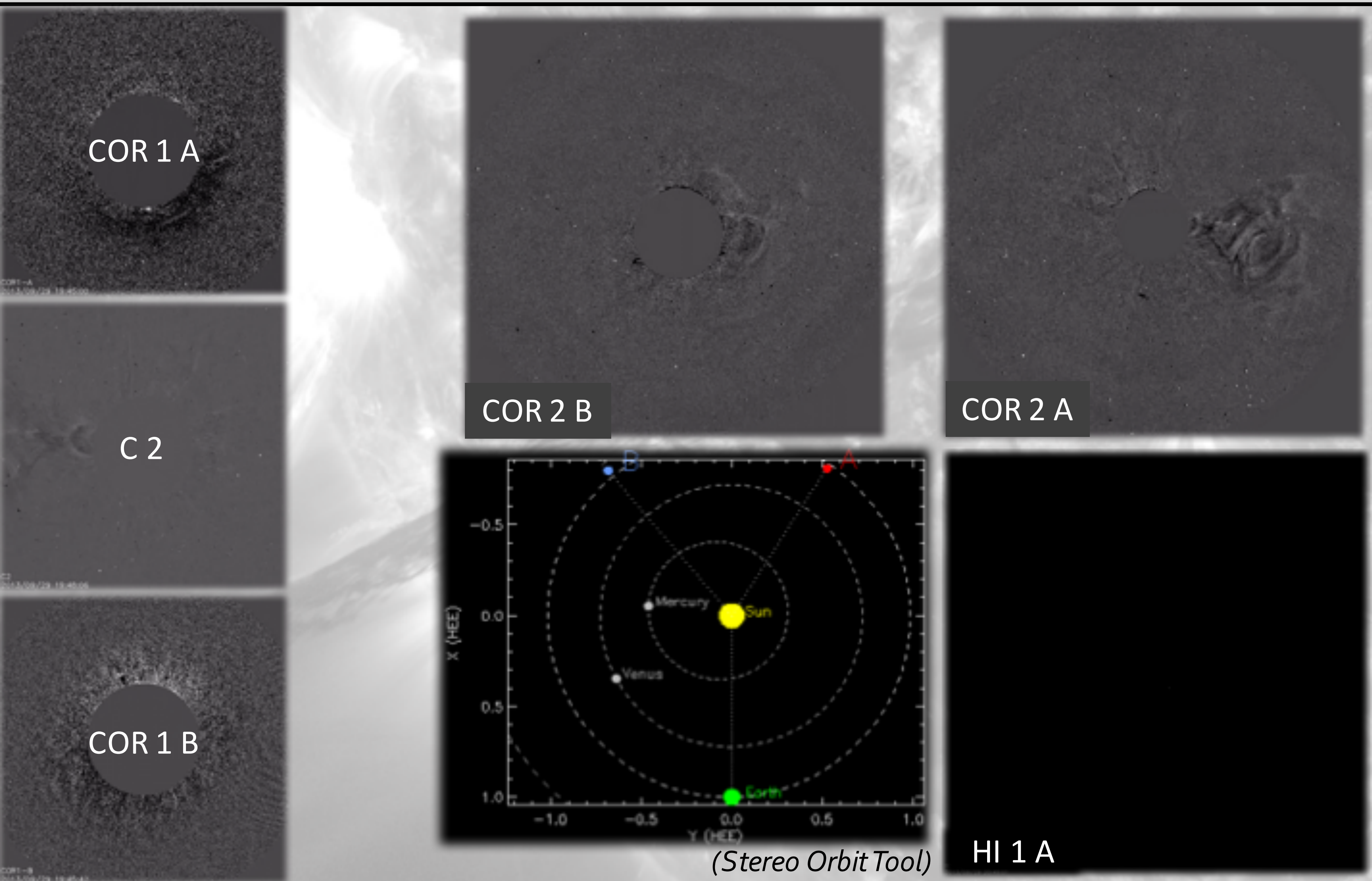
Emerging Flux Triggering the CME





Institut für Astrophysik Göttingen

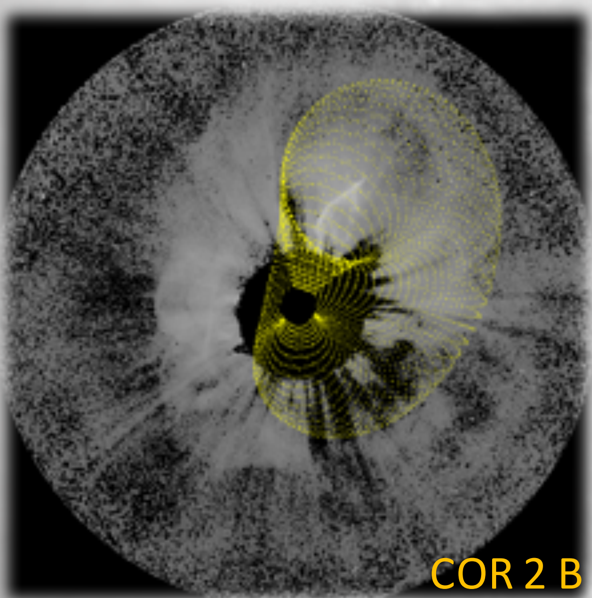
CME on 29 September 2013

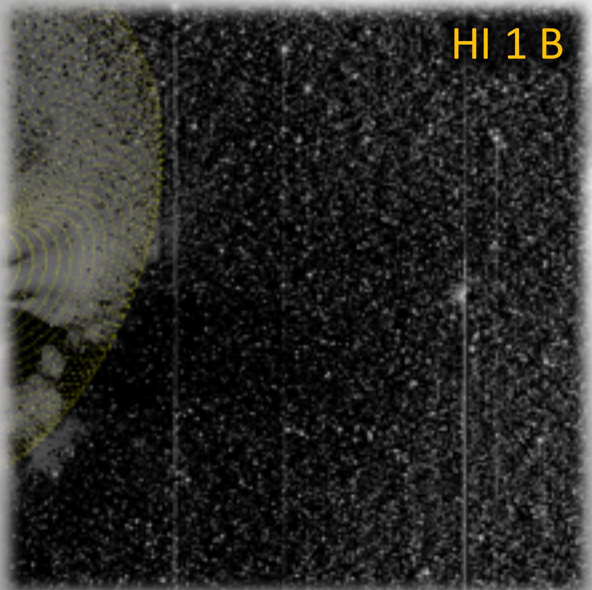


(Stereo Orbit Tool)

INSTITUT FÜR ASTROPHYSIK GÖTTINGEN

GCS Modelling of Multipoint Observations



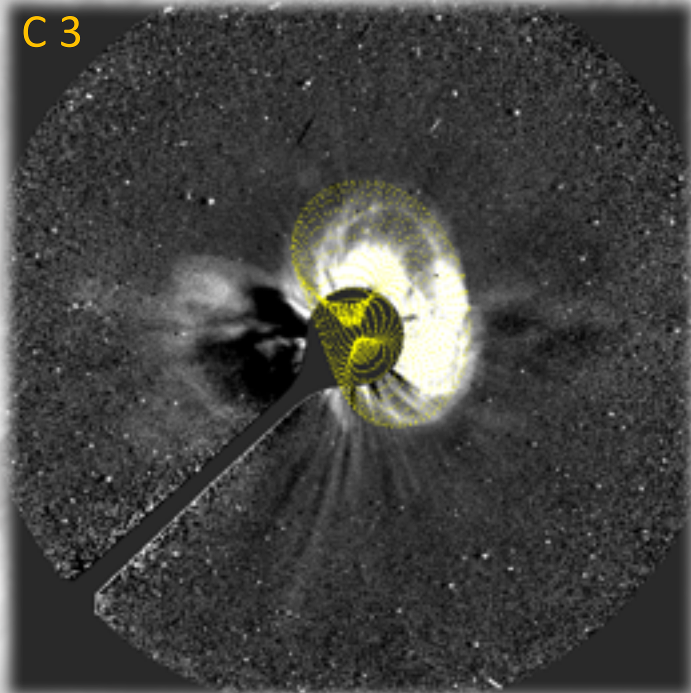


Position on Sun:

Φ = 12°   θ = 25.12°

Associated C1.2 Flare at:

Φ = 33°   θ = 10°

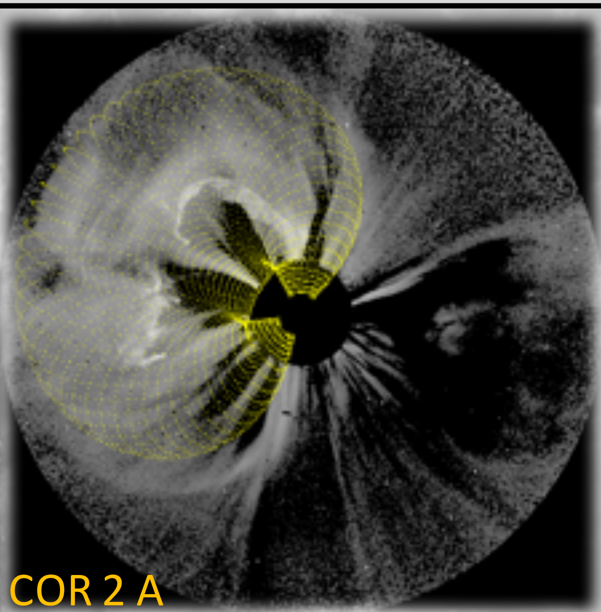


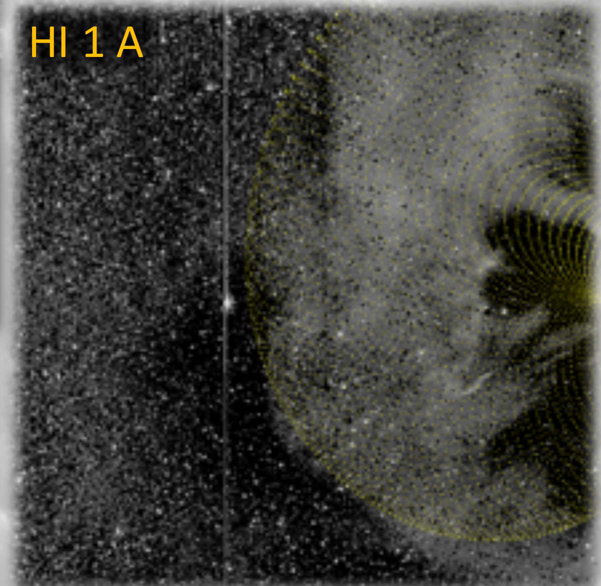
Geometrical parameter:

α = 63°

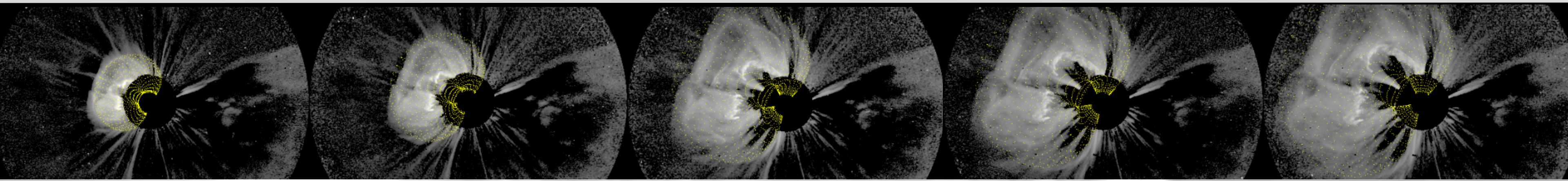
γ = -74.87°

κ = a/r = 0.54

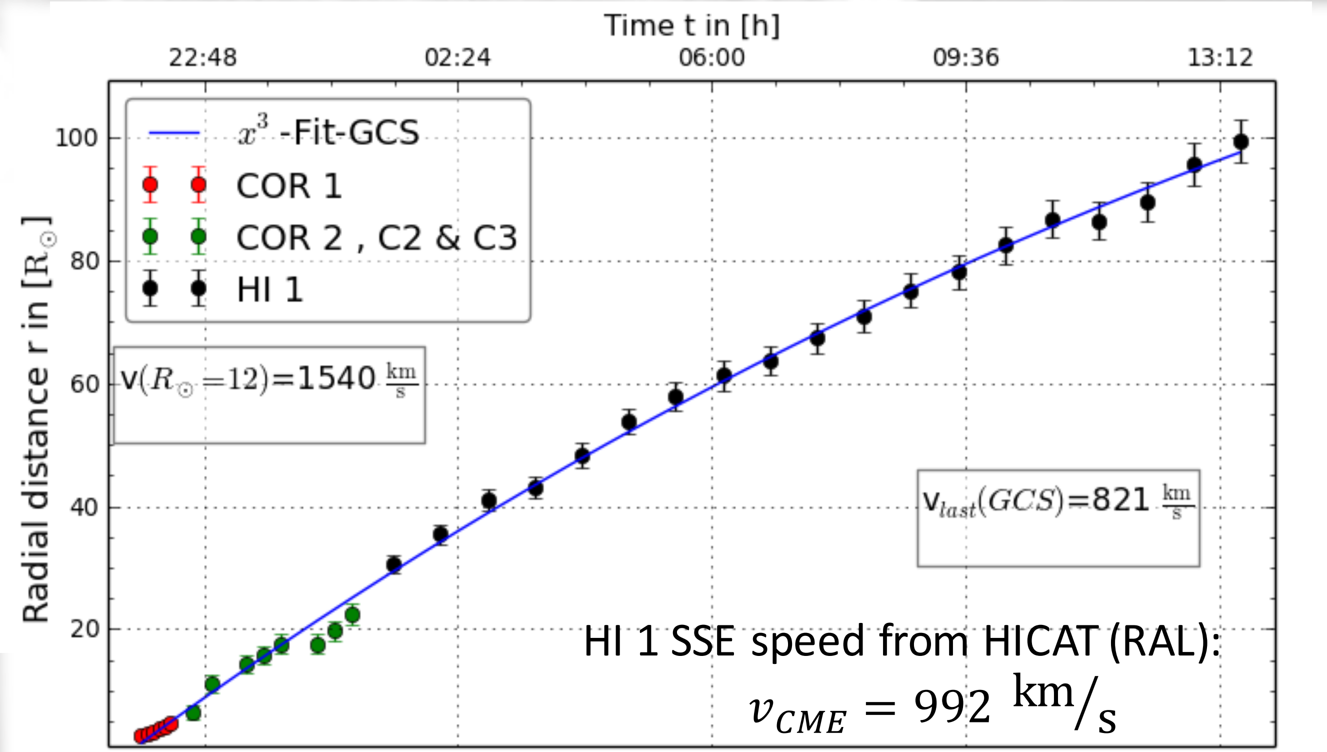


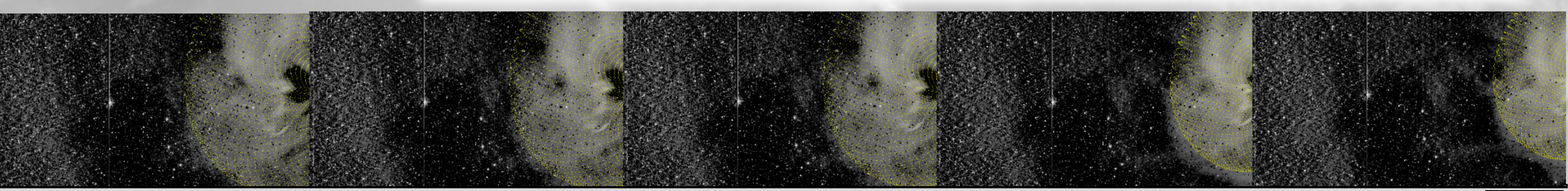


Height-Time Profile from GCS Modelling

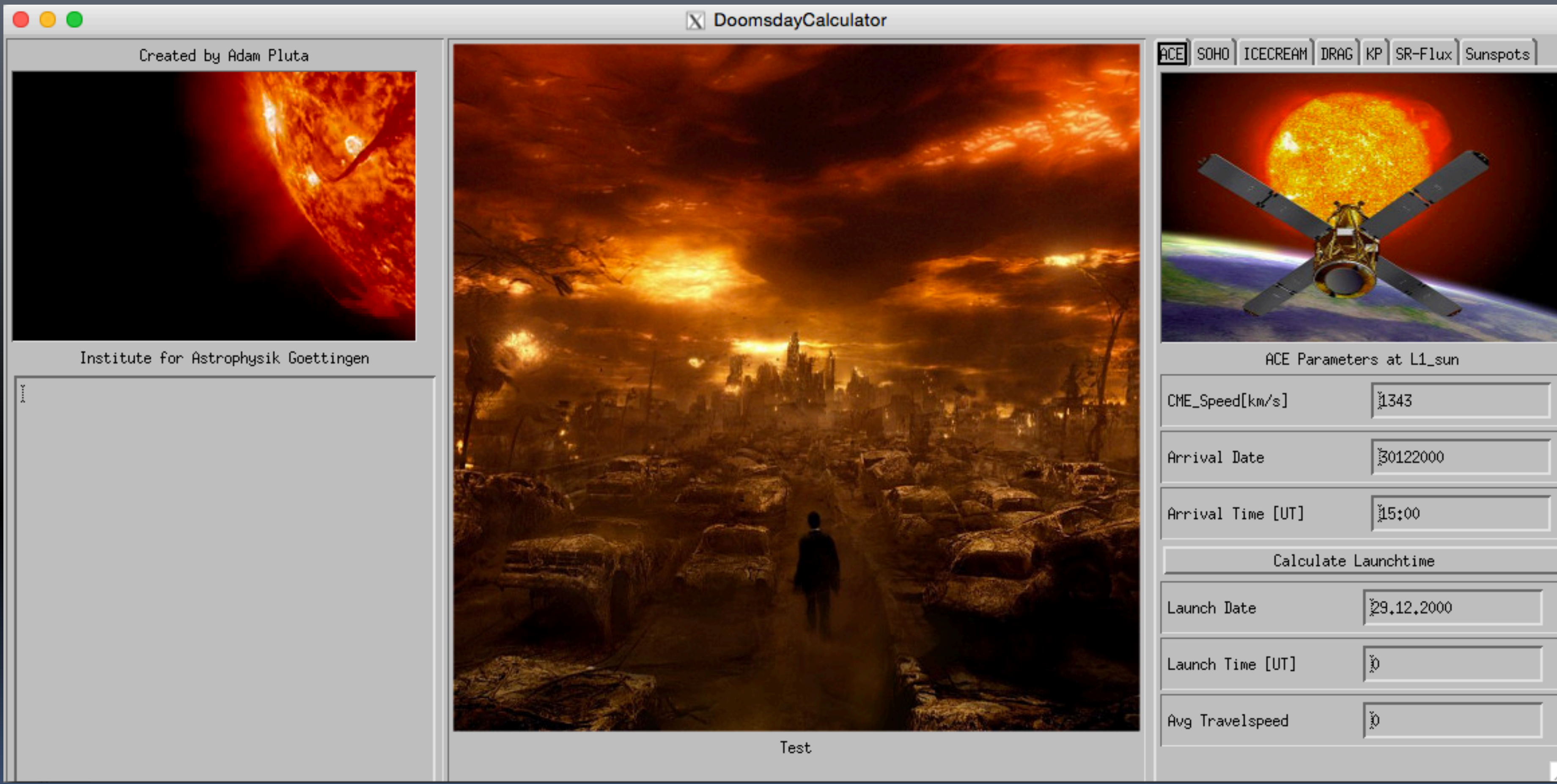


- Fit coronagraph Images for HT-Data.
- Fit polynomial to get inital CME speed.
- Use fit result for Drag-Fit.



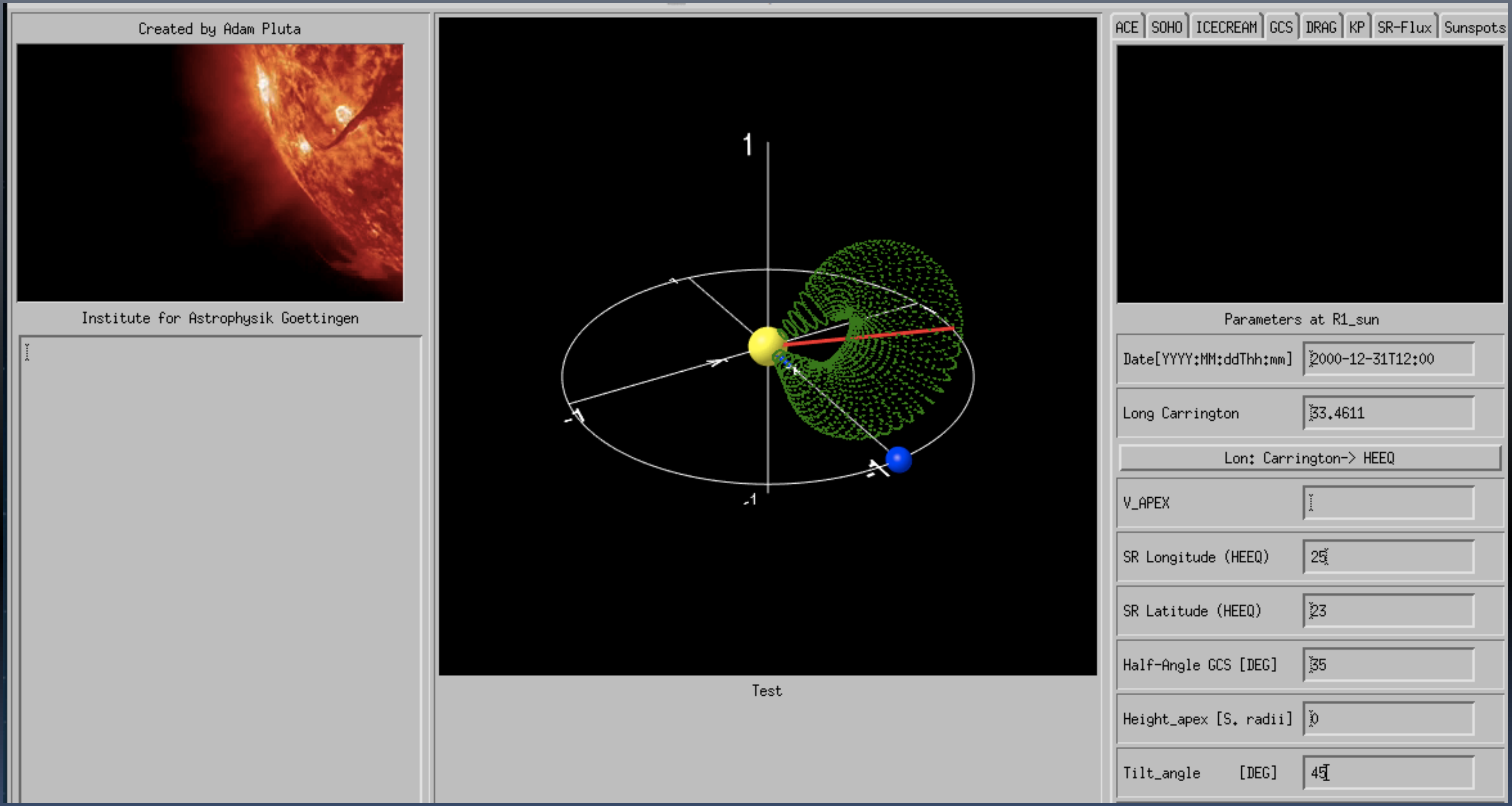


Modelling Results as Input to UGOE AFFECTS DDC

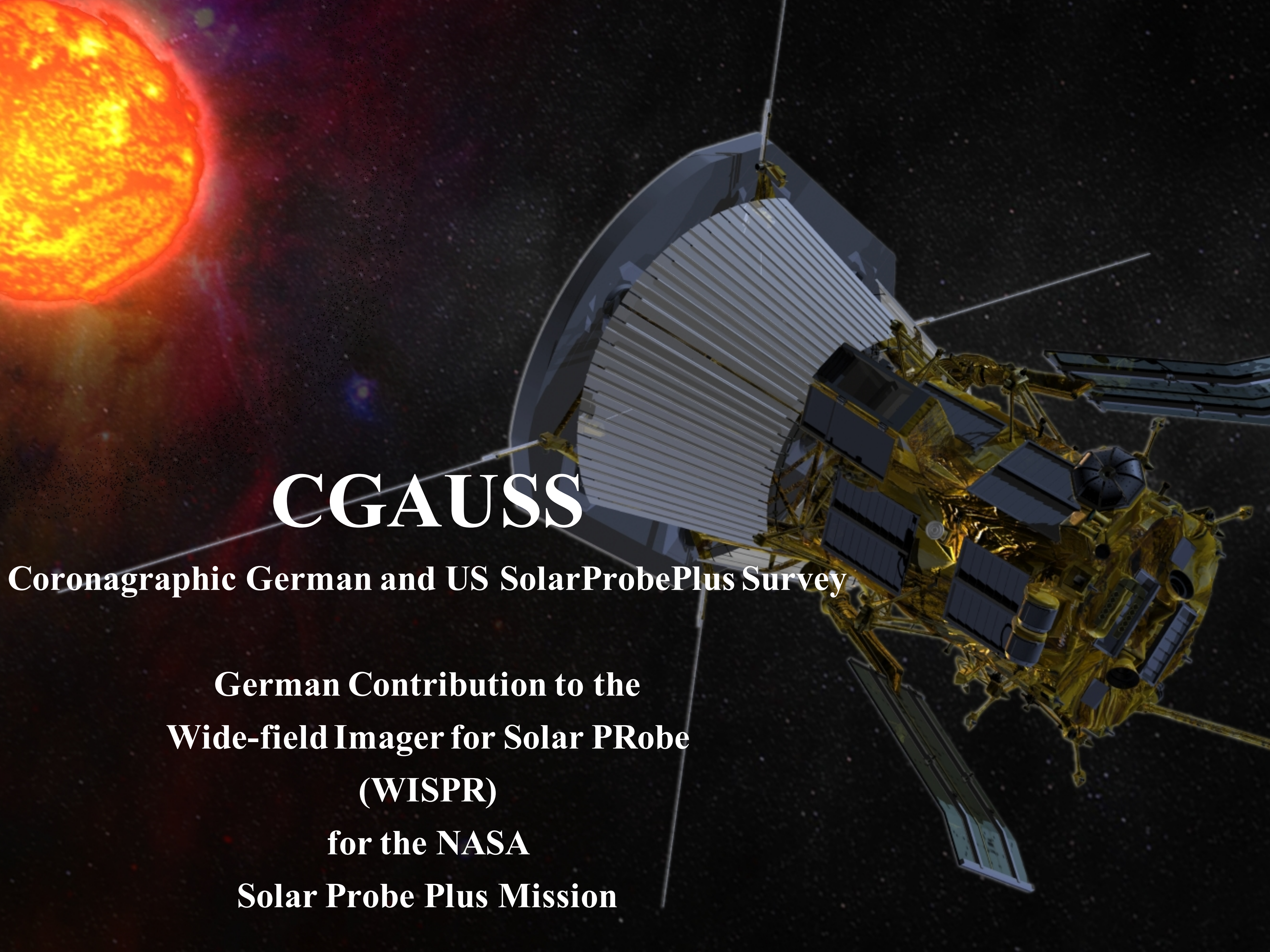


Credit: A. Pluta, AFFECTS, HELCATS

DDC Forecast bases on 3D CME Modelling



Credit: A. Pluta, AFFECTS, HELCATS

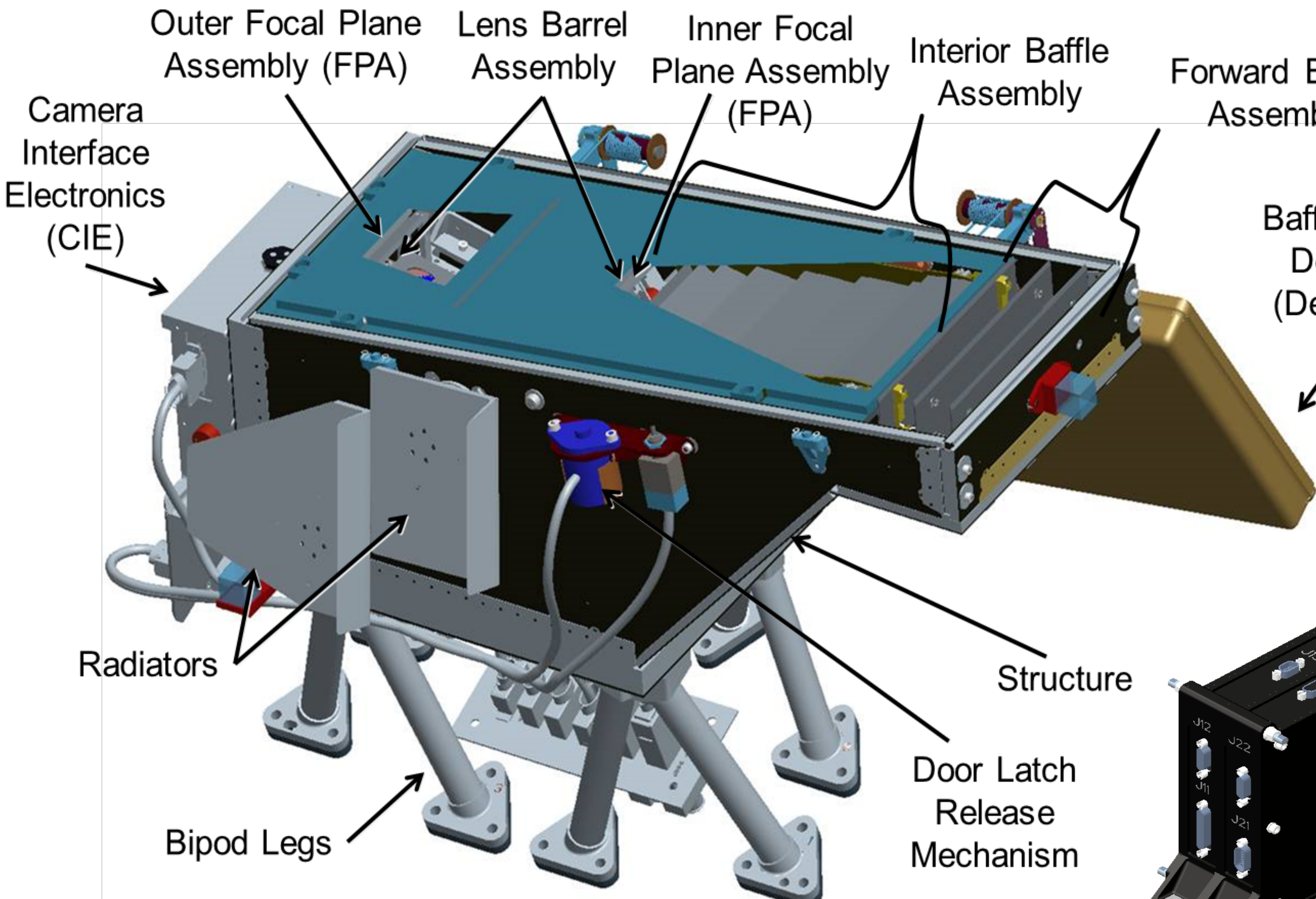


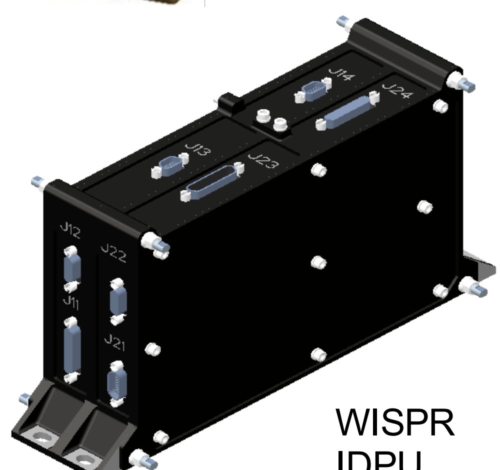
CGAUSS

Coronagraphic German and US SolarProbePlus Survey

**German Contribution to the
Wide-field Imager for Solar PRobe
(WISPR)
for the NASA
Solar Probe Plus Mission**

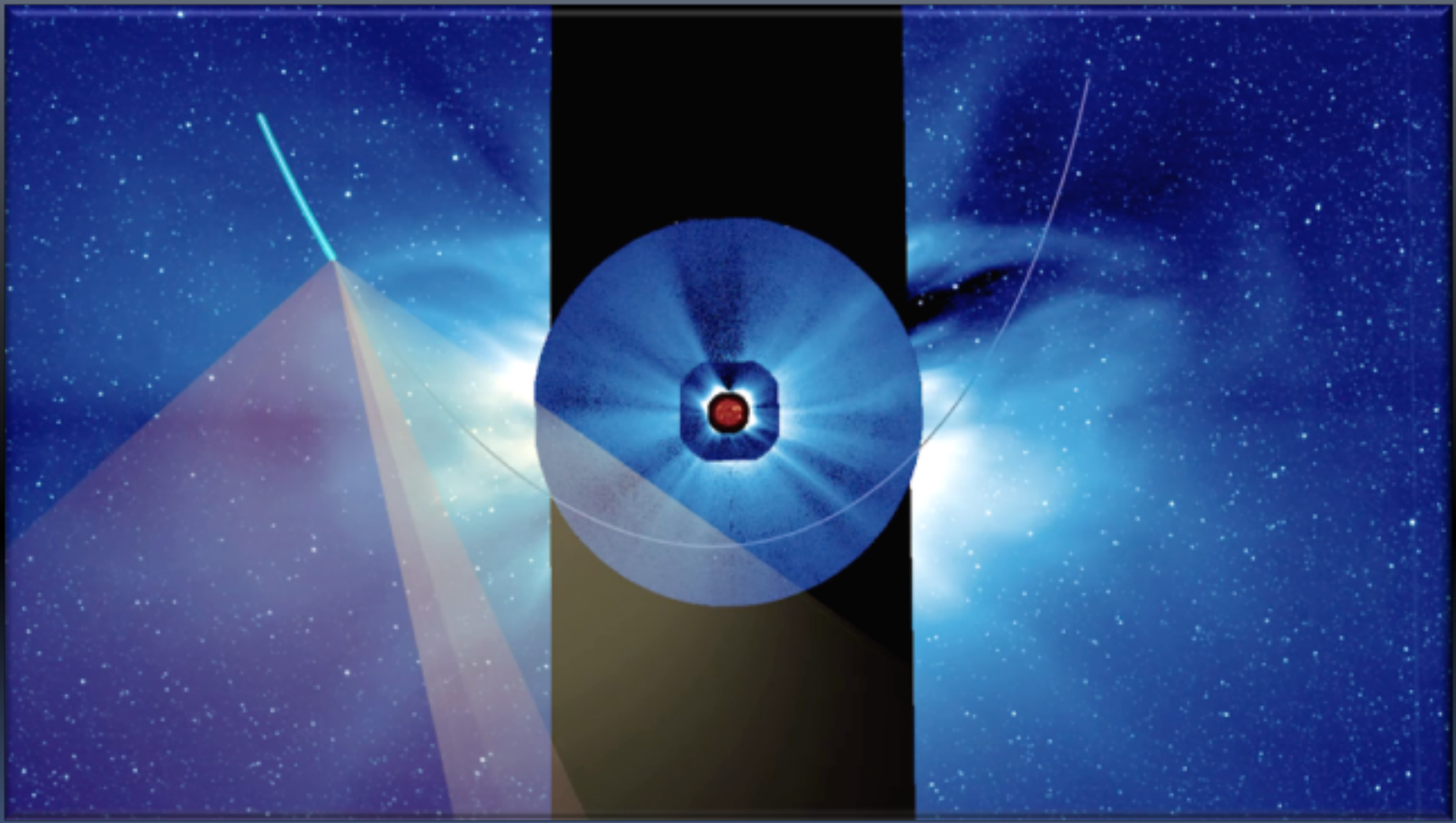
What is WISPR (Wide Field Imager for Solar Probe Plus) Instrument Overview





WISPR IDPU

Simulation of WISPR Observations During a 10 R_s SPP Perihelion



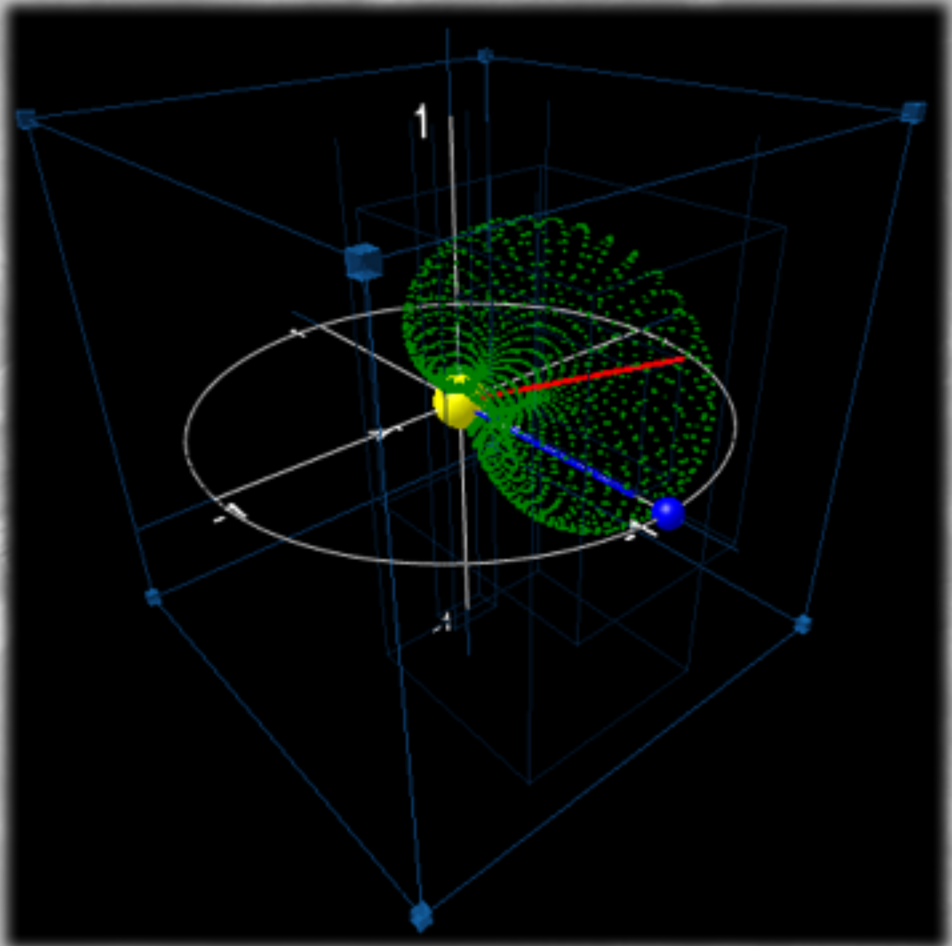
SPP/WISPR Consortium

CME Propagation

- Which part of the CME hits earth?
- Assuming self similar expansion of the CME!
- Calculate Expansion factor using GCS parameters.
- Combining the EF with the arrival time in L1 we can calculate the distance of the APEX for this time.

Event from 29. Sep. 2013:

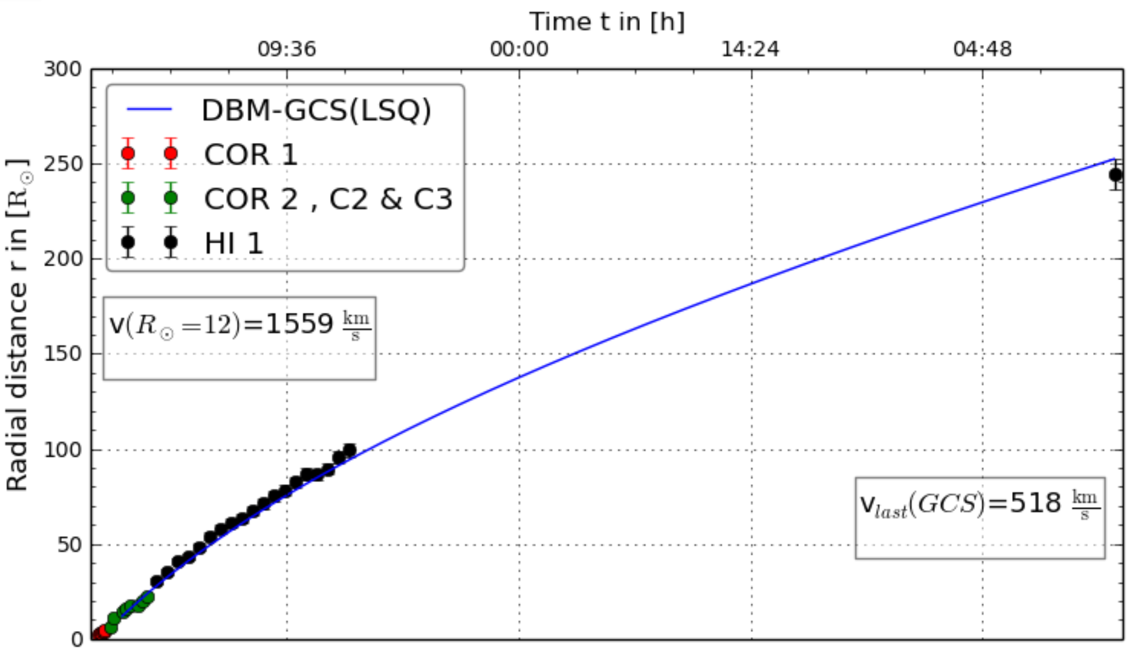
$$EF = \frac{h_{Earth}}{h_{Apex}} = \frac{v_{Earth}}{v_{Apex}} = 0.88$$

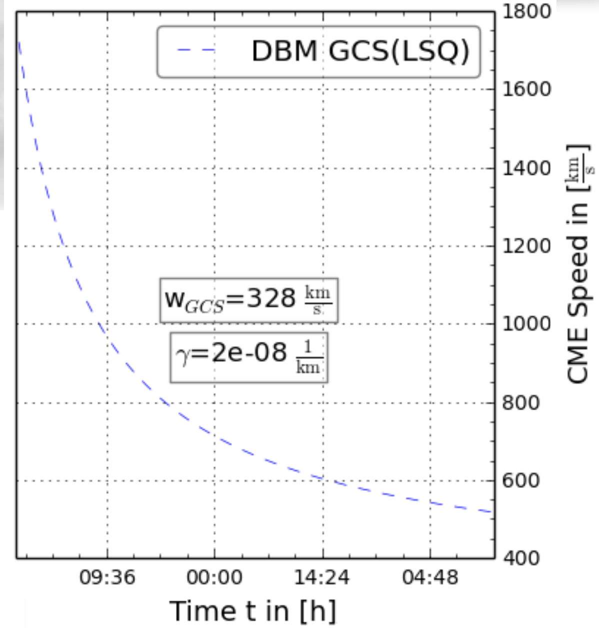


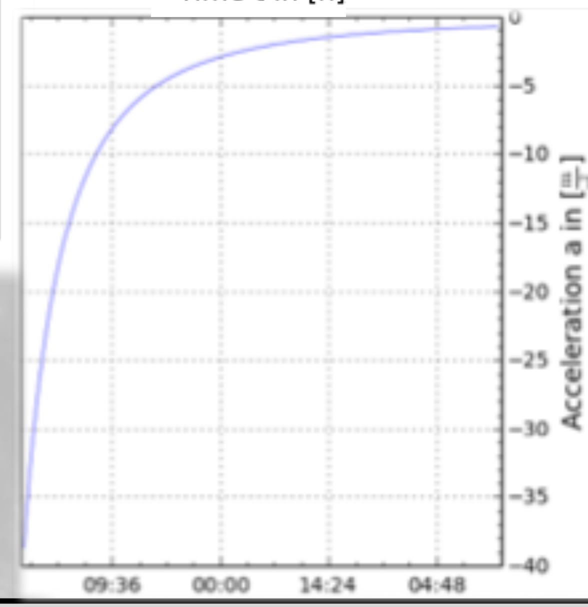
Final Drag fit

Expansion factor: $EF = \frac{v_{Earth}}{v_{Apex}} = 0.88$

$v_{Earth} = 456\,{}^{\text{km}}/_{\text{s}}$





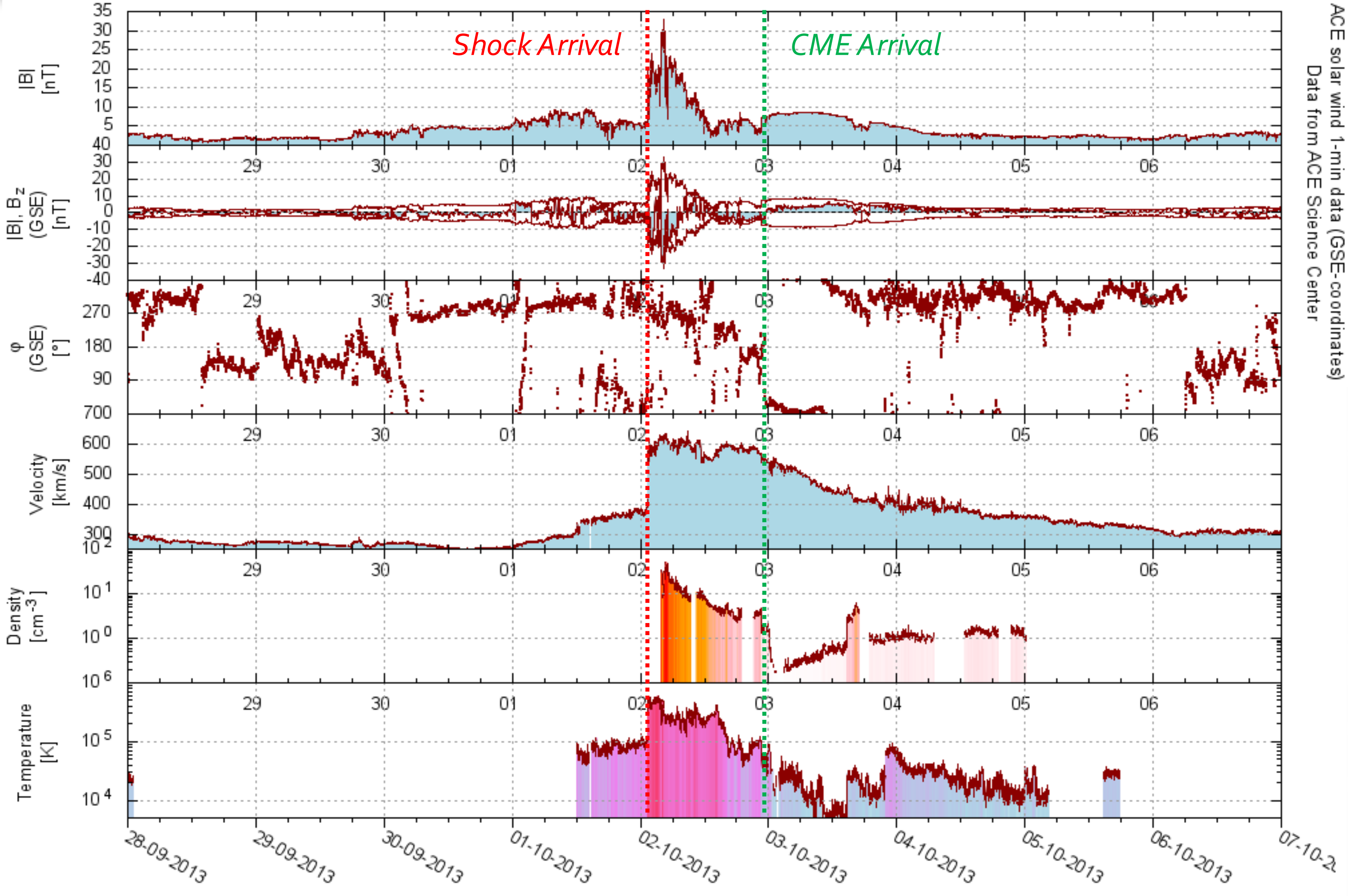


Measurements from ACE:

Solar Wind speed: $w = 280 - 300\,{}^{\text{km}}/_{\text{s}}$

CME arrival speed: $v_{CME} \sim 550\,{}^{\text{km}}/_{\text{s}}$

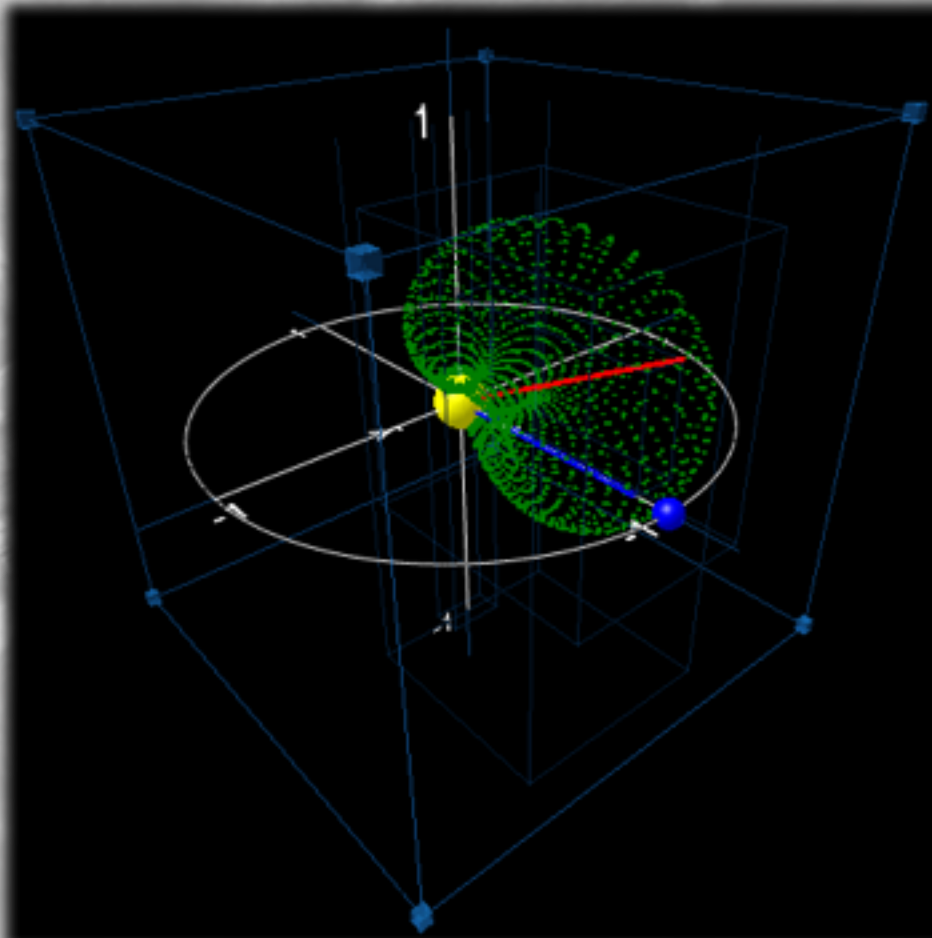
CME Signature in ACE Solar Wind Data



SPP/WISPR/CGAUSS Team UGOE, M. Venzmer

CME Propagation

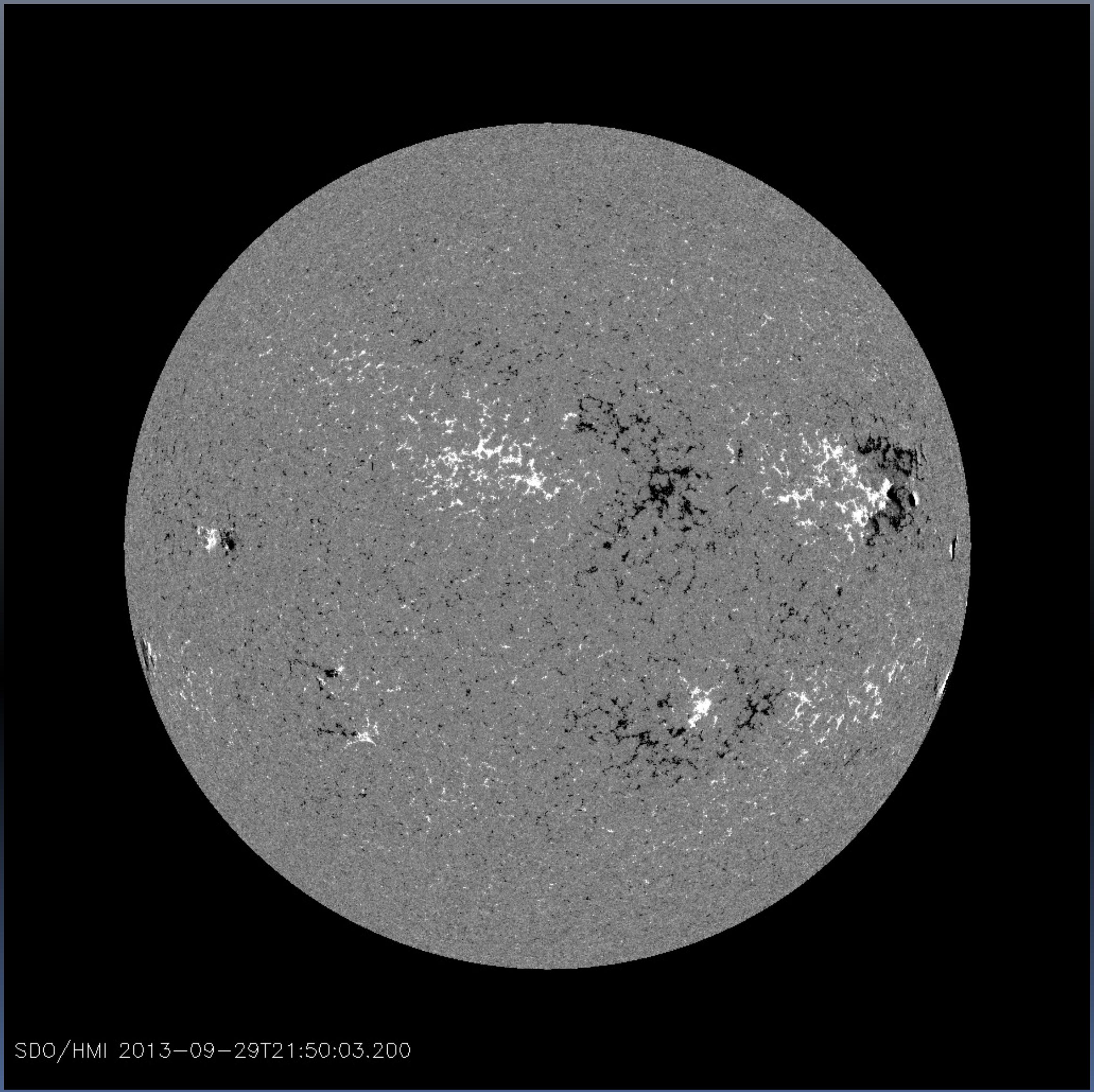
- Which part of the CME hits earth?
- Assuming self similar expansion of the CME!
- Calculate Expansion factor using GCS parameters.
- Combining the EF with the arrival time in L1 we can calculate the distance of the APEX for this time.



Event from 29. Sep. 2013:

$$EF = \frac{h_{Earth}}{h_{Apex}} = \frac{v_{Earth}}{v_{Apex}} = 0.88$$

CME QP Source Region



Summary & Conclusions

- Multipoint space observations have provided unique insights into heliospheric physics
- CMEs are 3D Magnetic Flux Ropes
- CMEs are intimately connected to the photospheric magnetic fields
- Reliable forecasts require a precise understanding of the underlying science (drag, self-similar expansion, 3D topology, expansion of magnetic fields, shock formation)

→ State-of-the-art science and applications do not necessarily contradict each other