PNST : Colloque Scientifique Marseille, 16-20 mai 2022 – Thème 1 : Simulations et Outils Numériques

Automatic Detection of Martian bow shock crossings using data of the Mars Express mission: A Deep Learning Approach

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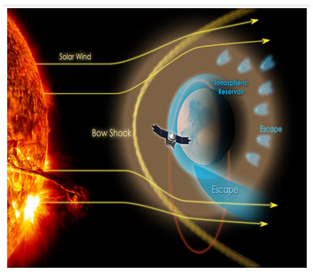
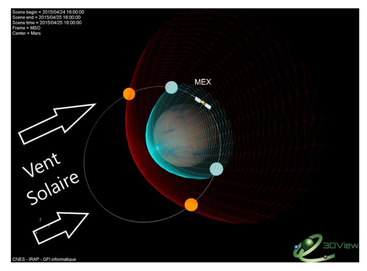
In order to detect and analyze physical events such as plasma boundary crossings, the most common and well-known method is to manually walk through these time series to identify such events and then create catalogs. This work is often biased and time-consuming. In this article, we illustrate how deep learning techniques combined with a well-adapted scientific post-processing method can automatically detect Mars bow shock passes using data from the Mars Express mission.



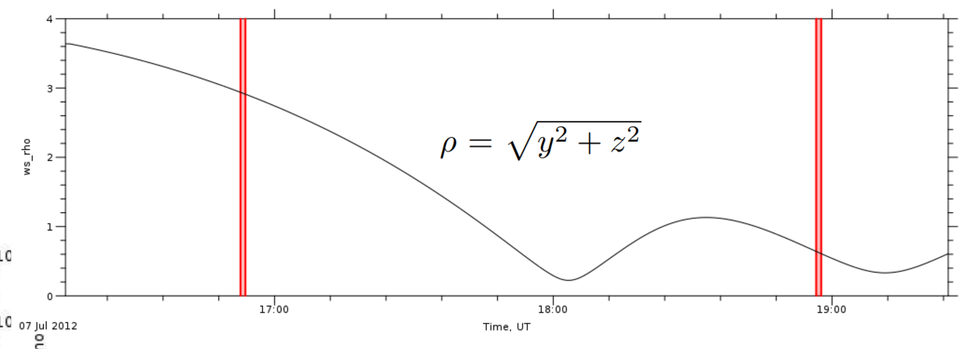
In this paper, we investigate to automatically detect the Martian bow shock crossings using the data of the Mars Express mission provided by CDPP-AMDA. Using a Multilayer Perceptron Neural Network, we provide an automatic classifier to predict the Martian bow shock crossings. A published catalog with around 11800 bow shock crossings has been used for labeling the data [1]. The challenging task was to deal with the unbalanced data, indeed, in our dataset, we have unequal distribution of classes: shocks and no shocks. Classification of unbalanced data is a difficult task because there are so few samples (shocks) to learn from. To tackle this problem is to penalize the misclassification made by the minority class by setting a higher class weight and at the same time reducing weight for the majority class.

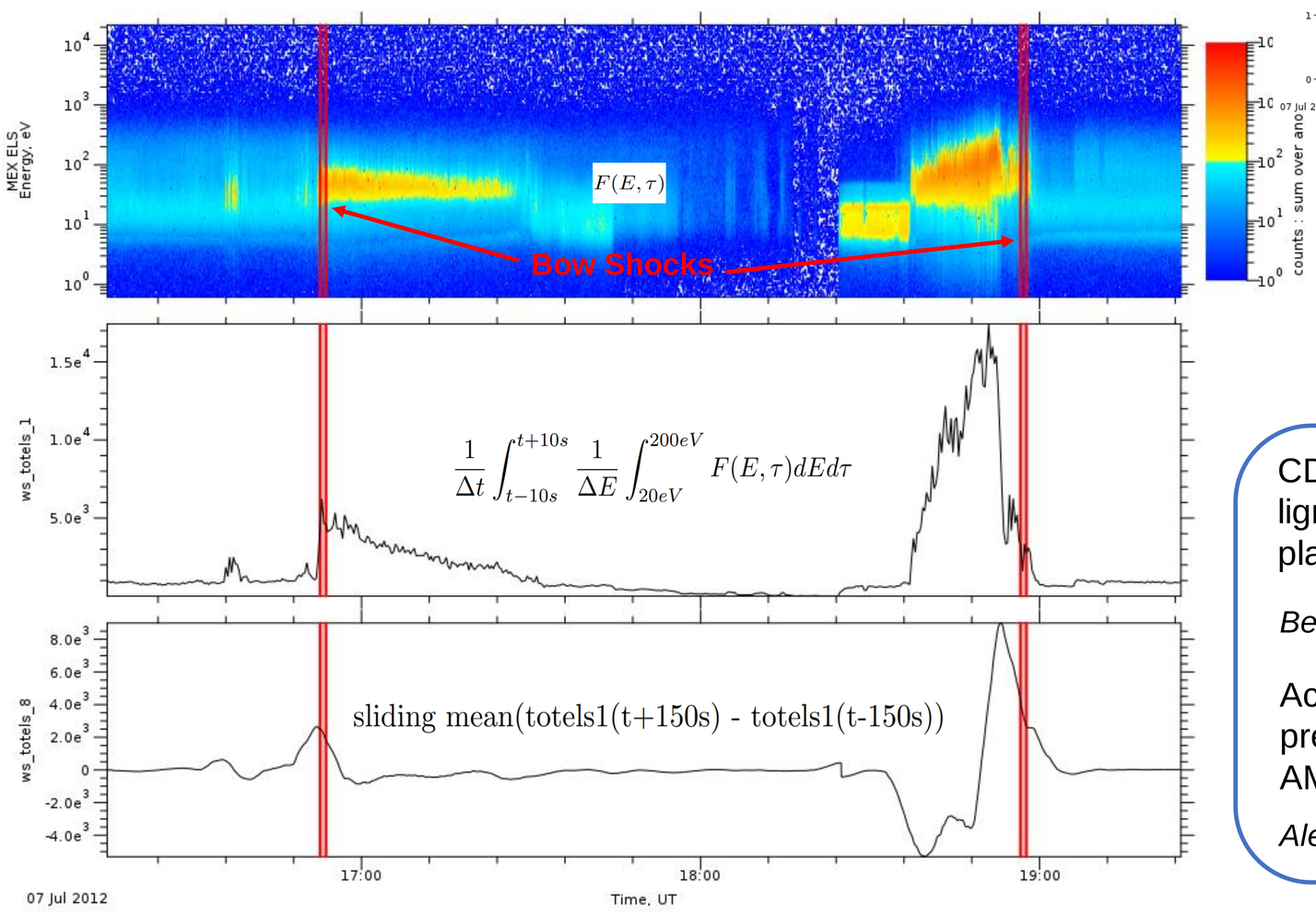
Context - Objective

The interaction of the Mars magnetosphere with the solar wind is characterized by parameters such as particle densities (electrons, protons, or heavy ions). These parameters are measured by the spacecraft, thus producing extensive time series over the time span of a mission.



MEX Data - Features





AMDA - Speasy

CDPP/AMDA, une base de données et un outil d'analyse en ligne pour les données plasma héliosphériques et planétaires

Benjamin Renard et al. sciencesconf.org:pnst-2022:399972

Access AMDA data in Python with Speasy module & view predictions produced by machine learning algorithms in AMDA

Alexandre Schulz et al. sciencesconf.org:pnst-2022:400219

Classification of unbalanced data: deep learning approach

Training: 1-7/07/2012

```
Nb shocks:  33
Class imbalanced:
    Total: 10032
    Positive: 32 (0.32% of total)
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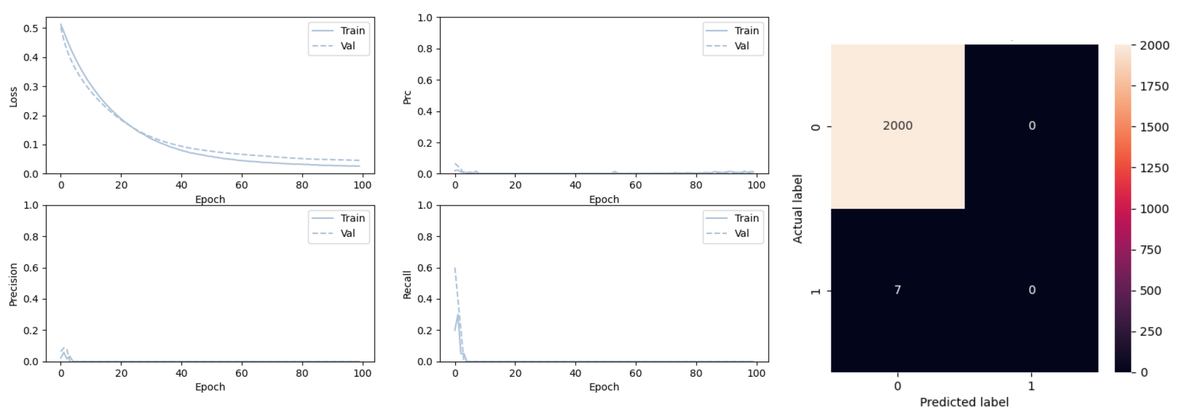
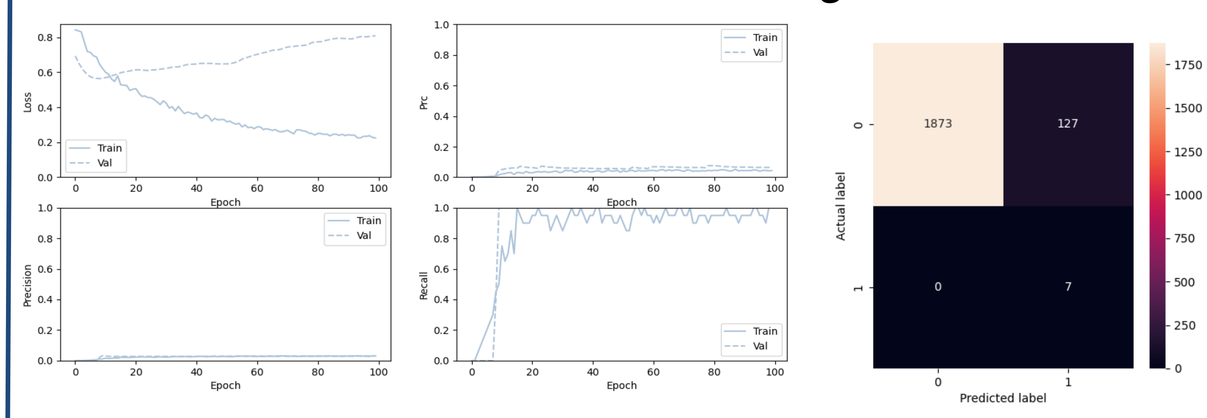
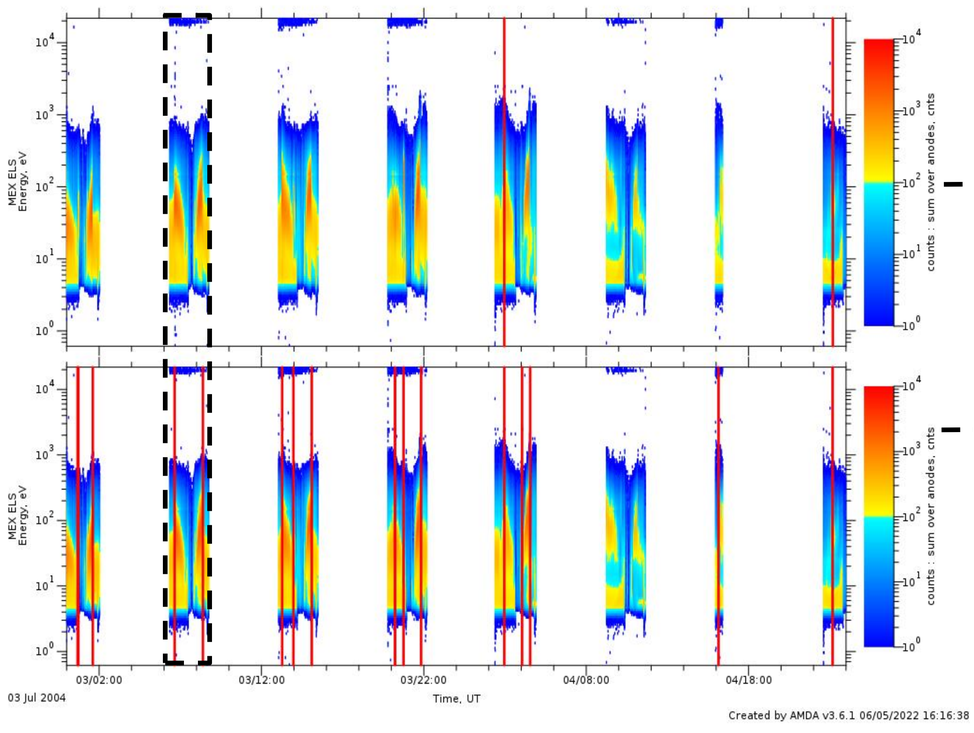
Test: Without Class Weight

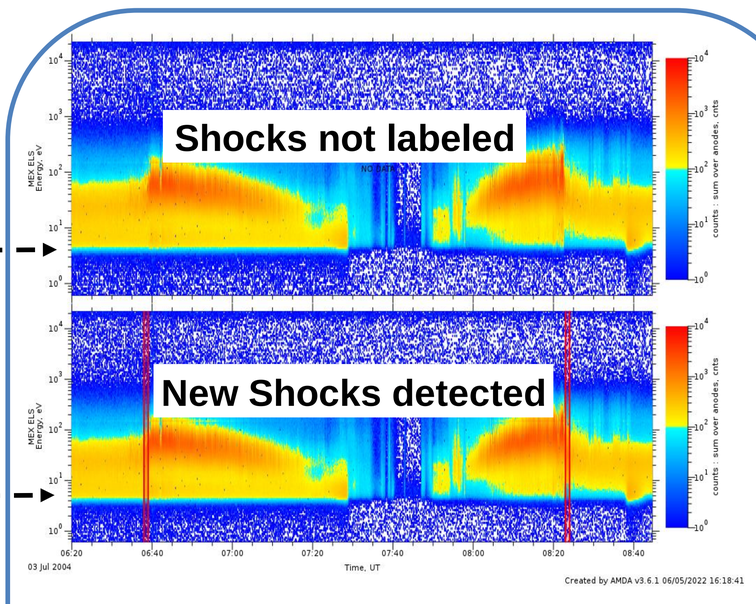


Test: With Class Weight



Test – 07/2004





Our model detects all shocks present in the test set while generating many false positives. The most likely of them are indeed valid events and will be added to the catalog.

Perspectives

Test other sophisticated network architectures (CNN, LSTM).

[1] B. E. S. Hall et al. "Annual variations in the Martian bow shock location as observed by the Mars Express mission". In: Journal of Geophysical Research: Space Physics 121.11 (2016), pp. 11, 474–11, 494