Discrete structures in Solar Wind

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Introduction

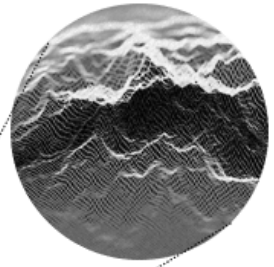
What are discrete structures?

Discrete structures are usually:

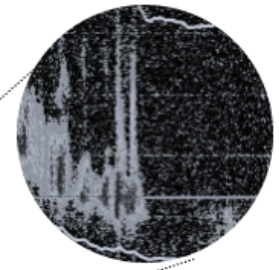
- Part of the solar wind – like orange juice pulp!
- They cannot be observed by the naked eye. We measure it using instruments in the solar wind and focus on characterizing its footprint and impact on the magnetosphere.
- They have a distinct signature in instrument readings, they often show up after an ICME.

ICME is short for Interplanetary Coronal Mass Ejection

Observed discrete structures!



Observed EMIC-waves!



EMIC waves are one of many factors affected by solar wind.

Spacecraft in outside Earth's magnetosphere

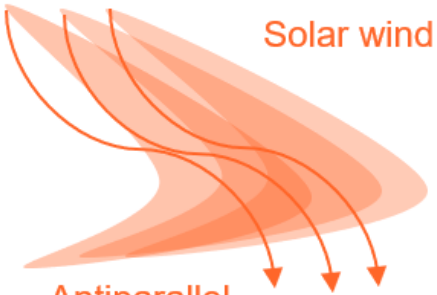
Spacecraft inside magnetosphere

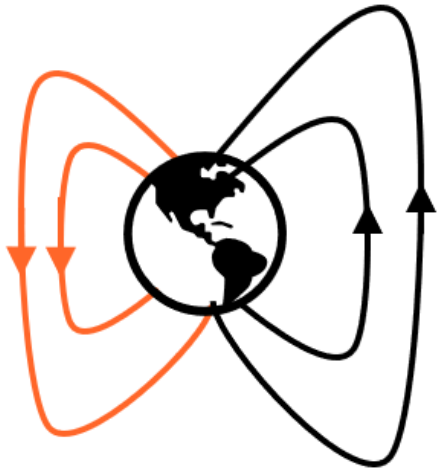
Solar Wind Disturbance

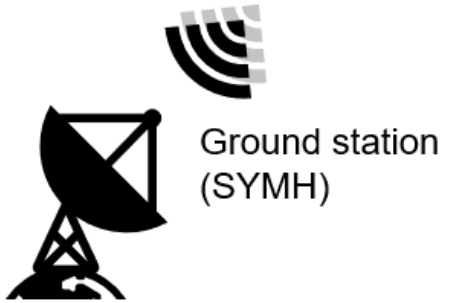
Magnetic Reconnection

Geo-Magnetic Event

Detected Disturbance in the Magnetosphere







EMIC is short for Electromagnetic Ion Cyclotron, and are a subset of EM Waves

SYMH measures how far is the Earth's magnetic field from its baseline.

Main challenges

How do we recognize them?

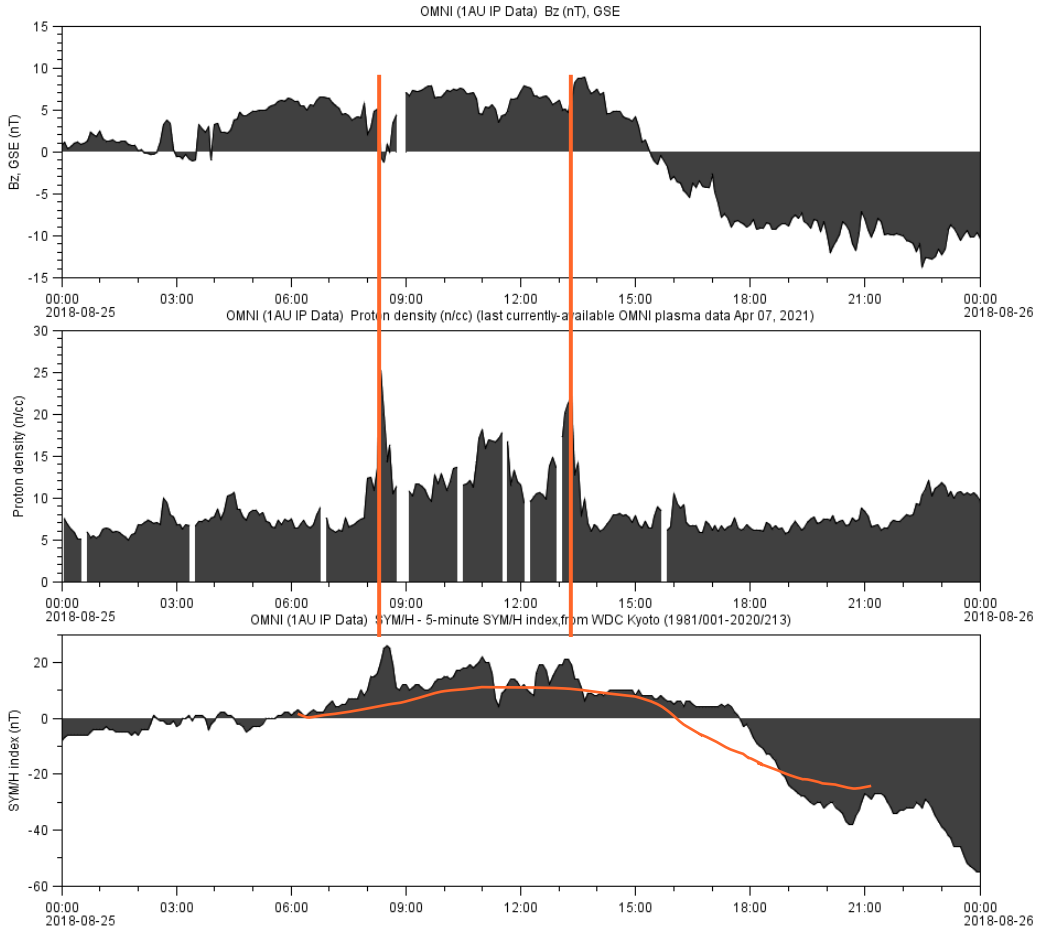
- No two discrete structures are alike
- They vary in shape, size, time of occurrence.
- They don’t always show up in the same spacecraft.
- There are nonetheless certain patterns that can help us find them.

Discrete structure signature?

How do we recognize them?

From our data, they usually:

- Have a small peak, big valley signature.
- Appear in proton density, changes in magnetic field & SYMH.



The SYMH signature is often an indicator for geo-magnetic storms.

Objective

Why are we interested in discrete structures?

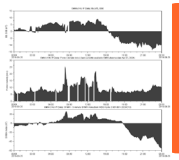
They will help us better understand the Sun-Earth connection by:

- Observing solar wind caused geomagnetic events.
- Piecing together a 3D image of the solar wind, as well as its impact on the magnetosphere, by looking at EMIC wave activity from multiple spacecraft simultaneously.
- **Determining whether these solar wind structures cause EMIC wave activity inside the magnetosphere.**

Methods

How did we capture the data?

List of ICME events from 2016-2018

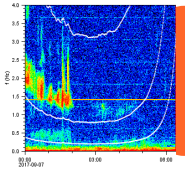


Using OMNI* Instrument readings and SYMH**

Events that have a discrete structure signature

Events categorized as geomagnetic storms

Cross referencing data from space weather activity website



Using spectrograms

Events with significant EMIC wave activity

*OMNI is a collection of various spacecraft that can measure magnetic field, proton density, temperature.

**SYMH measures how far is the Earth's magnetic field from its baseline.

Results

OMNI, Spectrogram readings & spacecraft locations

But first! A brief overview on how the results are shown

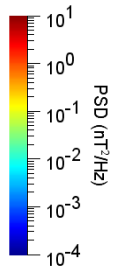
hh:mm

Broad, transparent line to indicate the time interval currently being observed

Thin, contrasting line indicates the event's hour listed on the ICME database

OMNI instrument readings goes here

Colorbar measures the wave's power, applies to all spectrograms



Spacecraft instrument readings from 04:00 to 06:00 UT

Spacecraft positions goes here

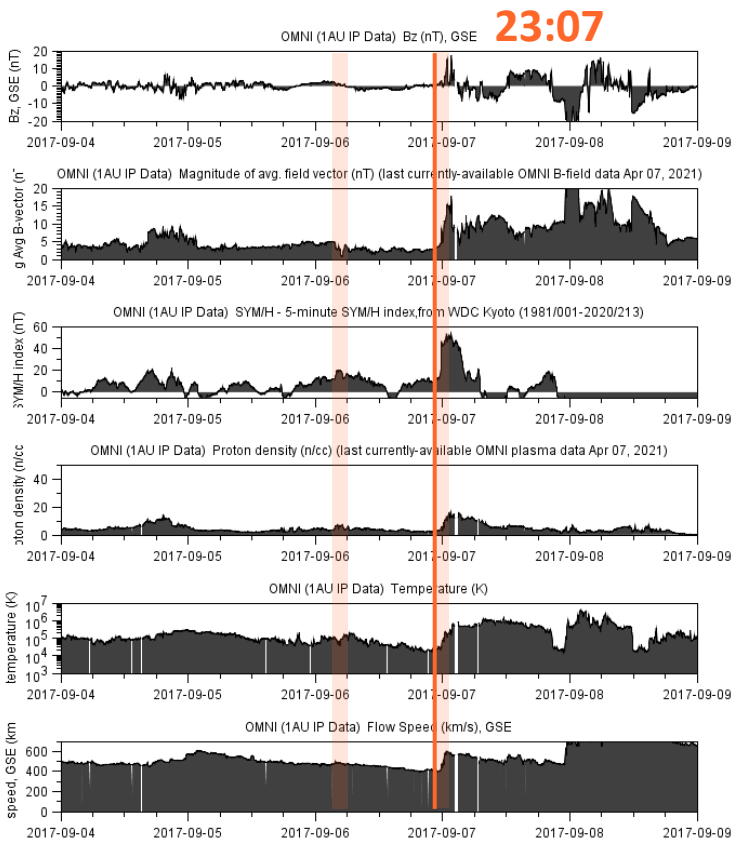
Each spacecraft is plotted with their corresponding color

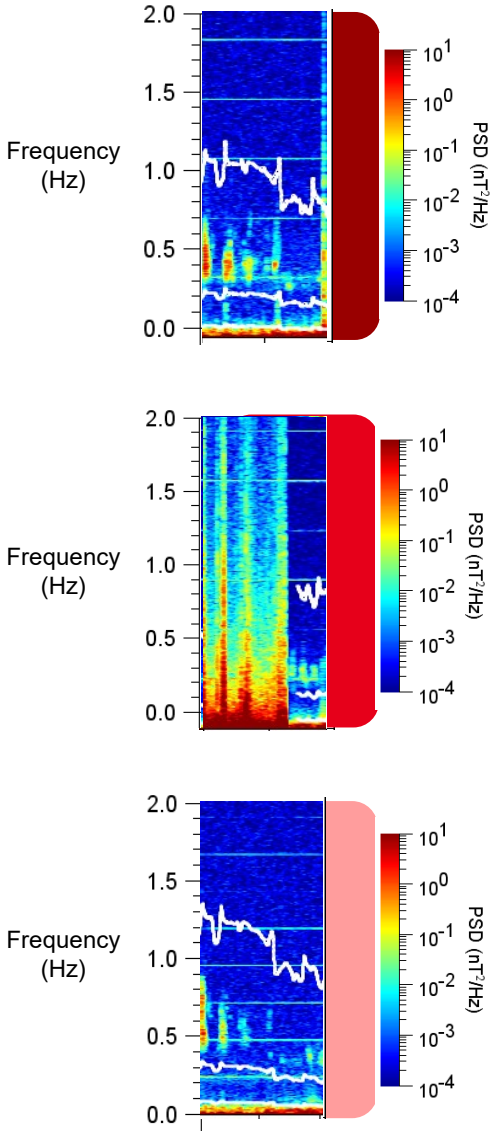
Each colored square represents the corresponding spacecraft's spectrogram

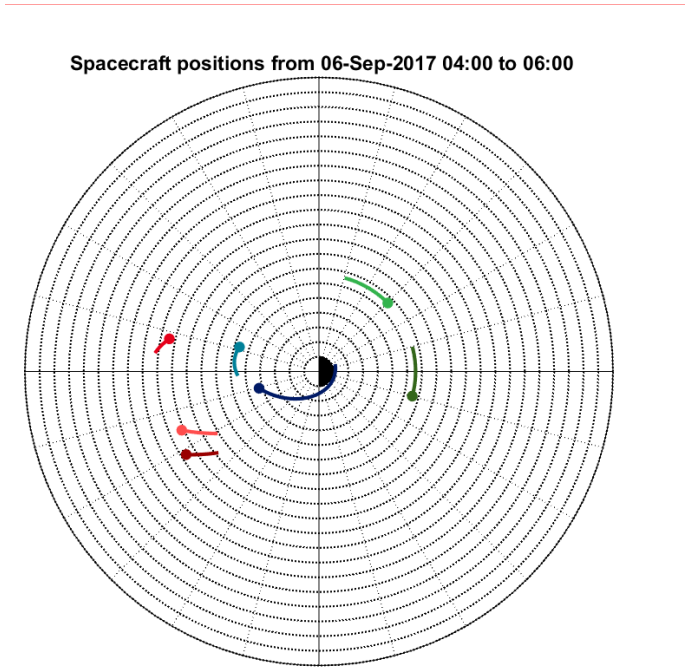
THEMIS A
THEMIS D
THEMIS E
GOES 13
GOES 15
RBSP A
RBSP B
MMS 1-2

Month ddth, yyyy

- Each event has their corresponding notes.







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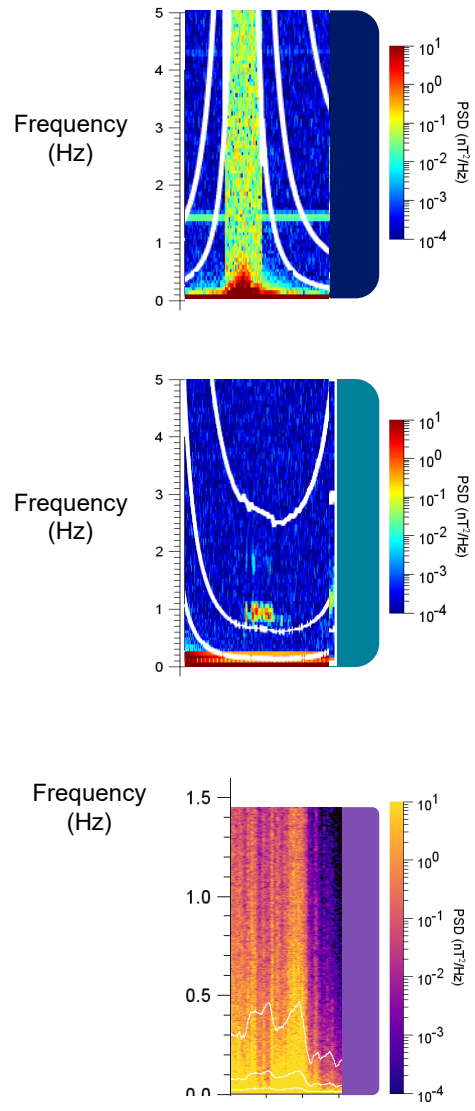
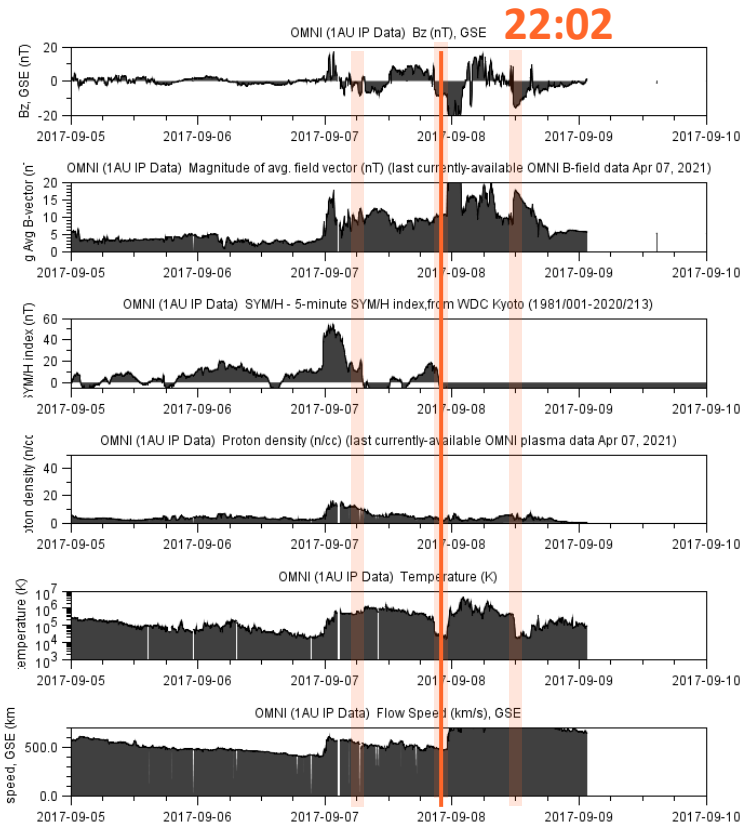
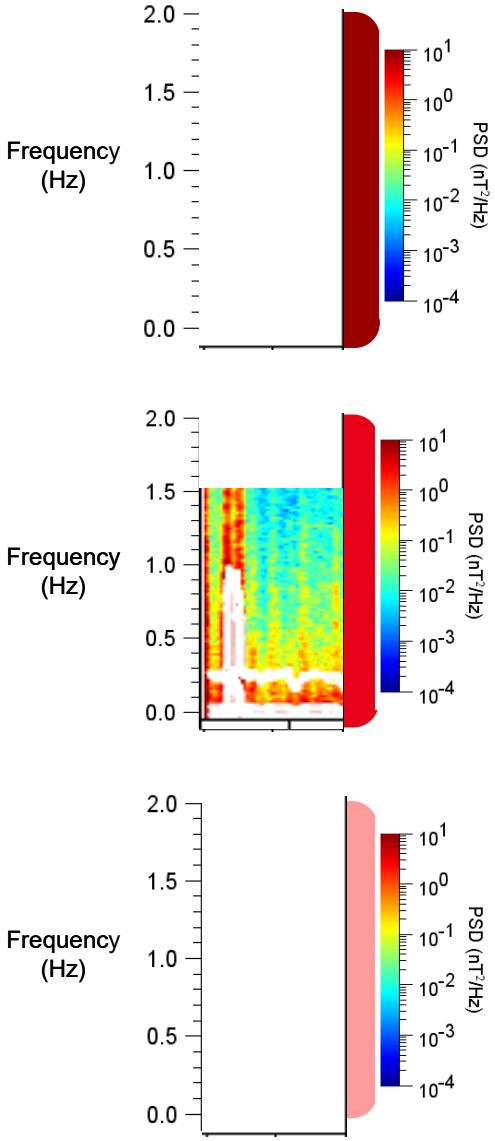
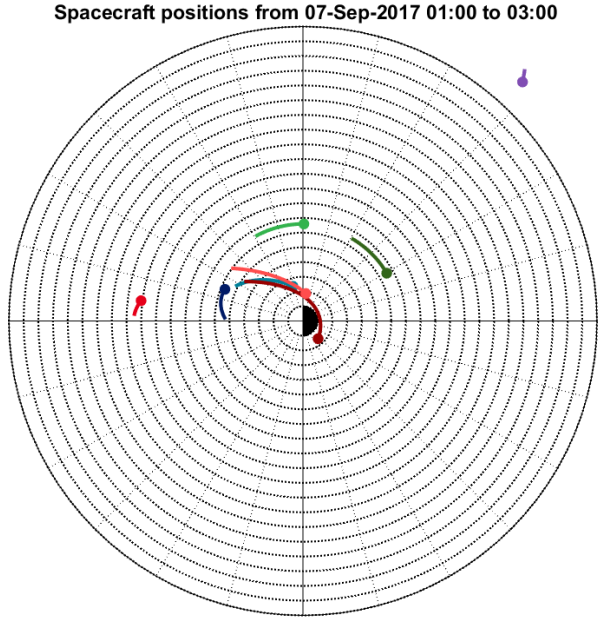


September 6th, 2017

- RBSP B, THEMIS A & E shows clear EMIC wave activity within the time frame,
- Similar activity near the end of day.







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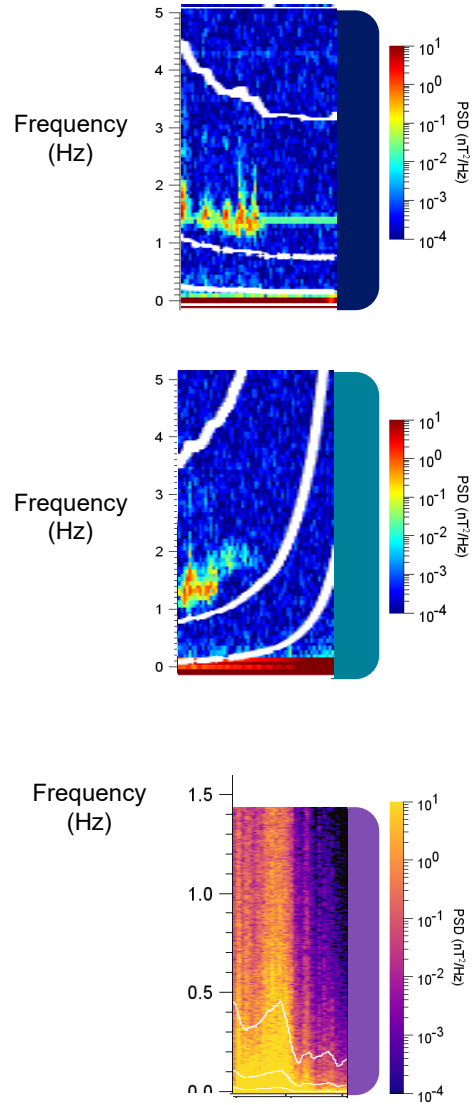
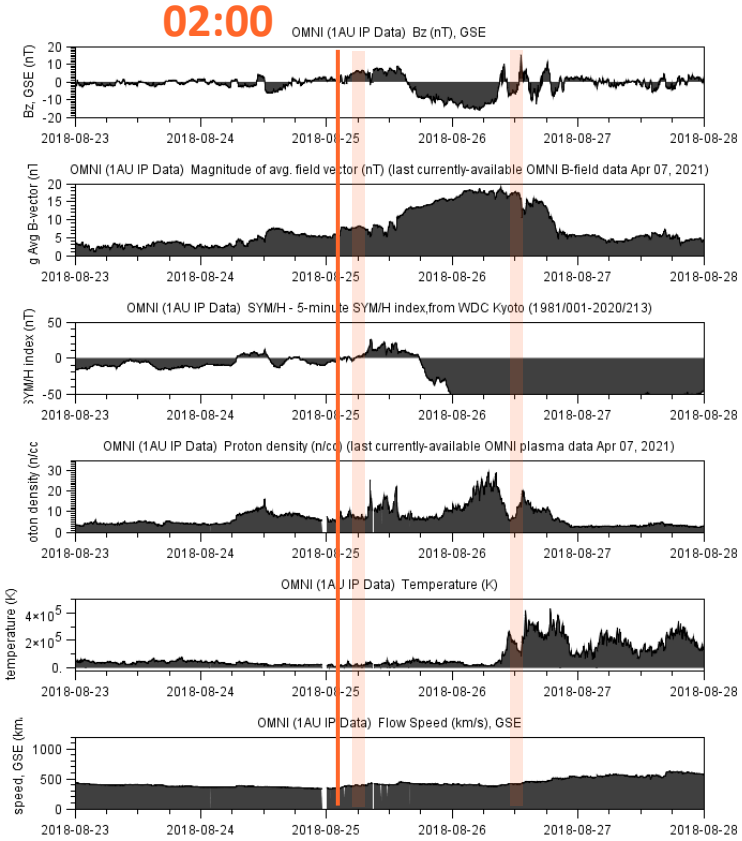
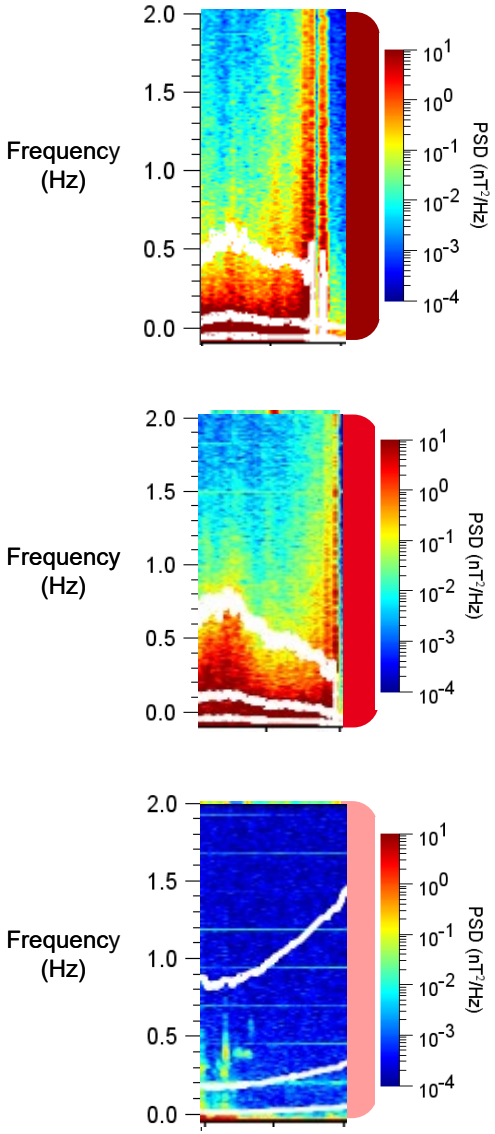
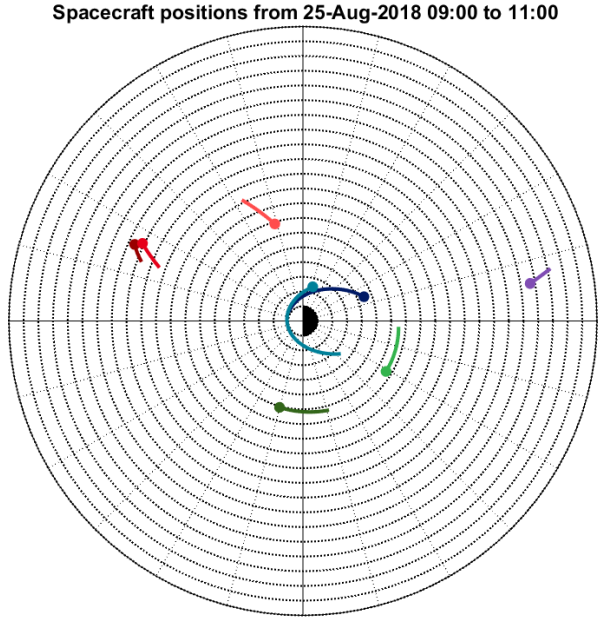


September 7th, 2017

- RBSP show the continuation of the initial discrete structure shown in the day before.
- THEMIS D shows a lookalike EMIC wave but no discernable change in gyrofr.
- MMS shows activity spikes within the time frame but no discernable discrete structures.







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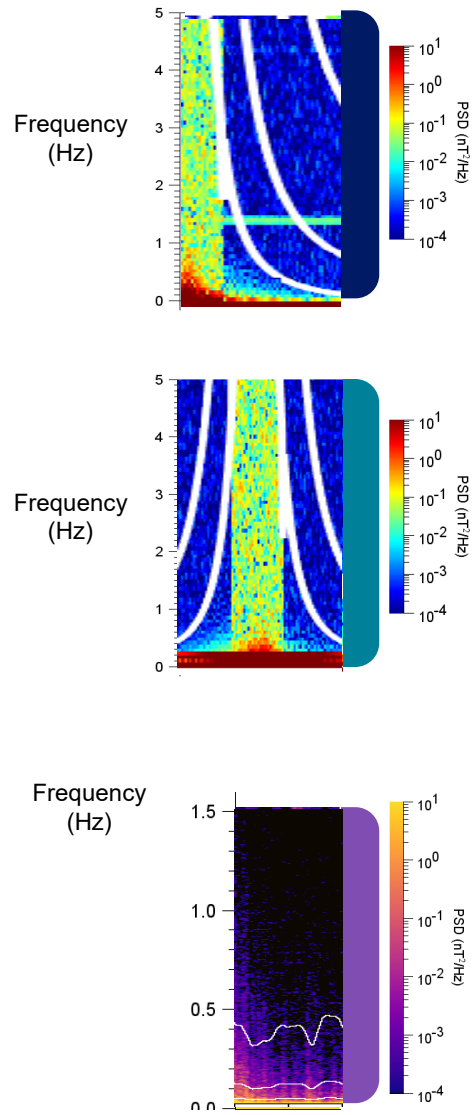


August 25th, 2018

- THEMIS A&D shows broadband wave activity.
- THEMS E shows EMIC wave activity.
- No activity in RBSP or MMS.

Conclusions

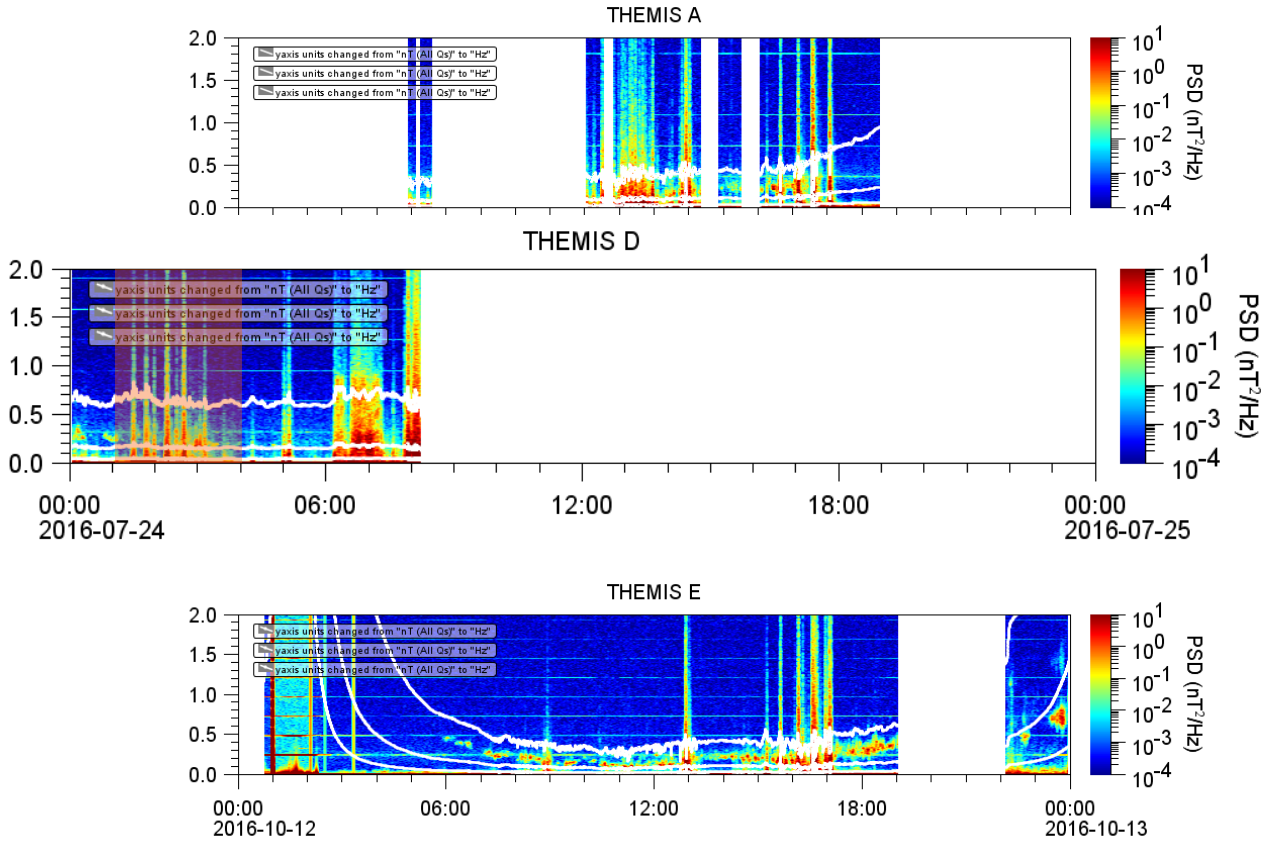
What did we learn?

- MMS Spacecraft were usually outside of the magnetosphere and only saw EMIC wave activity once because it was inside.
- RBSP probes always registered EMIC wave activity within 24 hrs. of the event.
- EMIC wave activity at the moment of impact was always found on the dayside.
- RBSP probes, ~24 hrs. after the solar wind hits, can still see some EMIC wave activity even if it is on the nightside.
- When OMNI B-field and proton density readings saw increases in activity, THEMIS spacecraft saw broadband activity.
- As long as the spacecraft are inside the magnetosphere, within a 24-hr. timeframe, there is a very high chance of seeing EMIC wave activity on the dayside *and* nightside.

Discoveries?

What were some unexpected results?

- Super long series of EMIC waves
- THEMIS spacecraft show EMIC waves at the beginning and end of broadband waves.



Future work

What needs further research?

- Find more examples of nightside EMIC waves caused by solar wind events.
- Add more spacecraft spectrograms (GOES, POES).
- Expand dataset to span more years.

Summary

Why are discrete structures important?

- Discrete structures often accompany solar wind that causes geo-magnetic storms
- They often generate EMIC waves in the magnetosphere, which can be observed by multiple spacecraft in a variety of situations.
- Helps us create a better Sun-Earth model.

Questions?