ICME-driven Sheath Regions

Julia Pukarinen

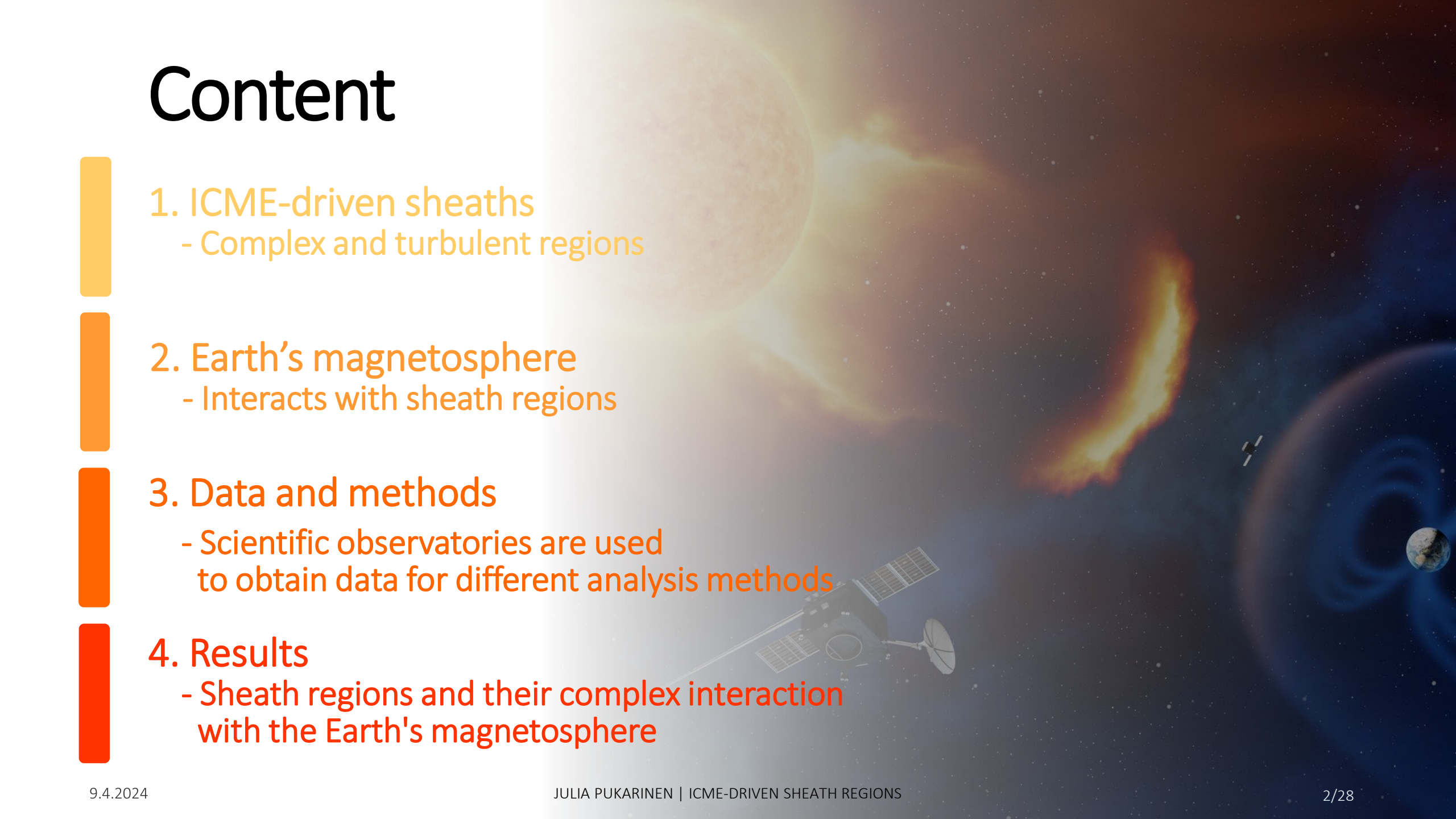
Content

1. ICME-driven sheaths
   - Complex and turbulent regions

2. Earth’s magnetosphere
   - Interacts with sheath regions

3. Data and methods
   - Scientific observatories are used to obtain data for different analysis methods

4. Results
   - Sheath regions and their complex interaction with the Earth's magnetosphere



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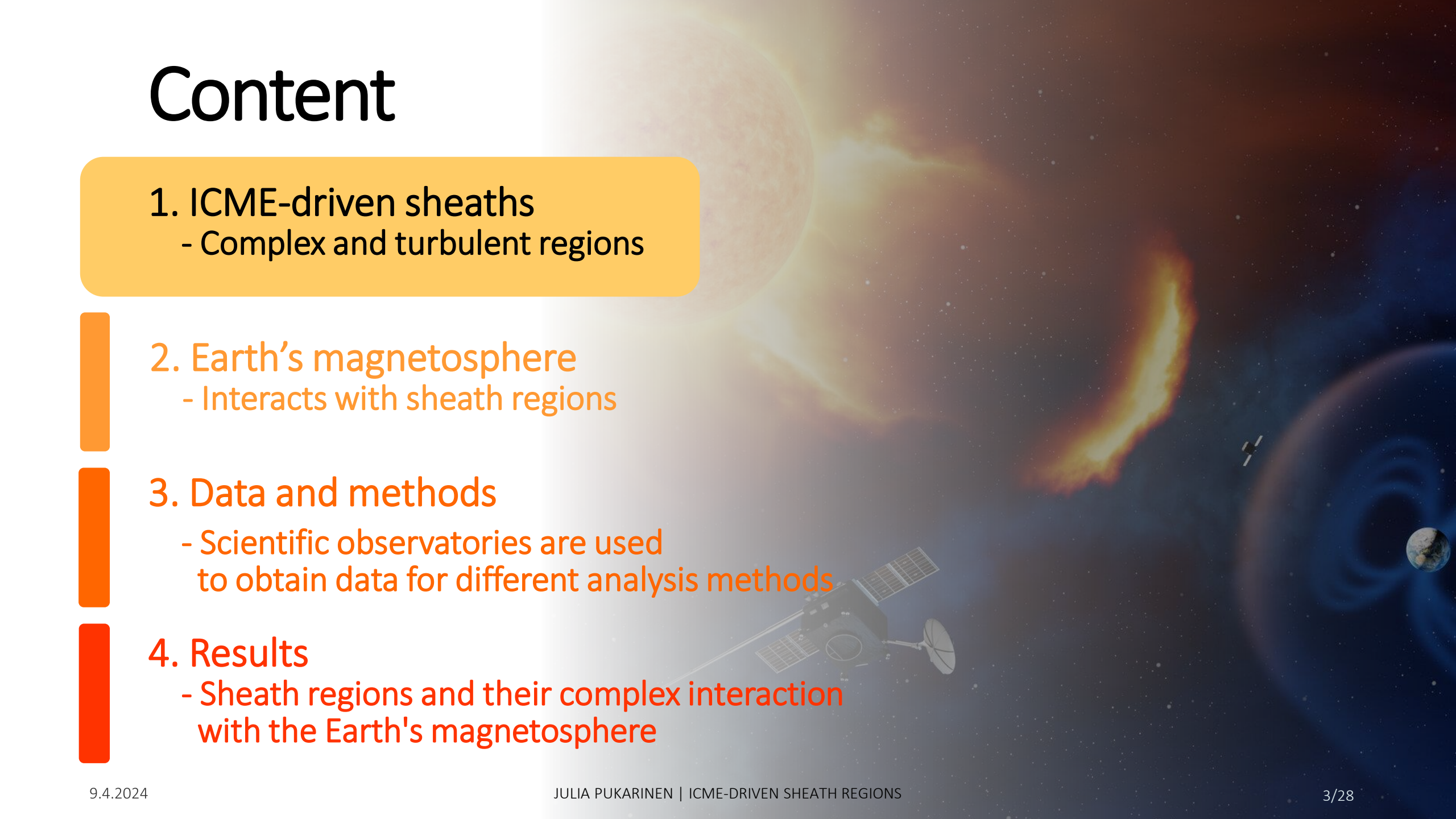
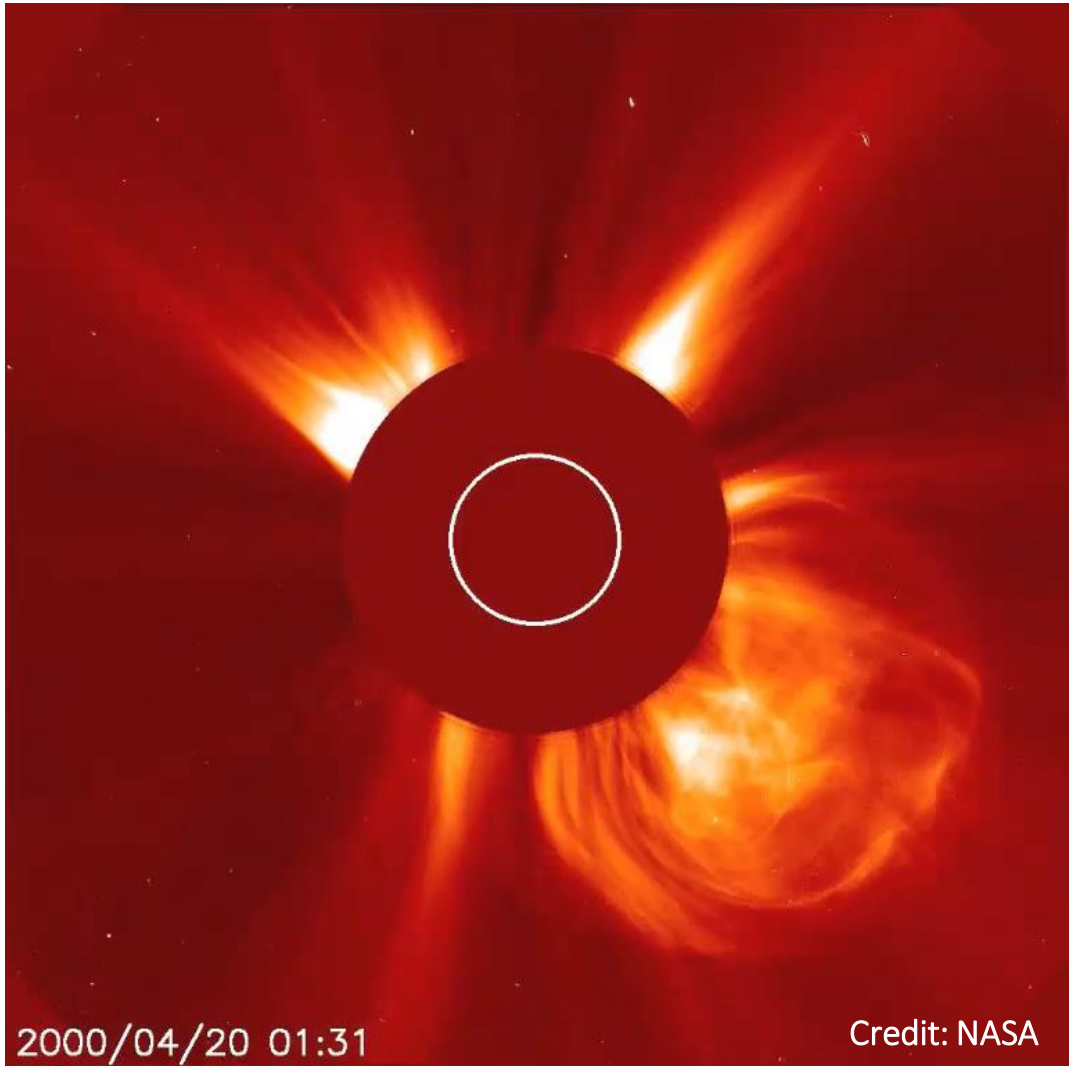


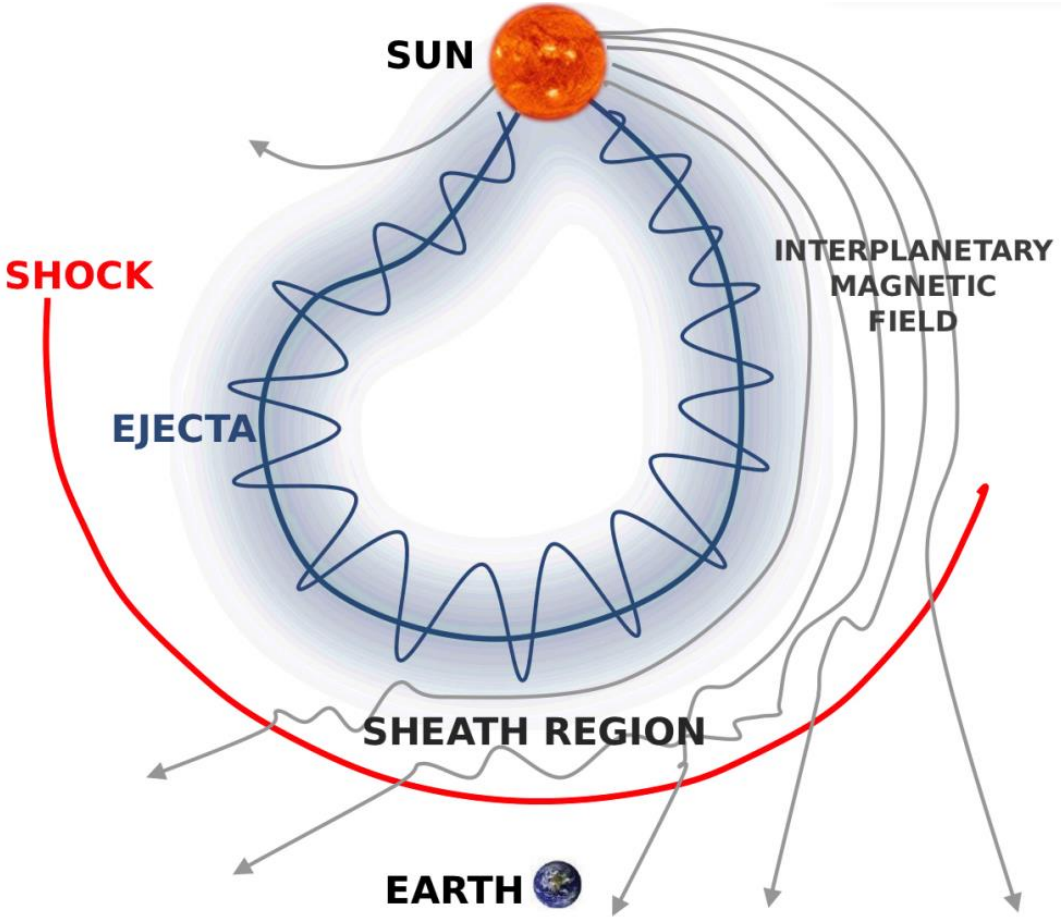
Interplanetary coronal mass ejections (ICMEs)

- ICMES are enormous plasma clouds erupting from the Sun.
- When an ICME erupts, the coronal magnetic field extends outward and massive amounts of plasma and magnetic field are released into interplanetary space.



Interplanetary coronal mass ejections (ICMEs)

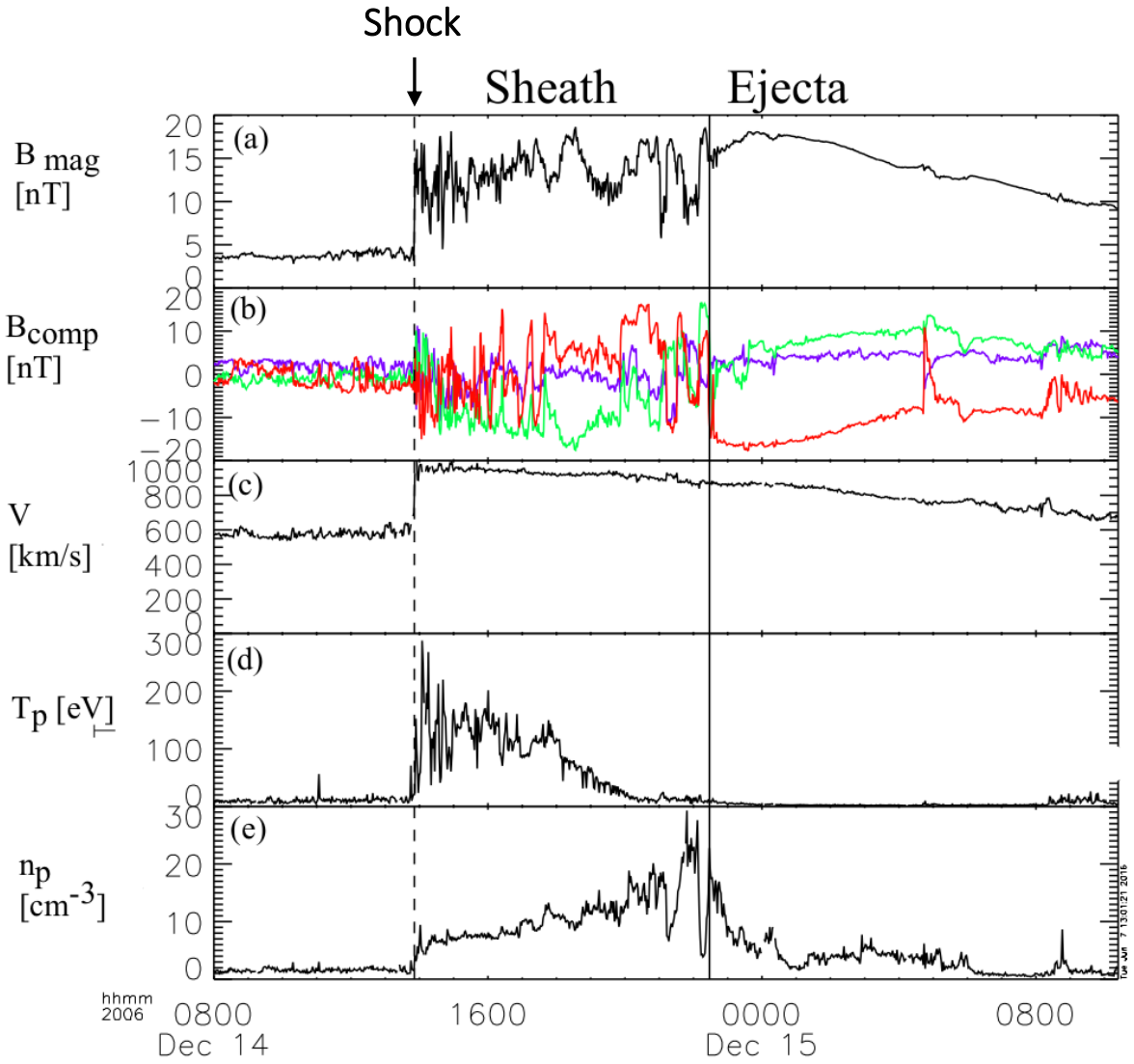
- When an ICME propagates through the interplanetary space at a speed that exceeds the speed of the ambient solar wind, a shock wave forms in front of it.
- Plasma and magnetic field are compressed between the shock and the ICME, forming a turbulent sheath region.



Credit: Kilpua et al. (2017)

Highly complex sheath regions

- As the ICME propagates, the plasma and magnetic field accumulate in the sheath.
- The magnetic field fluctuates significantly and the temperature T and density n are much higher compared to the ambient solar wind and ejecta.



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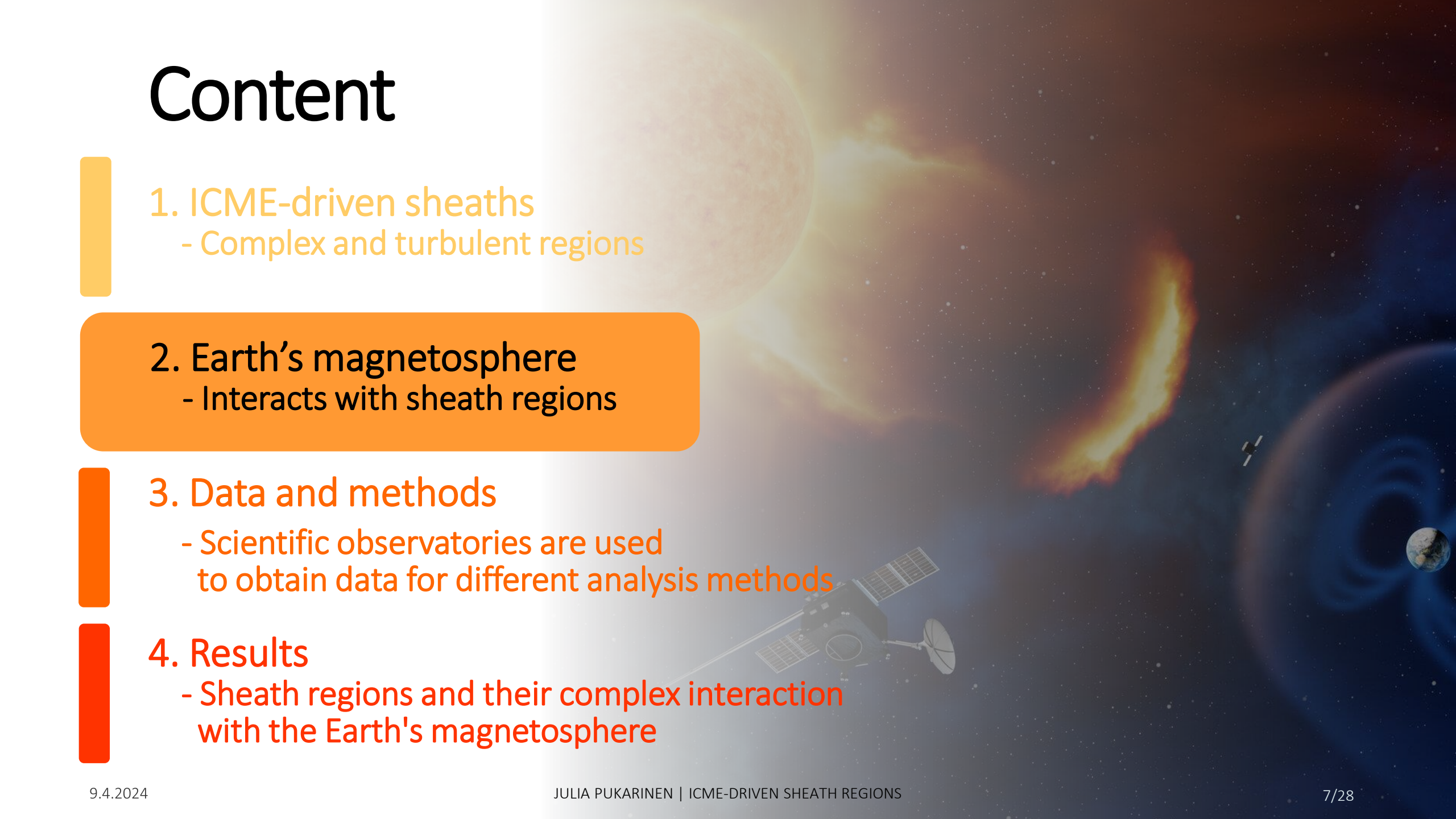


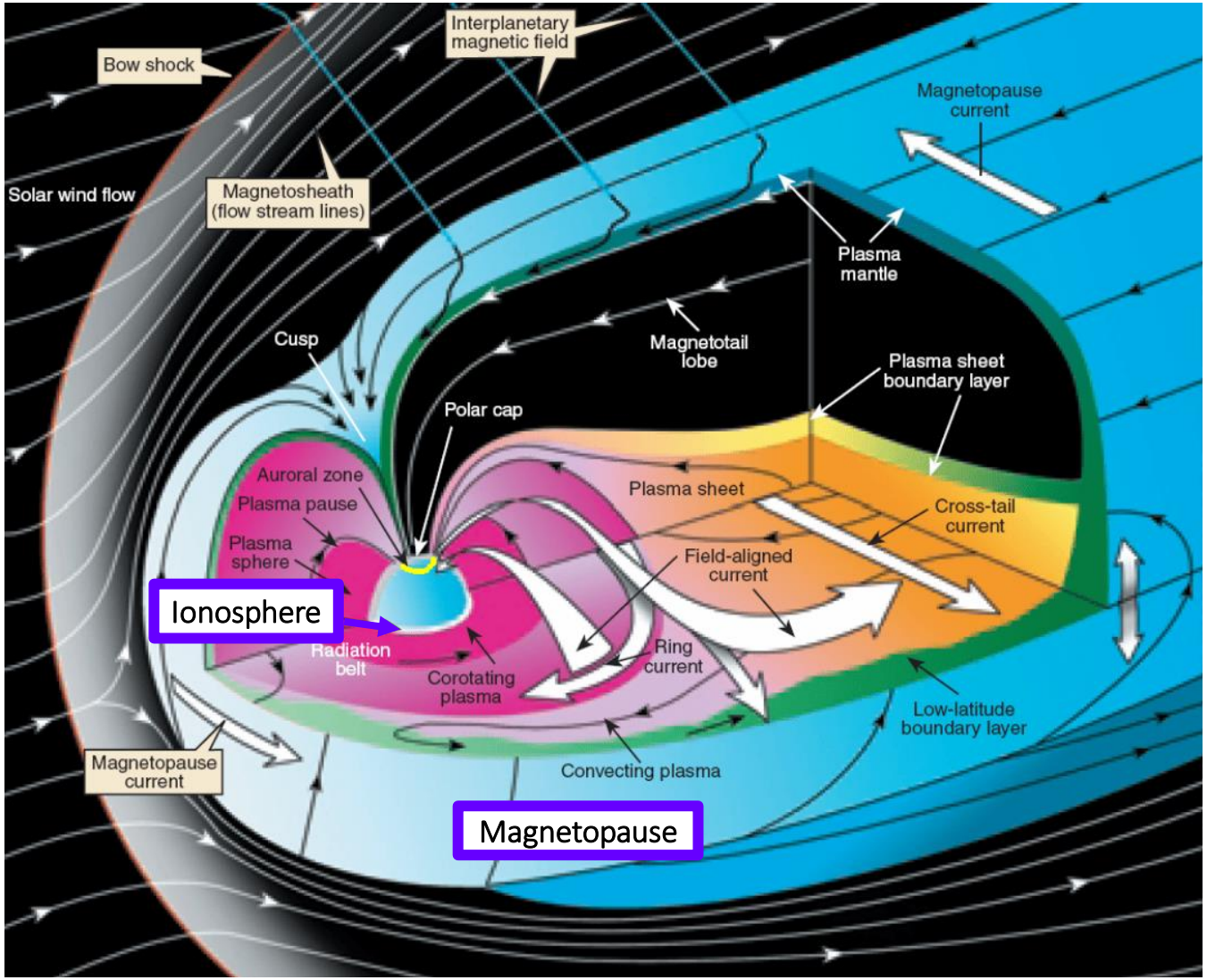
Earth's magnetosphere

Magnetopause:

- Part of the outer magnetosphere.
- The boundary between the solar wind and the Earth's magnetic field.

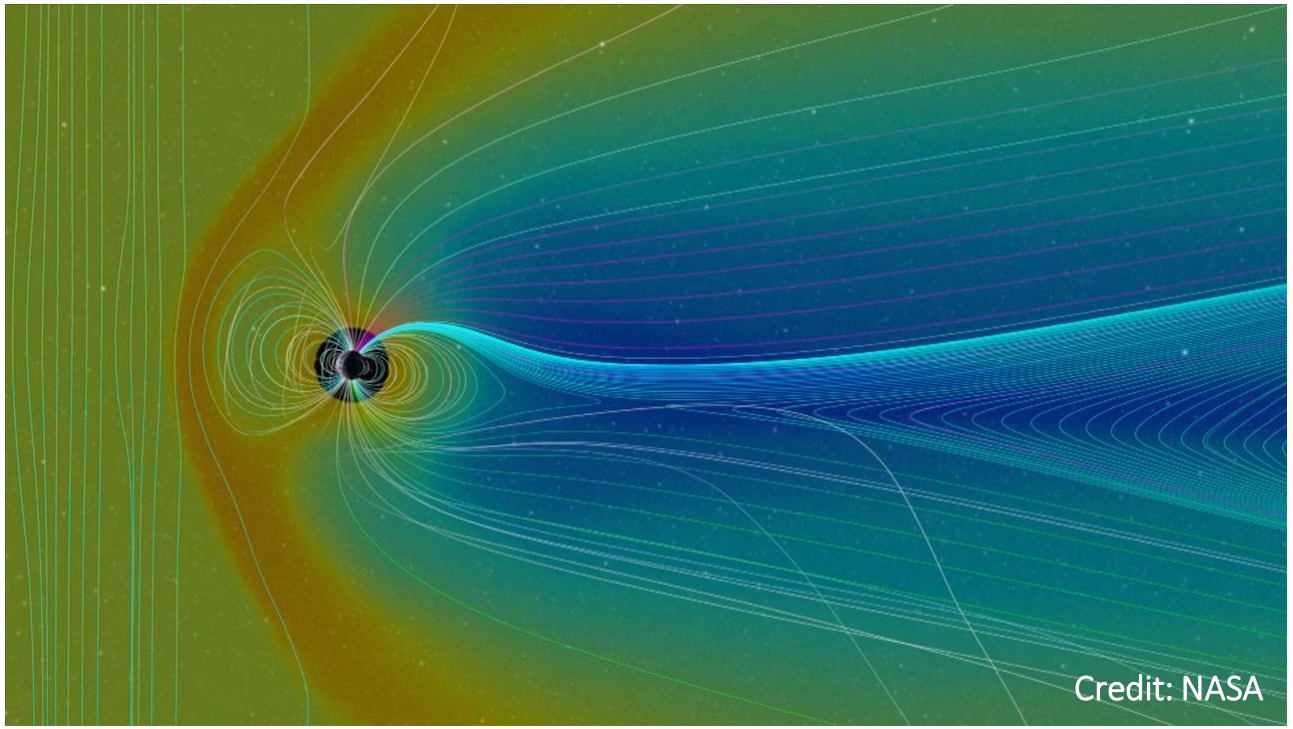
Ionosphere:

- Part of the upper atmosphere.
- Composed of ionized particles.



Ultra Low Frequency (ULF) waves: 0.001–1 Hz (1–1000 s)

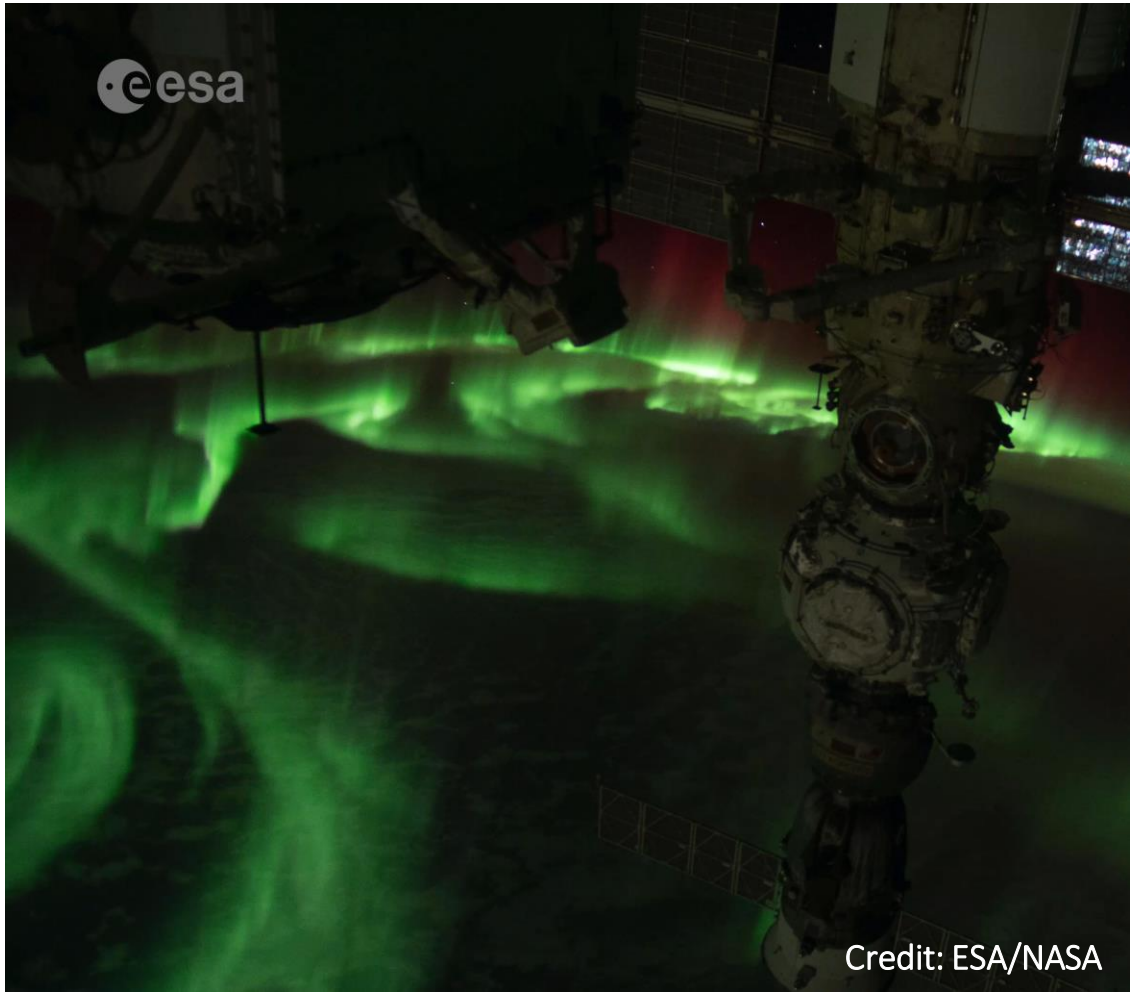
- ULF waves are the lowest frequency plasma waves in the Earth's magnetosphere.
- Pc5 (150–600 s) waves play a crucial role in the dynamics of the Earth's magnetosphere.



- The sources of ULF waves exist both internally and externally to the magnetosphere: external sources include solar wind pressure fluctuations that push the magnetopause.

Geomagnetic storms

- Geomagnetic storms are major disturbances of Earth's magnetosphere.
- They arise from solar wind variations that produce major changes in the Earth's magnetosphere.
- Space weather refers to phenomena caused by the Sun in the near-Earth space.



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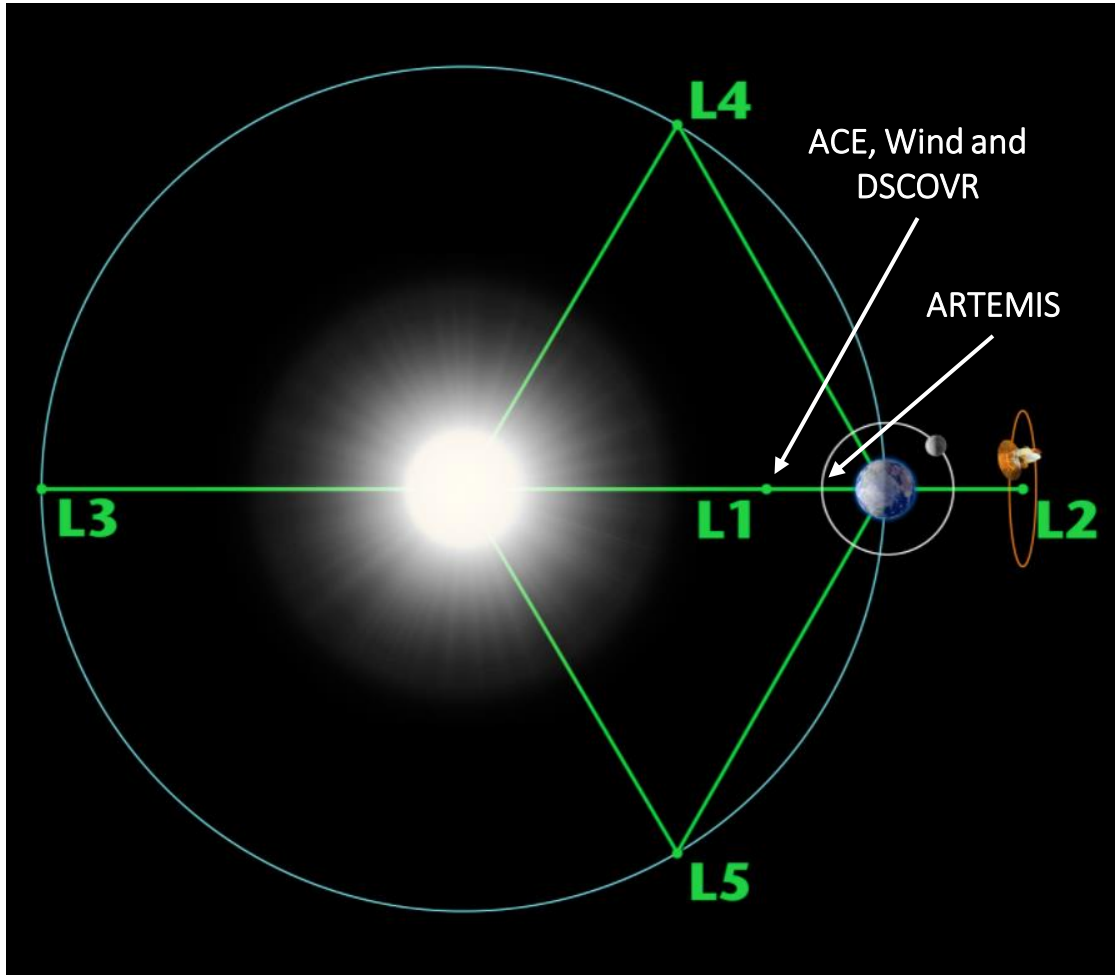
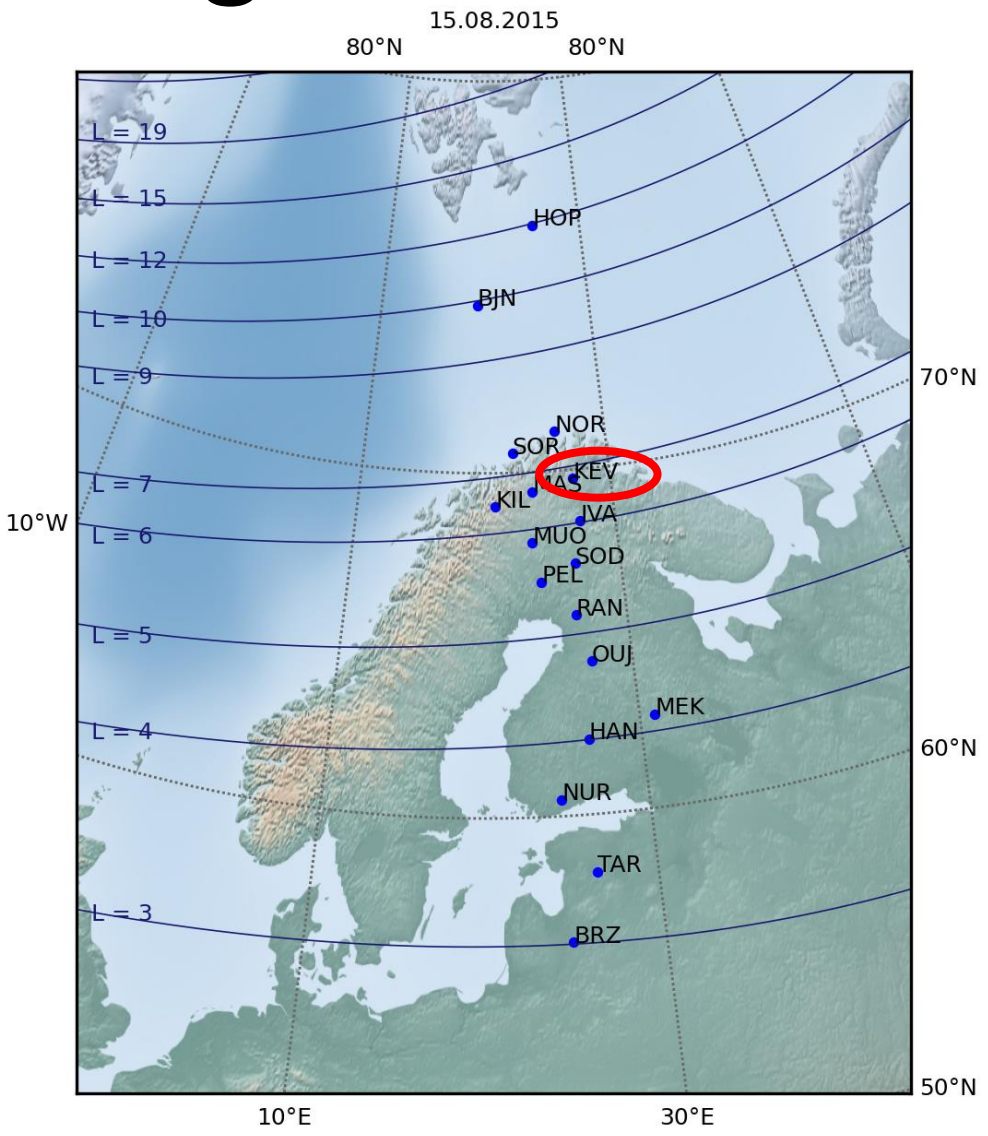
Solar wind is measured by multiple spacecraft

- Spacecraft in the solar wind are used to investigate the evolution of the sheath region.
- They measure the magnetic field and solar wind particles.
- ACE, Wind and DSCOVR orbit around the L1 Lagrangian point.
- ARTEMIS orbits the Moon.



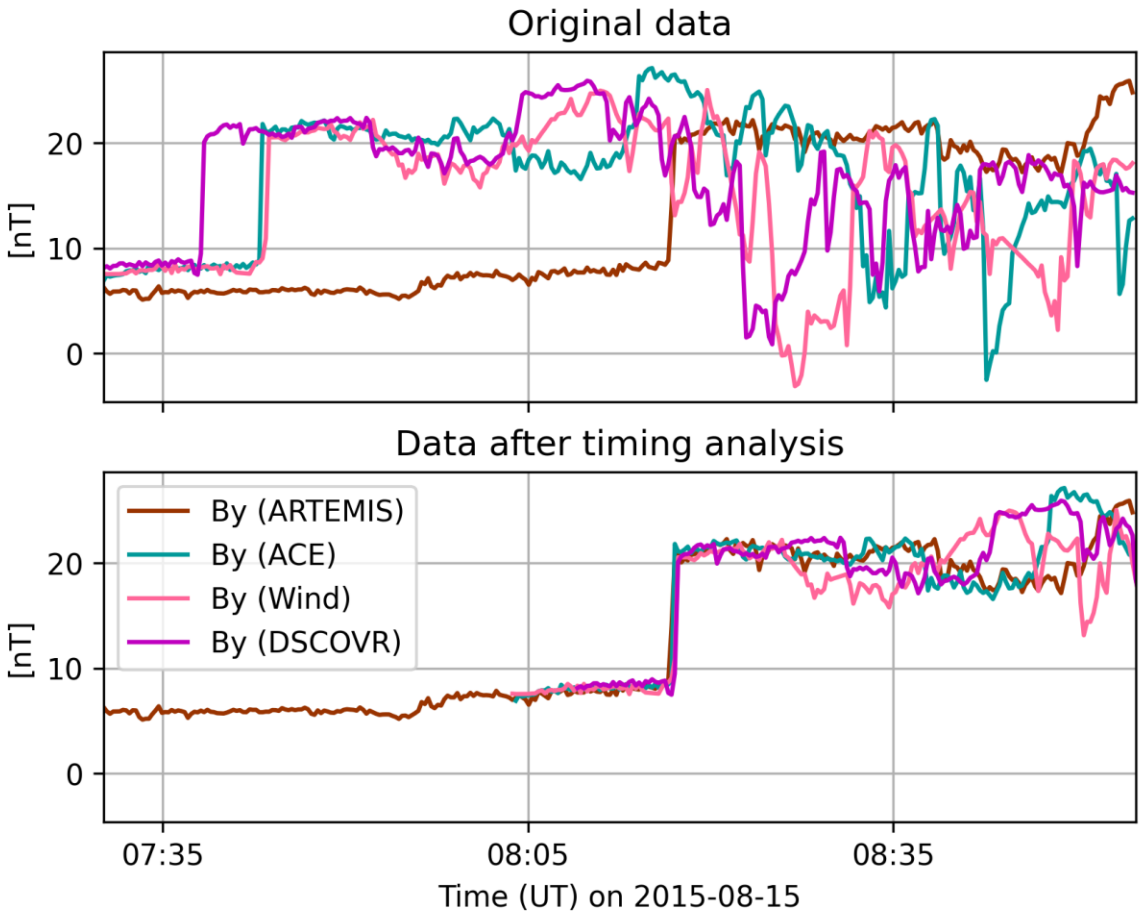
Kevo’s ground-based magnetometer

- Kevo is located in a latitude that is magnetically connected to the outer magnetosphere.
- We expect that the interaction of the sheath with the outer magnetosphere could cause large amplitude fluctuations, and therefore would be detected in the Kevo measurements.



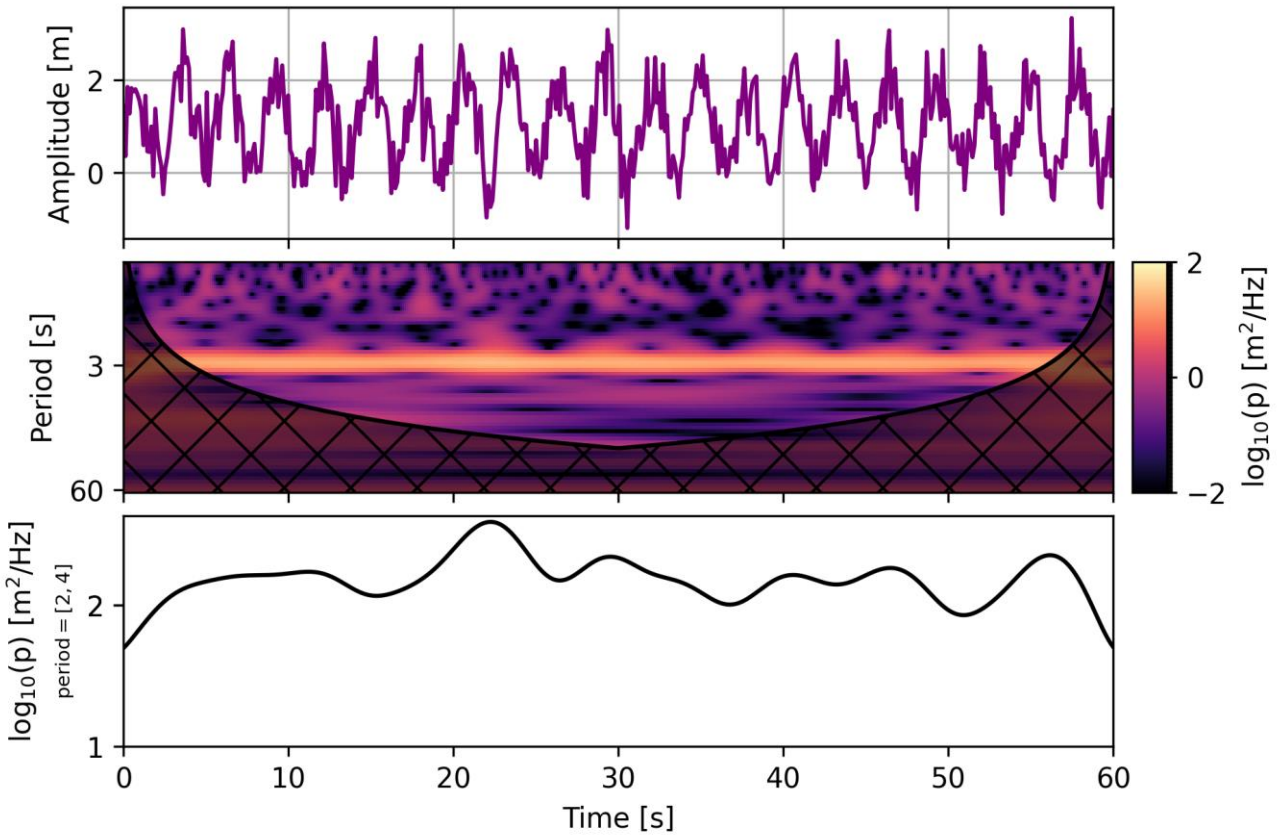
Multi-spacecraft timing analysis

- Information about the structure of the sheath can be obtained based on its travel time from one spacecraft to another.
- When a discontinuity of the sheath is observed by multiple spacecraft, the normal direction and the speed of the discontinuity can be constructed.



Wavelet analysis is a common tool for analyzing time series

- Wavelet analysis enables decomposing a one-dimensional time series into two-dimensional time-frequency space.
- It reveals the frequency and the power of the dominant fluctuations and their temporal evolution.



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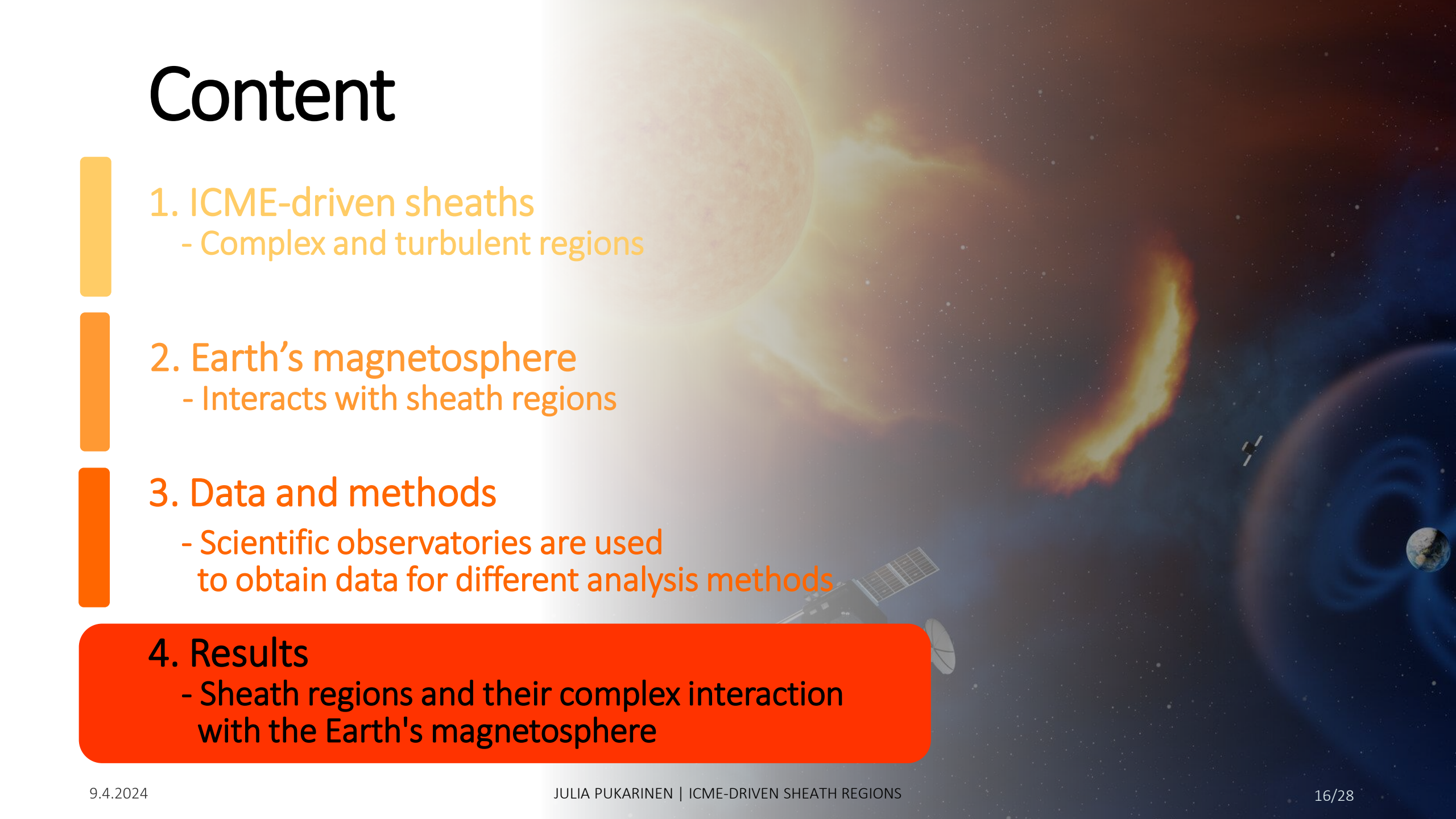
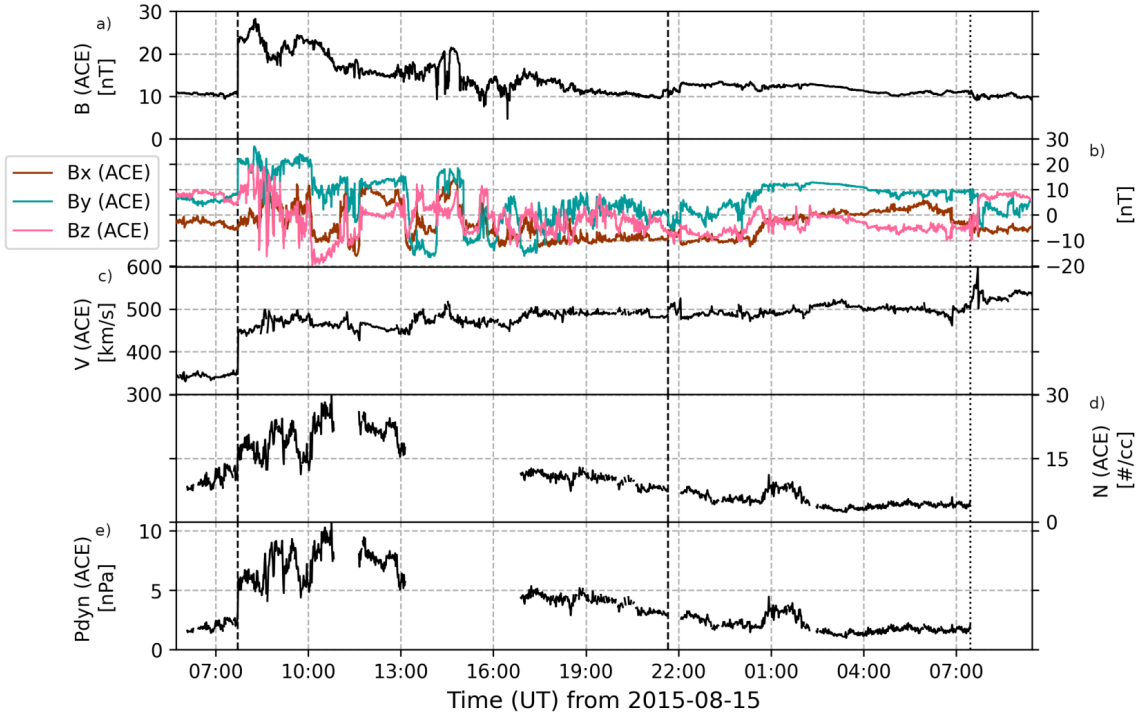


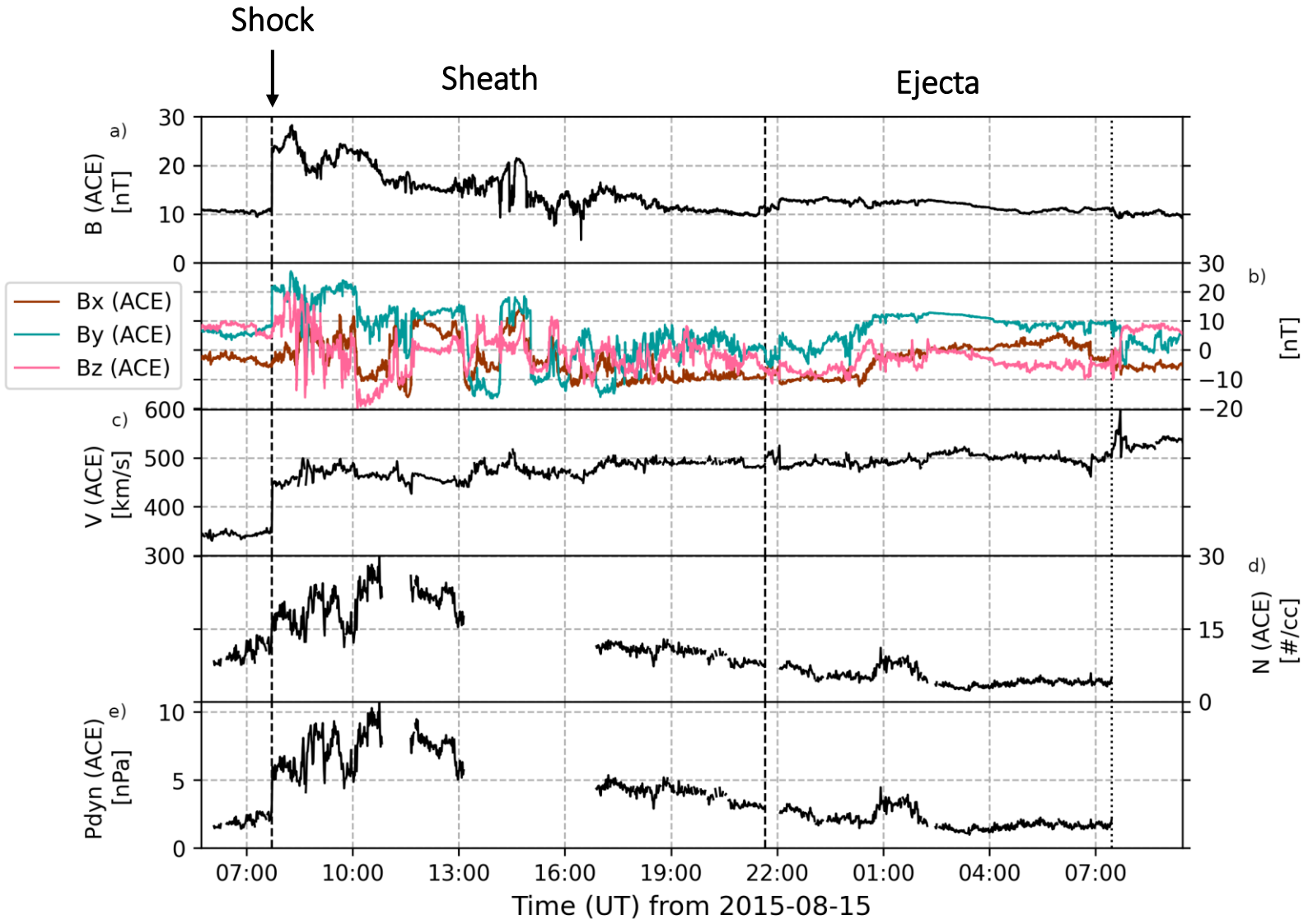
An event from 15 August 2015 is selected for the study

The selection was based on two criteria:

1. The event had to occur during the morning hours (time in UT) so that the magnetometers would be on the dayside.
2. There had to be multiple spacecraft in the solar wind aligned close to the Sun-Earth line in order to get direct measurements of the sheath from different locations.

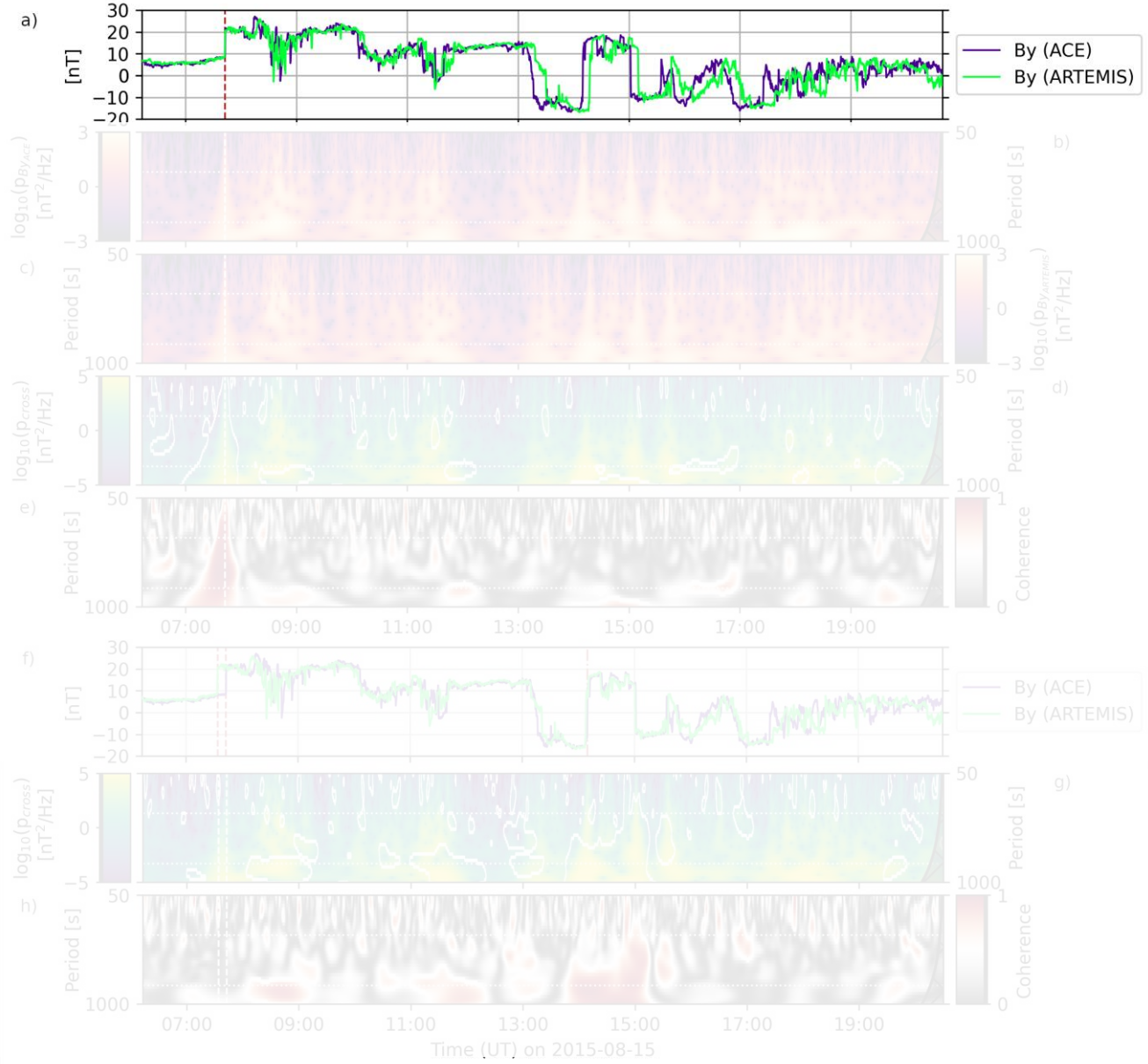


Closer look of the event



Comparing data from different spacecraft

Time series



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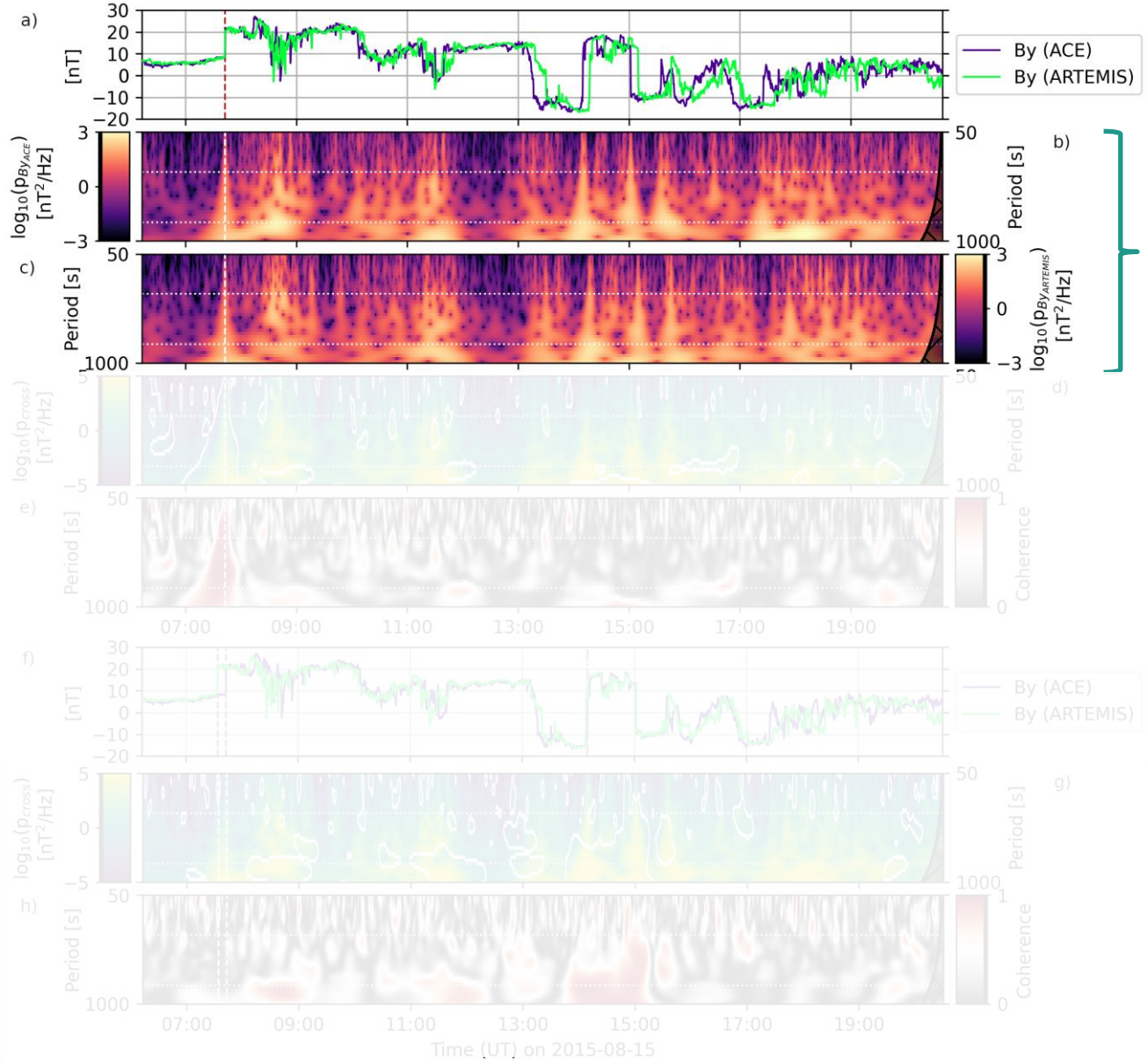
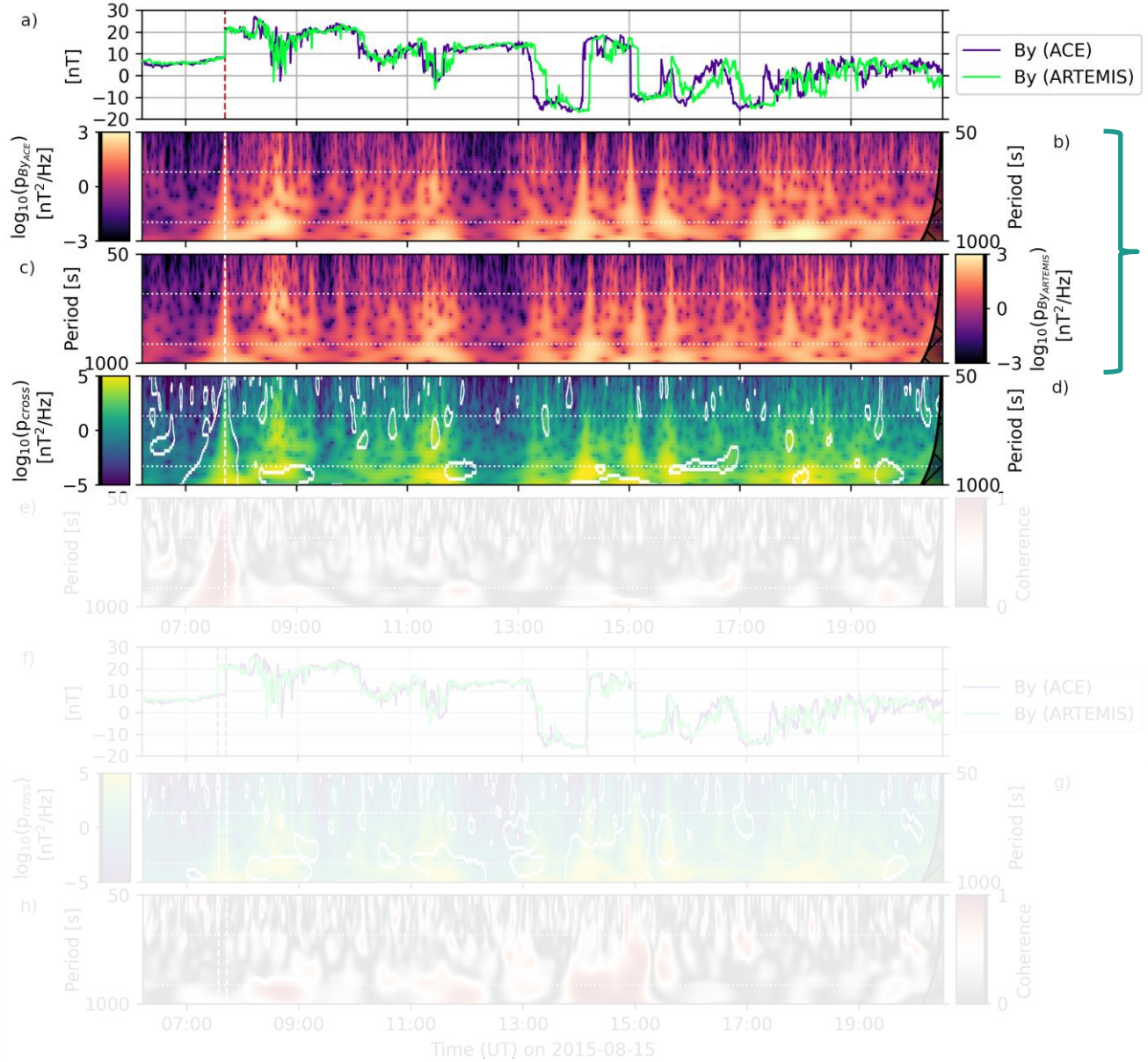


Wavelet power spectra

Comparing data from different spacecraft

Time series



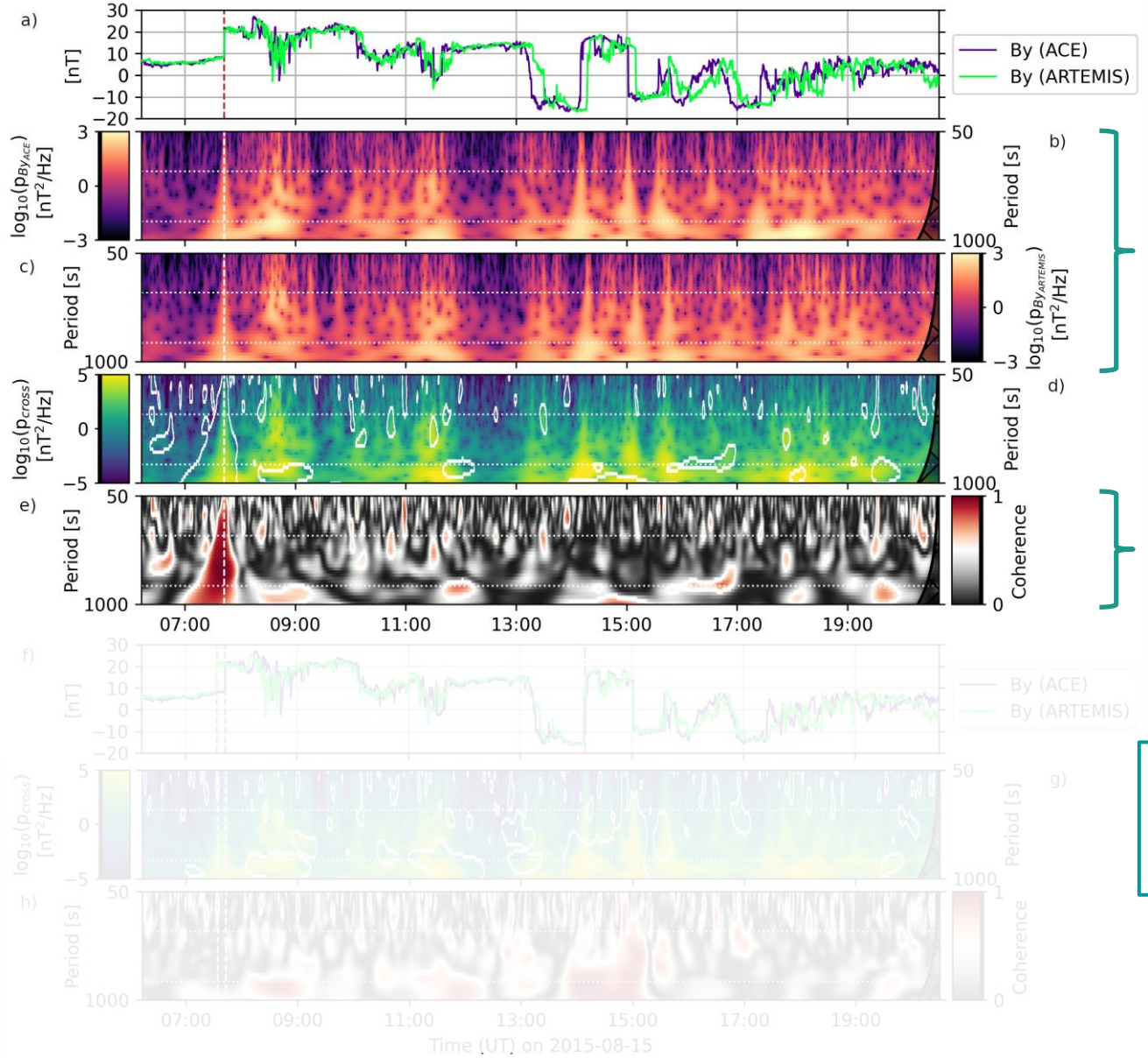
Wavelet power spectra

Cross wavelet power spectrum obtained from the two time series

Shows where in time-frequency space the two time series have high common wave power.

Comparing data from different spacecraft

Time series



Wavelet power spectra

Cross wavelet power spectrum obtained from the two time series

Shows where in time-frequency space the two time series have high common power.

Wavelet coherence between the two time series

Shows where in time-frequency space the two time series co-vary.

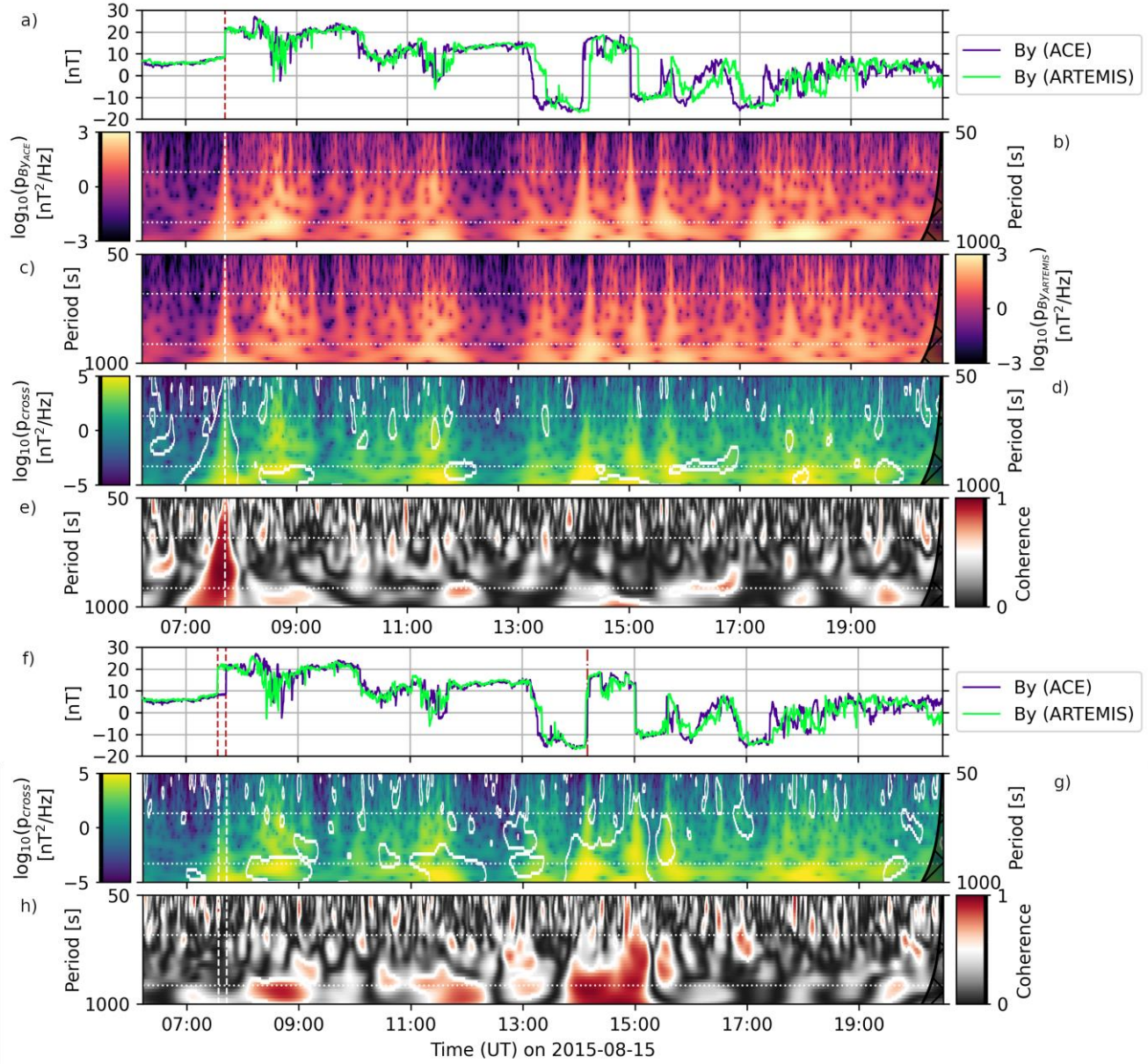
Comparing data from different spacecraft

Time series

Wavelet power spectra

Cross wavelet power spectrum

Wavelet coherence

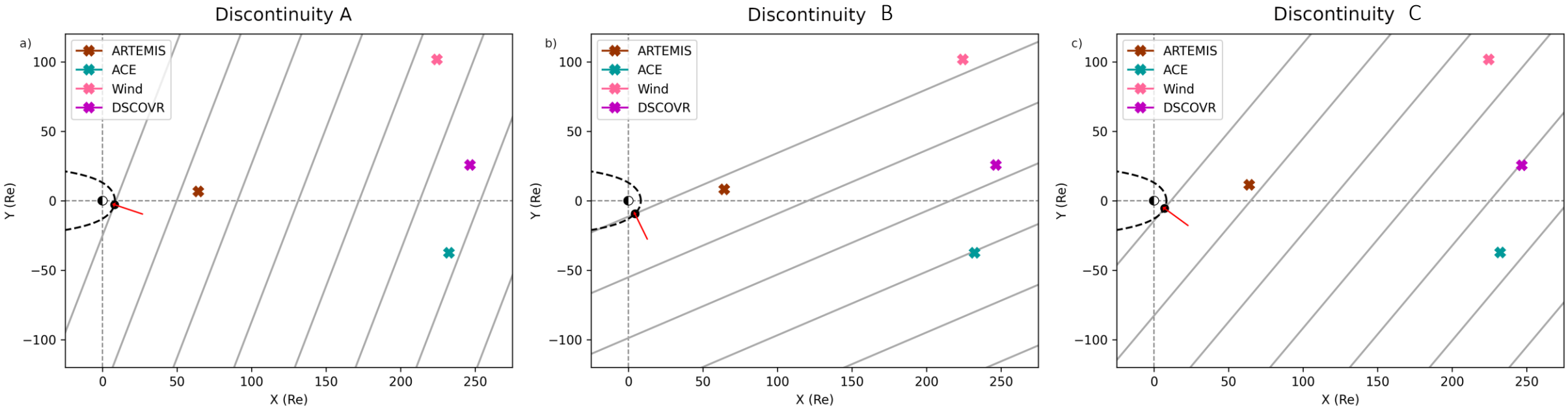


Time series are matched with shocks (34 min)

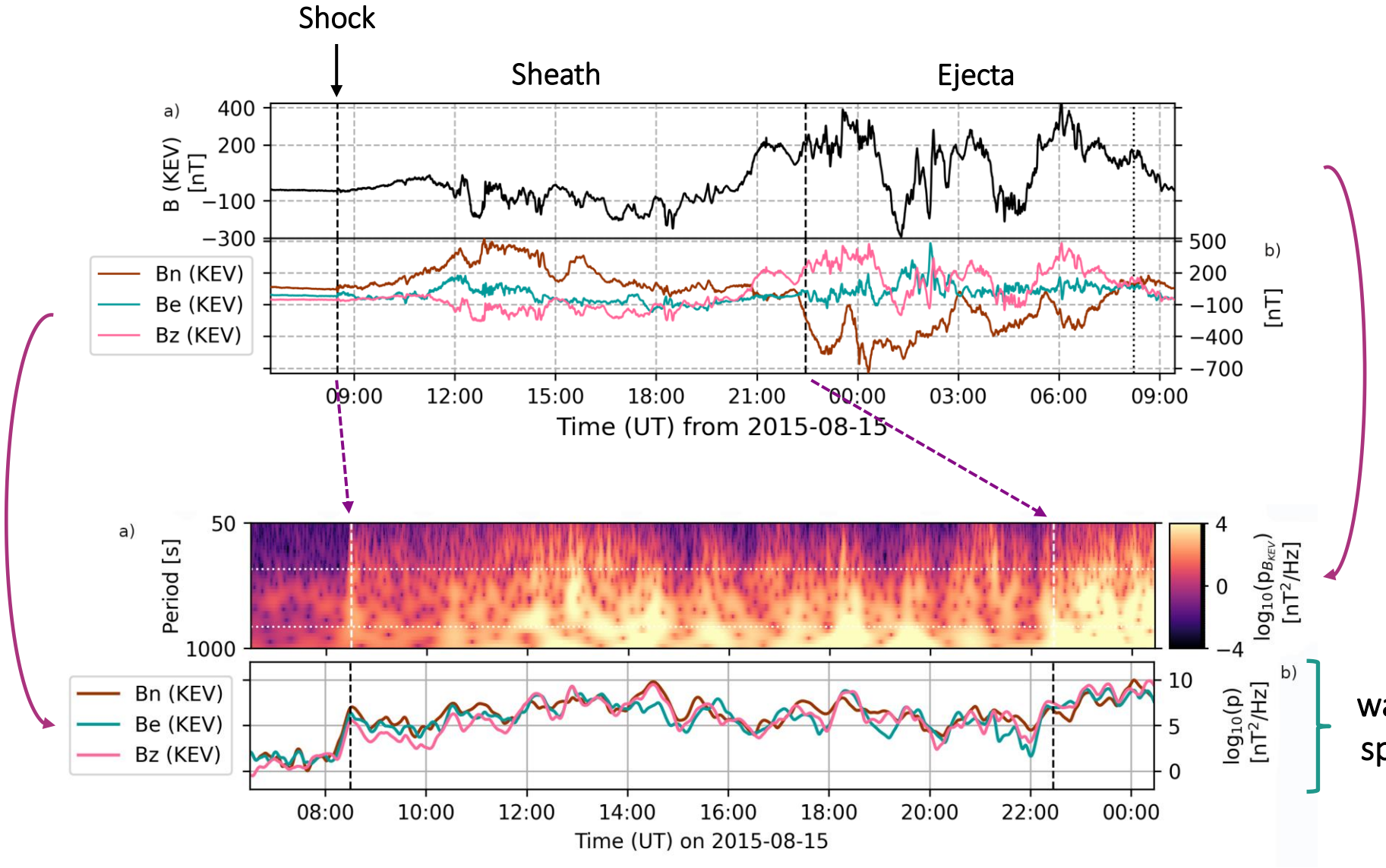
Time series are matched with the large-amplitude variation around 14 UT (43 min)

Timing analysis demonstrates the complexity of the sheath region

Discontinuity	A (shock)	B	C
Time on ARTEMIS	08:17	10:46	15:44
Time lag to DSCOVR	-39min	-42min	-47min
Time lag to ACE	-34min	-39min	-42min
Time lag to Wind	-34min	-19min	-35min
Time lag to the ground	+14min	+16min	+17min



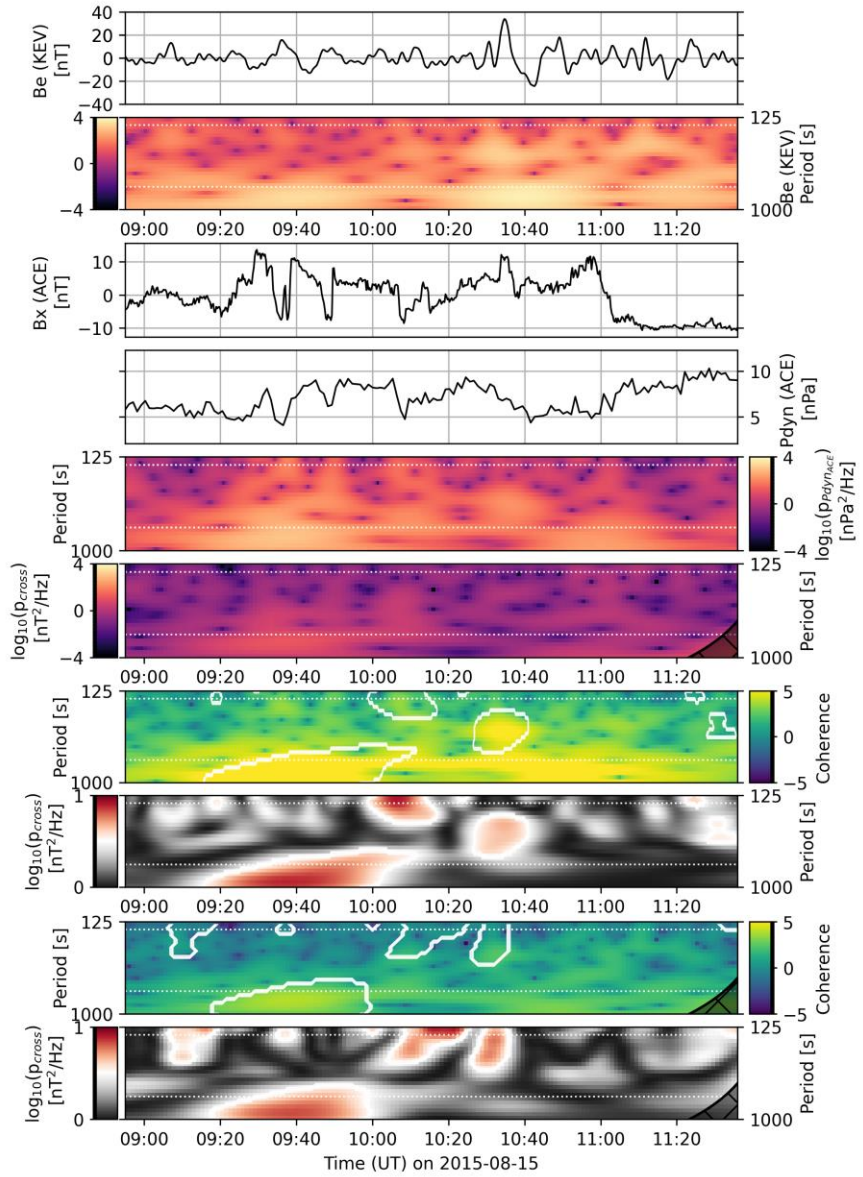
So what is observed on Earth?



Integrated wavelet power spectra within pc5 range

A brief overview of comparing space and ground-based measurements

Be-component observed by Kevo



Bx-component and Pdyn observed by ACE

Between Be and Bx

Between Be and Pdyn

Conclusions

- Sheath regions are highly complex and they can cause extreme geomagnetic disturbances.
- Sheaths can undergo considerable changes as they propagate in space.
- The Earth's magnetosphere can have a significant influence on the fluctuations caused by sheath regions.
- Deeper understanding of sheaths and their geomagnetic consequences can lead to enhanced predictions of space weather.

Thank you :) Questions?