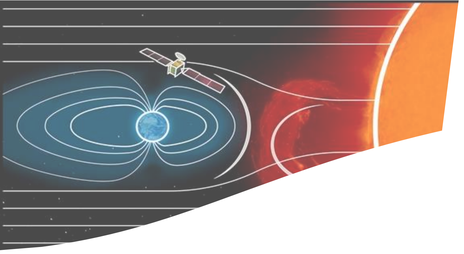

Electron Scattering by Electrostatic Electron Cyclotron Harmonic Waves and Time Domain Structures During Storm-Time

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X4.93 | EGU25-7086

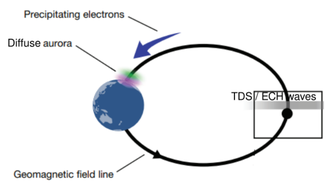
1. Introduction

Electrostatic electron cyclotron harmonic (ECH) waves

- Occur in **bands between the harmonics of the electron gyrofrequency f_{ce}**
- Are excited by a loss cone velocity distribution
- Occur predominantly on the **nightside** (20 < MLT < 6) of the **inner magnetosphere** (4 < L < 8) close to the **magnetic equator** (-3° < λ < 3°)

Time domain structures (TDS)

- Are ~ 1 ms pulses containing large parallel electric fields, including e.g. electron-acoustic double layers, **electron phase space holes**
- Produce broadband **electrostatic turbulence**
- Occur frequently around **injection fronts** in the **inner magnetosphere**



Adapted from [2]

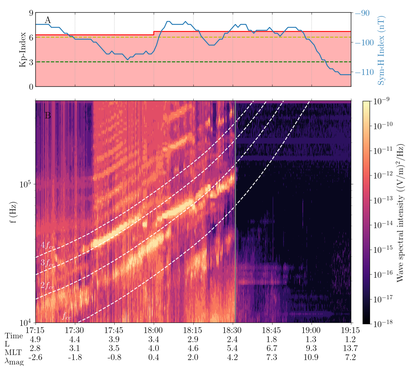
2. Motivation

ECH waves and TDS

- Can resonantly interact with plasma sheet electrons and scatter them into the atmospheric loss cone leading to **diffuse auroral precipitation**
- Are currently not included in typical quasi-linear studies of radiation belt and ring current dynamics
- Are **potential candidates to explain the missing loss of ~ 10 keV ring current electrons** in the pre-midnight sector reported by [1]

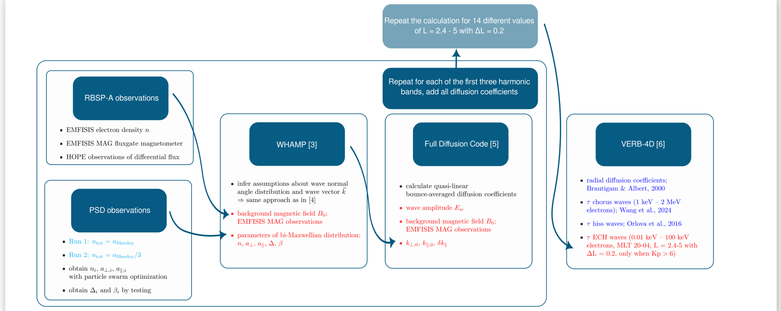
See X4.91

3. Electron Cyclotron Harmonic Waves

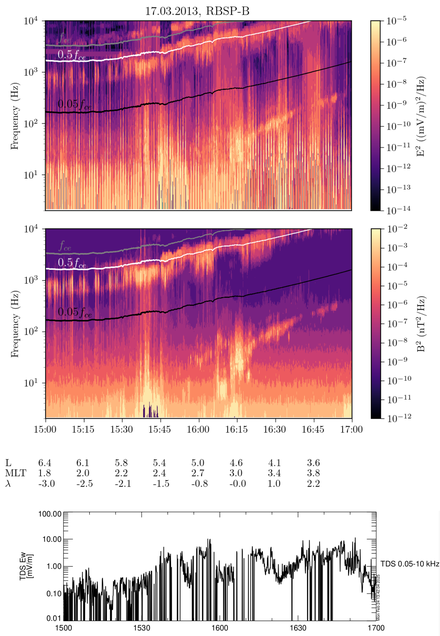


Overview of the **ECH wave event** observed by RBSP-A on **17 March 2013**. **A** Kp and Sym-H indices of geomagnetic activity during the event. **B** Electric field spectral intensity from the high-frequency receiver instrument. The white dashed lines indicate f_{ce} and its harmonics. The gray line represents the position of the plasmapause.

Calculation of quasi-linear bounce-averaged **diffusion coefficients and lifetimes** resulting from the interaction between electrons and ECH waves based on the observed wave properties, and **implementation to the Versatile Electron Radiation Belt (VERB-4D) code.**



4. Time Domain Structures



Overview of the **TDS event** observed by RBSP-B on **17 March 2013**. Electric (top) and magnetic (bottom) field spectral intensity from the waveform receiver instrument.

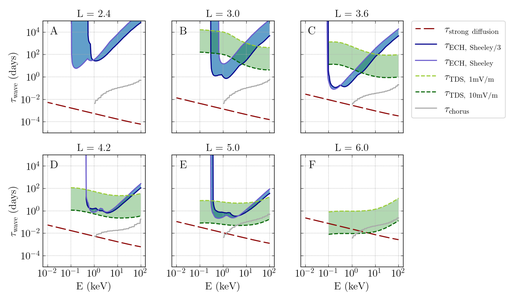
Frequency range of TDS from wavelet / FFT spectra

Integration within the frequency range to obtain TDS amplitudes E_w

Scale diffusion coefficients from [7] with E_w and calculate electron lifetimes

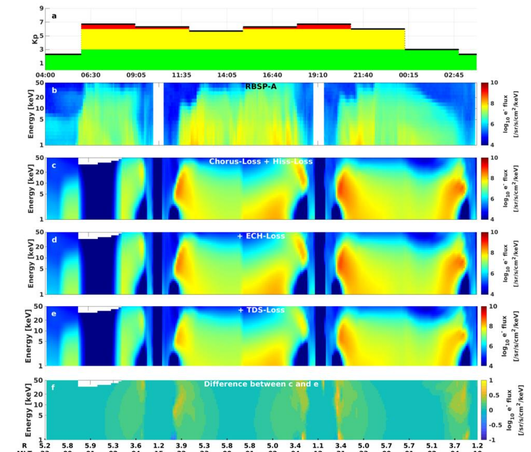
TDS amplitudes integrated within 0.05 – 10 kHz, excluding whistler-mode and ECH wave amplitudes.

5. Results: Electron Lifetimes



- Lifetimes due to **ECH waves** are at least about an order of magnitude greater than those due to chorus waves and **longer than the strong diffusion limit** for all energies
- Lifetimes due to **TDS** can **reach the strong diffusion limit** and become comparable to chorus lifetimes **for L ≳ 5.0**

6. Results: VERB-4D Simulations



- **Insignificant change** in modeled flux **when adding ECH waves** compared to the results including only chorus and hiss waves
- The flux in the regions where the model overestimates the observations decreases when **TDS scattering** is taken into account → **Better agreement** between model and observations

7. Summary & Conclusions

- Calculated **event-specific diffusion coefficients** for the interaction between electrons and ECH waves / TDS during the **geomagnetic storm on 17 March 2013**
- Implemented **resulting electron lifetimes in the loss term of the VERB-4D model** to evaluate whether ECH waves / TDS can account for the missing loss described by [1]
- Main findings:
  - Electron lifetimes due to ECH wave interaction are significantly greater than the strong diffusion limit and those due to chorus wave interaction → Direct scattering by **ECH waves** in the inner magnetosphere **cannot explain the missing loss process** of 10-50 keV electrons in ring current models [8]
  - Electron lifetimes resulting from **TDS scattering** can reach the strong diffusion limit for L ≳ 5.0, **leading to a decrease of the overestimation** and better agreement between observed and modeled flux
  - Further investigation of ECH wave / TDS scattering at L > 6.0 needed
  - **Other physical processes** need to be included to fully remove the overestimation

References

[1] Haas, B. et al. (2023), *A missing dusk-side loss process in the terrestrial electron ring current*, Sci Rep, 13

[2] Kasahara, S. et al. (2018), *Pulsating aurora from electron scattering by chorus waves*, Nature, Vol. 554, p. 337-340

[3] Stoll, K. et al. (2023*), Variation of electron lifetime due to scattering by electrostatic electron cyclotron harmonic waves in the inner magnetosphere with electron distribution parameters*, J. Geophys. Res., Vol. 128

[4] Roennmark, K. (1982), *Waves in homogeneous, anisotropic multicomponent plasmas (WHAMP)*

[5] Shprits, Y. and Ni, B. (2009), *Dependence of the quasi-linear scattering rates on the wave normaldistribution of chorus waves*, J. Geophys. Res., Vol. 114, No. A11205

[6] Shprits, Y. et al. (2015), *Combined convective and diffusive simulations: VERB-4D comparison with 17 March 2013 Van Allen Probes observations*, GRL, 42(22), p. 9600-9608

[7] Shen, Y. (2021), *Realistic Electron Diffusion Rates and Lifetimes Due to Scattering by Electron Holes*, J. Geophys. Res., Vol. 126, No. 9

[8] Stoll, K. et al. (2025), *Can ECH wave scattering explain the unaccounted electron loss during the 17 March 2013 geomagnetic storm?* [Manuscript submitted for publication], J. Geophys Res

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