MAGNETOSPHERIC FORMATION PROCESSES OF THE DIFFUSE AURORA

Sensitivity of wave-induced electron scattering to the hot electron distribution

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Outline

1. Diffuse aurora
2. Basic concept of wave-induced electron scattering
3. Calculation of wave-induced diffusion coefficients
4. Results
5. Summary


Image Credit: NASA

Different types of aurora

- Discrete aurora
  - Localized regions of intense auroral arcs
  - Associated with field-aligned currents and acceleration of the electrons
- Diffuse aurora
  - Broad regions of lower intensity emissions
  - Precipitation of magnetospheric plasma involving wave-particle interactions

Image courtesy of the Earth Science and Remote Sensing Unit, NASA Johnson Space Center

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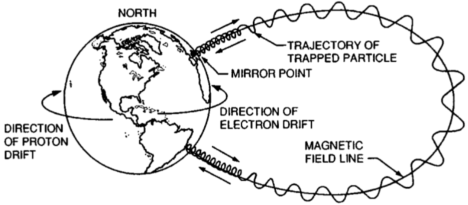
Adiabatic invariants

- 3 types of cyclic motion for particles trapped in the geomagnetic field:
  - Gyration around magnetic field line
  - Bounce motion between the mirror points
  - Azimuthal drift around the Earth
- Approximate conservation law associated with each cyclic motion: adiabatic invariants



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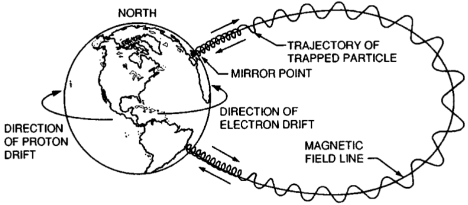
- Approximate conservation law associated with each cyclic motion: adiabatic invariants
- Electrons with $\alpha > \alpha_{\mathrm{LC}}$ remain trapped
- Electrons with $\alpha < \alpha_{\mathrm{LC}}$ are lost to the atmosphere: precipitation



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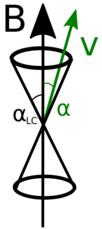

Plasma waves

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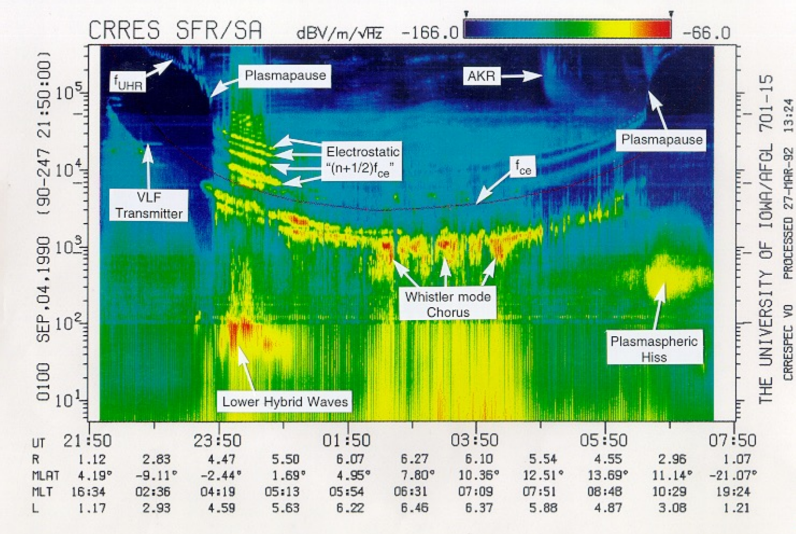
- Waves can interact resonantly with particles: $\omega - k_{\parallel} v_{\parallel} = \frac{n\Omega_\sigma}{\gamma}$, $\Omega_\sigma = \frac{|q|B}{mc}$
- Describe the effect of wave-particle interactions on the particle distribution by quasi-linear diffusion
- Diffusion coefficient $D_{\alpha\alpha}$ captures the effects of pitch-angle scattering

Violation of 1^{st} adiabatic invariant by plasma waves $\Rightarrow$ Pitch-angle scattering into the loss cone and precipitation

Electrostatic electron cyclotron harmonic waves



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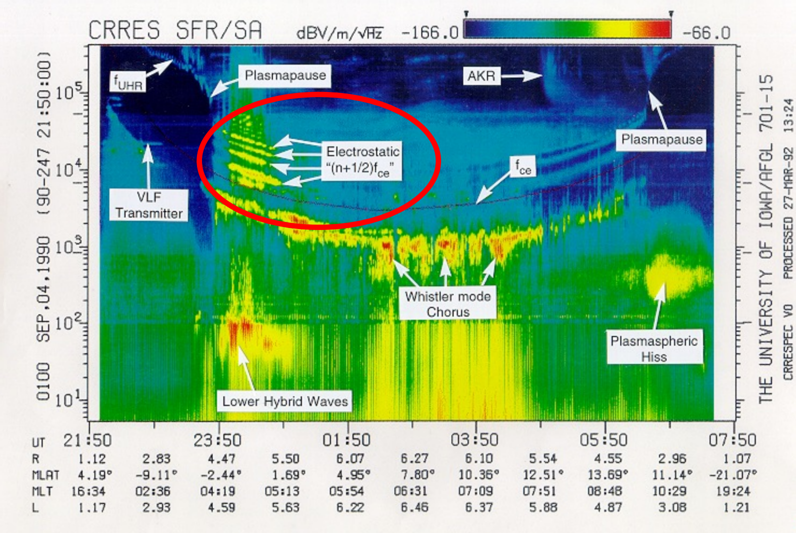

Calculation of ECH wave-induced diffusion coefficients

- Use Full Diffusion Code to calculate bounce-averaged momentum and pitch angle diffusion coefficients (Ni et al., 2008; Shprits et al., 2009)
- Solve the hot plasma dispersion relation along with the resonance condition
- Depends on:
  - Wave power spectrum
  - Wave normal angle distribution
  - Number of resonances
  - Background magnetic field } Lou et al. (2022)
  - Plasma density }
  - Properties of the hot plasma sheet electrons responsible for wave excitation

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Calculation of ECH wave-induced diffusion coefficients

Model the electron distribution by

$$f(v_\perp, v_\parallel) = \sum_{i=1}^{m} \frac{n_i}{\pi^{3/2} a_{\perp,i}^2 a_{\parallel,i}} \exp\left(-\frac{v_\parallel^2}{a_{\parallel,i}^2}\right) \cdot \left\{ \Delta_i \exp\left(-\frac{v_\perp^2}{a_{\perp,i}^2}\right) + \frac{1-\Delta_i}{1-\beta_i} \left[\exp\left(-\frac{v_\perp^2}{a_{\perp,i}^2}\right) - \exp\left(-\frac{v_\perp^2}{\beta_i a_{\perp,i}^2}\right) \right] \right\}$$

with electron density n_i, loss cone parameters Δ_i and β_i, and perpendicular and parallel thermal velocity $a_{\perp,i}$ and $a_{\parallel,i}$ (related to hot plasma temperature)

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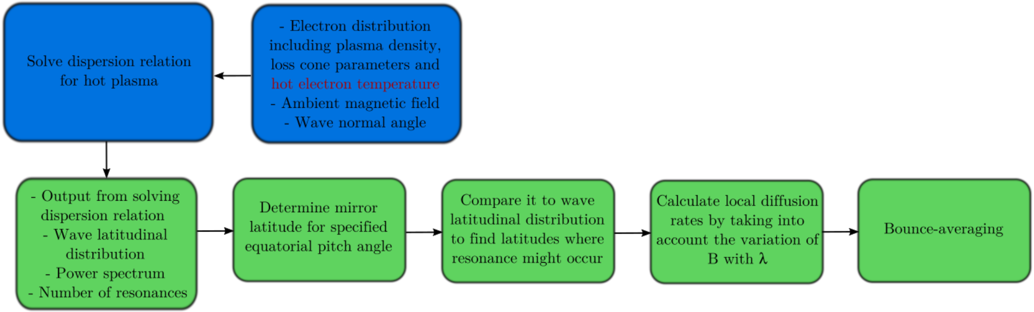
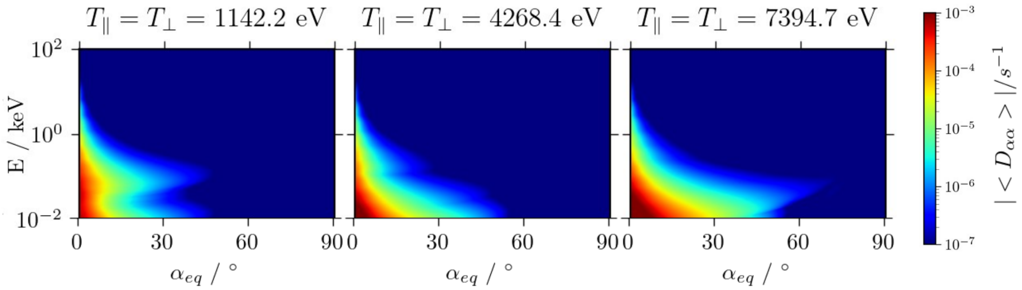


Calculation of ECH wave-induced diffusion coefficients

Model electron distribution with one cold and one hot plasma component



Summary

- Precipitation of electrons with $0.1 - 10$s keV produces diffuse aurora
- Resonant wave-particle interactions $\Rightarrow$ Pitch-angle scattering into the loss cone
- Model the process by quasi-linear theory $\Rightarrow$ calculate diffusion coefficients
- Diffusion coefficients depend on several wave and plasma properties, including the hot plasma sheet electrons responsible for wave excitation
- Hot electron temperature changes the resonant pitch angle and energy range of the pitch angle diffusion coefficients

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Outlook

- Use observational data to calculate event-specific diffusion coefficients
- Implement diffusion coefficients in radiation belt simulations