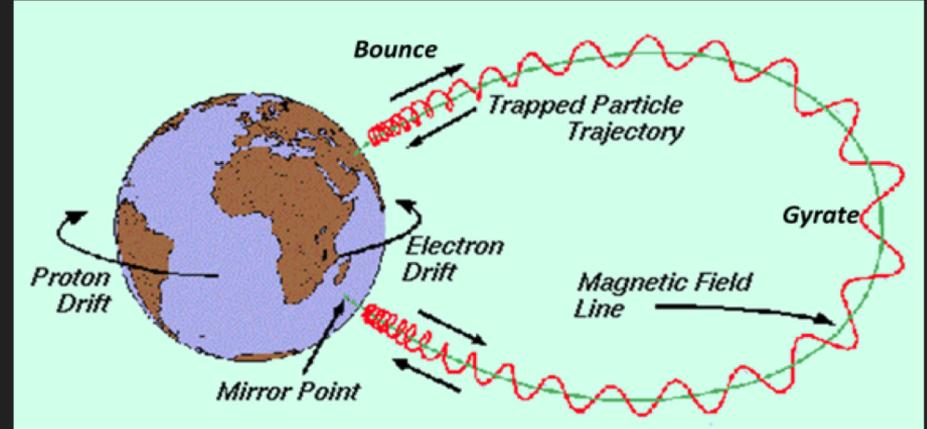


# Conjunctive Measurements of Energetic Particle Injections

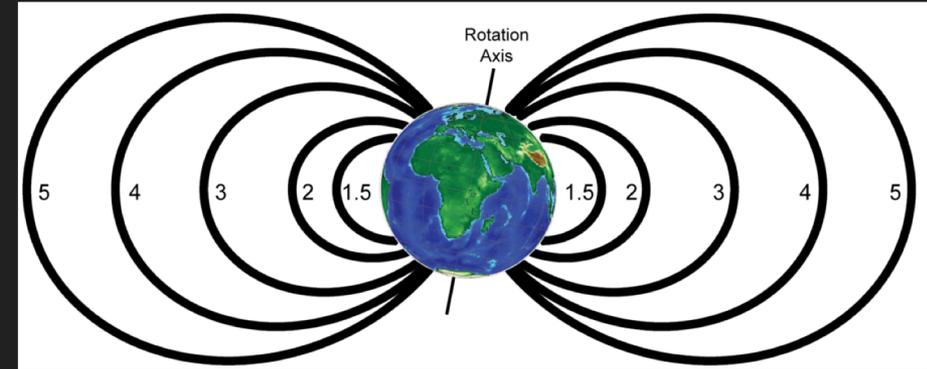
Nicki Mullins, Dr. Hong Zhao, Dr. Trevor Leonard

# The Inner Magnetosphere

- The radiation belts are two concentric rings of energetic particles trapped in the Earth's magnetic field lines.
- Particles in the radiation belts gyrate, bounce and drift.
- L-shell is a way to represent the magnetic field lines around Earth.

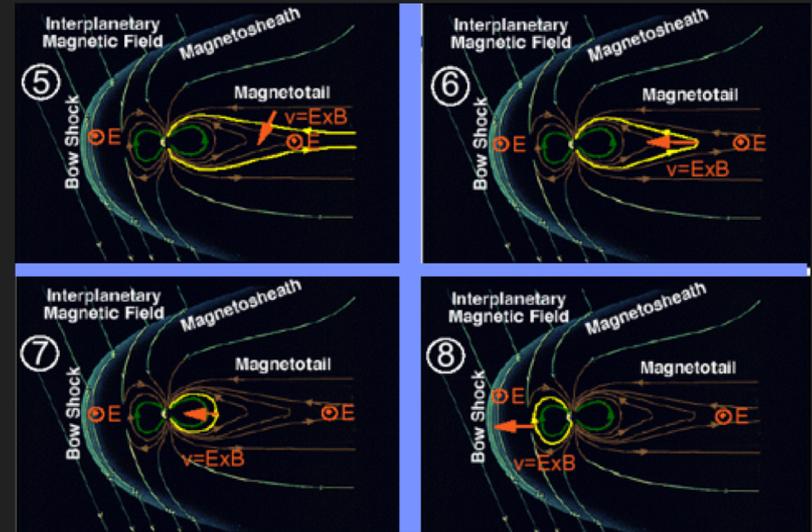


Source: Institut d'Aeronomie Spatiale de Belgique



# What we Know About Particle Injections

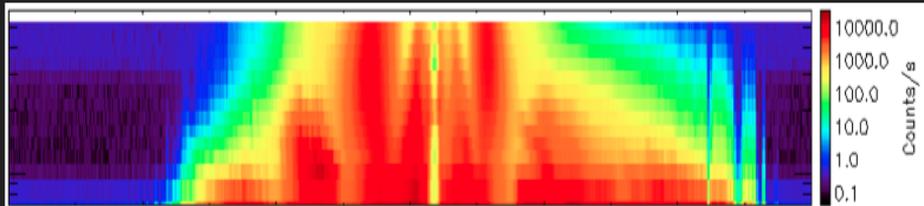
- Particle Injections are the Earthward transport of energetic particles from tens to hundreds of keV.
- Particle injections typically originate in the magnetotail from magnetic reconnection.
- Particle injections are classified as dispersed or dispersionless.



# Missions

## Magnetospheric Multiscale (MMS)

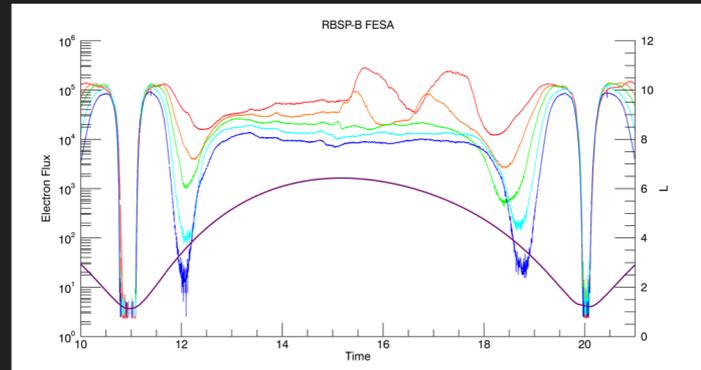
- Designed to study magnetic reconnection in the outer magnetosphere.
- Operates in three different types of data collection modes: burst, fast, and slow.
- Highly elliptical orbit which leads to the spacecraft typically being in the outer magnetosphere.



Credit: MMS Science Data Center

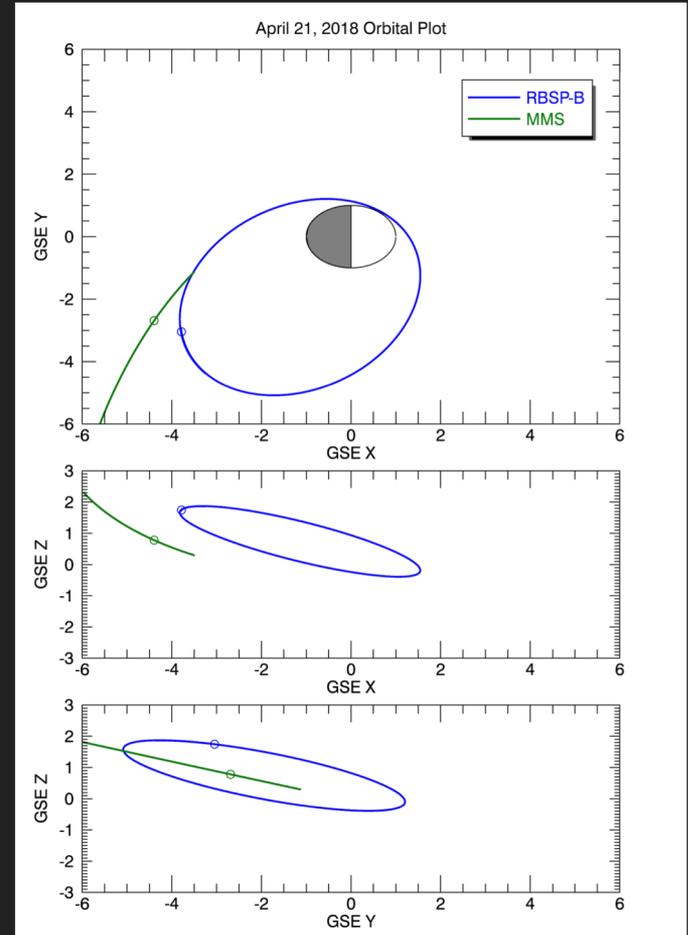
## Van Allen Probes (RBSP)

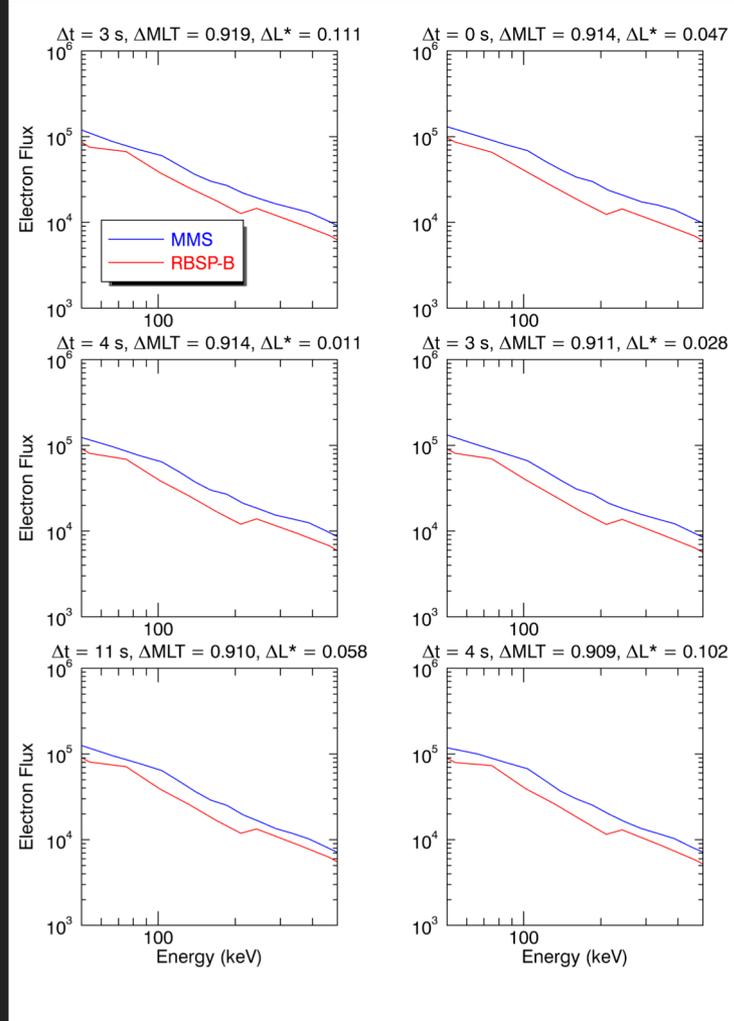
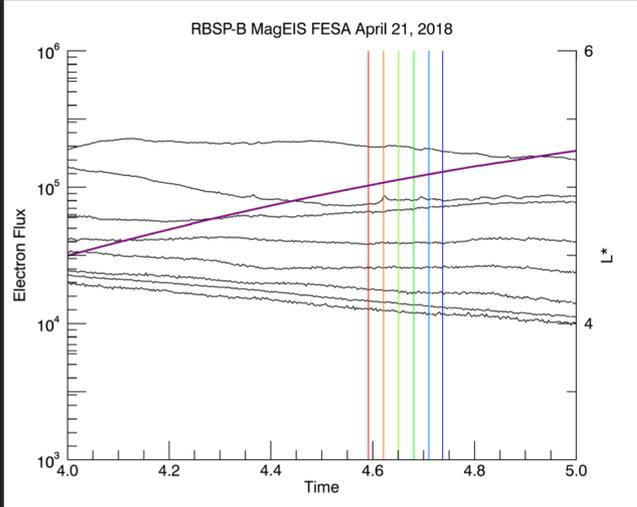
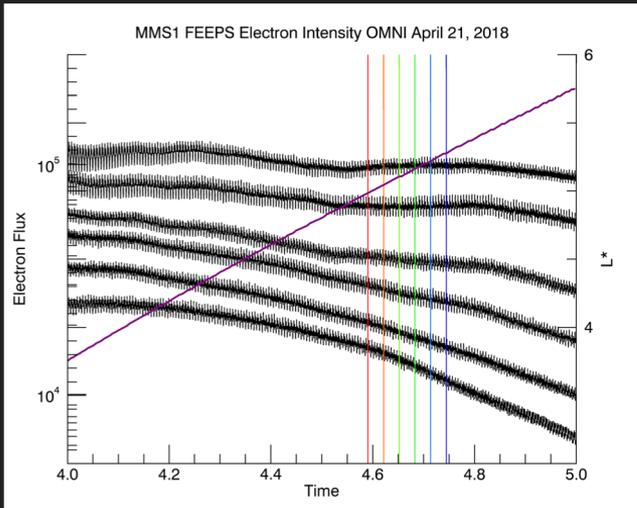
- Mission goal is to study energetic particles in the radiation belts.
- The Van Allen Probes consist of two spacecraft in similar orbits.
- The MagEIS particle detector consists of four different units: MagEIS low, two MagEIS medium and MagEIS high.



# Comparing Spacecraft

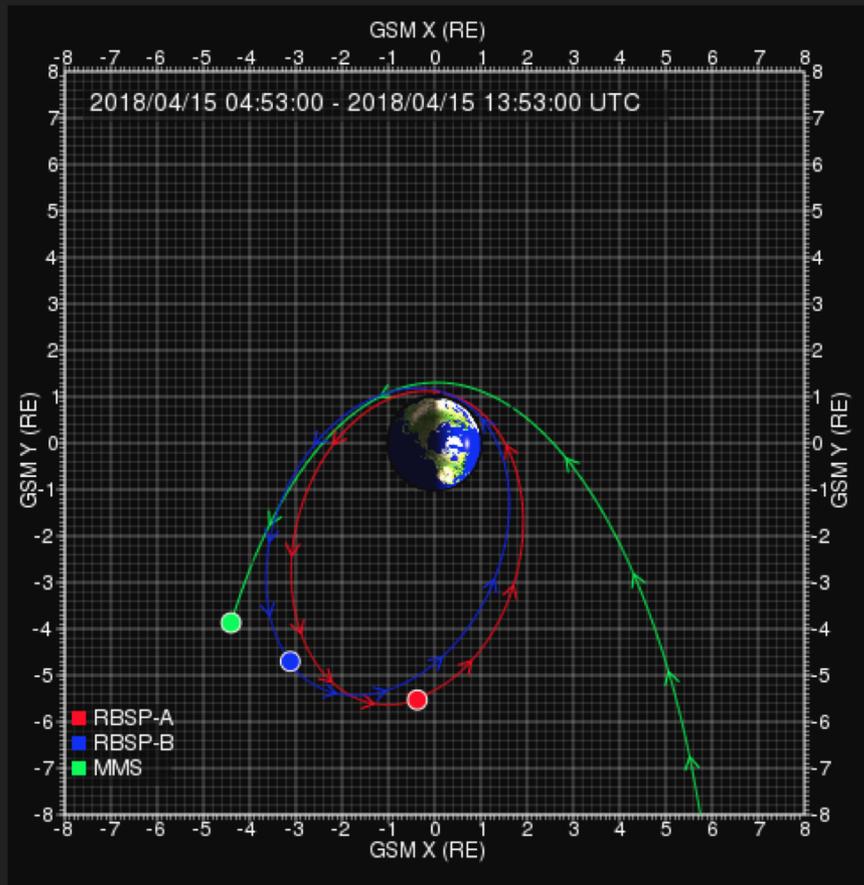
- In order to determine whether the measurements of the Van Allen Probes and Magnetospheric Multiscale are consistent, energy spectra were compared during close conjunctions.
- These conjunctions were chosen based on L-shell primarily and spatial proximity secondarily
- MMS has an apogee of 153,000 km, while RBSP has an apogee of 30,000 km



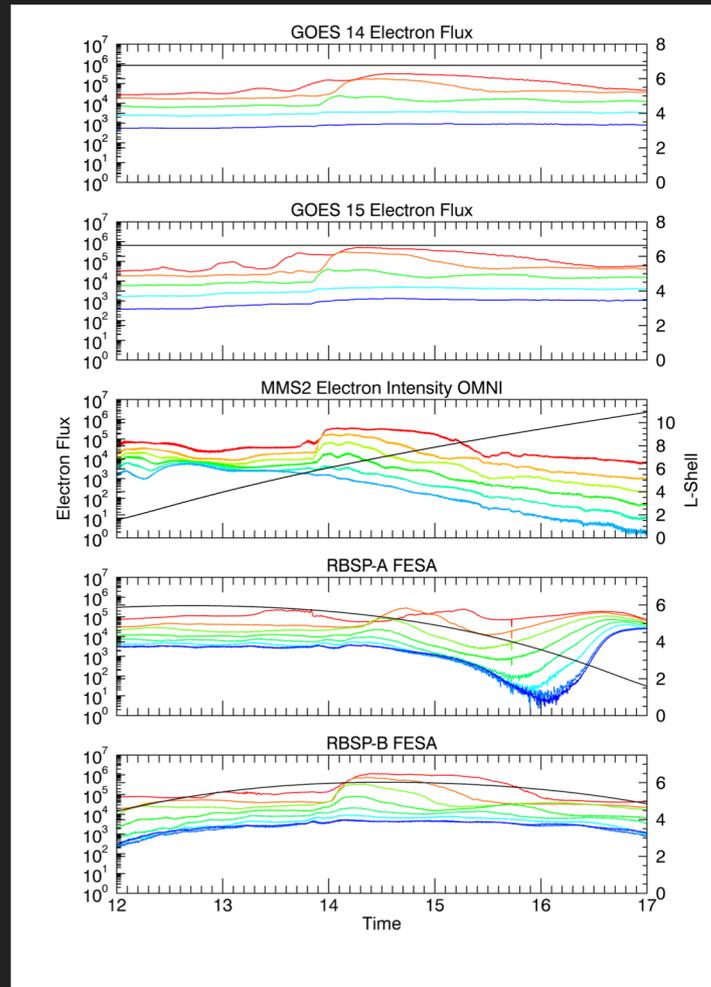
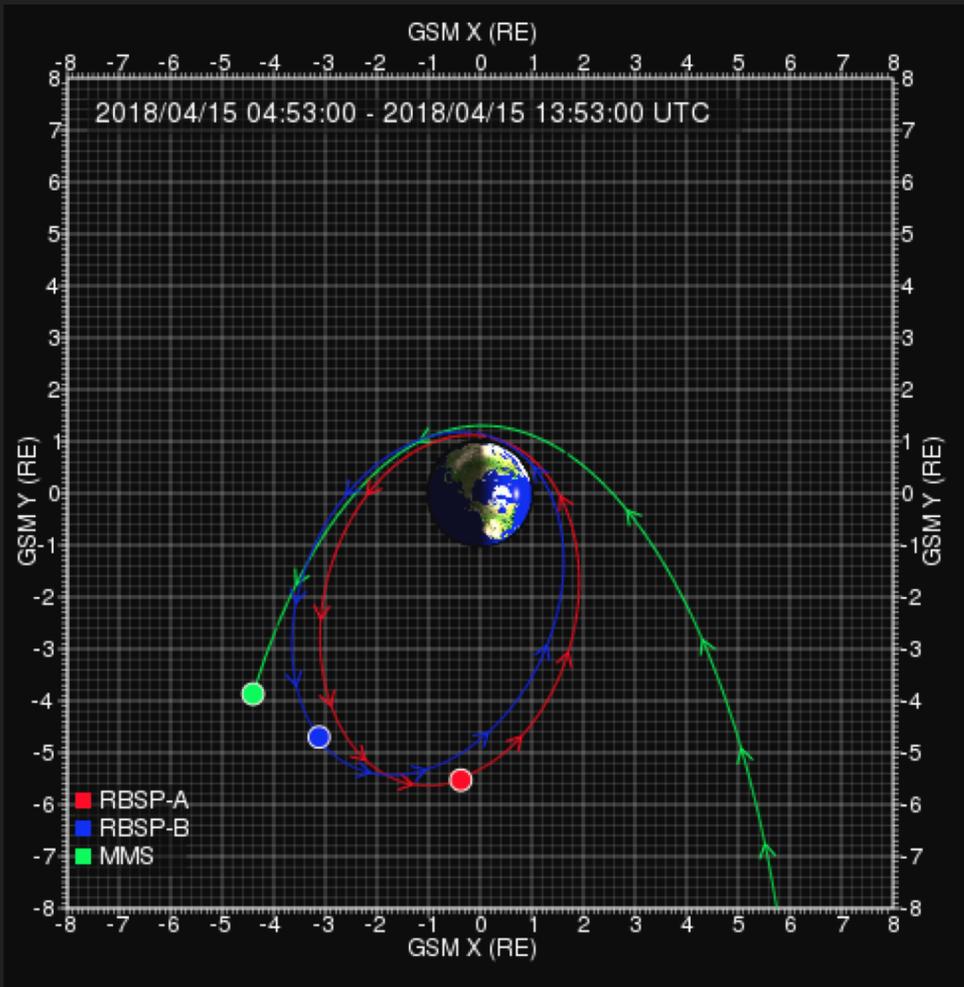


# Case Study

- This injection from April 15 is a good case to start with because MMS and RBSP-B are on similar L-shells.
- RBSP-A is slightly separated in L-shell and inbound.
- GOES are added because they are at a higher L-shell.

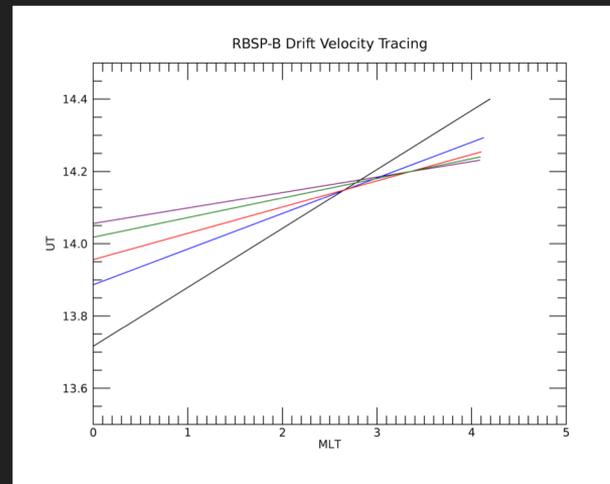
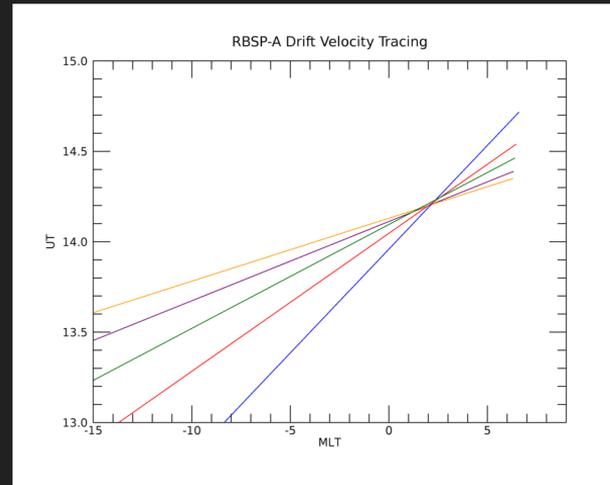


Credit: Van Allen Probes Science Gateway



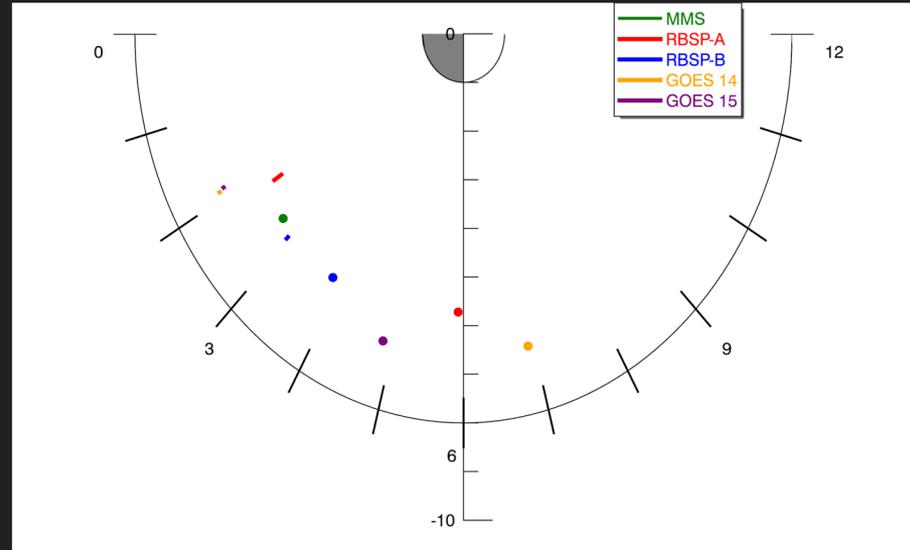
# Drift Velocity Tracing

- Assuming a dipole magnetic field of Earth provides accurate results and allows for calculation of the drift period of energetic particles.
- This allows particles in each energy channel to be traced backwards.
- Ideally there will have been a time and location at which all particles were at the same place, this would be the boundary of the injection region.



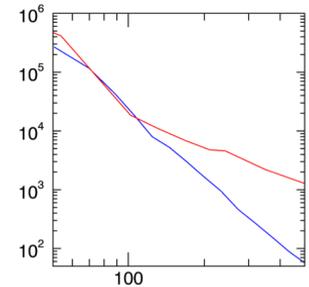
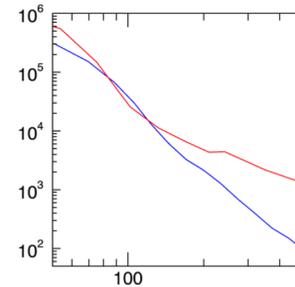
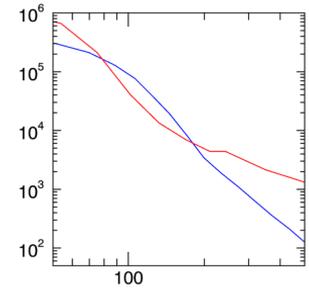
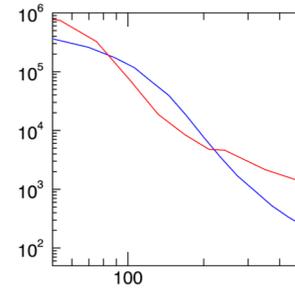
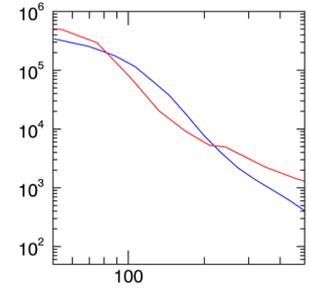
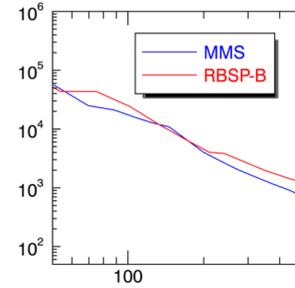
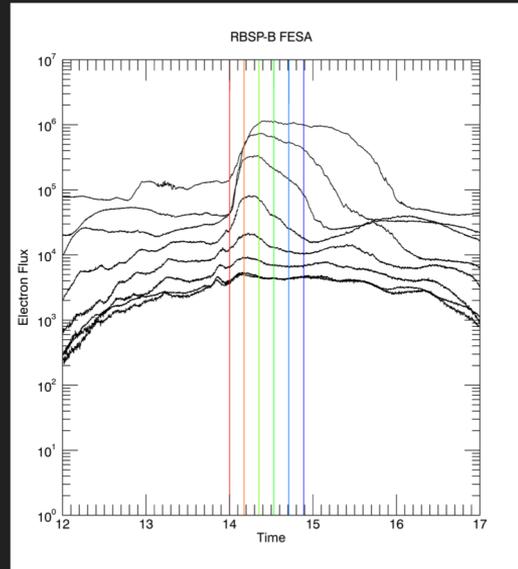
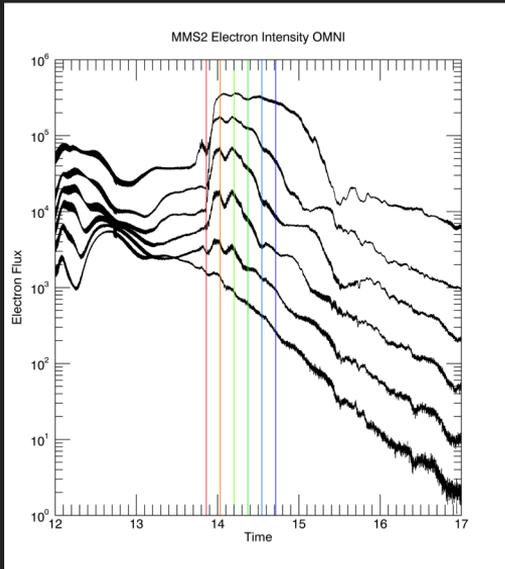
# Injection Boundaries and Velocity Calculations

- Using drift velocity tracing for each dispersed injection the boundaries of the injection region are determined at various radial distances.
- Taking the difference in L-shell and dividing by the time between injection regions should give an estimate of the propagation speed, however this calculation can be unreliable.



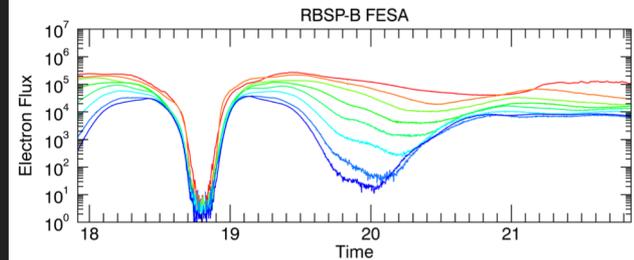
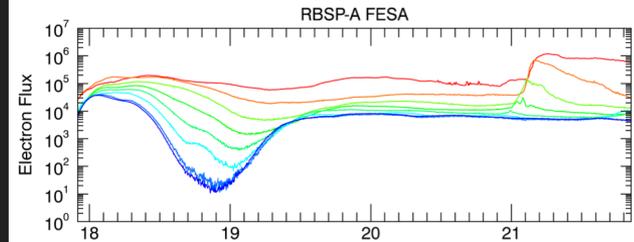
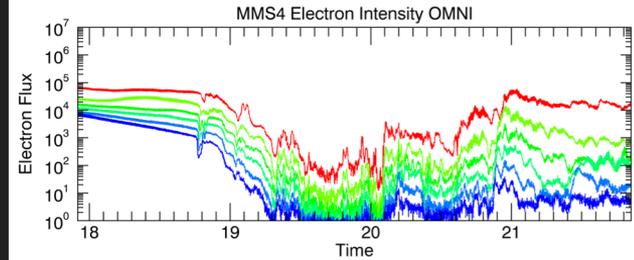
# Energy Spectra Comparison

- Energy spectra were compared during the injection to see if they could be used to map the injection progression.



# The Big Picture

- To better determine the properties of particle injections in general, a bigger sample must receive an in depth analysis.
- Looking at April of this year, it seems that only the largest injections are seen below an L-shell of 4, and injections which are observed at higher energies are more likely to penetrate to lower L-shells.



# Moving Forward

- Extending the larger view of energetic particle injections from part of one month to a larger time period.
- Adding data from concurrent magnetic field observations to individual case studies to examine how the progression of the injection region correlates with magnetic field data.
- Examining more injections in depth to determine how the correlated observations change as the spatial and L-shell separation increase.

# Acknowledgments

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