Classification of Magnetosheath Jets using Neural Networks, Solar Wind Observations and High-resolution IMF Measurements

Savvas Raptis[1], Sigiava Aminalragia-Giamini[2], Tomas Karlsson[1], Per-Arne L. Lindqvist[1]

[1]Space and Plasma Physics, School of Electrical Engineering and Computer Science, KTH Royal Institute of Technology, Sweden
[2]Space Applications & Research Consultancy (SPARC), Greece

MMS – Magnetosheath Jets

Solar wind **foreshock fluctuations** interacting with the bow shock, can create a transient phenomenon called "**magnetosheath jet**". These jets are local enhancement of dynamic pressure above the surrounding background level, possibly order of magnitudes higher than that of the surrounding plasma, reaching values higher than the upstream solar wind.

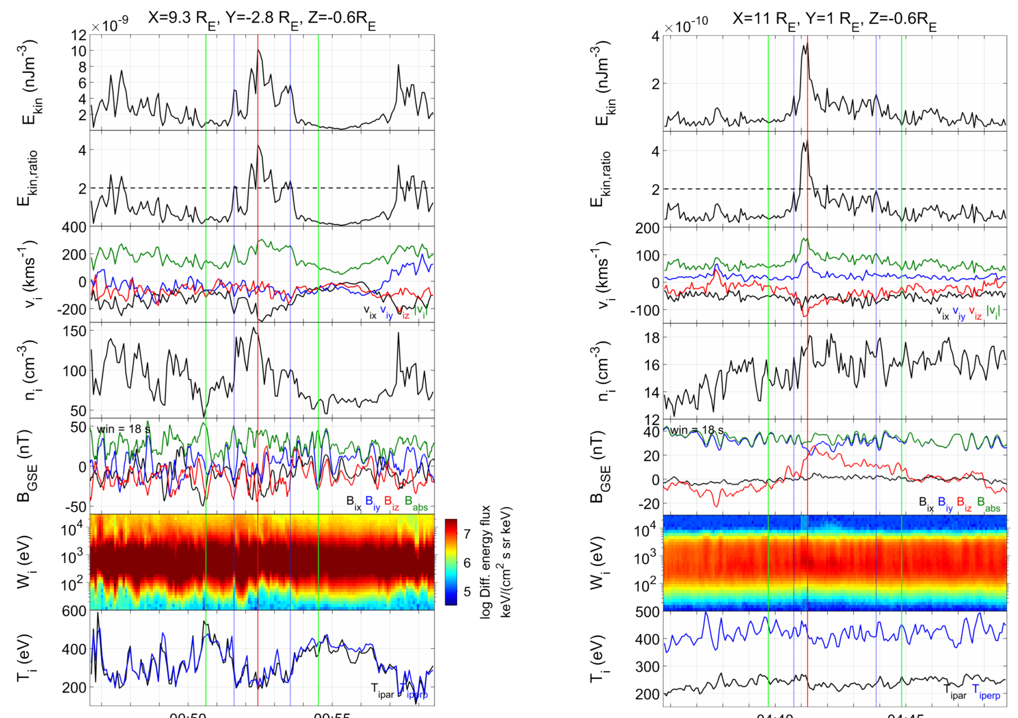


Figure 1: Examples of a **Quasi-parallel** and a **Quasi-perpendicular**. The different properties of the plasma moment and the magnetic field can be seen both during the jet period but also in the surrounding magnetosheath plasma.

*See **Poster 14.p03** for more information on magnetosheath jets and how the presented database is derived.

OMNIweb – Solar Wind

Input: upstream solar wind measurements, available at the OMNI database.

This dataset is created using multiple spacecraft measurements (primarily ACE & Wind) and is automatically smoothed and time-shifted to the nose of Earth's bow shock.

The bow shock location changes according to the solar wind parameters and is automatically adjusted for every time-shifted measurement.

Artificial Neural Networks

Artificial Neural Network (ANNs) is specialized machine learning algorithm "trained" to perform a specific task. The training is being done by introducing several data multiple times to the network and by then optimizing its parameters according to the presented examples ("*back-propagation*"). The main principle behind neural networks is that after parametrizing a network based on known data, the network can then be used for the trained task when given new unknown information.

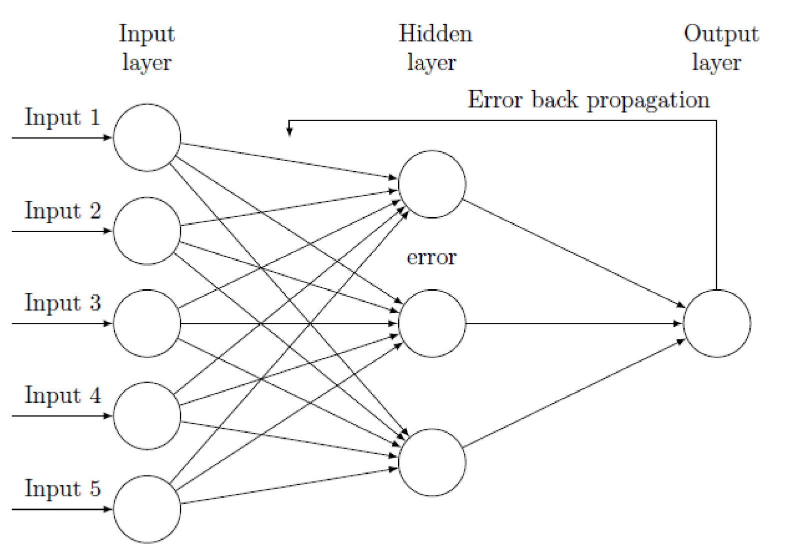
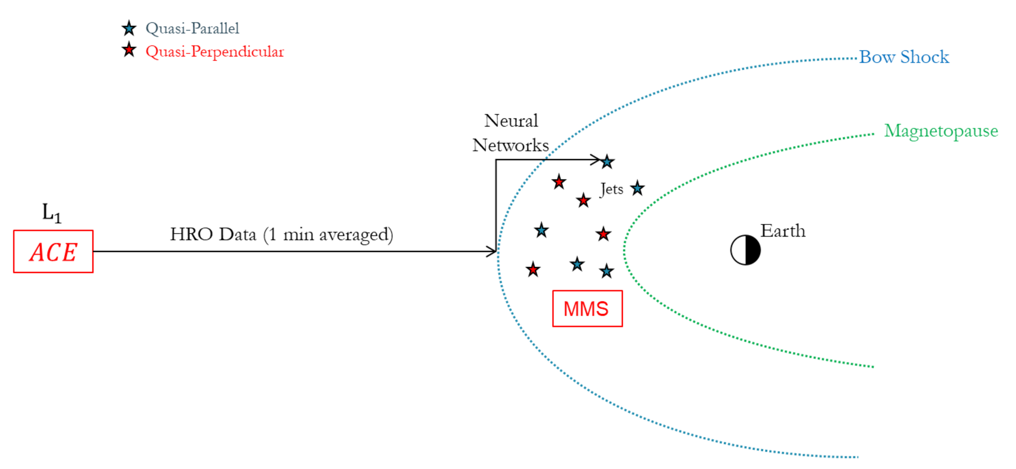


Figure 2: Visualization of a fully connected neural network and the basic principle of error back propagation.

Procedure

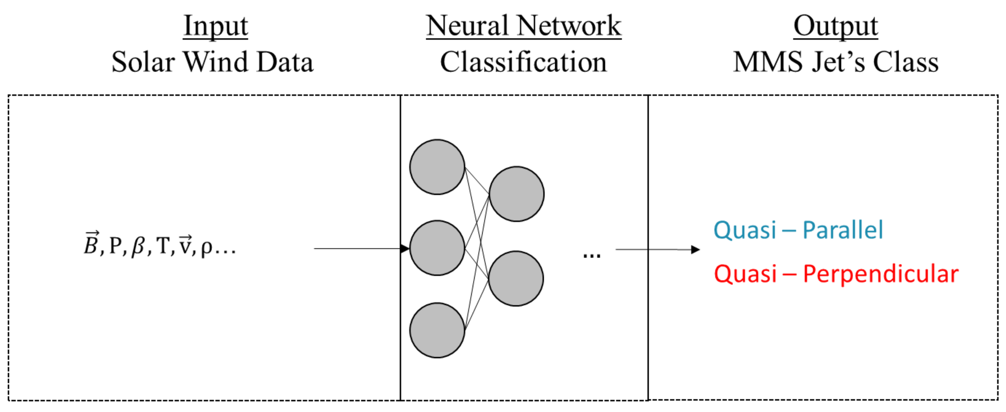
Motivation:

Connect solar wind measurements to jet's class



Main Procedure:

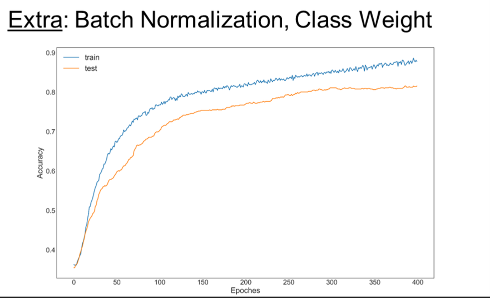
Use data from OMNIweb to find the class of jets as measured by MMS



ANN – Architecture

Neural Network Parameters

Training – Test set : 80 – 20%
Optimizer: Nadam
Activation Function: (P)ReLu, Softmax
Extra: Batch Normalization, Class Weight



Input Evaluation

Most important:

Alfvenic Mach Number
Magnetosonic Mach Number
Temperature
Beta parameter
Velocity
Density

Applications

Assist initial database (Unclassified Jets)

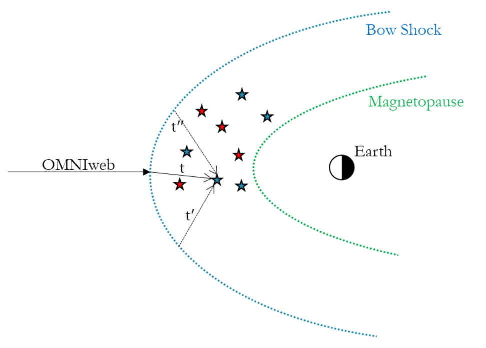
Subset	Number	Percentage (%)
Other	4890	57.5
Uncertain	3499	41.2
Border	1346	15.8
Data Gap	45	0.5

Compare with traditional methods of estimating θ_{Bn}

	Certain Jets [728, 181] [139, 42]		
Mean$(t_0 - 5, t_0)$	109	30	78%
	10	32	76%

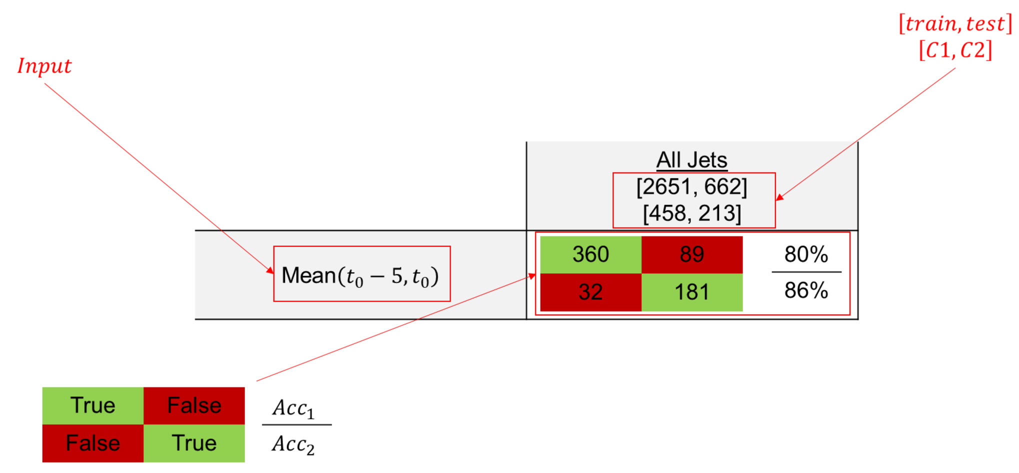
Results

Input analysis:



- Solar Wind at $t_0 = t_{MMS}$ ✗
- Mean Solar Wind $(t_0 - 10, t_0 + 5)$ ✗
- Mean Solar Wind $(t_0 - 5, t_0)$ ✓
- Max Solar Wind $(t_0 - 5, t_0)$ ✓

Result representation:



Total summarized results:

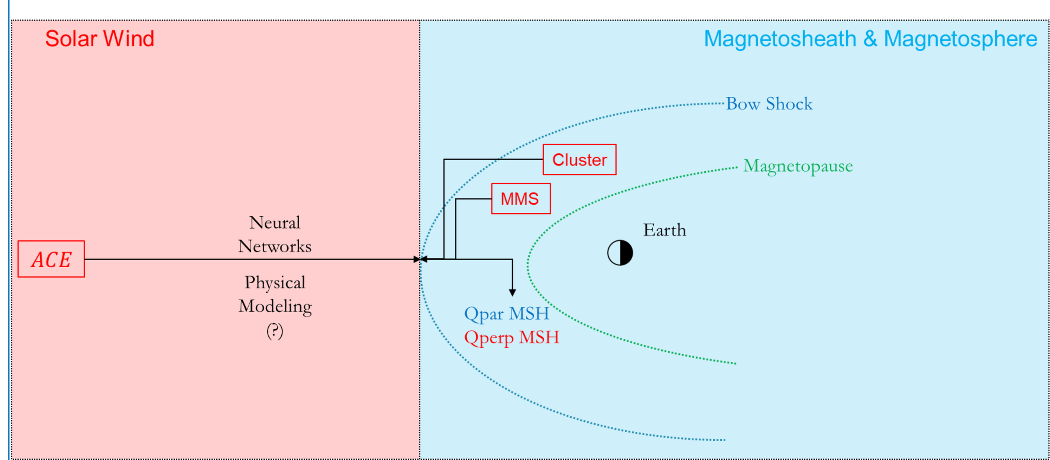
	All Jets [2651, 662] [458, 213]			Certain Jets [728, 181] [139, 42]		
Mean$(t_0 - 5, t_0)$	360	89	80%	135	4	97%
	32	181	86%	2	40	95%
Max$(t_0 - 5, t_0)$	345	104	77%	131	8	94%
	55	158	74%	4	38	90%

Maximum accuracy was reached with 97% and only 6 jets out of the 181 being misclassified.

When looking at all the jets, 82% accuracy was reached.

Future Research

Connecting Solar Wind to Magnetosphere:



- Connecting solar wind conditions to different magnetosheath and magnetosphere plasma populations.
- Using different satellites data and physical modeling to model the interaction of solar wind particles with the bow shock.

Conclusions

- Provided support to the initial magnetosheath jet database.
- Successfully classified jets with 80 – 97% accuracies.
- Investigated different solar wind parameter for input and found new interesting results.
- Compared with physical methods (estimating θ_{Bn}) and derived preliminary superior results.

Contact / More information: Savvas Raptis, savvra@kth.se