Search for electron precipitation associated with high power VLF transmissions from the DSX satellite: Results from DSX and POES observations

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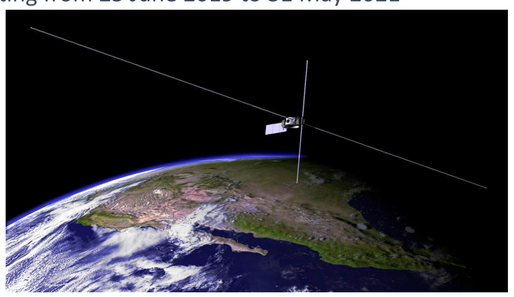
Abstract: The **Demonstration and Science Experiments (DSX)** satellite mission from June 2019 to May 2021 conducted high-power VLF transmission in the medium Earth orbit (MEO) region. Such transmissions are capable of producing (to a limited degree) precipitation of radiation belt electrons via wave-particle interactions, and could be useful for confirming and improving the theoretical underpinnings of these interactions. DSX carried the **Loss Cone Imager High Sensitivity Telescope (LCI-HST)** to look for evidence of such precipitation. In addition DSX conducted dozens of transmissions during magnetic field line conjunctions with **POES** satellites. We report results and constraints from searches for precipitation during these events.

Demonstration and Science Experiments (DSX)

- **DSX** is in a 6000 x 12000 km altitude orbit, 42.2° inclination, operating from 25 June 2019 to 31 May 2021



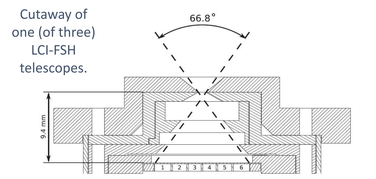
- The **Wave Particle Interactions Experiment (WPIx)** is its primary mission, conducting high power VLF transmissions in the MEO plasmasphere: with the potential to produce particle precipitation.
- High power VLF transmissions during **DCEs (Data Collection Experiments)** executed in pulse patterns

Search For DSX Induced Particle Precipitation via LCI

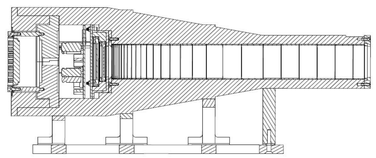
- Particle precipitation induced by **DSX** VLF transmissions could manifest as increase in local loss cone fluxes with a cadence matching that of the transmission pulses
- We search **LCI** particle flux data during VLF transmission times for such a pulse signal here as follows:
  - Remove large background signal by subtracting rolling mean (average of flux 15 sec before and after each observation)
  - Create spectrograms of remaining flux signal observed
- Case shown here: DCE 2021-02-23 21:13:00
  - 40 min of transmission, high frequency sweep 2.8 kHz

Loss Cone Imager (LCI)

- **LCI** has two components, FSH and HST:
  - The **Fixed Sensor Head (FSH)** permits characterization of the full local electron pitch angle distribution. FOV = 180° x 10° divided into 18 pixels, geometric factor = 0.0045 cm^2 sr, detects electron energies 30-850 keV in 5 channels, sampling variable at 2, 6, or 20 Hz.



Cutaway of LCI-HST telescope, aperture at right.

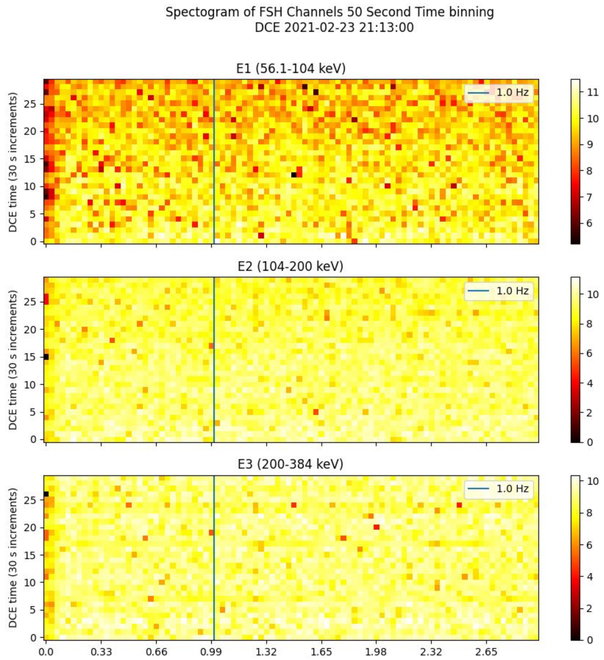


  - The **High Sensitivity Telescope (HST)** is designed to detect low electron fluxes within the loss cone. FOV = 14° full angle, geometric factor = 0.088 cm^2 sr, detects electron energies 30-550 keV in 11 channels, sampling variable at 2, 6, or 20/100 Hz (depends on energy channel).
  - During most DSX transmission experiments, HST look direction is just inside the loss cone and FSH look direction spans 180° in pitch angle, overlapping HST look direction, with FSH pixel 5 offset 15° from HST

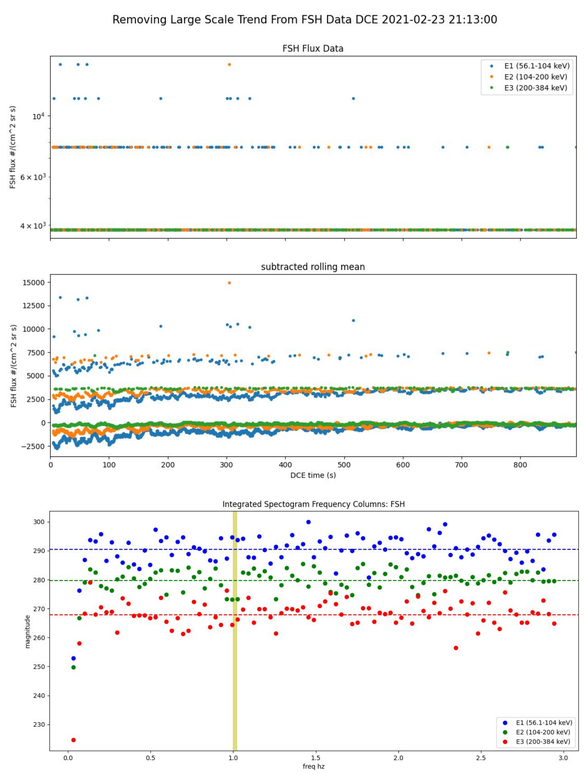
Ref: Parker et al. (2016), *Nucl. Instrum. Methods Phys. Res. A*, 808:11.

Figures for both HST and FSH analyses are:

- Time series with/without background subtraction
- Spectrograms with DFTs of flux vs. time for 50 sec bins, each energy channel
- DFT magnitude vs. frequency for entire DCE
- Low count rate FSH time series data are consistent with a look direction inside the loss cone



FSH Pixel 5 Data



DCE at 2021-02-23 21:13:00

- During this **DCE**, **DSX** was transmitting an on/off pulse pattern of VLF waves with a three second cadence—any induced precipitation would produce 0.33 Hz signal
- Time series show increasing fluxes as DSX moves towards magnetic equator
- Integrating the frequency columns of the spectrogram does not show a signal at 0.33 Hz which could be attributed to **DSX** transmissions

Conclusions

- We do not find a particle precipitation signal in LCI observations during the DCE considered
- Though unsurprising given low sensitivity, this type of analysis will yield upper limit estimates for precipitation, combined with analyses of multiple events, LCI calibration, and estimates of transmitted wave power

Future Work

- Repeat analysis from LCI-FSH data during other DCEs
- Search for DSX induced particle precipitation in observed **POES/MEPED** data:
  - DSX conducted high power transmissions during 48 magnetic footprint conjunctions with POES/METOP satellites—check for bounce loss cone precipitation
  - Develop criteria for possible drift loss cone conjunctions and check for precipitation
  - Lower time resolution of MEPED electron channels plus more complex DSX transmission patterns for many DCEs will require modified analyses
- Examine LCI-HST data from July-Nov 2019 for possible natural electron precipitation, complimented by VLF wave observations

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