Relativistic electron flux decay and recovery: relative role of EMIC waves, whistler-mode waves, and plasmasheet injections

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Motivation & Questions

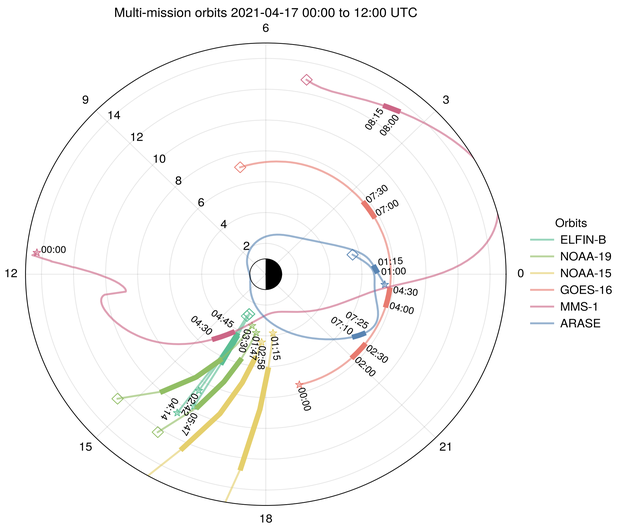
- Relativistic electron scattering and precipitation by electromagnetic ion cyclotron (EMIC) waves is one of the key mechanisms for electron losses and radiation belt depletion.

- Low-altitude polar-orbiting ELFIN CubeSat provides high-energy high-resolution dataset allowing us to evaluate a contribution of EMIC-driven losses into electron flux dynamics.

Approach: Analysis of particle and wave data from multiple missions.

Questions: Can EMIC waves combined with whister waves deplete the flux of relativistic electrons?

Overview of the Half-day Observation



- 01:15 ARASE observed strong electron injection likely supporting whistler-mode wave generation (wave onset coincides with injection)

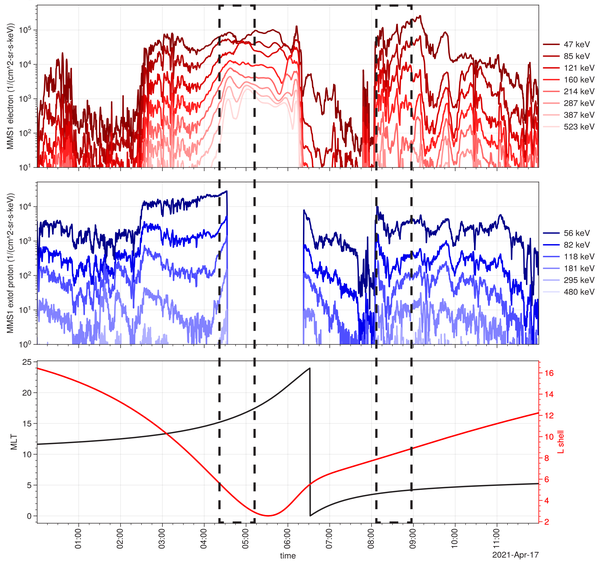
- 01:30-02:30 GOES16&17 observed strong ion injection that arrives to ELFIN MLT~16.5 around 02:30-03:00 and drives EMIC generation

- 02:40-06:00 ELFIN observed continues precipitations of relativistic electrons; ERG see whistler waves that continuously scatter relativistic electrons into the pitch-angle range resonating with EMICs

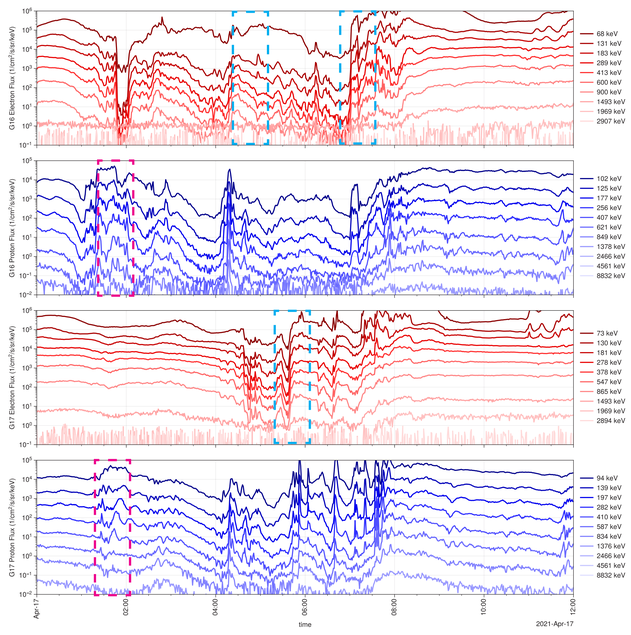
- 07:10-07:30 ARASE and GOES observed strong electron injection: this injection restore electron fluxes and largely compensate losses by EMIC-driven scattering

Plasma Sheet Injections

MMS observations of localized decrease of electron fluxes and strong electron injection



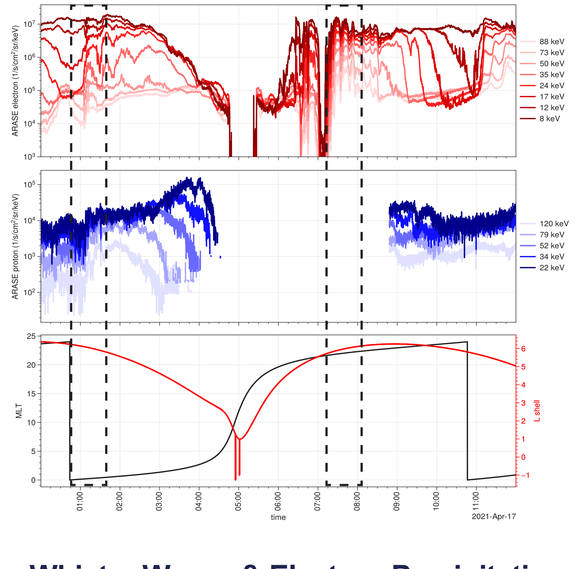
GOES 16&17 observations of strong ion injections and strong electron injection



- Ion injection that likely drives EMIC generation; GOES observed it at dawn flank, after drift around the Earth.

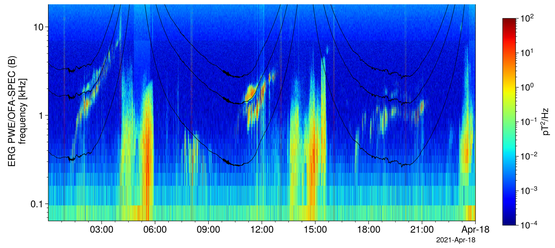
- Series of strong electron injections observed around noon (after drifting from the midnight).

ERG observations of strong electron injection at the beginning of EMIC-driven electron precipitations and strong electron injection at the end of interval

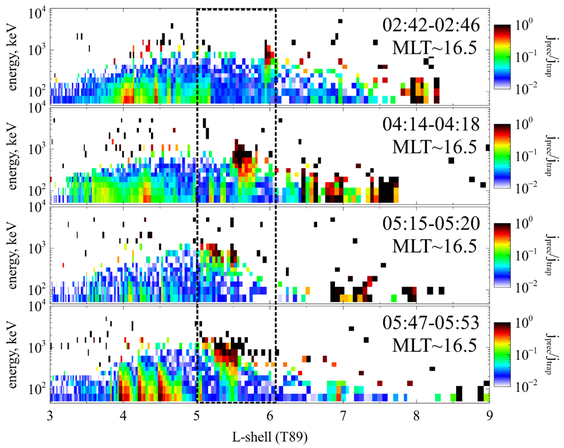


Whister Waves & Electron Precipitation

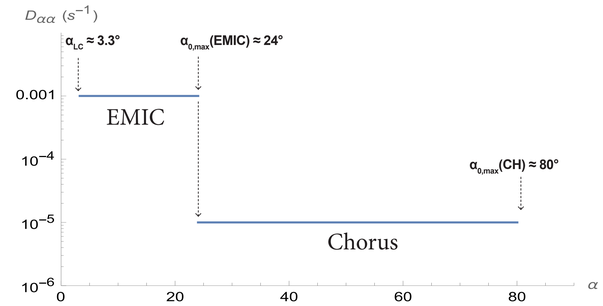
Whistler-mode wave observed by ERG wavespectrum



ELFIN observations of EMIC driven precipitations during >3 hour interval.



Estimation of Diffusion Coefficient



$$\cos\alpha_{0,\max}(\mathrm{EMIC}) \approx \frac{\Omega_{ce0}^2}{2\omega_{\mathrm{EMIC}}\Omega_{pe0}} \times \sqrt{\frac{(1-\omega_{\mathrm{EMIC}}/\Omega_{cp0})(m_e/m_p)}{(1-\Omega_{cp0}(1-\eta_p)/\omega_{\mathrm{EMIC}})(E^2+E)}}$$

$$\cos\alpha_{0,\max}(\mathrm{CH}) \approx \frac{0.5\Omega_{ce0}}{(E^2+E)(\omega_{m,\mathrm{CH}}+\Delta\omega_{\mathrm{CH}})} \left(\frac{\Omega_{ce0}}{\Omega_{pe0}}\right)_{\mathrm{CH}}$$

$$D_{\alpha\alpha}\left(\mathrm{CH}, \alpha_0 > \alpha_{0,\max}(\mathrm{EMIC})\right) \simeq \frac{B_w^2(\mathrm{CH})\Omega_{ce0}^{5/2}}{B_0^2\omega_{m,\mathrm{CH}}^{1/2}\Omega_{pe0}} \frac{\tan^{-1}\Delta\theta_{\mathrm{CH}}}{2\sqrt{3}\gamma^2}$$

$$D_{\alpha\alpha}\left(\mathrm{EMIC}, \alpha_0 < \alpha_{0,\max}(\mathrm{EMIC})\right) \simeq 4\,\alpha_{\mathrm{LC,eq}}{}^2 \left(\frac{j_{\mathrm{prec}}}{j_{\mathrm{trap}}}\right)^2 \frac{1}{\tau_B}$$

Conclusion

- We have analyzed the event with >3 hours continuous precipitation of relativistic electrons observed by ELFIN and likely associated with EMIC-driven precipitations.

- This event is characterized by combined effect of whistler-mode waves, scattering relativistic electrons from high pitch-angles into the low pitch-angle range, where resonance with EMIC waves results in quick electrons losses.

- Such effective mechanism of relativistic electron losses is expected to contribute significantly to the depletion of electron fluxes in the outer radiation belt. However, near-equatorial spacecraft observations do not show such depletion.

- We suggest that the serious of strong injections penetrating to L~5-6 supplement the radiation belt fluxes and compensate EMIC-driven losses.

Reference

Mourenas, et al. Fast Dropouts of Multi-MeV Electrons Due to Combined Effects of EMIC and Whistler Mode Waves. 2016.

Angelopoulos, et al., Energetic electron precipitation driven by electromagnetic ion cyclotron waves from ELFIN's low altitude perspective. 2022.

Miyoshi Y., et al., Geospace exploration project: Arase (ERG). 2017.