The Impacts of Substorms on the Ring Current

- Substorms are associated with a significant **enhancement in ring current energy content** and a **reduction in ion temperature anisotropy**
- Storm time variations show substantial **discrepancies with ring current indices** (e.g. Sym-H), attributed to enhanced substorm occurrence

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Measuring the Ring Current

We use Van Allen Probes observations of the ring current population provided by the RBSPICE and HOPE instruments (2012 - 2019) for statistical analyses of the ring current ions during substorms.

We focus on 2 key properties of the population:

1. Energy content
    - Estimate energy contained in a region of space from ion energy flux data [Gkioulidou et al., 2016]
2. Temperature anisotropy, $T_\perp / T_\parallel$

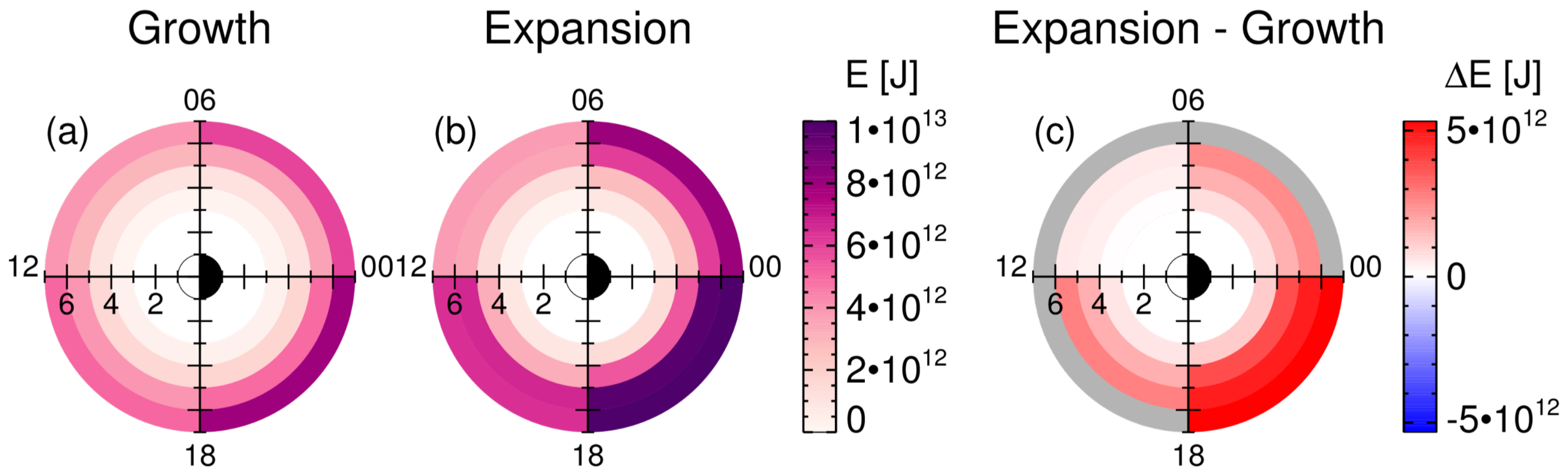
H^+	1 eV – 50 keV	HOPE
O^+	1 eV – 50 keV	
H^+	50 – 660 keV	RBSPICE
O^+	120 – 990 keV	
He^+	60 – 980 keV	

- Substorm identifications from the SML and SMU indices [Forsyth et al., 2015]
- Storm identifications from the Sym-H index [Walach & Grocott, 2019]

Changes in Energy Content

We compare L-MLT maps of energy content for the substorm growth & expansion phases.

The figure shows a representative example for H^+ 1 eV – 50 keV ions.

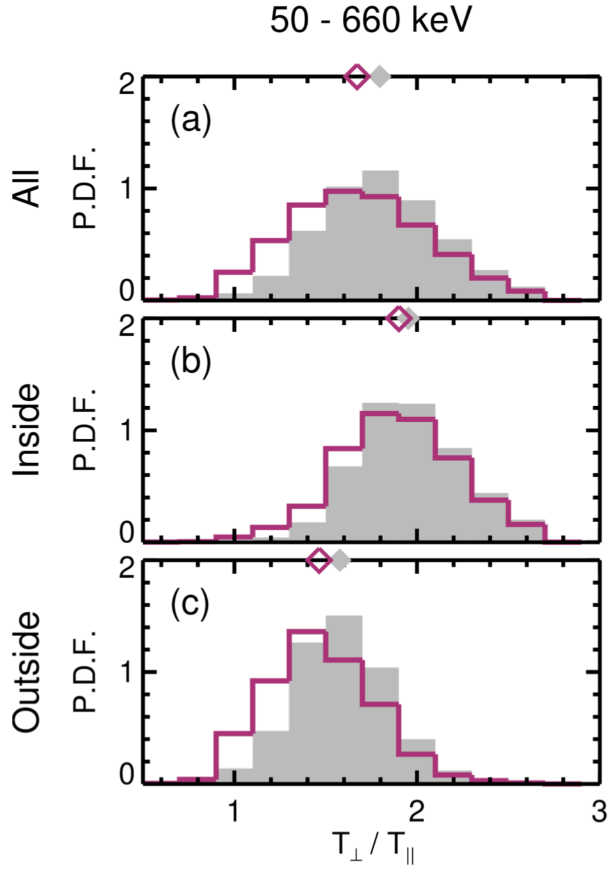


[Sandhu et al., 2018]

- The total ring current energy content is increased by 12% over substorm onset
- Large relative changes for < 50 keV ions and O^+ ions.
- Large enhancements in premidnight MLT sector.

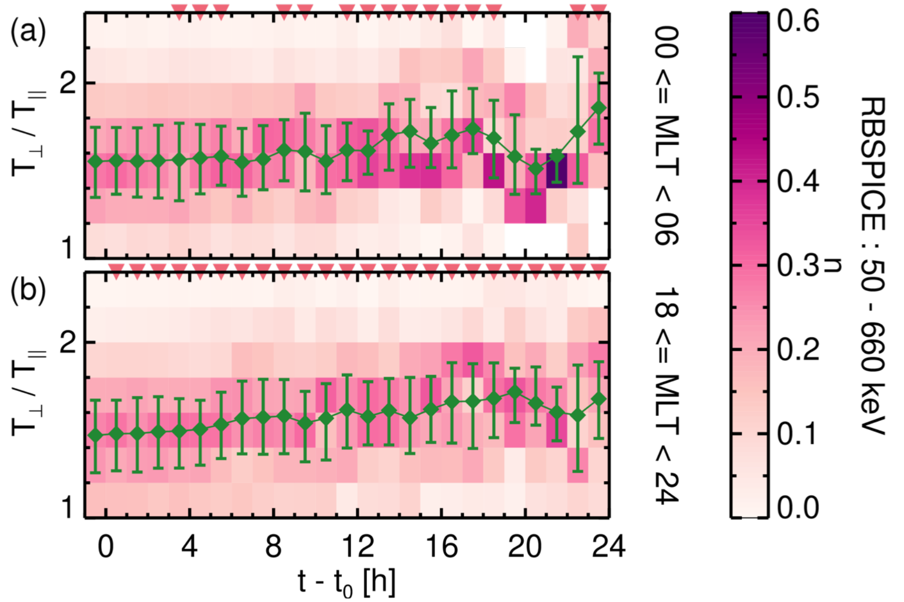
Changes in Temperature Anisotropy

Compare H^+ temperature anisotropy for growth (grey shaded) & expansion (pink line) phases



- Quasi-global reduction of temperature anisotropy following onset, with largest changes occurring outside the plasmapause (panel c).
- Evidence shows **non-dominant role of EMIC waves** *(see slide 7)*.

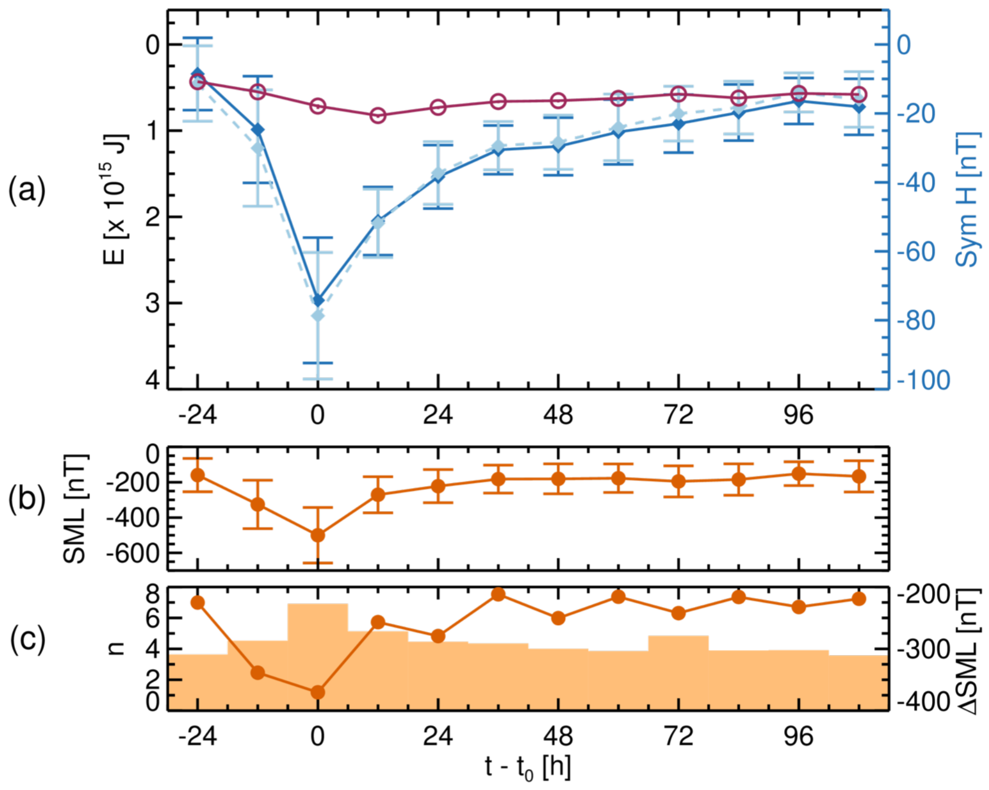
“New” vs “old” plasma



Changes driven by superposition of “new” isotropic plasma with “old” anisotropic plasma. Figure shows plasma becoming **increasingly anisotropic with time** since substorm onset (t0). This is due to **pitch angle dependent losses.**

Energy Content Variations During Storms

Superposed epoch analysis of storms relative to time of Sym-H minima. In situ estimates of total energy content (pink) are compared to Sym-H values (blue) using the Dessler-Parker-Sckopke relation.



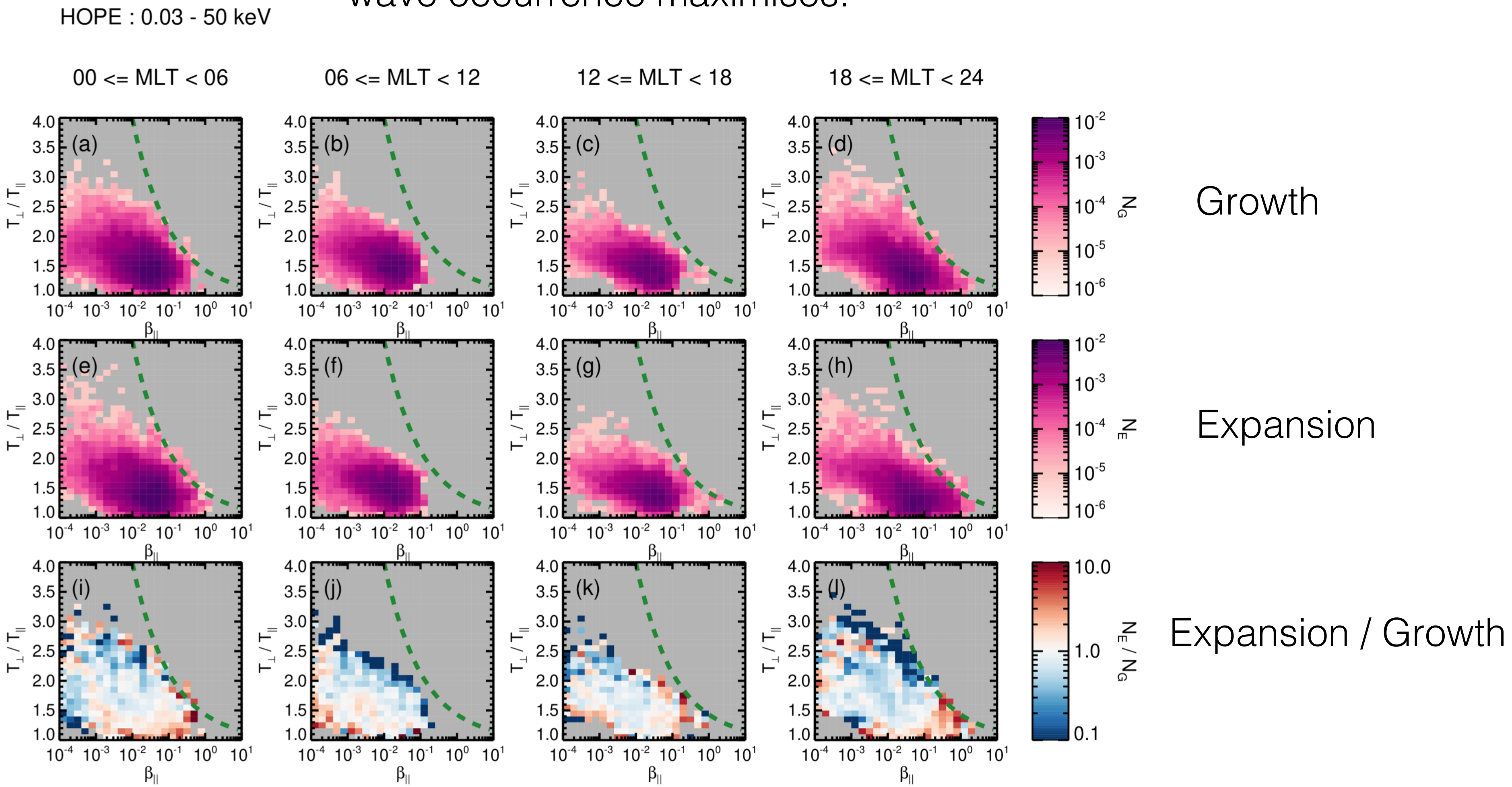
- Large differences in magnitude:
  - Agrees with existing literature and due to presence of other current systems.
- Temporal discrepancy is reported:
  - Continued ring current energization follows the Sym-H minima.
  - Increased number of large substorms may drive significant tail current variations that contaminate the Sym-H index.

Key Findings

- Substorms are associated with a **significant enhancement in ring current energy content** of ~12% *[Sandhu et al., 2018, 2019]*.
- A **quasi-global reduction in ion temperature anisotropy** is observed following onset *[Sandhu et al., in prep]*.
- Storm time variations show **substantial discrepancies with ring current indices** (e.g. Sym-H), attributed to enhanced substorm occurrence *[Sandhu et al., in prep]*.

Extra: Are EMIC waves dominant?

Distributions are not well constrained by EMIC wave growth rate in the afternoon sector (where EMIC wave occurrence maximises.



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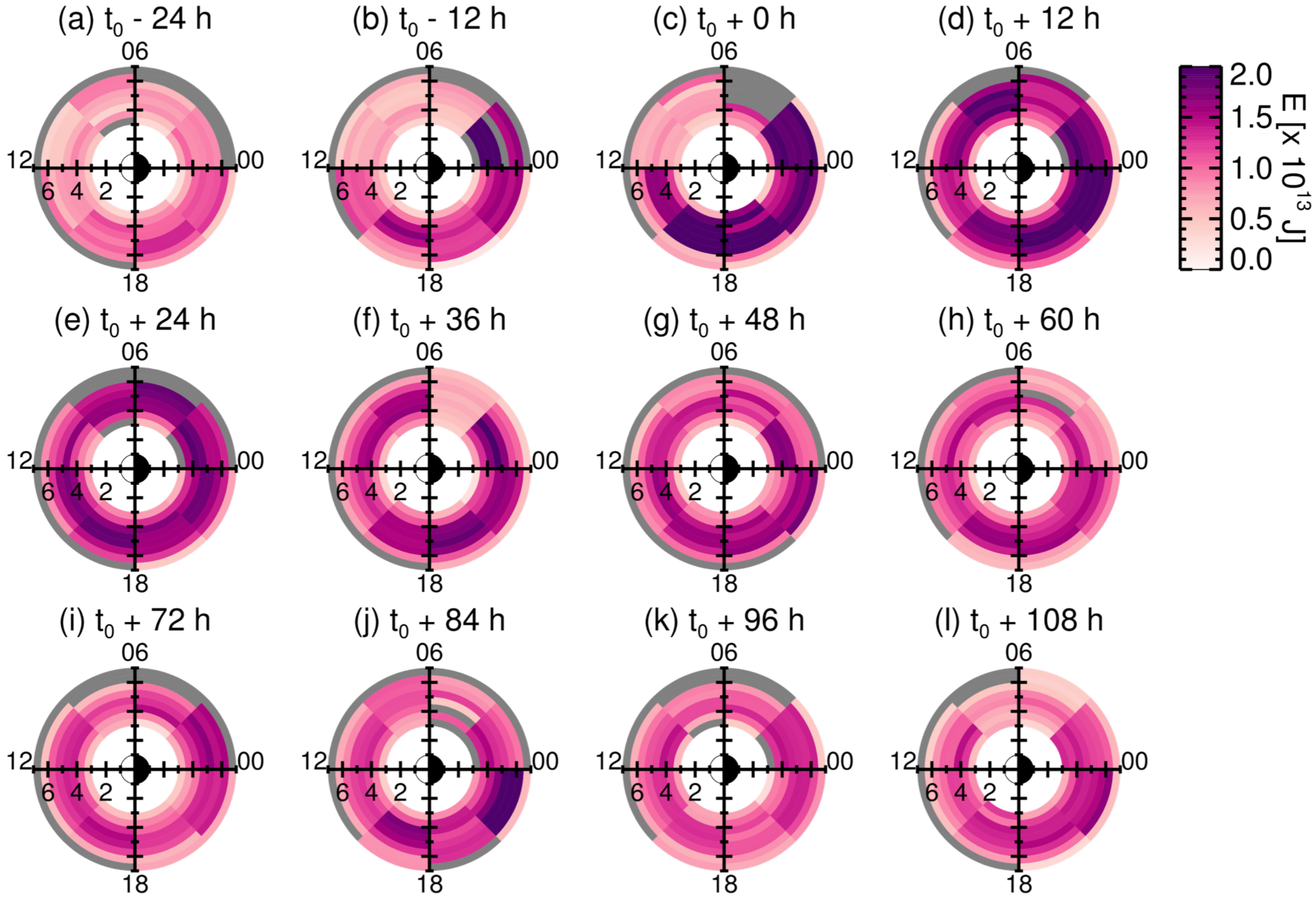
Extra: How we calculate the total ring current energy content



- We construct L-MLT maps for the mean energy content, in time bins relative to the storm peak.
- We sum over all spatial bins for a given L-MLT map to estimate the total ring current energy at a given time.

Extra: Spatial variations during storm times