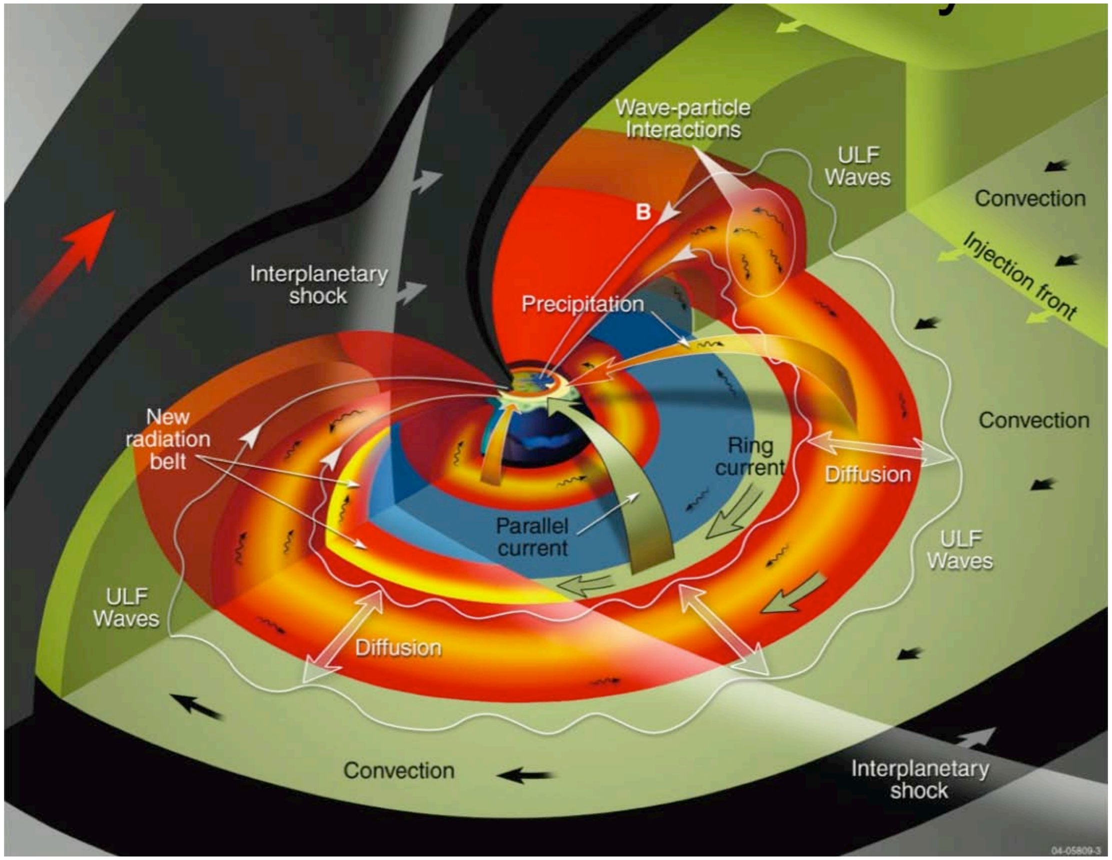
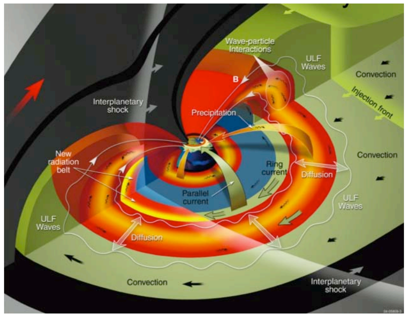
Inner Magnetosphere: A very quick introduction



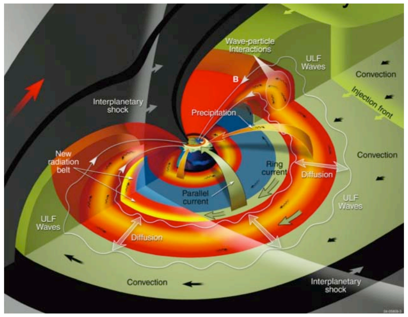
Wm. Robert Johnston

GEM Workshop - Midway, UT - 22 June 2008



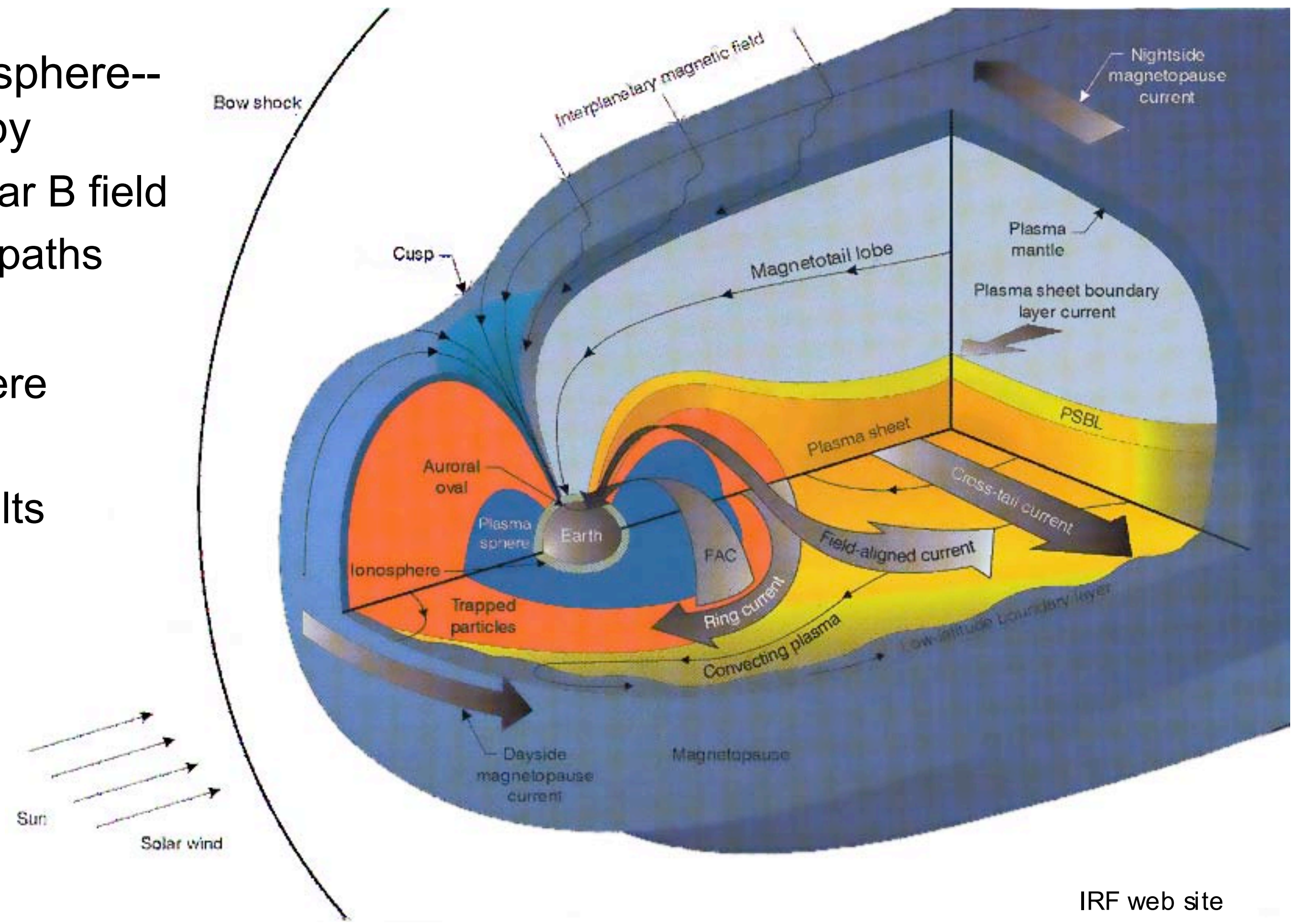
Outline

- Overview
- Plasmasphere
- Ring current
- Radiation belts
- Summary

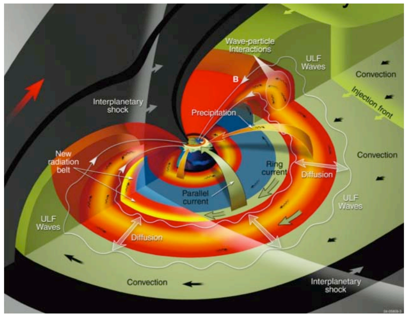


The big picture

- Inner magnetosphere--characterized by
  - nearly dipolar B field
  - closed drift paths
- Includes--
  - plasmasphere
  - ring current
  - radiation belts

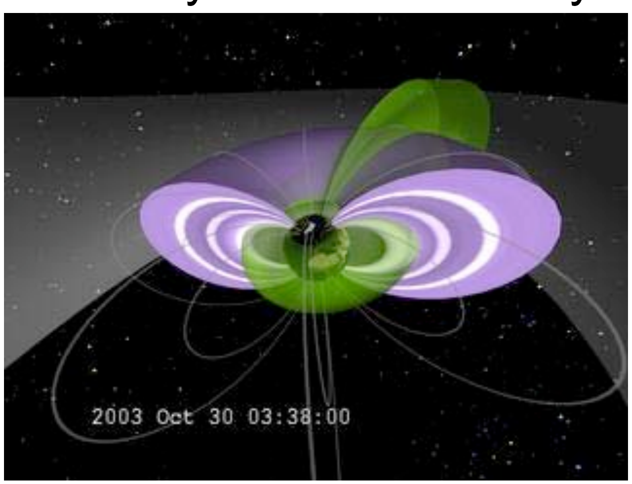


IRF web site



Plasmasphere

- Plasmasphere--a torus of cold (~1 eV), dense (10-10^3 cm^{-3}) plasma trapped on field lines in corotation region of the inner magnetosphere
  - outer boundary (plasmapause) tends to correlate with inner boundary of outer radiation belt
  - typically extends to L=3-5, but can be very structured and dynamic



NASA/GSFC

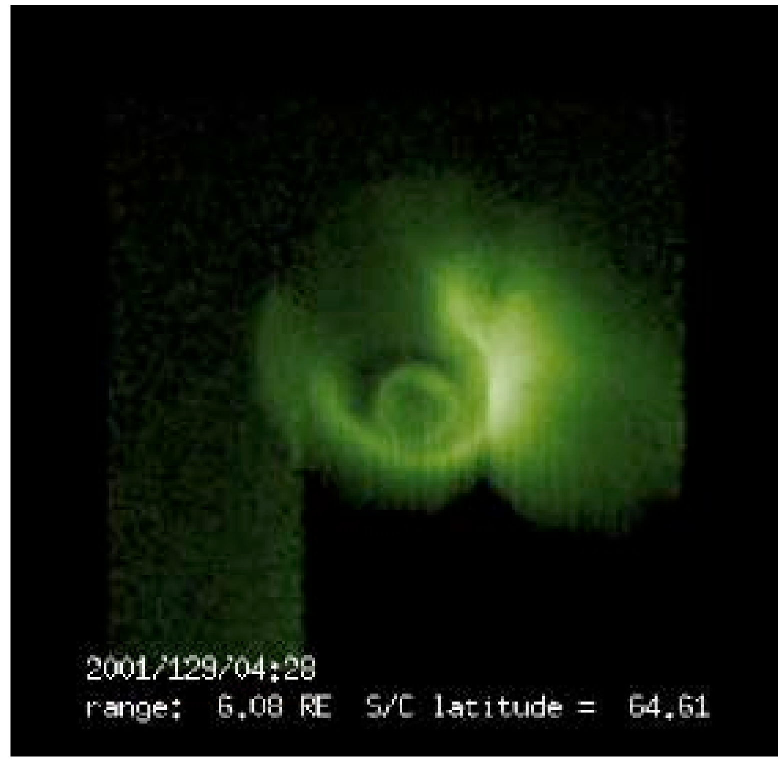
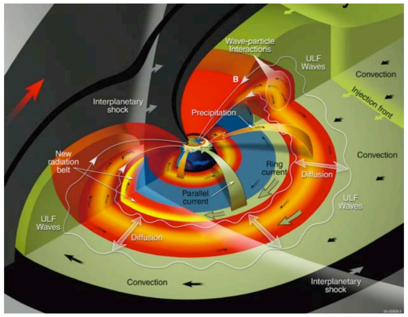
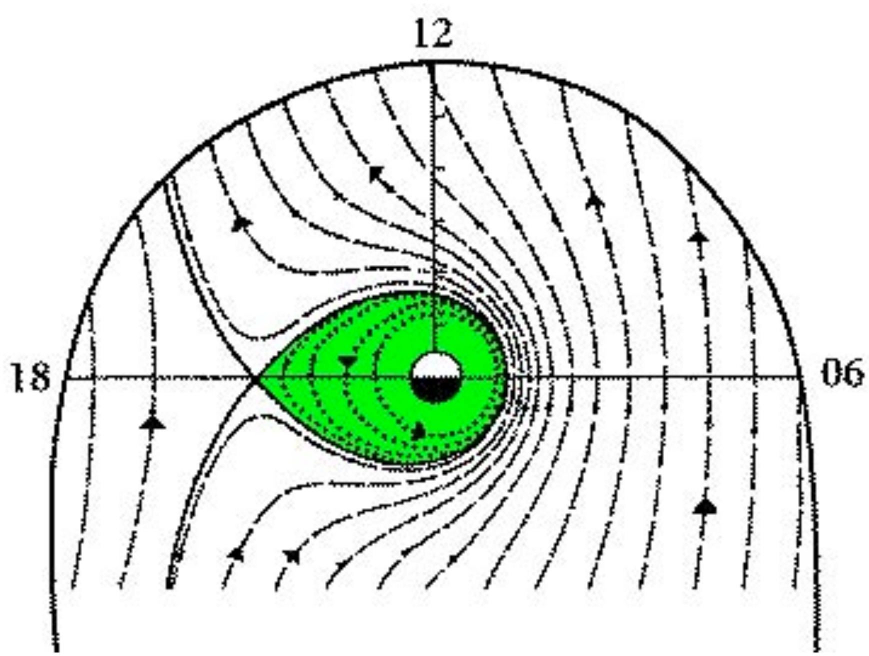


IMAGE EUV web site

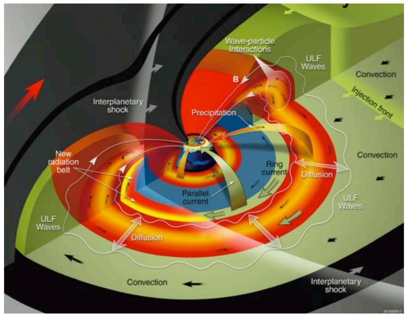


Plasmasphere in steady state

- Consider sum of cross tail E-field and corotation E-field:
  - Result is a region of closed equipotentials or closed drift paths
  - Inside, flux tubes fill with plasma escaping from ionosphere
  - Outside, flux tubes convect to magnetopause and empty

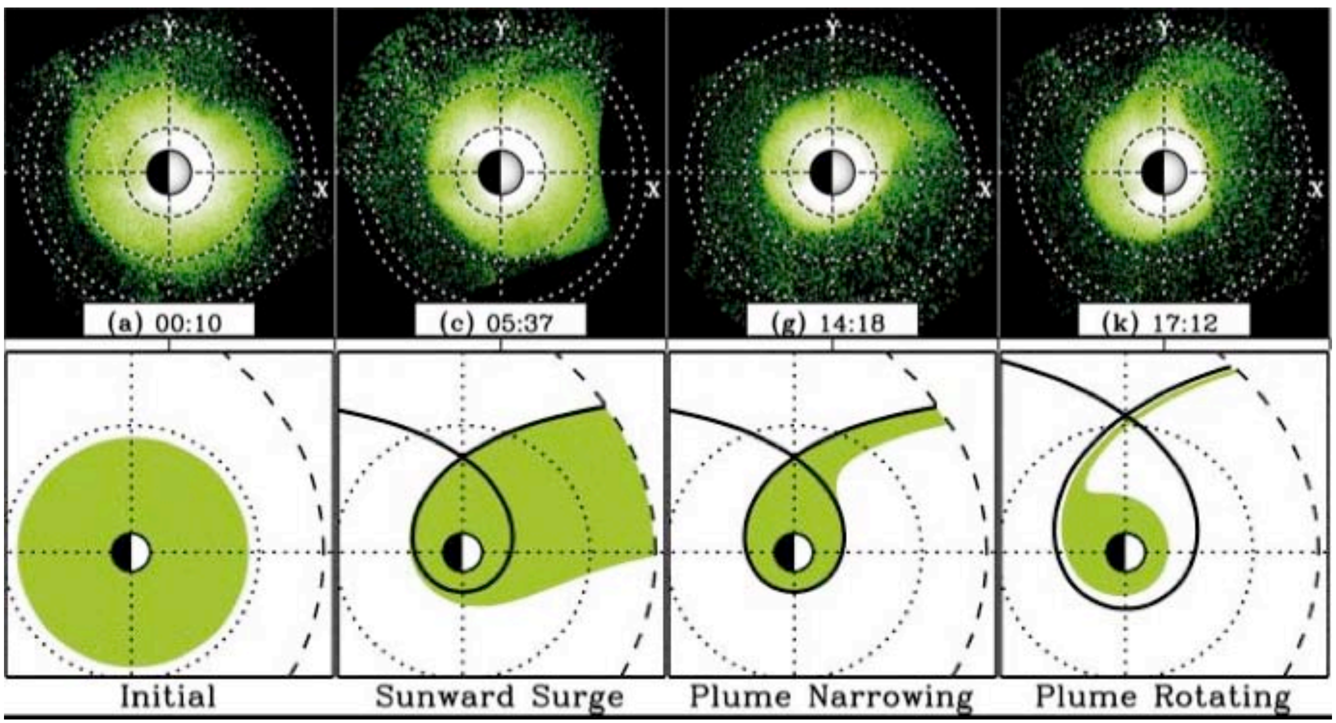


after Kavanagh et al., 1968

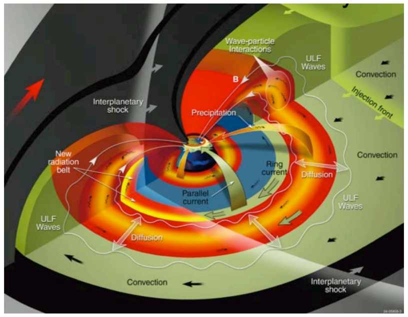


Plasmasphere in stormtime

- Stronger convection field -> contraction, emptying (hours)
- Weaker convection field -> refilling (days)
- Plasmapause location depends on history, not just convective E-field

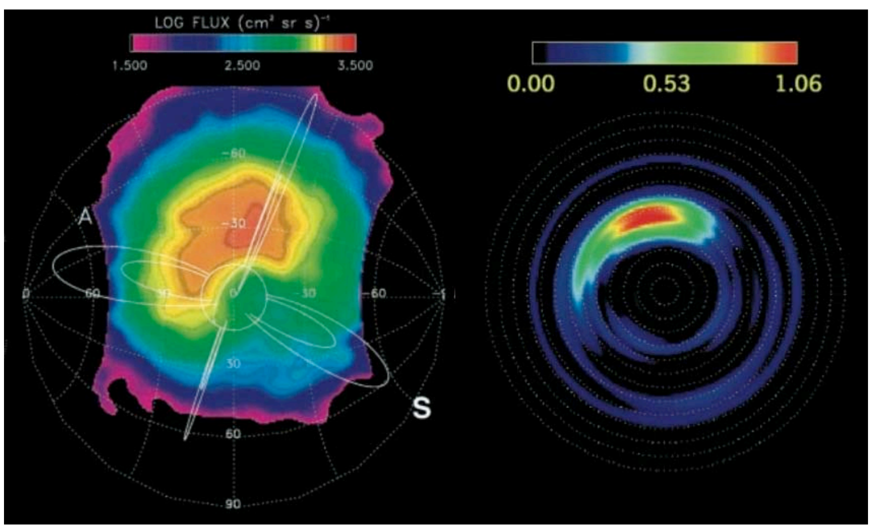


Goldstein (2004) ORBITALS workshop

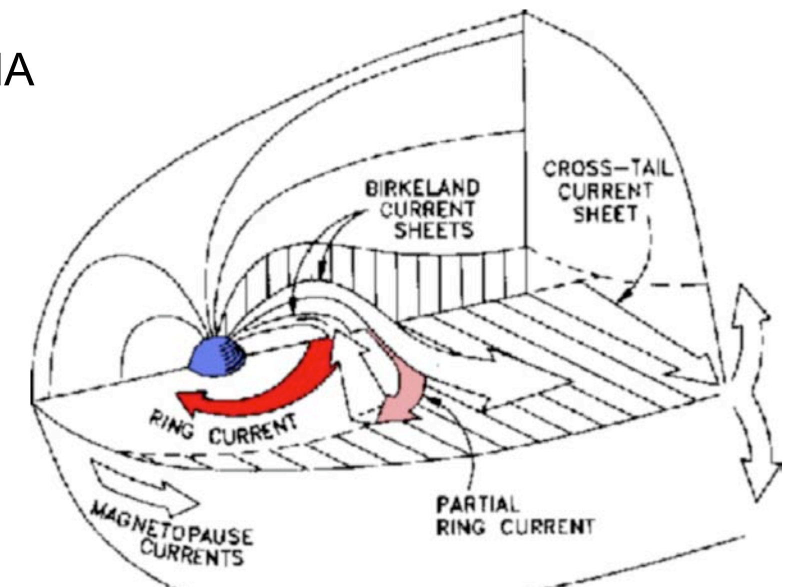


Ring current

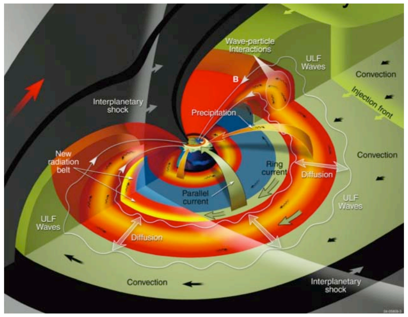
- As plasma convects from magnetotail towards Earth, gradient drift causes electrons to drift eastward, protons westward
- Result is ring current (westward)
- Dst index is measure of magnetic field induced at equator of Earth by ring current
- Ring current (and hence Dst) increases during storms
- Ring current may be partially closed through ionosphere by parallel currents
- Below: image of ring current by IMAGE HENA



Burch et al. (2001)

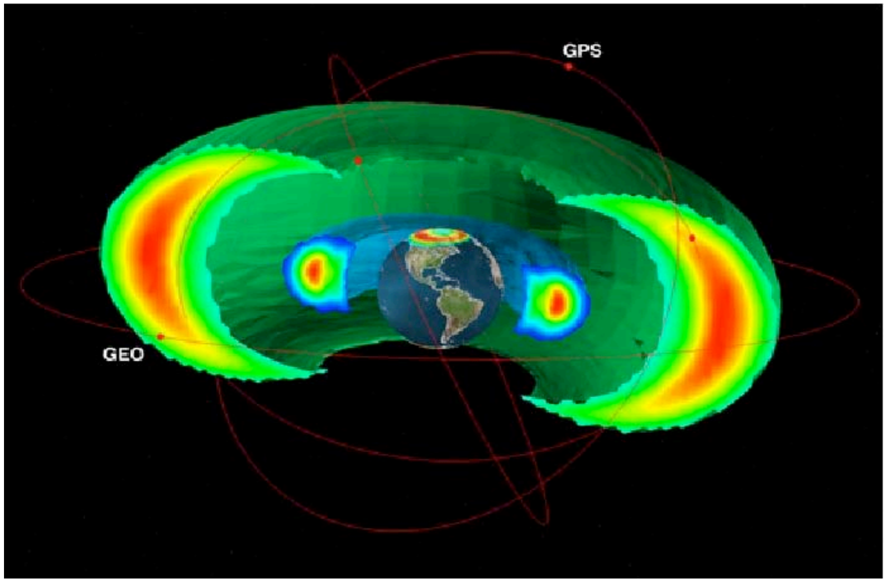


Cairns

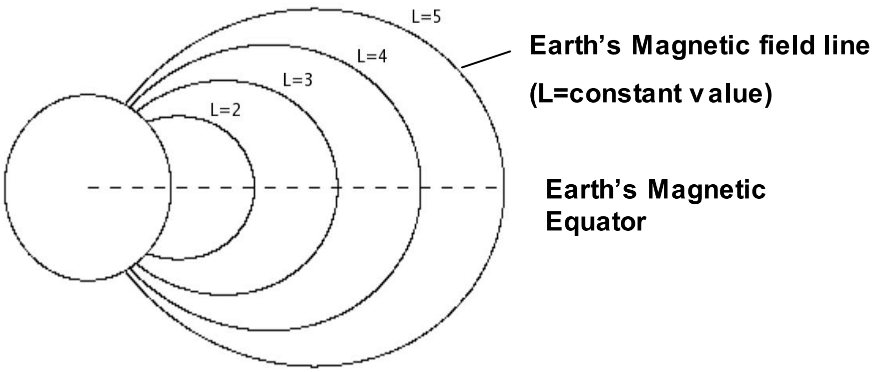


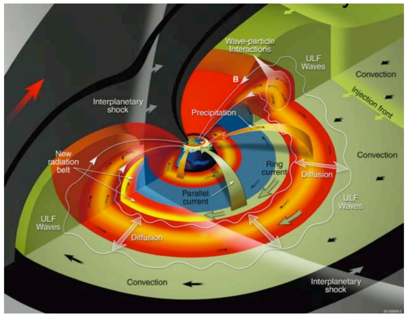
Radiation belts

- Radiation belts comprise energetic charged particles trapped by the Earth's magnetic field. (from keV to MeV)
- A given field line is described by its L value *(radial location, in R_E, of its intersection with magnetic equator)*
- Inner belt region:
  - Located at L~1.5-2
  - Contains electrons, protons, and ions.
  - Very stable.
- Outer belt region:
  - Located at L~3-6
  - Contains mostly electrons.
  - Very dynamic.
- Slot region: lower radiation region between the belts

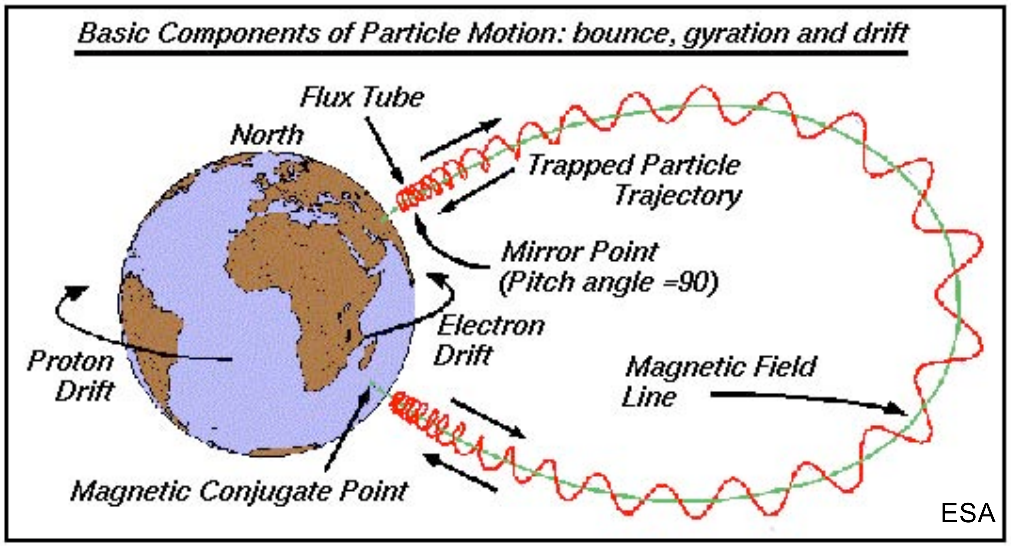


NASA



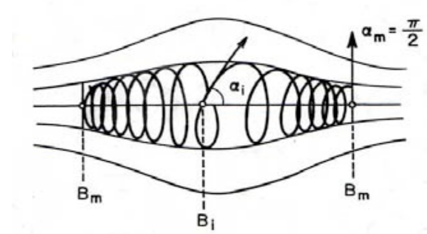


Periodic motions of trapped particles

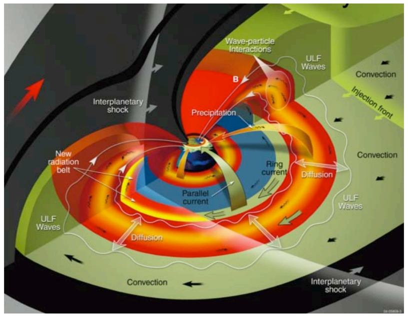


- Three types of periodic motion of trapped particles
- Each motion has an associated adiabatic invariant
  - invariant phase space more useful for modeling
- Pitch angle:

$$\tan\alpha = \frac{V_\perp}{V_\parallel}$$

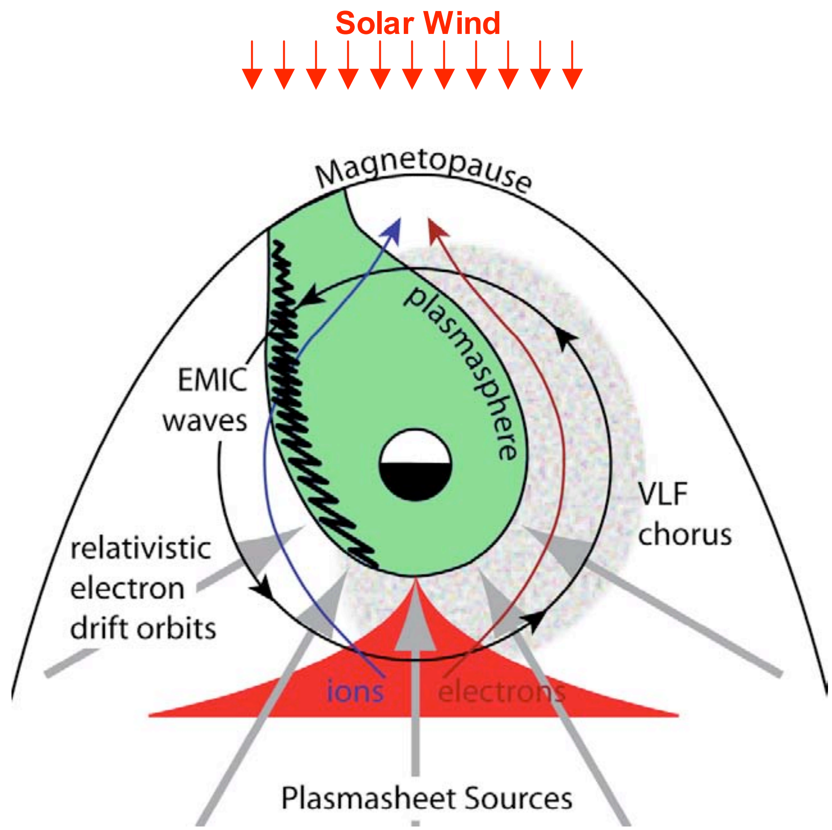


Gyro motion	V x B acceleration leads to gyro motion about field lines	F~ kHz
Bounce motion	As a particle gyrates down a field line, the pitch angle increases as B increases; Motion along field line reverses when pitch angle reaches 90° (mirror point)	F~ Hz
Drift motion	Gradient in magnetic field leads to drift motion around Earth: east for electrons, west for protons/ions	F~mHz

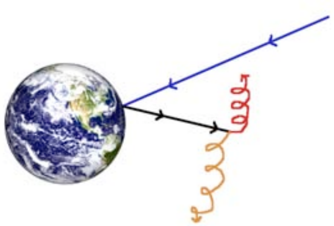


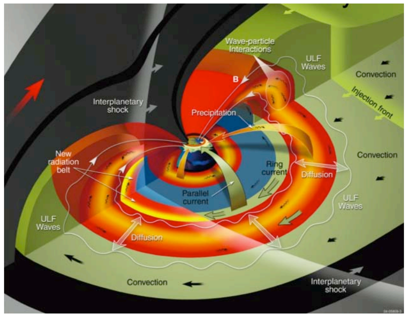
Sources, energization, diffusion, and losses

- Sources: solar wind or plasmasheet plasma, cosmic ray albedo neutrons
- Energized by wave-particle interactions (e.g. whistler waves), crosstail E field fluctuations
- Diffusion: by wave-particle interactions
- Losses: by magnetopause shadowing or scattering into loss cone (loss to atmosphere)
  - Scattering by wave-particle interactions, Coulomb collisions



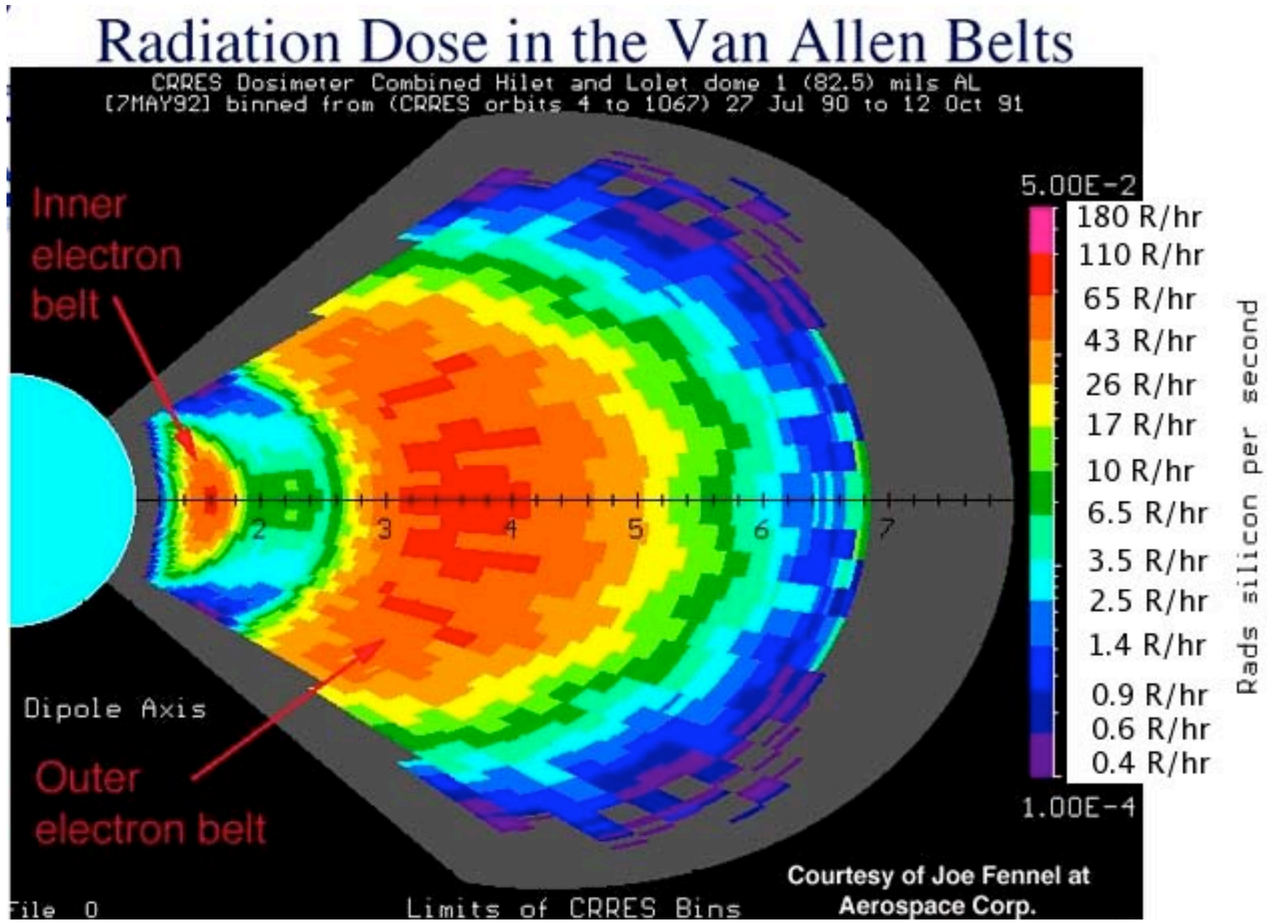
Reeves, after Summers et al., 1998



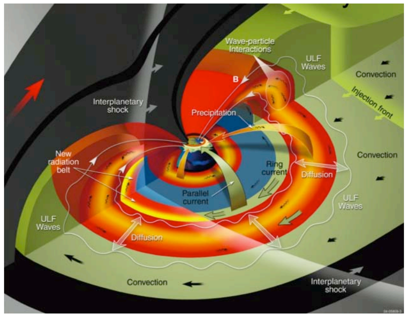


Radiation fluxes from CRRES

- CRRES= Combined Release and Radiation Effects Satellite
- radiation flux observations from CRRES, 1990-91
- scale converted to rads/hour



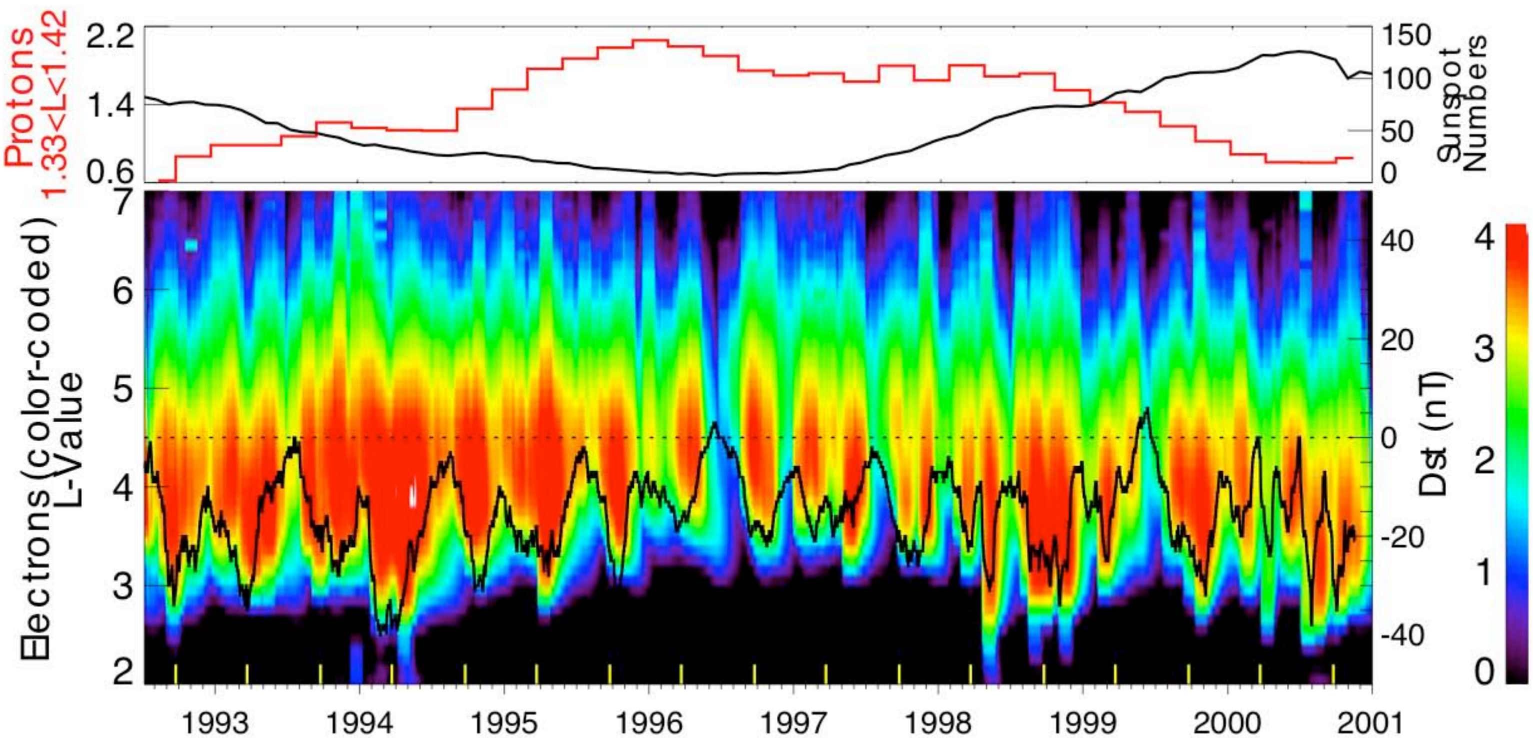
Fennel/Aerospace Corp., 2003

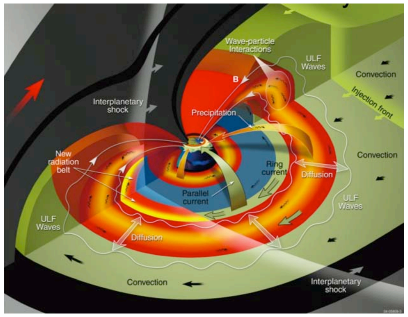


Long term dynamics from SAMPEX

- SAMPEX=Solar Anomalous and Magnetospheric Particle Explorer
- SAMPEX observations over most of a solar cycle
- shows long-term dynamics in outer radiation belt

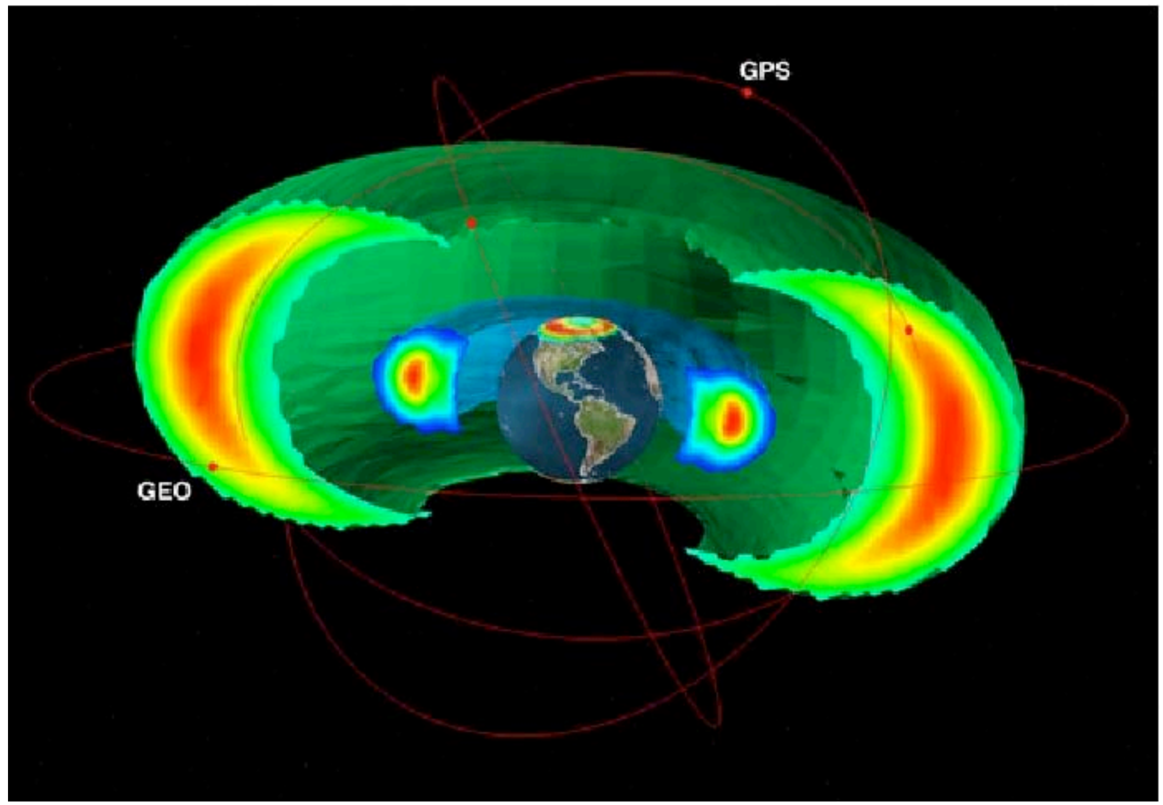
Li et al., 2001





Observation locations

- Satellites
  - low Earth orbit (SAMPEX, DMSP)
  - Geosynchronous orbit (GOES)
  - Eccentric orbit (IMAGE, CRRES, CLUSTER, RBSP)
- Ground based systems



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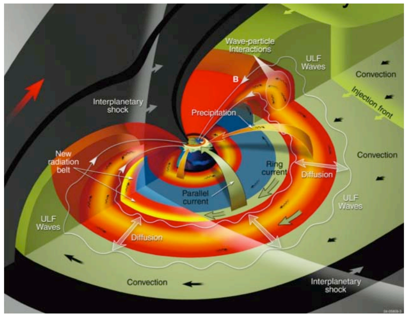
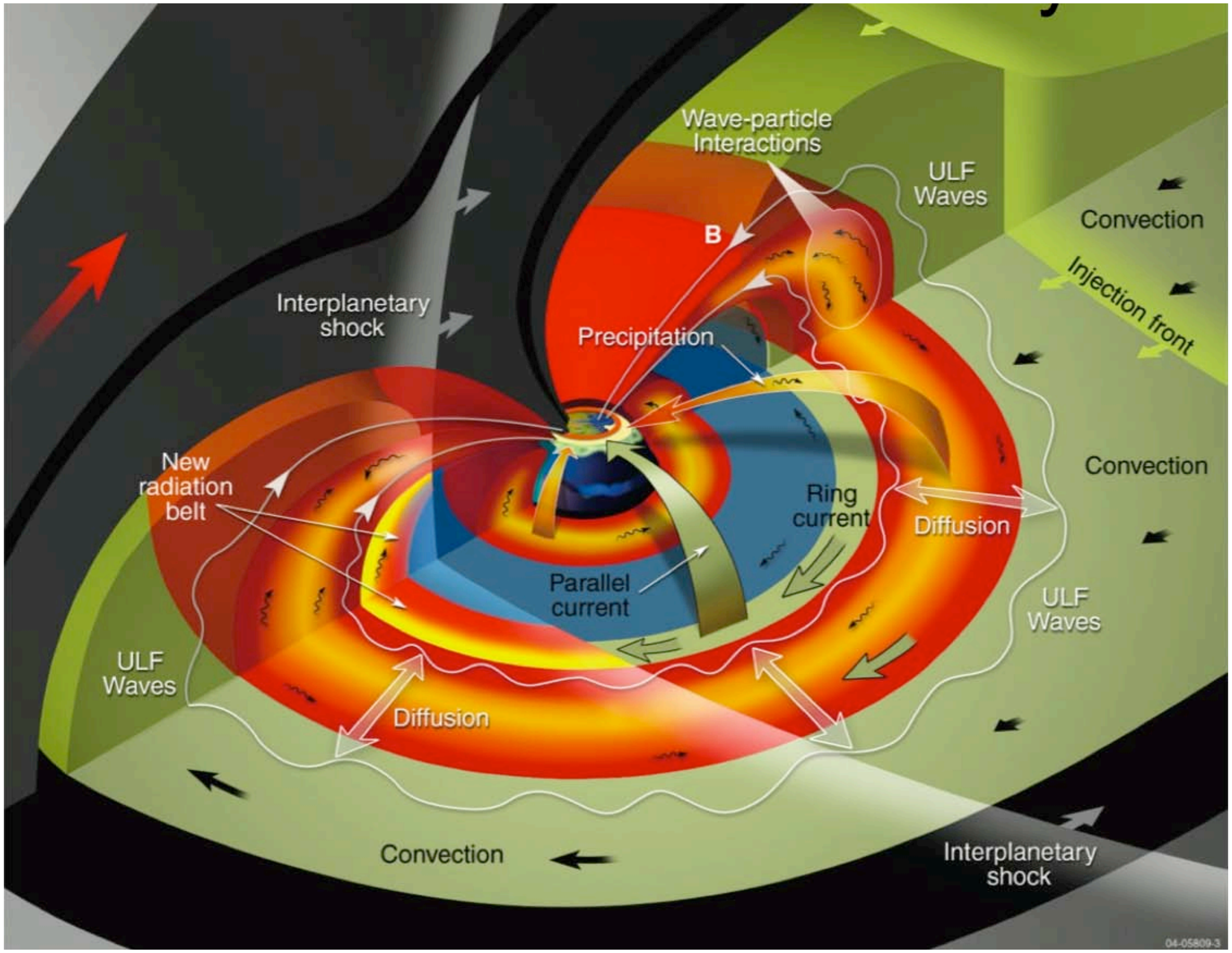


Summary

- Inner magnetosphere: near-dipolar B field, closed drift paths

- Plasmasphere
- Ring current
- Radiation belts

- These systems are very dynamic
- They interact with each other and with ionosphere, outer magnetosphere
- Understanding is important for both science and applications



NASA web site

Thank you !

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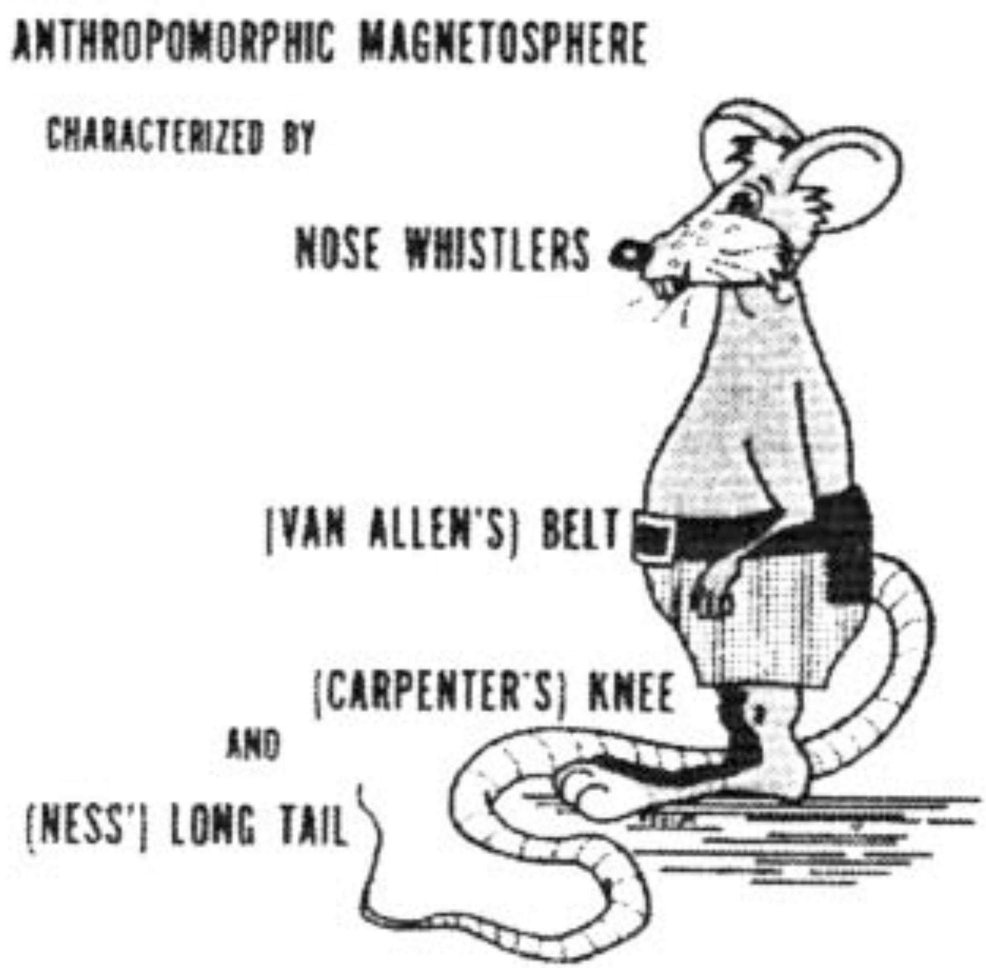

O'Brien, in Lemaire and Gringauz (1998)

see my poster Monday