Quasi – parallel & Quasi – perpendicular Magnetosheath Jets Using MMS

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Introduction

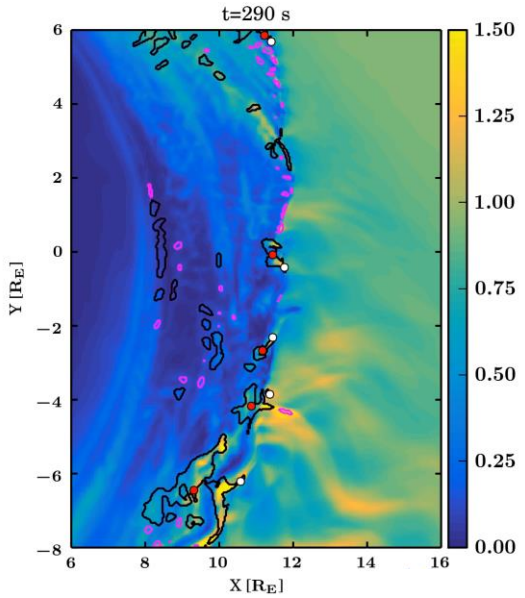
Magnetosheath Jets

What: Enhancements of dynamic pressure above the general fluctuations level

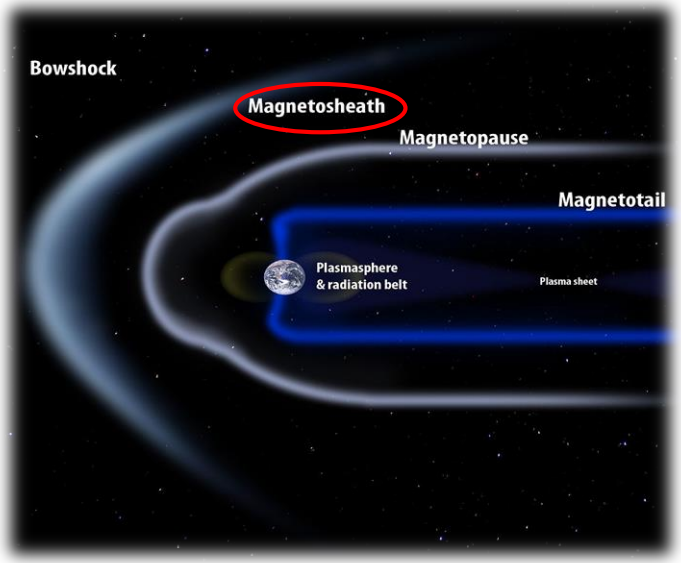
Where: Magnetosheath

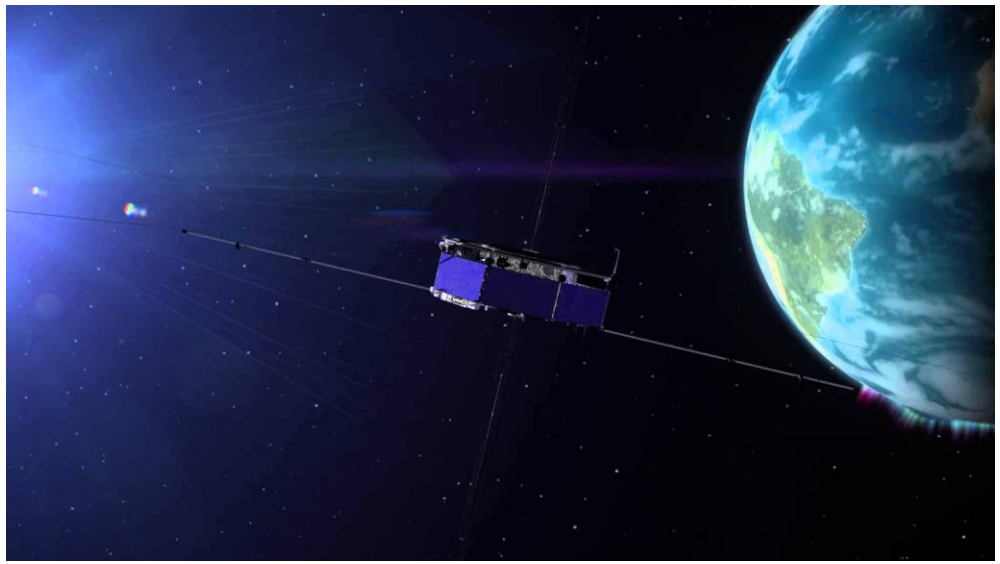
Data: MMS (Magnetospheric Multiscale Mission)

Why: Interaction of SW & Magnetosphere, magnetopause reconnection, radiation belts, auroral features…

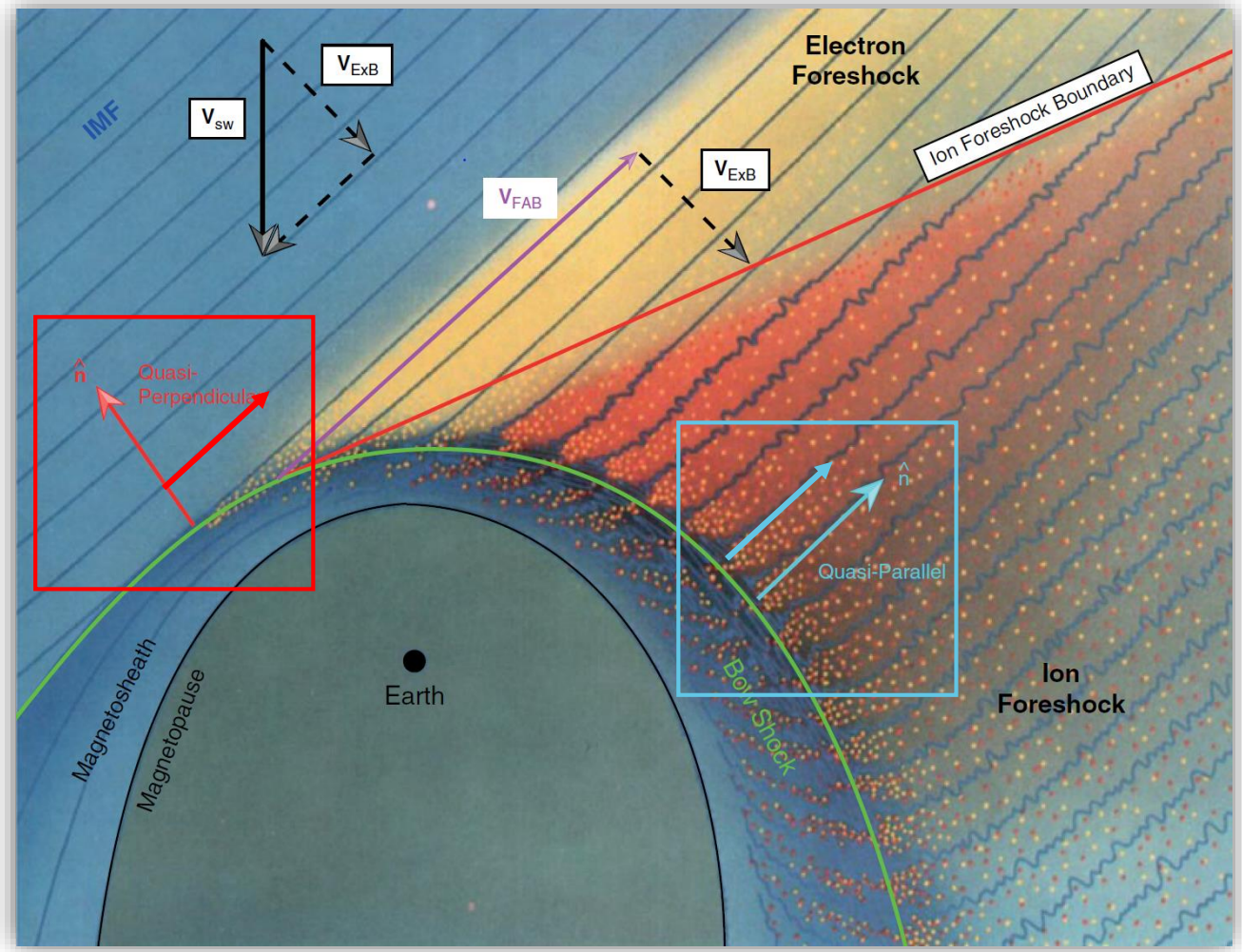


Palmroth Minna et al. (2018)





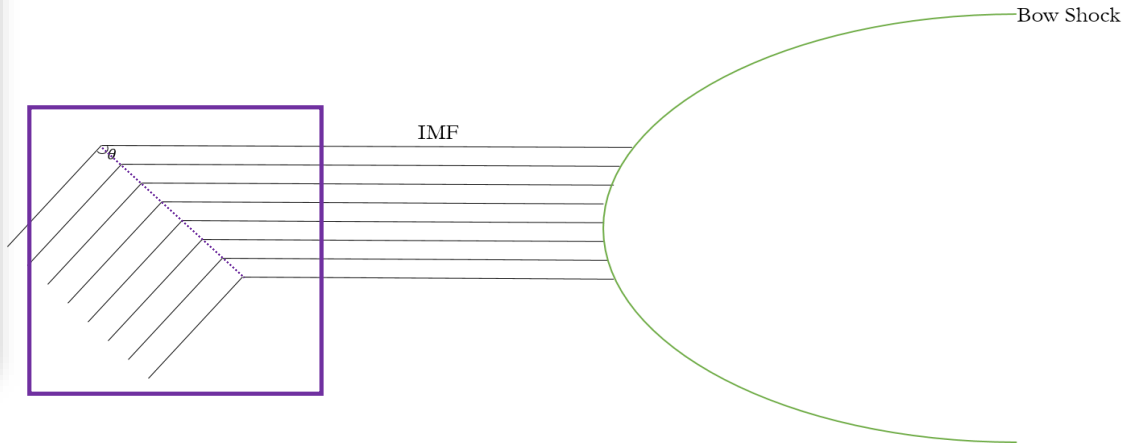
Motivation – Main Subcategories



L. B. Wilson (2016)

Jets are found mainly in Quasi-parallel shock ($\theta_n < 45°$). However, fluctuations also found in Quasi Perpendicular regions.

Q_{par}	Q_{per}	$Boundary$



How Jet look like – Quasi Parallel

High B Variance, High Energetic Particles, Low Anisotropy

Kinetic Energy Density

Kinetic Energy Density Ratio

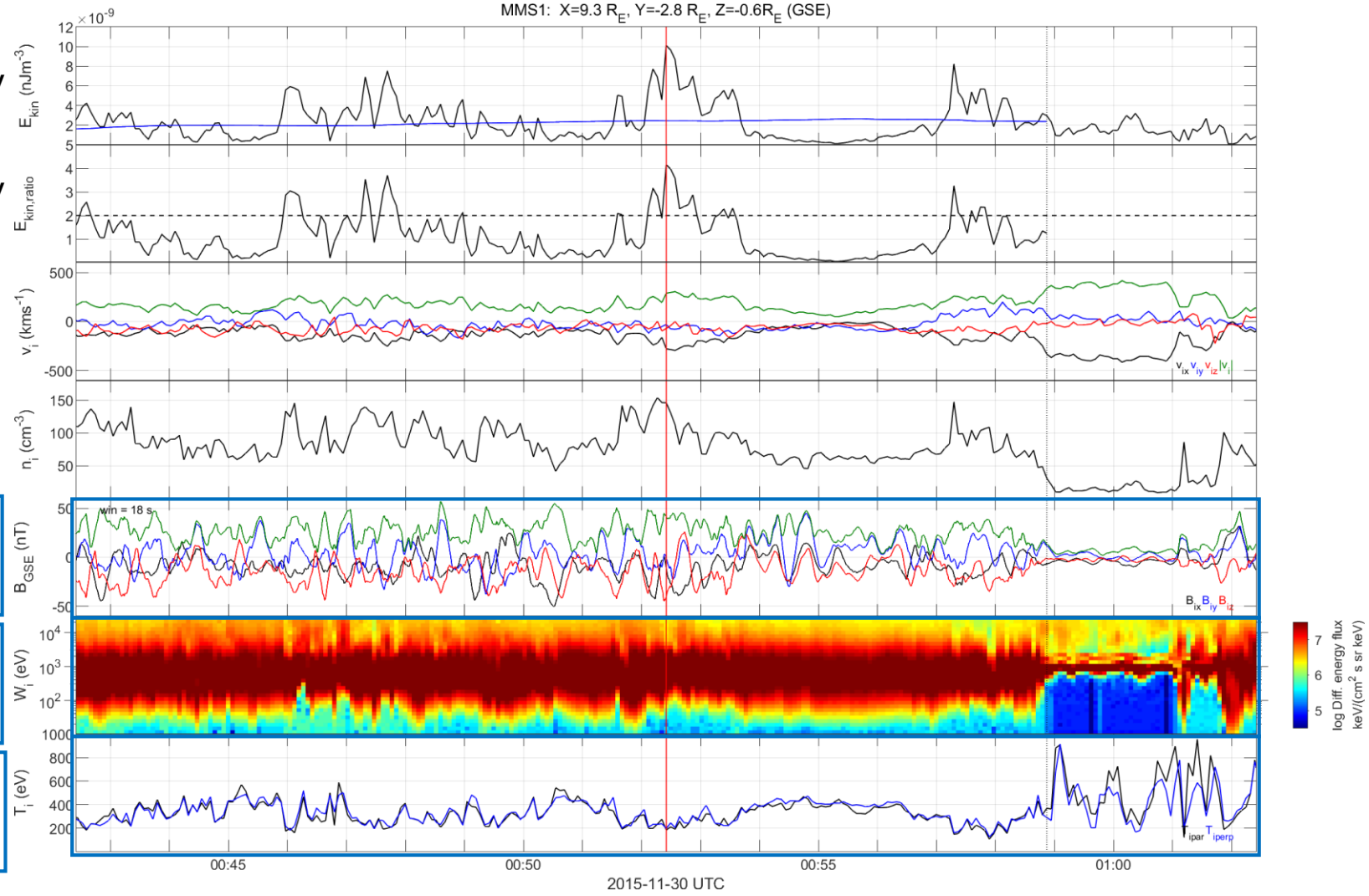
Velocity

Density

Magnetic Field

Ion Energy Spectrum

Temperature



How Jet look like – Quasi Perpendicular

Low B Variance, Low Energetic Particles, High Anisotropy

Kinetic Energy Density

Kinetic Energy Density Ratio

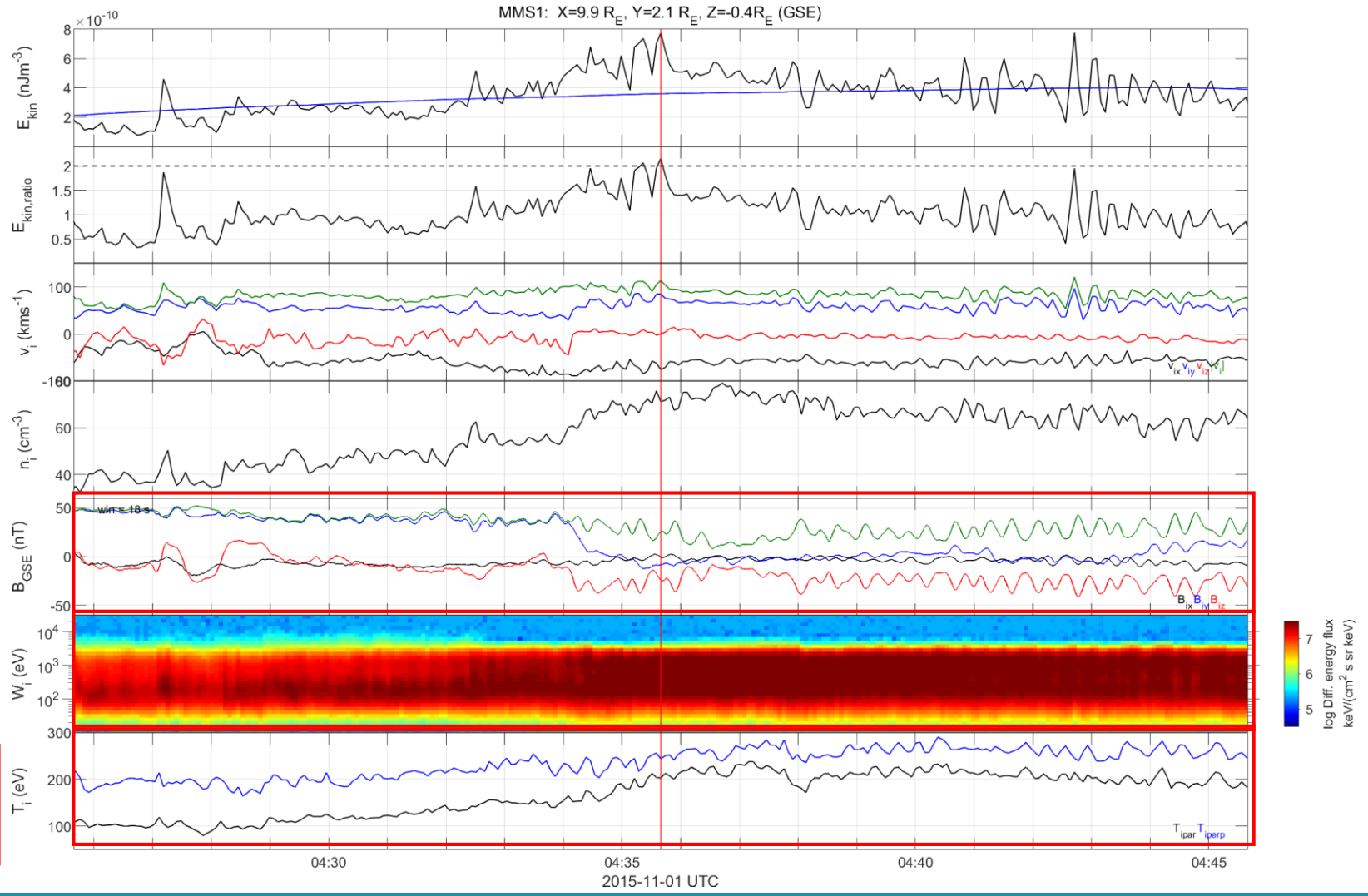
Velocity

Density

Magnetic Field

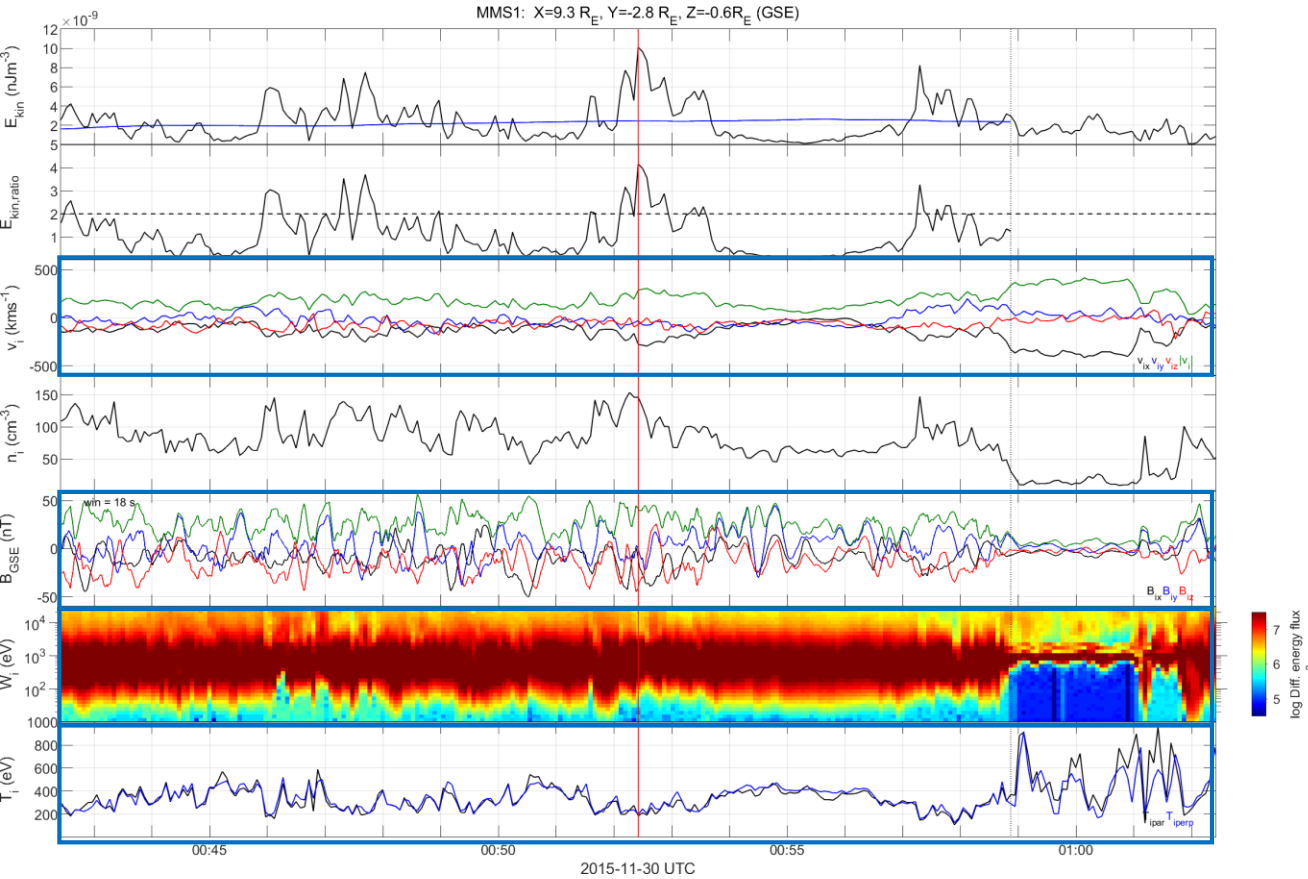
Ion Energy Spectrum

Temperature



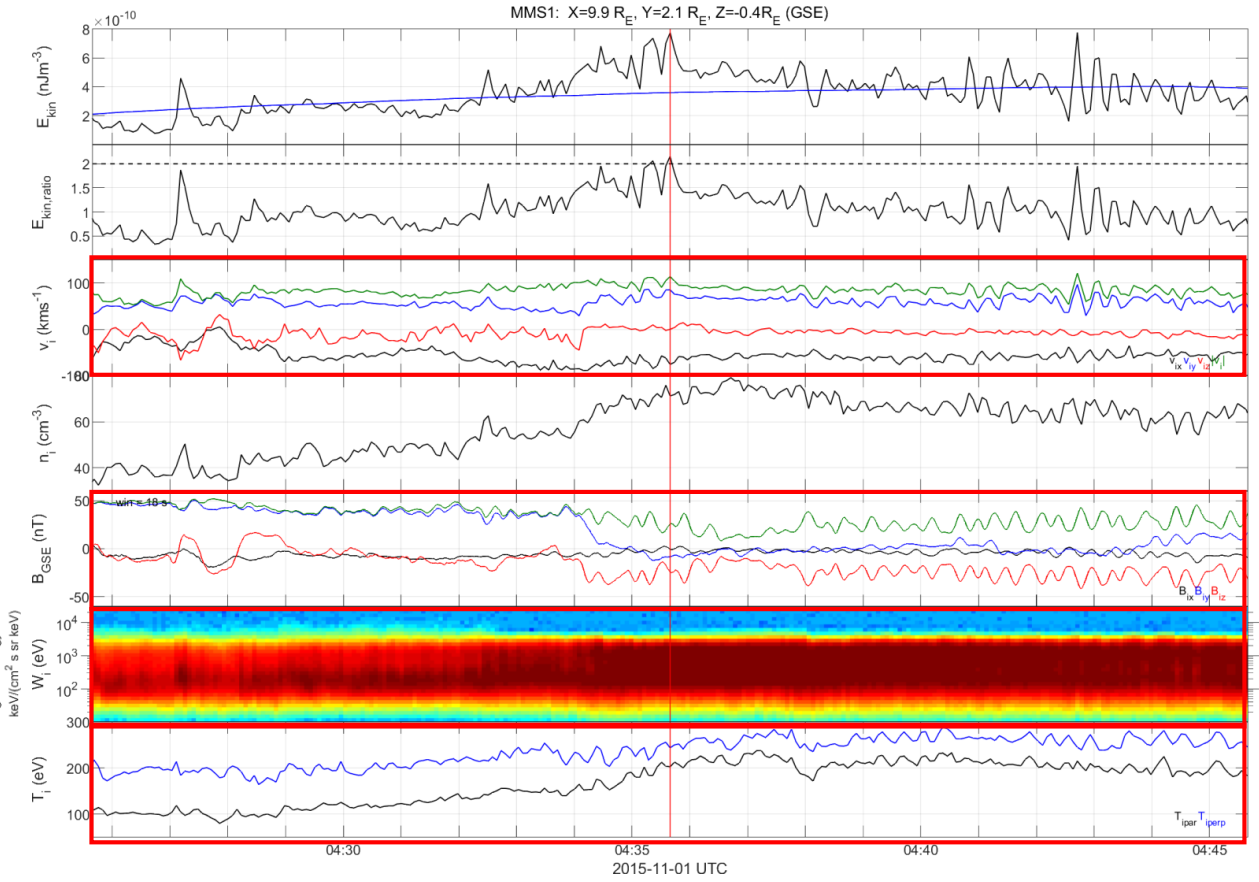
See the differences?

High Variance, High Energetic Particles, Low Anisotropy



Quasi – Parallel Jet

Low Variance, No Energetic Particles, High Anisotropy

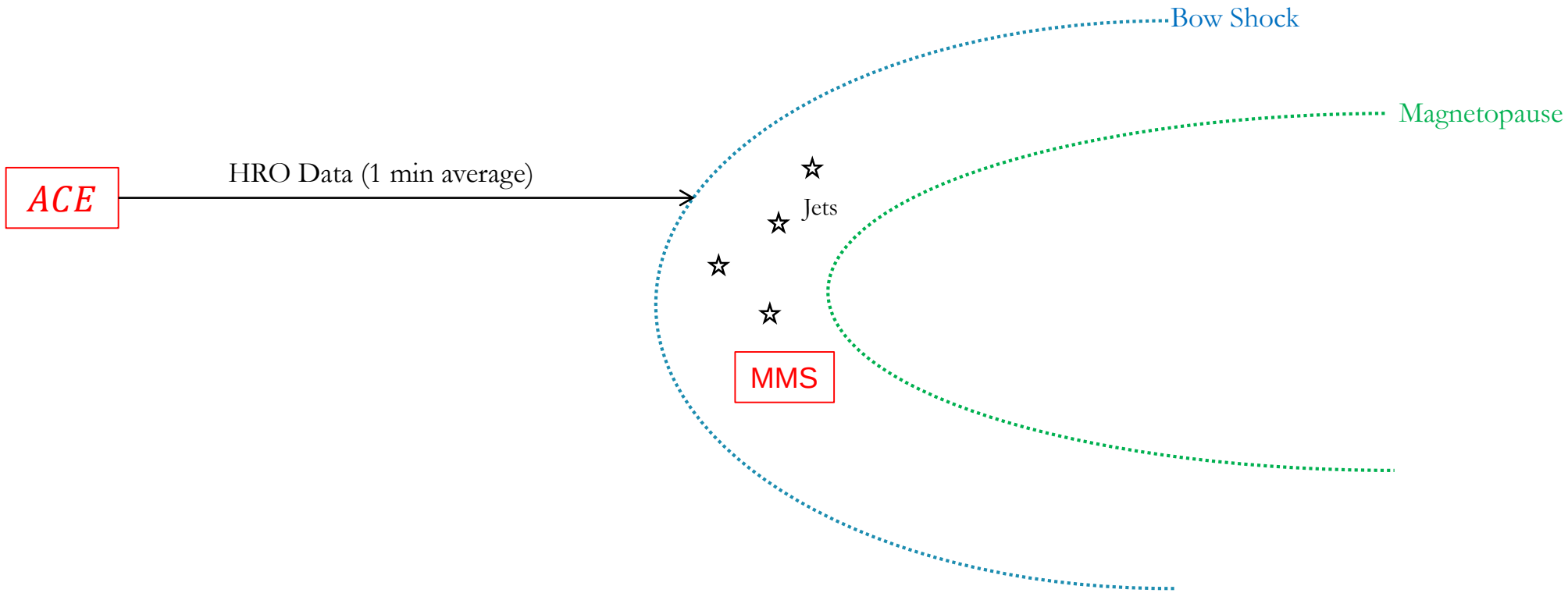


Quasi – Perpendicular

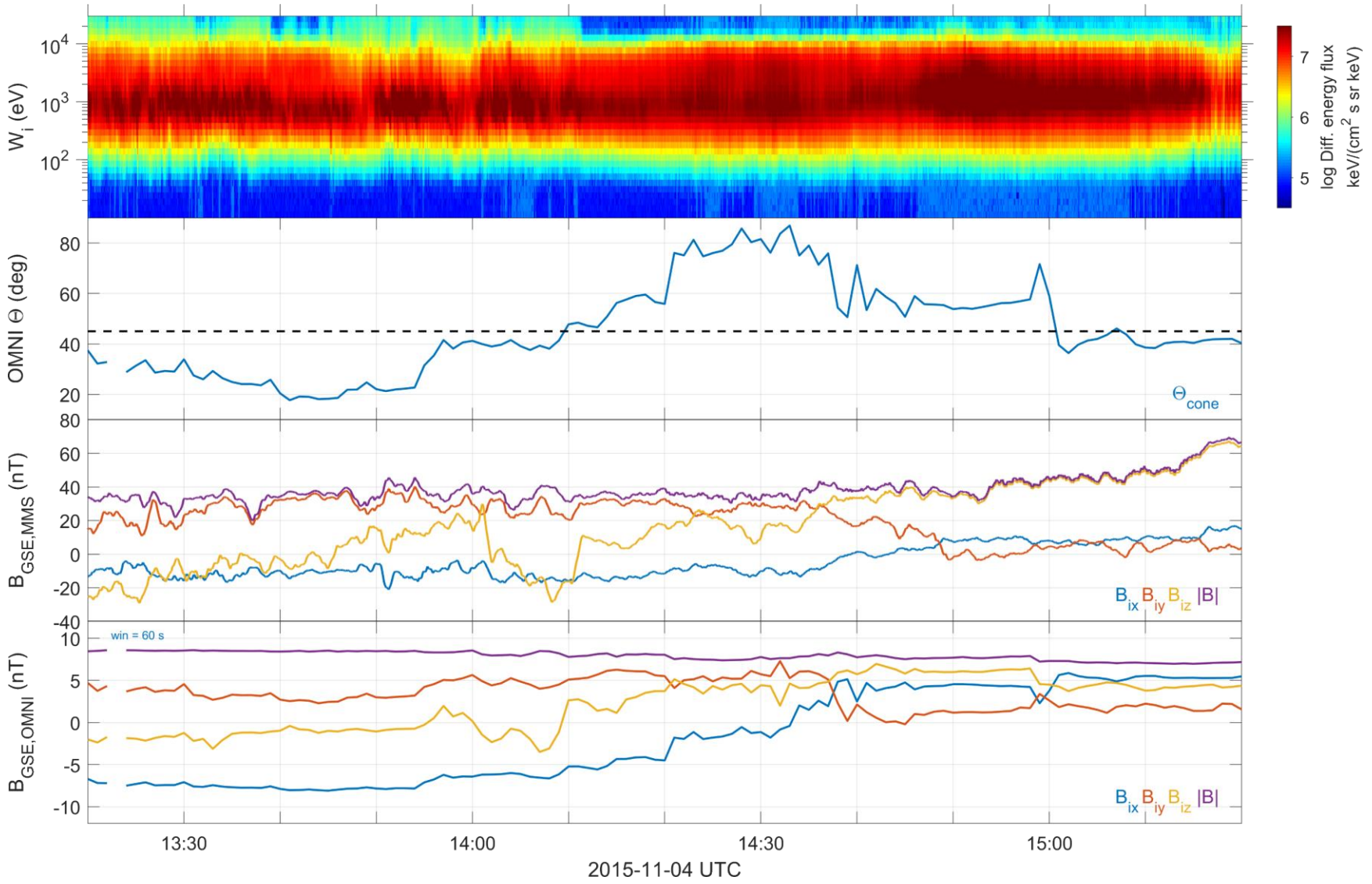
Angle & Bow shock configuration

Why not directly θ_n from Solar wind data ?

- Worse availability
- Error in propagating to Bow shock



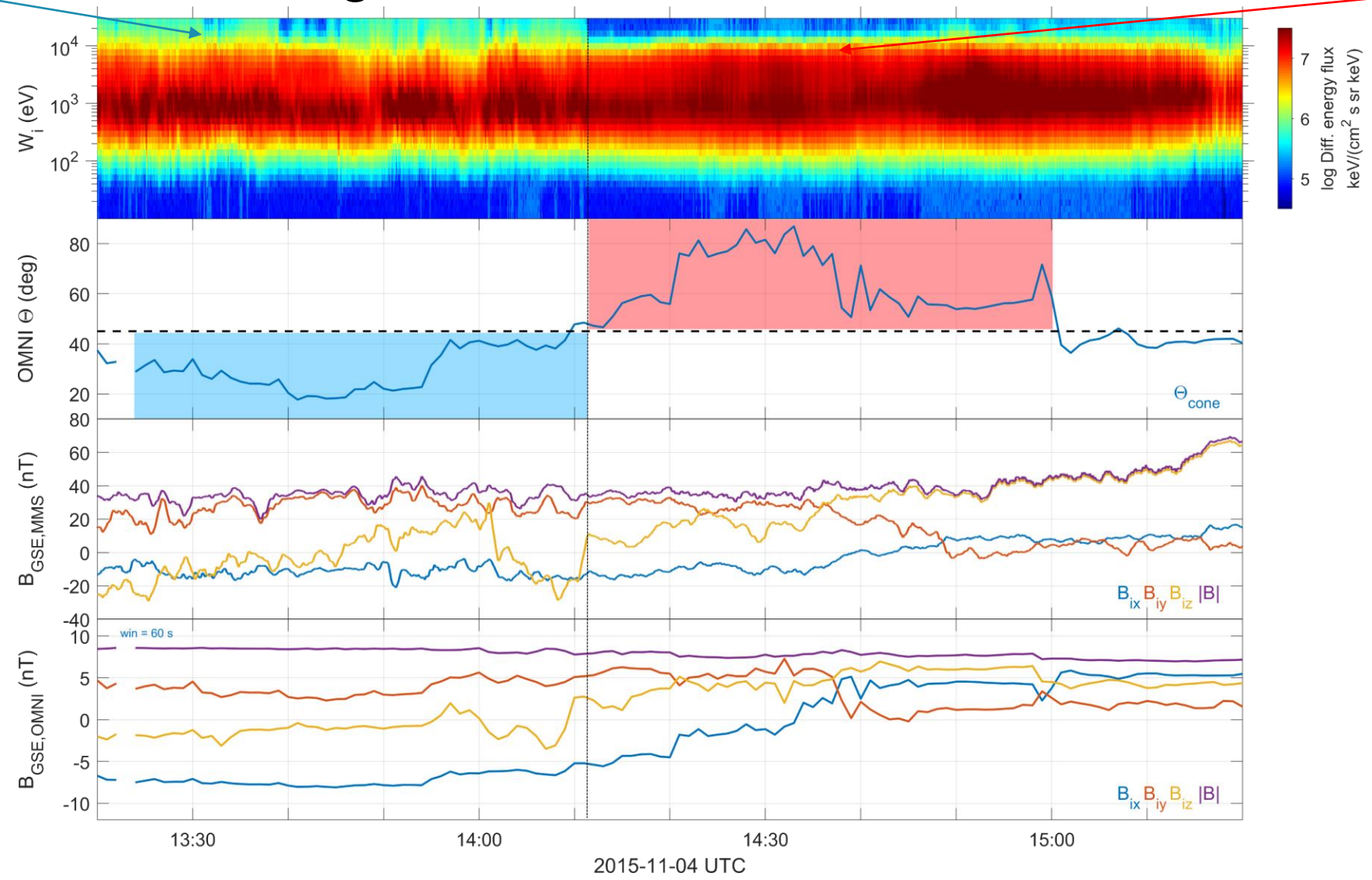
Angle & Bow shock Verification



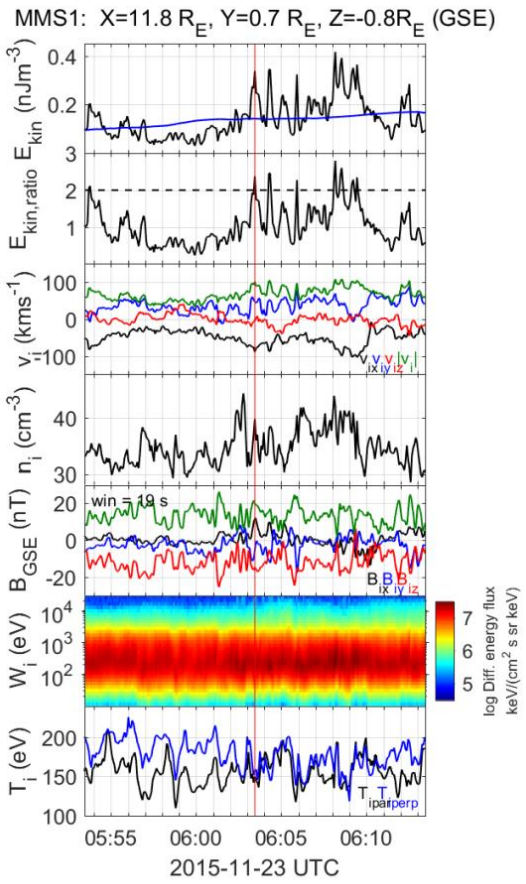
Angle & Bow shock Verification

Q-par region

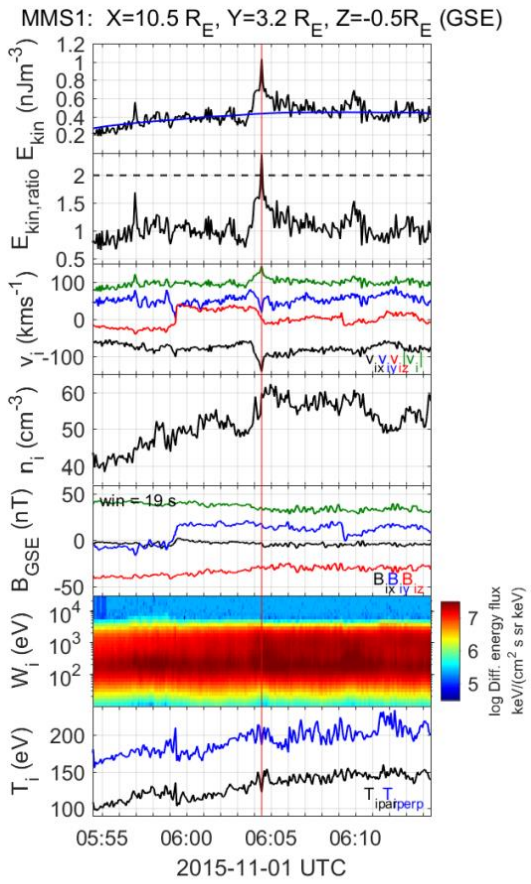
Q-perp region



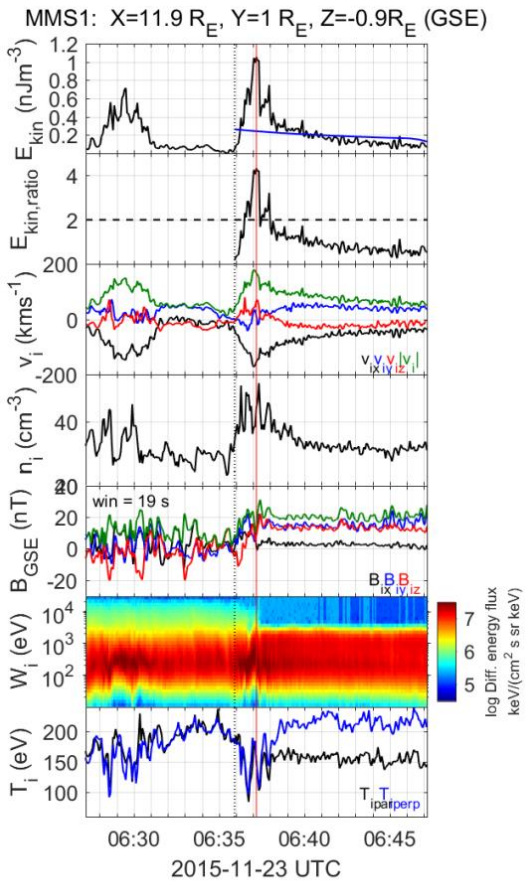
Main Categories



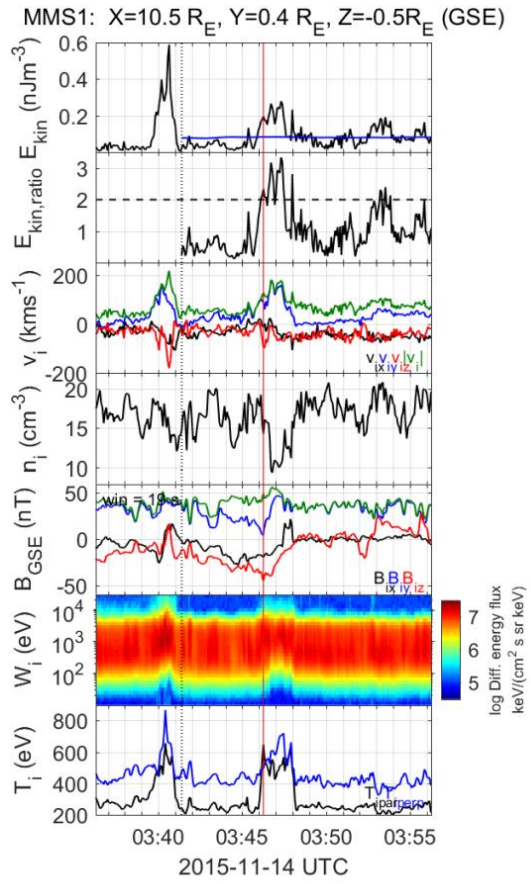
Qpar Jet



Qperp Jet



Boundary Jet



Encapsulated Jet

Results

Classification in progress!

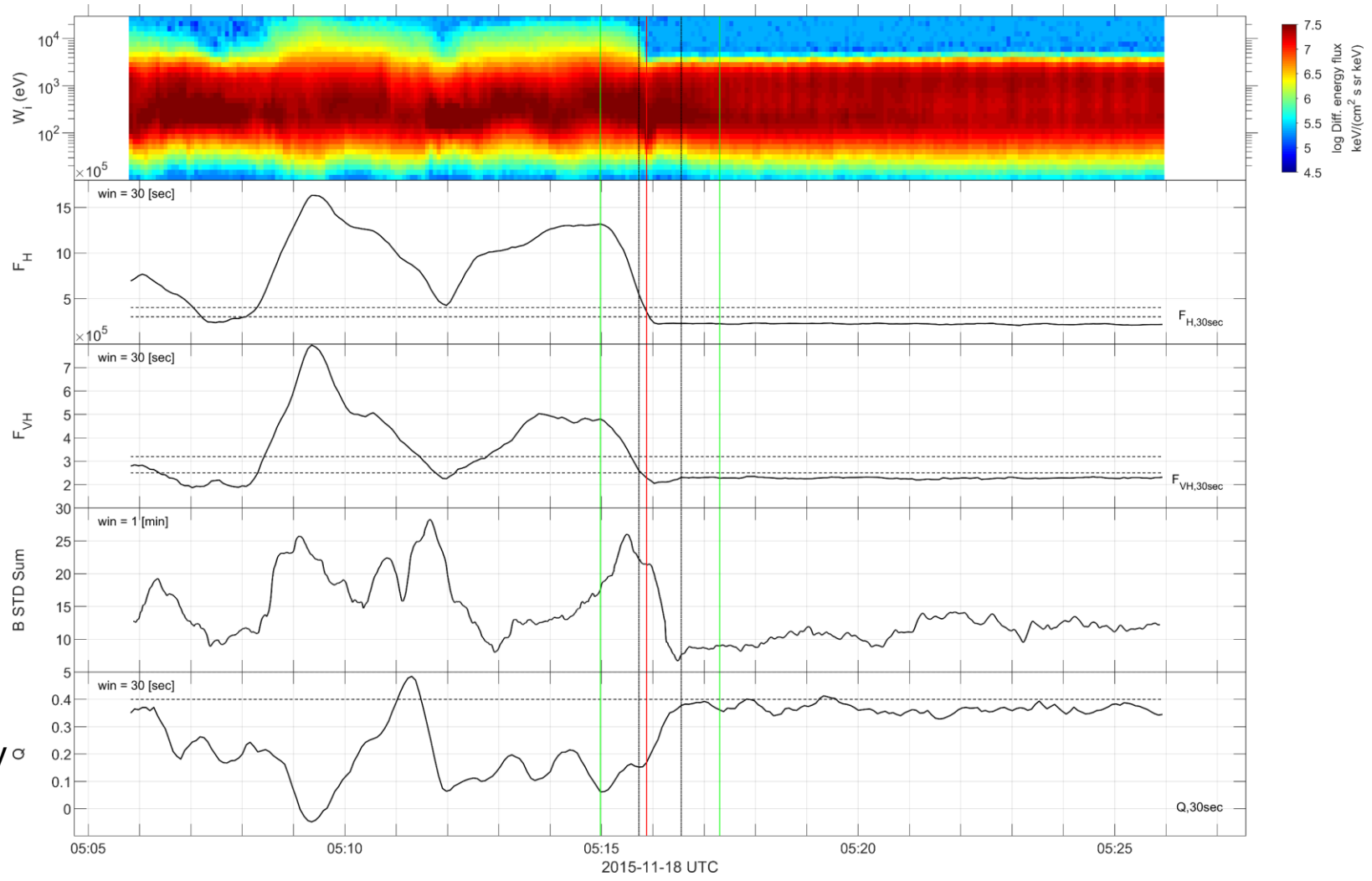
Ion Spectrum (1:32)

High Flux (27:29)

Very High Flux (30:32)

$$\sum_i \sigma(B_i)$$

Temperature Anisotropy



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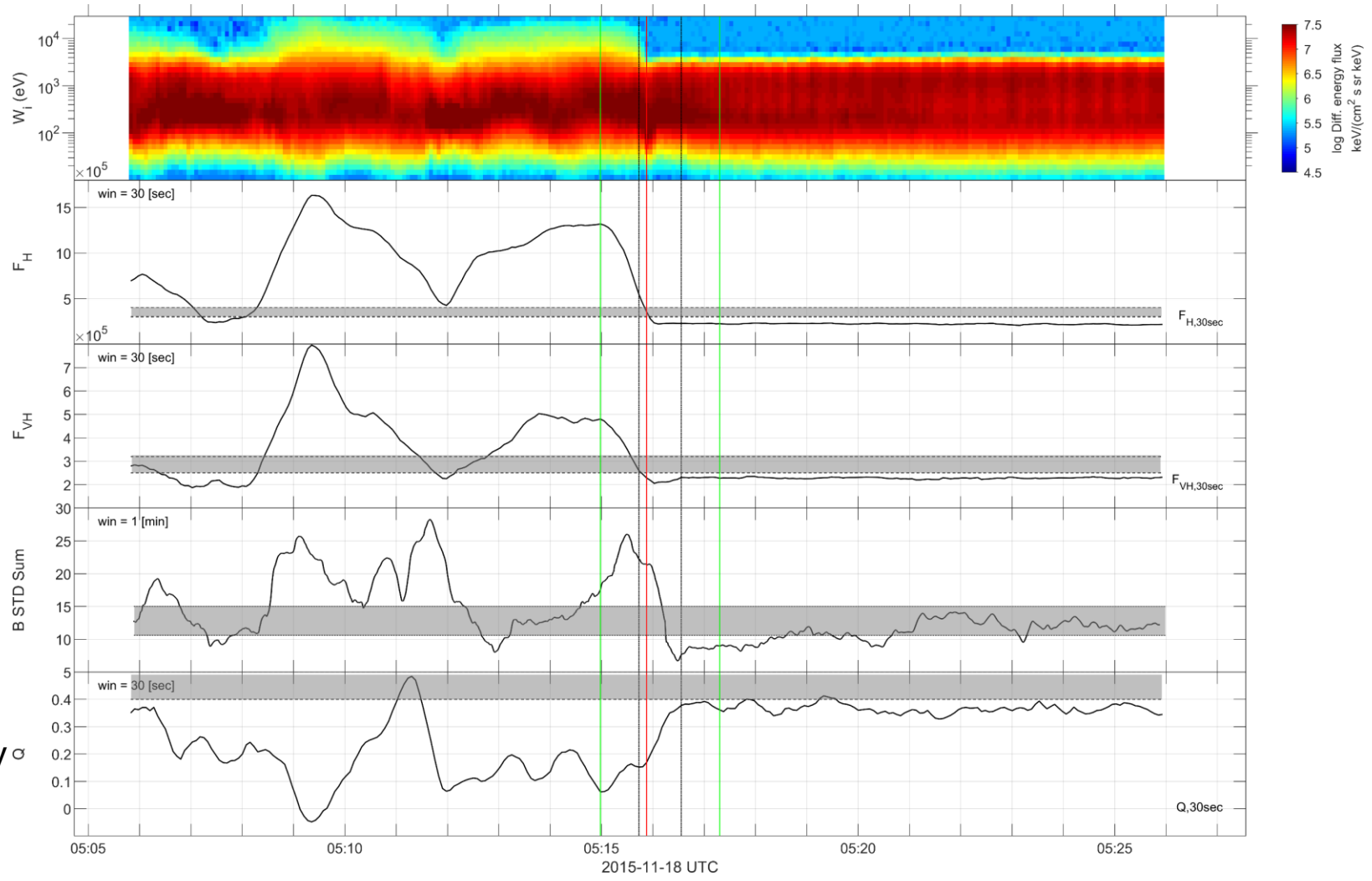

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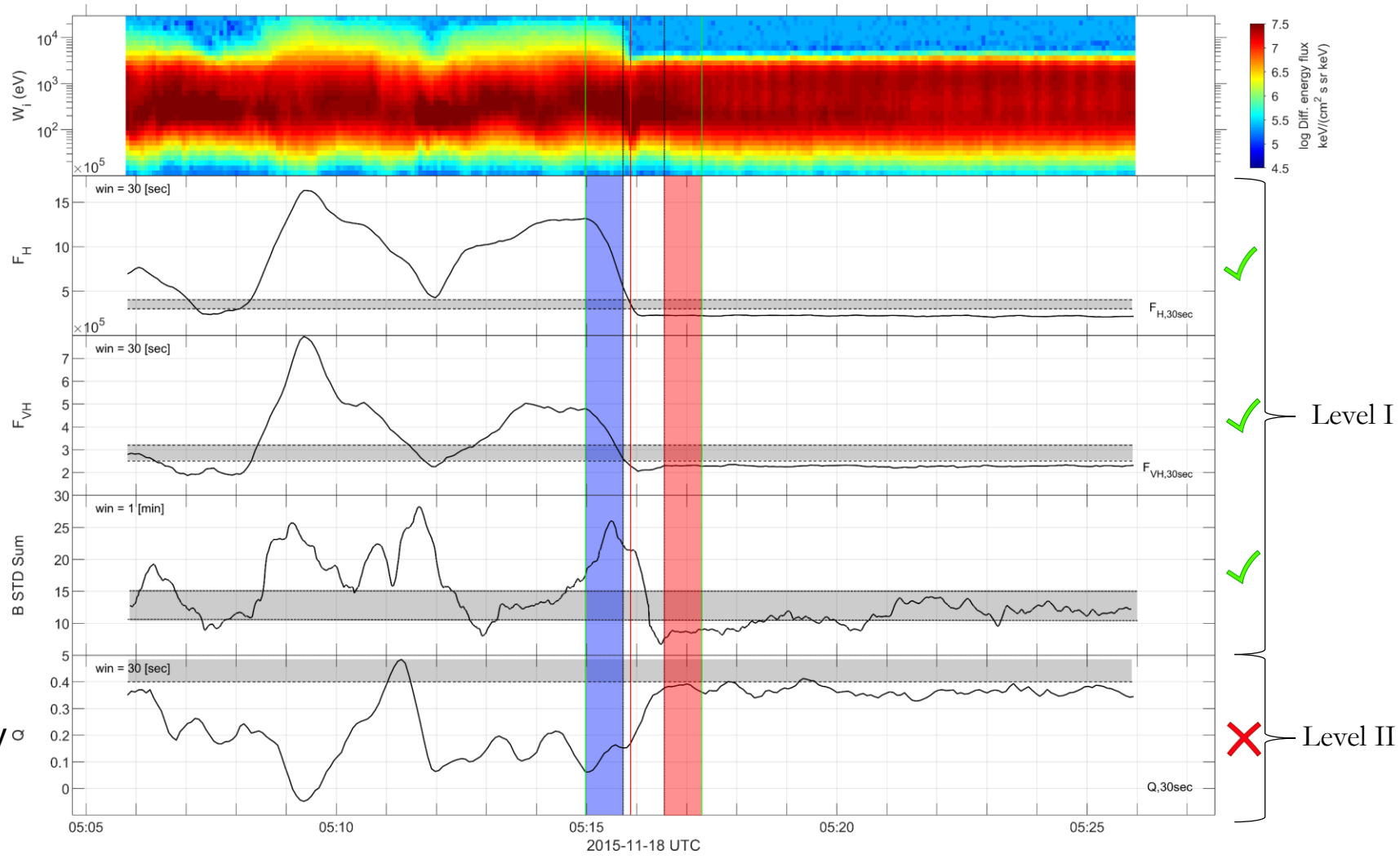


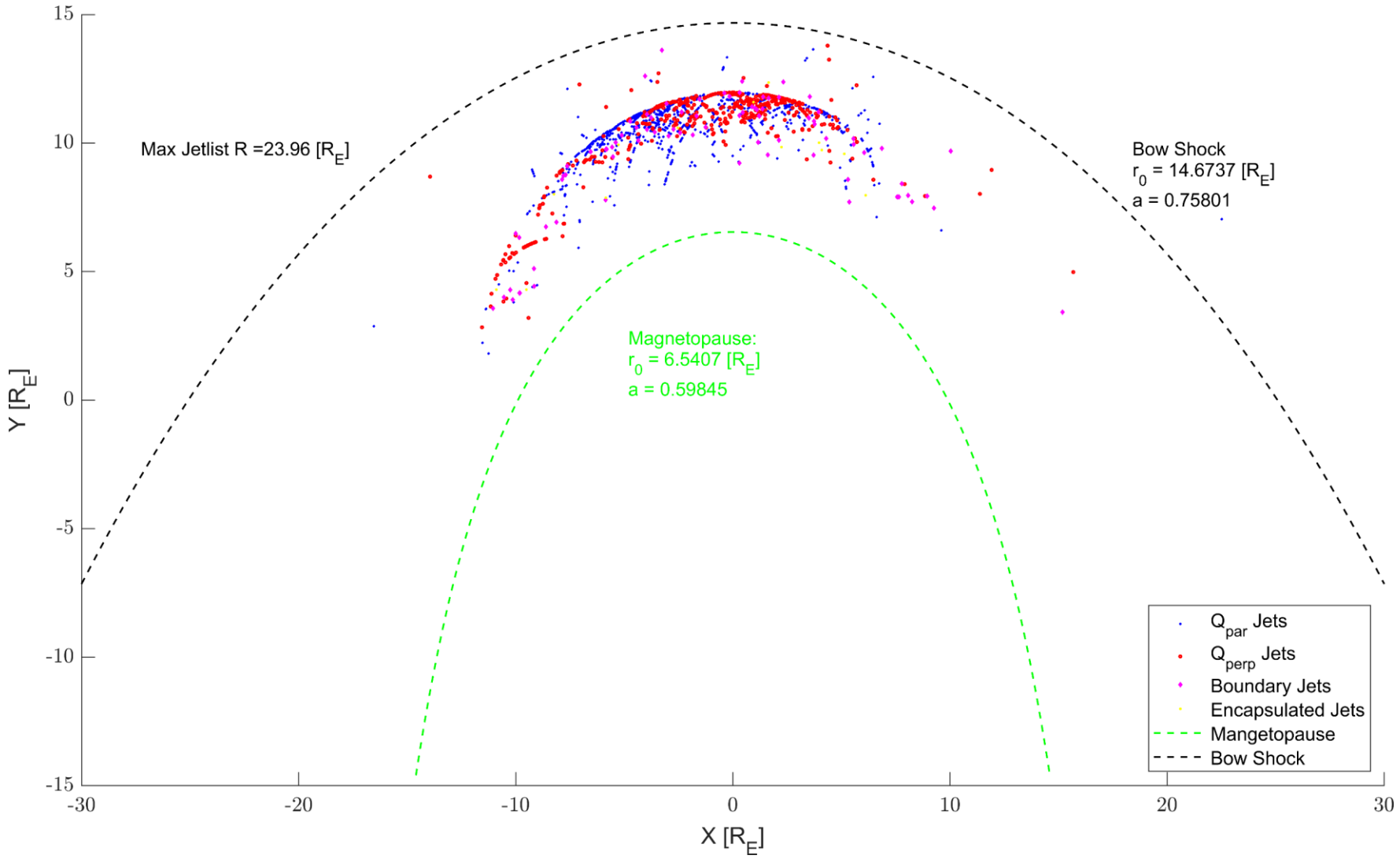
Updated database for Jets: 11/2015 – 01/2019

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

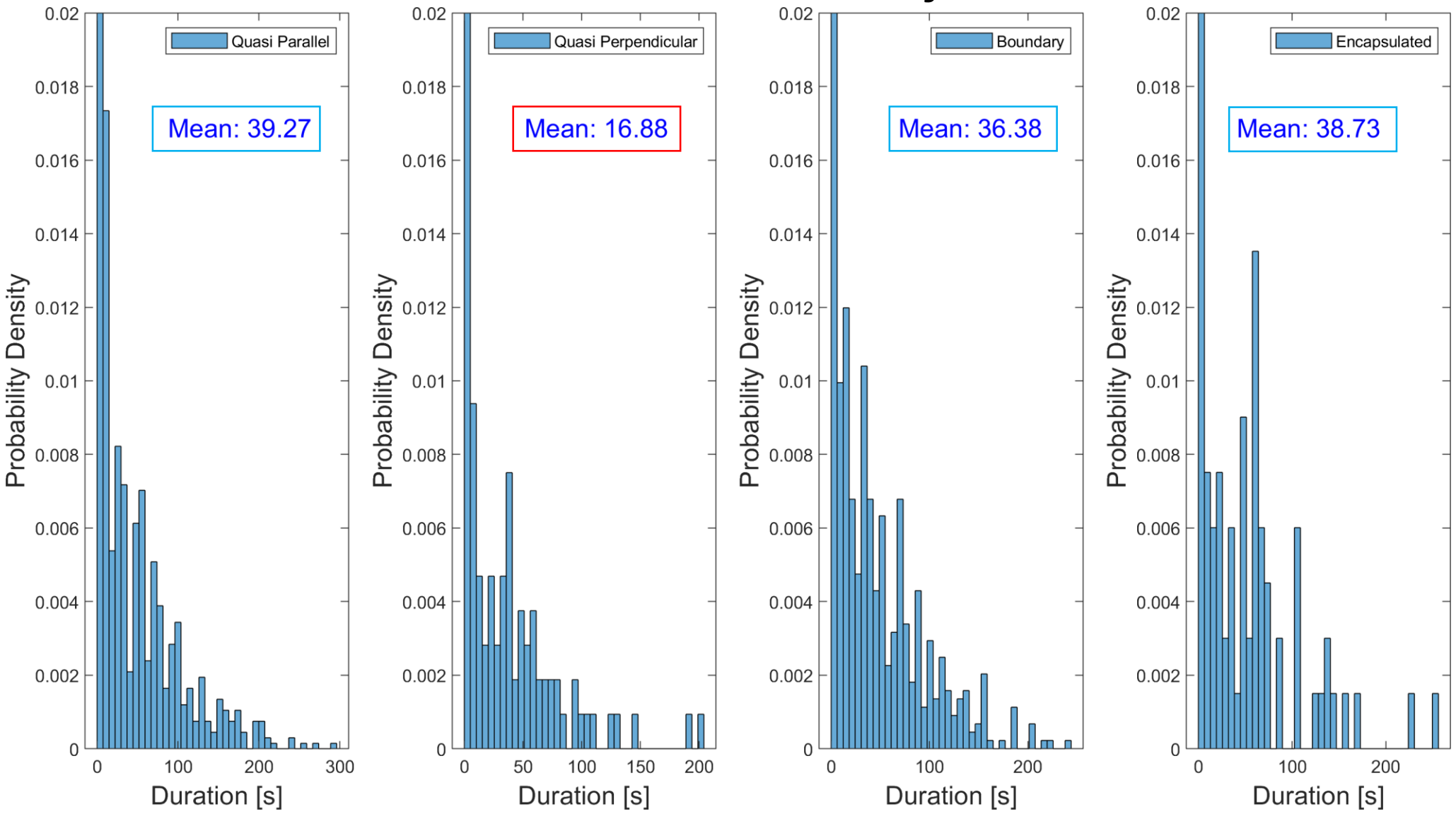
Q_{par} *	Q_{perp} *	Boundary †	Encapsulated †
2201	506	725	105

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

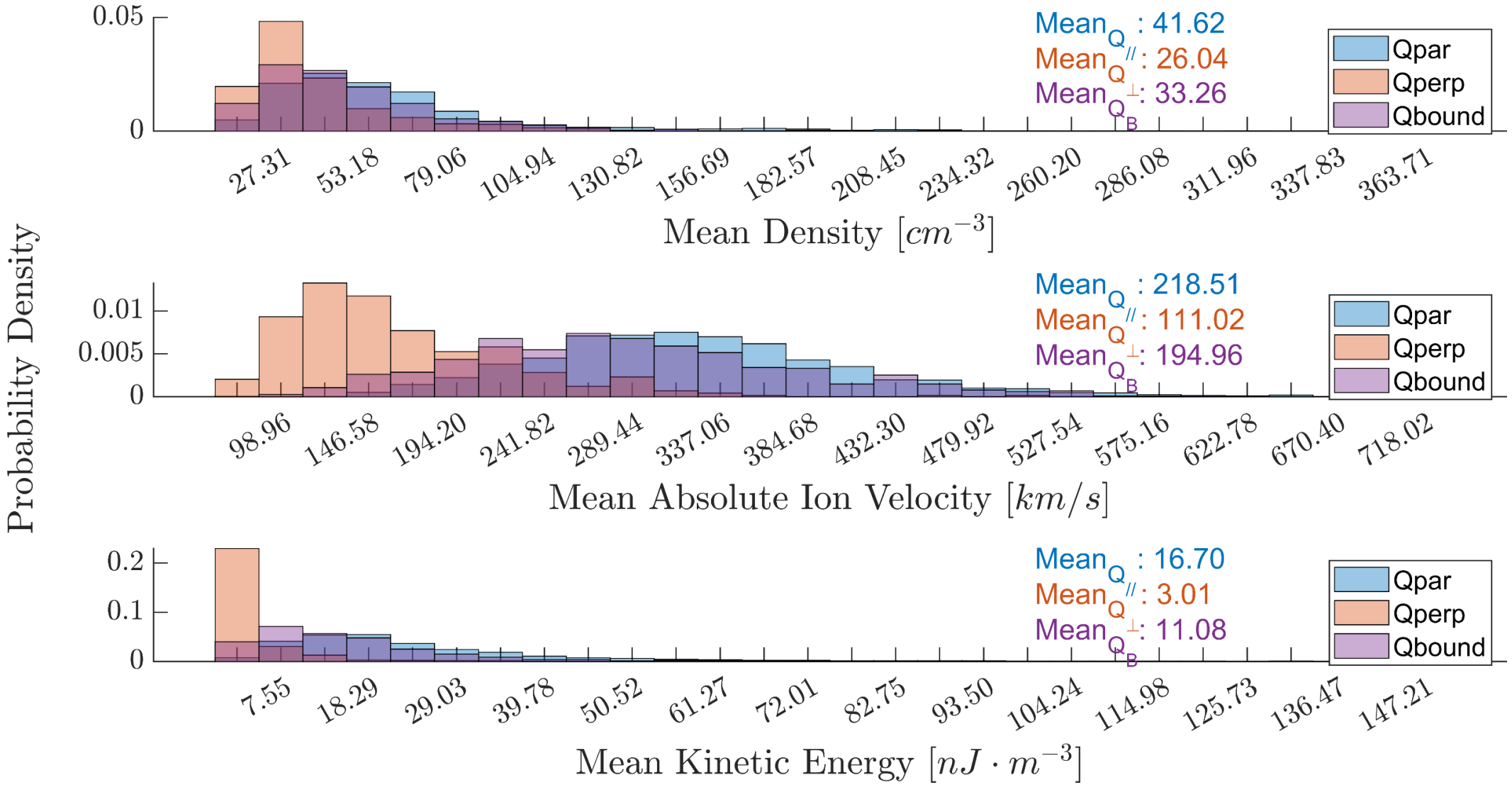
Where are they?



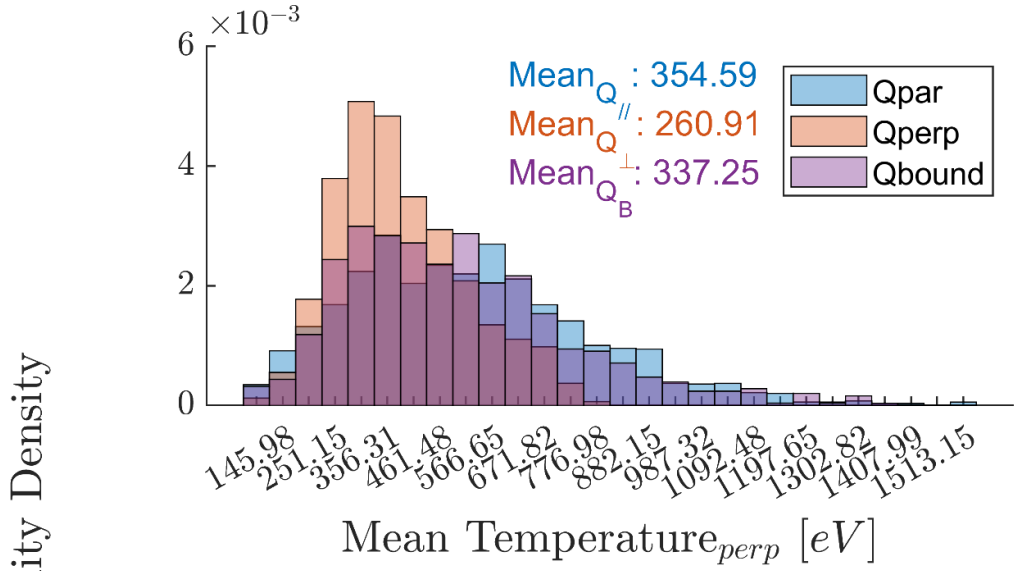
Duration of each jet

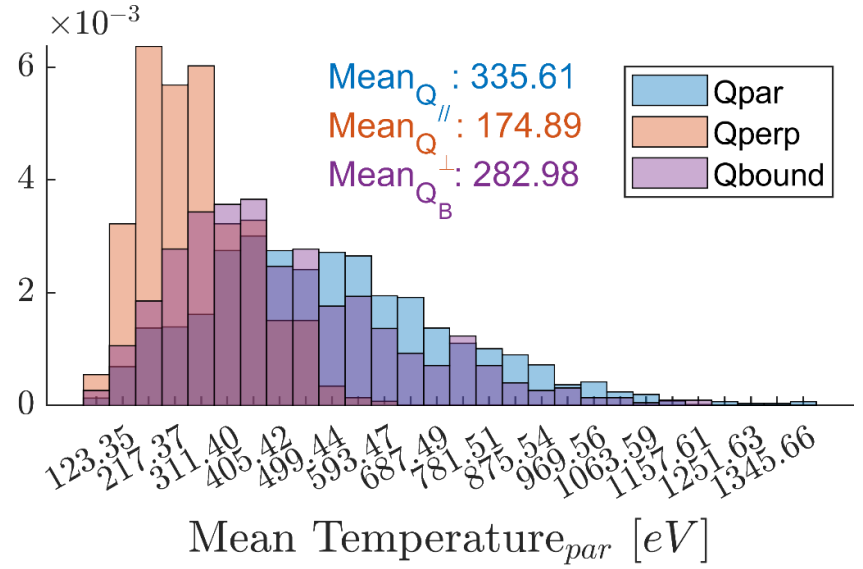


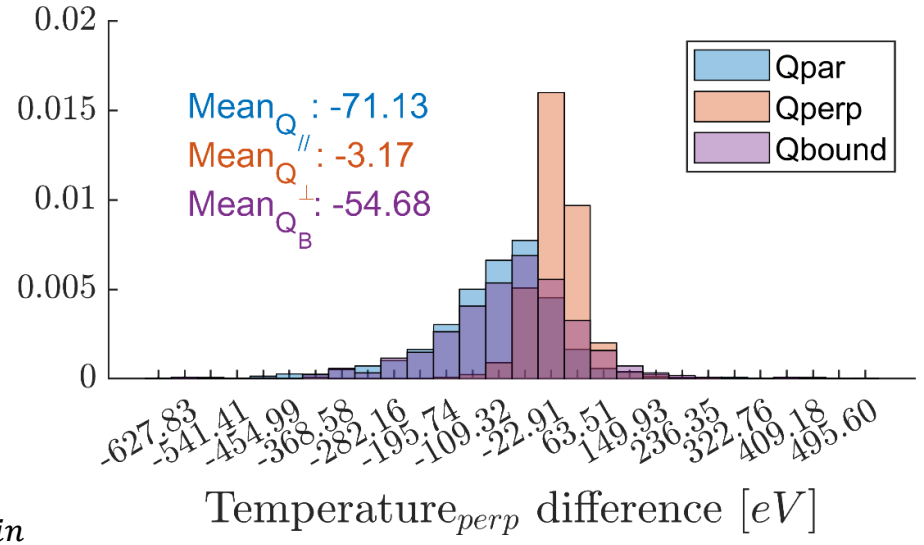
Characteristics of Qpar – Qperp – Boundary

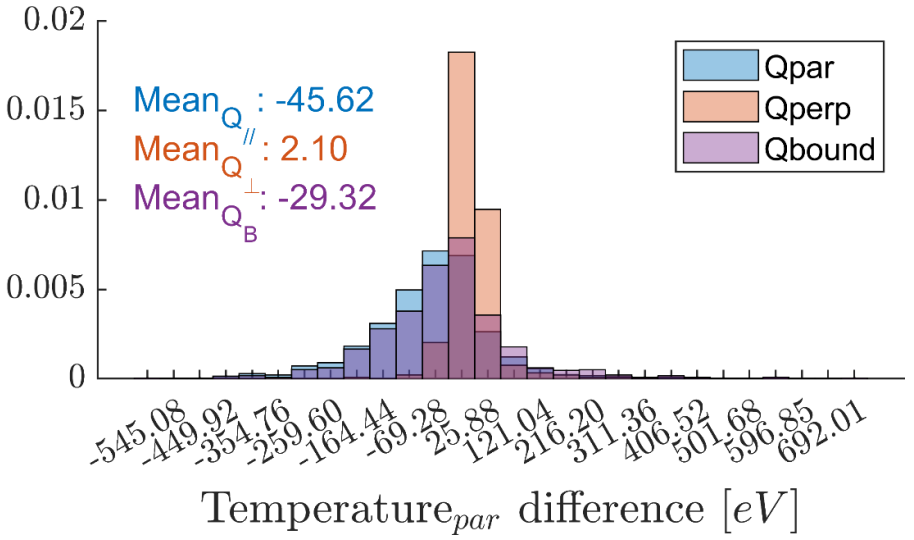


Characteristics of Qpar – Qperp – Boundary



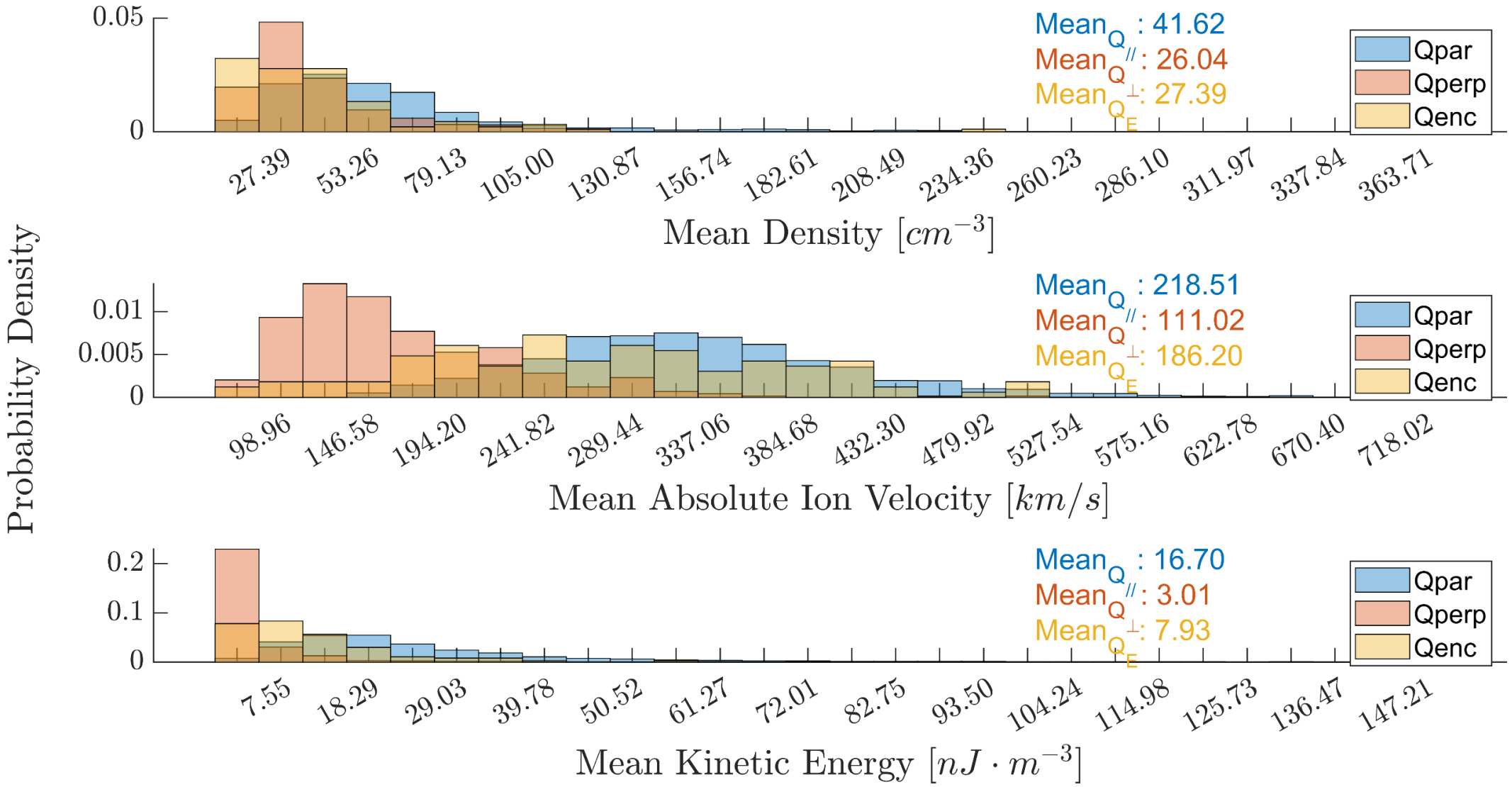






*Diff = $X - \langle X \rangle_{10min}$

Characteristics of Qpar – Qperp – Encapsulated



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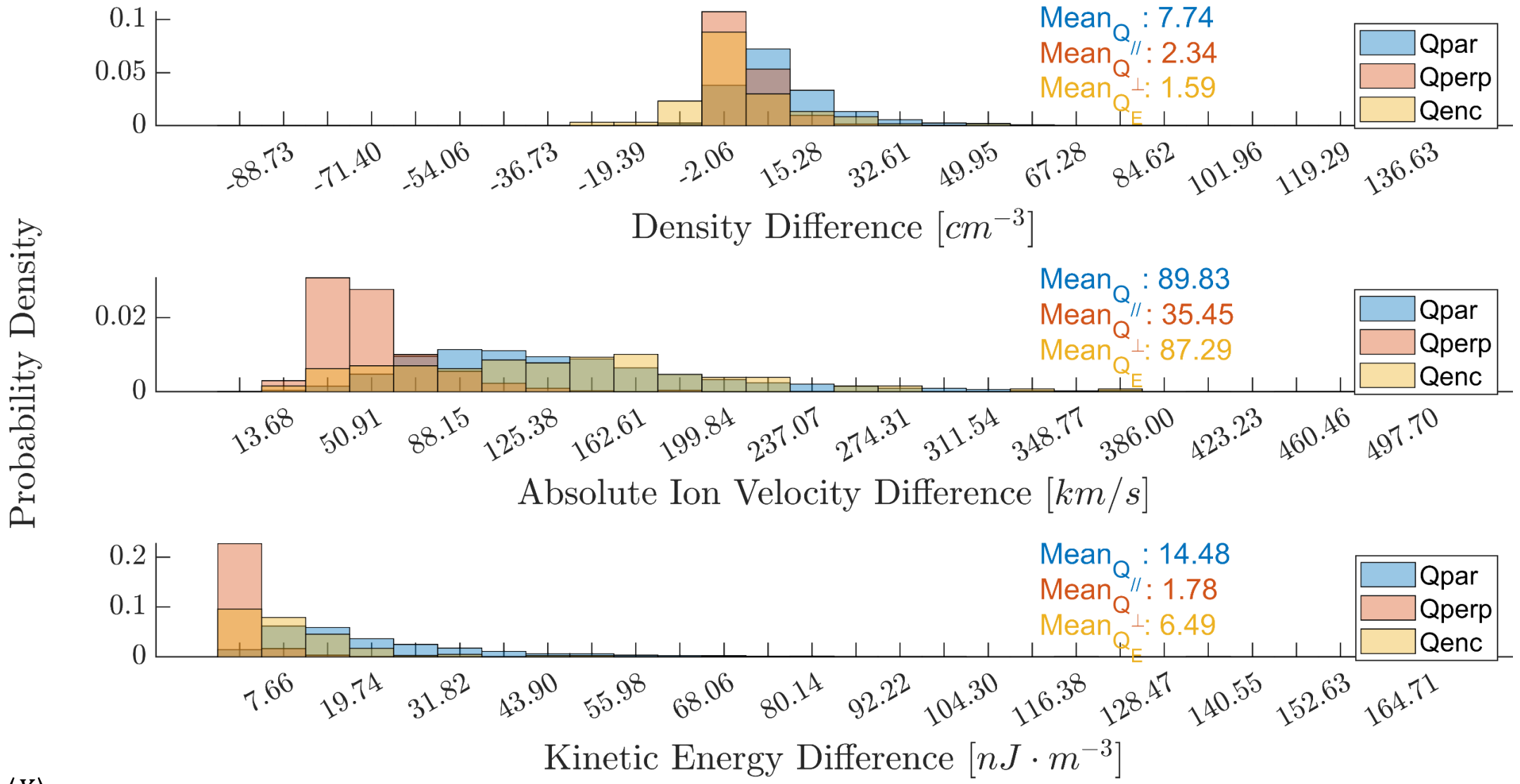

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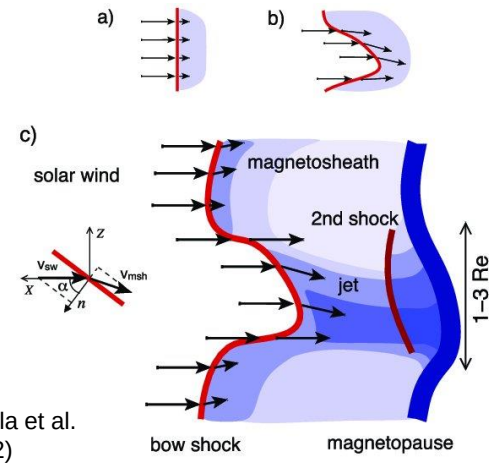
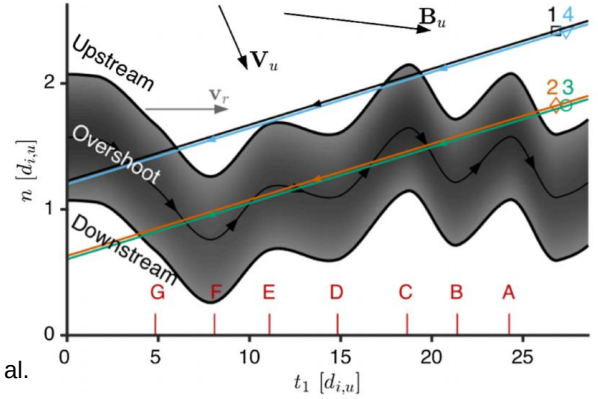
Mechanisms ideas for each jets

Quasi – Parallel



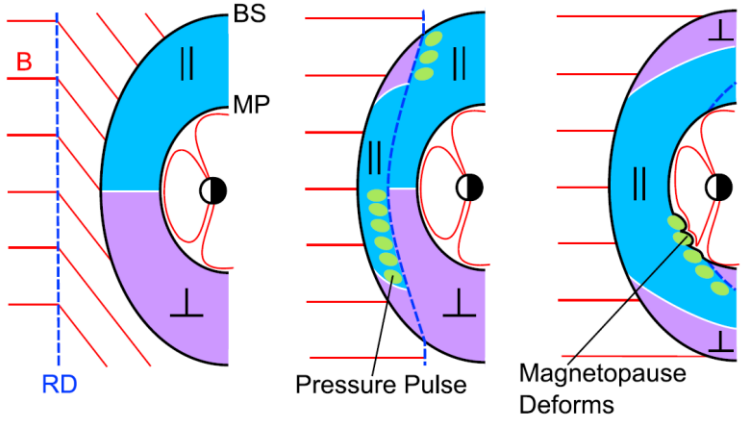
Hietala et al. (2012)

Quasi – Perpendicular



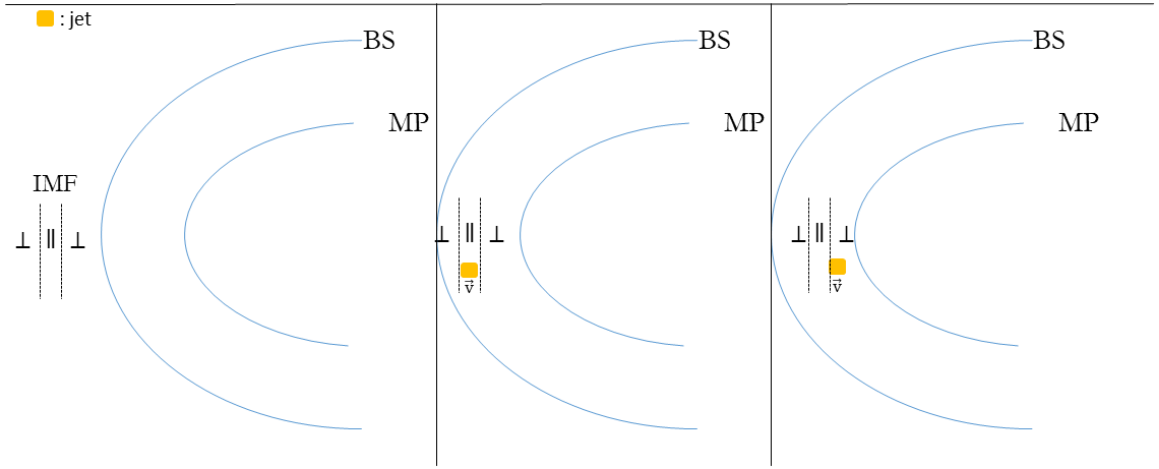
Johlander et al. (2016)

Boundary

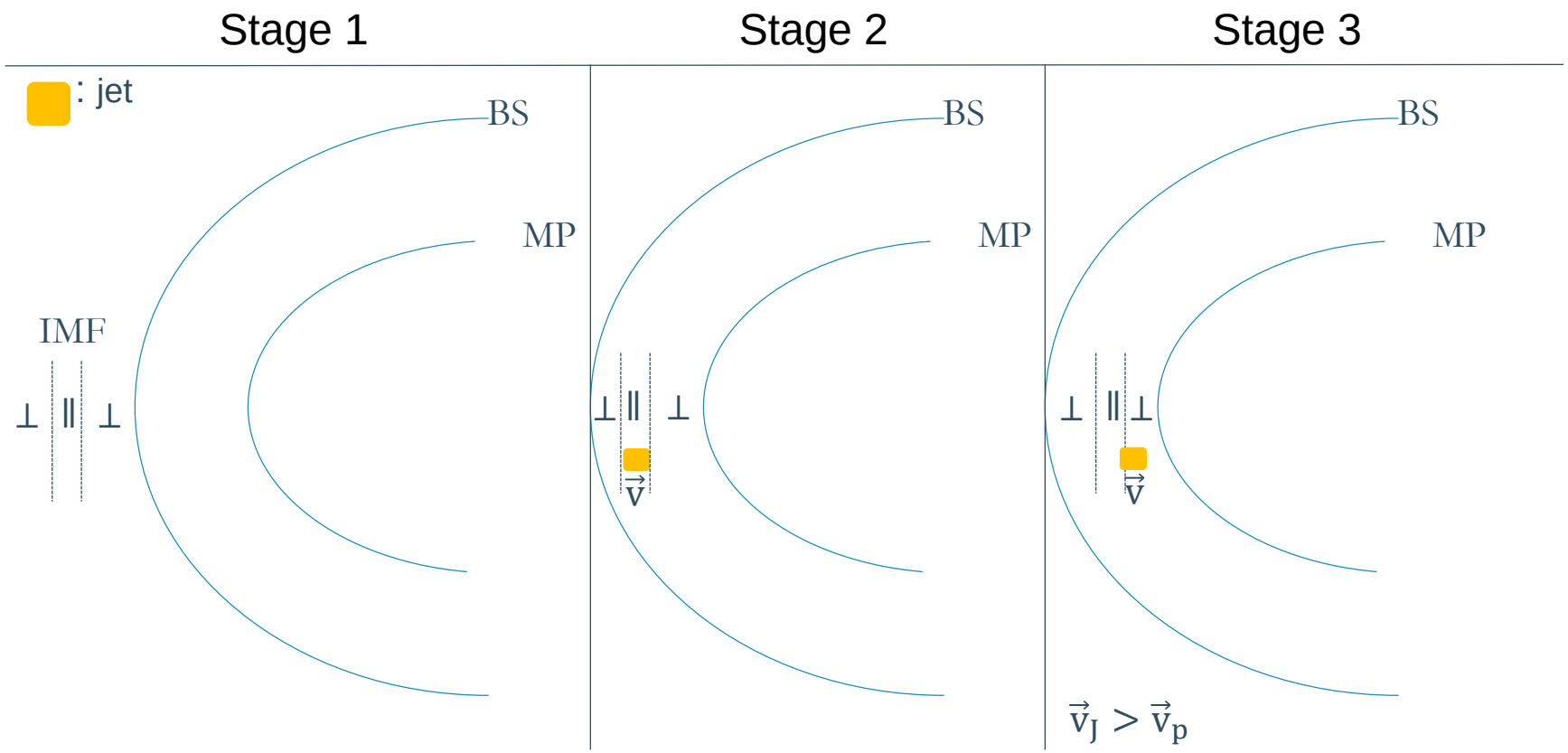


Archer et al. (2012)

Encapsulated



Encapsulated Jet – Idea proposed



Conclusion

Summary

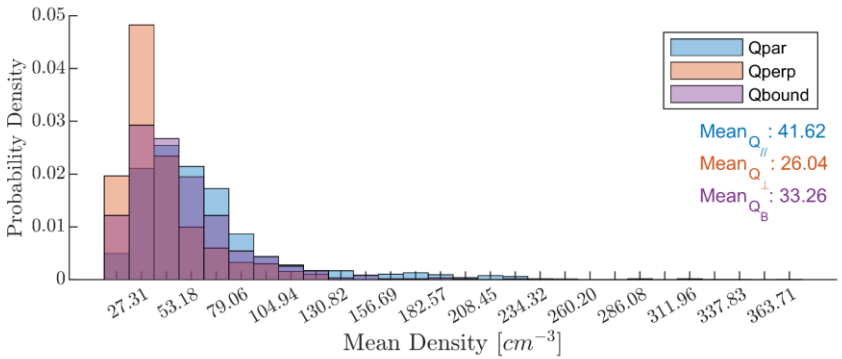
- Obtained a vast database of Magnetosheath Jets (~10.000) using all available MMS data.
- Successfully classified jets into several different categories showing different attributes.
- Analyzed their characteristics and found interesting similarities & differences compared to earlier results.
- Proposed a different generation mechanism for each jet class that was found.

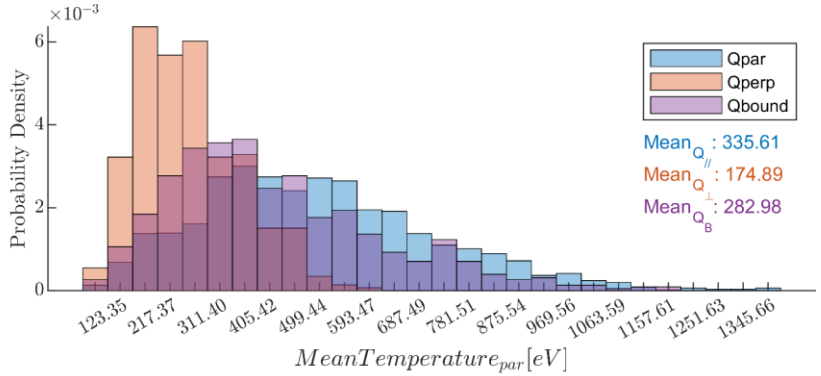
Future Work

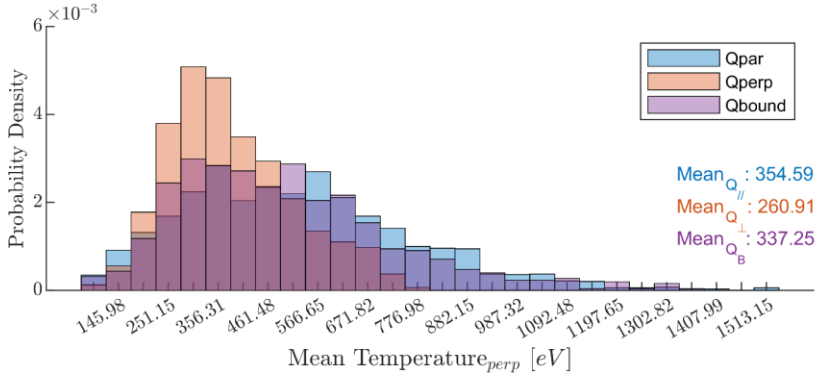
- Quantify true negative and false positive situations for all classes derived from classification scheme.
- Apply machine learning techniques to predict our classification scheme with other data.
- Investigate more quantities ($\beta, \theta_v, \theta_B, f(e), ...$).
- Confirm the connection of each category to a generation mechanism.

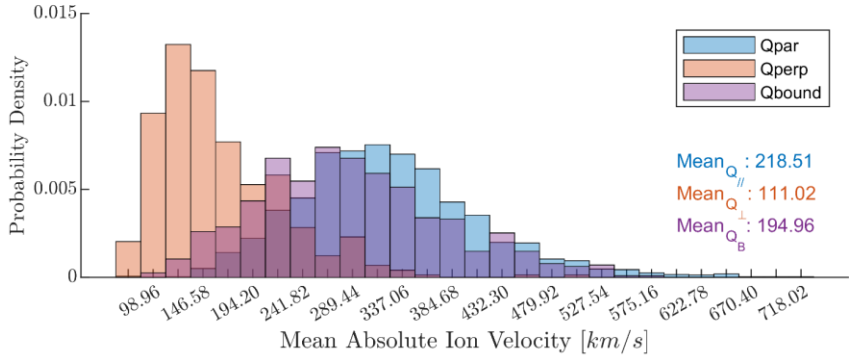
Extras

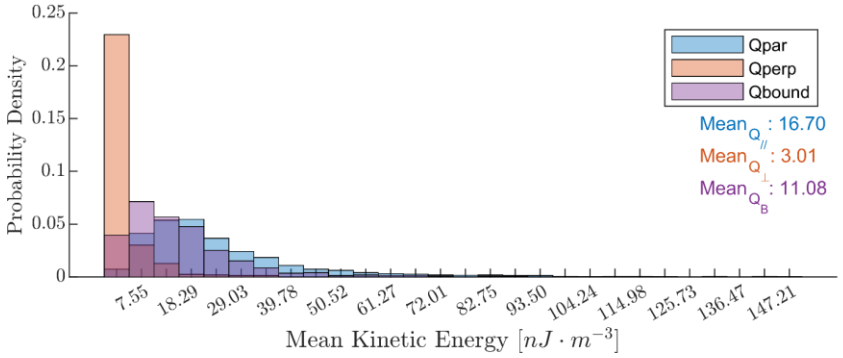
Characteristics of Qpar – Qperp – Boundary

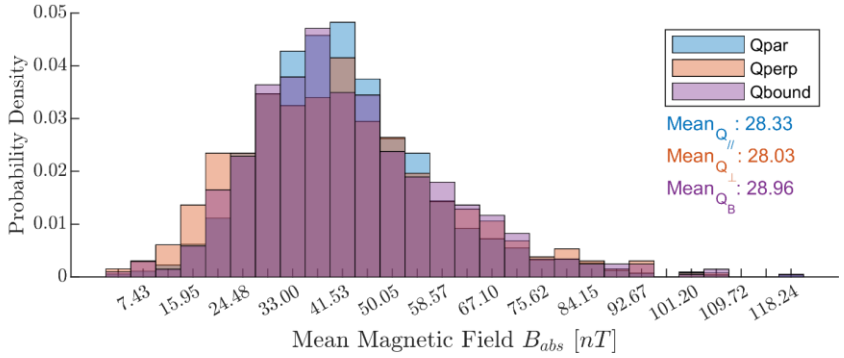






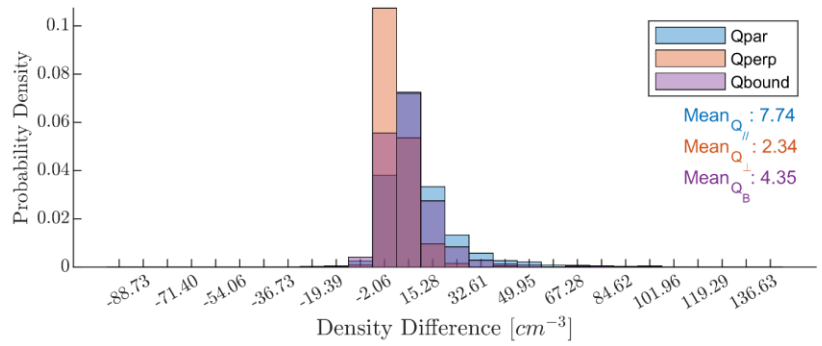


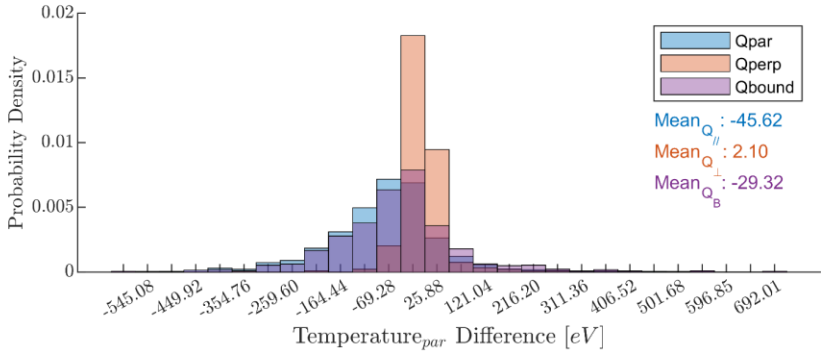


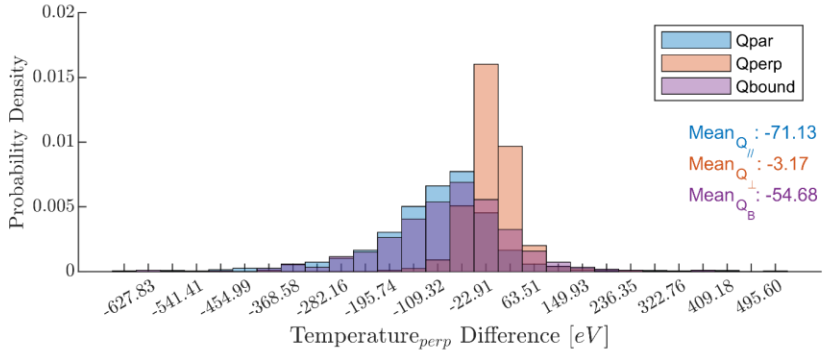


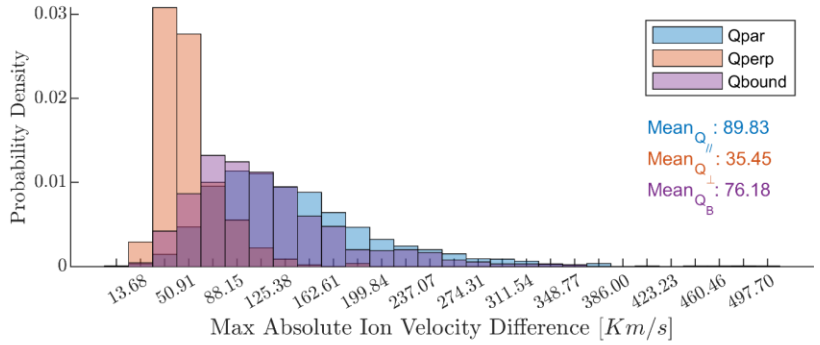
Characteristics of Qpar – Qperp – Boundary

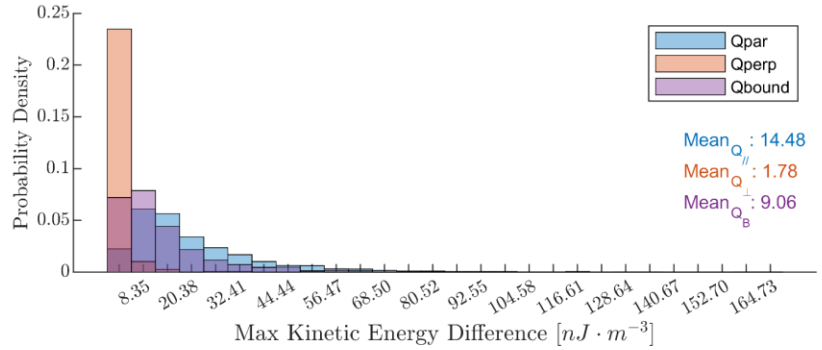
Quantity Analyzed: X - $X_{mean,10min}$

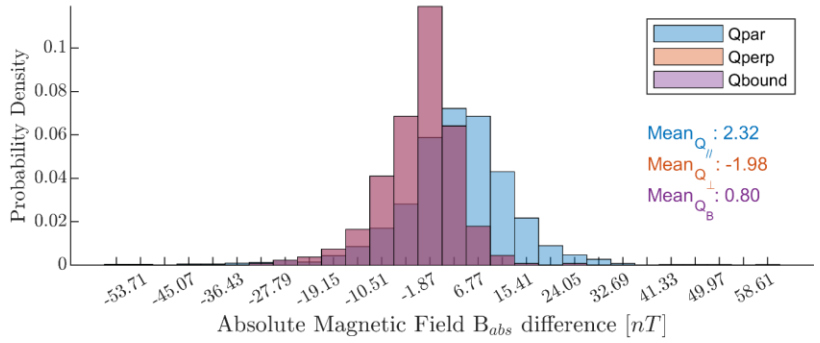




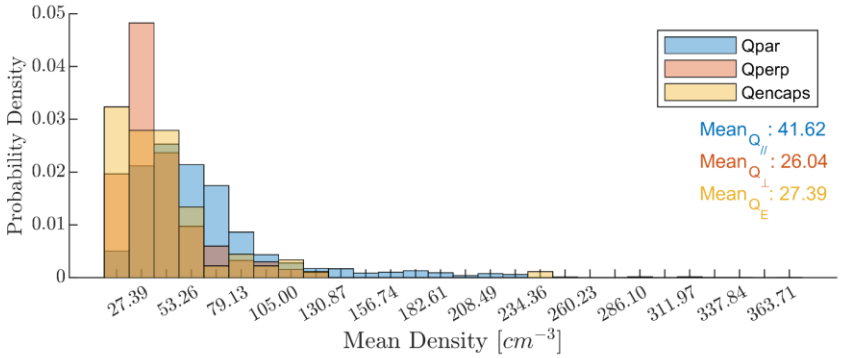


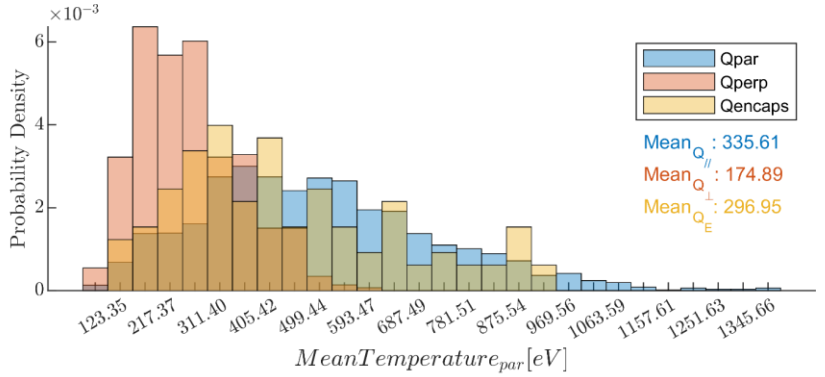


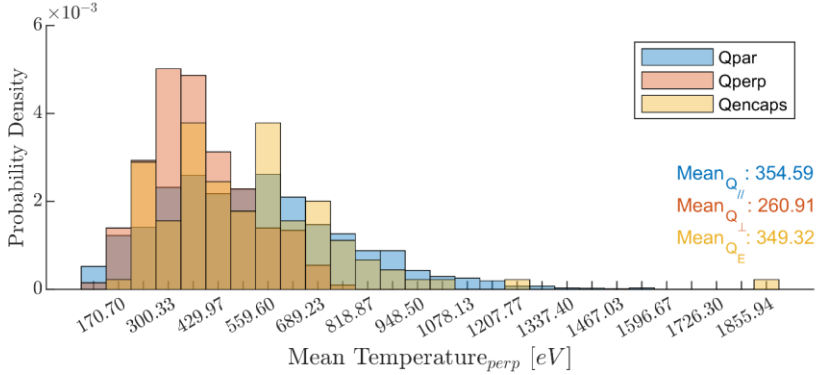


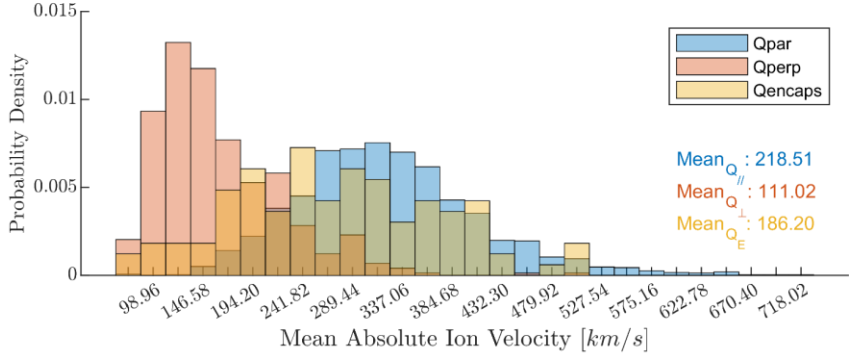


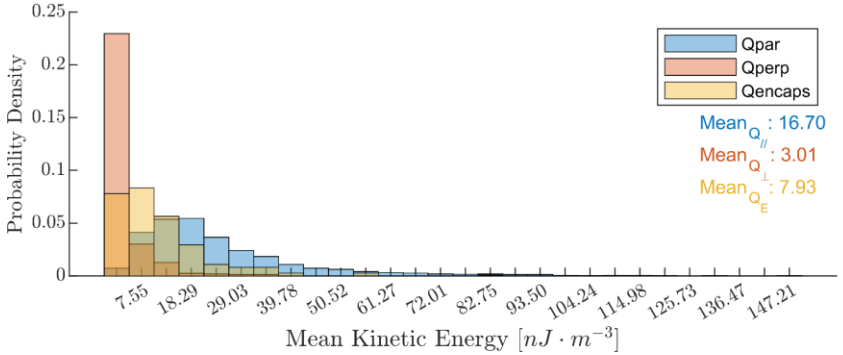
Characteristics of Qpar – Qperp – Encapsulated

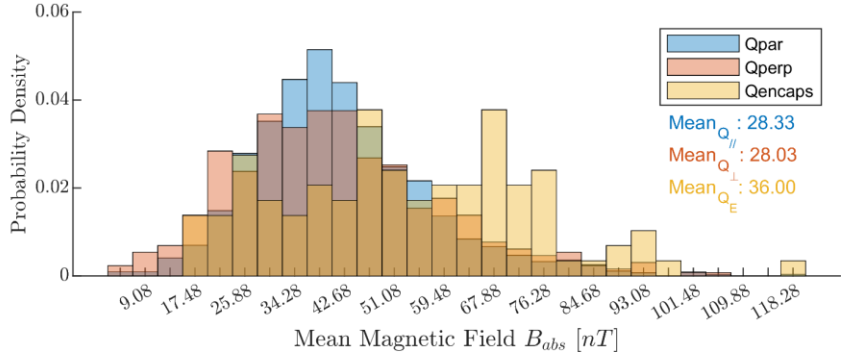












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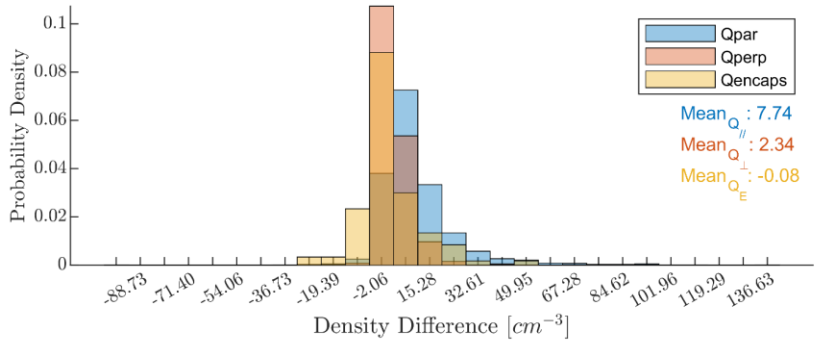
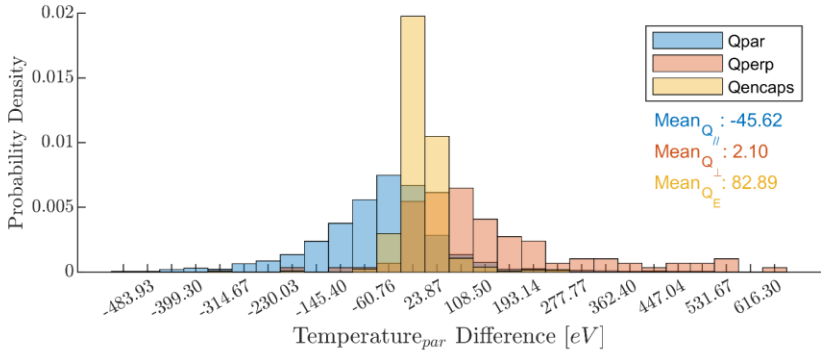
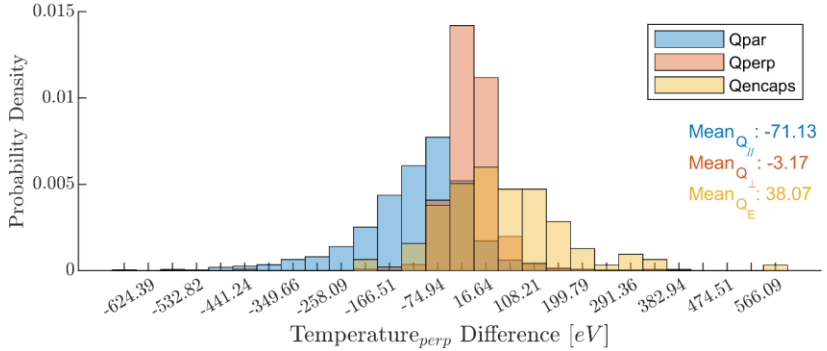
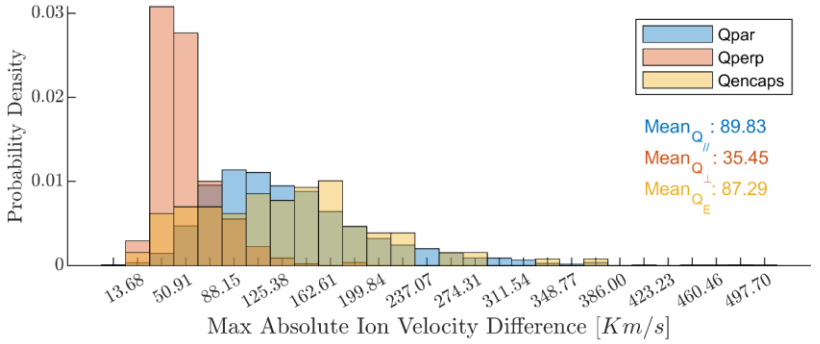
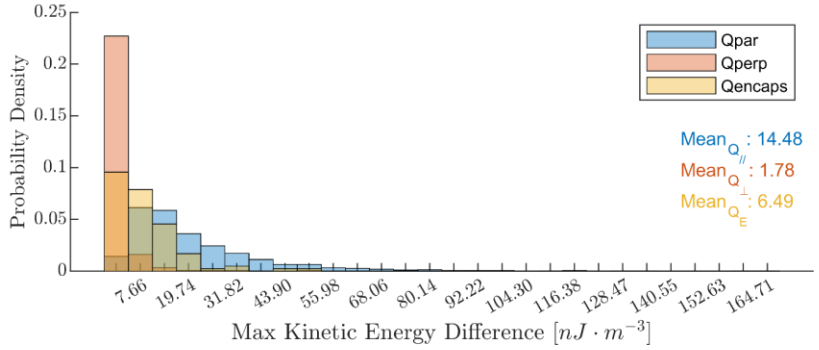
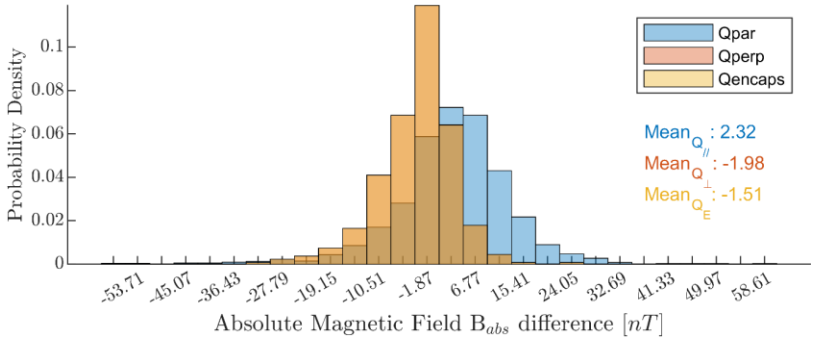




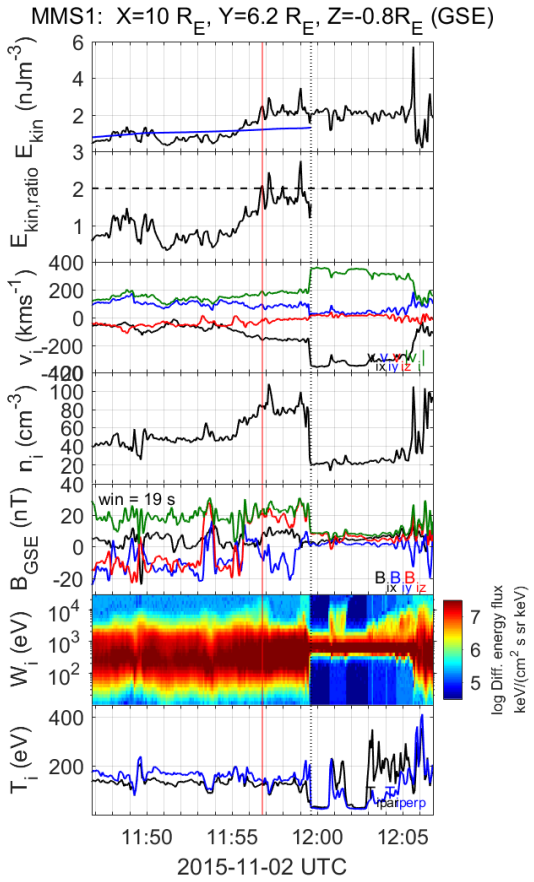




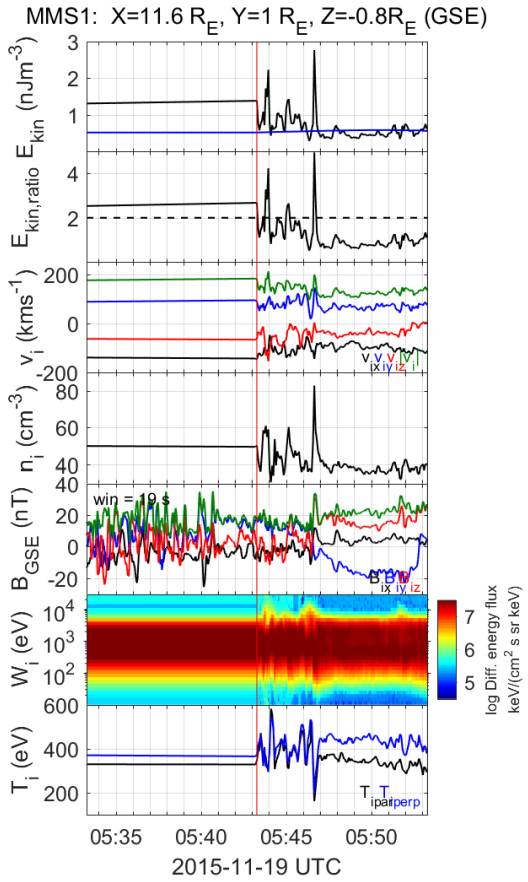




“Extra” Categories



Border Jets



Unclassified Jets

Multistage Classification – Simplified Scheme

<u>Stages</u>

(1) Pre-jet-post

<u>Categories</u>

1. Quasi – Par.
2. Quasi – Perp.
3. Boundary
4. Encapsulated
5. Unknown

<u>Quality Check</u>

- Criteria Number

  Level I – III

Multistage Classification – Simplified Scheme

Stages

(1) Pre-jet-post

(2) Adjust times & Values

(a) Jet Period

(b) Pre/post Period

Categories

1. Quasi – Par.
2. Quasi – Perp.
3. Boundary
4. Encapsulated
5. Unknown

Quality Check

- Criteria Number

Level I – III

- Tries Required

1 – 5 / stage

Multistage Classification – Simplified Scheme

<u>Stages</u>

(1) Pre-jet-post

(2) Adjust times & Values

(a) Jet Period

(b) Pre/post Period

<u>Categories</u>

1. Quasi – Par.
2. Quasi – Perp.
3. Boundary
4. Encapsulated
5. Unknown

<u>Quality Check</u>

- Criteria Number

Level I – III

- Tries Required

1 – 5 / stage

Multistage Classification – Simplified Scheme

Stages

(1) Pre-jet-post

(2) Adjust times & Values

(a) Jet Period

(b) Pre/post Period

(3) Normalizing

Categories

1. Quasi – Par.
2. Quasi – Perp.
3. Boundary
4. Encapsulated
5. Unknown

Quality Check

- Criteria Number

Level I – III

- Tries Required

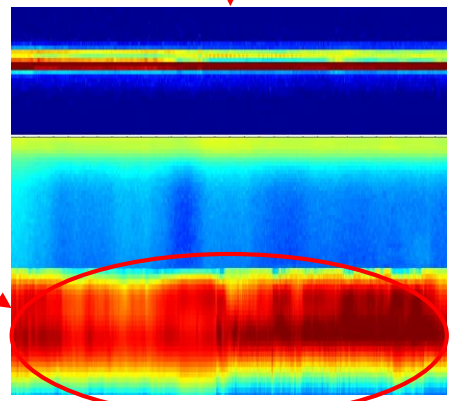
1 – 5 / stage

Searching for Jets

Loading MMS data

Classify regions (MS/SW/PSH)

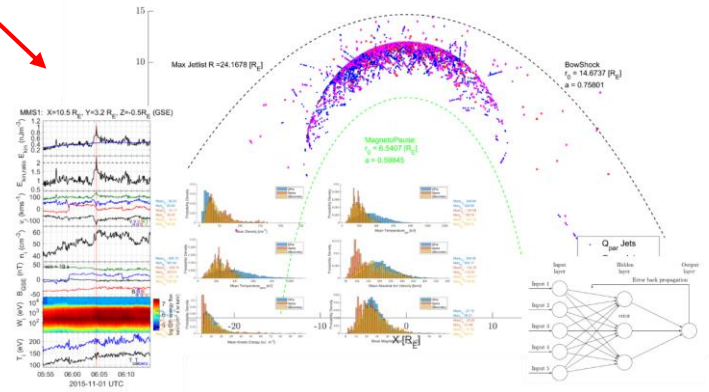
Search for Magnetosheath Jets on MS



Save Area and Jet Values
$(\mathrm{v}, P_{dyn}, \rho, P, \mathrm{B}, \mathrm{E}, \mathrm{T}, \theta \ldots)$

Jet Classification

Statistics – Jet Comparison



Find patterns & Possible origin and generation mechanism

TBD …