Inner Radiation Zone and Slot Region Electron Fluxes (Revised): ECT/MagEIS Data

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Geospace Revisited WWW
Revised 10/6/2014

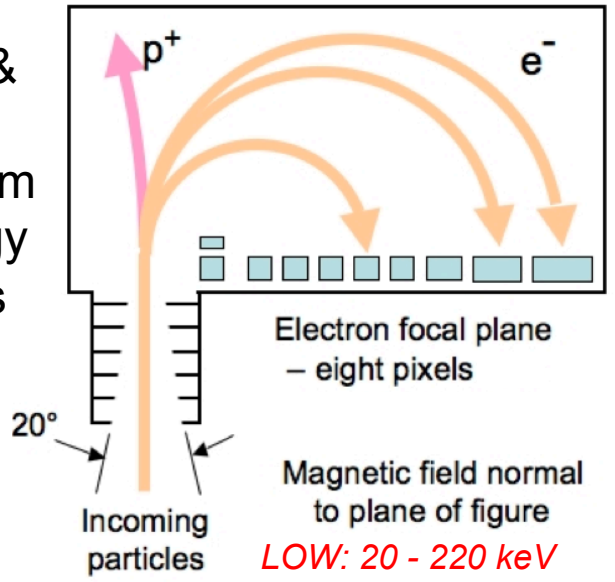
Overview of Presentation

- Introduction to MagEIS sensors
  - *Overview of sensor design and features*
- MagEIS observations of inner zone and slot region during March 2013
  - *Overview of MagEIS observations in March including the CIR and CME generated storms*
  - *MagEIS observations of electron spectra in the inner radiation zone for L=1.15 - 2 before and following the 1 & 17 March events*
    - These preliminary electron spectra have been corrected for proton backgrounds
  - *MagEIS observations of electron spectra in the slot region and inner edge of the outer radiation belts (L=2-4) before and following the March events*
- Discussion and Summary

MagEIS Electron Sensors

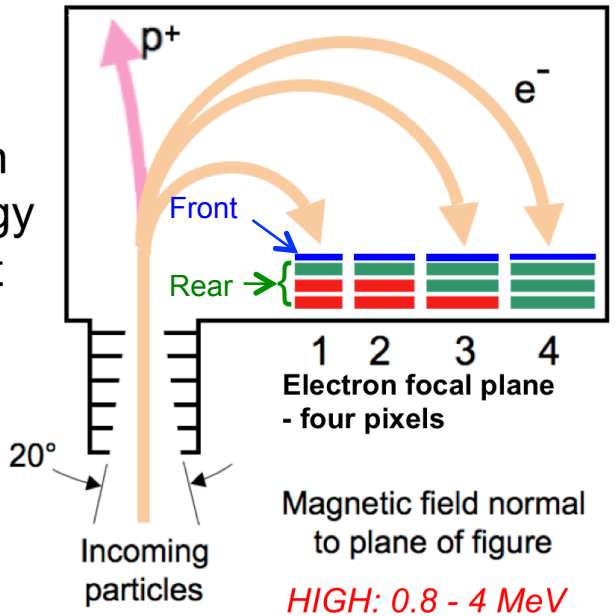
- MagEIS uses magnetic spectrometers to measure electron fluxes
- The spectrometer's magnetic field momentum analyzes the electrons focusing a limited energy range on each detector pixel
- The energy deposits are digitized by a 256 channel pulse-height analyzer
- Look-Up-Tables (LUTs) are used to extract only those energy deposits that are consistent with the momentum of the electron and the position of the detector pixel in the magnet's focal plane
  - *This allows us to determine the background from the "wings" of the pulse-height distribution and subtract it out later*
- The high energy unit uses coincidence between its Front and Back detectors to further reduce the background response

Low & Two Medium Energy Units



LOW: 20 - 220 keV
MED: 230 - 1000 keV

High Energy Unit

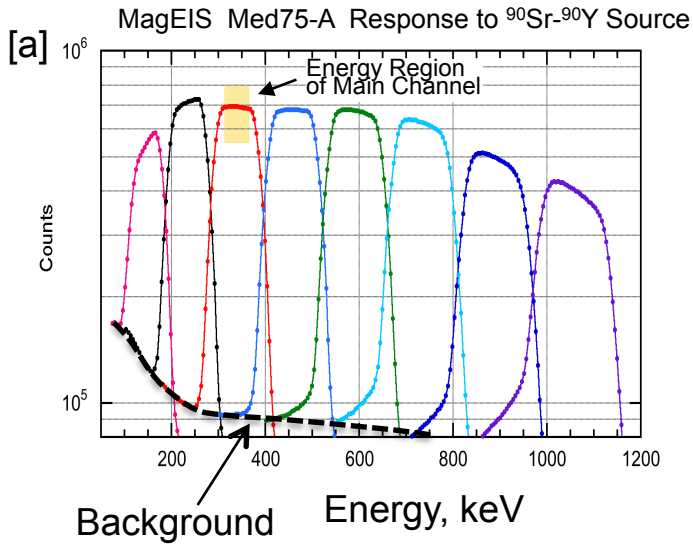


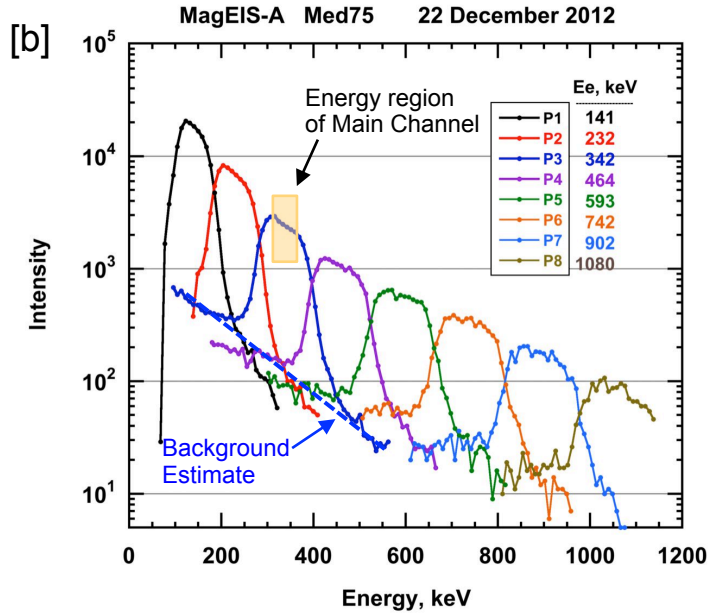
HIGH: 0.8 - 4 MeV

AEROSPACE

MagEIS Energy Channels and Histograms

- Plot [a] shows the response of the MagEIS-A Med75 spectrometer to a ^{90}Sr-^{90}Y beta source
  - *The source has a broad relatively flat beta spectrum covering the full energy range of the Med75 unit*
- The points indicate the individual pulse-height energy channels that define the response peaks
- The histogram data for this unit extends over a larger range of energies than shown here for each energy channel
- The main channels are taken from the "sweet spot" of each detector's response as shown by the shading on the red curve.
- Plot [b] shows the steep electron spectrum observed by the same spectrometer in the radiation belts for L~4
  - *These are from the on-orbit histogram data*
  - *The center energy of each channel is indicated in the legend*
  - *Background was estimated from the "wings" of the histograms*

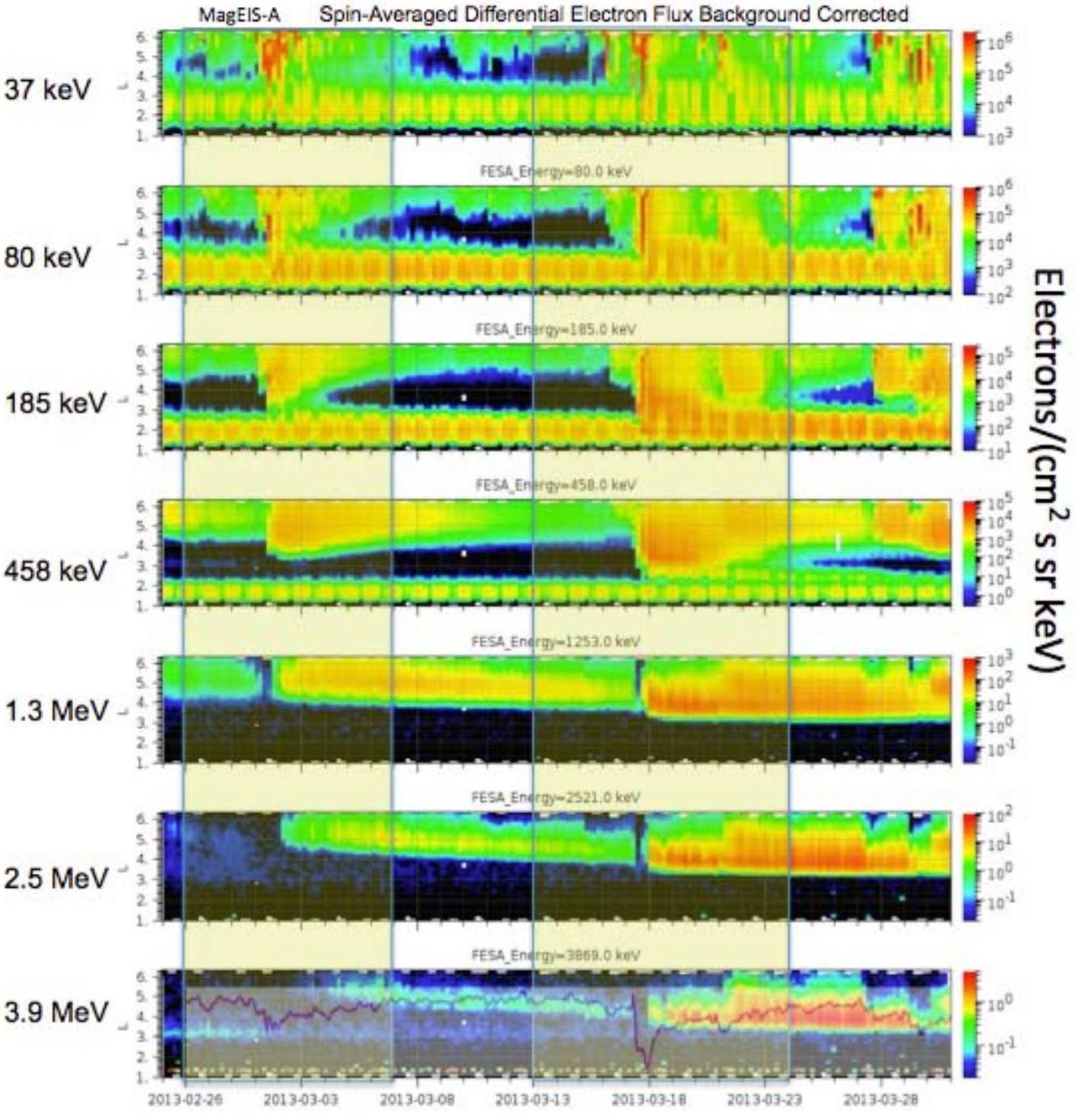




AEROSPACE

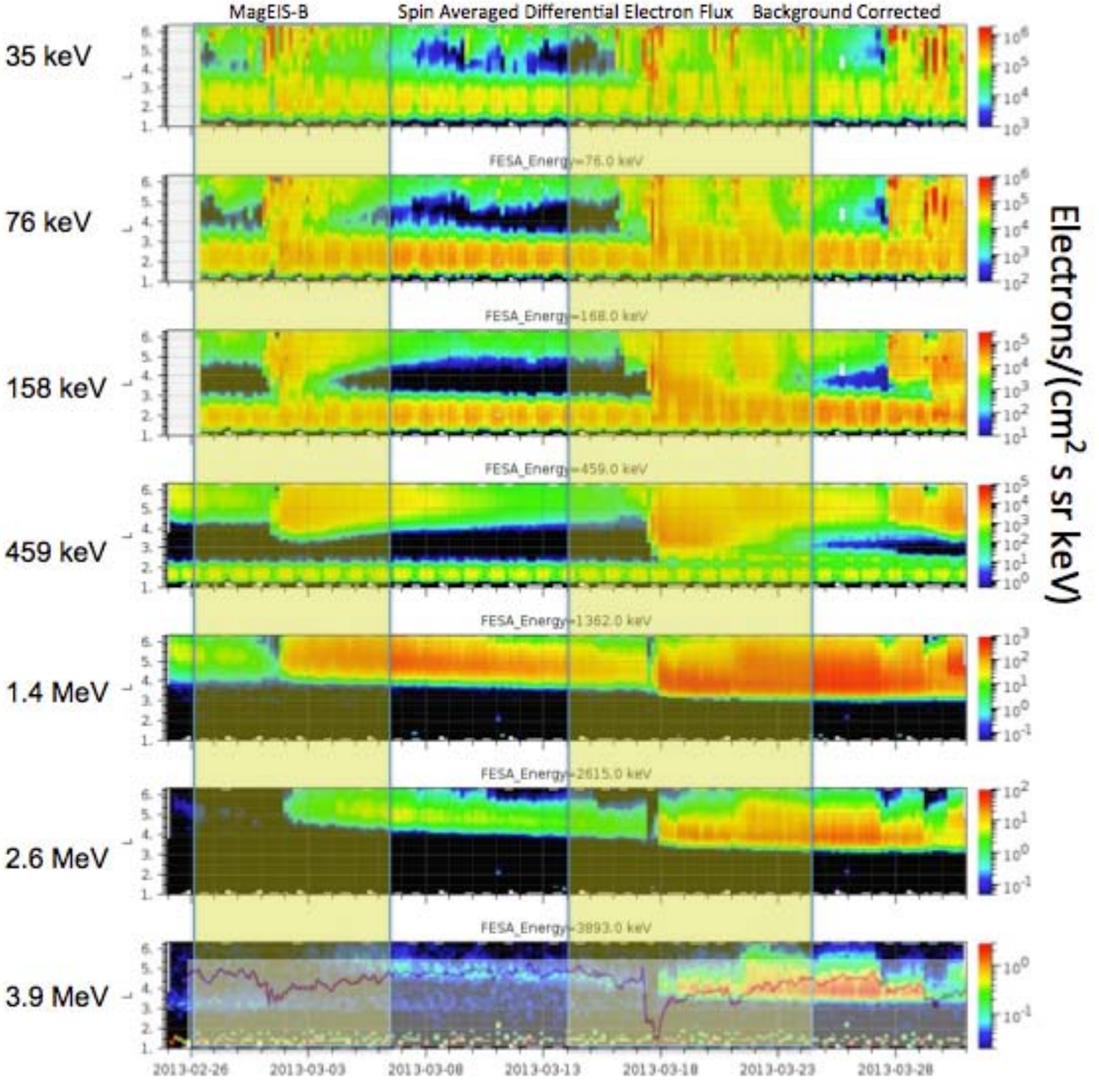
MagEIS-A L vs. Time Spectrograms for Selected Energies Feb. 26 – Mar. 30, 2013

- Selected MagEIS energy channels are plotted as electron flux as a function of L and UT for the 26 Feb. through 30 Mar. period
- We focus on the two intervals highlighted by the rectangles for our pre and post storm inner zone, slot region and inner edge of outer zone study
- Both the 1 March CIR and the CME arriving 17 March generated significant flux enhancements
  - *However only the lower energies were enhanced in the slot region and even the inner zone as we show in what follows*
- Note the slow diffusive transport of the ≤ 464 keV electrons into the slot region and outer part of inner zone following the 17 March event



MagEIS-B L vs. Time Spectrograms for Selected Energies
Feb. 26 – Apr. 5, 2013

- Same as previous slide but for RBSP-B



MagEIS-B Corrected & Uncorrected E-T Spectrograms
26 February – 6 March 2013

[a] Fluxes **Not** Corrected for Background

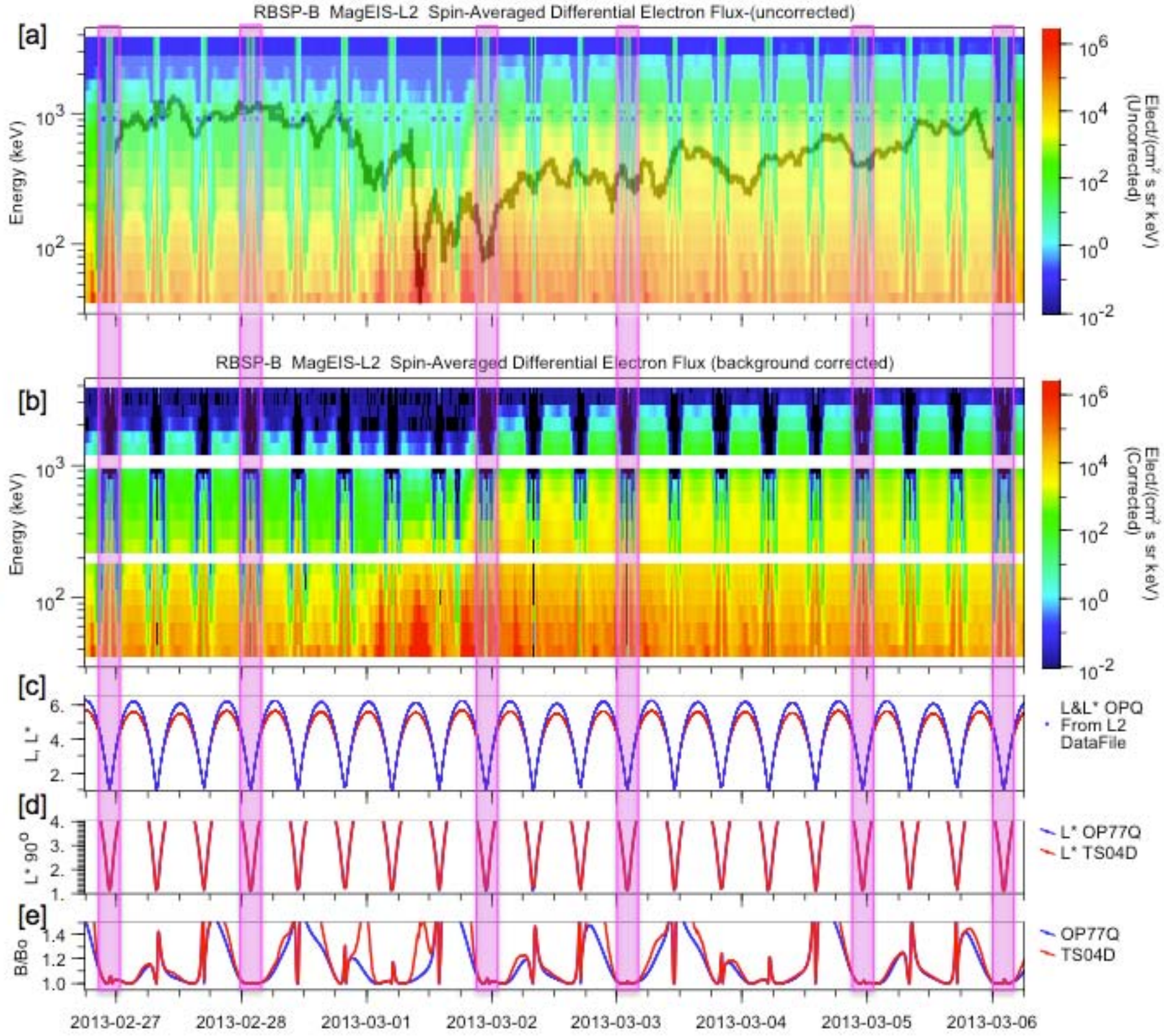
[b] Fluxes Corrected for Background

[c] OP77Q L & L*

[d] OP77Q and TSY04D L* for L* ≤ 4

[e] B/Bo from OP77Q & TSY04D

- Highlighted regions, with B/Bo~1 were used to get pre and post onset spectra
- The black line over-plotted on the spectrogram in [a] shows SYM-H scaled such that 0 nT is at the 10^3 flux level and the plot y-axis base is -60 nT



MagEIS-A Corrected & Uncorrected E-T Spectrograms 26 February – 6 March 2013

Like previous slide: with sample intervals for both spacecraft high-lighted

[a] Fluxes **Not** Corrected for Background

[b] Fluxes Corrected for Background

[c] OP77Q L & L*

[d] OP77Q and TSY04D L* for L* ≤ 4

[e] B/Bo from OP77Q & TSY04D

- Highlighted regions, where B/B_0 ~1, were used to get pre and post onset spectra
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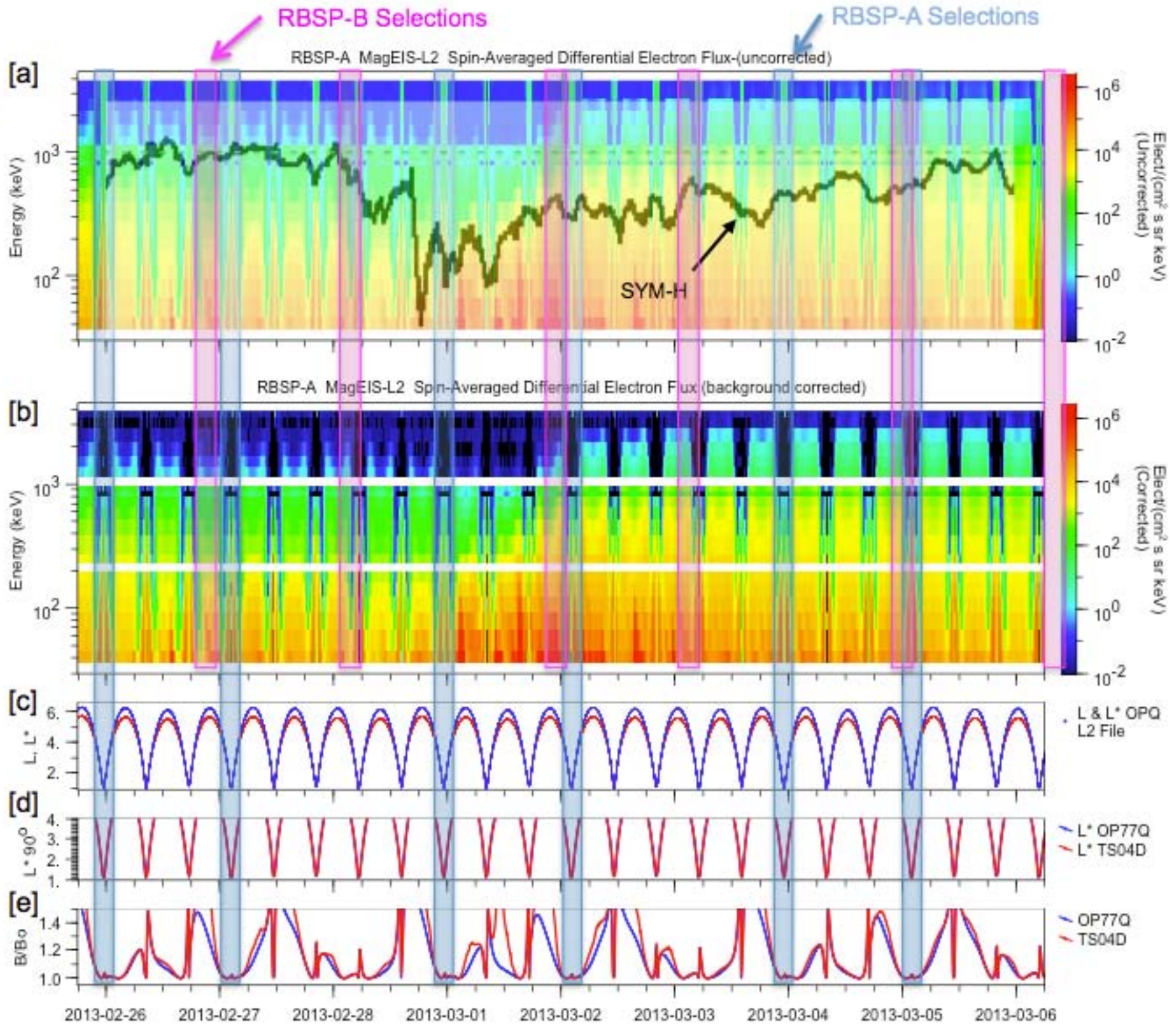
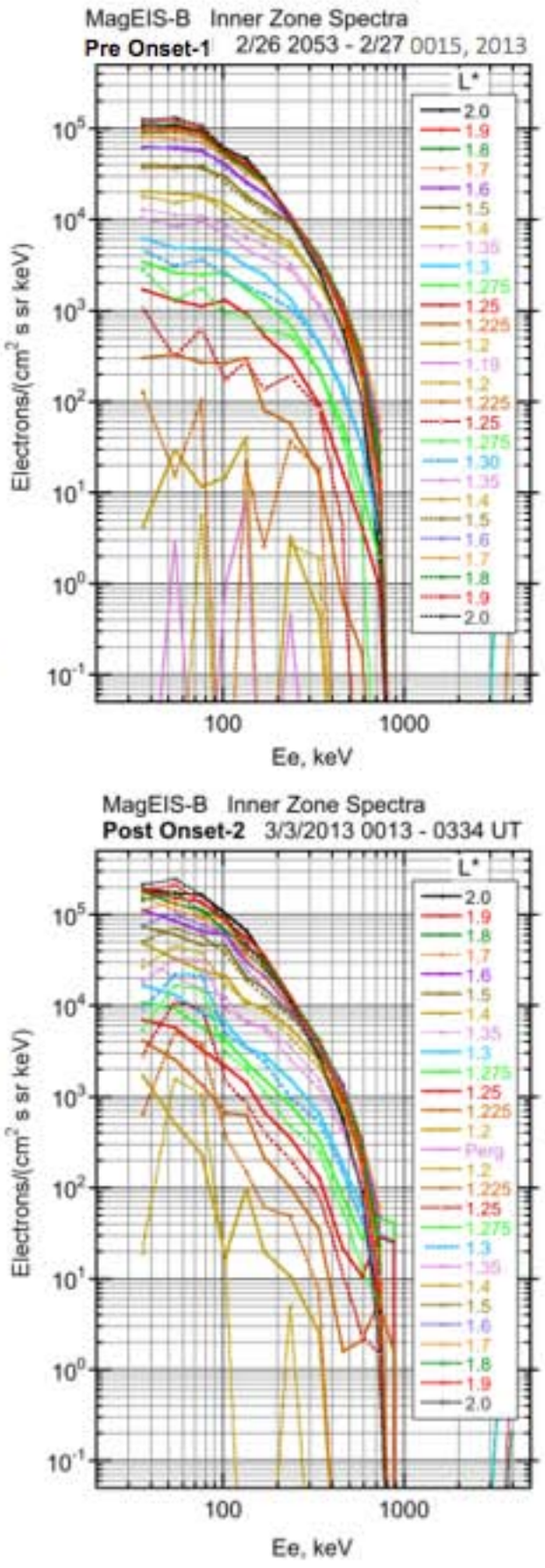


MagEIS-B Inner Zone Spectra (1.175≤L*≤2) For March 1, 2013 Event

- Plots show Pre Storm ([a]-[b]), Transition [c], and Post Onset ([d]-[f]) Electron spectra taken in the Inner Zone (1.175 ≤ L* ≤ 2.0)
- There were moderate increases in electron fluxes for Ee≤200 keV at 1.3<L*<2 in response to the weak CIR driven storm
- There were no electron fluxes above MagEIS background in the Inner Zone for >800 keV electrons at any time in this early March period
  - *No MeV electrons in the inner zone!*



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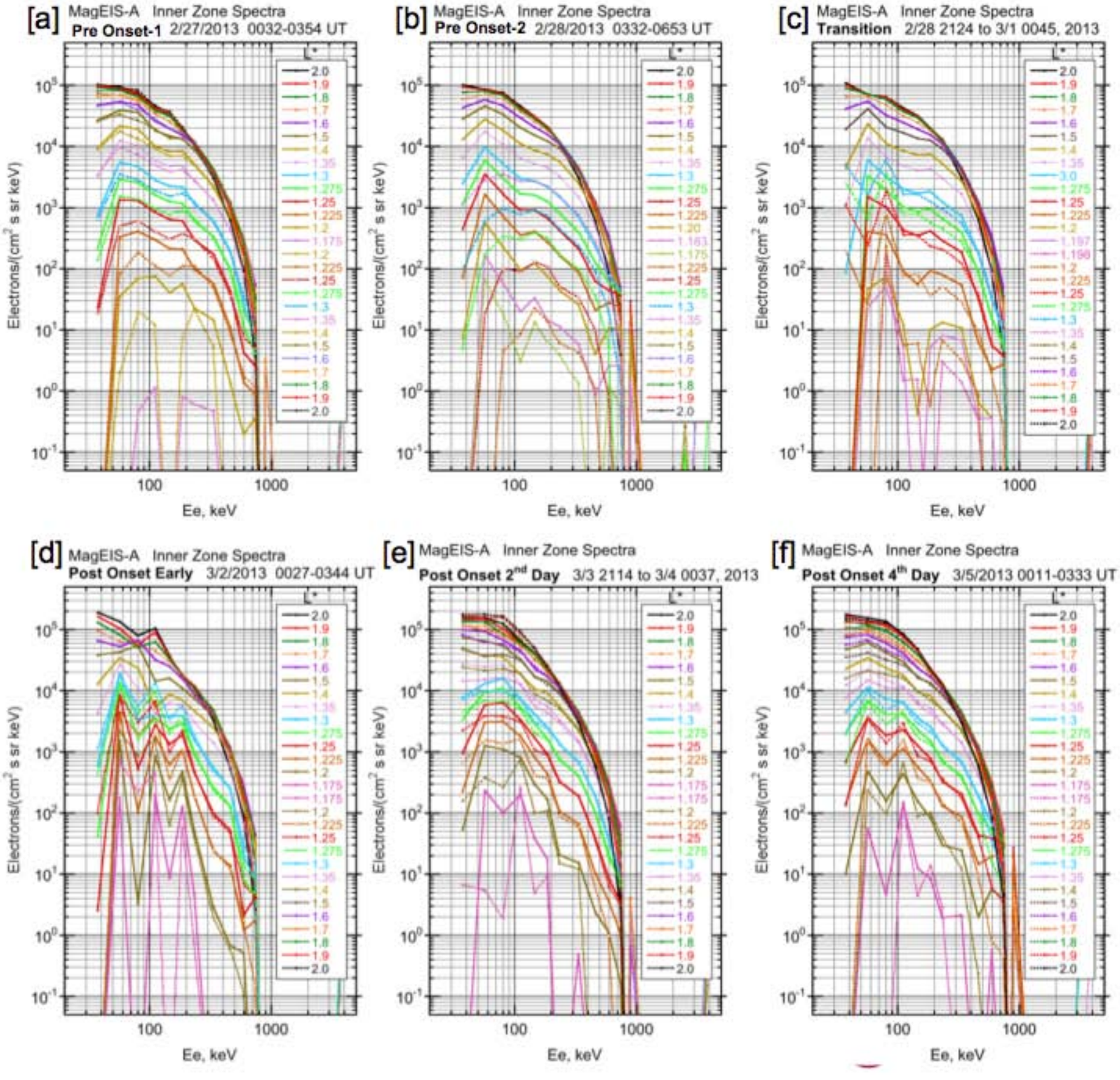
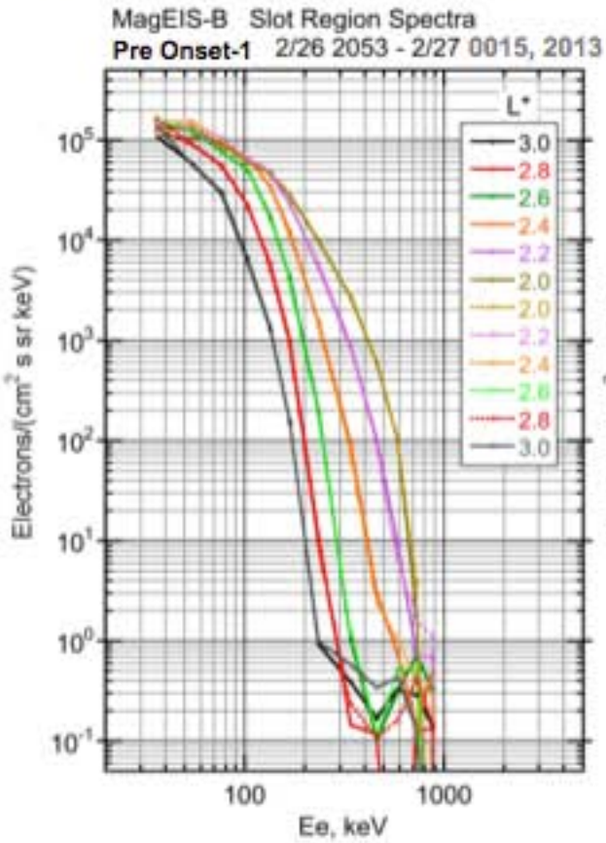
- There were no electron fluxes above MagEIS background in the Inner Zone for Ee>800 keV at any time in this early March period
  - *No MeV electrons in the inner zone!*

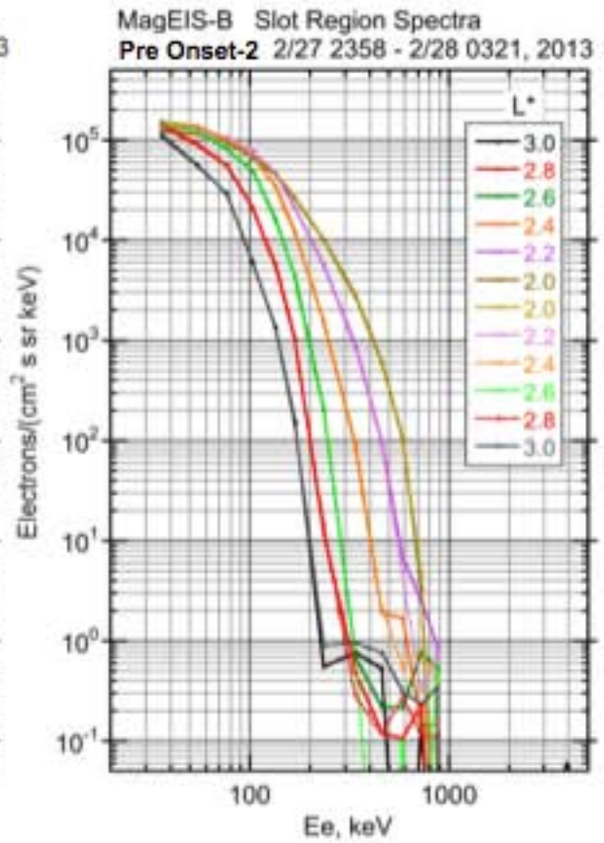


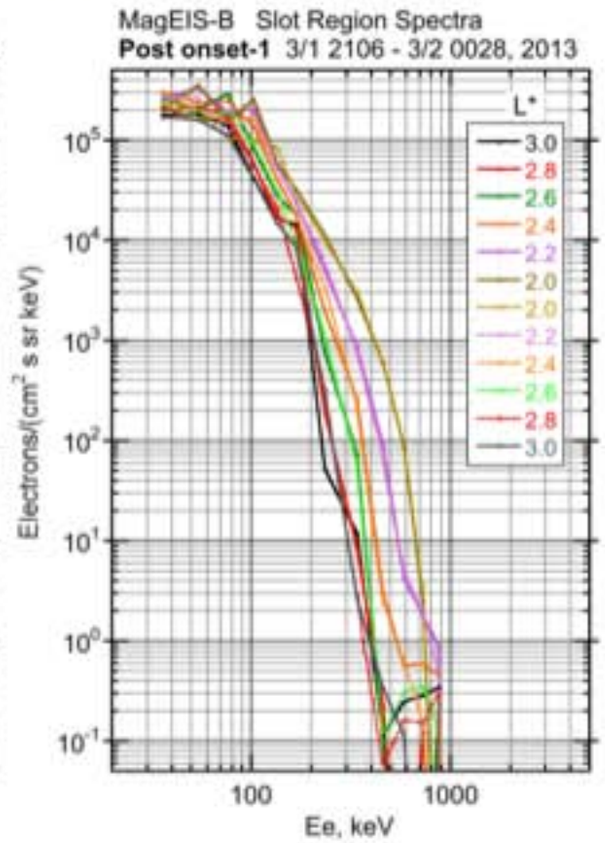
MagEIS-B Slot Region Spectra (2≤L*≤3) For March 1, 2013 Event

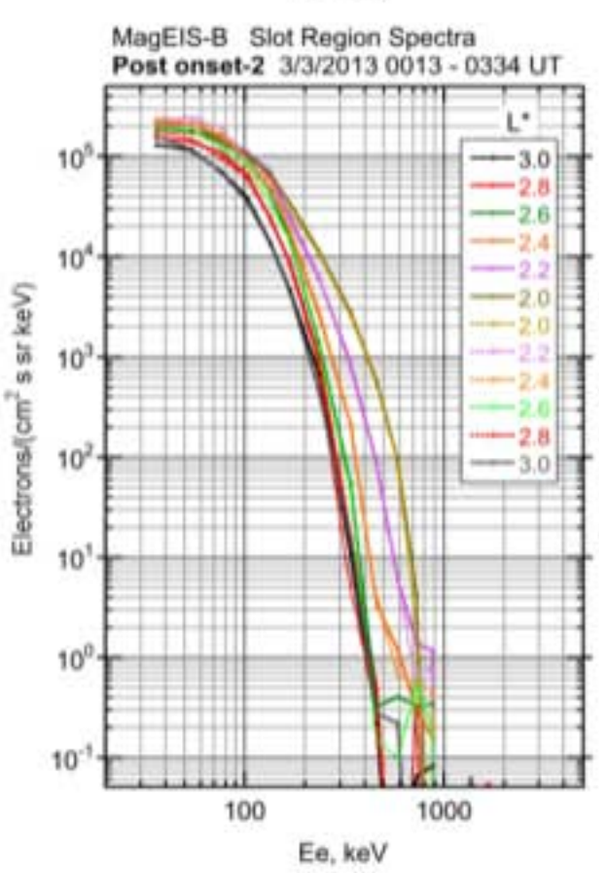
Spectra like those observed by A spacecraft but sampled at different times

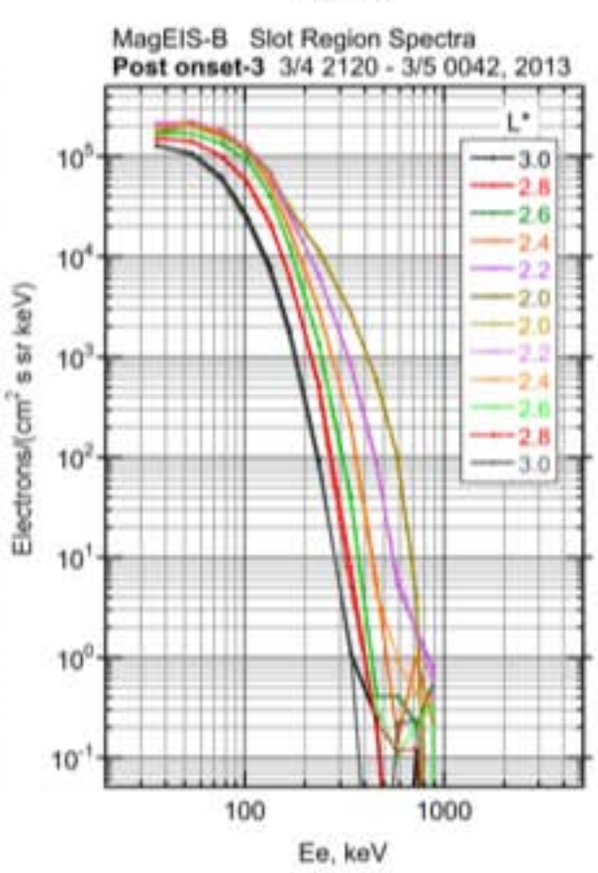
- Essentially no change in slot fluxes up through "Transition" period
- Enhanced fluxes observed at the outer edge (L*>2.4) of the slot region in the early post onset interval
  - *Lowest energy electrons (<200 keV) show slight enhancements (~factor of 2) at all L* values in slot region*
  - *For > 200 keV only the outer most regions of slot showed a flux increase*
- Enhanced electron fluxes start their decay back towards the pre storm levels at 2nd day after onset
  - *Most pronounced at outer edge of slot*
- No electrons >1 MeV were observed above background levels in the slow region

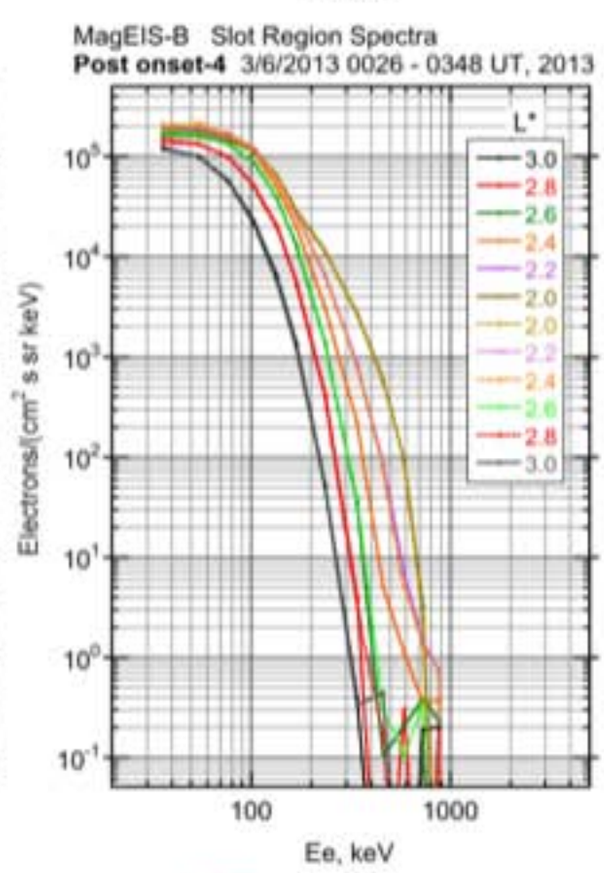












MagEIS-A Slot Region Spectra (2≤L*≤3) For March 1, 2013 Event

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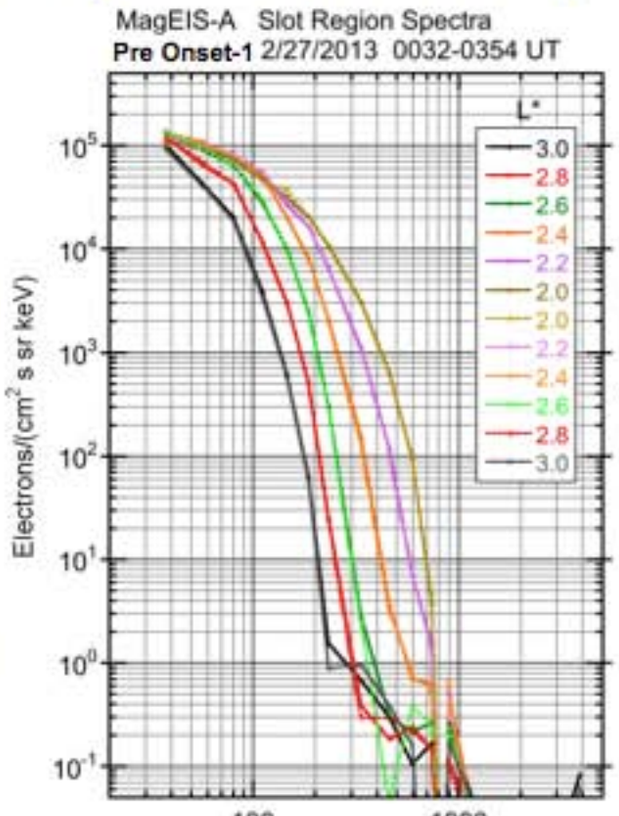
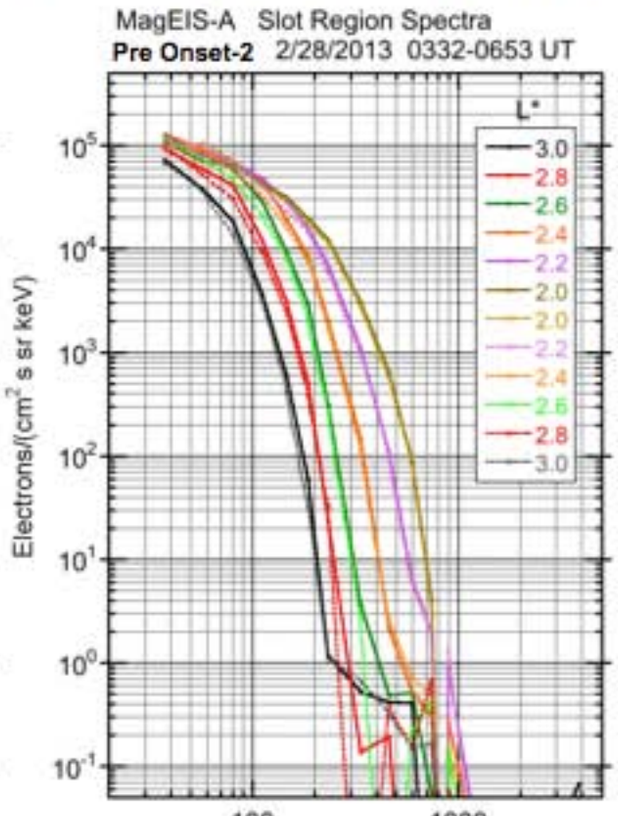
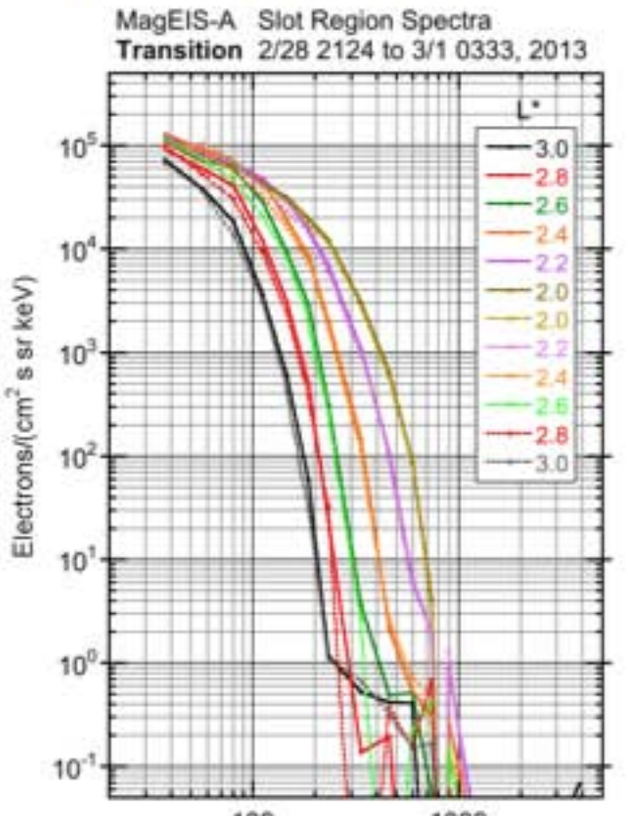
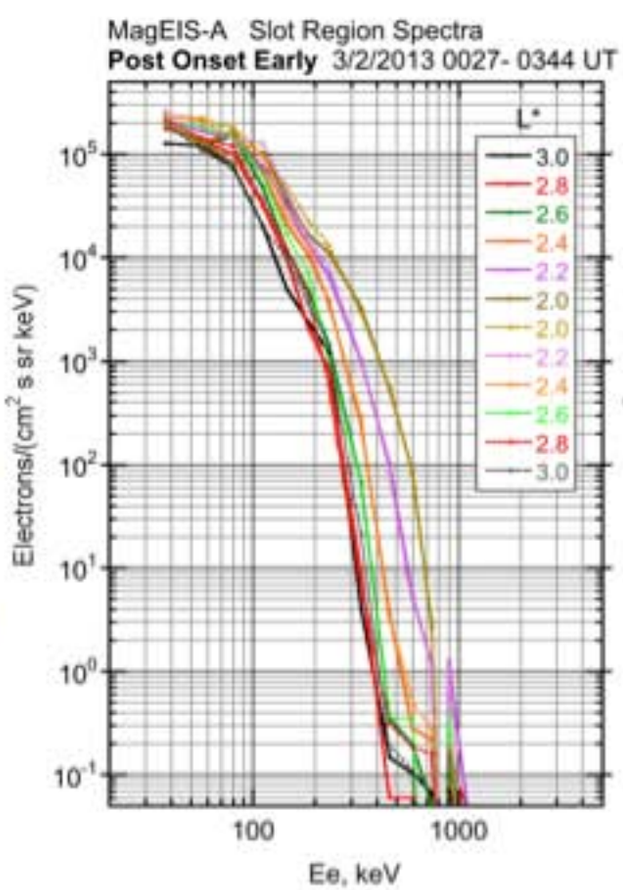
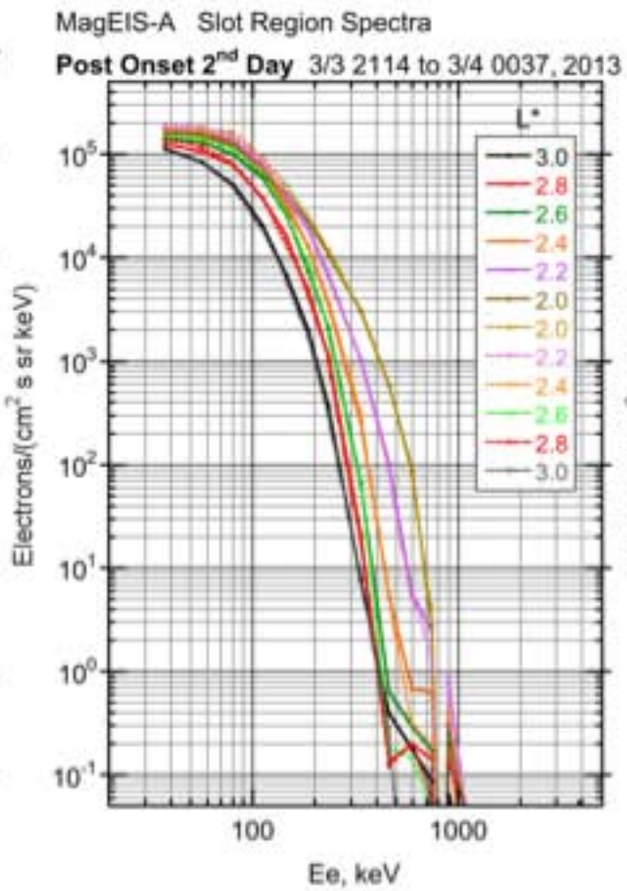
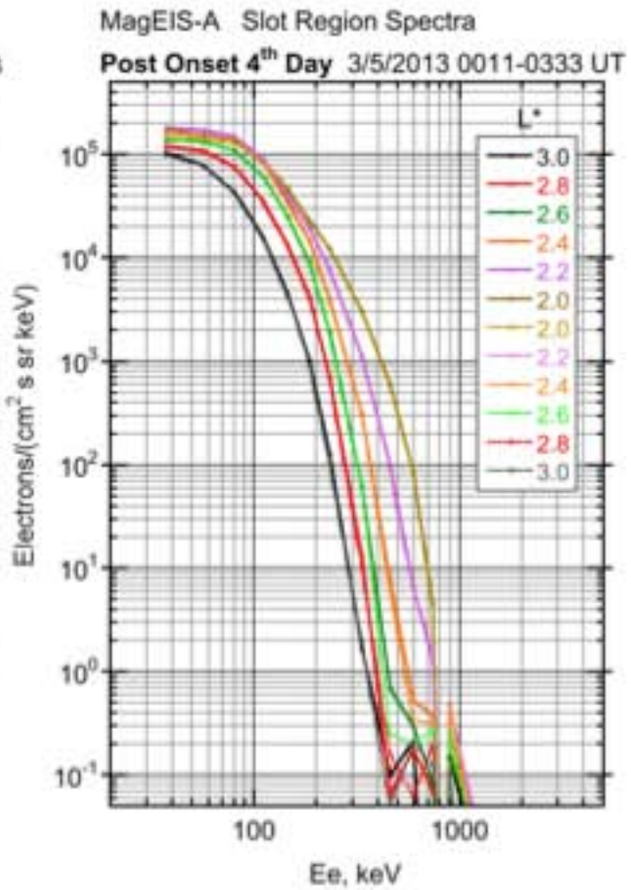






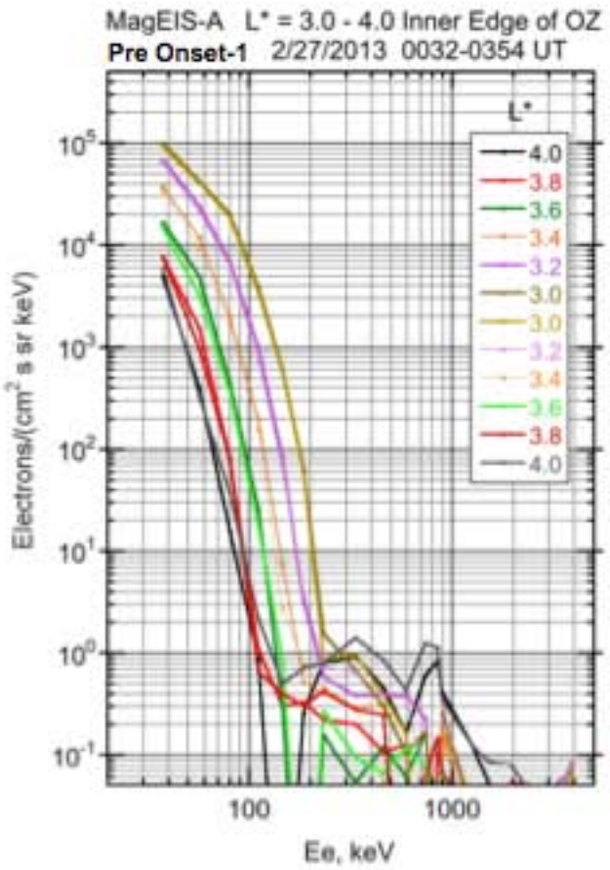


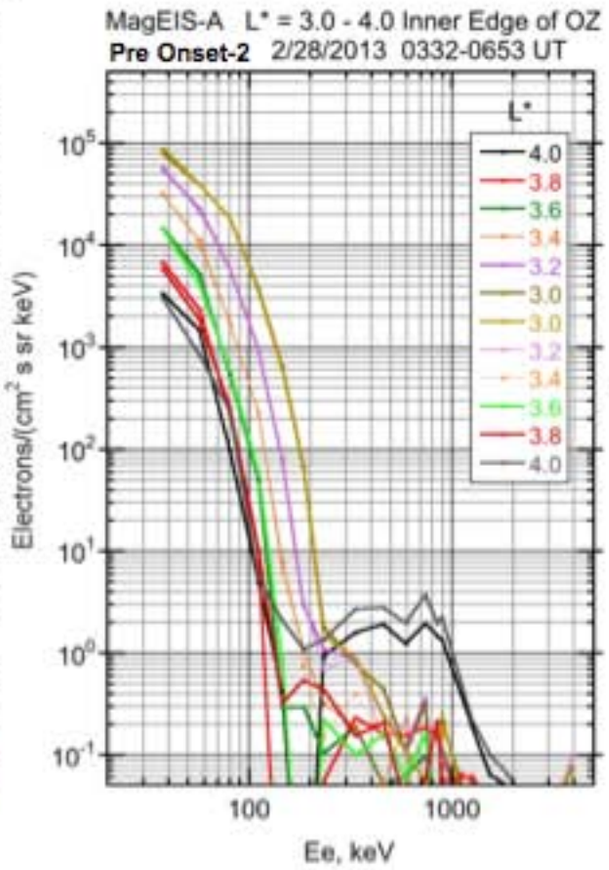


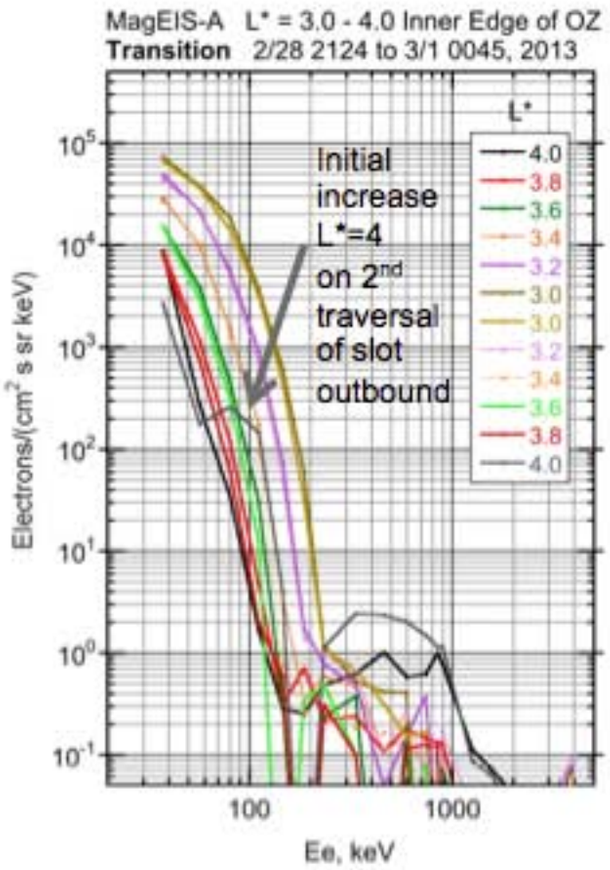


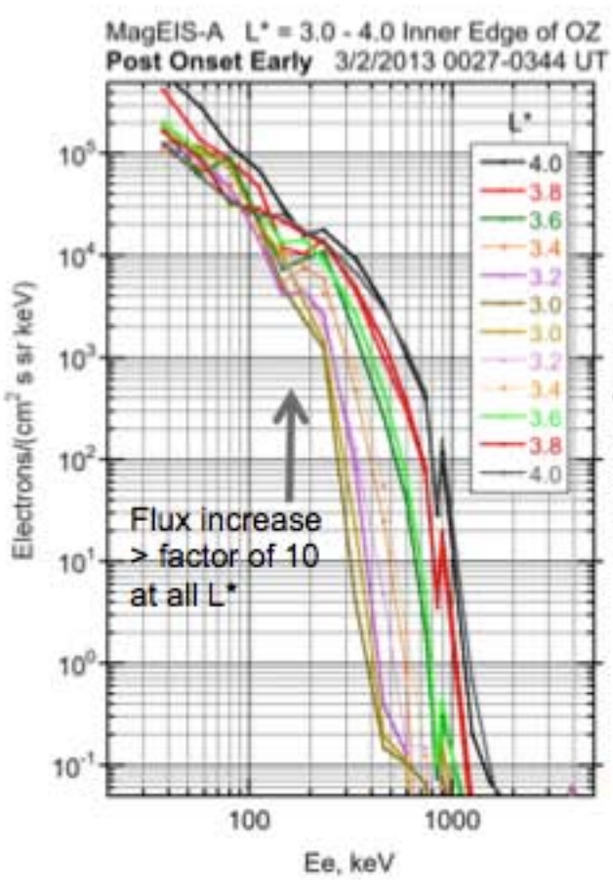
MagEIS-A OZ Inner Edge Spectra (3≤L*≤4) For March 1, 2013 Event

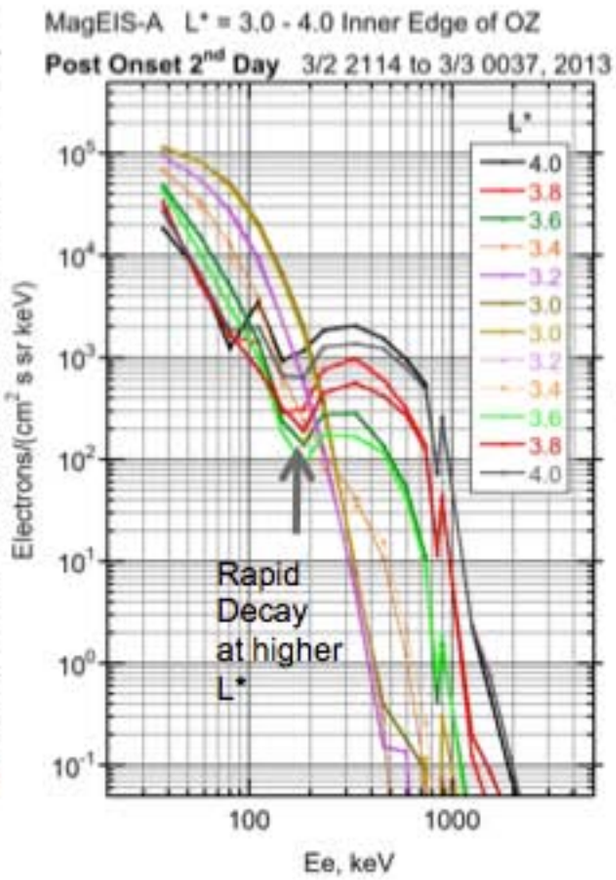
- The outer zone inner edge (OZIE: 3≤L*≤4) spectra remained essentially the same up through the Transition interval
  - *Small flux increase was observed for 70-150 keV at L*=4 during Transition (gray curve)*
  - *Flux highest for small L* at <300 keV*
- Fluxes at all energies and L* values had increased early in the post onset interval with the greatest increases at larger L* values (>3 orders of magnitude for 150 keV for L*=4)
  - *Fluxes at the lowest L* had the smallest increases*
- By the 2nd day post onset, the <400 keV higher L fluxes had decayed by over an order of magnitude giving rise to peaks in the spectrum for L*>3.4 reminiscent of the peak at few MeV observed pre onset for L*=4
- The spectral peaks remained on Post onset day 4 but continued to decay

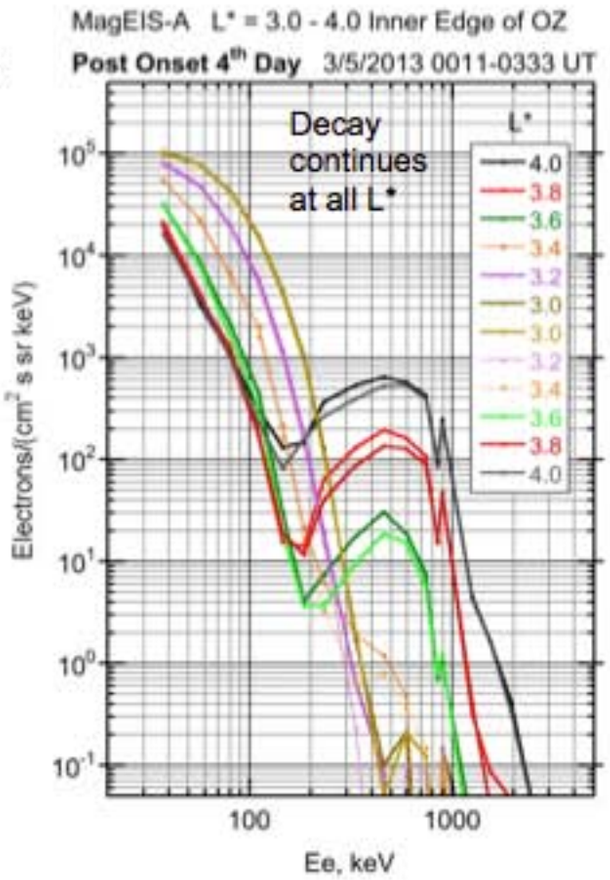








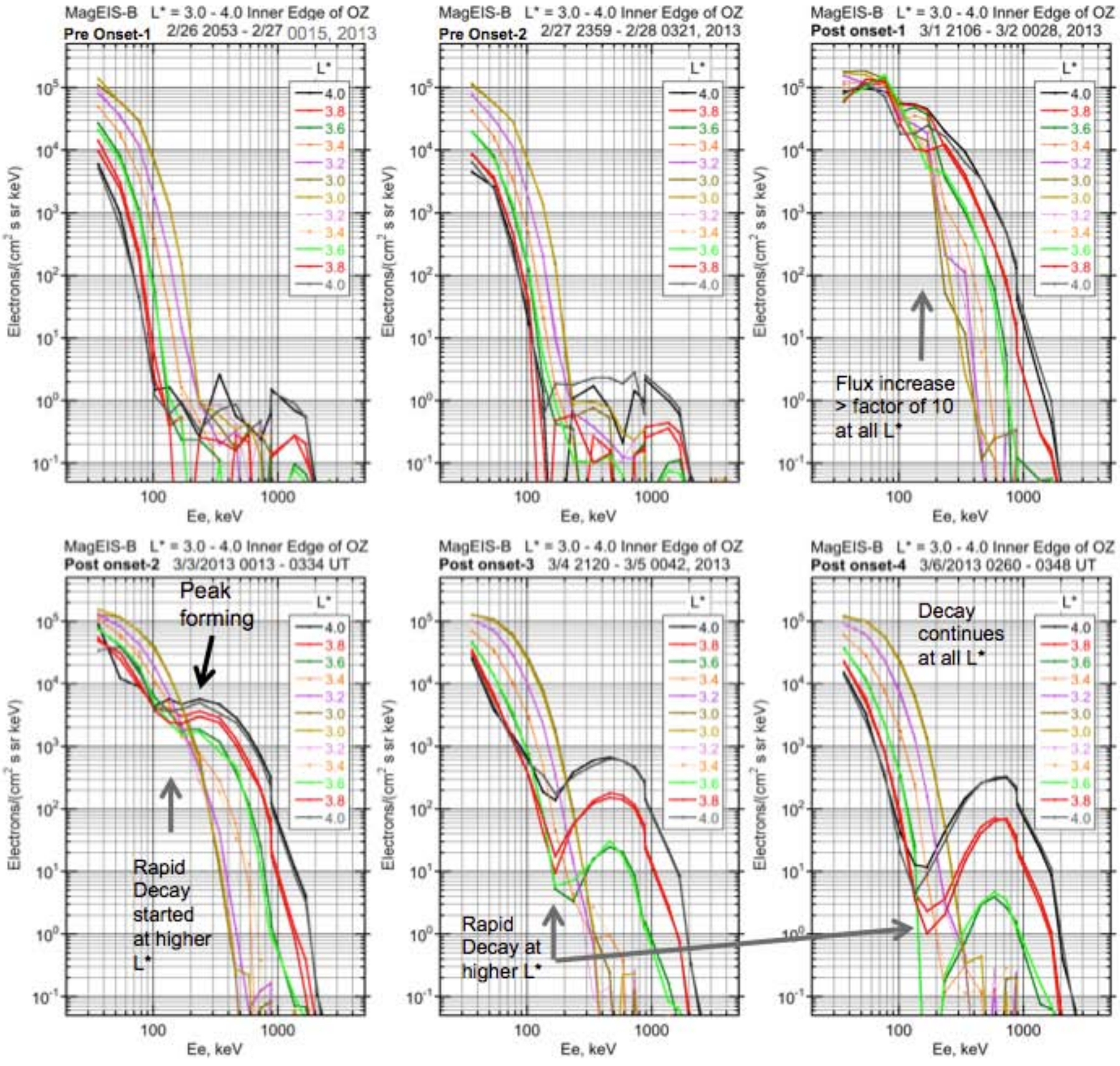




MagEIS-B OZ Inner Edge Spectra (3≤L*≤4) For March 1, 2013 Event

Same as for A spacecraft

- The outer zone inner edge (OZIE: 3≤L*≤4) spectra remained the same up through the Pre onset interval
  - Flux highest at small L*
- Flux increase observed at all energies by Post onset-1 interval
  - *Increases greatest for largest L* (e.g. black & red curves)*
- Fluxes at all energies and L* values had increased early in the post onset interval with the greatest increases at the larger L* values (>3 orders of magnitude for 150 keV at L*=4)
  - *Fluxes at the lowest L* had the smallest increases*
- By the 2nd day post onset, the low energy higher L fluxes had decayed by over an order of magnitude giving rise to peaks in the spectrum for L*>3.4 reminiscent of the peak at few MeV observed pre storm for L*=4
- The spectral peaks remained on day 4 but continued to decay



MagEIS-A Corrected & Uncorrected E-T Spectrograms
March 13-23, 2013

[a] Fluxes **Not** Corrected for Background

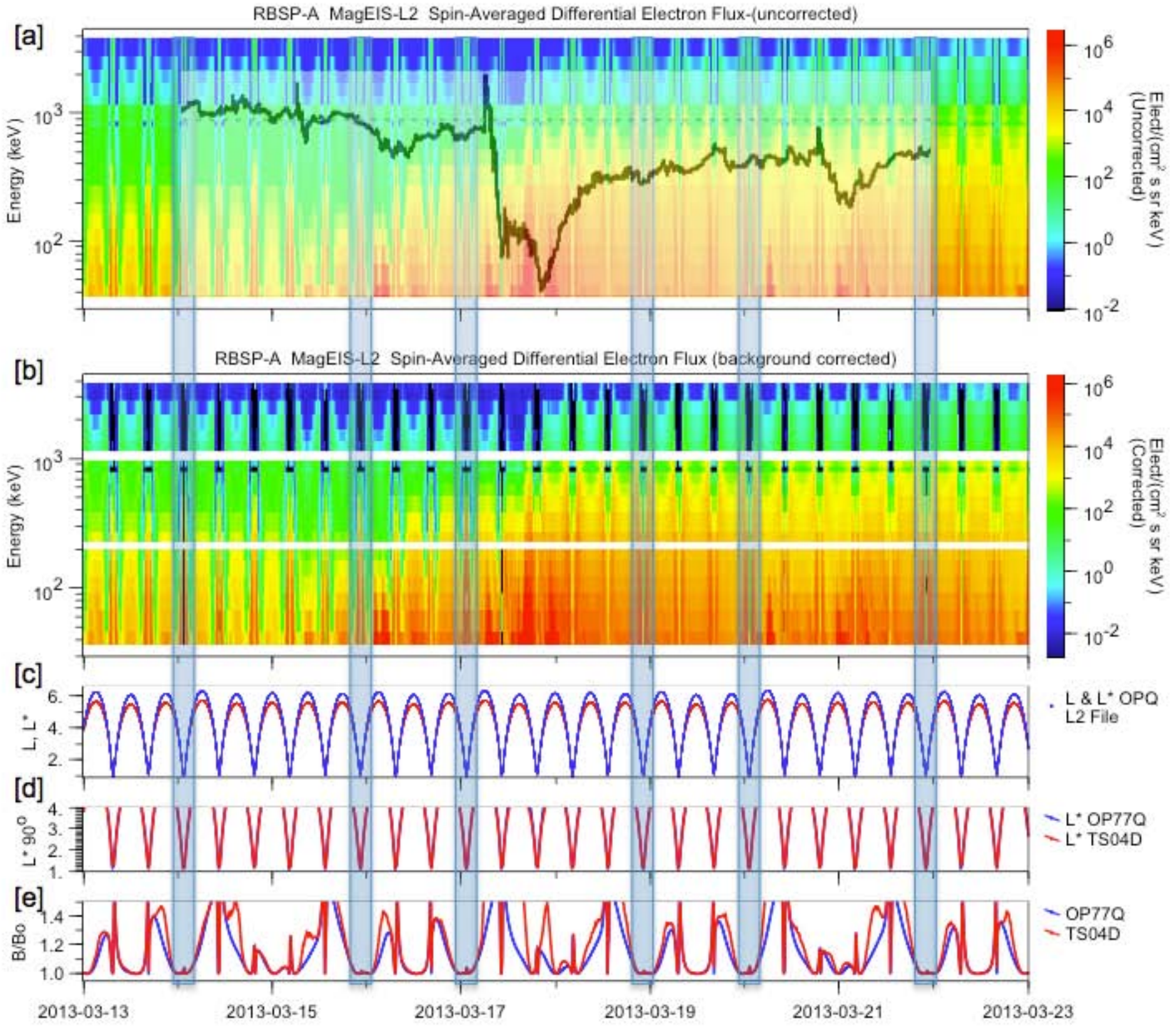
[b] Fluxes Corrected for Background

[c] OP77Q L & L*

[d] OP77Q and TSY04D for L* ≤ 4

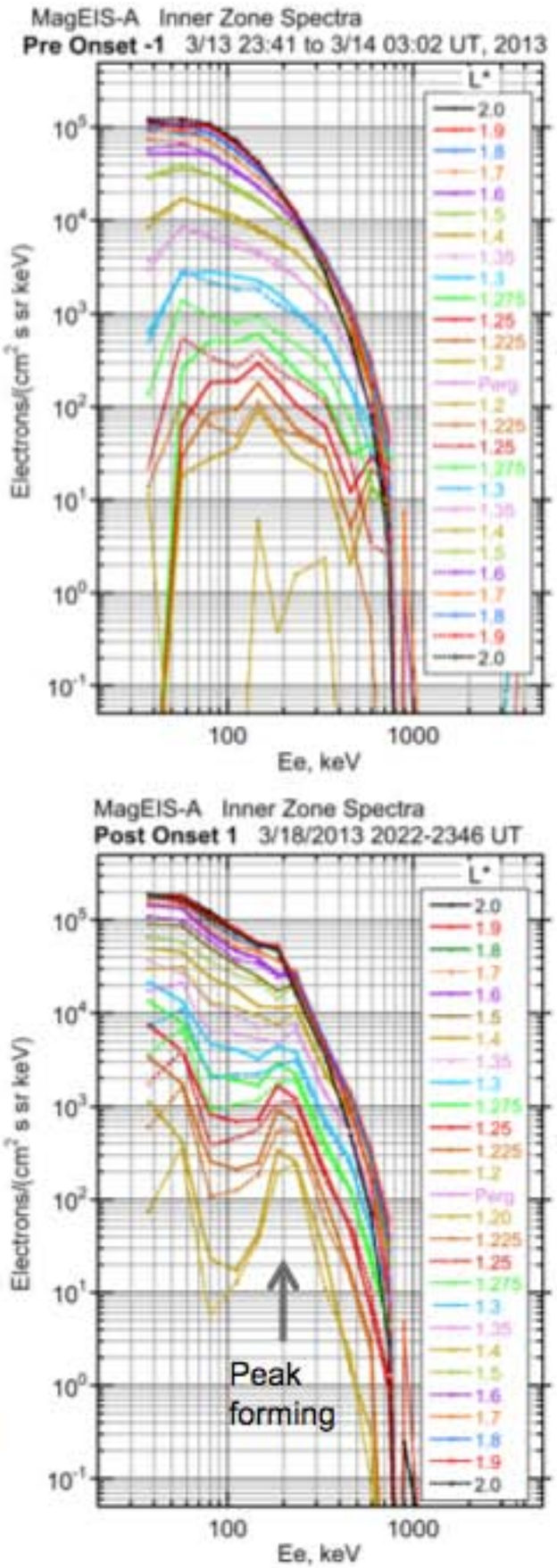
[e] B/B_0 from OP77Q & TSY04D

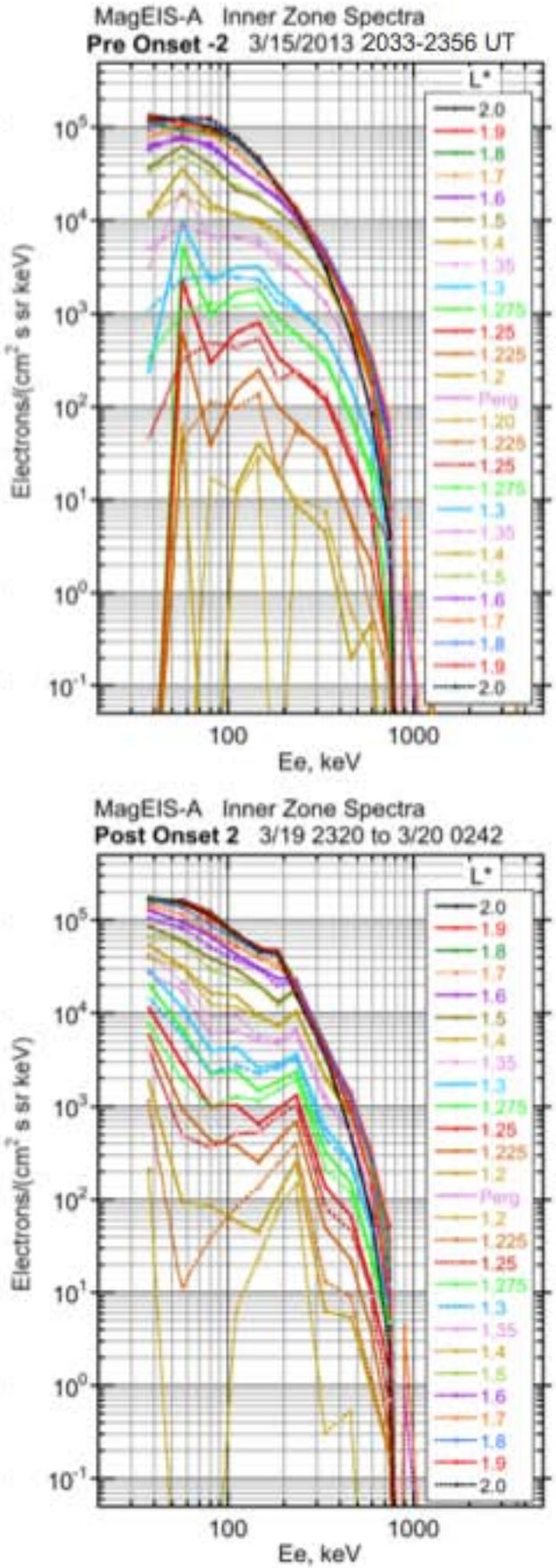
- Highlighted regions used to get pre and post onset spectra
- The regions for RBSP-B overlap those for RBSP-A
- The black line over-plotted on the spectrogram in [a] shows SYM-H scaled such that 0 nT is at the 10^3 flux level and the plot y-axis base is -150 T

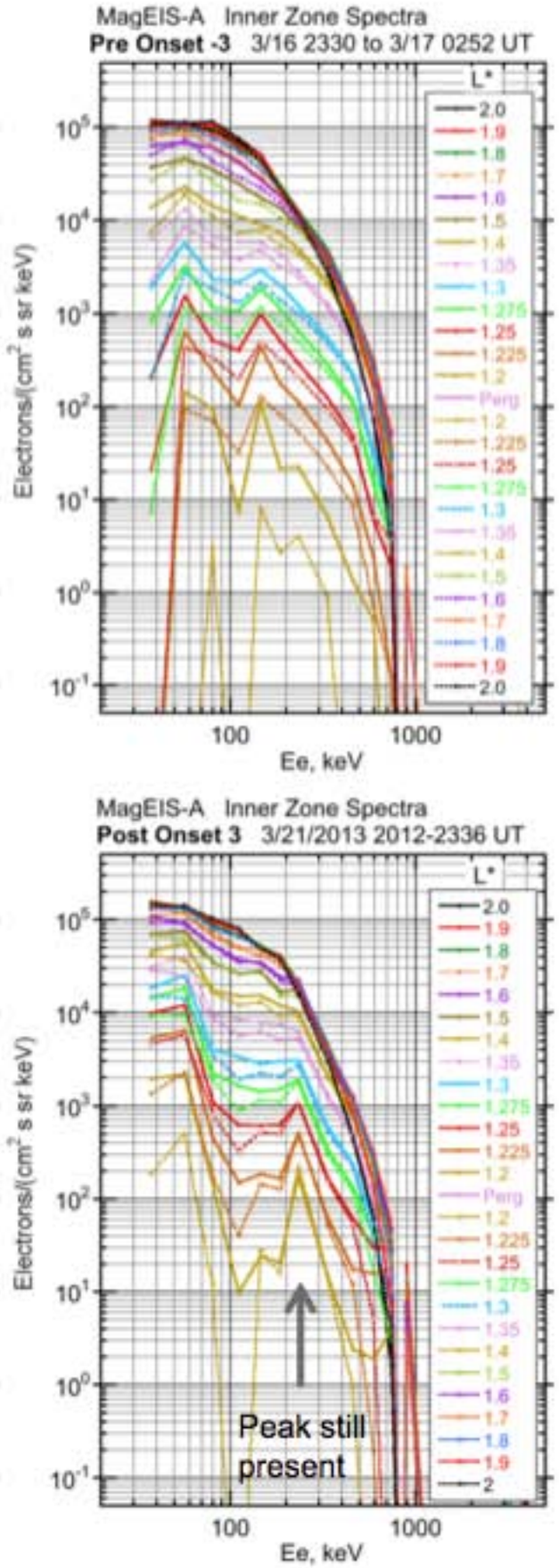


MagEIS-A Inner Zone Spectra (1.175≤L*≤2) For March 17, 2013 Event

- The spectra were very similar throughout the Pre onset intervals
- Electron spectra may peak near 60 keV during quiet time
- Electrons >800 keV are at MagEIS's background levels throughout the inner zone
  - ***No MeV electrons in the inner zone!***
- Strong radial gradient for L<1.5
- Fluxes somewhat enhanced post onset consistent with appearance of penetration in L vs. Time spectrograms
- Peak formed in low L* spectra near 200 keV
  - No such peak appeared after 1 March event onset



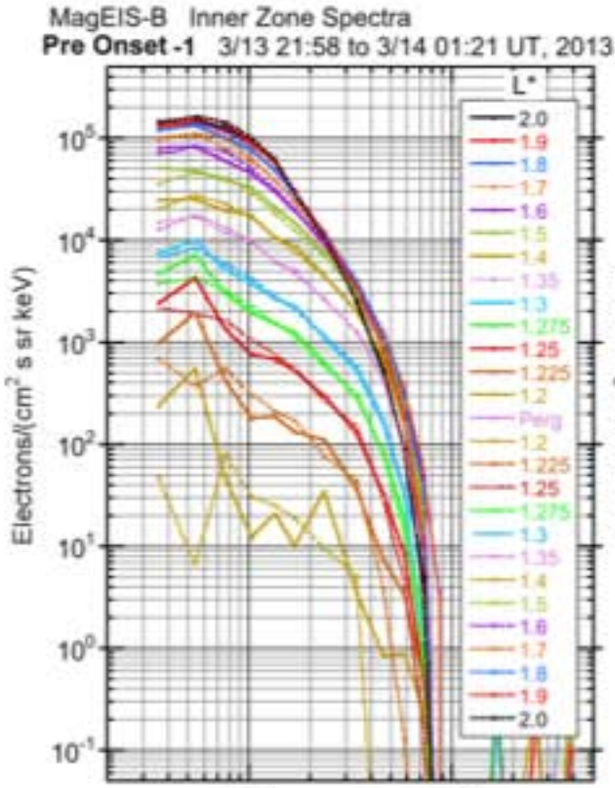


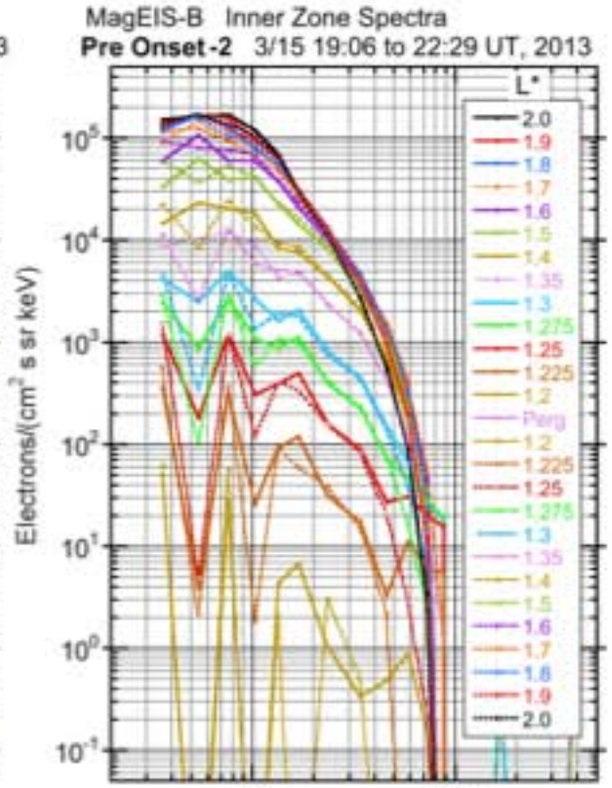


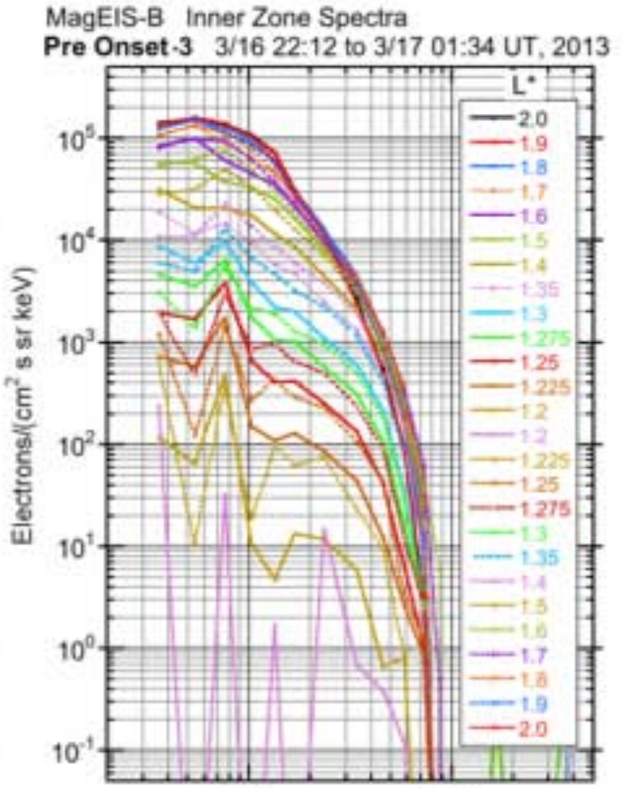
MagEIS-B Inner Zone Spectra (1.175≤L*≤2) For March 17, 2013 Event

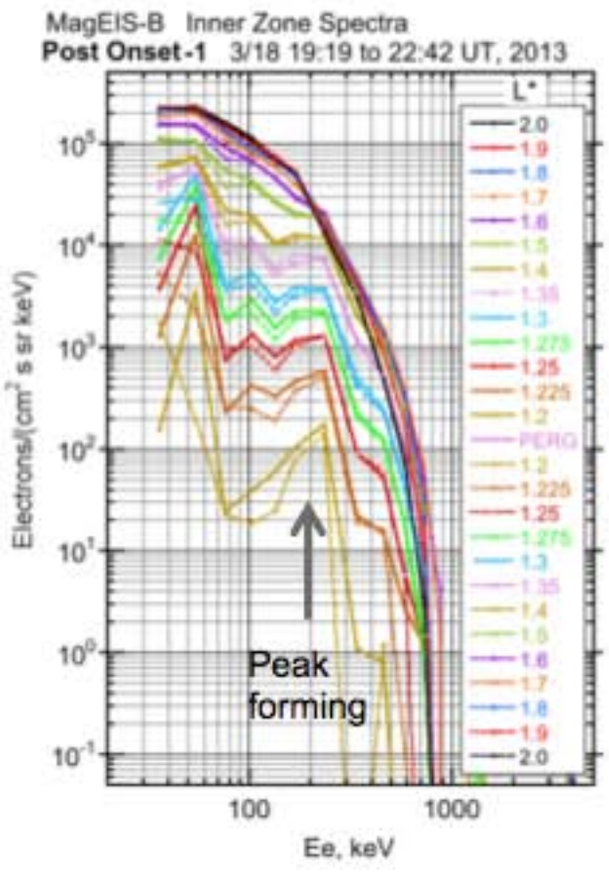
Like RBSP-A

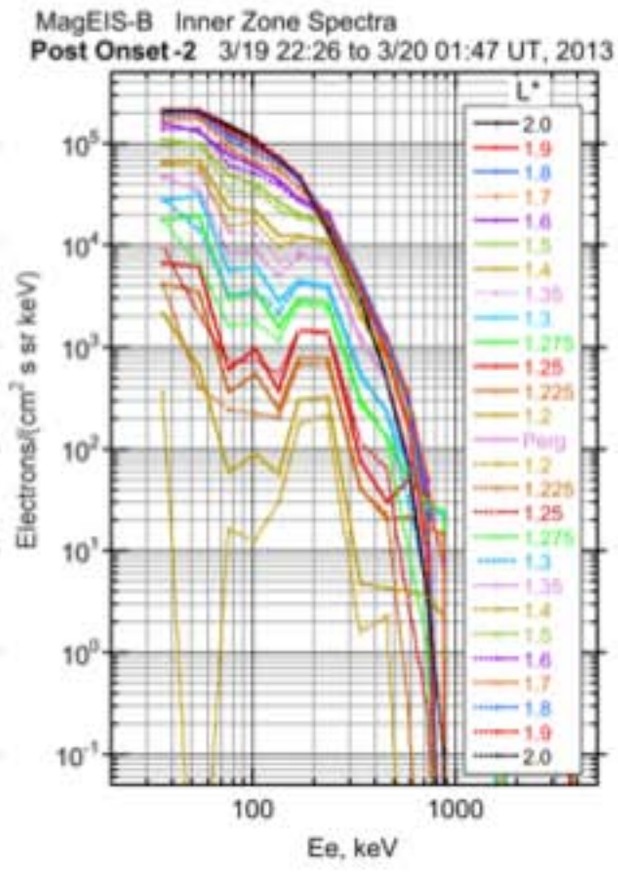
- The spectra were very similar throughout the Pre onset intervals
- Electron spectra may peak near 60 keV during quiet time
- Electrons >800 keV are at MagEIS background levels throughout the inner zone
  - *No MeV electrons in the inner zone!*
- Strong radial gradient for L<1.5
- Fluxes somewhat enhanced post onset consistent with penetration seen in L vs. Time spectrograms
- Spectral peak formed near 200 keV at the lower L*
  - No such peak appeared after 1 March event onset

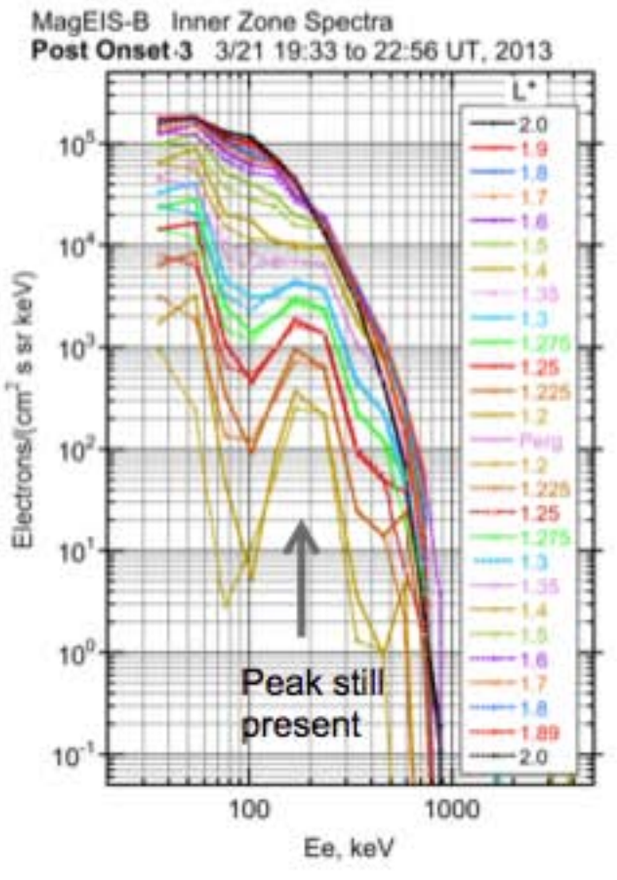






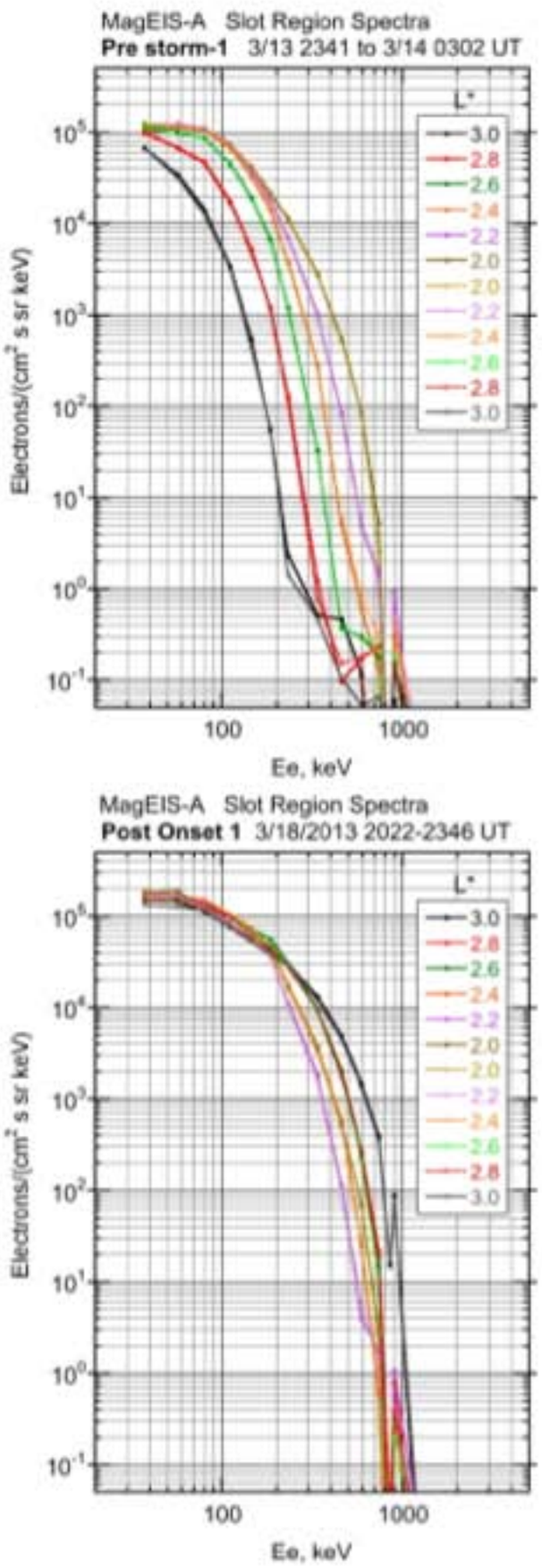


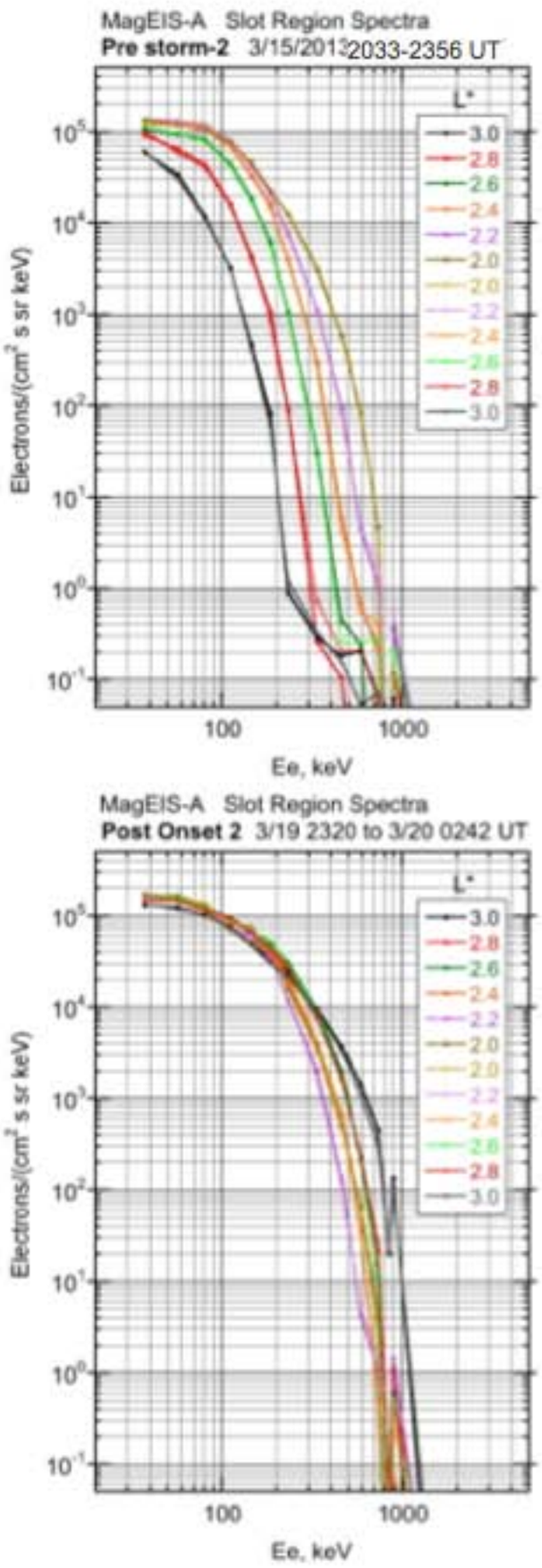


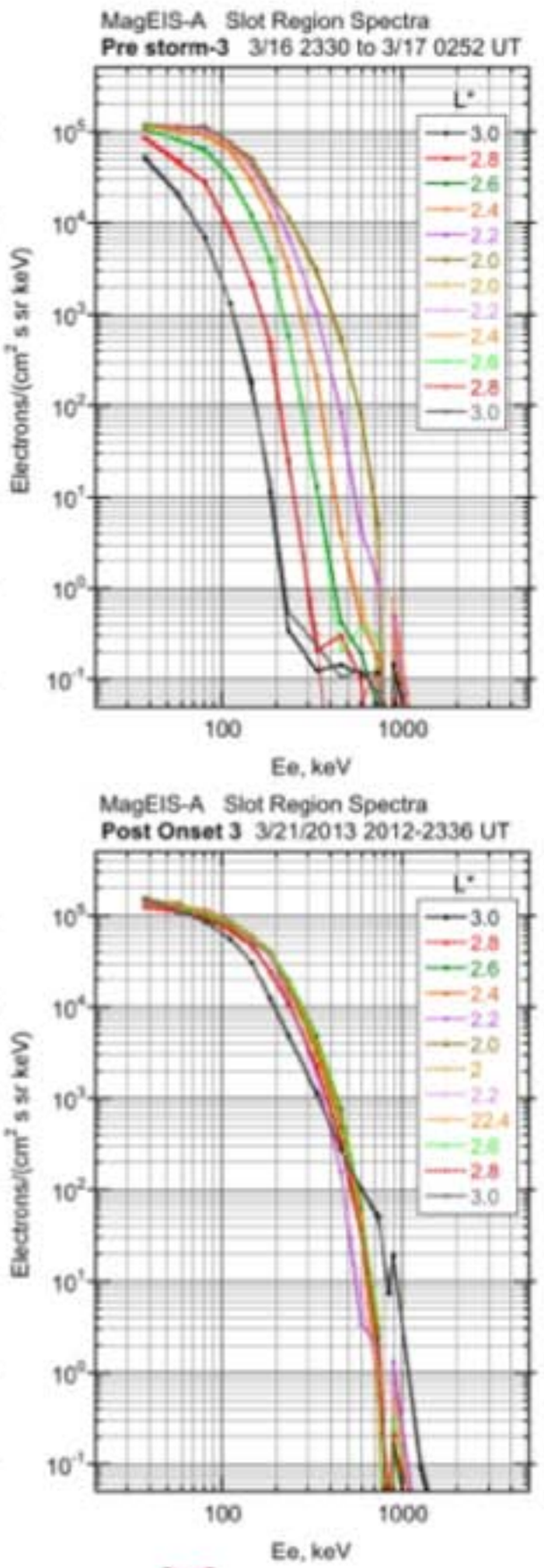


MagEIS-A Slot Region Spectra (2≤L*≤3) For March 17, 2013 Event

- No change in slot fluxes through the pre onset intervals (like pre 1 Mar.)
- Enhanced fluxes observed at the outer edge (L*>2.6) of the slot region in the first post onset interval
  - *Lowest energy electrons (<200 keV) show slight enhancements (~50%) at all L* values in slot region*
- Enhanced electron fluxes start their decay back towards the pre storm levels during 2nd and 3rd day after onset
  - *Most pronounced at outer edge of slot*
- No MeV electrons above background at all L* in slot
- Post onset rise in slot fluxes slightly greater for this event though similar to the 1 March event
- Post onset spectra can be well fit by exponential form



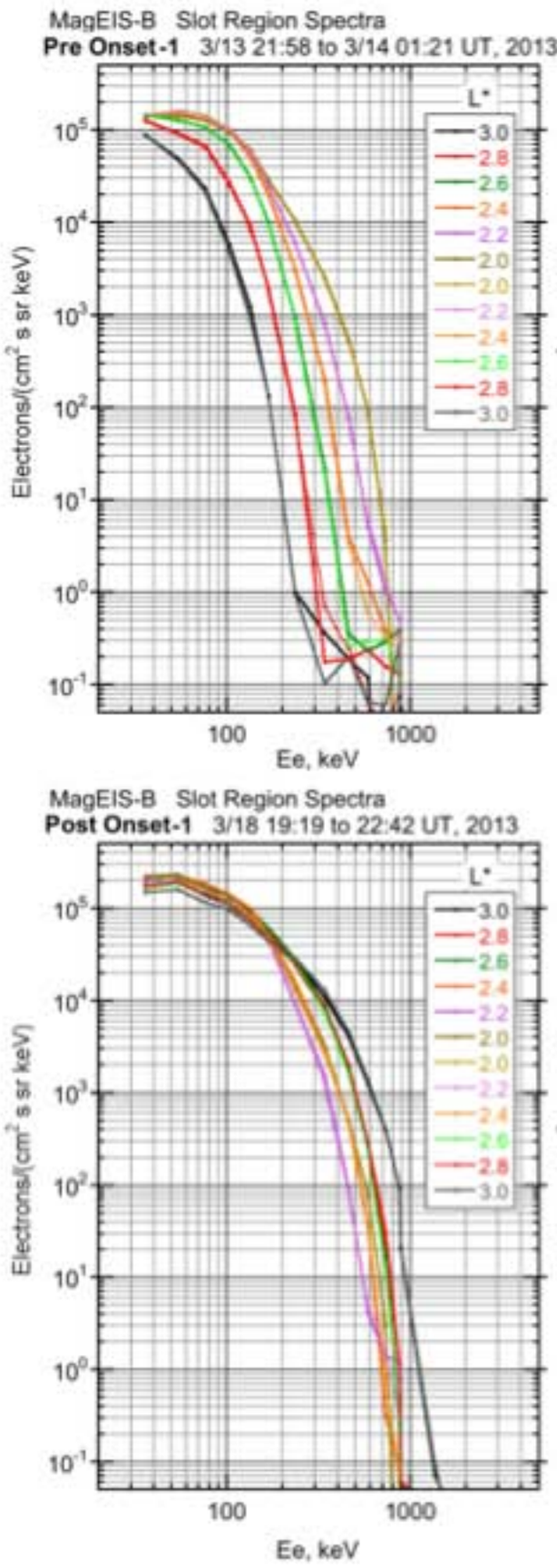


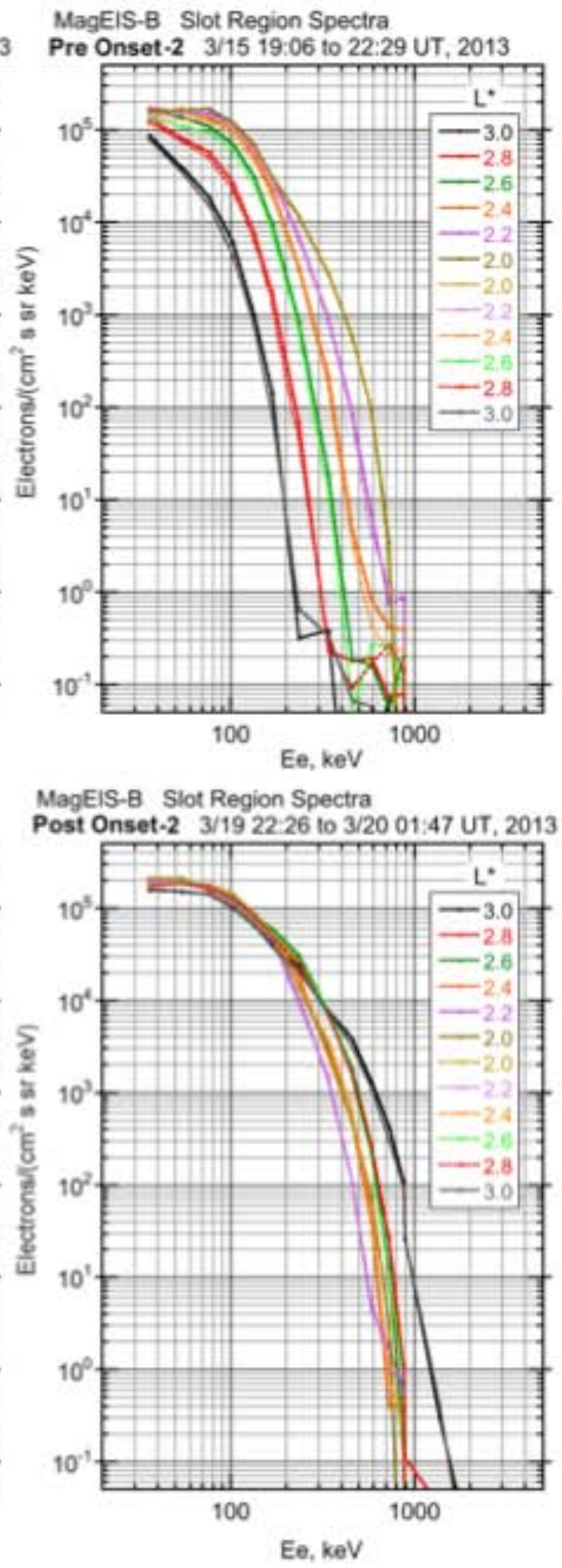


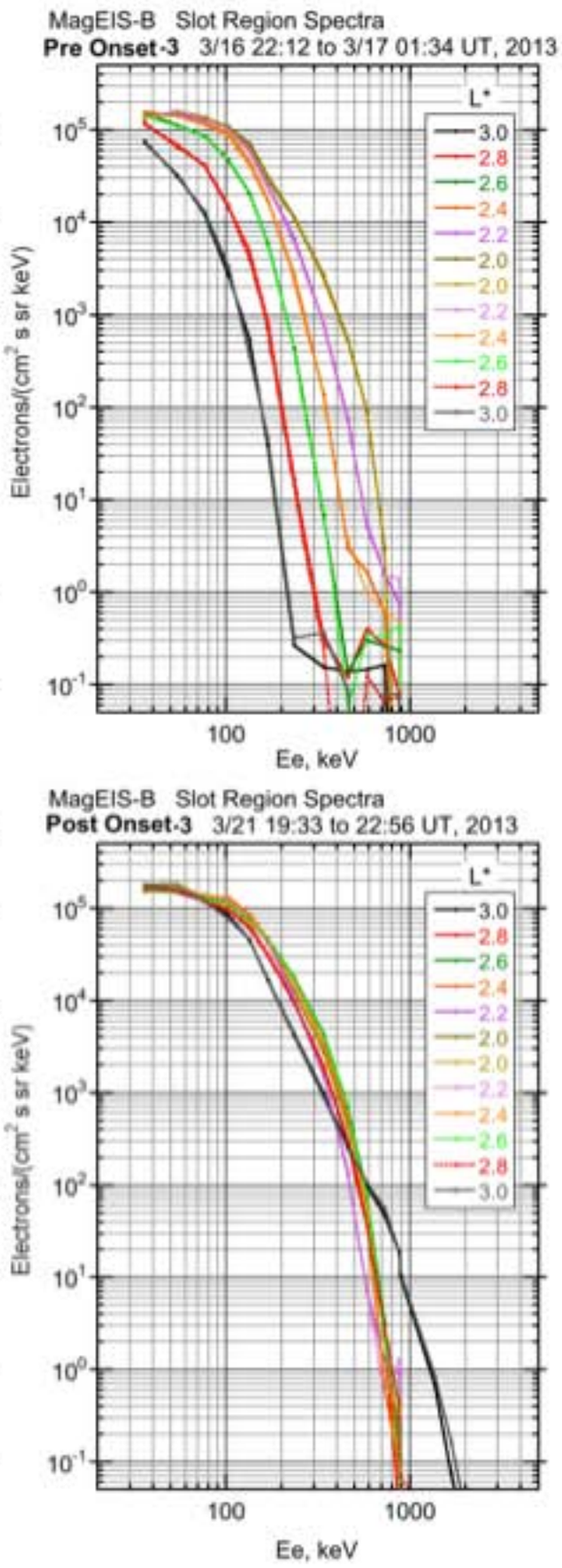
MagEIS-B Slot Region Spectra (2≤L*≤3) For March 17, 2013 Event

Essentially identical to A satellite observations

- Enhanced fluxes observed at the outer edge (L*>2.6) of the slot region in the first post onset interval
  - *Lowest energy electrons (<200 keV) show slight enhancements (~50%) at all L* values in slot region*
- Enhanced electron fluxes start their decay back towards the pre storm levels during 2nd and 3rd day after onset
  - *Most pronounced at outer edge of slot (larger L*)*
- No MeV electrons above background at all L* in slot
- Post onset rise in slot fluxes slightly greater for this event though similar to the 1 March event
- Post onset spectra can be well fit by exponential form

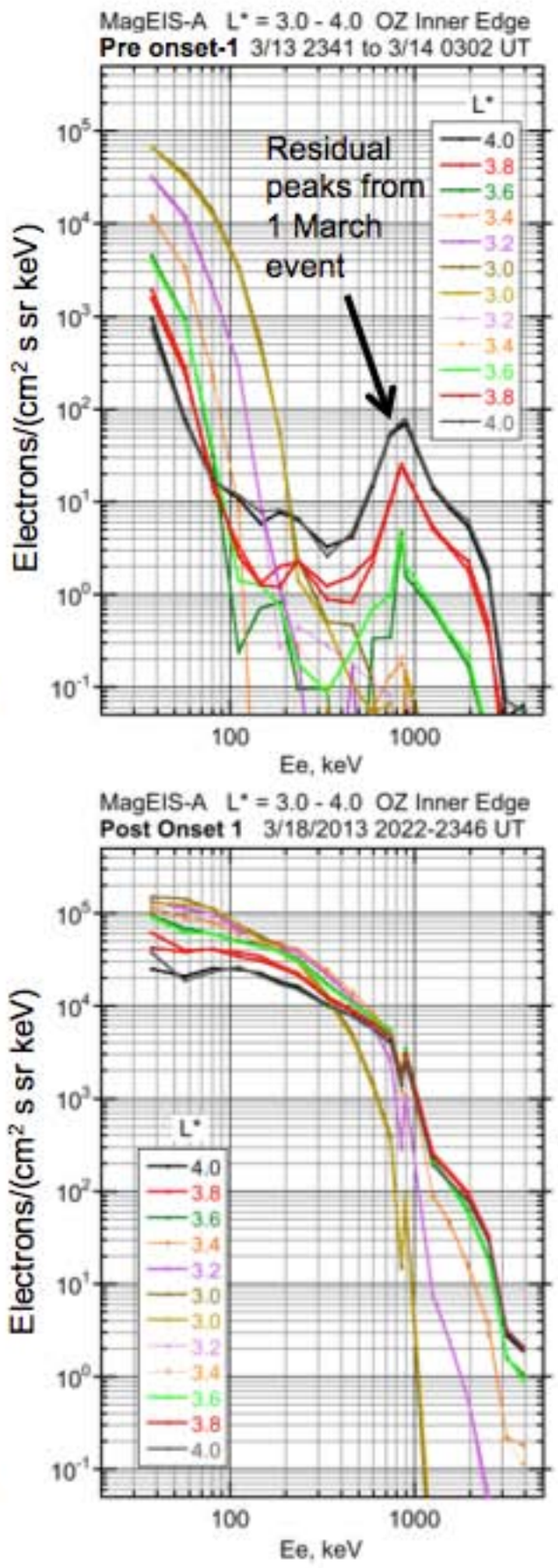


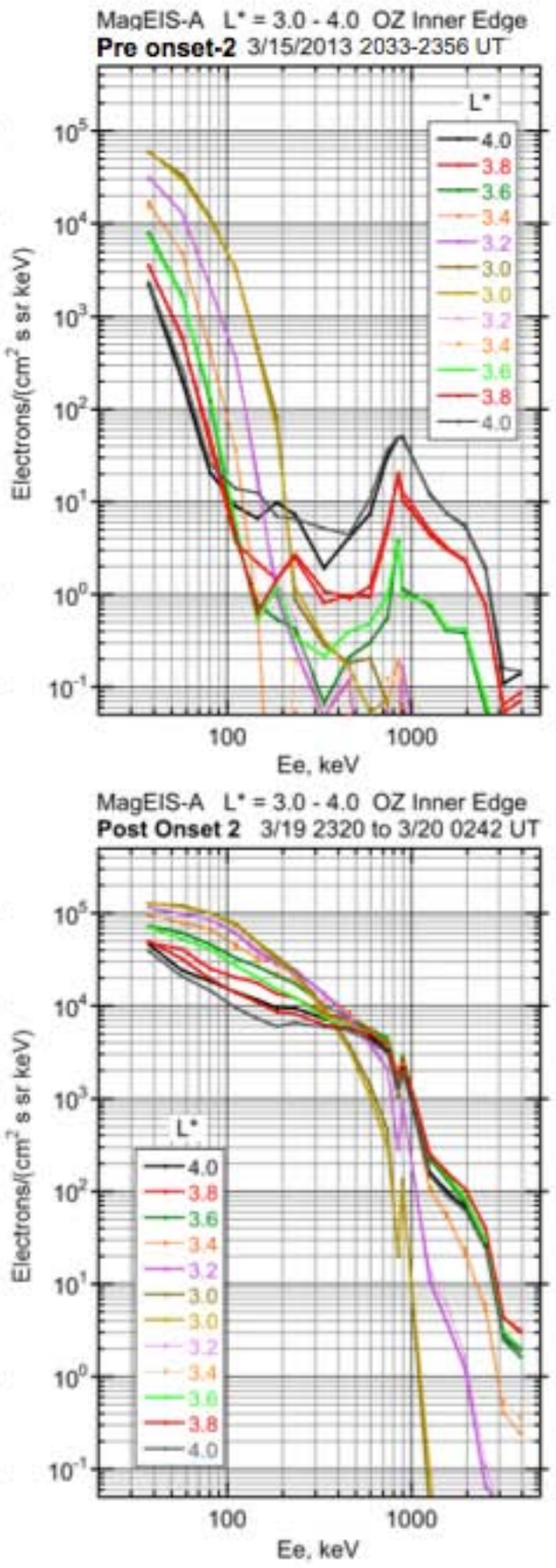


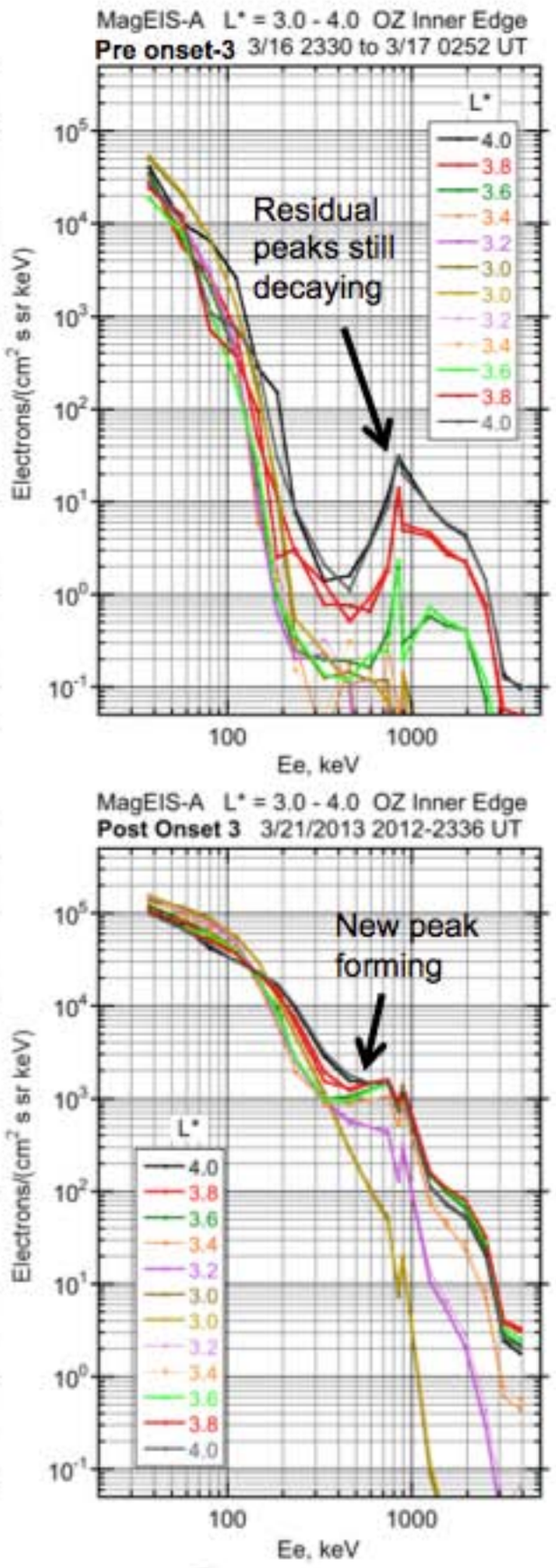


MagEIS-A OZ Inner Edge Spectra (3≤L*≤4) For March 17, 2013 Event

- The outer zone inner edge (3≤L*≤4) spectra remained essentially the same through the first two pre onset intervals
  - *The L*>3.2 fluxes at < 100 keV rose significantly during the 3rd pre onset interval*
- Fluxes at all energies and L* values had increased by the 1st post onset interval with the greatest increases at the larger L* values (>2 orders of magnitude for 100-500 keV at L*=4)
  - *Fluxes at the lowest L* had the smallest increases but still quite significant, especially at >100 keV*
- By the 3rd post onset interval, the 300- 800 keV fluxes had decayed to <1/2 their peak values and the spectra were starting to show a peaking in the 0.7-1 MeV range similar to that observed pre onset
  - The fluxes <200 keV at largest L* were still increasing at post onset 3



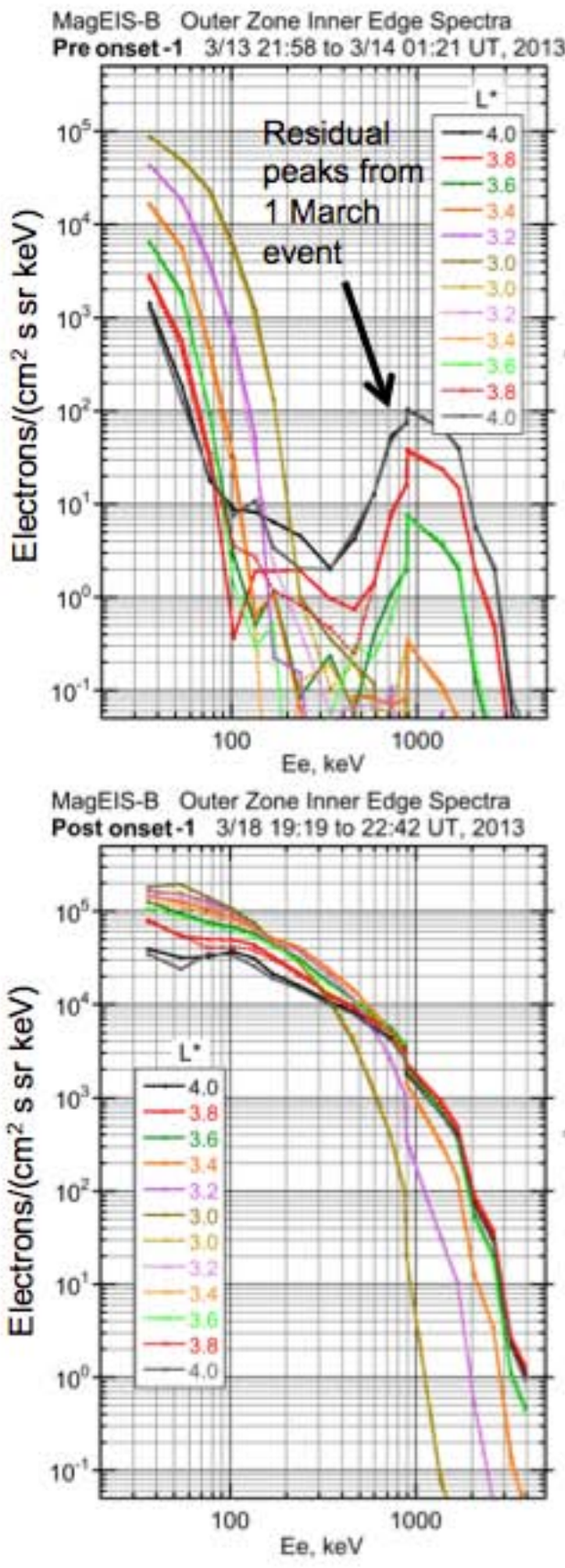


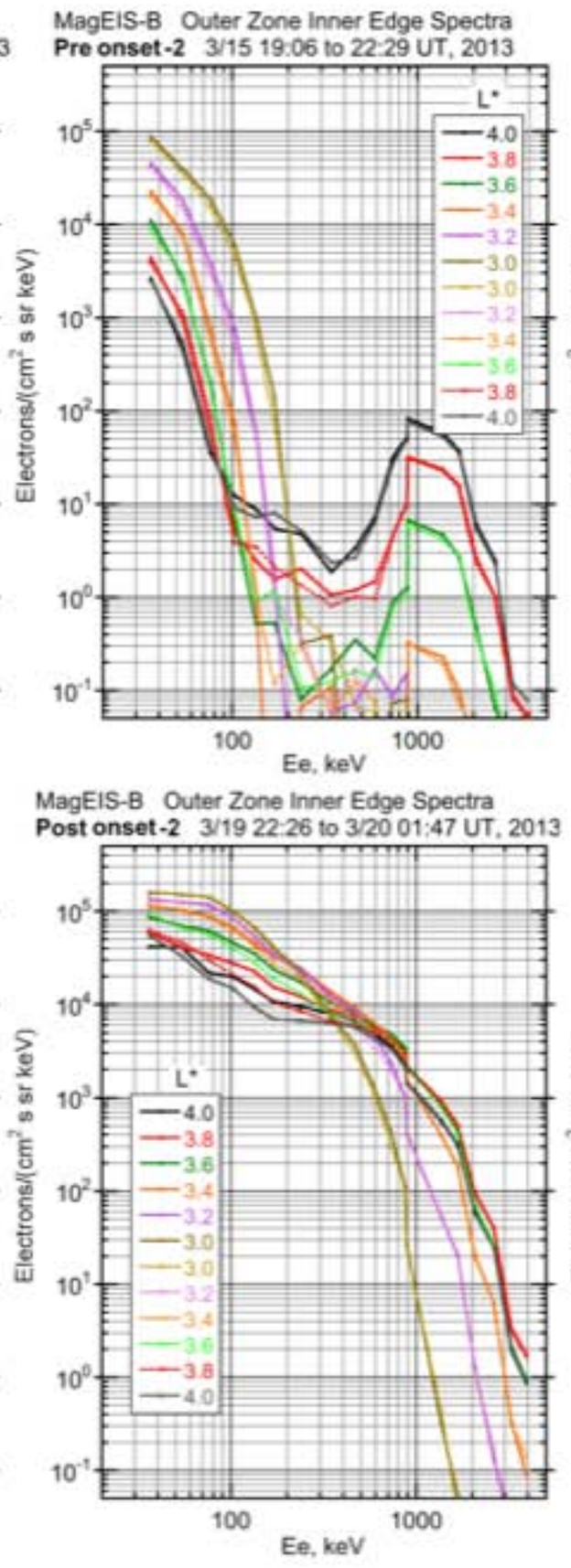


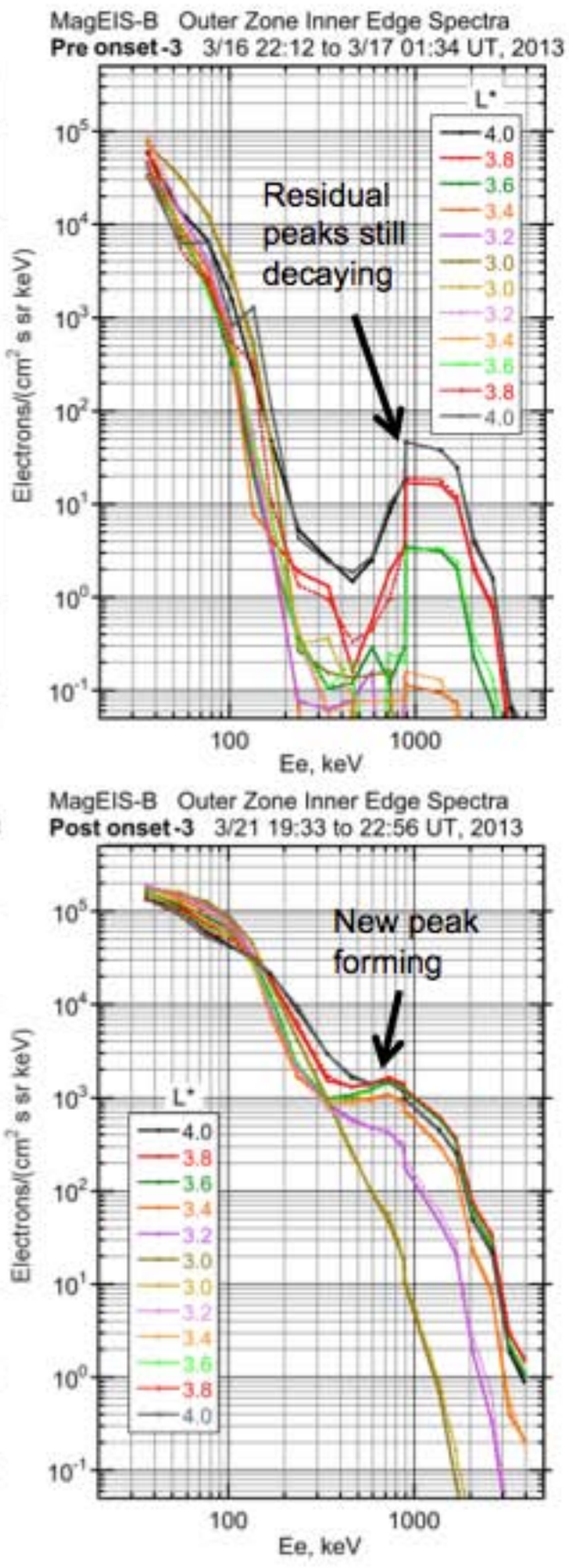
MagEIS-B OZ Inner Edge Spectra (3≤L*≤4) For March 17, 2013 Event

Like previous plot but for B spacecraft

- Shows same flux response as observed by A spacecraft

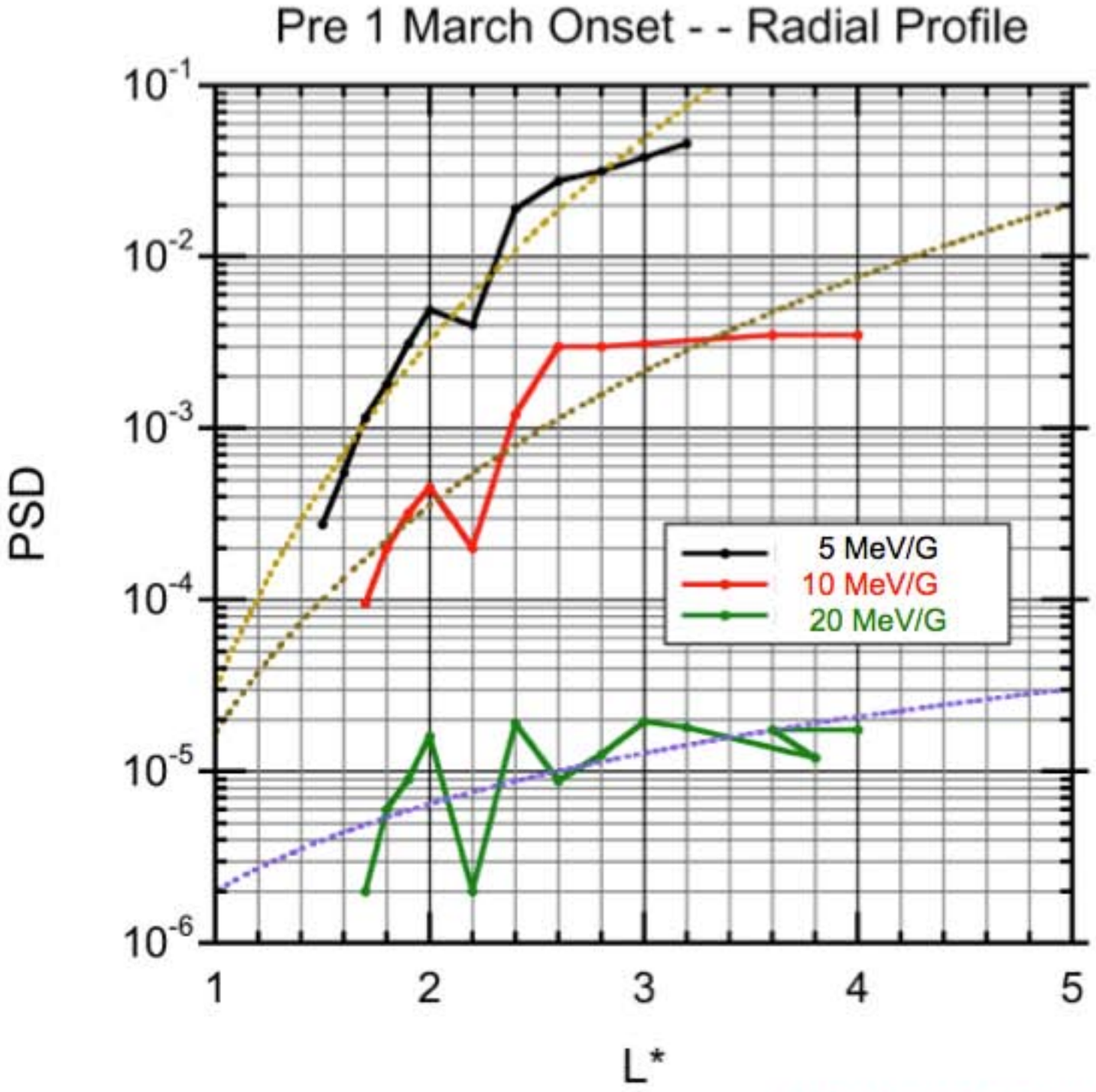






PSD Estimate for pre onset Interval of 1 March Event

- Estimate assumes spin average flux ~ j_{perp} at magnetic equator and $\mathbf{p}_{perp}$ ~ spin average momentum
- μ is calculated using OPQ field model assuming satellite at magnetic equator
- Electron energy spectra are converted to PSD versus μ spectrum for each L*
- PSD versus μ spectra are then fit and evaluated to obtain PSD at constant μ which are plotted versus L* as shown
- The dashed lines are power law fits to the points in PSD-L* space



Summary

- MagEIS has made relatively clean measurements throughout the inner zone and slot region where backgrounds from high energy protons often mask the electron fluxes
  - *No electrons, above background, were observed for energies >800-1000 keV by MagEIS in the Inner Zone and Slot regions*
- The slot region fluxes were highest for small L* during the pre event periods for both intervals
- Low energy electrons were observed to be enhanced throughout the inner zone, slot and and inner edge of the outer zone in response to both the CIR and CME magnetic storms in March 2013
- On the whole, the responses in these three regions were similar for both events with the 17 March event causing somewhat larger flux enhancements in the slot and inner edge of the outer zone
- The one feature unique to the 17 March event was the formation of a spectral peak near 200 keV at the lower L* values in the inner zone
  - *Need to look at other events to see if this reoccurs*
- The 30-800 keV fluxes filled the electron slot region following the 17 March onset, resulting in the same spectral shape at all L* 3 to 4 days after onset
- The initial quiet time radial profiles rise with increasing L* indicating the electrons probably diffused inward from larger L*

Inner Radiation Zone and Slot Region Electron Fluxes (Revised): ECT/MagEIS Data

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