Spacecraft Observation of a Central Engine of Magnetic Reconnection

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Magnetic reconnection is a driver of explosive events in space and astrophysical plasmas. It has been thought that the reconnection process is controlled by magnetic dissipation physics in a small-scale region near the reconnection point (X-line). In other words, the dissipation region plays a role as a central engine of magnetic reconnection. Although it was not clearly defined before, recent theory suggests that the dissipation region is best identified by a frame-independent dissipation measure [1].

In the Earth's magnetosphere, spacecrafts have observed reconnection events for many years. Such "in-situ" measurements have provided key information for reconnection theories. So far, there has been no clear observation of the dissipation region, mainly because the present instruments can hardly resolve the small dissipation region whose typical size is 1000 km × 100 km.

The Geotail spacecraft, developed by JAXA/ISAS in collaboration with NASA, has been observing the Earth's magnetosphere since 1992. On 15 May 2003, it encountered a reconnection event in the night side of the magnetosphere [2]. This is the best reconnection event in 20 years of Geotail observation. The top panel in Figure 1 shows selected Geotail data during the event [3]. Both an ion flow (blue) and an electron flow (red) reverse their directions, and electrons are outrunning ions. This is a signature of reconnection jets from the X-line. The gray histogram shows an approximate form of the energy dissipation,

$$D_e^* = j_x(\vec{E} + \vec{v}_e \times \vec{B})_x + j_y(\vec{E} + \vec{v}_e \times \vec{B})_y, \quad (1)$$

which is useful in this specific configuration [3]. As indicated by the arrow, there is a characteristic structure with energy dissipation at the plasma jet reversals. The picture is qualitatively similar to one in a kinetic simulation, as shown in the bottom panel in Figure 1.

We extensively check our dataset, including raw instrumental data of the electric field. We confirm that several possible factors such as an offset in E_x do not change the picture around the jet reversal. Therefore, although our resolution is quite limited, we are convinced that the Geotail encountered the dissipation region. To our knowledge, this is the first clear detection of the dissipation region of magnetic reconnection in the planetary magnetotail.

In 2014, NASA will launch magnetospheric multiscale (MMS) satellites to directly probe reconnection sites with ultra-high-resolution instruments on four spacecrafts. When the spacecrafts will encounter the dissipation region, we will hopefully be able to identify it by using our diagnosis. The high-resolution data of the dissipation region will be transferred to the ground with the highest priority, and then it will provide key information about the breaking mechanism of magnetic field lines.

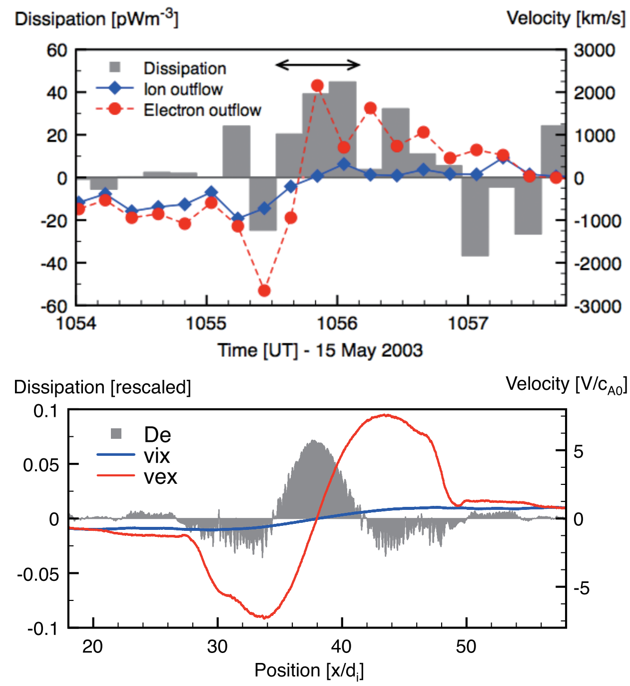

Figure 1: (Top) Geotail observation from 1054:00 UT to 1057:45 UT on 15 May 2003. The outflow component of the perpendicular ion (blue) and electron (red) velocities, and the approximate dissipation measure D_e^* (Eq. 1) are presented. (Bottom) The same quantities in a 2D kinetic simulation. 1D cut along the outflow direction.

References

[1] Zenitani, S., et al.: 2011, *Phys. Rev. Lett.*, **106**, 195003.
[2] Nagai, T., et al.: 2011, *J. Geophys. Res.*, **116**, A04222.
[3] Zenitani, S., et al.: 2012, *Geophys. Res. Lett.*, **39**, L11102.