Summary of precipitation events observed by BARREL during storms

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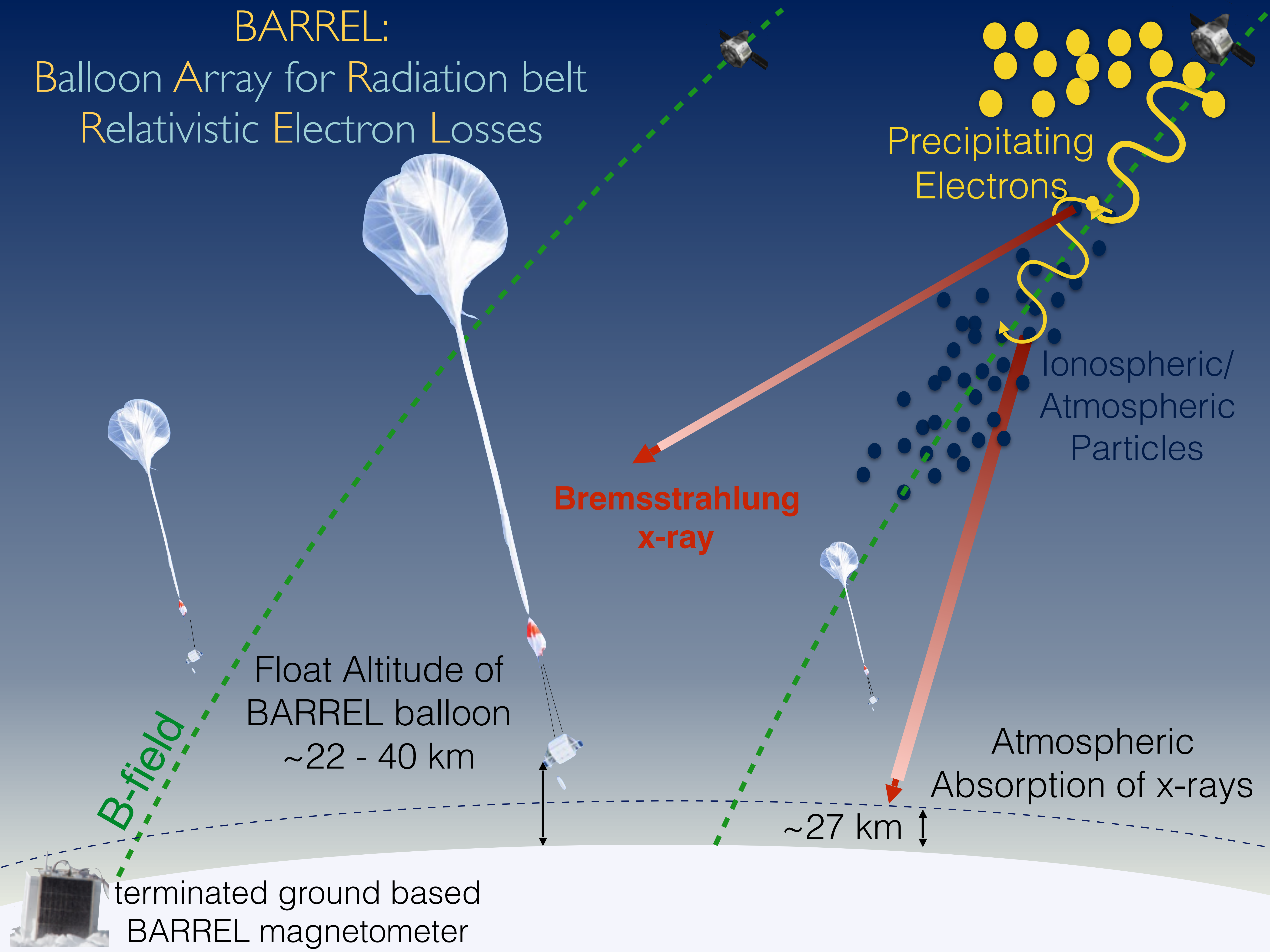
Key Points:

1) A single instrument on an array of balloons can help answer many questions about radiation belt dynamics as well as other heliospheric science.

2) Remote sensing and in situ instruments working together provide a more complete understanding.

3) Geomagnetic storms exhibit many different types of Radiation belt loss processes.


BARREL:
Balloon Array for Radiation belt
Relativistic Electron Losses
Precipitating
Electrons
Ionospheric/
Atmospheric
Particles
Bremsstrahlung
x-ray
Float Altitude of
BARREL balloon
~22 - 40 km
B-field
Atmospheric
Absorption of x-rays
~27 km
terminated ground based
BARREL magnetometer

Type of events observed by BARREL

100s ms

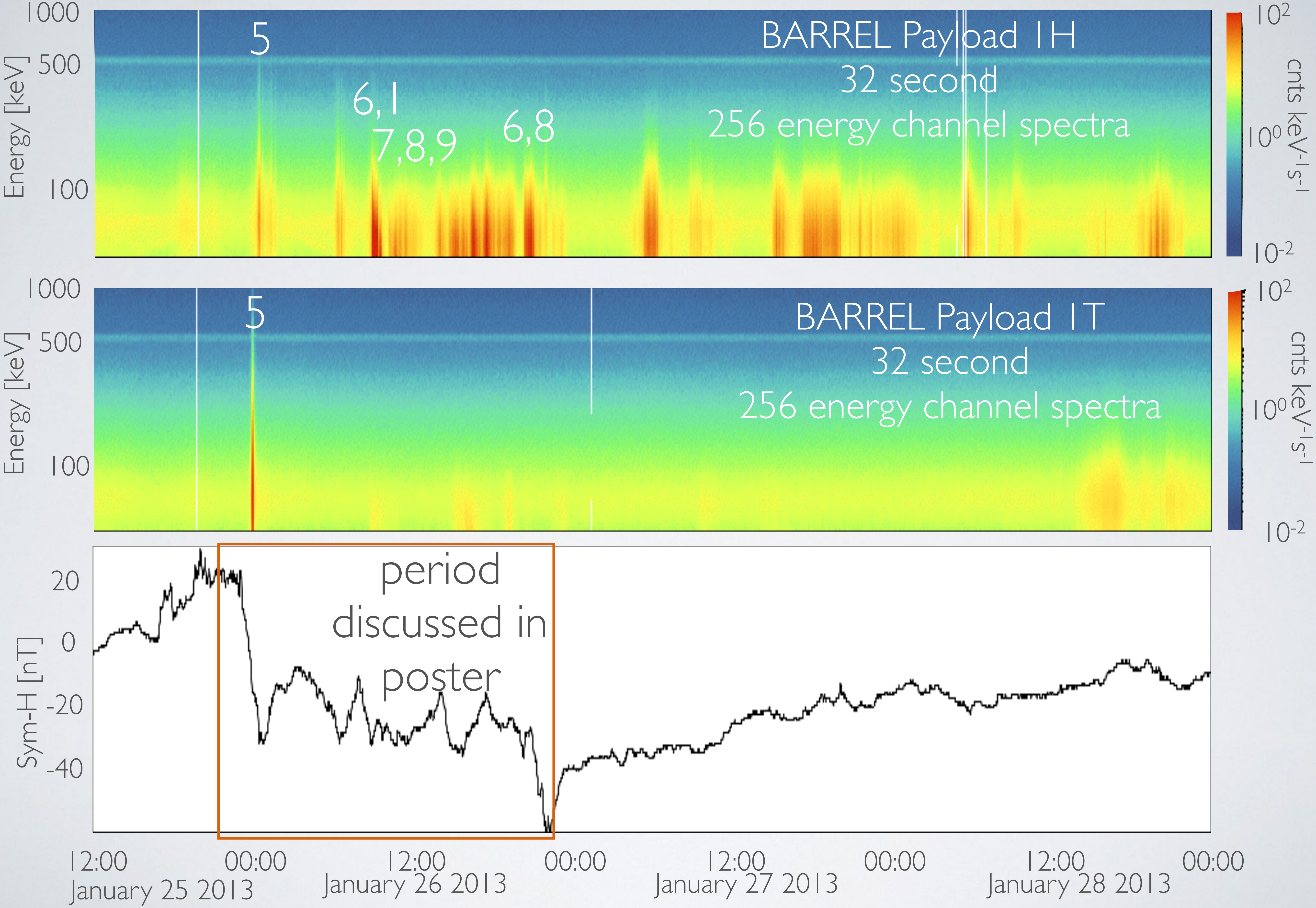
1) **Microbursts**
2) Precipitation due to lightning induced whistlers?
3) GRBs
4) Solar Flare
5) **Relativistic Electron Precipitation**
6) **Precipitation due to substorm injection**
7) **Precipitation due to whistler mode waves**
8) **ULF time scale modulations**
9) **Drift echo time scale modulations**
10) Solar Energetic Proton events

associated time scale

days

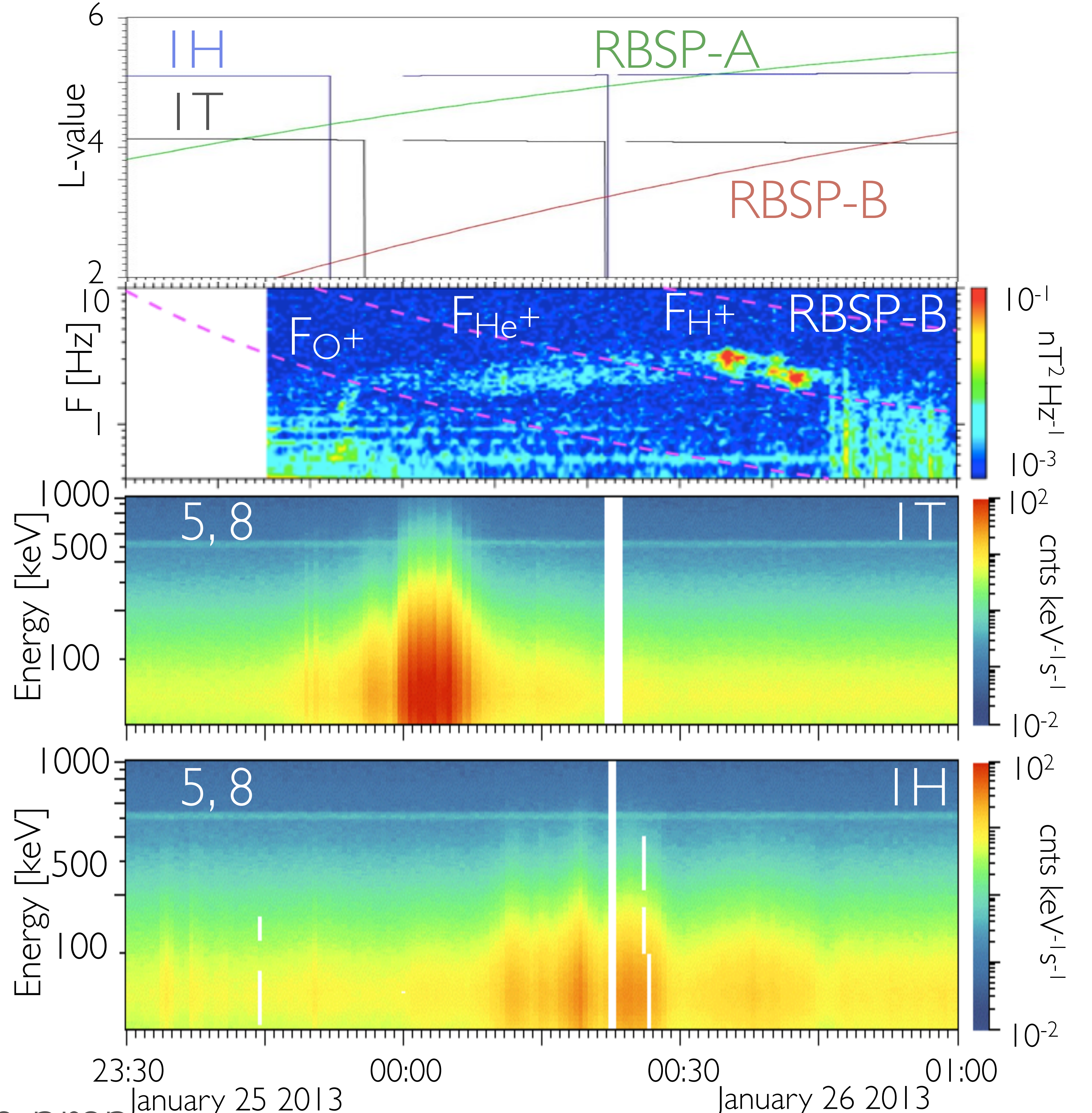
Here we cover numbered topics 1, 5-9 in detail

The storm that (almost) had it all - Jan 25 - 28 2013



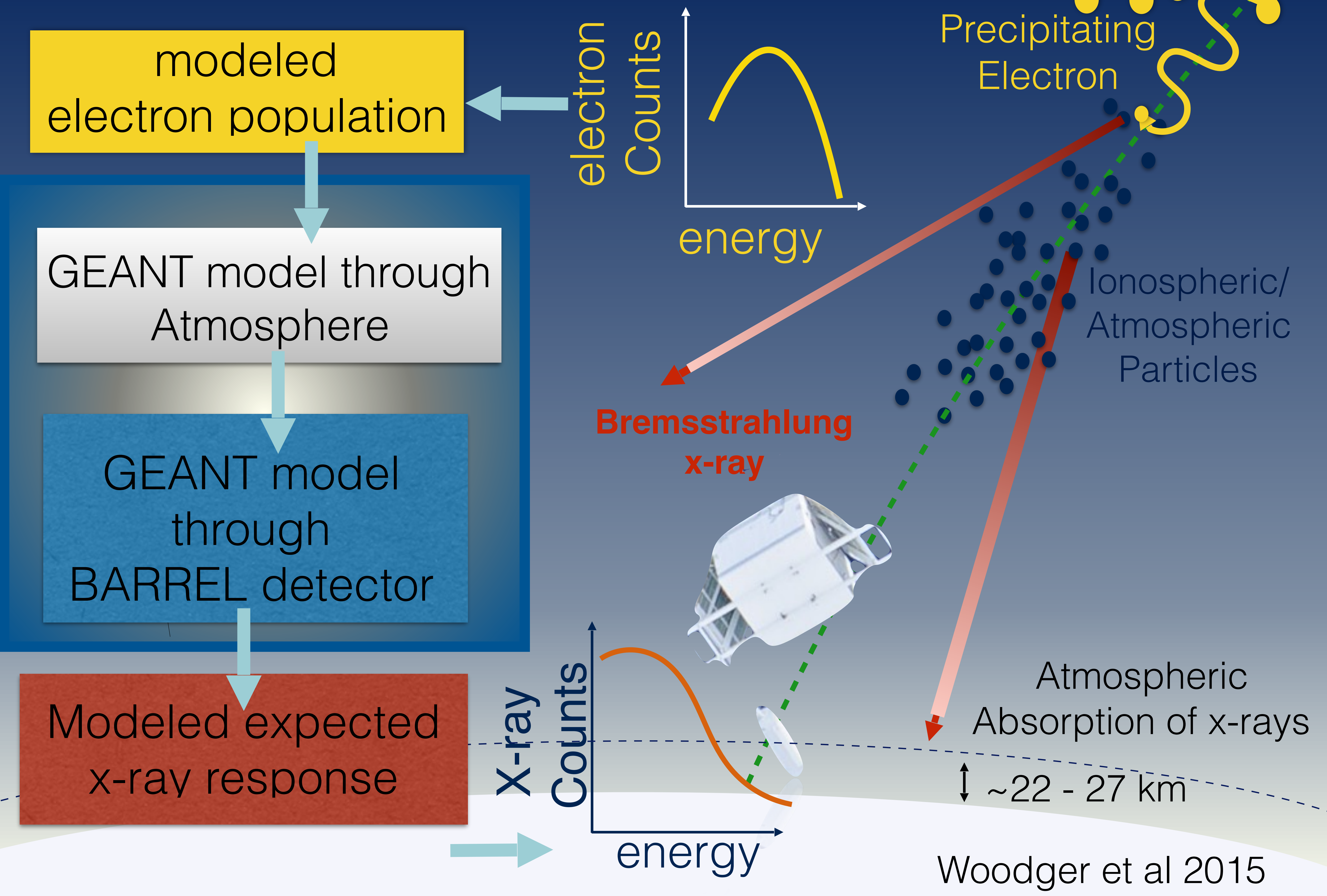
5) Relativistic Electron Precipitation: BARREL observed REPS in the dusk sector at an L-value and MLT similar to that where Van Allen Probe B saw EMIC waves.

Although Van Allen Probe A was close in L to the two BARREL payloads, it was on the dawn side of the magnetosphere and did not seen an EMIC wave.

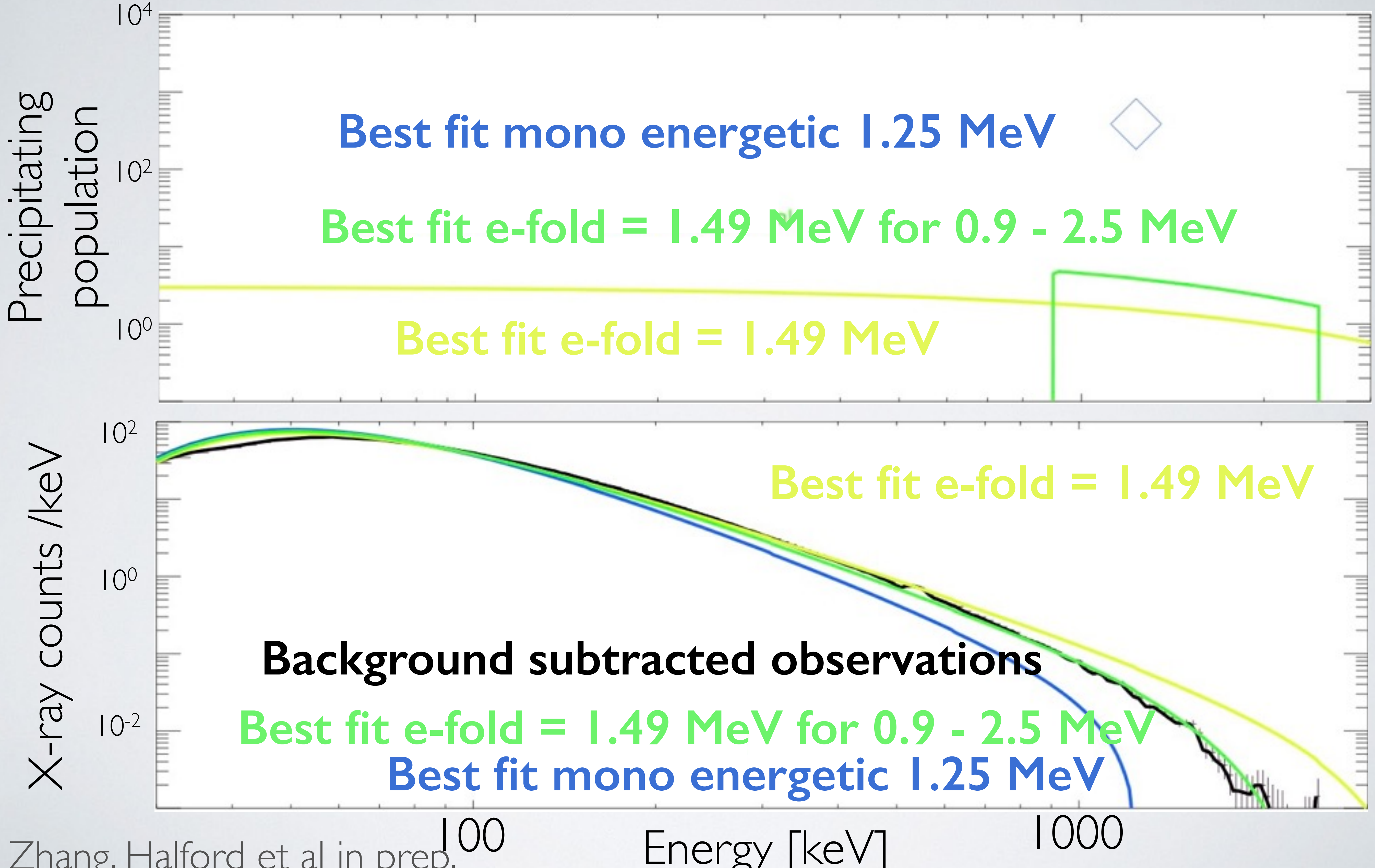


Zhang, Halford et al in prep.

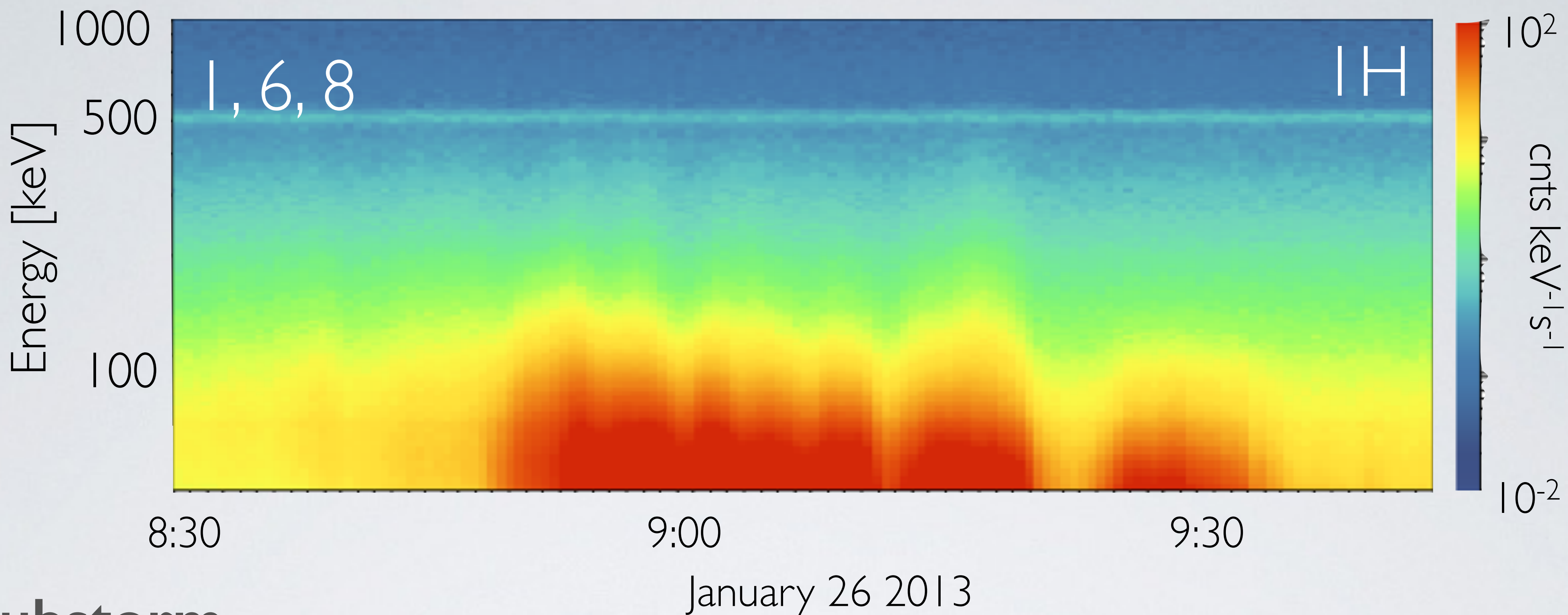
Spectral analysis with BARREL



5) Relativistic Electron Precipitation: Using the approx. min resonant energy and an upper limit of observed electrons at MagEIS,/REPT we can see that EMIC waves may have precipitated the inferred particle population generating the observed X-rays.



Zhang, Halford et al in prep.



6) Substorm injection:

Payload 1H saw X-rays upwards of 450 keV and was conjugate to observations from the CARISMA array in Canada as well as GOES and LANL satellites.

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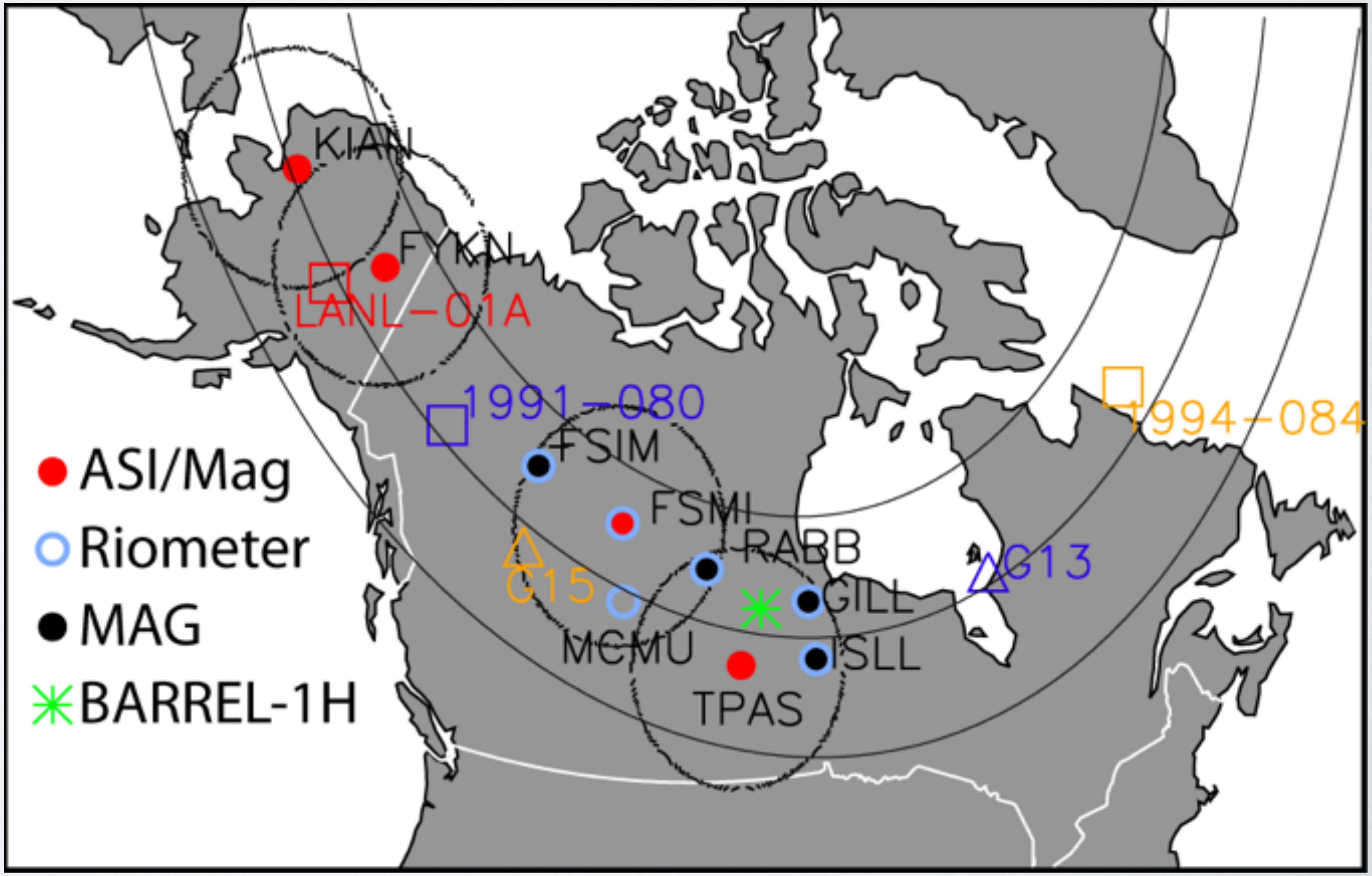

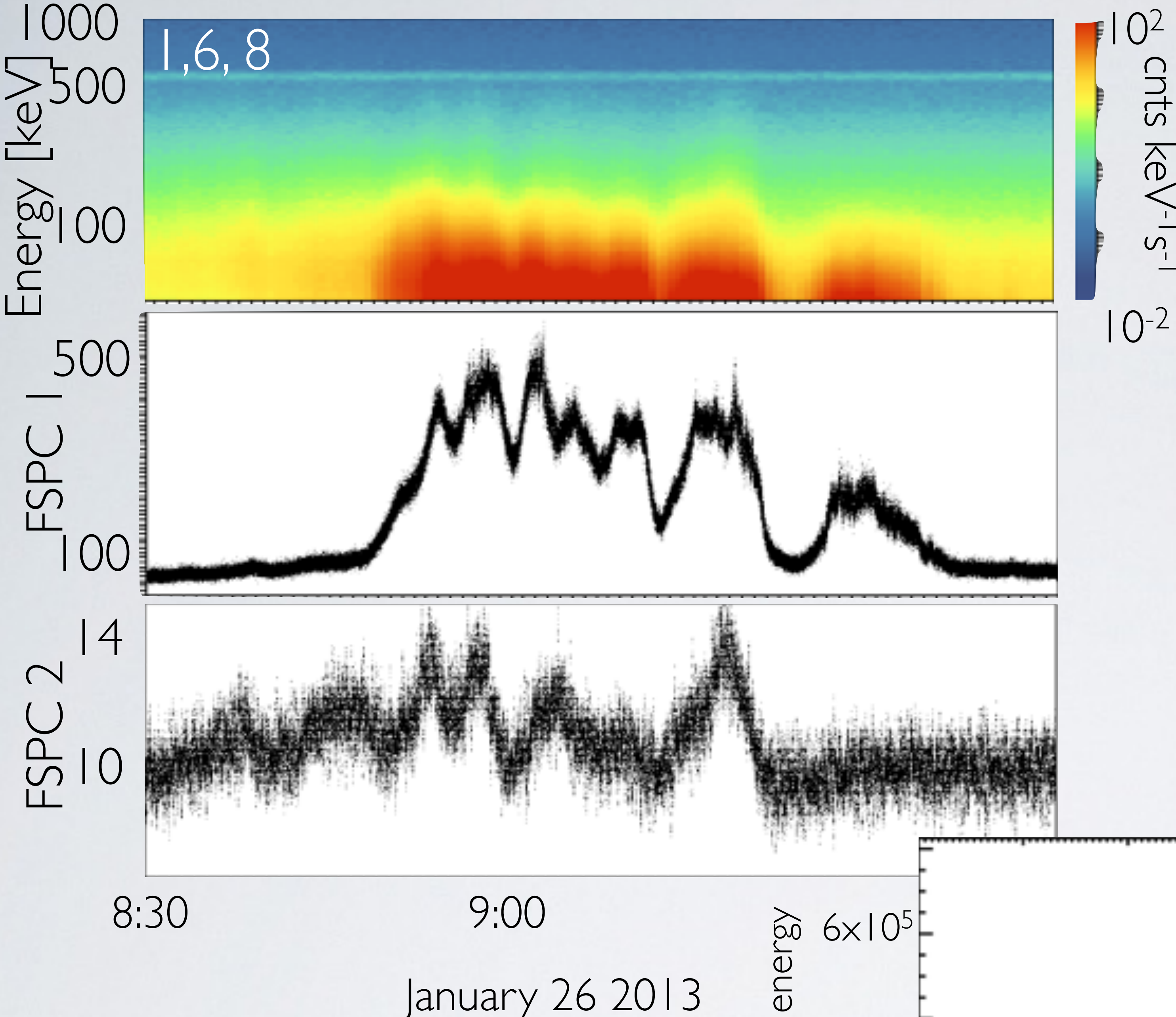

6) Substorm injection:

The differing structures seen in FSPC1(<180 keV) and FSPC2 (180 - 550 keV) X-rays indicate two separate precipitating electron populations.

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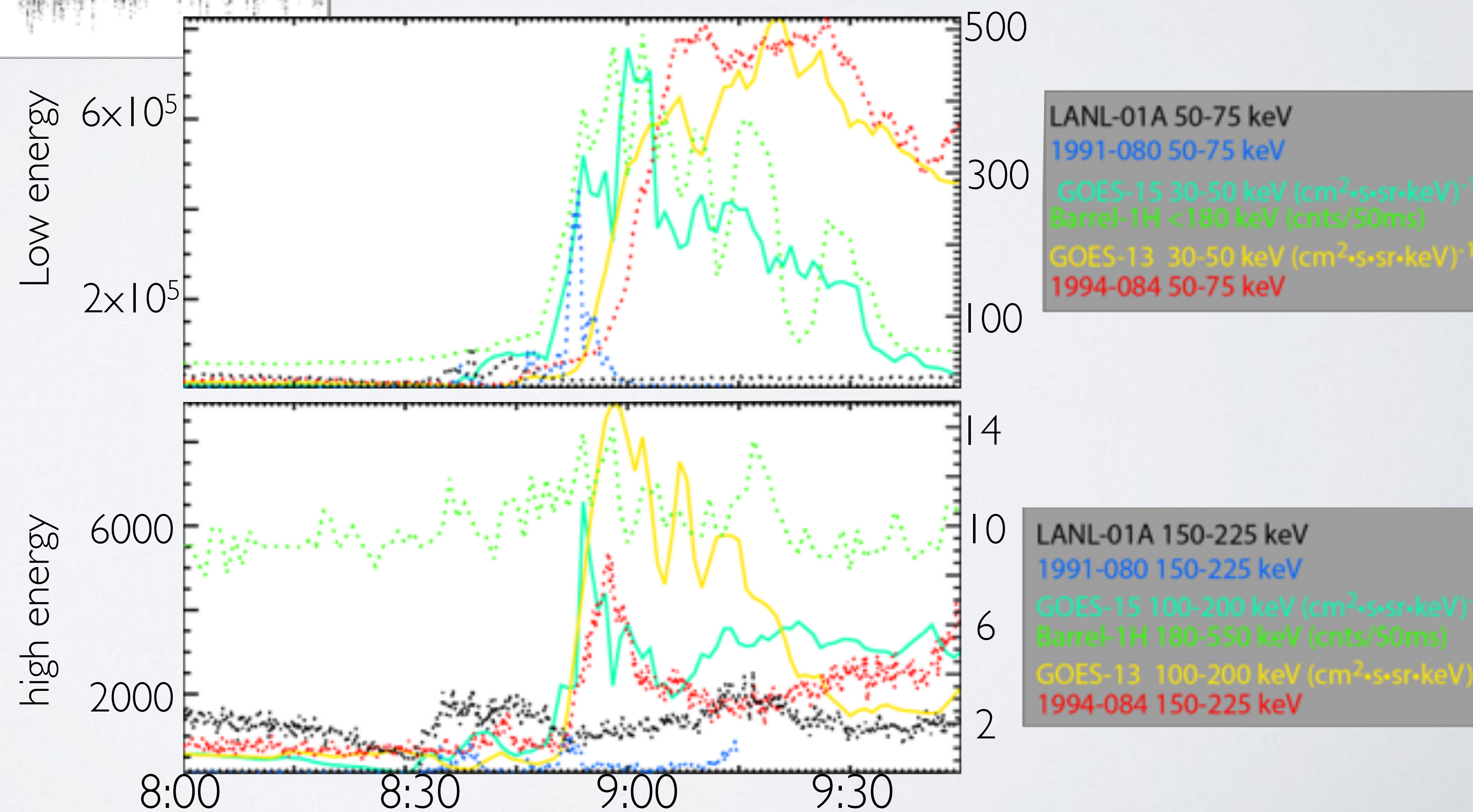
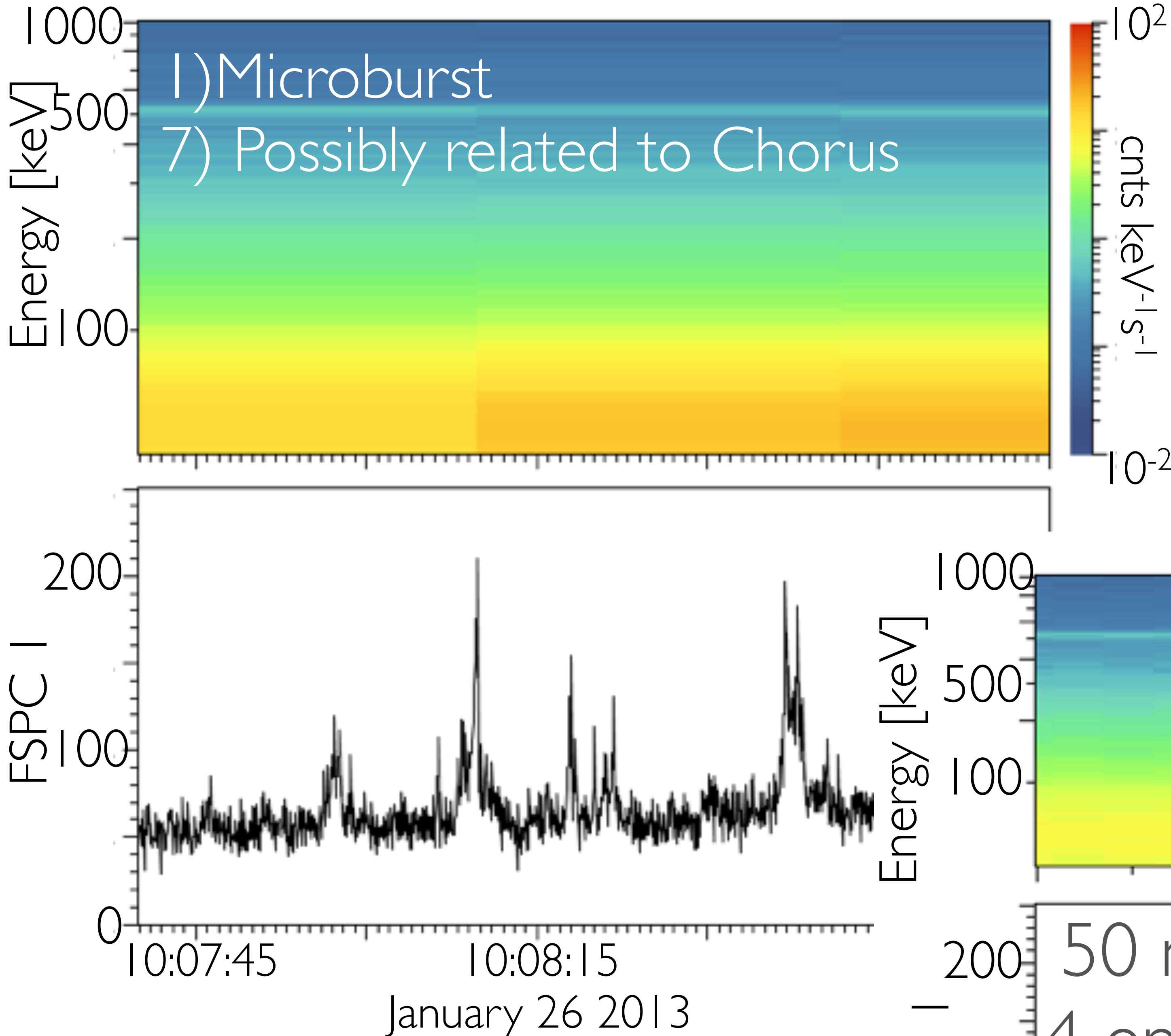
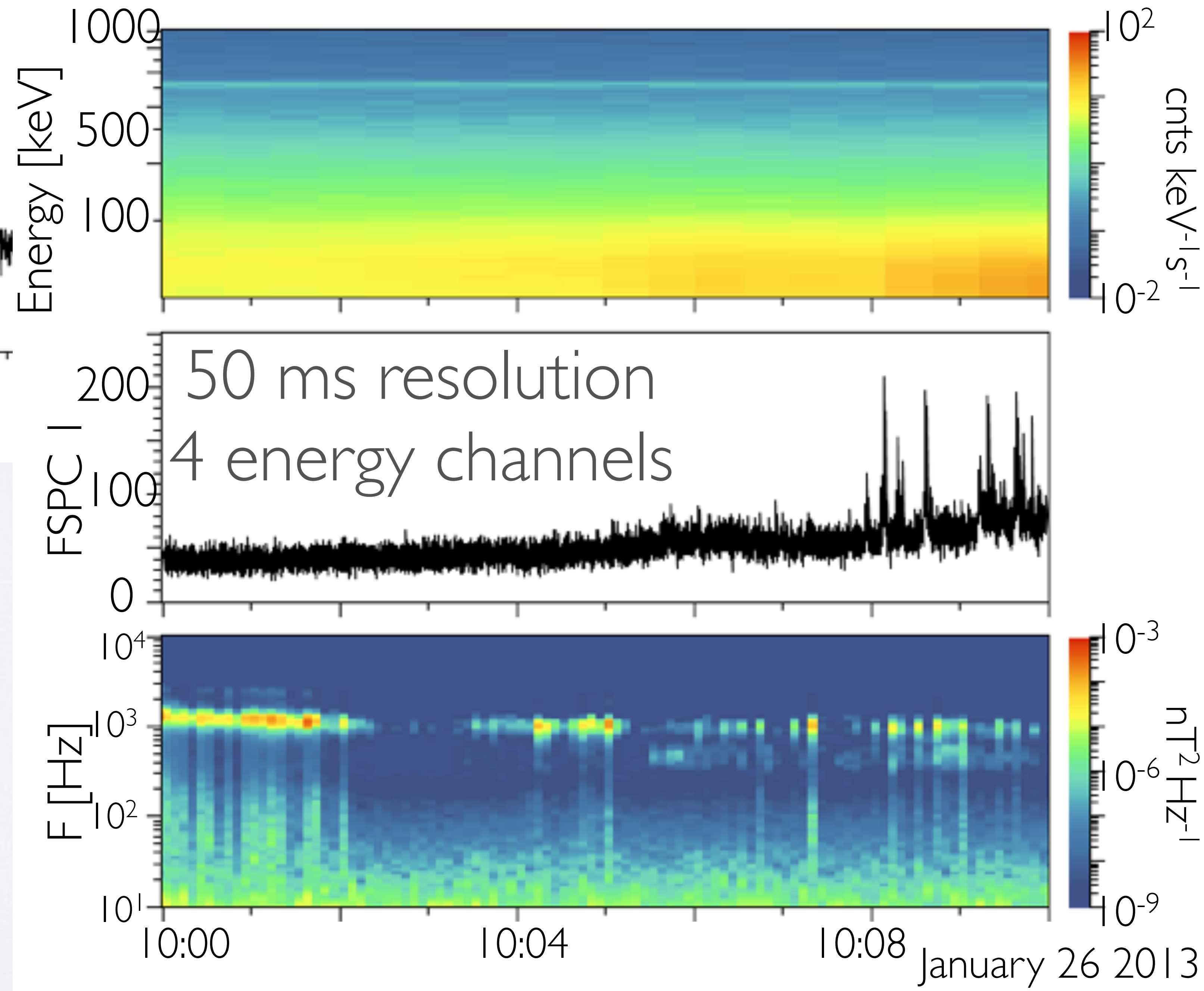


6) Substorm injection:

The higher energy electrons arrive at all the satellite locations prior to the lower energy channels.



1)Microbursts: Microburst were observed during and after the substorm event. As RBSP-A came out of perigee, it observed chorus waves and time domain structures.



1)Microbursts: Because RBSP-A was not directly conjugate to payload 1H, one-to-one correlations were not observed.

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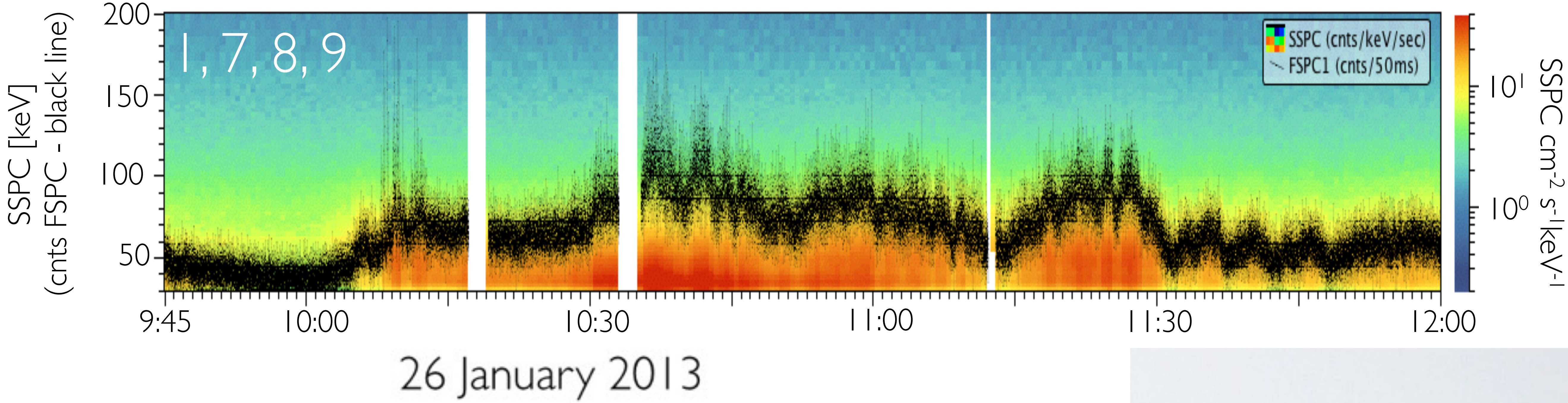
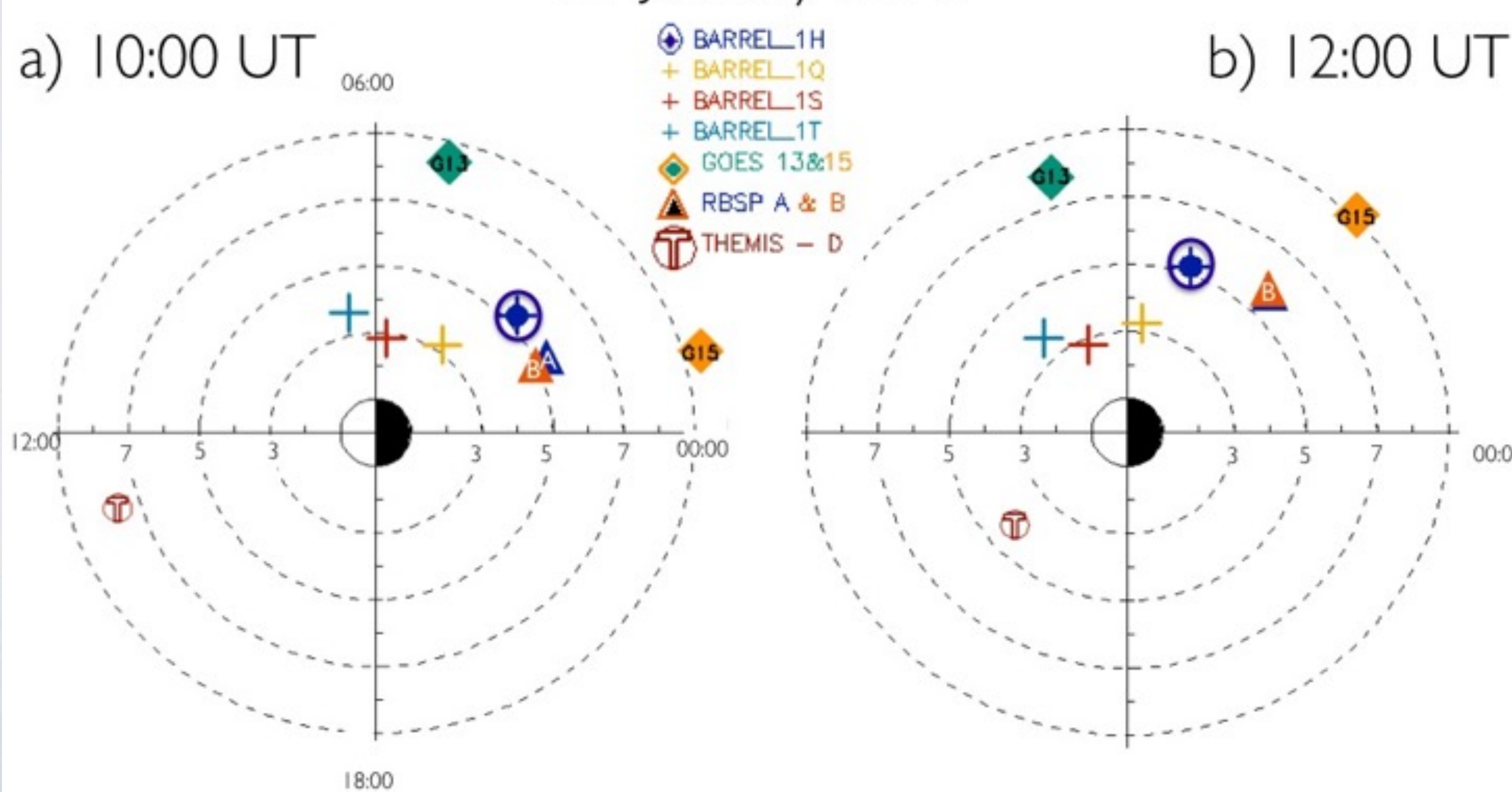
9)Drift echo time scales: BARREL and other balloon missions have observed structures comparable to drift time scales (5 - 30 minutes). During this interval both microbursts and ULF time scales were observed.





9)Drift echo time scales: During this event, the Van Allen probes were at a similar L-value and about 5 mins away for a 45 deg, 300 keV electron.

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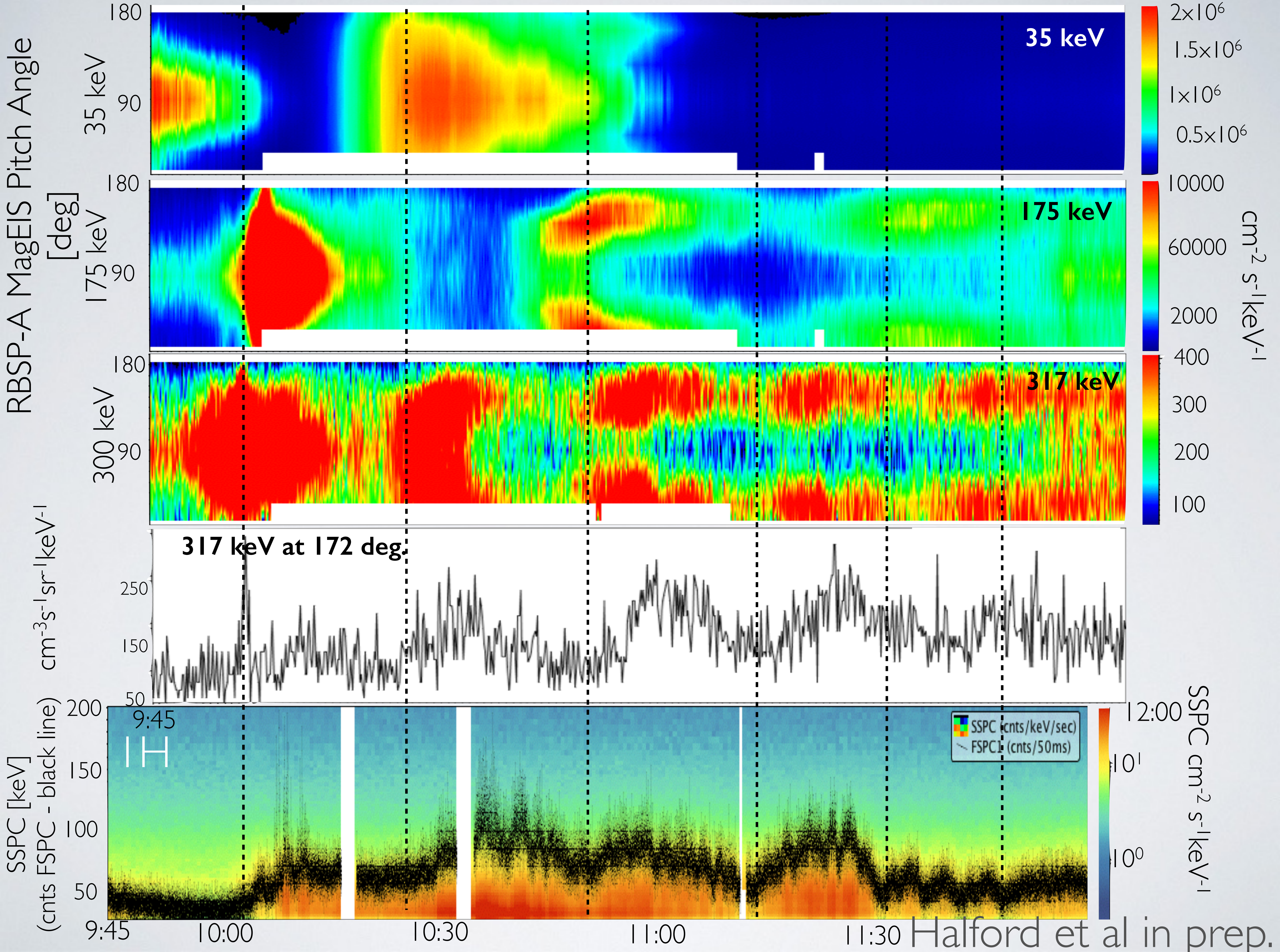

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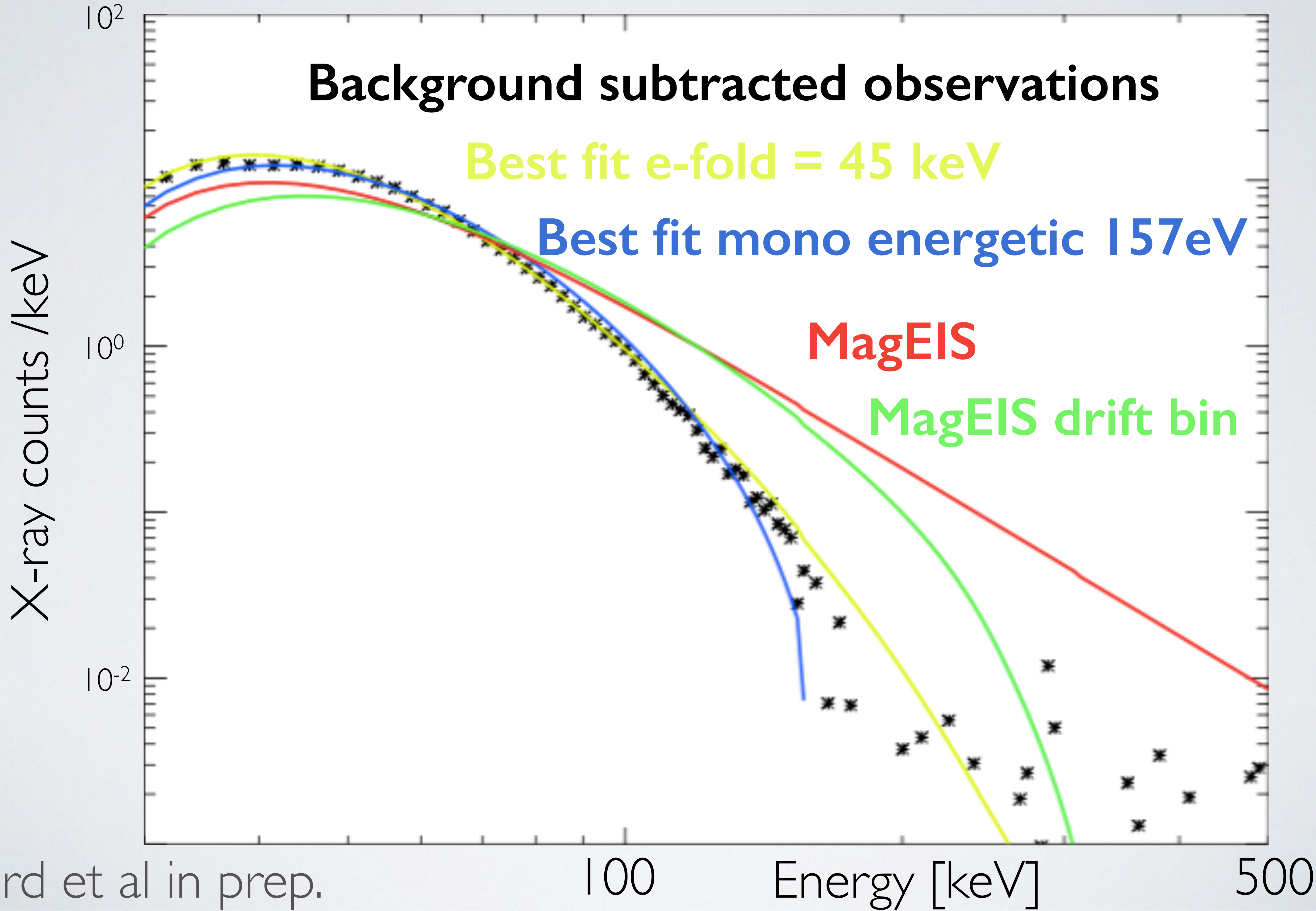
9)Drift echo time scales: The best fit e-folding energy describing the observed X-ray response is 45 keV and the best fit mono-energetic value is 157 keV. By comparison, the expected X-ray response to either the MagEIS spectra, or the MagEIS energy bin with a drift time similar to that observed in the X-rays, are too hard.



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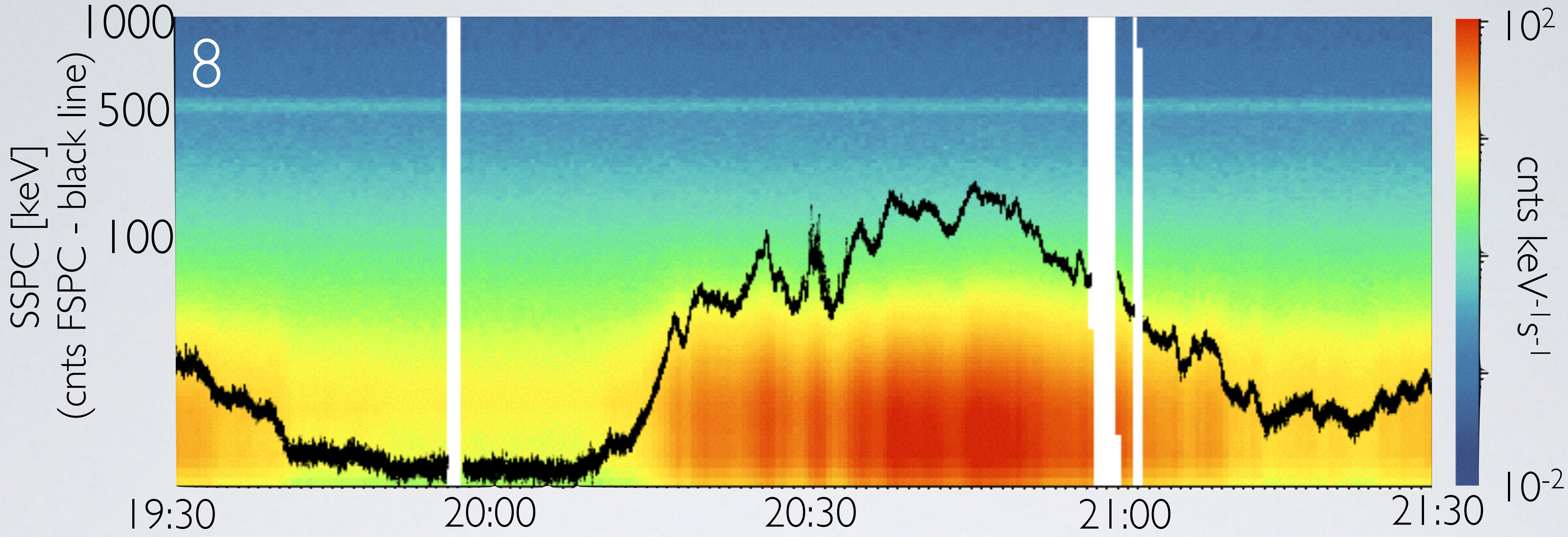
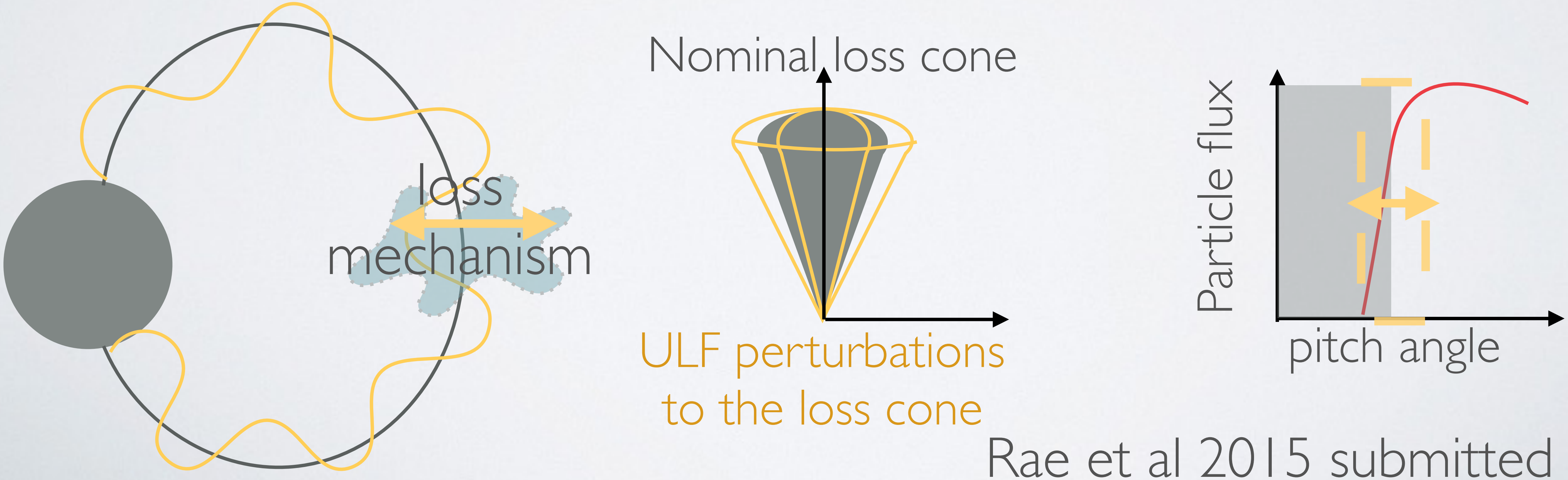


8)ULF time scales: ULF period oscillations modulate the precipitation envelope, by changing in the size of the loss cone during the precipitation event. Although the ULF wave does not change the loss cone size much, very small increases/decreases will result in a large change in the precipitating population if the pitch angle distribution is very steep near the loss cone.



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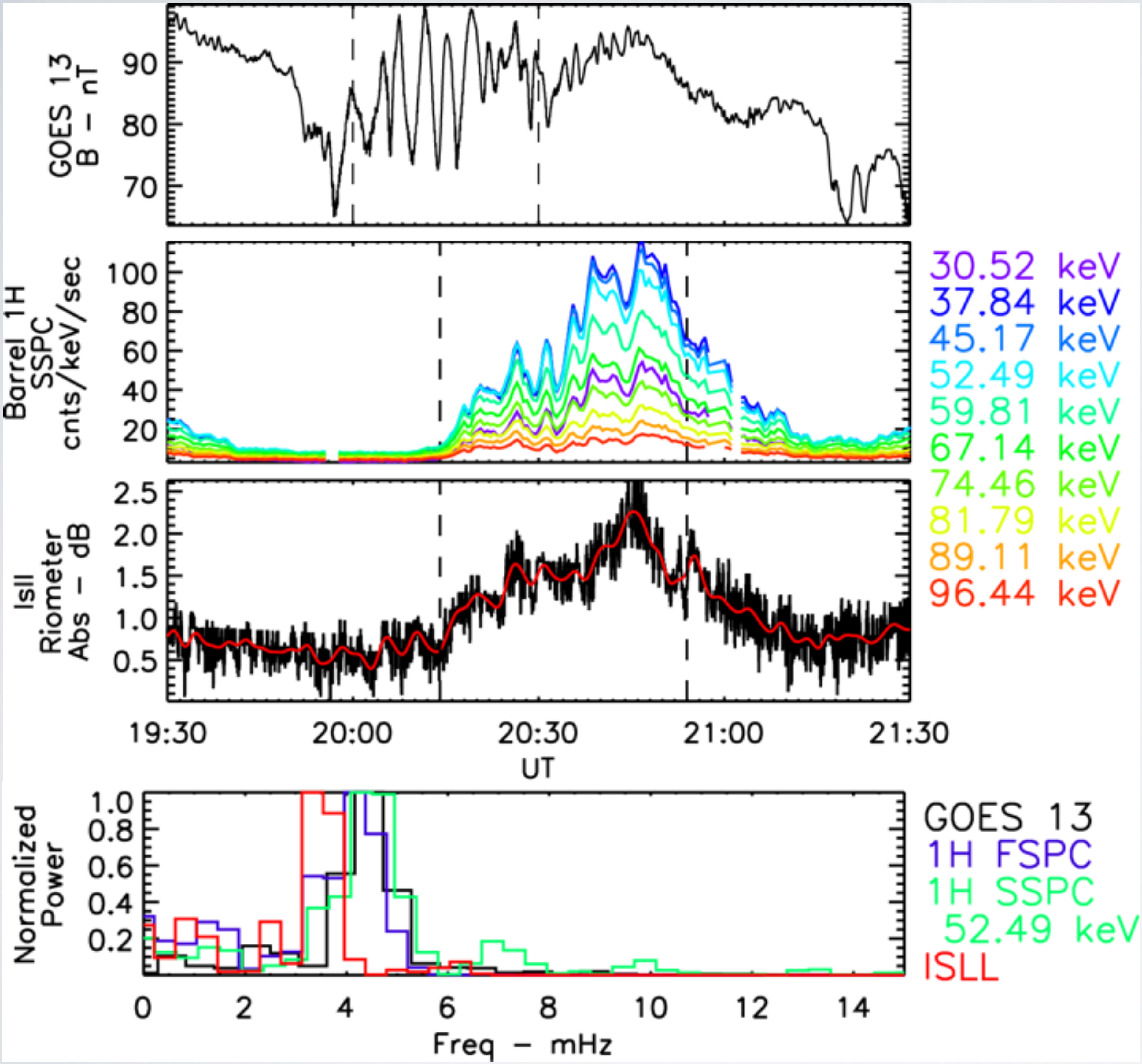

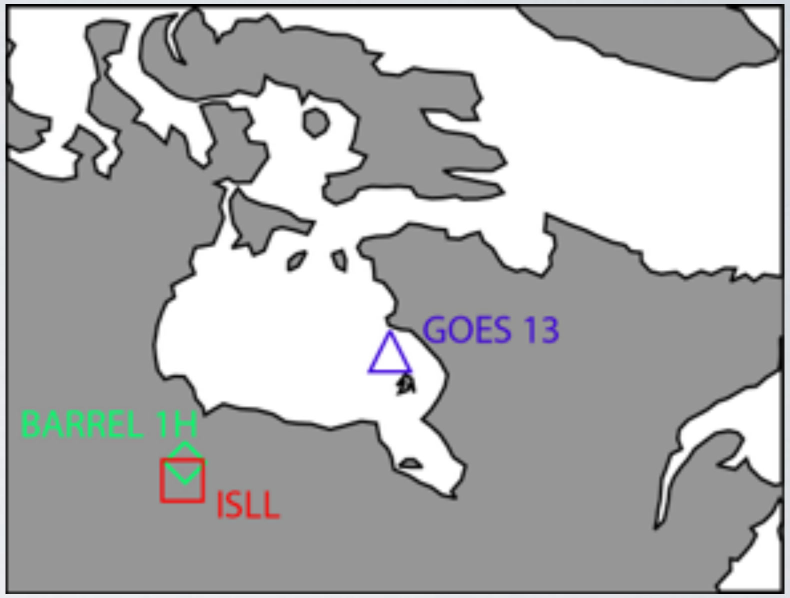

<u>8)ULF time scales:</u> ULF wave activity was also observed in ISLL riometer data, and GOES at similar frequencies, consistent with a spatially localized ULF wave modulation of BARREL precipitation.

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Conclusions

Storms are often complicated with multiple mechanisms acting throughout causing radiation belt loss to the atmosphere. BARREL is able to examine the range of radiation belt loss from ms to days, and 10s keV - 10 MeV energies.

1/25/13 23:30 - 1/26/13 1:00 The Relativistic electron precipitation event observed by BARREL may be explained by the observed EMIC wave from the Van Allen Probe.

1/26/13 8:30 - 9:45 During the substorm, both microbursts and ULF time scales were observed. The precipitation follows the populations observed to be injected by in situ instruments.

1/26/13 10:00 - 10:08 Microbursts, rising tone chorus, and time domain structures were observed at similar times and locations.

1/26/13 10:00 - 12:00 Although drift echo times scales can be observed in the X-ray counts, the process remains unclear.

1/26/13 19:30 - 21:30 ULF periods are often observed in the data. One mechanism which may contribute to this is ULF waves modulating the size of the loss cone.