Quasi Parallel and Quasi Perpendicular Magnetosheath Jets using MMS data

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Introduction

Earth's **Magnetosphere** is filled with fascinating phenomena originating from the interaction of Solar Energetic Particles with Earth's Magnetic Field.

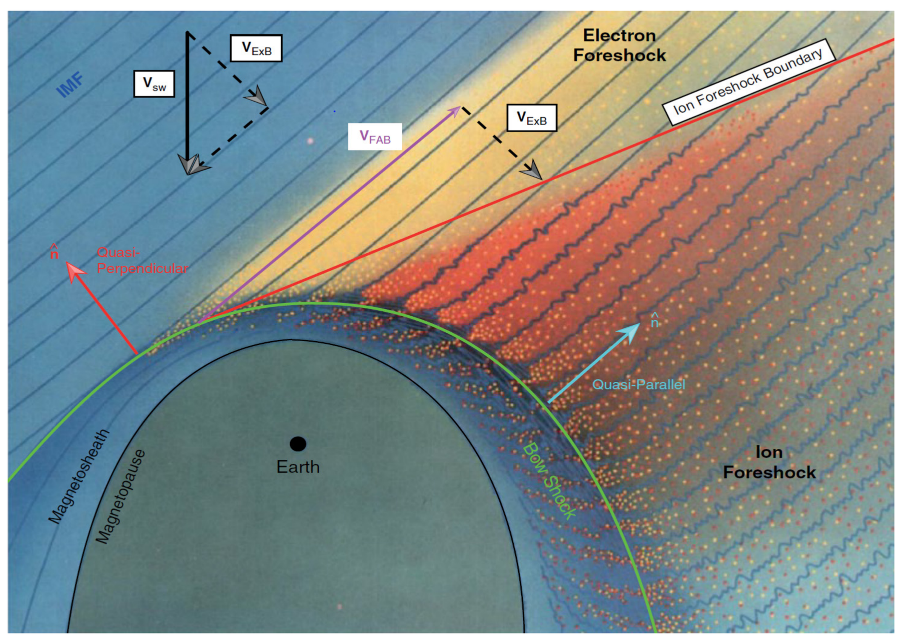


Figure 1: Visualization of the Quasi parallel and perpendicular region. The ion foreshock is much patchier and disturbed in the quasi parallel case. Figure Courtesy: L. B. Wilson (2016).

The region of interest in this work is the **Magnetosheath** which is a highly disturbed region between the *Bowshock* and the *Magnetopause*. In this region, several phenomena manifest, one of which is the "**Magnetosheath Jet**". These jets are enhancements of dynamic pressure above the general fluctuation level, indicating a local plasma flow.

Jets are believed to be a key element to the **coupling of Solar Wind and Magnetosphere** while being possibly associated with other physical phenomena such as magnetic reconnection and radiations belts. Finally, it is assumed that they are a universal phenomenon that can appear in other planetary and Astrophysical shocks.

Magnetosheath Jets

Fluctuations of plasma moments are commonly found in **quasi-parallel shock** configuration ($\theta_{Bn} < 45°$). This is a direct result of MHD theory, where it can be shown that a shock in Qpar configuration can no longer remain stationary without an energy dissipation mechanism (jet) occurring.

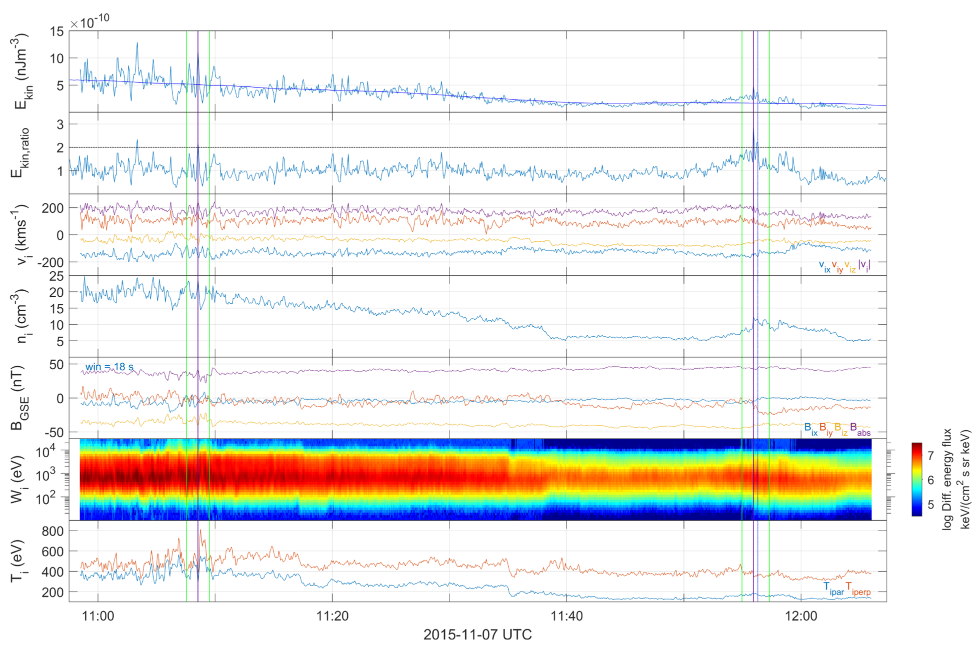


Figure 2: Example of a **Quasi-Parallel** and a **Quasi-Perpendicular Jet**. We can see the vast difference in the plasma moments and in the magnetic field if we compare the two phenomena.

On the other hand, in the **quasi-perpendicular shock**, we have a much smoother situation, with less variance in magnetic field and plasma moments, which however still allows jet formation to occur.

For **Magnetosheath jet** definition, we require the ion kinetic energy ($m_i v_i^2/2$) to be at least twice as much as the average kinetic energy of a 10-min window time around the jet.

It is hypothesized that different mechanisms create these jets under different Bow shock and IMF configurations. We believe that the characteristics of jets being created under different angle between the bow shock and the IMF can provide insight regarding their origin and generation mechanism.

Simplified Algorithm

Step 1: Finding Jets

$$\frac{E_{kin}}{\langle E_{kin}\rangle_{10(min)}} > 2$$

Step 2: Combining adjacent Jets (1, 2, … ,n)

$$T_{end,i} - T_{start,i+1} < 60\ sec$$

Step 3: Subcategories

1. Quasi Parallel Jets
2. Quasi Perpendicular Jets
3. Boundary & Soft – Boundary Jets
4. Encapsulated & Soft – Encapsulated Jets
5. Border Jets
6. Unclassified/Unknown Jets

Step 4: Thresholds & Classification Quantities

Level I
- Variance of B
- Very High Energy Flux
- High Energy Flux

Level II
- Temperature Anisotropy
- Total high to Medium flux ratio

Level III
- IMF cone angle (Bow shock)

Step 5: Quality level & Number of tries

- Separate the jet database into **Quality levels** from 1 ("Good") to 3 ("Excellent").
- Saving **number of tries** needed to classify the jet as quality measurement.

Step 6: Adaptive time of unknown jets

Repeat steps 3-5 by implementing different Pre-jet and Post-jet periods to classify jets of different timescales. The initial values are from starting and ending jet point respectively :

Jet Duration T (sec)	Pre/Post Jet Period (sec)
$[9, 45]$	± 45
$(45, 90]$	± 60
$(90, T_{max})$	± 75

Notes

"Soft" refers to transitions from or to "unclassified" to or from Quasi par/perp areas. E.g.

Prejet $\rightarrow$ Jet $\rightarrow$ Postjet

$2 \rightarrow 1 \rightarrow 2$: Encapsulated Jet

$0 \rightarrow 1 \rightarrow 2$: "Soft" Encapsulated jet

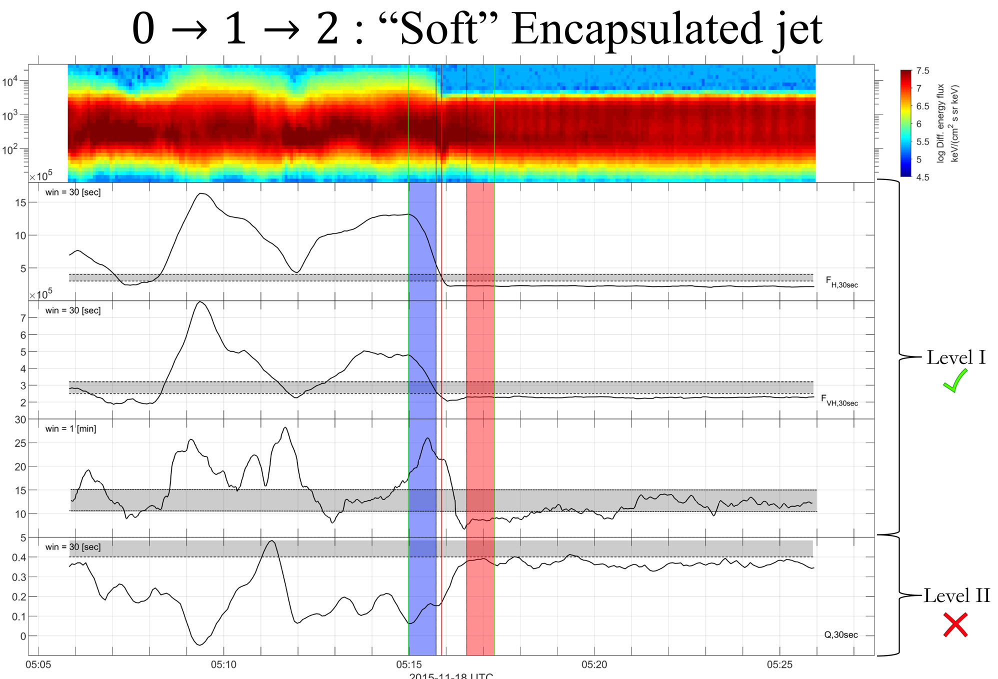


Figure 3: Example of an a "**Boundary**" jet classified during the 1st stage with level 1 quality Quasi parallel and Quasi perpendicular classifications on each side of the jet. Blue = Qpar, Red = Qperp region.

Preliminary Results

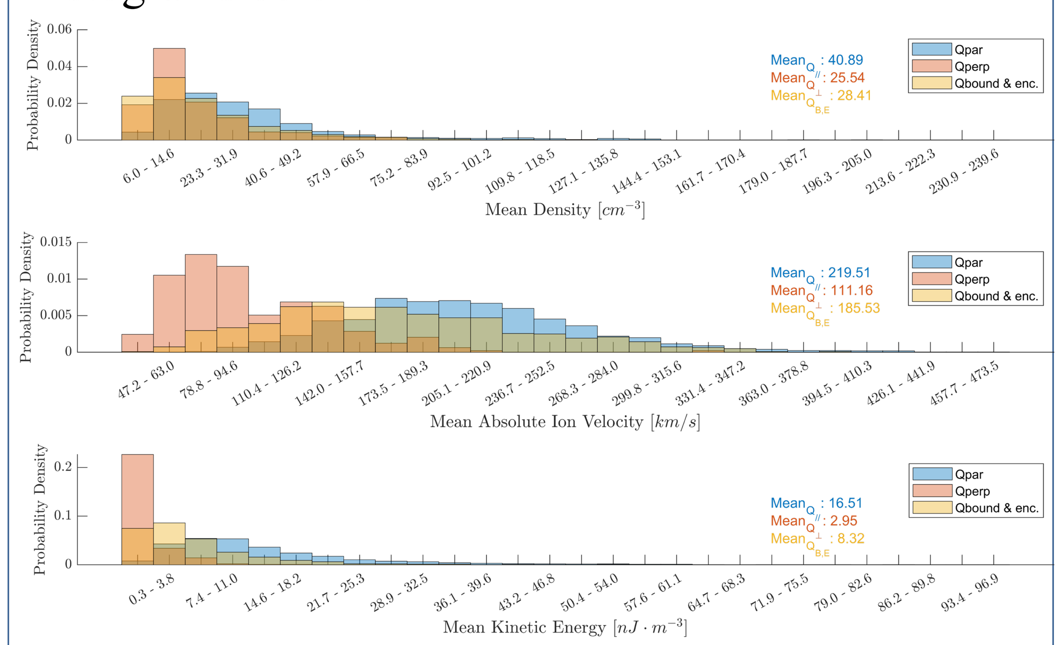
Using all available MMS Data (11/2015 – 01/2019)

Jets	Downsampled $dt < 60\ (s)$	High Energetic $E_{kin} > 1\ (nJ \cdot m^{-3})$
15477	7957	4082

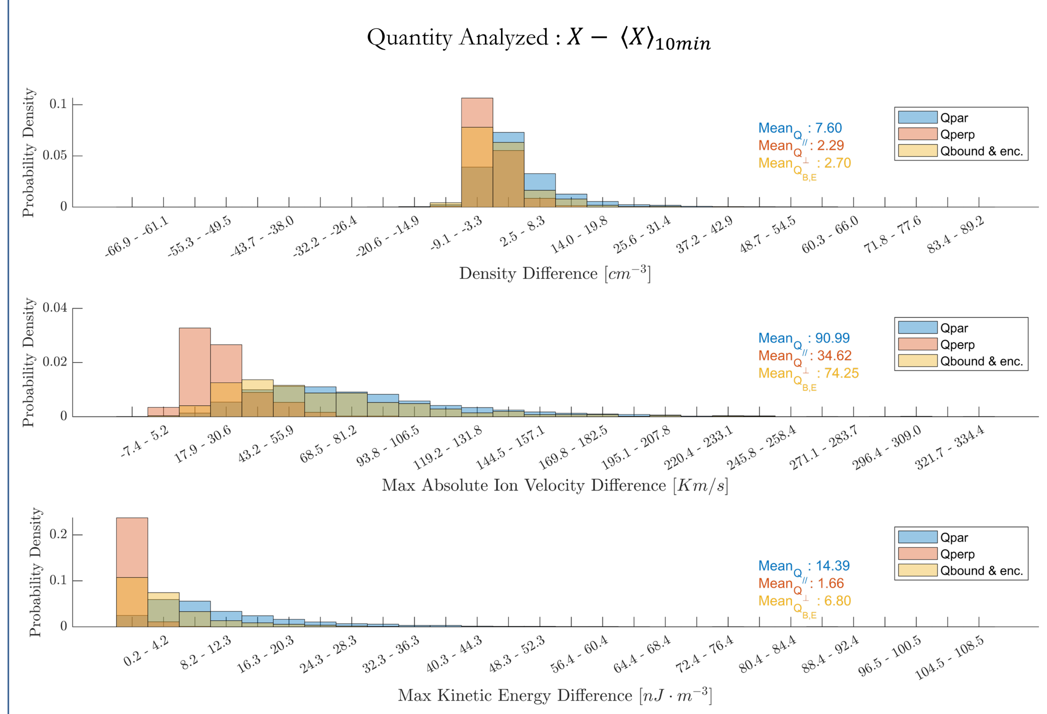
Q_{par} *	Q_{perp} *	Boundary †	Encapsulated †	Border
2201	506	725	105	1225

* Including all quality levels, 2 adaptive schemes and up to 5 tries.
† Including all quality levels, 4 adaptive schemes and up to 15 tries.

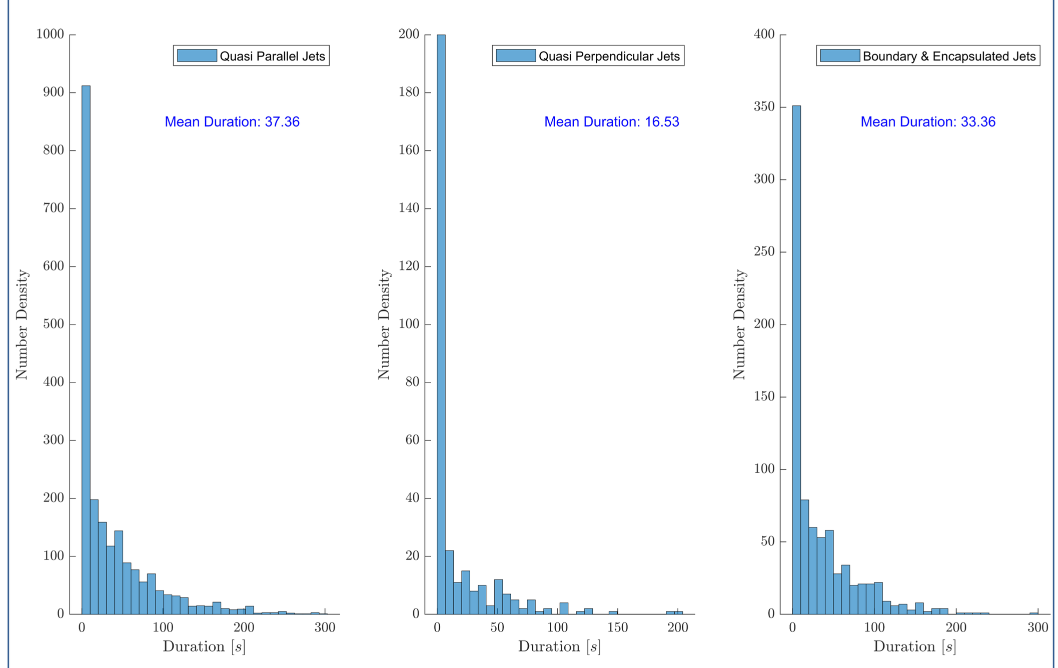
The most noticeable differences of the database and its classification scheme can be summarized in the histograms below.



The most interesting differences between the **Quasi-parallel** and **Quasi-perpendicular** jets are found in the Velocity and Density distributions. These differences remain even after subtracting the average values of the surrounding plasma region.



Regarding **Boundary** and **Encapsulated** jets, their characteristics lie somewhere in between of the two previous classes. This is expected due to the nature of the surrounding plasma that they are found (both Quasi parallel & perpendicular).



Summary & Discussion

- **Successfully developed a multistage classification scheme** that classifies jets into different categories according to the characteristics of their magnetic field and the surrounding plasma moments.
- A preliminary statistical analysis of these **classes' properties show differences**, that may be attributed to intrinsic properties of their generation mechanism. More work on this connection is in the immediate future plans along with a creation of a test set to measure the accuracy of the presented classification scheme.

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FORSKNING
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