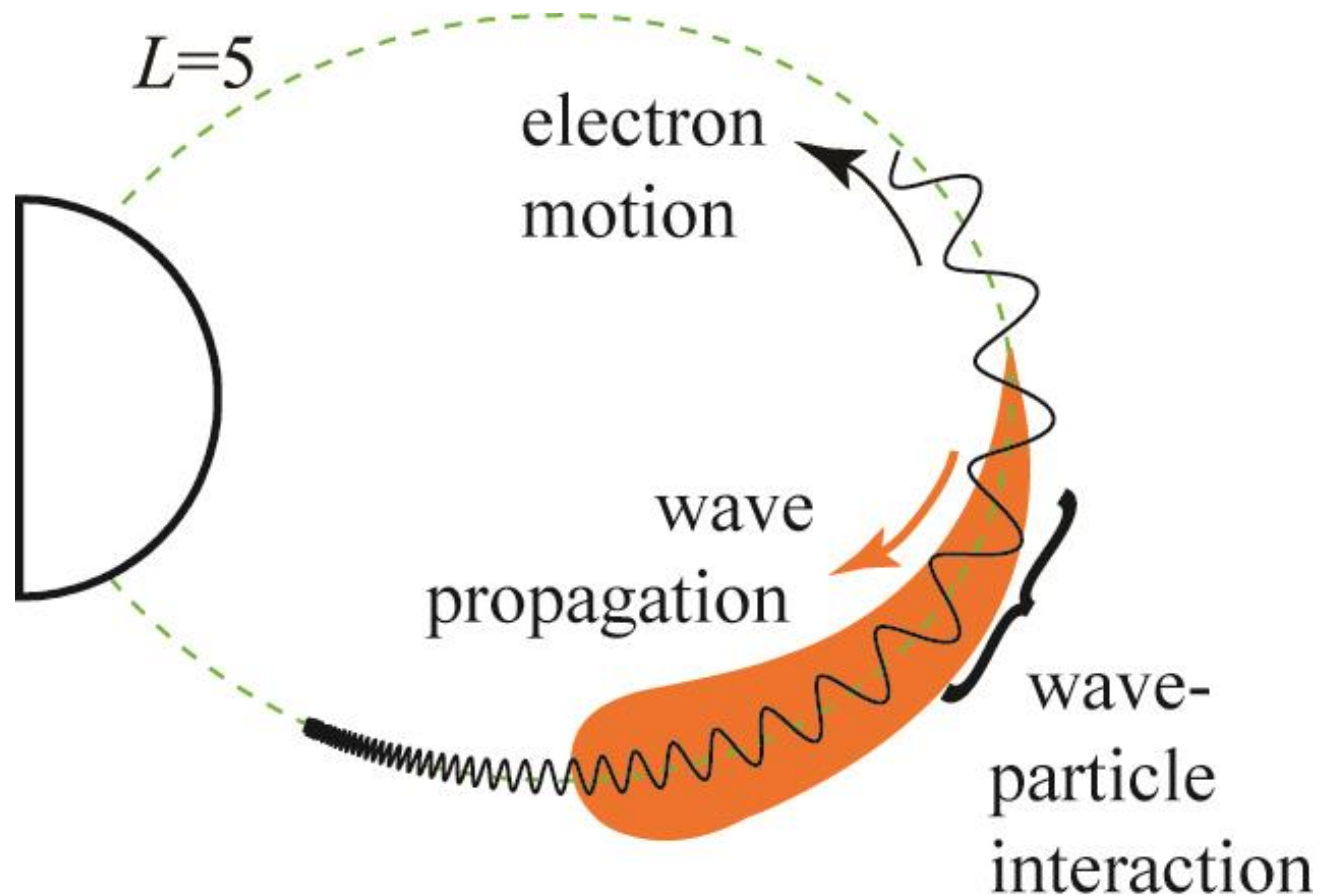


Space Physics Master's Course

Lecture 6



RECOMMENDED READING

Διαστημική Φυσική: Δαγκλής, Κατσαβριάς,
Γεωργίου, Σέργης. Κεφάλαιο 4

(<https://repository.kallipos.gr/handle/11419/11507>)

Physics of Earth's Radiation Belts: Koskinen and
Kilpua. Κεφάλαιο 3

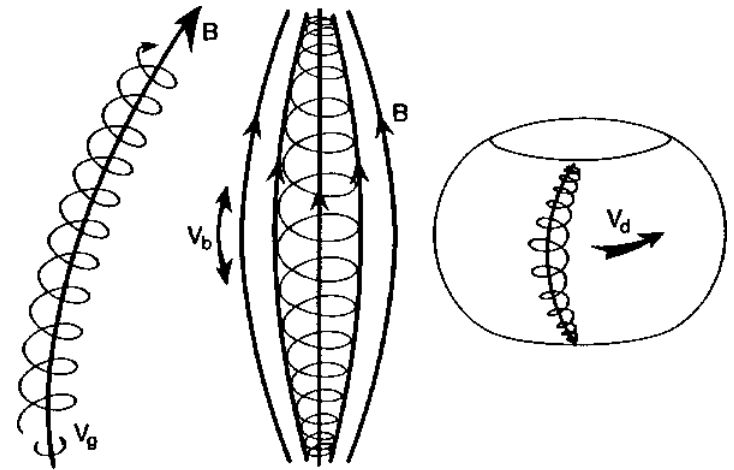
(<https://link.springer.com/content/pdf/10.1007/978-3-030-82167-8.pdf>)

Space Physics: May-Britt Kallenrode. Κεφάλαιο 5

Periodic motion

1 MeV electron, $\alpha = 45^\circ$, $L = 4.5$

- Energetic particles undergo three types of periodic motion:
 - They **gyrate** around the magnetic field
 - They **bounce** between the mirror points
 - They **drift** around the Earth



gyro
motion

bounce
motion

drift
motion

f

10 kHz

3 Hz

1 mHz

T

0.1 ms

0.36 s

15 min

$$\mu = \frac{p_{\perp}^2}{2mB}$$

$$J = \int_{\text{bounce}} p_{\parallel} ds$$

$$\Phi = \int_{\text{drift}} B dS$$

- Associated adiabatic invariant

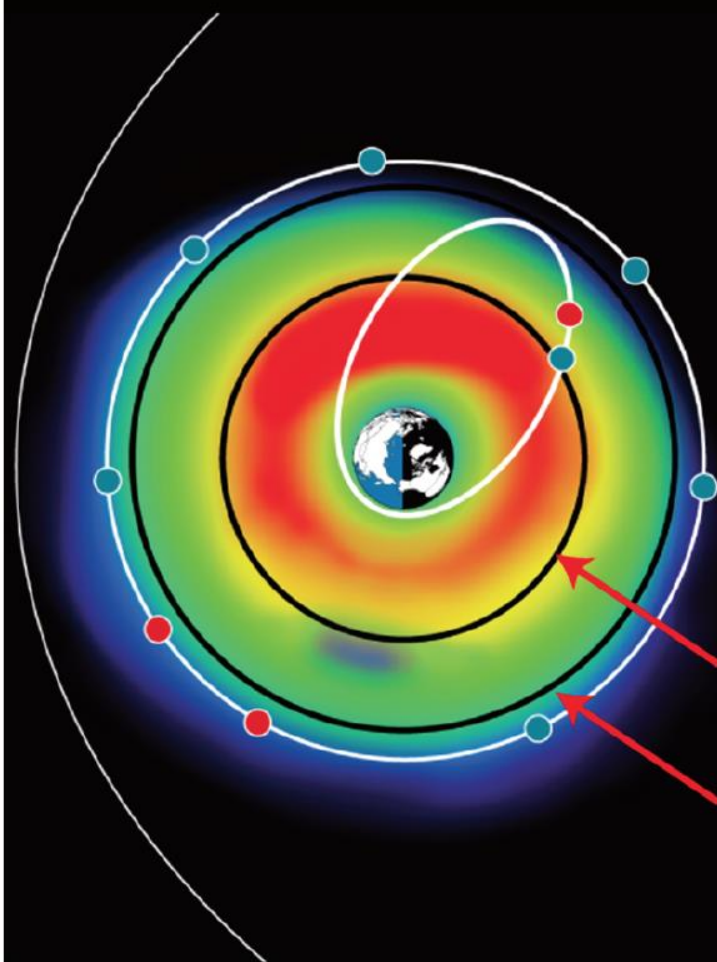
Μεταβολές:
χωρικές; χρονικές;

χωρική ή χρονική παράγωγος:

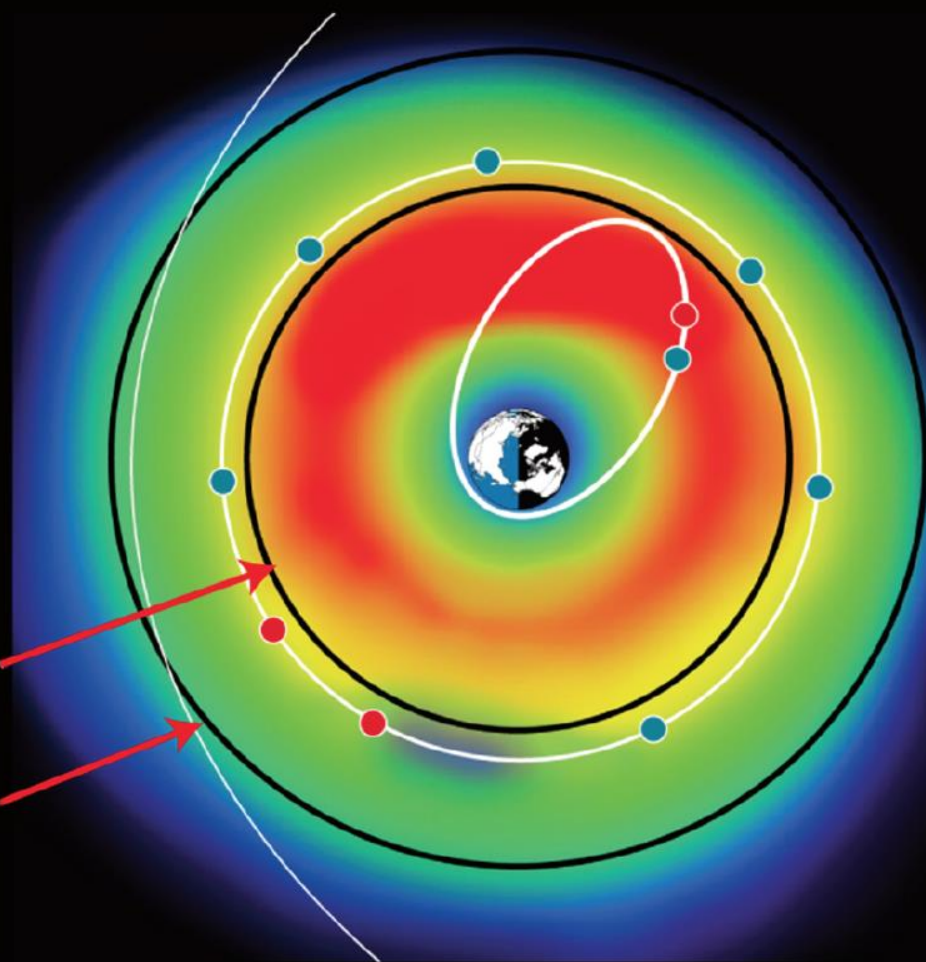
αλλάζει κάτι στο σύστημα με
το πέρασμα του χρόνου ή
συναντά το σκάφος κάποια
άλλη χωρική δομή;

αδιαβατικές ή μή;

Quiet-Time Field



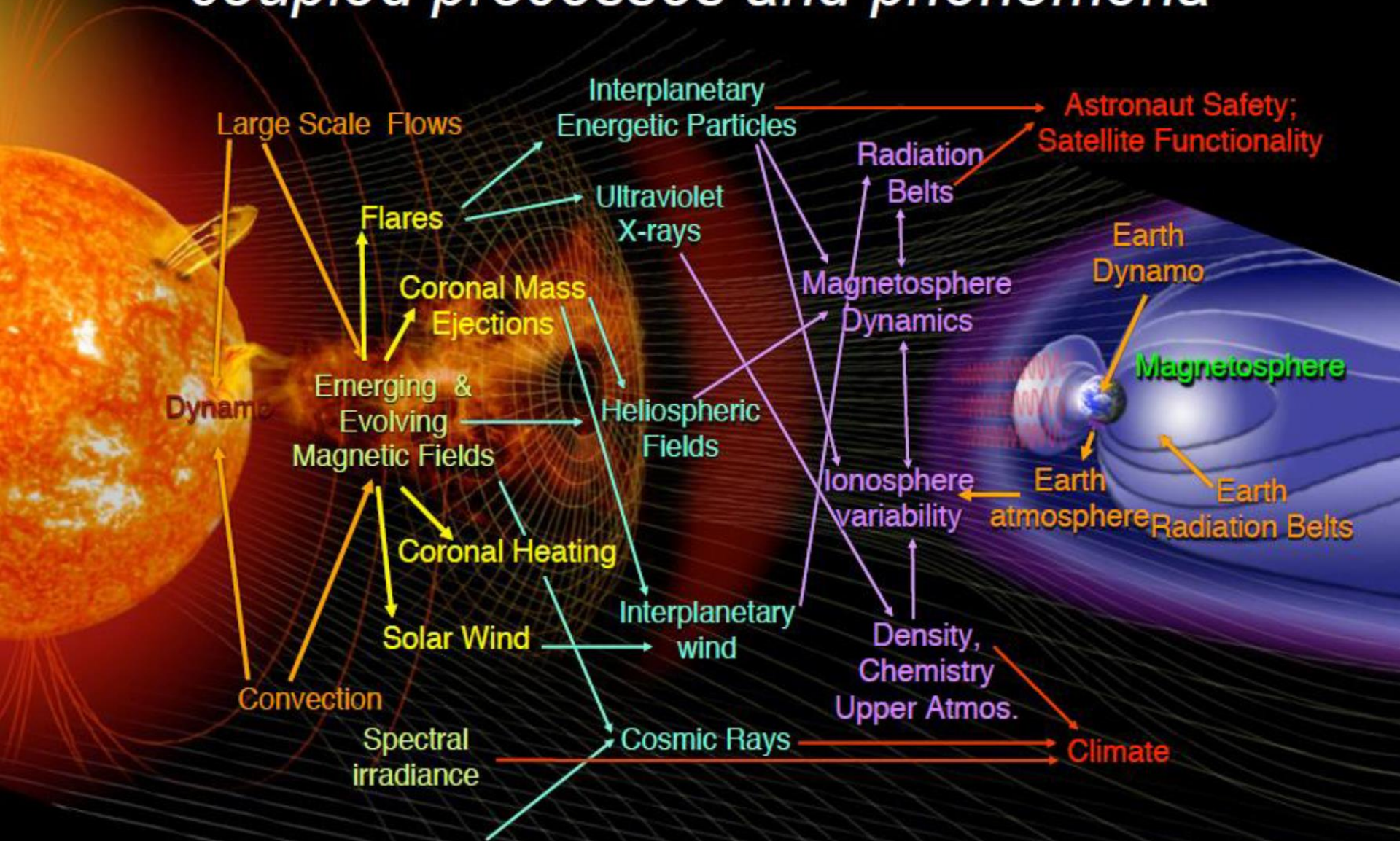
Storm-Time Field



$L^* = 4$

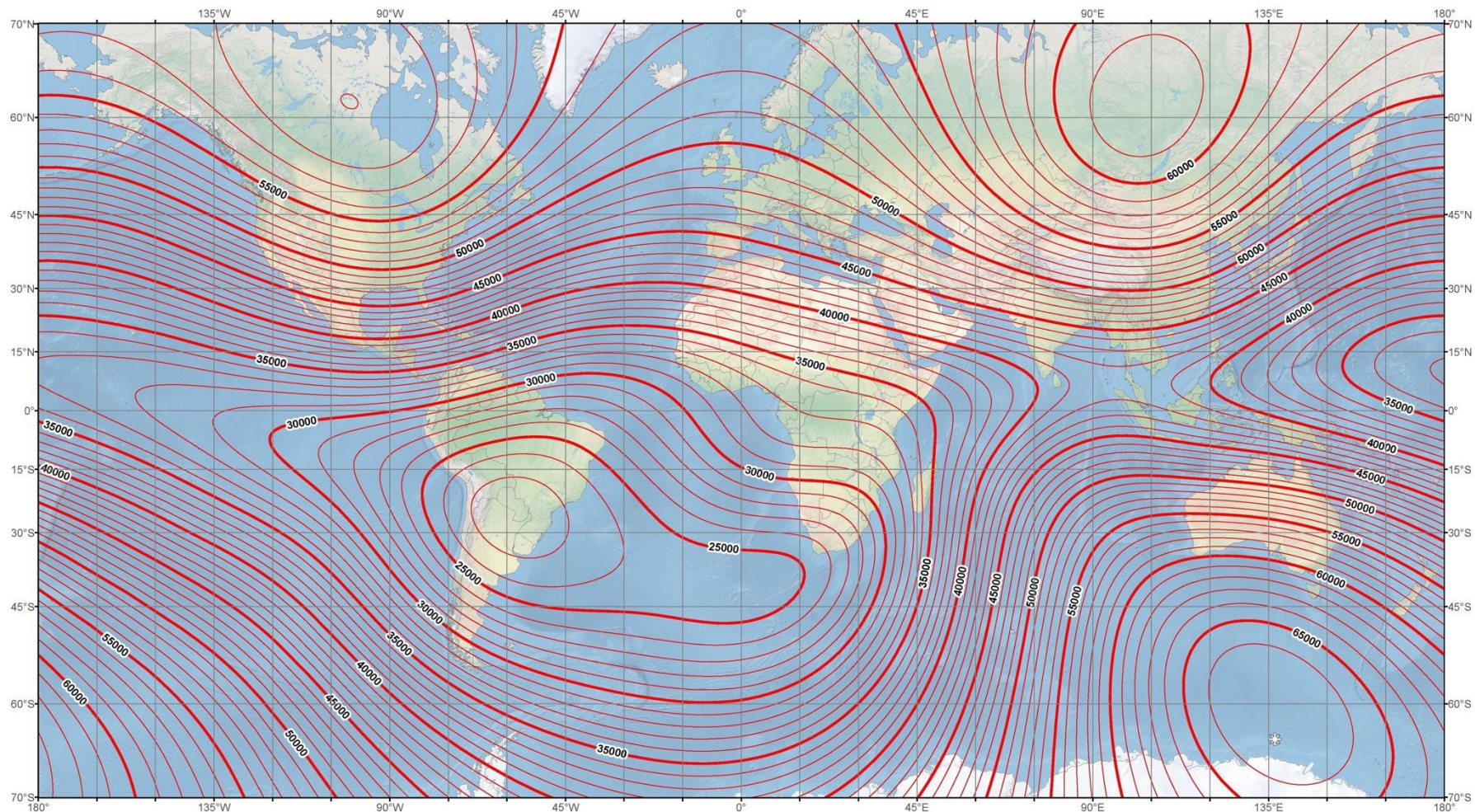
$L^* = 6$

Sun-Earth connections: a complex system of coupled processes and phenomena



US/UK World Magnetic Model - Epoch 2015.0

Main Field Total Intensity (F)

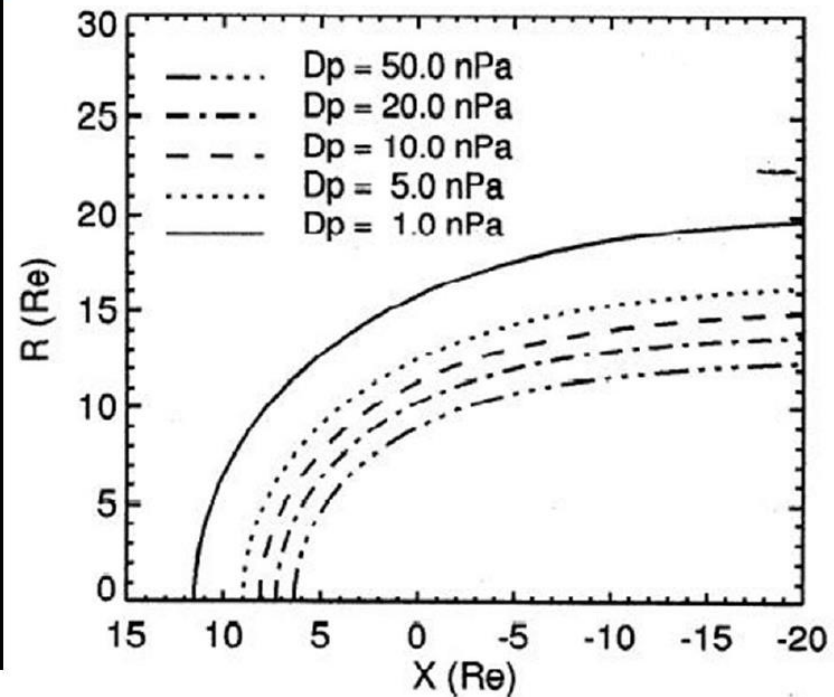
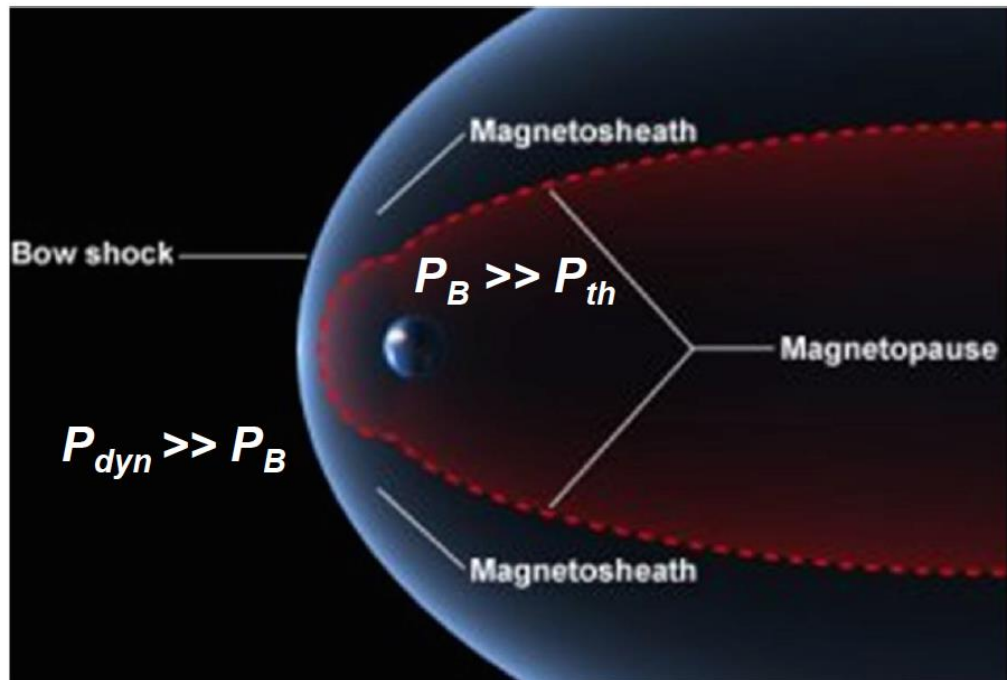


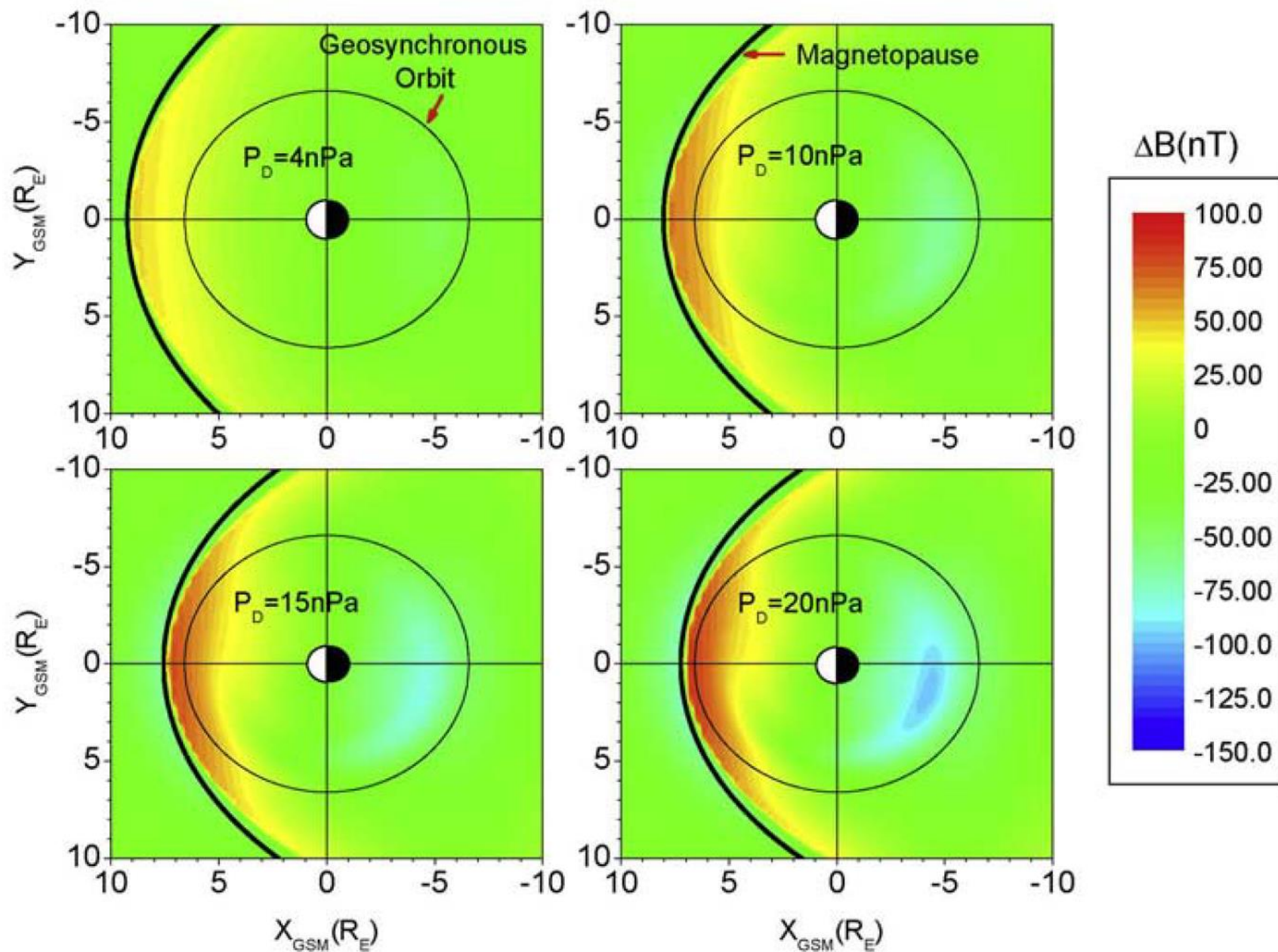
Main Field Total Intensity (F)
Contour interval: 1000 nT.
Mercator Projection.
☉: Position of dip poles

Map developed by NOAA/NGDC & CIRES
<http://ngdc.noaa.gov/geomag/WMM>
Map reviewed by NGA and BGS
Published December 2014

Magnetopause

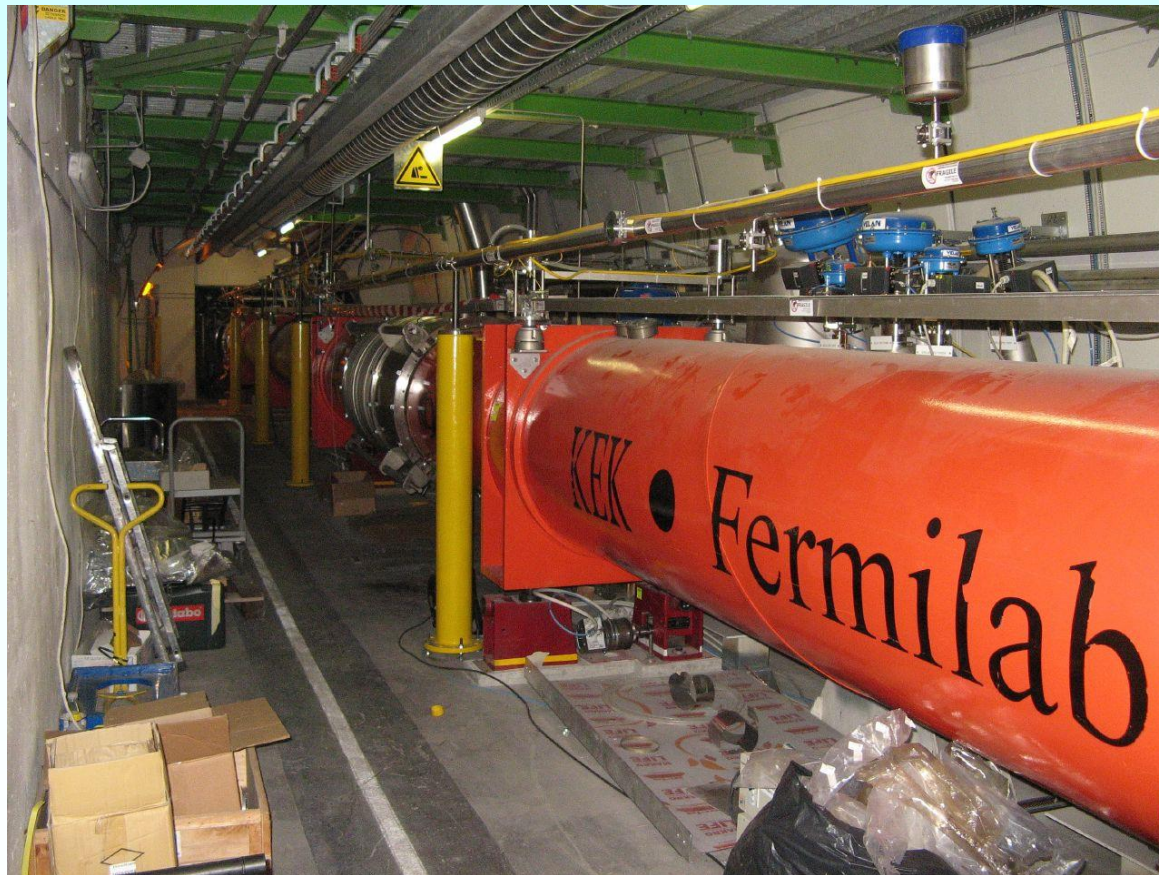
- 1930 Chapman and Ferraro
- 1960s: in-situ evidence (Explorer 10&12)
- nose at ~10 RE





Δυναμική πίεση ηλιακού ανέμου
1 nPa

1 nPa: Large Hadron Collider



Δυναμική πίεση ηλιακού ανέμου
 1 nPa

Ατμοσφαιρική πίεση
 10^5 Pa

Δυναμική πίεση ηλιακού ανέμου

$$1 \text{ nPa} = 10^{-9} \text{ Pa}$$

Ατμοσφαιρική πίεση

$$10^5 \text{ Pa}$$

Διαφορά 14 τάξεων μεγέθους

Δυναμική πίεση ηλιακού ανέμου

$$1 \text{ nPa} = 10^{-9} \text{ Pa}$$

Ατμοσφαιρική πίεση

$$10^5 \text{ Pa}$$

Διαφορά 14 τάξεων μεγέθους

Αρτηριακή πίεση: ? Pa

Δυναμική πίεση ηλιακού ανέμου

$$1 \text{ nPa} = 10^{-9} \text{ Pa}$$

Ατμοσφαιρική πίεση

$$10^5 \text{ Pa}$$

Διαφορά 14 τάξεων μεγέθους

Αρτηριακή πίεση:

$$10^5 + 10^4 \text{ Pa} = 115 \text{ kPa}$$

1 Pa



1 Ρα



**Πίεση ένα δισεκατομμύριο φορές μεγαλύτερη
από του ηλιακού ανέμου!**

TIME

100PHOTOS

THE COLLECTION

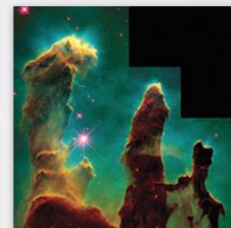
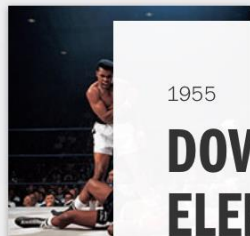
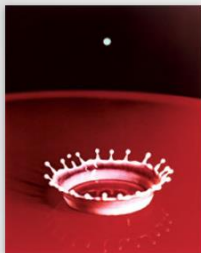
VIDEOS

[SHOP](#) 

1955

**DOVIMA WITH
ELEPHANTS,
EVENING
DRESS BY
DIOR, CIRQUE
D'HIVER,
PARIS, AUGUST
1955**

RICHARD AVEDON





Dovima and the Elephants
by Richard Avedon



Richard Avedon:
Dovima and
the Elephants



Elephant foot: ? Pa

Stiletto heel: ? Pa



Richard Avedon:
Dovima and
the Elephants



Elephant foot: 6×10^5 Pa

Stiletto heel: 10^7 Pa



10^{-9} Pa

10^7 Pa



1 Pa



10^6 Pa



10^{-9} Pa

10^7 Pa



1 Pa



Intergalactic void
 10^{-17} Pa

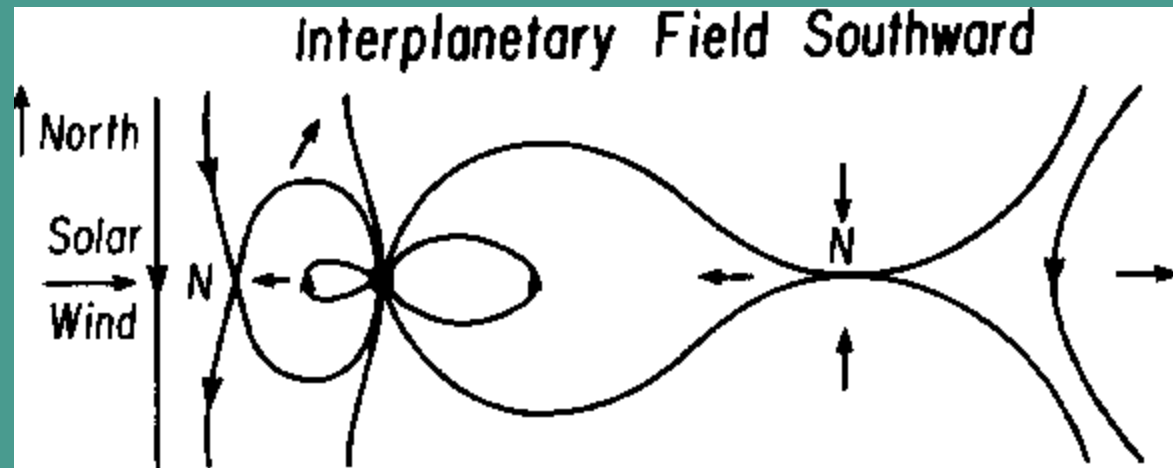
Neutron star
 10^{34} Pa

10^6 Pa

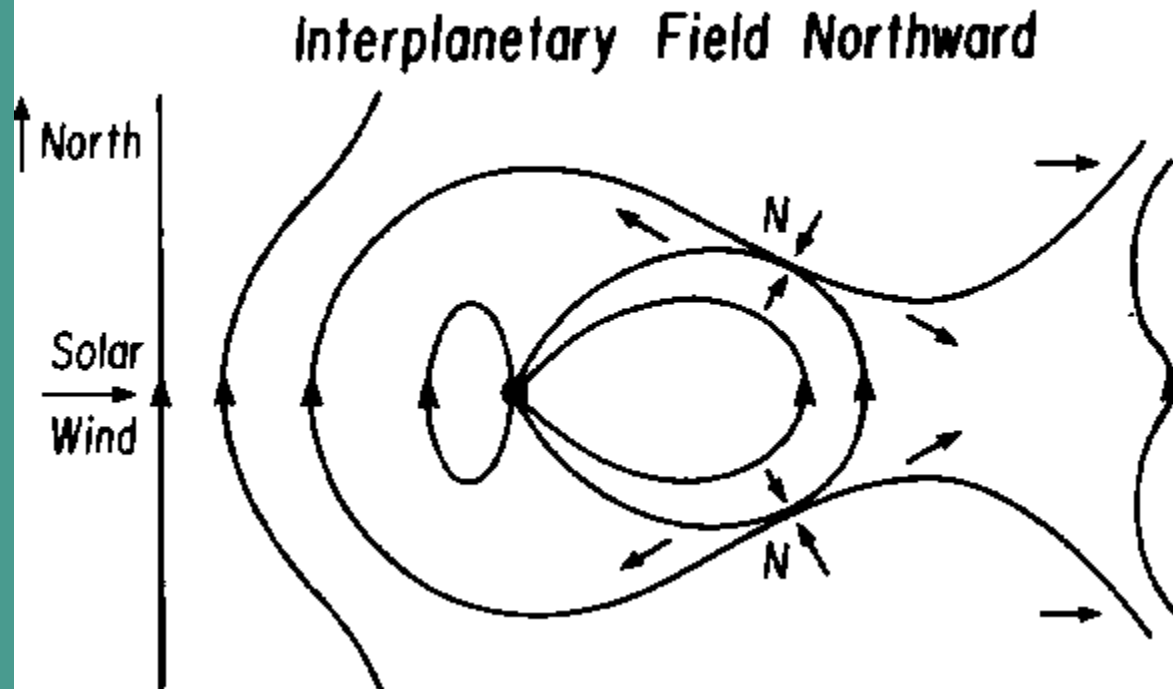


Magnetosphere for IMF B_{ZS} and B_{ZN}

Dayside
Shrinks
by Flux
Ablation

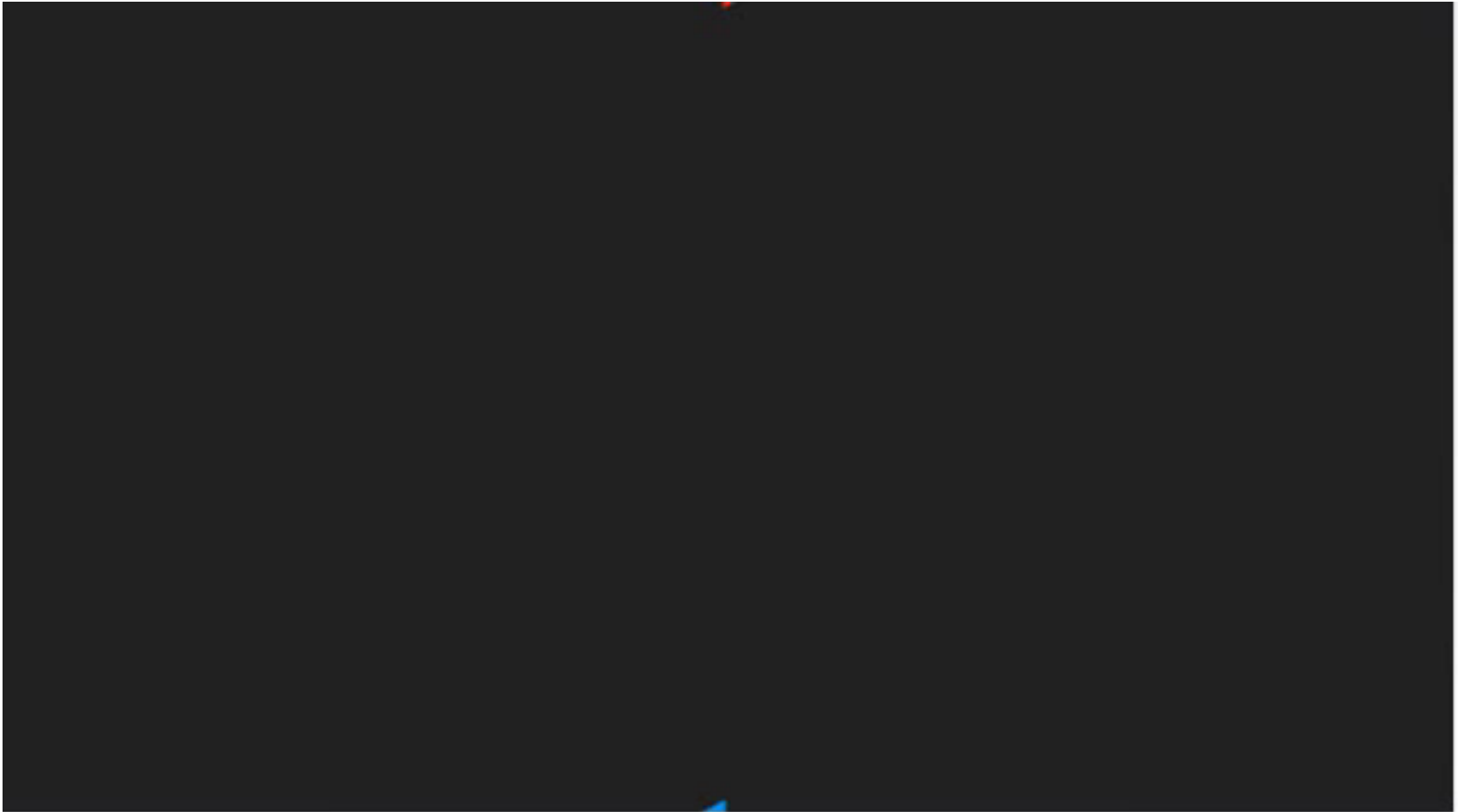


Dayside
Grows
by Flux
Accretion

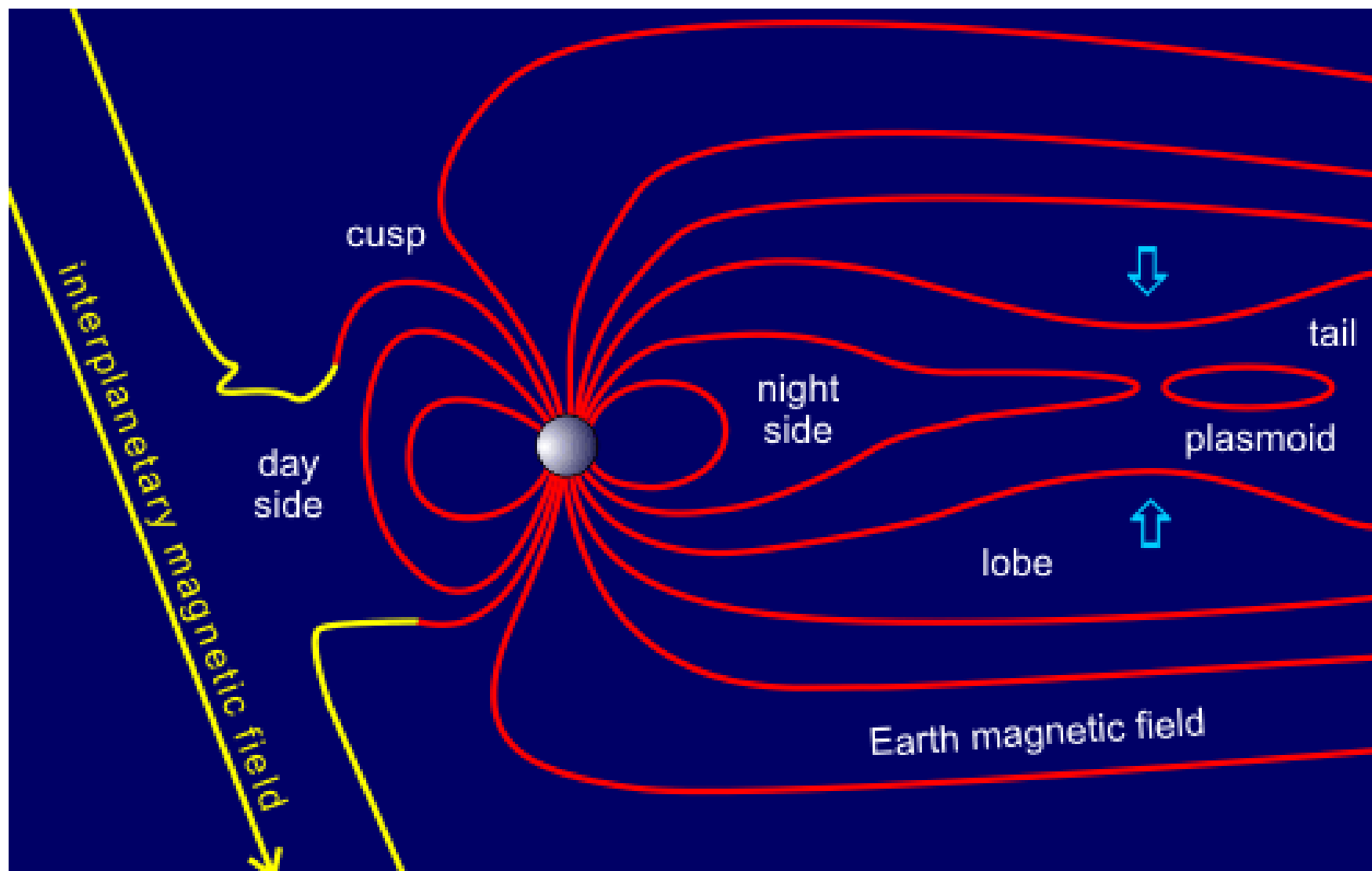


Magnetic reconnection

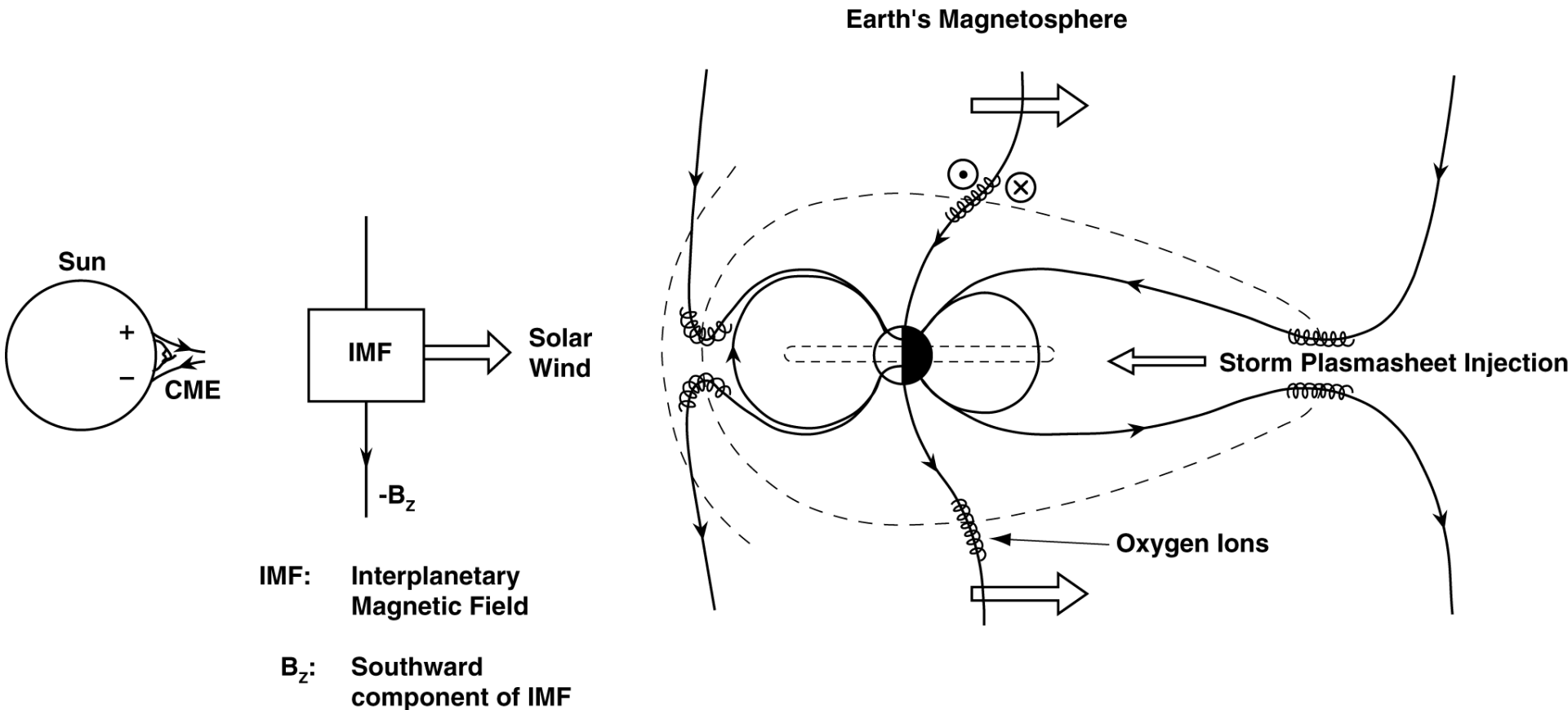
<https://www.youtube.com/watch?v=7sS3Lpzh0Zw>



<https://www.youtube.com/watch?v=K-YAPFcy6Wk>



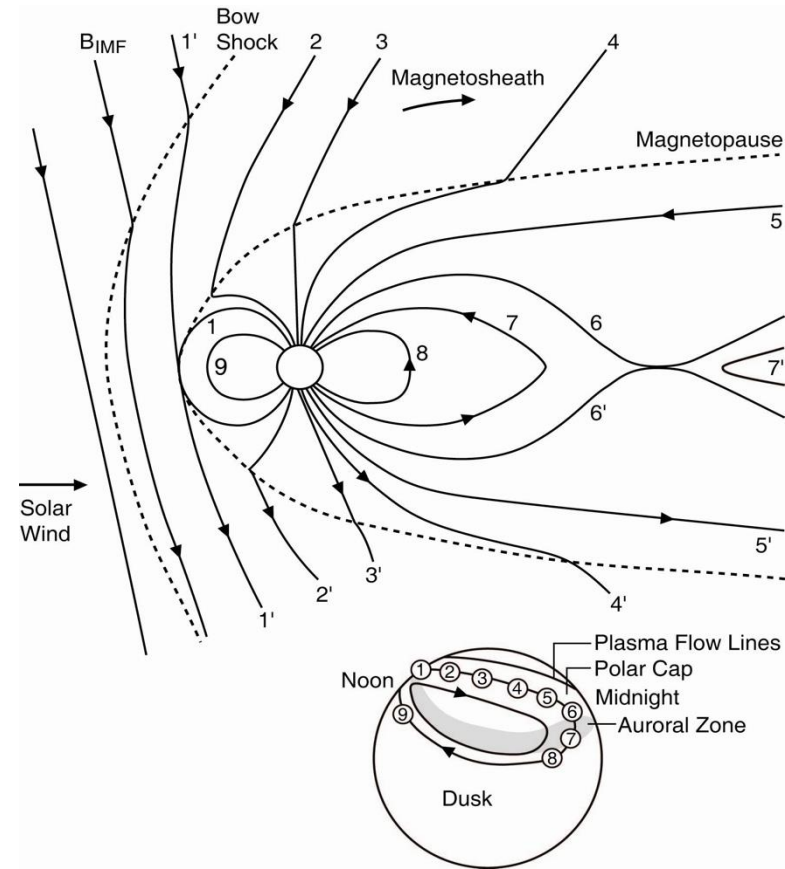
Solar wind – magnetosphere coupling

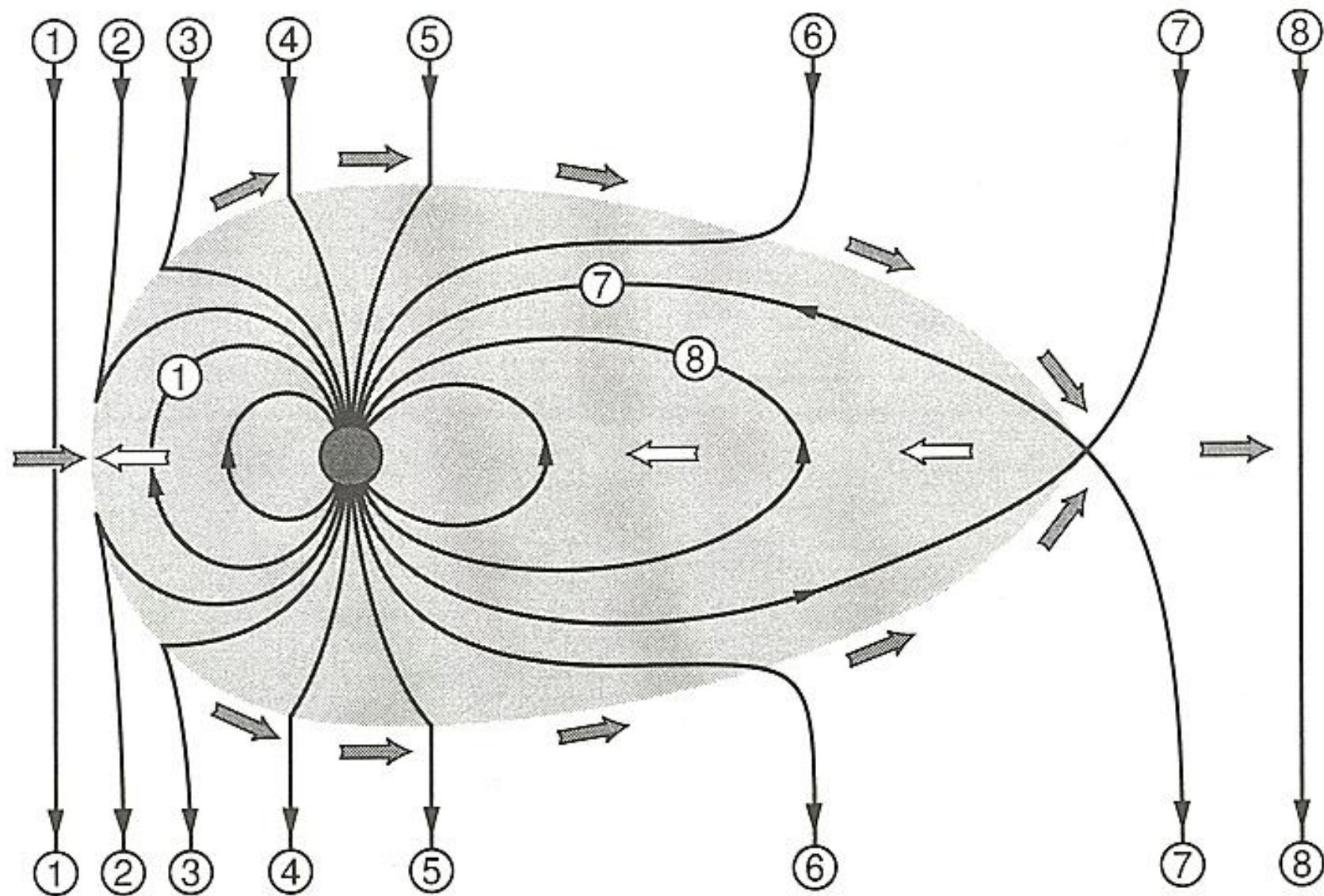


Energy transfer and storage

Given that **reconnection** links the solar and terrestrial B fields, the **energy transfer** from the solar wind to the tail occurs quite naturally.

On the night-side, the field lines in the tail stretch and the solar wind plasma slows down. Hence, energy is removed from the flow and stored in the magnetic field in the tail. The rate of energization can be calculated from the Poynting vector integrated over the surface of the tail. The magnetic energy, flux and field strength of the tail increase.



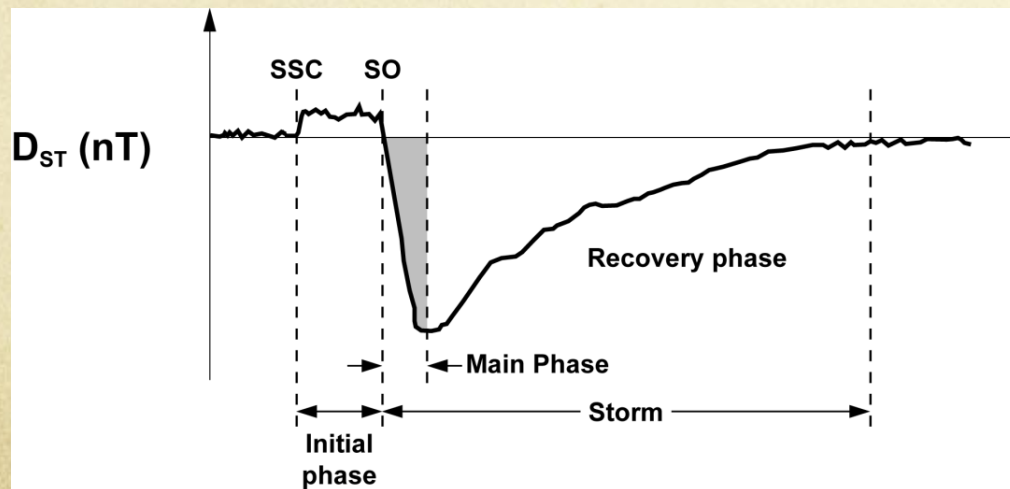


Μεταφορά ισχύος
(δηλαδή ρυθμός μεταφοράς ενέργειας)
ανάλογη του:

$$P_{\text{dyn}} \propto V_{\text{sw}} B_s$$

Space Storms

- Historically defined (and identified) as prolonged world-wide depressions of H-component of geomagnetic field
- Associated with aurora and solar eruptions
- Now recognized as the most complex, multi-faceted dynamic phenomenon in geospace



Space Storms

Not to be confused with Solar Storms,
(aka Solar Radiation Storms)
which are episodes of intense acceleration
of solar particles to very high energies
(Solar Energetic Particles – SEPs)
by solar flares and/or CMEs.

Space Storms

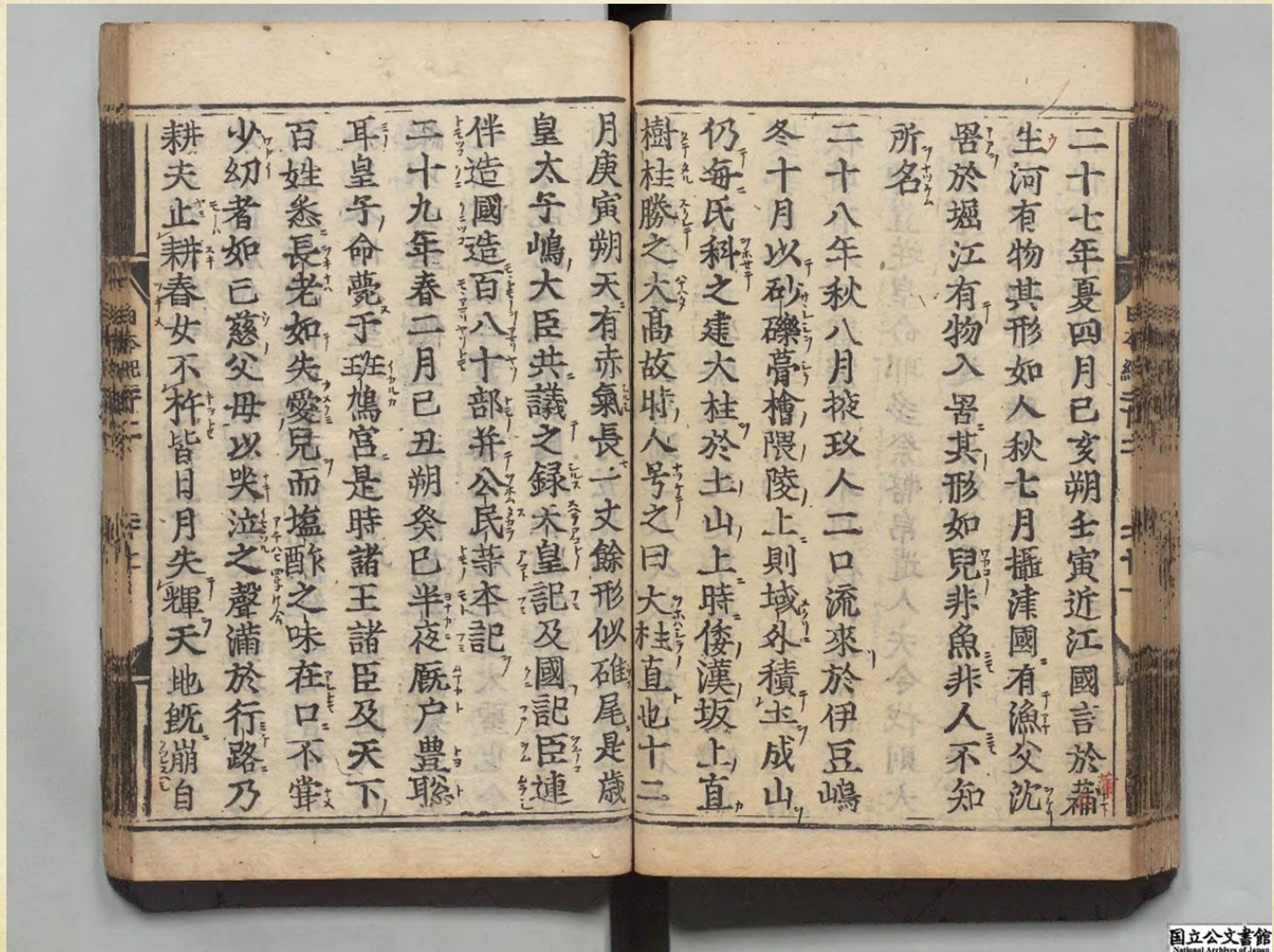
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which are episodes of intense acceleration
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(Solar Energetic Particles – SEPs)
by solar flares and/or CMEs.

Solar Storms and Space Storms **are not identical!**

Solar Storms **do not cause** Space Storms!

Aurora in *Rikkokushi* - chronicles of ancient Japan



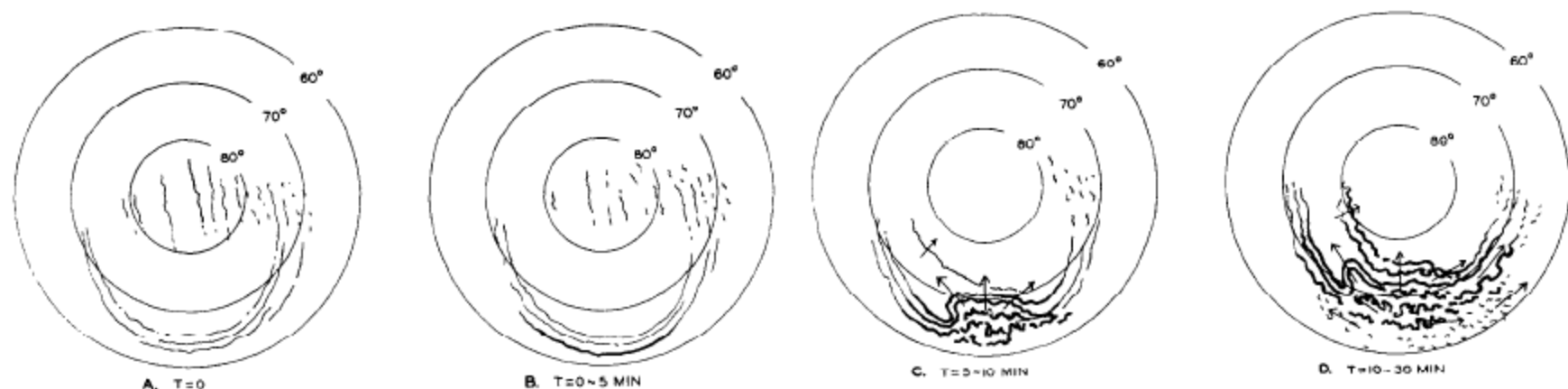
THE DEVELOPMENT OF THE AURORAL SUBSTORM

S.-I. AKASOFU

Geophysical Institute, University of Alaska, College, Alaska

(Received 13 January 1964)

Abstract—A working model of simultaneous auroral activity over the entire polar region is presented in terms of the auroral substorm. The substorm has two characteristic phases, an expansive phase and a recovery phase. Each phase is divided into three stages, and characteristic auroral displays over the entire polar region during each stage are described in detail. Further, all the major features seen at a single station are combined into a consistent picture of large-scale auroral activity.



Aurora – The magnificent northern lights

Ioannis Daglis* and Syun-Ichi Akasofu**

*Research Director, National Observatory of Athens, Athens, Greece

**Professor, University of Alaska, Director, International Arctic Research Center, Fairbanks, USA



Figure 1: Auroral bands with rays, Alaska. © Jan Curtis



Figure 2: Aurora in Manitoba, Canada. © Warren Justice

Aurora in Greece



Aurora in Greece



Aurora in Japan

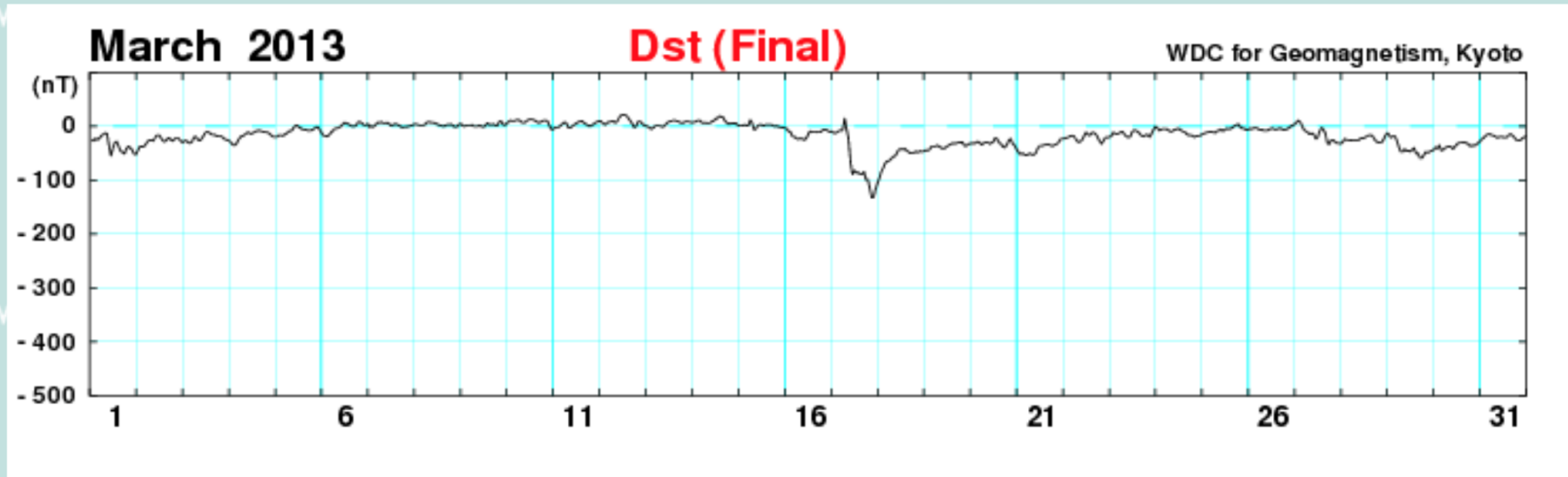


2003年10月30日 4:24 (JST) 20mm F2.8 ISO400 露出時間: 5分 キヤノンEOS55

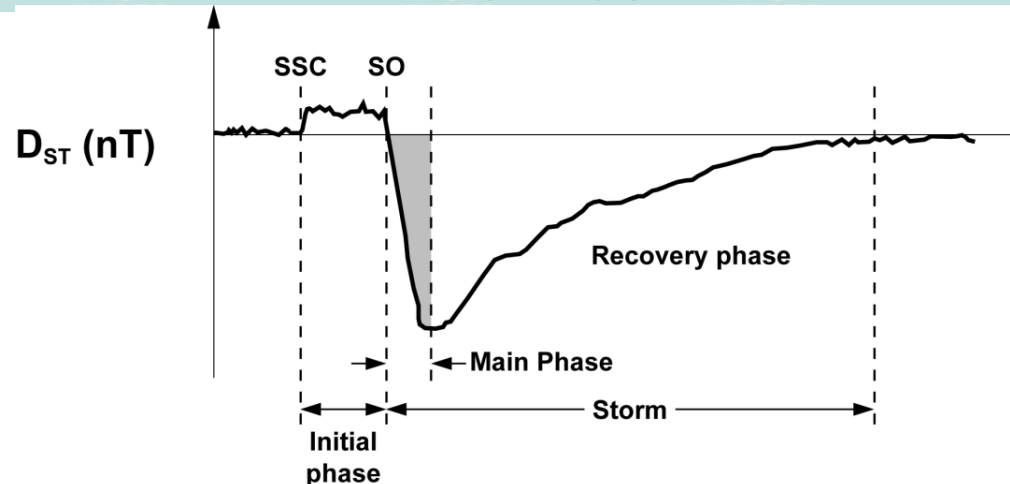


りくべつ宇宙地球科学館 (銀河の森天文台)

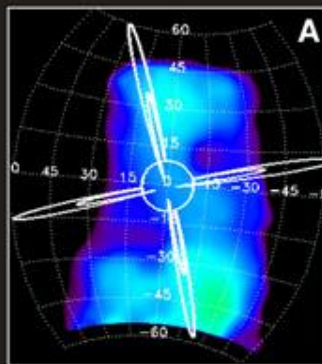
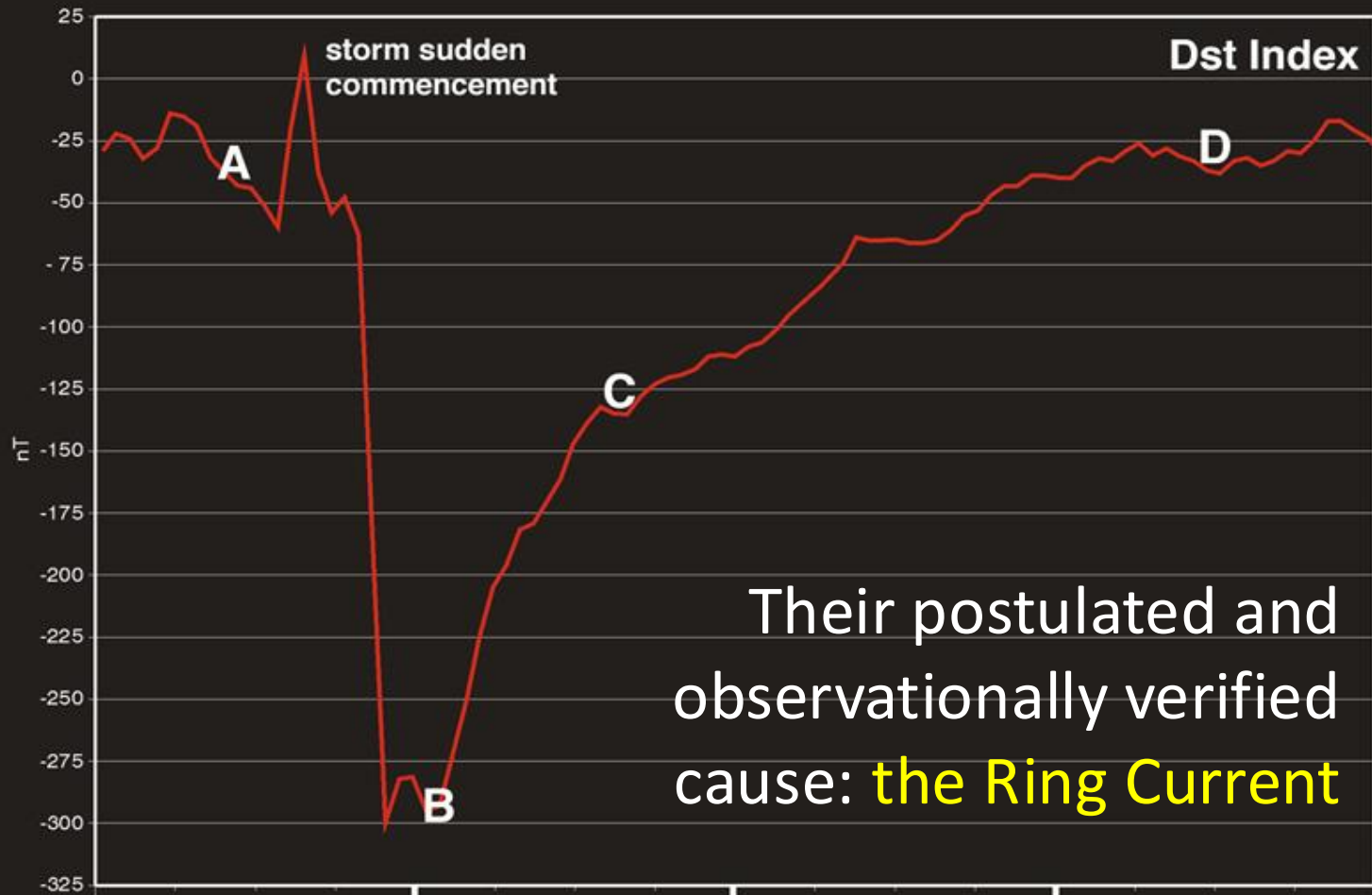
Kyoto World Data Center for Geomagnetism



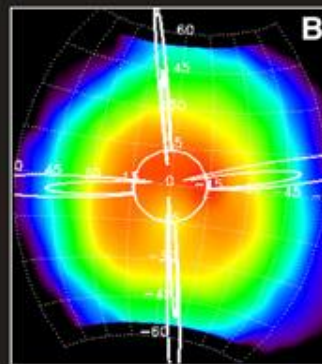
WDC for Geomagnetism, Kyoto
Hourly Equatorial Dst Values (FINAL)
MARCH 2013



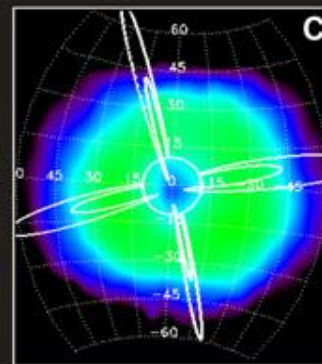
Magnetic Storms



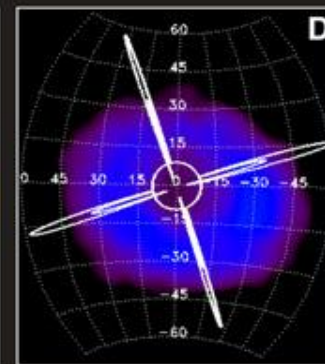
pre-storm



main phase



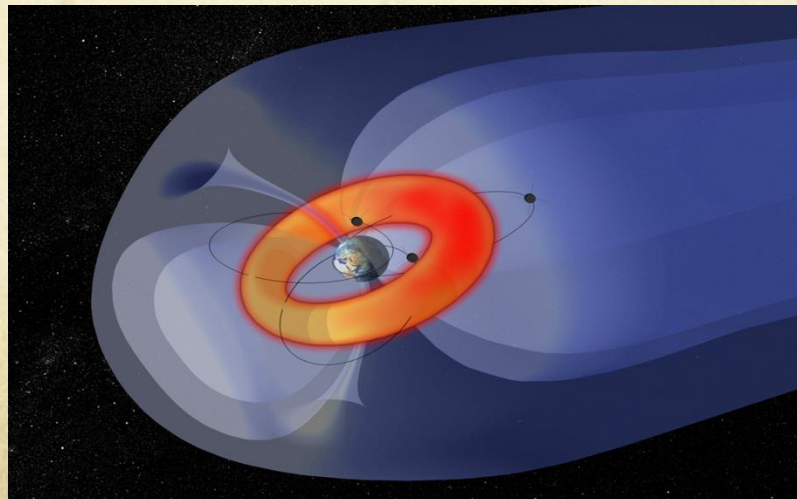
early recovery



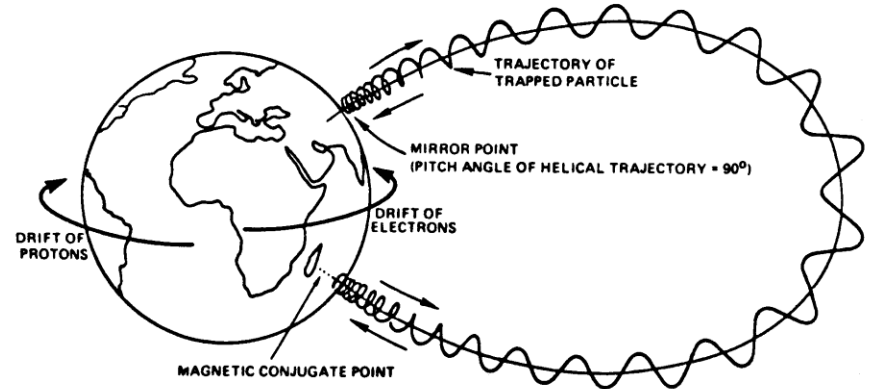
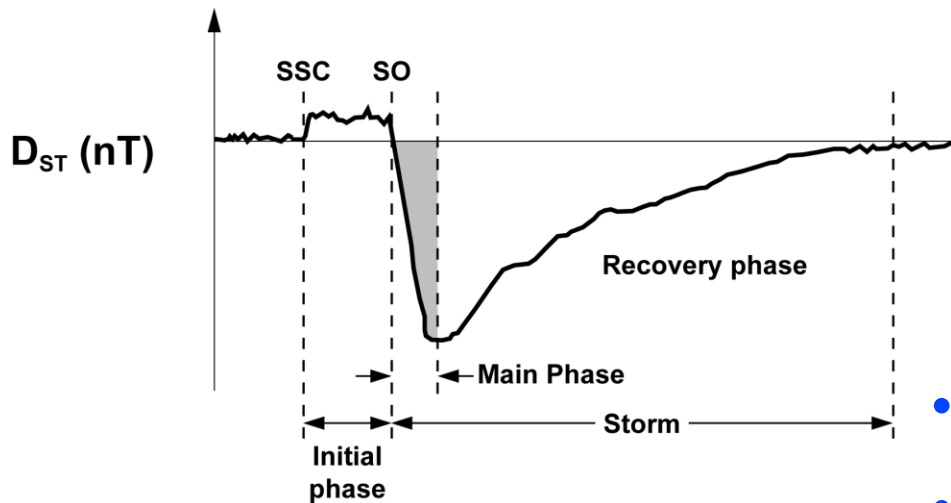
late recovery

Ring Current

- Carried mainly by ions (H^+ , O^+ , N^+ , He^{++} , He^+) in the energy range ~ 1 keV to a few 100s keV
- Bulk of energy within 50-100 keV
- Spatial extent: $\sim 2-8 R_E$ (geocentric)
- Maximum intensity at $\sim 3-5 R_E$ (geocentric)



Geomagnetic Storm: Ring Current Evolution



- Composition: e^- , H^+ , He^+ , O^+ , N^+ , He^{++}
- Energy Range: $\sim 1 \text{ keV} < E < 300 \text{ keV}$
- Location: $\sim 2 < L < 8$
- Energy Density: $\sim 10 - 1000 \text{ keV/cm}^3$

THE INTERRELATIONSHIP OF MAGNETOSPHERIC PROCESSES

VYTENIS M. VASYLIUNAS

*Dept. of Physics and Center for Space Research, Massachusetts Institute of Technology,
Cambridge, Mass., U.S.A.*

“One Ring to rule them all . . .”
J. R. R. TOLKIEN

1. Introduction

Convection of plasma in the magnetosphere is one of the major aspects of magnetospheric dynamics. Attempts during the past 10 yr to understand this complicated phenomenon have led to a sequence of theoretical models of constantly increasing sophistication (see, for example, Axford (1969)). Most of these models have been

Vasyliunas, in *Earth's Magnetospheric Processes*, 1972

THE INTERRELATIONSHIP OF MAGNETOSPHERIC PROCESSES

VYTENIS M. VASYLIUNAS

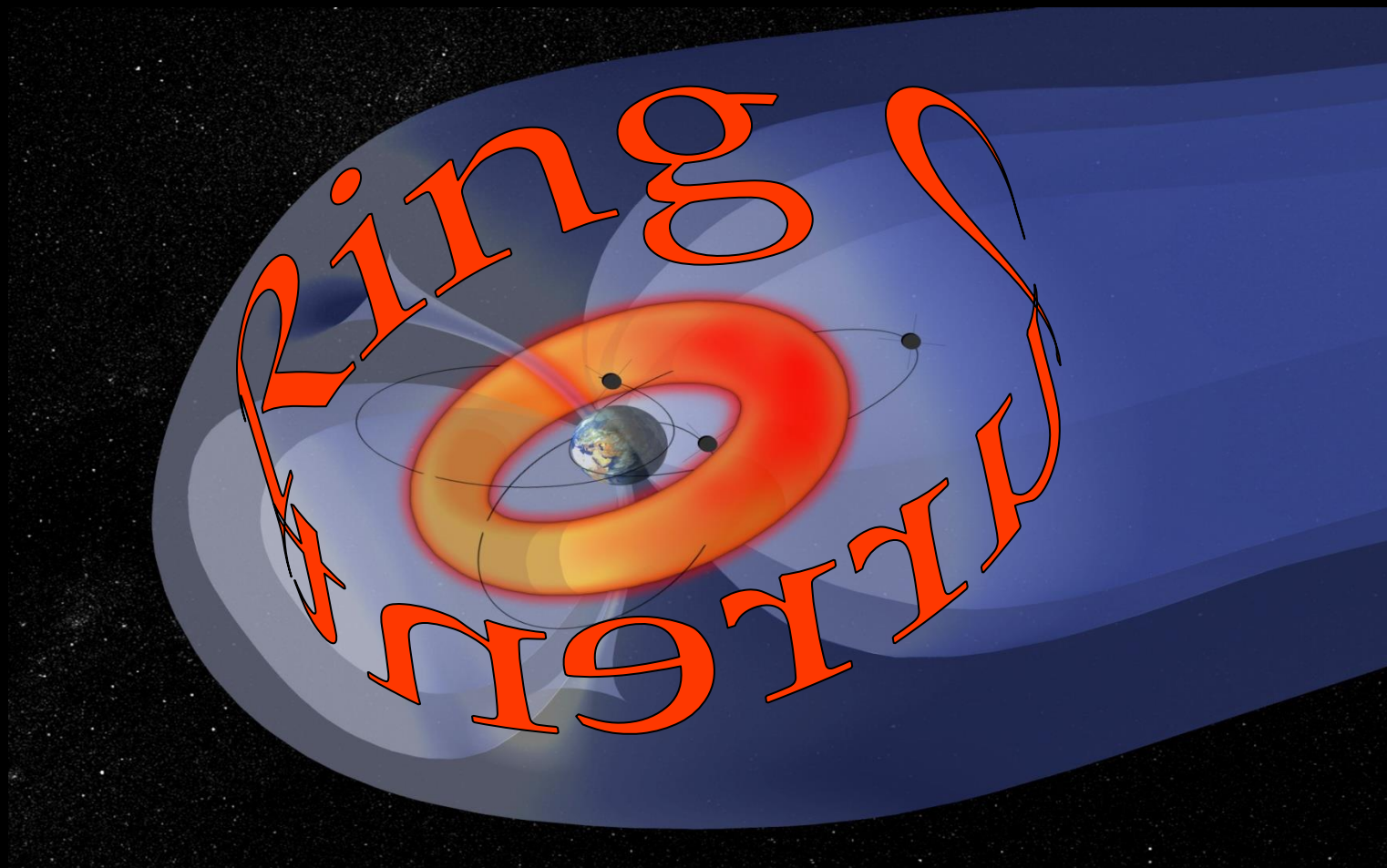
*Dept. of Physics and Center for Space Research, Massachusetts Institute of Technology,
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Vasyliunas, in *Earth's Magnetospheric Processes*, 1972



A golden ring, similar to the One Ring, is shown with Elvish script inscribed on its surface. Inside the ring, there is a blue and red spiral pattern. At the center of the spiral is a small globe of the Earth, with a black dot and lines suggesting orbits or a gravitational well.

One Ring to rule them All

A golden ring, similar to the One Ring, is shown against a dark, starry space background. The ring is inscribed with glowing yellow Elvish script. Inside the ring, a bright red sun is visible, and a blue planet with white clouds (resembling Earth) is shown in orbit around it. Several black lines represent orbital paths. The text "One Ring to rule them All" is superimposed over the center of the image in a bold, black font.

One Ring to rule them All