MULLARD SPACE SCIENCE LABORATORY

Magnetic Fluctuations at Substorm Onset

Smith et al., 2020

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Substorms are a cycle of energy storage and release in the Earth's magnetosphere. Energy is added to the system until it reaches a state of instability, known as substorm onset. Following onset, the clearest indicator of the explosive energy release is the bright auroral display that is triggered.

Recent work has shown that 'bead-like' structure in the brightening aurora (panels a - d) is likely related to an instability in the near-Earth magnetotail that generates magnetic fluctuations [Kalmoni et al., 2017; 2018].

First, we compare coincident ground and space observations during a substorm.

- The all sky camera shows the development of auroral beads (panels a - d) before onset.
- The coincident ground magnetic field wave power increases dramatically in the same interval (panel e)
- Three conjugate spacecraft in the near-Earth magnetotail show similar large increases in wave power (panel f).

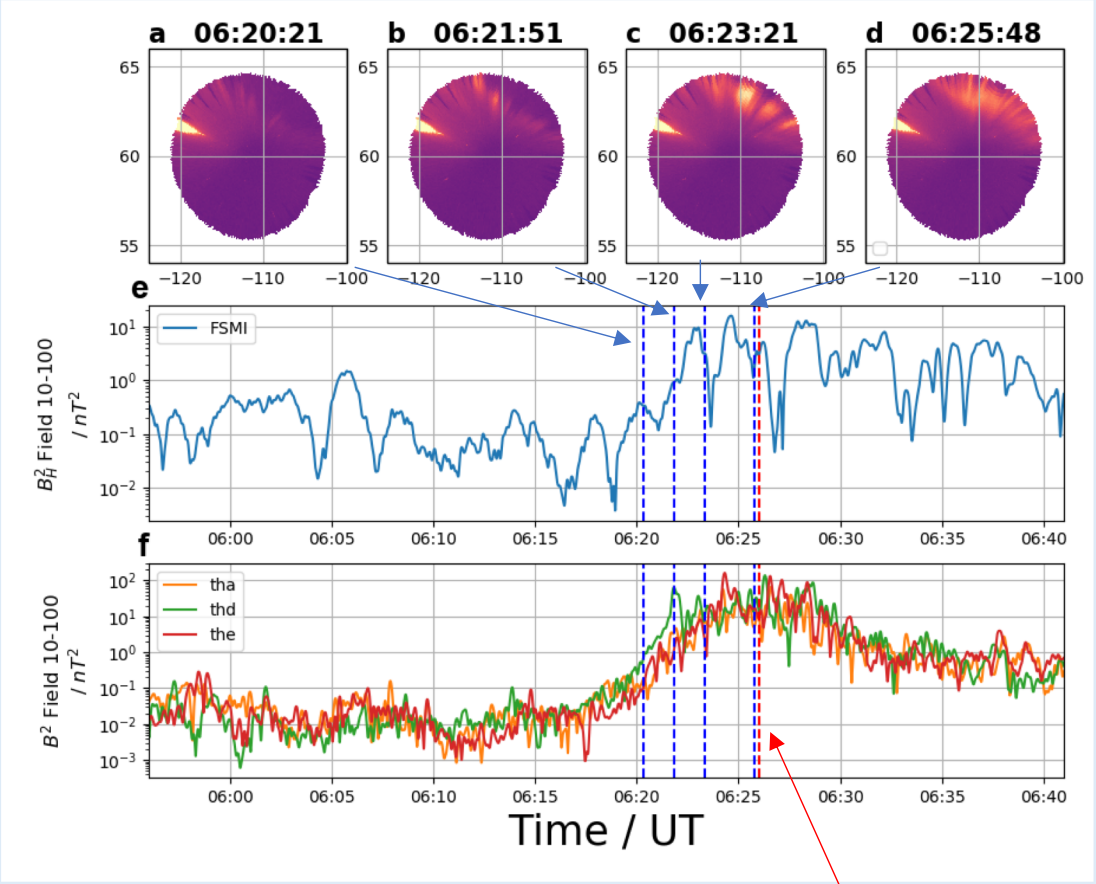

Figure 1. *THEMIS observations from the FSMI all sky imager (a - d), 10 – 100s filtered FSMI magnetometer data (e), conjugate THEMIS spacecraft observations (f).*

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Smith et al., [2020, under review]

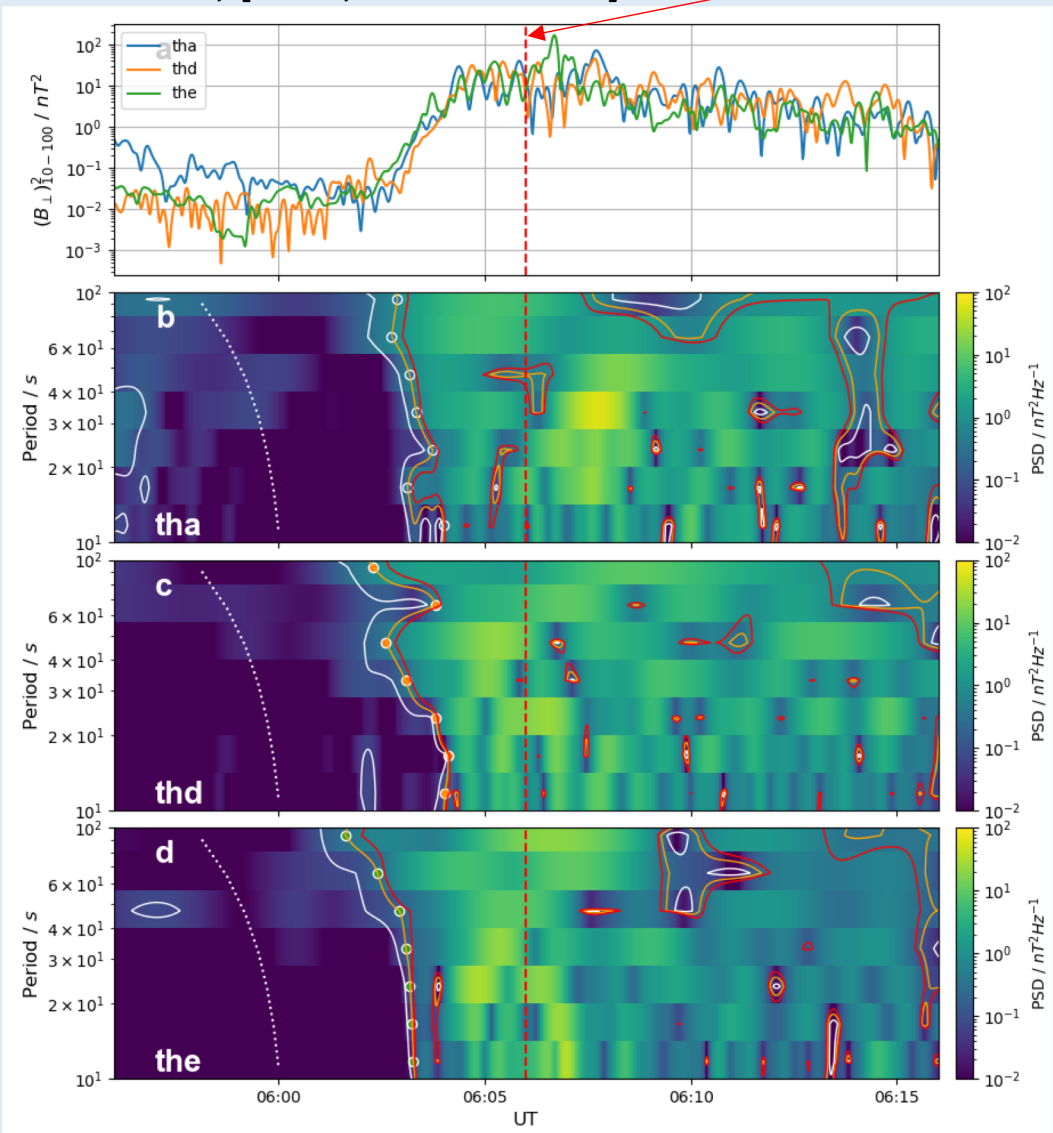

Figure 2. *THEMIS observations of 10-100s filtered wave power (a), wavelet power spectrograms from the three spacecraft individually (b - d). The white, orange and red contours indicate 1, 2 and 3 sigma of background.*

Period Dependence (Space)

We can break down the waves by period using wavelet spectrograms.

- Panel a shows the bandpass filtered wave power, all three spacecraft show strong increases prior to onset.
- In the spectrograms all three spacecraft see wave power spread across the full period bands presented (10 – 100s).
- The timing of the rise above background (e.g. orange contour) is consistent with a broadband signal (i.e. white dashed line on the left).
- The bottom spacecraft (the) observes the increase in wave power a few minutes before the other two, indicating it may be closer to the source.

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Period Dependence (Ground)

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We can do the same on the ground using an array of stations over North America, shown on the right for a few examples:

- Longer period waves appear to rise above background first.
- Some locations don't see the shorter period wave power (e.g. panels e, g).
- The relative delay of the shorter period waves depends on the station.

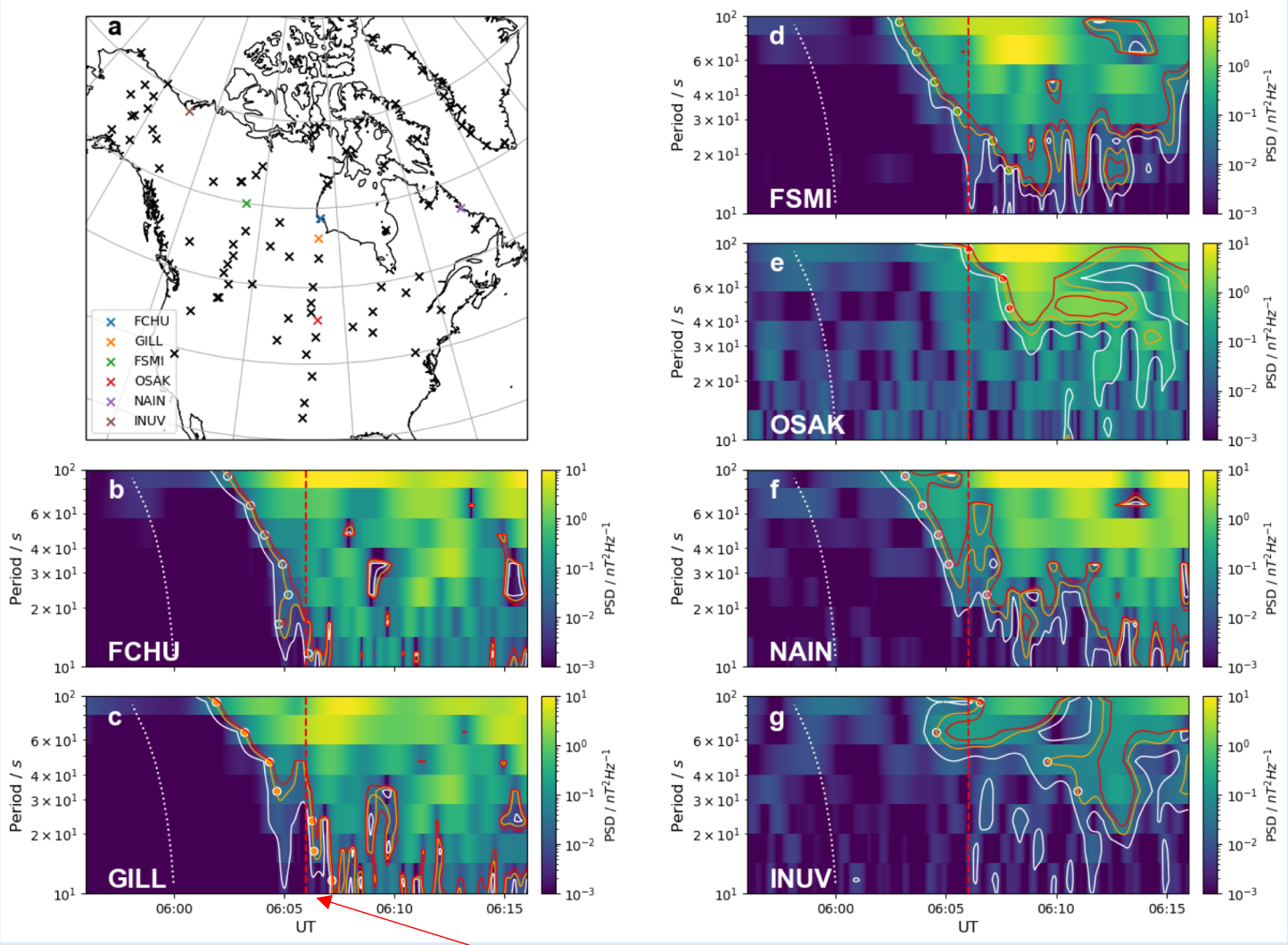

Figure 3. *Map of THEMIS ground stations (a), wavelet power spectrograms from selected ground stations (b - g). The white, orange and red contours indicate 1, 2 and 3 sigma of background.*

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Mapping Substorm Onset

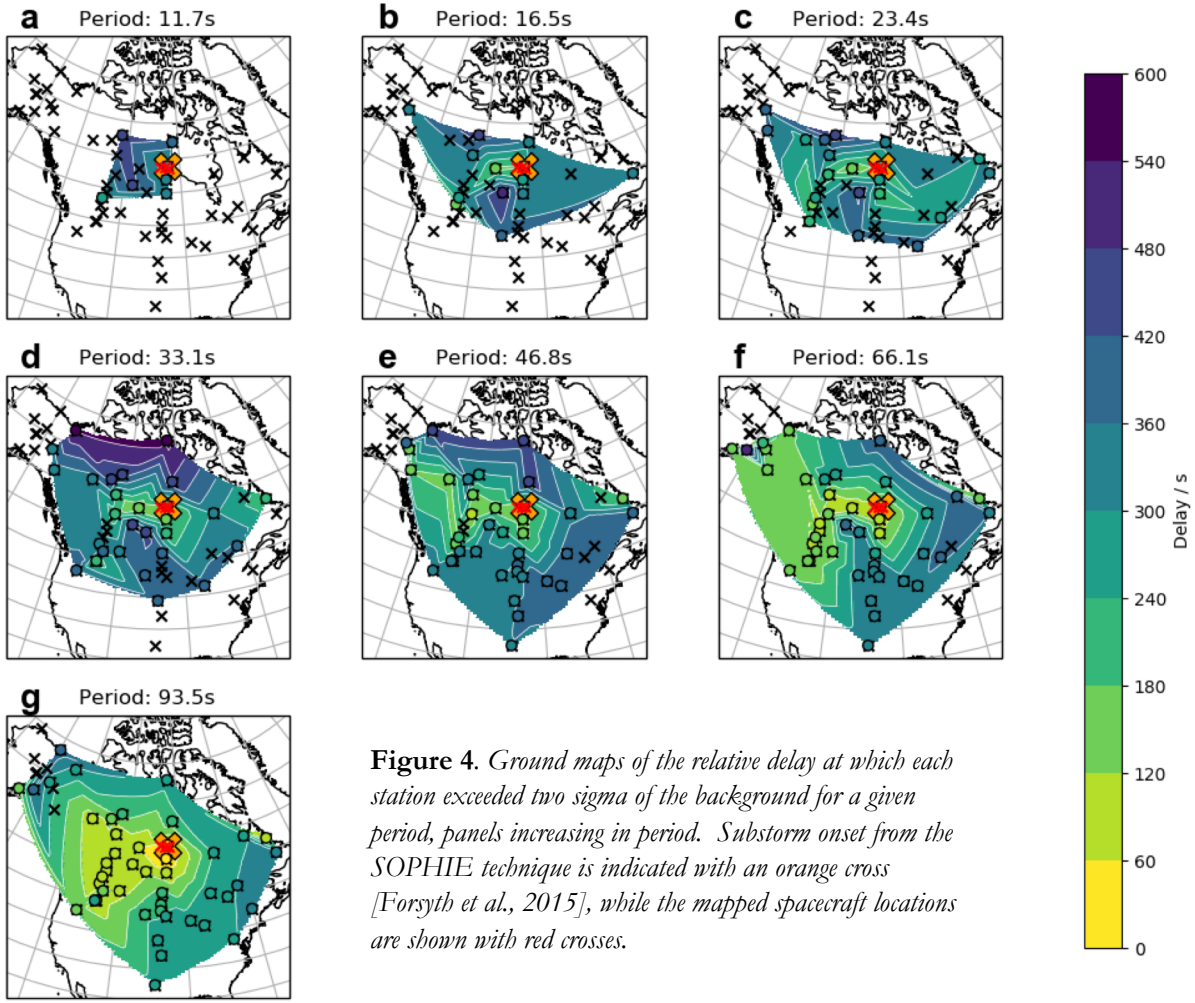

Figure 4. *Ground maps of the relative delay at which each station exceeded two sigma of the background for a given period, panels increasing in period. Substorm onset from the SOPHIE technique is indicated with an orange cross [Forsyth et al., 2015], while the mapped spacecraft locations are shown with red crosses.*

We can build maps of the relative time at which a location will first observe significant wave power:

- Shorter periods are only seen in a limited region close to onset (e.g. panel a).
- The signal spreads fastest westward of onset, and only slowly propagates in latitude.

The delay of the short period waves on the ground (but not in space) could be because the phase velocity of the waves depends on period, or that the shorter periods are more damped in the magnetotail.

Smith et al., [2020, under review]

References:
Forsyth et al., 2015, JGR, DOI: 10.1002/ 2015JA021343
Kalmoni et al., 2017, GRL, DOI: 10.1002/2016GL071826
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