Today

- Review Loss cone, introduce Drift loss cone
- Tail Currents
- Hot Plasma Drifts
- Start Inner magnetosphere discussion (co-rotation of plasmasphere)
Which particles are lost?

If \[ d \leq R + 100 \text{ km} \]
then

Find the \[ d_e \]

using

\[ M = \text{constant} = \frac{u^2 \sin^2 \theta}{Be} \]

Find \[ d_e \] such that \( \theta = 90^\circ \) at \( R = R_e + 100 \text{ km} \)
we find that \[ d_e \approx 3^\circ \] at \( L = 6 \)

So most particles are trapped.

Show pitch angle distributions along field line.
Ah! But the field is not a perfect dipole:

Drift loss cone

\[ \text{Drift loss cone} \]

Drift loss cone = largest cone at equator which equals the bounce loss cone at some longitude.

That is: all particles in the bounce loss cone are lost in 1 bounce period

While particles in the drift loss cone are lost sometime during their drift period.

Namely, somewhere in drift period they set the smallest Earth field so their mirror point is lowest.
waves are constantly affecting particles' pitch angles.

So, there is a random diffusion of particles from larger to smaller pitch angles. When particles get lost inside the loss cone, or drift loss cone.
Figure 4-11. Contours of constant total field $B$ at the surface of the earth from the model IGRF 1980.0.
Figure 5-33. Proton isointensity flux contours as measured in the South Atlantic anomaly at an altitude of 750 km. The solid lines depict 28-45 MeV proton (ion) fluxes and the dashed lines 5-7 MeV proton fluxes. The flux units are particles/(cm²-s-MeV).
Magnetic Field Minimum

Precipitating >80MeV protons

Single Event Upsets in the memory for Topex Satellite
**L-Shell drift:** How can you tell the drift motion always returns guiding center to starting point?

- Assume \( \omega_B \) = constant
- Then \( E = E_1 \) always
- \( L \) defines a closed shell for perfect dipole

**Answer:** if energy is conserved then \( B_1 \) with \( \mu = \text{constant} \), if start from \( r_1 \) where \( B = B_1 \)

\[
\mu = \frac{E}{B_1} \quad \text{at} \ r_1
\]

If returned at \( r \neq r_1 \), then

Then \( \mu = (E/B_1) \) constant means energy \( E \) is changed
Adiabatic Invariant

\[ I(\bar{P}, \bar{Q}) = \oint \frac{d\sigma}{2 \pi} \] 

usually abbreviated

\[ I = \oint \bar{P} \cdot d\bar{Q} \]

but \( \int d^3p d^3q \) has same value for any canonical \( \bar{P}, \bar{Q} \)

\[ \oint d^3p d^3q = \int d^3p d^3q = \oint \bar{P} \cdot d\bar{Q} \]

since transformation from unperturbed to perturbed \( \bar{P}, \bar{Q} \) is canonical

\[ z = \text{constant} \]
Now, let's look at magnetotail Tail currents.

Then combine cold and hot plasma drifts.

Cold:
- Sunward convection on closed field lines
- Plasmasphere co-rotatation

Hot:
- Ring current
- Partial ring current/Alfven layer

Then: Aurora and ionosphere.
View from Earth looking down the tail
View from the Tail looking back at Earth

Dusk  


dawn
View from Tail towards Earth
SUN

OPEN FIELD LINES

CROSS TAIL CURRENT

CURRENT ALONG FLANK OF THE TAIL
Example #1

Most accurate E field measurement in progress. Impact

moon

Satellite orbit

B

earth
tail

Omnidirectional Flux detector (100 eV electrons)

Model

Energy: Bow shock B field at E ~ 1 mV/m

Beam: ~1 mV/m
Fig. 5. The electron lunar shadow patterns of April 28, 1972, at four different energies. The patterns are labeled by M or IP, corresponding to magnetotail or interplanetary type field lines, and the magnetotail field line velocities for the best fit (light lines) are given for each orbit. Note the spikes in the region of transition from magnetotail to interplanetary near 0800 UT and also spikes near 1030 and 1710 UT.
The upper schematic illustrates the lunar shadow technique for determining magnetotail field line motions. Interplanetary and solar electrons enter the tail well beyond the orbit of the moon. Those not intersecting the moon on their way in are eventually mirrored by the stronger field near the earth. If the field lines are moving with velocity $V$, electrons on field lines just grazing the moon ($A$, $B$) will return after orbiting to point $A'$, thus leading to the shadow patterns shown in the lower left. For $V$ perpendicular to the spacecraft orbital plane the shadow patterns on the lower right are appropriate. By comparing the patterns for different energy electrons it is possible to obtain the velocity in both directions.
Next: Inner Magnetosphere

- Plasmasphere
- Field Aligned Currents
- Aurora
Proton Density (cm⁻³) vs. L Value (R_E) for different KP indices: K_P<1⁺, K_P=2, K_P=3, K_P=4-5. Magnetic activity index.
Plasma density 100 or 1000 times higher than outer magnetosphere
Magnetic activity index

Proton Density (cm$^{-3}$)

L Value ($R_E$)
Why does the plasmasphere co-rotate with the Earth?

- Because the earth is a
  1. Magnetized
  2. Rotating
  3. conductor
Equatorial Plane View