

Διαστημικό Περιβάλλον



Space Environment

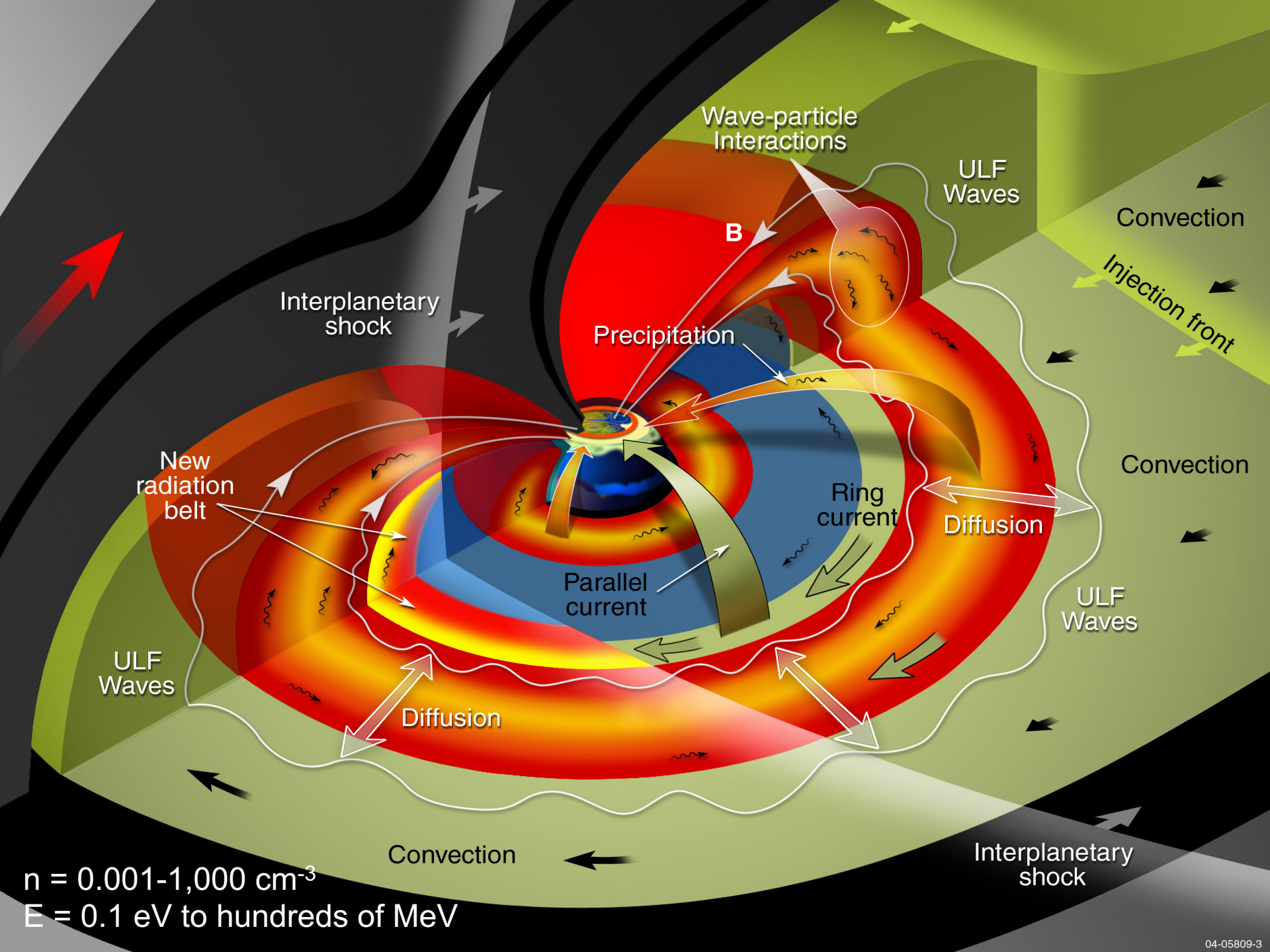
Space Environment Lecture 7



Plasma in the geospace environment

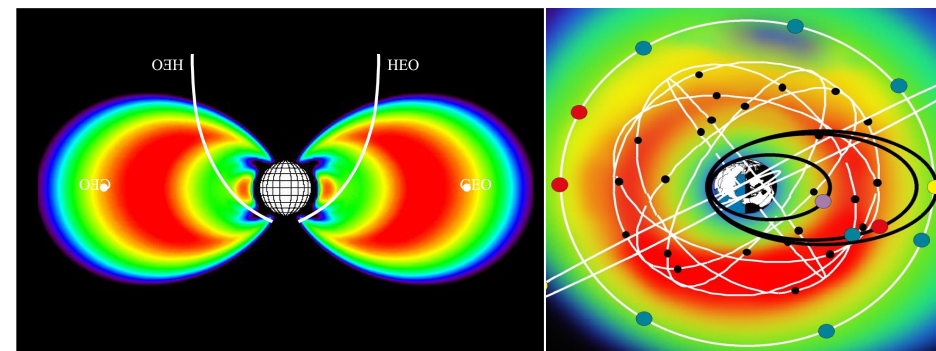
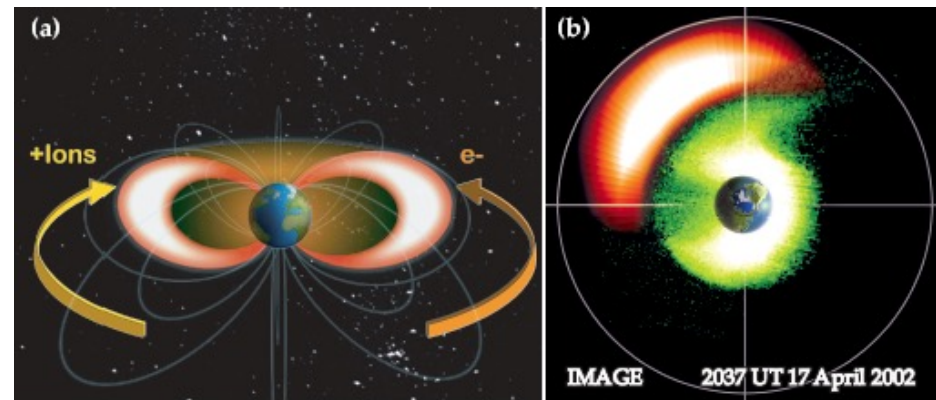
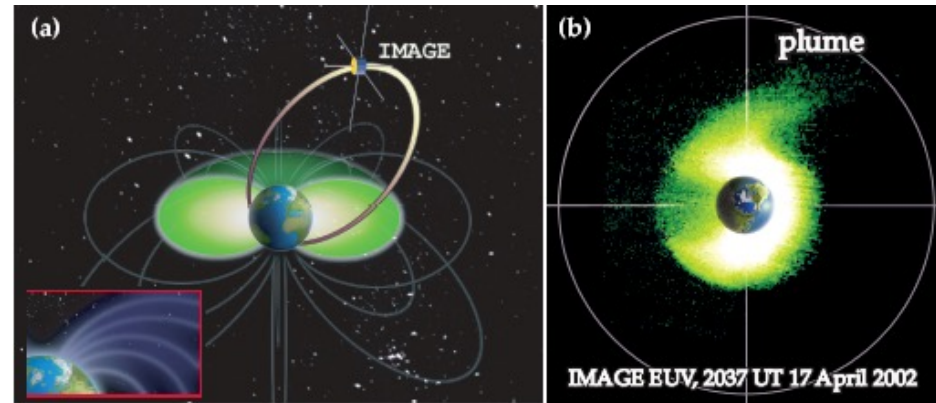
<http://www.swpc.noaa.gov/noaa-scales-explanation>



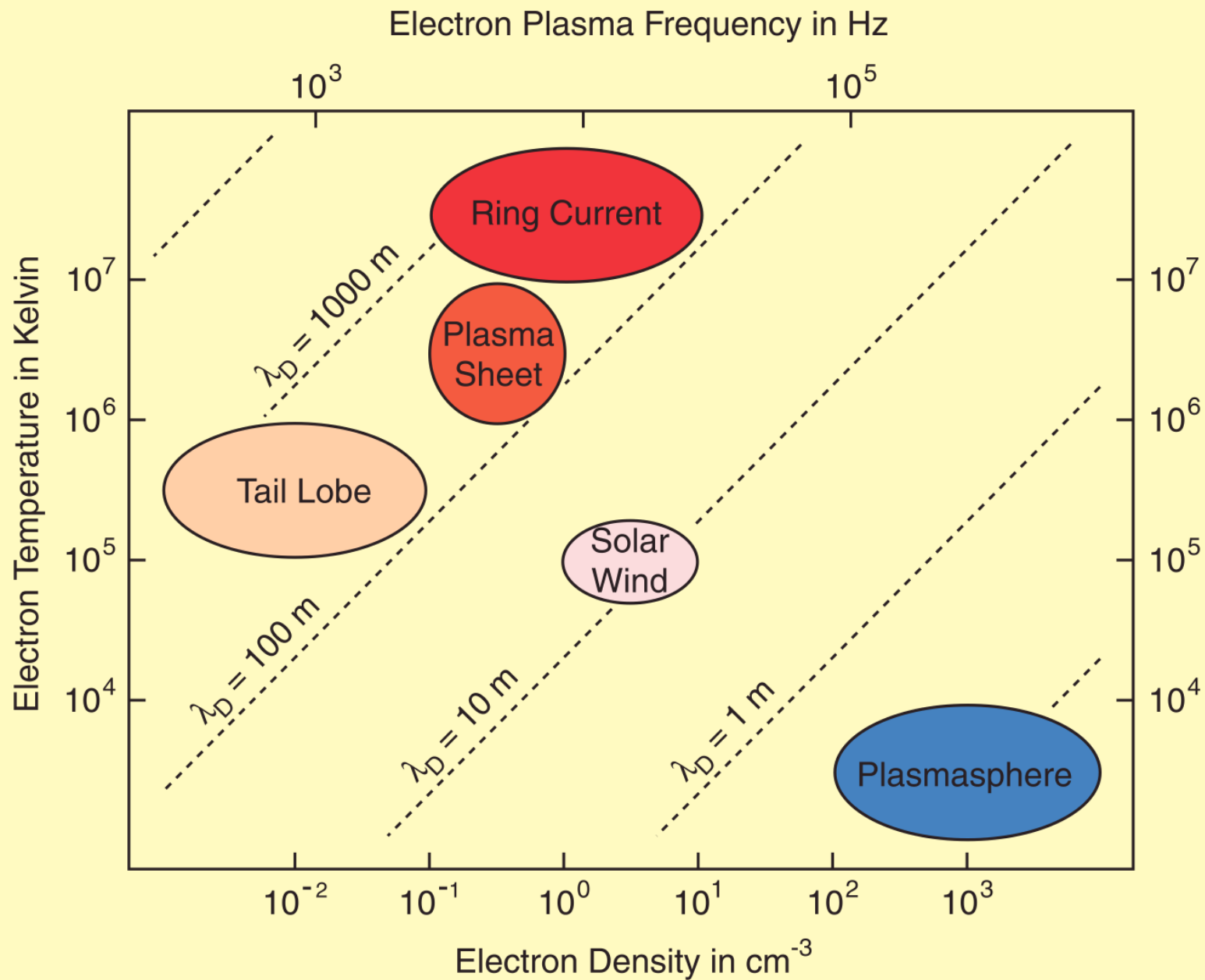


Inner magnetosphere plasmas

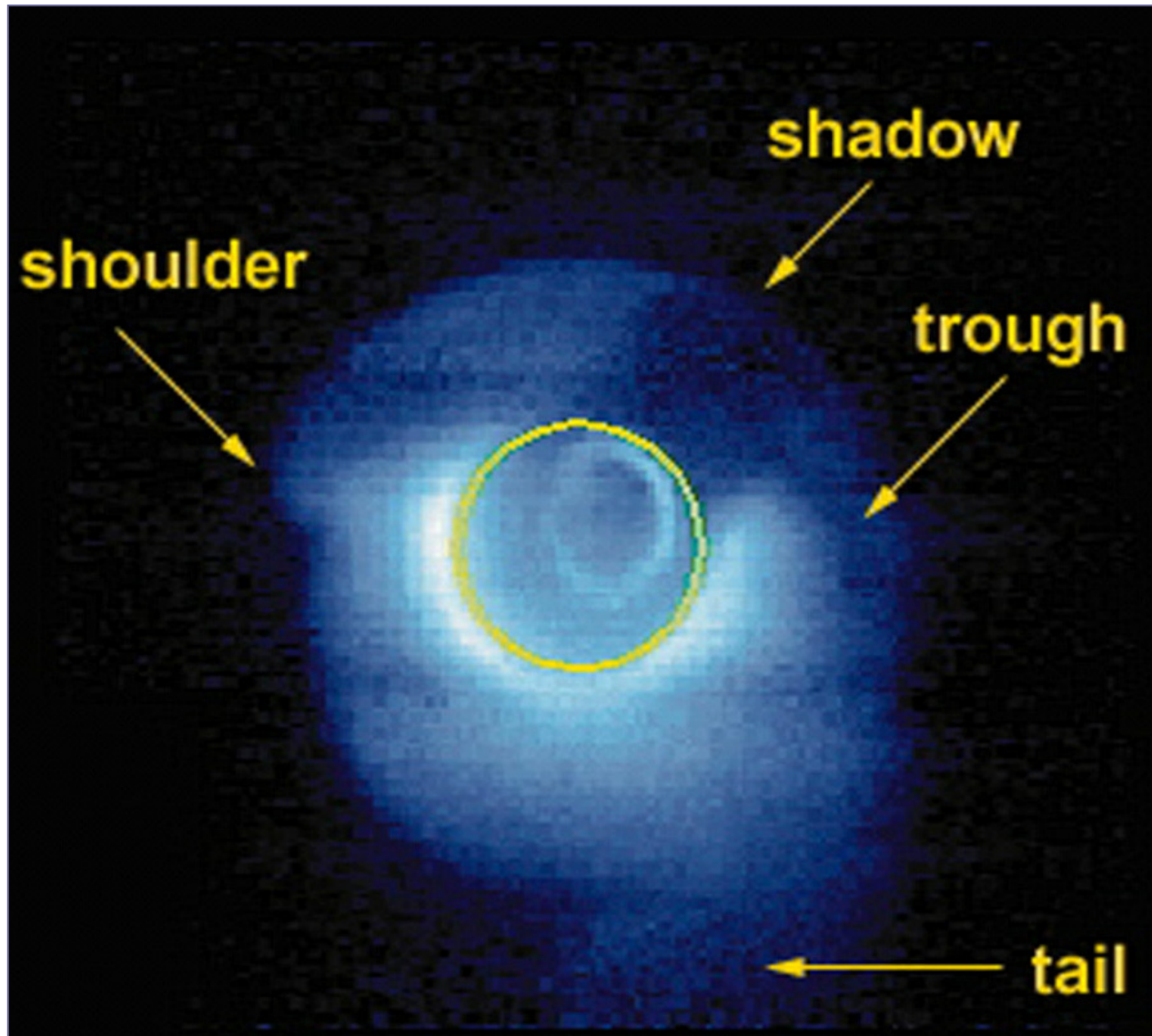
- Plasmasphere
 - 1-10 eV ions
 - ionospheric origin
- Ring current
 - 1-300 keV ions
 - ionospheric/solar wind origin
- Outer radiation belt
 - 0.5-10 MeV electrons
 - magnetospheric origin
- Inner radiation belt
 - 10s-100s MeV ions (GCR)
 - 100s keV electrons



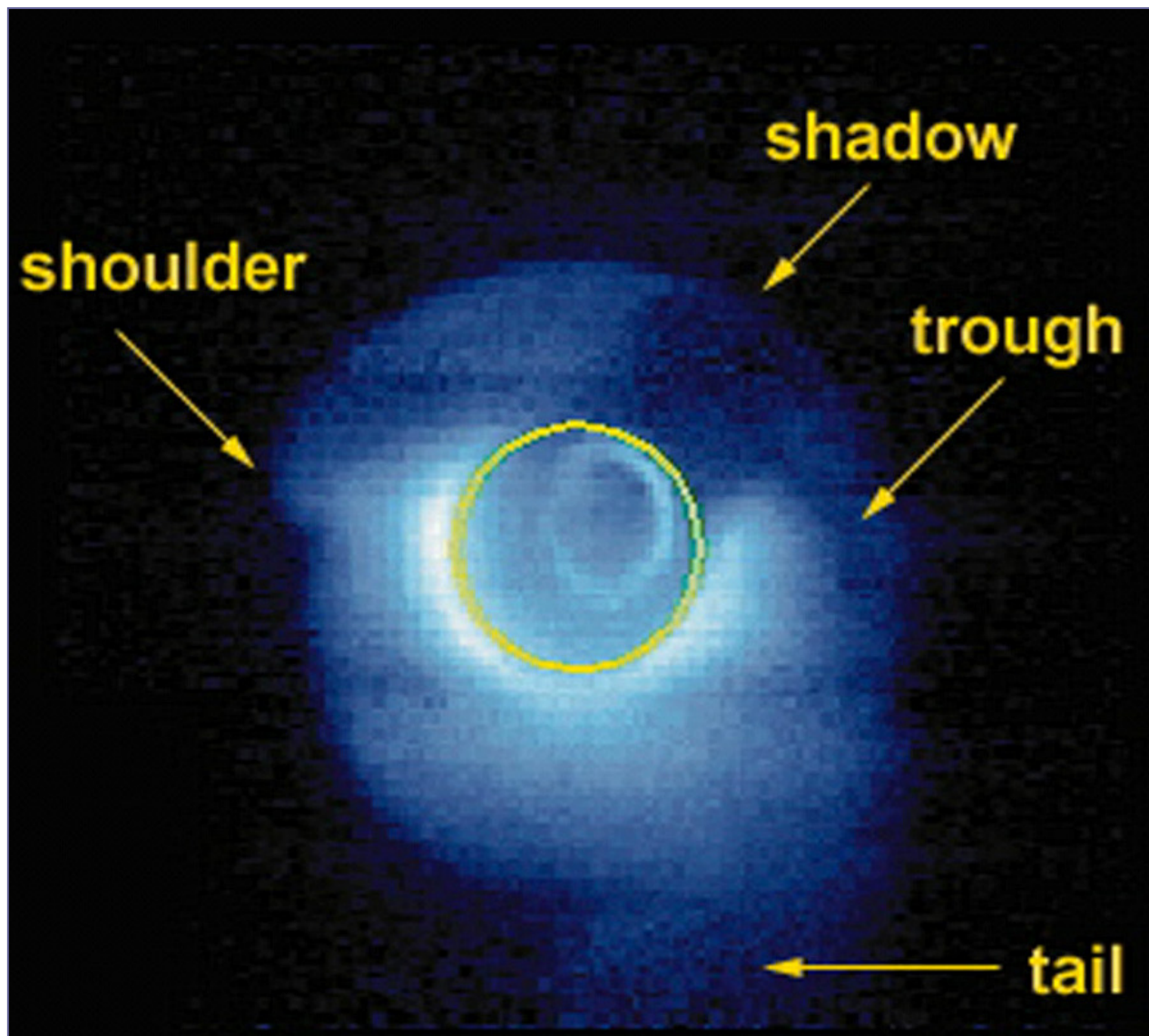
Geospace: Gigantic particle accelerator!



ΠΛΑΣΜΟΣΦΑΙΡΑ: ΚΡΥΟ ΚΑΙ ΠΥΚΝΟ ΠΛΑΣΜΑ



ΠΩΣ ΒΛΕΠΟΥΜΕ ΤΗΝ ΠΛΑΣΜΟΣΦΑΙΡΑ;

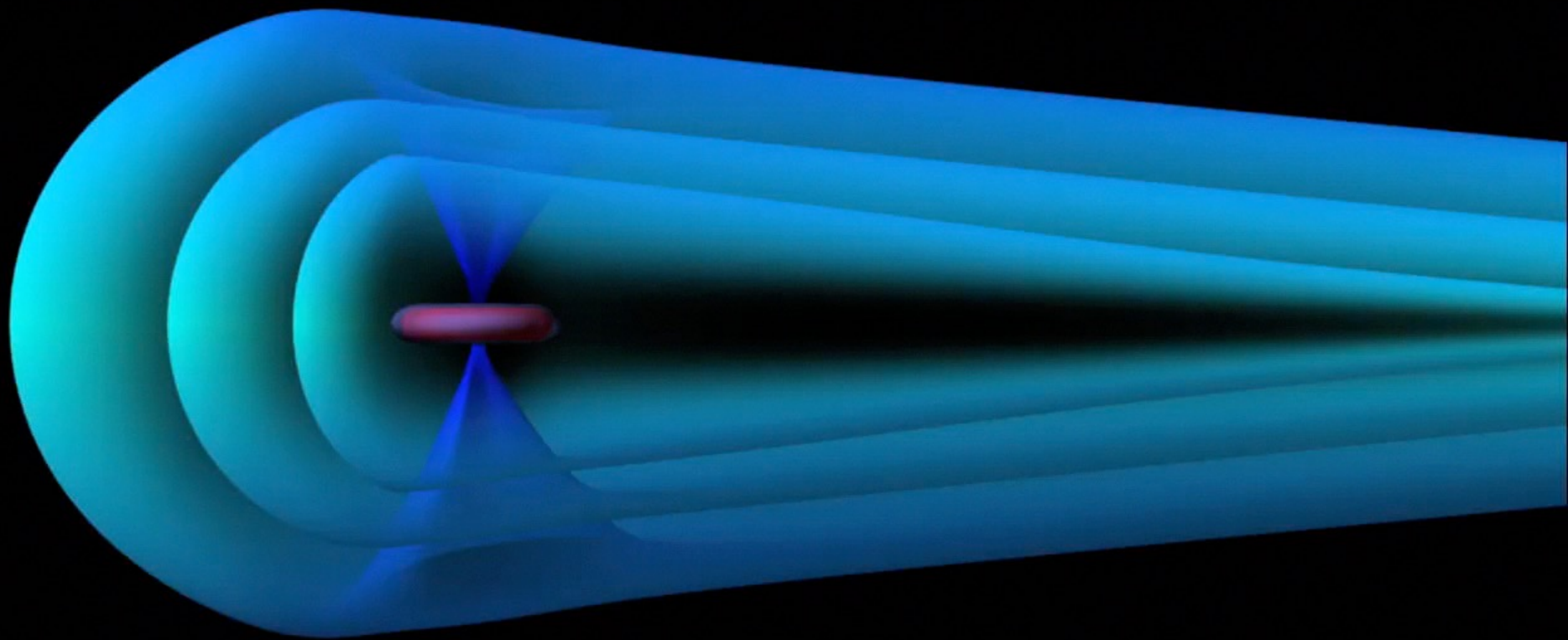


Imaging the plasmasphere

Extreme Ultraviolet Imager (EUV):

Απεικονίζει την κατανομή He^+ μέσω της εκπομπής τους στα 30.4nm.

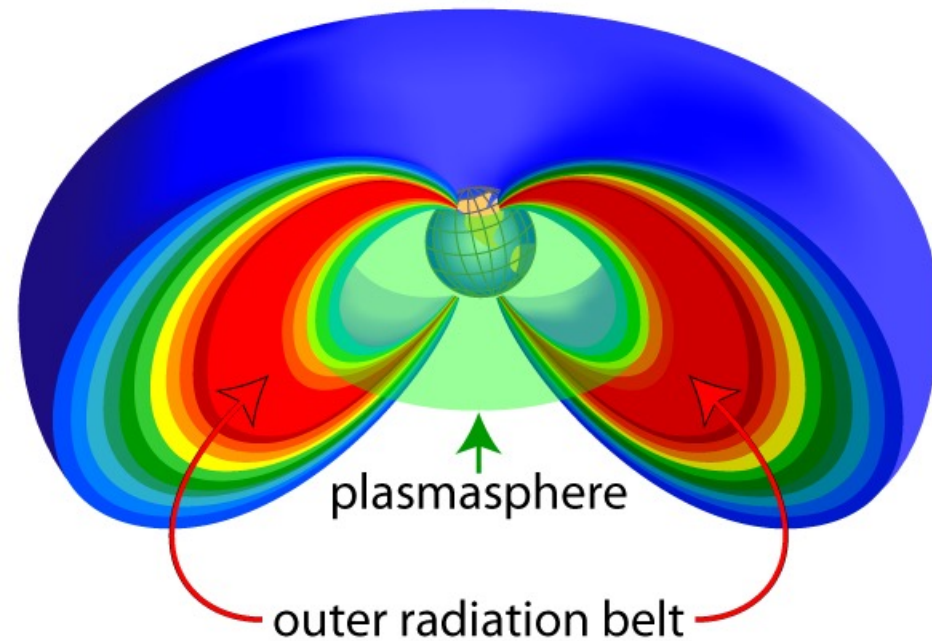
Τα ιόντα ηλίου απορροφούν την υπεριώδη ακτινοβολία του Ήλιου και την επανεκπέμπουν.



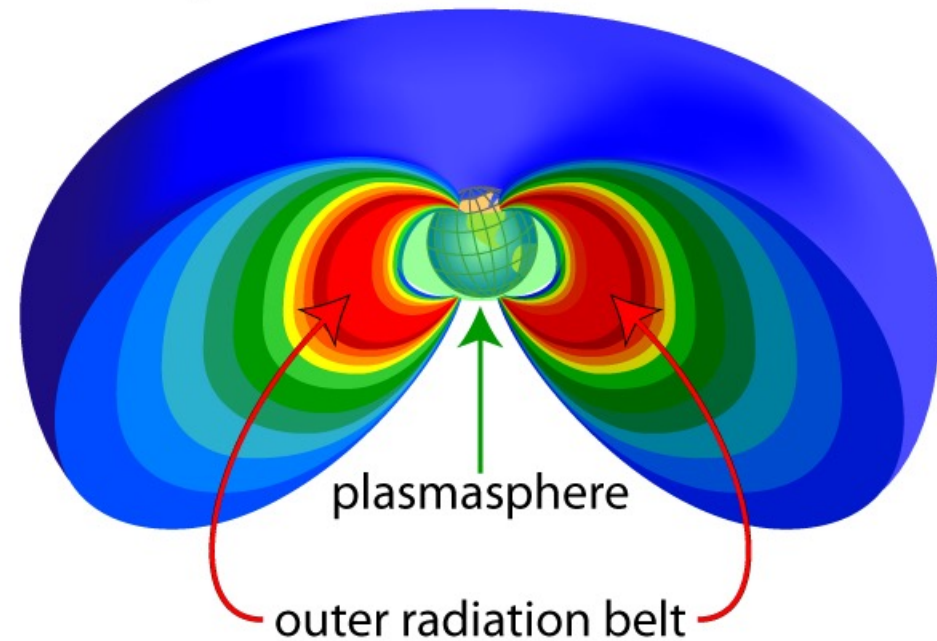


The coldest plasma controls the hottest particles


a. Normal plasmasphere/radiation belt location under typical conditions



b. Distorted plasmasphere/radiation belt during October/November 2003 storm



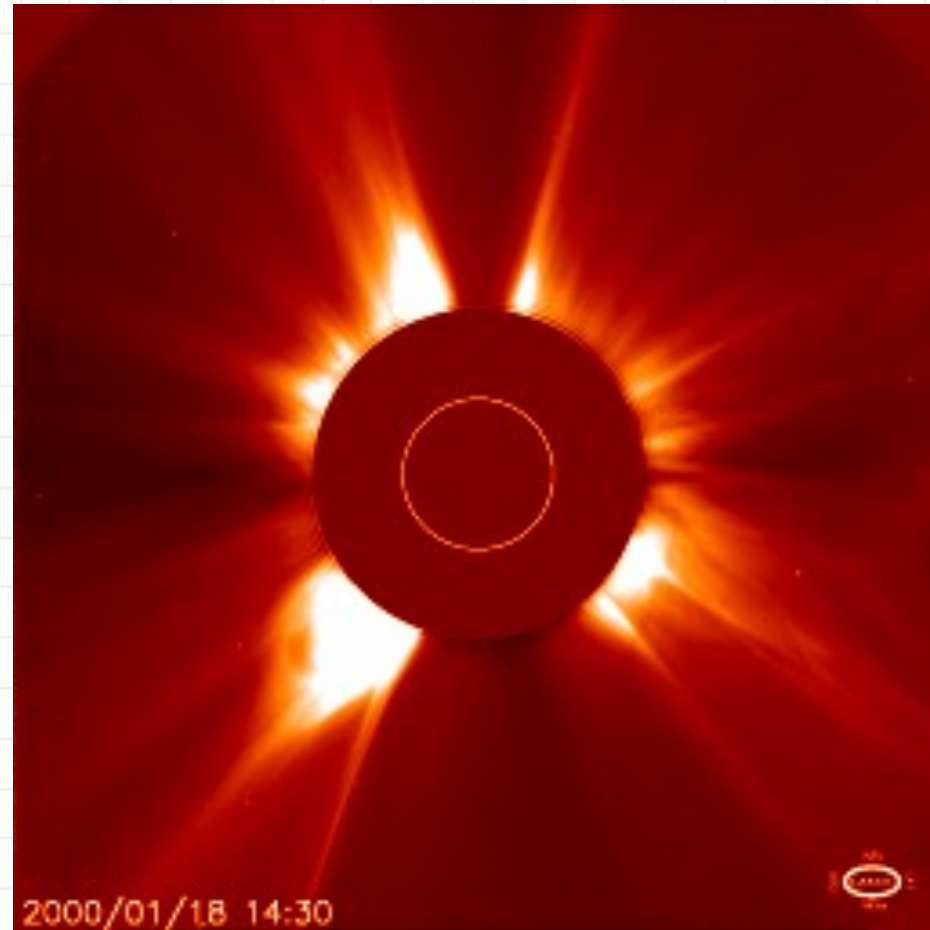
Sources and sinks of plasma in the geospace environment



Ποια είναι η πηγή του
μαγνητοσφαιρικού πλάσματος;

The Solar Source Paradigm

Το πρότυπο της ηλιακής προέλευσης



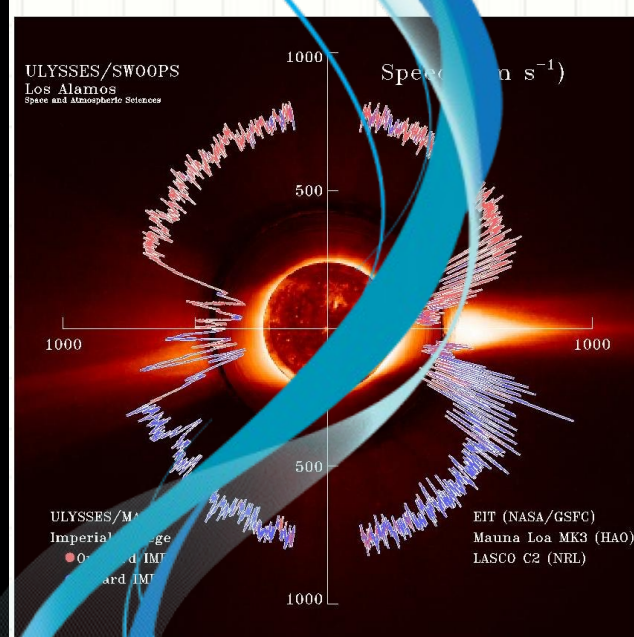
ΗΛΙΟΣ

Ηλιακός άνεμος:

Αποτελείται κυρίως από
πρωτόνια (96%),
σωμάτια άλφα (He^{2+} , 4%)
και ηλεκτρόνια

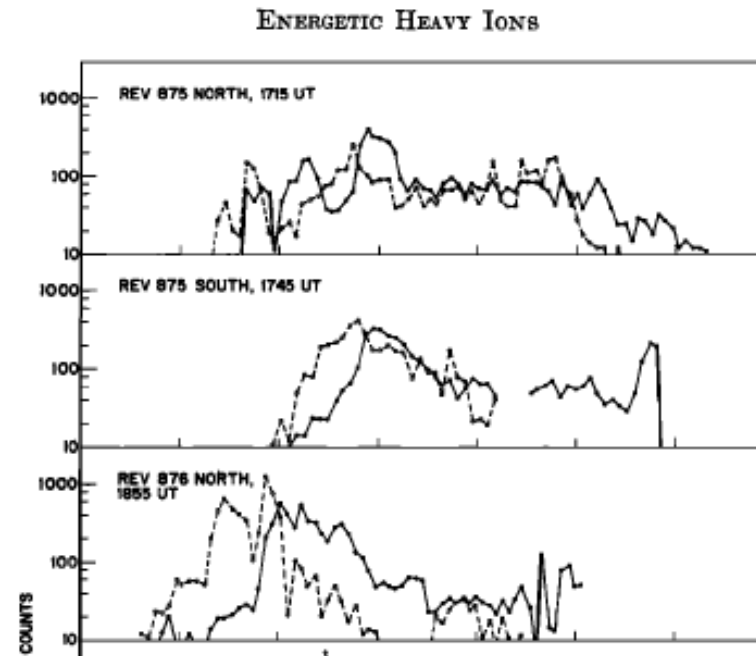
Μέσες τιμές:

- Ταχύτητα: 400 - 450 km/s
- Πυκνότητα: $\sim 5 \text{ cm}^{-3}$
- Θερμοκρασία: $\sim 10 \text{ eV}$ (10^5 K),
ως $\sim 1 \text{ keV}$



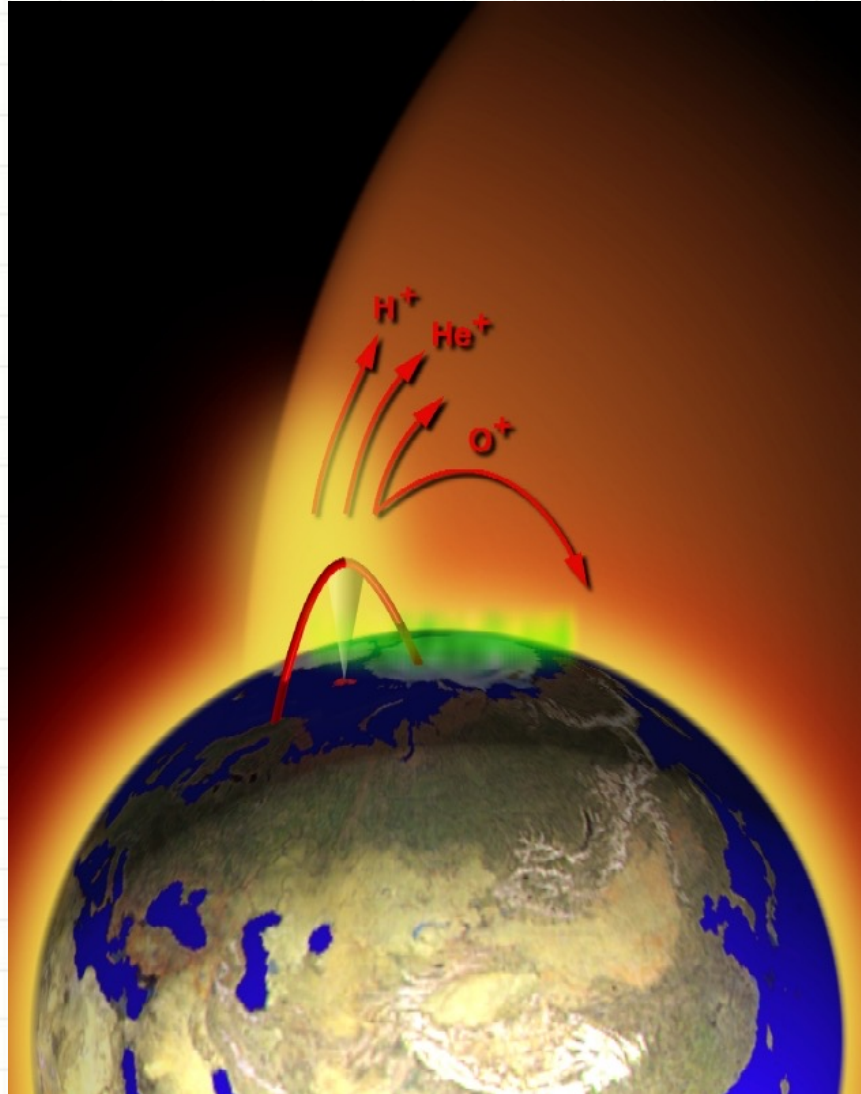
1972:

Η τεχνολογία αλλάζει το σκηνικό
Πρώτη ανίχνευση ιόντων O^+



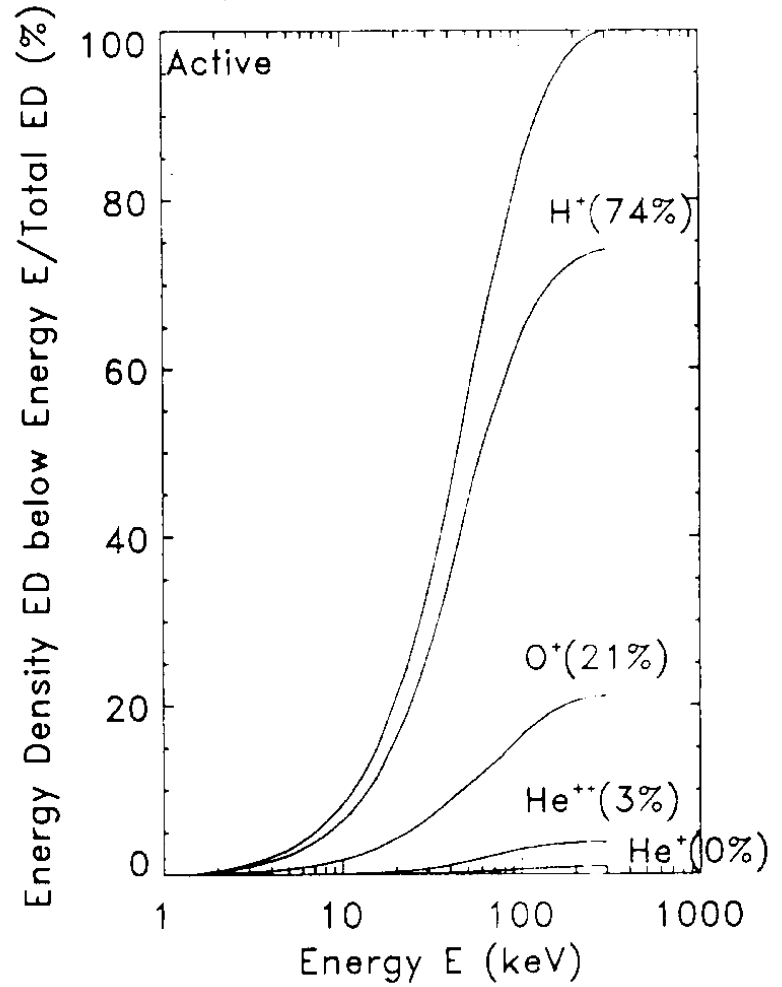
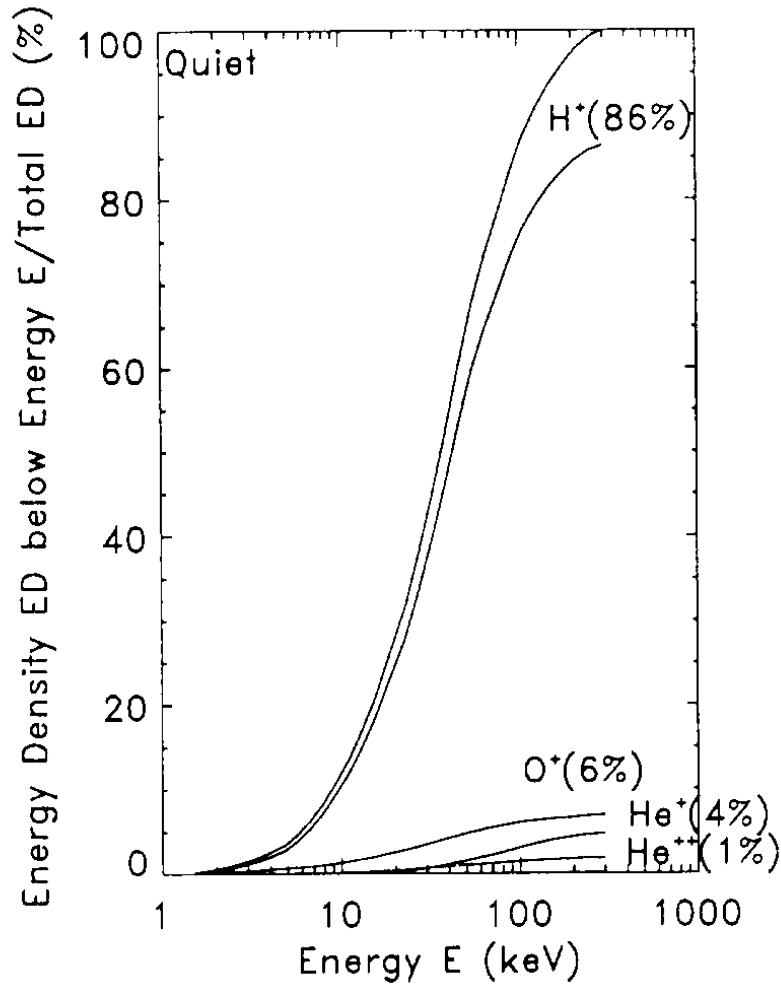
Shelley et al, 1972

Πηγή: η ιονόσφαιρα της Γης



AMPTE/CCE UMD/MPAE-CHEM

Geosynchronous altitude



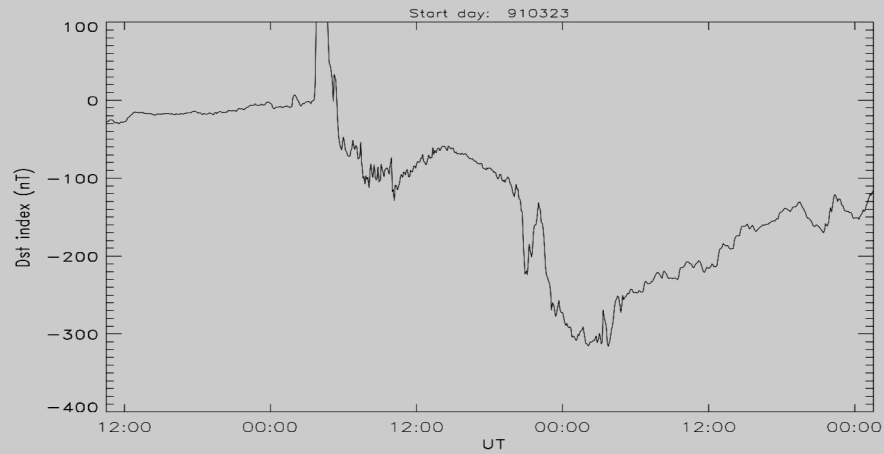
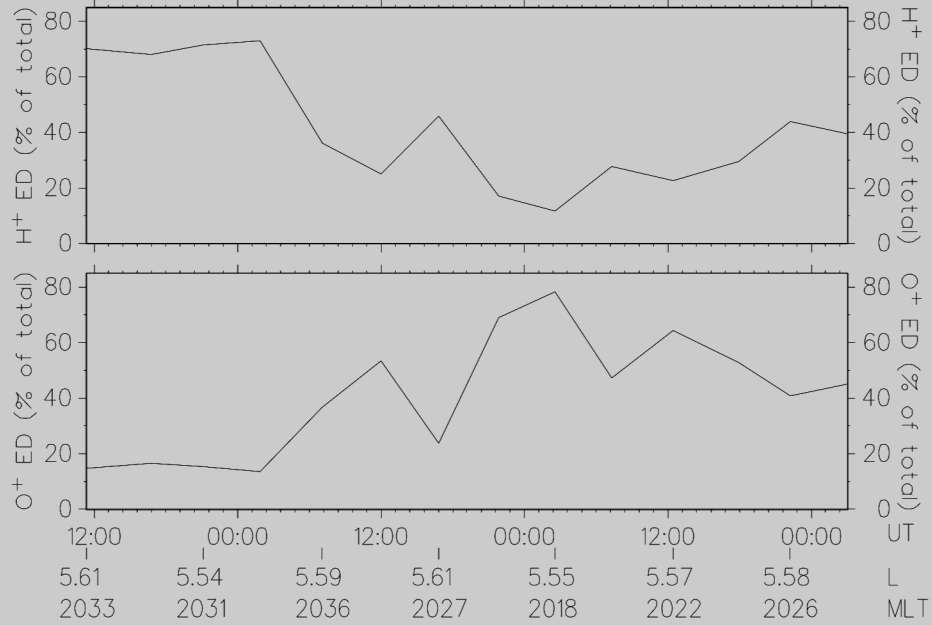
1984 - 1989

Daglis et al. 1993

CRRES orbits 0586-0592 MICS

Date: 23.03.91 DOY: 082

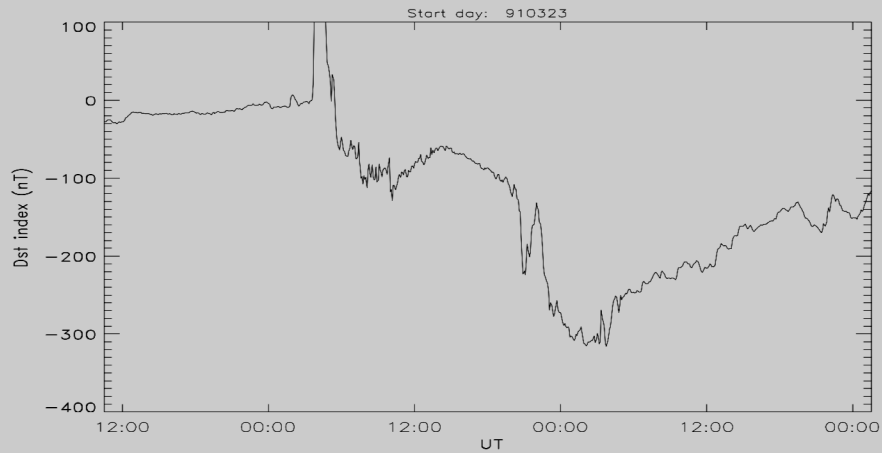
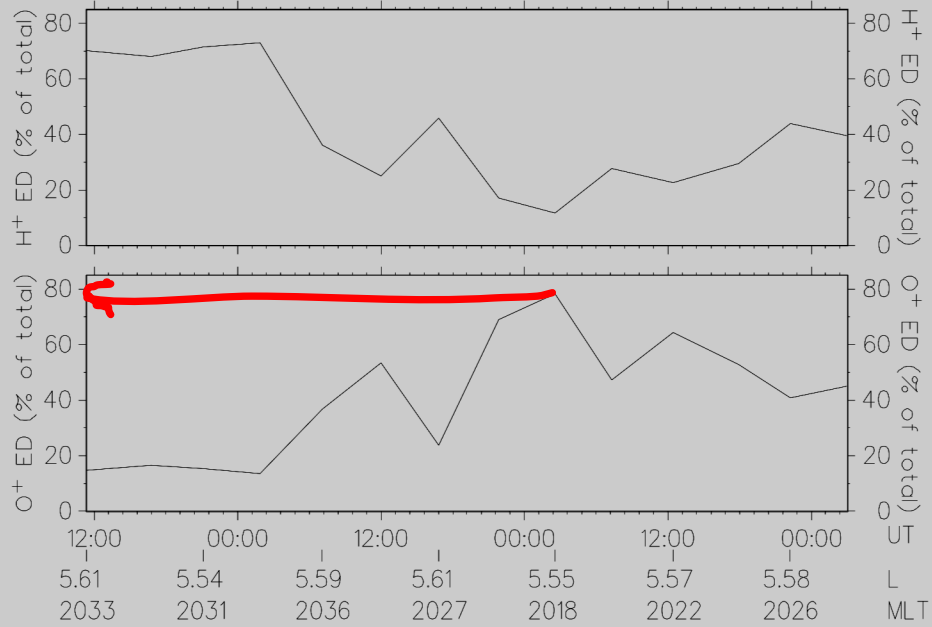
Energy range: 50.0-426.0 keV



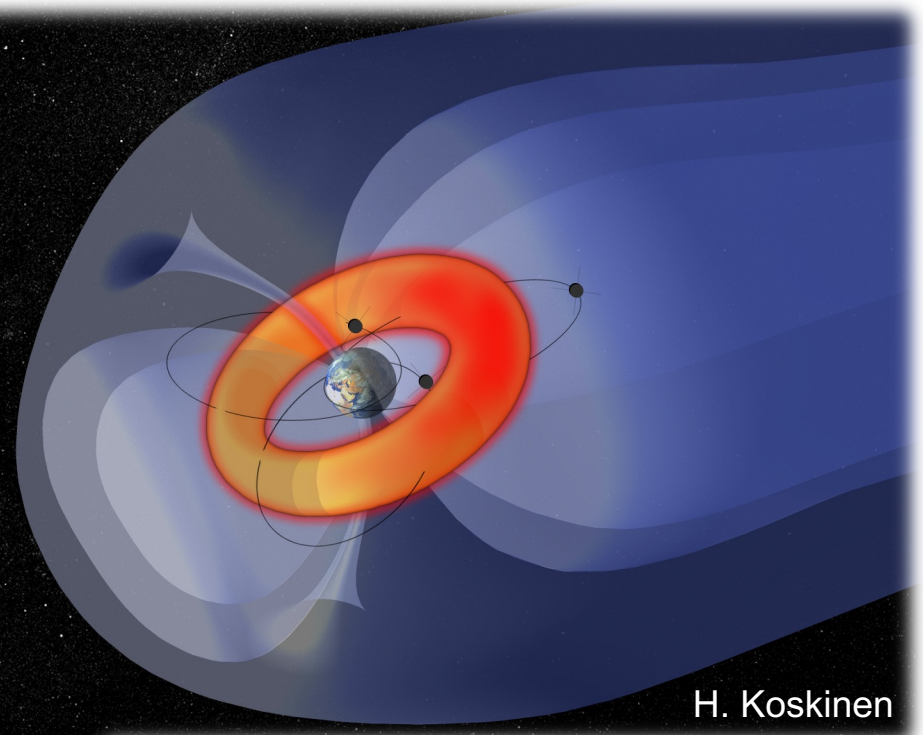
Daglis, 1997

CRRES orbits 0586-0592 MICS
Date: 23.03.91 DOY: 082

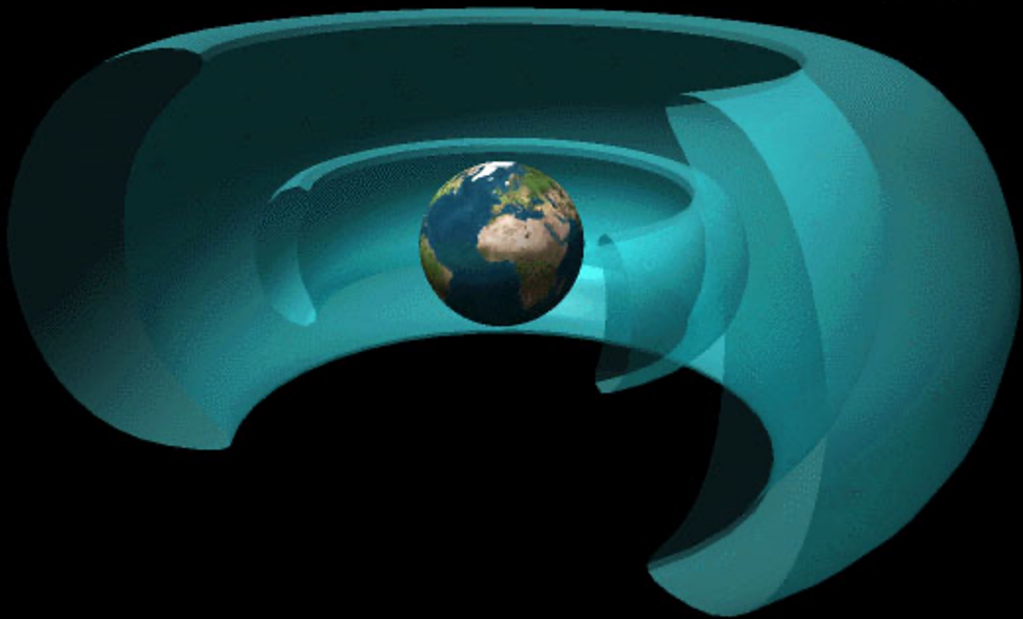
Energy range: 50.0-426.0 keV



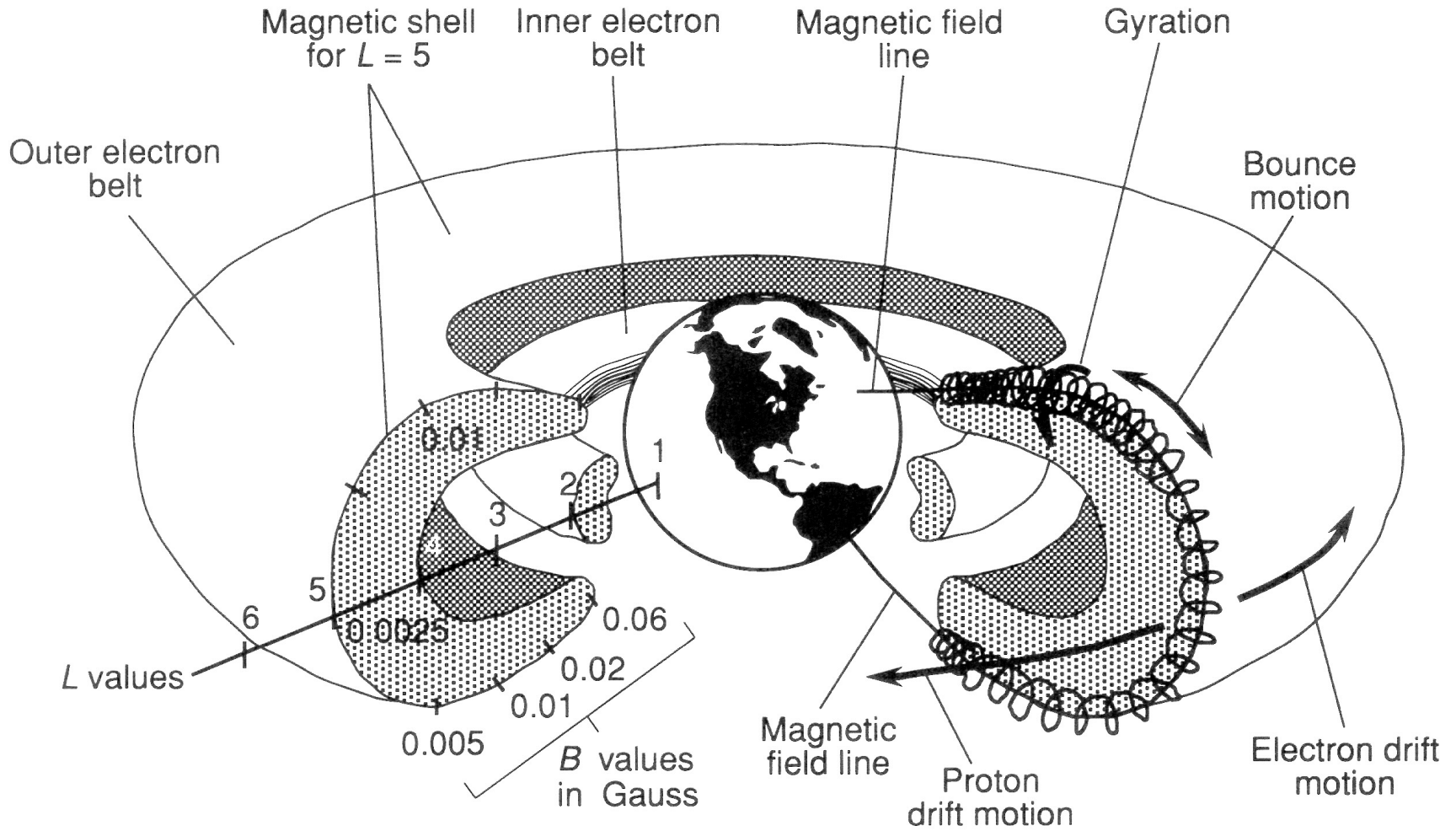
Daglis, 1997



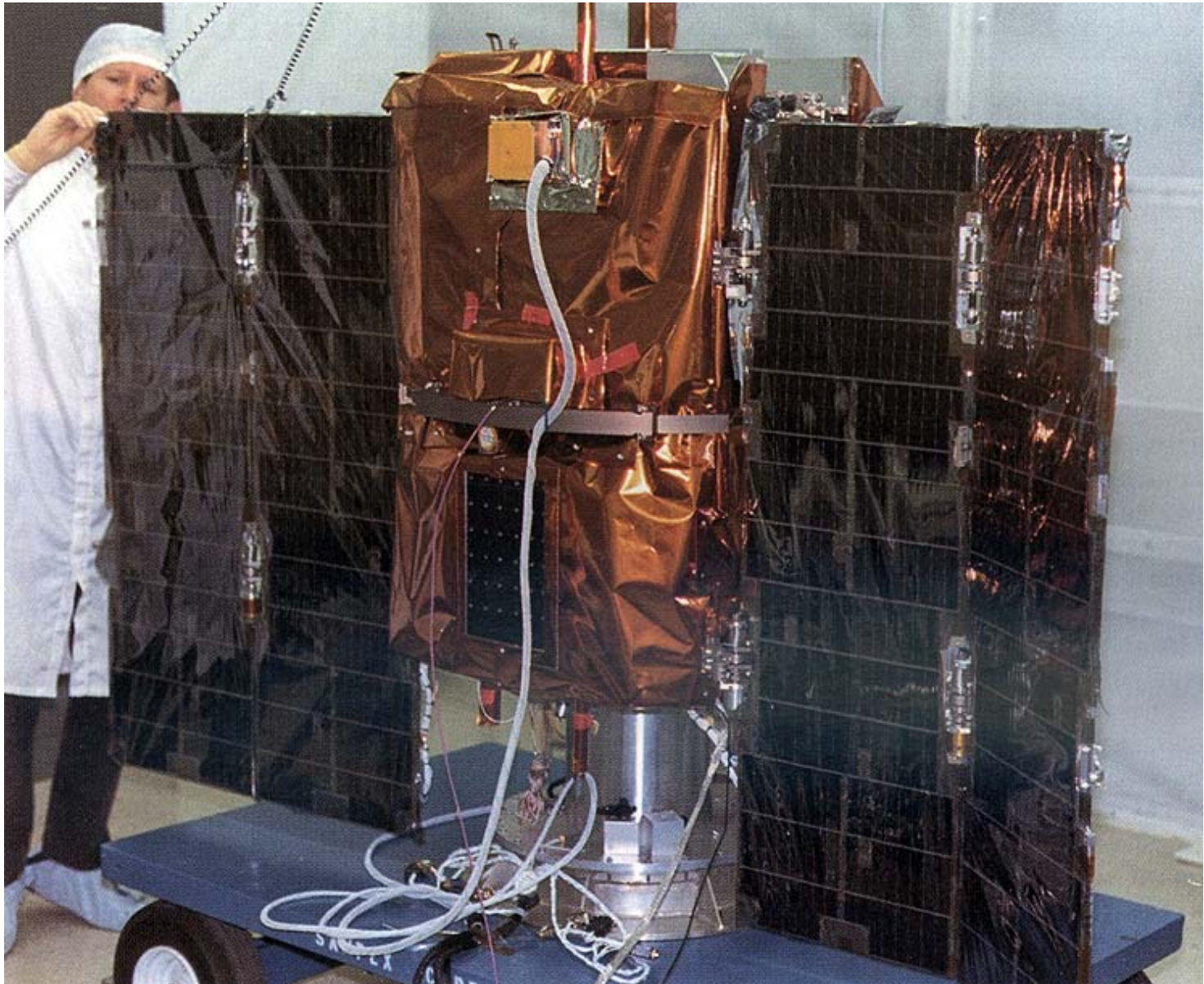
H. Koskinen



Radiation belts



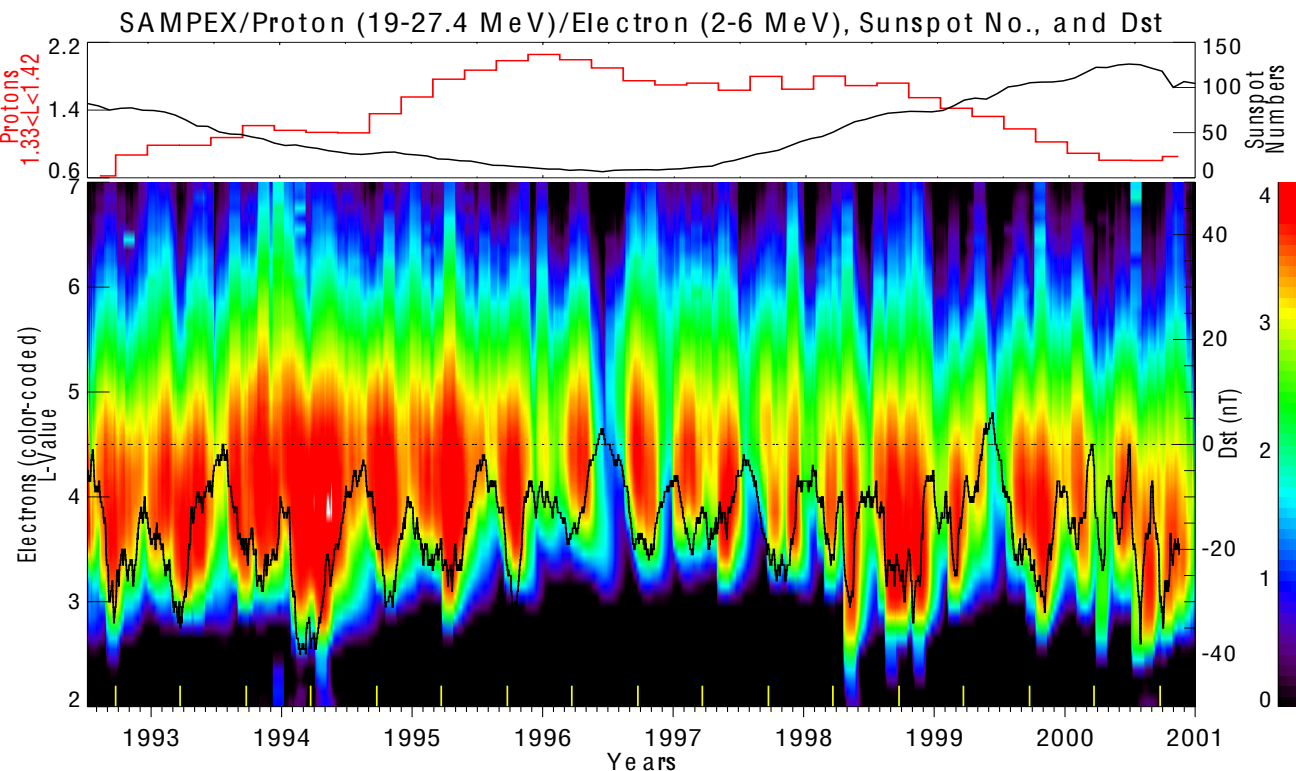
Planned: 3 years. Final: 20 years!



3/7/1992 – 30/6/2012

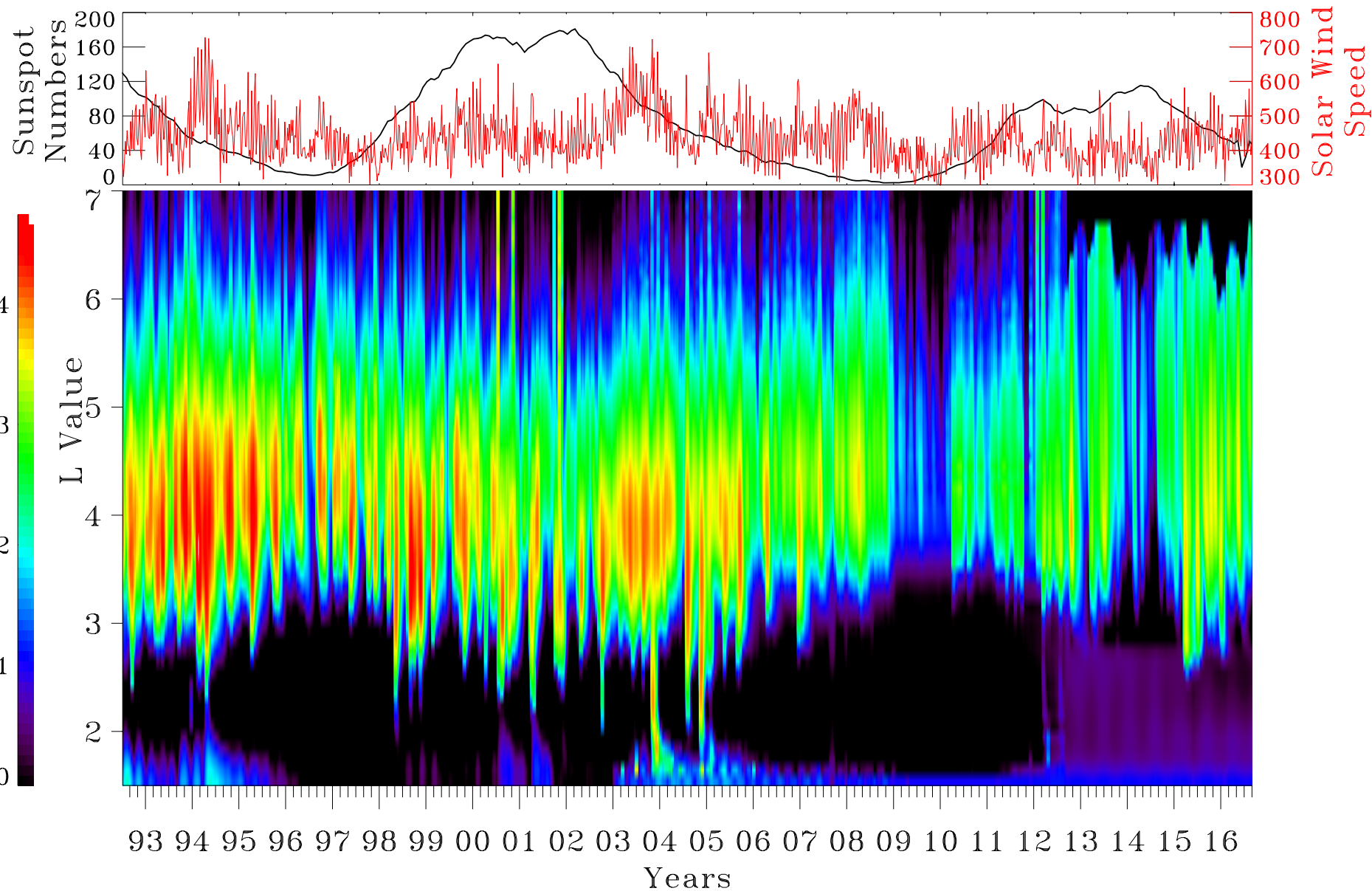
Flux variability in the radiation belts

The radiation belts exhibit substantial variation in time:



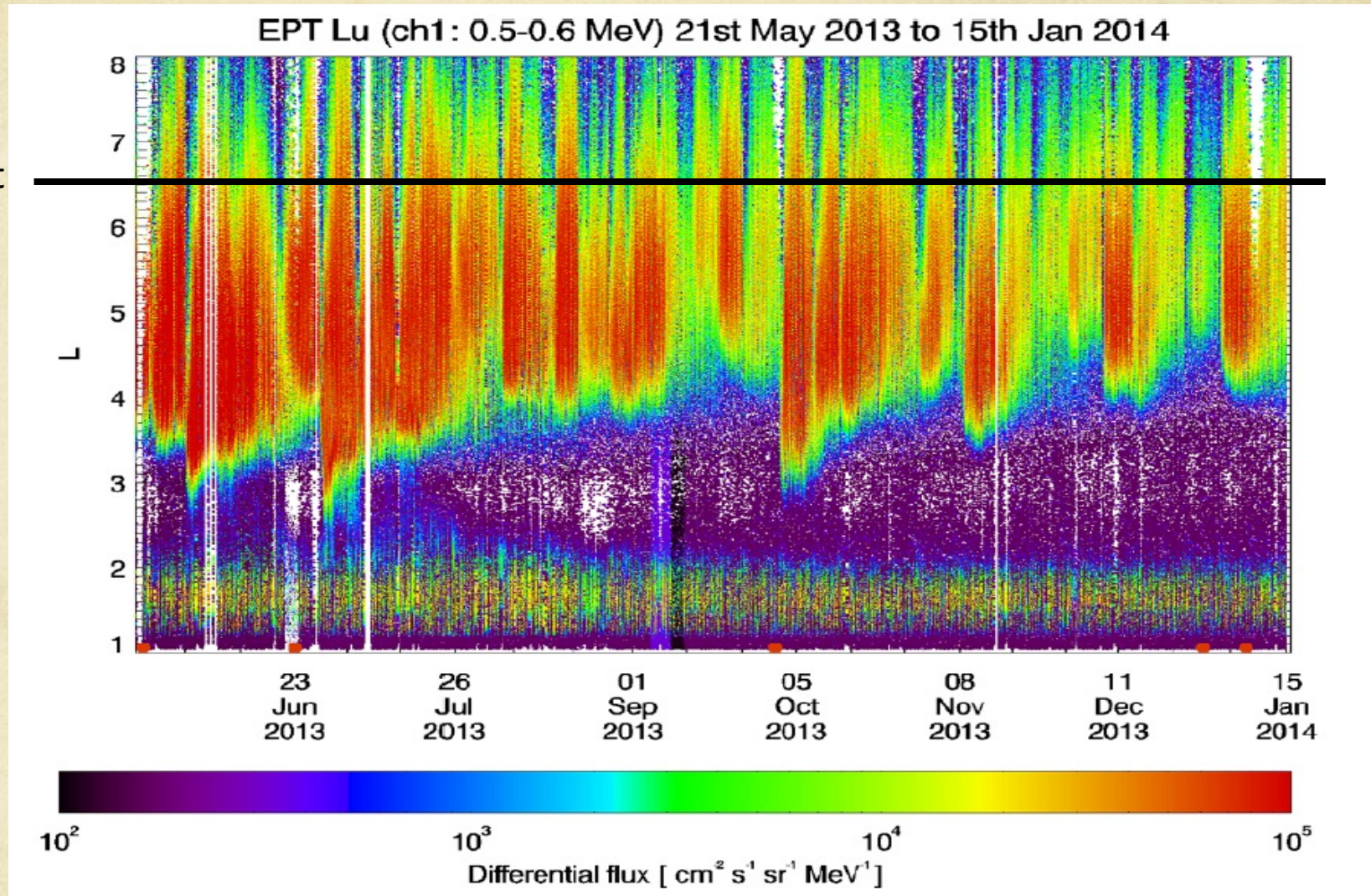
- Solar cycle: years
- Season: Months
- Solar rotation: 13-27 days
- Storm recovery: days
- Storm main phase: hours
- SSC: minutes

SAMPEX and Van Allen Probes (25 years!)



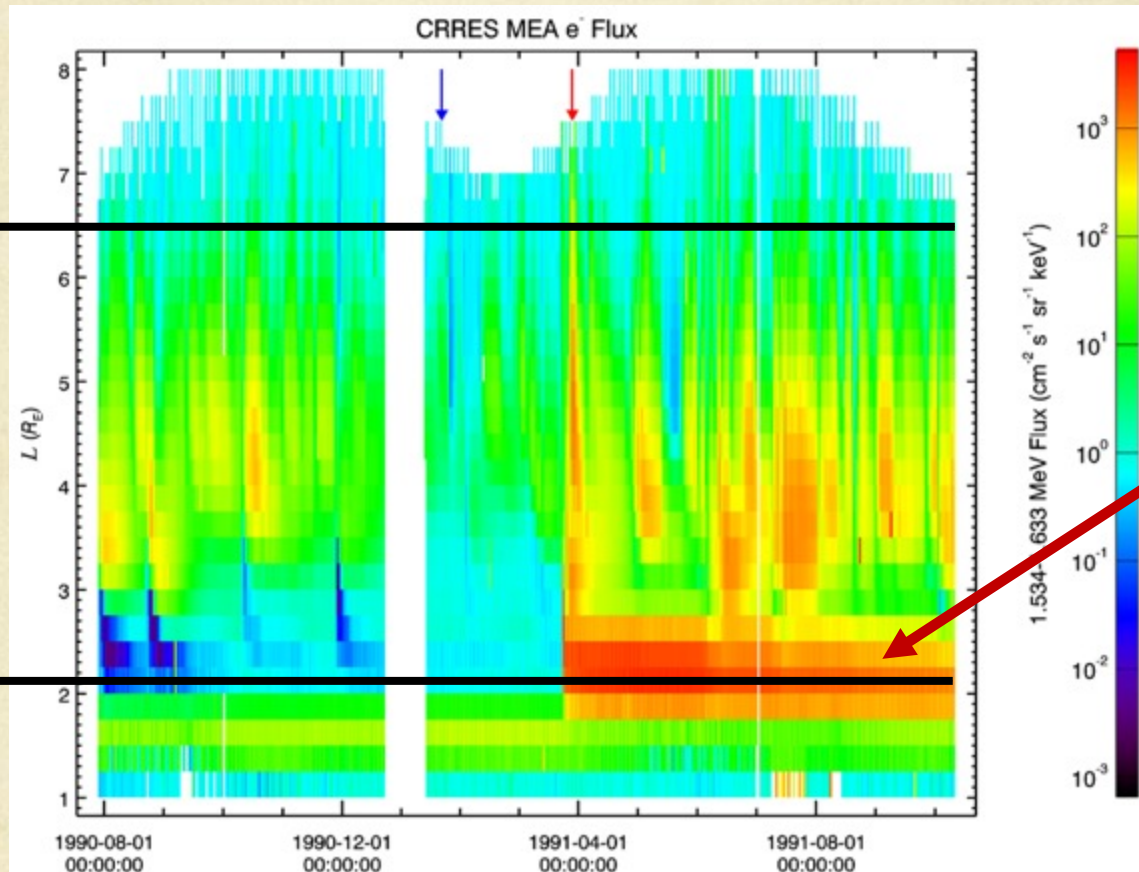
Variability of the Electron Belts - Day to Day

GEO orbit



- How do you produce high energy ($>1 \text{ MeV}$) electrons?
- What causes the variations?
- No electrons greater than $\sim 800 \text{ keV}$ in the inner belt

Variability of the Electron Belts – CME/Shock Compression



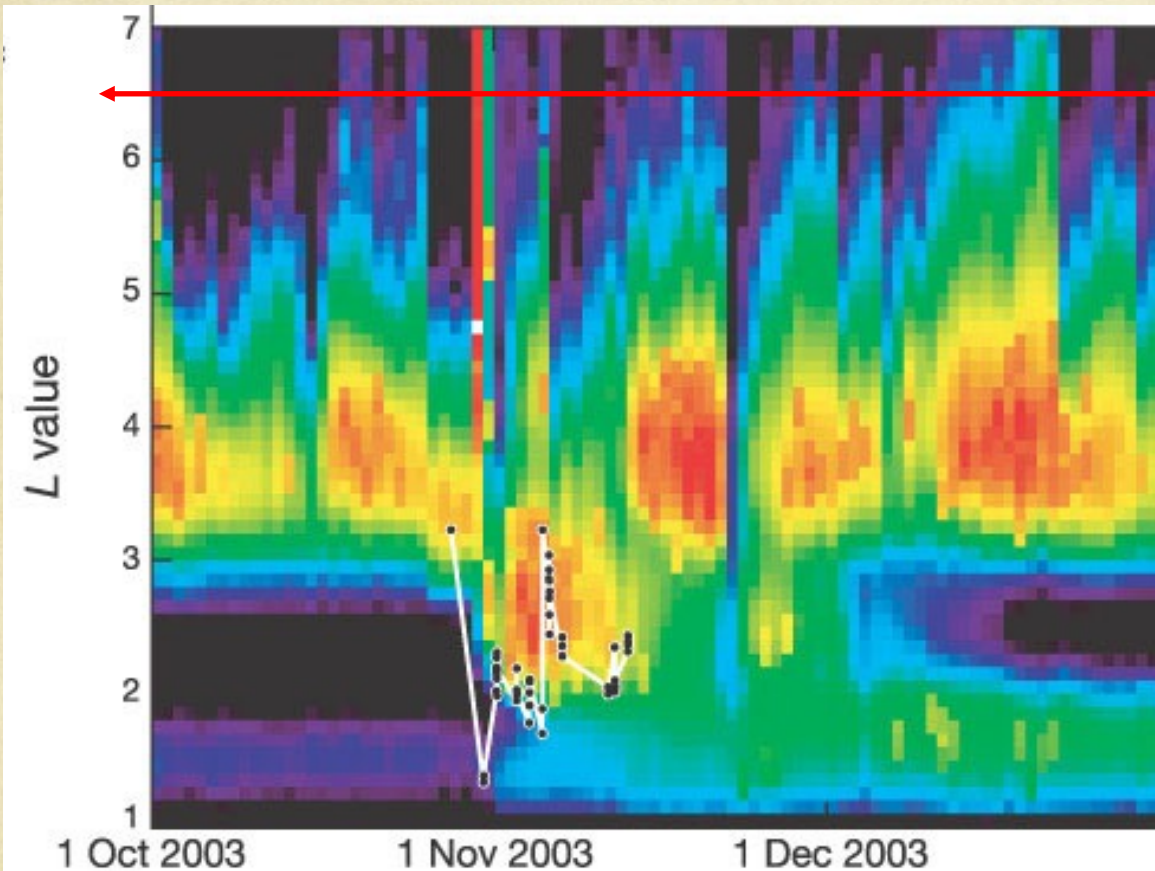
GEO orbit

8,000 km Slot region

- New Electron Belt Formed in 2 Minutes
- Slot region 'filled-in'
- Decay timescale ~ year

Variability of the Electron Belts – Major Geomagnetic Storms

Baker et al. Nature (2004)



GEO orbit

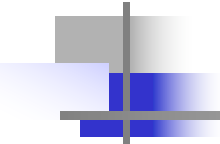
Halloween storms 23
Oct to 6 Nov 2003

- 47 satellites reported malfunctions
- 1 total loss
- 10 satellites – loss of service for more than 1 day

- Electrons at much lower L
- Decay time ~ year



Γεωδιασθημικές μαγνητικές καταγίδες

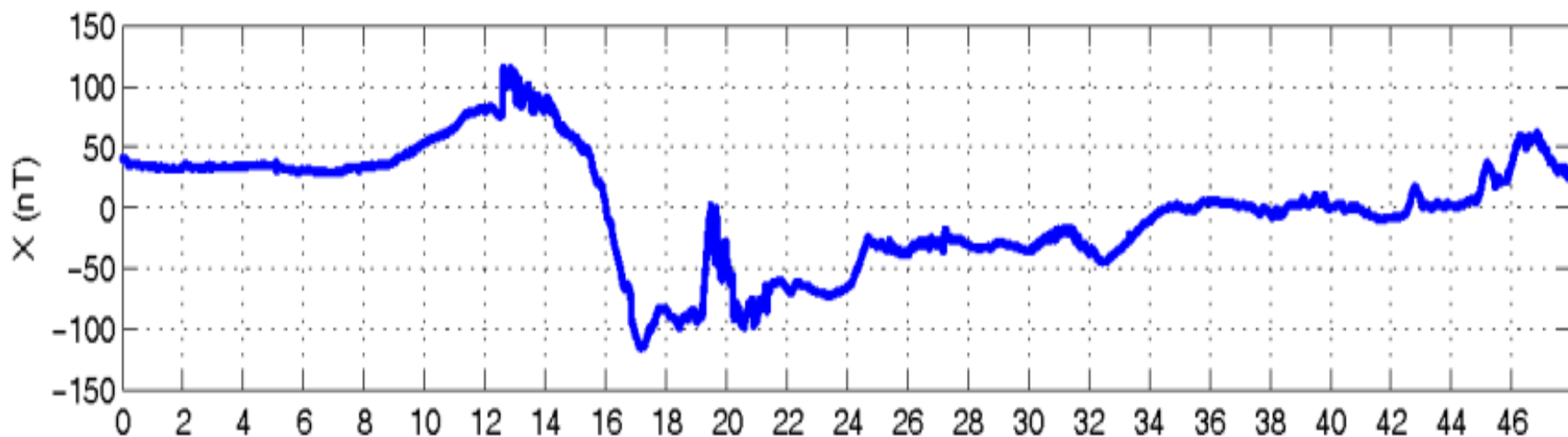
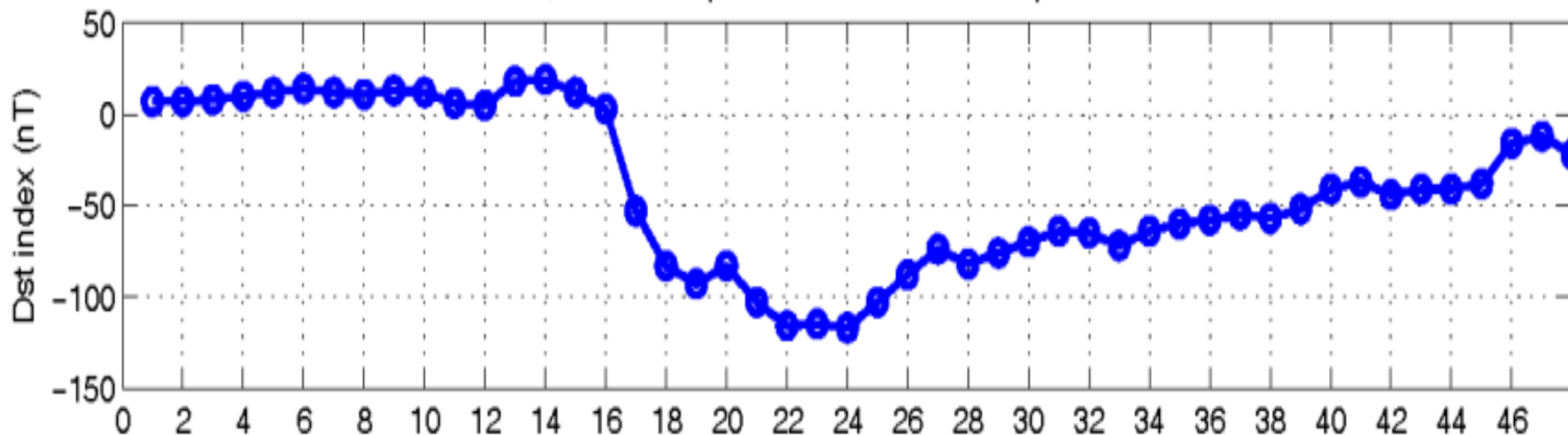


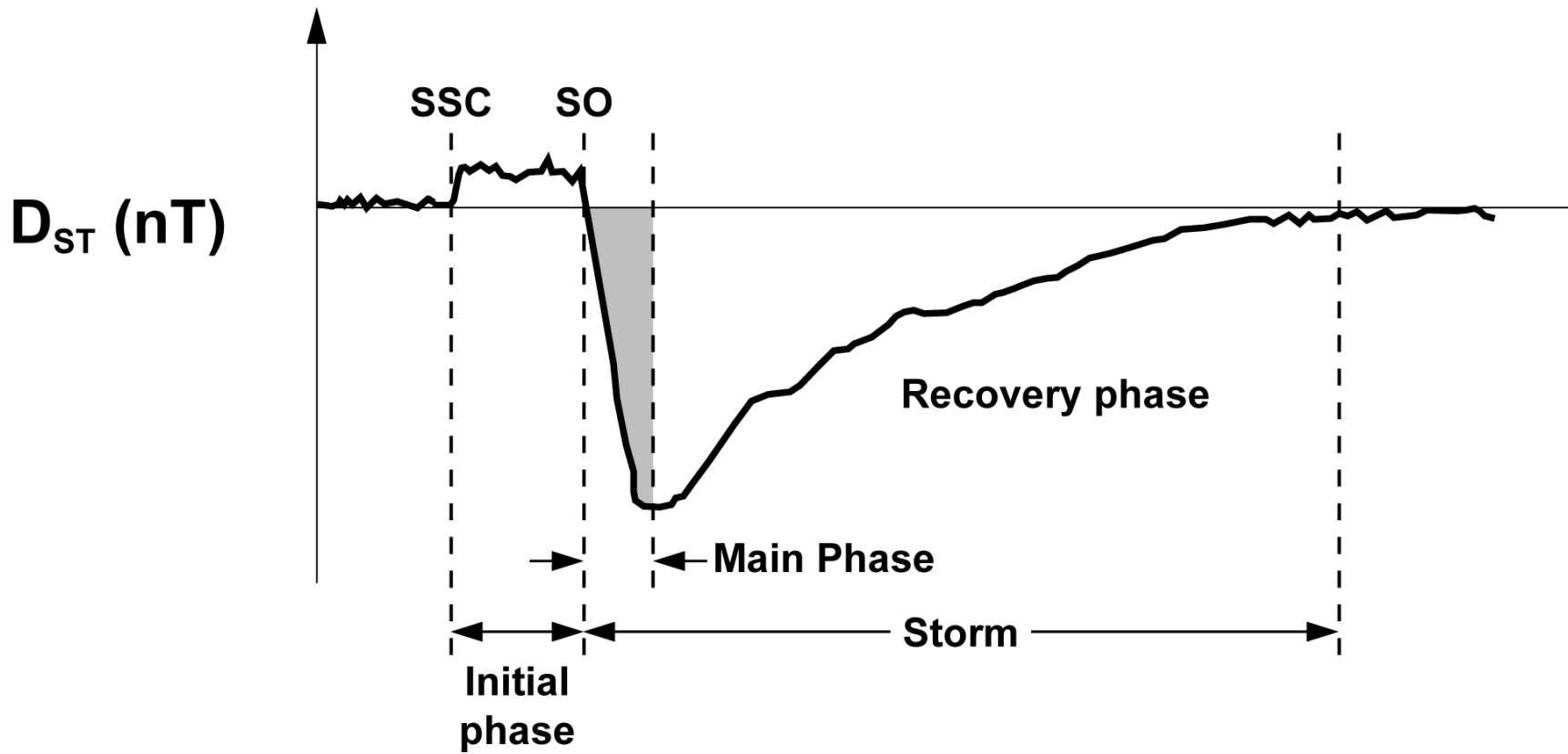
Καθοριστικό χαρακτηριστικό
της μαγνητικής καταιγίδας:

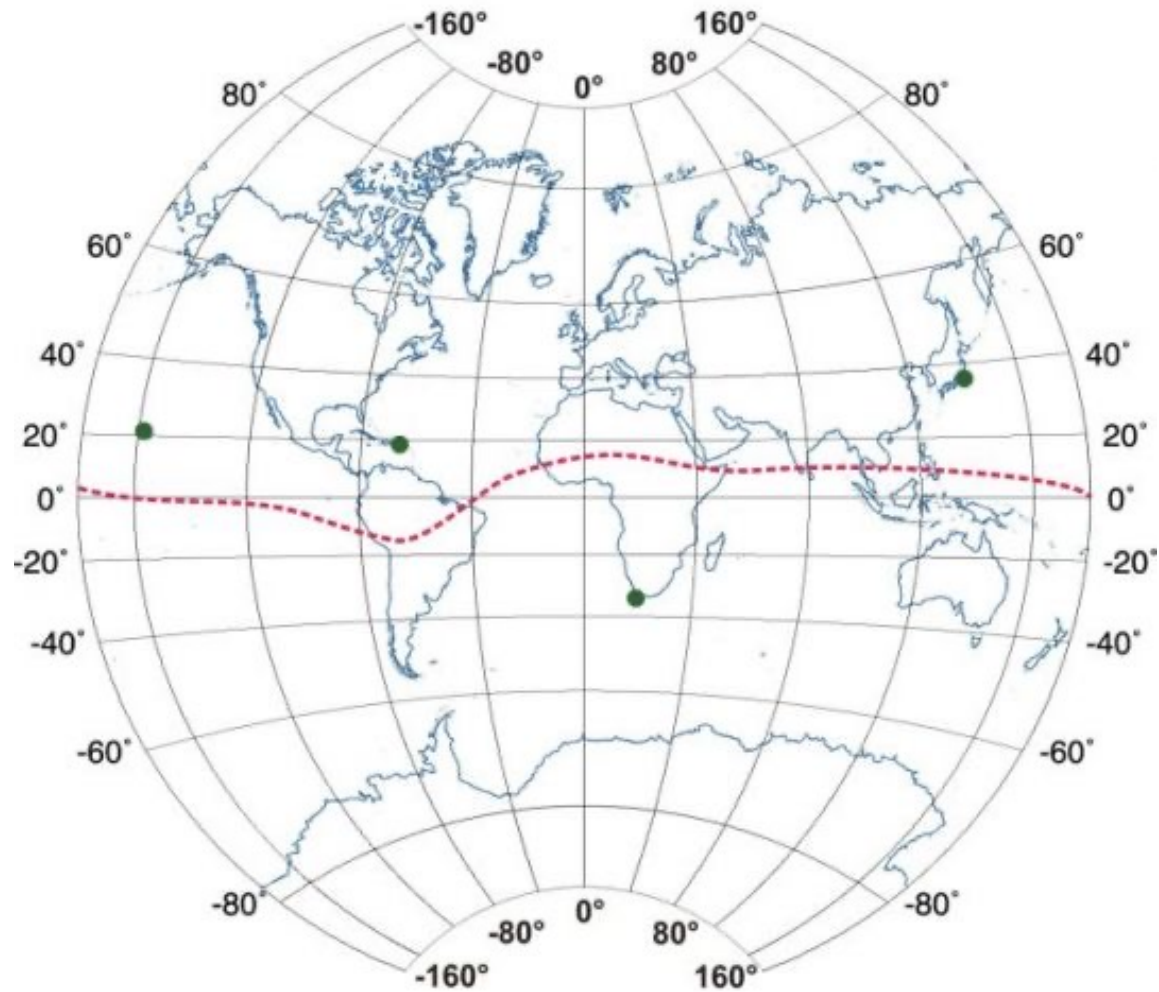
Παγκόσμια Μείωση
της έντασης
του Γεωμαγνητικού Πεδίου

Μαγνητικές καταιγίδες

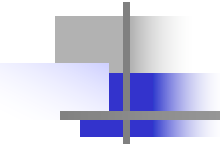
VELIES, from 26-Sep-2011 00:00:00 to 27-Sep-2011 23:59:59







Honolulu, San Juan, Hermanus, Kakioka



Καθοριστικό χαρακτηριστικό
της μαγνητικής καταιγίδας:

Παγκόσμια Μείωση του Γεωμαγνητικού Πεδίου

που μπορεί να ερμηνευθεί με το

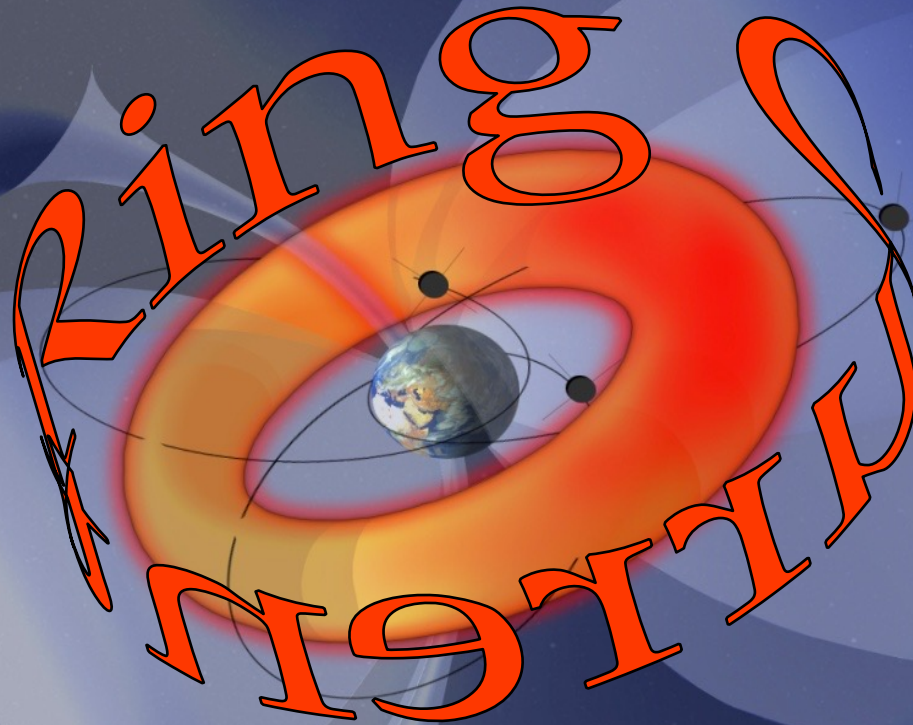
διαμαγνητικό αποτέλεσμα

ενός γιγάντιου

κυκλικού/δακτυλιοειδούς ρεύματος

που ρέει στο διάστημα γύρω από τη Γη

The Ring Current



A golden ring, similar to the One Ring, is shown against a dark, starry background. The ring is inscribed with glowing yellow Elvish script. Inside the ring, a diagram of a solar system is visible, featuring a central red star, a blue and white planet (Earth) on an inner orbit, and a black dot on an outer orbit. The text "One Ring to rule them All" is overlaid in the center of the ring.

One Ring to rule them All

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*,
Astrophysics and Space Science Library Vol. 32, 1972

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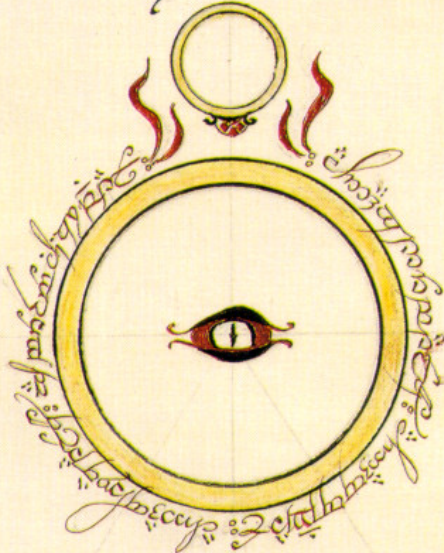
Vasyliunas, in *Earth's Magnetospheric Processes*
Astrophysics and Space Science Library Vol. 32

1972

THE LORD OF THE RINGS

PART
I

The Fellowship



of the

Ring

by

J.R.R. TOLKIEN

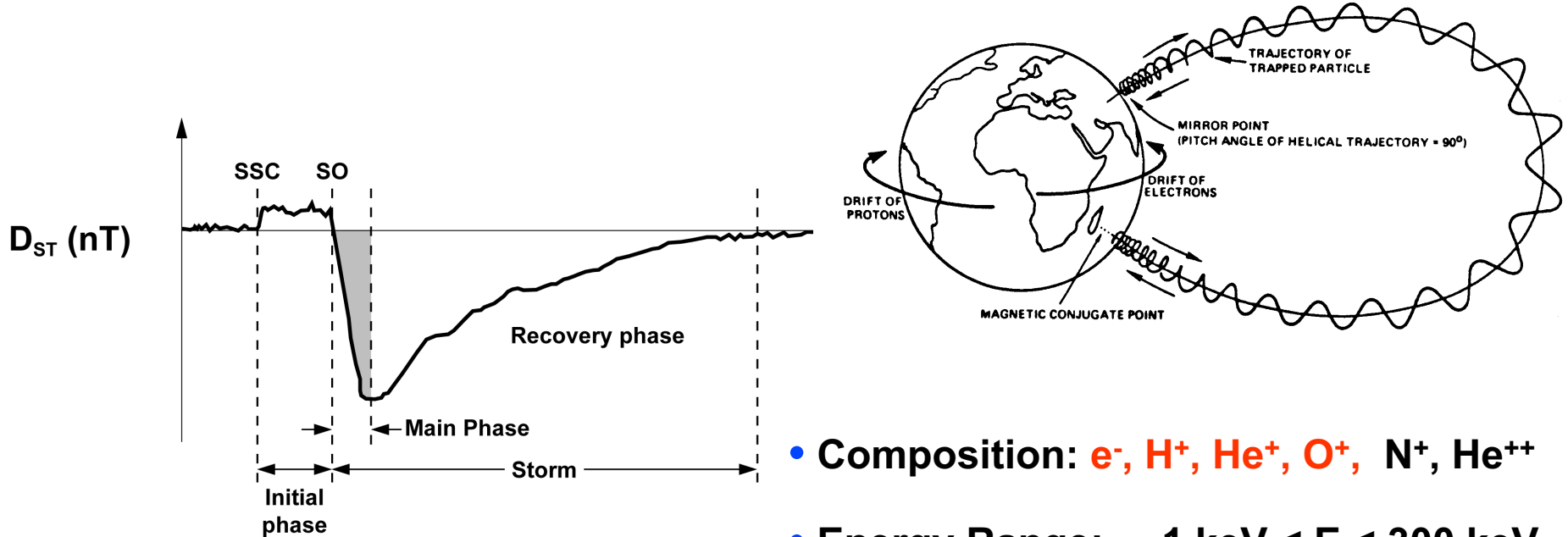
One Ring

John Ronald Reuel Tolkien

Κυριότερα χαρακτηριστικά του:

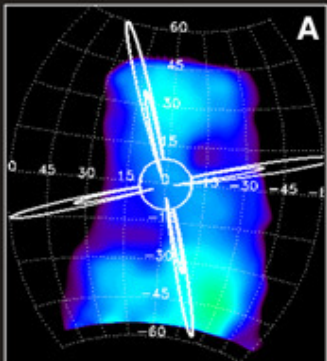
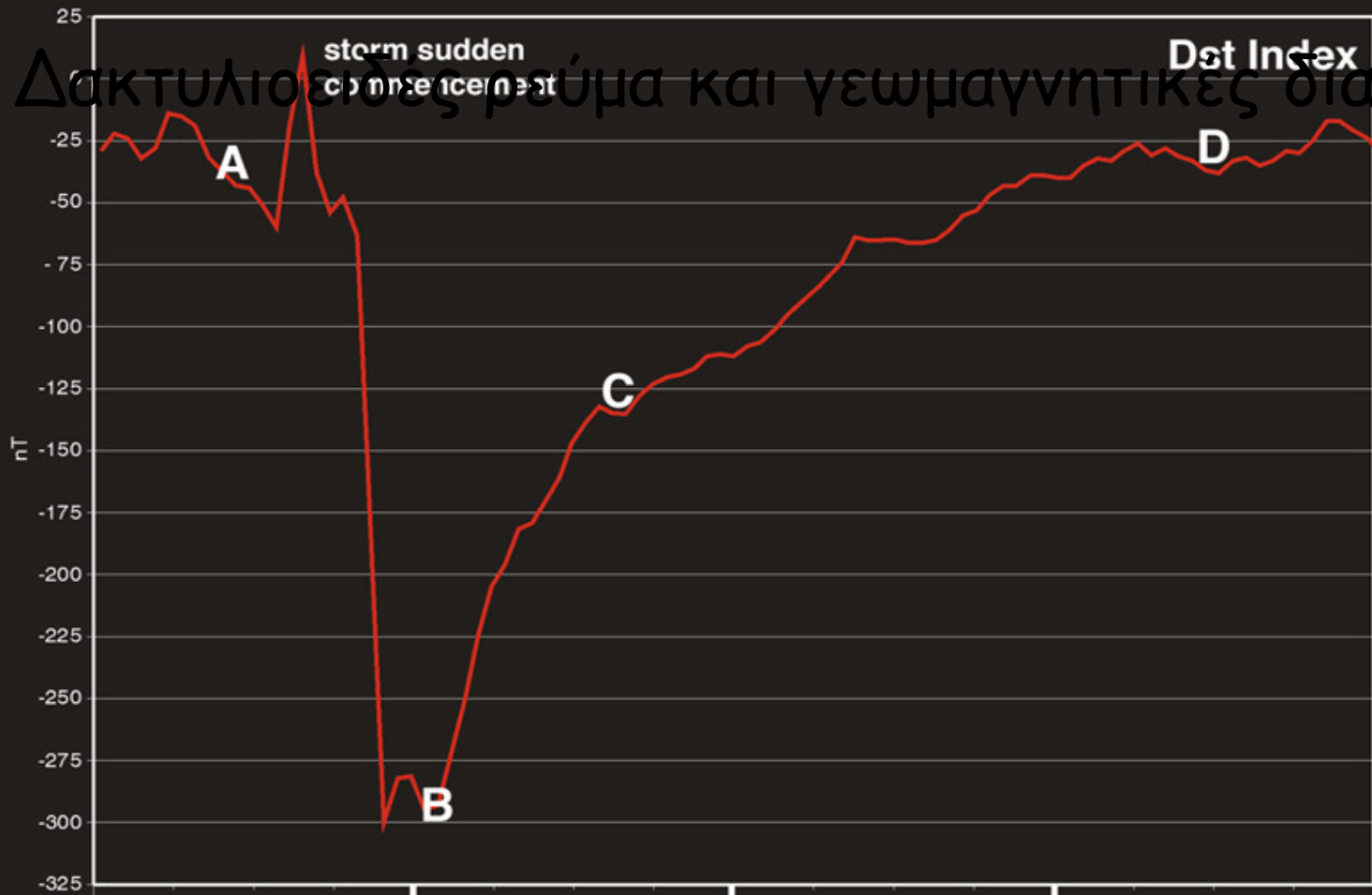
- Current carried mainly by ions (H^+ , O^+ , He^{++} , He^+) in the energy range ~ 10 keV to a few 100s keV
- Bulk of energy within 50-100 keV
- Spatial extent: 2-9 R_E (geocentric)
- Maximum intensity at 3-5 R_E (geocentric)

Geomagnetic Storm Ring Current

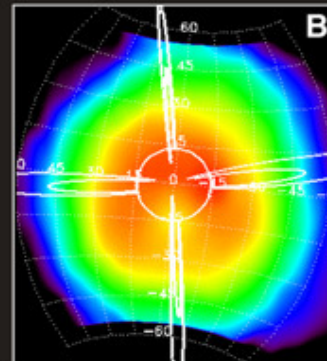


- **Composition:** e^- , H^+ , He^+ , O^+ , N^+ , He^{++}
- **Energy Range:** $\sim 1 \text{ keV} < E < 300 \text{ keV}$
- **Location:** $\sim 2 < L < 8$
- **Energy Density:** $\sim 10 - 1000 \text{ keV/cm}^3$

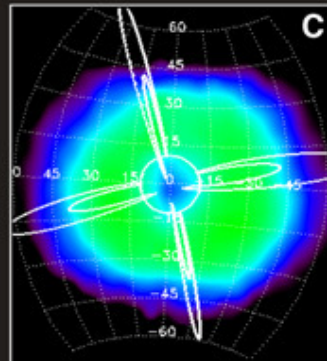
Δακτυλιοειδές ρεύμα και γεωμαγνητικές διαταραχές



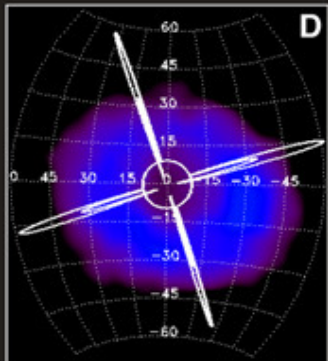
pre-storm



main phase



early recovery



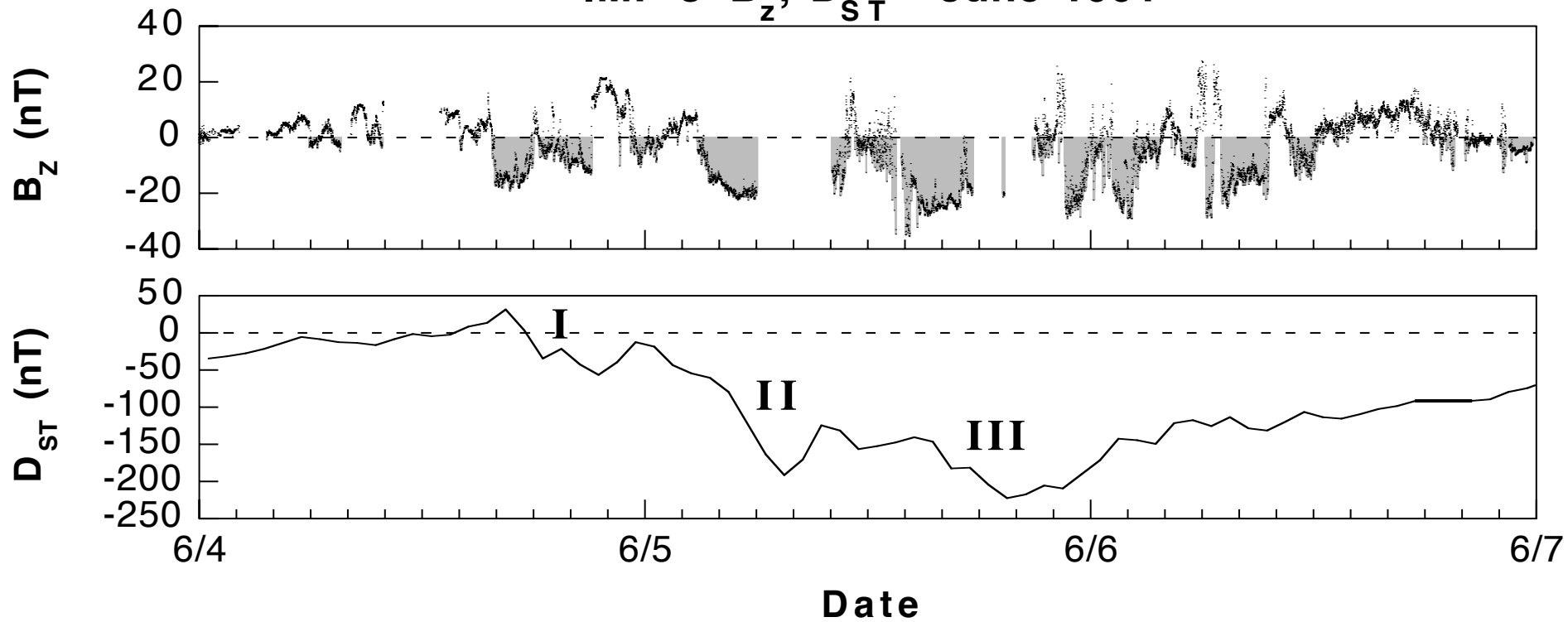
late recovery

«Προαπαιτούμενο» καταιγίδων

Ισχυρό νότιο διαπλανητικό μαγνητικό πεδίο
μεγάλης διάρκειας (= πολλές ώρες)



IMP-8 B_z , D_{ST} - June 1991



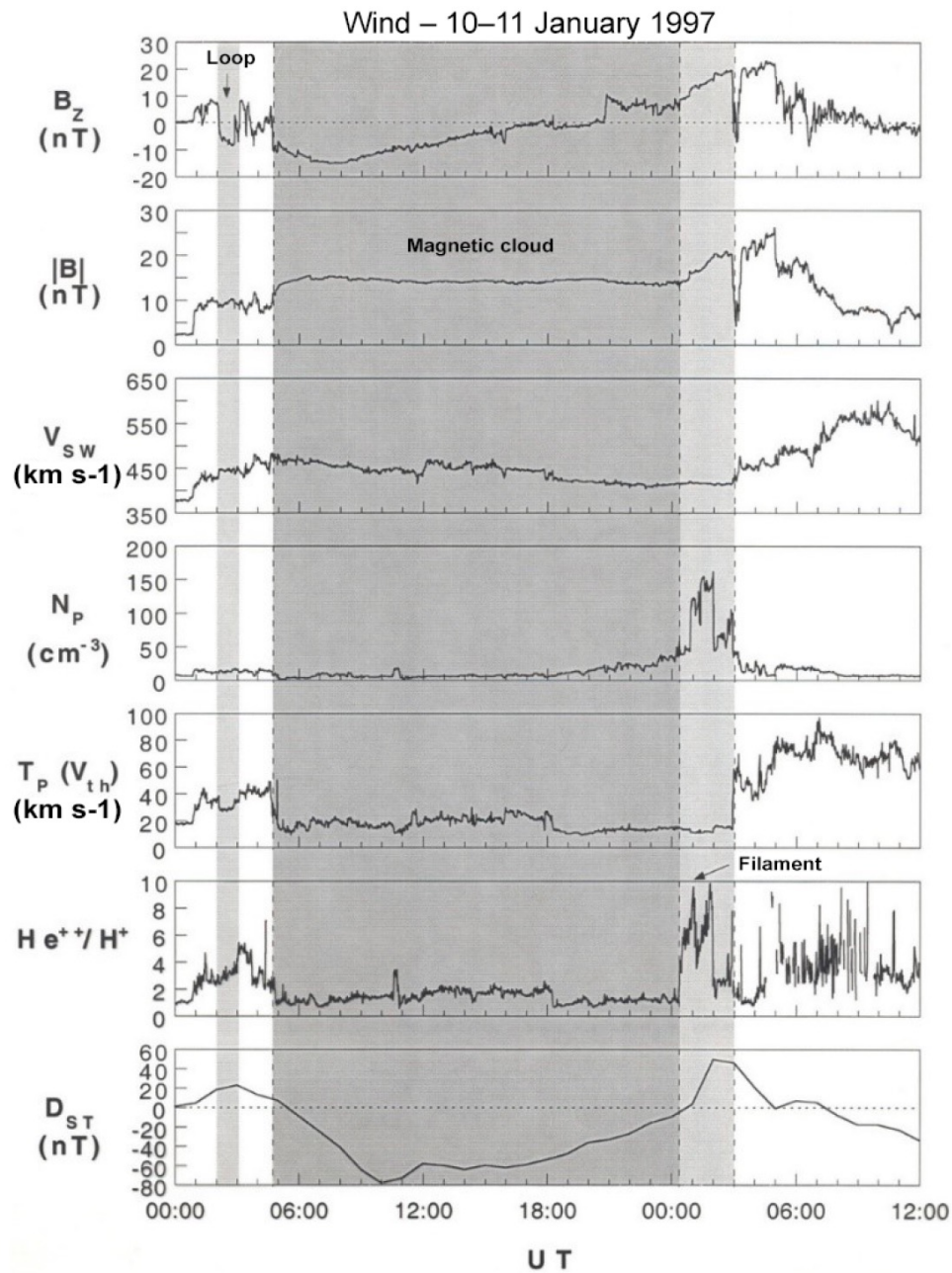


Figure 3. An ICME detected at 1 AU just upstream of the Earth.

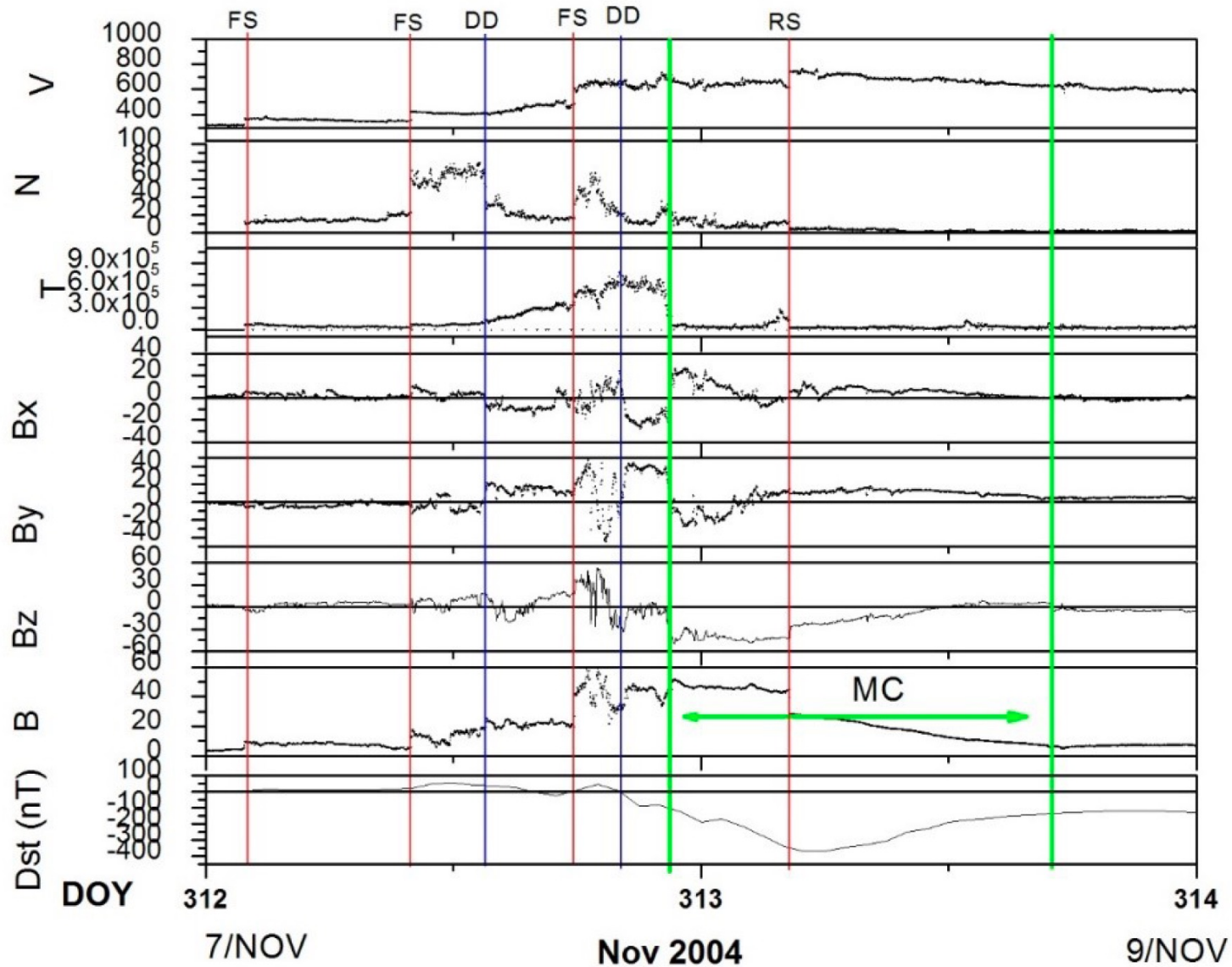


Figure 5. An example of three fast forward shocks pumping up the interplanetary magnetic field intensity. Taken from Tsurutani et al. (2008a). ⁴⁷

Ισχυρό νότιο διαπλανητικό μαγνητικό πεδίο μεγάλης διάρκειας έχει ως αποτέλεσμα την παρατεταμένη μεταφορά μαγνητικής ροής στη μαγνητοουρά και την αυξημένη συσσώρευση διαθέσιμης μαγνητικής ενέργειας. Πέρα από το ιδιαίτερα λαμπρό και χωρικά πολύ εκτεταμένο σέλας, που το συνοδεύουν συνεχείς γεωμαγνητικές διαταραχές σε υψηλά γεωγραφικά πλάτη, καταγράφονται και γεωμαγνητικές διαταραχές σε μεσαία και χαμηλά πλάτη και σε όλα τα γεωγραφικά μήκη (δηλ. παγκοσμίως), καθώς επίσης και παρατεταμένη επιτάχυνση και έγχυση ενεργητικών ιόντων και ηλεκτρονίων, με αποτέλεσμα τη δημιουργία ενός δακτυλιοειδούς ηλεκτρικού ρεύματος γύρω από τη Γη.

Ενέργεια και ύλη για τις καταιγίδες

Carrington-class CME Narrowly Misses Earth

<https://youtu.be/7ukQhycKOFw?si=-RW-juN2EIAzWlIf>

