Relativistic Electron Precipitation Observations with CALET

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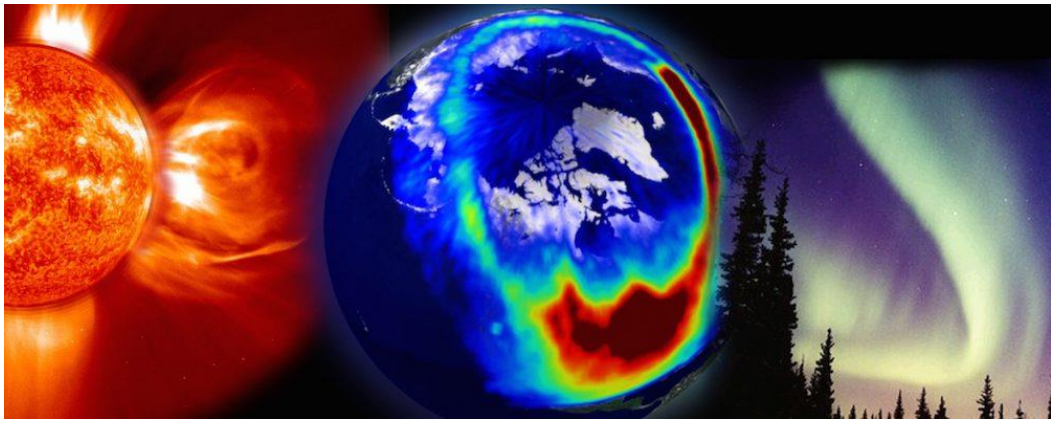
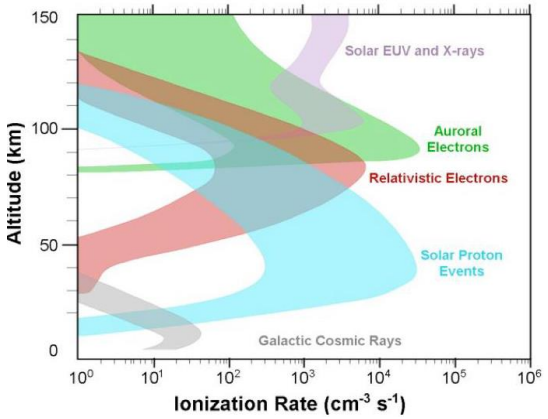
Outline

- Introduction
- Identification of REP Events
- Data Interpretation
- Summary and Future Tasks

Introduction





Relativistic Electron Precipitation (REP) is a Space Weather phenomenon in which energetic electrons from the Sun or the Earth's magnetosphere penetrate into the upper or middle atmosphere, strongly influencing the electrodynamics and chemical structure

Globally, REP events occur mostly during the declining phase of the solar cycle when high-speed streams (recurrent solar wind disturbances) are found and under active geomagnetic conditions

Identification of REP Events

- The data sample used in this analysis consists of LD count rates, in particular, CHDX and CHDY

- To identify REP event candidates, a search was performed using the methods used by Ueno et al. (2020), using data from CALET and the Radiation Burst Monitor (RBM) aboard MAXI on the ISS.

- An event window is flagged when the derivative count rates of the RBM rise above 500 s^{-2} .

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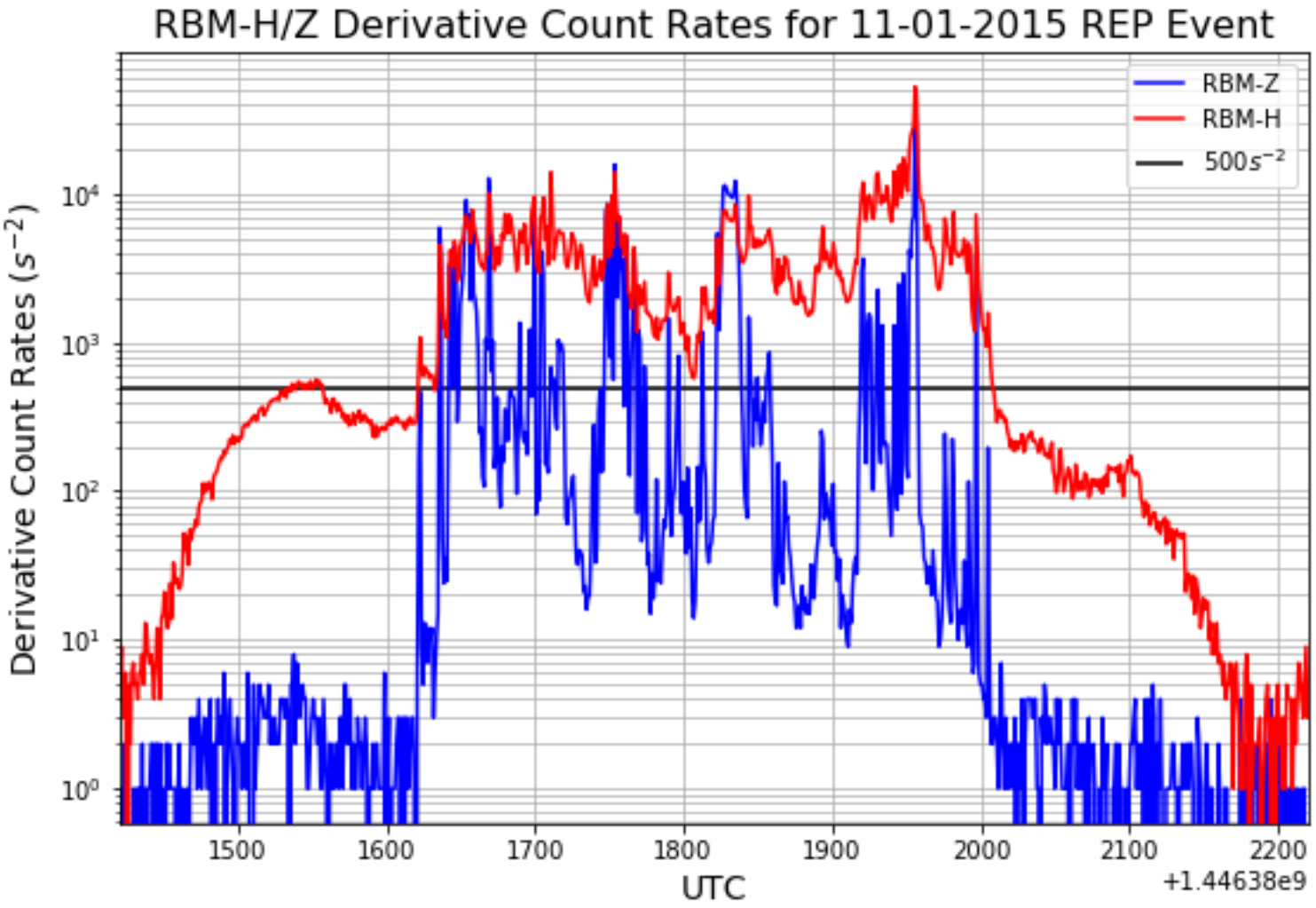

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- Peaks associated with trapped protons in the South Atlantic Anomaly (SAA) are removed by filtering times where B < 0.25 G and L < 2.6 Re.

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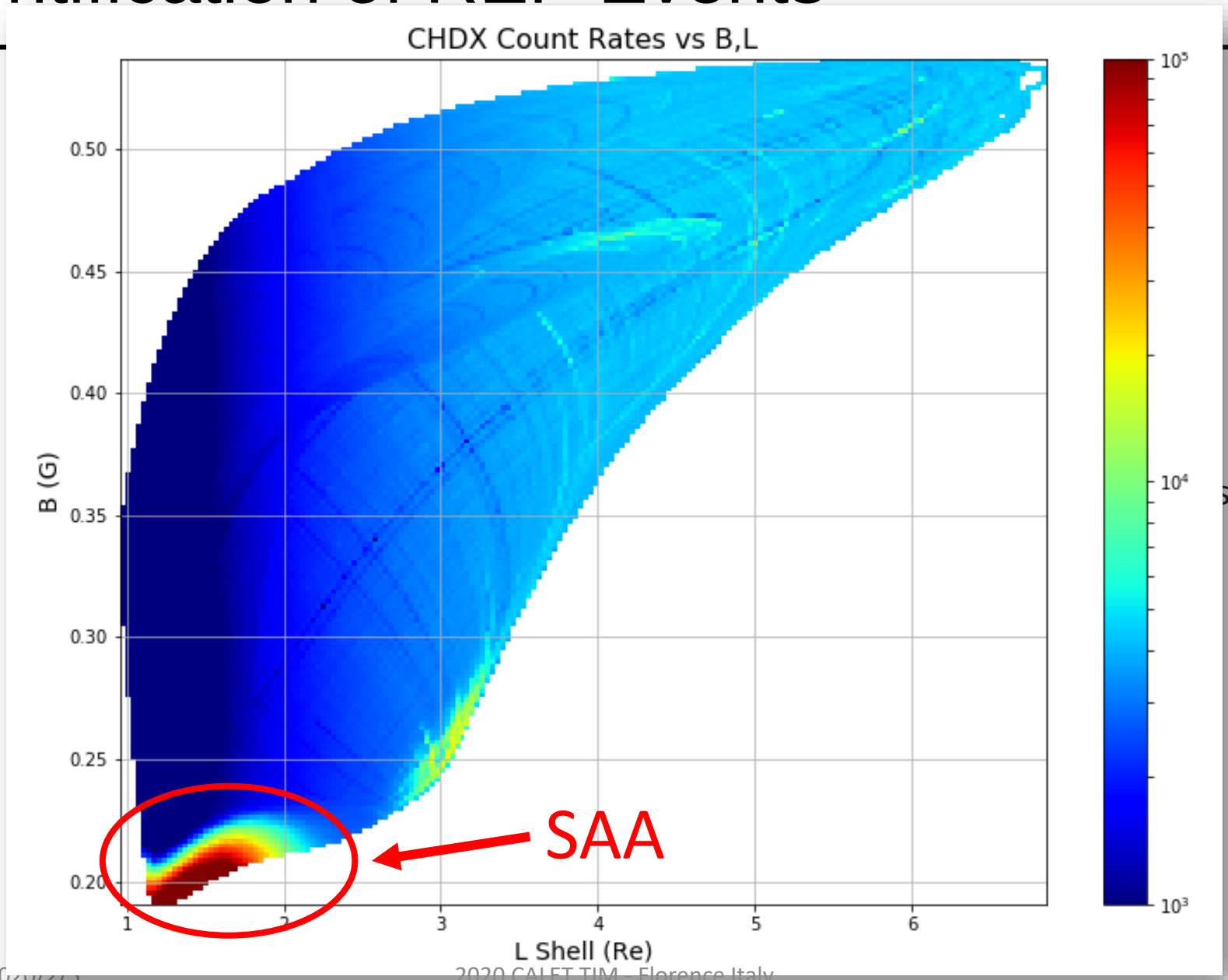

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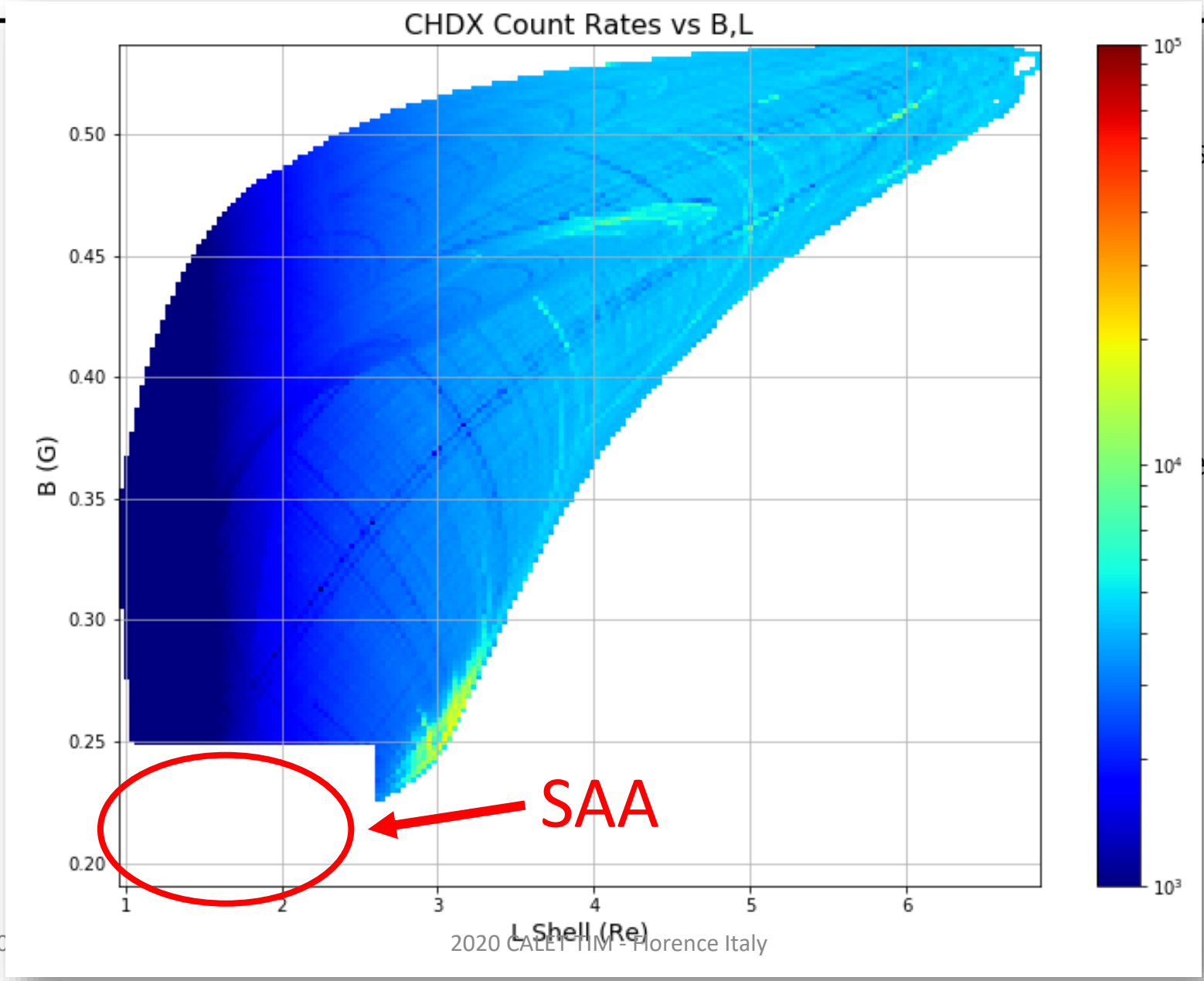

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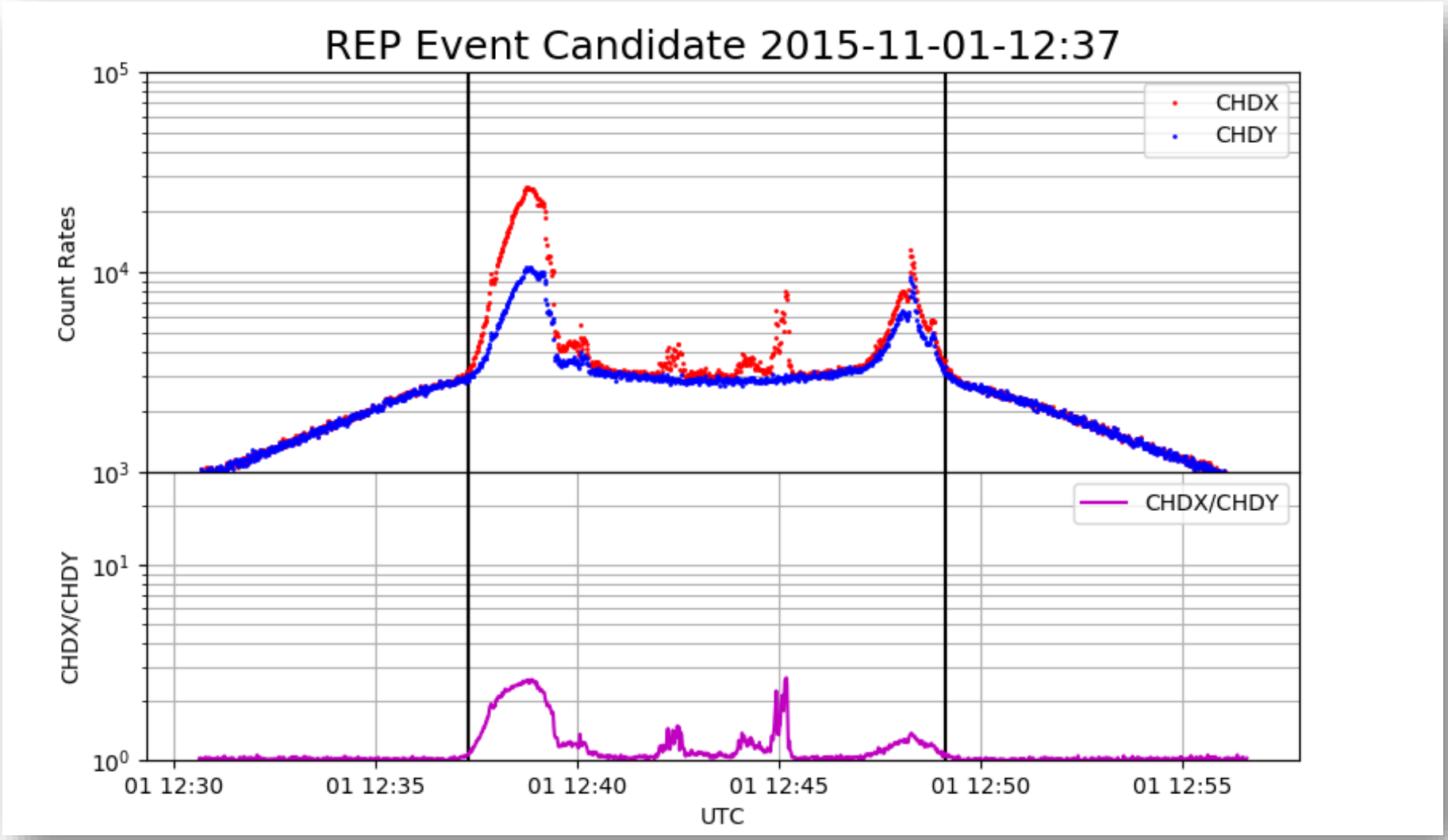

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- Using the International Geomagnetic Reference Field in combination with a dynamical external magnetic field model (Tsyganenko), magnetic local time (MLT), magnetic lat/lon, B, and L are calculated.

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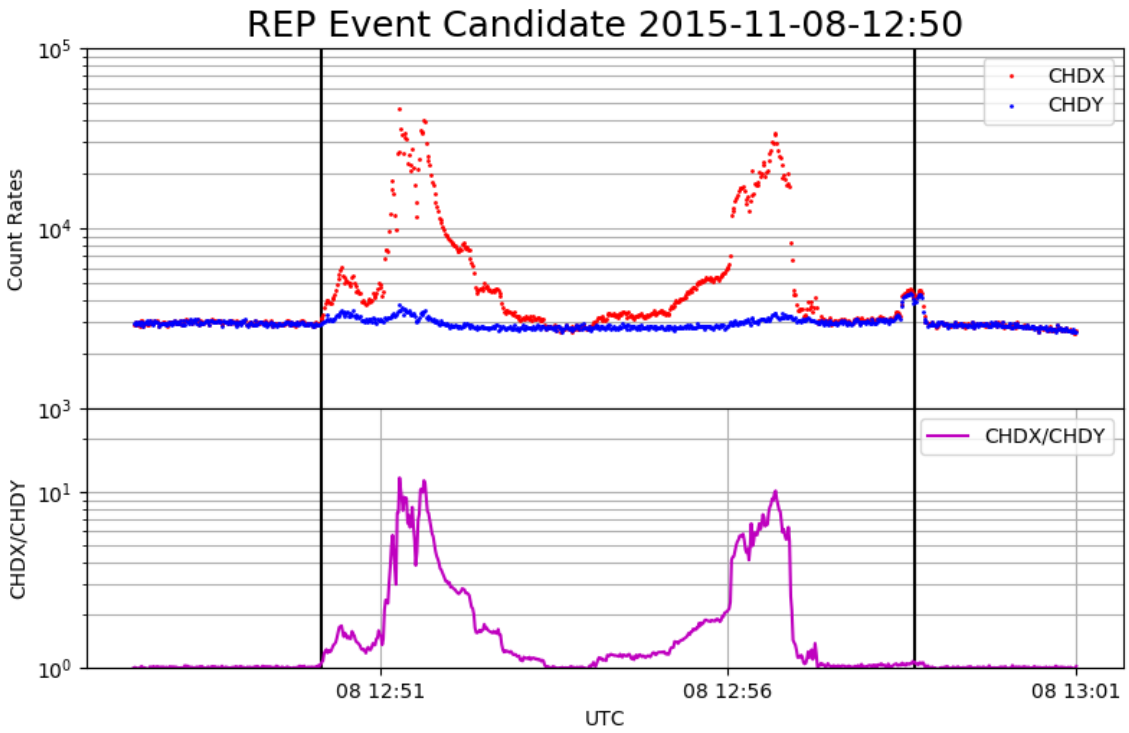
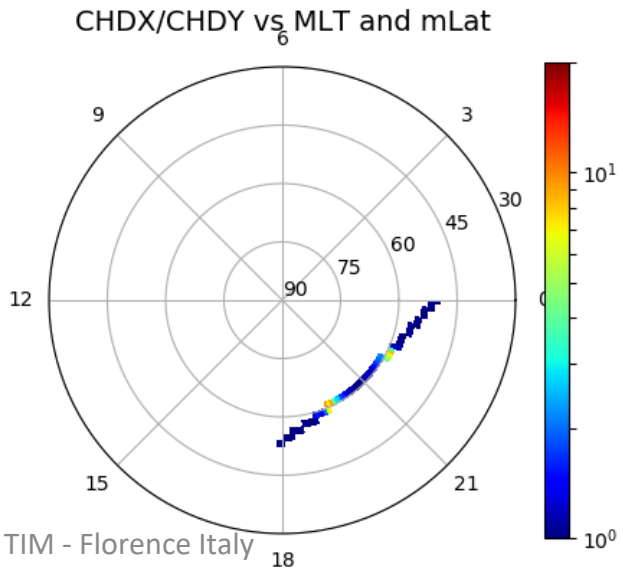


Event ID = 2015 − 11 − 08 − 12 : 50
MLT = 19.55
Start = 12 : 50 : 09.925125
Stop = 12 : 58 : 40.943625
Duration(s) = 511.02
Magnetic Lat = − 59.94
Magnetic Lon = 167.04
B (G) = 0.49
LShell (Re) = 5.49



Identification of REP Events

- The REP event search was verified by comparing to previous results by Ueno et al. who identified 762 event candidates between November 2015 and March 2018.
- Our search identified 848 event candidates during the same time period, but included all 762 event candidates listed by the previous publication.
- The excess 86 events were identified as a result of using a slightly less restrictive SAA cut by using values of B and L in place of latitude and longitude.

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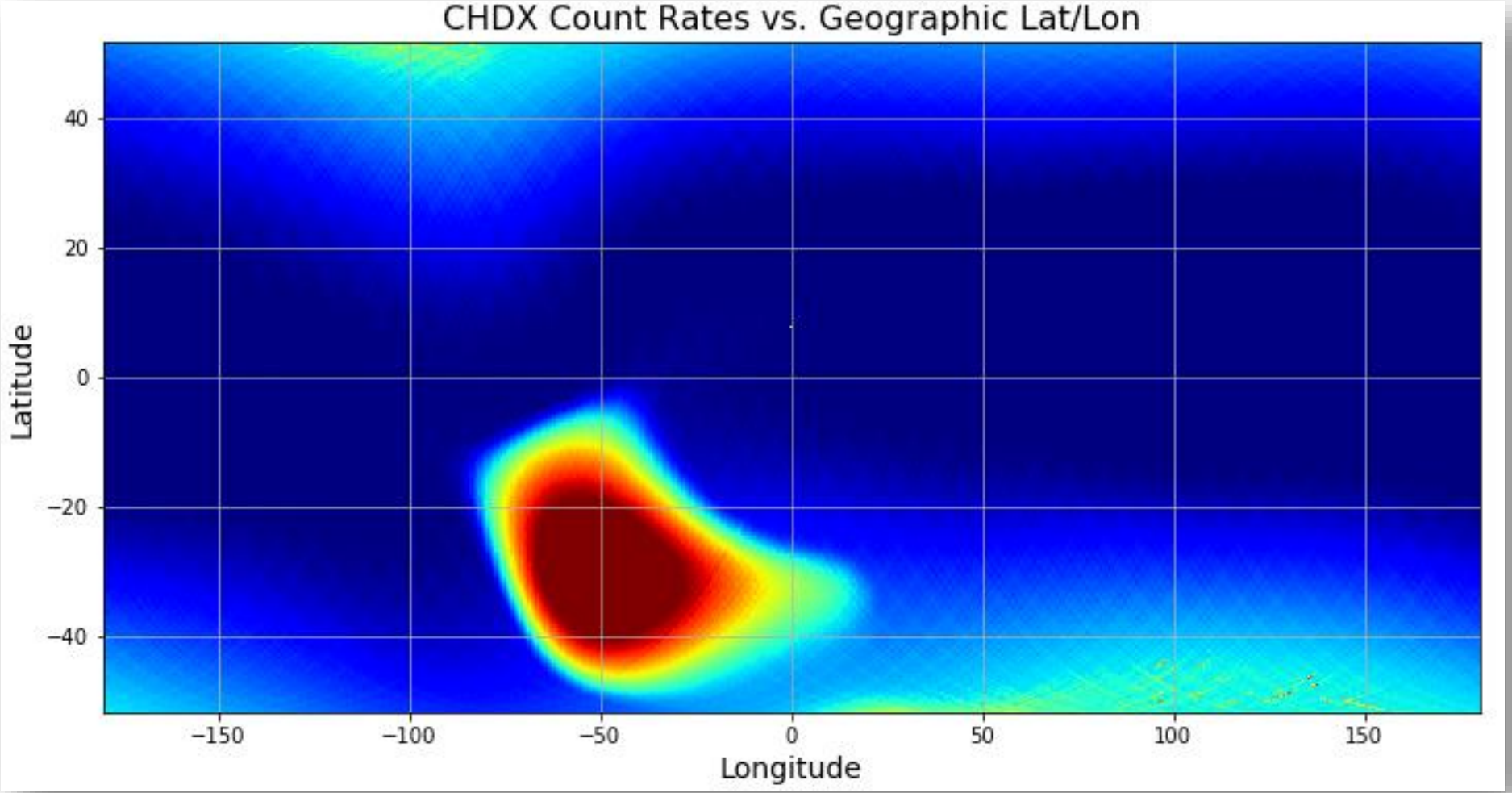

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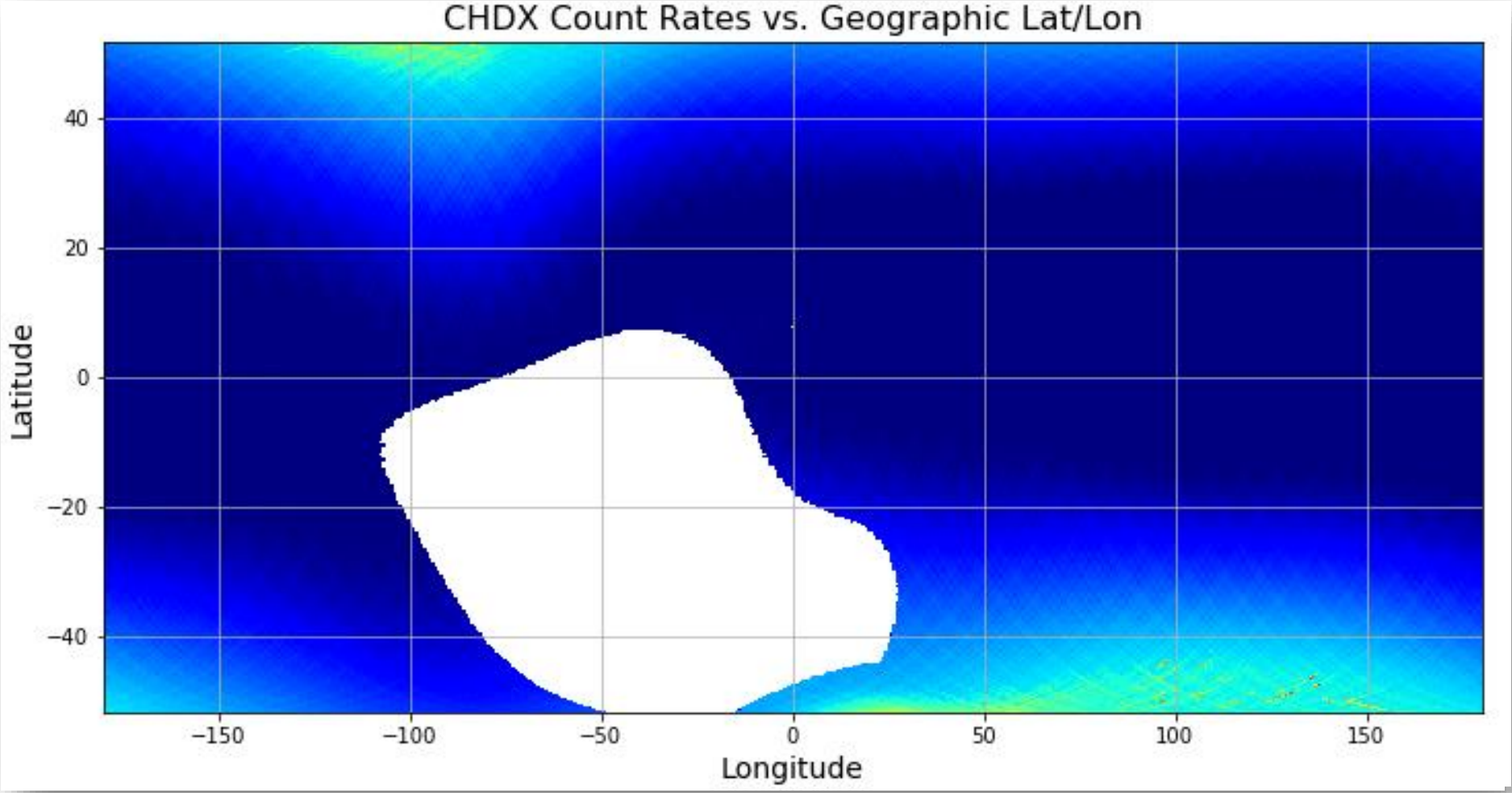

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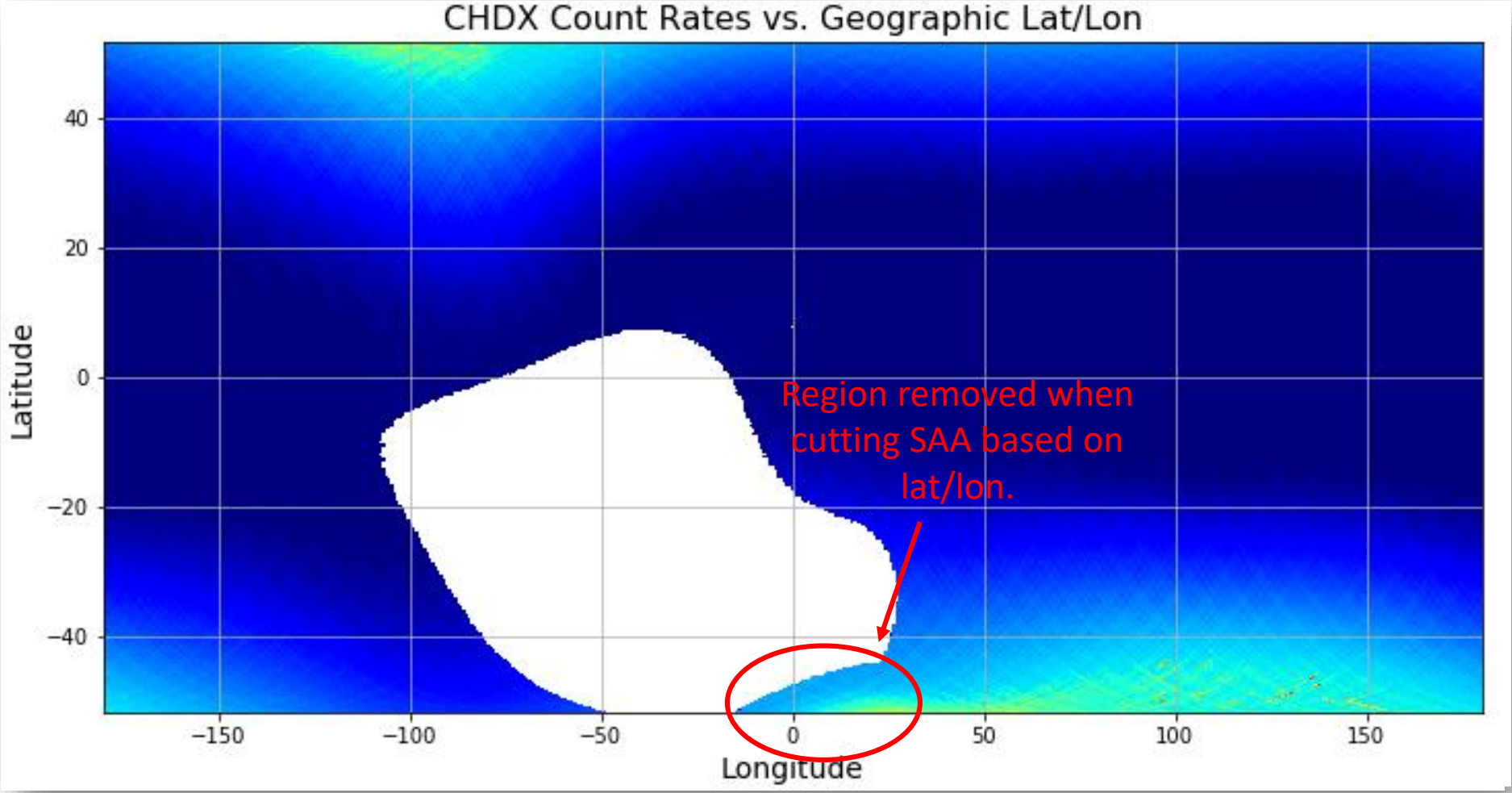

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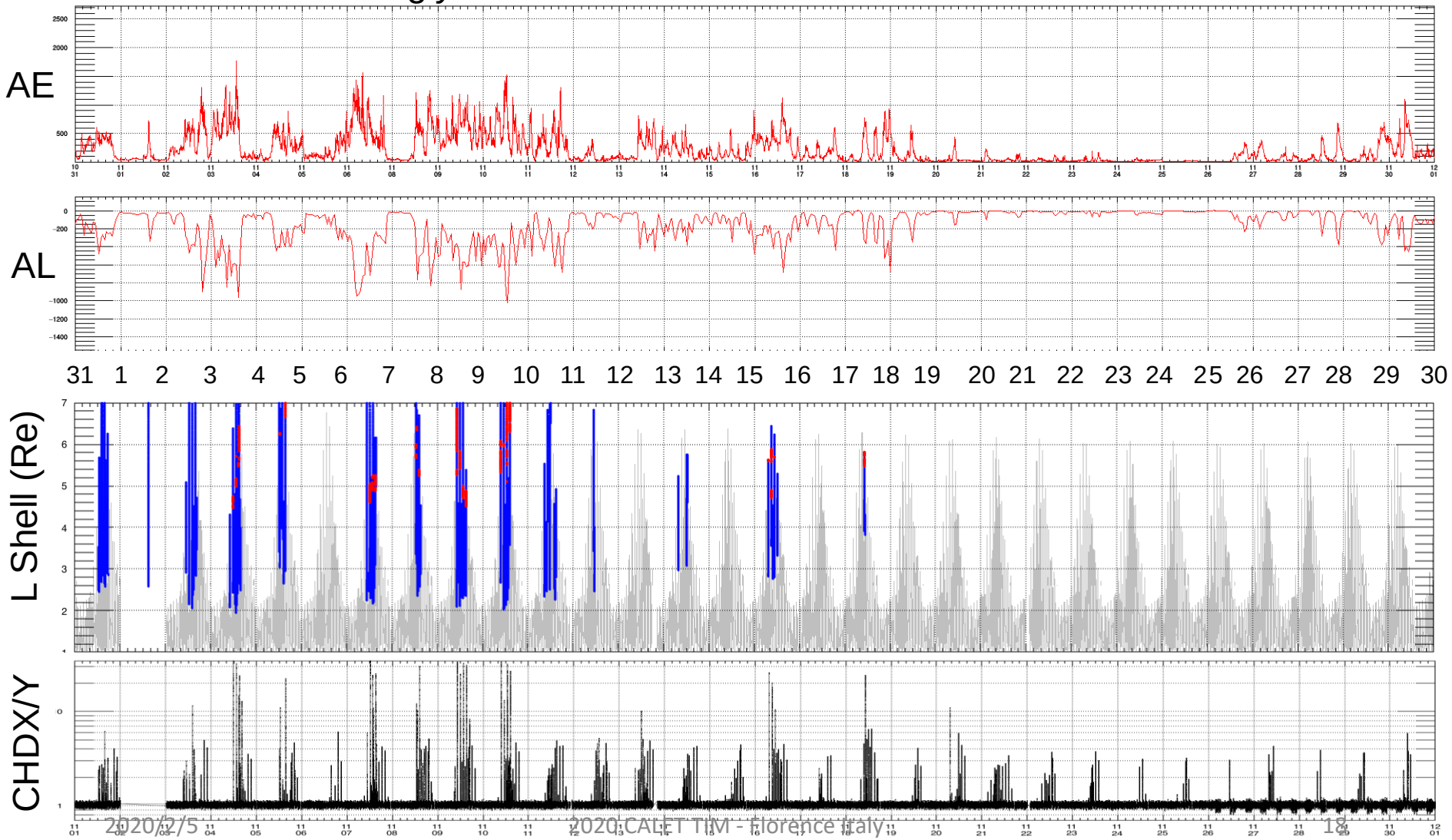
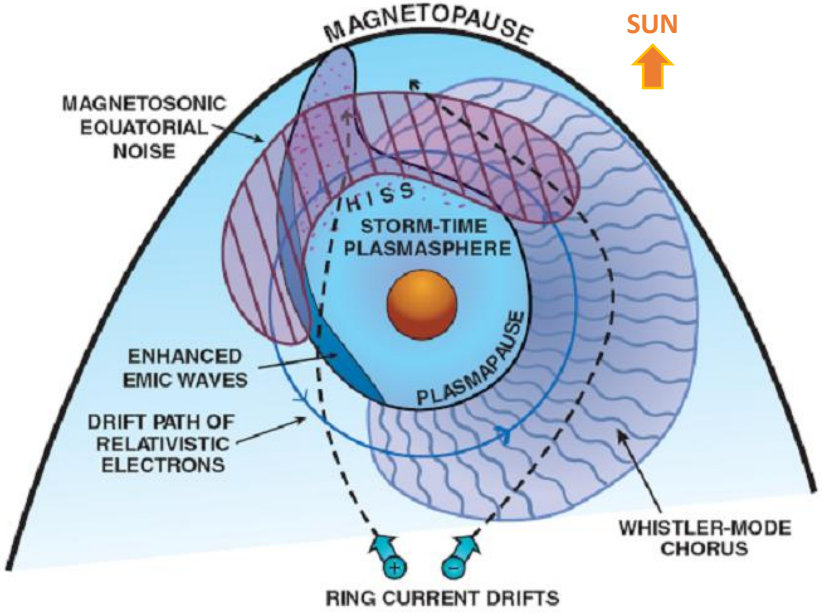
- The excess 86 events were identified as a result of using a slightly less restrictive SAA cut by using values of B and L in place of latitude and longitude.
- For a period between November 2015 and September 2019, a total of 1020 events candidates were found and catalogued.

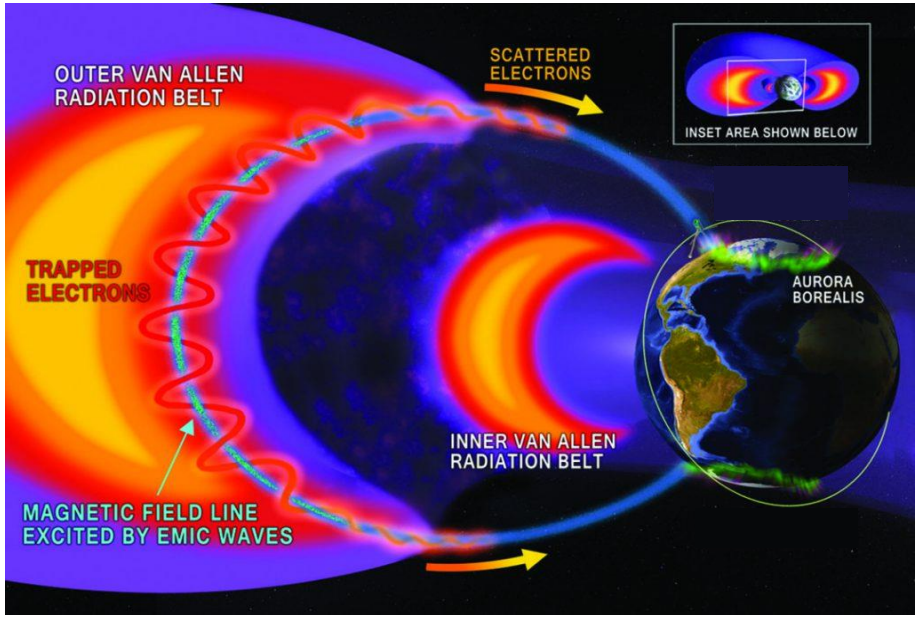
Correlation with geomagnetic activity

- REP events are typically registered during the decaying phase of geomagnetic storms and are strongly correlated with the aurora index.



Source mechanisms for REP





- Scattering of relativistic electrons by electromagnetic ion cyclotron (EMIC) waves is a good candidate for the precipitation mechanism of MeV events.

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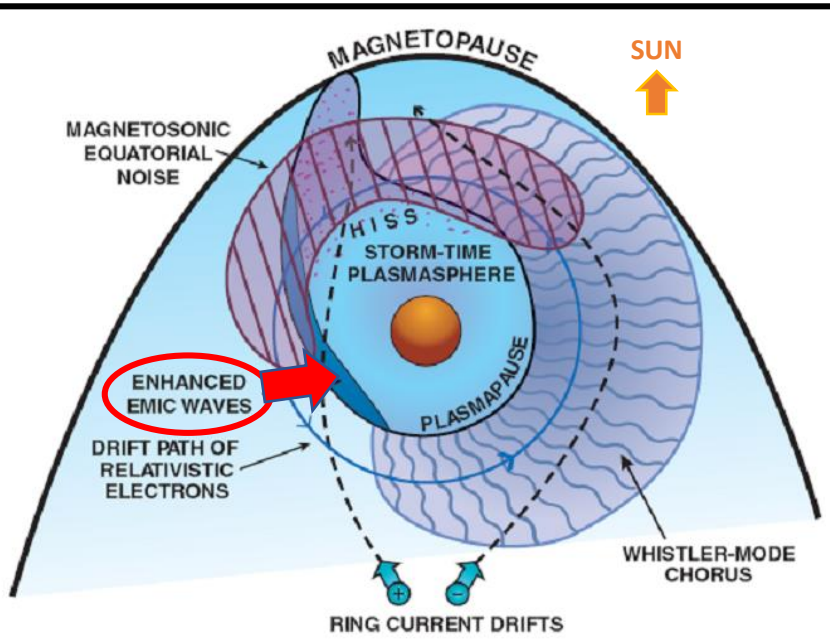
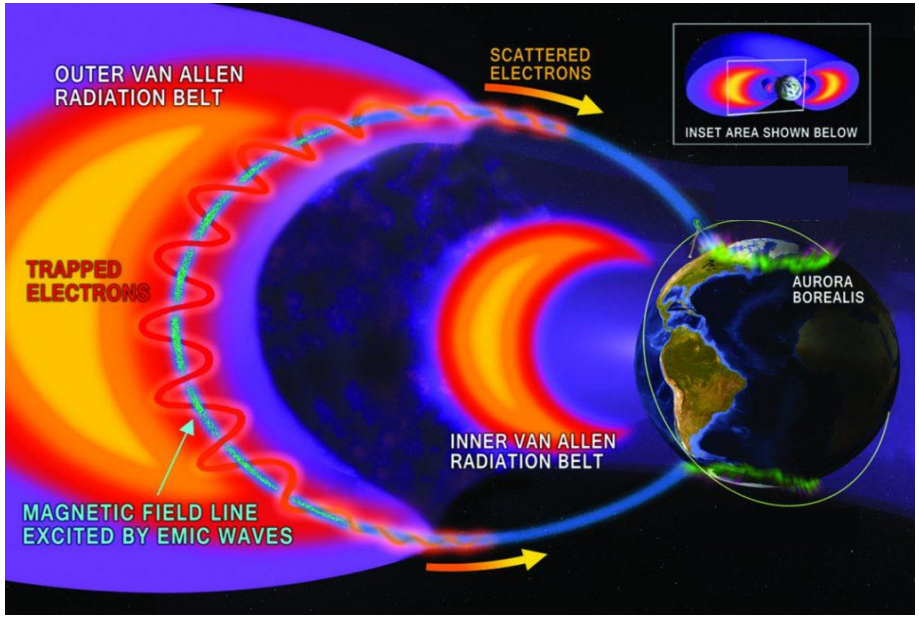
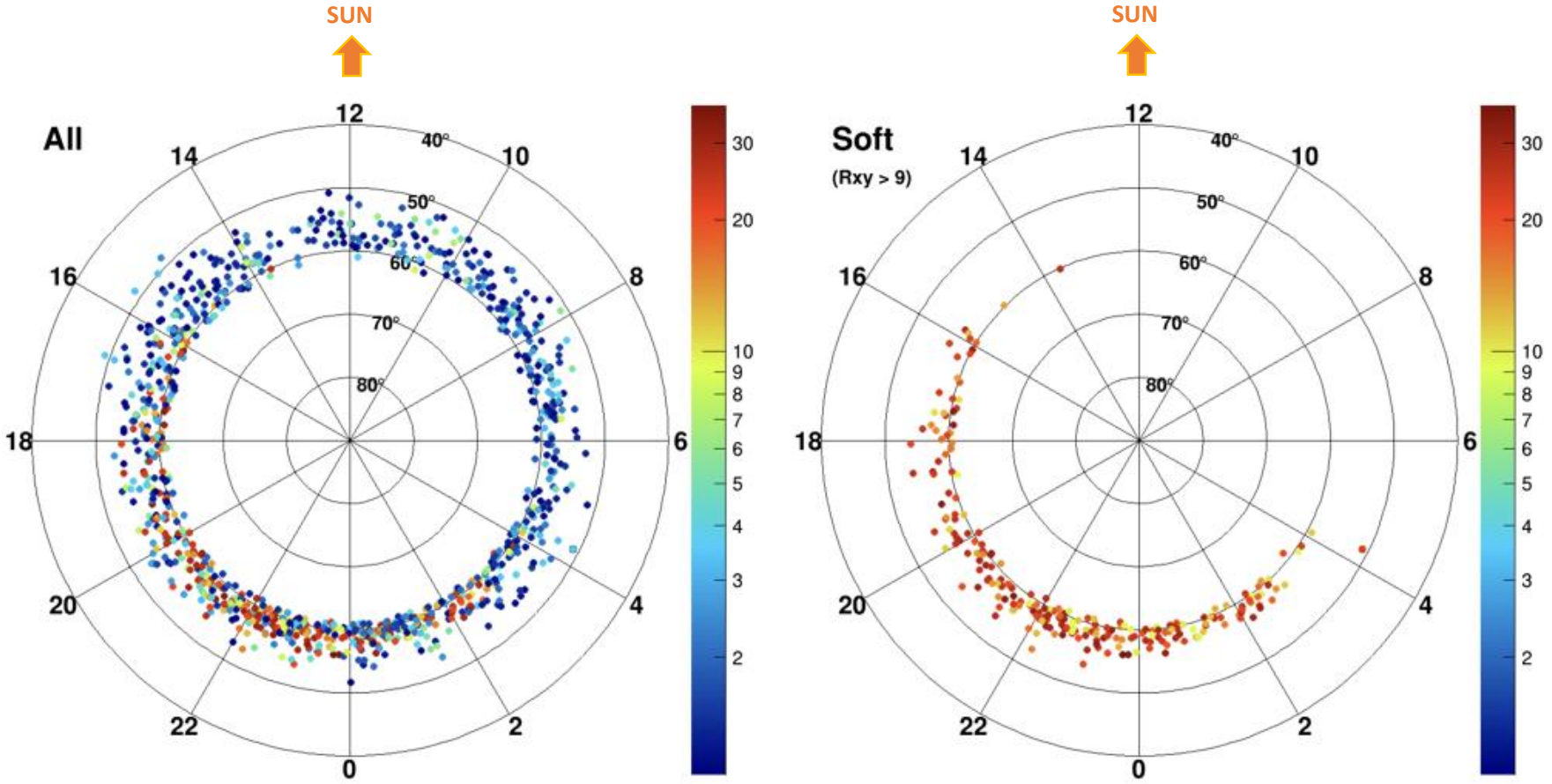




- Scattering of relativistic electrons by electromagnetic ion cyclotron (EMIC) waves is a good candidate for the precipitation mechanism of MeV events.

- These waves are observed along the plasmapause boundary in the dusk sector where the plasmapause bulges outward.

Spatial distribution of REP Events



Distribution of REP events as a function of magnetic latitude and magnetic local time (MLT). Each point corresponds to the position of the highest CHDX/CHDY count-rate ratio (color code) during the corresponding REP event.

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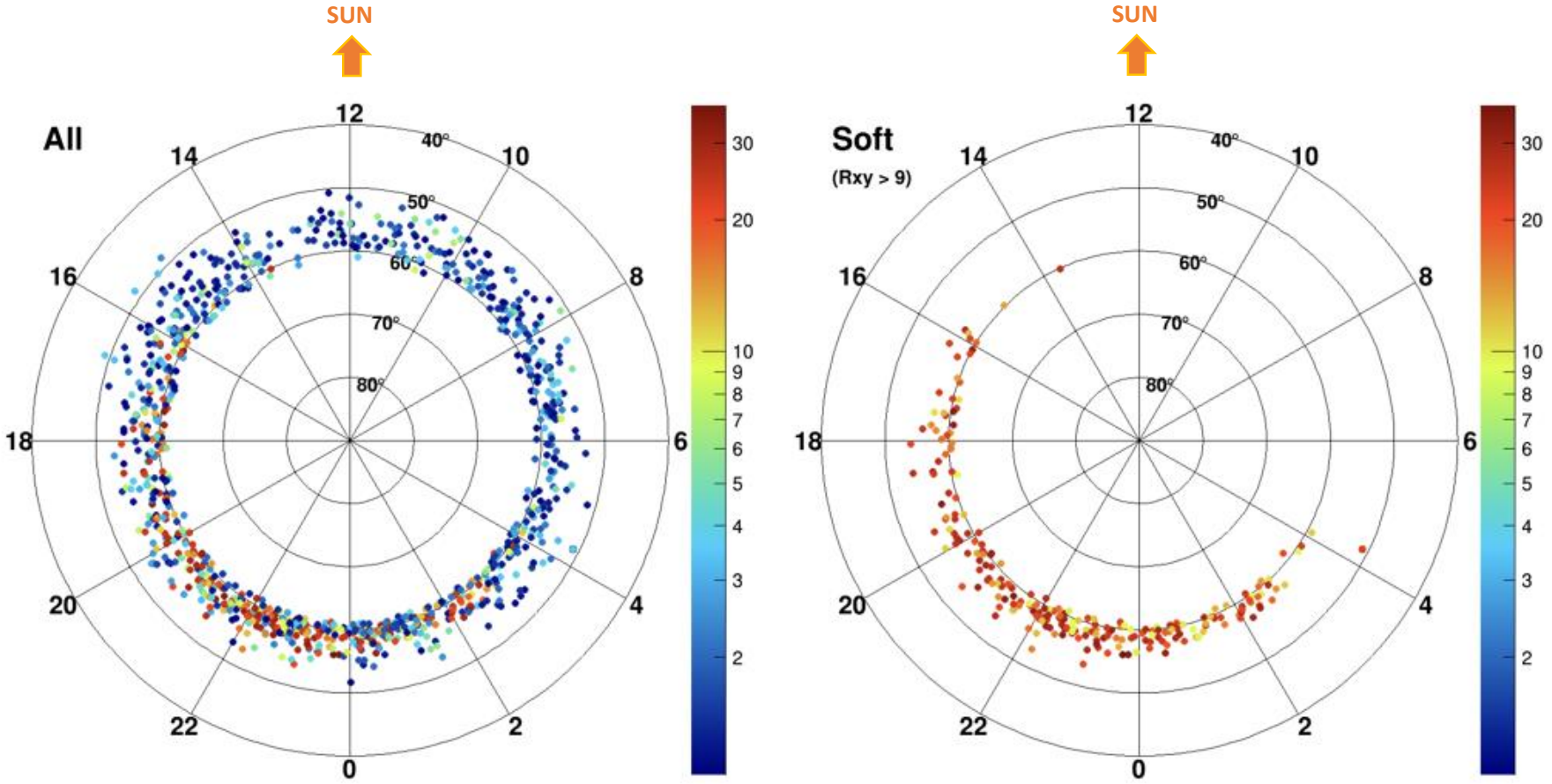
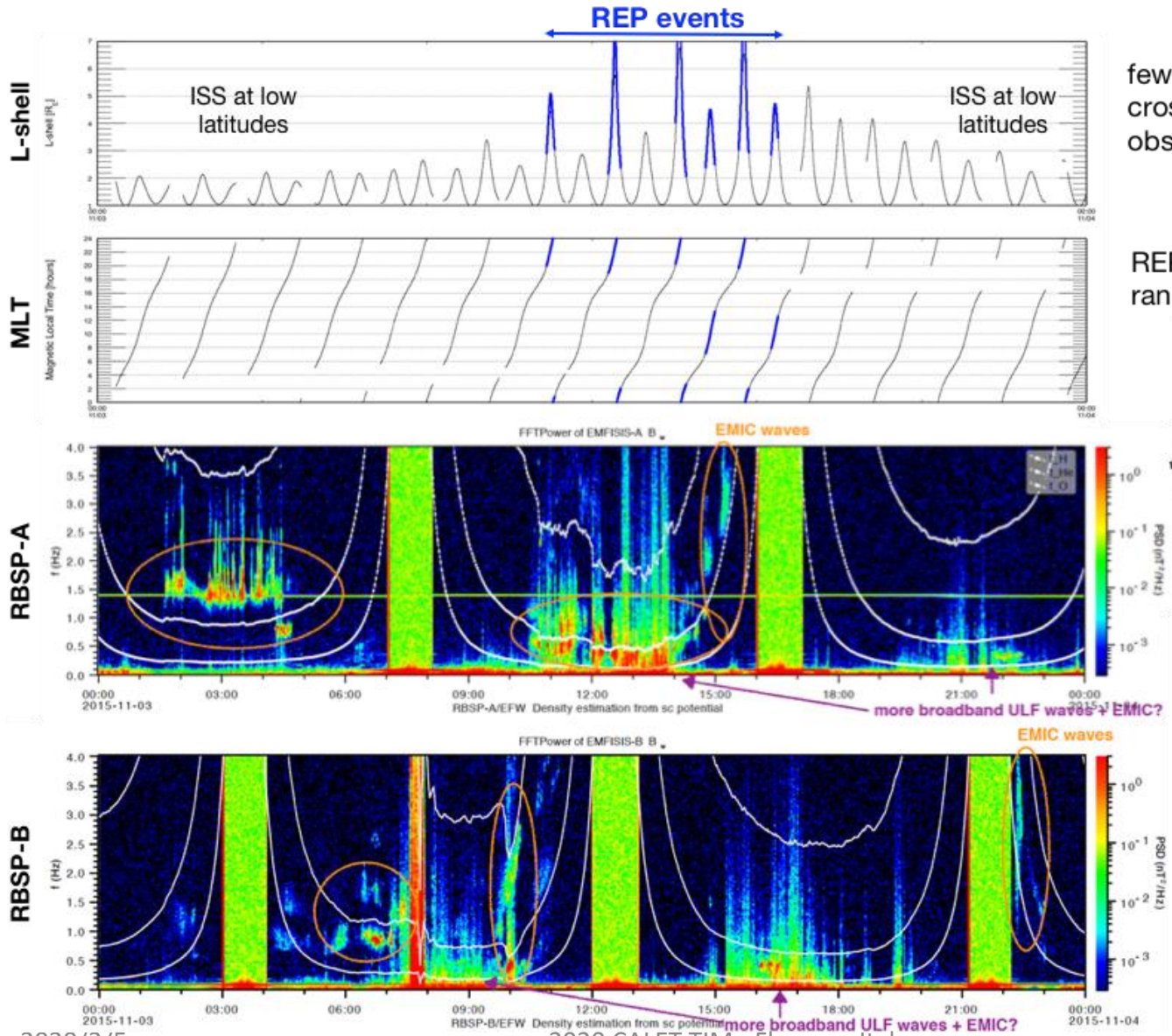


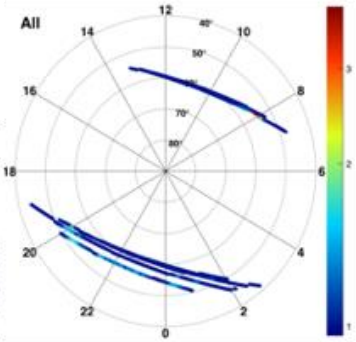
Events with high CHDX/CHDY ratio value (soft spectra, right panel) concentrate around the pre-midnight sector (dawn/dusk asymmetry), and can be the result of a very efficient precipitation associated with EMIC waves. The more uniform background with lower ratio can be likely attributed to "loss cone" electrons.

Correlation with EMIC waves



few outer radiation belt crossings, REPs observed at L>3-4 Re

REP events in a wide MLT range (when at L>3-4)



EMIC waves typically occur below and approaching the ion cyclotron frequencies (marked with white lines) and at discrete frequencies (compared to the more broadband ULF waves that occur at other times)

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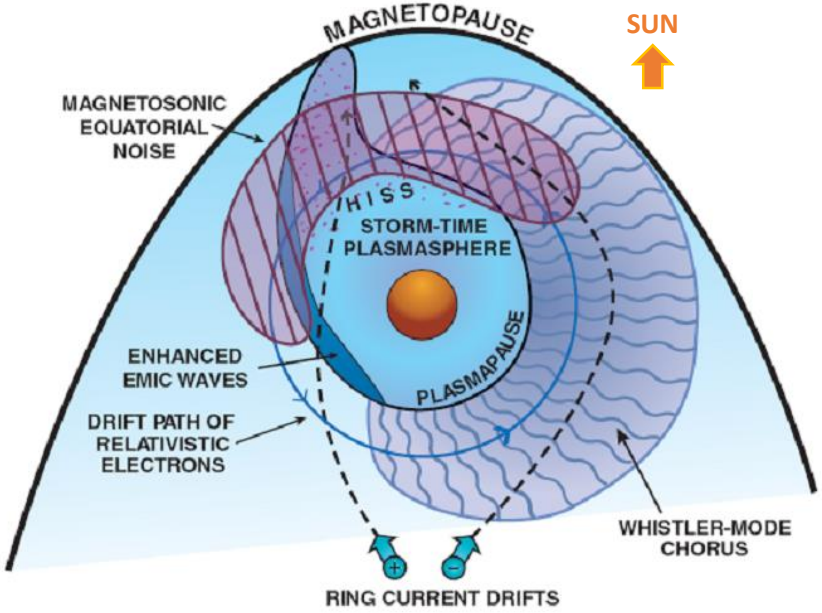

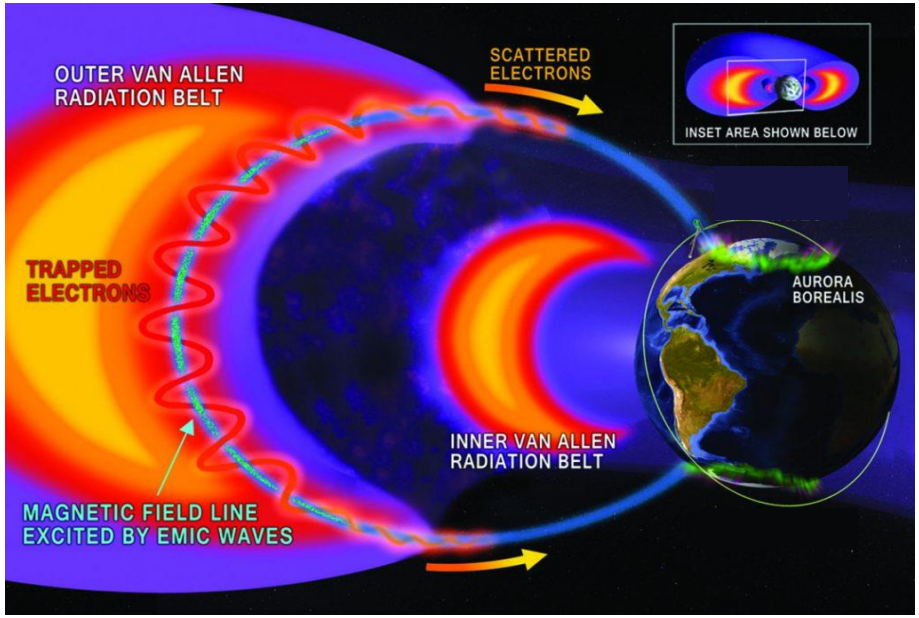

- Scattering of relativistic electrons by electromagnetic ion cyclotron (EMIC) waves is a good candidate for the precipitation mechanism of MeV events.
- These waves are observed along the plasmapause boundary in the dusk sector where the plasmapause bulges outward.
- The plasmapause controls particle distributions and dynamics in the inner magnetosphere, strongly impacting the formation and propagation of electromagnetic waves.

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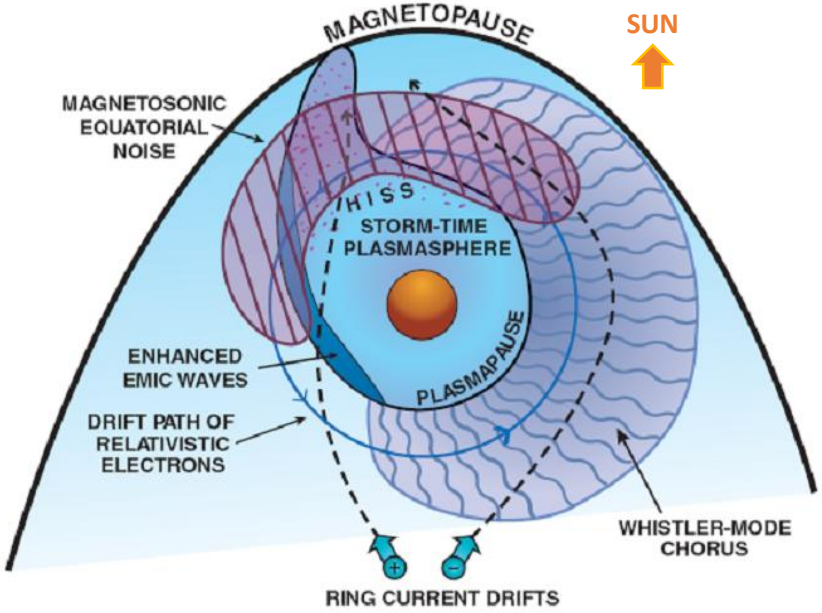

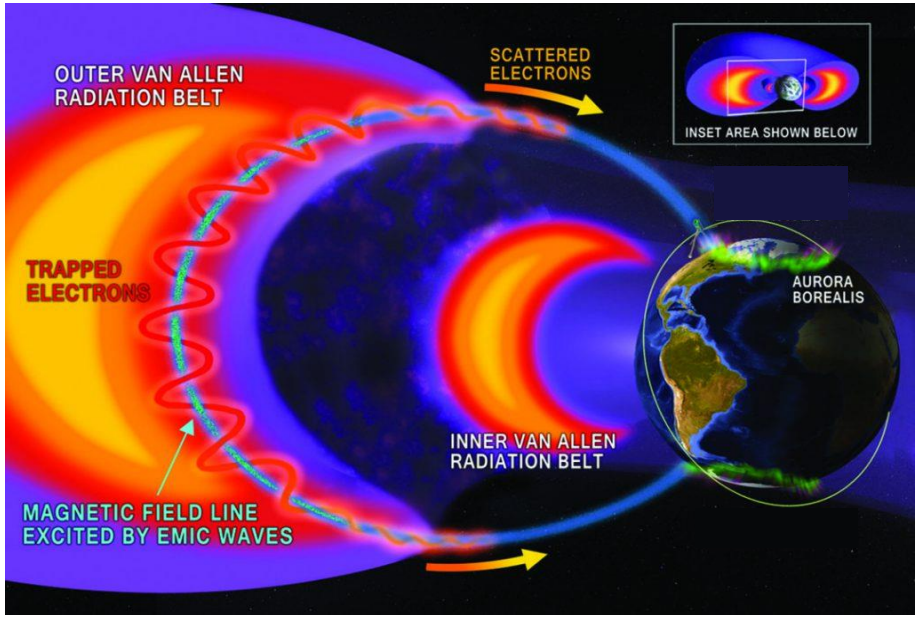

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- These waves are observed along the plasmapause boundary in the dusk sector where the plasmapause bulges outward.
- The plasmapause controls particle distributions and dynamics in the inner magnetosphere, strongly impacting the formation and propagation of electromagnetic waves.
- In this study we use the empirical dynamic plasmapause model by Liu et al. (2015), based on THEMIS measurements with 5 geomagnetic indices (Kp, Dst, AE, AL, AU) as input.

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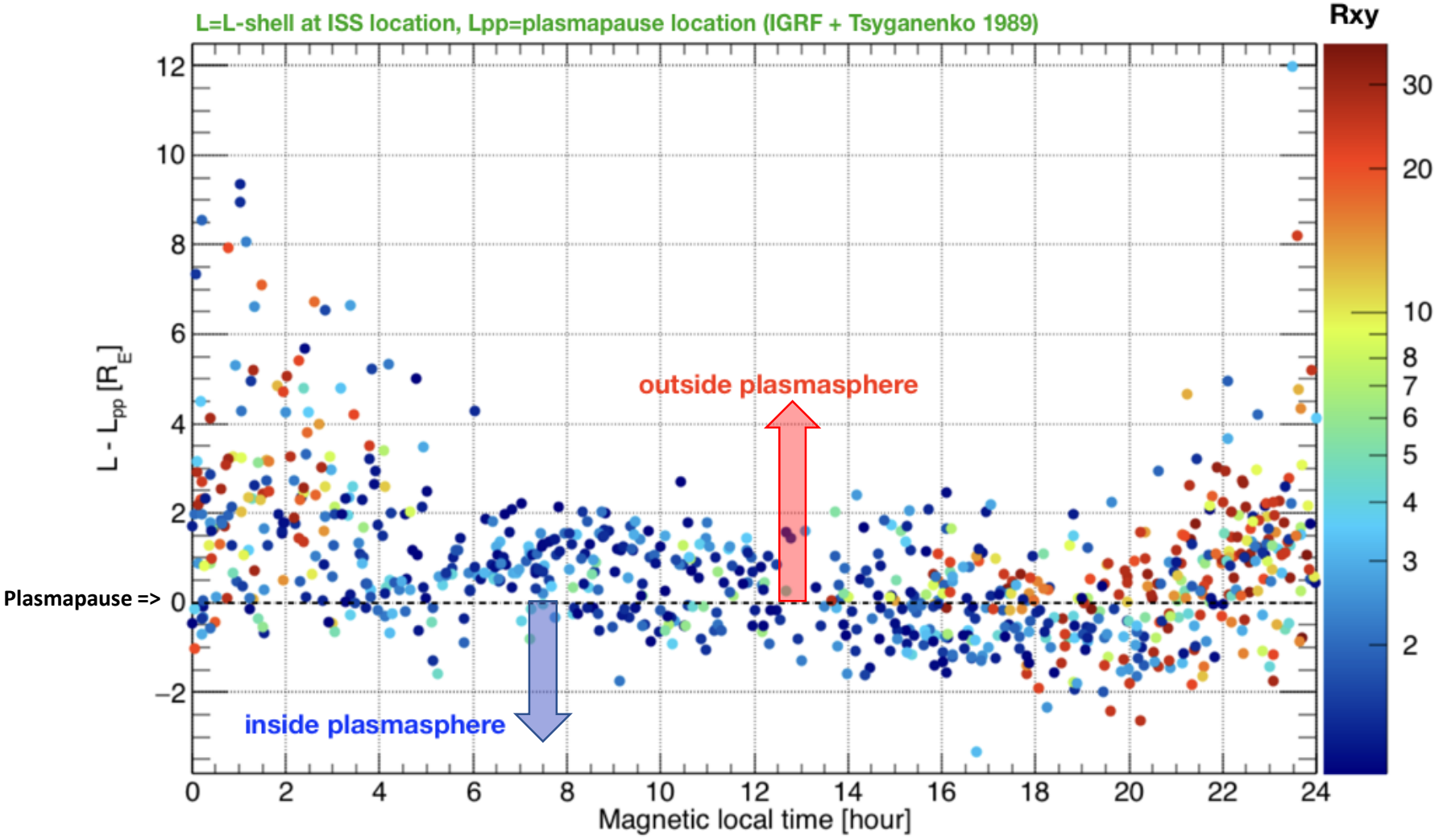
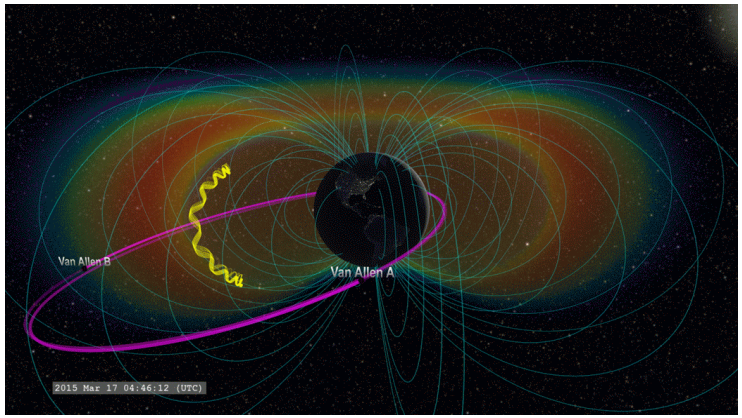


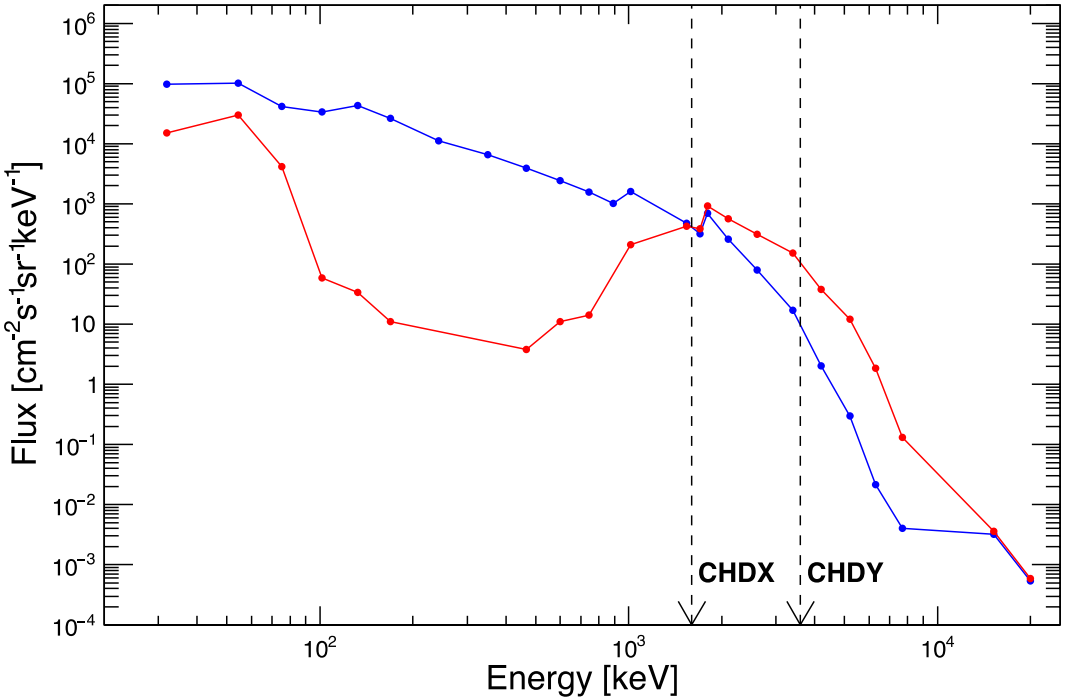
REP events are found to concentrate around the plasmapause. On average, the distribution corresponding to high CHDX/CHDY count-rate ratio (red) is located outside the plasmasphere

Preliminary comparison with Van Allen Probes (RBSPs)



For two REP events (one inside and the other outside the plasmasphere), CALET data was compared with the observations from one of the twin RBSPs made at same time and same magnetic location (MLT and L).

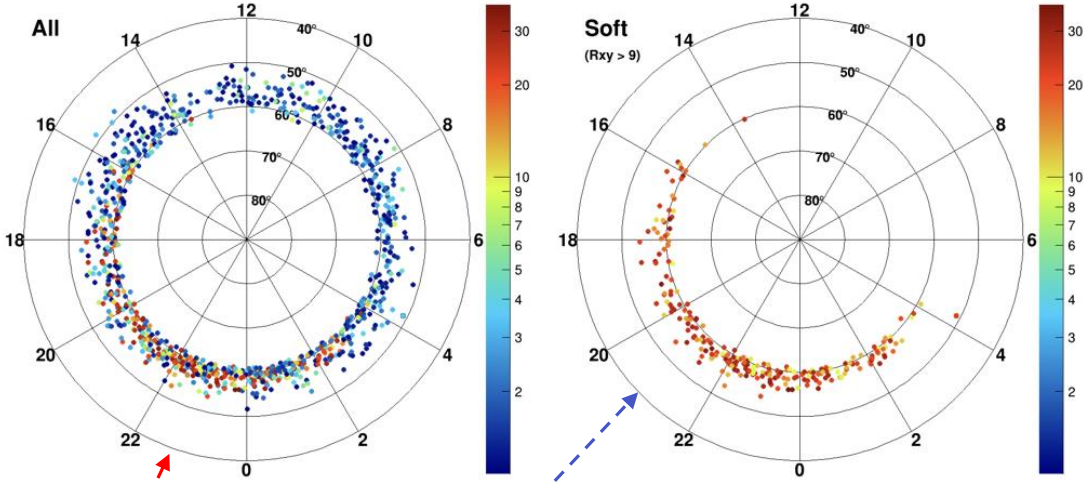
CHDX/CHDY ratios consistent with the spectral shapes in the MeV range.

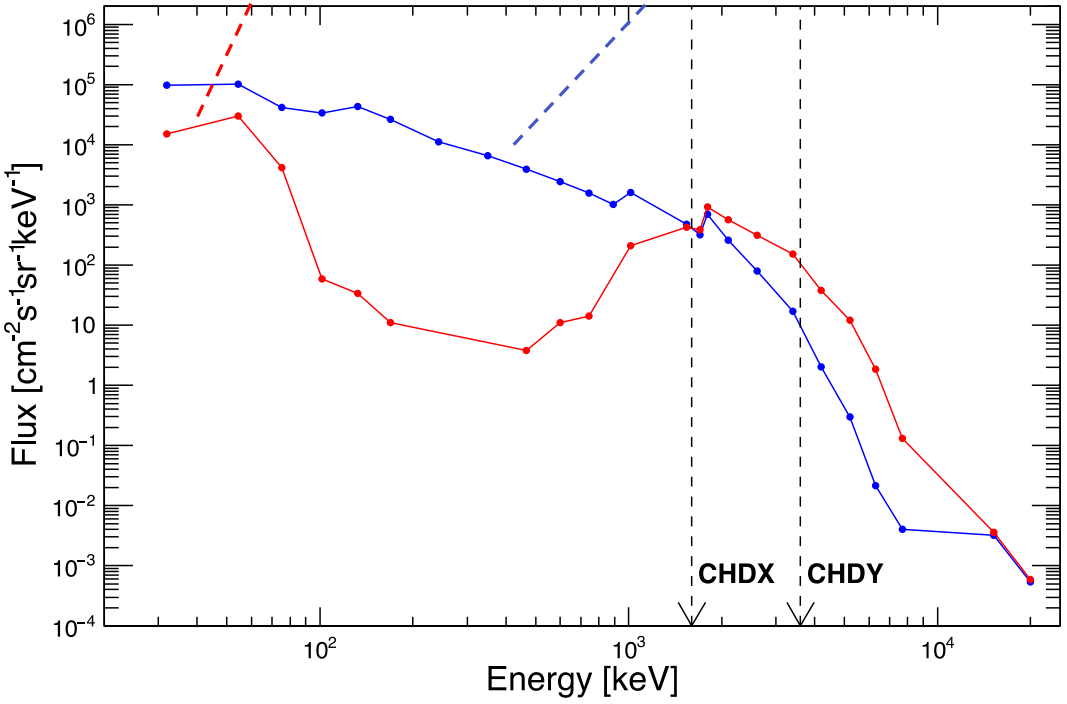


REP1 (hard spectrum, inside plasmasphere)
UTC = 2017-05-16 07:28:45
L_{RBSP} = 3.9, MLT_{RBSP} = 14.0
L_{ISS} = 3.8, MLT_{ISS} = 13.0
L_{PP} = 5.1, $L_{ISS} - L_{PP}$ = -1.31
N_{CHDX} = 3.2e+03, **$R_{CHDX/CHDY}$ = 2.34**

REP2 (soft spectrum, outside plasmasphere)
UTC = 2016-11-03 12:00:26
L_{RBSP} = 5.3, MLT_{RBSP} = 22.9
L_{ISS} = 5.3, MLT_{ISS} = 22.6
L_{PP} = 4.0, $L_{ISS} - L_{PP}$ = 1.64
N_{CHDX} = 4.3e+03, **$R_{CHDX/CHDY}$ = 21.56**

Preliminary comparison with Van Allen Probes (RBSPs)





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N_{CHDX} = 4.3e+03, **$R_{CHDX/CHDY}$ = 21.56**

Summary

- >1000 REP events have been identified between 2015 and 2019
- They typically occurred during the decaying phase of geomagnetic storms associated with high-speed streams, exhibiting a strong correlation with the aurora index
- REP events were found to be located around the plasmapause, with a soft spectrum sub-sample concentrating in the pre-midnight sector consistent with an origin related to scattering with EMIC-waves (dawn/dusk asymmetry)
- We compared our data with Van Allen Probe observations for a few REP events, confirming the correlation with EMIC waves

Future tasks

- Optimize REP identification/selection
- Perform a statistical study to identify correlations with solar wind / geomagnetic parameters
- Complement/compare with the Van Allen Probe observations (and possibly other space-/ground-based instruments) to quantify the spatial extent and dynamic evolution of REP events in the magnetosphere (energy spectra, pitch angle distributions, association with plasma waves, etc.)