Lecture 12

Polarization Drift

$$\bar{V}_p = \frac{m}{qB^2}\frac{\partial \vec{E}}{\partial t}$$

in direction of $\vec{E}$
depends on charge
and mass (indirectly)

comes from the

$$\langle V_G \rangle = \dots \frac{1}{e}\frac{B}{B^2} \times \left[m \frac{d}{dt_0} V \right]$$

term
Dropped because
we assumed steady state

$$\bar{V}_p = \frac{\pm 1}{\Omega B}\frac{\partial \vec{E}}{\partial t} \propto \frac{\tau_g}{T}\Delta E$$

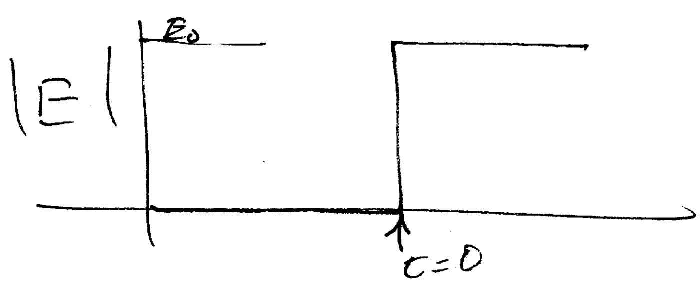
If $E = E_0 e^{i\omega t}$

Then

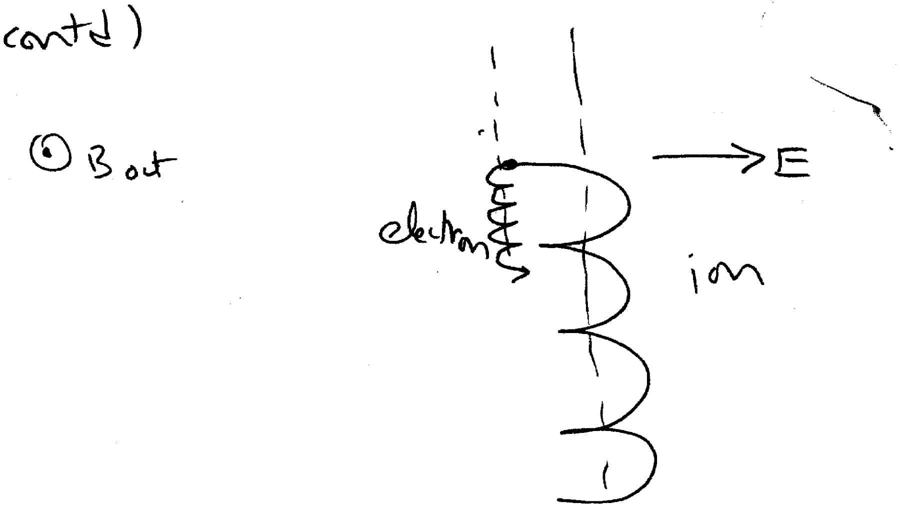
$$|\bar{V}_p| = \frac{\omega}{\Omega}\frac{E_0}{B}$$

→ gets small if frequency is much lower than gyro frequency

Example:
Imagine particles at rest in a B field and suddenly turning on E field



Ex (contd)



during 1st 1/4 gyro period there is a net shift of ⊕ to right by ρ_i and ⊖ charge to left by ρ_e

This is a transient current which disappears after E becomes steady and after one ion gyro period. After that the particles just E×B drift.

What about $\frac{d\bar{B}}{dt}$; time varying B field?

Cannot energize a particle with a B field, but $\dot{B} = \bar{\nabla} \times \bar{E}$

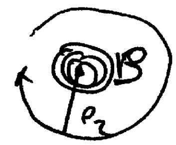
since $\mu = \text{const}$ for slowly varying B fields

as B changes, $\frac{1}{2} m v_\perp^2$ must increase

⇒ Adiabatic Compression or heating occurs

Flux through gyro orbit is conserved

if $B \uparrow$ $\rho \downarrow$
and $V_\perp \uparrow$

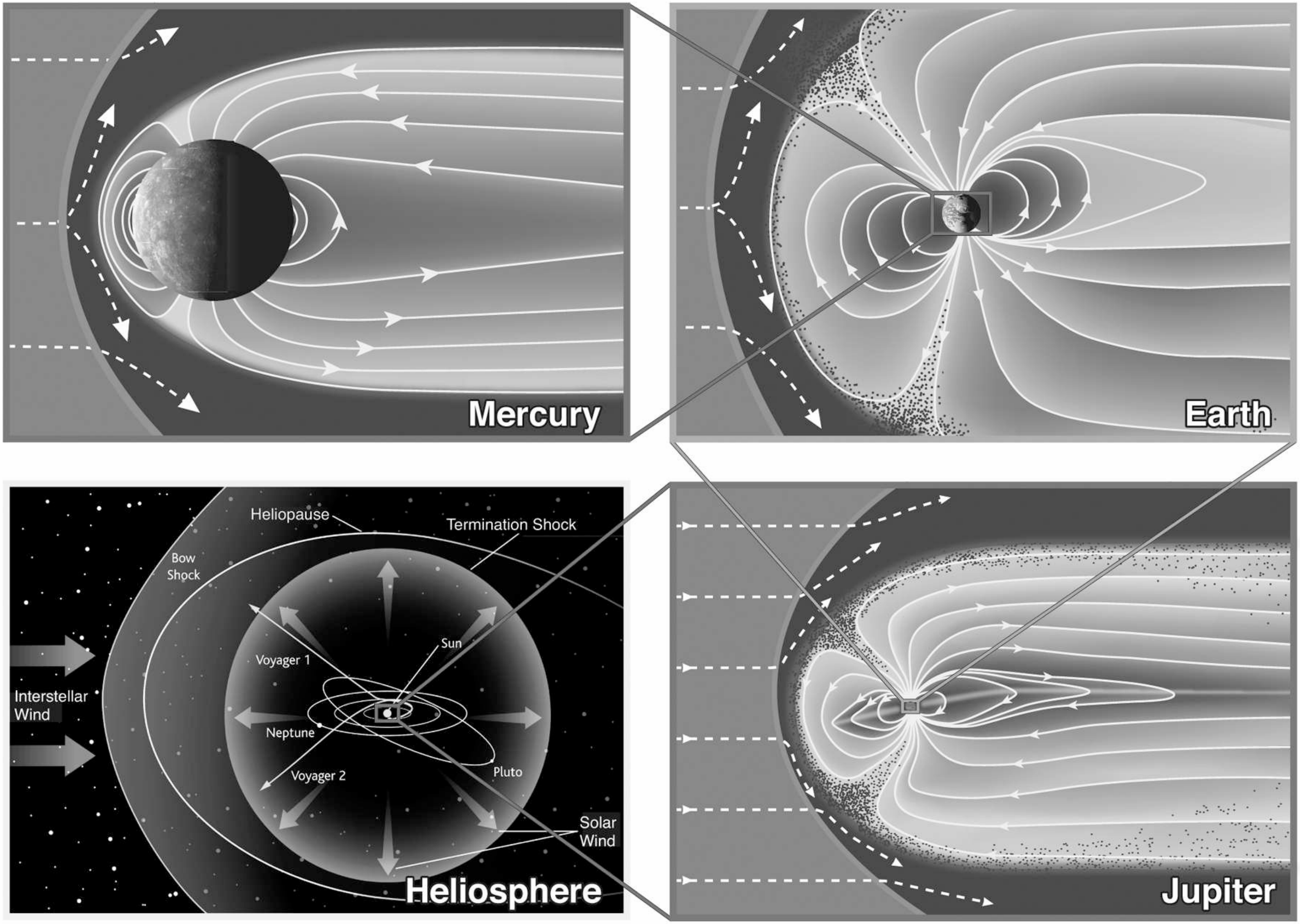


$$\mu = \frac{m v_\perp^2}{2B} = \text{const} \qquad \rho = \frac{m v_\perp}{qB}$$

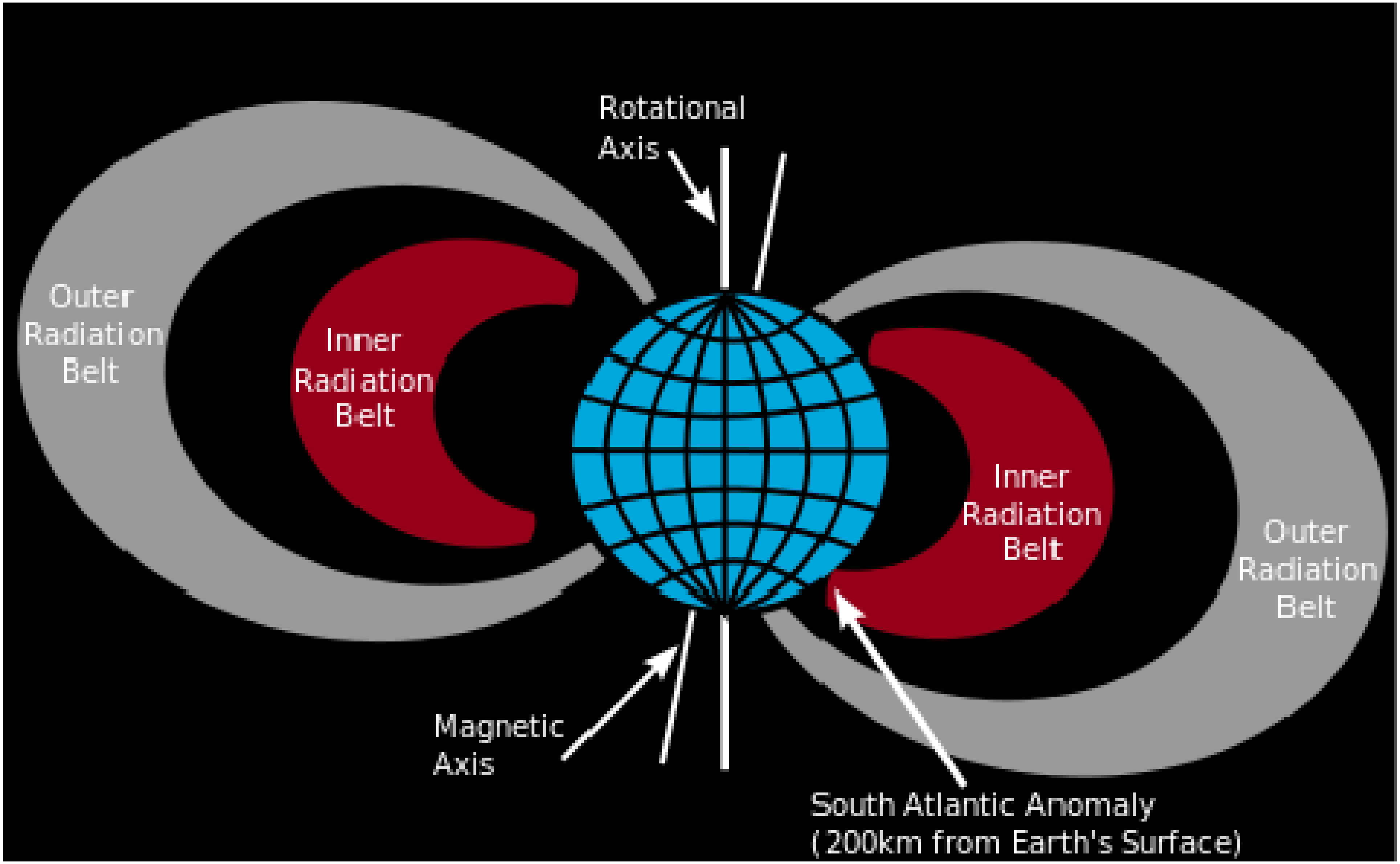
$$v_\perp = \sqrt{\frac{\mu 2 B}{m}}$$

$V_\perp \uparrow$ by square root of
$B \uparrow$ as B
So ρ gets smaller.

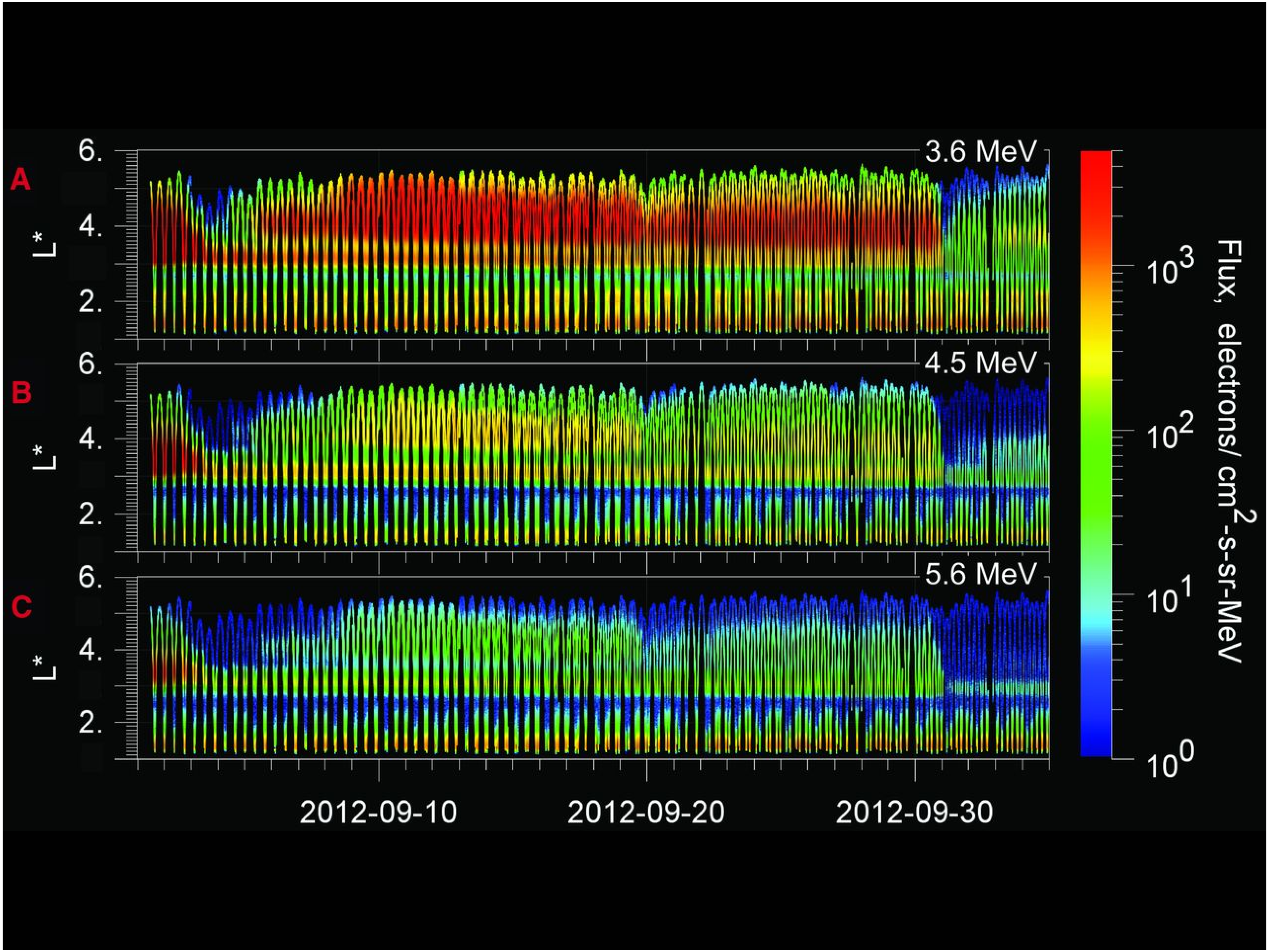
Early plasma heating devices used this technique.
Similar effects occur in magnetosphere when magnetosphere is suddenly compressed by enhanced solar wind.

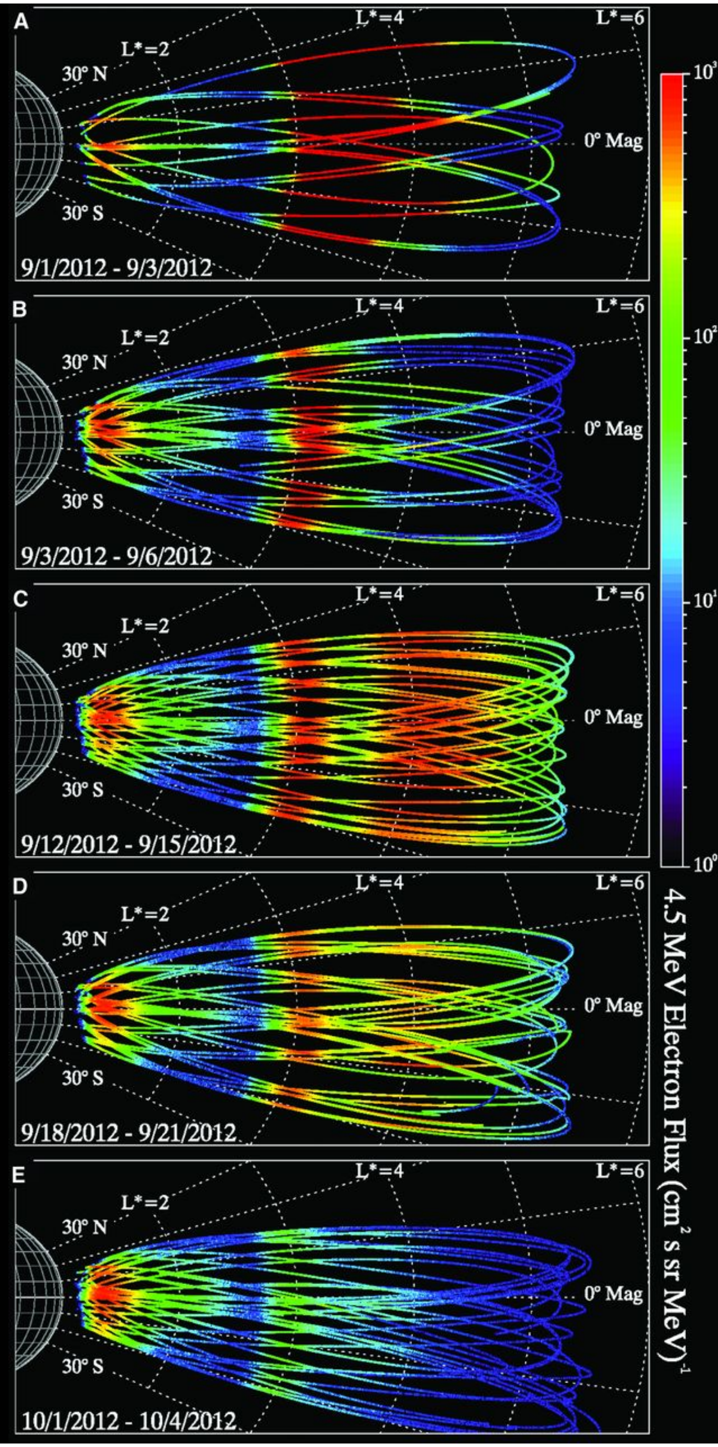


http://www.youtube.com/watch?v=c9qKIVlhXpQ#t=16

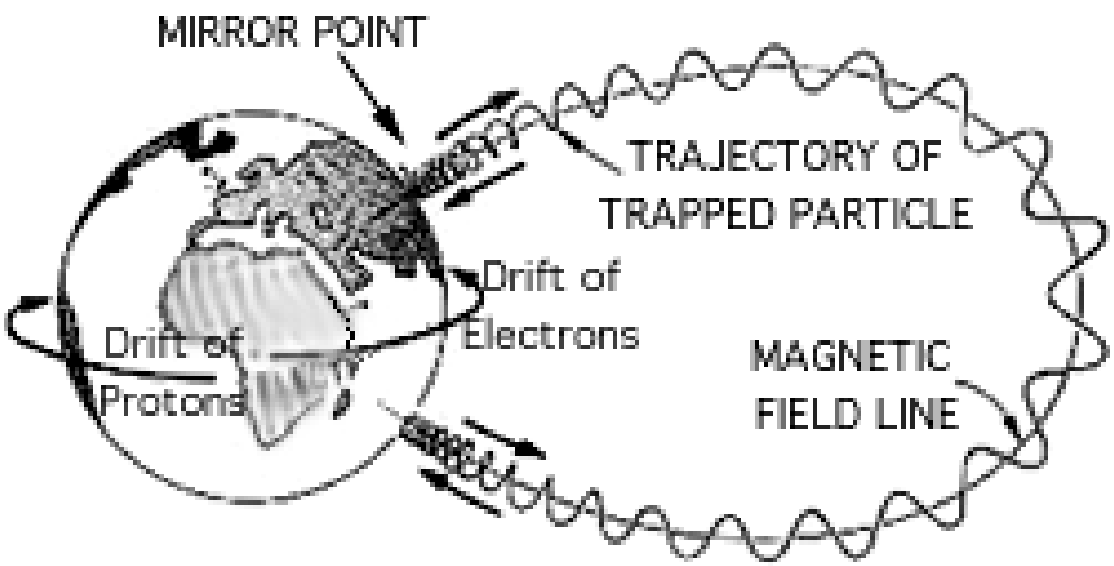


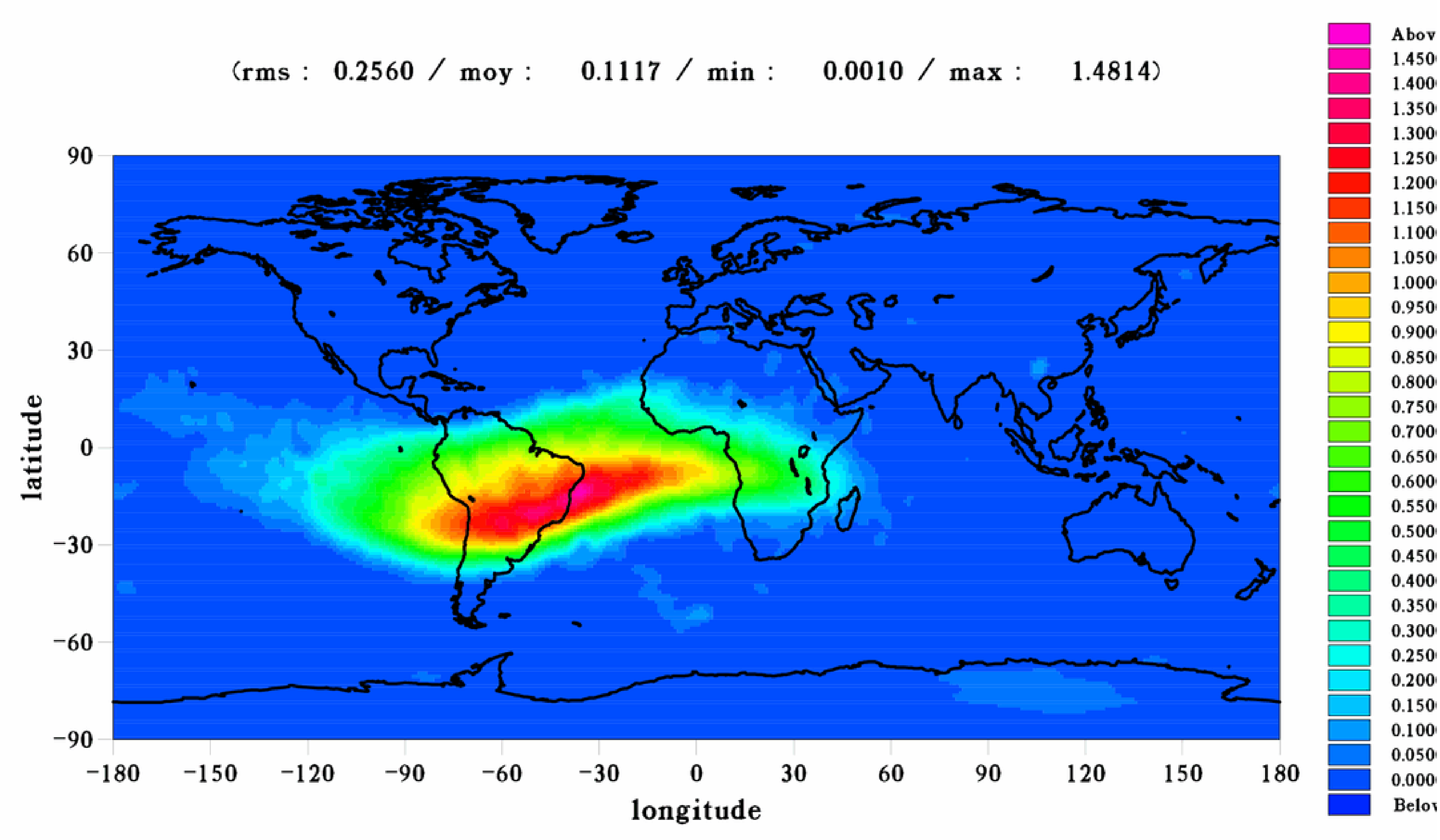
Rotational Axis
Outer Radiation Belt
Inner Radiation Belt
Inner Radiation Belt
Outer Radiation Belt
Magnetic Axis
South Atlantic Anomaly (200km from Earth's Surface)

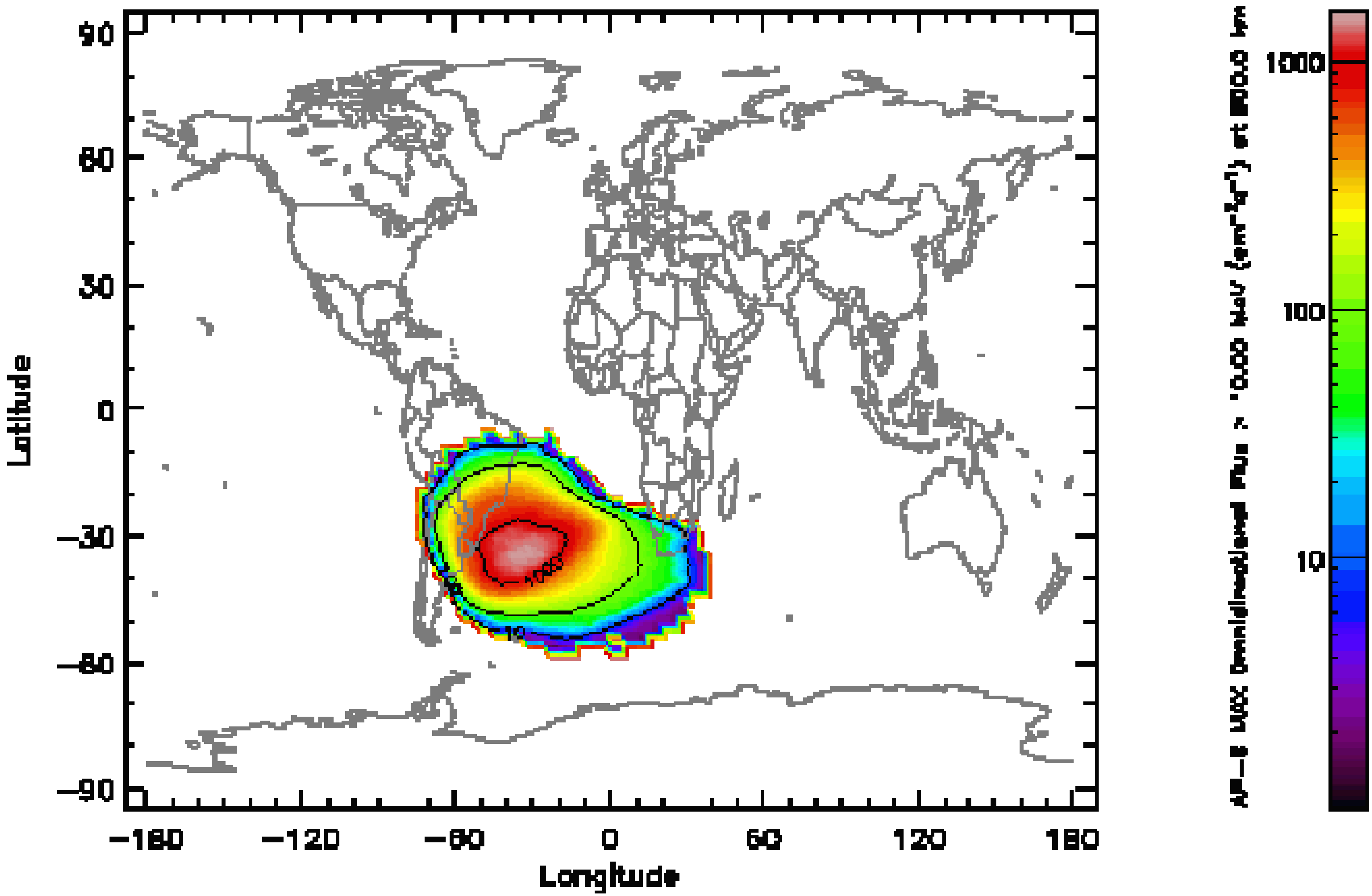

A
B
C
3.6 MeV
4.5 MeV
5.6 MeV
L*
6.
4.
2.
2012-09-10
2012-09-20
2012-09-30
Flux, electrons/ cm^2-s-sr-MeV
10^3
10^2
10^1
10^0


A
L*=2
L*=4
L*=6
30° N
0° Mag
30° S
9/1/2012 - 9/3/2012
B
9/3/2012 - 9/6/2012
C
9/12/2012 - 9/15/2012
D
9/18/2012 - 9/21/2012
E
10/1/2012 - 10/4/2012
10³
10²
10¹
10⁰
4.5 MeV Electron Flux (cm² s sr MeV)⁻¹

single particle motion in radiation belts




(rms :   0.2560 / moy :   0.1117 / min :   0.0010 / max :   1.4814)
latitude
longitude
90
60
30
0
−30
−60
−90
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
Abov
1.450
1.400
1.350
1.300
1.250
1.200
1.150
1.100
1.050
1.000
0.950
0.900
0.850
0.800
0.750
0.700
0.650
0.600
0.550
0.500
0.450
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Belov



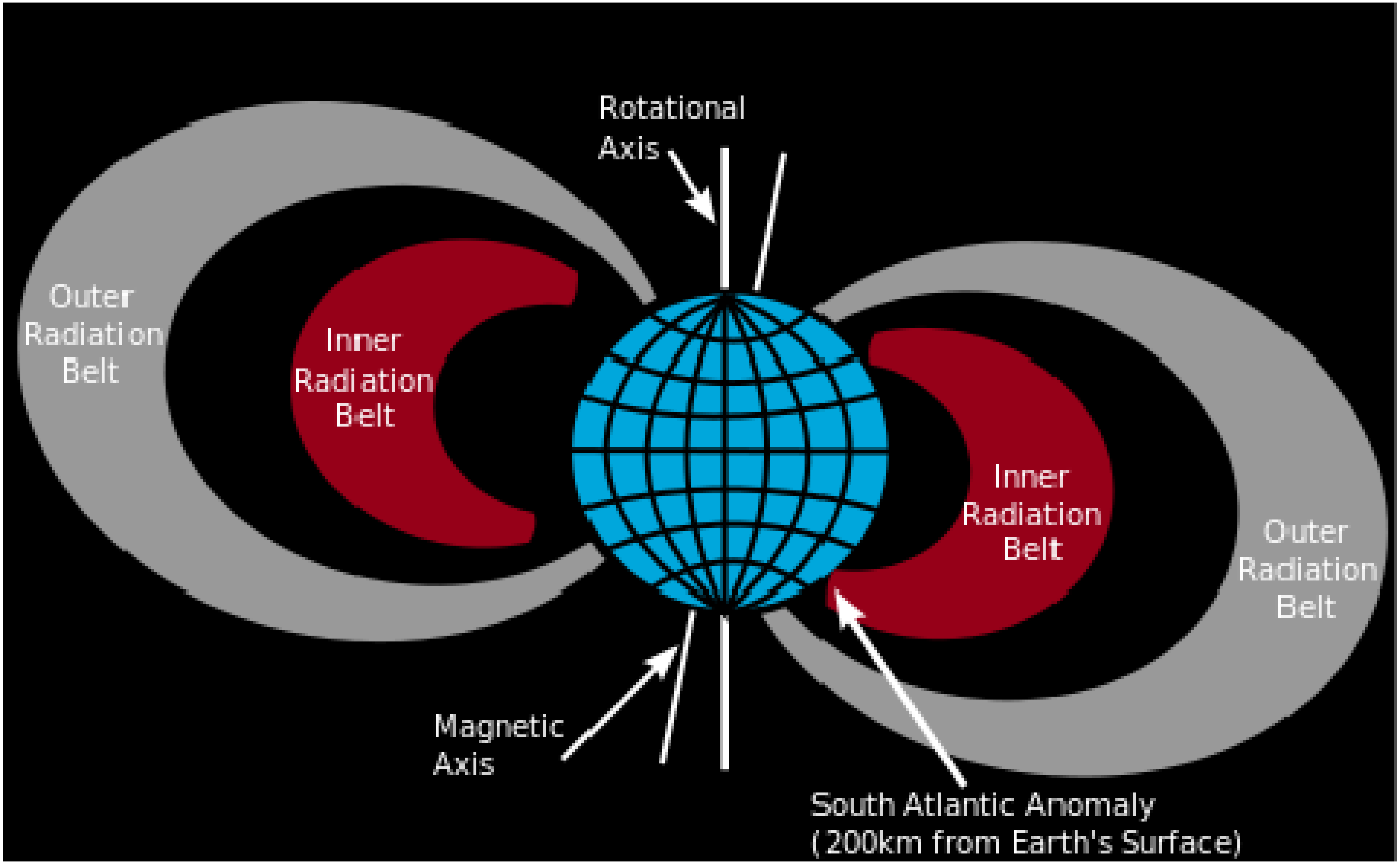
90
60
30
0
−30
−60
−90
Latitude
−180
−120
−60
0
60
120
180
Longitude
1000
10
1000
100
10
AP-8 MAX Omnidirectional Flux > 10.00 MeV (cm^{-2}s^{-1}) at 800.0 km

Today: Three topics using Single Partical Dynamics in the mgnetosphere

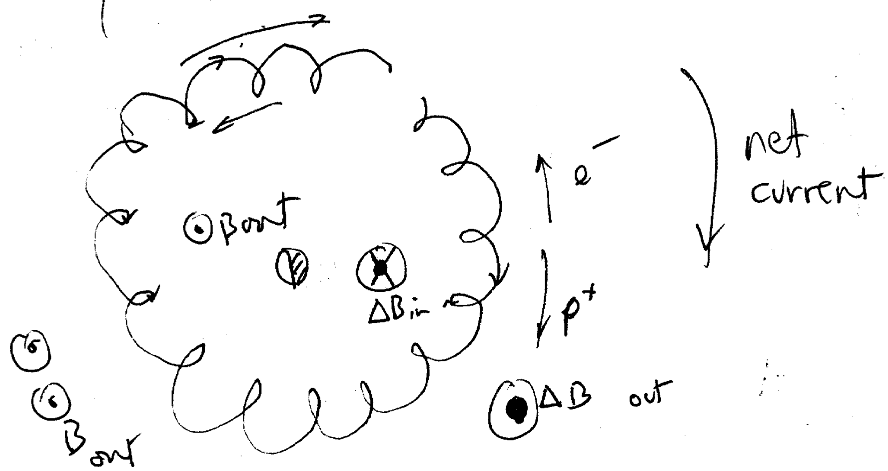
Radial Diffusion
(Grad-B drifting particles experience a cross-magnetosphere Electric field which varies at the Drift Period)

Corotation of the Plasmasphere
(The inner magnetosphere rotates once/day because of the conducting, magnetized, rotating ionosphere generating an electric field which gives just the right the ExB drift)

Alfven Shielding Layer
(Energetic particles, approaching from the magnetotail, make a partial ring current, leaving predominantly positive charge on the Dusk side, and Negative charge on the Dawn side)


Rotational Axis
Outer Radiation Belt
Inner Radiation Belt
Inner Radiation Belt
Outer Radiation Belt
Magnetic Axis
South Atlantic Anomaly
(200km from Earth's Surface)

Ring Current



ΔB on surface is opposed to B of earth's field

How Big is ΔB? See p. 545 of Parks

* D_{ST} Figures

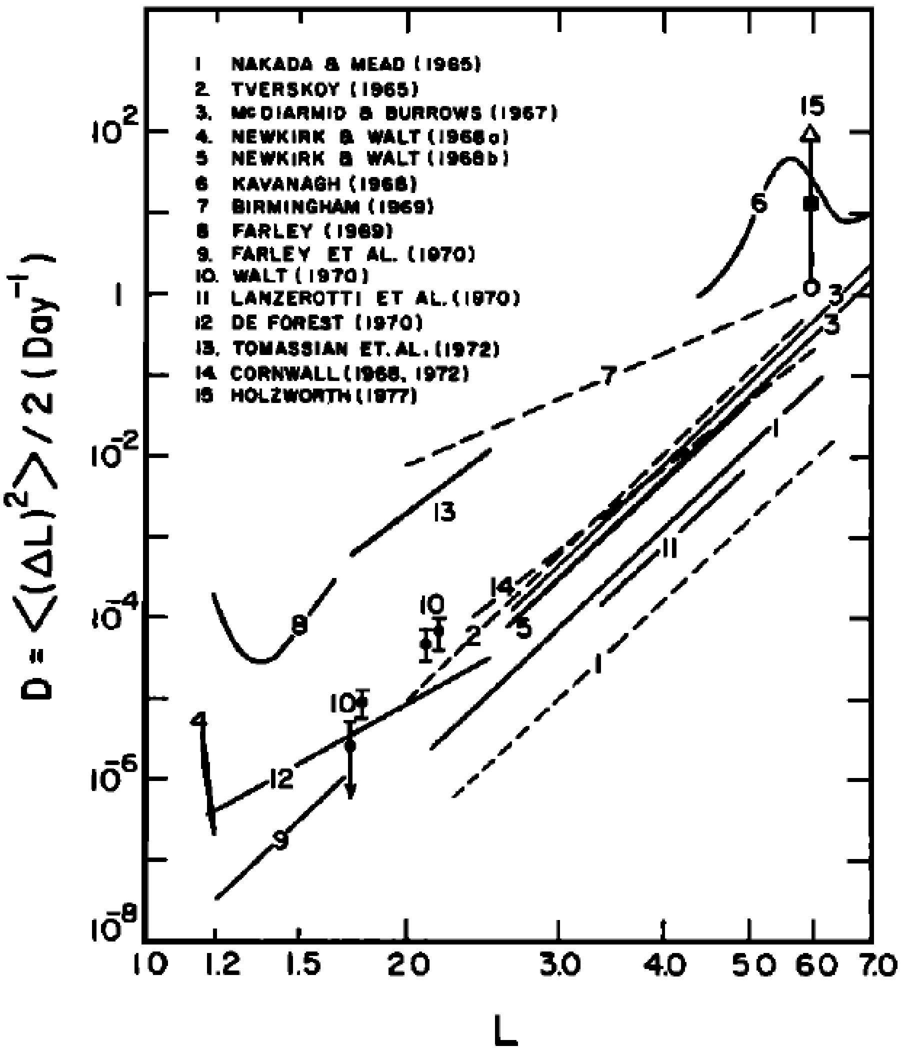


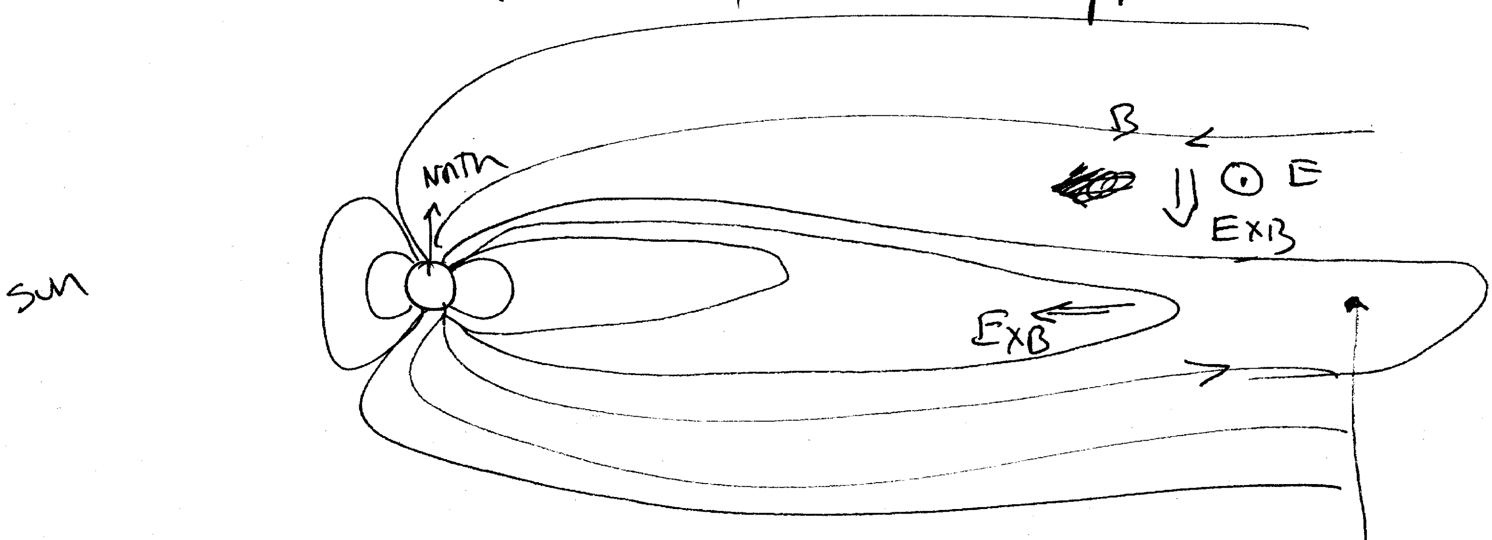
Fig. 5. Radial diffusion coefficients derived by various methods and by many experimenters [after Walt, 1971, Figure 6]. Solid lines are derived with some assumptions from experimental data, while dashed lines are theoretical determinations. The sources are given in the inset; see the text for explanation of the data.

Applications of Adiabatic Particle Motion to Magnetospheric Problems

1. South Atlantic Anomaly

   B is weaker, so mirror points are lower. Hence more precipitation. (see figures)

2. Energy distribution shaped by radial diffusion



$$\mu = \text{const} = \frac{\frac{1}{2} m v_\perp^2}{B}$$

assume source at $r = 10 R_e$

assume $V_{\parallel} = 0$

if particle drifts from $L=10$ to $L=1$

Then $$\mu = \frac{\text{Energy}(10)}{B(10 R_e)} = \frac{\text{Energy}(1)}{B(R_e)}$$

$B \propto \frac{1}{r^3}$ so $$\text{Energy}(R=R_e) = \frac{B(1 R_e)}{B(10 R_e)} \text{ Starting Energy}$$

$$\frac{B(1)}{B(10)} = \frac{\left(\frac{1}{R_e}\right)^3}{\left(\frac{1}{10R_e}\right)^3} = 1000$$

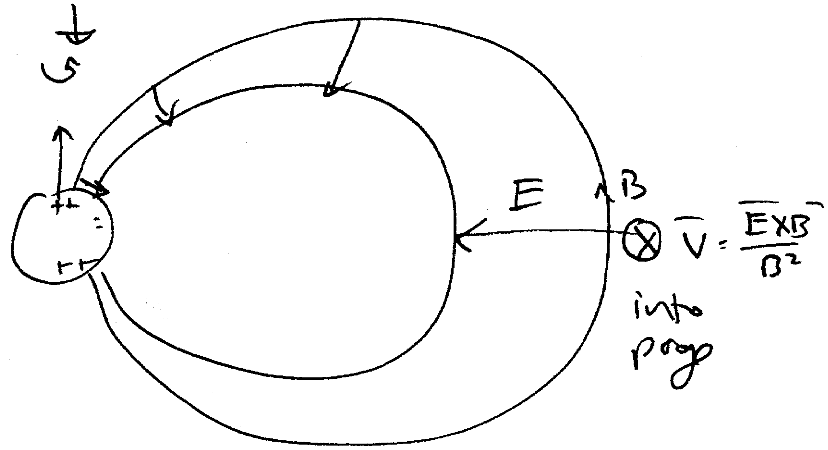
So Energy Gain is 1000 times!

inner radiation belts have highest energy

Show figure

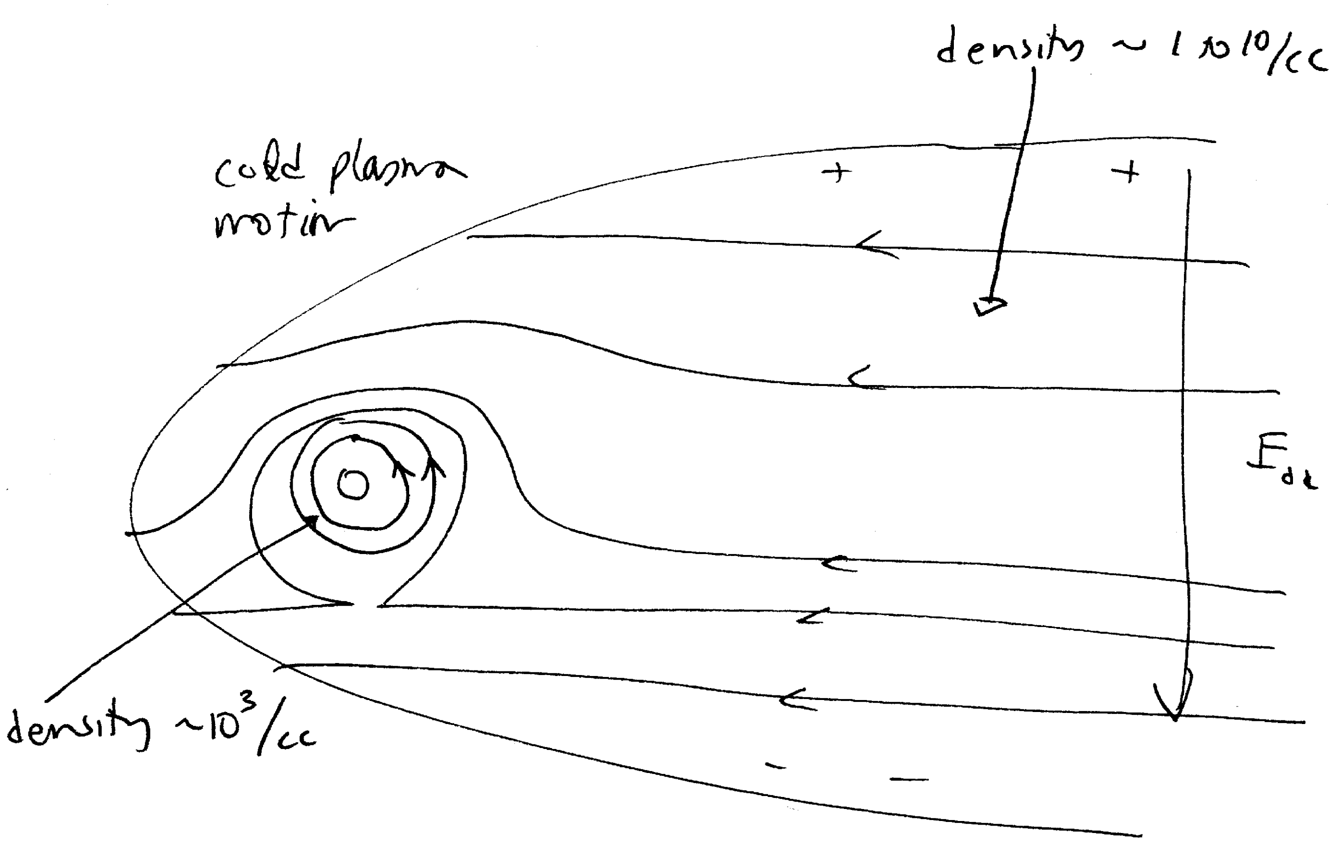
Corotation Electric field

rotating, magnetised, conducting earth



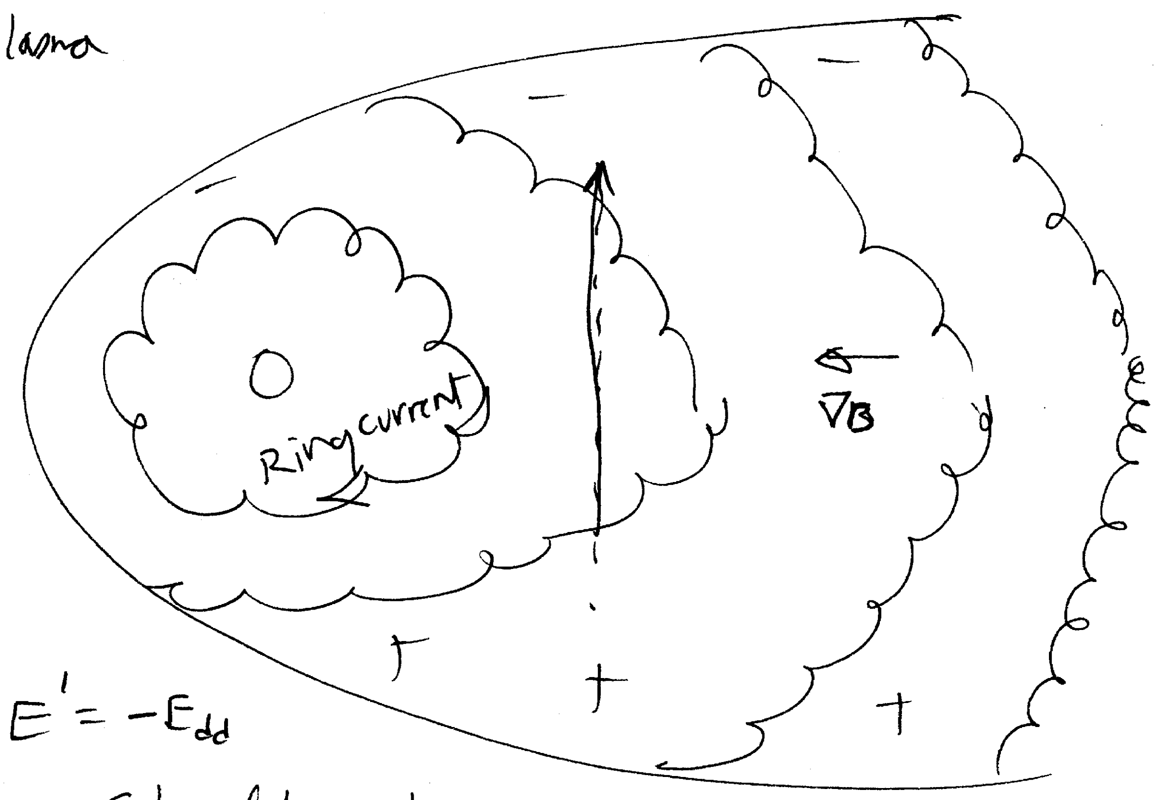
Plasmasphere corotates.

The ionosphere polarizes because of Lorentz Force
⊕ Goes north and ⊖ toward equator
Giving Corotation Field (~ 10 to 15 mV/m)
$\sigma_{\parallel} \to \infty$ Good conductor along field lines
so ΔV ionosphere = ΔV magnetosphere



E_{dd} = dawn to dusk electric field across magnetosphere (due to MHD Generator - see Next section of course)

Hot plasma



causes $E' = -E_{dd}$

Alfven Shielding Layer