

# IMPRS Retreat 2011

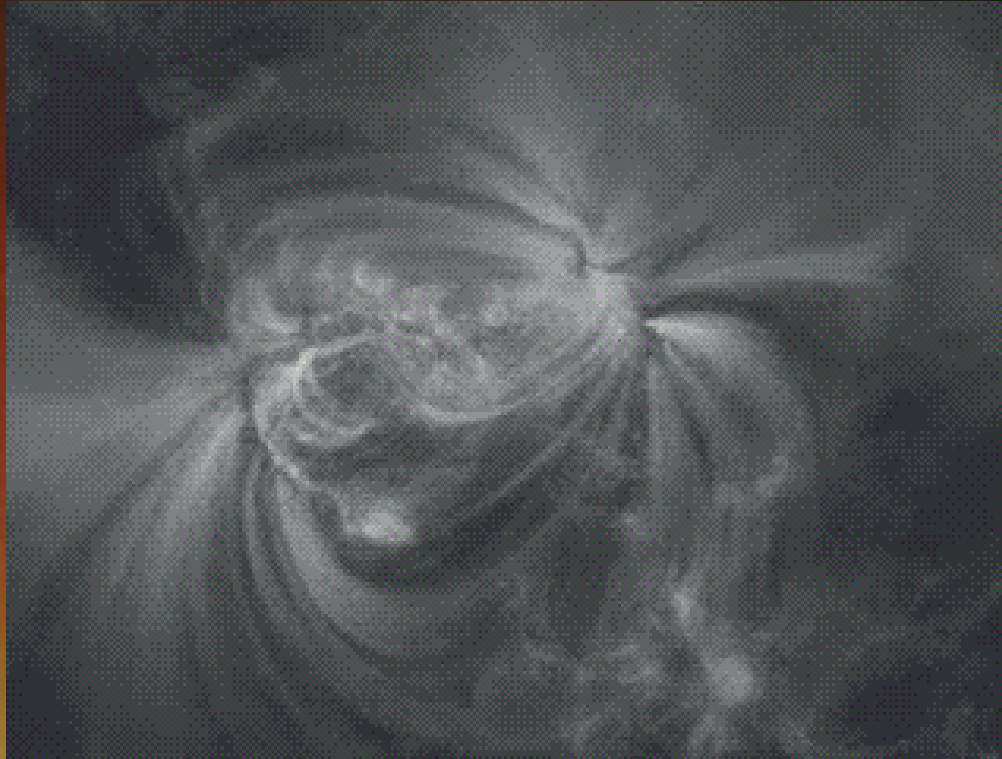
Lecture on June 21  
by Rainer Schwenn

## c) Space weather

- The source of space weather
- Why should we care?
- How does the Sun shape space weather?
- The role of Bz south
- M-regions and high-speed streams
- CMEs: piled-up plasma and ejecta clouds
- Problems in forecasting
- Open issues, future work needed

The term "space weather" refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and that can affect human life or health.

# Flares and the begin of space weather research



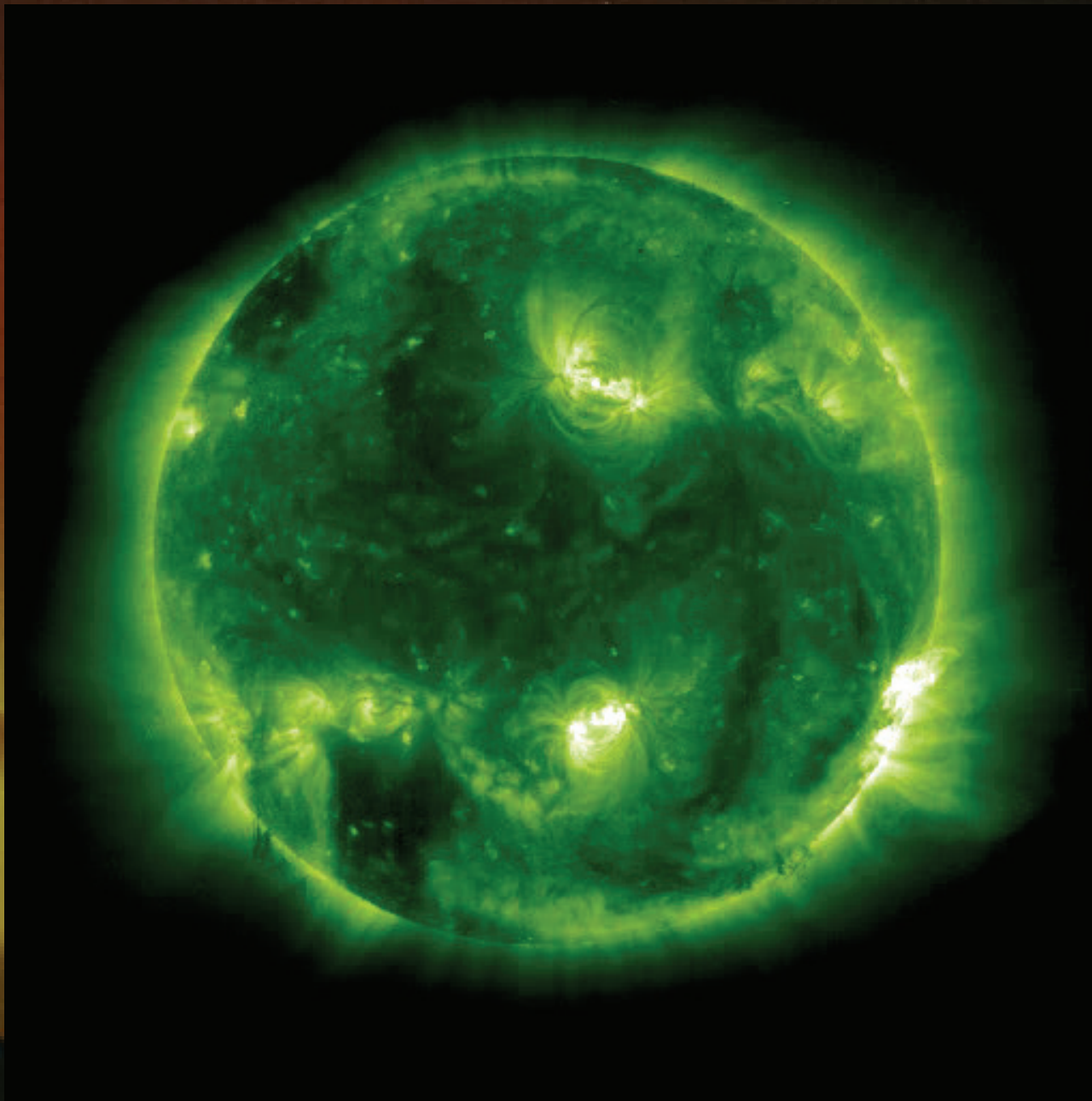
A solar flare, as observed by TRACE

Carrington was the first man who happened in 1859 to observe a flare and also to notice the connection with the strong geomagnetic storm 17 hours later. Note what the "father of space weather" noted at the end of his report:

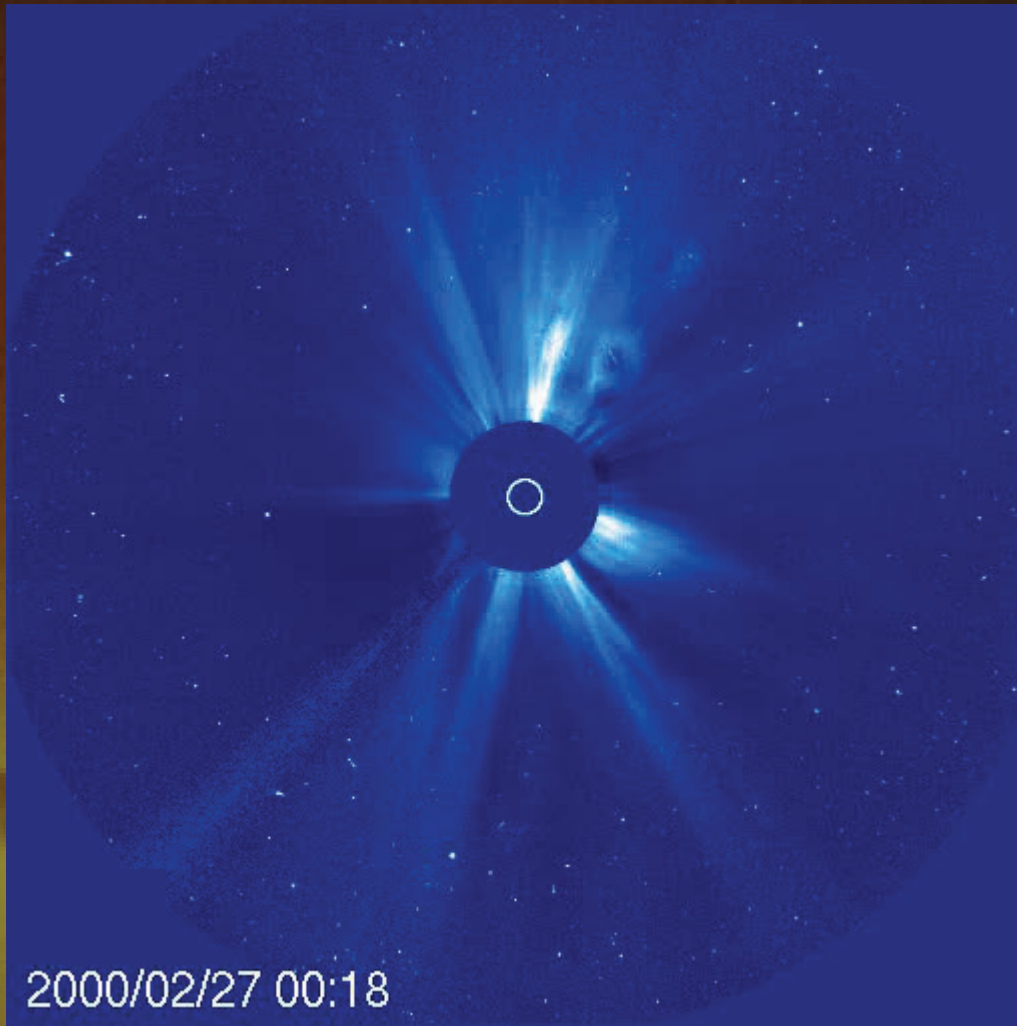
**"...one swallow does not make a summer!"**



# The source of space weather: the dynamic Sun!



# The source of space weather: the dynamic Sun!



*At times she releases  
gigantic explosions!*

The „thunder“ from  
such explosions  
literally shatters  
the whole solar  
system!

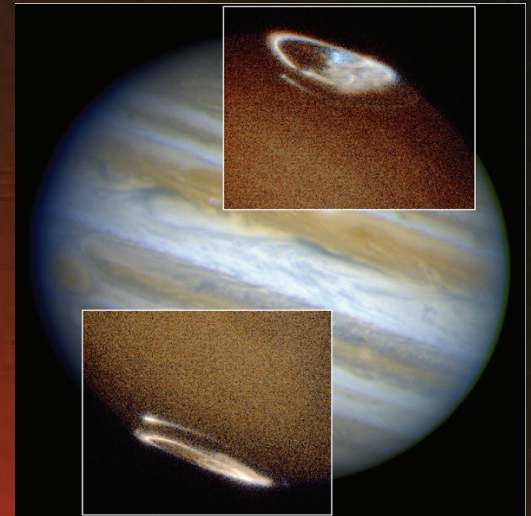
A huge „Coronal Mass Ejection“ (CME), observed  
by the LASCO coronagraph on SOHO



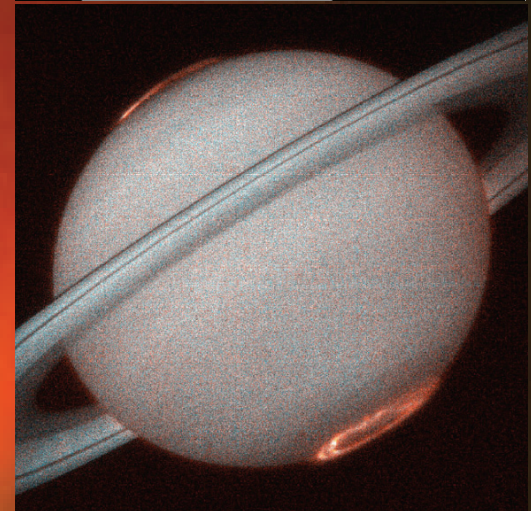
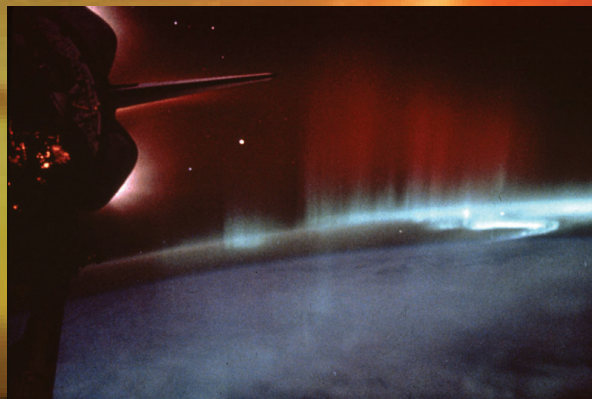
# Space storms all over the solar system!



but also on Jupiter



On Earth,



and on Saturn

# Space weather: why should we care?

Our society is much more dependent on technology than ever before.

The most rapidly growing sector of the communication market is satellite based:

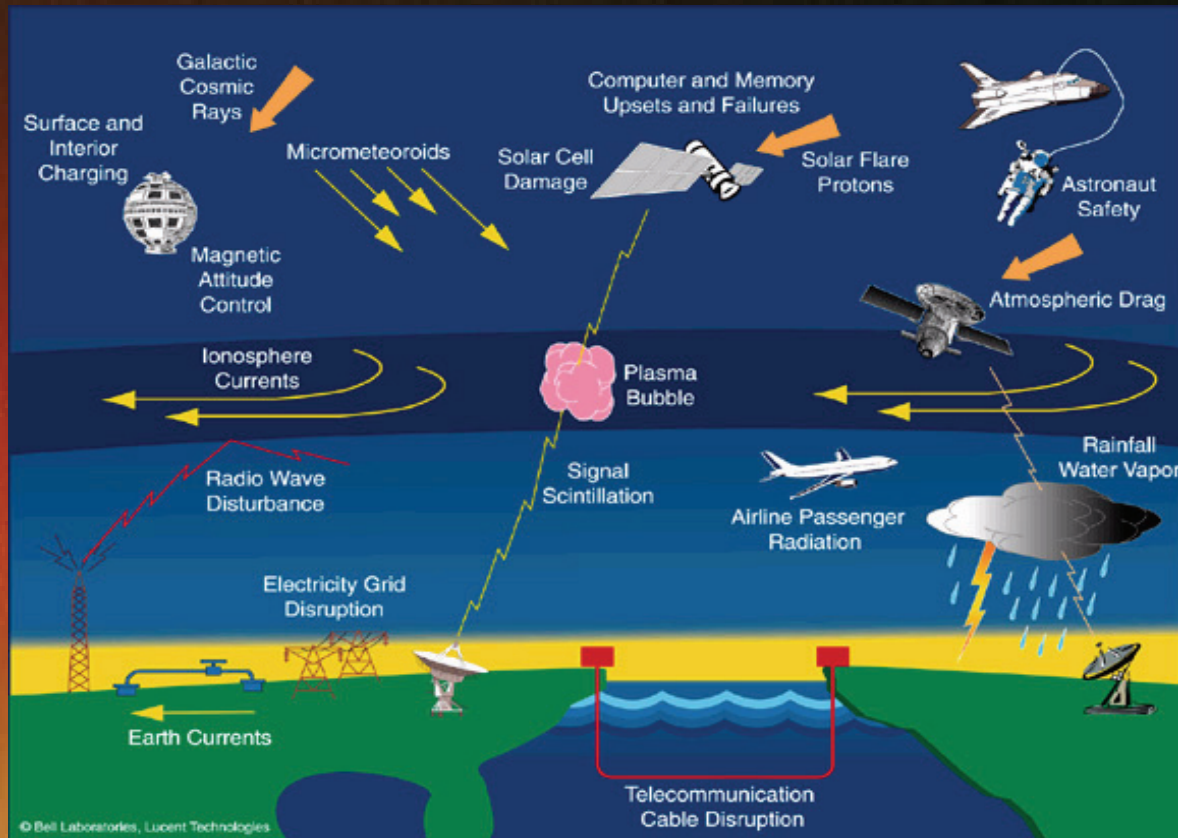
- broadcast TV/Radio
- long-distance telephone service, cell phones, pagers
- internet, finance transactions

Change in technology:

- more sensitive payloads
- high performance components
- lightweight and low cost

Humans in space:

- more and longer manned missions

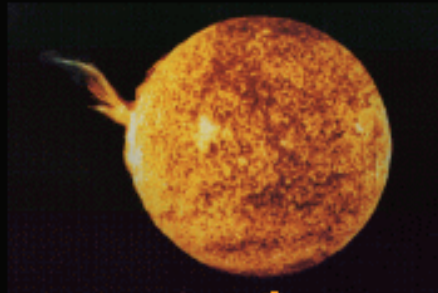


Consequences:

- Intensify fundamental research,
- Improve prediction capabilities,
- Invent technical measures.



# Effects from solar storms



Flares

CMEs/Flares

CMEs/Coronal Holes

**ELECTROMAGNETIC RADIATION**

ARRIVAL: IMMEDIATELY  
DURATION: 1-2 HOURS

X-RAYS, EUV,  
RADIO BURSTS

SATCOM INTERFERENCE  
RADAR INTERFERENCE  
SHORTWAVE RADIO FADES

**HIGH ENERGY PARTICLES**

ARRIVAL: 15 MIN TO FEW HOURS  
DURATION: DAYS

PROTON EVENTS

SATELLITE DISORIENTATION  
FALSE SENSOR READINGS  
SPACECRAFT DAMAGE  
LAUNCH PAYLOAD FAILURE  
HIGH ALTITUDE AIRCRAFT RADIATION  
SHORTWAVE RADIO FADES

**LOW-MEDIUM ENERGY PARTICLES**

ARRIVAL: 2-4 DAYS  
DURATION: DAYS

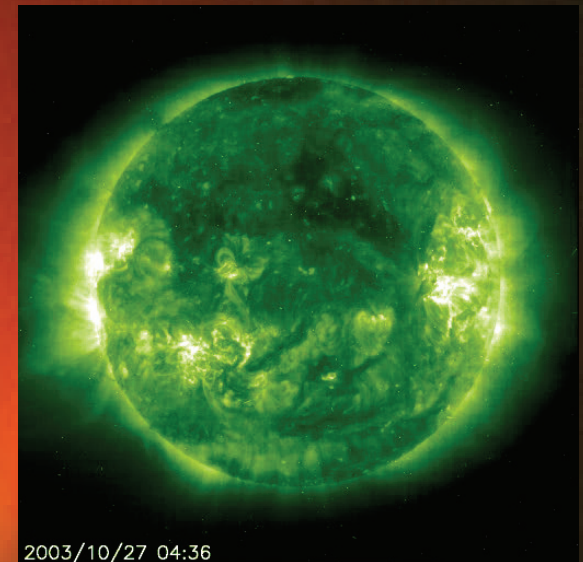
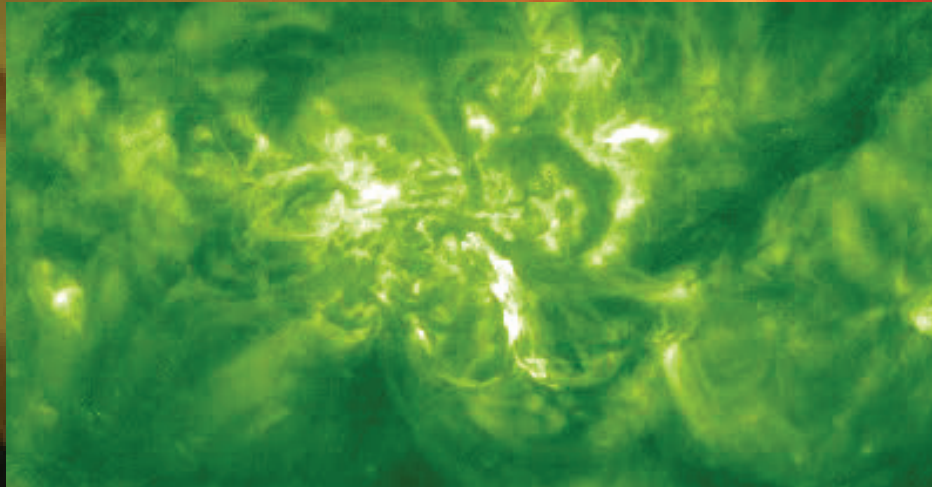
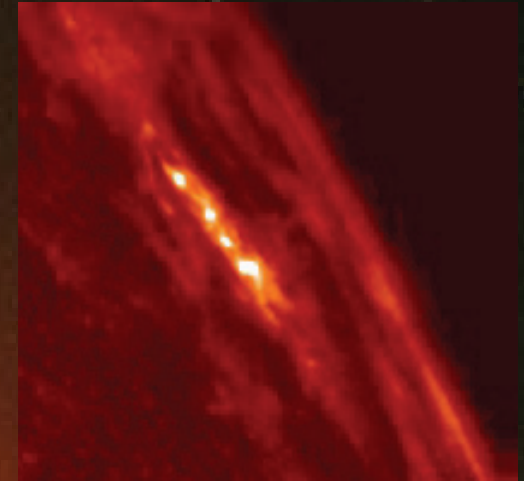
GEOMAGNETIC STORMS

SPACECRAFT CHARGING & DRAG  
SPACETRACK ERRORS  
LAUNCH TRAJECTORY ERRORS  
RADAR INTERFERENCE  
RADIO PROPAGATION ANOMALIES  
POWER BLACKOUTS

# 1. Electromagnetic radiation from flares

Radio, visible light, EUV, X-rays, Gamma-rays

- Physics: Unclear, but under intense study...
- Arrival: Simultaneously in all wavelengths
- Duration: Minutes to hours
- Predictions: Still impossible!
- Effects: Sudden heating of the Earth's upper atmosphere
- Impacts: \* Radio communications disturbed,  
\* Sudden satellite drag.



2003/10/27 04:36

A solar research satellite (SMM) was brought down by the Sun itself!

In March 1989 SMM ran into a „brick wall“, built by UV flux from a major solar flare

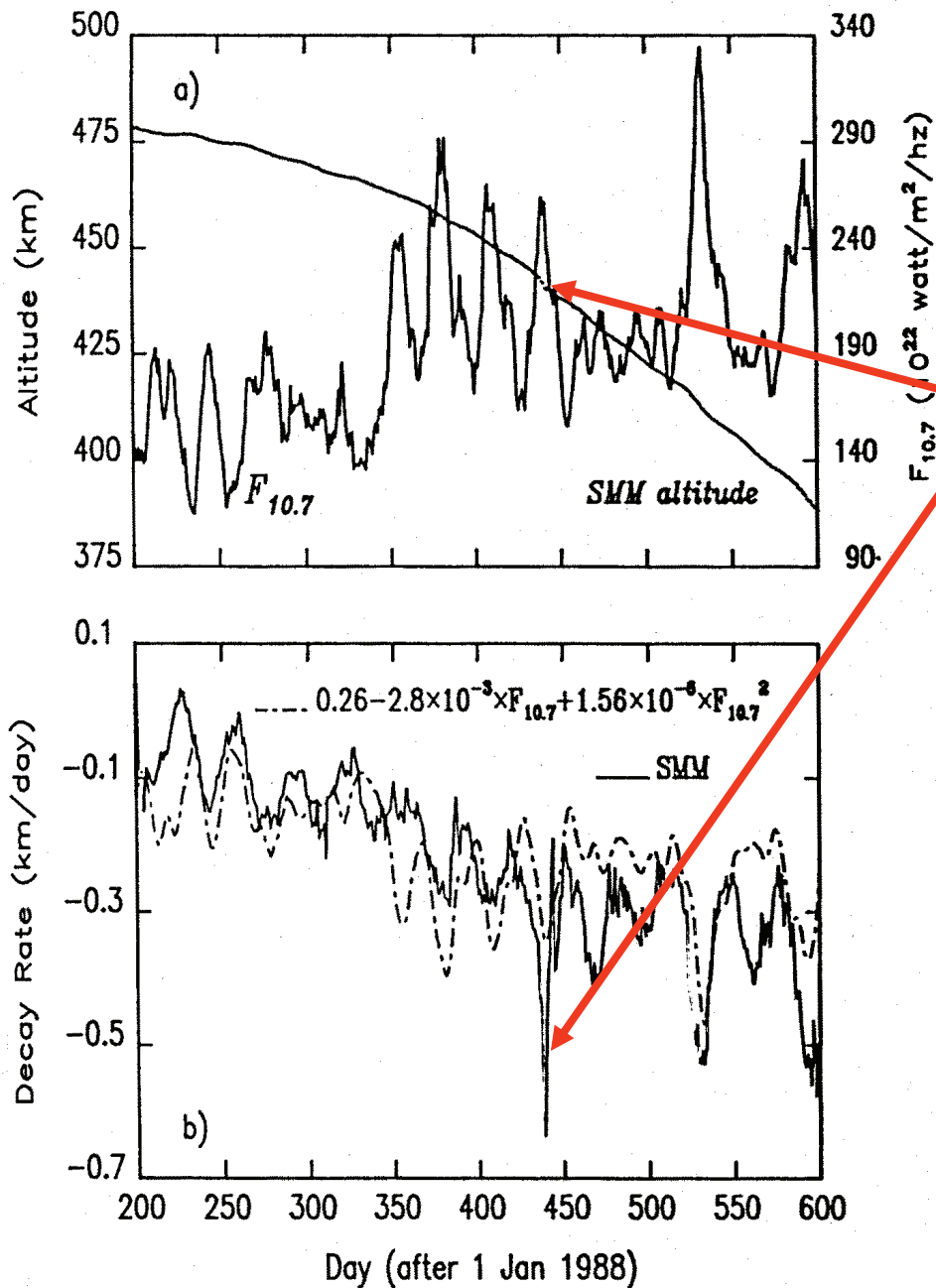


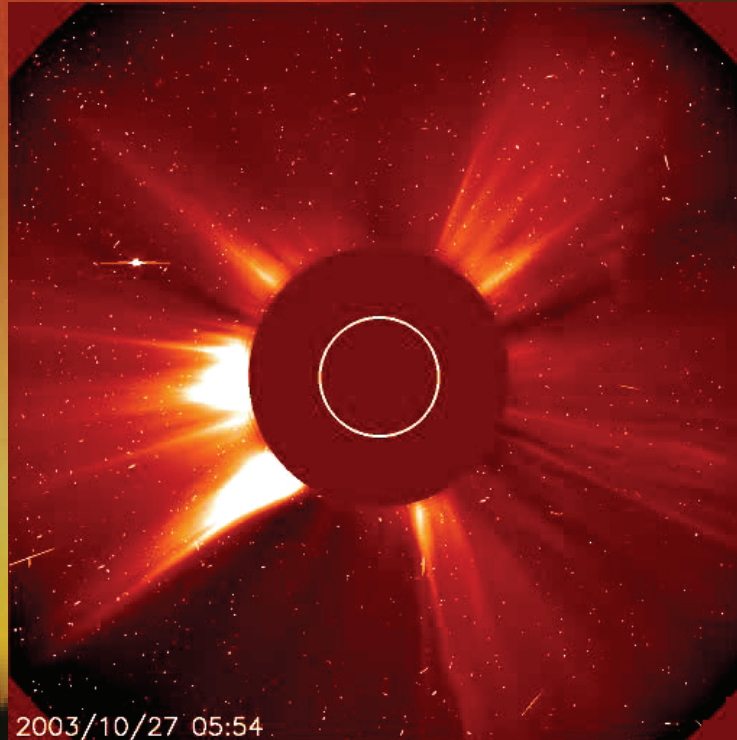
Figure 5. (a) The decreasing altitude of the Solar Maximum Mission (SMM) satellite (D. Messina and G. Share, private communication, 1990), just prior to its reentry into the Earth's atmosphere in December 1989, coincident with increasing solar activity as encapsulated in the Sun's 10.7-cm radio flux,  $F_{10.7}$ . (b) The orbital decay rate (solid line), determined as the change per day in the altitude shown in Figure 5a, is compared with variations in the daily  $F_{10.7}$  flux (linearly transformed to an equivalent decay rate (dashed line)). A definite but imperfect correlation is apparent between the two. The dominant cycle of  $\sim 27$  days occurs because the Sun's rotation causes active regions to move across the face of the solar disc seen at the Earth, modulating its output of UV radiation. When the Sun's UV radiation is brightest, the Earth's atmosphere expands outward, and the rate of decay of the satellite orbit increases. Active regions that cause enhancements of the UV radiative output also modify the 10.7-cm radio flux.



## 2. High energy particles from flares and CME shocks

Electrons, protons and other ions with energies of few 100 MeV, at times several GeV

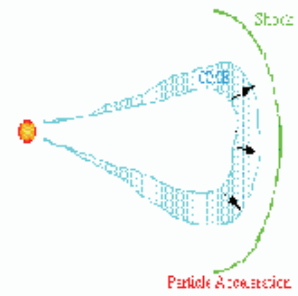
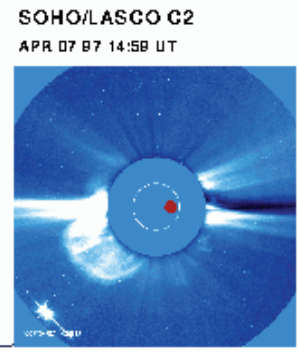
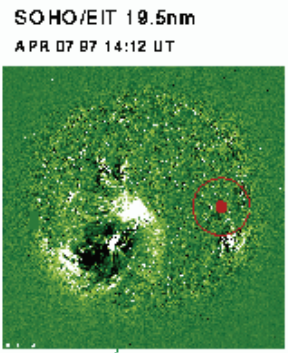
- Physics: Onset still unclear, particle acceleration under intense study...
- Arrival: Some 10 minutes to 1 hour after the flare
- Duration: Hours to days
- Predictions: Very uncertain, in all aspects!



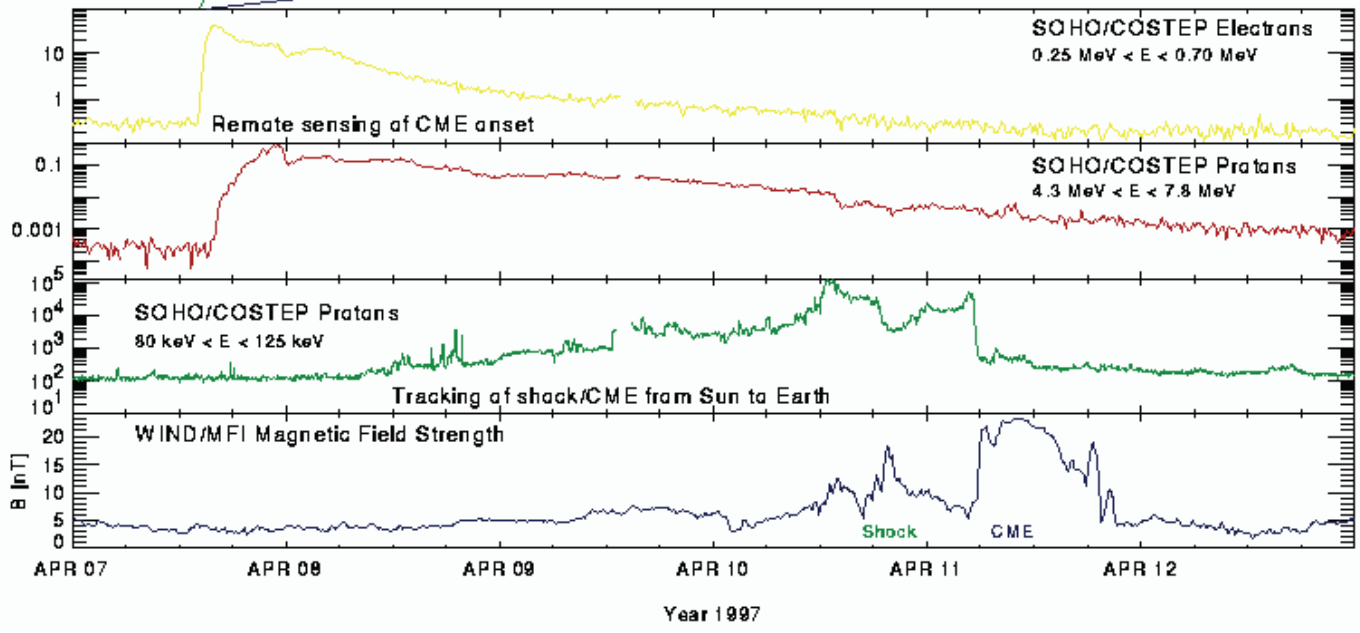
# 2. High energy particles from flares and CME shocks

Electrons, protons and other ions with energies of few 100 MeV, at times several GeV

EIT-wave



CME + shock



Flare-accelerated

Shock-accelerated energetic particles



## 2. High energy particles from flares and CME shocks

Effects:

- \* Heating and ionization of the Earth's upper atmosphere,

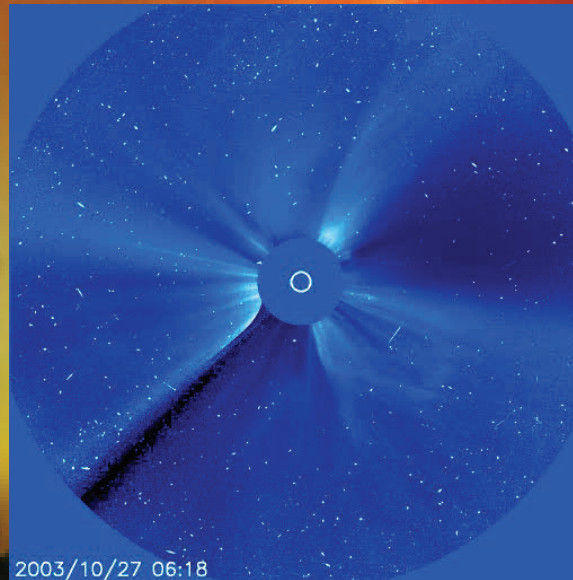
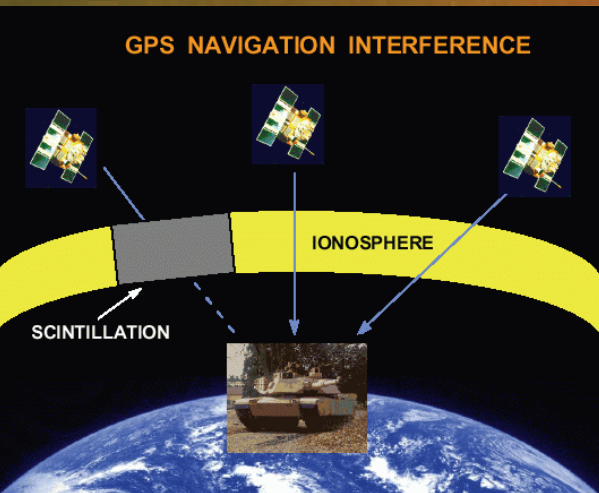
Impacts:

- \* Radio communications disturbed, damage to exterior satellite surfaces,

- \* Damage to solid state devices, leading to malfunctions, single event upsets, latch-ups etc. in satellite electronics,

- \* Blinding of CCD cameras in Earth orbit,

- \* Enhanced radiation doses for astronauts, particularly dangerous during EVAs.

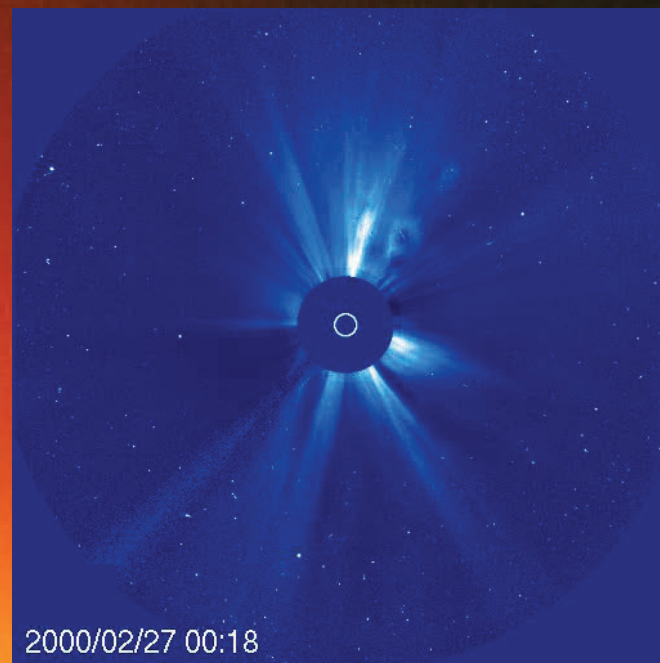




### 3. Low to medium-energy particles, plasma clouds

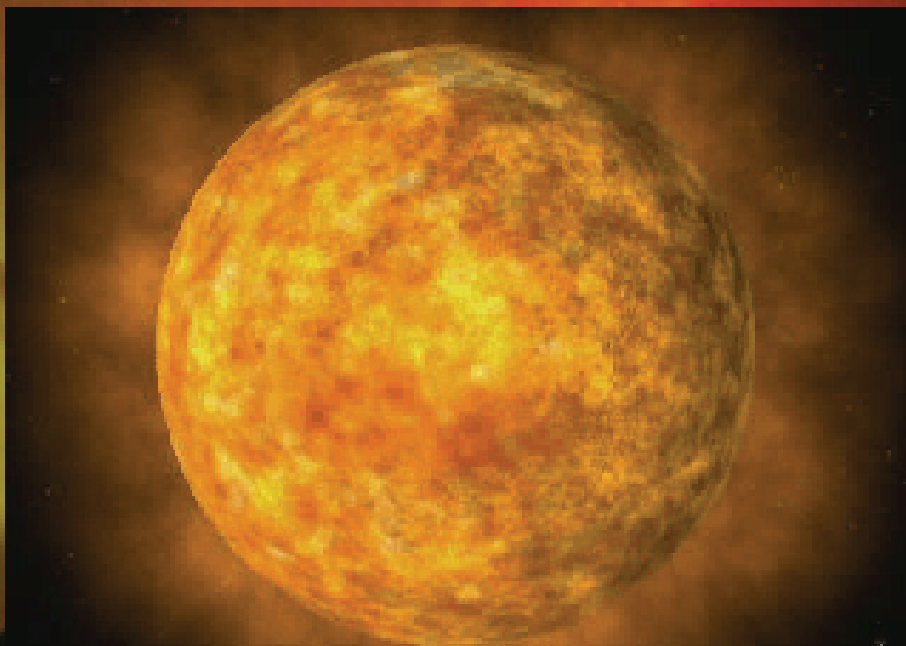
CMEs, interplanetary shocks, magnetic clouds, plasma turbulence as products of coronal mass ejections, all contributing to generate **Geomagnetic storms.**

- Physics: \* Origin of CMEs unclear, but under intense study.  
\* Propagation is being modelled, empirical approaches under development.
- Arrival: 1 to 5 days after CME launch
- Duration: hours to days
- Prediction: +/- 24 hrs after halo CME



### 3. Low to medium-energy particles, plasma clouds

- Effects:
- \* Sudden compression of the Earth's magnetosphere,
  - \* Distortion and depletion of the radiation belts, leading to release of large fluxes of energetic particles,
  - \* Injection of plasma from magnetotail into polar magnetosphere/ionosphere, thus causing aurorae,
  - \* Severe disturbances of ring currents, i.e. geomagnetic storms,
  - \* Heating of ionosphere and upper atmosphere,



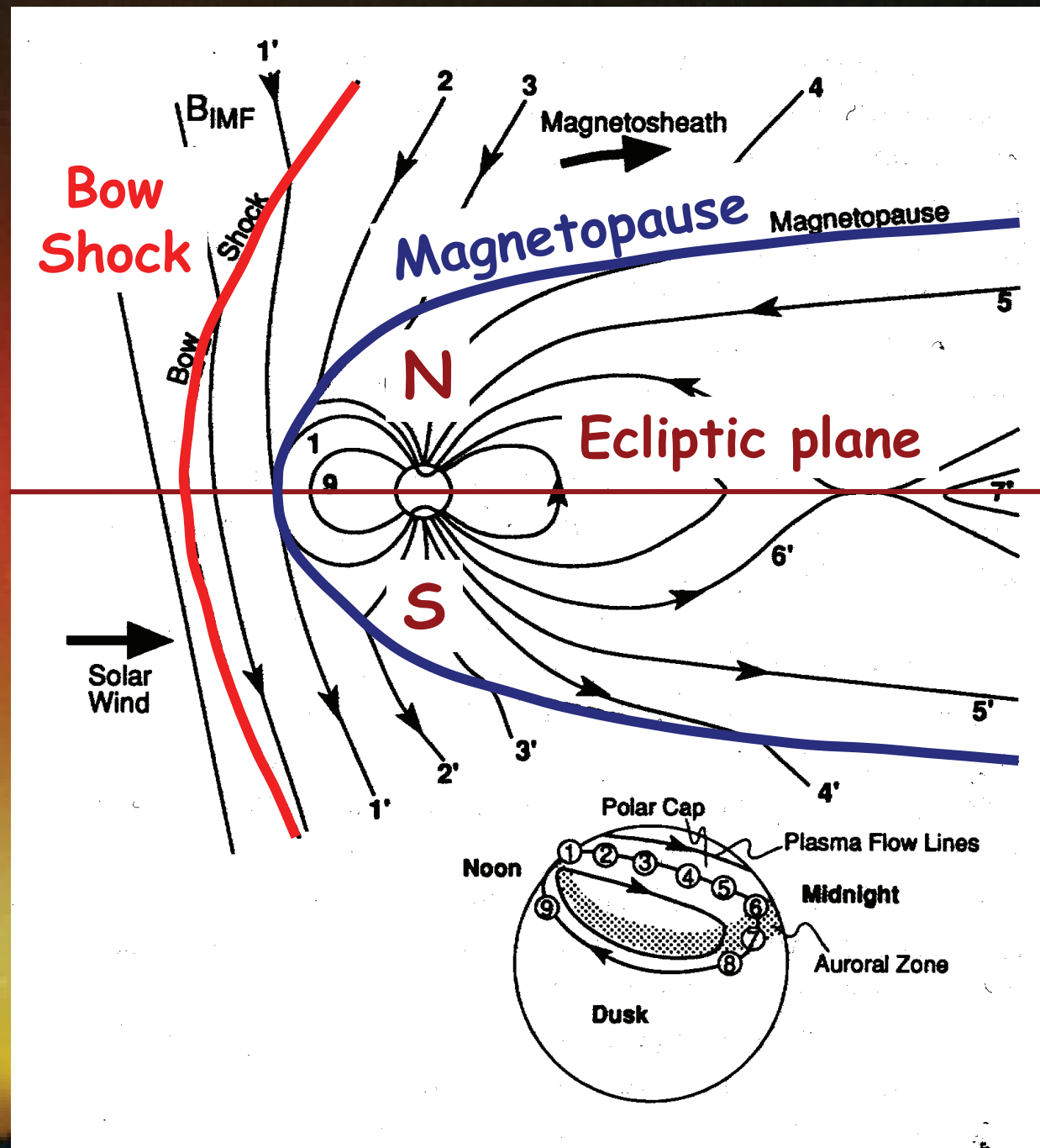


# A magnetosphere at work

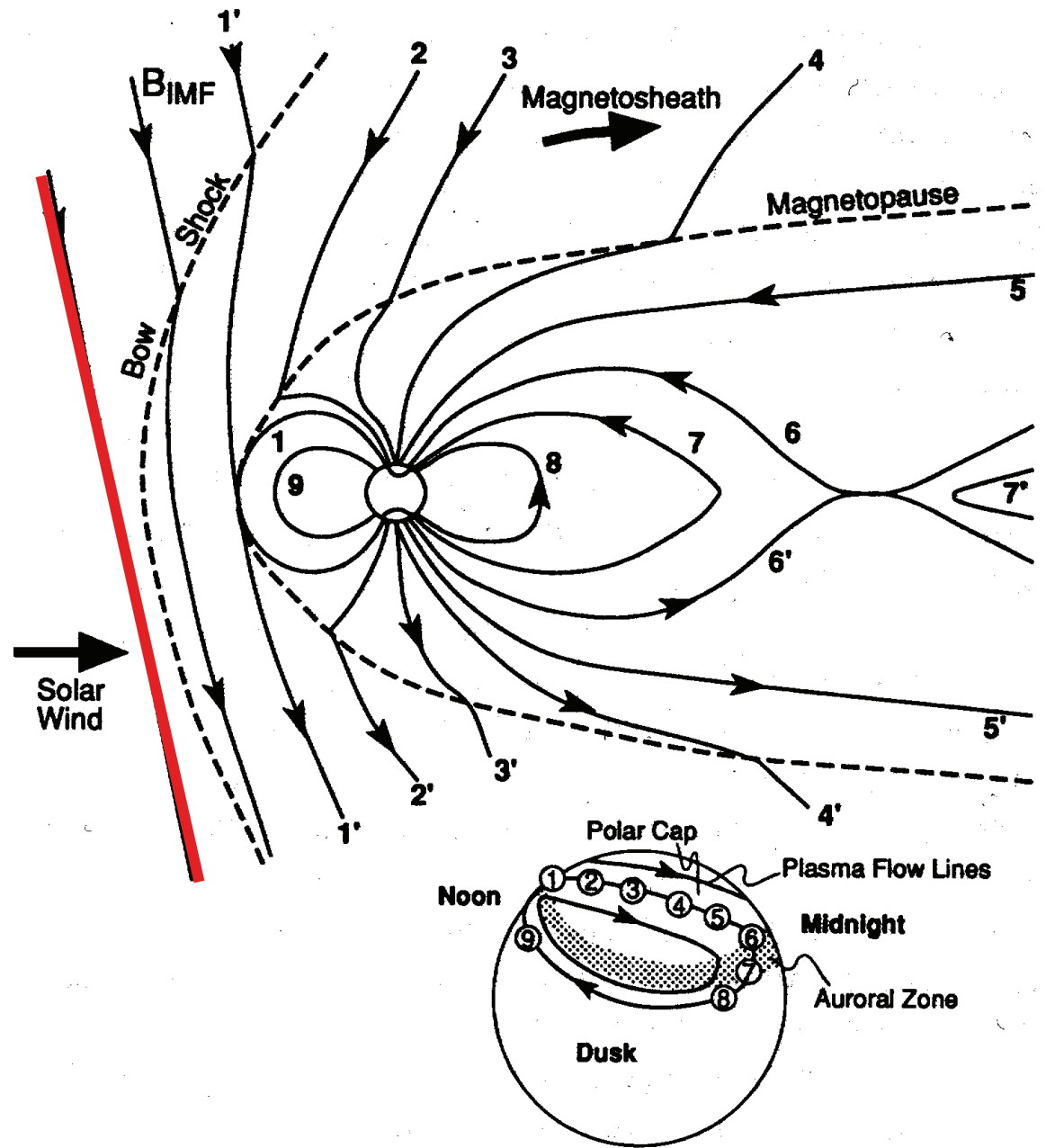
What makes geospace vulnerable?

**$B_z$  south!**

Magnetic reconnection at the front side of the magnetosphere occurs, when the interplanetary  $B_z$  turns south, i.e. anti-parallel to the Earth's intrinsic field.

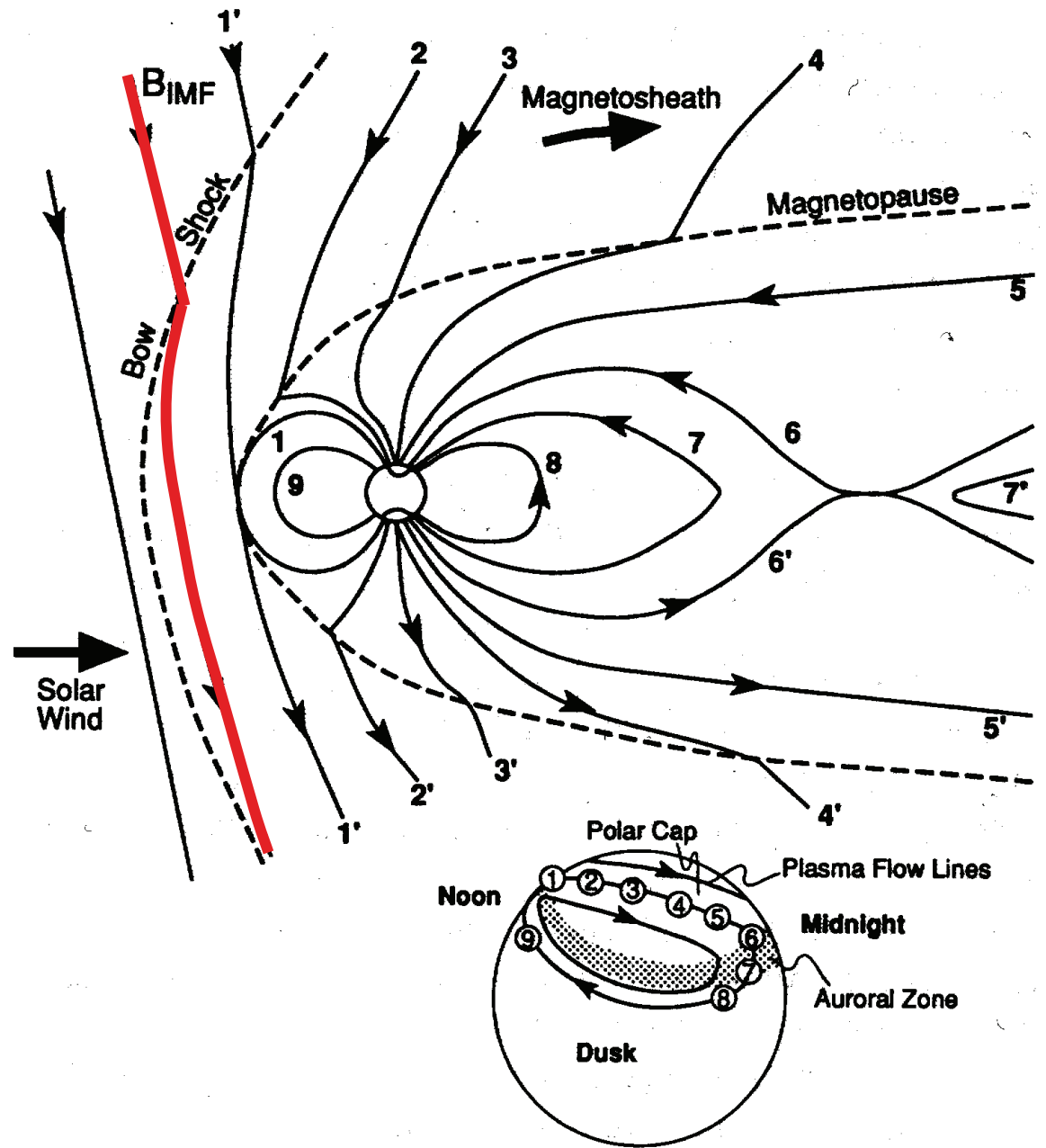


# A magnetosphere at work



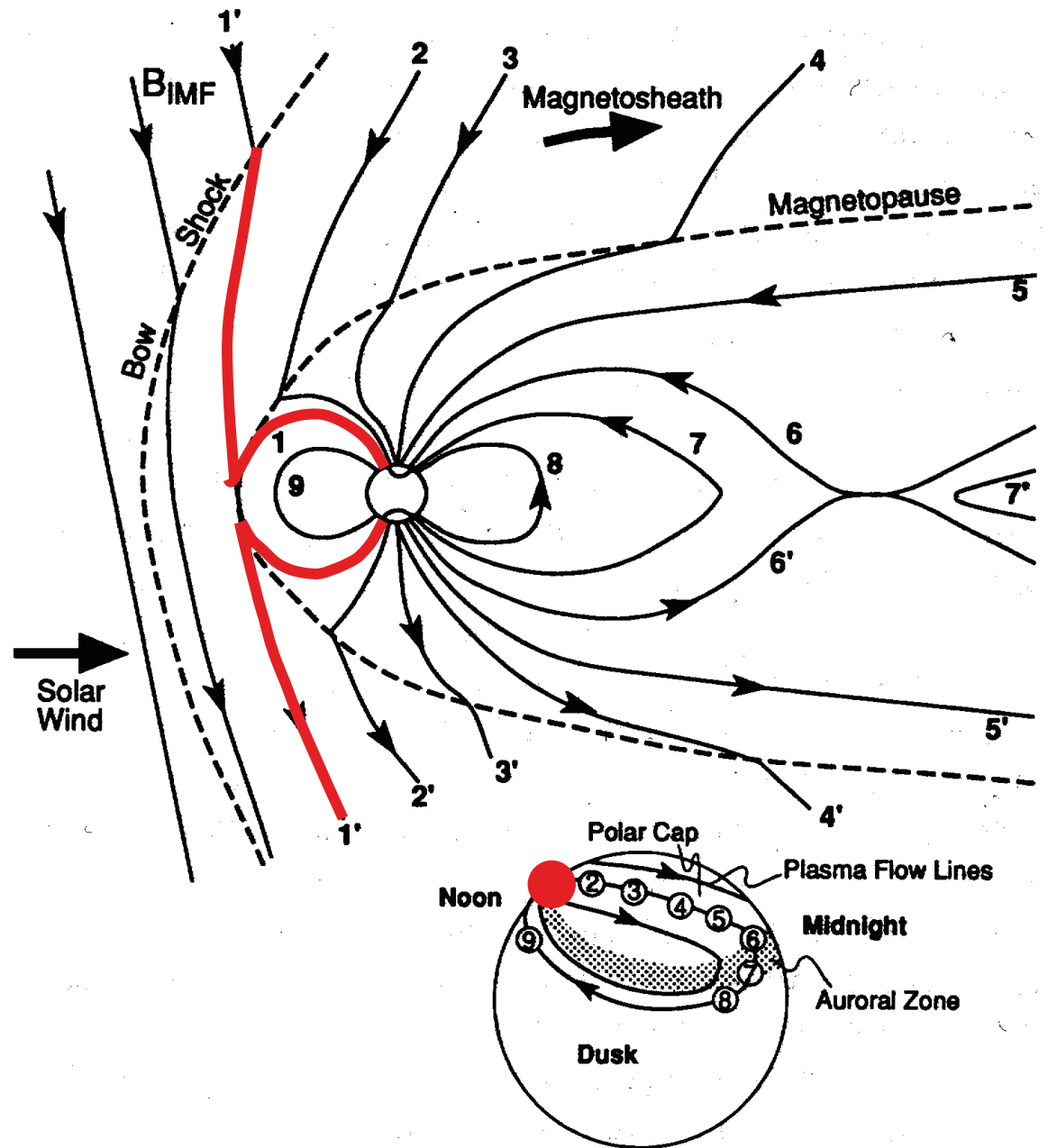
In case of  $B_z$  south:

# A magnetosphere at work



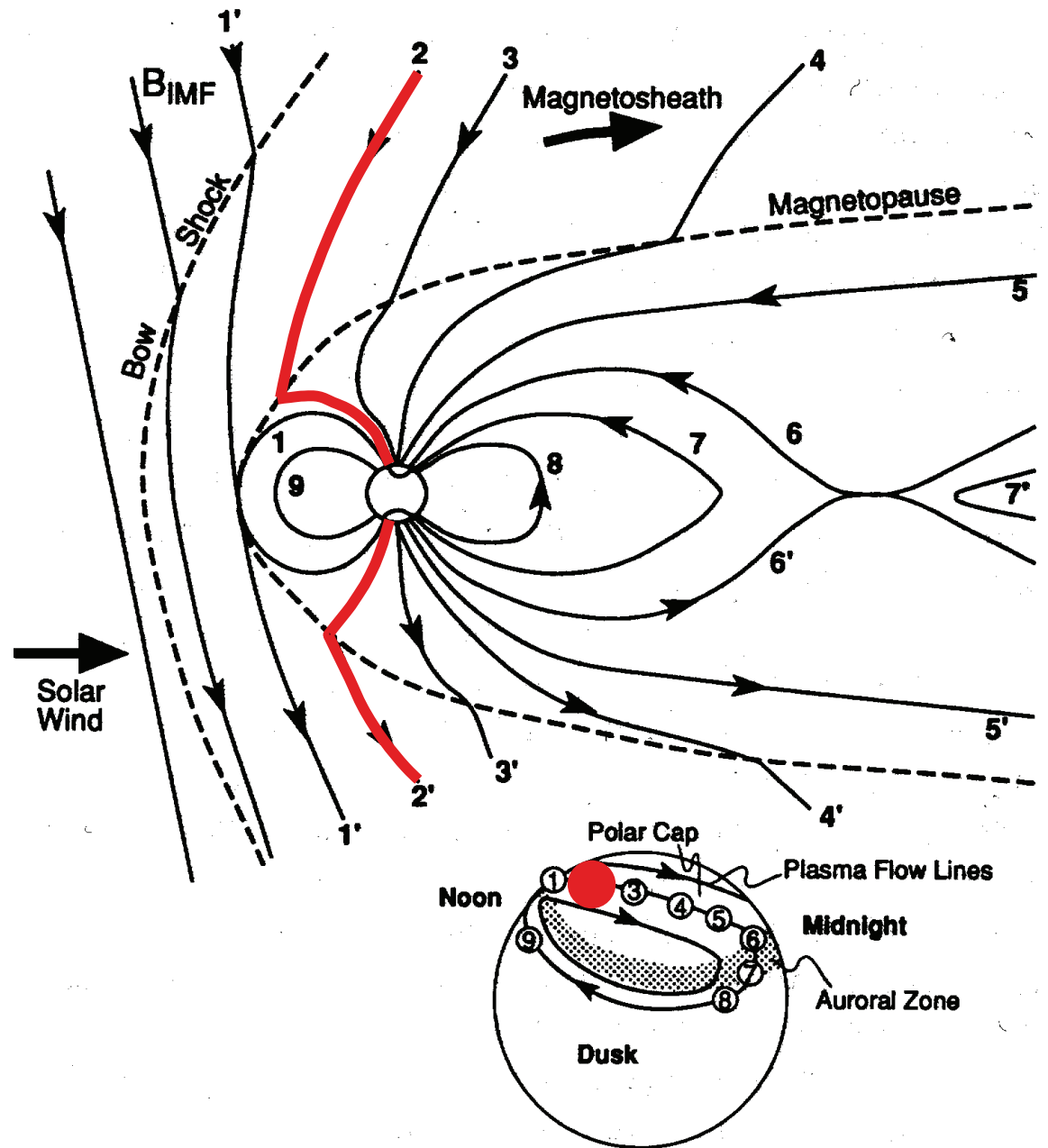
In case of  $B_z$  south:

# A magnetosphere at work



In case of  $B_z$  south:  
reconnection at the  
magnetopause!

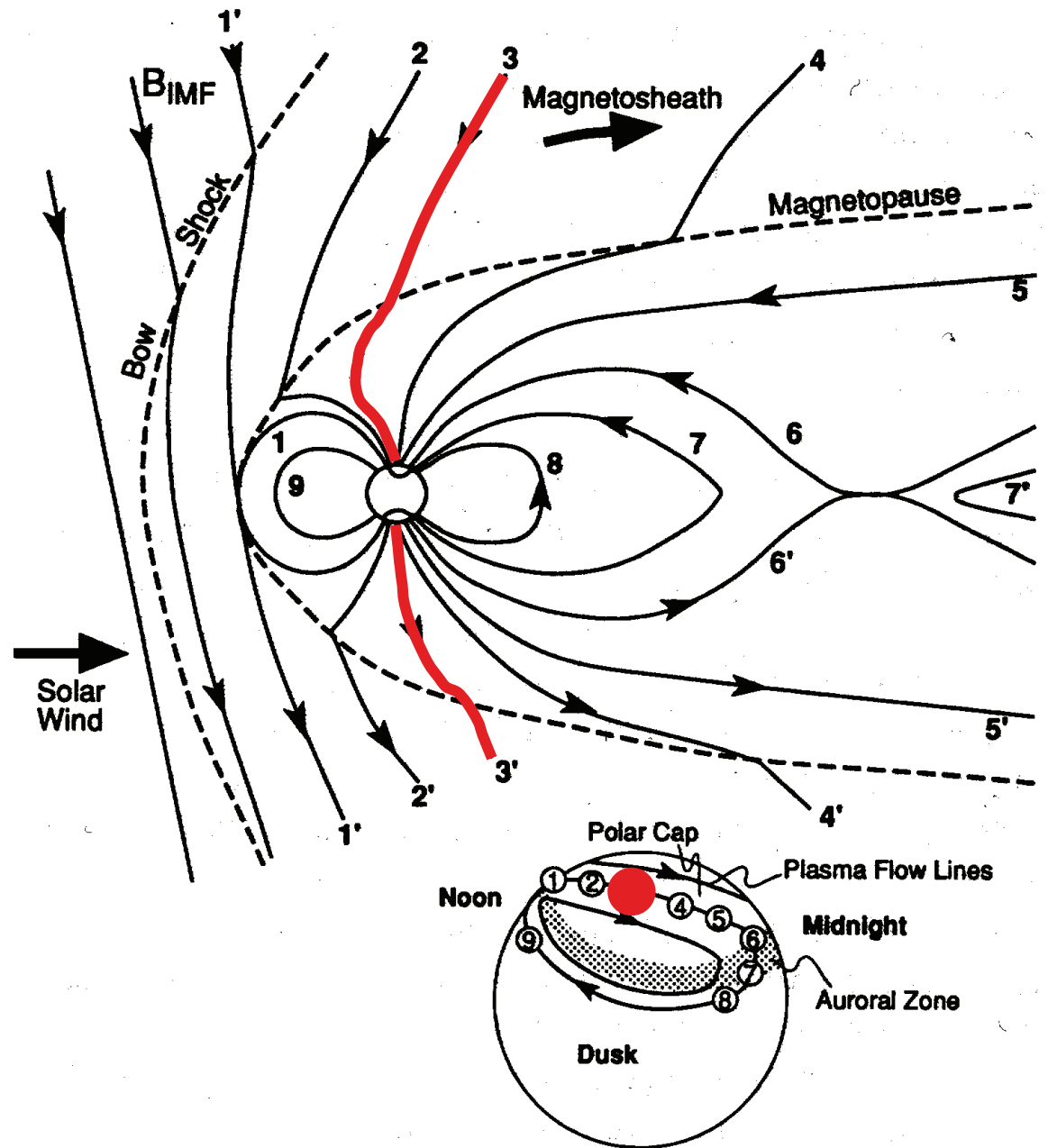
# A magnetosphere at work



In case of  $B_z$  south:  
reconnection at the  
magnetopause!

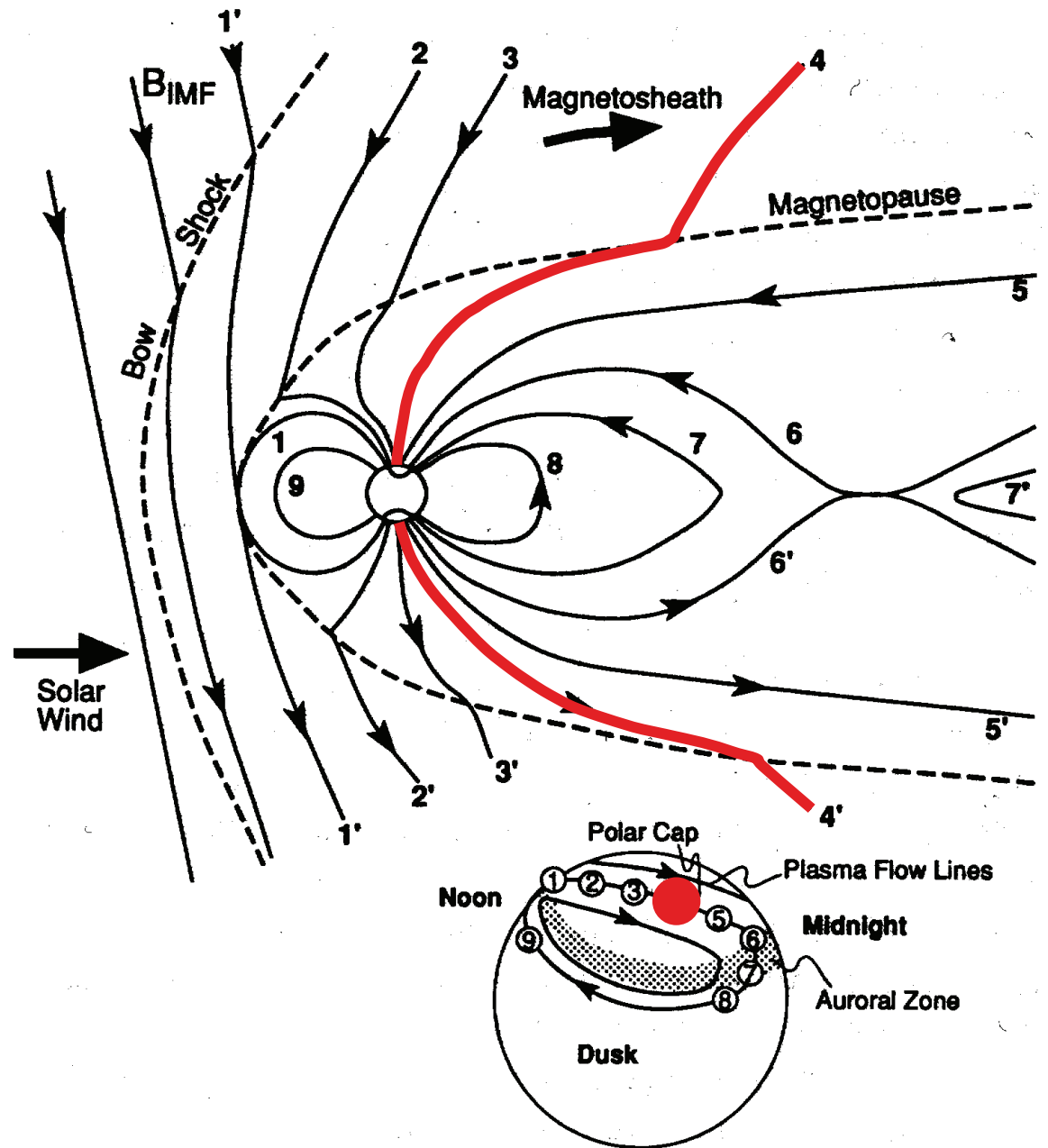


# A magnetosphere at work



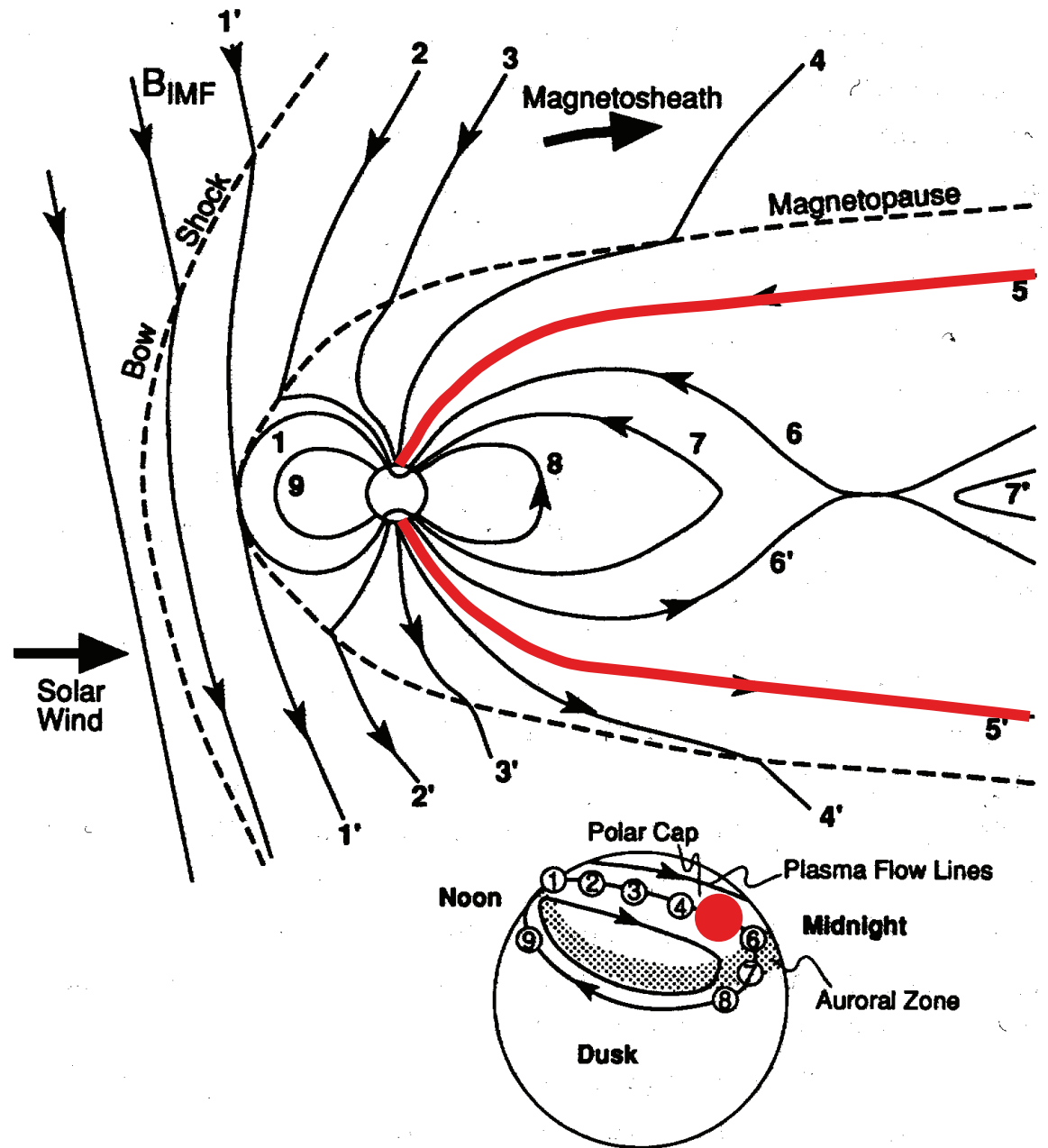
In case of  $B_z$  south:  
reconnection at the  
magnetopause!

# A magnetosphere at work



In case of  $B_z$  south:  
reconnection at the  
magnetopause!

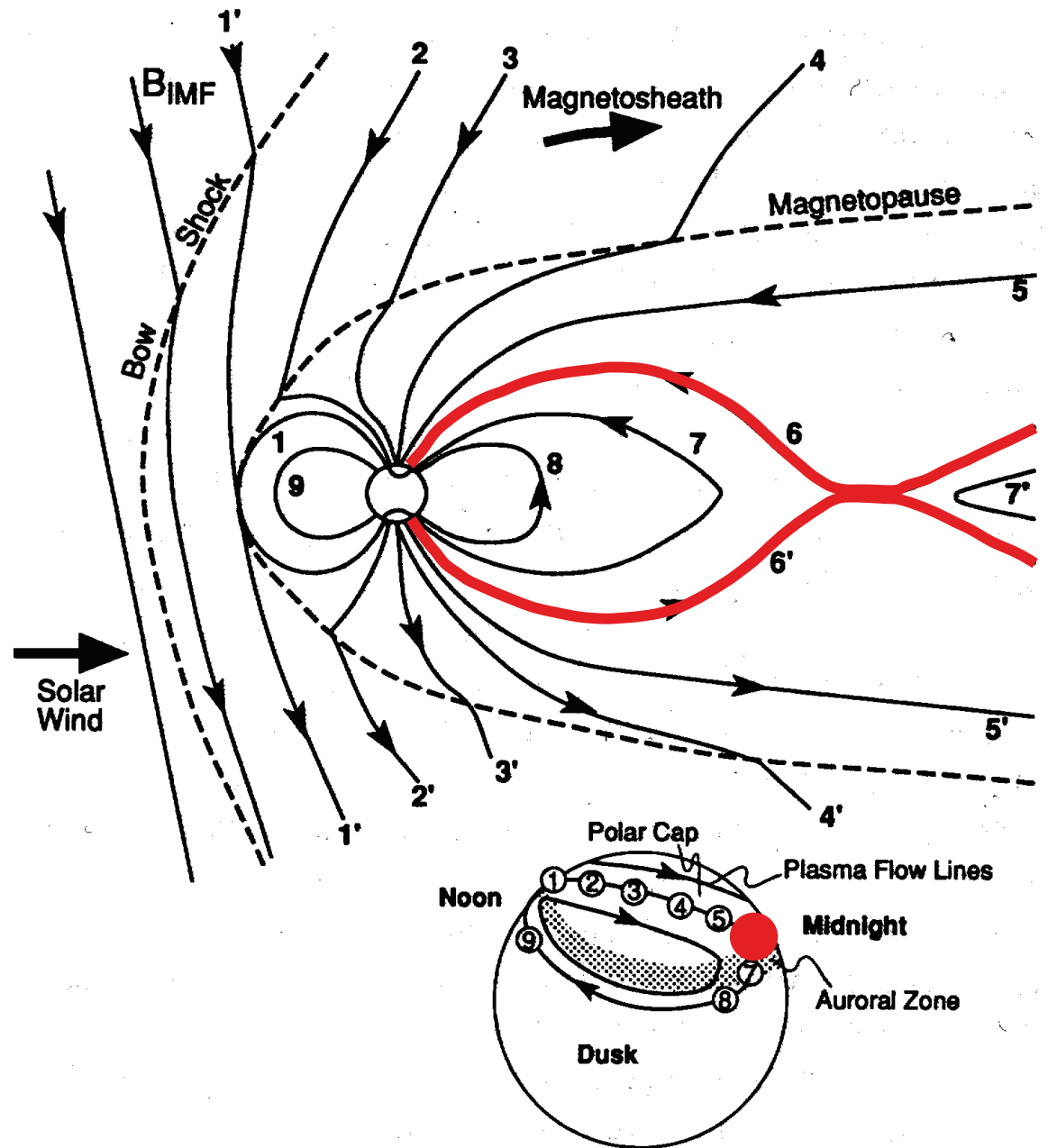
# A magnetosphere at work



In case of  $B_z$  south:  
reconnection at the  
magnetopause!

# A magnetosphere at work

In case of  $B_z$  south:  
reconnection at the magnetopause, and  
reconnection in the magnetotail!

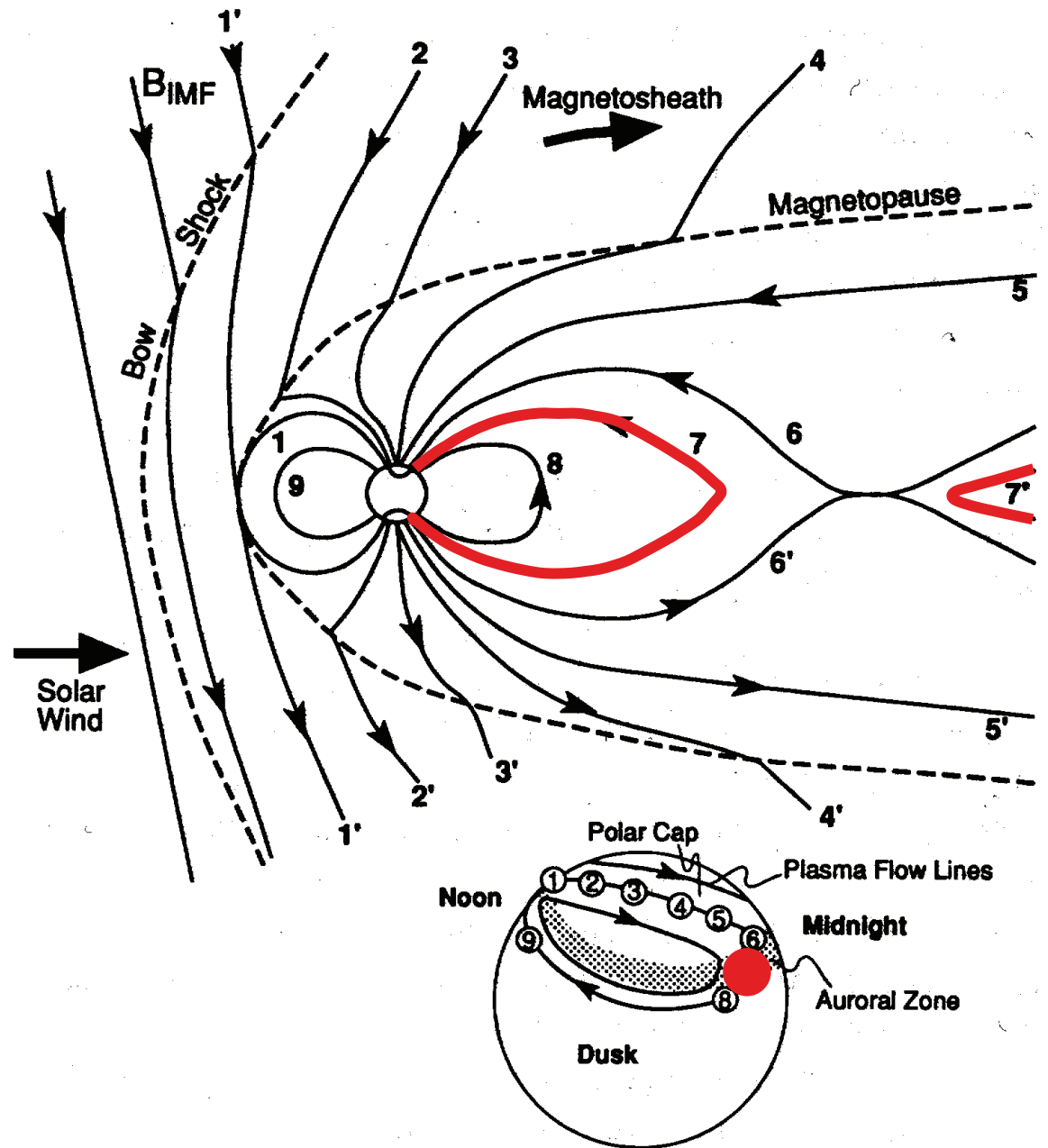






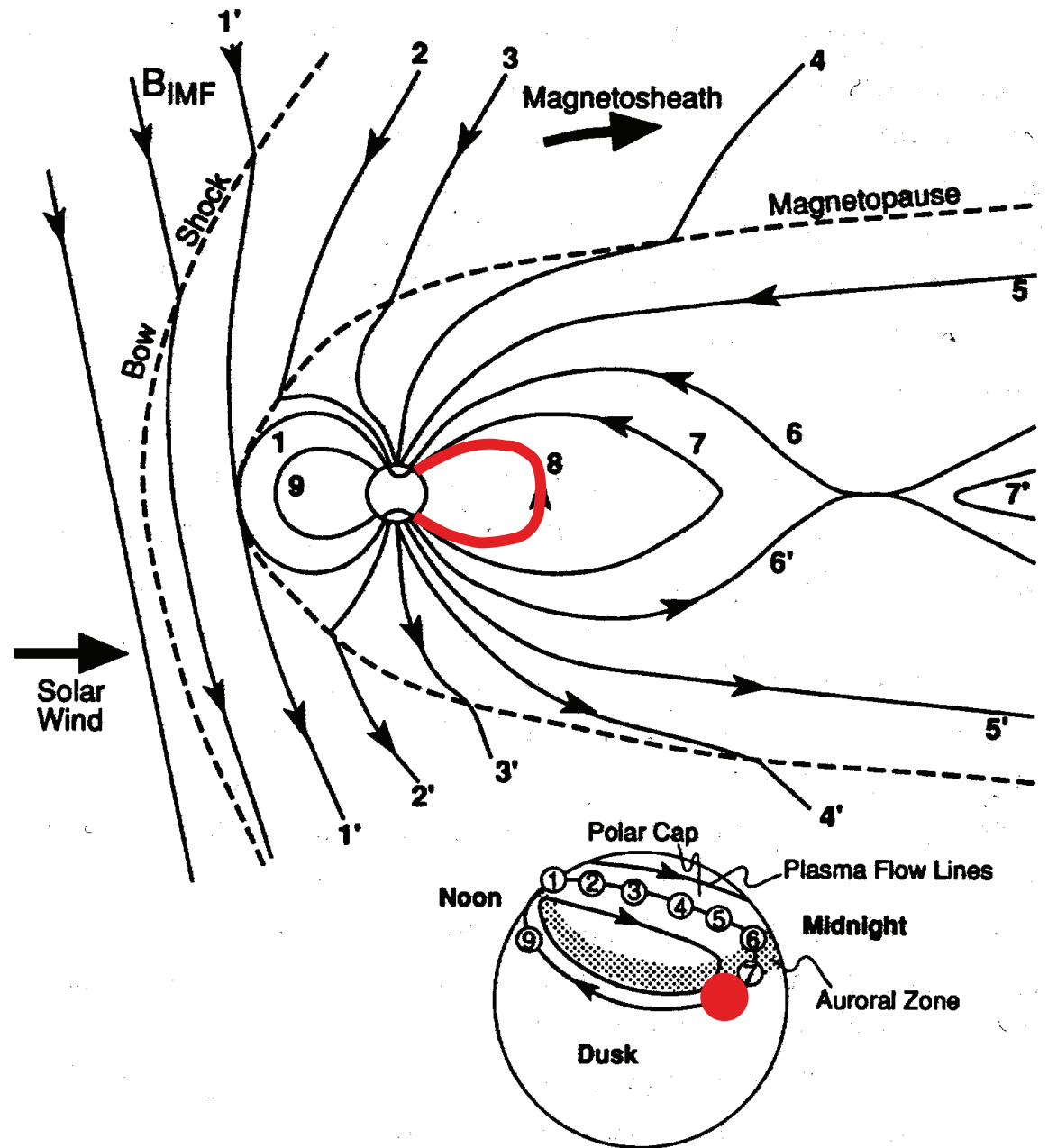
# A magnetosphere at work

In case of  $B_z$  south:  
reconnection in the  
magnetotail and  
plasma injection into  
the high latitude  
ionosphere!



# A magnetosphere at work

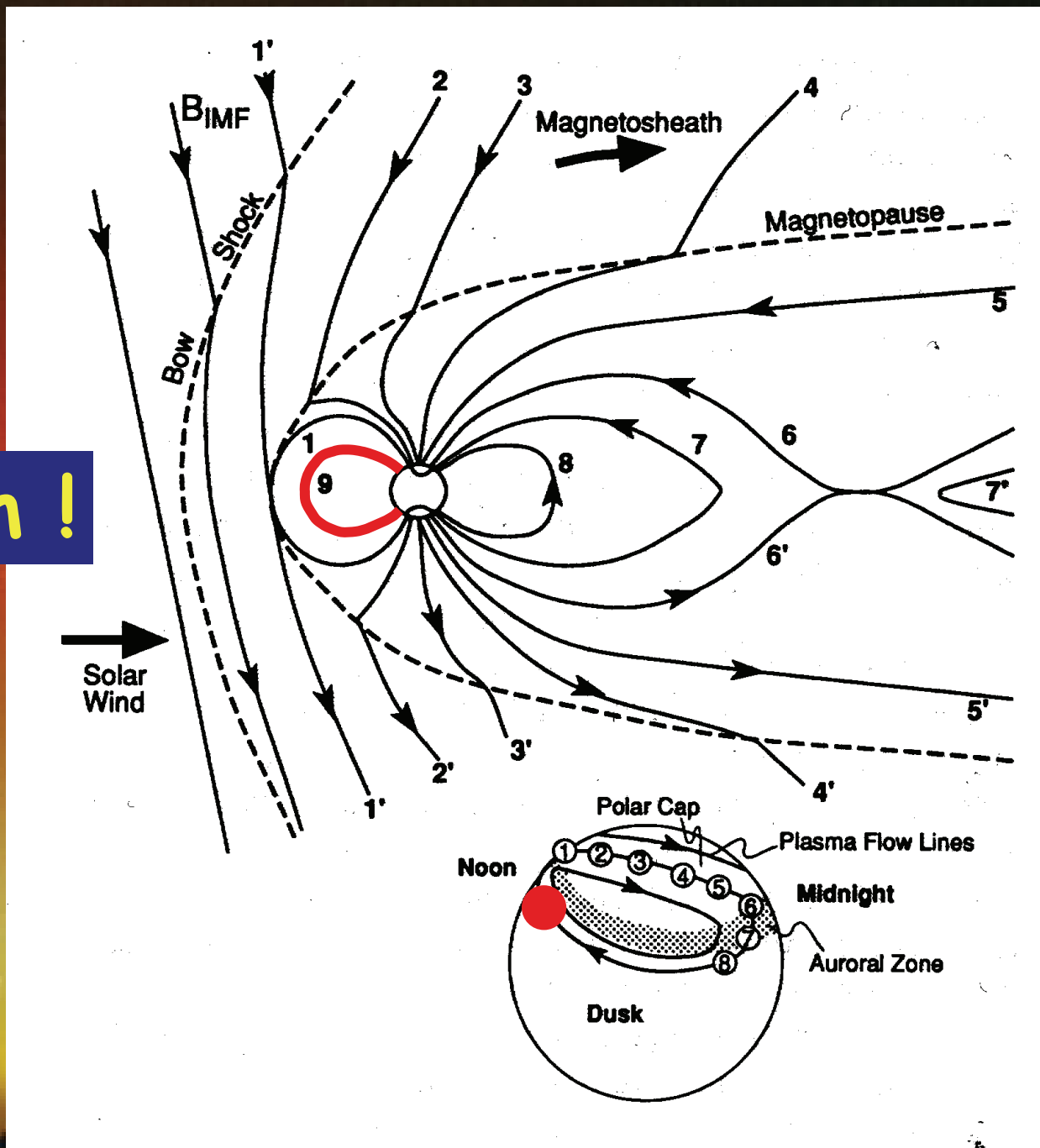
In case of  $B_z$  south:  
reconnection in the  
magnetotail and  
plasma injection into  
the high latitude  
ionosphere!



# A magnetosphere at work

## A substorm !

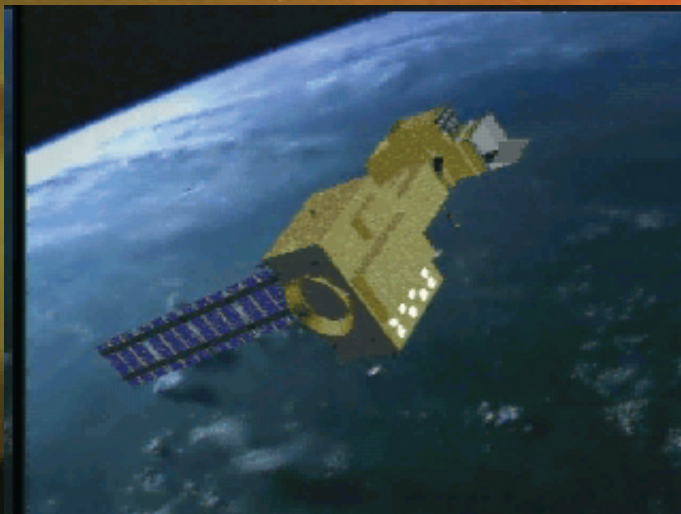
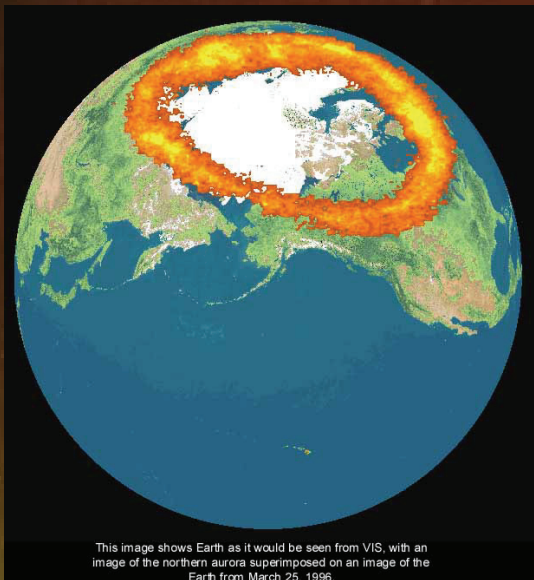
In case of  $B_z$  south:  
Finally, the stored radiation belt particles are released and may cause damage!



### 3. Low to medium-energy particles, plasma clouds

#### Impacts:

- \* Bright aurorae, even at low latitudes,
- \* Strong fluctuations of geomagnetic field,
- \* Radio communications disturbed,
- \* Sudden satellite drag due to heating of the upper atmosphere,
- \* Charge-up of satellite surfaces due to high fluxes of energetic electrons.

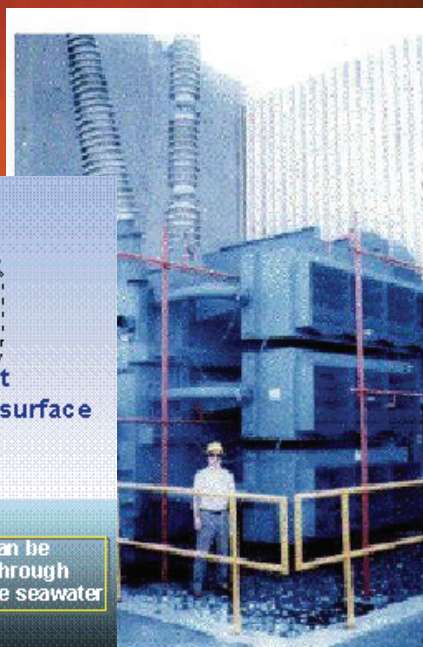
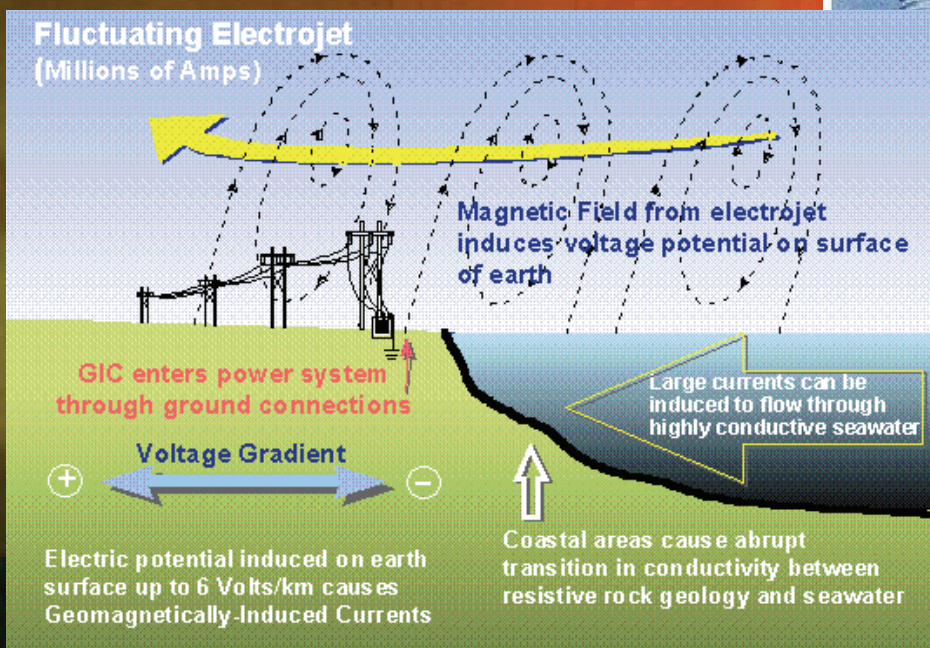




# 3. Low to medium-energy particles, plasma clouds

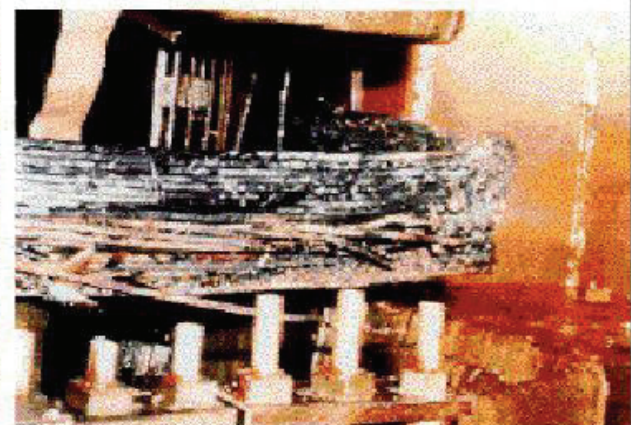
Impacts:

- \* Satellite damages from penetrating energetic particles,
- \* Satellite disorientation due to magnetic field distortion,
- \* GICs endangering power distribution nets, pipelines, telecommunication lines etc,
- \* Effects on biological systems.

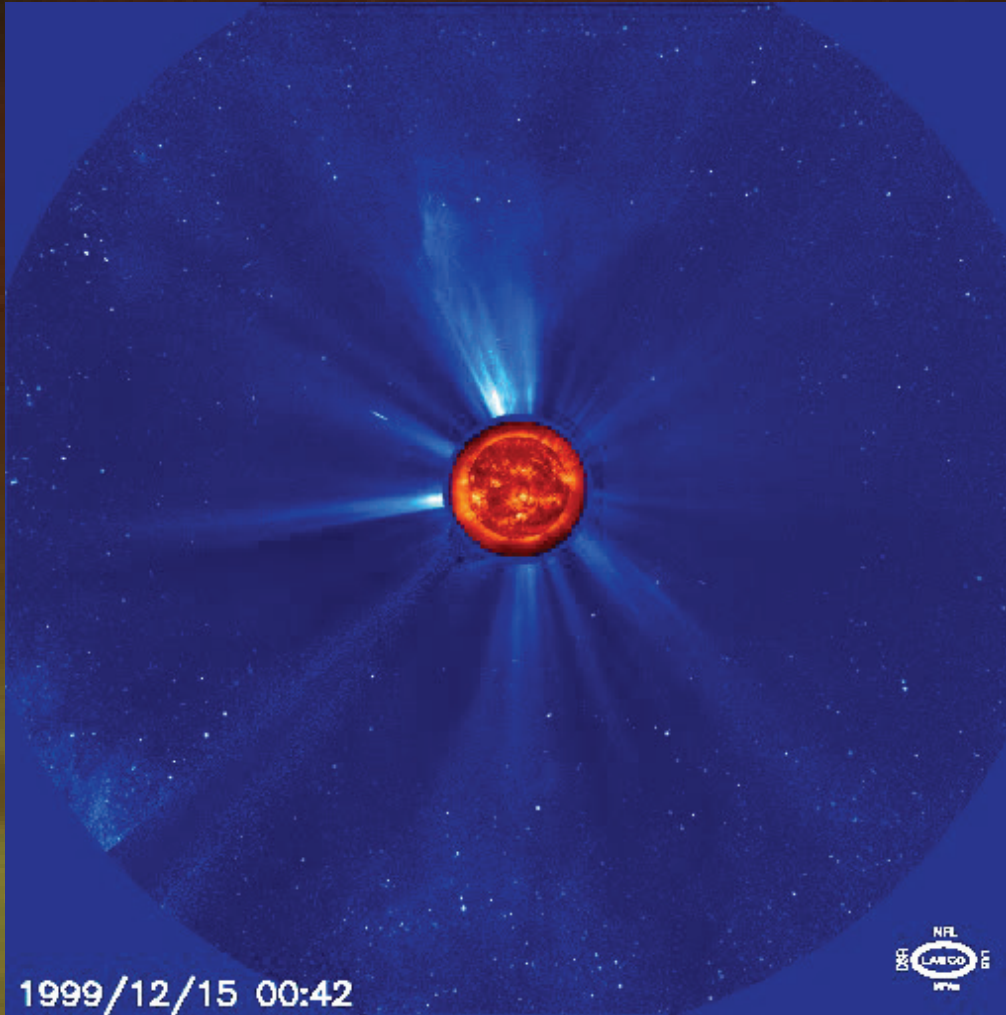


PJM Public Service Step Up Transformer

Severe internal damage caused by the space storm of 13 March, 1989



# What makes the interplanetary $B_z$ turn southward?



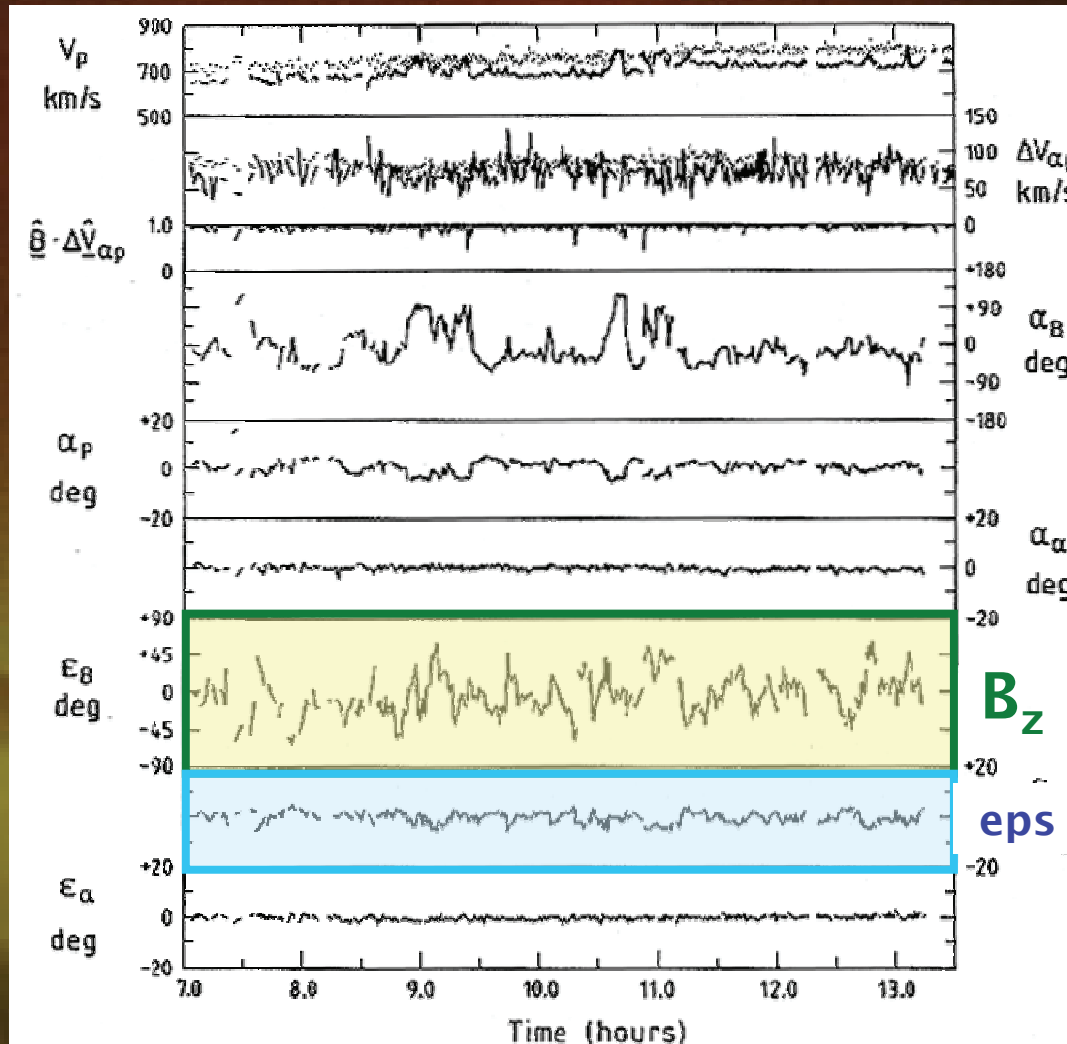
1) Fluctuations (Alfvénic) in high speed streams from the **quiet Sun**

2) Deflections in front of and inside ejecta from transient events on the **active Sun**



# What makes the interplanetary $B_z$ turn southward?

## 1. Alfvén waves in high speed streams



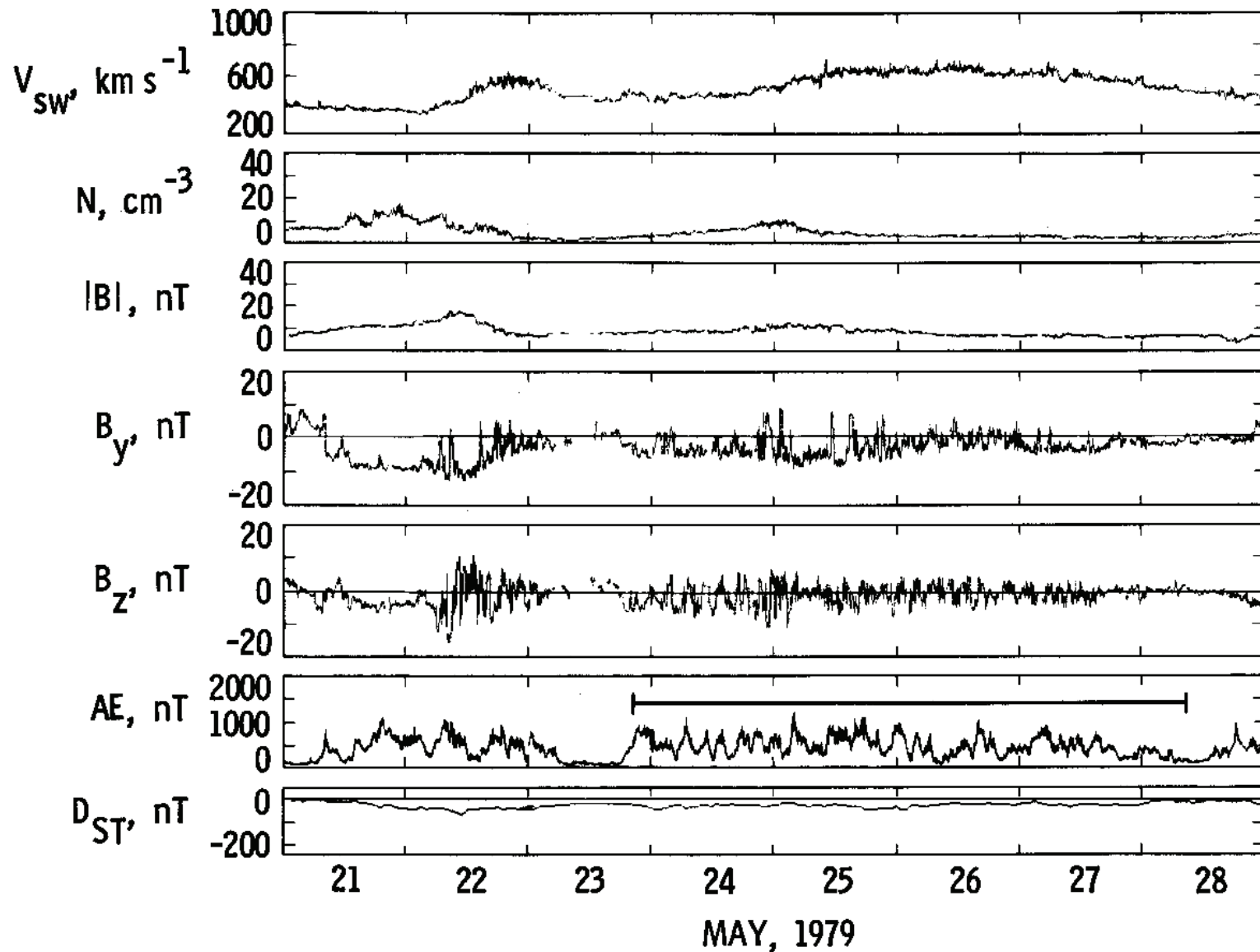
Alfvén waves occur only in high speed streams from coronal holes, i.e., the quiet Sun.

Alfvén waves cause substantial deflections in both: flow direction and magnetic field.

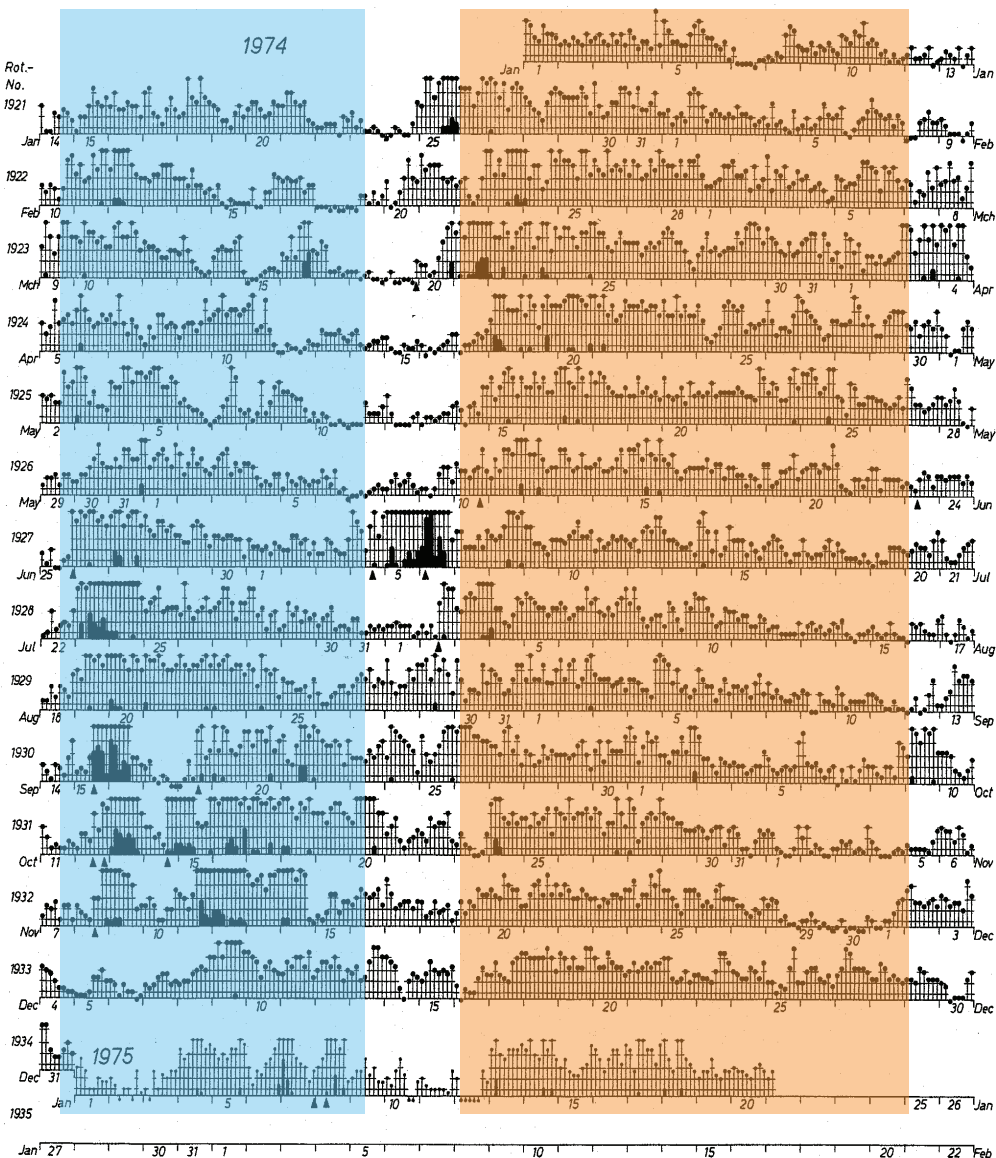
That is the origin of north-south field excursions in high speed wind streams that cause moderate geomagnetic effects:

**“M-regions”**

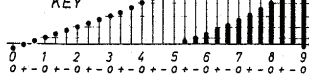
# High speed streams: M-regions!







KEY



▲ = sudden commencement

PLANETARY MAGNETIC  
THREE - HOUR - RANGE INDICES

Kp 1974

(preliminary indices to 1975 January 21)

# High speed streams: M-regions!

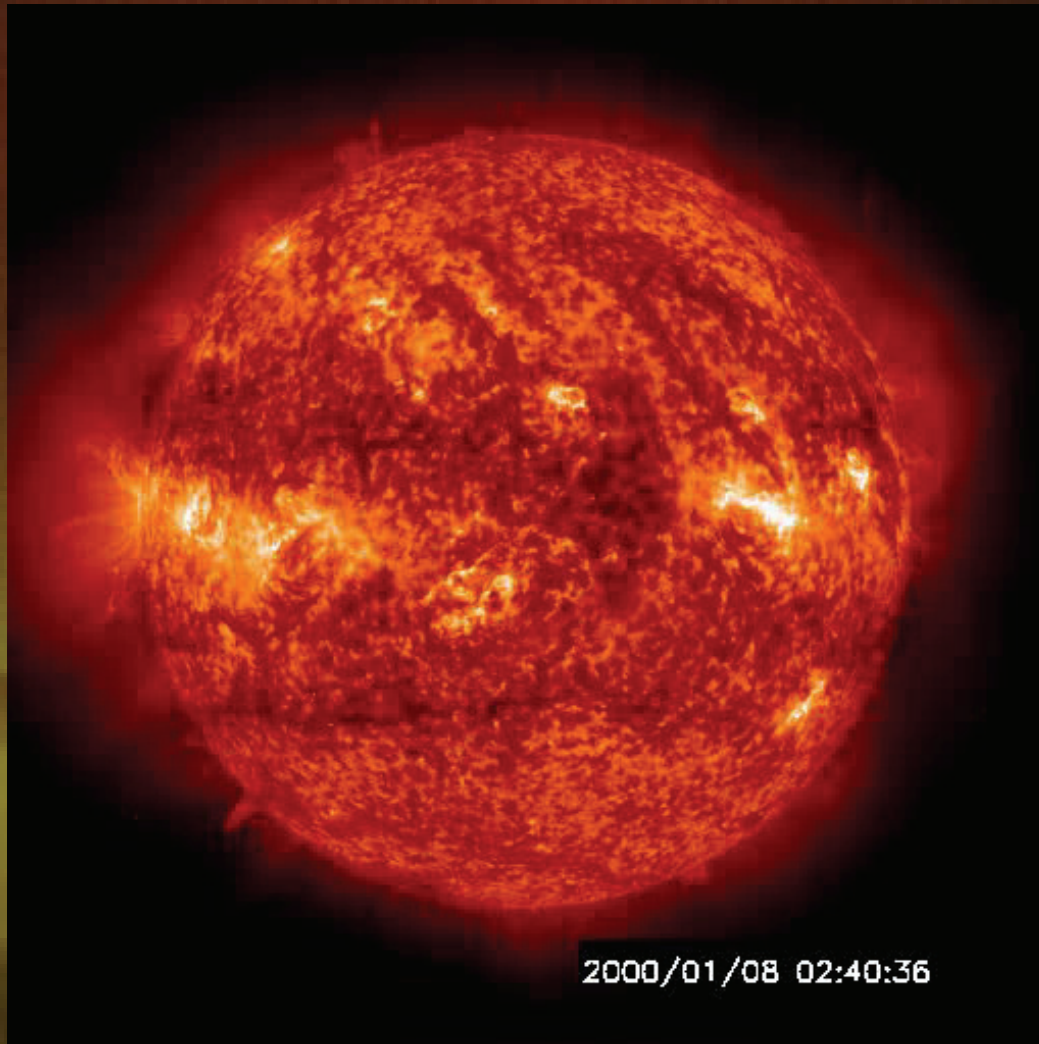
M-regions often persist for many solar rotations, in particular at low solar activity. So do high speed streams from coronal holes (i.e. the „inactive“ Sun).

These effects on space weather are fairly well predictable, using particle&field observations at L1

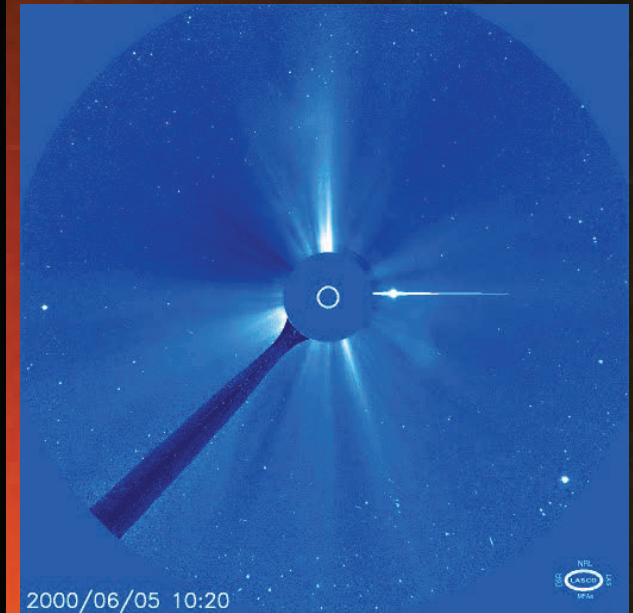
The “musical diagram” of geomagnetic activity, according to the scheme introduced by Bartels (1930)

# How to obtain $B_z$ south?

## 2. Here comes the active Sun!

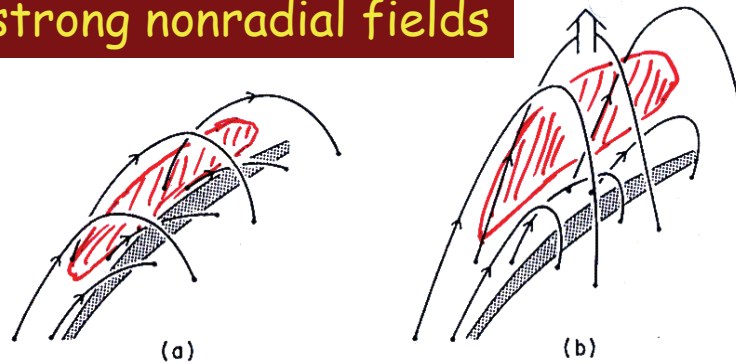


Flares/CMEs,  
interplanetary shocks,  
turbulence, SEPs...



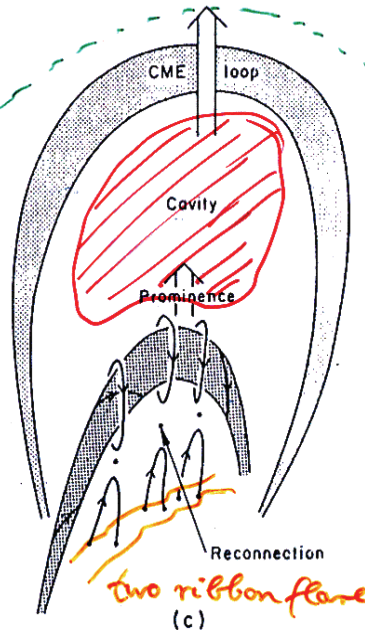
# Why does $B_z$ turn south following CMEs?

It is generally accepted that CMEs involve fluxrope structures with strong nonradial fields



Three-part structure:

1. CME loop (coronal plasma)
2. Prominence cavity
3. Cold prominence mat.



Note:  
Filament orientation  
allows prediction of  
cloud orientation at  
earth's orbit!

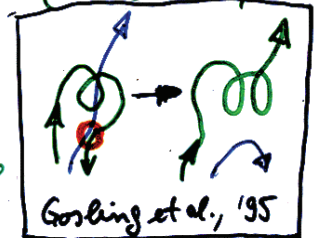
Shock front

alternative:

flux rope model  
(Mandrashki, '86)

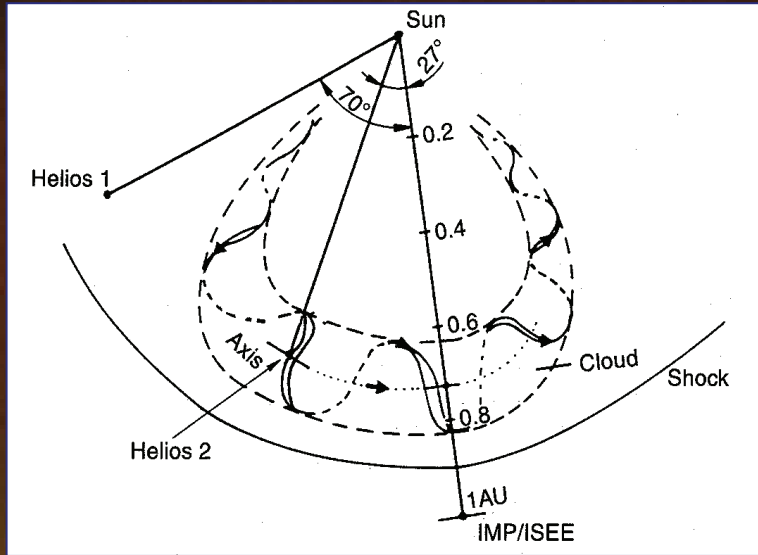


Priest '88





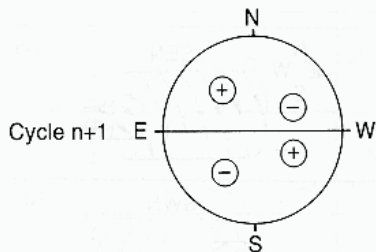
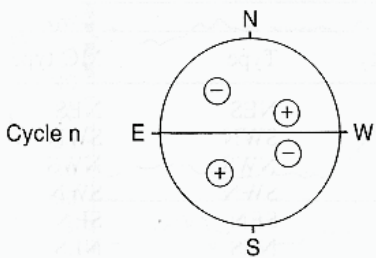
# Ejected plasma clouds in space



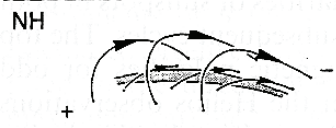
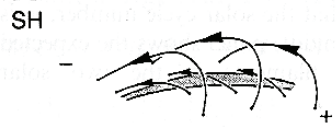
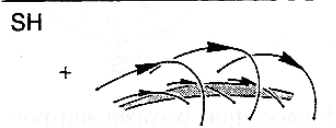
When a flux rope passes an observer, he may encounter  $B_z$  south fields at times!

Also possible at times

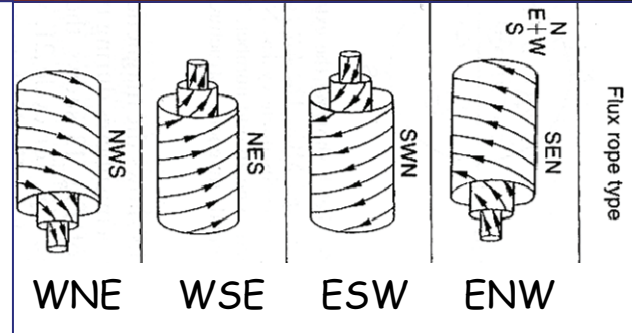
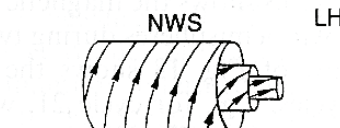
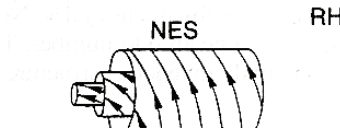
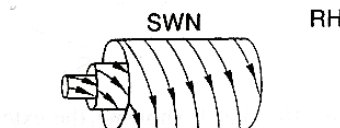
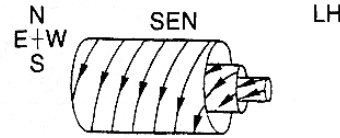
Magnetic polarity of sunspots



Polarity and orientation of the filament

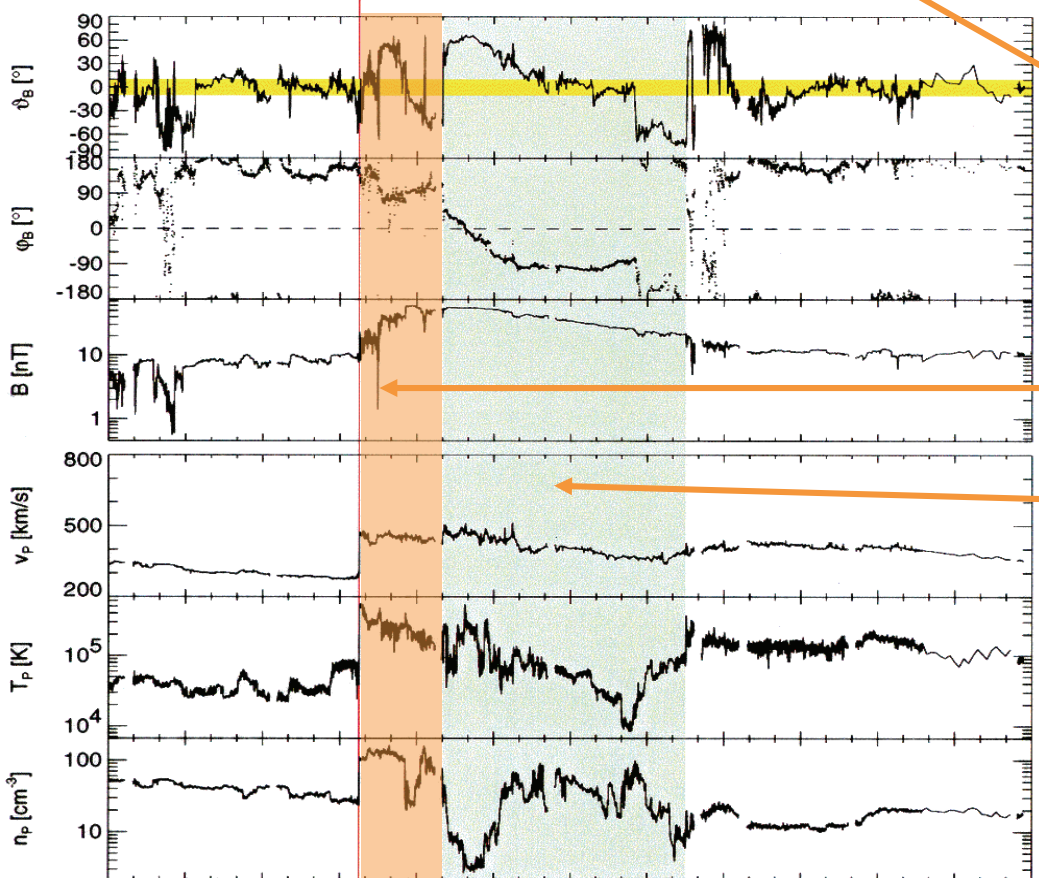
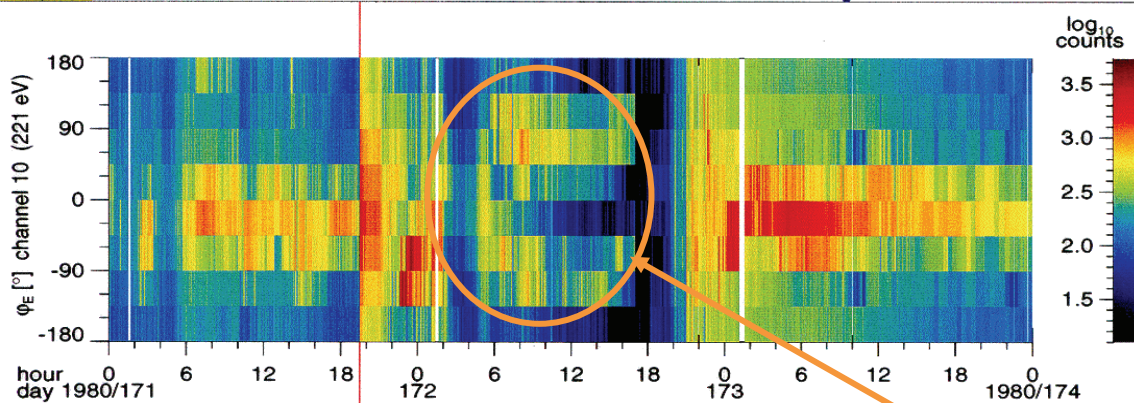


Flux rope type



Note: No S in WNE and ENW clouds!



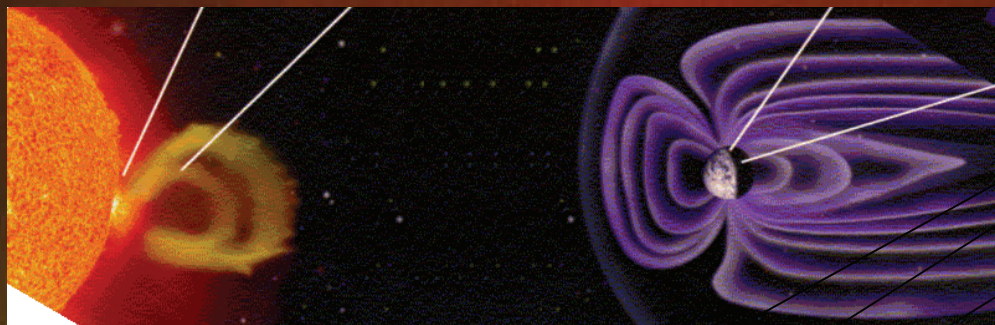


Fast ICMEs may involve magnetic clouds with major  $B_z$  south components.

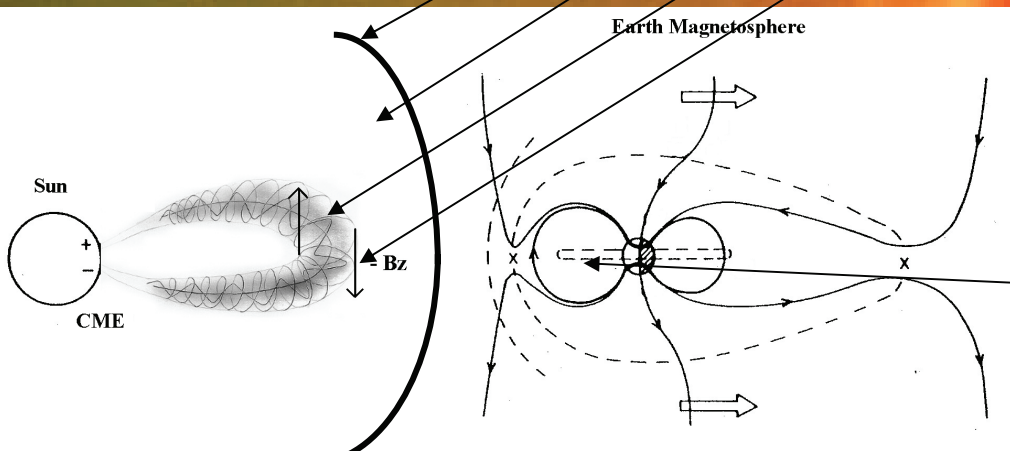
This cloud contains "bidirectional electrons", evidence for magnetic cut-off

- Typical CME products in the interplanetary medium:
- shocked "sheath" plasma (compressed and heated),
  - and sometimes "driver gas", including magnetic clouds,

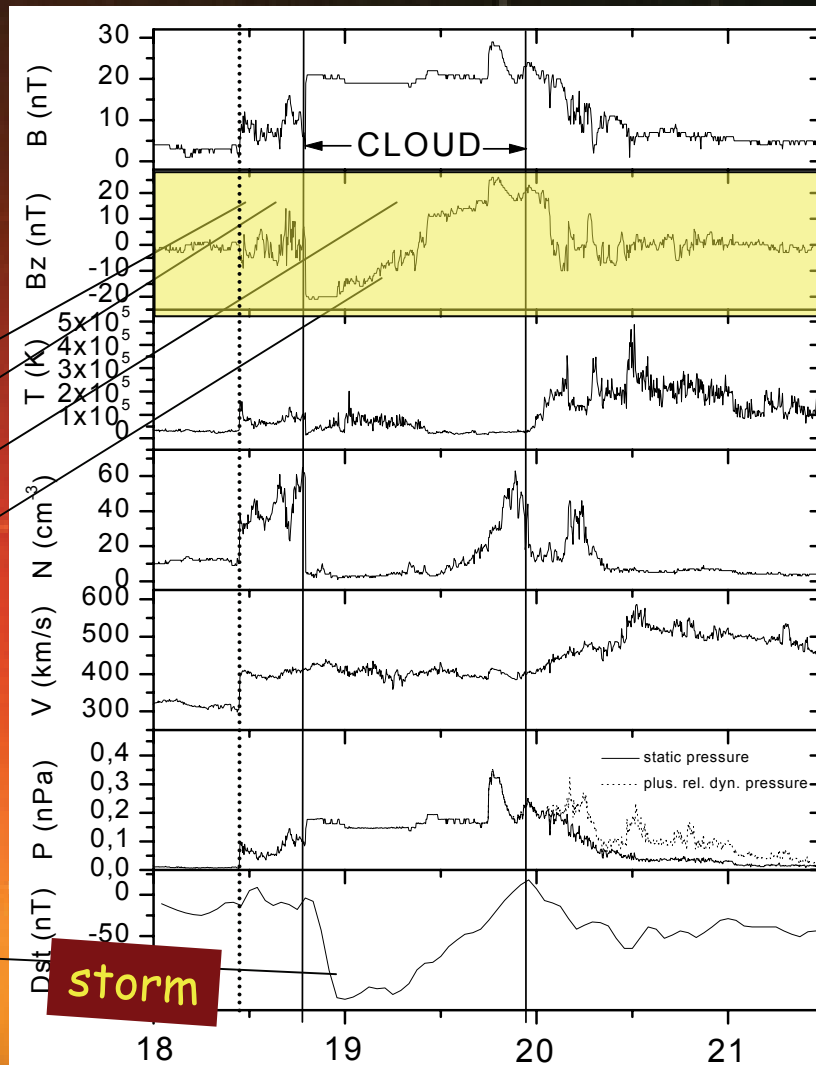
# What happens at Earth when ICMEs arrive?

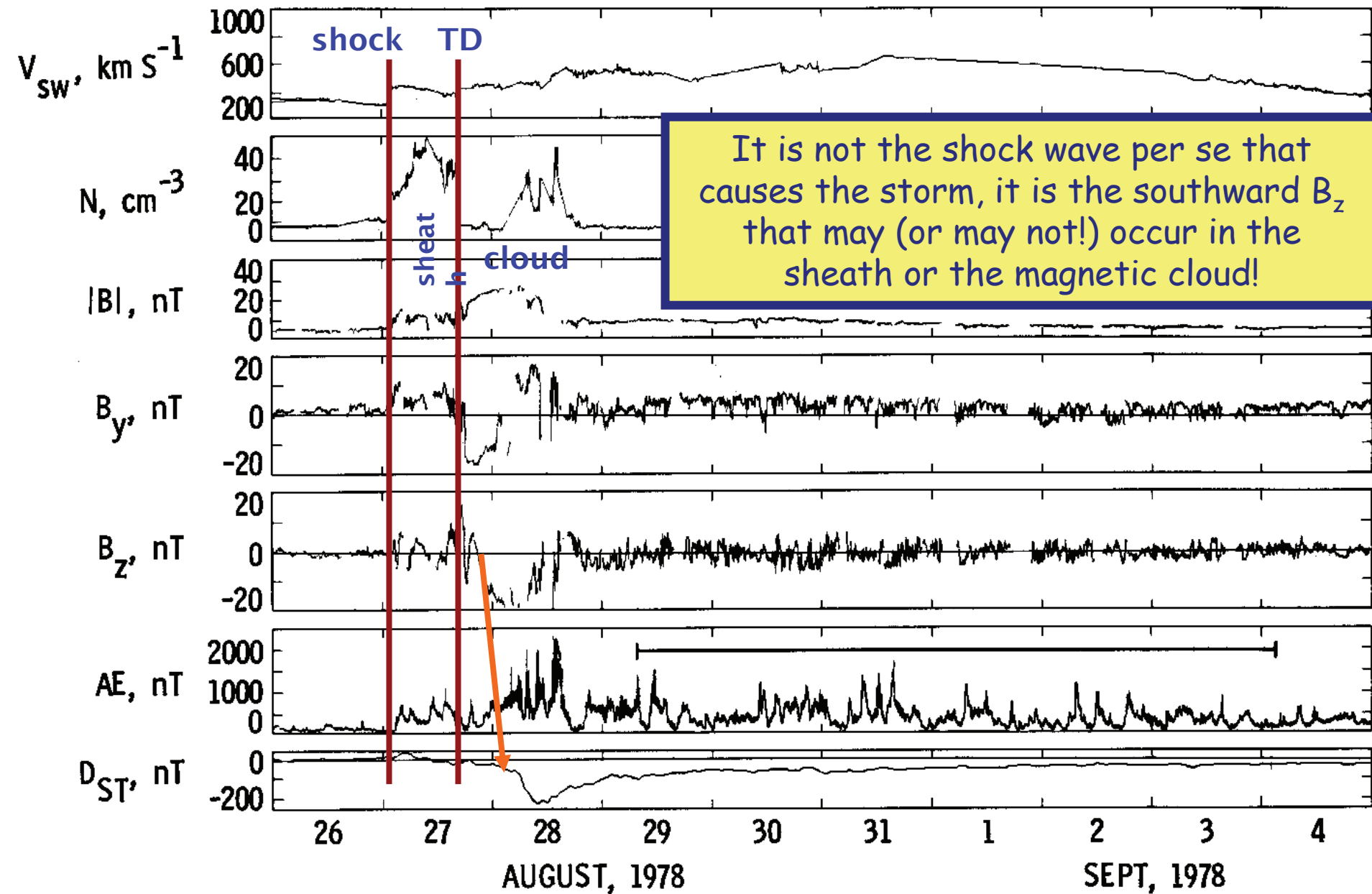


shock sheath cloud  $B_z$  south



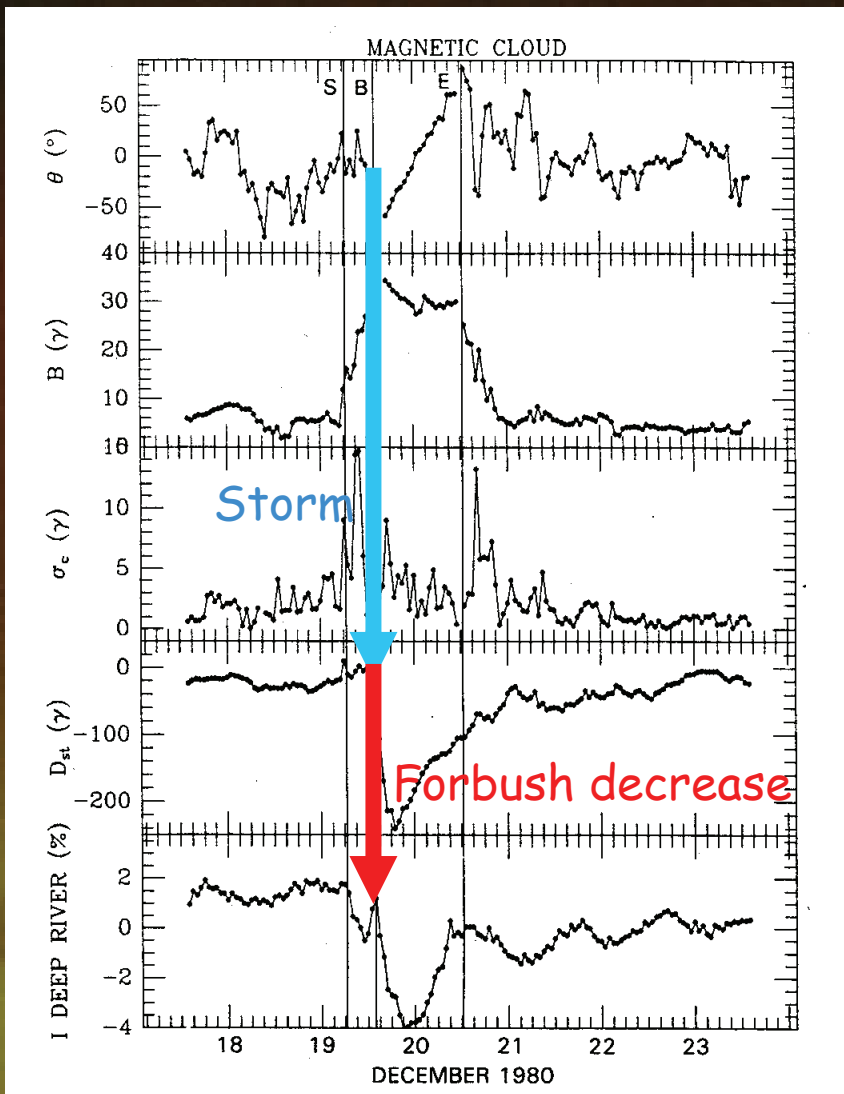
Shock



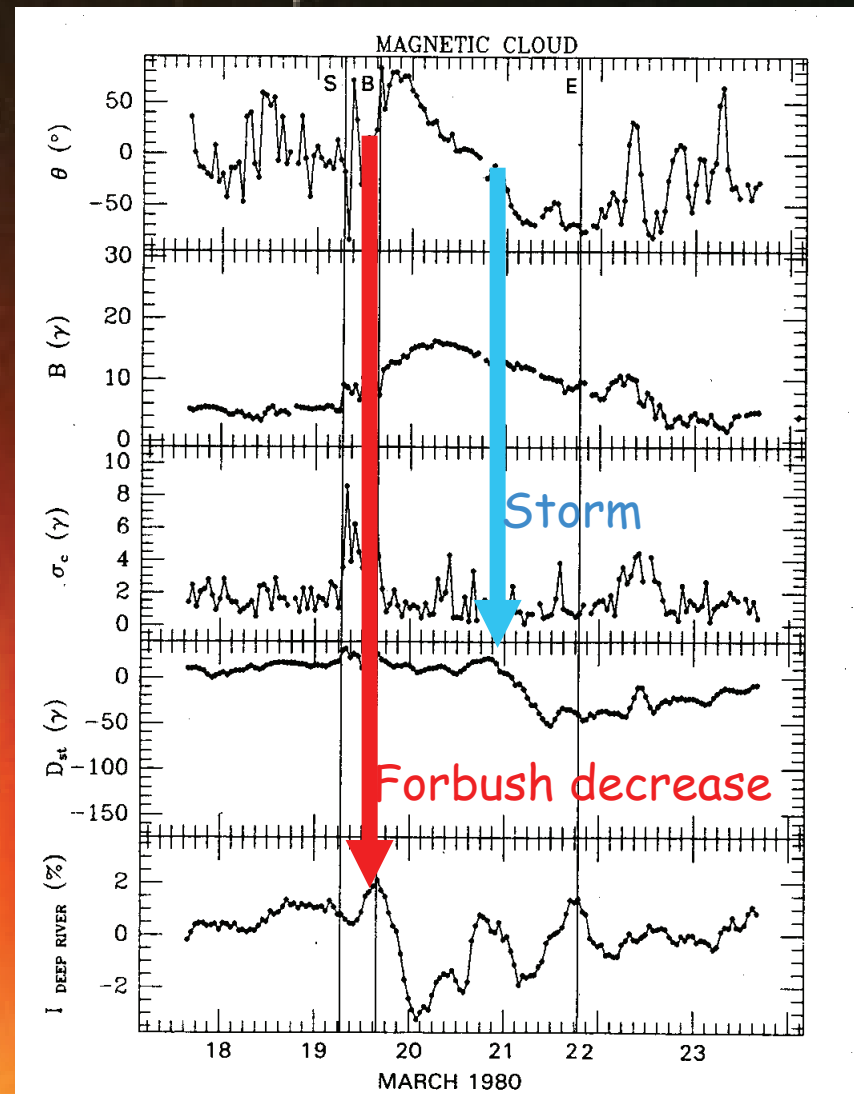


Relation of a strong geomagnetic storm with the arrival of a magnetic cloud





A SEN cloud at 1 AU



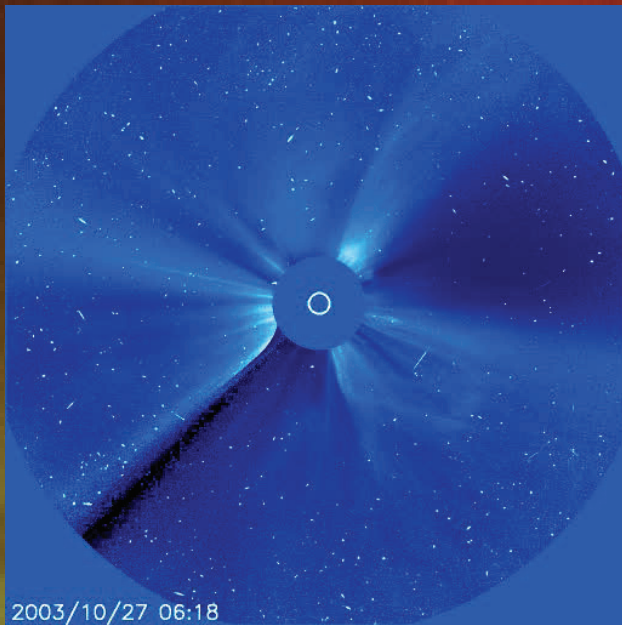
A NES cloud at 1 AU

Note how different the geomagnetic response is, despite the similarity of both: the cloud pattern and the Forbush decrease!

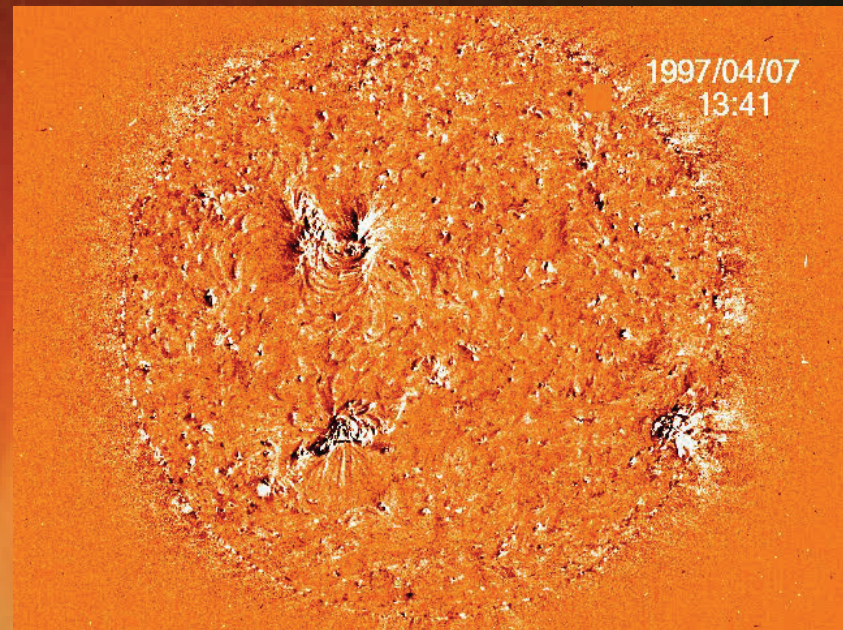


# What progress have we made in understanding space weather and predicting it?

Halo CMEs: a new quality from SOHO  
We can now watch earthward pointed CMEs early on!



A classical "halo" CME,  
observed by LASCO-C3  
on 29.10.2003

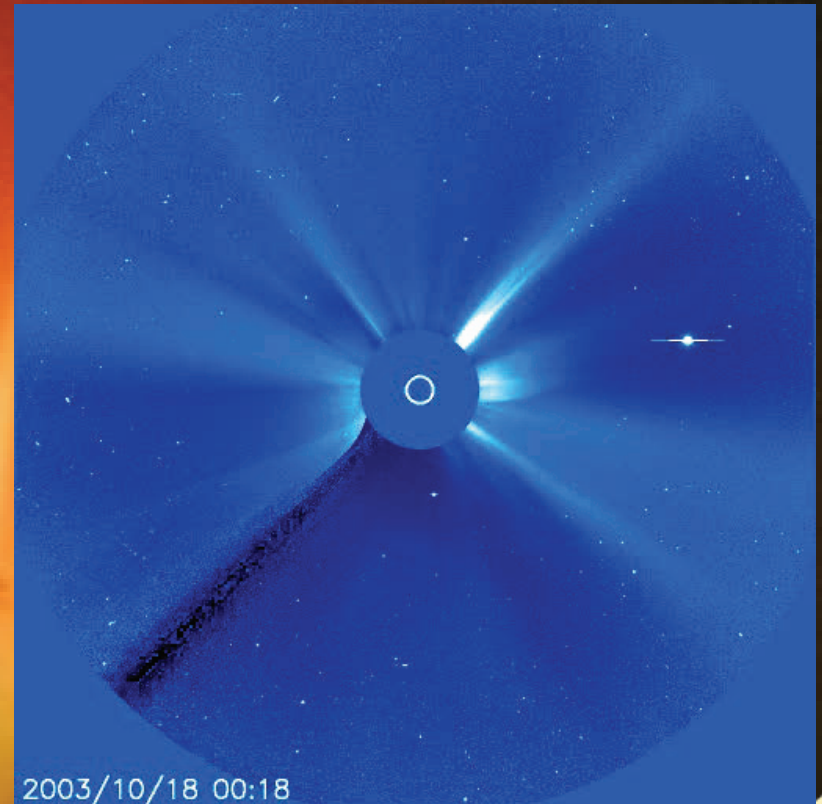
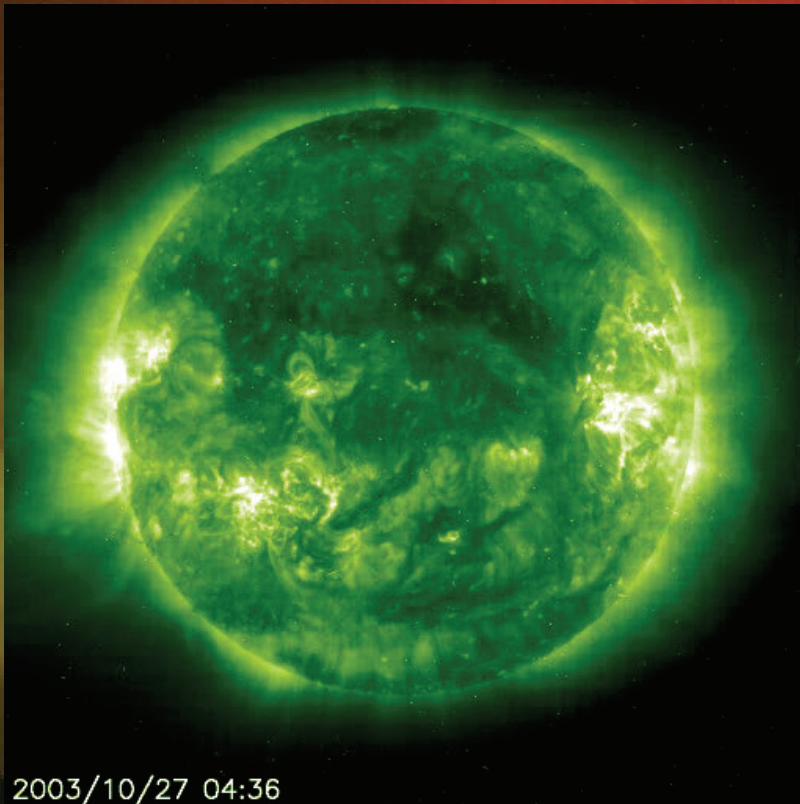


A pressure wave (EIT wave) in the  
solar atmosphere, pushed by a flare on  
7.4.1997,  
Evidence for front side CME!

Towards or away from Earth? That knowledge alone grants  
space weather predictions a new quality!

# Why are space weather predictions still that uncertain?

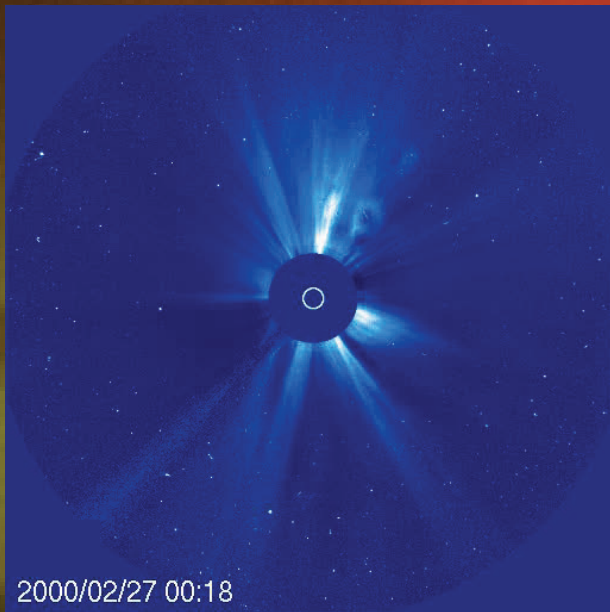
1. We cannot predict eruptions before they occur!!!
2. We cannot measure the propagation speed of halo CMEs towards Earth!
3. We do not yet have a unique handle on what determines geo-efficiency.





# Why are space weather predictions still that uncertain?

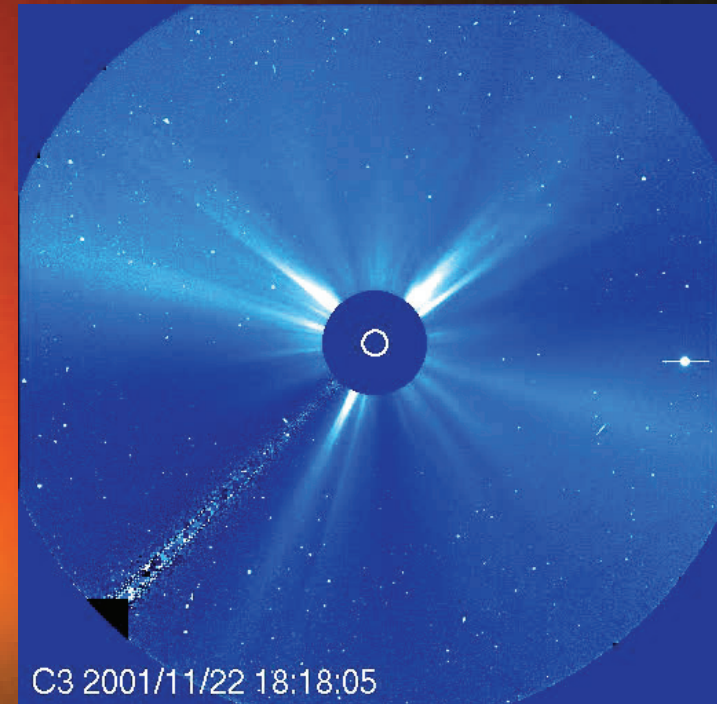
1. We cannot predict eruptions before they occur!!!
2. We cannot measure the propagation speed of halo CMEs towards Earth. We have to infer it from other information.



A limb CME: front speed and expansion speed can both be measured



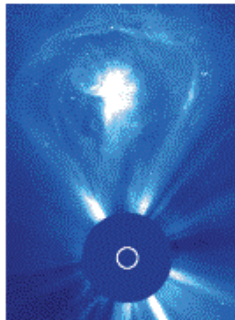
A halo CME: only the expansion speed can be measured



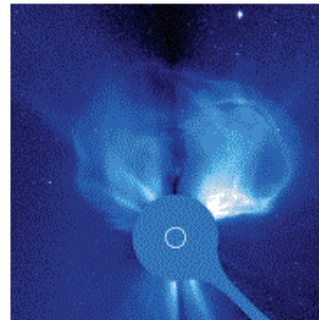
# Why are space weather predictions still that uncertain?

2. We cannot measure the propagation speed of halo CMEs towards Earth. We have to infer it from other information.

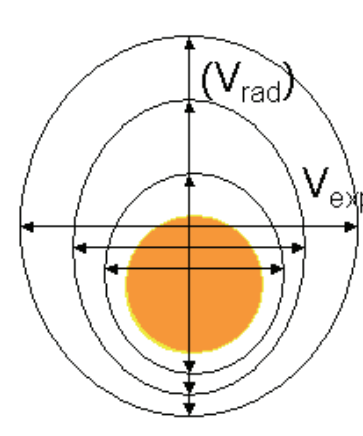
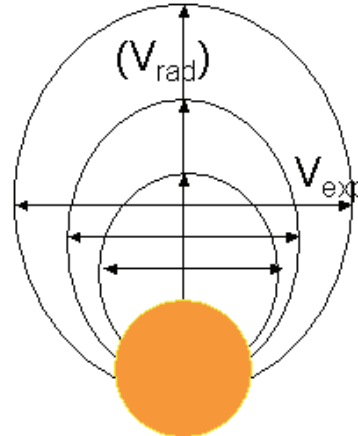
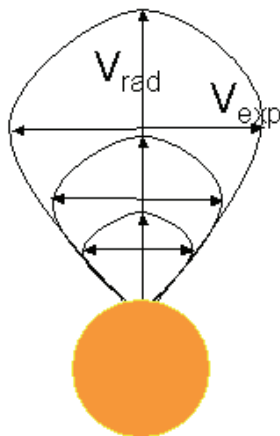
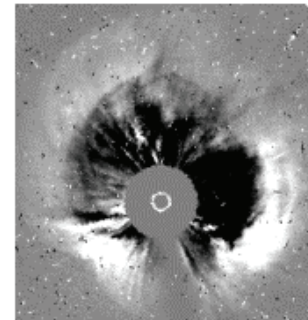
Limb CME



partial halo CME  
angular span  $>120^\circ$



full halo CME  
 $360^\circ$

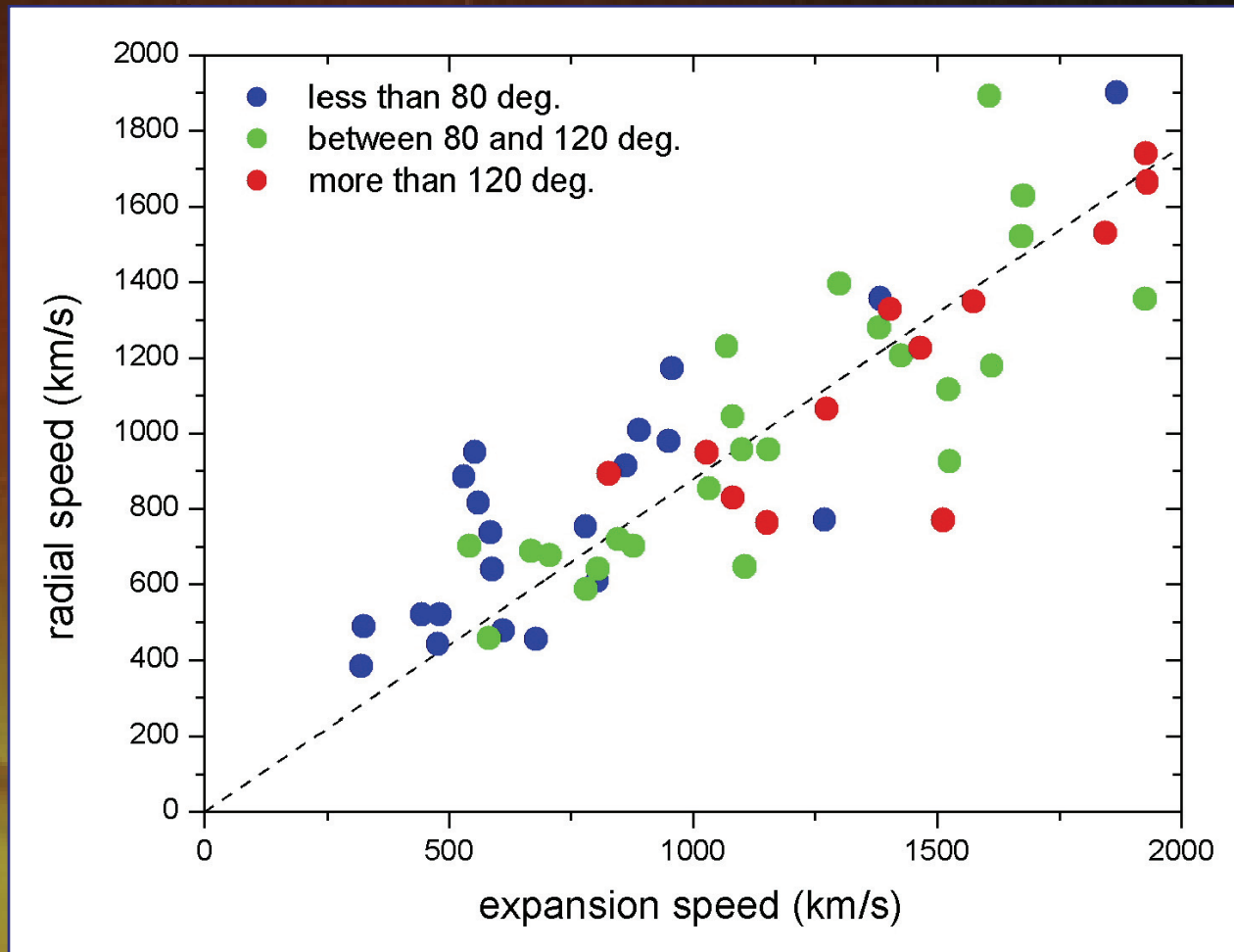


As a unique proxy, we take the „expansion speed“  $V_{exp}$  and derive an empirical relation.

The apparent „plane of the sky speed“  $V_{rad}$  depends on the ejection direction.

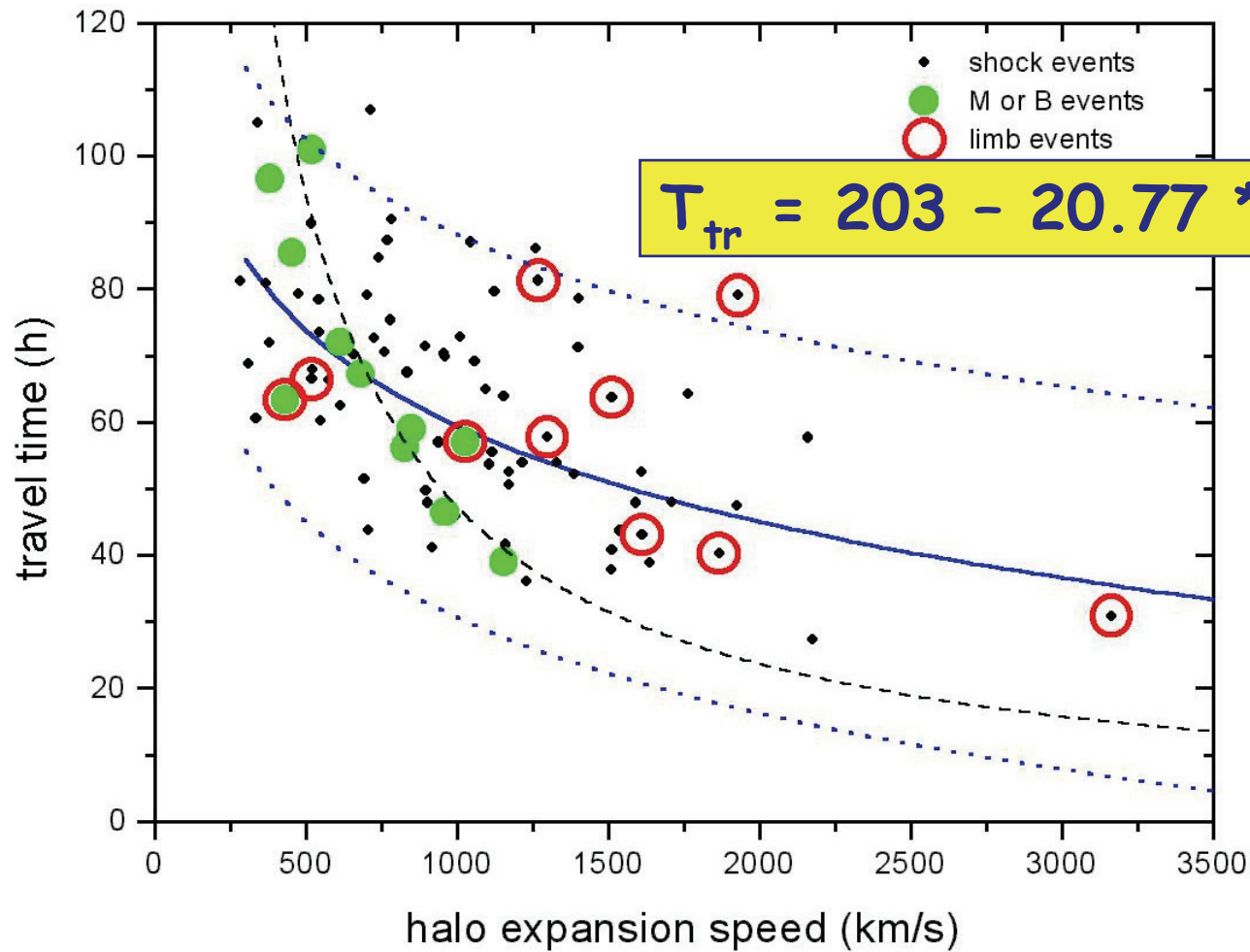


# Radial and expansion speeds for limb CMEs



The correlation between radial CME speed  $V_{rad}$  and the expansion speed  $V_{exp}$  for limb CMEs observed by LASCO between 1996 and 2001.

# Correlation of CME expansion speed with travel time



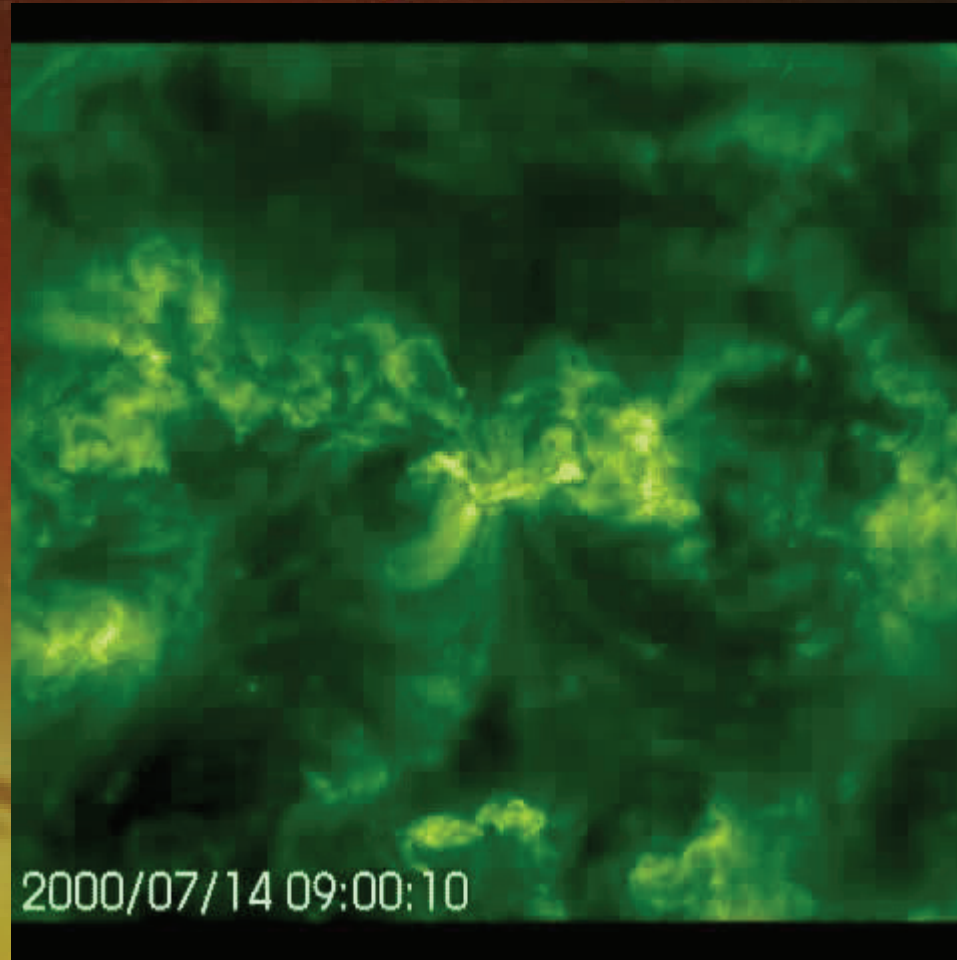
For 75 halo CMEs, the expansion speed and the travel times to 1 AU were determined.

An empirical function was derived: an improved prediction tool!

# Recent studies of CME/ICME correlations show:

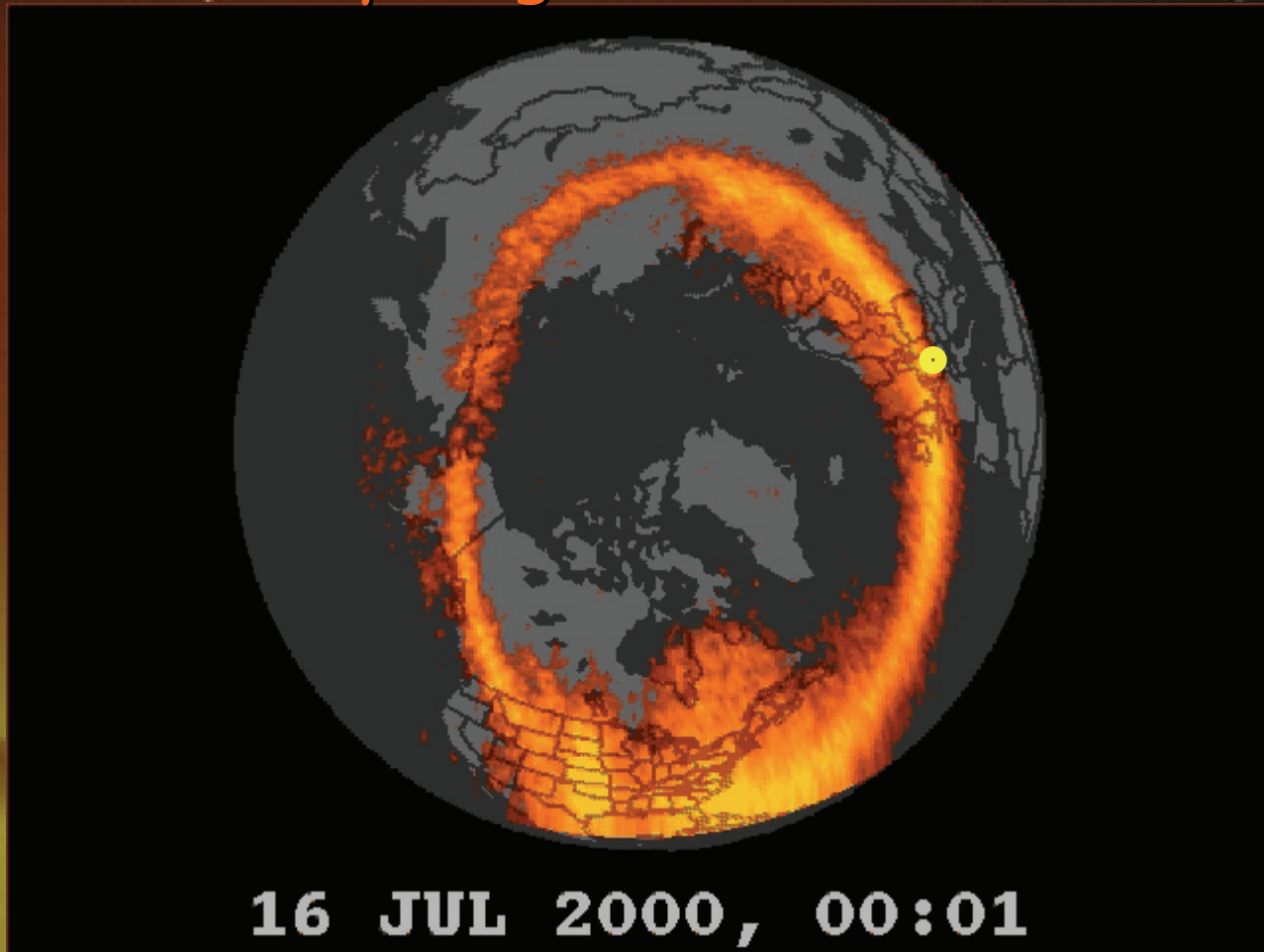
- In 85% of all full or partial front side halo CMEs an ICME effect at the Earth can be expected (based on 163 cases).
- The remaining 15 % missed the Earth: potential **false alarms!** That applies also to 7.7 % of the most relevant front side full halo CMEs!
- Among the safely associated CME/ICME cases, 8.6 % are due to NON-halos. Predictors focused on halos would have ignored them: **Missing alarms!** In total, the number of unpredicted shock/storm events amounts to 25 %!
- All very intense storms ( $D_{st} < -200$  nT) were related to halo CMEs.

# The famous „Bastille-Day“-event on July 14, 2000



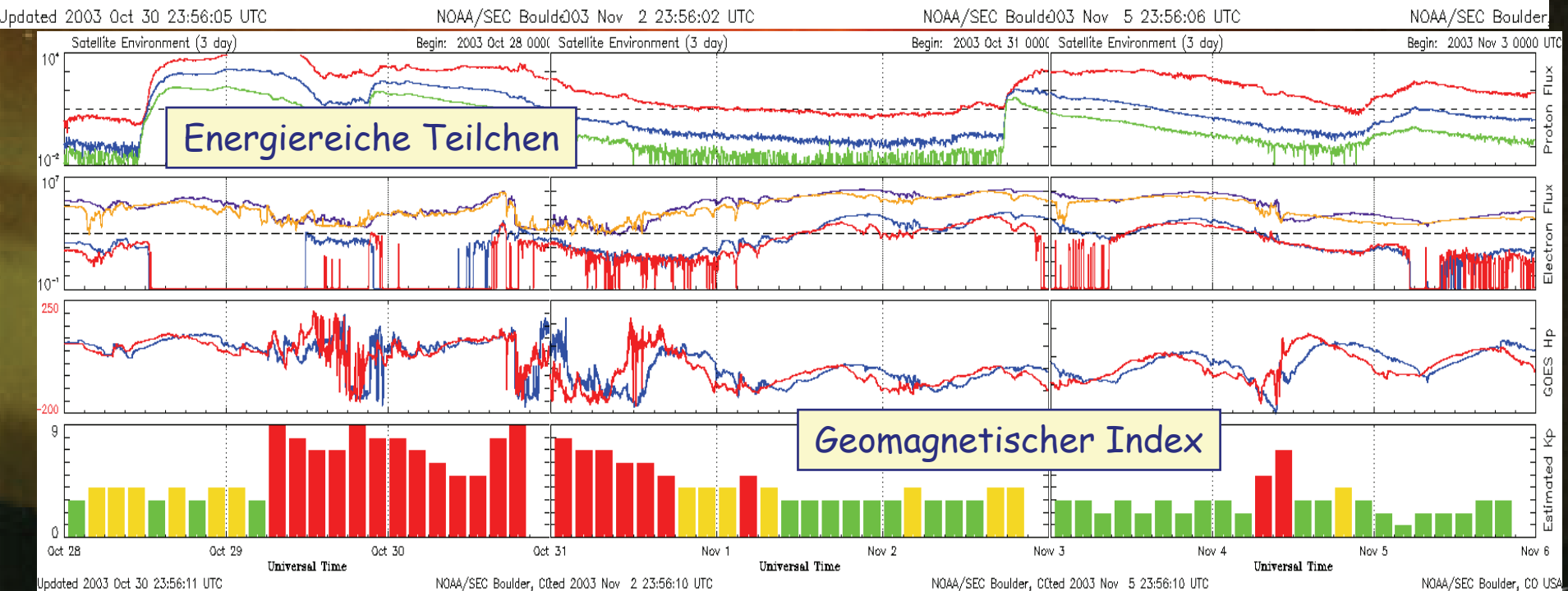
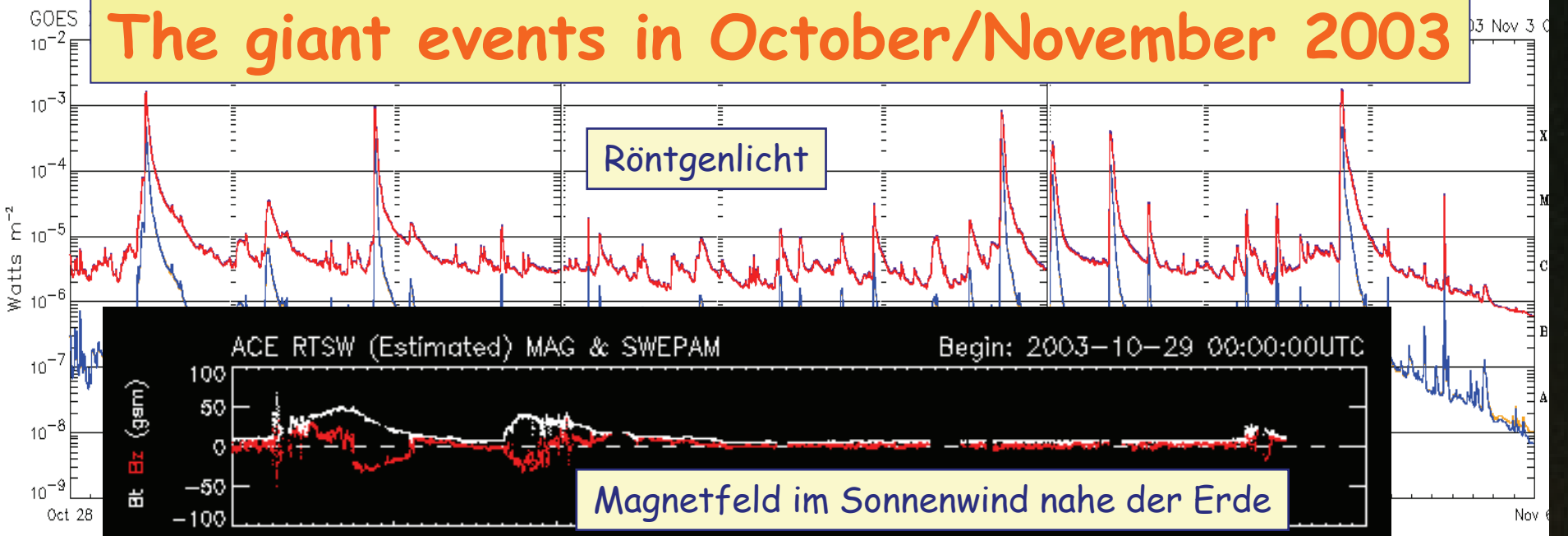


# The famous „Bastille-Day“-event on July 14, 2000 Extremely bright extended Aurora

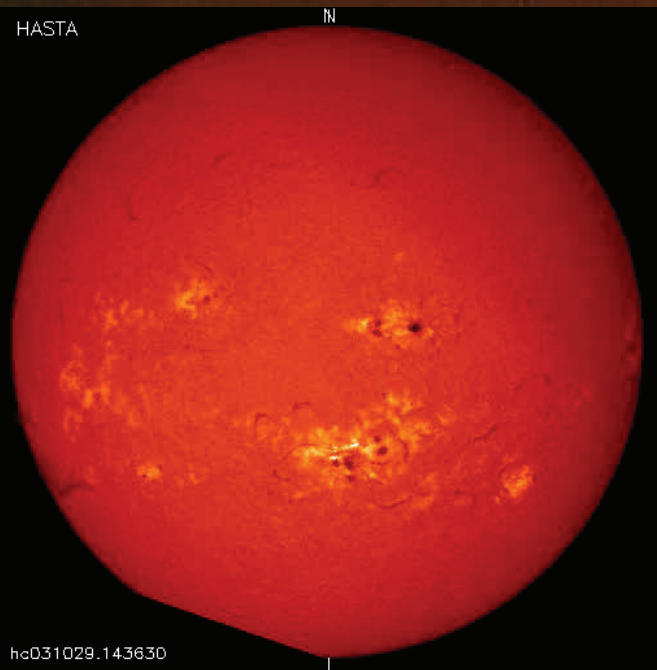


That was the auroral oval on July 16, 2000:  
aurorae all over the USA and even middle Europe!

# The giant events in October/November 2003

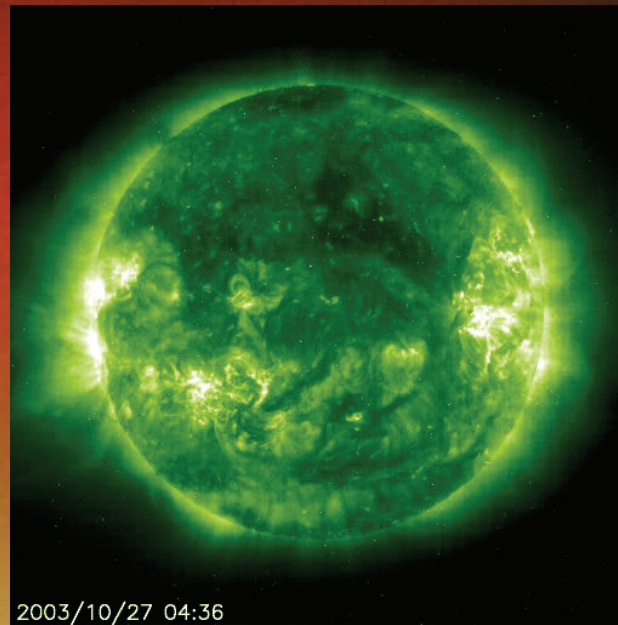


# The super events on October 28/29, 2003

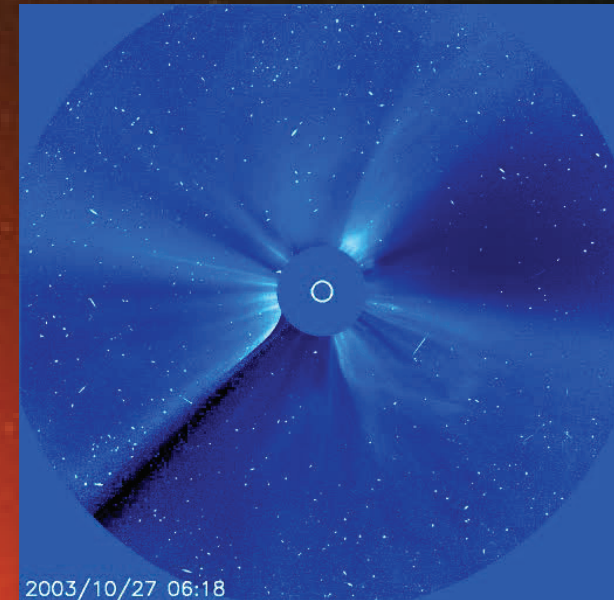


HASTA in El Leoncito

A X 17,2 flare on 28.10.2003,  
A X 10,0 flare on 29.10.2003



EIT on SOHO



LASCO-C3 on SOHO

The „snowstorm“ is due to high-energy particles accelerated during the flare process. They can penetrate spacecraft and instrument skins!



# The super events on October 28/29, 2003

## Juhnke-Sohn spricht

# Ich habe mich für Vater geschämt

Oliver Juhnke (51) Harald Juhnke (74)

Über sein Leben als Juhnke-Sohn. Wie er als Kind unter den Alkoholexzessen gelitten hat, wie er sich schämte, wie sehr er seinem Vater. Harald Juhnke trotz allem vermisst. Seite 6.

Man kann ja über alles reden. Das ganze Wochenende für **0 Cent!**

Die neue DVD-Reihe "Hörst du mich?" kommt jetzt samstags, sonntags und an allen gesetzlichen Feiertagen für 0 Cent! Telefonieren! Anmelden unter: www.com.de oder 0800 33 03333

Einblick magisch. T + Com

Donnerstag, 25344  
30. Oktober 2003, 0,50 €

# BILD

UNABHÄNGIG · ÜBERPARTeilICH

www.bild.de

## Papa Franz soo stolz

Er hat gerade Joel sein Schwwestertochter gezeig!

Franz Beckenbauer (59) kommt mit seinem Sohn Joel (13) aus der Schweiz. Die Fot der kleine sein Schwwestertochter Francesco das erste Mal gesehen über Kaiser über seine weitere Familieneplanung. Seite 18

**SUPER-BINGO**  
Gewinnen?  
Die Spielregeln und Gewinnere - Seite 15

5. 103 300 200 61906727  
404 413 488 522 **Glücklose** Zahl!

## Flammensturm im All

# Explodiert die Sonne?

Noch nie geschaut, gigantische Eruptionen auf der Sonne! Entsetzt fotografieren Forscher durch grünlich abgedunkeltes Teleskope ungeheure Feuerstöße - die hellen Flecken, Mitte, links und rechts. Wie Raketen jagen Magnetimpulse durchs All zur Erde. Was passiert mit uns? Kann das ganze Gestirn explodieren? Seite 8

## Betonfertiggaragen bis zu 60% günstiger als gemauerte!

Chevere Bauherren sparen an den Kosten - nicht an der Qualität. Beispiel Garage: Bis zu 60 Prozent günstiger sind Betonfertiggaragen im Vergleich zu gemauerten. Das zeigt die Studienforschungschaft für Fertighäuser e.V. In einem aktuellen Preis-Leistungsvergleich. Mehr Infos unter:

www.betonfertiggaragen.de

## Hat er Kalifornien angezündet?

Los Angeles - 18 Tote, über 75 000 Menschen auf der Flucht, die unberechenbaren Notwendigkeiten sind die schlimmsten in der Geschichte. Kalifornien! Mit seinem Phänomen (Foto oben) und 50 000 Dollar Kogelgeld fahenden die Behörden nun nach dem etwa 20-jährigen Weißen, der die Brande gelegt hat.

Das Feuer hat dieses Rob abgebrannt

## Kein Platz mehr auf Friedhöfen

Hamburg - Es ist eine unheimliche Nachricht: Auf den deutschen Friedhöfen wird es eng. Rund 40 Prozent der Begrabenen haben keinen Platzgraben. Der Grund: Durch zunehmende Leichendurchlässigkeit der Boden sowie Wassereintritt in die Grabstörche der Deutschen werden laut Forso die Spaltdemonkraten wählen, wenn am Sonntag Bundestage.

## Wieder Erhöhung der TV-Gebühren?

Mainz - Die Intendanten von ARD und ZDF fordern eine Erhöhung von 1,80 Euro mehr pro Monat (17,50 statt 16,50 Euro). Die zuständige Rundfunkkommission schlägt eine Anhebung von 1,05 Euro vor. Edmund Stoiber (CSU) plädiert für eine Nullrunde.

## Nina und die Rücken-Gymnastik

Nina ist 'ne ganz fleißige. Den ganzen Tag sitzt die Sprech-Studieninft artig am Schreibtisch und lernt. Abends tut ihr immer der Rücken ganz doll weh. Aber jetzt geht's schon viel besser, weil sie beim Arzt

war. Der hatte einen ganz privaten Tipp: Öfter mal auf allen Vieren. Das wirkt ja soo entspannend...

## Umfrage Merkel holt Schröder bei Beliebtheit ein

Hamburg - Historischer Tiefpunkt für die SPD: Nur noch 24 % der Deutschen würden laut Forso die Sozialdemokraten wählen, wenn am Sonntag Bundestage. Wohl wäre ein Tied bei CDU/Christen Merkel ist jetzt genauso beliebt wie Konrad Schröder (SPD). Jeweils 36 % der Deutschen würden sie wählen.

## NACHRICHTEN

Leserbriefe Seite 6

**Jet stürzte ab**  
Köselheim - Ein zwei-jähriger Kolibri-Jet stürzte bei Kitzingen ab und bohrte sich in einen Acker. Pilot und Copilot erlitten sich mit dem Fallschirm.

**SARS durch Katzen**  
London - Die gefährliche Lungenerkrankung SARS (Säckerkrankheit) kann sich bei Hauskatzen und Freilebenden einschleichen und von diesen Tieren auf weitergegeben werden. Das fanden niederländische Wissenschaftler heraus.

**Rakent bei Air Berlin**  
Berlin - Passagier Rekord bei Air Berlin. Die Fluglinie bebrachte in diesem Jahr bereits über 8 Mio. Passagiere. Bis Ende des Jahres soll die Zahl auf 9,5 Mio. steigen.

**CD von Berlusconi**  
Rom - Italijos Präsident Silvio Berlusconi (67) bringt eine CD mit selbstgeschriebenen Liedern heraus. Sie werden von seinem Lieblingspaar Maria-Apicella gesungen.

**Börse**  
Frankfurt - Dax (18 Uhr) 5411

**21.15 Uhr, ZDF**

## Die kalte Jahreszeit

GIBT'S HAFTUNG INKLUSIVE.

- We watched them in detail and made predictions.
- They were absorbed and announced by the media (e.g. TV news)
- They were pretty correct!
- But weather in most parts of Europe was too bad for aurora sighting.

## Halsschmerzen?

Tipp: Lutschen, lutschen, lutschen!





# The super events on October 28/29, 2003

Aurorae all over Europe!



Kroschenbroich



Dortmund



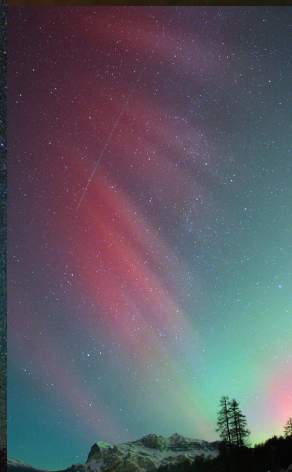
Linz



Bopfingen



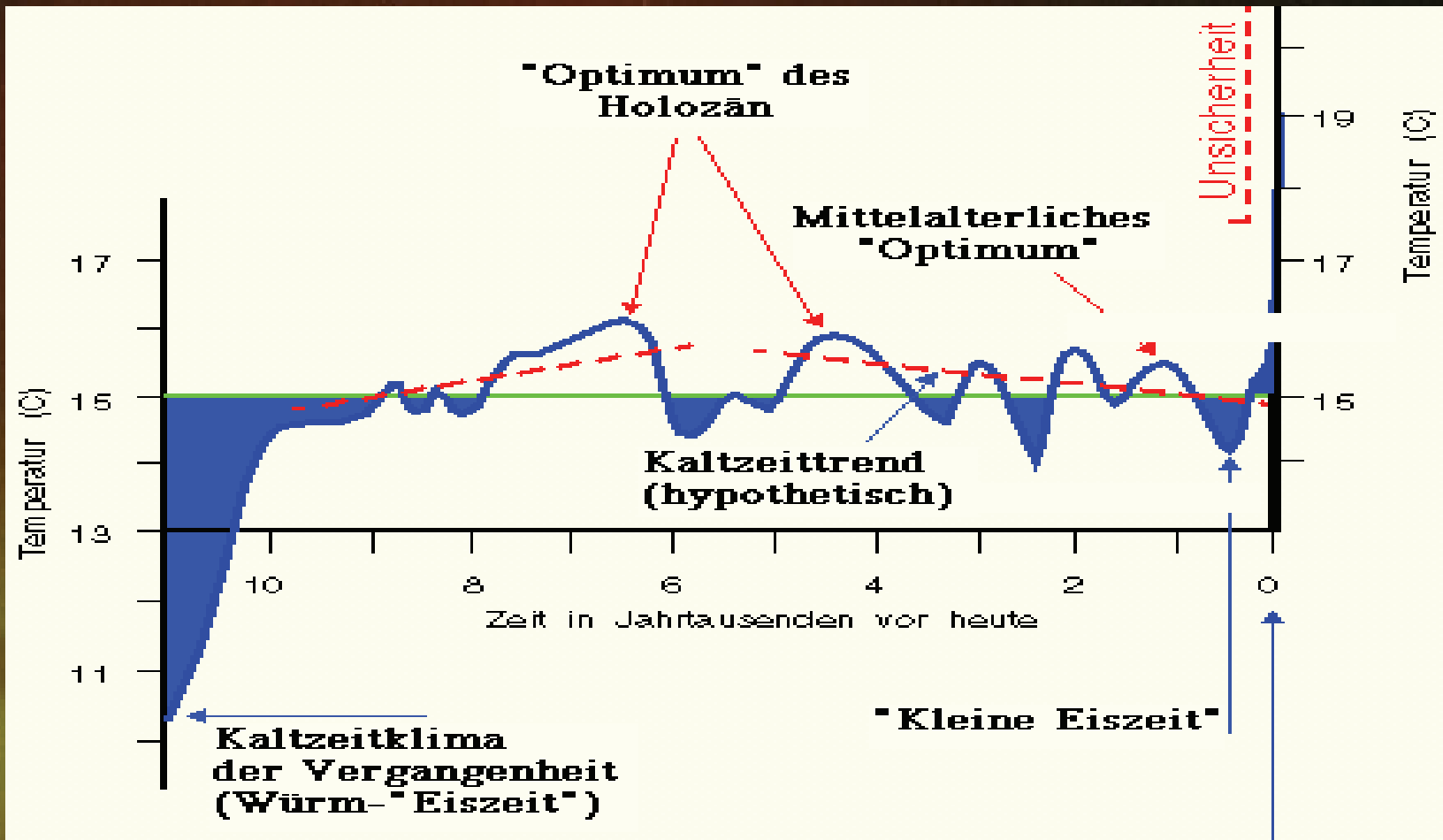
Dolomiten



Cortina



# Impact of space weather on Earth's weather and climate?



Major climatic fluctuations occurred long before the man-made greenhouse effect became significant

# Future activities for understanding space weather

- \* Fundamental research for understanding basic mechanism of CME release,
- \* High time resolution optical observations of CME onset and propagation, simultaneously from different view points (stereo view),
- \* On-line computer model of the heliosphere, continuously updated, that allows to simulate CME ejections and propagation in realistic and near-real-time way.

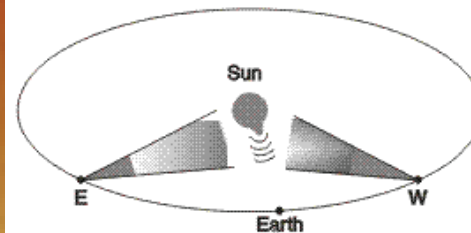
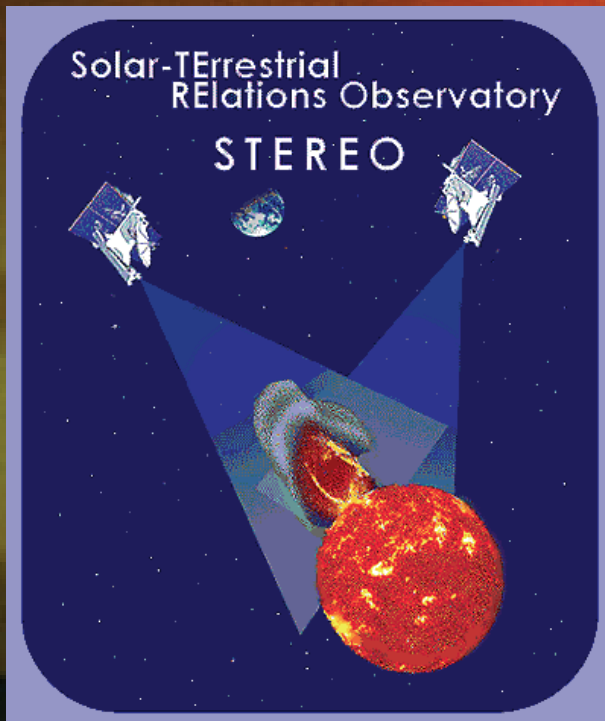
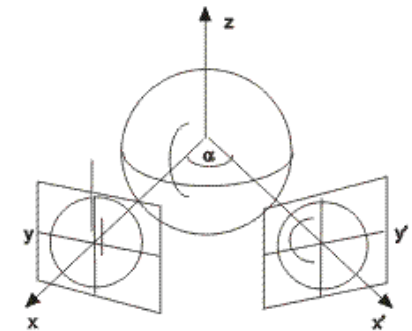


Figure 20. Position of the STEREO spacecraft after about 1 year. STEREO #1, leading Earth, can see around the west limb; STEREO #2, lagging Earth, can see around the east limb.



Coronal loop viewed from two angles separated by  $\alpha$

Coordinates of two views related by simple rotational transform

$$x = x' \cos \alpha + y' \sin \alpha$$

$$y = y' \cos \alpha - x' \sin \alpha$$

$$z = z'$$

Given  $y, y'$ , Solve for  $x, x'$

$$x = \frac{y' - y \cos \alpha}{\sin \alpha}$$

Just launched, October 25, 2006



# Future activities for understanding space weather

- \* A dedicated spacecraft at L1 (or closer to the Sun!), carrying:
  - an EUV/X-ray imager of the Sun,
  - a sensitive coronagraph, for quantifying halo CMEs,
  - a complete set of standard particle and field instruments,
- \* A space weather warning center on the ground, equipped with real-time data links both to the spacecraft in orbit and to the modelling computers, to produce near-real-time reports through the Web in order to avoid this:





# IMPRS Retreat 2011

Lecture on June 21  
by Rainer Schwenn

## c) Space weather

- The source of space weather
- Why should we care?
- How does the Sun shape space weather?
- The role of Bz south
- M-regions and high-speed streams
- CMEs: piled-up plasma and ejecta clouds
- Problems in forecasting
- Open issues, future work needed

The term "space weather" refers to conditions on the Sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and that can affect human life or health.