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Geotail Observations of Thin Current Sheets in the Magnetotail: A Review

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The formation of a thin current sheet, in which particle inertial effects are significant, is believed to be essential for initiation of magnetic reconnection in collisionless plasmas. GEOTAIL observations have revealed that extremely thin current sheets are really formed in the Earth's mid-tail region in the late growth phase to the expansion onset of a substorm. The cross-tail current density is significantly intensified, and the estimated thickness becomes several hundreds of km, comparable to the ion inertial length, where ions are decoupled from electrons. One of the most significant findings is that the intense current sheet is bifurcated from the neutral sheet and forms a double-peaked structure. Near the near-Earth neutral line, the Hall current system into/out of an X line caused by a large separation between ion and electron motions is fully identified. In spite of single-point observations, these and other important results from GEOTAIL are due largely to the success in direct estimation of the current density from both ion and electron moments, leading to identification of current carriers. The intense current is mainly carried by fast dawnward moving electrons associated with the strong ambipolar electric field toward the neutral sheet. Ion dynamics in the thin current sheet is well understood, but electron dynamics and the cross-scale coupling remain unresolved due to the lack of time resolutions of the GEOTAIL measurements and the single-point observations. In Japan, we are planning a future magnetospheric mission called SCOPE (Scale COupling in Plasma universE) with very high time resolutions and multi-satellite observations. International collaborations are highly expected.