Previously hidden low-energy ions and a new length-scale in magnetic reconnection

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Low-energy ions (< 10 eV) from the ionosphere are common just inside the magnetopause.

During reconnection events, these low-energy ions remain magnetized down to smaller length-scales than the hot (keV) ions, introducing a new scale. The Hall currents, carried by electrons, will be partially cancelled by magnetized low-energy ions.

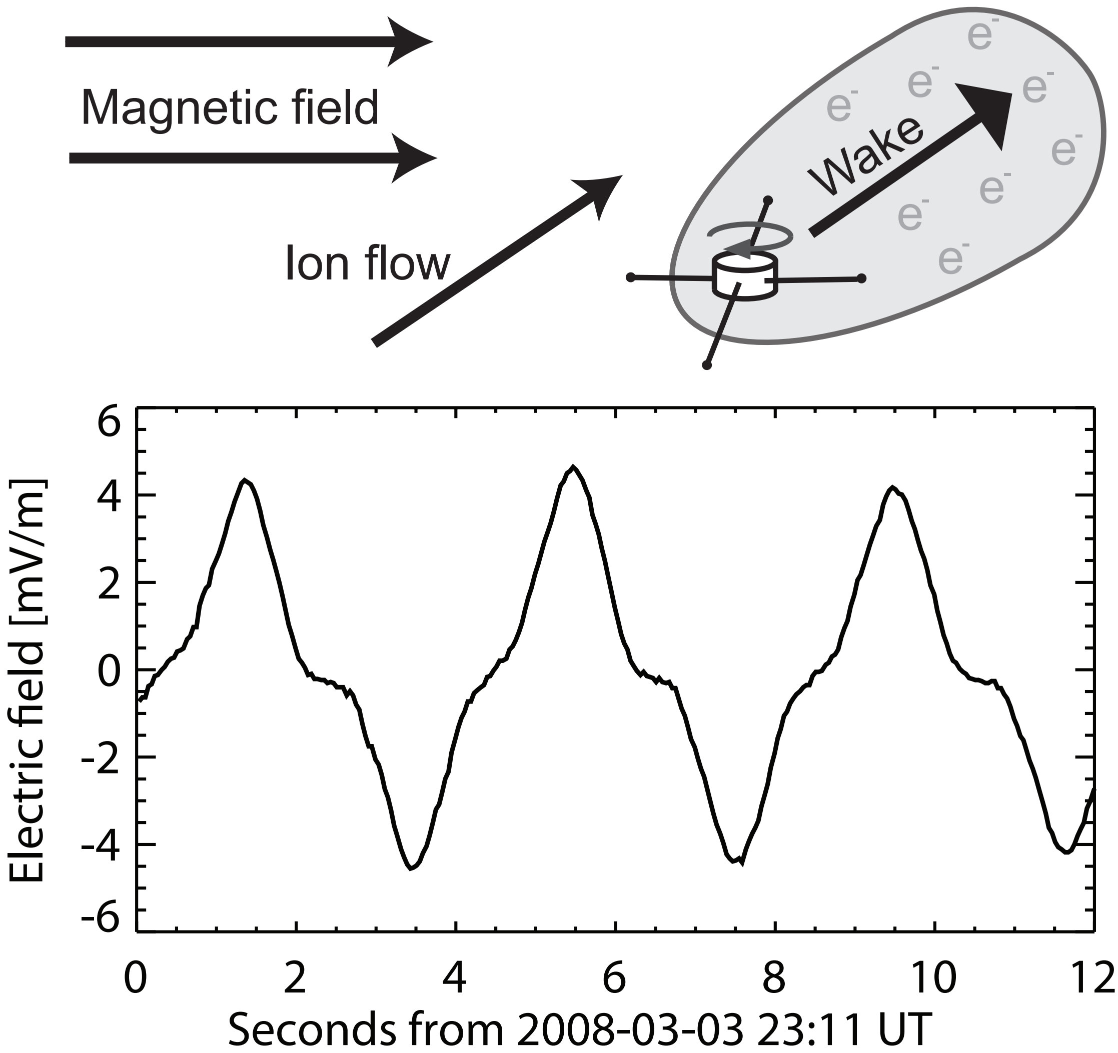
Low-energy ions

Low-energy: thermal energy, and drift energy, less than 10 eV (sometimes 100 eV).

From the ionosphere.

Low-energy positive ions are hard to detect on a spacecraft charged to several Volts positive.

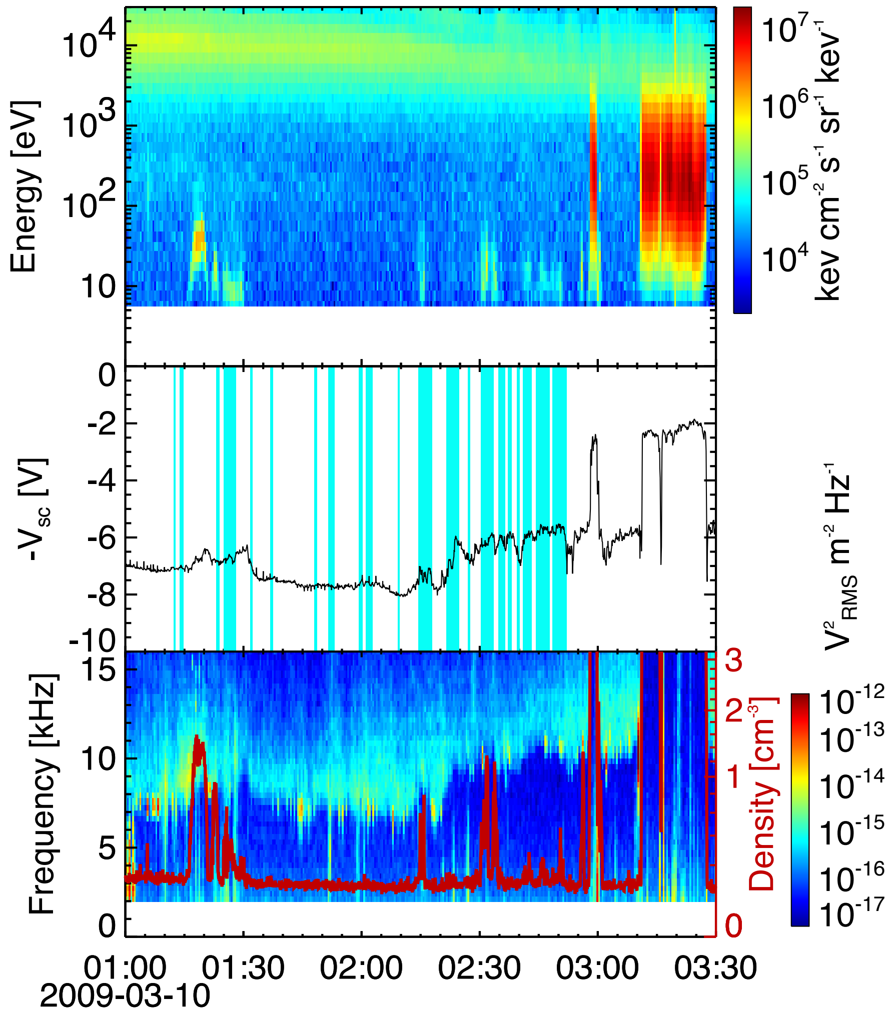
Low-energy ions: Wake method



Low-energy positive ions can not reach a positively charged spacecraft.

A supersonic ion flow will cause a wake and a local electric field. This can be used to indirectly detect the ions. (Observed by the Cluster EFW Electric Field and Wave instrument.)

Low-energy ions: 3 methods

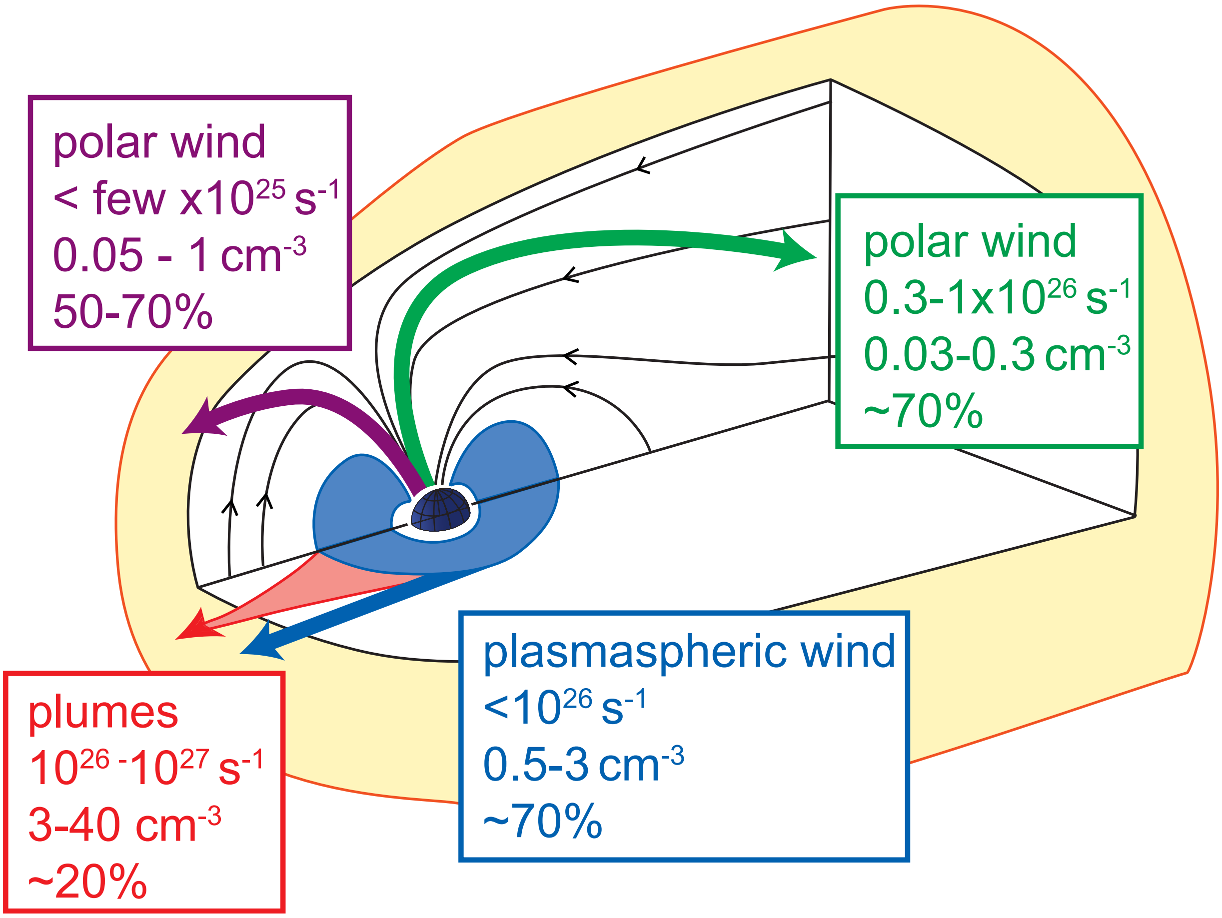


Three ways to detect positive low-energy ions (can not reach the positively charged spacecraft).

Upper panel: Sometimes drifting into a particle detector.
Middle panel: New wake method.
Lower panel: Plasma frequency.

(André and Cully, GRL, 2012)

Low-energy ions: Statistics



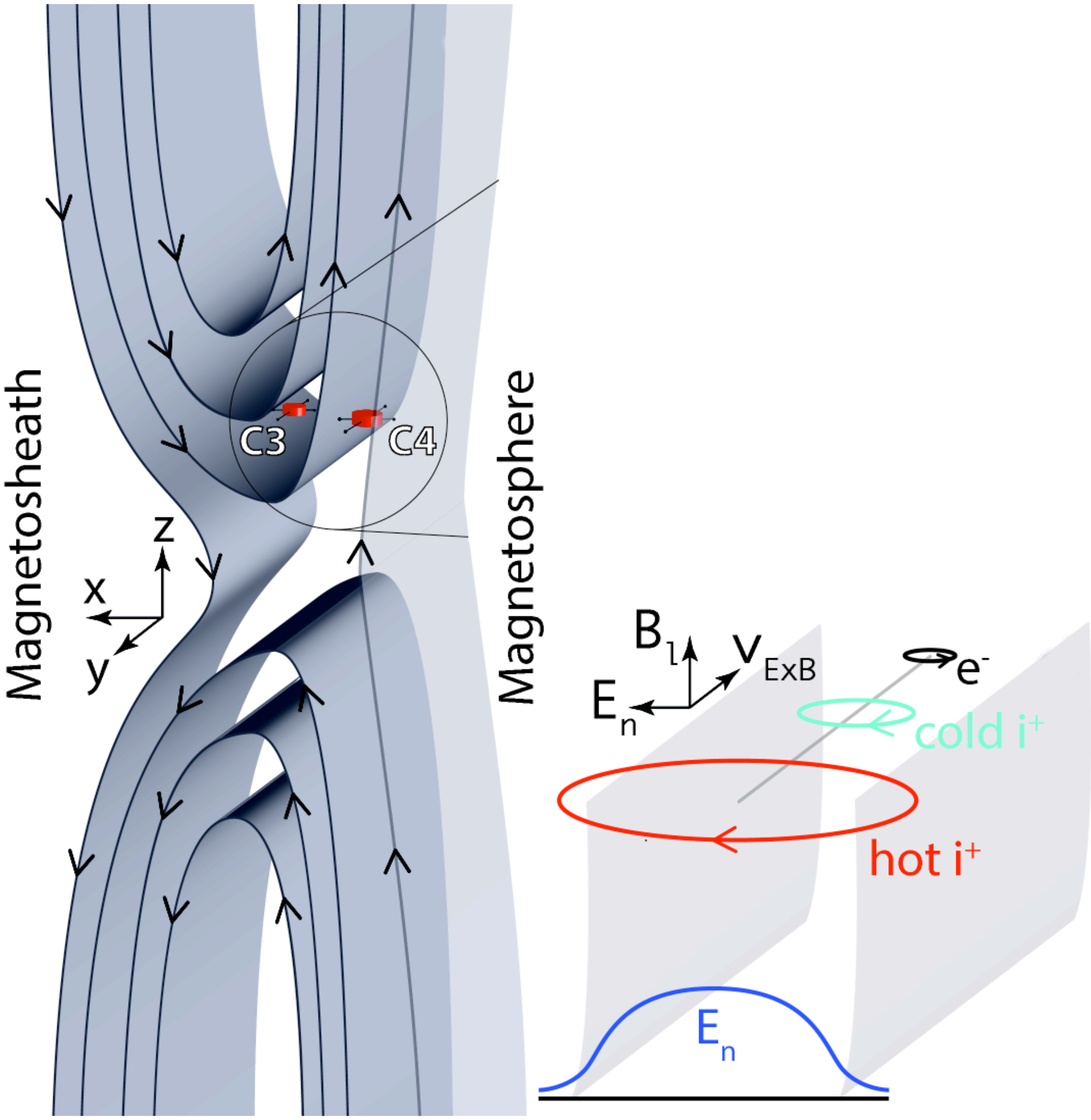
Low-energy ions observed by Cluster:
Percentage of time low-energy ions dominate, approximate density and outflow rate.

The global outflow is of the order of 10^{26} ions/s, increasing with solar EUV (increasing density of the outflow) and with magnetospheric activity (increasing polar cap area).

Database
Nightside: Cluster 1 and 3, 2001-2010
Dayside: Cluster 3, 2006-2009

(André and Cully, GRL, 2012;
André et al., JGR, 2015)

Reconnection at the magnetopause

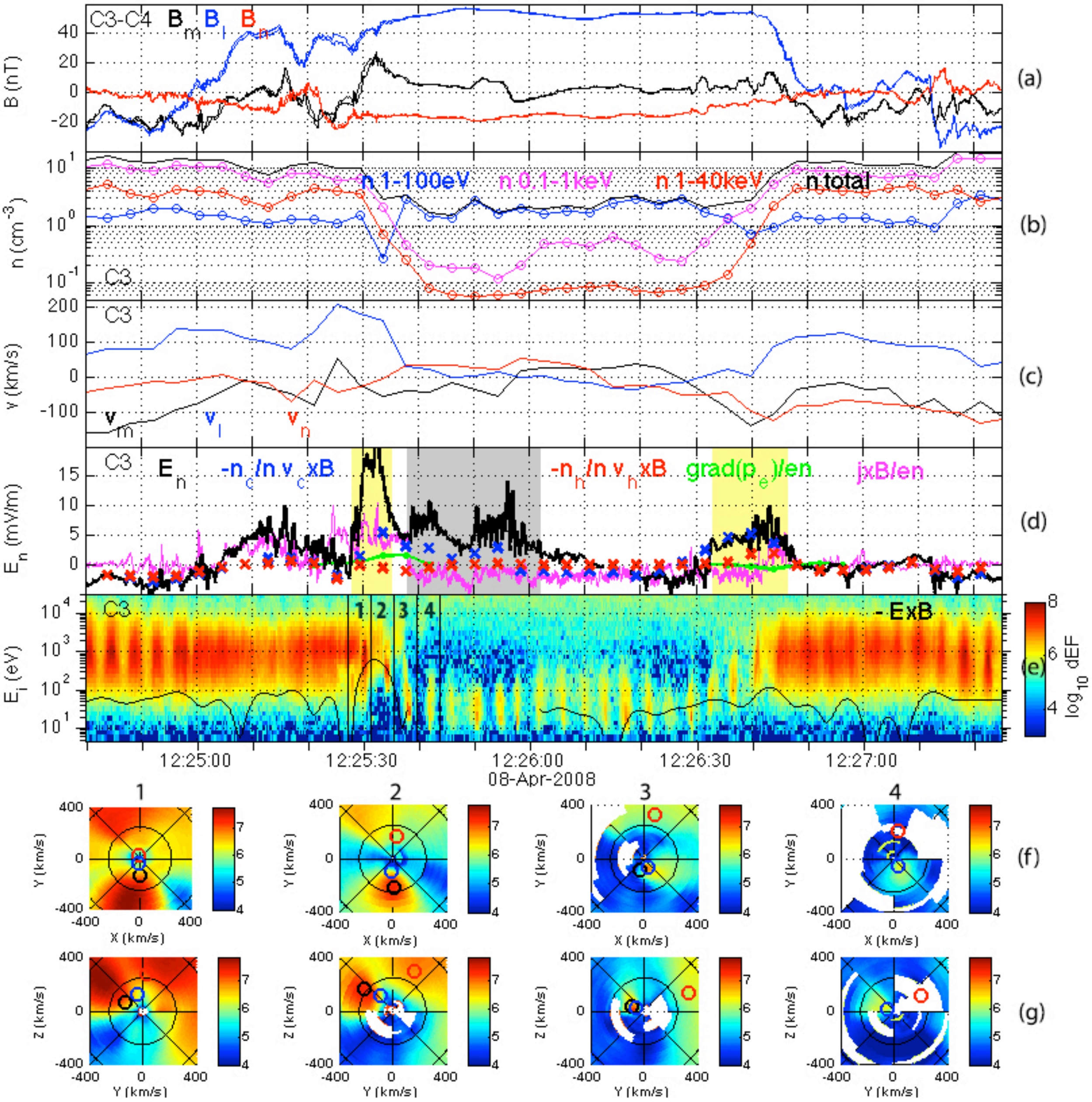


Three length-scales in narrow (separatrix) current layers:
Hot ions (not magnetized)
Cold ions and electrons (both magnetized)

The cold ions can E×B drift together with the electrons, and partly cancel the Hall currents.

(Toledo-Redondo et al, GRL, 2015; André et al, GRL, 2010)

Reconnection at the magnetopause



Cluster subsolar magnetopause crossing.

Panel d: Normal component of the electric field E_n and the balancing terms $(j \times B/en)_n$ (electrons) and $-(v_c \times B)_n$ (cold ions) in Ohm's law. Both terms contribute to E_n in narrow regions (yellow).

(Toledo-Redondo et al, GRL, 2015)

Conclusions

Low-energy ions are common at the magnetopause. In reconnection, these ions significantly modify the microphysics related to the Hall effect.

Low-energy ions introduce a new length-scale, between the scales of electrons and hot ions. In narrow regions the cold ions can E×B drift together with the electrons. They can partly cancel the Hall currents and can partly balance E_n.

Adding low-energy ions will change the microphysics of reconnection. In addition, a lower Alfvén speed will lower the reconnection rate.

The effect of adding cold ions (small gyroradius) is somewhat similar to the effect of adding heavy ions (large gyroradius), both modifications introduce a new length-scale.

Some references

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