

Inner Magnetosphere: Plasma Sheet and Ring Current

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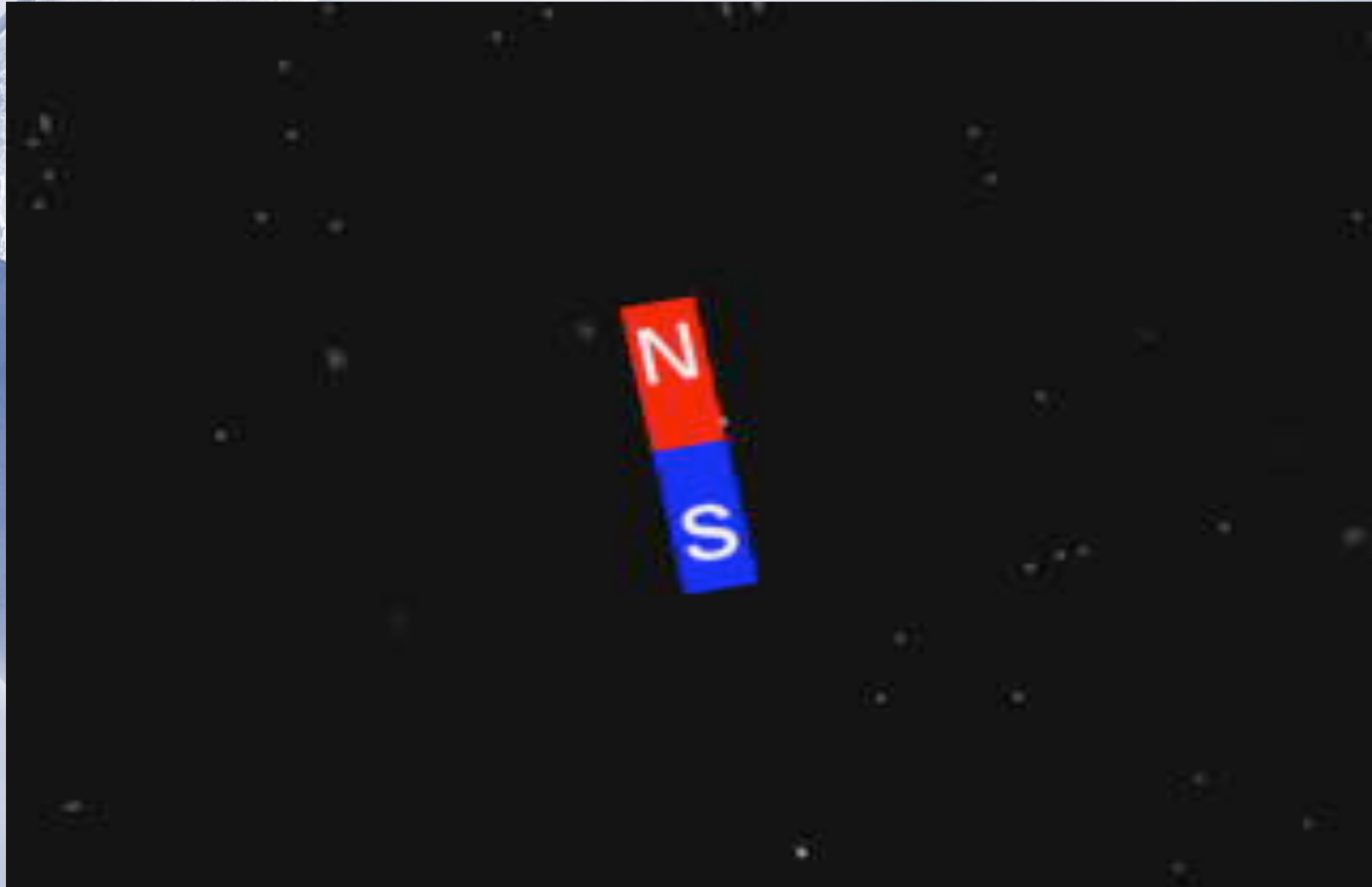
GEM 2007 - Student Tutorial



Outline

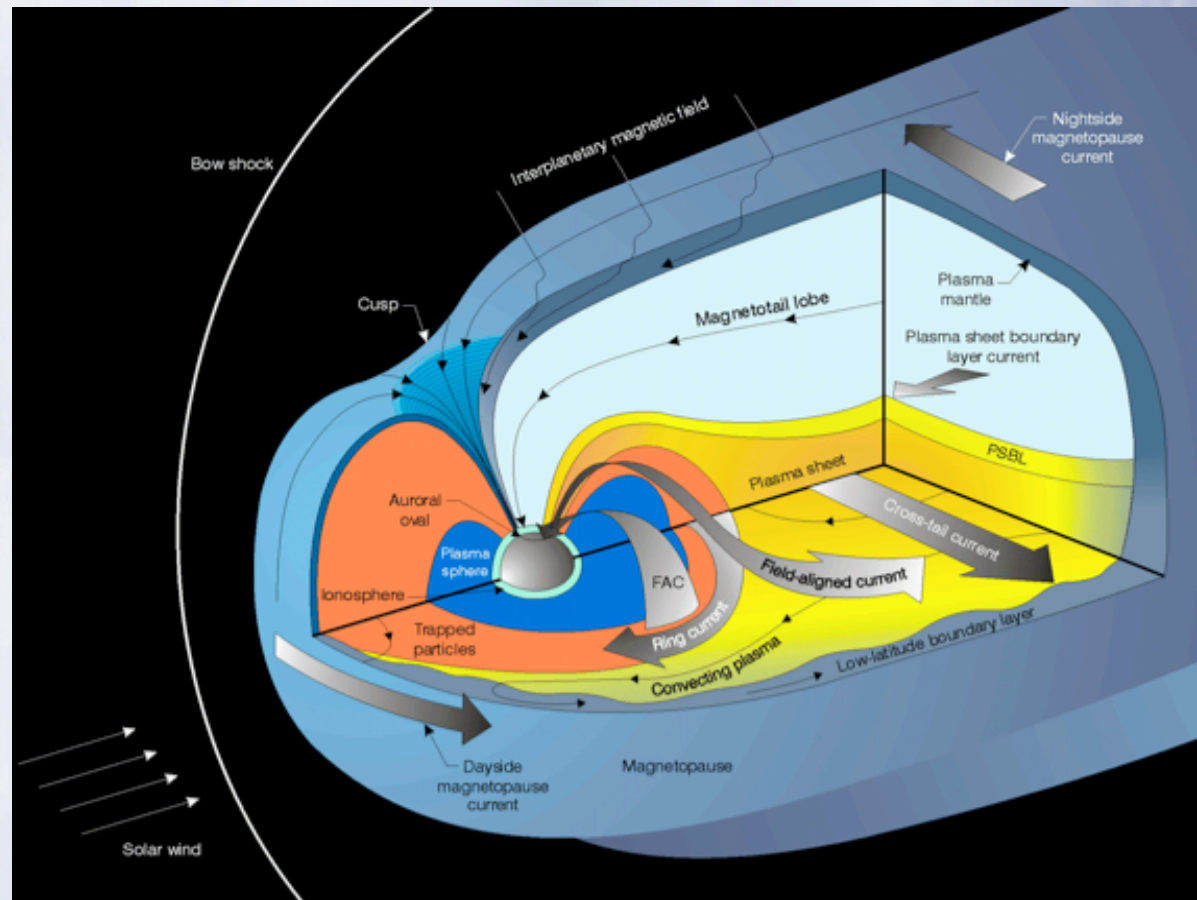
- ✧ Magnetosphere
- ✧ Inner Magnetosphere
 - ✧ Plasmasphere
 - ✧ Plasma Sheet
 - ✧ Ring Current
- ✧ Summary

Magnetosphere: Formation



Magnetosphere: Main Regions

- ✧ Bow Shock: fast magnetosonic shock
- ✧ Magnetosheath: turbulence
- ✧ Magnetopause: tangential discontinuity, magnetic reconnection, KH instability
- ✧ Cusp Region: turbulence, edge flows
- ✧ Trapping regions: particle trapping, currents, drift motion
- ✧ Neutral sheet: magnetic reconnection

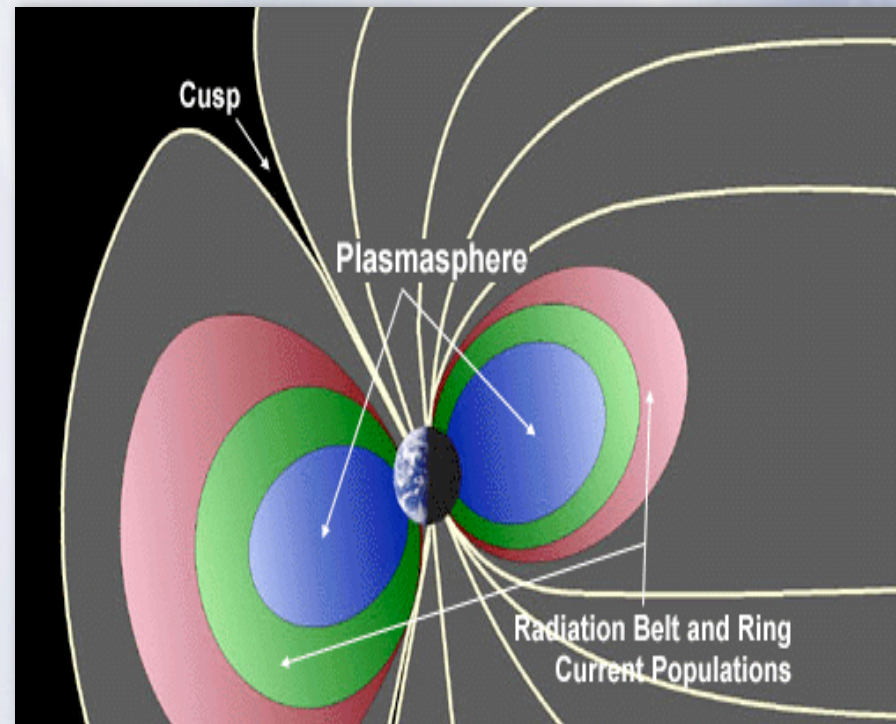


The Inner Magnetosphere

- ✧ Inner magnetosphere is where space weather matters
 - ✧ This is where we fly lots of commercial and military satellites
 - ✧ Even the calm times are full of dynamic processes
- ✧ There are 3 main plasma populations in the inner magnetosphere
 - ✧ Plasmasphere: contains the mass
 - ✧ Ring current: contains the energy
 - ✧ Radiation belt: contains the dangerous particles

Plasmasphere: Basic Definition

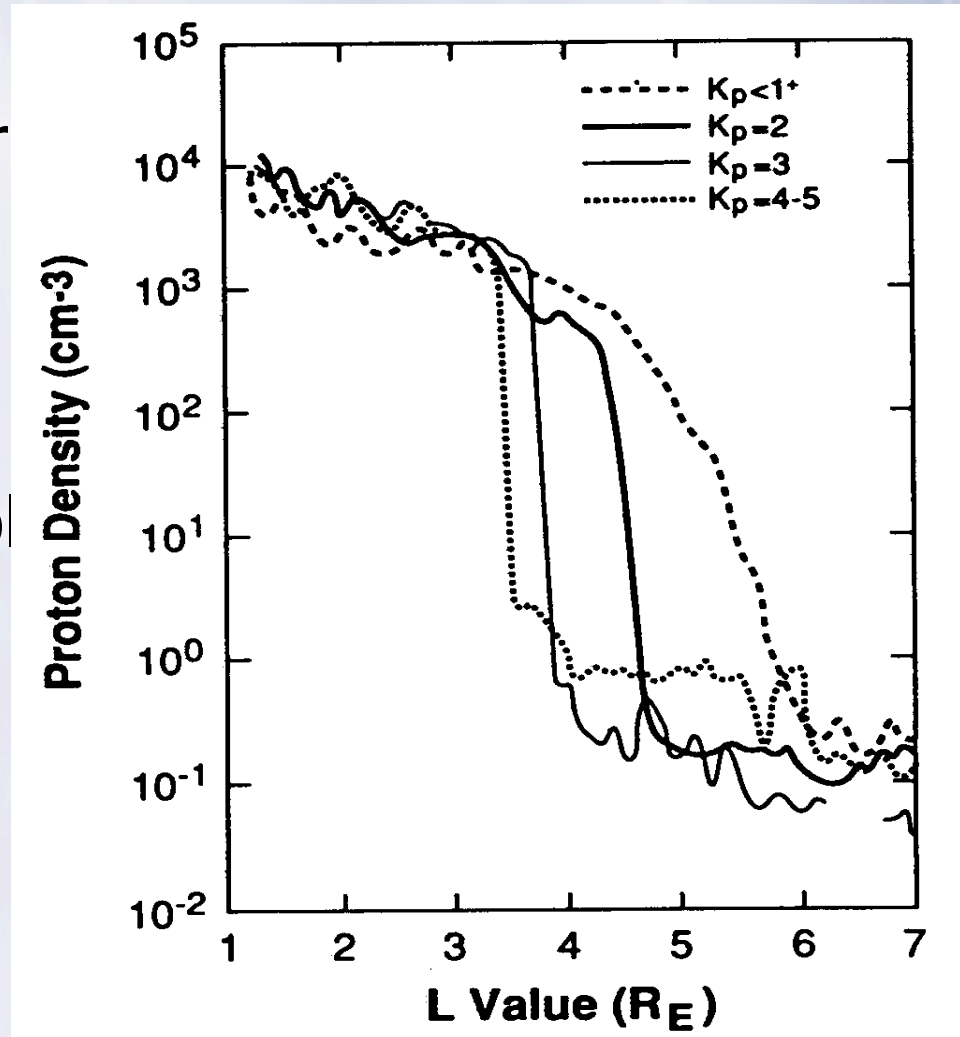
- ✧ Cold: Less than 1eV, maybe up to 10eV
- ✧ Dense: Number densities : 10^2 to 10^3 cm^{-3}
- ✧ Ionospheric: Source is in the subauroral ionosphere
- ✧ Mostly Protons: often-quoted composition, 77% H^+ , 20% He^+ , and 3% O^+
- ✧ E-field dominated: spatial extent governed by magnetospheric electric field time history
- ✧ Important: dominates the mass density of the inner magnetosphere



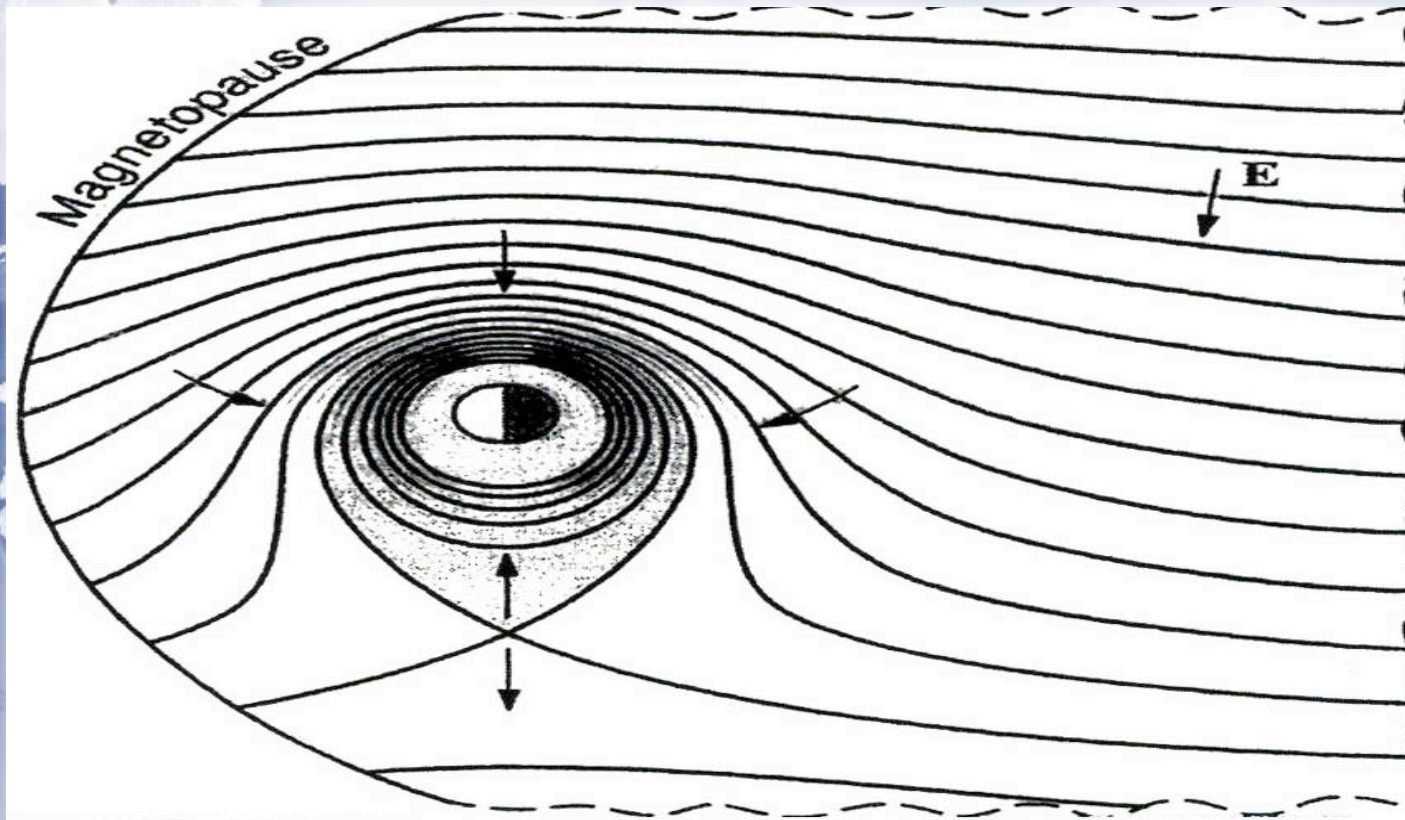
Plasmasphere

✧ Terminated at a sharp drop at plasmopause.

✧ The location of the plasmopause is related to the level of magnetic activity.

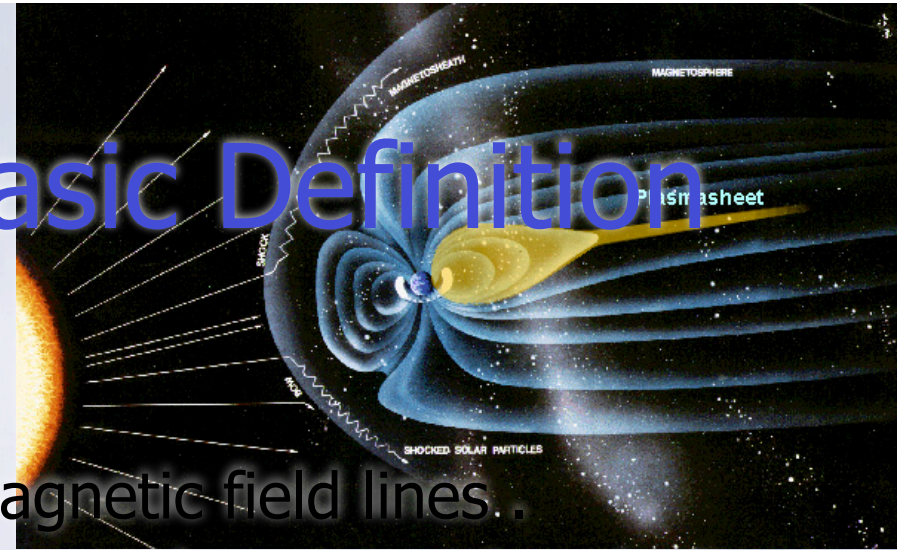


Plasmasphere



Plasma drifts paths: due to the corotational electric field combined with the convection electric field

Plasma Sheet: Basic Definition

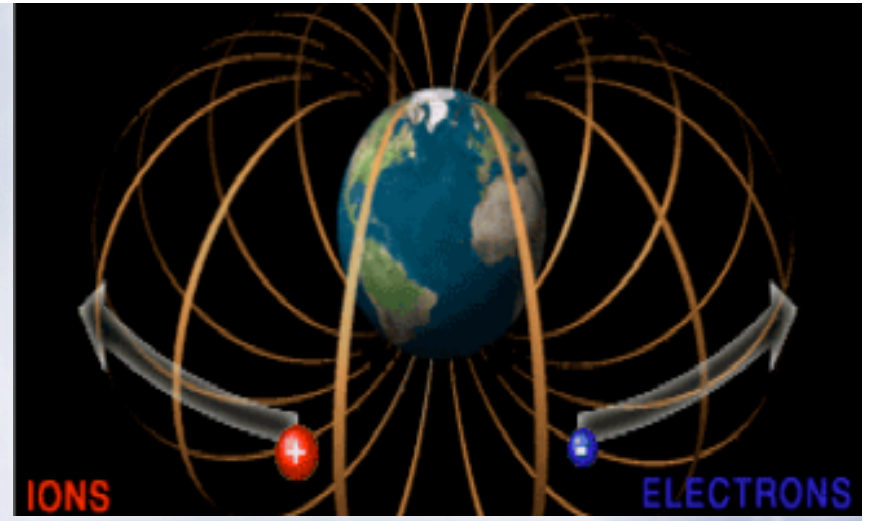


- ✧ Contains highly stretched magnetic field lines.
- ✧ Hot (keV particles) that have nearly symmetric velocity distributions)
- ✧ Dense :Number densities are typically: $0.1-1\text{cm}^{-3}$
- ✧ Composed of H^+ and O^+ (in modest concentrations during quiet time but almost as abundant as H^+ during storm time).
- ✧ Almost invariably $T_i=7T_e$
- ✧ For the most part, plasma sheet lies on closed field lines; might sometime contain plasmoids.

Ring Current: Basic Definition

- ✧ Hot: 1-400 keV
- ✧ Tenuous: quiet, 1 cm^{-3} ; active, 10s cm^{-3}
- ✧ Plasma sheet: source is near-Earth magnetotail, wherever that comes from
- ✧ Mostly Protons: During big storms, O^+ can dominate
- ✧ Complicated Drift: E-field, B-field, Gradient-curvature terms
- ✧ Important: Dominates the energy density of the inner magnetosphere

Ring Current



- ❖ Located between 2 and 7 Earth Radii
- ❖ Toroidal shaped current that flows westward.
- ❖ Ions and electrons move in opposite directions
- ❖ Electrons contribute little to the ring current due to their negligible energy density.
- ❖ Associated with strong perturbations in the magnetic field measured at Earth.
- ❖ Prevents the dynamo-generated electric fields at high latitudes from penetrating to middle and low latitudes.

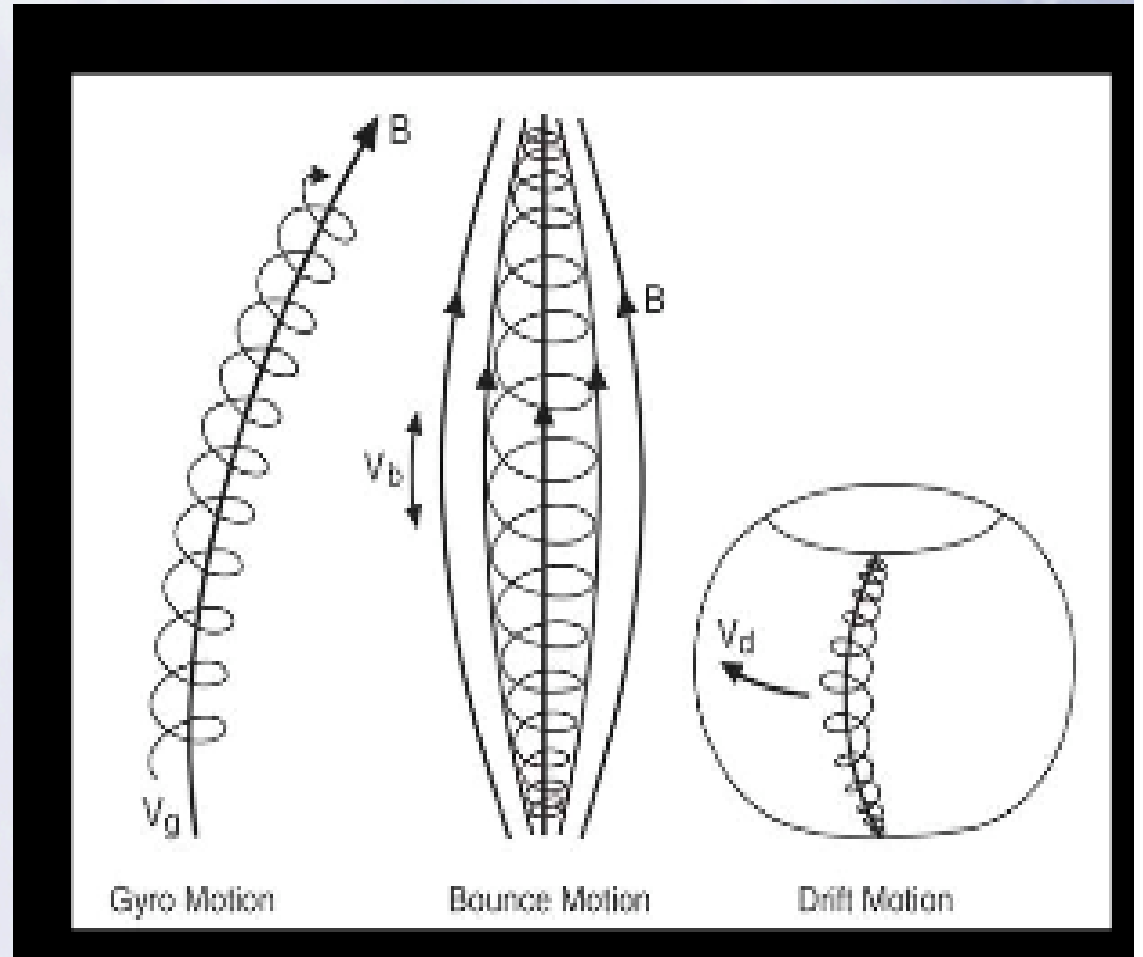
Ring Current

- ✧ Gradient-curvature drift of equatorial trapped particles with:

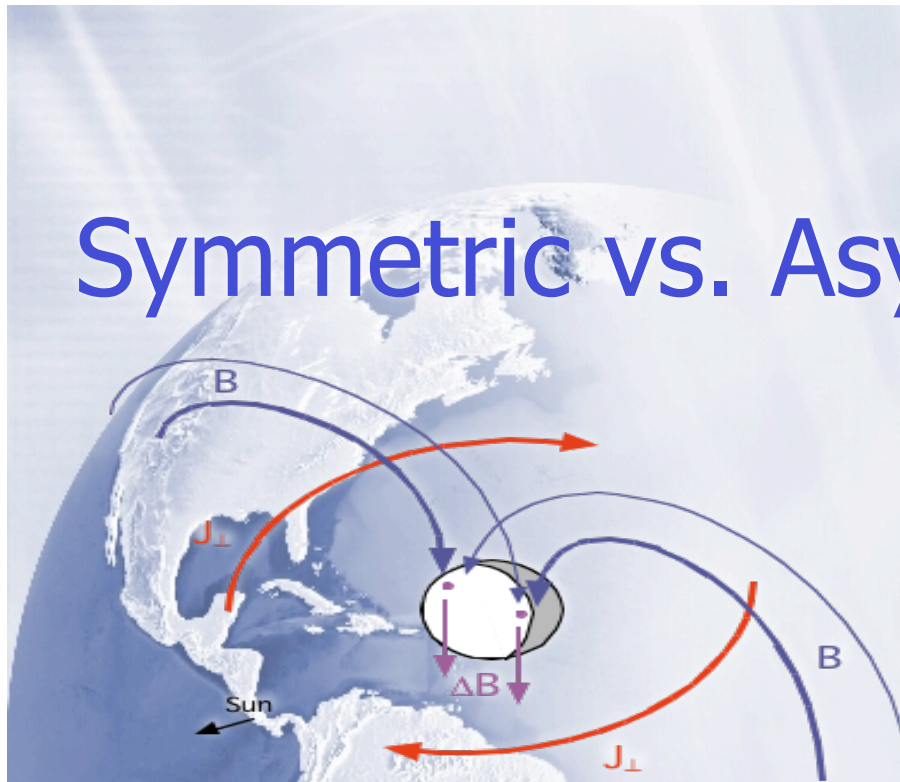
$$\vec{V}_{GC} = -\frac{3}{2} \frac{mv^2}{q} \frac{L^2}{B_e R_e} \hat{e}_\phi$$

- ✧ The total current:

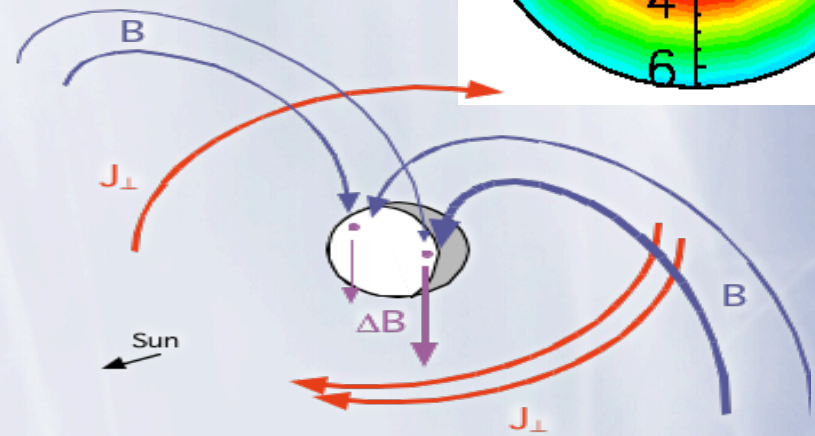
$$I_\phi = -3 \frac{L^2}{B_e R_e} \sum_{e,i} N_t \frac{m_t v_t^2}{2}$$



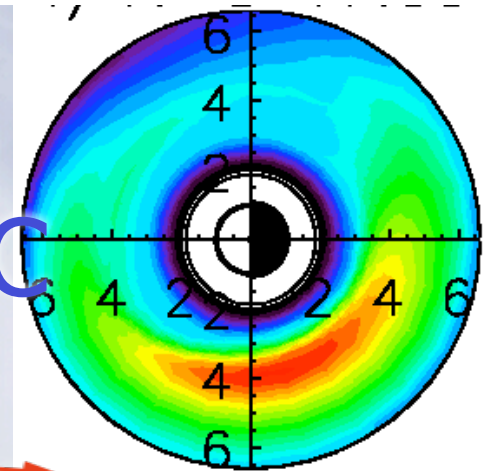
Symmetric vs. Asymmetric RC



Right-hand rule (Biot-Savart Law): Westward current induces an southward B at Earth. Symmetric current produces a symmetric perturbation

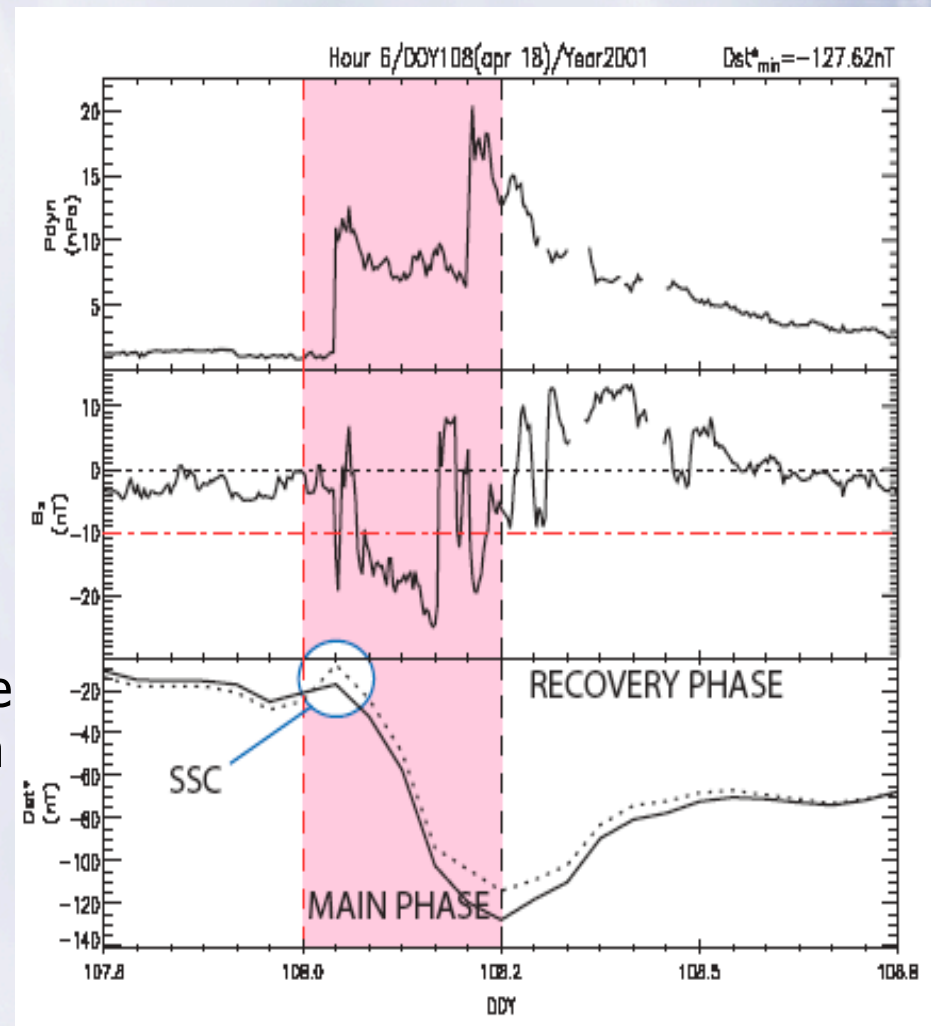


Weaker RC at some local time makes the perturbation asymmetric. A completely asymmetric ring current also adds a symmetric component to the perturbation.



Dst Index

- ✧ The Dst index monitors the magnetic storm level
- ✧ Constructed by averaging the horizontal component of the Earth magnetic field from midlatitude and equatorial stations from all over the world.
- ✧ The negative deflections in the Dst index are caused by storm time ring current which flows around the Earth from east to west in the equatorial plane.



SUMMARY

POPULATION	DENSITY	TEMPERATURE	SOURCE	COMPOSITION	DRIVER	IMPORTANCE
<i>Plasmasphere</i>	<i>100s cm³ to 1000</i>	<i><1eV, and up to 10s of eV</i>	<i>Subauroral ionosphere</i>	<i>H⁺, some He⁺ and O⁺</i>	<i>E field</i>	<i>Dominates mass energy</i>
<i>Ring Current</i>	<i>~few cm³ up to 10s</i>	<i>1-400keV</i>	<i>Plasma sheet (Solar Wind and ionosphere)</i>	<i>H⁺ and O⁺ during storms</i>	<i>E and B fields</i>	<i>Dominates energy density</i>