Study of a dayside magnetopause reconnection event detected by MMS and related to a large-scale solar wind perturbation and cold ions

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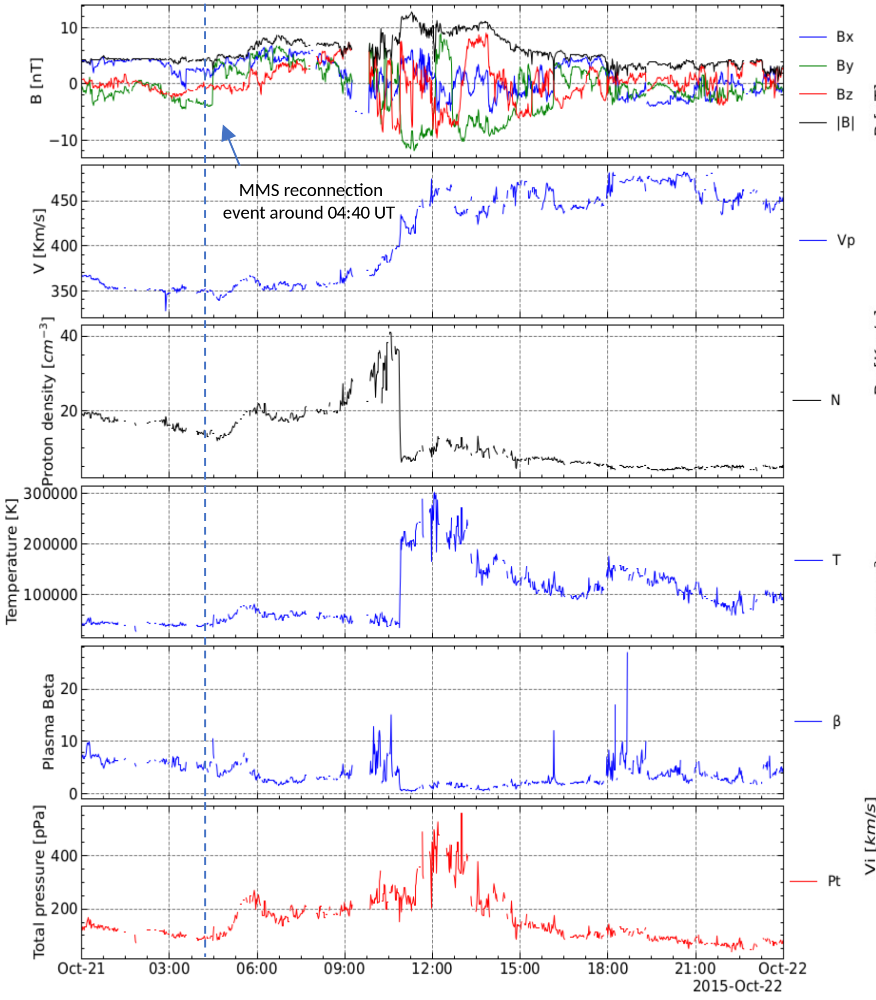
Introduction

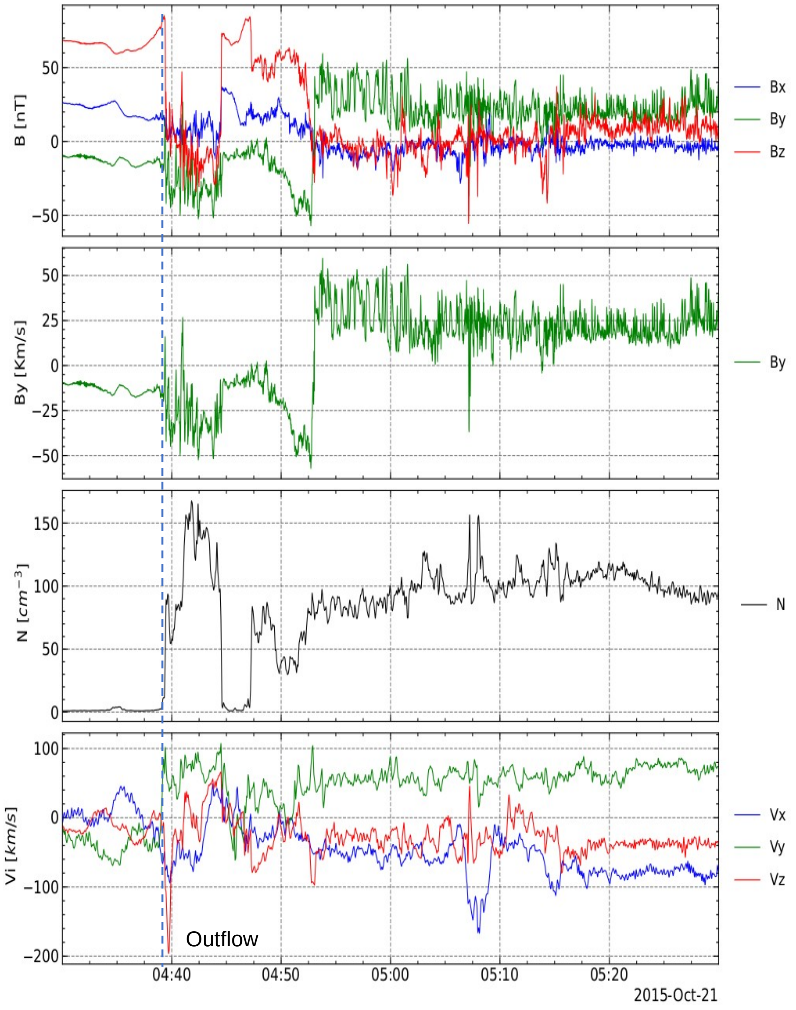
- We investigate the role of the pile-up of the density in front of large-scale solar wind perturbation on the reconnection process at the magnetopause.
- The very large density and the $\mathbf{B_y}$ reversal detected by MMS in the magnetosheath is a consequence of the arrival of the compressed solar wind that's observed at L1.
- The Stream Interaction Region SIR is considered as shock-less event (Jian et al, 2006).

21/10/2015 Shock-less SIR event
OMNI data (Observation at L1)



OMNI data from 21-22/Oct/2015 (Data shifted to the bow shock time scale) with 1-MIN resolution.

21/10/2015 reconnection event
Related MMS Observation



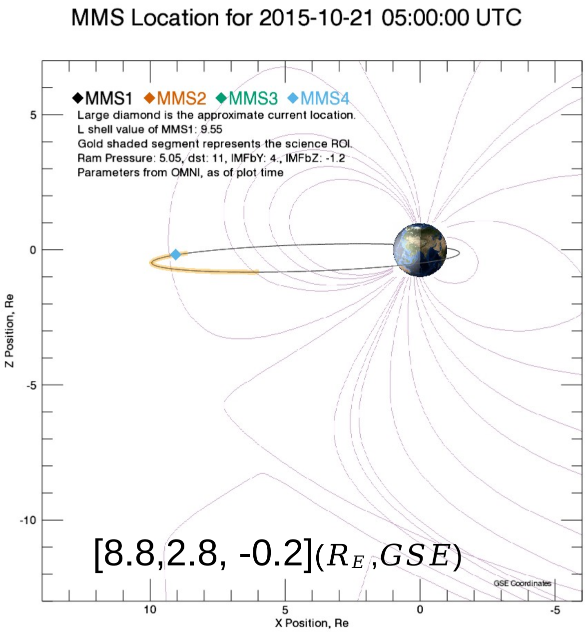
MMS fast data in GSE coordinates from 04:30 UT-05:30 UT 21/Oct/2015

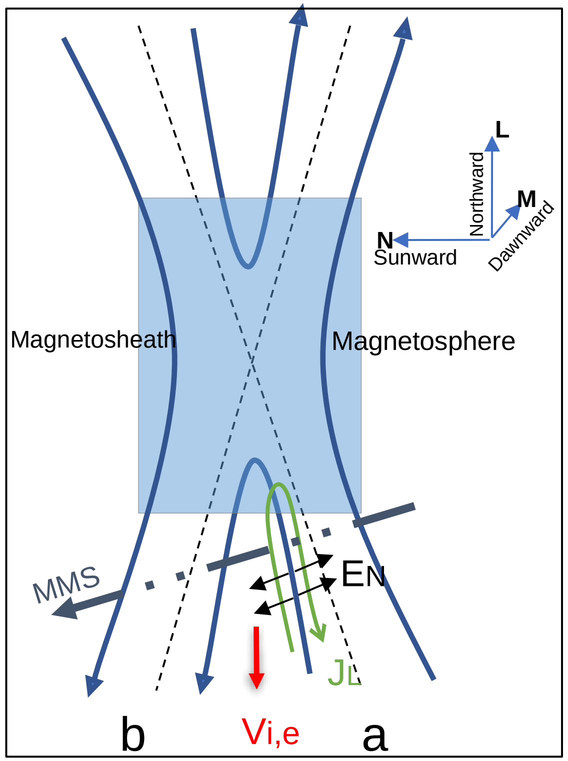
Event overview

- Highly asymmetric reconnection: N_{SH}/N_{SP} = 50, B_{SP}/B_{SH}=2.46
- A moderate guide field directed dawnward: 0.42 B_{SP}, 0.96 B_{SH}
- Ion and electron jets V_L -200 km/s
- First peak in density (10 cm^{-3}) is dominated by cold ions.
- Reversal of E_N (directed away from the magnetopause).
- Current density peaks ($-J_M$ and $–J_L$) at 04:39:25 UT.

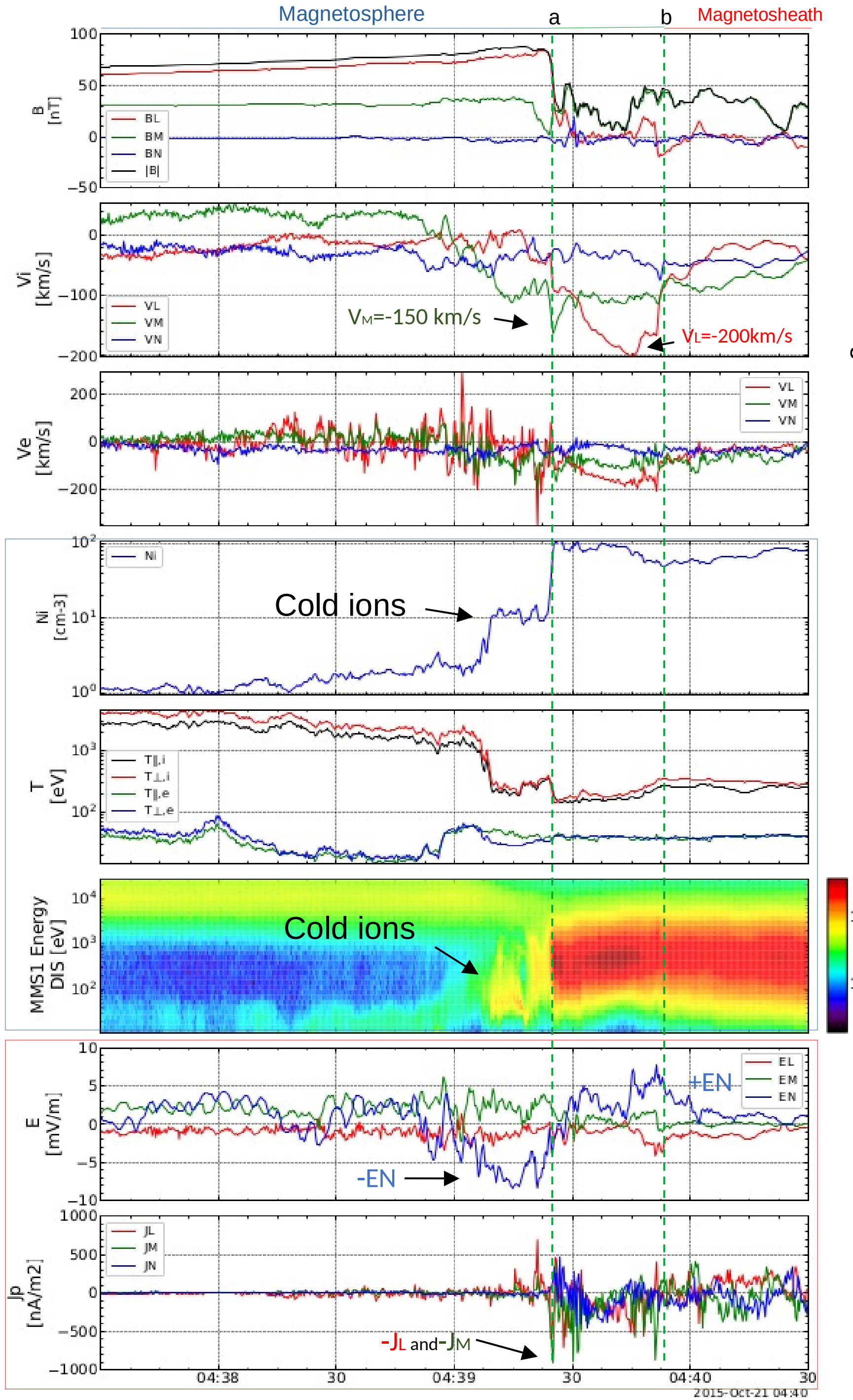
	MSP	MSH
| **B** | (nT)	76	31
| **BL** | (nT)	67	0.5
| **BM** | (nT)	32	30
| **N** | (cm^{-3})	1.5	73.67

L =[0.11,0.24,0.96]
M =[0.30,-0.93,0.19]
N =[0.94,0.26,-0.17]
V_{MP}= -47 km/s **N** (TA)





All data set have been averaged at 0.3 s and transformed into LMN frame



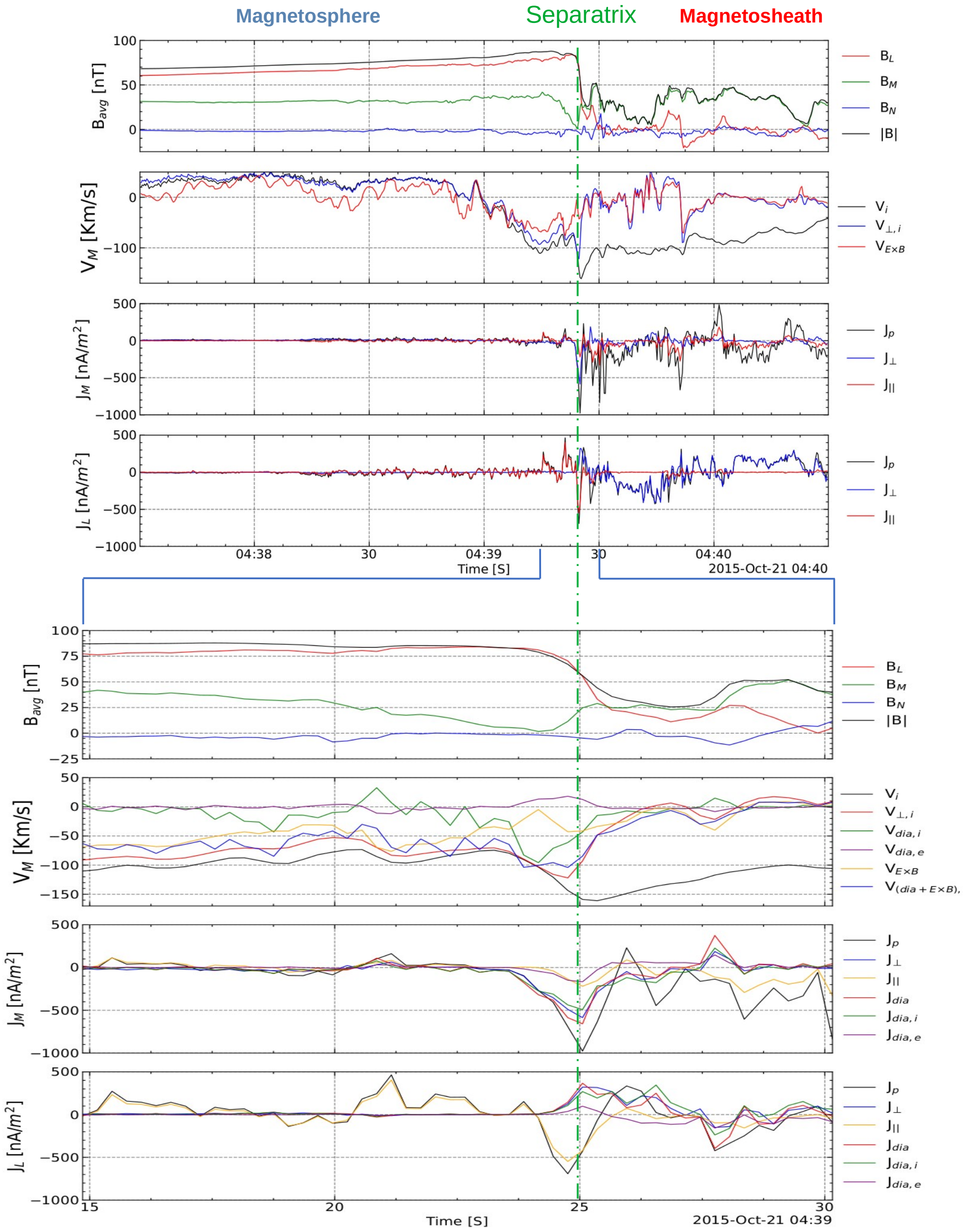
Diamagnetic currents analysis

Equations:

$$\boldsymbol{V}_{\boldsymbol{dia,e}} \equiv \frac{\nabla P_e \times B}{enB^2}, \quad \boldsymbol{V}_{\boldsymbol{dia,i}} \equiv -\frac{\nabla P_i \times B}{enB^2}$$

$$\boldsymbol{J}_{\boldsymbol{dia}} = -en\left(V_{dia,e} - V_{dia,i}\right) = \frac{B \times \nabla P}{B^2}$$

- $V_{\perp,i}$ is consistent with $V_{(dia+E\times B)}$
- $V_{dia,i}$ $V_{\perp,i}$ in the separatrix region where the pressure gradient is large.
- Most of the source of the perpendicular current in M direction is $\mathbf{J}_{\mathbf{dia,I}}$ (although $\mathbf{J}_{\mathbf{dia,e}}$ Is not negligible)
- The current in L direction is mostly field aligned at the peak



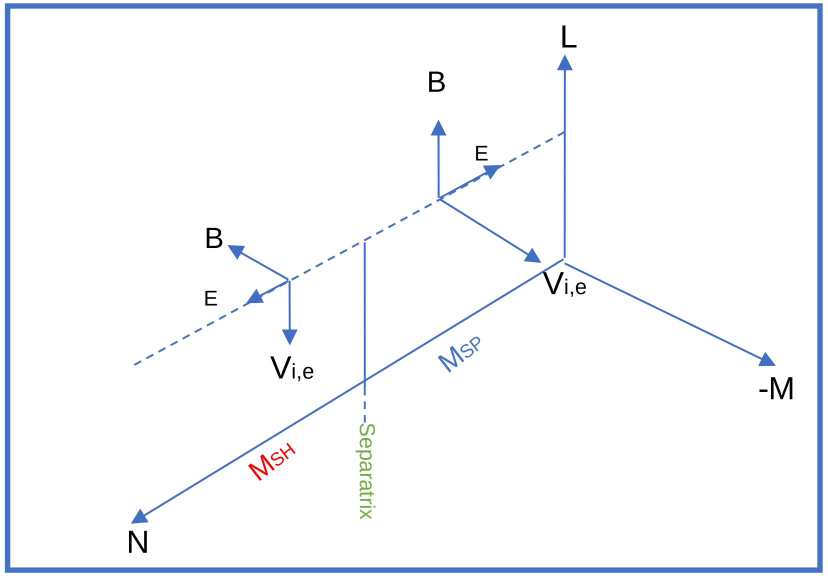
Generalized Ohm's law

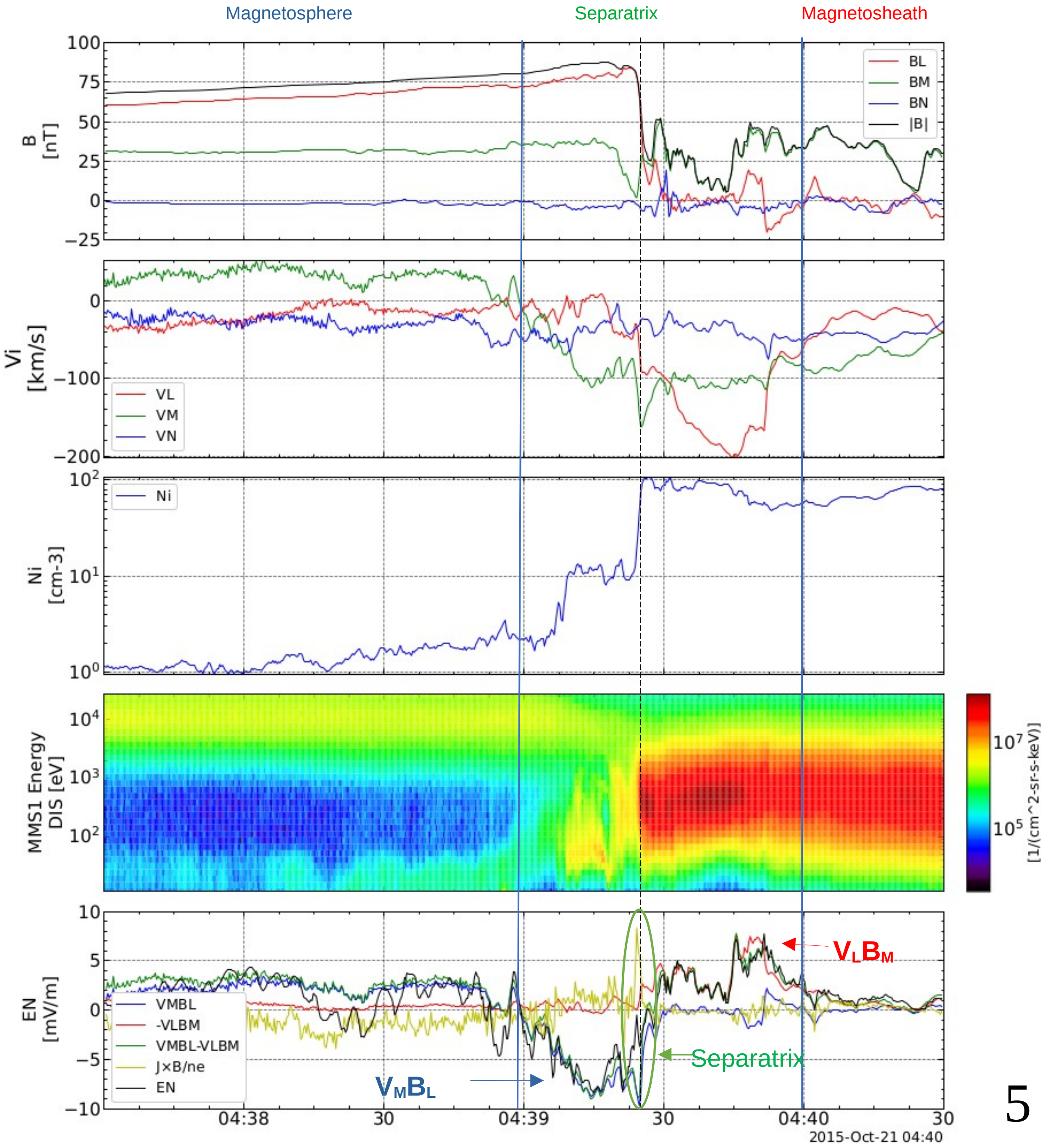
$$\mathbf{E} + [\mathbf{u}_i \times \mathbf{B}] = \frac{1}{ne}\mathbf{j} \times \mathbf{B} - \frac{1}{ne}\nabla p_e.$$

$V_M B_L - V_L B_M$

- Outflow region is far from EDR and IDR.
- Magnetospheric Separatrix crossing at 04:39:24 UT
  Ions are decoupled, Electrons remained magnetized (not shown).
- **J**×**B** term is compensated by **v**×**B** term (vertical black line)

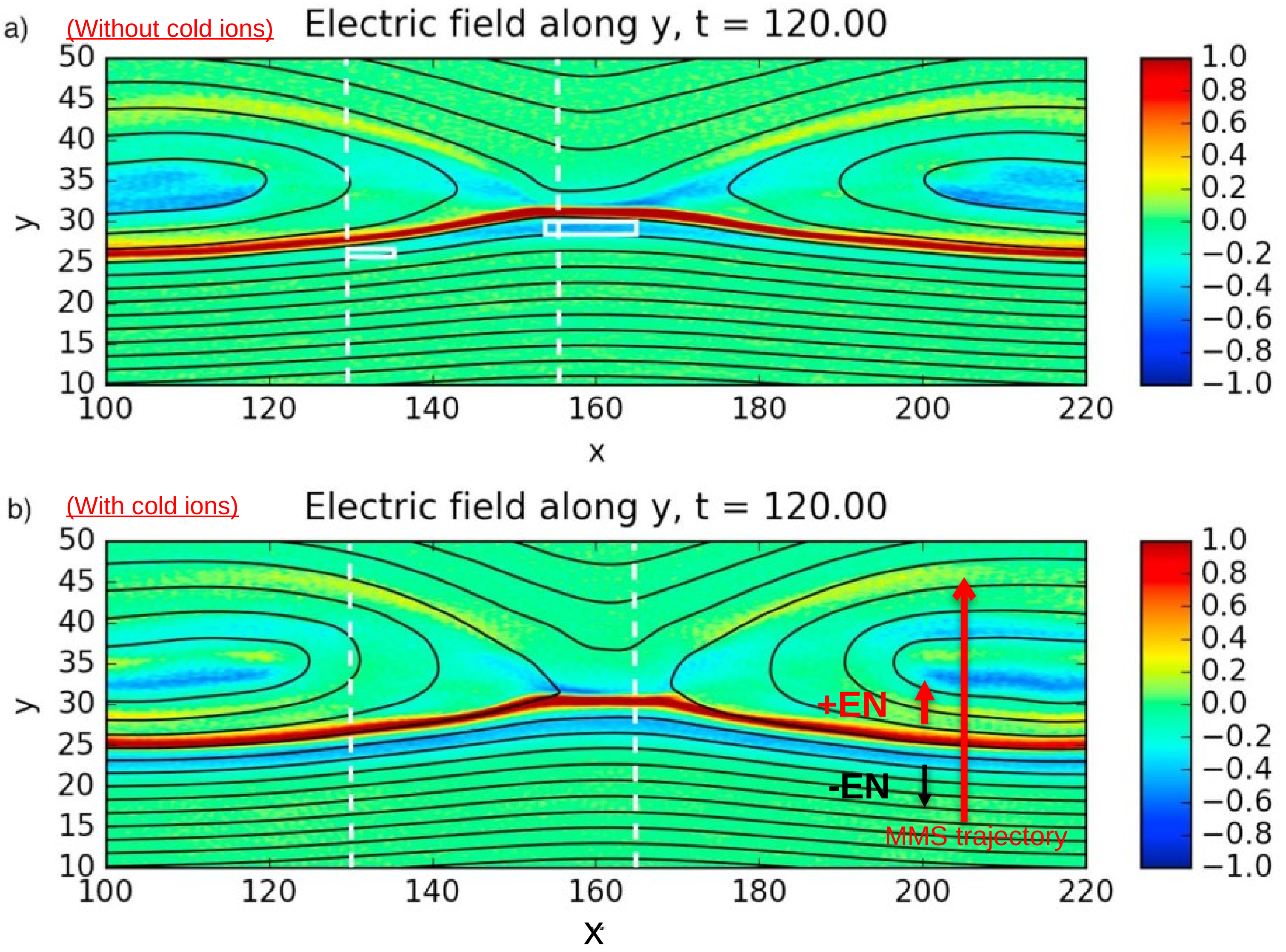
The following schematic illustrates the process between the two blue vertical lines in the figure:





Cold ions effect

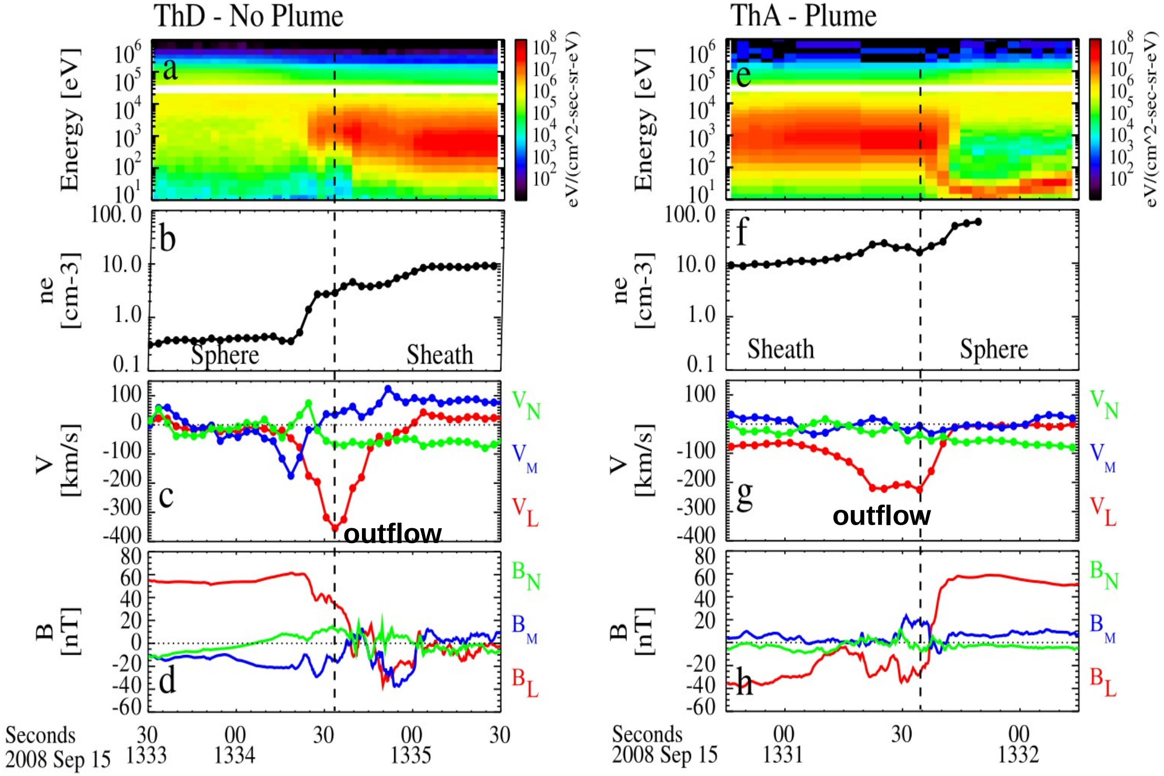
- Kinetic simulation of asymmetric magnetic reconnection with cold ions (without guide field).
- Cold ion very low temperature (below 300 eV) enables them to E × B drift in the electric field structure.
- This signature maintained away from the x-line see panel (b).

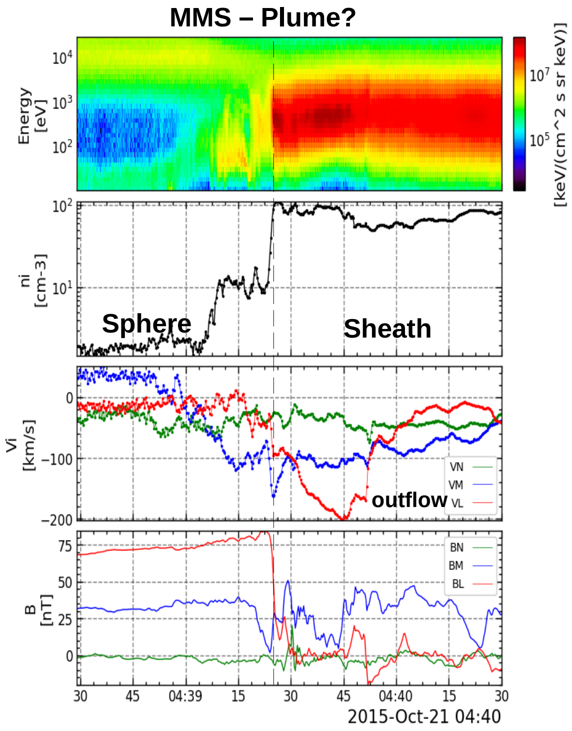


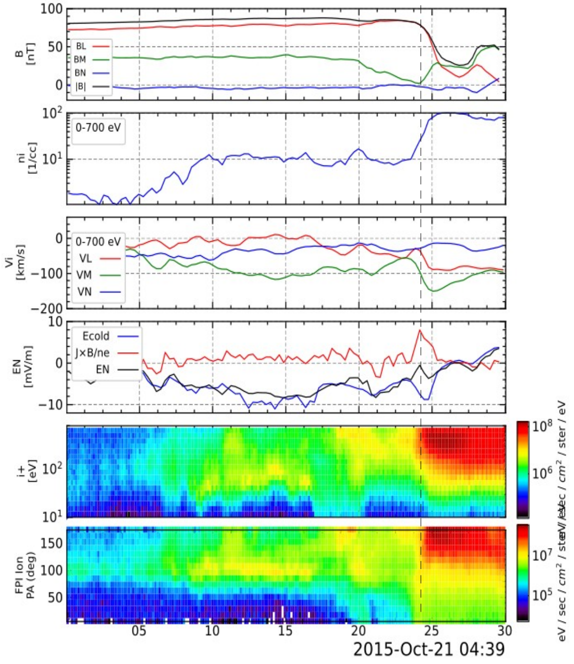
[Dargent et al, 2017]

(We thank J. Dargent and S. Toledo-Redondo for the useful discussions)

What is the source of the cold ions?

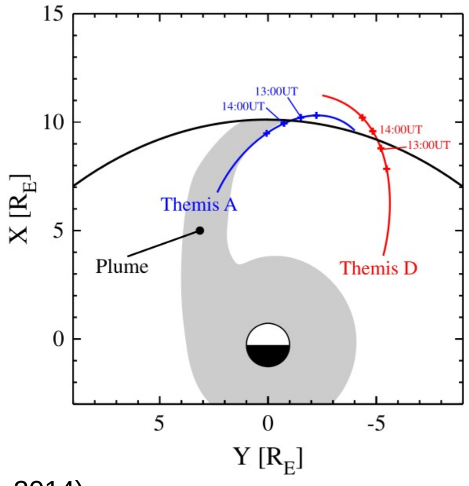






Particle moments and spectrograms for energy range 0-700 eV from level 2 MMS3 FPI velocity distribution data.

- ThD and ThA were separated by 1.5 h in magnetic local time, both spacecraft measure magnetic reconnection; however, only one measures the high-density plume.
- ThA measures the density of the plume plasma contacting the magnetopause to be 18–72 cm^{-3}
- When the plume is present, the reconnection jets have lower velocities and larger densities.



(Walsh et al, 2014)

	V_{jet} (km/s)	V_{C+S} (km/s)	n_{jet} (cm^{-3})	n_s (cm^{-3})	n_m (cm^{-3})	B_s (nT)	B_m (nT)	Mass inflow	Jet field
ThD No-plume	361	364	2.9	8.4	0.4	24	63	0.05	Sphere
ThA Plume	221	176	15.9	9.4	55	38	56	3.97	Sheath
MMS	200	188	92	60	10.5	31	76	0.07	Sheath

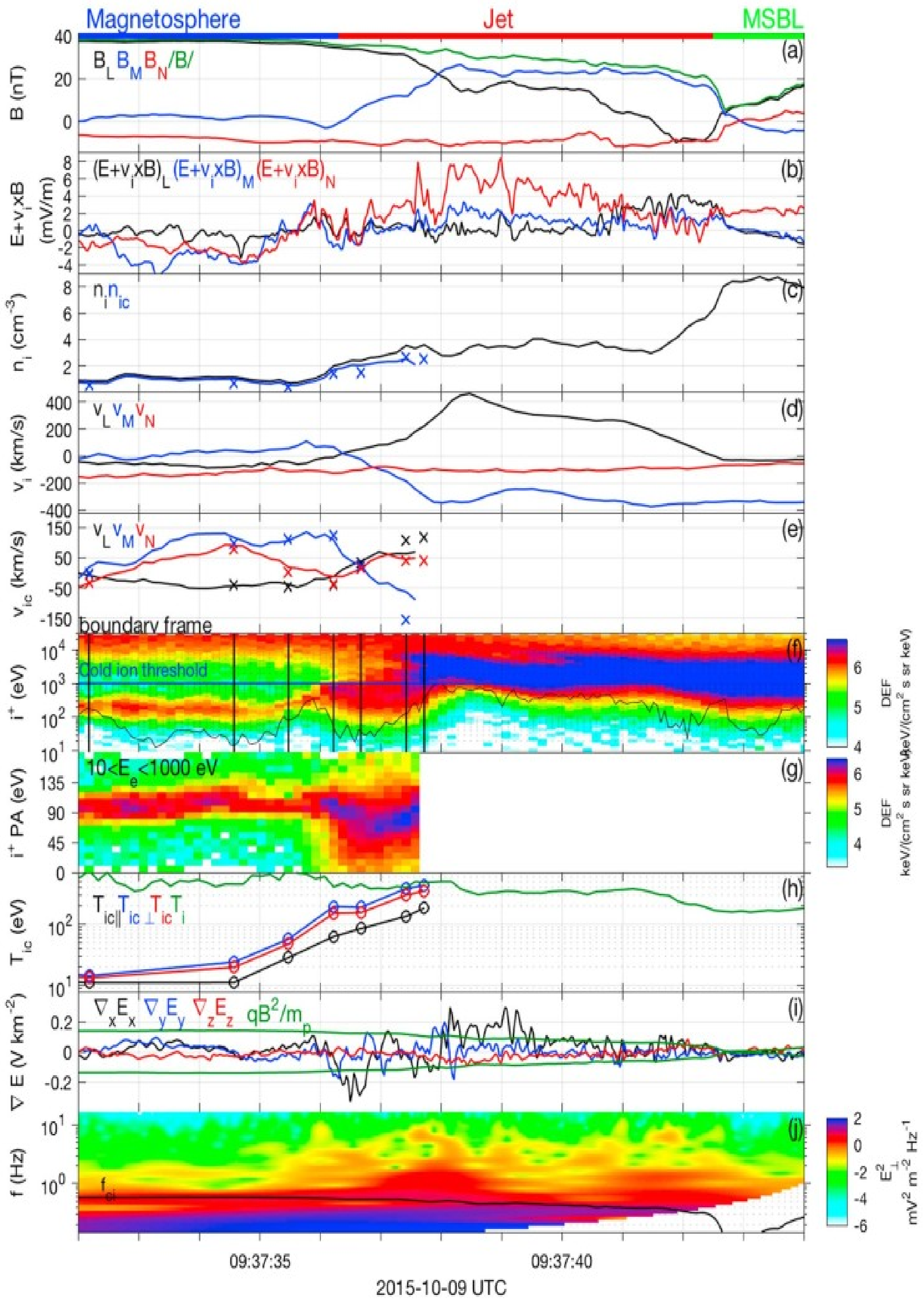
Conclusions

- The reconnection event which is far away from the x-line detected by MMS on Oct. 21, 2015 during a period when the magnetosheath density is very large (up to 160 cm^{-3}) is related to the arrival of a weak SIR.
- The pile-up of the density near the boundary layer in the magnetospheric side is due to cold ions.
- The negative values of $\mathbf{E}_N$ (Earthward) on the magnetospheric side is due to the relative motion of cold ions in the out of plane direction ($\mathbf{V}_M\mathbf{B}_L$).
- The positive values of $\mathbf{E}_N$ (Sunward) on the magnetosheath side is due to the existence of the guide field ($-\mathbf{V}_L\mathbf{B}_M$).
- $\mathbf{J}\times\mathbf{B}$ term is due to the large diamagnetic current which is the largest contributor in the out of plane current ($-\mathbf{J}_M$) at the separatrix (mostly produced by ion pressure gradient).

Thank you

Appendix

Is the cold ions heated when they reached the boundary layer?



(Toledo et al, 2017)