Automatic detection of the electron density from the WHISPER instrument onboard CLUSTER

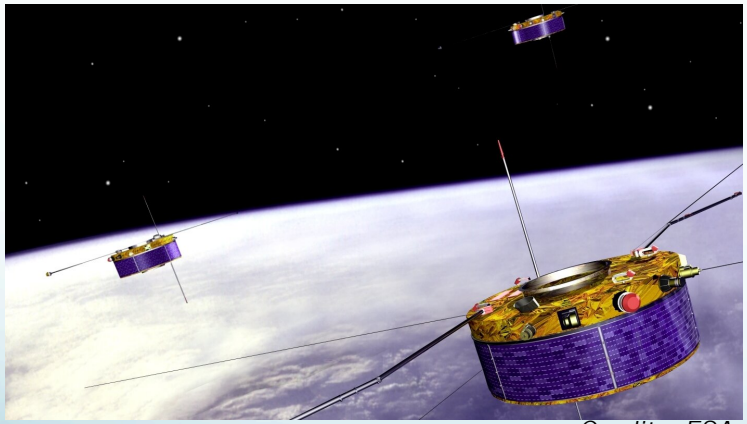
N. Gilet[1], E. De Leon[1], R. Gallé[1], X. Vallières[1], J-L Rauch[1], K. Jegou[1], L. Bucciantini[1], P. Décréau[1]

[1] Laboratoire de Physique et Chimie de l'Environnement et de l'Espace (LPC2E/CNRS), Orléans, France

Cluster mission

Earth magnetospheric mission

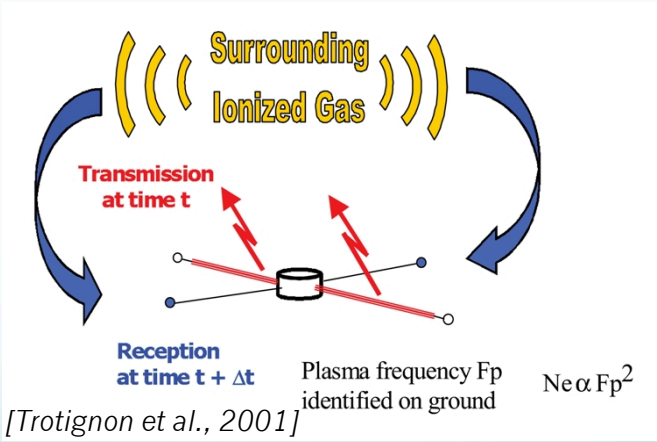
Launched in 2000
Still in operations (until 2025 ?)



Credits: ESA

Four identical spacecraft
in tetrahedral configuration

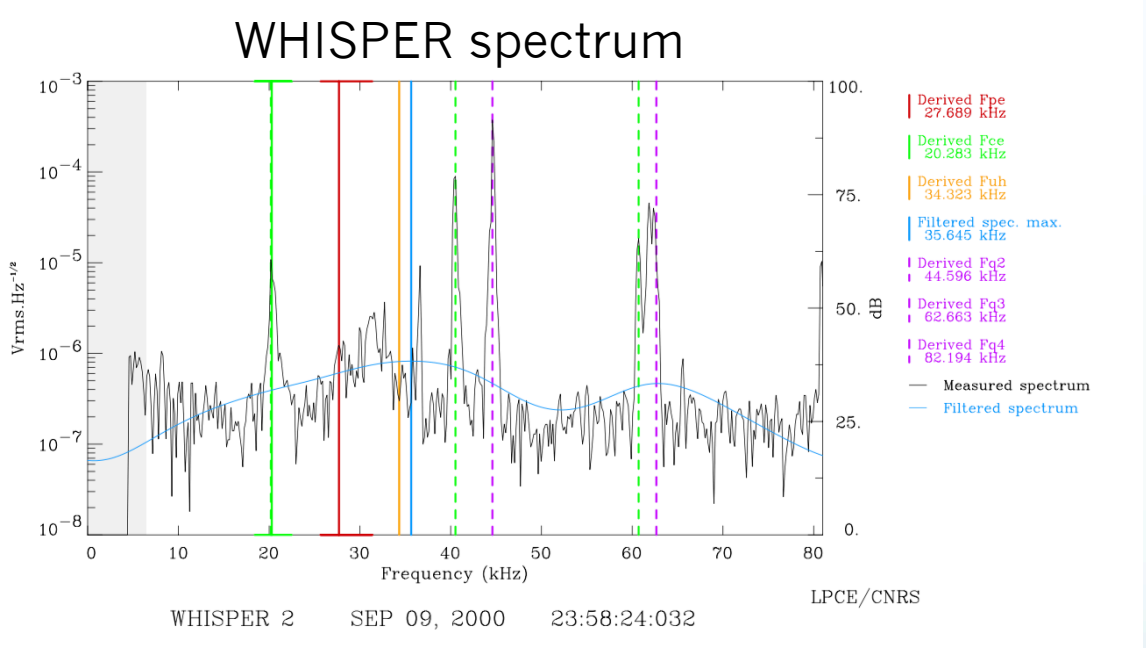
WHISPER (Waves of High frequency and Sounder for Probing of Electron density by Relaxation)



[Trotignon et al., 2001]

Measurement of key plasma parameters:
Electron density, magnetic field amplitude

Extraction of the plasma resonances



[Trotignon et al., 2001]

Electron plasma frequency:
f_{pe} [kHz] = 9 sqrt(n_e [cm^{-3}])

Electron cyclotron frequency:
f_{ce} [kHz] = 0.028. **B** [nT] and its harmonics

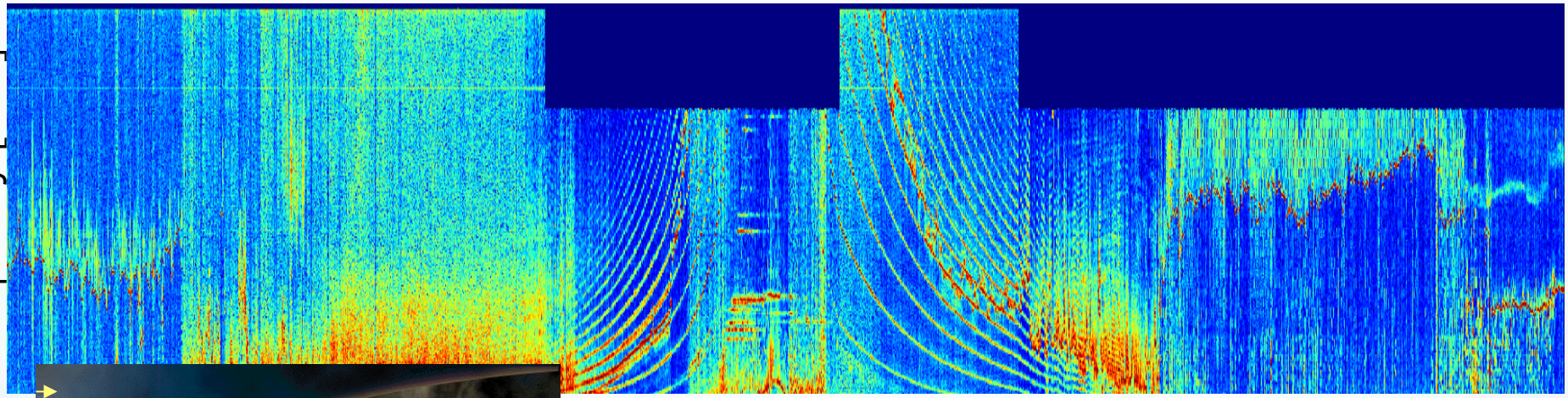
Bernstein's resonances f_{qn}

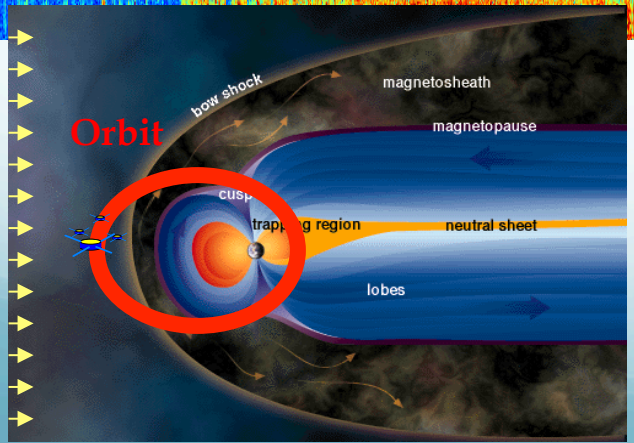
Electron density n_e by extraction of the **plasma frequency f_{pe}**

Dependance of the plasma regime

Magnetosheath | Magnetosphere/Tail | Plasmasphere | Magnetosphere/Tail | Magnetosheath | Solar Wind

frequency [kHz]





Time (~57h)

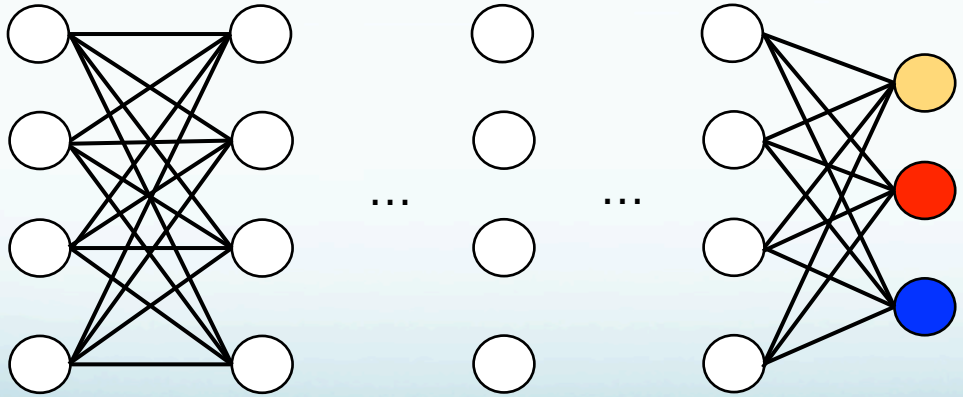
Extraction of the **plasma frequency** strongly depends on the plasma regime

Dependance of the plasma regime

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime

Input:
WHISPER spectrum (480 bins)



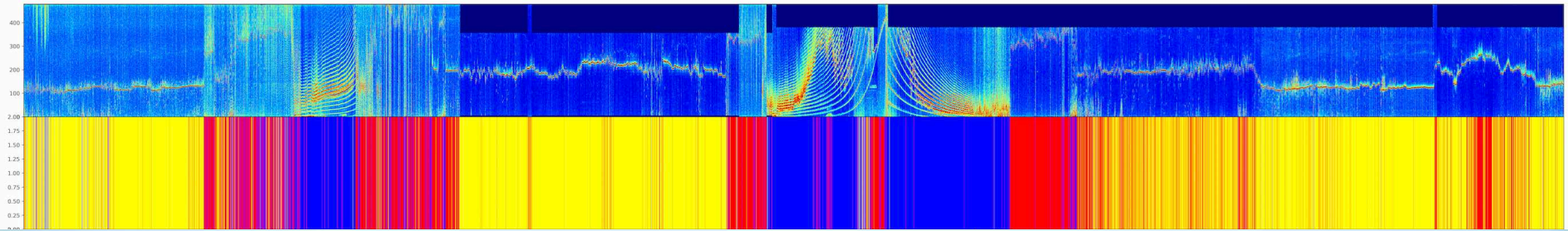
Output:
- Solar Wind
- Magnetosheath
- Plasmasphere
- + Others

Dependance of the plasma regime

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime

Example of classification by Neural Networks (RNN-GRU)



- Solar Wind
- Magnetosheath
- Plasmasphere + Others

Dependance of the plasma regime

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime

➢ Neural networks (Recurrent): **97% of accuracy** but **poor explanations of what he learnt**

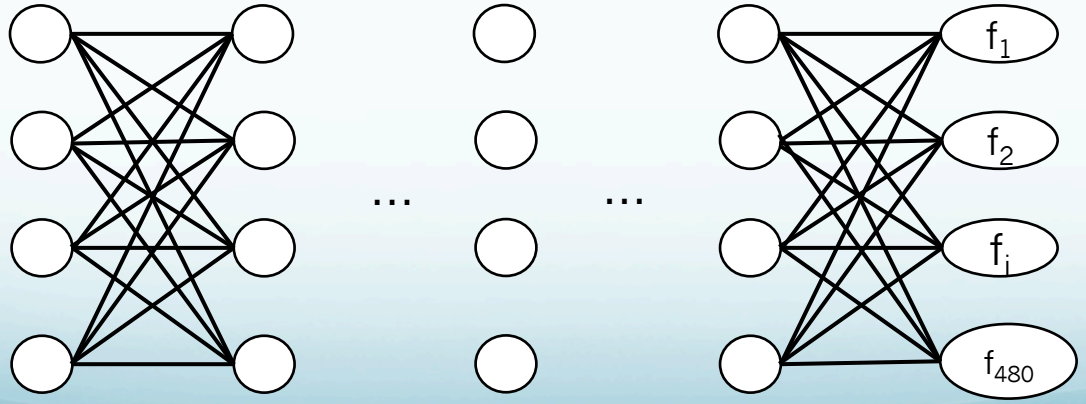
➢ Classification (Decision Tree/Random Forest) or Clustering method (DBSCAN/OPTICS): **80% of accuracy** with only descriptors (no spectrum in input)

Dependance of the plasma regime

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime
- **2nd step**: Extraction of the plasma frequency

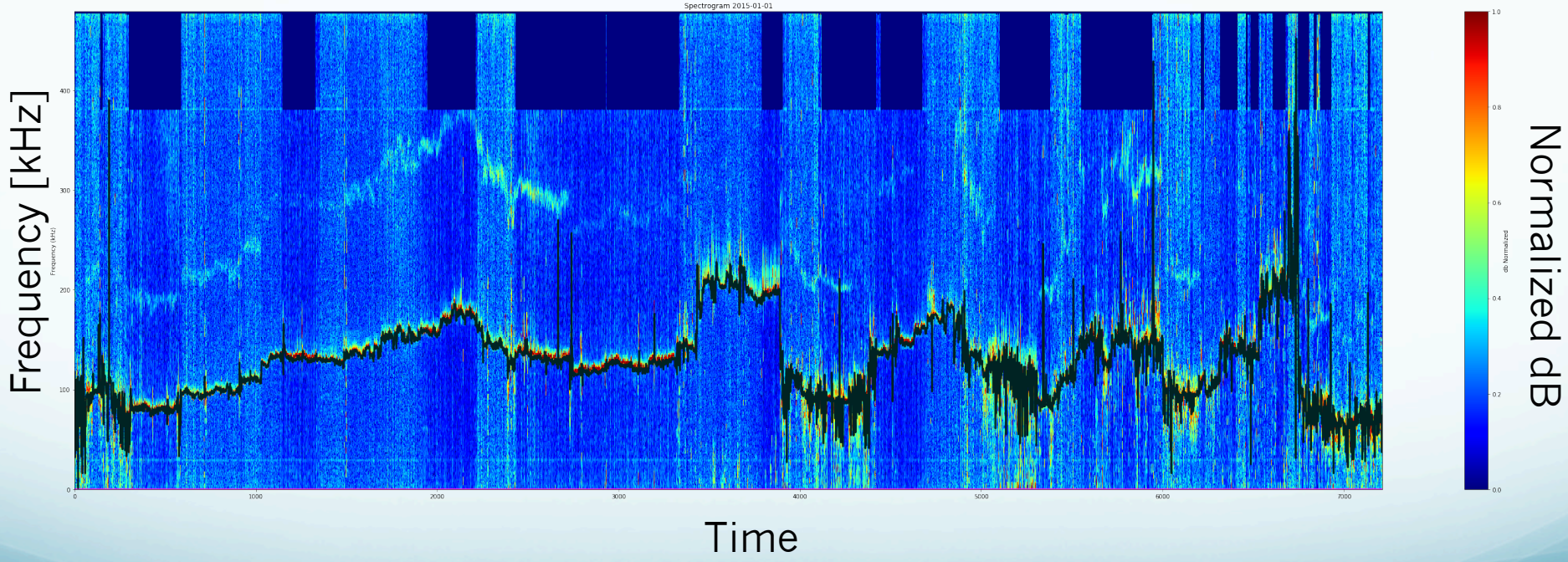
Input
WHISPER spectrum (480 bins)



Output:
480 frequency bins

Extraction of the plasma frequency

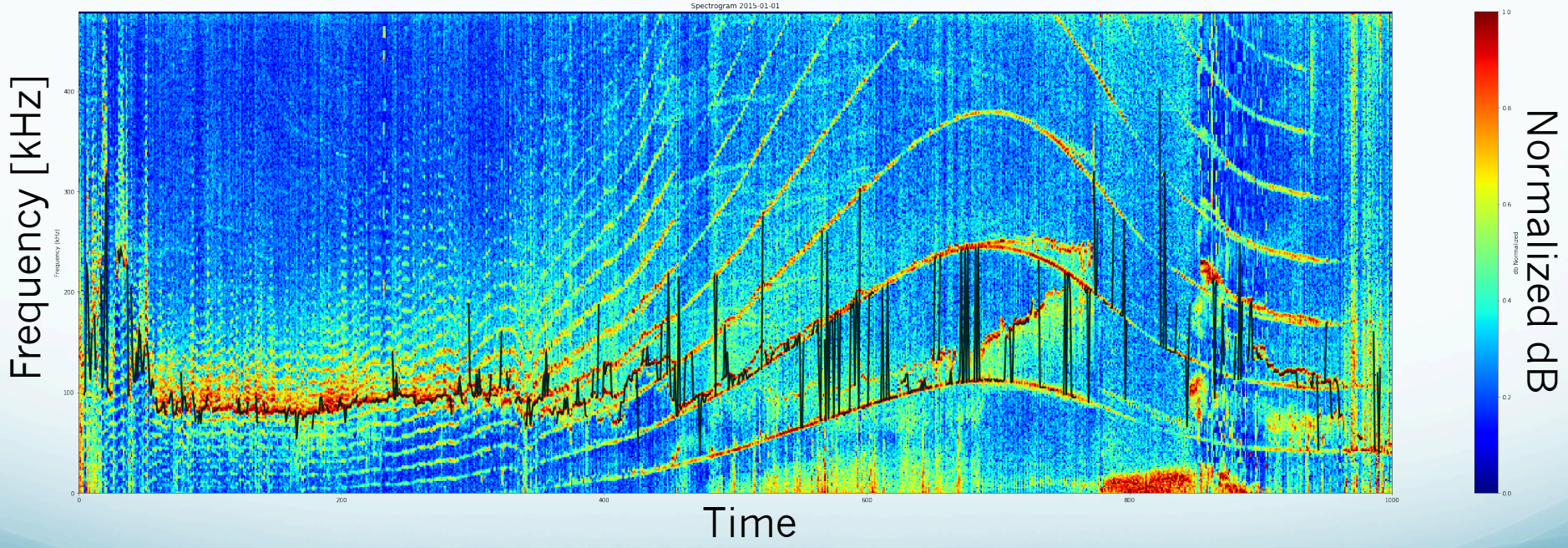
Solar Wind/Magnetosheath:



Accuracy: 96% with +/- 1 frequency bin

Extraction of the plasma frequency

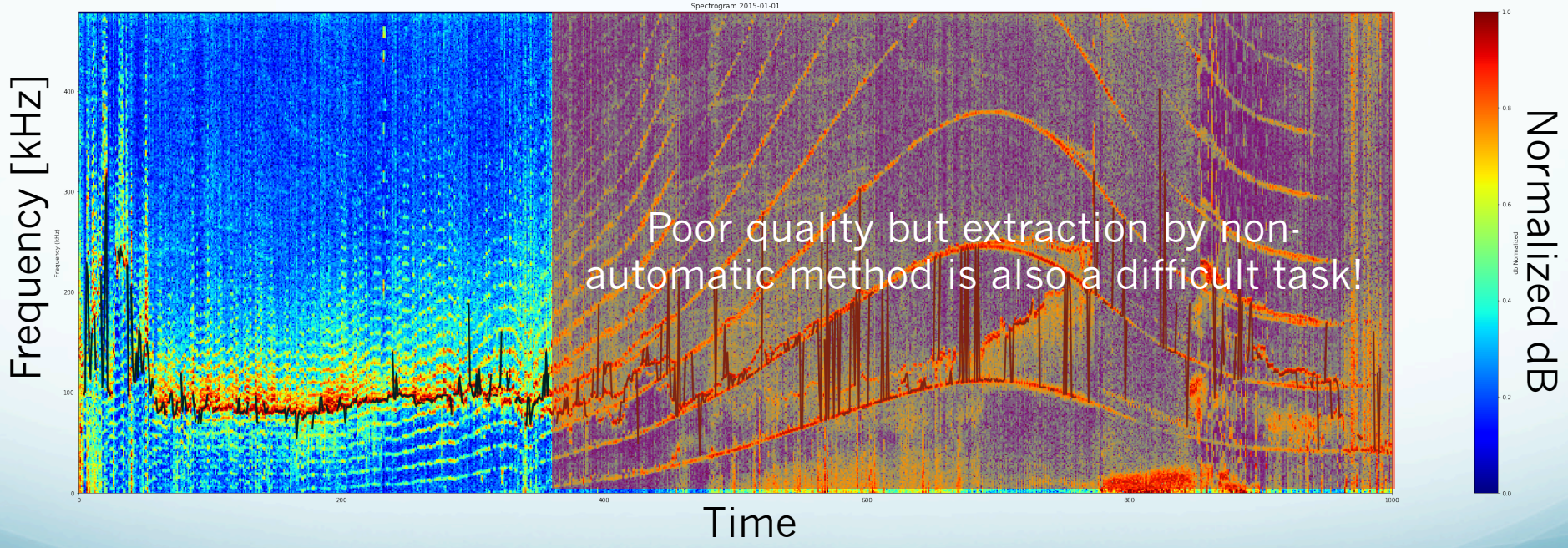
Plasmasphère:



Accuracy: 20% with +/- 1 frequency bin

Extraction of the plasma frequency

Plasmasphère:



Accuracy: 20% with +/- 1 frequency bin

Conclusion

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime
  - **Neural networks (97%)**
  - **Classification/Clustering (80%)**

- **2nd step**: Extraction of the plasma frequency
  - **Neural networks :**
    - **Solar Wind/Magnetosheath (96%)**
    - **Plasmasphere and Tail (20%)**

Conclusion

Main goal: Automatic detection of the electron density by the extraction of the plasma frequency ($n_e \alpha f_{pe}^2$)

- **1st step**: Detection of the plasma regime
  - **Neural networks (97%)**
  - **Classification/Clustering (80%)** ← **Improve the descriptors**

- **2nd step**: Extraction of the plasma frequency
  - **Neural networks :**
    - **Solar Wind/Magnetosheath (96%)**
    - **Plasmasphere and Tail (20%)** ← **Improve the training dataset**