Multiple Scale Structures of Dayside Current System: Joint observations by MMS, Cluster and Swarm

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Abstract

The conjunction of different spacecraft missions provide the opportunity to investigate the multiple scale of the magnetospheric current system. In our work, we use the data from MMS, Cluster and Swarm to study the characteristics of both the dayside current, including the magnetopause, and other current systems connected by the field aligned currents. Using the MMS four spacecraft data, we investigated the small-scale physical process of the magnetopause current, e.g. current carriers and current sources, which show features beyond the classic Chapman-Ferraro model. We compare MMS crossings to simultaneous crossings at different locations on the MP current layer observed by Cluster. Cluster is an order of magnitude lower than MMS and cannot reveal the detailed current structure due to its large separation. However, we find that the MP at the above two locations can have similar magnetic field structure. This may suggest that the MP has similar current structure across wide region during specific IMF conditions. We also used the conjunction of MMS and Swarm and Cluster and Swarm to investigate the behaviour of field-aligned currents. MMS and Swarm can calculate the current in the dayside inner low latitude boundary and the mapped ionospheric region simultaneously. Comparing the observed current signatures, we can investigate the correlation between them, which may reveal the nature of the magnetopause-ionosphere coupling between the field aligned current systems.

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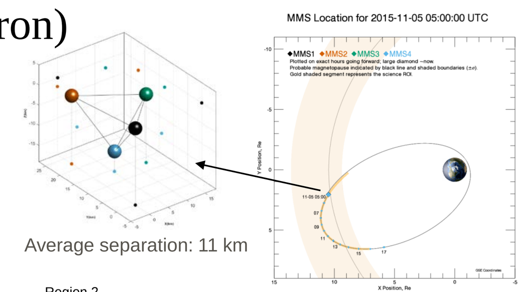
Outline

- Using the MMS four spacecraft data, we investigated the small-scale physical process of the magnetopause current, e.g. current carriers and current sources, which show features beyond the classic Chapman-Ferraro model.
- We compare MMS crossings to simultaneous crossings at different locations on the MP current layer observed by Cluster and find that the MP at the above two locations can have similar magnetic field structure. This may suggest that the MP has similar current structure across wide region.
- We used the conjunction of MMS and Swarm to investigate the field aligned current.

Current carriers

Total (perpendicular) drift current for two-fluids: (ion and electron)

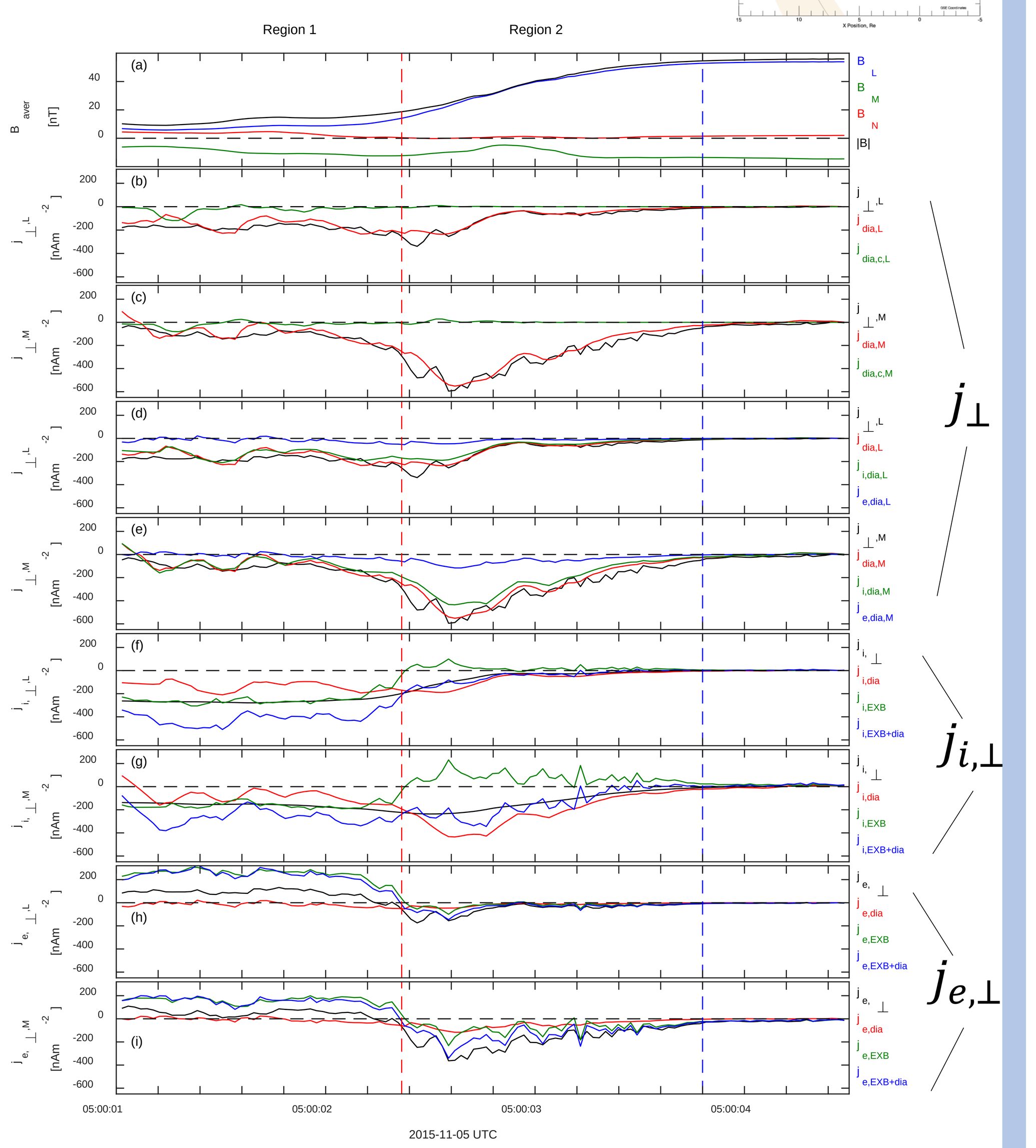
$$\mathbf{j}_{\perp} = \underbrace{\frac{\mathbf{B}\times\nabla_{\perp}p_{i\perp}}{B^2}}_{\mathbf{j}_{i,dia}} + \underbrace{\frac{\mathbf{B}\times\nabla_{\perp}p_{e\perp}}{B^2}}_{\mathbf{j}_{e,dia}} - \underbrace{\frac{p_{i\parallel}-p_{i\perp}}{B^2R_c}\mathbf{B}\times\mathbf{n}}_{\mathbf{j}_{i,dia,c}} - \underbrace{\frac{p_{e\parallel}-p_{e\perp}}{B^2R_c}\mathbf{B}\times\mathbf{n}}_{\mathbf{j}_{e,dia,c}}$$



Case 1: thin MP current layer (~100km)

For the perpendicular currents:

- J_{dia} terms (from MMS data) with the directly measured J shows good agreement.
- Curvature current $j_{dia,c}$ can be neglected (green).
- Total diamagnetic current j_{dia} is broadly consistent with the total $j_{\perp}$ except for some substructures. (red and black)
- Perpendicular current is dominated by the ion diamagnetic current ($j_{i,dia}$: 85%, $j_{e,dia}$: 15%) – plasma frame. (electron current in blue)



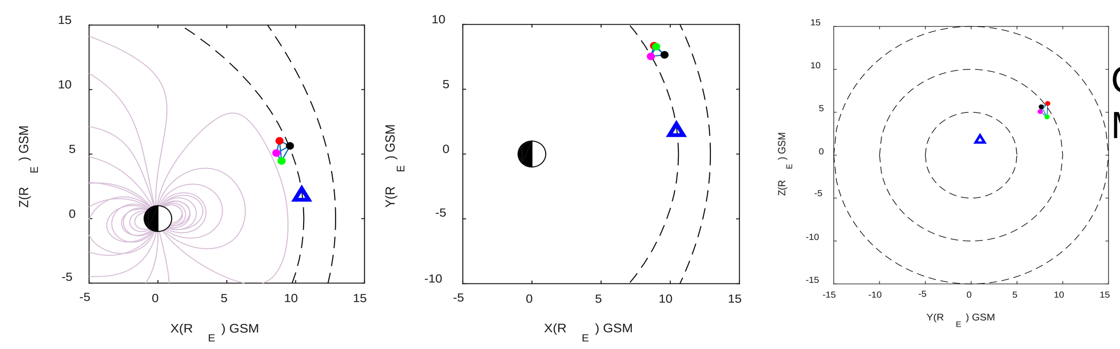
✓ **Dominant diamagnetic current carried by the ions.**

✓ **Even for a thin MPBL field line curvature >> the ion gyroradius: two fluid MHD may apply.**

✓ **Find: J_{dia} curvature terms on the right are << pressure gradient terms for this case.**

✓ **Electron current deviates at a narrow front layer in region 2: suggesting non-MHD behaviour (beyond Chapman-Ferraro)**

Cluster-MMS conjunction



Cluster: [9.6, 7.6, 5.7] R_E (GSM)
MMS: [10.4, 1.0, 1.8] R_E (GSM)

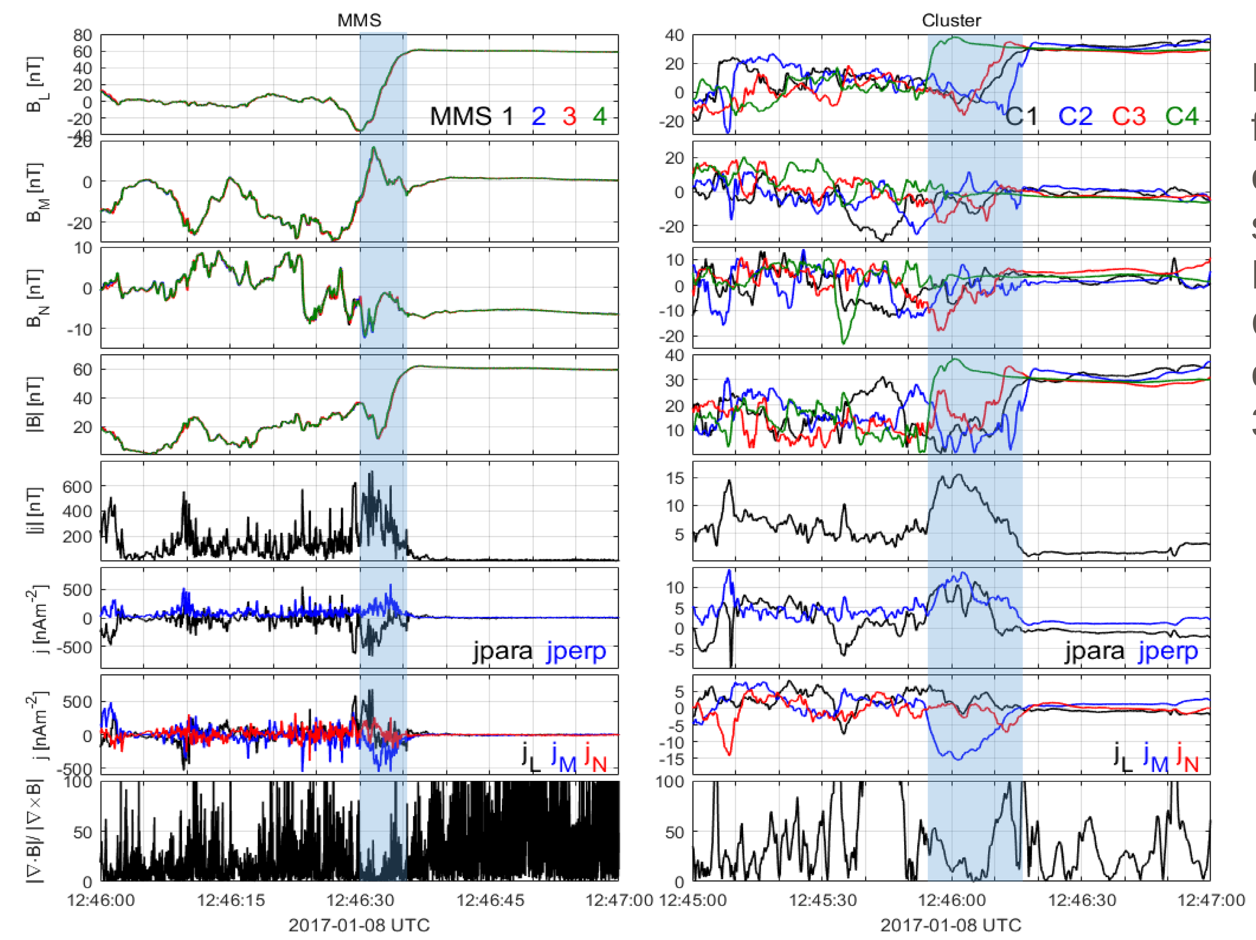


Figure. Magnetic field and current observed by a simultaneous MMS (left) and Cluster (right) MP crossing within 30s.

MMS:

V_{timing}=86.8 * [0.98 0.13 -0.14] km/s GSM

Thickness~440km

$\delta D = 440km$

δBL = 60nT

$\delta BL/\delta D$~110nAm^{-2};

Aver |j| = 223 nAm^{-2};

Aver j_{perp} = 133 nAm^{-2}

Cluster:

V_{timing}=169 * [0.47 0.81 0.35] km/s GSM

Thickness~700-1400km

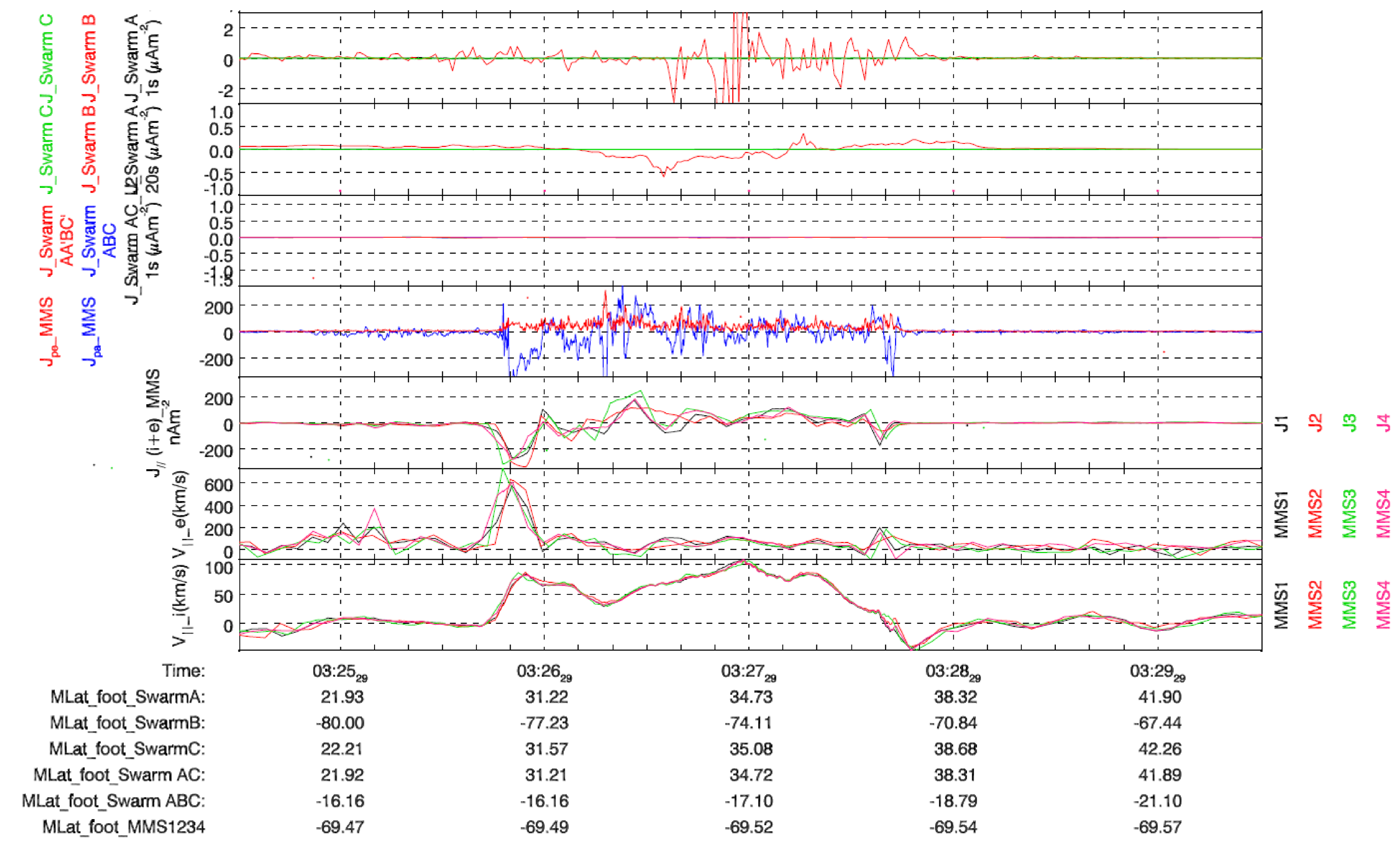
$\delta D = 1400km$

δBL = 60nT

$\delta BL/\delta D$~35-70 nAm^{-2}

- Cluster separation is of order the MP thickness (c.f. non-planar).
- The larger separation scales for Cluster shows the B_L is not planar so Cluster underestimates the main current layer.
- The Curlometer at Cluster gives a low estimate compared to δB/δD (planar current sheet), which is similar at both MMS and Cluster.
- The total current at MMS is much greater than at Cluster (j_{MMS}>>$j_{Cluster}$).
- A large parallel current is resolved by MMS (not seen by Cluster) – small filamentary || currents (this is separate from the main current layer).
- The direction of parallel currents are different (at MMS and Cluster).
- Similar bifurcated current sheet are observed by MMS, C1 and C2, while not clear at C3 and C4 which may suggest the temporal effect of current structure.
- MMS resolves more detail on the structure of the current layer than Cluster (large, small-scale field-aligned currents before the main current layer contribute to the large current seen by MMS: not captured by Cluster).
- Also evidence of filamentary perpendicular currents.

MMS-Swarm conjunction



We compare the field-aligned current form MMS at magnetopause and Swarm from the corresponding ionospheric foot-point.

- The Swarm results show no common feature during the MP main current layer.
- Some common features may exist when MMS located in the magnetopause inner low latitude boundary layer region
- However, the mapping result from MMS around magnetopause to ionosphere may bring some uncertainties for the results.

Summary and Discussion

1. MMS shows that while the curvature current remains small, the diamagnetic current is the source of perpendicular current, with the ion diamagnetic current being dominant.
2. The MP B_L sampled at two locations has a similar overall form for the magnetic field: suggests that the MP should have similar current structure across a wide region during specific IMF conditions.

   [dB/dD broadly similar at each location]
3. Comparatively, the larger Cluster scales show non-planar structure, while the small MMS scale reveals additional large filamentary currents.
4. Typically, can check whether the plasma physics seen by MMS is consistent with the larger scale features seen by Cluster using simultaneous observations.
5. MMS-Swarm conjunction show some possible common field-aligned features but still need further confirmation.