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Magnetosheath Jet Formation and Propagation to the Magnetopause

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What Are Magnetosheath Jets?

- Magnetosheath jets are pulses of **high dynamic pressure** that originate at the bow shock and propagate Earthward.
- They are thought to originate at **ripples** in the bow shock (Hietala et al., 2009, 2012).
- Large (> 2 R_E) jets are predicted to hit the magnetopause **several times an hour**, with smaller jets impacting hundreds of times an hour (Plaschke et al., 2016, 2020).
- If they **impact the magnetopause**, they can cause magnetospheric effects such as magnetopause reconnection (Hietala et al., 2018, Nykyri et al., 2019) and surface waves (e.g., Archer et al., 2019).

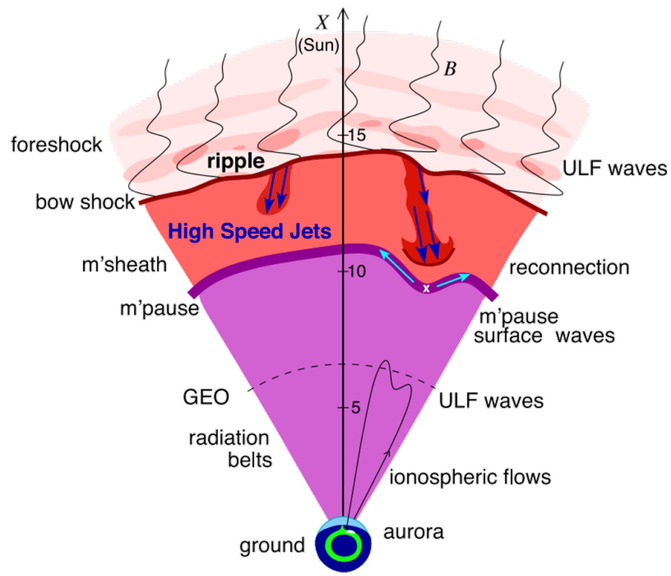

Figure 1: Cartoon illustrating the role of magnetosheath jets and their observed effects in the dayside magnetosphere.

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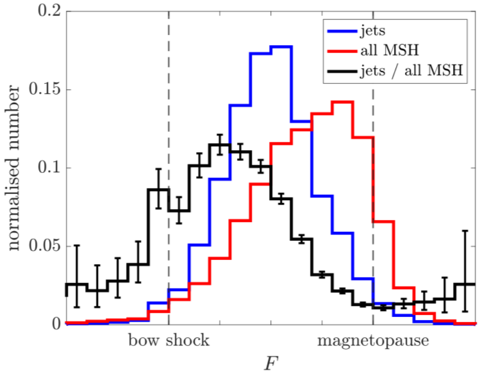
Not All Jets Hit the Magnetopause

We see that a large majority of jets are dissipated or broken up before they reach the magnetopause.



$$F = \frac{R - R_{MP}}{R_{BS} - R_{MP}}$$

= 0 at magnetopause
= 1 at bow shock

Figure 2: Probability distribution (black) for jet observation location within a model magnetosheath. Jets are most likely to be observed shortly downstream of the bow shock. Observation locations are expressed in terms of the fractional distance through the magnetosheath, F.

Research Questions

In order to forecast the effects of magnetosheath jets, we need to know:

1. **What solar wind conditions control jet formation?**
2. **What solar wind conditions control jet propagation?**
3. **When will jets impact the magnetopause most often?**

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Data Set and Methods

- We use a data set of 13,096 jet observations made by the THEMIS spacecraft from 2008-2018, selected from 8949.4 hours where THEMIS was in the magnetosheath.
- Each magnetosheath measurement is associated with upstream solar wind conditions from the OMNI database.

We use two techniques to determine how a solar wind quantity affects jet propagation:

1. **We compare solar wind quantity histograms for jets observed near the bow shock and near the magnetopause.**
2. **We compare observation location in the magnetosheath for high and low values of each solar wind quantity.**

Differences in the compared distributions indicate that the solar wind quantity under study has some control on jet propagation depth.

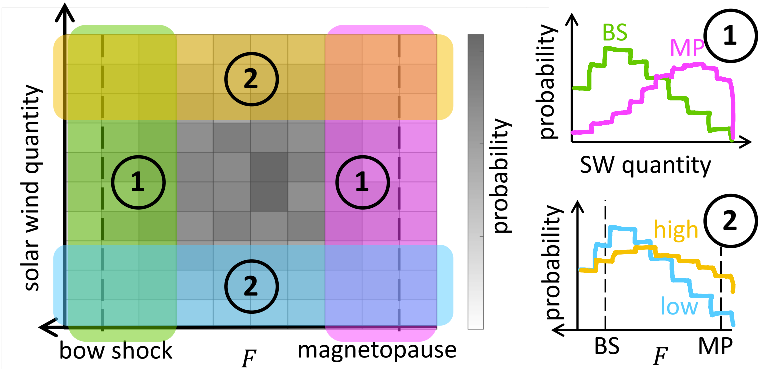

Figure 4: Cartoon of the parameter space explored to determine how solar wind conditions affect jet propagation.

What Solar Wind Conditions Control Jet Formation?

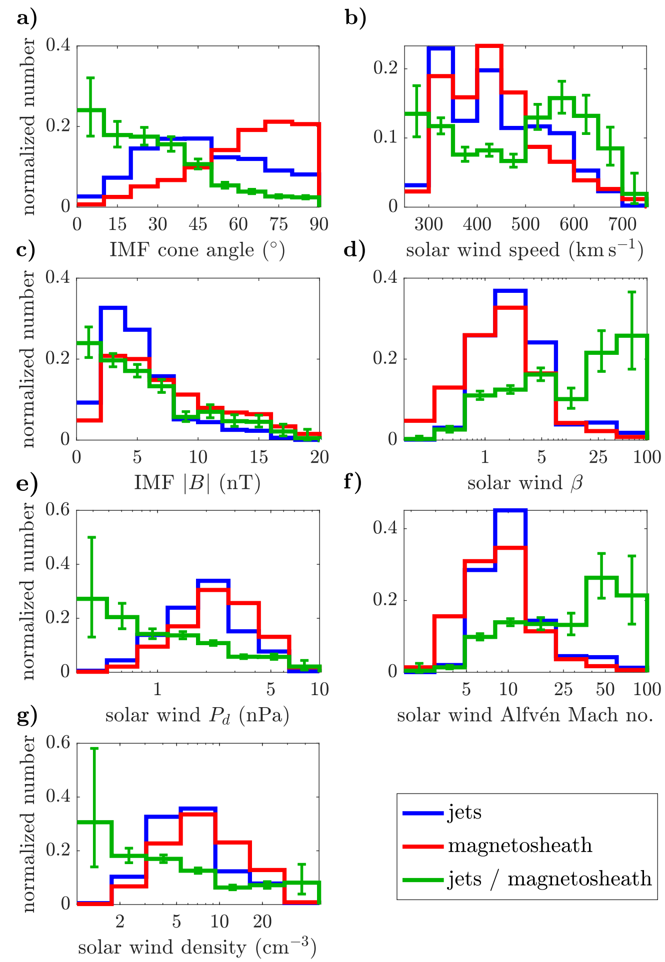

Figure 3: Distributions of upstream solar wind conditions. In each panel, red histograms show distributions for all THEMIS magnetosheath data, while blue histograms show only observations associated with jets. By dividing blue by red, the green histograms (those with error bars) give probability distributions for jet formation at the bow shock under varying solar wind conditions.

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What Solar Wind Conditions Control Jet Propagation?

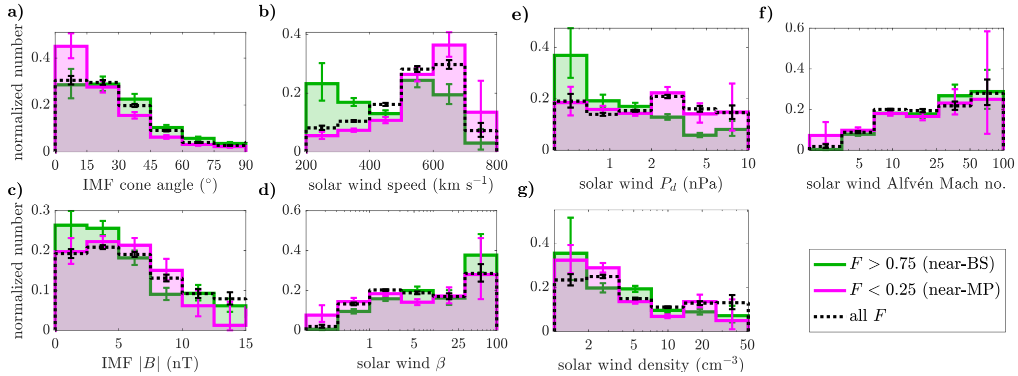

Figure 5: Separating near-magnetopause and near-bow shock jets. Differences in the distributions indicate a parameter may influence jet propagation depth.

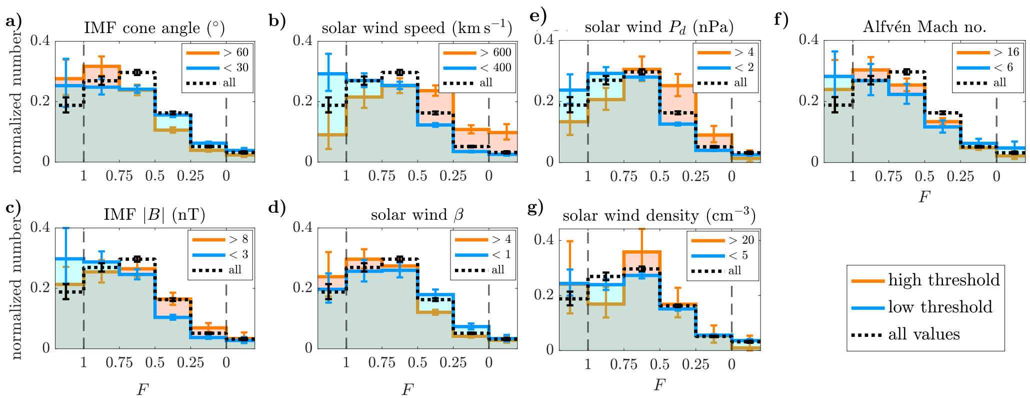

Figure 6: Separating jets by high and low threshold values of each solar wind parameter. Low IMF cone angle, high solar wind speed, high dynamic pressure, high IMF magnitude, and low β appear to promote jet propagation.

When Will Jets Impact the Magnetopause Most Often?

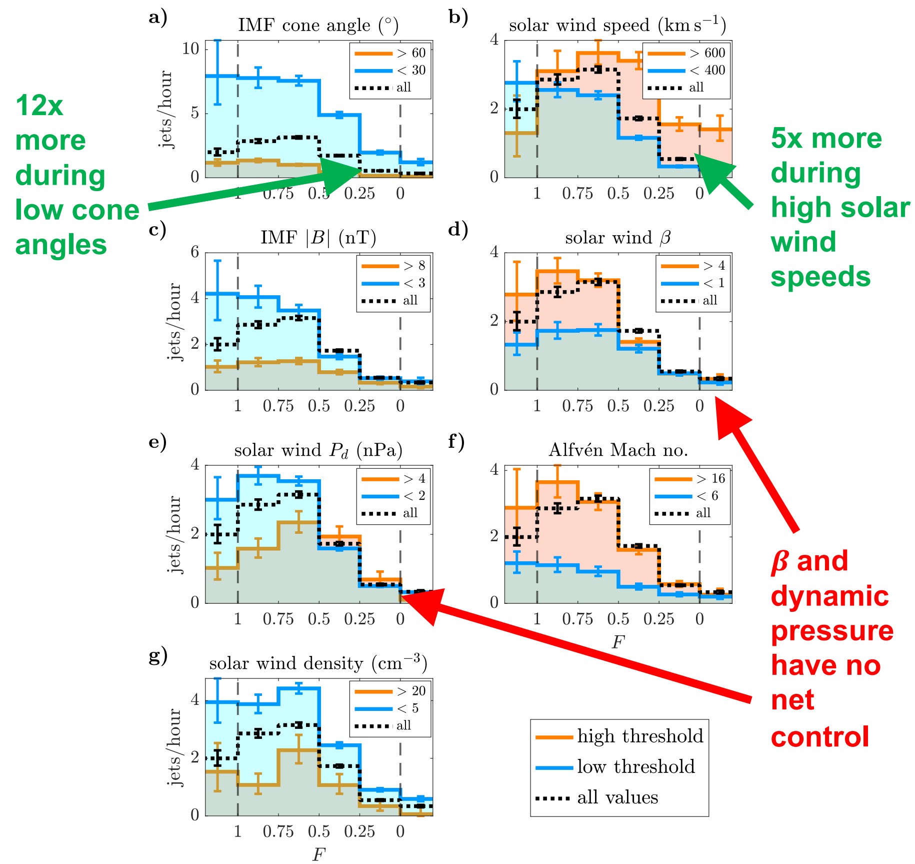

Figure 7: Histograms combining jet formation and propagation effects to assess the difference in rates of jets reaching the magnetopause under different solar wind conditions.

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Conclusions and Future

- Our results may help **inform future** forecasting regimes for magnetosheath jet impacts based on measurements of the upstream solar wind.
- Due to the dependence of jet impacts on solar wind speed, it may be interesting to study the variation of impact rates with **solar cycle**, and during solar wind transients (e.g., coronal mass ejections).
- Next, we want to know how jets may influence **magnetopause reconnection**.
- We therefore need to understand the properties of **jets near the magnetopause** to see how likely they are to satisfy the magnetic reconnection onset condition (Swisdak et al., 2010):

$$\Delta\beta < 2(L/d_i)\tan(\theta/2)$$

How Might Jets Affect Magnetopause Reconnection?

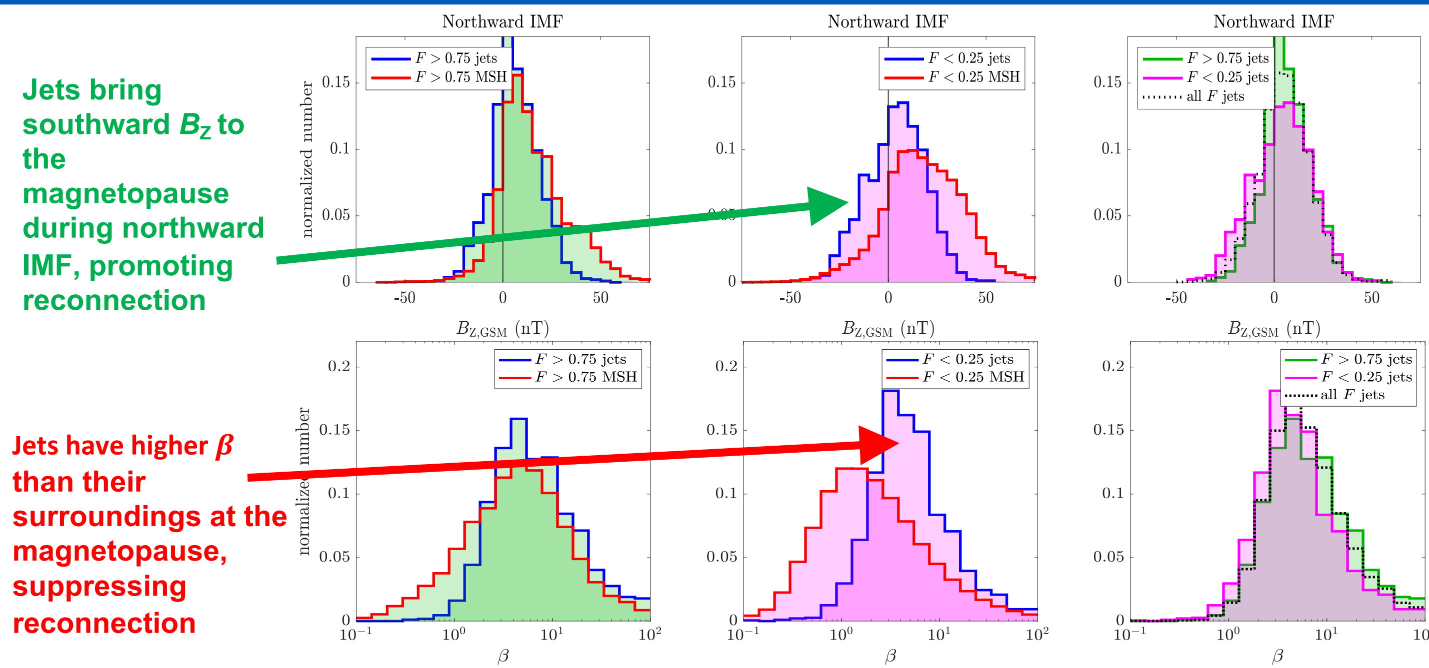

Figure 8: Preliminary studies on jet properties at the magnetopause. Their magnetic field vectors may promote reconnection, but they may suppress it by virtue of their β. The overall effect on magnetopause reconnection is therefore not yet clear.

REFERENCES: **Archer, M.O., et al. (2019)**. *Direct observations of a surface eigenmode of the dayside magnetopause*. Nature Communications. **Hietala, H., et al. (2009)**. *Supermagnetosonic jets behind a collisionless quasiparallel shock.* Physical Review Letters. **Hietala, H., et al. (2012).** *Supermagnetosonic subsolar magnetosheath jets and their effects: From solar wind to the ionospheric convection.* Annales Geophysicae. **Hietala, H., et al. (2018).** *In situ observations of a magnetosheath high-speed jet triggering magnetopause reconnection.* Geophysical Research Letters. **Nykyri, K., et al. (2019).** *Can enhanced flux loading by high-speed jets lead to a substorm? Multipoint detection of the Christmas Day substorm onset at 08:17 UT, 2015.* Journal of Geophysical Research: Space Physics. **Plaschke, F., et al. (2016)**. *Geoeffective jets impacting the magnetopause.* Journal of Geophysical Research: Space Physics. **Plaschke, F., et al. (2018)**. *Jets downstream of collisionless shocks*. Space Science Reviews. **Plaschke, F., et al. (2020)**. *Scale sizes of magnetosheath jets.* Journal of Geophysical Research: Space Physics. **Swisdak, M., et al. (2010).** *The vector direction of the interstellar magnetic field outside the heliosphere.* Astrophysical Journal.