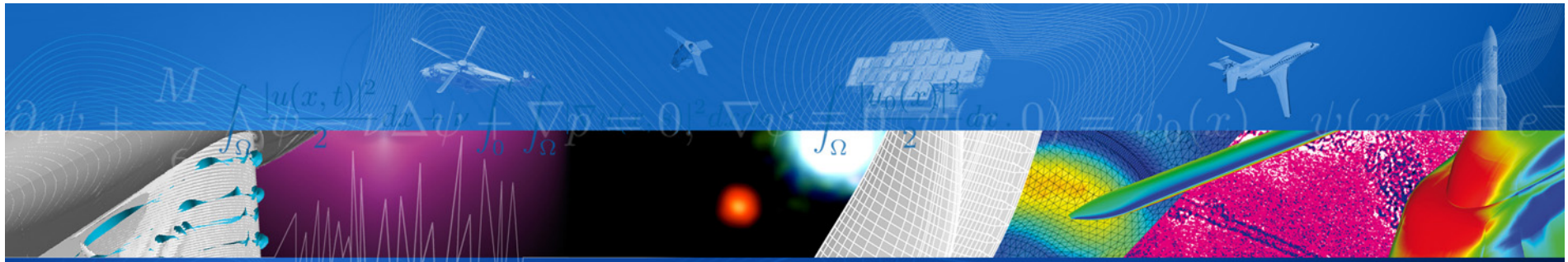


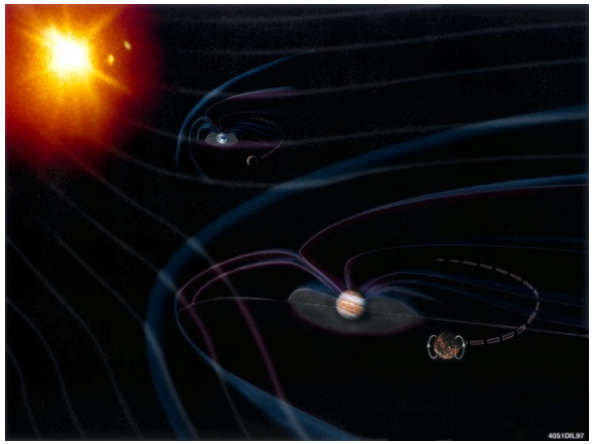
Les ceintures de radiation de la Terre, Jupiter et Saturne: similitudes et différences

A.Sicard-Piet, *S. Bourdarie, D. Boscher,*
L. Lorenzato, V. Maget, D. Lazaro, S. Rochel
ONERA/DESP, Toulouse, France

ONERA
THE FRENCH AEROSPACE LAB

retour sur innovation

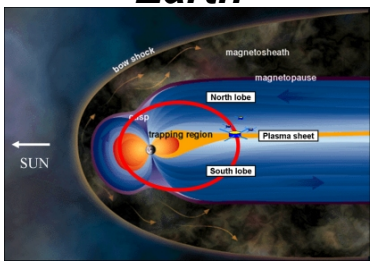
Introduction



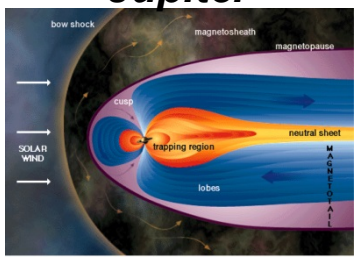
Planetary magnetospheres:

Planet	Mercury	Earth	Jupiter	Saturn	Uranus	Neptune
Obliquity to orbit (^{o})	0.01	23.5	3.1	26.7	97.8	28.3
Magnetic moment ($G.Rp^3$)	0.0033	0.301*	4.28	0.21	0.228	0.142
Dipole tilt to rotation axis (^{o})	169	169.5*	9.6	< 1	58.6	46.9
Rp (km)	2439	6371	71398	60330	25600	24765

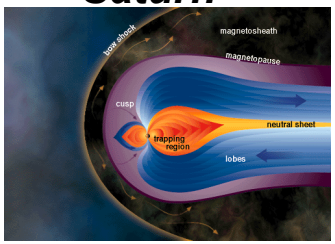
Earth



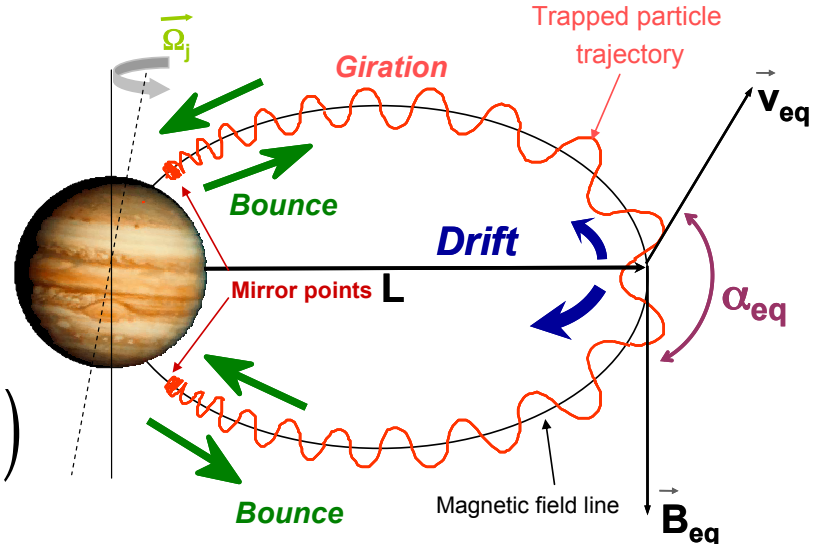
Jupiter



Saturn

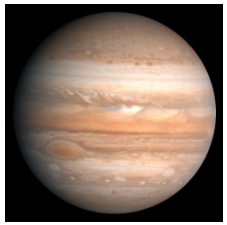


$$\vec{F} = q\left(\vec{E} + \vec{v} \wedge \vec{B}\right)$$

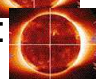


Radiation belts composition and structure

- **Electrons**
  - Spectrum: 10 keV-10 MeV
  - Location: 1-10 Re
  - Origin: 
- **Protons**
  - Spectrum: 10 keV- 300 MeV
  - Location: 1-10 Re
  - Origin:  + CRAND
- **Heavy ions**
  - Helium: 
  - Oxygen ?: 

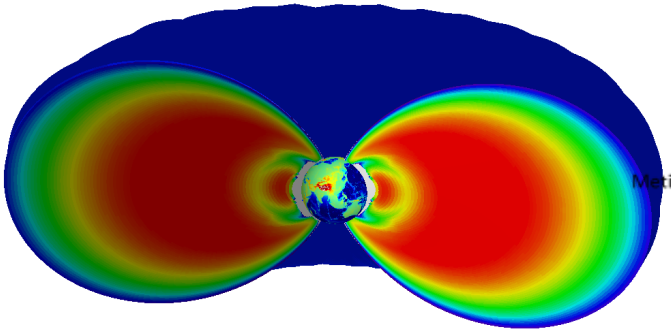


- **Electrons**
  - Spectrum: 100 keV-300 MeV
  - Location: 1-20 Rj
  - Origin: 
- **Protons**
  - Spectrum: 100 keV- 1 GeV
  - Location: 1-20 Rj
  - Origin:  + CRAND
- **Heavy ions**
  - Helium:  + Io
  - Oxygen: Io + 
  - Sulphur: Io

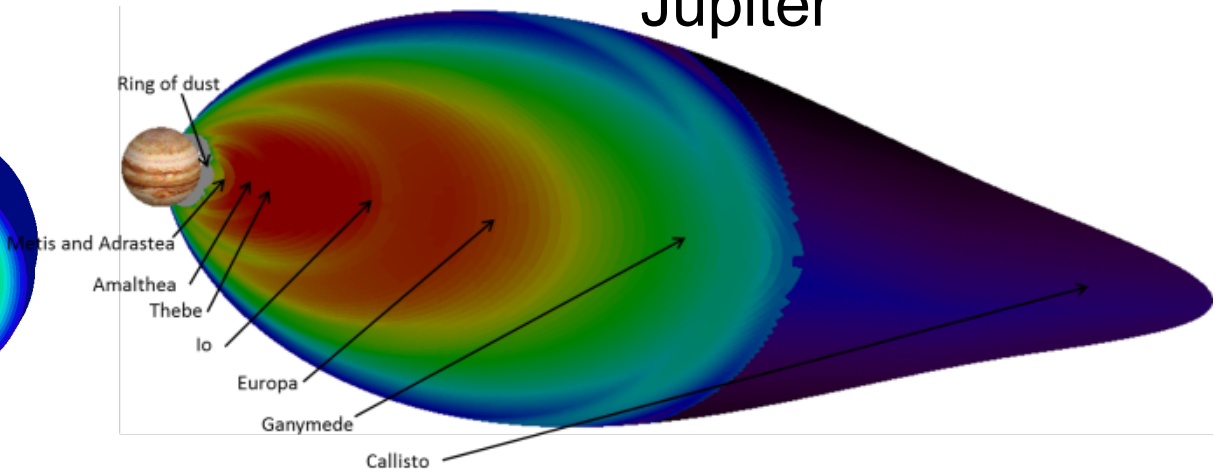
- **Electrons**
  - Spectrum: 10 keV-10 MeV
  - Location: 1-10 Rs
  - Origin: 
- **Protons**
  - Spectrum: 10 keV- 100 MeV
  - Location: 1-10 Rs
  - Origin:  + CRAND
- **Heavy ions**
  - Helium:  + Enceladus
  - Oxygen:  + Enceladus

Radiation belts composition and structure

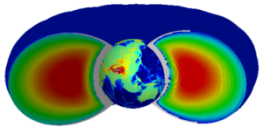
Earth



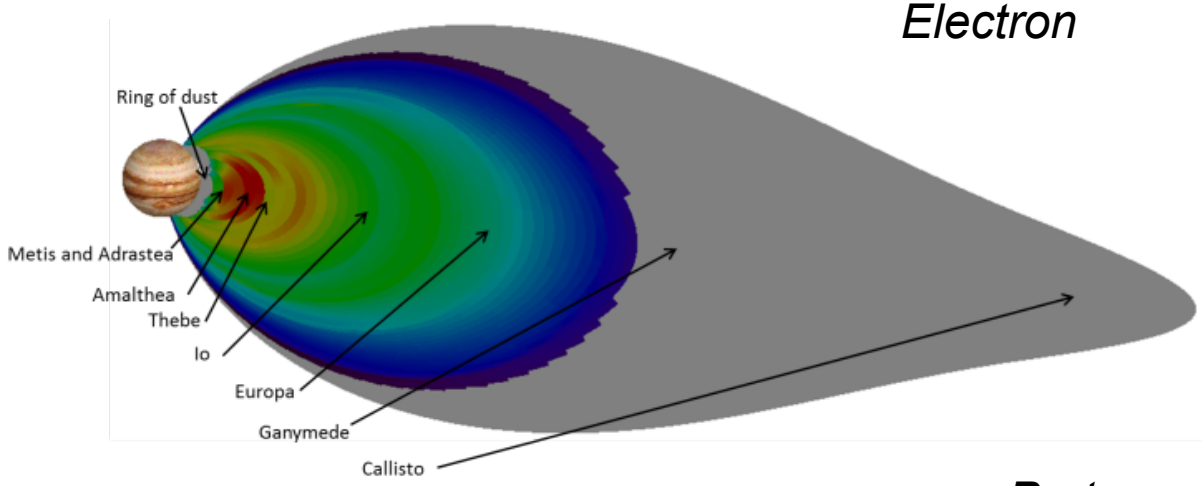
Jupiter



Electron



Electron

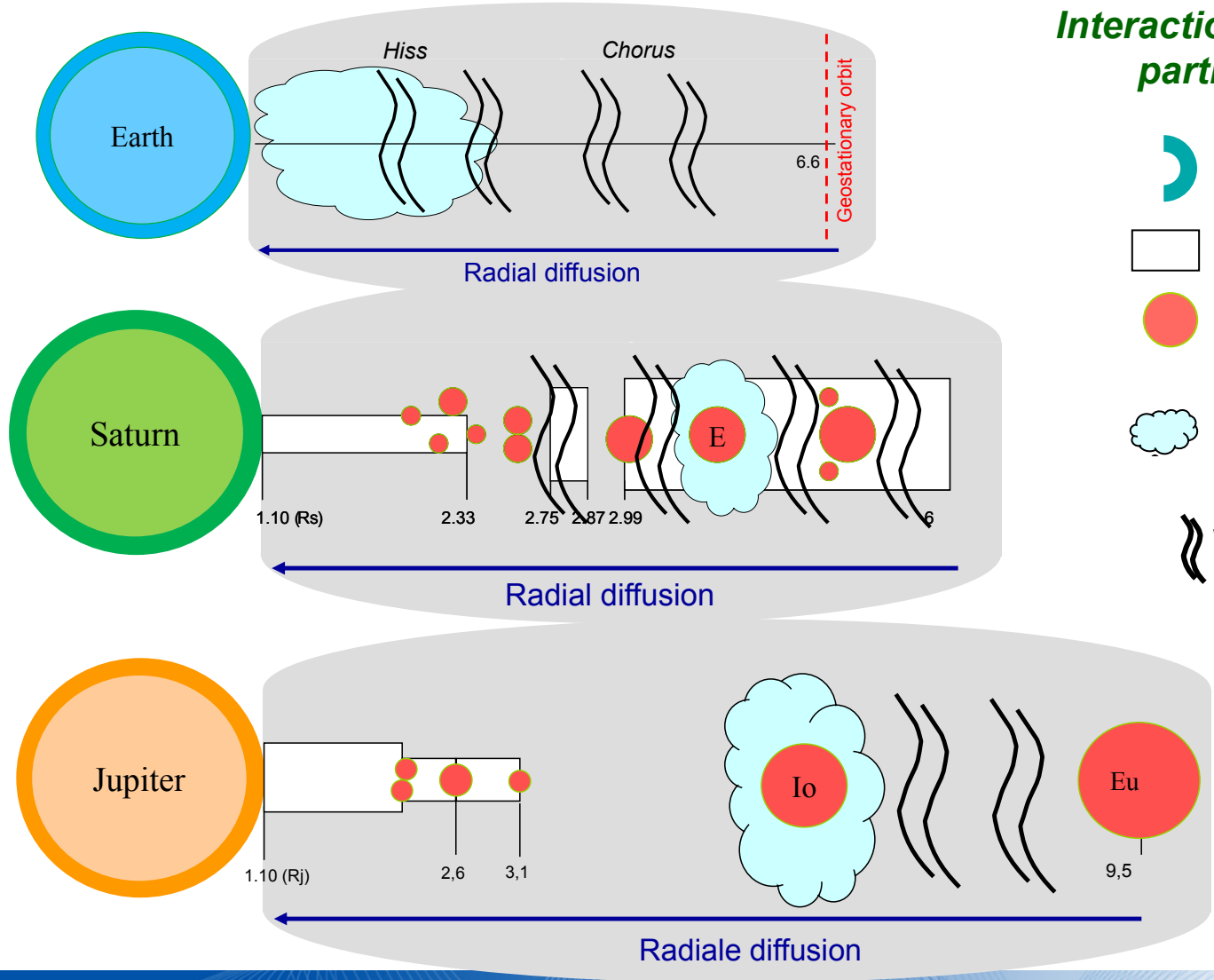


Proton

Proton

Radiation belts composition and structure

Main physical processes in the radiation belts



Interaction of energetic particles with:

- Atmosphere
- Rings
- Moons
- Plasmasphere or Neutral cloud or Io torus
- Waves

Radiation belts composition and structure

Electrons

Earth

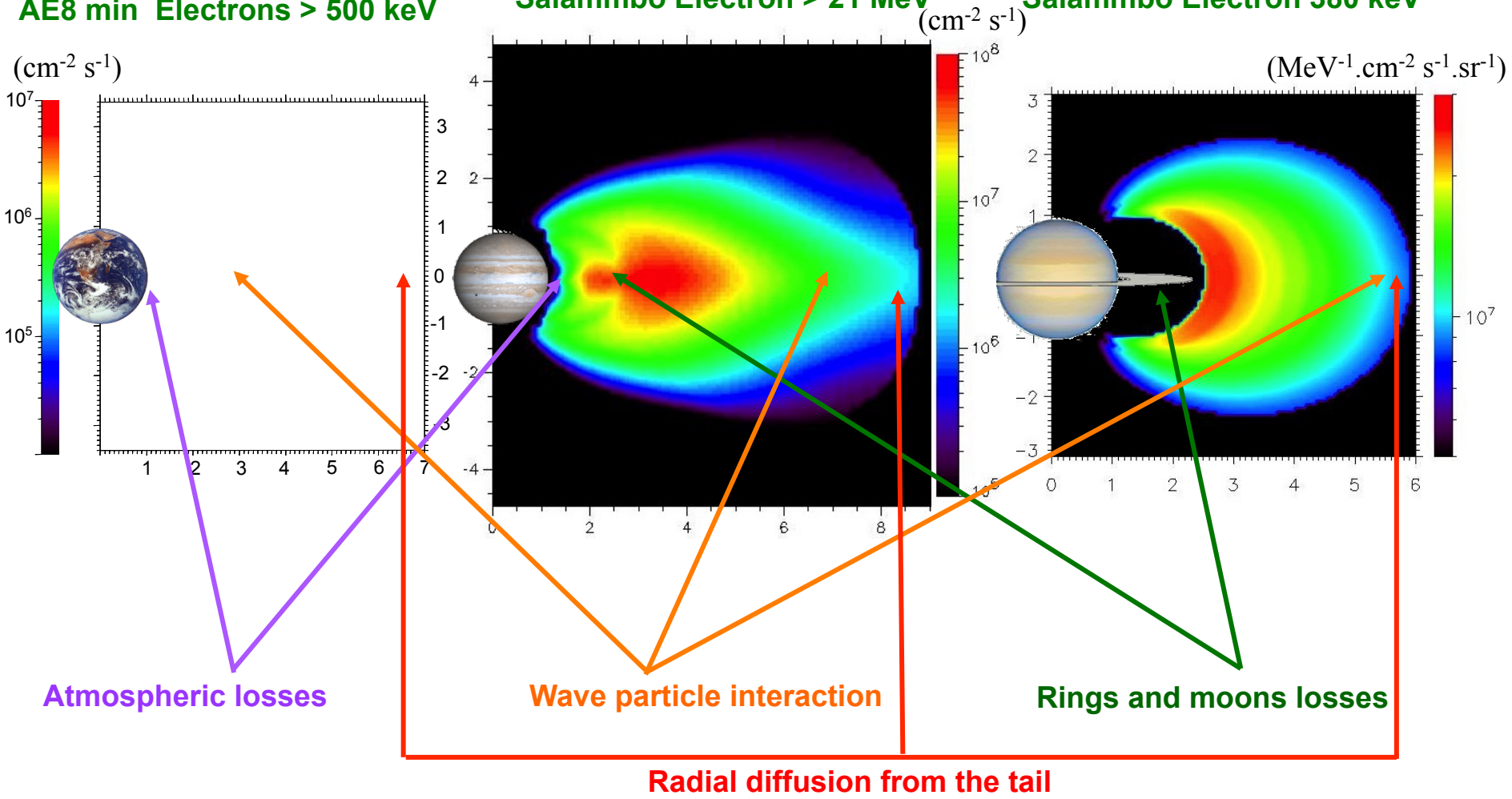
AE8 min Electrons > 500 keV

Jupiter

Salammbô Electron > 21 MeV

Saturn

Salammbô Electron 380 keV



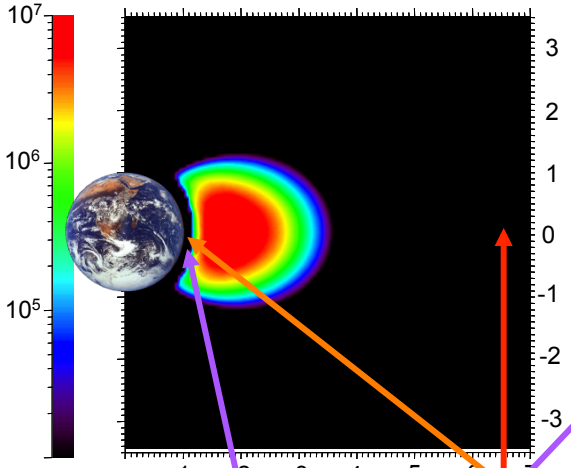
Radiation belts composition and structure

Protons

Earth

AP8 min Electrons > 10 MeV

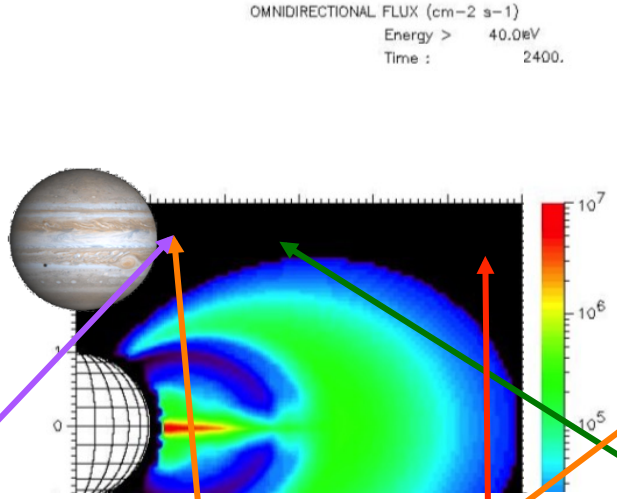
(cm^{-2} s^{-1})



Jupiter

Salammbô Proton > 30 MeV

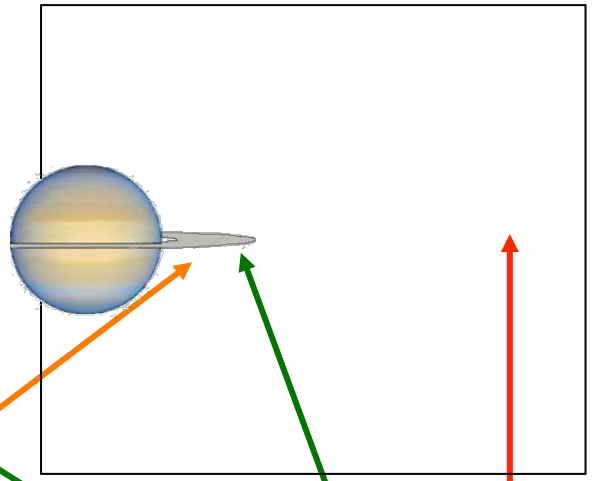
(cm^{-2} s^{-1})



Saturn

Salammbô Proton not developed yet

($MeV^{-1}.cm^{-2}$ $s^{-1}.sr^{-1}$)



Atmospheric losses

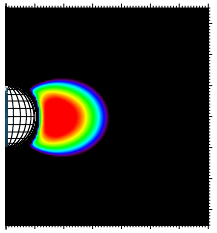
CRAND

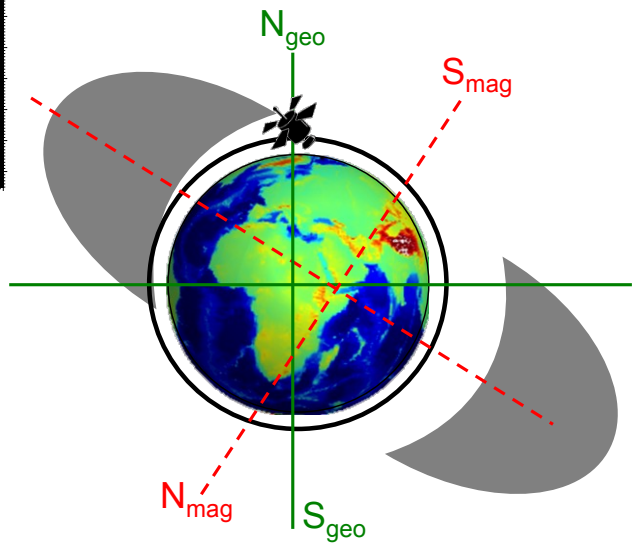
Rings and moons losses

Radial diffusion from the tail

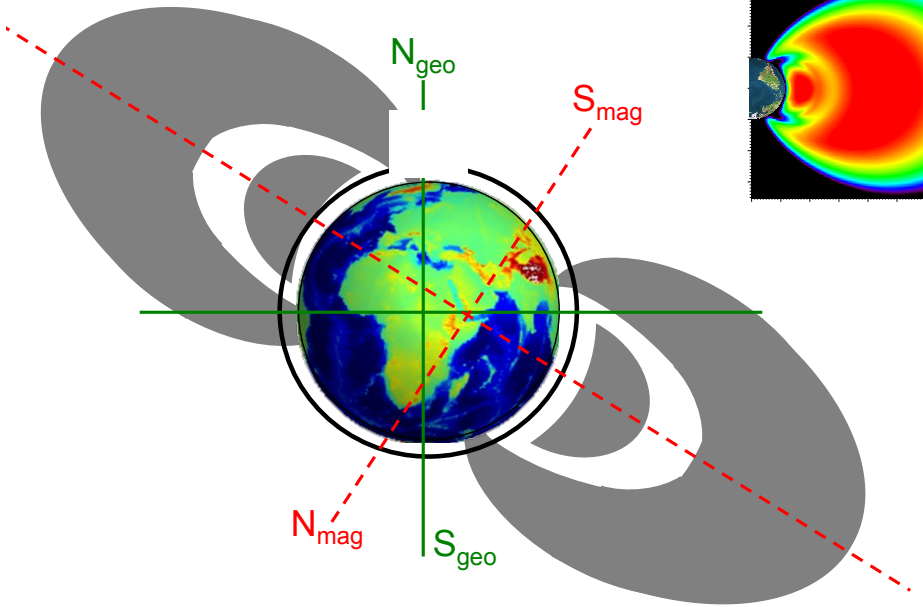
Radiation belts composition and structure

Protons

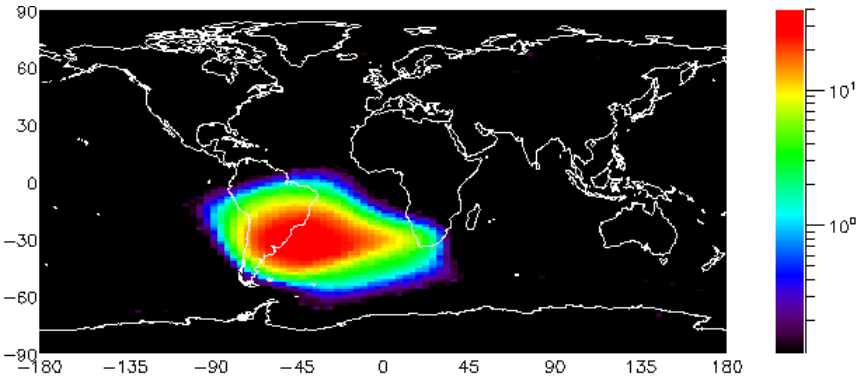




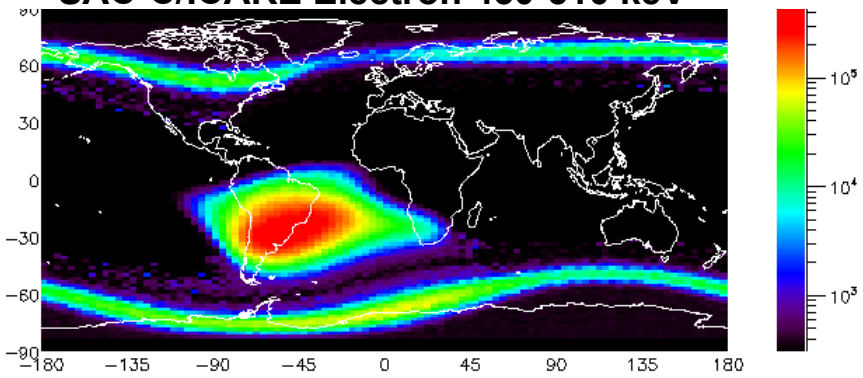
Electrons



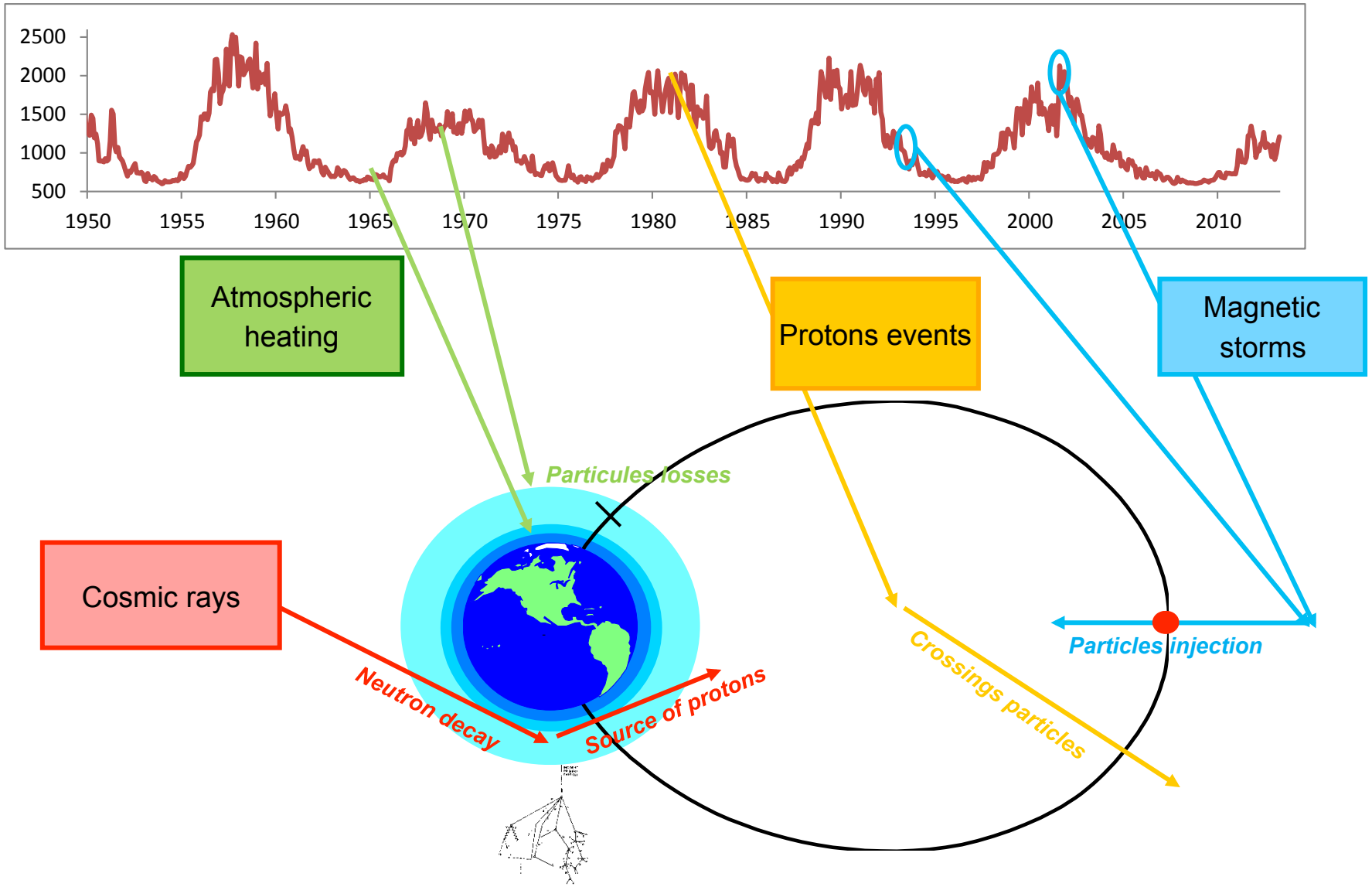
SAC-C/ICARE Proton 9.65-11.35 MeV



SAC-C/ICARE Electron 450-510 keV



Radiation belts dynamics

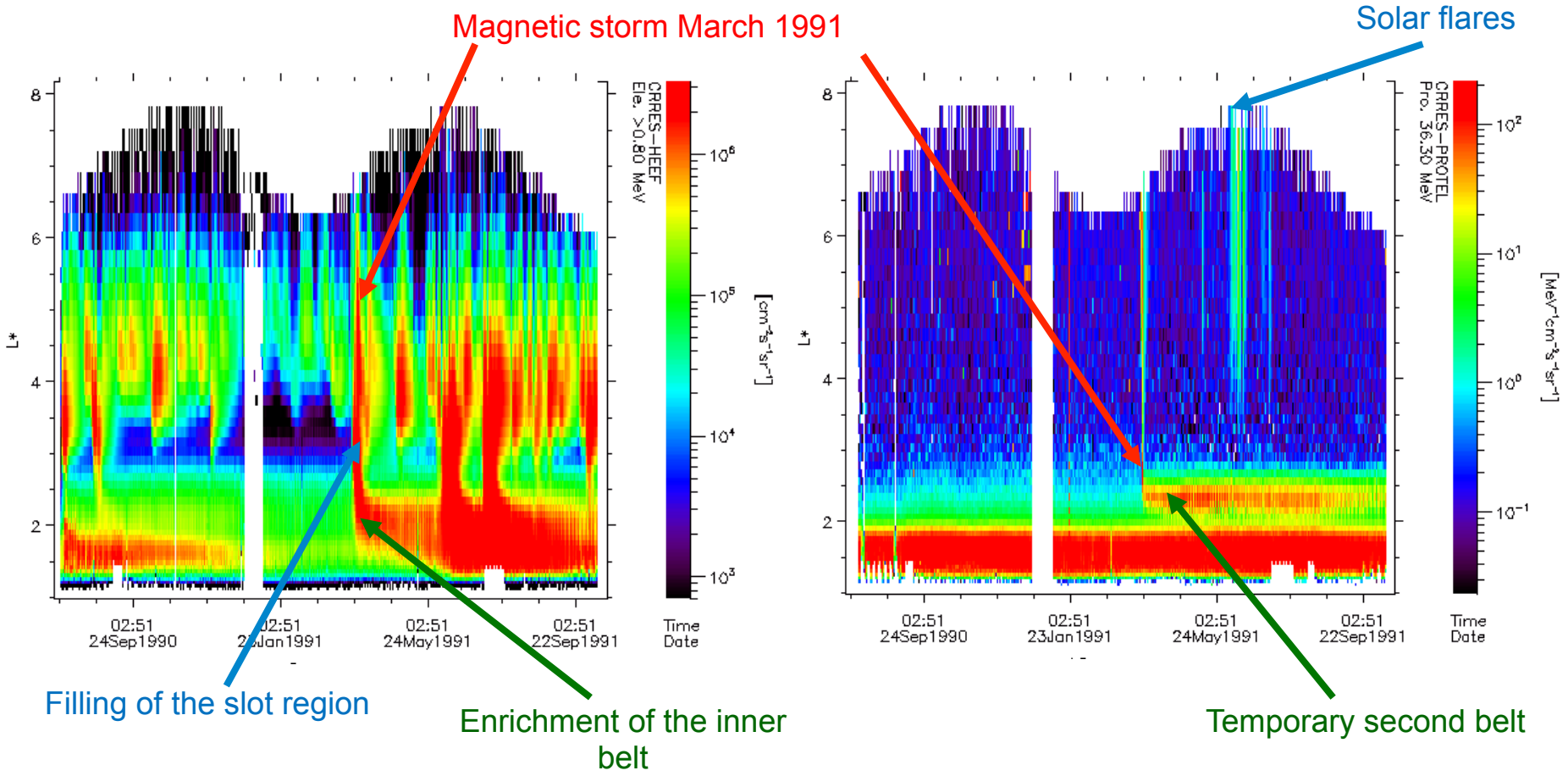


Radiation belts dynamics

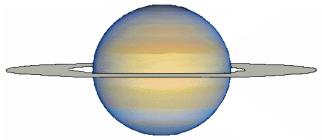
Short time scale dynamics

Electrons

Protons



Radiation belts dynamics



Short time scale dynamics

Plasma injection events seen by CASSINI/CAPS/ELS

on October 30, 2005 at L=7

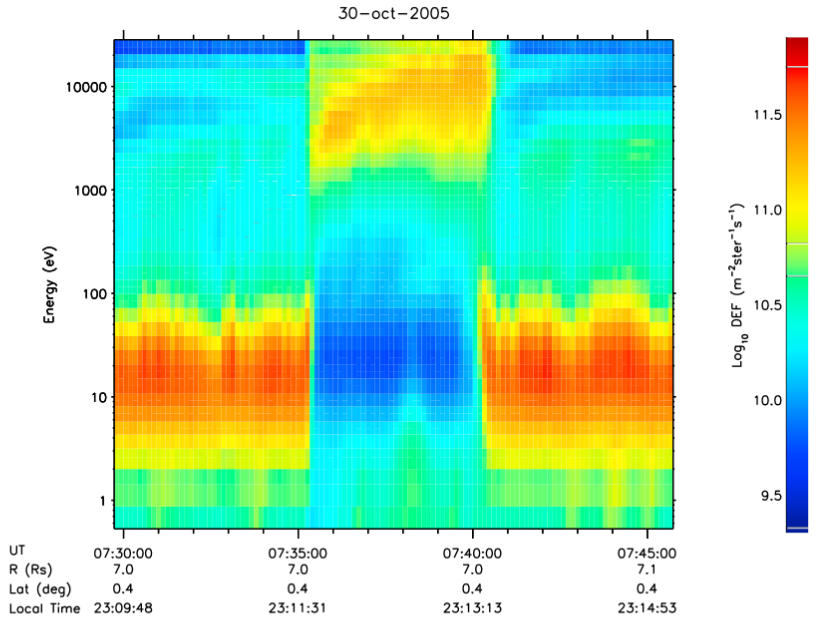
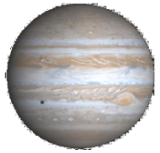
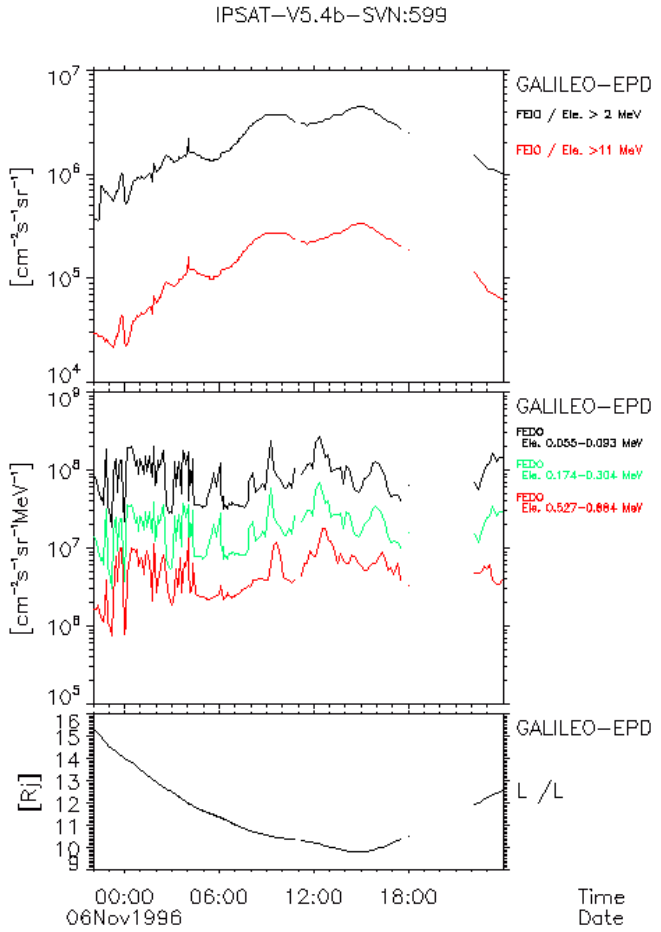


Figure 1. Logarithm of electron differential energy flux ($\log_{10}$ DEF) plotted as a function of time and energy around 0737 UT on day 303 of 2005.

Tao X. et al., J. Geophys. Res., VOL. 115, A12204,doi:10.1029/2010JA015598, 2010

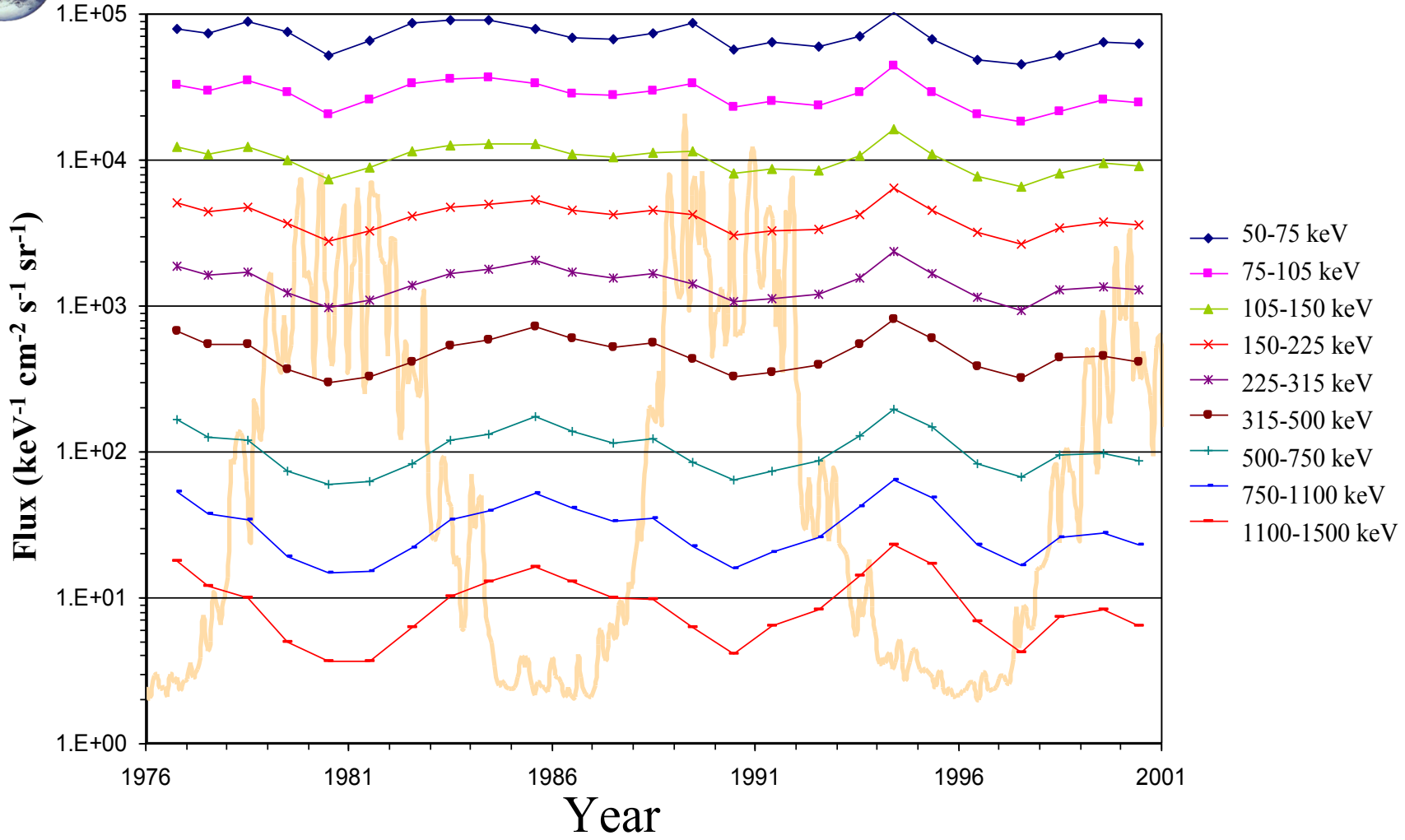


Injection events seen by Galileo/EPD on November 06, 1996 between Ganymede and Europa

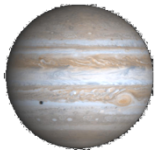


Radiation belts dynamics

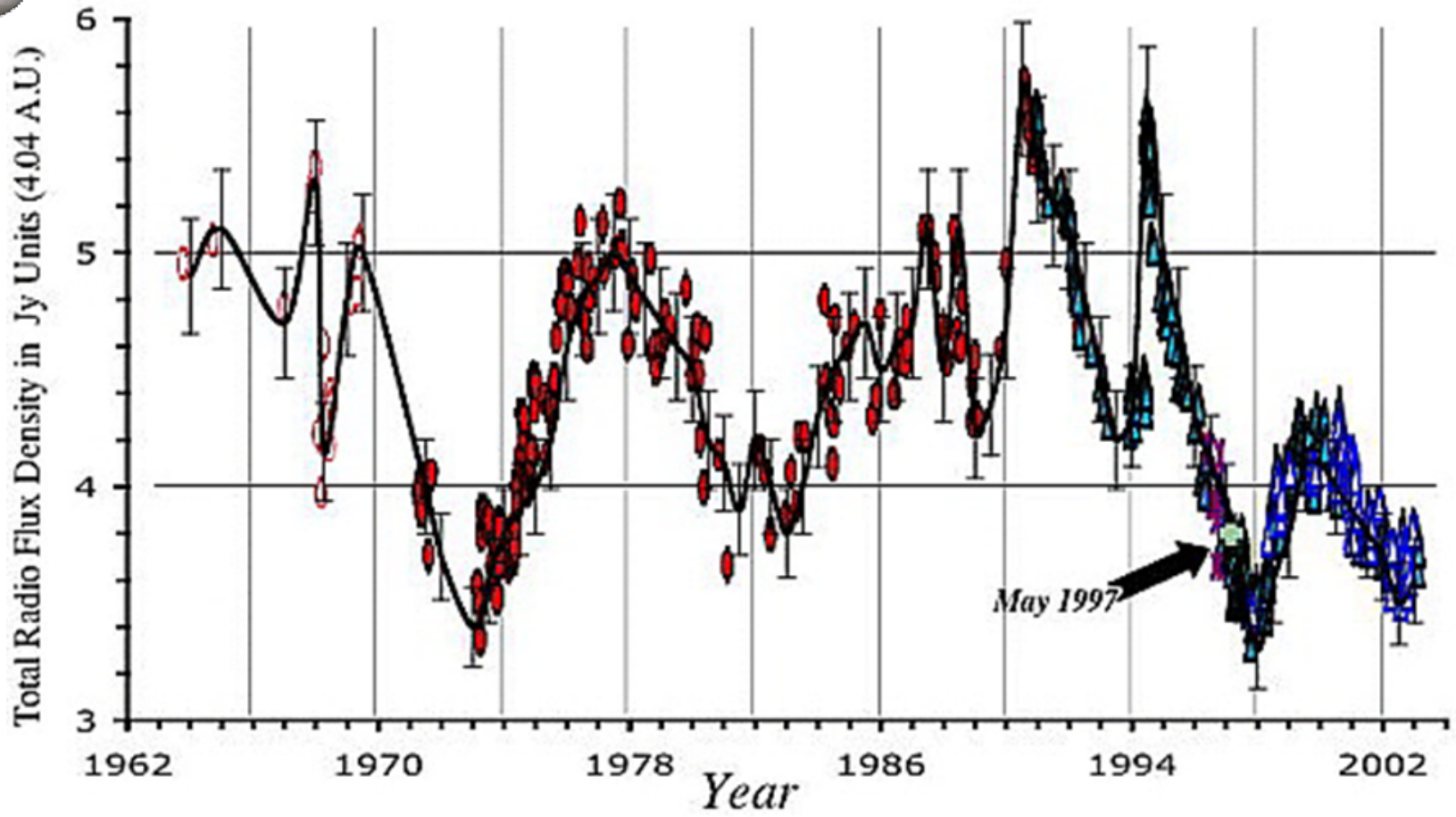
Long time scale dynamics



Radiation belts dynamics



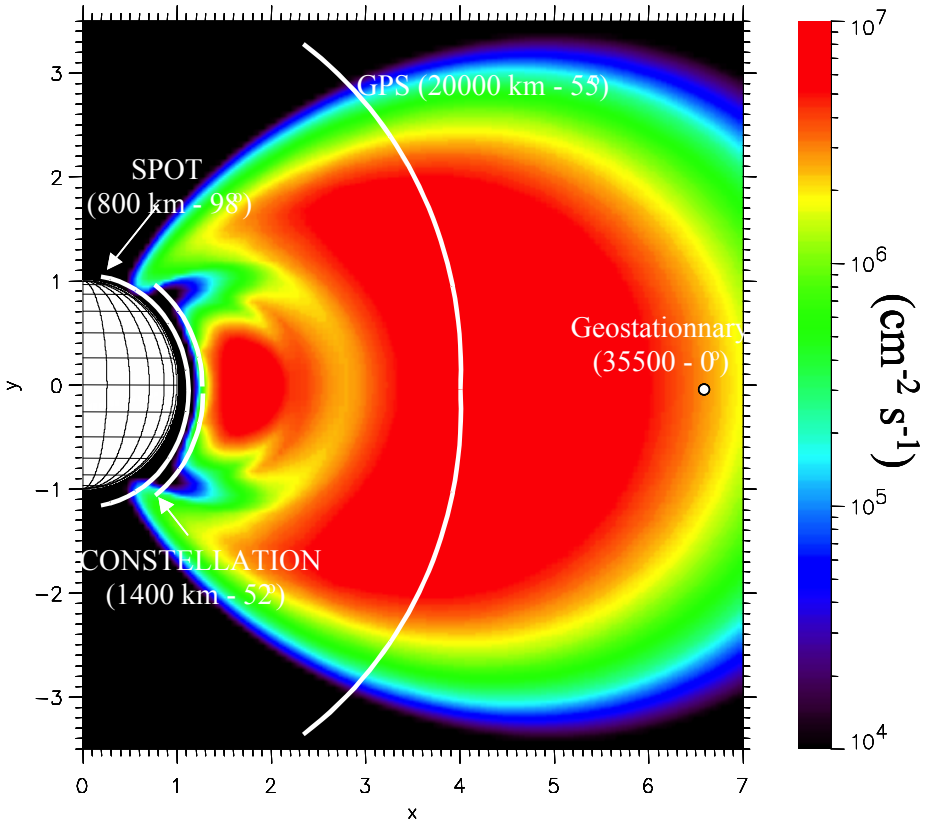
Long time scale dynamics

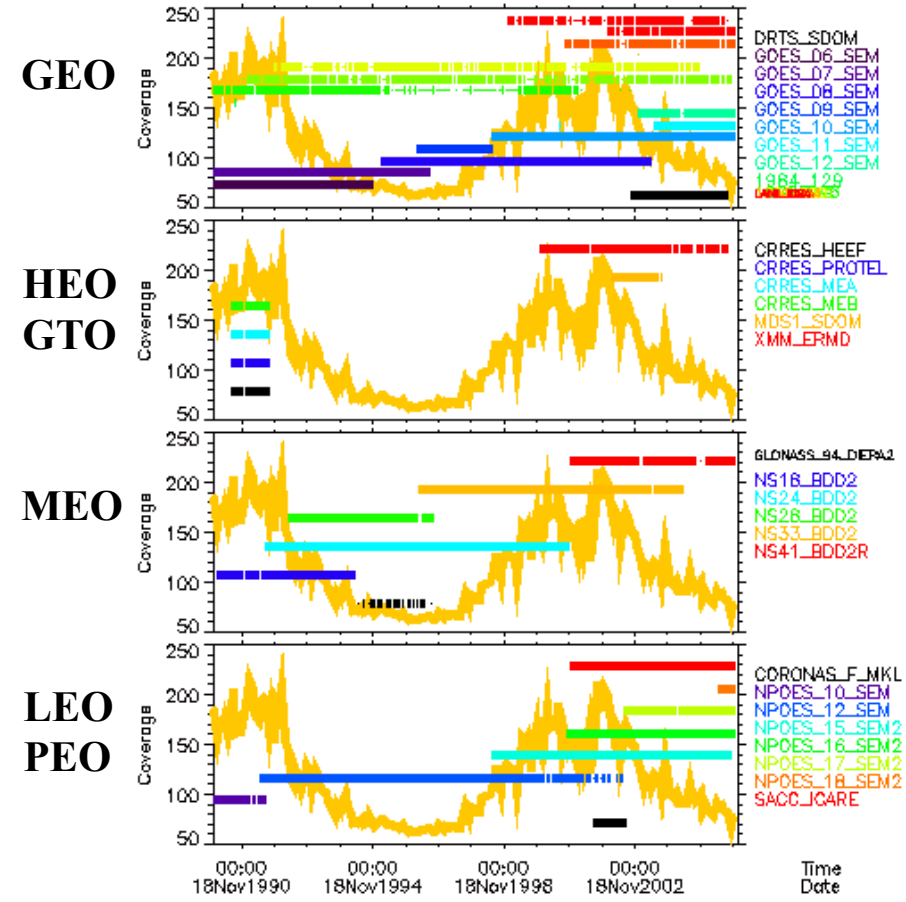


D. Santos-Costa, S. J. Bolton, R. M. Thorne, Y. Miyoshi, and S. M. Levin, « Investigating the origins of the Jovian decimetric emission's variability », Journal of Geophysical Research: Space Physics, vol. 113, no A1, 2008

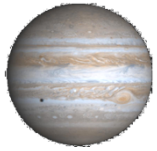
Radiation belts observations

Many different orbits and many observations of the Earth radiation belts

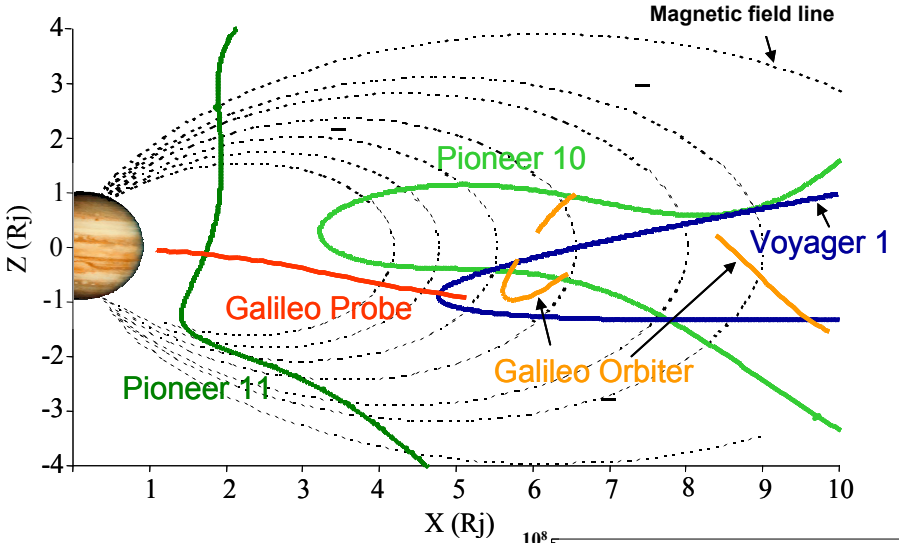




Radiation belts observations



Few observations: in-situ measurements by interplanetary missions and synchrotron measurements on the ground



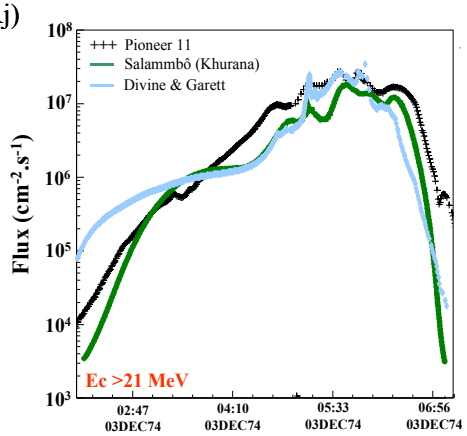
Pioneer 10 and 11

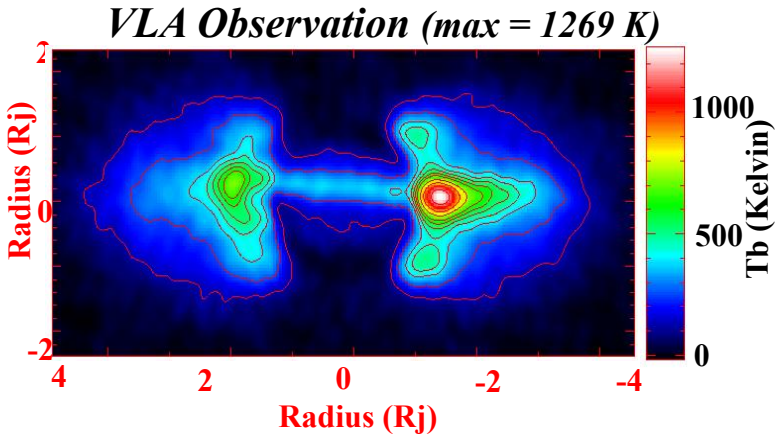
Voyager 1 and 2

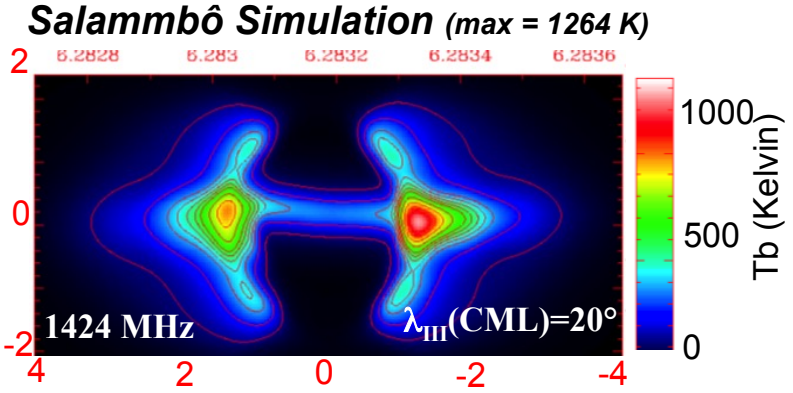
Galileo Orbiter

Galileo Probe

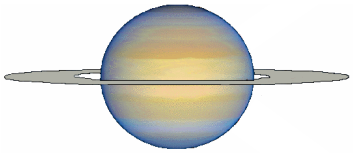
Ulysses





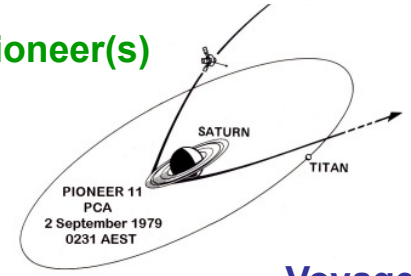


Radiation belts observations

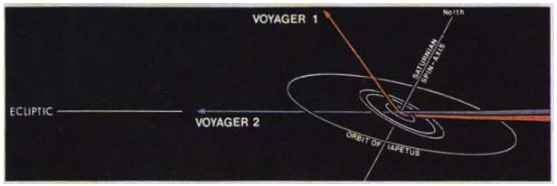


Even few observations: in-situ measurements by interplanetary missions

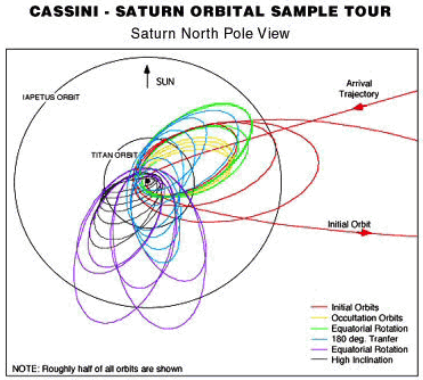
Pioneer(s)



Voyager(s)

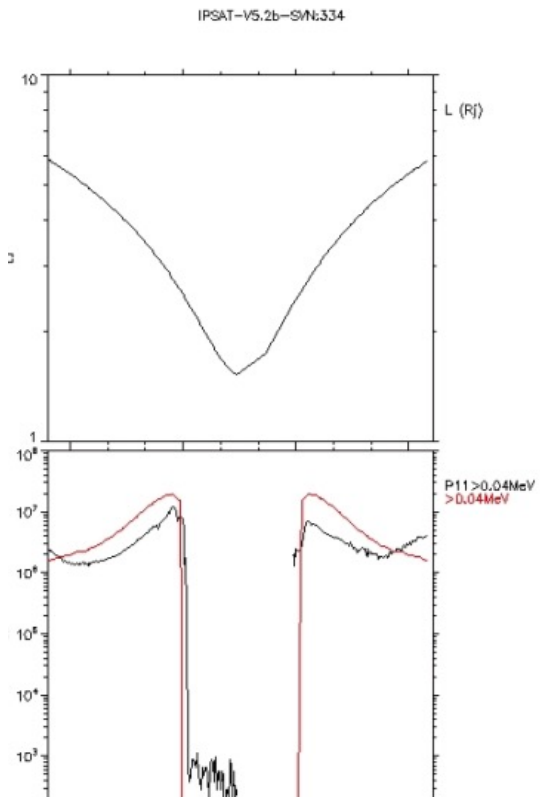


Cassini

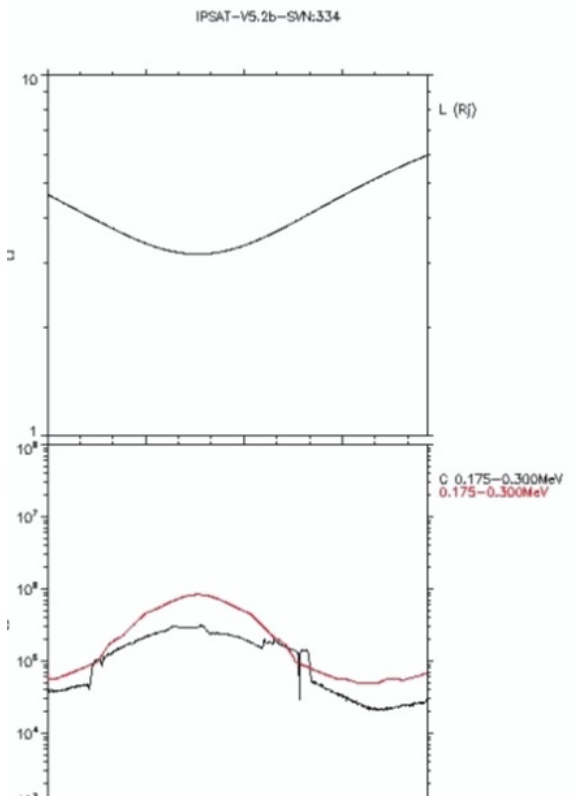


Comparaison with Salammbo

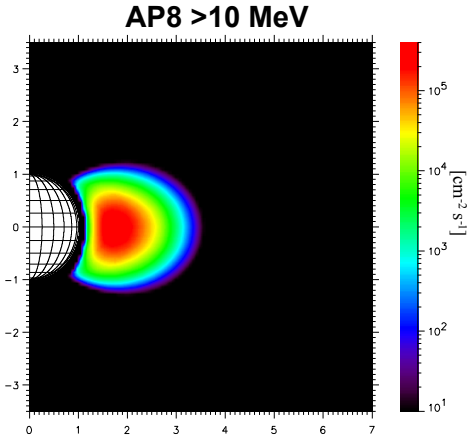
Pioneer 11
e- : >40 keV



Cassini
e- : 175-300 keV



Specification models

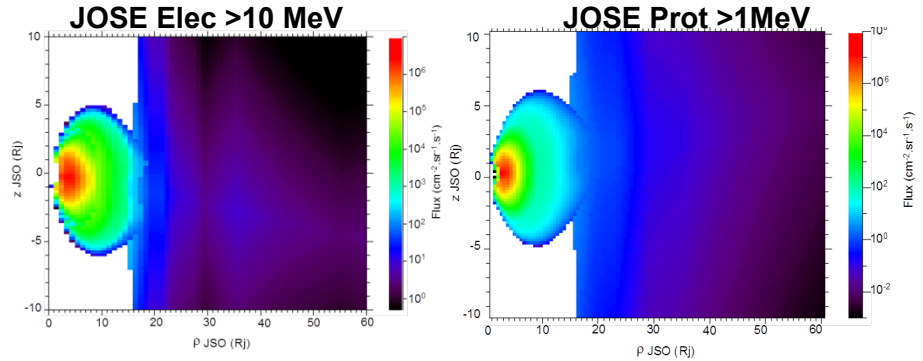


Global models

- AE8/AP8 (NASA)
- AE9/AP9 (Aerospace)

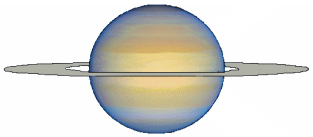
Local models

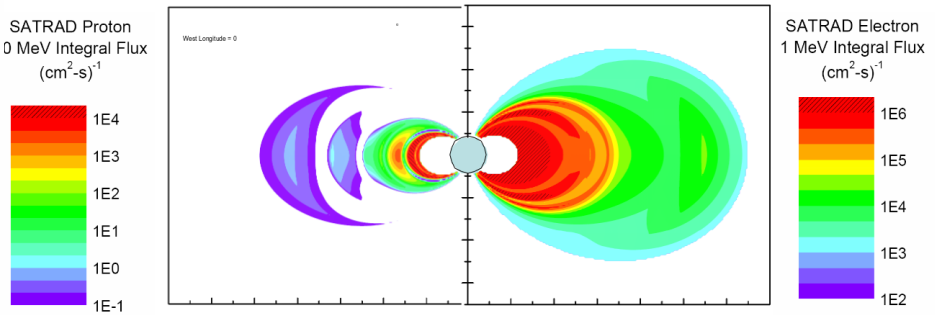
- IGE-2006 at GEO (ONERA)
- MEO-V2 at MEO (ONERA)
- Slot model (ONERA)
- OPAL protons at LEO (ONERA)



Global models

- D&G 1983 (JPL)
- GIRE (JPL)
- JOSE (ONERA)



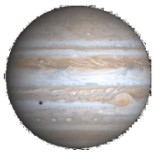


Global model

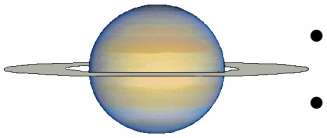
- SATRAD(JPL)

Perspectives

- Improvement of the understanding and modeling of the physical processes in the radiation belts
- Study of the link between solar wind parameters and radiation belts dynamics (space weather)
- Development of a global model for Earth radiation belts



- Comparison of synchrotron mapping derived from Salammbô results and LOFAR observations
- Study of the dynamics of the Jovian radiation belts (link with solar wind)



- Modeling of protons radiation belts
- Modeling of Uranus radiation belts