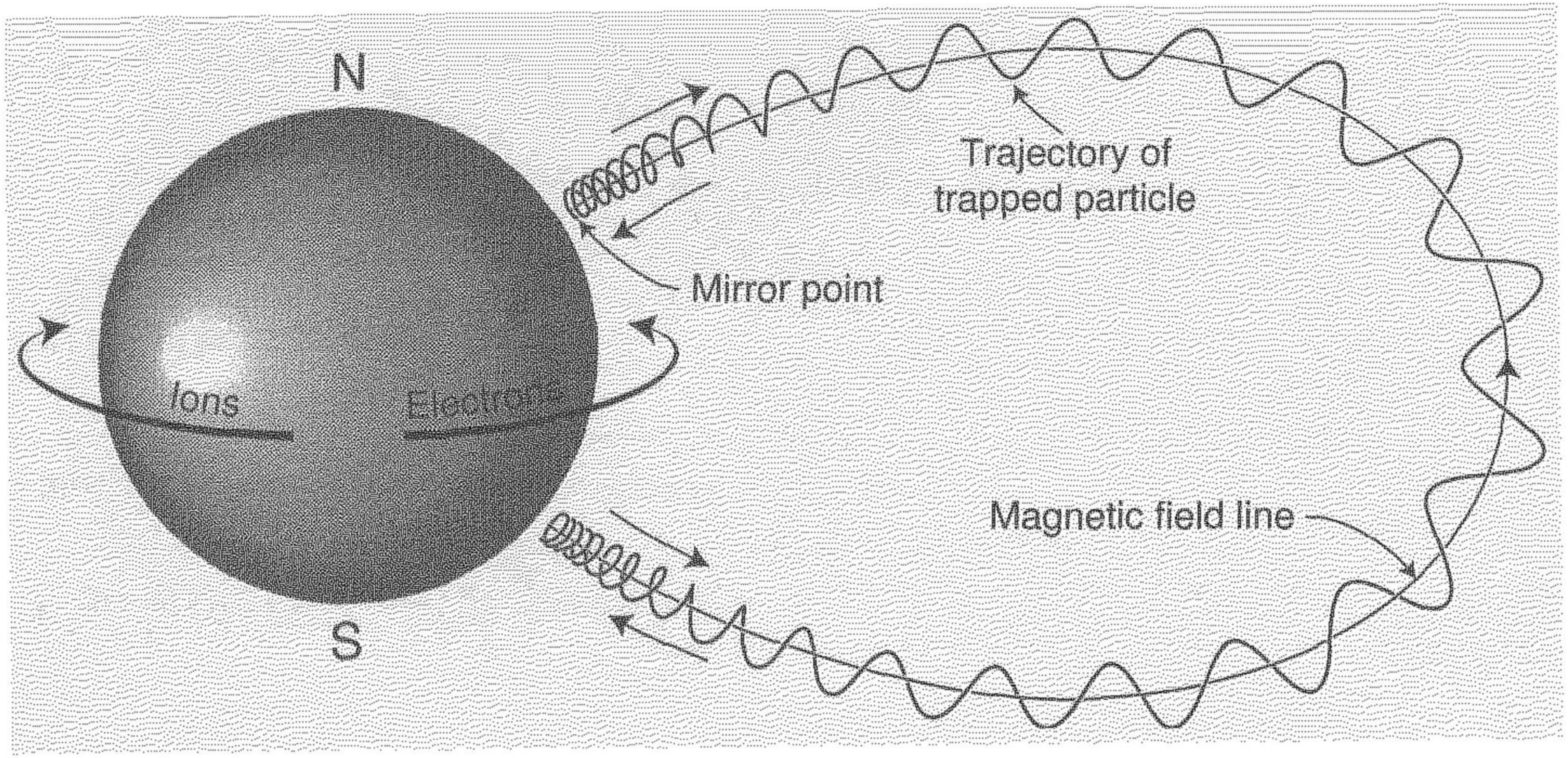
Magnetically trapped particles and adiabatic motions

Reading material: Baumjohann & Treumann’s book, Chapters 2-3

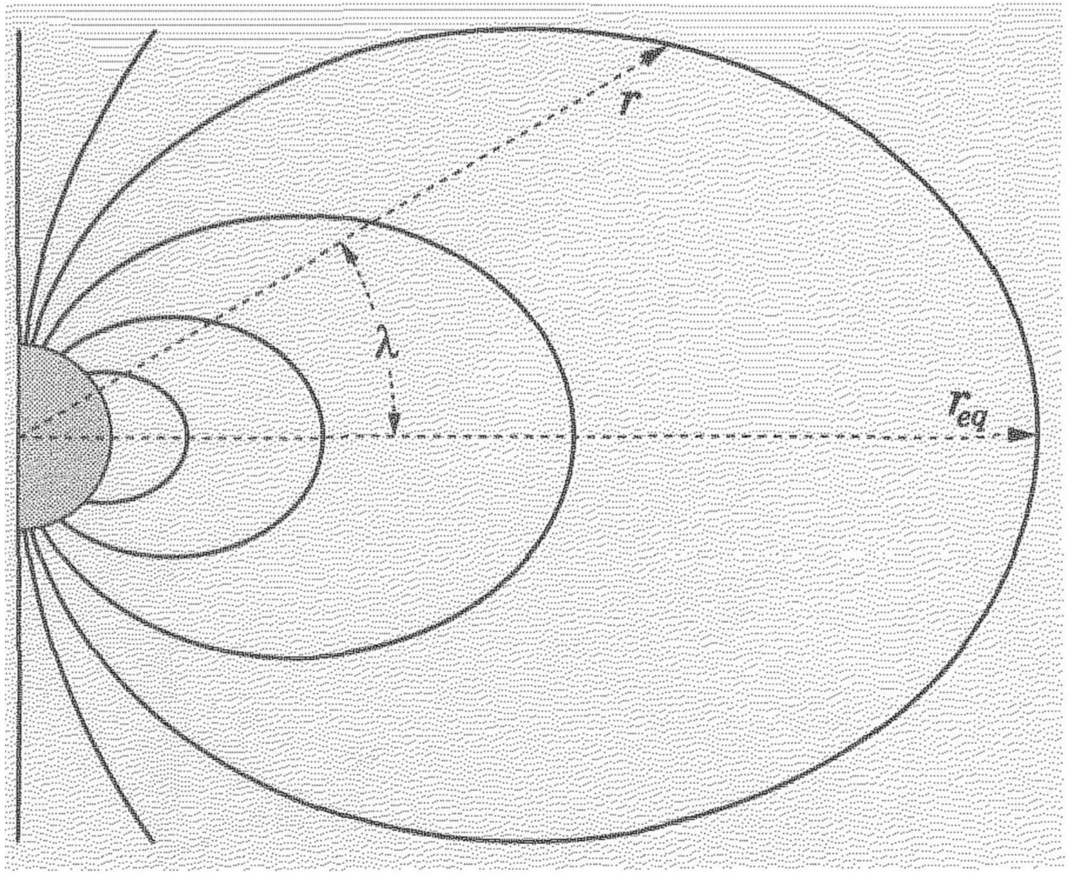
Magnetically trapped particles



- Ions and electrons drift in opposite directions around the Earth due to a combined curvature/gradient plasma drifts.

- Both ions and electrons experience drift, bounce, and cyclotron motions.

Magnetic dipole field



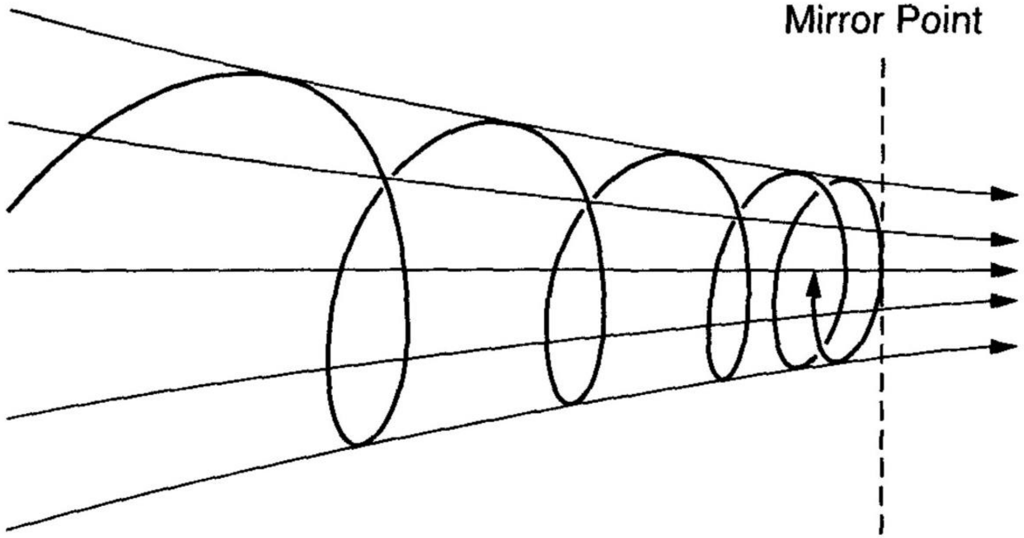
An ideal dipole can be expressed as a function of magnetic latitude and radial distance

$$B(\lambda, L) = \frac{B_E}{L^3} \frac{(1 + 3\sin^2\lambda)^{1/2}}{\cos^6\lambda}$$

- B_E is the main magnetic field at the ground at the geomagnetic equator.
- L is the magnetic shell, aka McIlwain parameter.
- Latitude of the magnetic shell

$$\cos^2\lambda_E = L^{-1}$$

Gyromotion and magnetic mirror force



Magnetic moment should be conserved
(1st adiabatic invariant)

$$\mu = \frac{mv^2 \sin^2 \alpha}{2B}$$

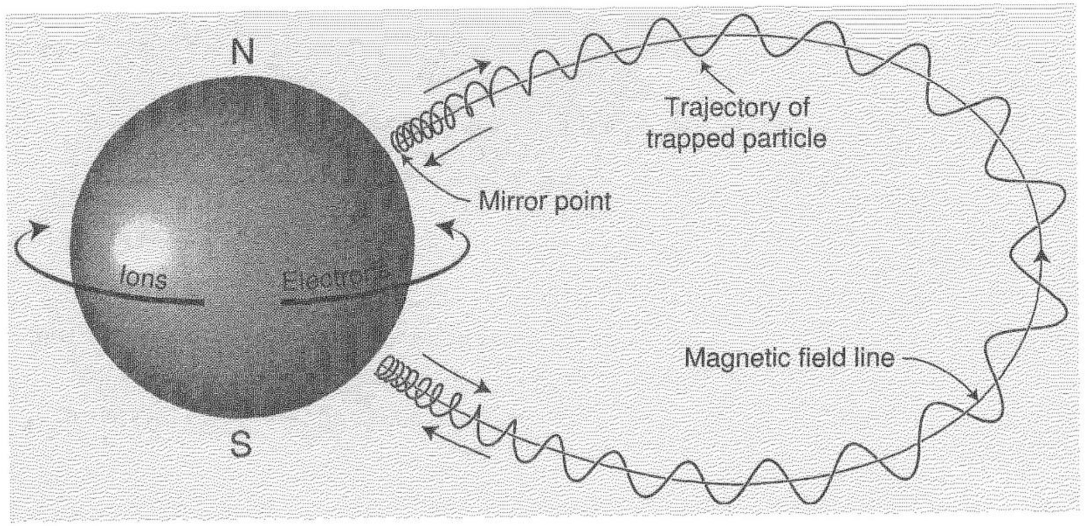
Magnetic mirror effect

$$\frac{\sin^2 \alpha_2}{\sin^2 \alpha_1} = \frac{B_2}{B_1}$$

Pitch angle $$\sin\alpha = \left(\frac{B}{B_m}\right)^{1/2}$$

Second (bounce) and third (drift) adiabatic invariants

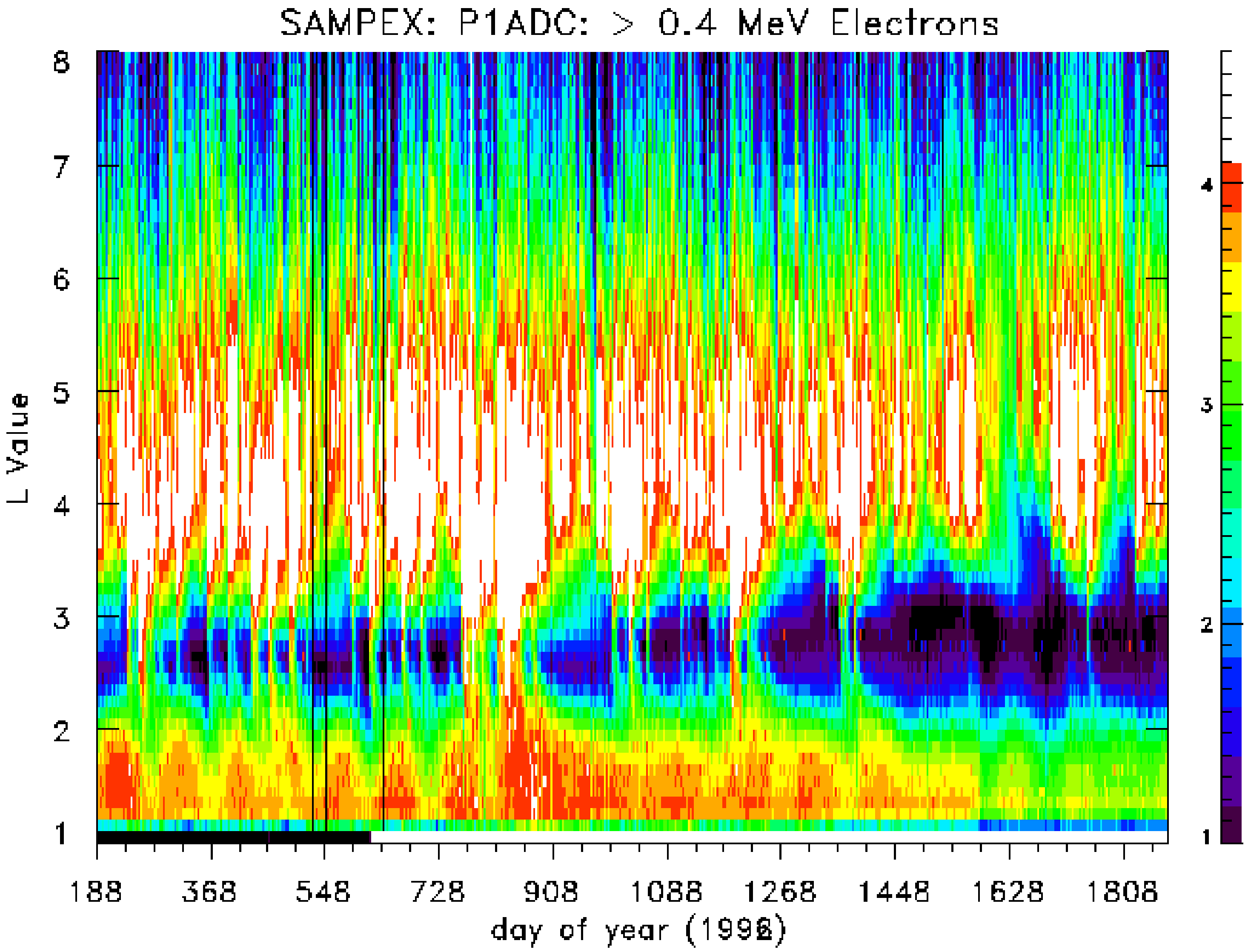
Longitudinal (2nd invariant) $J = \oint m v_{\parallel} ds$



Radial drift (3nd invariant) $$\Phi = \frac{2\pi m}{q^2} M = \mathrm{const}$$

M is a total magnetic moment of the (dipolar) field

Example: SAMPEX satellite data



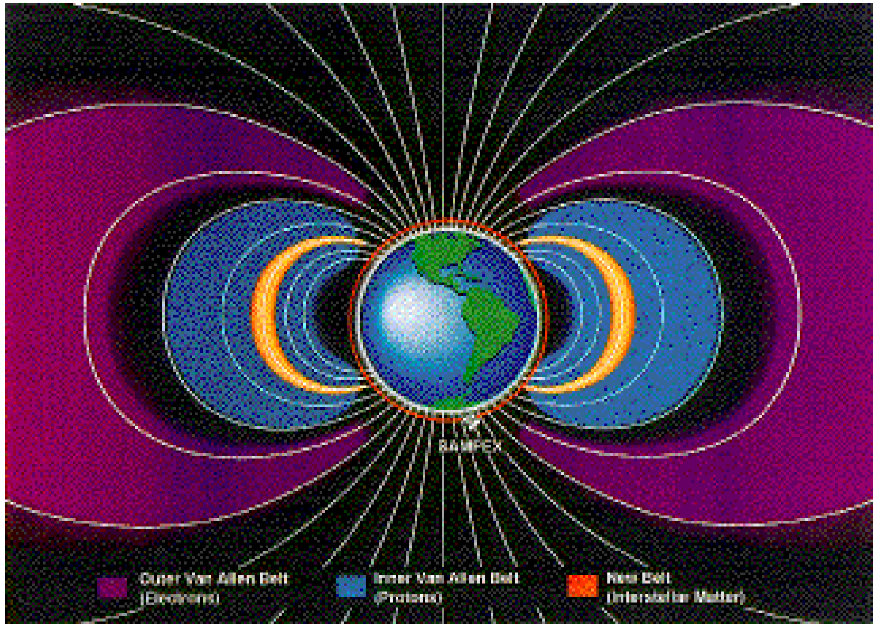
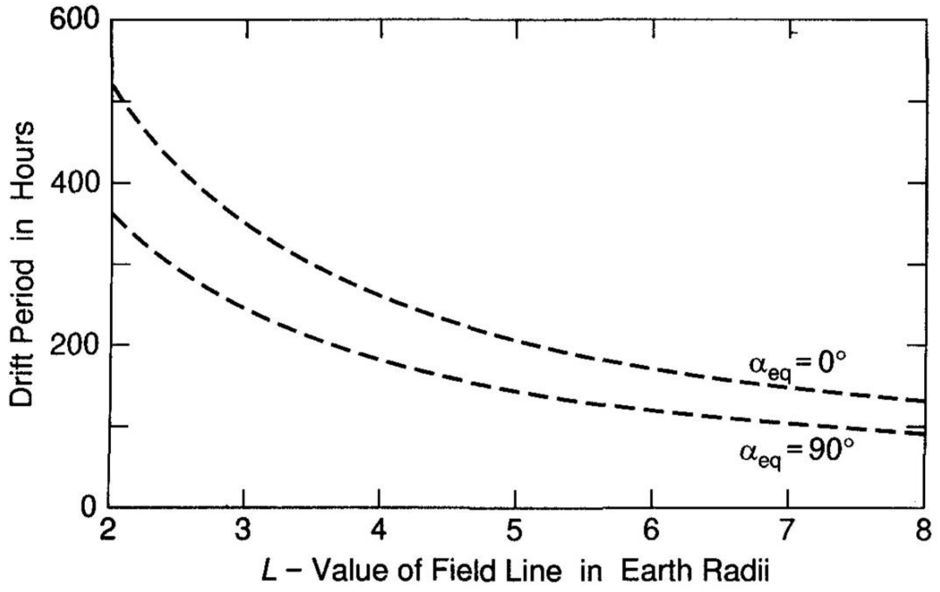


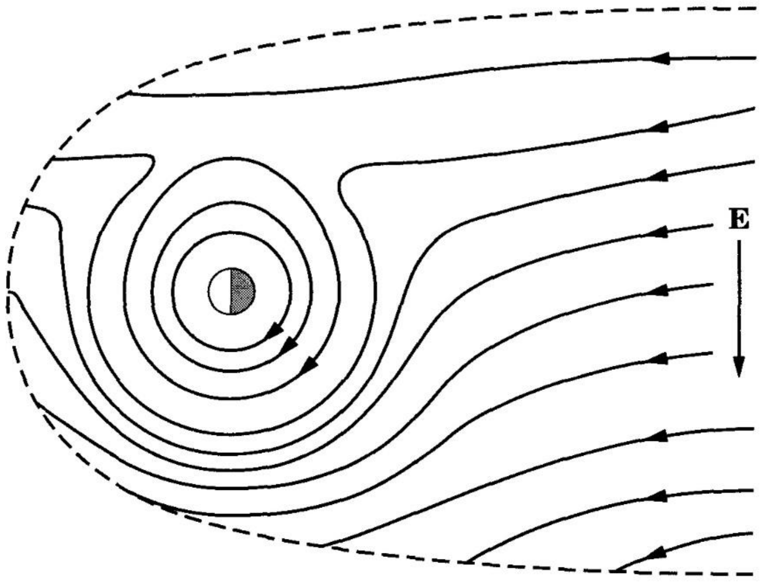
Image from LASP

Drift motion and the ring current

Average drift velocity for the trapped particles
(all 3 adiabatic invariants are conserved)

$$\langle v_d \rangle \approx \frac{6L^2 W}{q B_E R_E}(0.35 + 0.15 \sin \alpha_{eq})$$





Average drift periods (top) and drift passes (left) of energetic ions ~1keV (typical auroral particle energy).

Overview of the magnetospheric currents