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MMS observations of multi-scale Hall physics in the magnetotail

Love Alm, Andris Vaivads, Yuri Khotyaintsev, and Daniel Graham
Swedish Institute of Space Physics, Uppsala, Sweden

Magnetic reconnection is typically viewed as a two-scale process, referring to different the length scales associated with electron and ion demagnetization. When cold ions are introduced to the reconnection region, they have to potential of introducing an additional, intermediate length scale, resulting in multi-scale Hall physics. While cold plasma is frequently observed in the tail lobes, it has not been clearly established if these cold ions can remain magnetized when encountering the much hotter and denser plasma sheet.

We present in situ observations made by MMS of magnetotail ion diffusion regions containing a mixture of cold magnetized ions and hot demagnetized ions. The effects of the cold ions on the Hall physics is investigating by modeling the observed Hall electric field using a two ion-species generalized Ohm's law.

Similar to what has been observed in dayside reconnection, the magnetotail Hall electric field is mainly supported by the $\mathbf{j} \times \mathbf{B}$ term of the generalized Ohm's law, with contributions from the $\mathrm{v}_c \times \mathbf{B} term. In contrast to previous studies we can report significant contributions from the \nabla \cdot \mathbf{P_e}$ term, indicating a degree of non-ideal electron motion. Our results shows that even when the cold ions are a minority species they have a significant impact on the Hall electric field, highlighting the importance of including multi-scale physics in modeling magnetic reconnection.