Impact of Interplanetary Coronal Mass Ejections on Radiation Belt Dynamics

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Outline

- **Brief introduction**
- **Data selection and methodology**
- **Results**
- **Conclusions**

Background

ACCELERATION:

i) Inward Radial Transport
(e.g. Mann et al., 2012)

ii) In situ Acceleration via Wave – Particle Interactions
(e.g. Meredith et al., 2002)

LOSSES:

i) Precipitation into Atmosphere via Wave – Particle Interactions
(e.g. Summers et al., 1998)

ii) Magnetopause Shadowing followed by Outward Radial Diffusion
(e.g. Turner et al., 2012)

Motivation – Goal

- **Focus on the contribution of various mechanisms on the variability of the outer Radiation Belt**

- **Field of study the impact of ICMEs to the variability of the relativistic electrons**

- **ICMEs: Stronger Ring Current and Substorm activity**
  (Borovsky and Denton, 2006)

Multi – Satellite Data

1. **Fluxes**
   - THEMIS A, D and E (SST): 300 – 800 keV and α = 90°
   - RBSP A and B (MagEIS): 340 – 1100 keV and α = 90°
   - GOES 13 and 15 (MAGED): 30 – 600 keV (omnidirectional)
   - INTEGRAL (REM): 690 – 1820 keV (omnidirectional)
   - XMM (EPIC): 160 – 1060 keV (omnidirectional)

2. **Pc5 ULF Waves (1 – 22 mHz)**
   - GOES 13 and 15
   - Themis A, D and E
   - RBSP A and B as well as
   - IMAGE, CARISMA and ENIGMA ground based magnetometers

3. **Solar Wind, Geomagnetic Indices and Plasmapause/Magnetopause Models**
   - solar wind speed and pressure
   - interplanetary magnetic field (IMF) and its southward component (Bz) as well as
   - geomagnetic indices SYM-H and AL
   - plasmapause (O'Brien et al. 2003) and magnetopause prediction model (Shue et al. 1998)

Methodology
(Electrons)

The electron PSD is calculated as a function of fixed first (μ) and second (K) adiabatic invariants using the method described by Chen et al. 2005.

- Power law fit in energy, E, at each observation time

$$j(E) = AE^{\gamma}\left[\frac{\#}{cm^2 \cdot s \cdot sr \cdot keV}\right]$$

- Calculation of energy matrix for fixed μ

$$\mu(E,B) = \frac{E(E+2m_0c^2)}{2Bm_0c^2}\left[\frac{Mev}{G}\right]$$

- Calculation of PSD as a function of μ

$$f(E) = 3.325 \times 10^{-8}\frac{j(E)}{E(E+2m_0c^2)}\left[\left(\frac{c}{MeV \cdot cm}\right)^3\right]$$

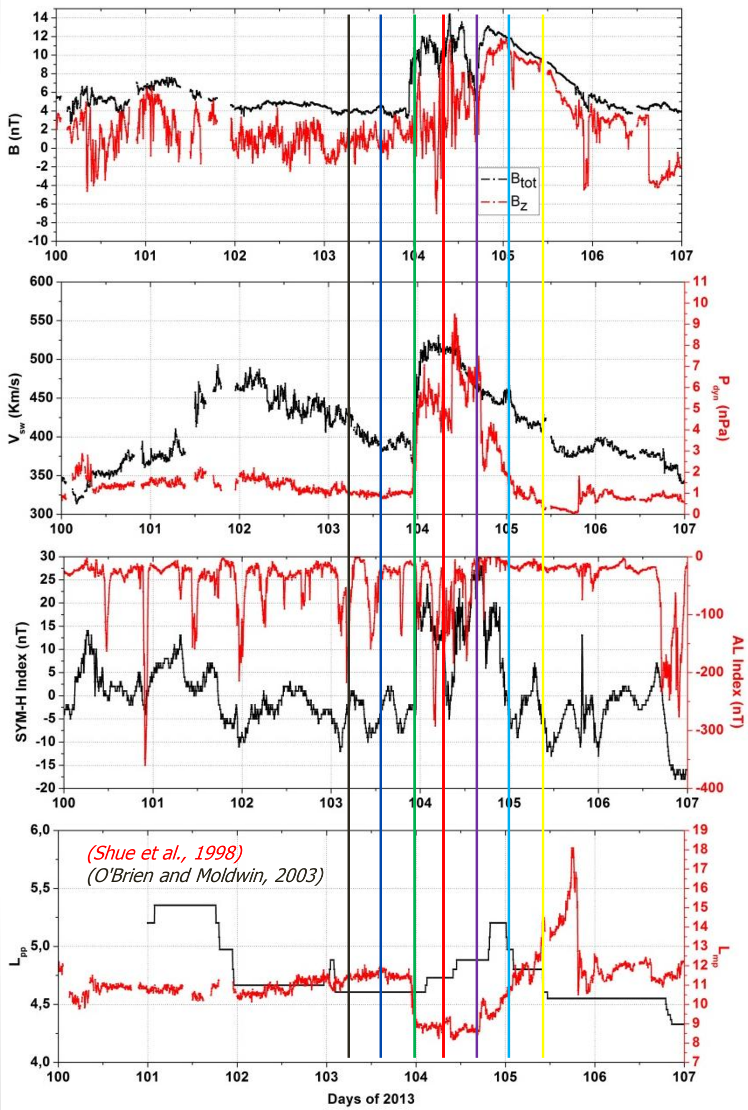
Methodology
(ULF waves)

We apply:

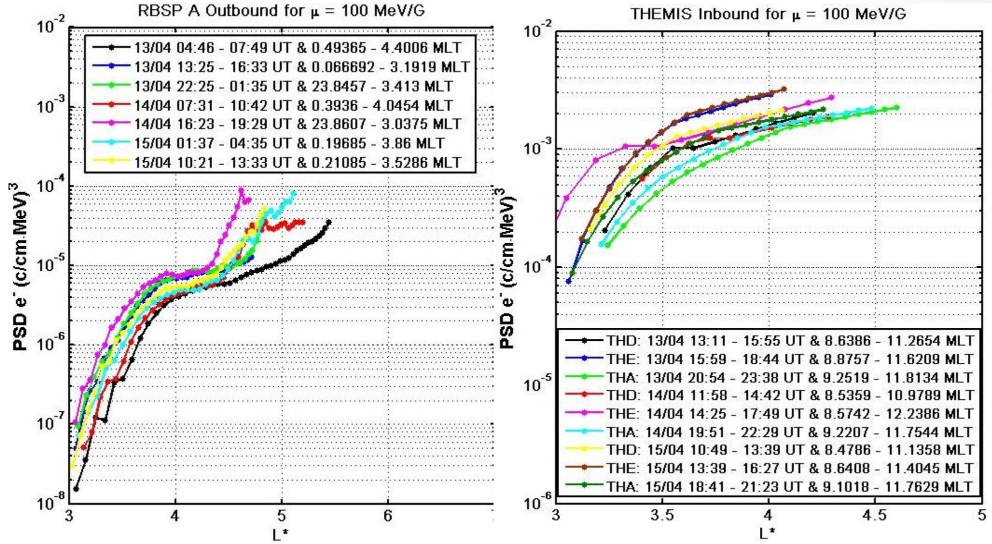
- A fifth order high-pass Butterworth filter with a cut-off frequency at 0.9 mHz is used to eliminate low-varying background activity.

- Wavelet transform (Torrence et al., 1998), with Morlet function as the wavelet basis function, is employed for the time-frequency representation and identification of ULF waves. Then the average power is calculated from the global wavelet spectrum.

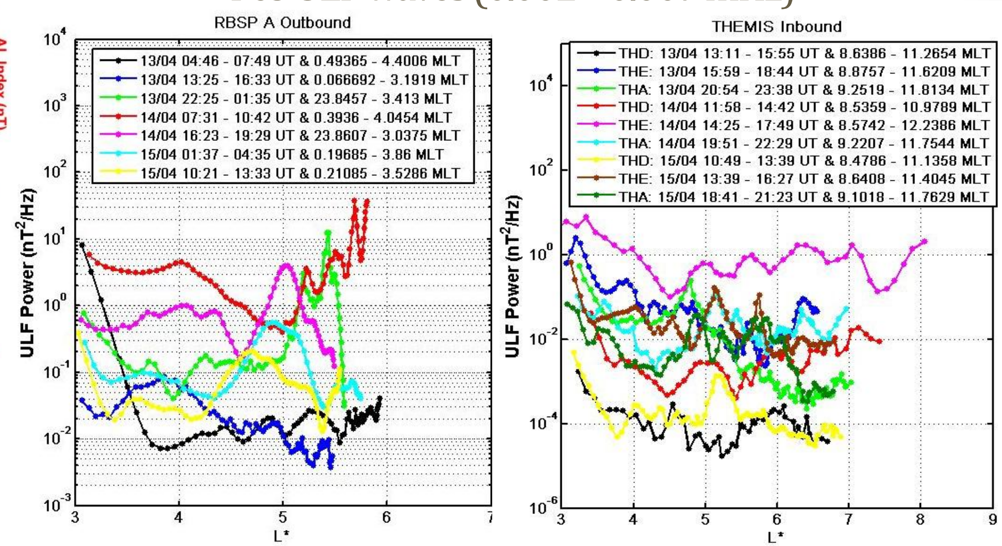
Non-Storm Event (April 13-15, 2013)



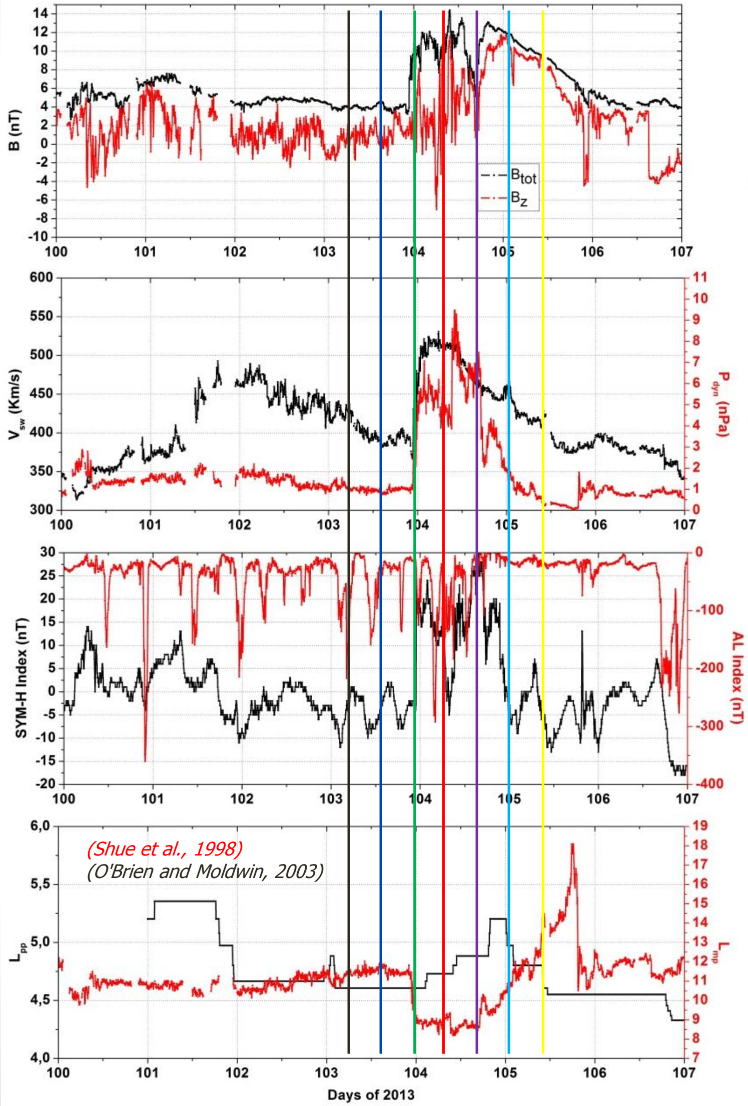
Electrons with μ=100MeV/G and K<0.01 $G^{1/2} R_E$



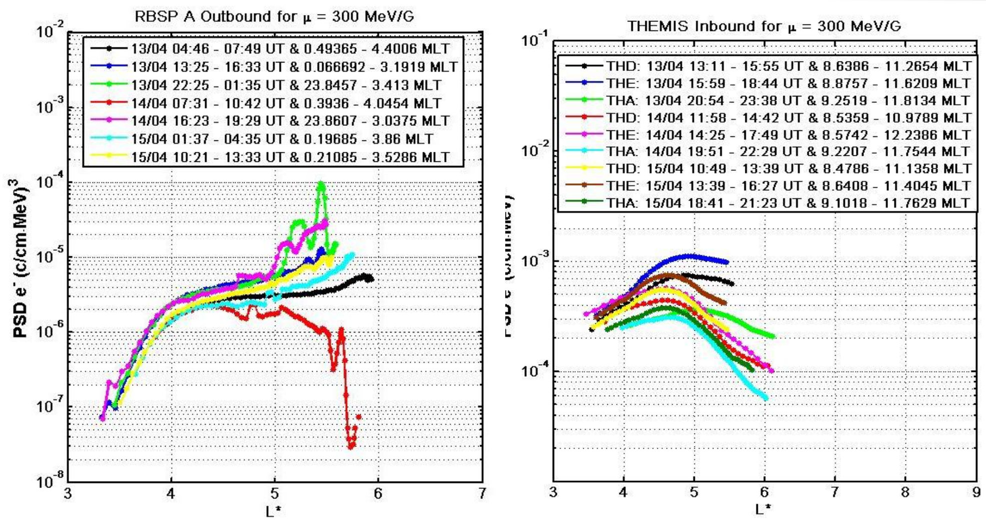
Pc5 ULF waves (0.002 – 0.007 mHz)



Non-Storm Event (April 13-15, 2013)



Electrons with μ=300MeV/G and K<0.01 $G^{1/2}$ R_E



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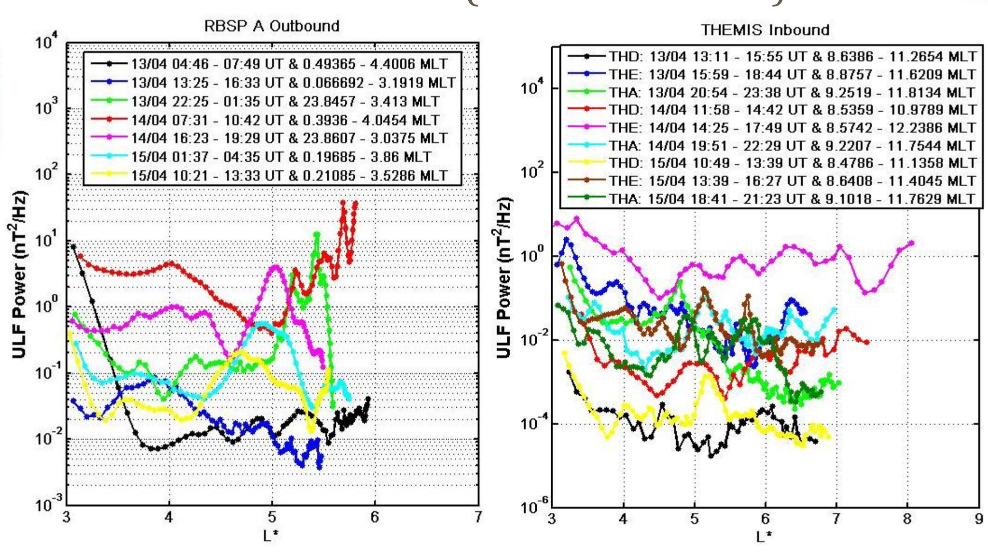
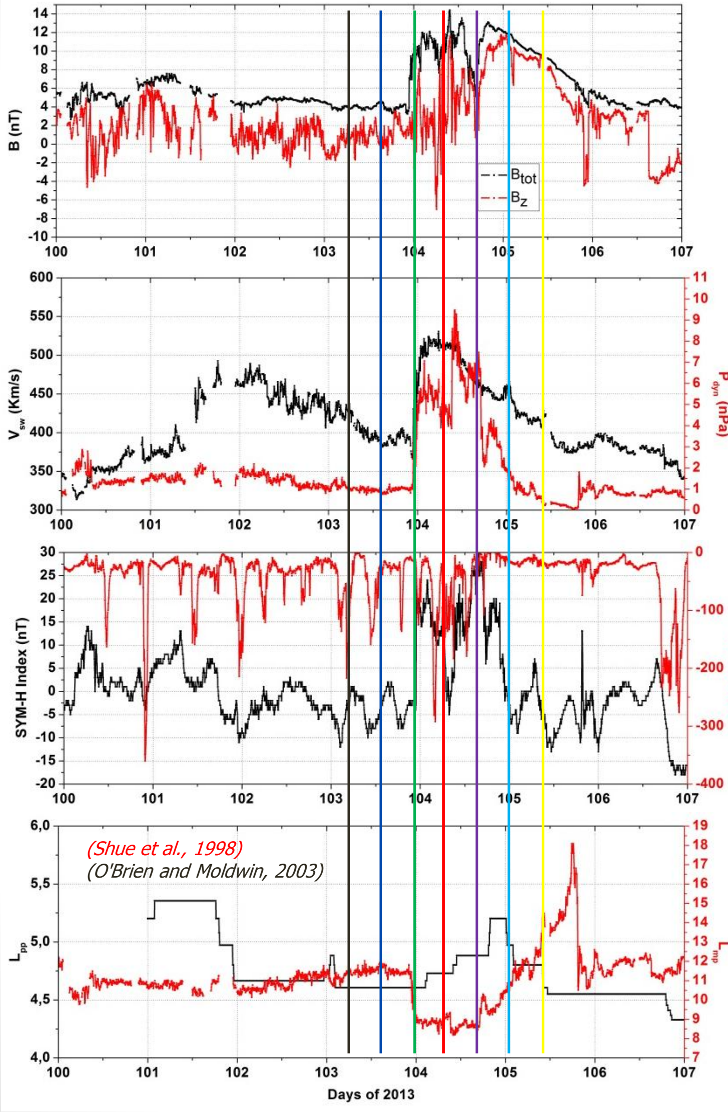
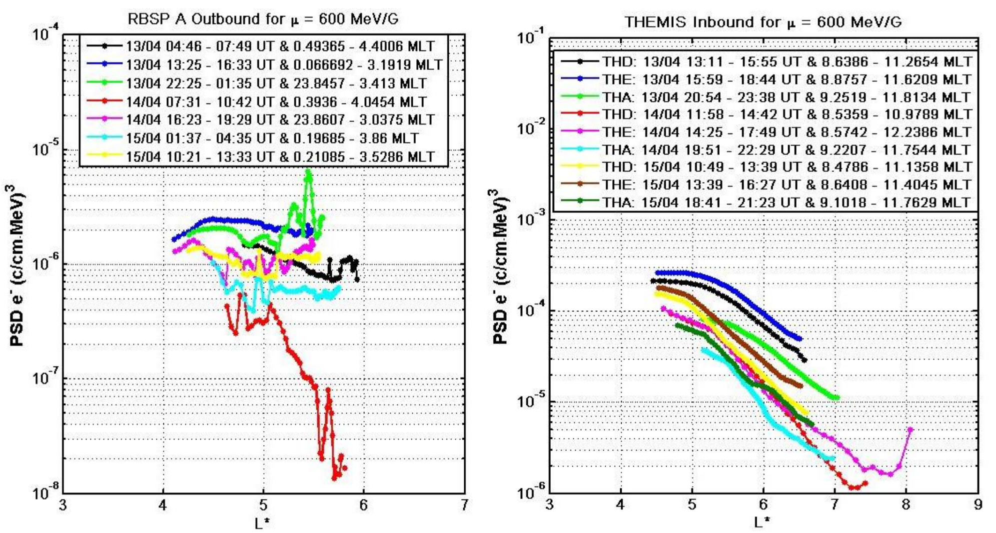


Non-Storm Event (April 13-15, 2013)

Electrons with μ=600MeV/G and $K<0.01\ G^{1/2}\ R_E$





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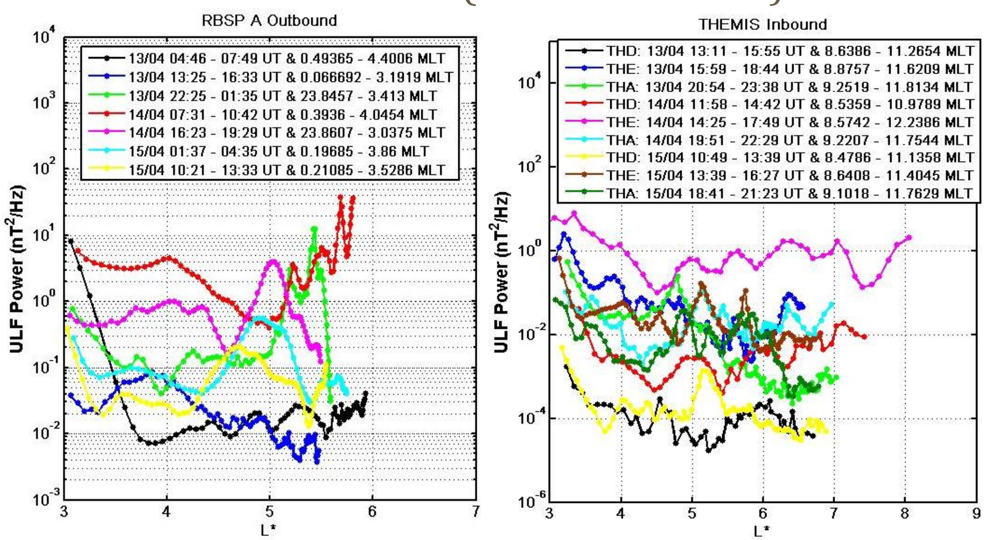
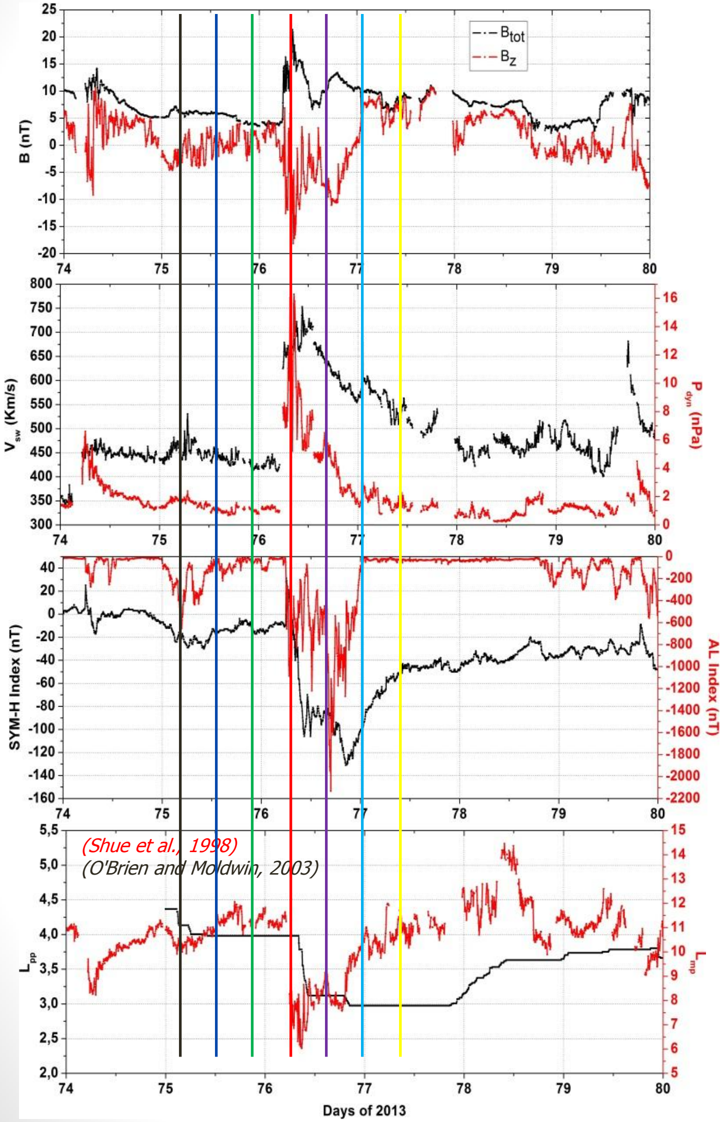
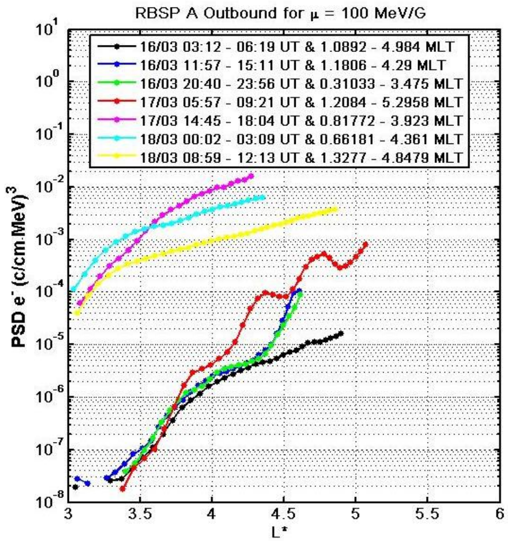


Electron Enhancement Event (March 16-18, 2013)



Electrons with μ=100MeV/G and K<0.01 $G^{1/2}$ R_E



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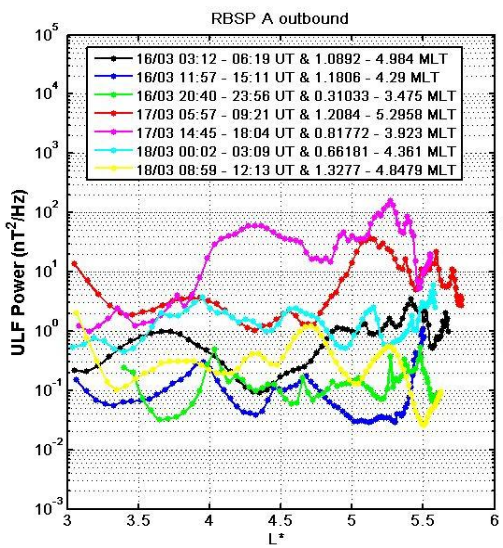
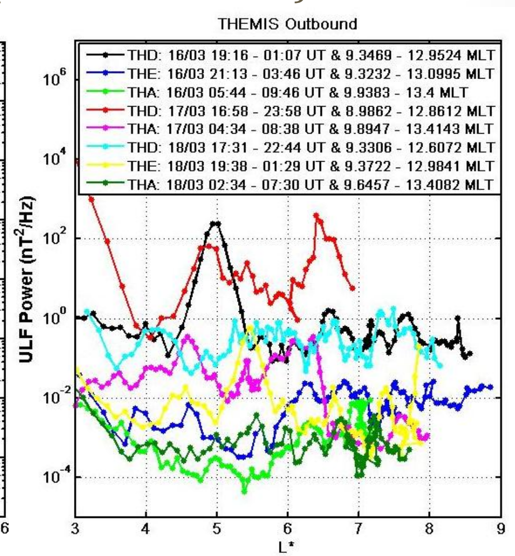
Pc5 ULF waves (0.002 – 0.007 mHz)





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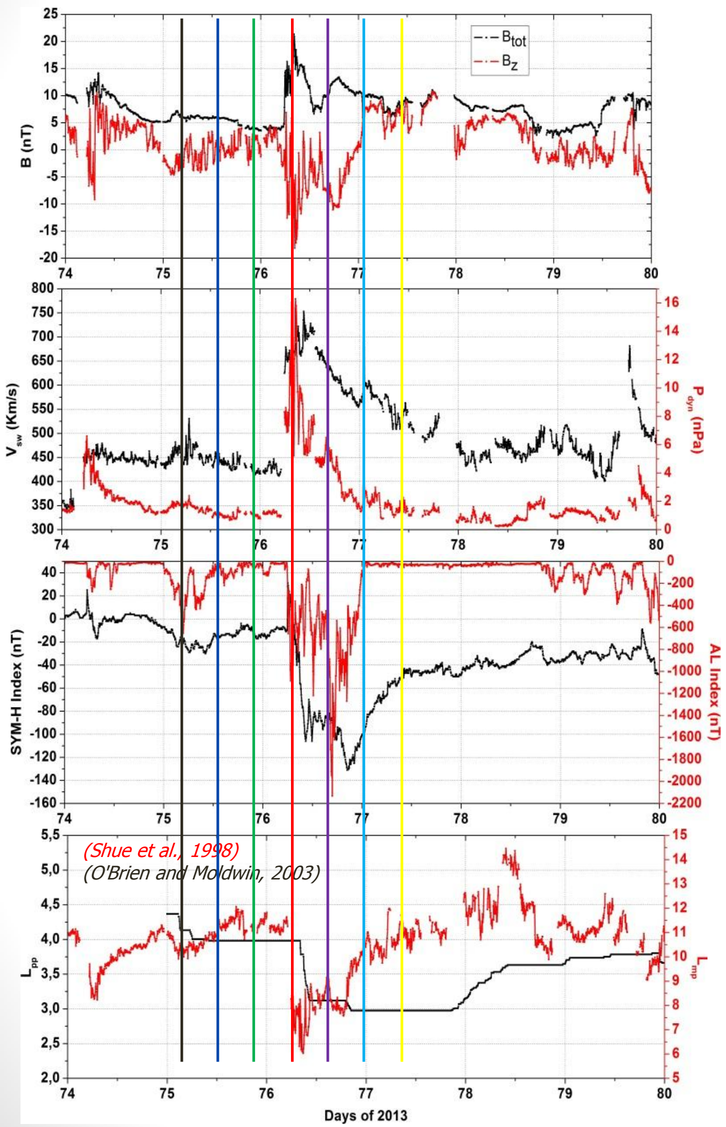

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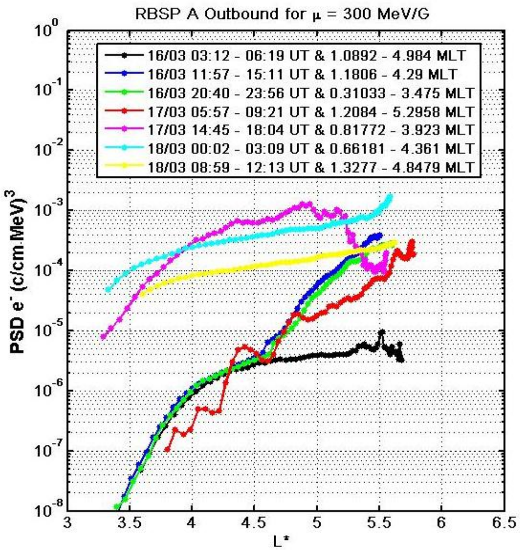
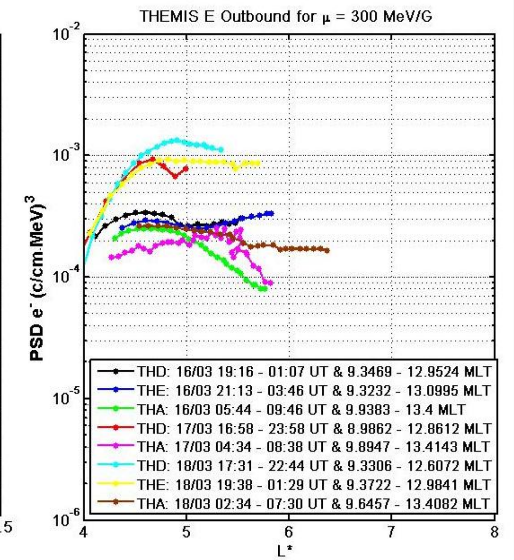
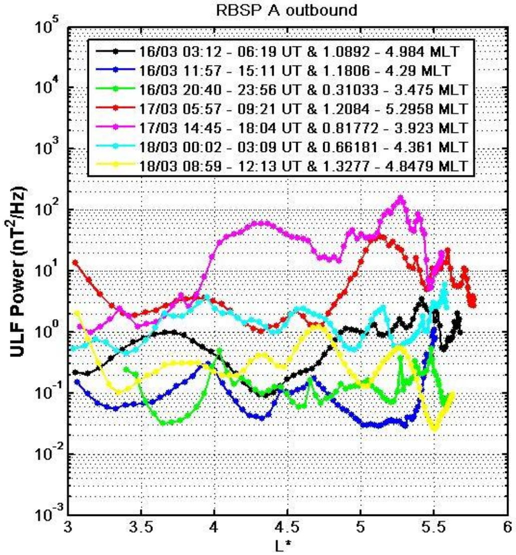
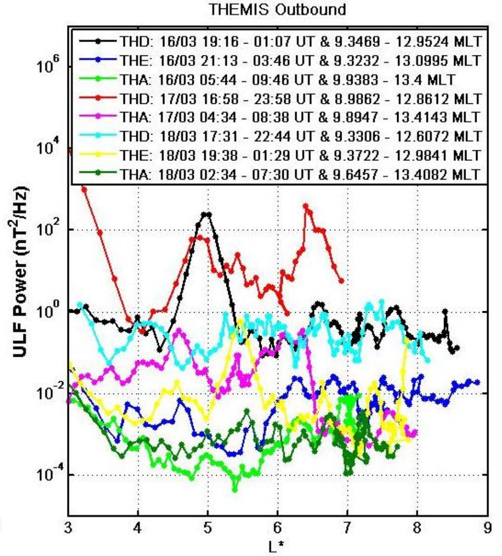




Pc5 ULF waves (0.002 – 0.007 mHz)





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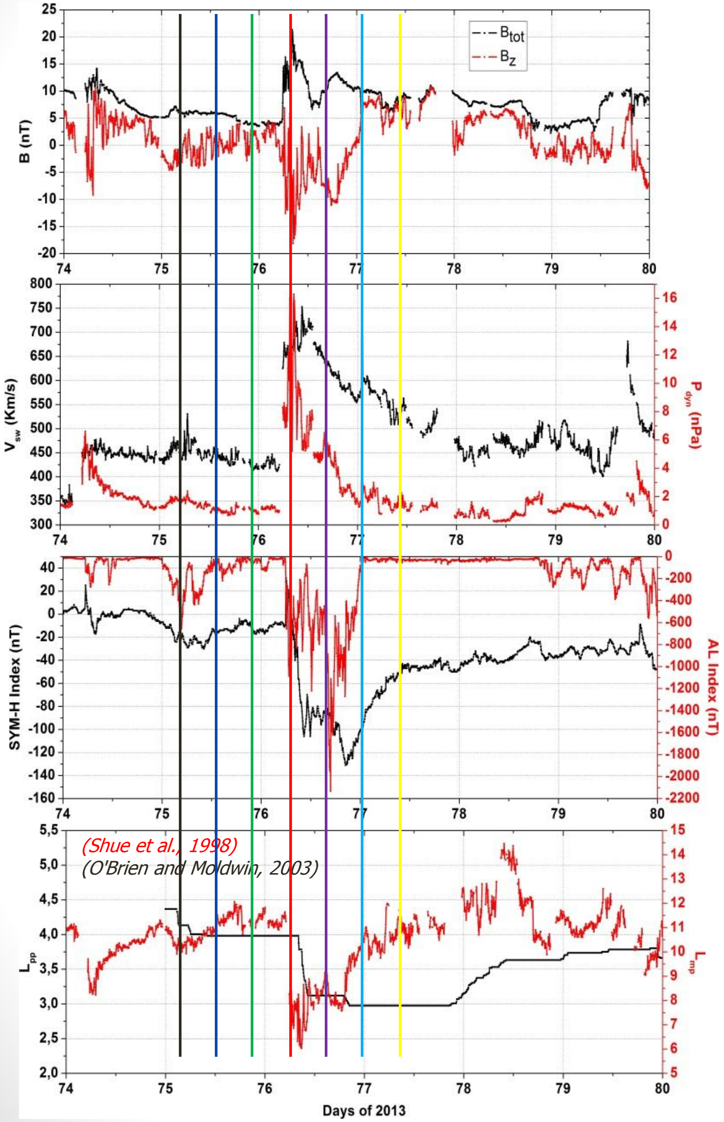
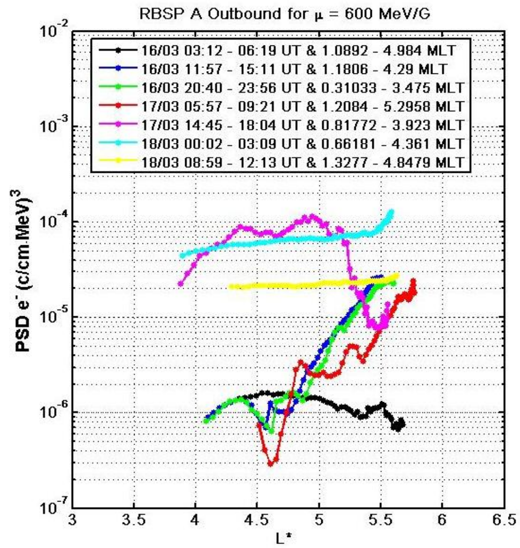
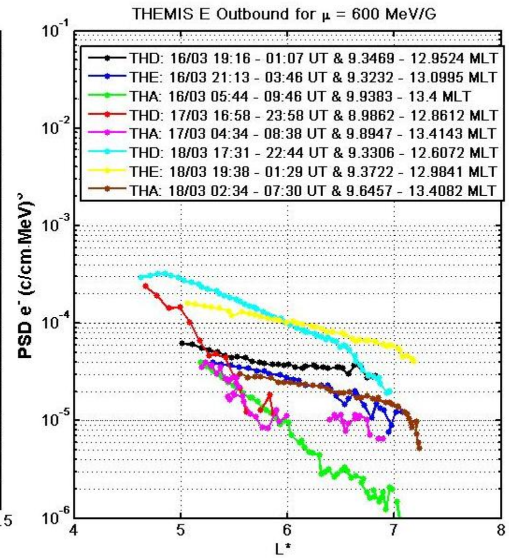
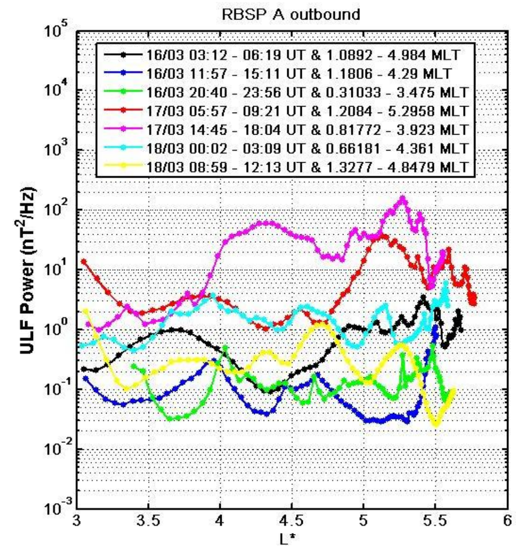


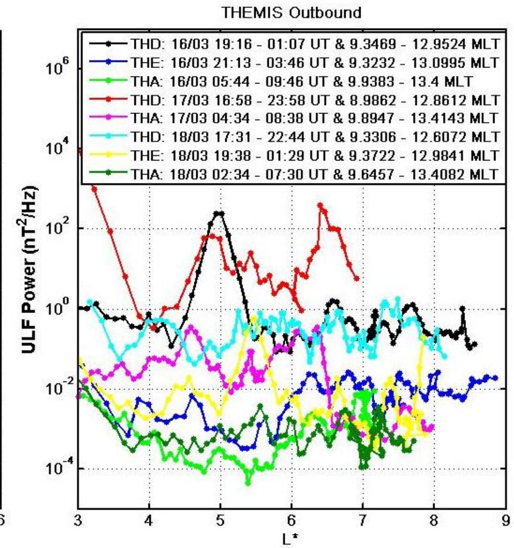
Electrons with μ=600MeV/G and K<0.01 $G^{1/2}$ R_E



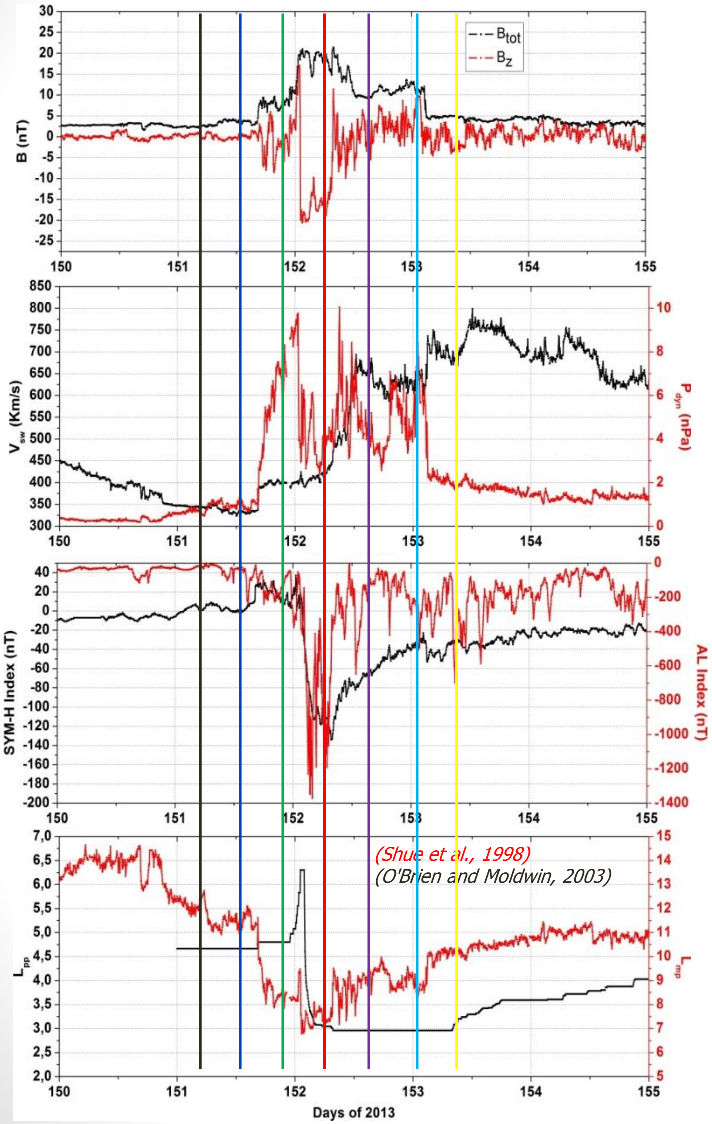


Pc5 ULF waves (0.002 – 0.007 mHz)

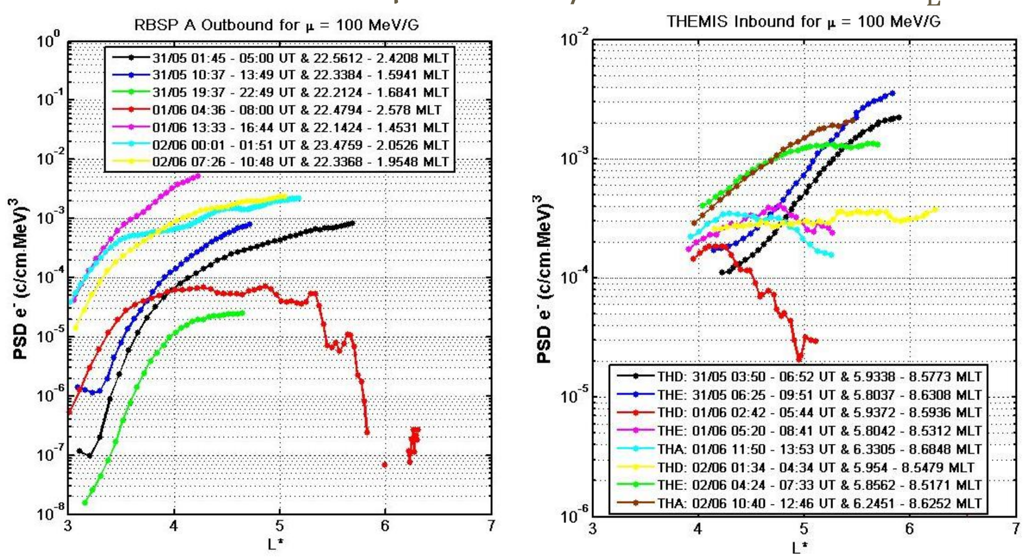




Electron Dropout Event (May 31- June 02, 2013)



Electrons with μ=100MeV/G and K<0.01 $G^{1/2} R_E$



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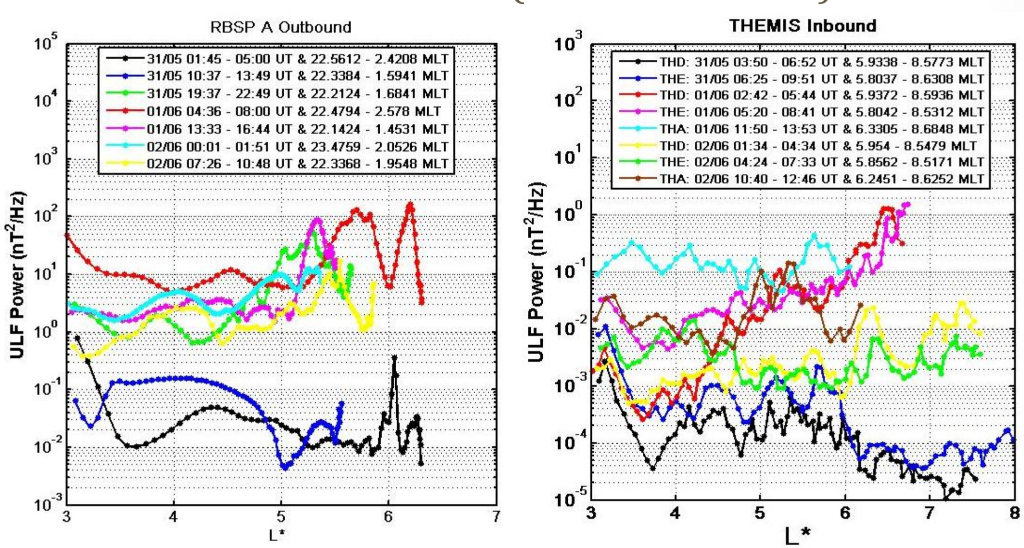

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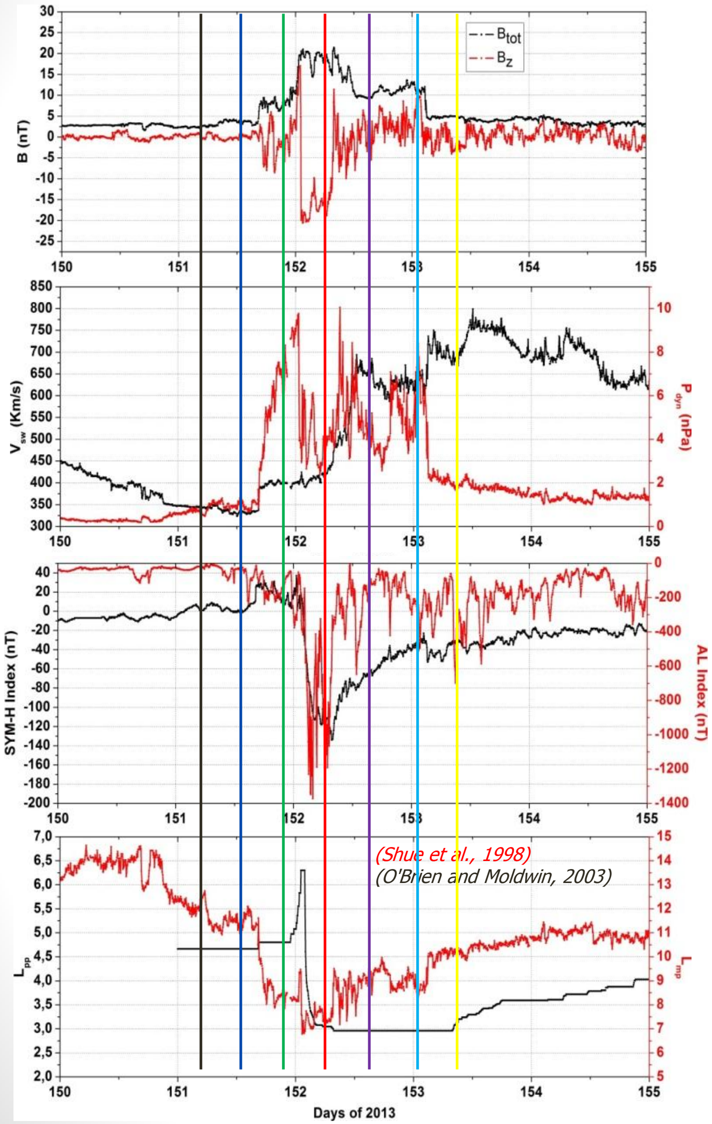
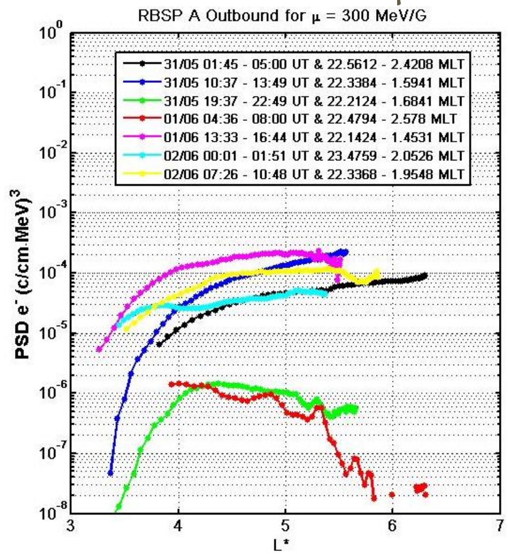
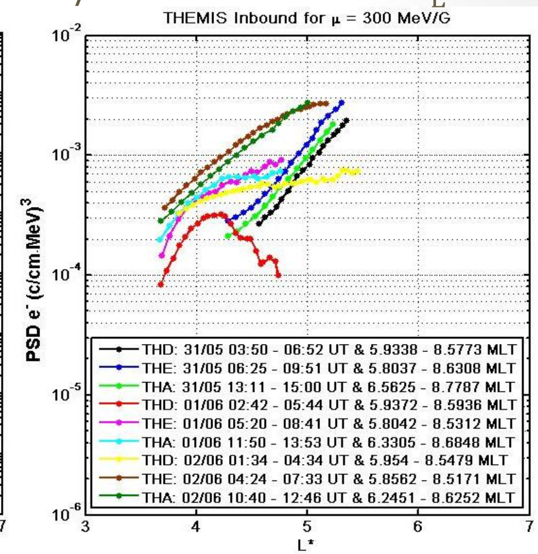


Electrons with μ=300MeV/G and K<0.01 $G^{1/2} R_E$





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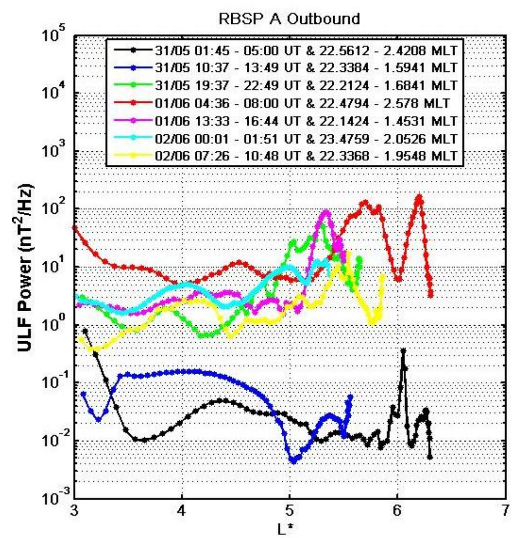

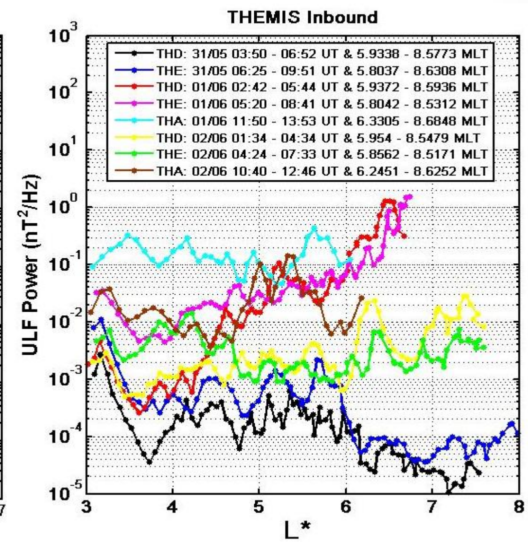

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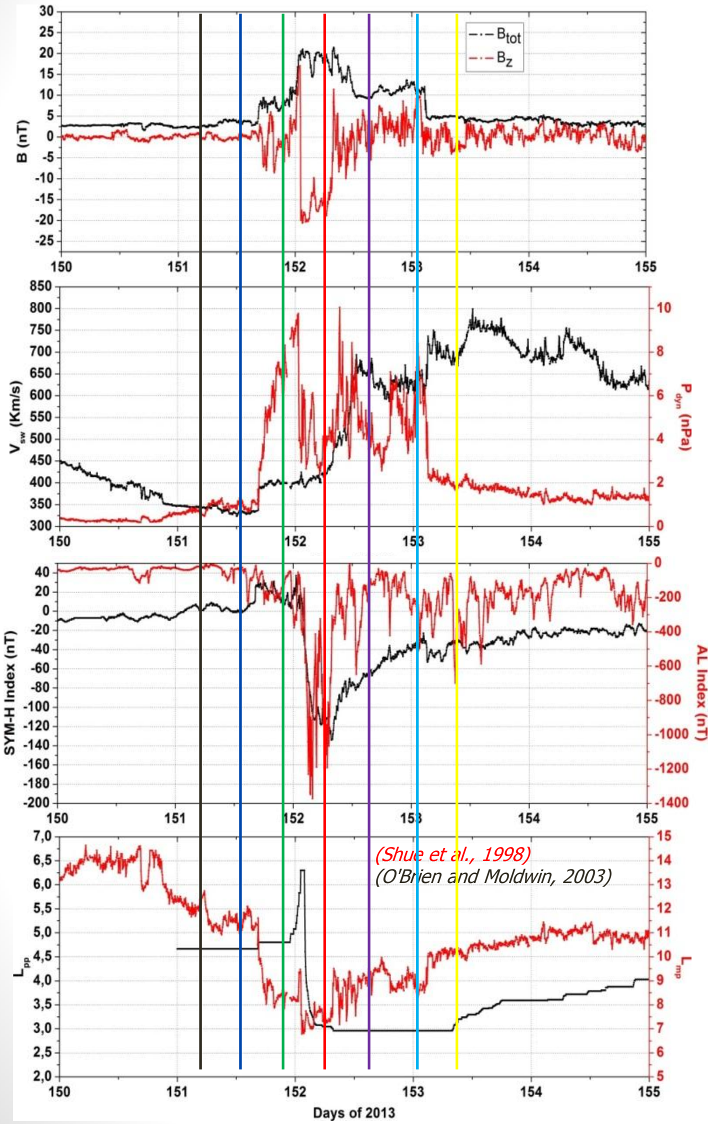
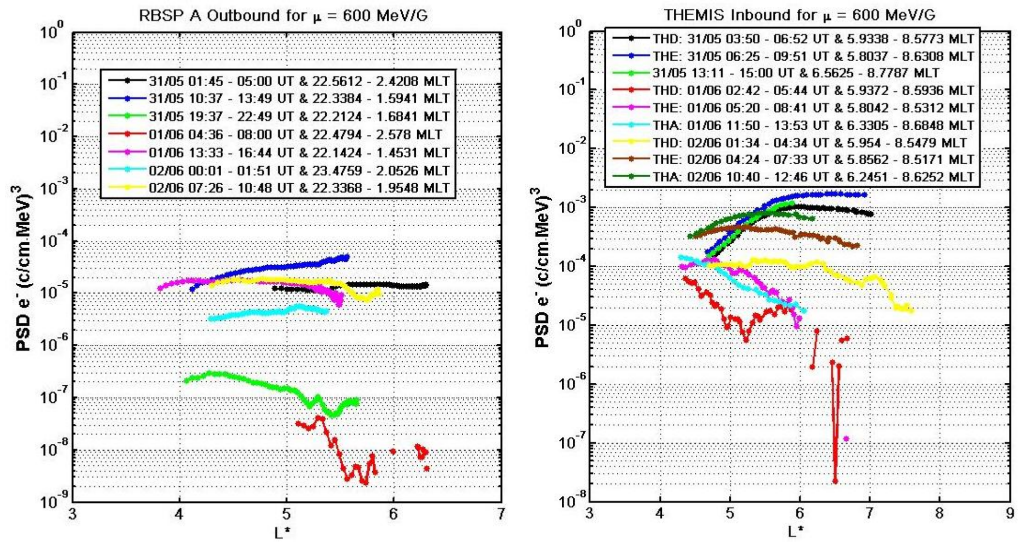
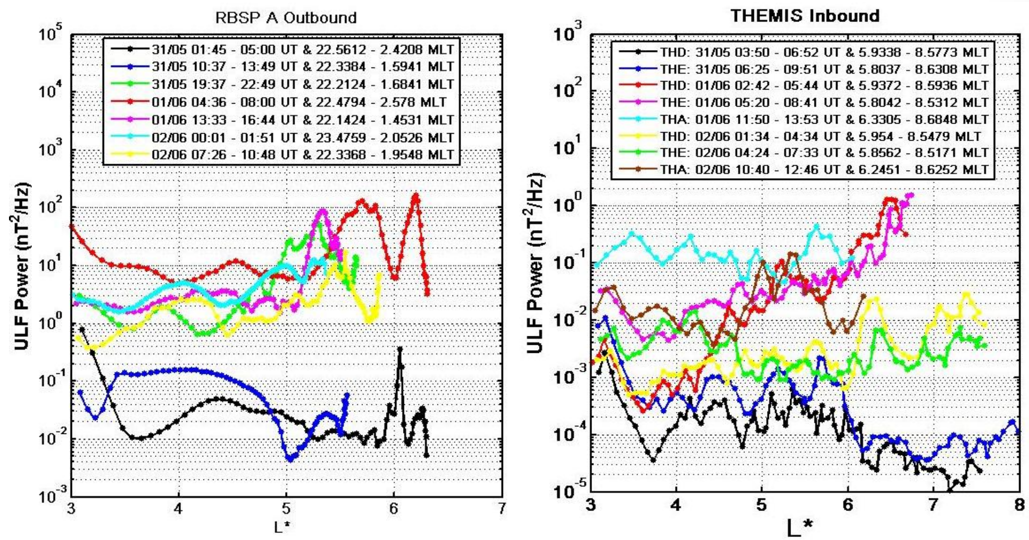


Electrons with μ=600MeV/G and K<0.01 $G^{1/2}$ R_E



Pc5 ULF waves (0.002 – 0.007 mHz)



Summary

We investigated the connection between ICMEs and PSD enhancements based on 3 events:

1. April 13-15, 2013: Non-storm event with positive SYM-H that resulted in electron loss via magnetopause shadowing and recovery of PSD at previous levels for μ>300 MeV/G.

2. March 16-18, 2013: Severe-storm event that caused a short PSD dropout due to magnetopause shadowing and resulted in PSD enhancement even though Pc5 power had recovered at pre-storm levels.

3. May 31-June 02, 2013: Severe-storm event that caused a strong PSD dropout due to magnetopause shadowing and resulted in recovery of PSD at previous levels for μ>300 MeV/G even though Pc5 power was enhanced even after the end of the storm.

Conclusions

- Magnetopause Shadowing occurred in all studied cases independently the pressure magnitude.
- An electron PSD dropout of – approximately – two orders of magnitude took place during a non-storm period with continuously positive SYM-H (April 14, 2013).
- Changes in electron PSD occurred only outside the plasmapause.
- For the selected events no clear correlation between ULF Pc5 power and PSD was found.

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FP7-Space MAARBLE project

SEVENTH FRAMEWORK PROGRAMME

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