

FIREBIRD Science Overview

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FIREBIRD

- Focused Investigations of Relativistic Electron Burst Intensity, Range, and Dynamics
- 1.5-unit cube-satellite mission investigating relativistic electron microbursts
- Two low-earth-orbiting satellites studying radiation belt dynamics

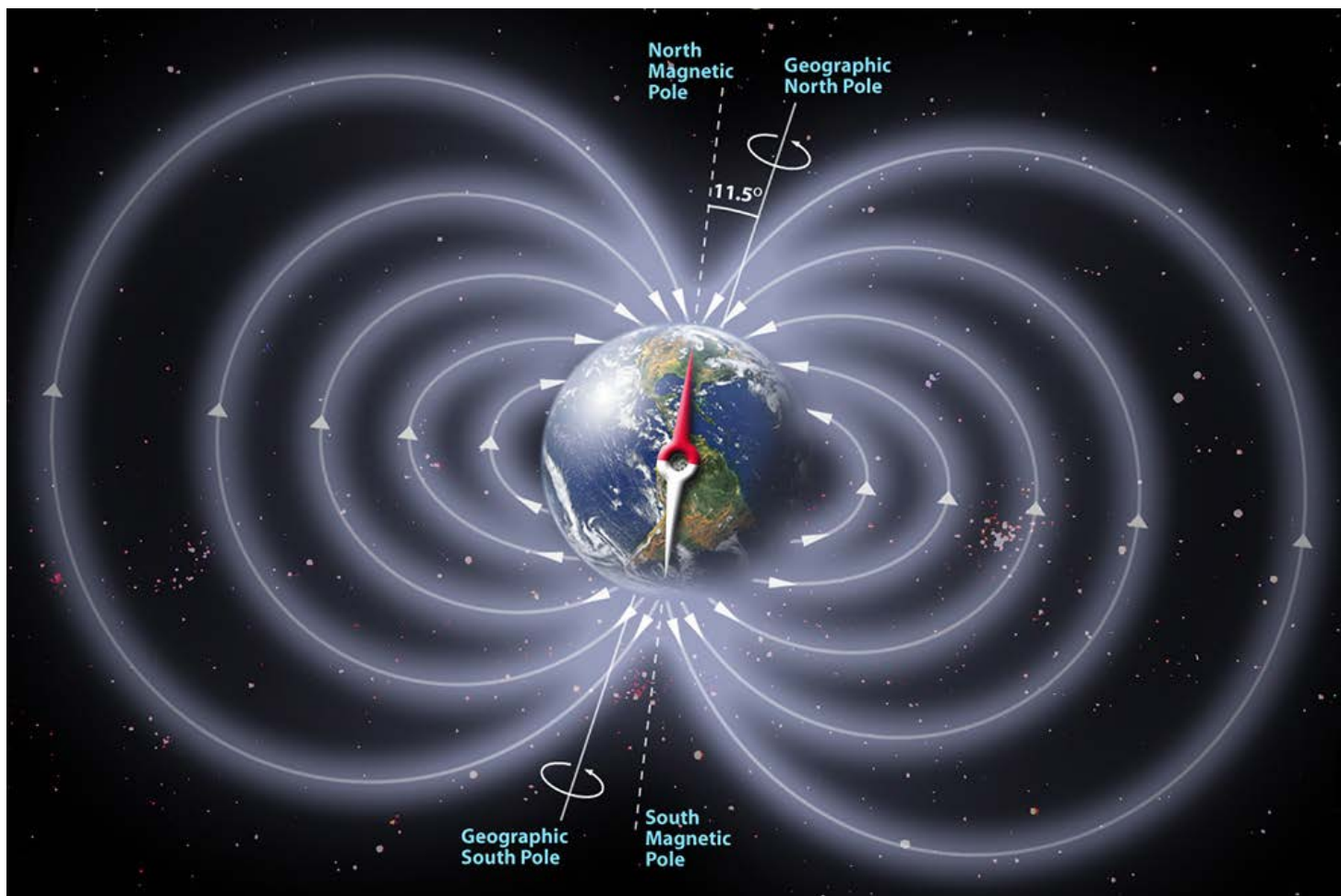


Fundamental Concepts

- Radiation Belts
- L-Shell
- Electron Microbursts
- Whistler-Mode Chorus
- Radiation Belt Electrons
- Loss Cone
- Gyro-Resonant Interaction

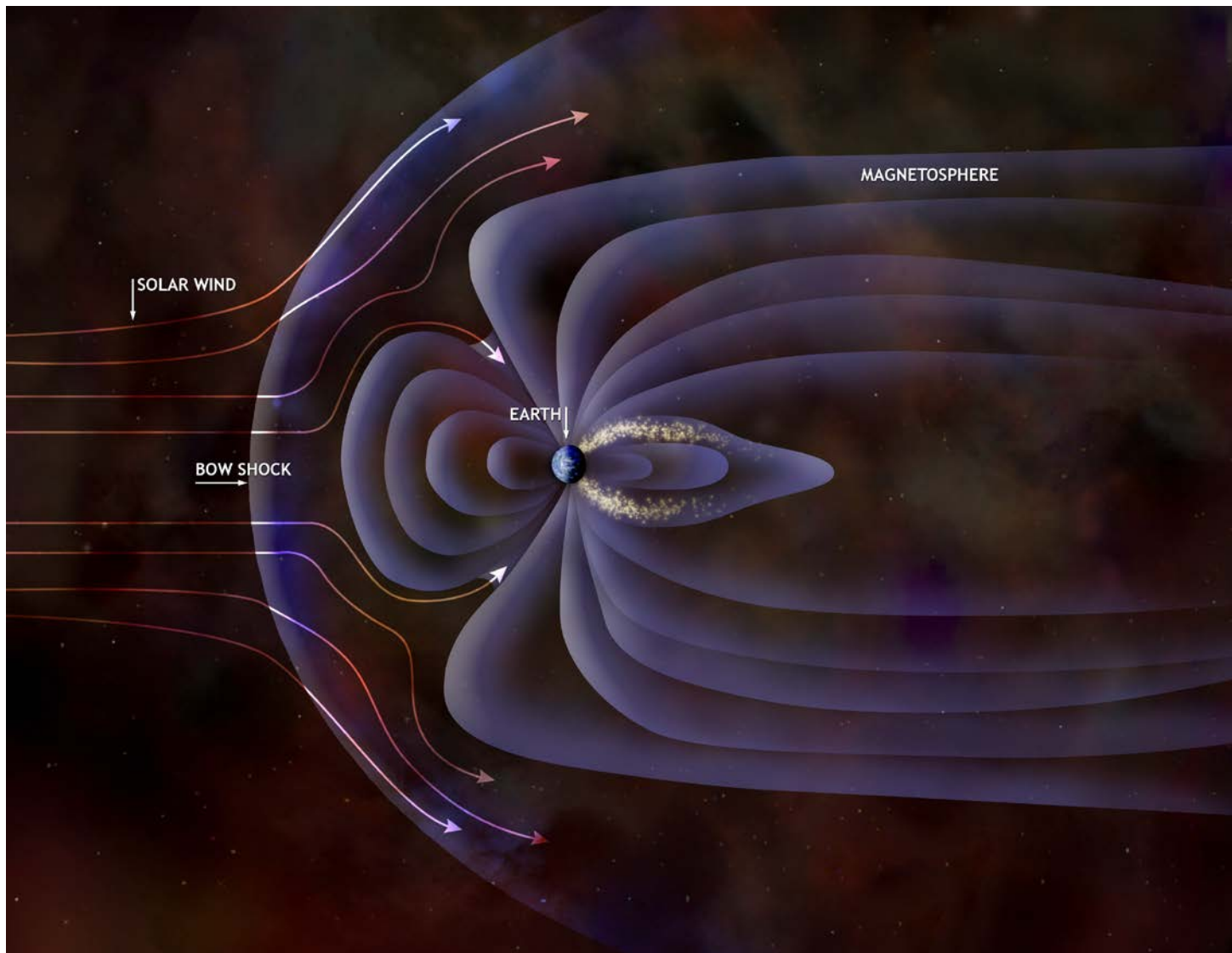
L-Shell

- Magnetic field strength calculated using L-shell, location, and time





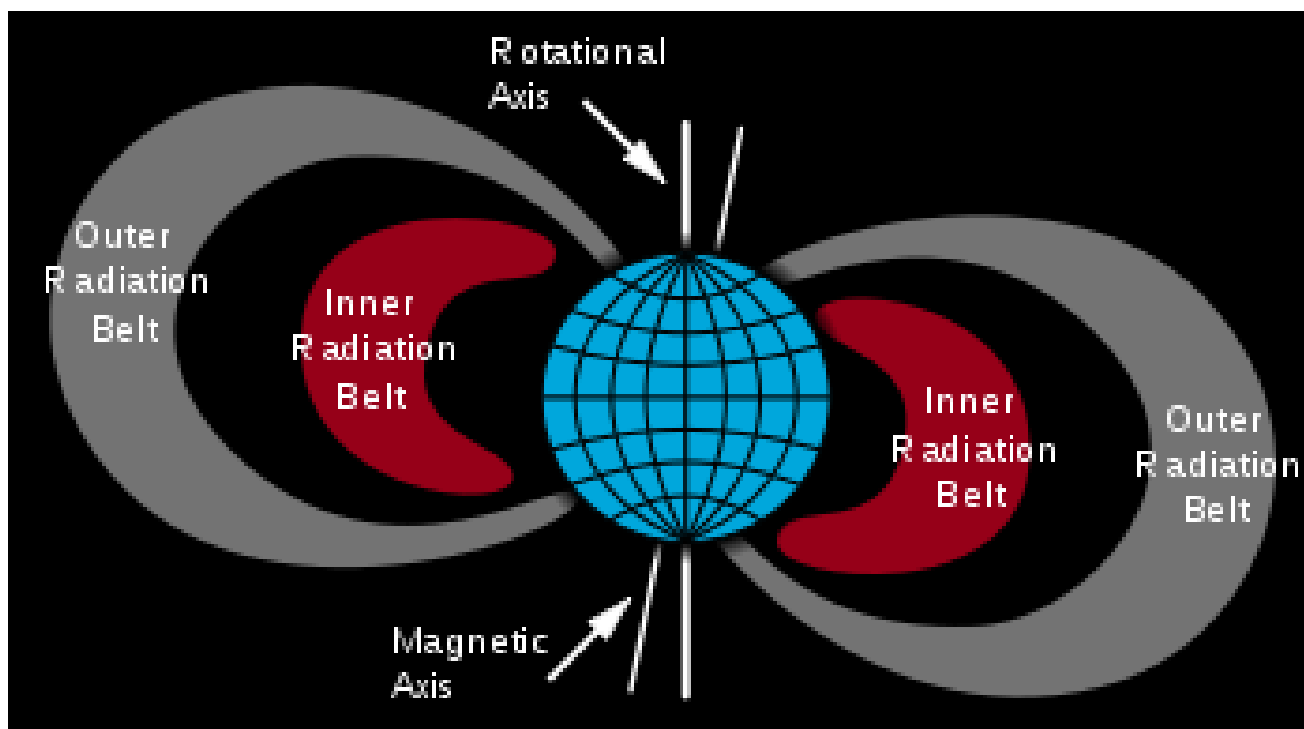
L-Shell





Radiation Belts

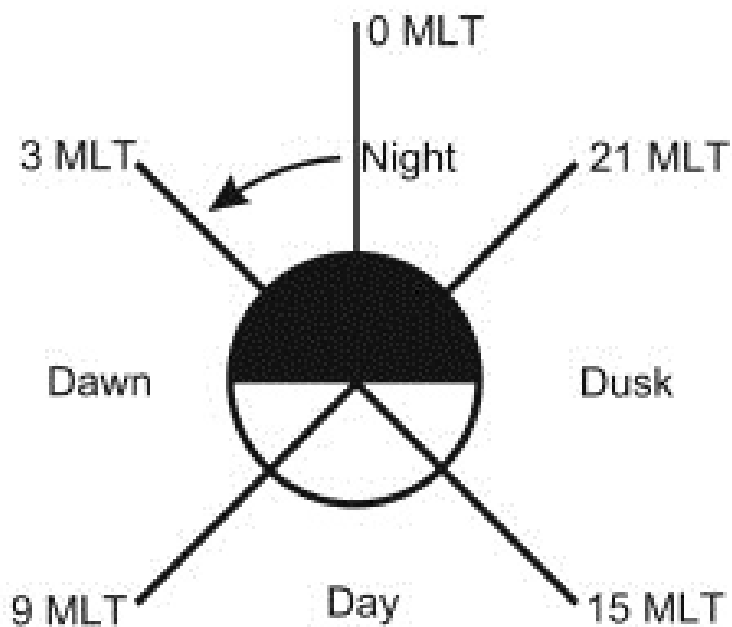
- Bands of charged particles trapped in Earth's magnetic fields
 - Inner belt from $L=1.5$ to $L=2$
 - Outer belt from $L=4$ to $L=6$





Magnetic Local Time

- Measurement of time with axis about the magnetic pole





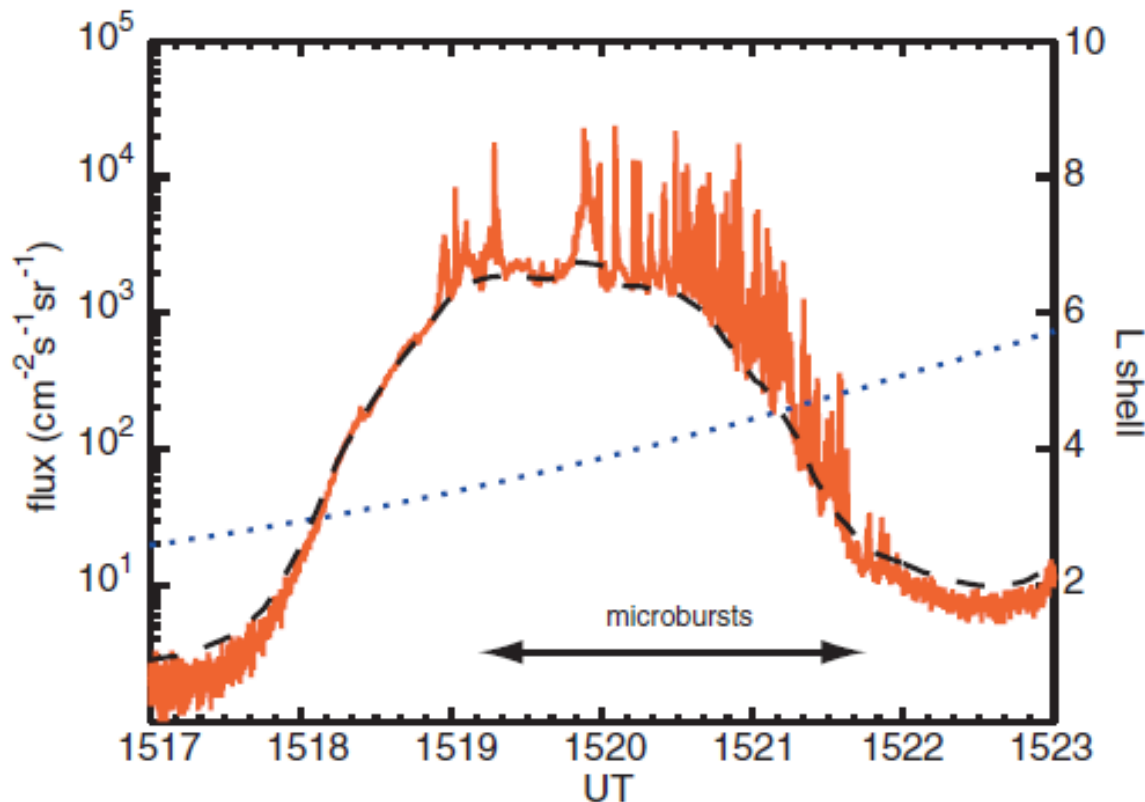
Electron Microbursts

- Localized region of precipitating electrons
 - Lost from the Van Allen radiation belts and precipitate down onto the ionosphere (upper atmosphere)
- Occur on a short timescale (~ 0.2 s)
- Observed predominantly from $L=4$ to $L=6$ in the morning sector (3MLT to 9MLT)
- Believed to be correlated to chorus waves generated in the near equatorial region



Electron Microbursts

- May occur in trains ranging from 10s to several hours with ~ 0.5 s spacing between bursts



Black-dashed line: Estimate of locally-trapped population

Blue-dotted line: Position in L-Shell

Orange spikes: Relativistic Microburst events

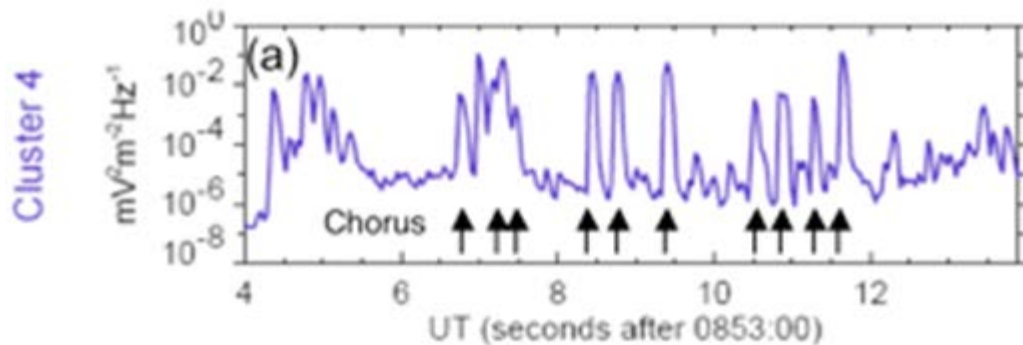


Whistler-Mode Chorus

- Bursts of very-low frequency (VLF) electromagnetic emissions
- Propagate within plasma in radiation belts
- Frequencies range from hundreds of Hz to several kHz
- Timescale of ~ 1 s, but may occur in trains
 - Train timescales match those of microbursts
- Right-hand polarized (RHP) waves



Whistler-Mode Chorus

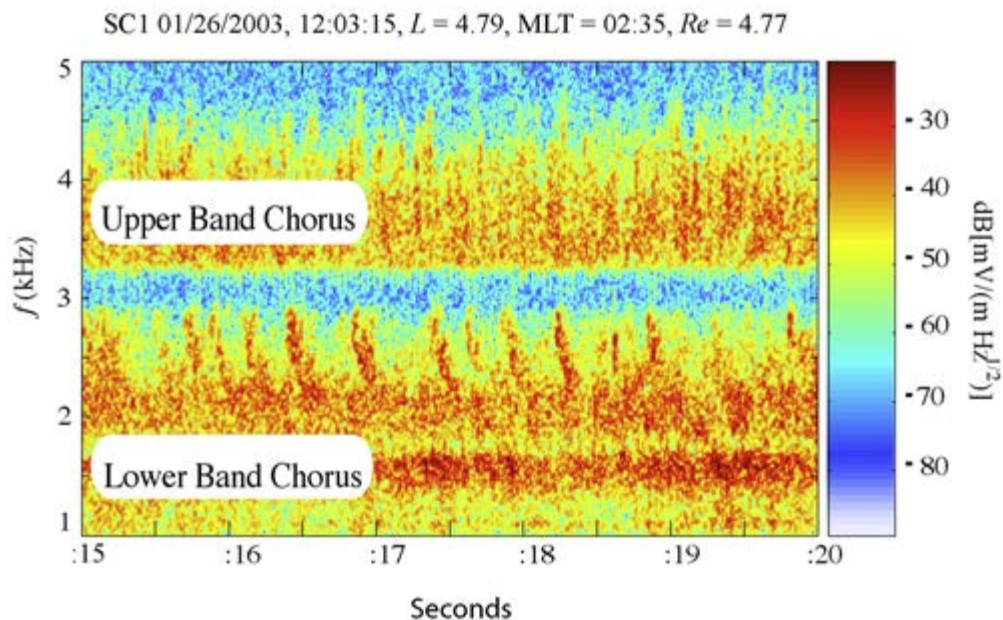


From Santolik et al., 2004, Figs 4(b) and 6(b)



Whistler-Mode Chorus

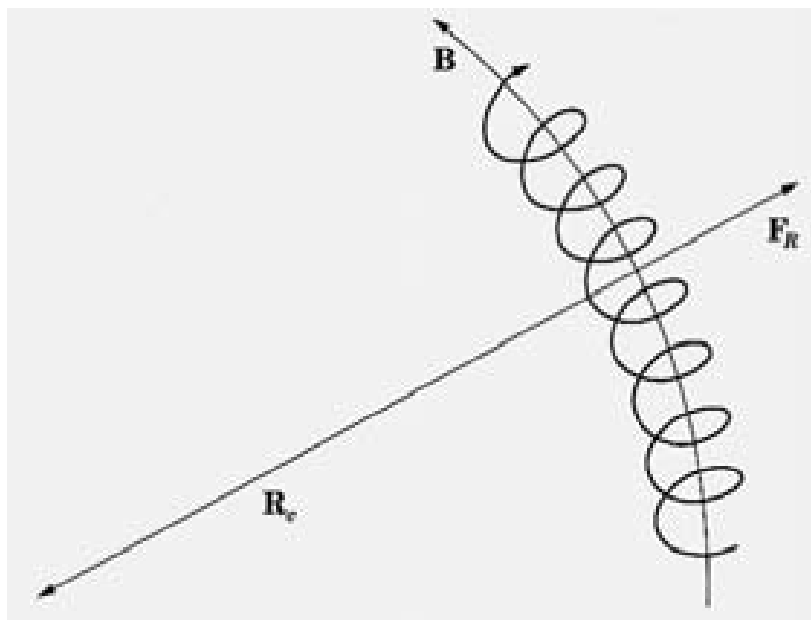
- Chorus appears in two bands
 - Upper-Band Chorus
 - Lower-Band Chorus
- Correlation with energy bands of microbursts



Bell et al 2009

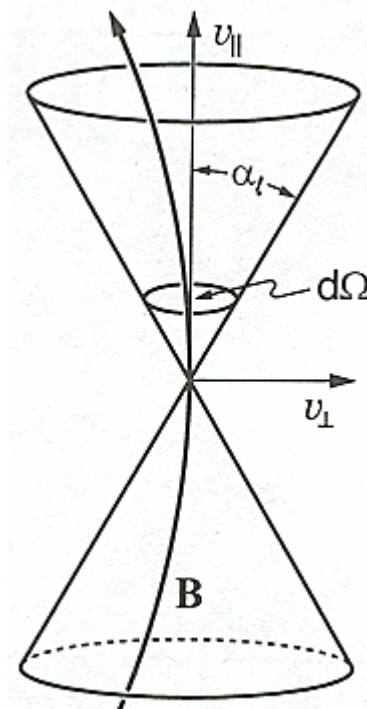
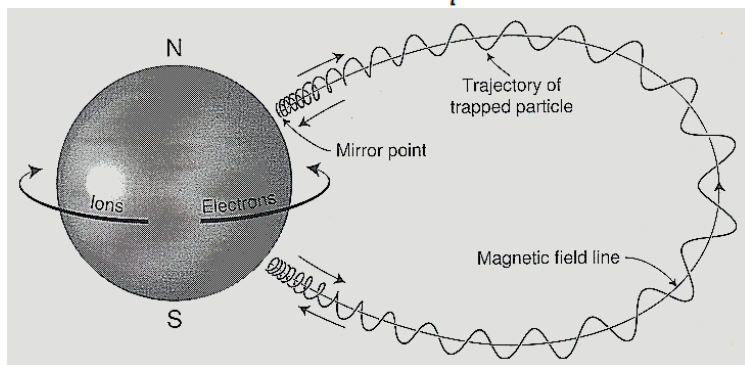
Radiation Belt Electrons

- Electrons have right-hand cyclotron motion about field lines
- Cyclotron frequency: $\omega_{ce} = \frac{eB}{m}$
- Electrons >1 MeV are relativistic: $\omega_{ce} = \frac{qB}{\gamma \cdot m}$



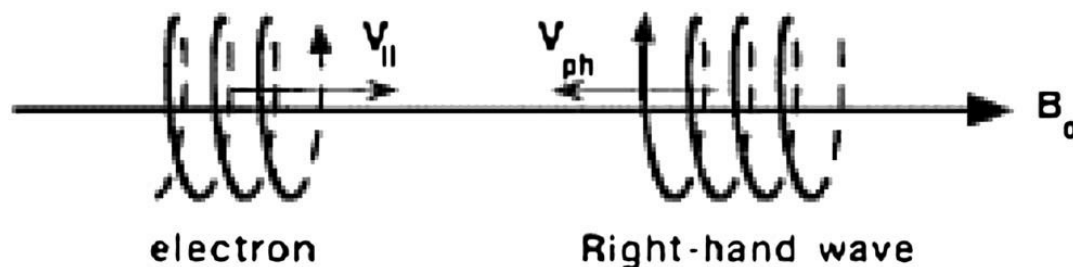
Loss Cone

- Shape in velocity space
 - Represents probability that electrons will precipitate off the magnetic field lines
 - Dimensions determined by angle between velocity and magnetic field lines (pitch angle)
- Condition for a loss cone: $\frac{v_{par}}{v_{perp}} \leq \sqrt{\frac{B_{max}}{B_{min}} - 1}$
 - Where $\frac{B_{max}}{B_{min}}$ is measured on a specific L-shell
 - Pitch angle: $\tan \alpha = \frac{v_{perp}}{v_{par}}$



Gyro-Resonant Interaction

- Interaction between radiation-belt electrons and whistler-mode chorus waves
- Conditions for interaction
 - Wave frequency equals electron gyro-resonant frequency
 - Wave frequency less than electron cyclotron frequency
 - Requires that wave and electron be travelling toward each other, so that Doppler-shift can allow for comparable frequencies



- Wave and electron must be similarly polarized
 - Whistler-mode chorus and electron cyclotron both RHP



Gyro-Resonant Interaction

- Gyro-resonant interaction scatters electron pitch angles
 - Some electrons have low enough pitch angles to enter loss cone and precipitate into ionosphere
 - This precipitation is an electron microburst
- Most accepted theory



FIREBIRD Mission

- The FIREBIRD mission consists of two satellites operating simultaneously to answer the following:
 - What is the spatial scale size of an individual microburst?
 - What is the energy dependence of an individual microburst?
 - How much total electron loss from the radiation belts do microburst's produce globally?



Spatial Scale Size

- Multi-point measurement required to determine spatial scale size
- FIREBIRD payloads separate at ~ 8 cm/s
 - Current orbital scenarios estimate payloads will exceed 150 km (a landmark value mentioned in the FIREBIRD proposal) after about 2.5 months
- GPS coordinates resolved with science data will provide estimates of spatial scale size



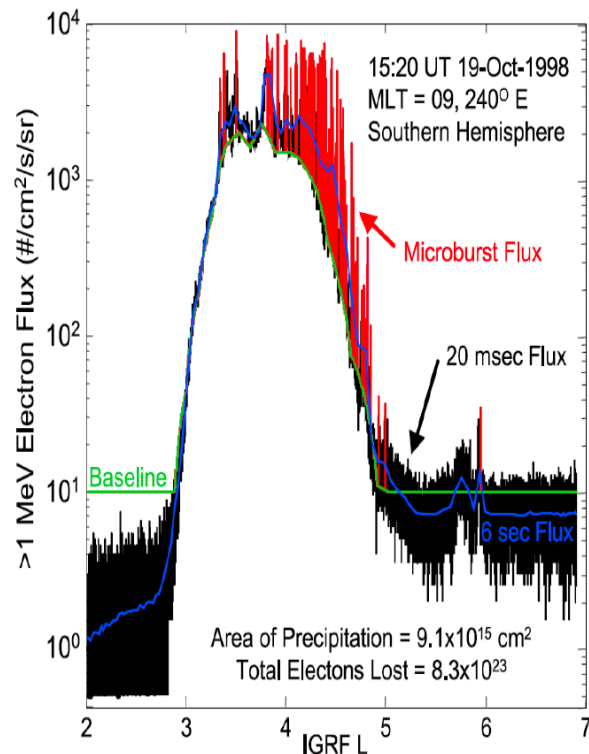
Energy Dependence

- Lower energy bursts (tens to hundreds of keV) can resonate at the equator with whistler-mode chorus waves
- Higher energy bursts typically occur between 60°-66° latitude
- Energy of microburst's correlated with chorus bands.



Global Electron Loss

- Use data from RBSP and BARREL to complement FIREBIRD
- Microbursts are believed to be a primary loss mechanism of radiation-belt electrons





Global Electron Loss

- Remove charged particles from the radiation belts
- Various mechanisms
 - Microbursts
 - General precipitation
 - Other less prevalent mechanisms (account for small percentage of loss)



Why do we care?

- Fill in gaps in understanding of radiation-belt phenomena
- Strengthening correlation between EMBs and whistler-mode chorus
- Enhancing conclusions drawn by past and present satellite missions by providing missing information
- Educational opportunity for students involved



Questions?