ELFIN Observations and Modelling: Energetic Electron Losses due to Non-Linear Resonant Scattering by Chorus Waves

Ethan Tsai[(1)], Anton Artemyev[(1)], Xiao-Jia Zhang[(1)], Vassilis Angelopoulos [(1)], Andrei Runov[(1)], Colin Wilkins[(1)], Jiang Liu[(1)], and the ELFIN Team

(1) Earth, Planetary, and Space Sciences, University of California, Los Angeles, 90095

e-mail: ethantsai@ucla.edu; aartemyev@igpp.ucla.edu; xjzhang@ucla.edu; vassilis@ucla.edu; arunov@igpp.ucla.edu; colinwilkins@ucla.edu; jliu@igpp.ucla.edu

The launch of the twin ELFIN CubeSats in 2018 have enabled studies on the relative contributions of electron precipitation mechanisms to electron loses in the radiation belts. For the first time, pitch angle resolved energy spectra (at smaller than loss cone angular resolution) at low altitudes can be compared directly with equatorial wave measurements to determine its scattering mechanism. ELFIN data shows evidence of precipitation bands from tens to hundreds of keV, which implies a significant number of electrons are scattered by chorus waves. An example is shown on the left, where ELFIN-A observed a strong precipitation event for nearly a minute up to a couple hundred keV. Such bands, observed as up to minute-long enhancements of fluxes within the loss-cone, are a common and significant contributor to the total loss of electrons from the radiation belts. Timescales of these bands are somehow shorter than typical timescales of quasi-linear electron scattering, which suggests that precipitation bands are potentially driven by a combination of quasi-linear and non-linear electron resonances with whistler-mode chorus waves. Shown below are large amplitude chorus waves observed by MMS-1 at the same time in the inner magnetosphere. The region of activity from 8:00-9:30 UTC on MMS corresponds with the roughly minute it takes ELFIN to cross the outer radiation belt at around 9:16. We examine events like these in conjunction with whistler wave measurements from THEMIS, ERG, and MMS and use large test particle simulations to explore non-linear interaction both theoretically and observationally. The work is intended to reveal the energy extent, pitch-angle spectral characteristics and relative contributions of quasi-linear (diffusion) and nonlinear (phase bunching) resonant interactions to precipitation bands. Numerical results are compared with observations to assess the validity of our findings and provide a comprehensive interpretation of the dominant scattering processes during precipitation bands.

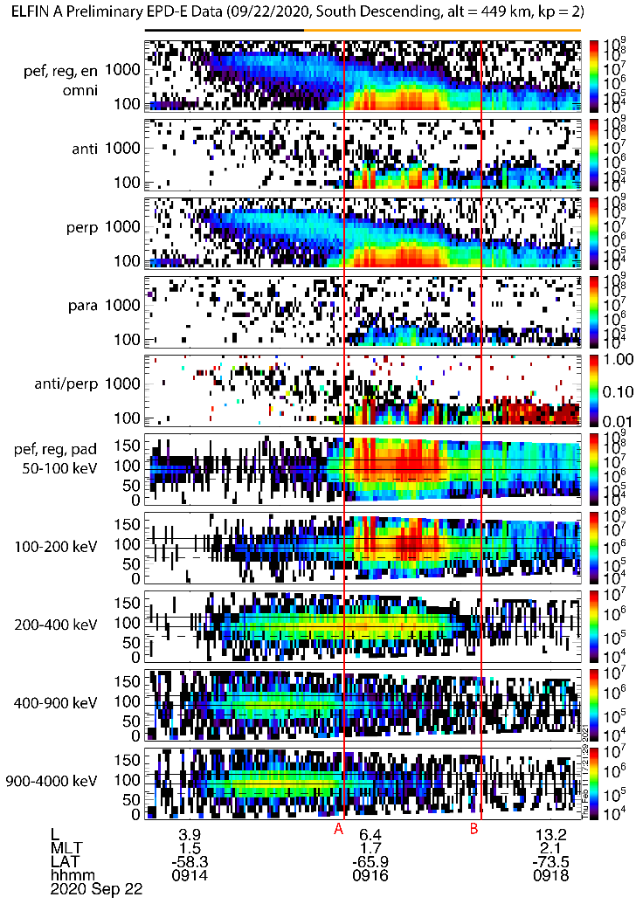

Figure 1 ELFIN-A energy spectra in omni, antiparallel, perpendicular, and parallel look directions in the first four panels. The anti/perp panel shows strong losses occurring both in the middle of the radiation belt, and isotropic boundary crossing near the end. The bottom five panels show pitch angle distributions with various energy ranges with the solid line denoting the loss cone (above) and dashed displaying the anti-loss cone (below). The first red line (A) denotes roughly when ELFIN-A leaves the plasmasphere and the second red line (B) denotes when ELFIN-A enters the plasma sheet.

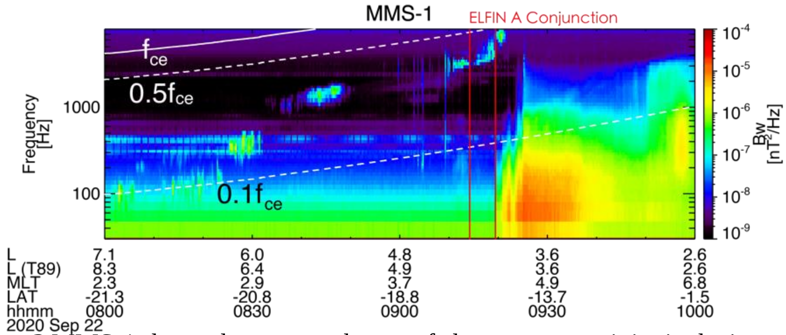

Figure 2 MMS-1 shows three strong bursts of chorus wave activity in the inner magnetosphere with amplitudes up to hundred of pT. MMS-1 has already left the plasma sheet by 08:00 UTC and enters the plasmasphere (as shown by the hiss) around 09:20 UTC. These three bursts are possibly repsonsible for the precipitation bands shown between red lines A and B in **Figure 1**.