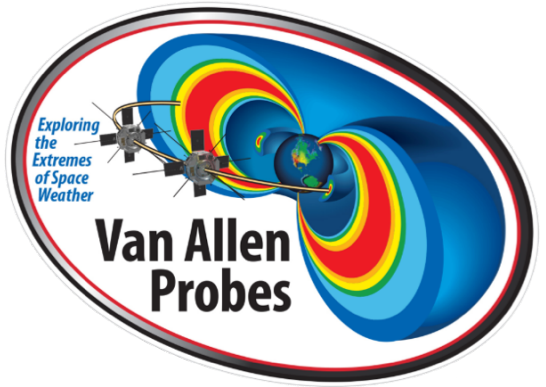
Growing Peaks in Phase Space Density: A Survey of the Van Allen Probes Era

Alexander Boyd, Drew Turner, Geoff Reeves, Harlan Spence, Dan Baker, Bern Blake

AGU Chapman Conference

March 5, 2018



What Causes Radiation Belt Enhancements: A Survey of the Van Allen Probes Era

Alexander Boyd, Drew Turner, Geoff Reeves, Harlan Spence, Dan Baker, Bern Blake

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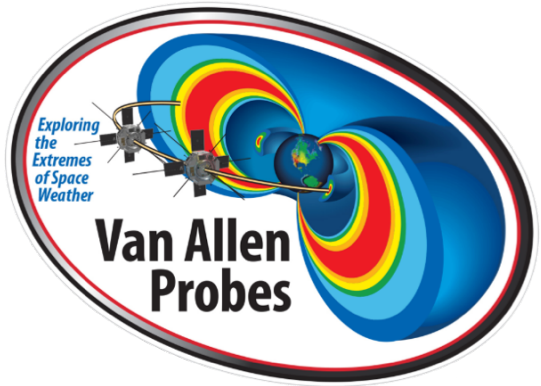
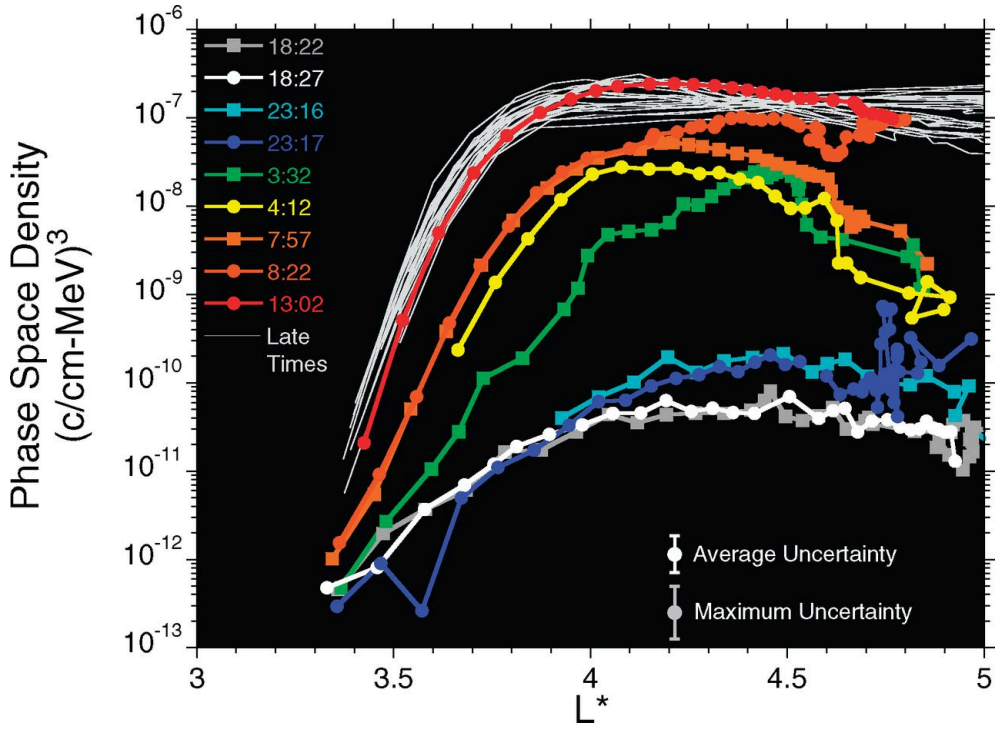
New Mexico CONSORTIUM



Motivation

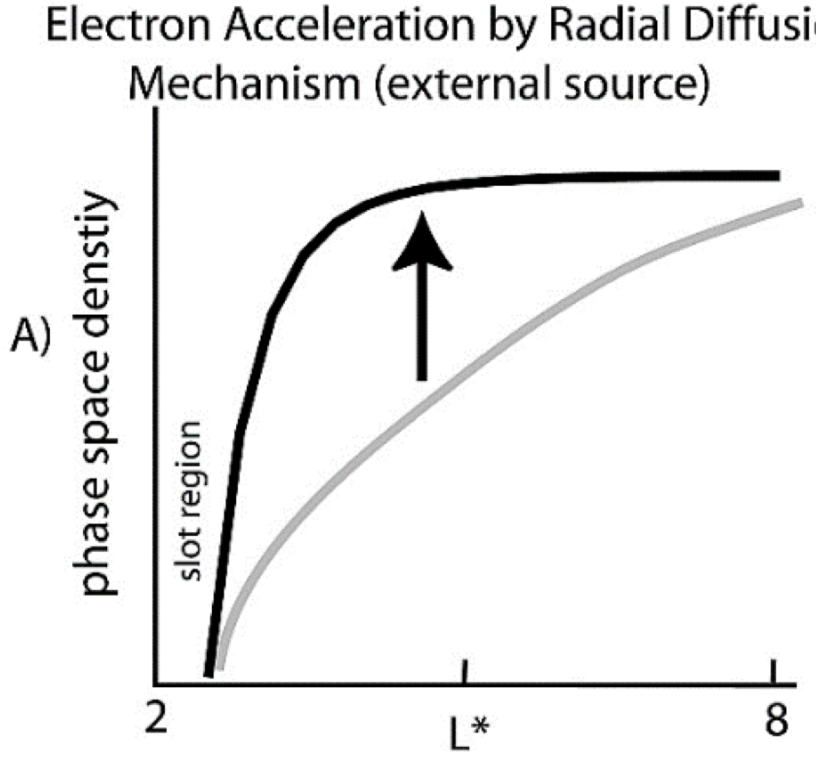
- In general, studies of PSD have focused on individual event studies
- Local Acceleration can be the dominant process for some events
- With more than 4 years of events: **when, where and how often are the different acceleration mechanisms dominant?**

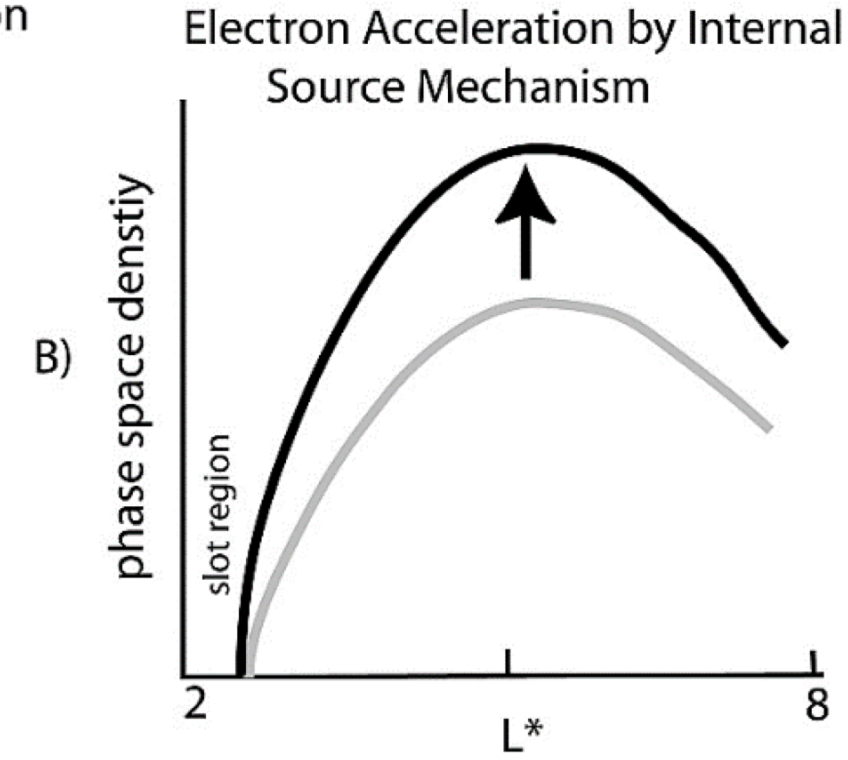


Reeves et al. [2013]

Differentiating with Phase Space Density

- Using Phase Space Density we can differentiate between radial diffusion (positive monotonic gradients) and local acceleration (growing peaks in PSD)





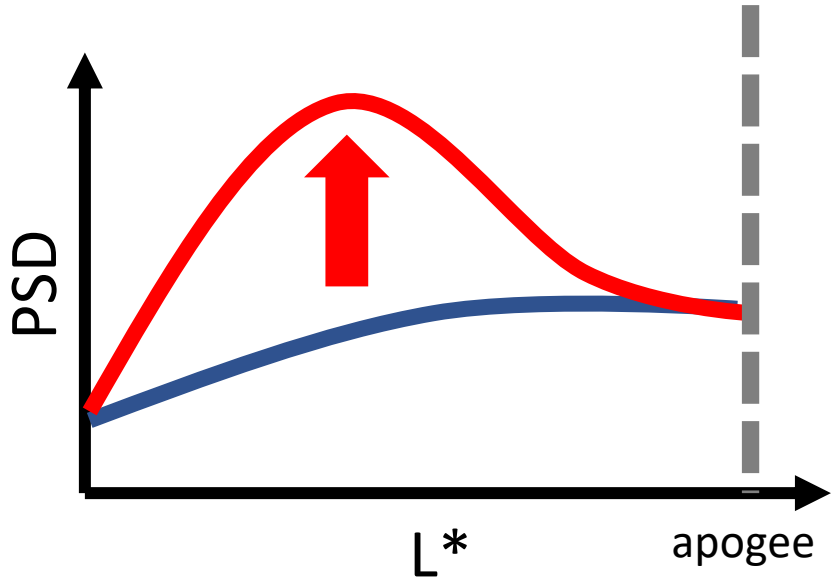
Green and Kivelson [2004]

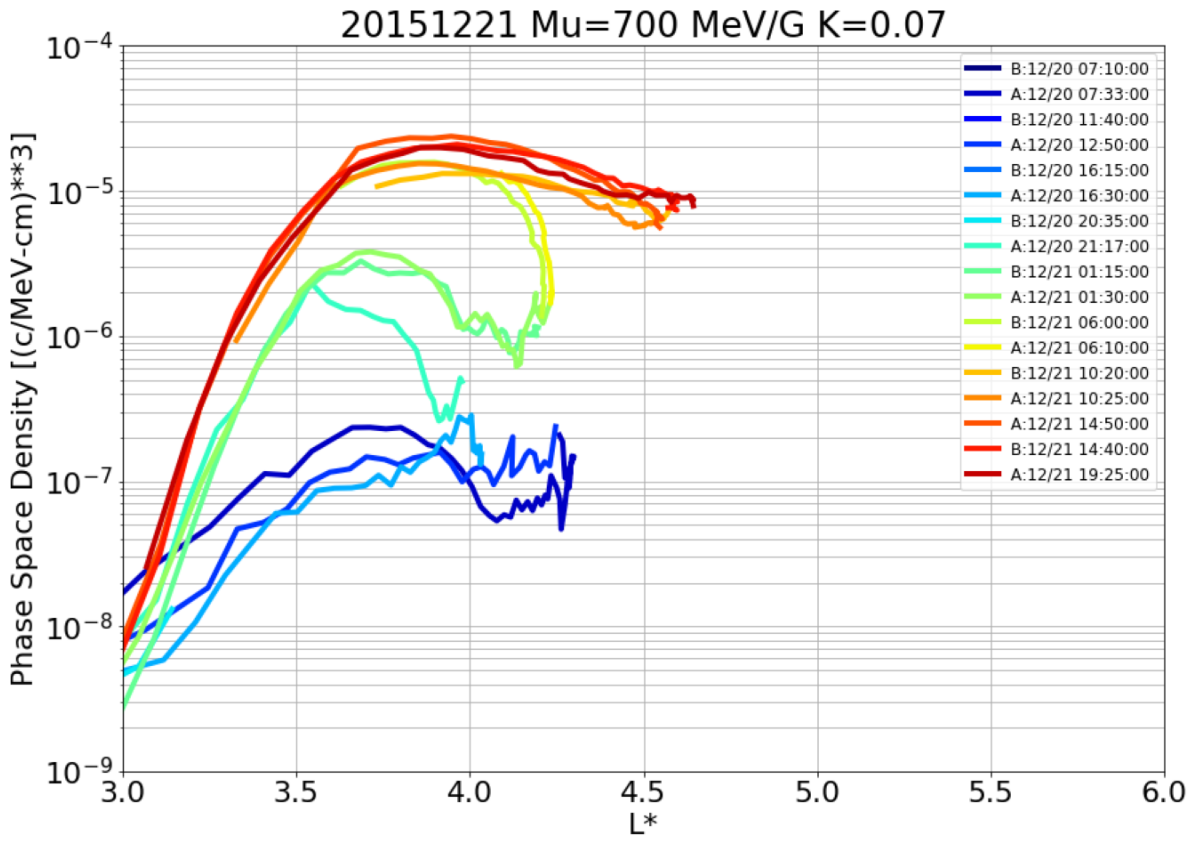
Data & Event Selection

- Enhancement Events from October 2012-April 2017
  - 80 Events where PSD at L*=5 went up by at least a factor of 2
- Using PSD data from Van Allen Probes and THEMIS
  - M = 700 MeV/G (~1.5 MeV in the Outer Belt)
  - K = 0.08 $R_E G^{1/2}$ for Van Allen Probes, K ≤ 0.025 $R_E G^{1/2}$ for THEMIS
  - Only Use data outside L=6 for THEMIS (to try and avoid background contamination)
- THEMIS PSDs are multiplied by a constant factor of 1/3 to get a match with Van Allen Probes observations

Van Allen Probes Events

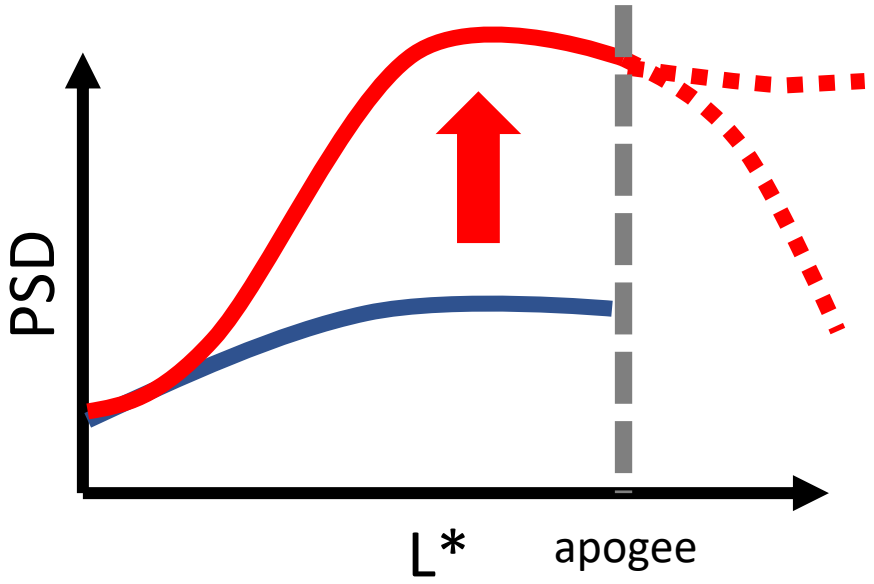
- Type 1 – Clearly defined growing peak

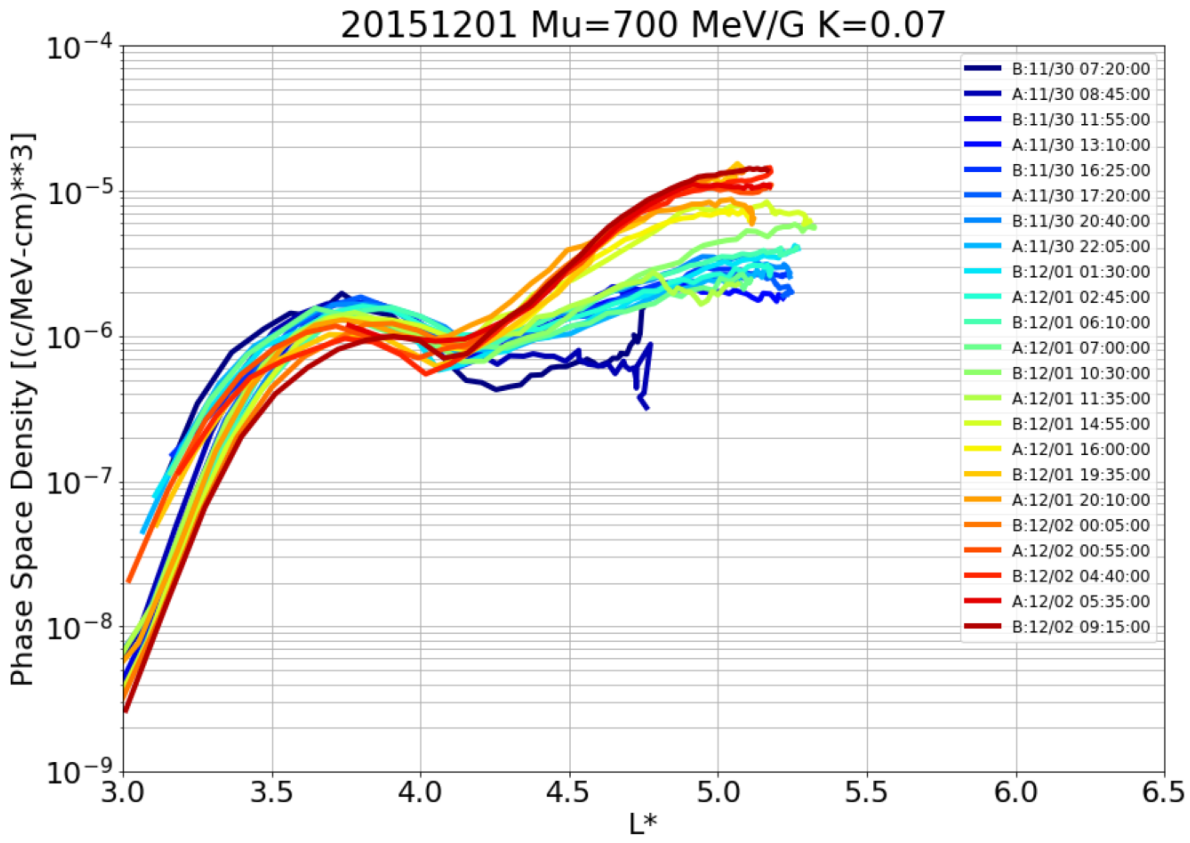




Van Allen Probe Events

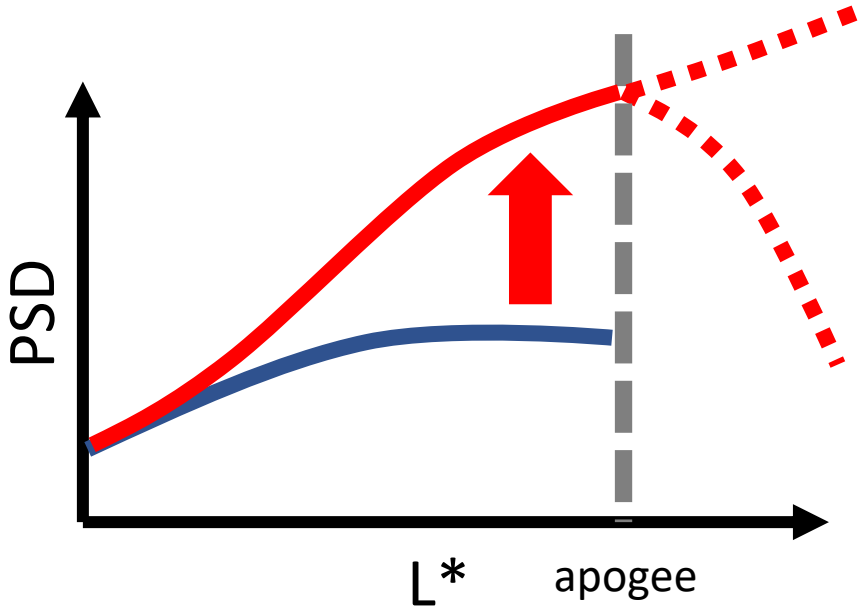
- Type 2: Flat/Slight Negative Gradients

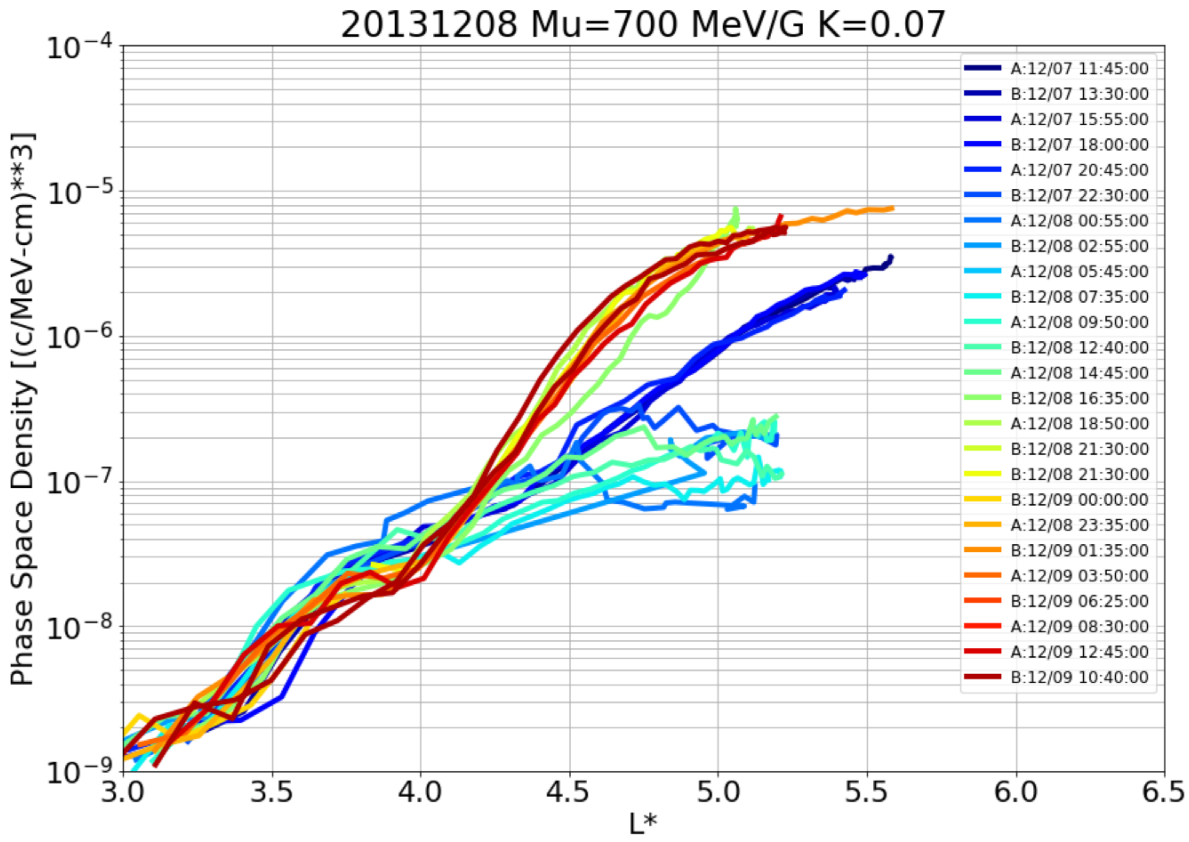




Van Allen Probe Events

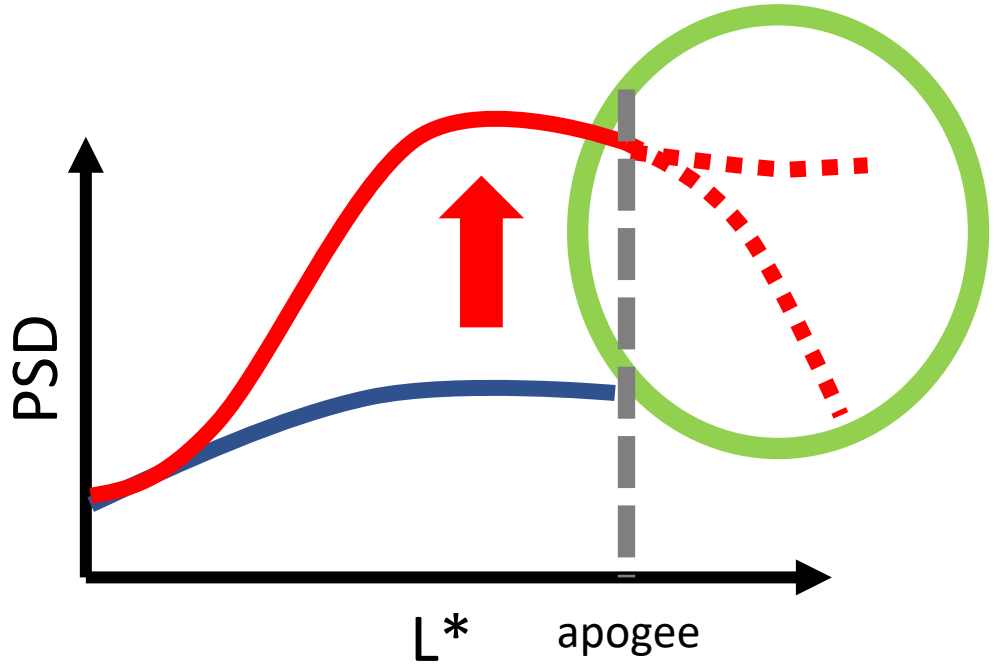
- Type 3 – Positive Gradients





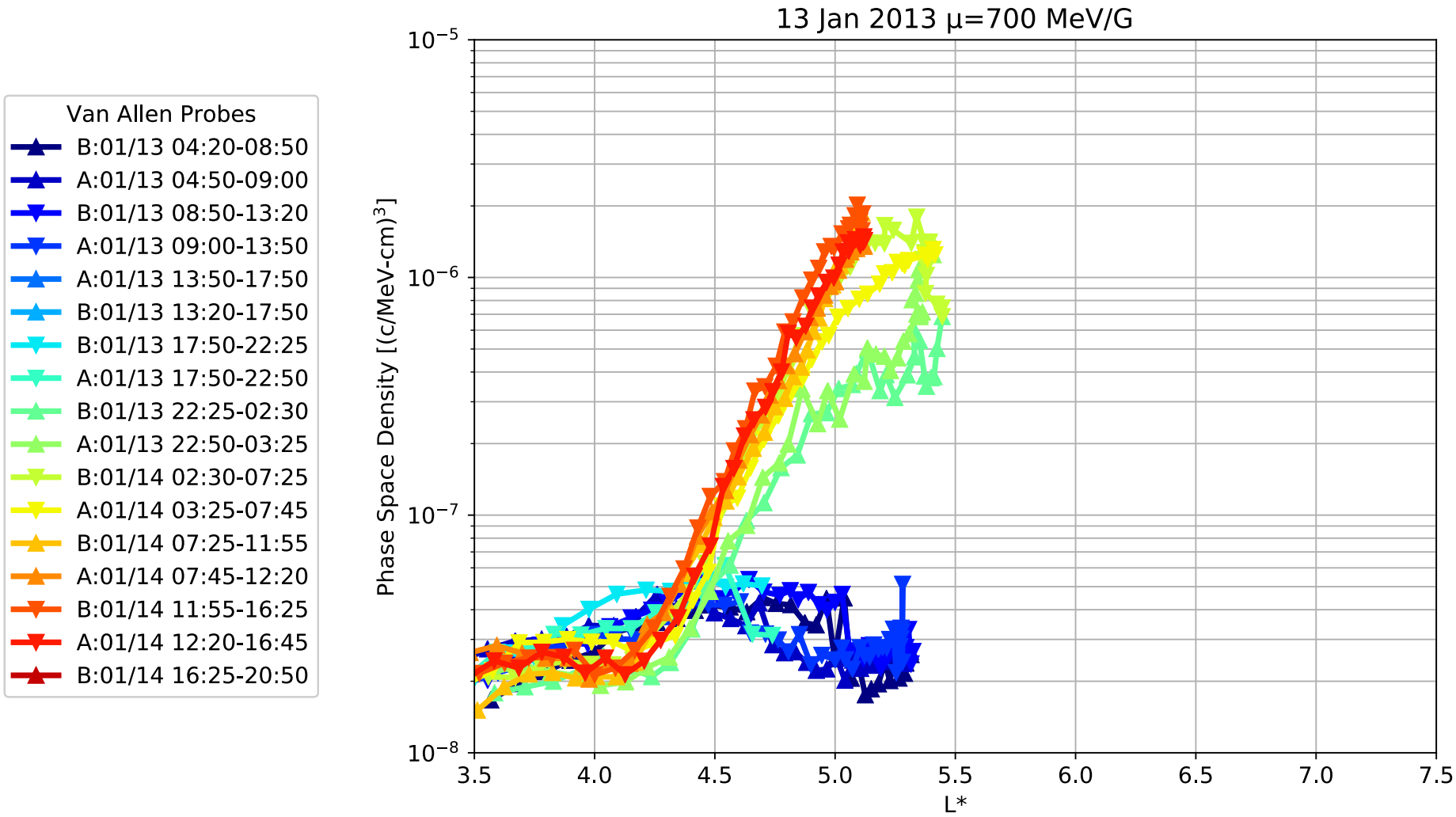
Van Allen Probes Statistics

Event Type	Van Allen Only
Growing Peaks	24
Flat	33
Positive	23

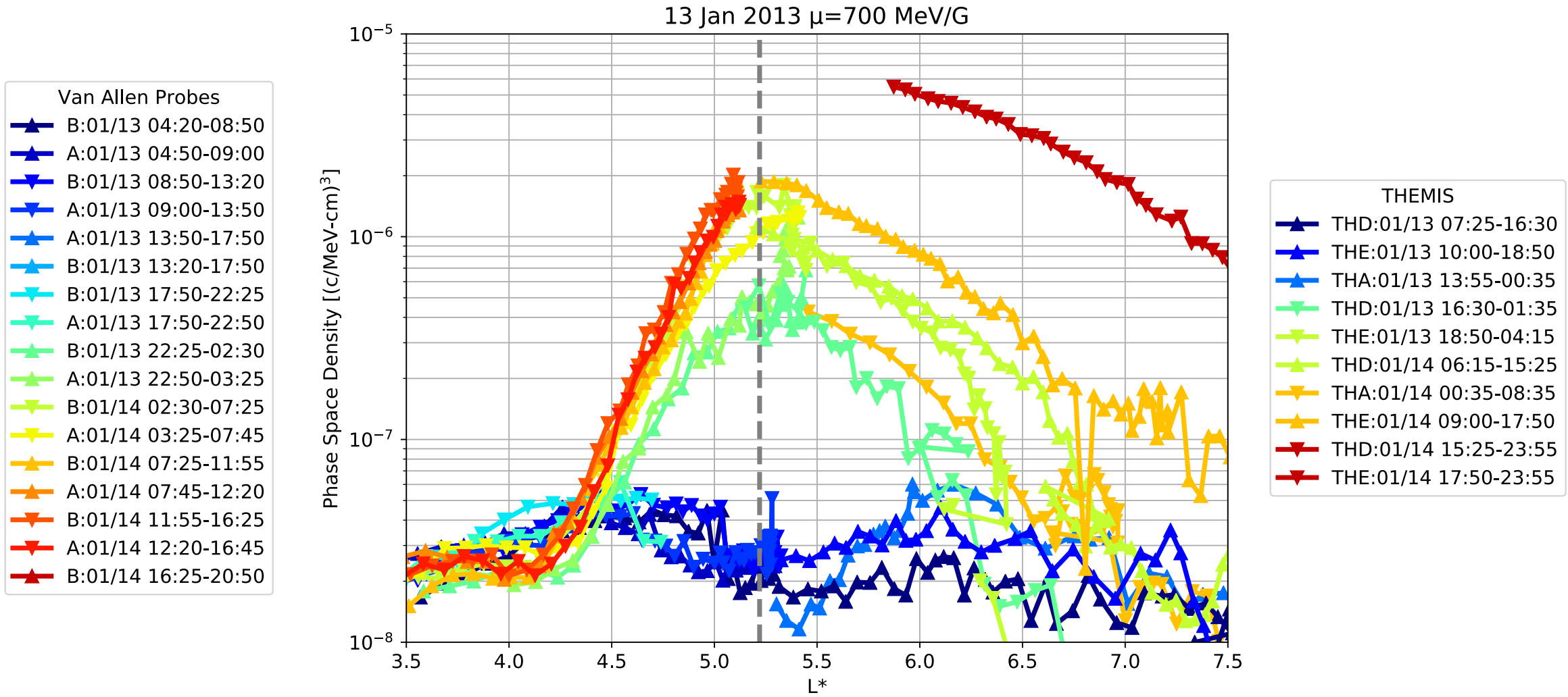


- **30% (24/80) of events have peak inside Van Allen Probes Apogee**

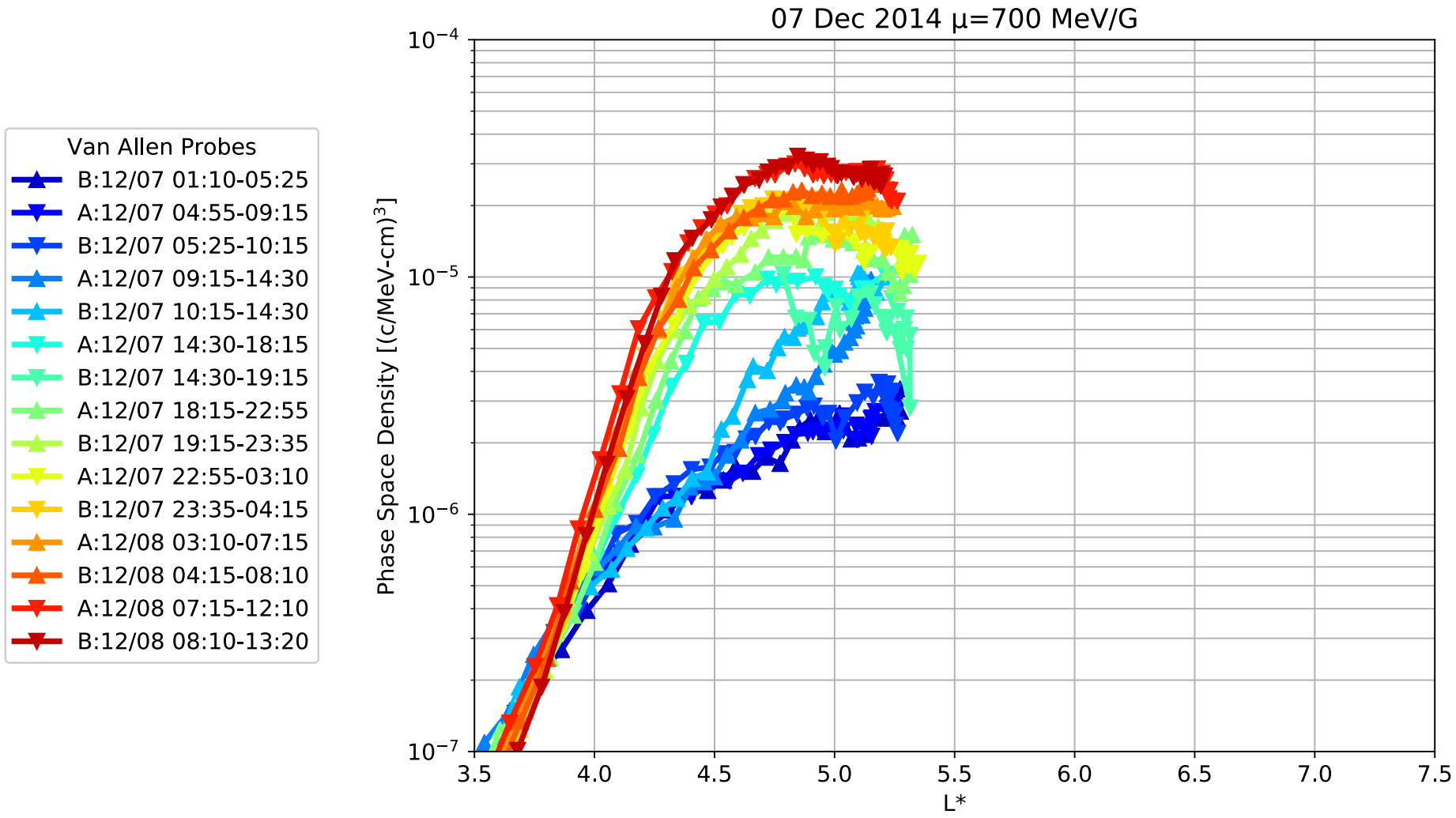
Van Allen-THEMIS Events



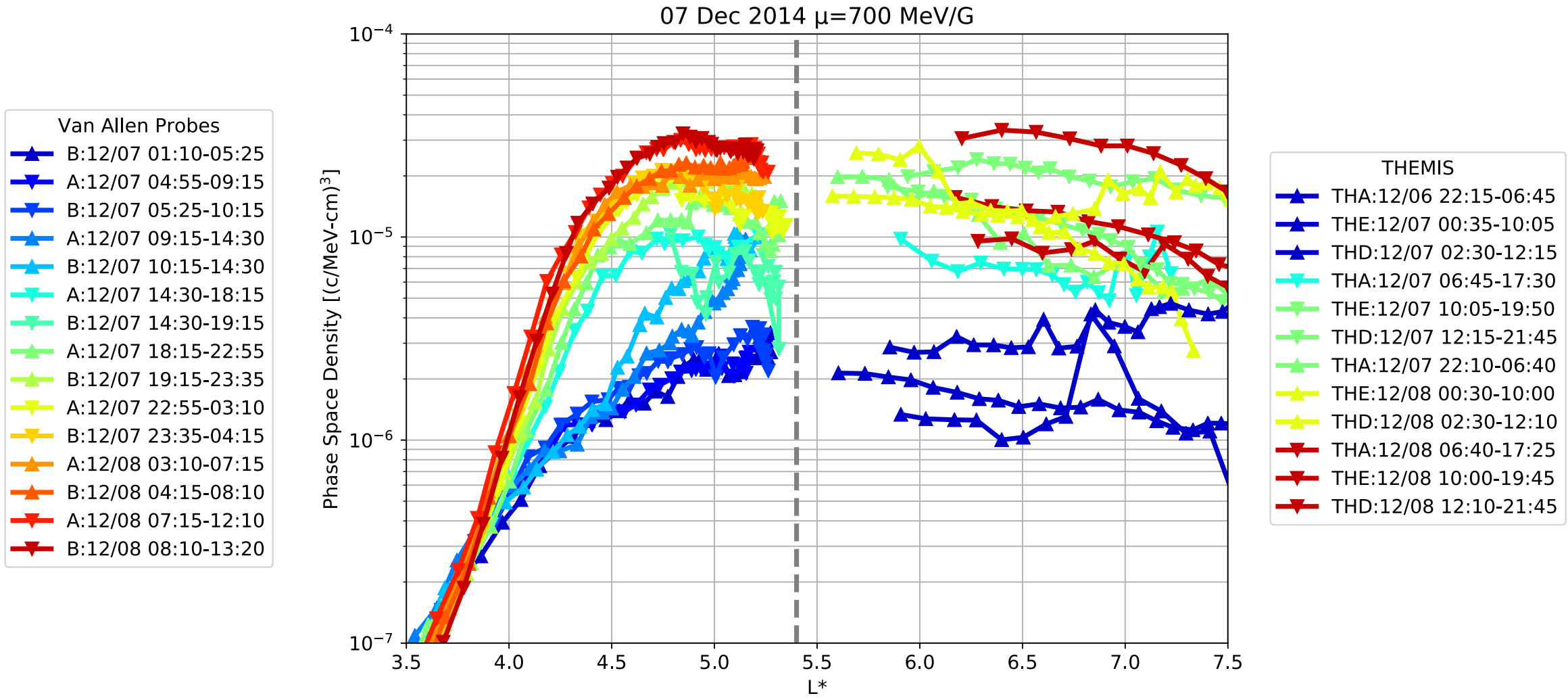
Van Allen-THEMIS Events



Van Allen-THEMIS Events



Van Allen-THEMIS Events



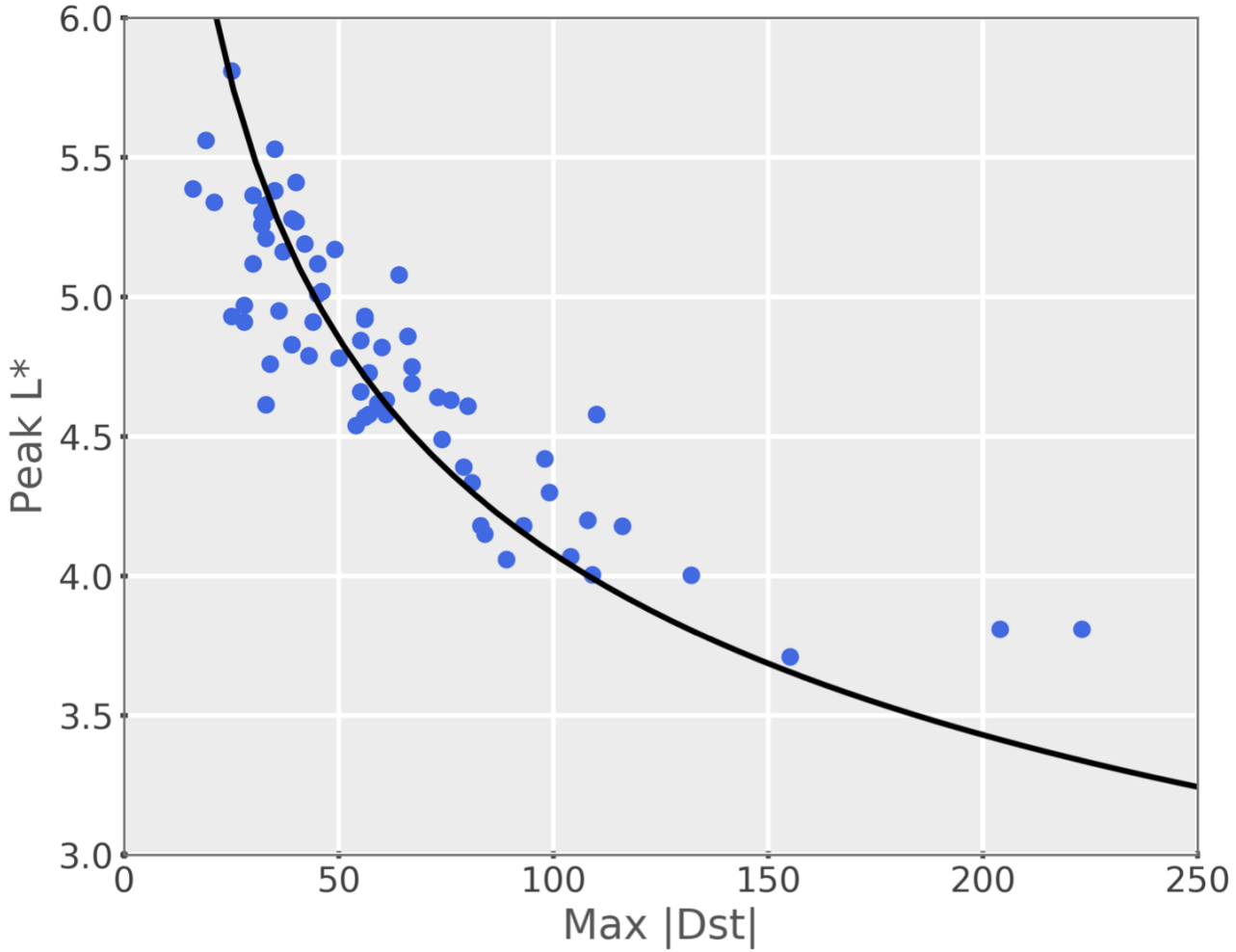
Van Allen-THEMIS Statistics

Events (Stormtime Events)

Event Type	Van Allen Probes Only	THEMIS & Van Allen Probes
Local Acceleration Dominant	24 (22)	**70 (38)**
Other	56 (20)	10 (4)
Total	80 (42)	80 (42)

- **70/80 (87.5 %) of the events have growing peaks, consistent with local acceleration**
- **Local acceleration is observed for both stormtime (Dst < -50 nT) and nonstormtime**

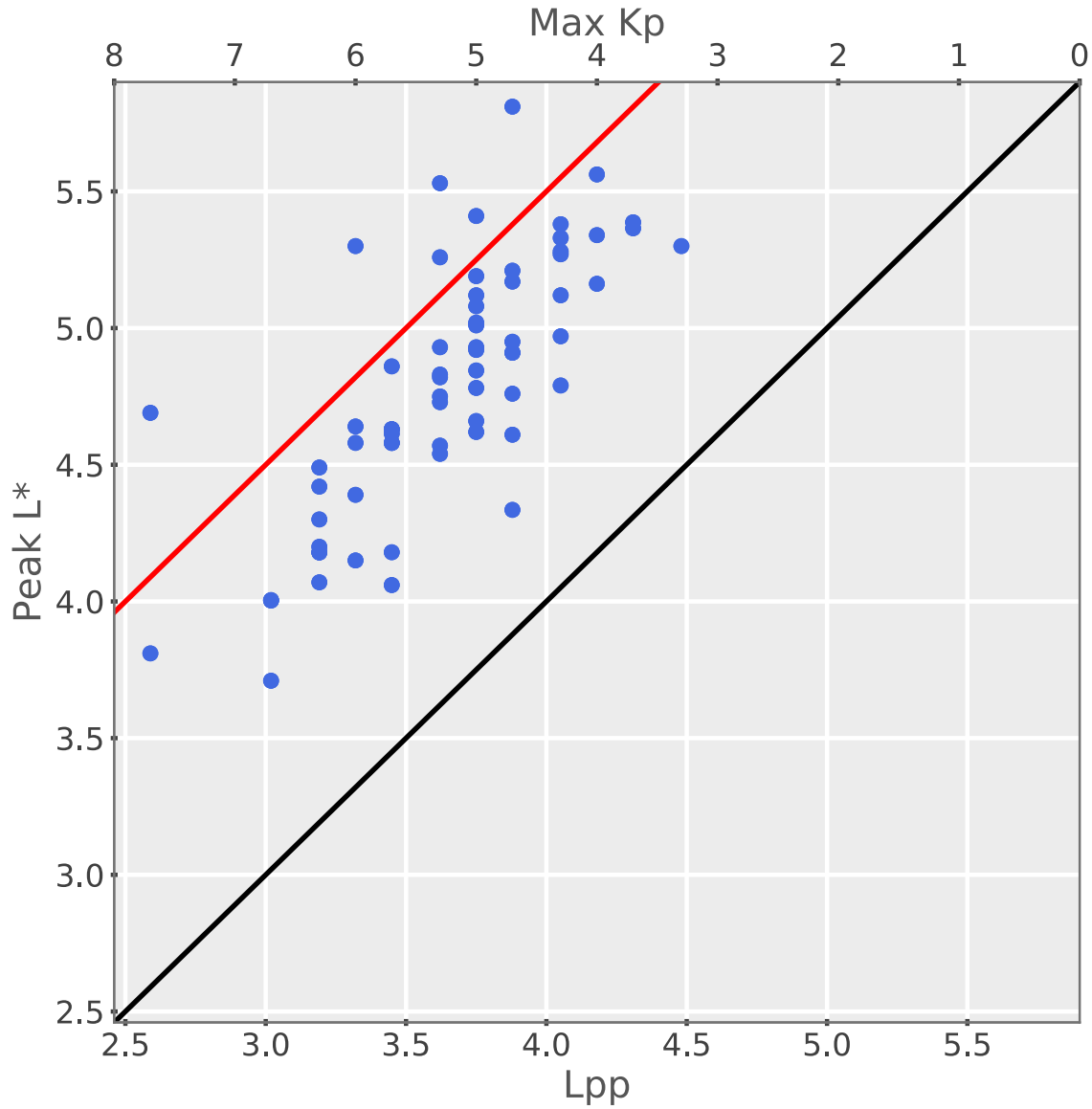
Relation to Dst

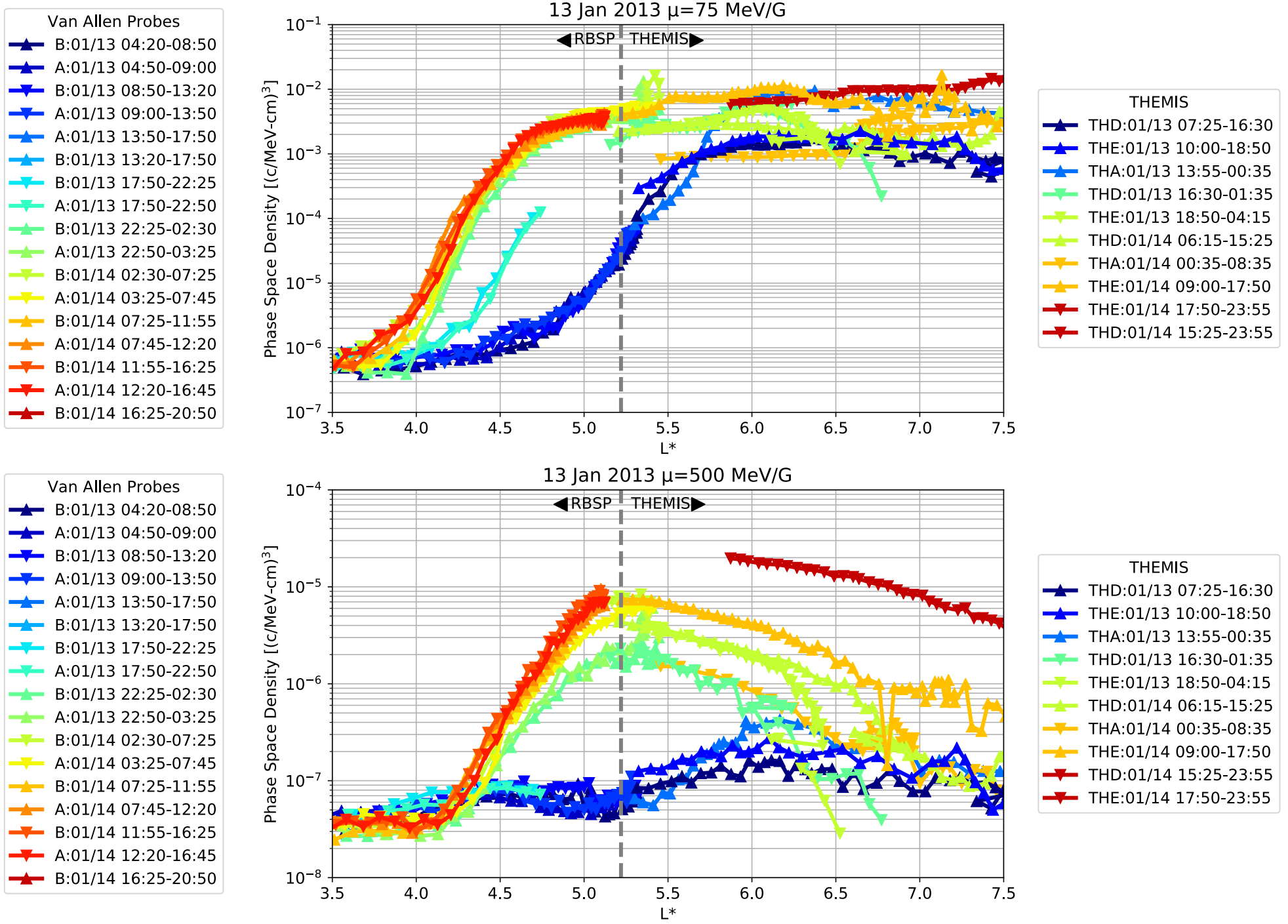


- Relation between minimum Dst and the peak location
- Black line is the relation from Tverskaya et al., 2003
  - $L_{max} = \frac{12.9}{|Dst_{max}|}$

Relation to the Plasmapause

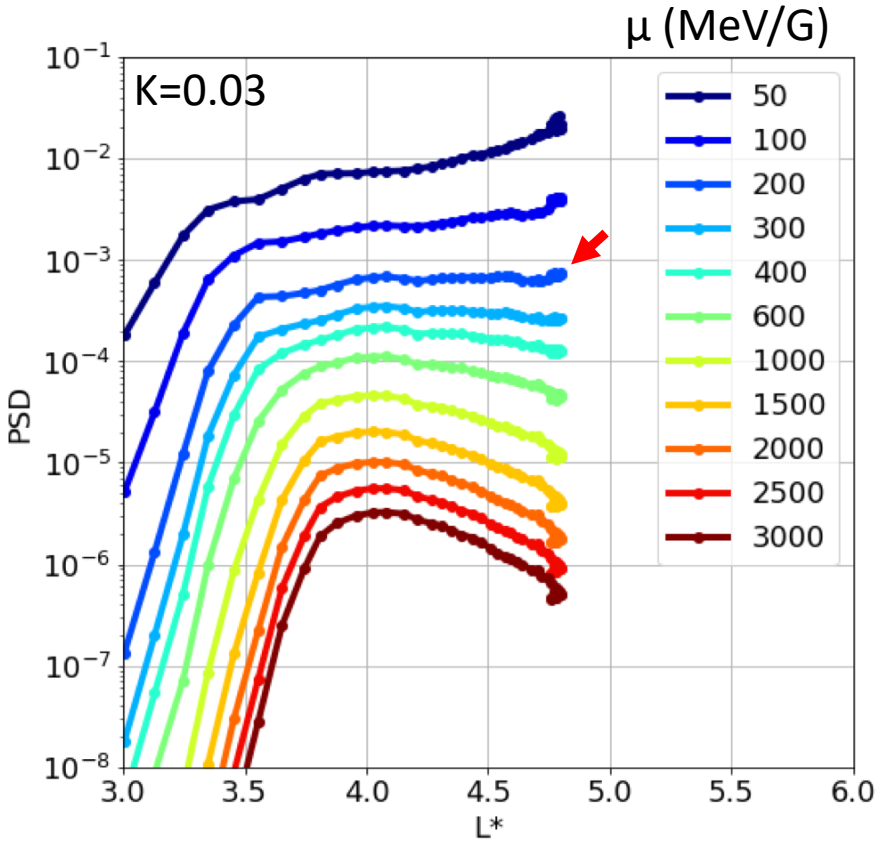
- Relation to the average Plasmapause location from O'Brien and Moldwin [2003] (parameterized by Kp)
- For all events, the peak location is just outside the plasmapause, with 65/70 within 1.5 RE



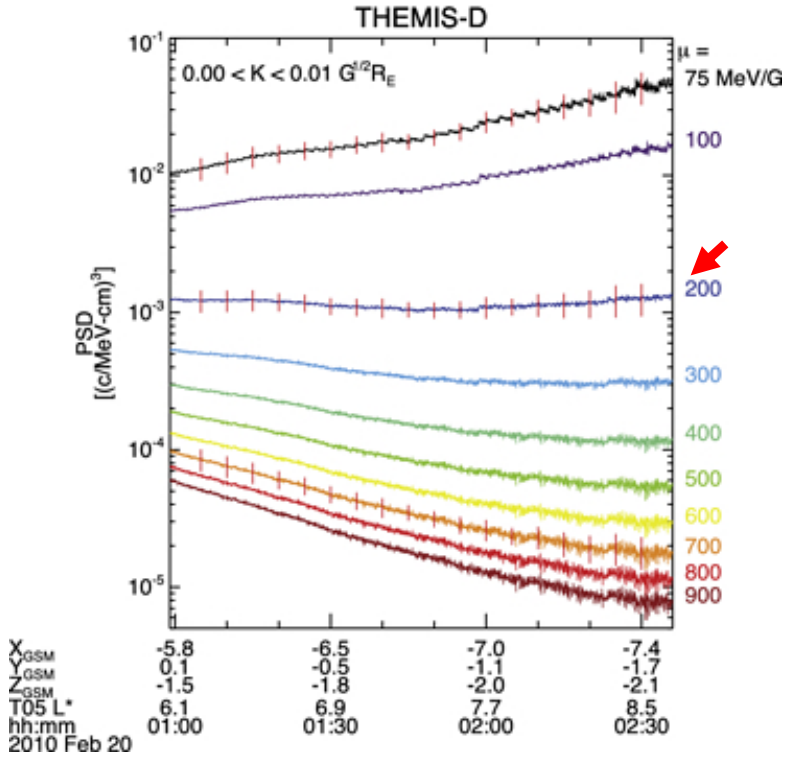

13 Jan 2013 μ=75 MeV/G
RBSP
THEMIS
Phase Space Density [(c/MeV-cm)³]
L*
Van Allen Probes
B:01/13 04:20-08:50
A:01/13 04:50-09:00
B:01/13 08:50-13:20
A:01/13 09:00-13:50
A:01/13 13:50-17:50
B:01/13 13:20-17:50
B:01/13 17:50-22:25
A:01/13 17:50-22:50
B:01/13 22:25-02:30
A:01/13 22:50-03:25
B:01/14 02:30-07:25
A:01/14 03:25-07:45
B:01/14 07:25-11:55
A:01/14 07:45-12:20
B:01/14 11:55-16:25
A:01/14 12:20-16:45
B:01/14 16:25-20:50
THEMIS
THD:01/13 07:25-16:30
THE:01/13 10:00-18:50
THA:01/13 13:55-00:35
THD:01/13 16:30-01:35
THE:01/13 18:50-04:15
THD:01/14 06:15-15:25
THA:01/14 00:35-08:35
THE:01/14 09:00-17:50
THE:01/14 17:50-23:55
THD:01/14 15:25-23:55
13 Jan 2013 μ=500 MeV/G
RBSP
THEMIS
Phase Space Density [(c/MeV-cm)³]
L*
Van Allen Probes
B:01/13 04:20-08:50
A:01/13 04:50-09:00
B:01/13 08:50-13:20
A:01/13 09:00-13:50
A:01/13 13:50-17:50
B:01/13 13:20-17:50
B:01/13 17:50-22:25
A:01/13 17:50-22:50
B:01/13 22:25-02:30
A:01/13 22:50-03:25
B:01/14 02:30-07:25
A:01/14 03:25-07:45
B:01/14 07:25-11:55
A:01/14 07:45-12:20
B:01/14 11:55-16:25
A:01/14 12:20-16:45
B:01/14 16:25-20:50
THEMIS
THD:01/13 07:25-16:30
THE:01/13 10:00-18:50
THA:01/13 13:55-00:35
THD:01/13 16:30-01:35
THE:01/13 18:50-04:15
THD:01/14 06:15-15:25
THA:01/14 00:35-08:35
THE:01/14 09:00-17:50
THD:01/14 15:25-23:55
THE:01/14 17:50-23:55

Mu Dependence of Gradients

- Transition at μ=200 MeV/G
- This corresponds to ~500 keV, which is the critical energy for chorus acceleration [Horne et al. 2005]



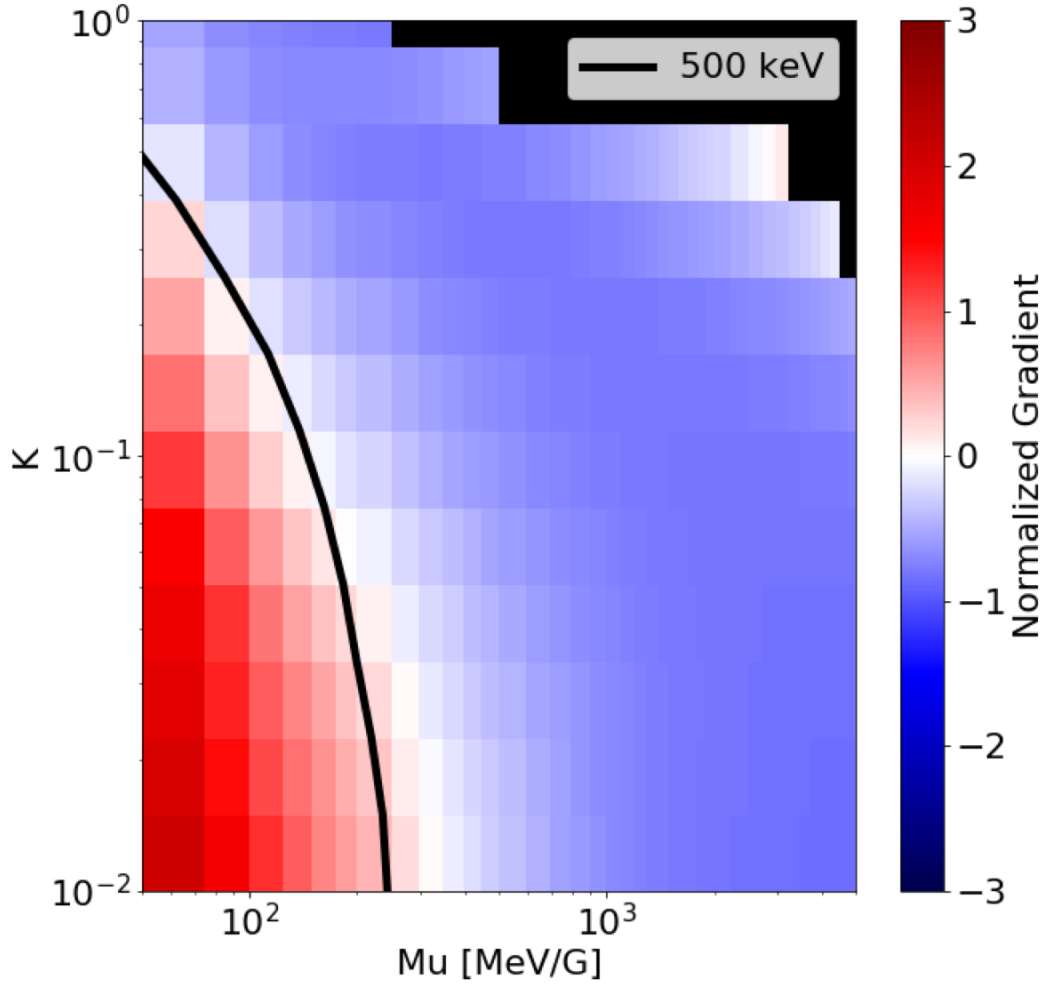
Boyd et al. [2014]

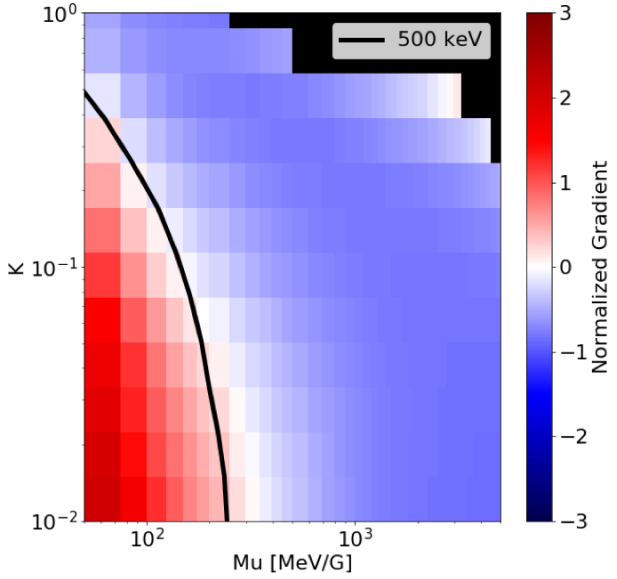


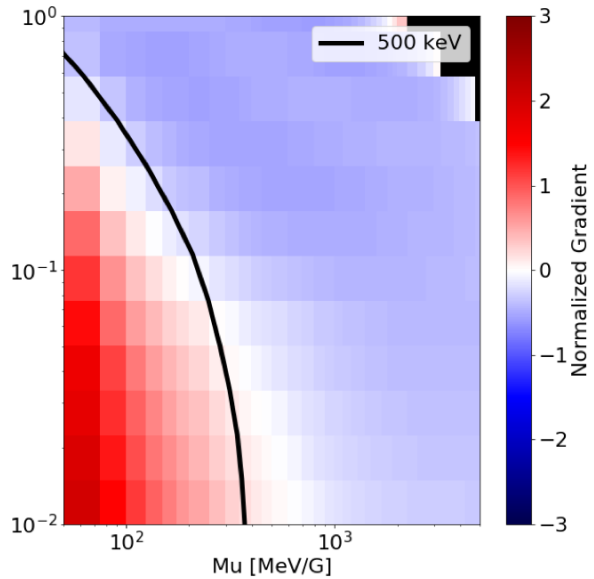
Turner et al. [2012]

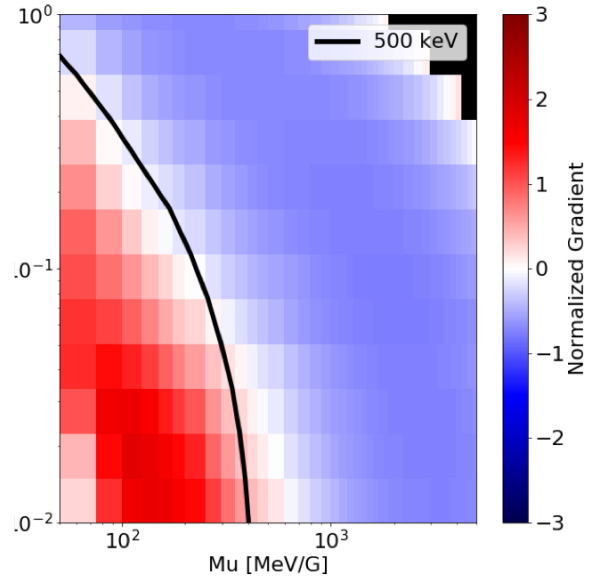
Mu Dependence of Gradients

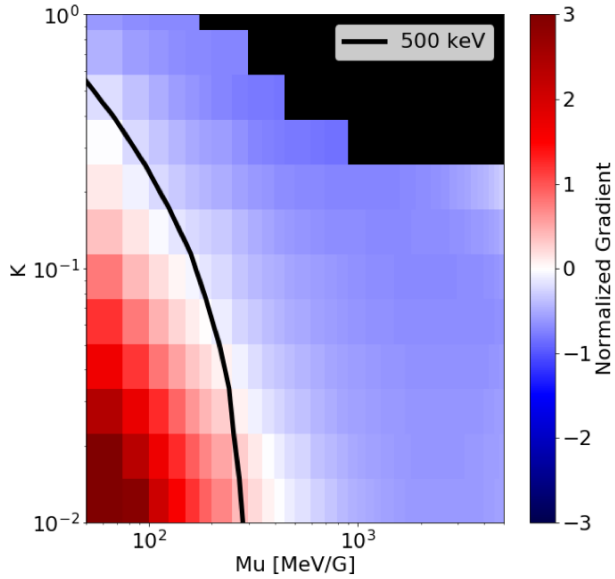
- Normalized gradient:
  - $\frac{PSD_{apogee} - PSD_{peak}}{PSD_{peak}}$
- Blue (negative gradient) indicates a peaked profile

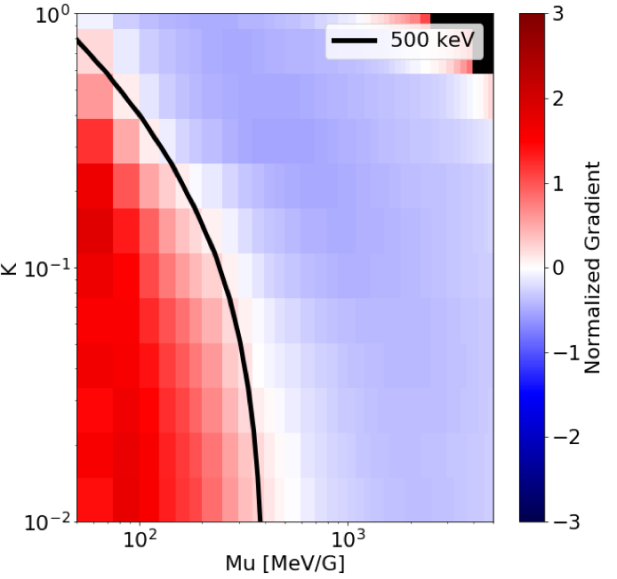


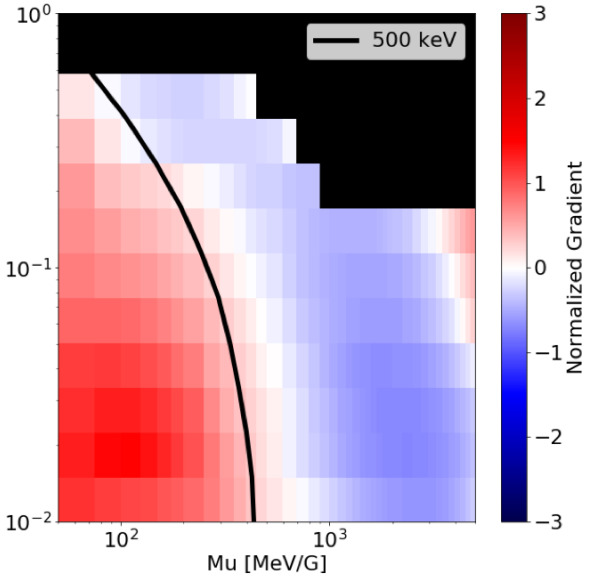

500 keV
K
Mu [MeV/G]
Normalized Gradient

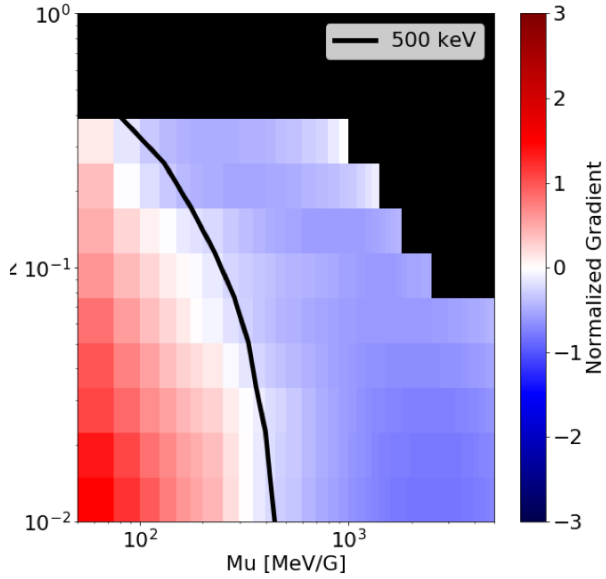

500 keV
Mu [MeV/G]
Normalized Gradient

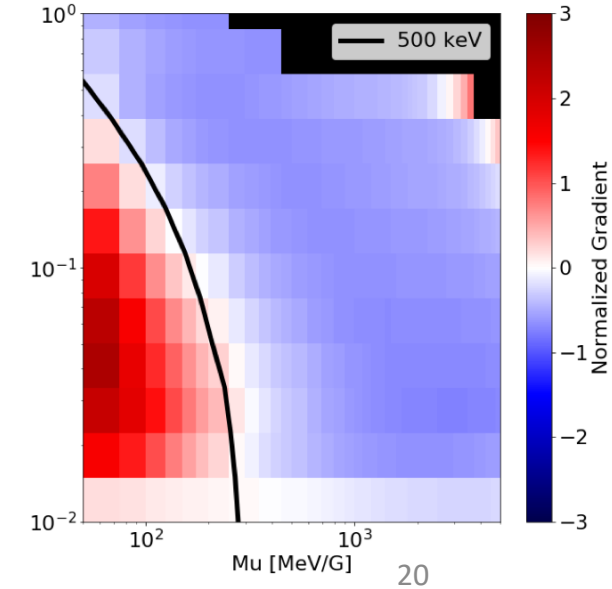

500 keV
Mu [MeV/G]
Normalized Gradient


500 keV
K
Mu [MeV/G]
Normalized Gradient


500 keV
K
Mu [MeV/G]
Normalized Gradient


500 keV
Mu [MeV/G]
Normalized Gradient


500 keV
Mu [MeV/G]
Normalized Gradient


500 keV
Mu [MeV/G]
Normalized Gradient

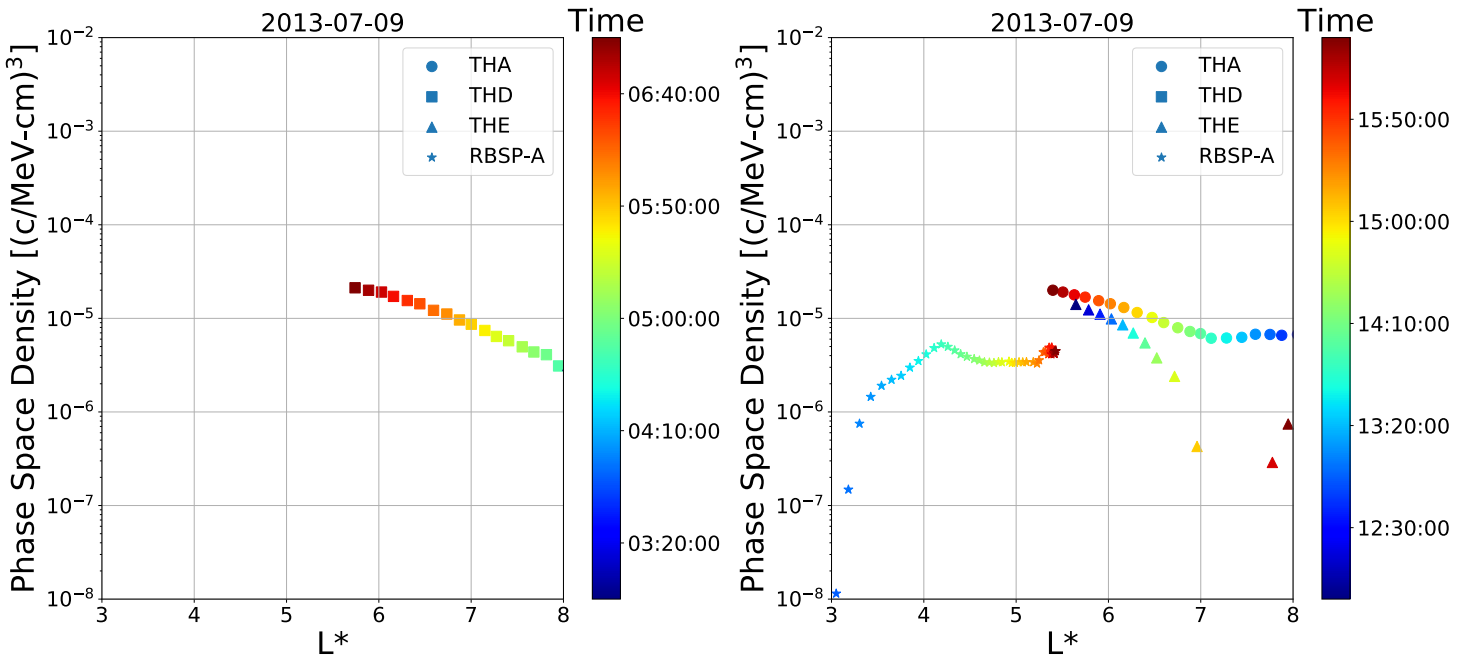
Conclusions

- Local acceleration is the dominant acceleration mechanism for most (87%) MeV electron enhancements
- The radial location of the peak is well correlated with geomagnetic activity
- Local acceleration is observed for both stormtime (min Dst < -50nT) and non-stormtime
- Clear consistent transition between monotonic and peaked profiles at 500 keV (~200 MeV/G in the outer belt)

Backup Slides

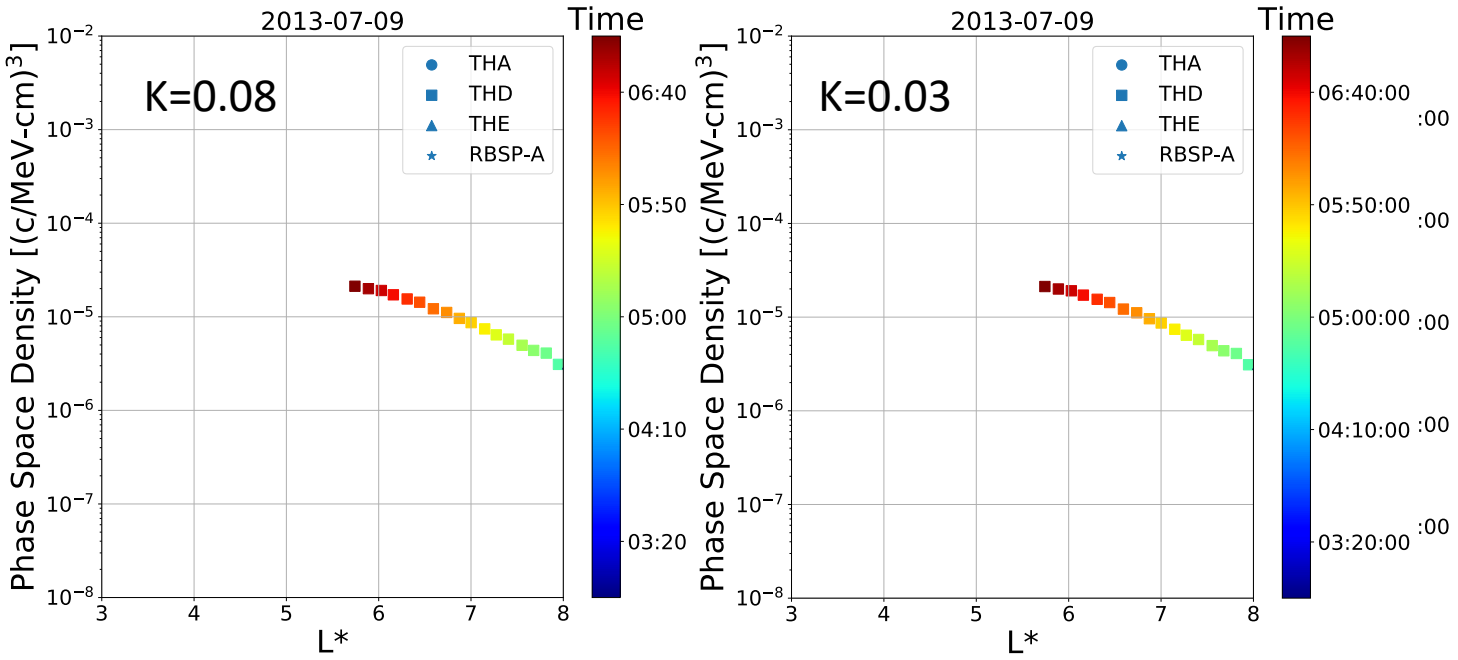
THEMIS-Van Allen Probes Factor

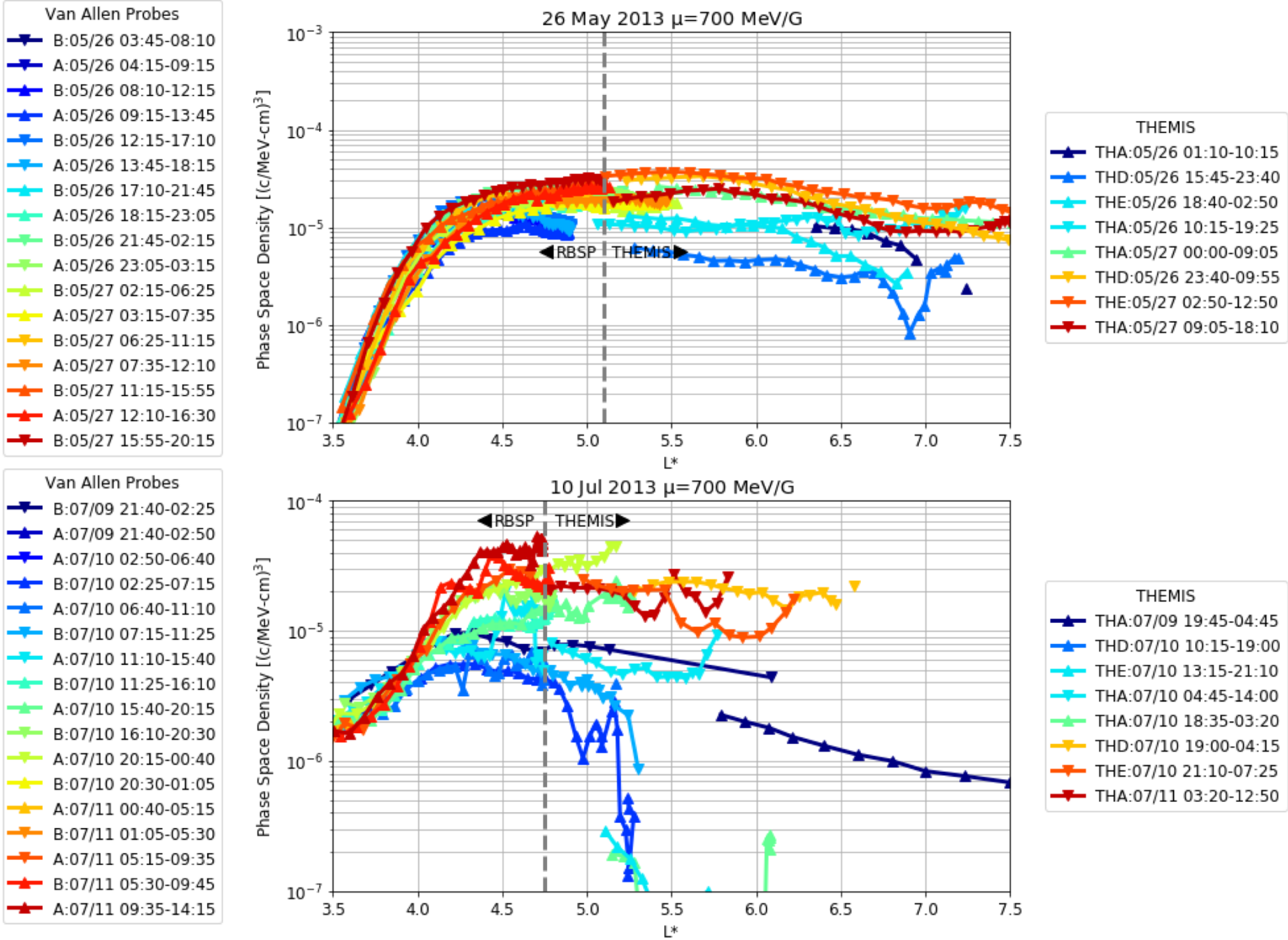
- Match observations during conjunctions (when Van Allen Probes and THEMIS see the same L* at the same time)

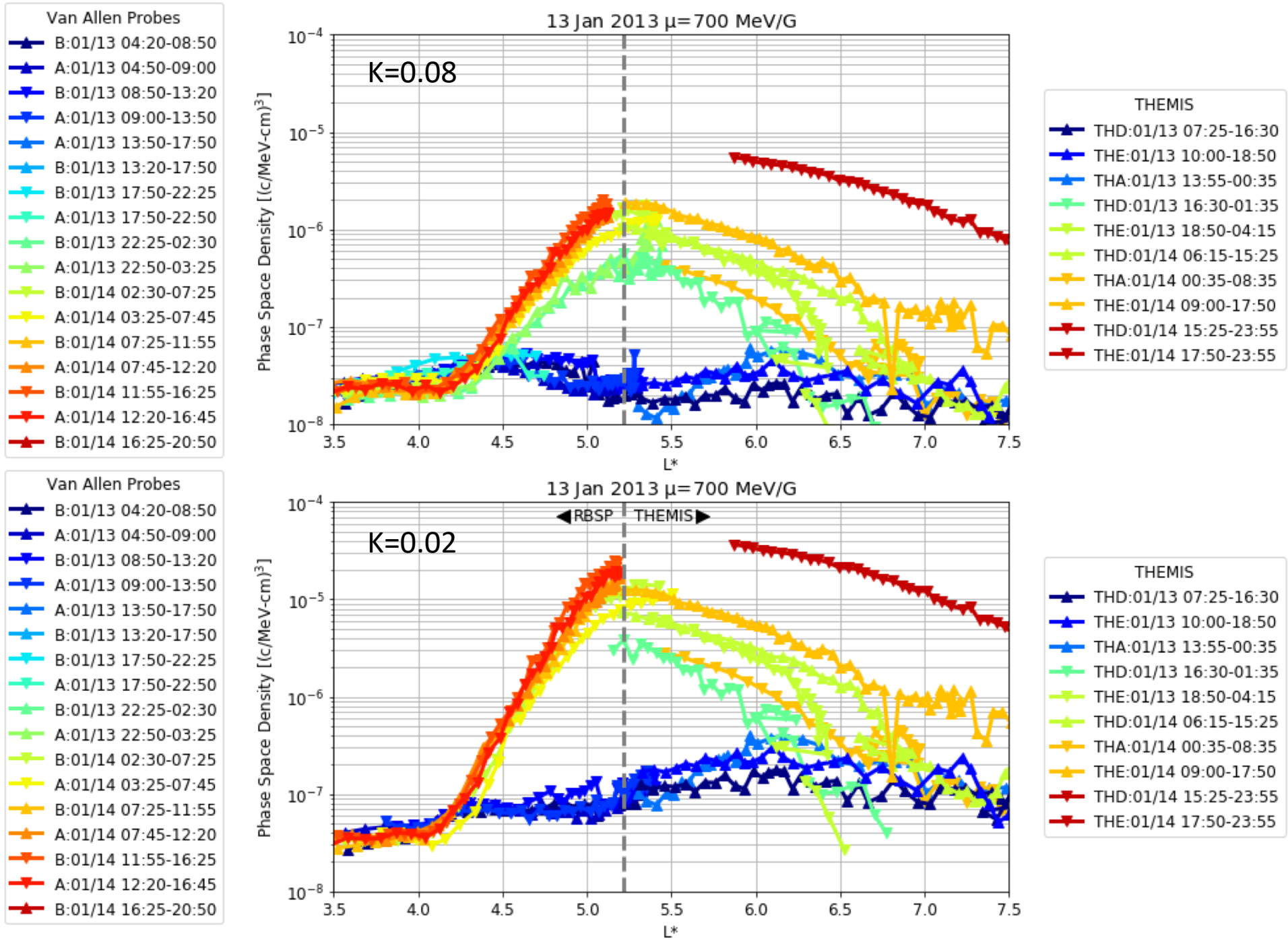


THEMIS-Van Allen Probes Factor (K)

- The factor is largely due to the difference in observed K




Van Allen Probes
B:05/26 03:45-08:10
A:05/26 04:15-09:15
B:05/26 08:10-12:15
A:05/26 09:15-13:45
B:05/26 12:15-17:10
A:05/26 13:45-18:15
B:05/26 17:10-21:45
A:05/26 18:15-23:05
B:05/26 21:45-02:15
A:05/26 23:05-03:15
B:05/27 02:15-06:25
A:05/27 03:15-07:35
B:05/27 06:25-11:15
A:05/27 07:35-12:10
B:05/27 11:15-15:55
A:05/27 12:10-16:30
B:05/27 15:55-20:15
26 May 2013 μ=700 MeV/G
Phase Space Density [(c/MeV-cm)³]
RBSP
THEMIS
L*
THEMIS
THA:05/26 01:10-10:15
THD:05/26 15:45-23:40
THE:05/26 18:40-02:50
THA:05/26 10:15-19:25
THA:05/27 00:00-09:05
THD:05/26 23:40-09:55
THE:05/27 02:50-12:50
THA:05/27 09:05-18:10
Van Allen Probes
B:07/09 21:40-02:25
A:07/09 21:40-02:50
A:07/10 02:50-06:40
B:07/10 02:25-07:15
A:07/10 06:40-11:10
B:07/10 07:15-11:25
A:07/10 11:10-15:40
B:07/10 11:25-16:10
A:07/10 15:40-20:15
B:07/10 16:10-20:30
A:07/10 20:15-00:40
B:07/10 20:30-01:05
A:07/11 00:40-05:15
B:07/11 01:05-05:30
A:07/11 05:15-09:35
B:07/11 05:30-09:45
A:07/11 09:35-14:15
10 Jul 2013 μ=700 MeV/G
Phase Space Density [(c/MeV-cm)³]
RBSP
THEMIS
L*
THEMIS
THA:07/09 19:45-04:45
THD:07/10 10:15-19:00
THE:07/10 13:15-21:10
THA:07/10 04:45-14:00
THA:07/10 18:35-03:20
THD:07/10 19:00-04:15
THE:07/10 21:10-07:25
THA:07/11 03:20-12:50


Van Allen Probes
B:01/13 04:20-08:50
A:01/13 04:50-09:00
B:01/13 08:50-13:20
A:01/13 09:00-13:50
A:01/13 13:50-17:50
B:01/13 13:20-17:50
B:01/13 17:50-22:25
A:01/13 17:50-22:50
B:01/13 22:25-02:30
A:01/13 22:50-03:25
B:01/14 02:30-07:25
A:01/14 03:25-07:45
B:01/14 07:25-11:55
A:01/14 07:45-12:20
B:01/14 11:55-16:25
A:01/14 12:20-16:45
B:01/14 16:25-20:50
13 Jan 2013 μ=700 MeV/G
K=0.08
Phase Space Density [(c/MeV-cm)³]
L*
THEMIS
THD:01/13 07:25-16:30
THE:01/13 10:00-18:50
THA:01/13 13:55-00:35
THD:01/13 16:30-01:35
THE:01/13 18:50-04:15
THD:01/14 06:15-15:25
THA:01/14 00:35-08:35
THE:01/14 09:00-17:50
THD:01/14 15:25-23:55
THE:01/14 17:50-23:55
Van Allen Probes
B:01/13 04:20-08:50
A:01/13 04:50-09:00
B:01/13 08:50-13:20
A:01/13 09:00-13:50
A:01/13 13:50-17:50
B:01/13 13:20-17:50
B:01/13 17:50-22:25
A:01/13 17:50-22:50
B:01/13 22:25-02:30
A:01/13 22:50-03:25
B:01/14 02:30-07:25
A:01/14 03:25-07:45
B:01/14 07:25-11:55
A:01/14 07:45-12:20
B:01/14 11:55-16:25
A:01/14 12:20-16:45
B:01/14 16:25-20:50
13 Jan 2013 μ=700 MeV/G
RBSP
THEMIS
K=0.02
Phase Space Density [(c/MeV-cm)³]
L*
THEMIS
THD:01/13 07:25-16:30
THE:01/13 10:00-18:50
THA:01/13 13:55-00:35
THD:01/13 16:30-01:35
THE:01/13 18:50-04:15
THD:01/14 06:15-15:25
THA:01/14 00:35-08:35
THE:01/14 09:00-17:50
THD:01/14 15:25-23:55
THE:01/14 17:50-23:55

		With THEMIS	With THEMIS
Event Type	**Van Allen Only**	**Growing Peaks**	**No Growing Peaks**
Type 1	24 (22)	**23 (21)**	1 (1)
Type 2	33 (16)	**28 (14)**	5 (2)
Type 3	23 (4)	**19 (3)**	4 (1)