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Automatic Detection and Classification of Boundary Crossings in Spacecraft in situ Data

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Abstract

Planetary magnetospheres create multiple sharp boundaries, such as the bow shock, where the solar wind plasma is decelerated and compressed, or the magnetopause, a transition between solar wind field and planetary field. We attempt to use convolutional neural networks (CNNs) to identify magnetospheric boundaries, i.e. planetary and interplanetary shocks crossings and magnetopause crossings in spacecraft in situ data. The boundaries are identified by a discontinuity in a magnetic field, plasma density, and in the spectrum of high-frequency waves. These measurements are available on many planetary missions. Data from Earth's missions Cluster and THEMIS are used for CNN training. We ultimately strive for successful classification of boundaries (shock, magnetopause, inbound, outbound) and the correct handling of multiple crossings.

Introduction

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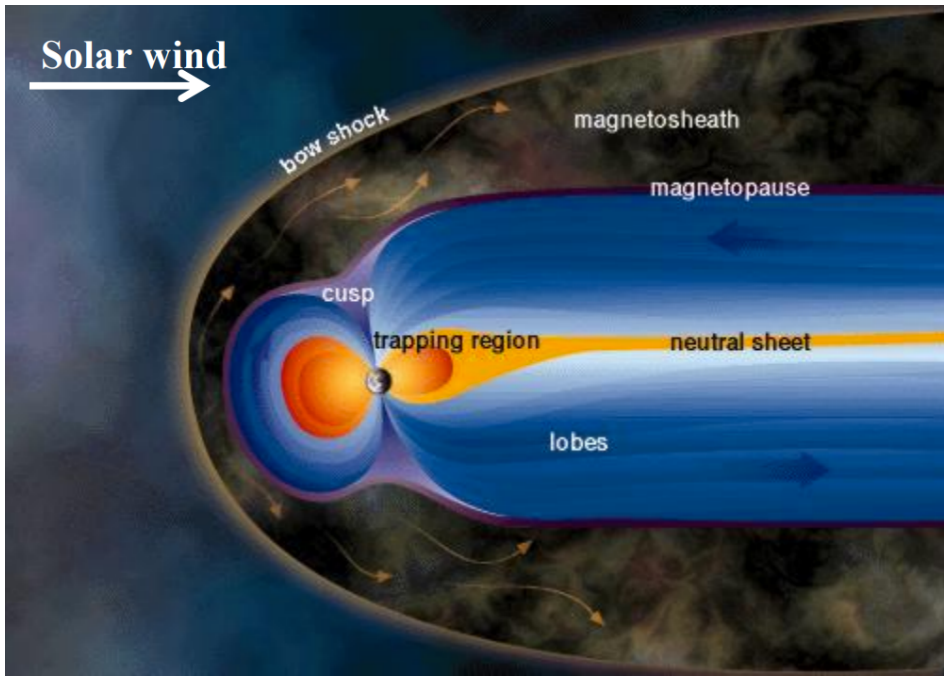


Solar wind and magnetosphere. Image: ESA

Introduction

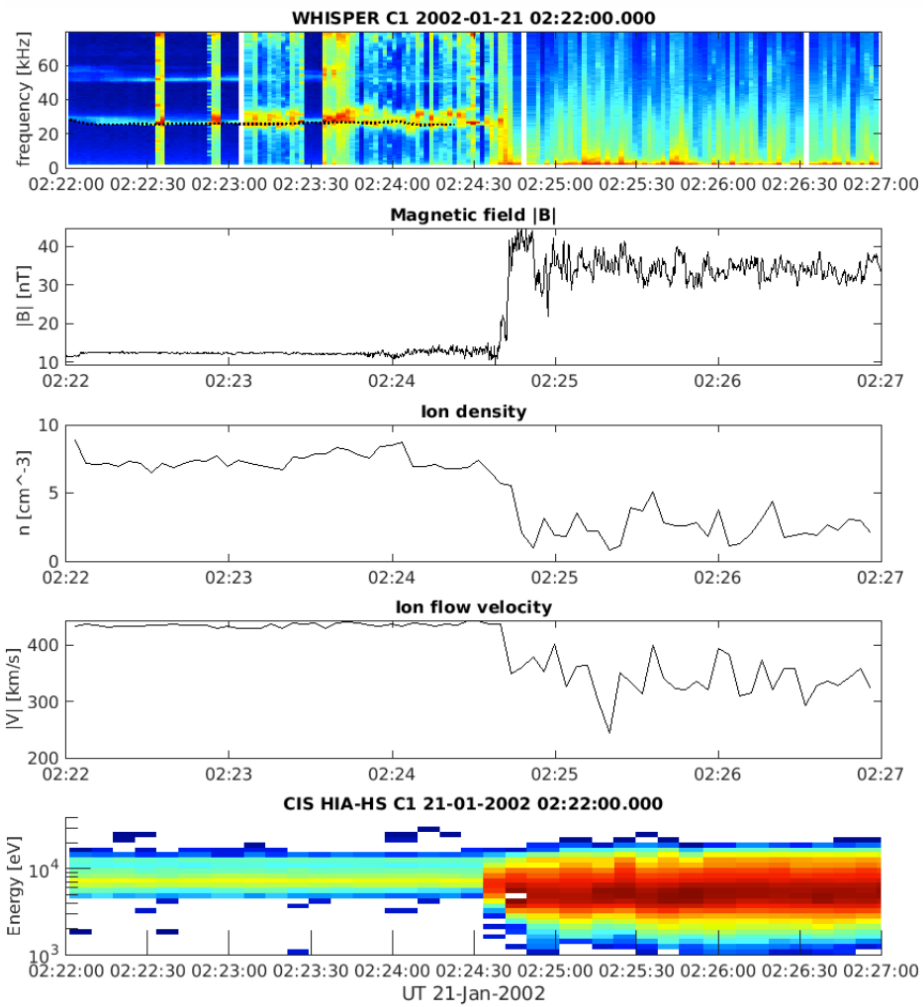
Shocks can be identified in multiple datasets:

- Magnetic field
- Ion density and speed
- Ion spectrum
- Electric field spectrum

Signatures

Signatures of a shock:

- Magnetic field increases
- Velocity decreases
- Density increases
- Electric field spectrum and ion spectrum change character



Example of a bow shock crossing. Data from WHISPER C1 and CIS-HIA-HS C1.

Data

There exist multiple spacecraft providing datasets for the identification of bow shock crossings.

- 4 Cluster spacecraft (since 2001, will operate atleast until the end of 2022)
- 5 THEMIS spacecraft (operational since 2007)

Usually, the shock is crossed by all 4 Cluster spacecraft. The relative timing of these crossings is valuable information for 3D modelling, but human expert labeling is time consuming. Since not all shocks look exactly the same and especially quasi parallel shocks can exhibit less sharp signatures, threshold based algorithms are not sufficient to reliably detect shocks.

Convolutional neural networks (CNNs) are commonly used for computer vision tasks, such as object detection. Nevertheless, patterns in time series can be detected as well. Large amounts of data can be processed in short time, once the training is completed.

Steps so far:

- Preprocessing Cluster data for training
- Labeling and defining NN achitecture

Next steps:

- Training on Cluster Data
- Hyperparameter tuning
- Testing algorithm on new, unseen data

Ultimately:

- Expanding possibility of algorithm to detect and label different regions
- Testing other machine learning methods on this use case

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