Magnetic Reconnection, Buoyancy and Flapping Motions in Magnetotail Explosions: Theory, observations and 3D full-particle simulations

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Magnetotails accumulate energy of the solar wind-magnetosphere interaction and then explosively release it. The most plausible mechanism of explosions is reconnection of magnetic field lines that are almost antiparallel in the tails. However, tail configurations, which have a potential for spontaneous reconnection, also facilitate interchange motions of sharply curved flux tubes. The magnetic tension in those tubes creates an effective gravity force, and a Rayleigh-Taylor-type instability becomes possible when sufficient magnetic flux is accumulated in the tail. Multi-spacecraft observations of Earth's magnetotail show signatures of both reconnection and interchange motions. They also reveal strong north-south oscillations of the tail plasma sheet making it similar to a flapping flag, with an important and puzzling distinction from the latter in that the magnetotail flapping waves propagate almost normal to the Sun-Earth direction. Understanding roles of these different plasma motions in magnetotail explosions requires three-dimensional plasma simulations taking into account kinetic effects of particle motion. Simulations show, that hat sufficiently far from the planet explosive processes in the tail are dominated by reconnection motions. These motions occur in the form of spontaneously generated dipolarization fronts accompanied by changes in magnetic topology which extend in the dawn-dusk direction over the size of the simulation box, suggesting that reconnection onset causes a macro-scale reconfiguration of the real magnetotail. Buoyancy and flapping motions significantly disturb the primary dipolarization front but neither destroy it nor change the near-2D picture of the front evolution critically. Consistent with recent multi-probe observations, dipolarization fronts are also found to be the main regions of energy conversion in the magnetotail.