SPATIAL AND TEMPORAL MONITORING OF THE INTERMITTENT DYNAMICS IN THE TERRESTRIAL FORESHOCK

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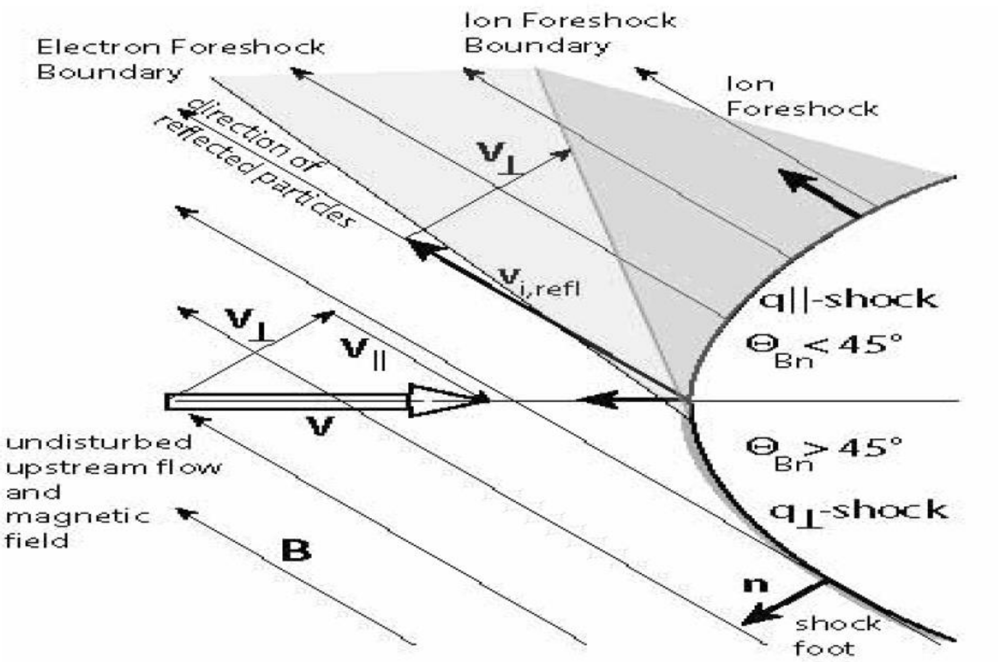
Outline

SPATIAL AND TEMPORAL MONITORING OF THE INTERMITTENT DYNAMICS IN THE TERRESTRIAL FORESHOCK

1. Basic dynamics of the terrestrial foreshock (wave and turbulent properties)
2. Study of intermittent turbulence in the foreshock using PDF analysis
3. Applying high-pass filtering to enhance the properties of small amplitude fluctuations
4. Study of intermittency in terms of the foreshock geometry and solar wind parameters
5. Summary

Basic dynamics of the terrestrial foreshock



Treumann, Jaroschek, 2008

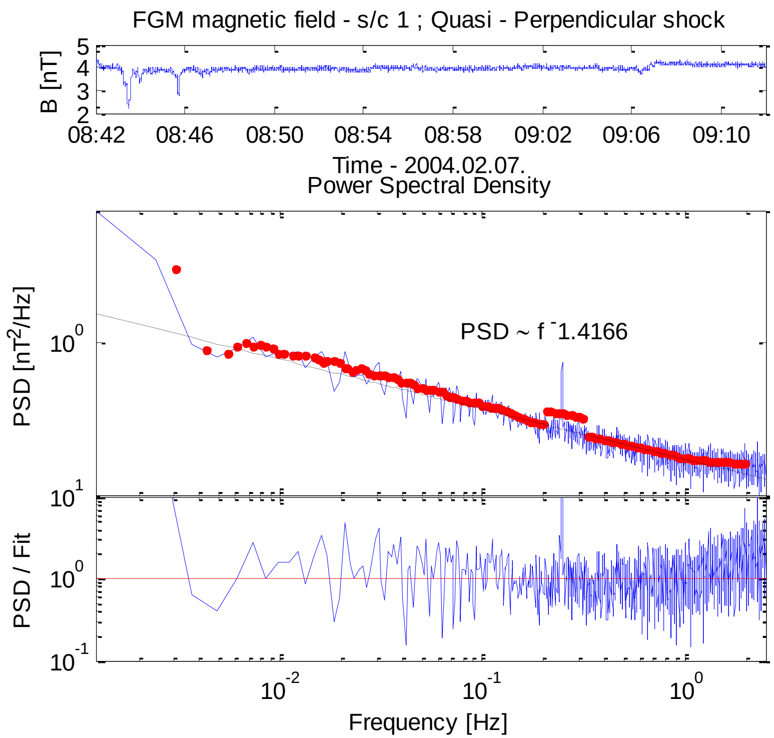
- The region that is magnetically connected to the solar wind is called foreshock.
- The dynamics of the foreshock is controlled by the angle between the IMF and the BS normal, Θ_{Bn}

  - $\Theta_{Bn} > 45°$: Quasi-perpendicular shock

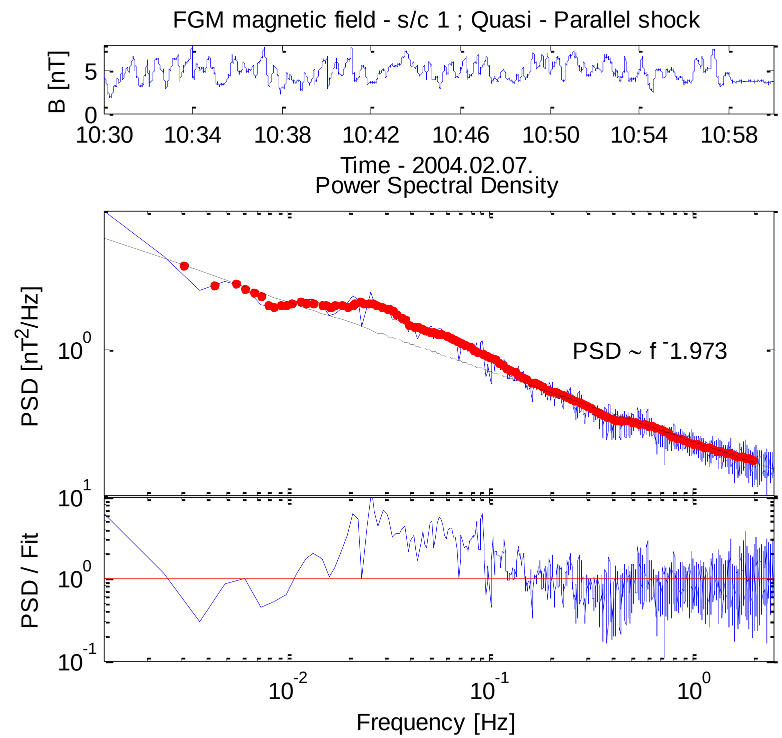
  - $\Theta_{Bn} < 45°$: Quasi-parallel shock
- The $Q_{||}$ shock region is the subject of various instabilities, therefore the place of various wave phenomena.

Magnetic field spectra in the foreshock

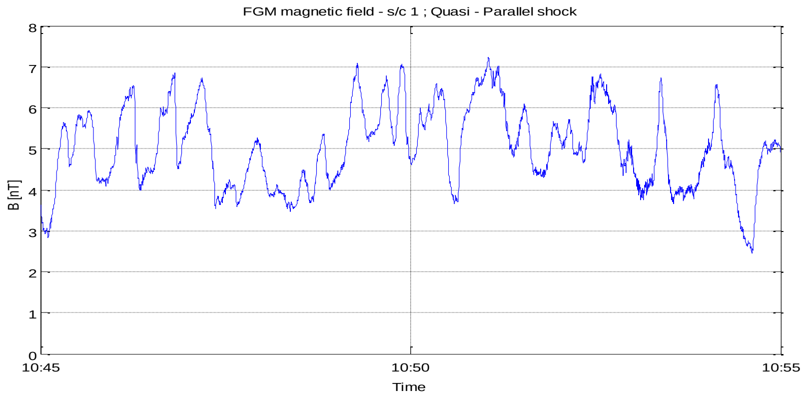
Quasi perpendicular foreshock - $\Theta_{Bn}\sim 65°$



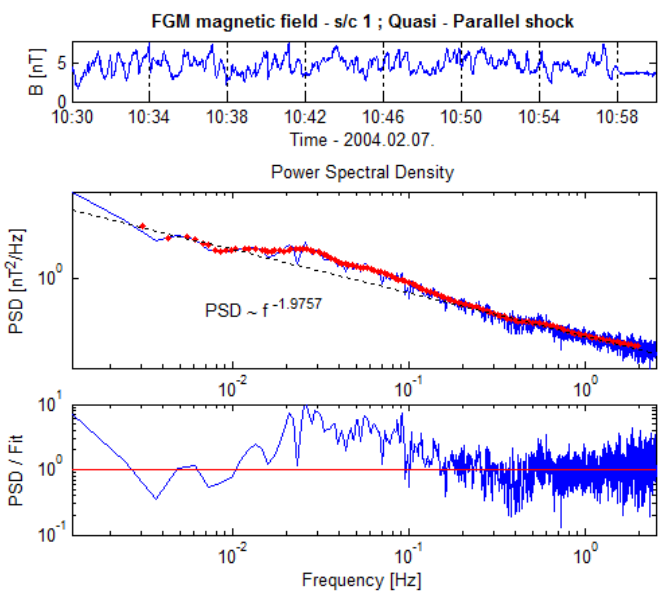
Quasi parallel foreshock - $\Theta_{Bn}\sim 30°$

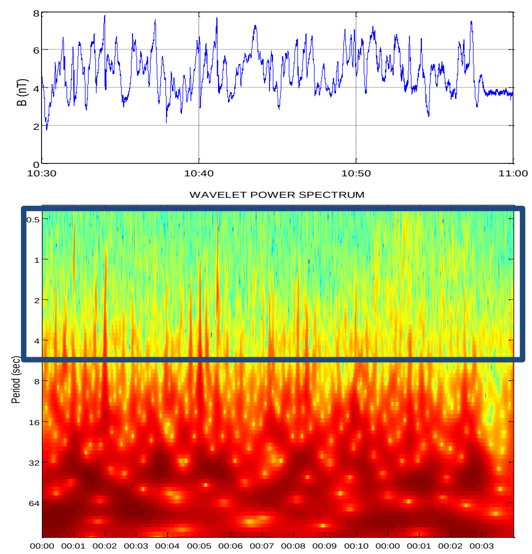


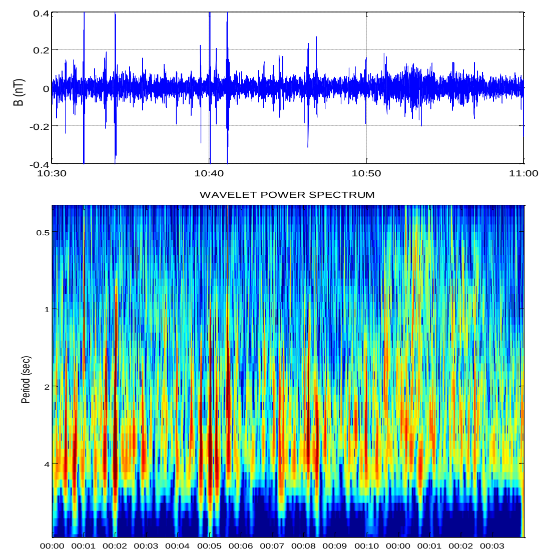
Basic properties of the waves in the $Q_{||}$ foreshock



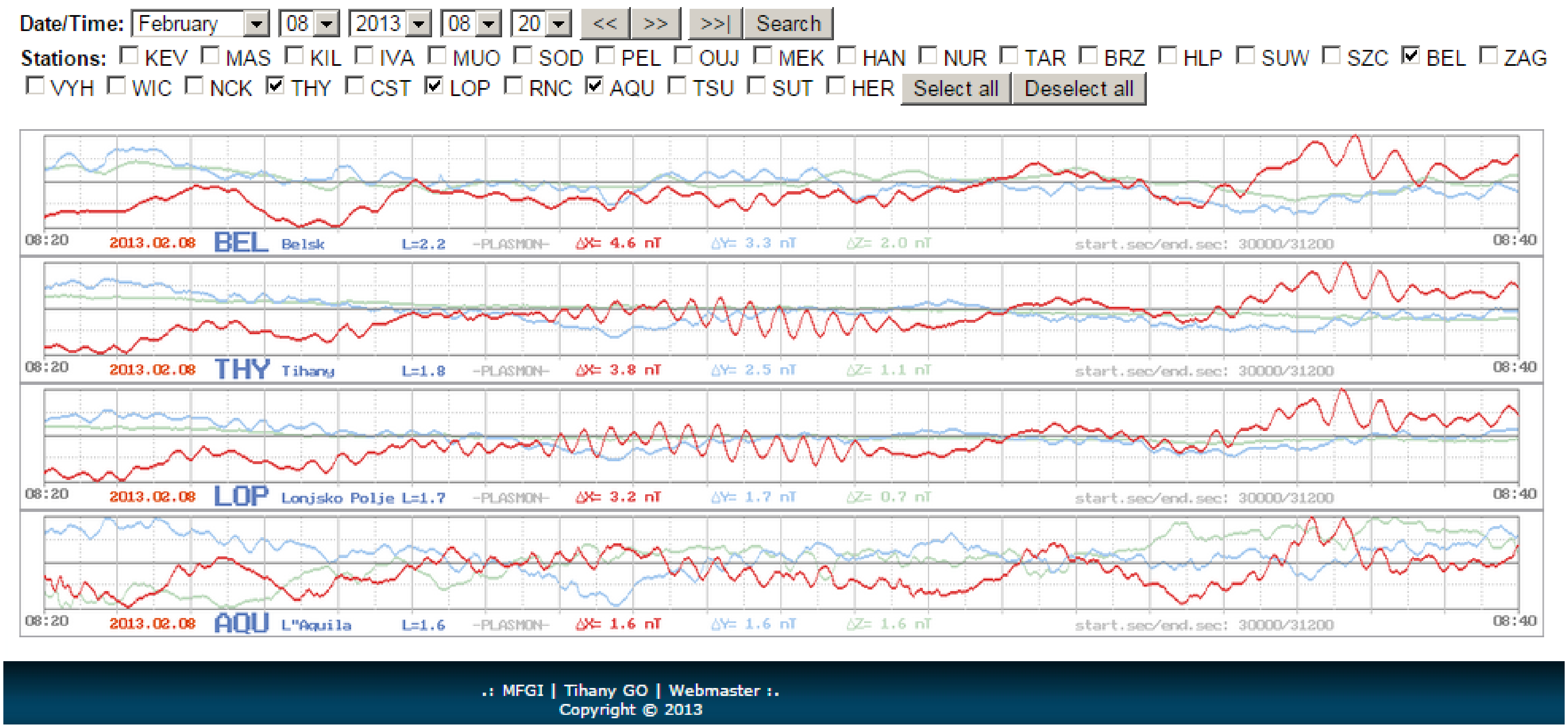
- Waves are developed by the BS reflected particles
- The waves frequencies are mostly in the Ultra low frequency (ULF) range (i.e. below 0.1 Hz)
- Waves have usually large amplitudes
- In the plasma rest frame they propagate upstream, but due to the convection they



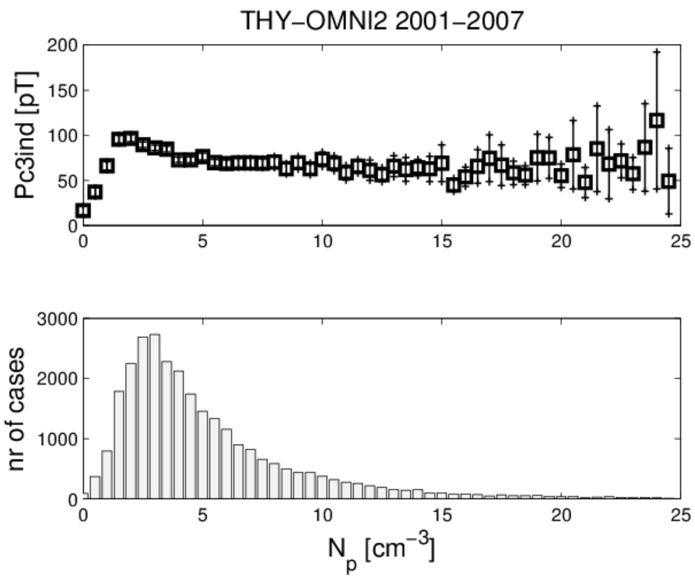


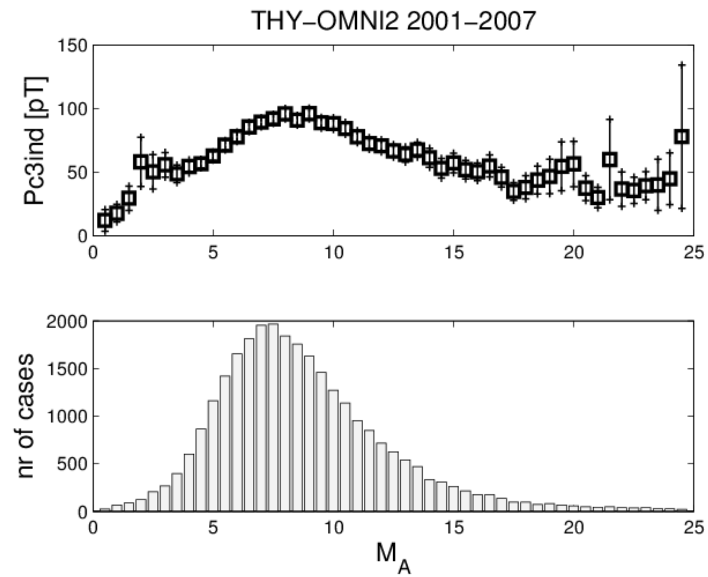


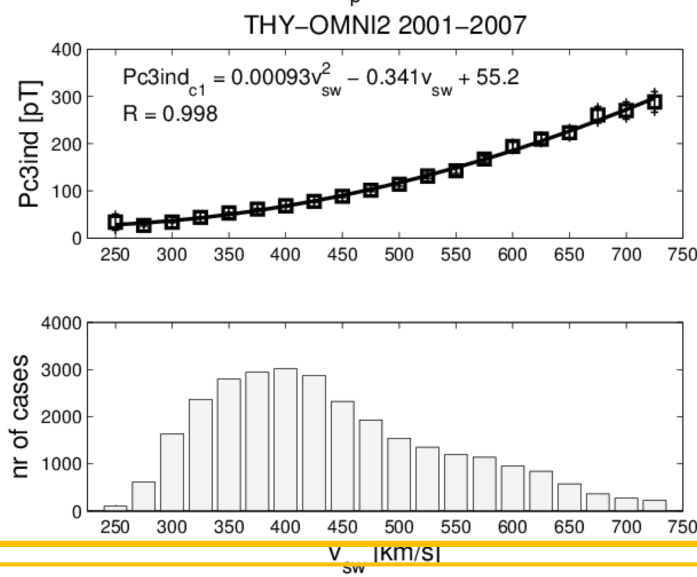
Upstream wave related geomagnetic pulsations



Upstream wave related geomagnetic pulsations







Heilig et al., Ann. Geophys., 2010

Aims, data, methodology

Aim:

- To show the turbulent properties of the foreshock in a wavy and non-stationary environment.
- To study the influence of the solar wind driver to the turbulent behaviour of the foreshock.

Data:

FGM 5 Hz (5VPS) data from Cluster 1,2,3,4

Time period: January-April, 2001-2010

Method:

PDF analysis of difference time-series

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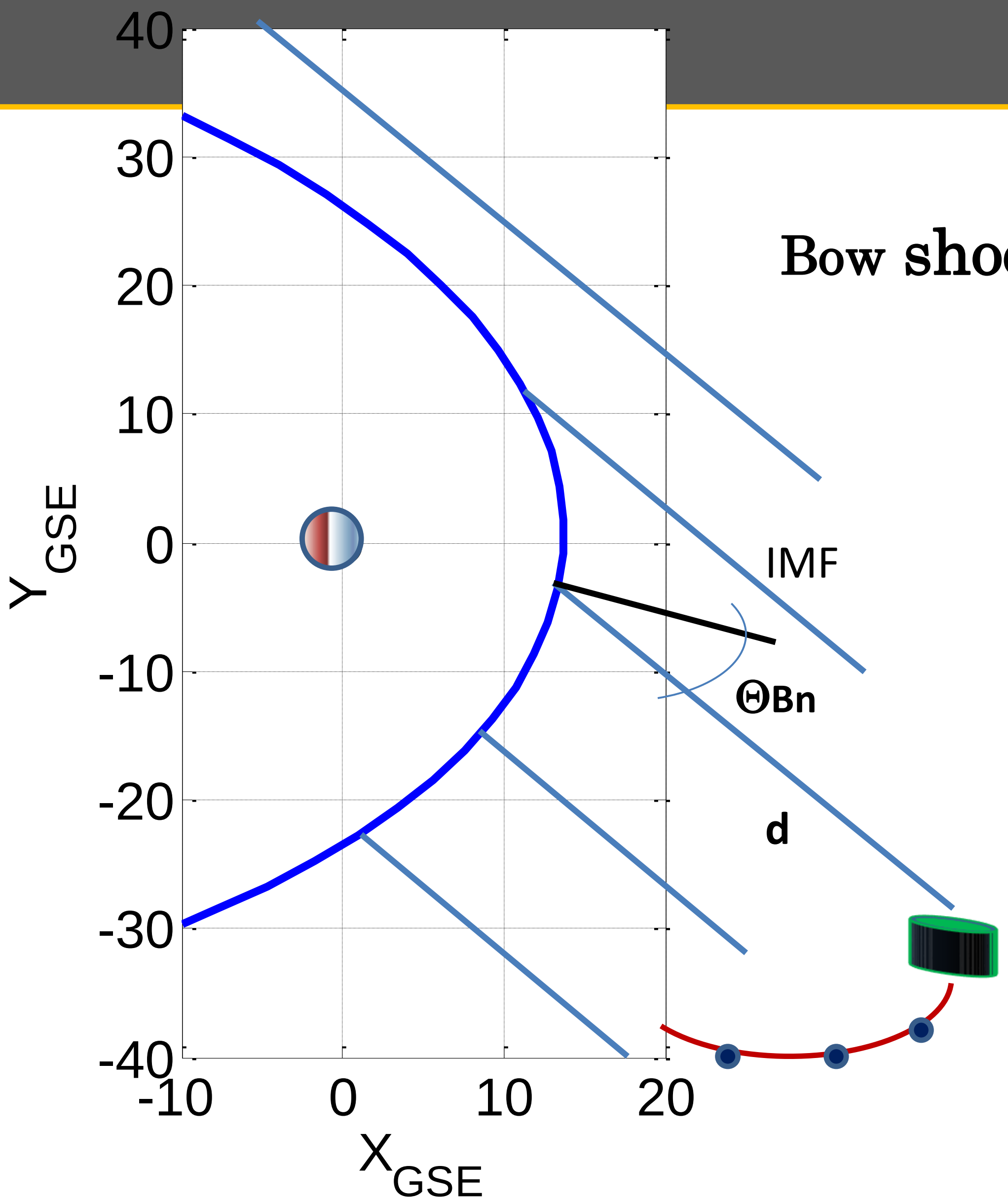
Main sources of the non-stationarity:

1. The movement of the spacecraft
2. The change of the downstream solar wind parameters (IMF, plasma pressure, bulk velocity, …) affecting the plasma environment and the configuration of the bow shock.



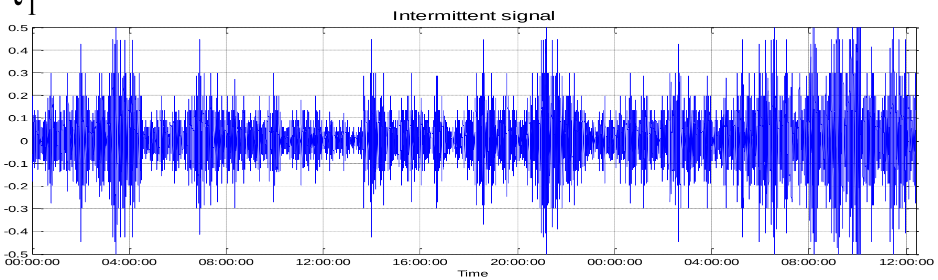
Bow shock model: Farris et al., 1995

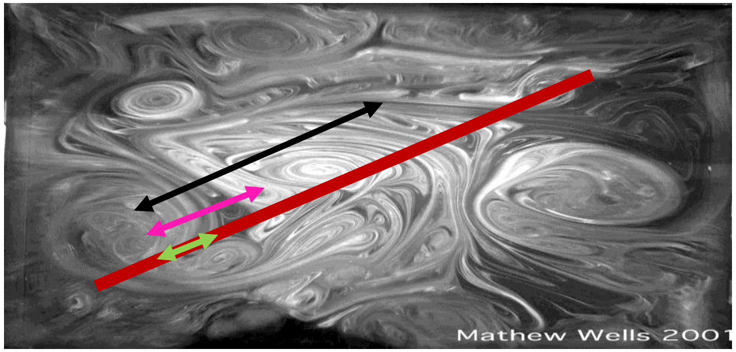
Model parameters (SW bulk velocity, proton density, MA number) have been obtained from Cluster CIS_HIA instrument records or optionally from OMNI2 database

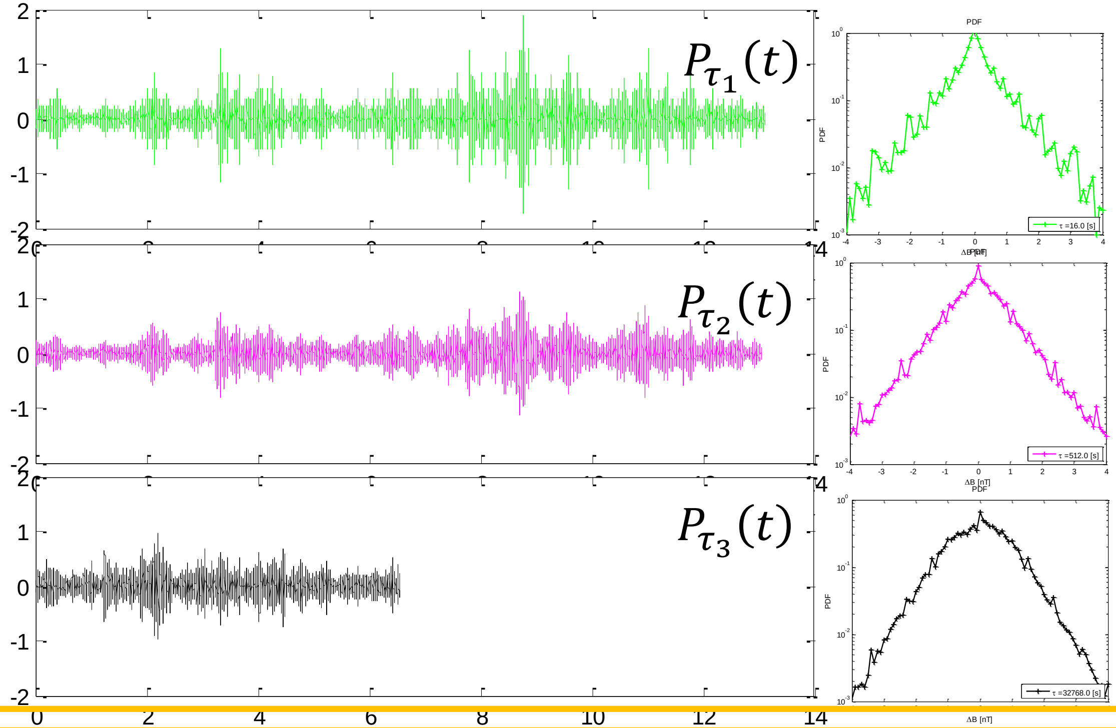
PDF analysis of temporal increments

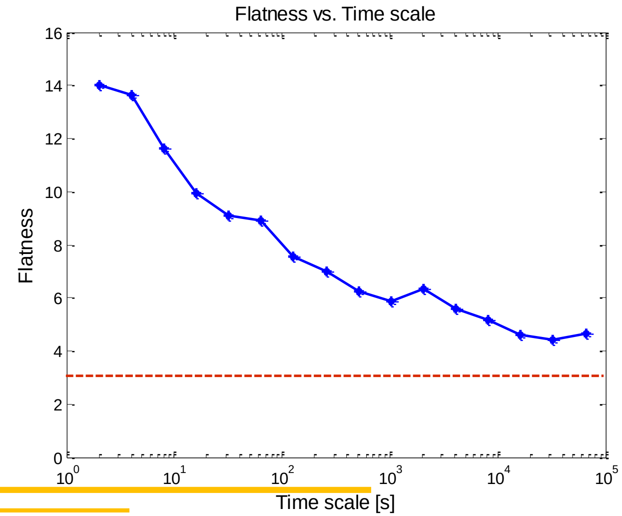
τ_3
τ_2
τ_1

$$P_{\tau_i}(t) = P(t + \tau_i) - P(t)$$

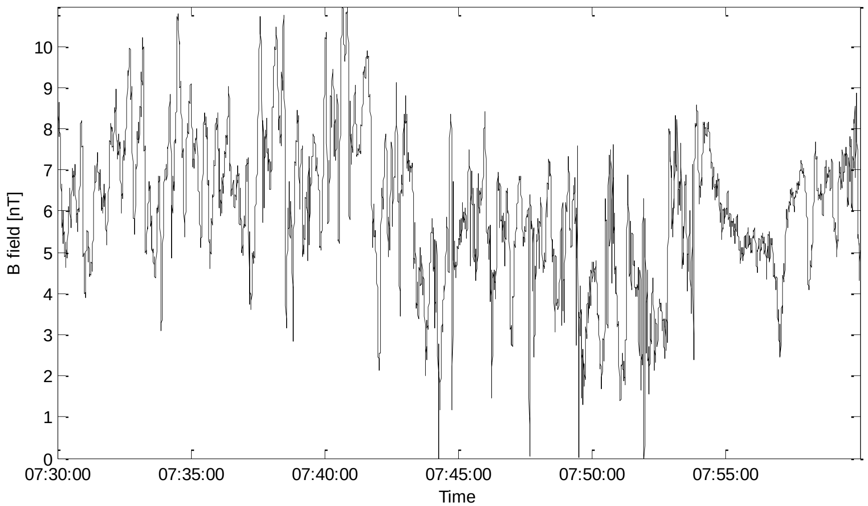


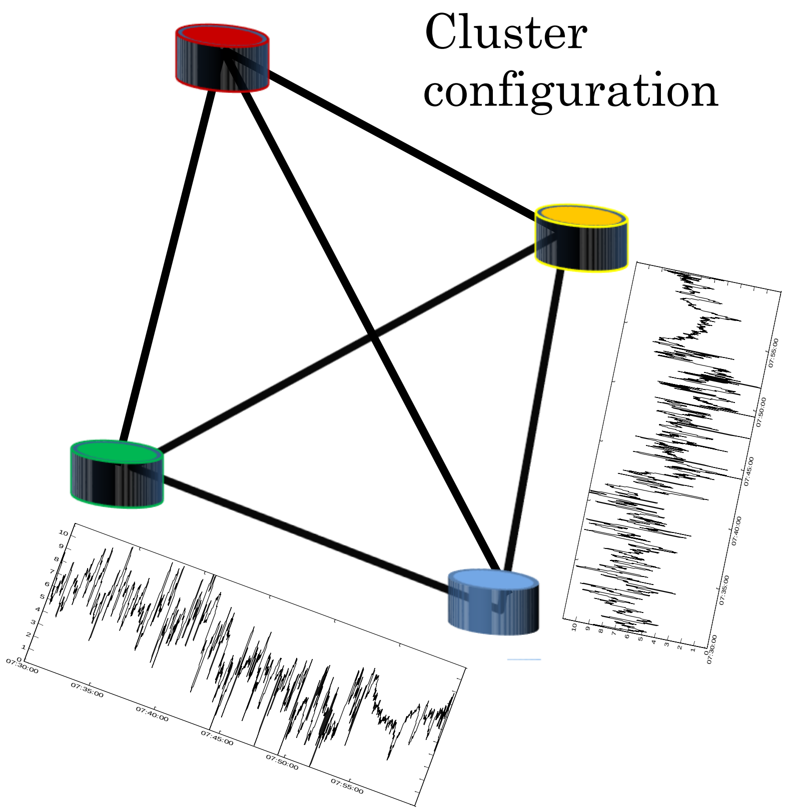




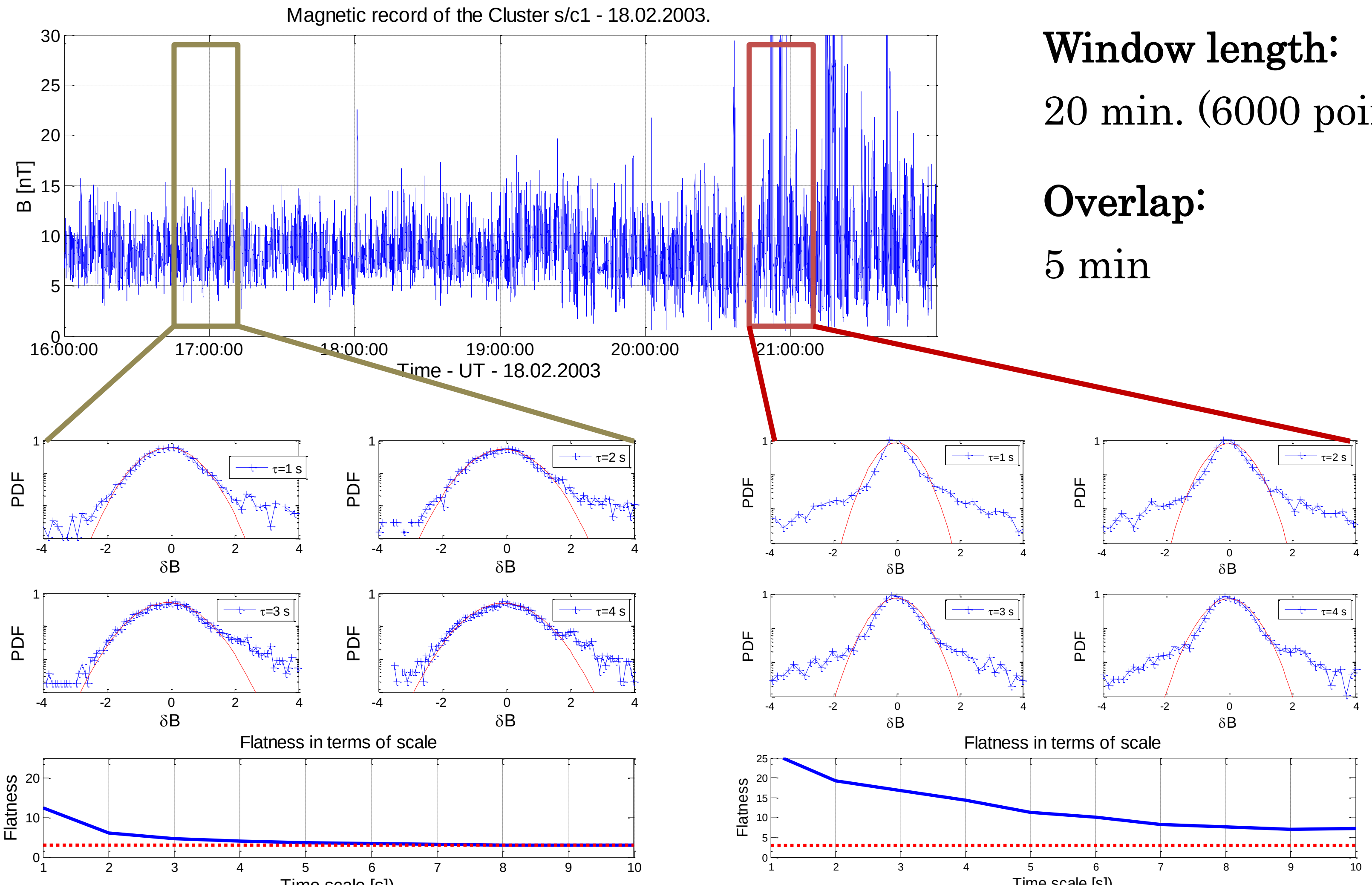


Study of intermittency in spatial scale





Sliding window PDF analysis



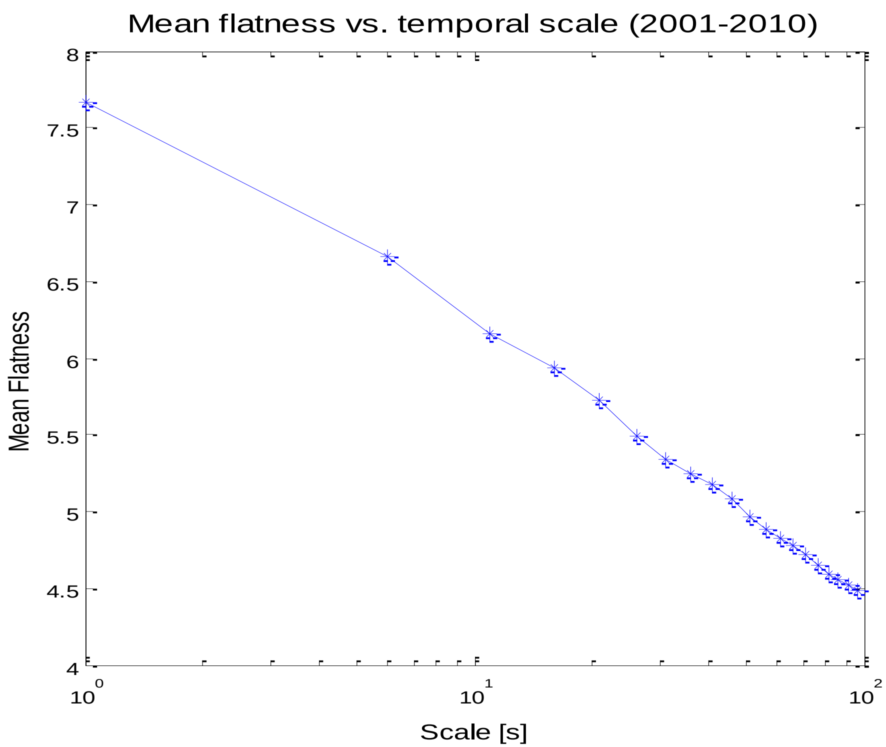
Window length:

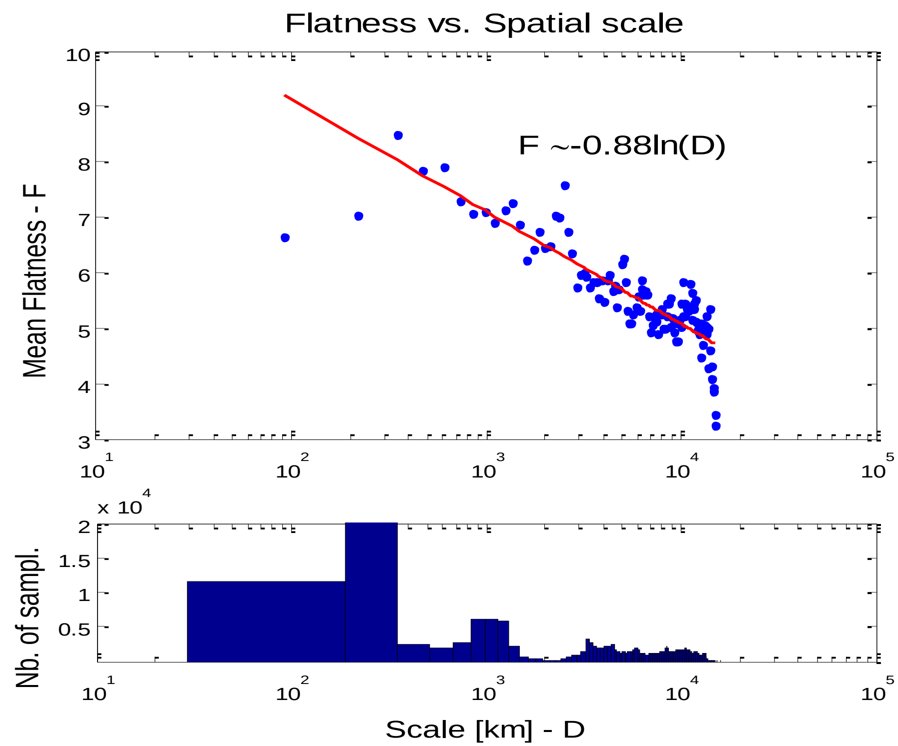
20 min. (6000 points)

Overlap:

5 min

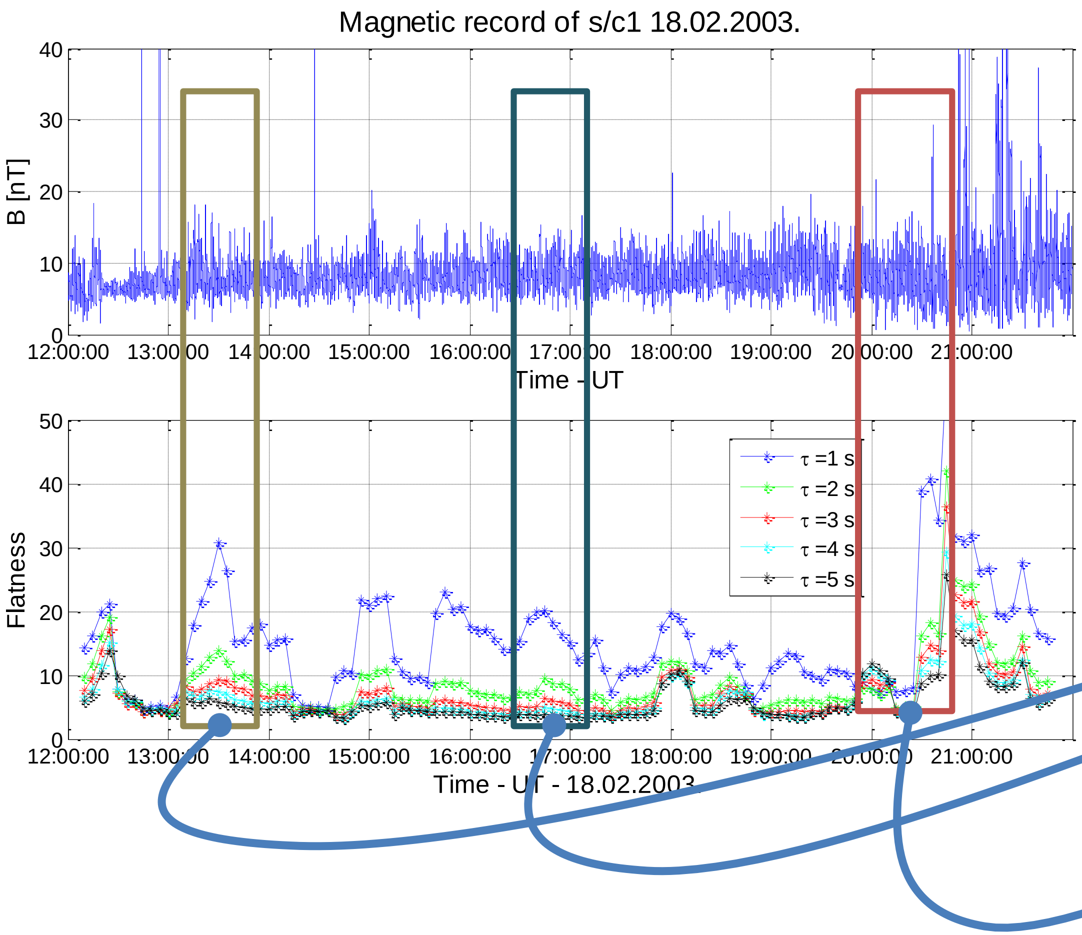
Mean flatness in terms of temporal and spatial scales





10 years of average, 2001-2010

Referencing of the temporal intermittency to space

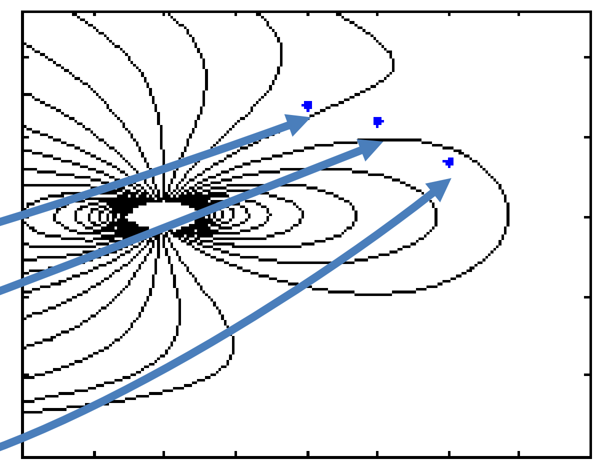


Window length:

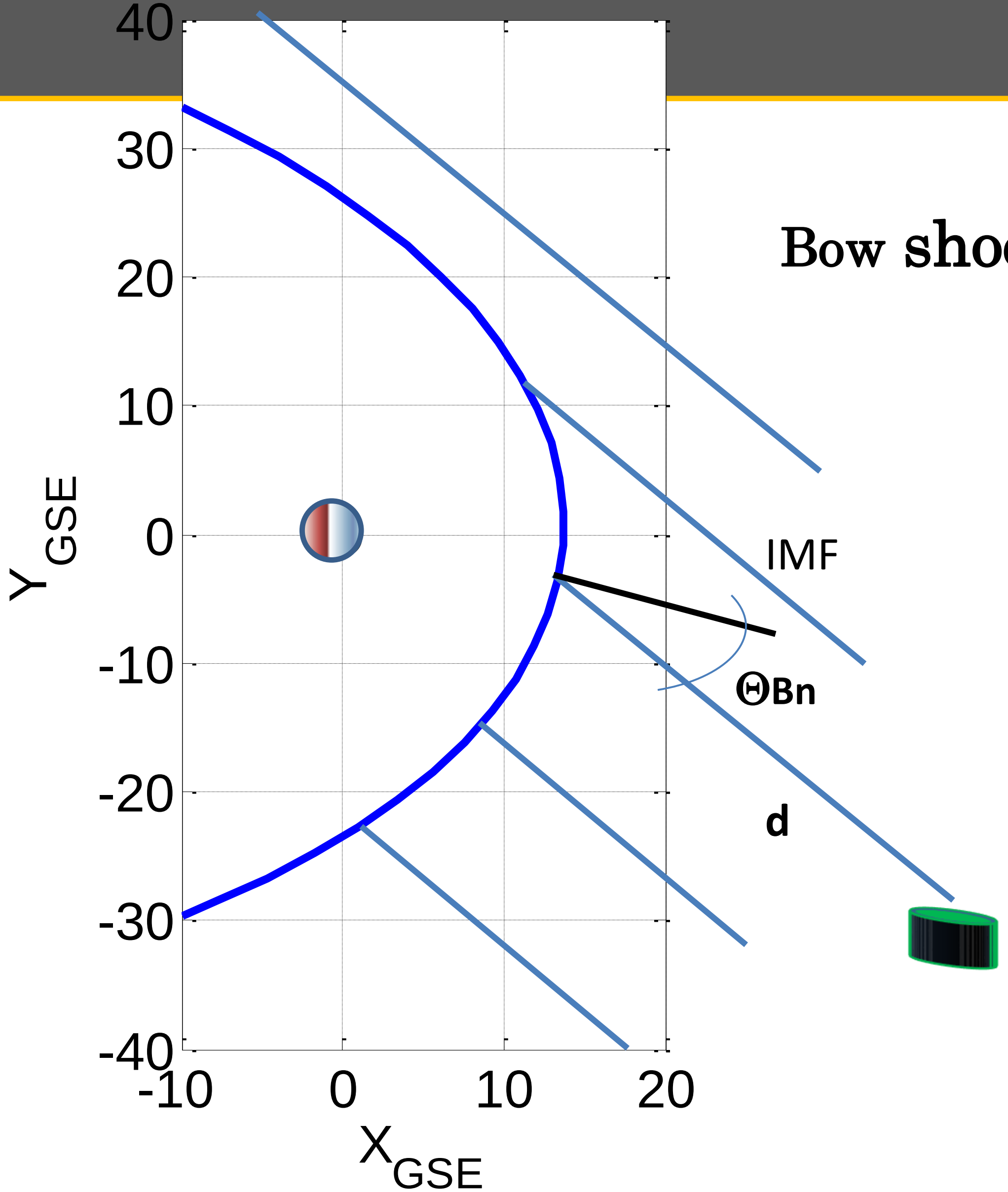
20 min. (6000 point)

Step length:

5 min



Reference frame of the observattions

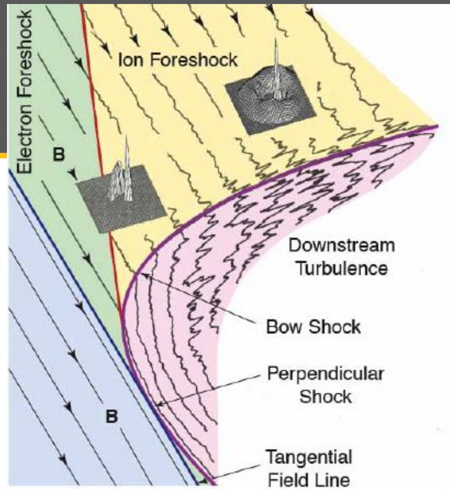


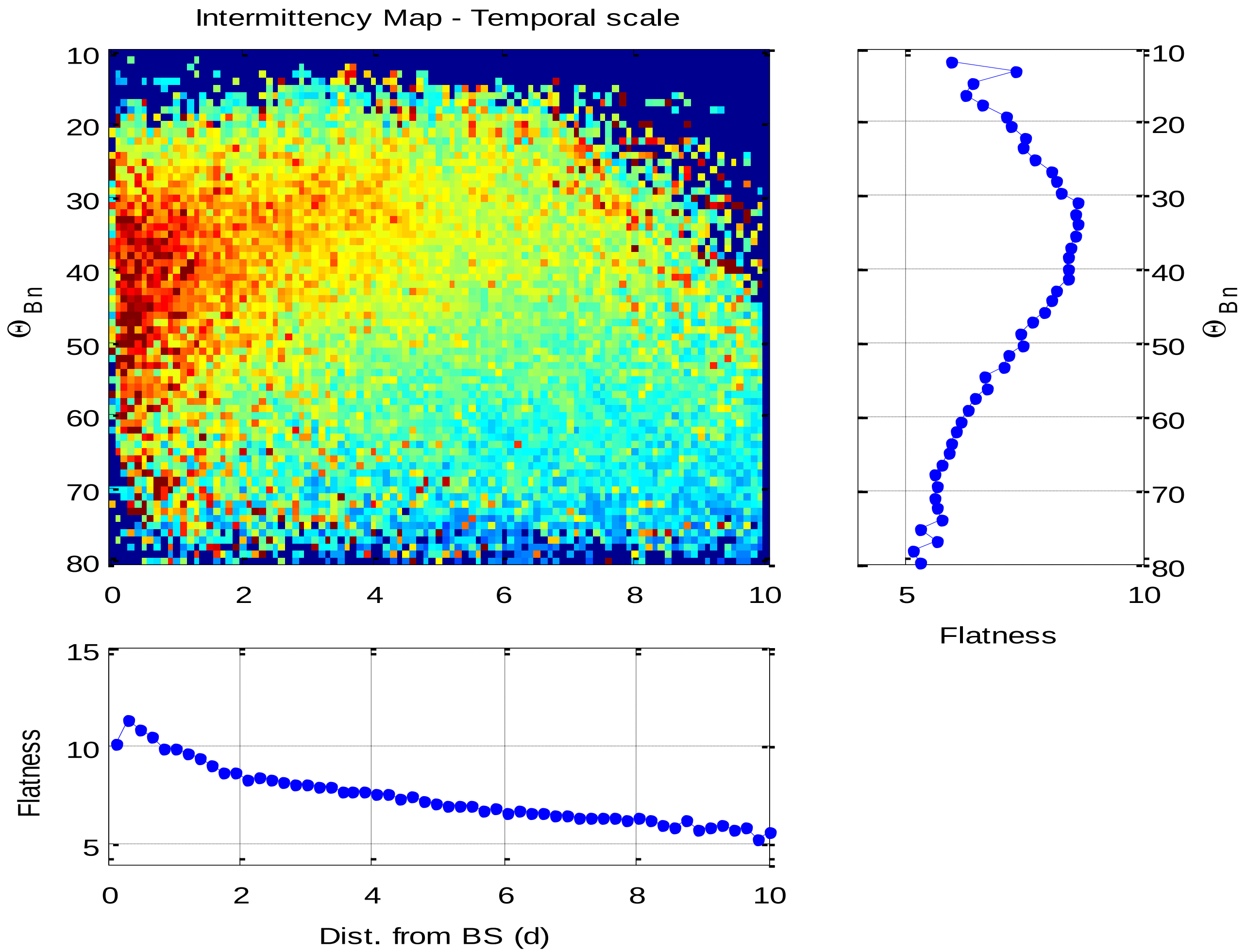
Bow shock model: Farris et al., 1995

Model parameters (SW bulk velocity, proton density, MA number) have been obtained from Cluster CIS_HIA instrument (Dandouras et al., 2001) records or optionally from OMNI2 database

Condition for quasi-parallel magnetic observation:
$\Theta_{Bn} < 50°$

„Map" of intermittency in the foreshock

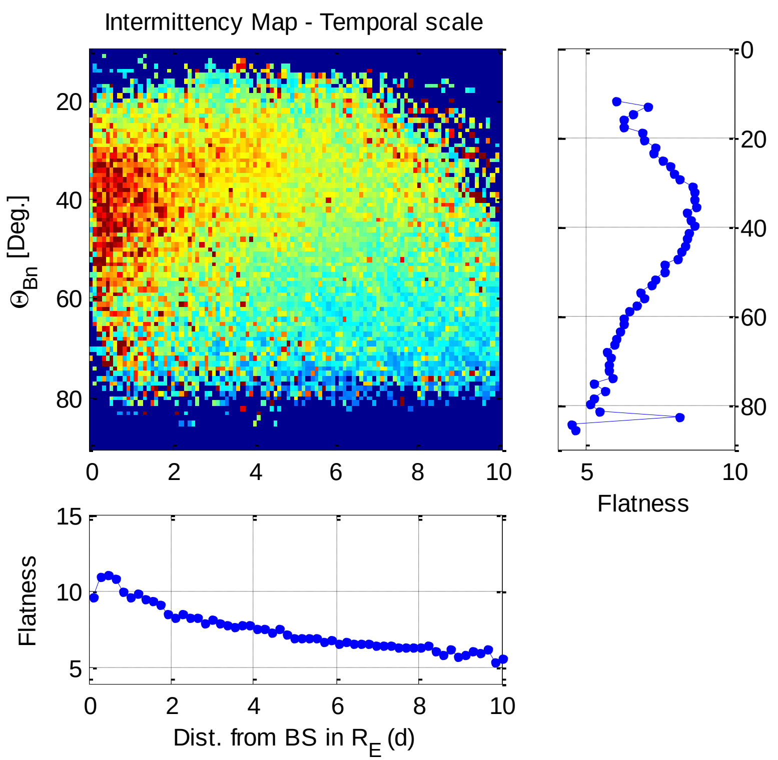




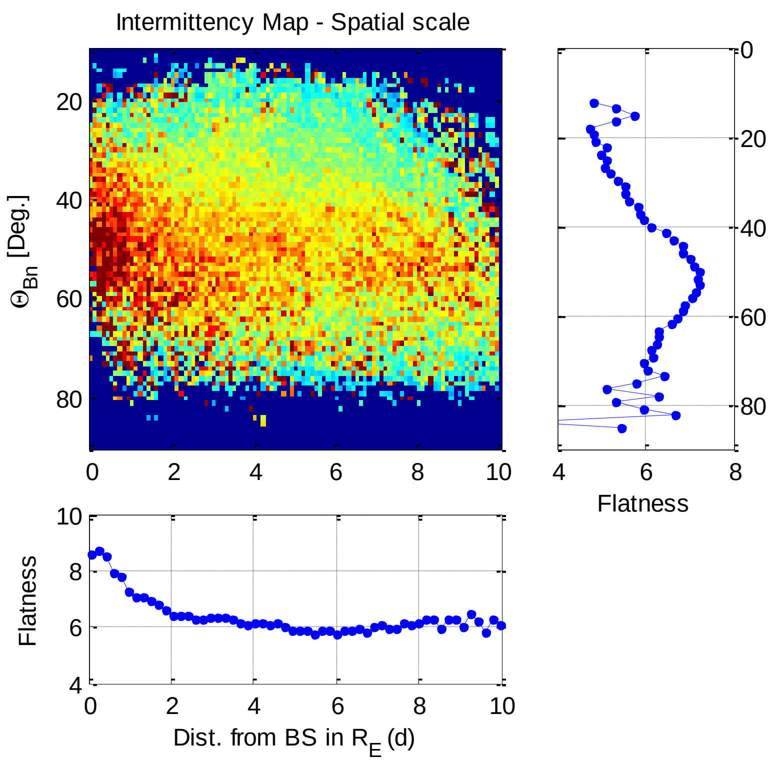
Strongest intermittency:
ΘBn ~ 35°

„Map” of intermittency in the foreshock

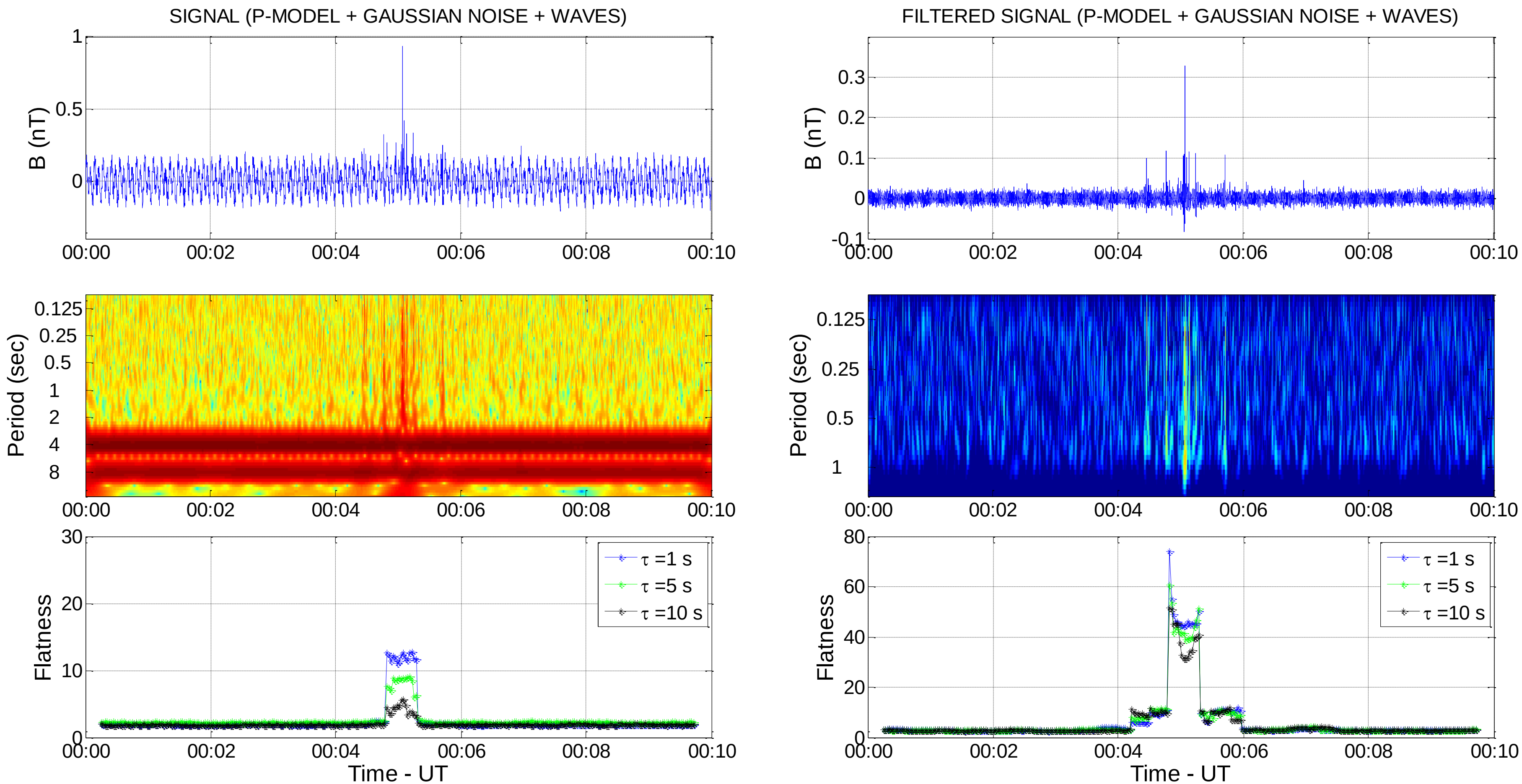
Intermittency in temporal scale



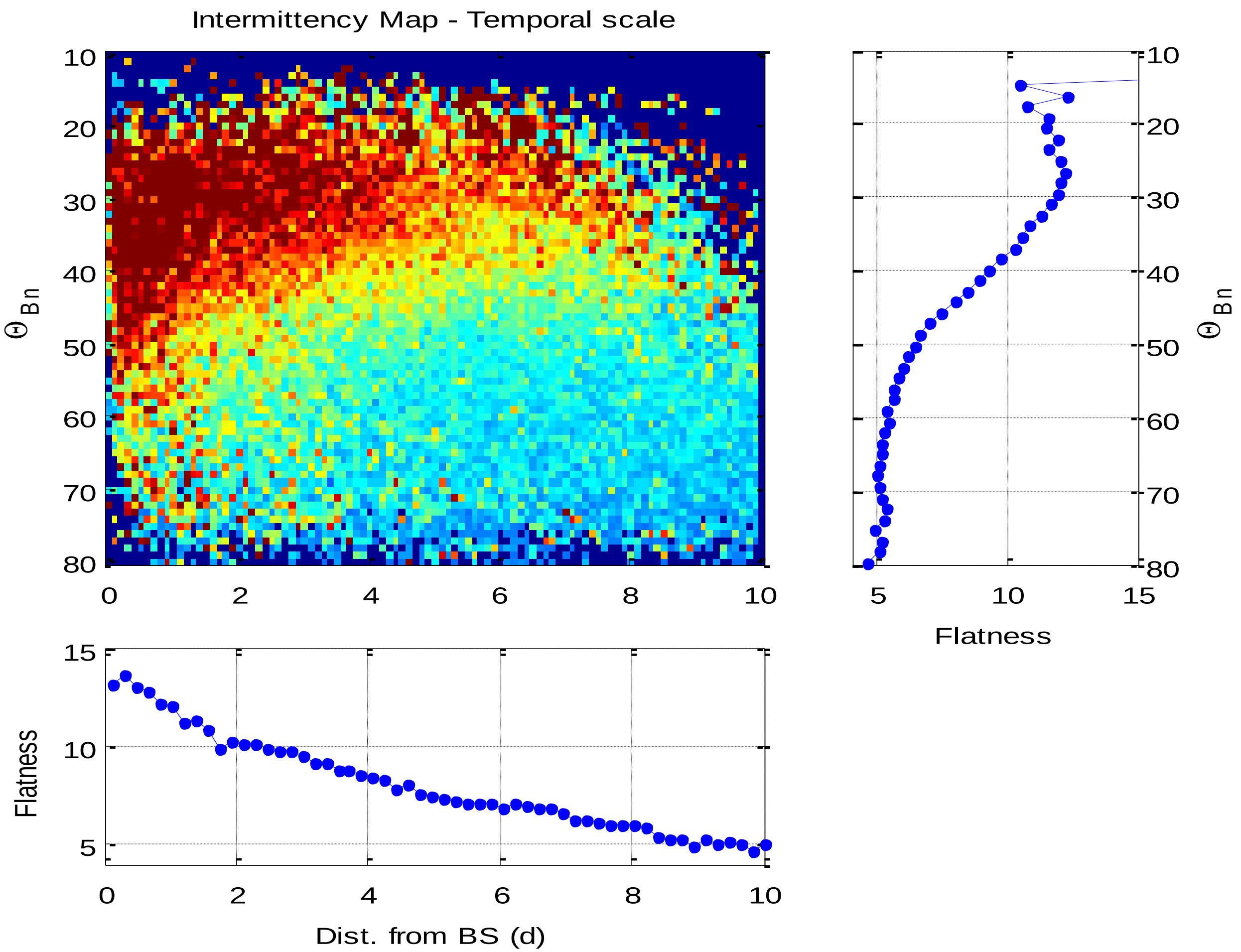
Intermittency in spatial scale

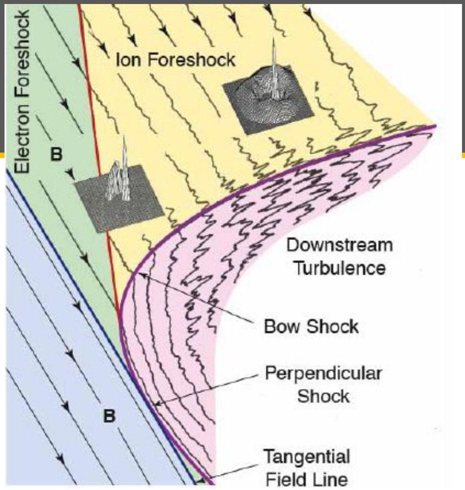


Investigation of turbulent noise in wavy environment – Synthetic analysis



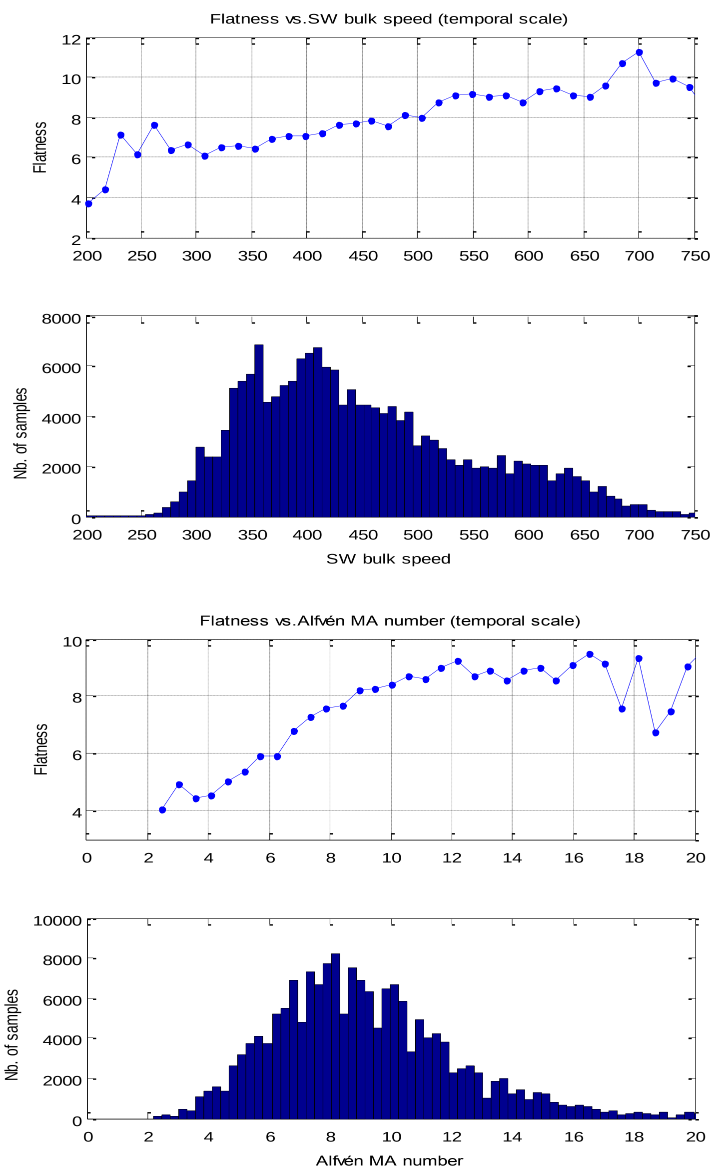
„Map" of intermittency in the foreshock

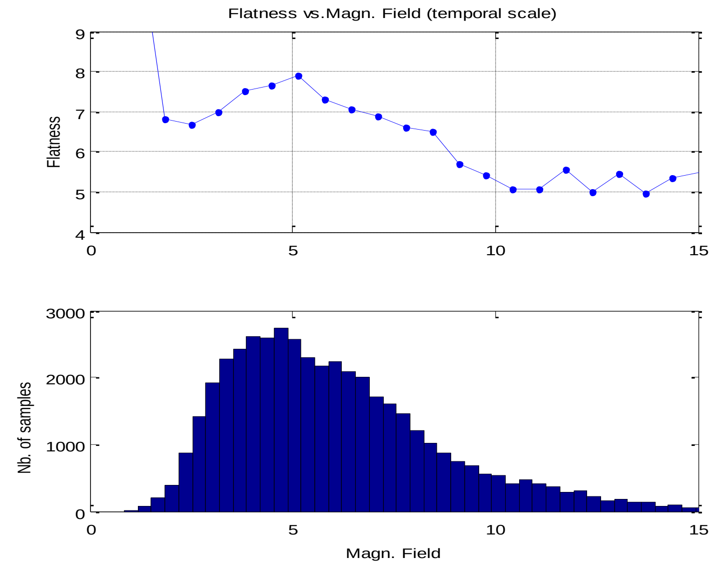




Strongest intermittency:
ΘBn ~ 15-25°

Mean flatness vs. Solar wind parameters





10 years of average, 2001-2010

Summary

- Cluster FGM data have been analysed from periods in the years of 2001-2010, when the mission located in the foreshock
- In 10 years of average, intermittent fluctuations were apparent in the foreshock, both in temporal and spatial scales
- It is argued that PDF analysis can give misleading results regarding to turbulence, if wave activitiy is strong in the analysed signal
- High-pass filtered FGM data exhibit decaying intermittency with the distance from the BS along the IMF and with angle of incidence of IMF to the BS
- In 10 years of average, intermittency increases with solar wind bulk speed and Alfvén Mach number. This behaviour is similar to that related to the ULF wave activities observed in ground observatories.