Multi-dimensional superposed-spoch analysis of Earth's magnetotail with Geotail data and implied model of substorm

Shinobu Machida[1]; Yukinaga Miyashita[2]; Akimasa Ieda[3]; Daisuke Nagata[4]; Kan Liou[5]; Tsugunobu Nagai[6]; Takahiro Obara[7]; Yoshifumi Saito[8]; Hajime Hayakawa[9]; Toshifumi Mukai[10]; Atsuhiro Nishida[11]
[1] Dept. of Geophys., Kyoto Univ.; [2] ISAS/JAXA; [3] STEL, Nagoya Univ.; [4] Dept. of Geophysics, Kyoto Univ.; [5] JHU/APL; [6] Tokyo Institue of Technology; [7] NICT; [8] ISAS; [9] ISAS/JAXA; [10] JAXA; [11] Grad. Univ. Advanced Studies

http://www-step.kugi.kyoto-u.ac.jp/~machida/

Time development of near-Earth magnetotail during substorms has been investigated by multi-dimensional superposed-epoch analysis with Geotail data. The start time of each substorm was determined by auroral data obtained by Polar and Image spacecraft. Key parameters derived from plasma and magnetic field data of Geotail were sorted in the meridional X(GSM) - Z(proxy) coordinates.

The result shows that the earthward flows exist in the plasma-sheet boundary layer of -20Re >X >-30Re prior to the substorm onset. The Poynting flux toward the plasma sheet center also enhances in the lobe region of -10Re >X >-15Re. Interestingly, earthward flow in the central plasma sheet of -13Re >X >-20Re starts about 4 min before the onset. A weak dipolarization starts at around 4 min prior to the onset at X = -10 Re as well. After t = 0, i.e., the auroral break-up, a notable dipolarization and the tailward flows with southward magnetic fields of plasmoid start. The earthward flows are accompanied by the increase of Bz, and the flow breaking occurs at X ~-14 Re. The initial location of the total pressure decrease, i.e., the rarefaction region is in the central plasma sheet around X = -16Re and seems to be created from t ~-4 min. And, this variation propagates to the surrounding regions. The tailward propagation is leaded by the front characterized by total pressure enhancement.

We could confirm various variations which relevant models of substorm are based on or predict. However, none of them can perfectly explain our results. Thereby, we propose a new model called slingshot current relaxation model, in which the Poynting flux toward the plasma sheet center enhances the cross-tail current resulting in excitation of large amplitude electromagnetic waves in the central plasma sheet. Also, an earthward convective flow due to the enhanced JxB force starts in a very limited region about 4 min before the onset. This flow can enhance the occurrence possibility of the ballooning instability or other instability associated with the current disruption, or the current disruption induces the fast earthward flow by the reduction of the pressure gradient force at the earthward edge of the stretched current sheet in turn. The formation of the magnetic neutral line is a natural consequence of the present model, namely, the relaxation of a highly stretched sling-shot current sheet produces the enhanced duskward electric field first followed by dawn-dusk fluctuations at its tailward edge, which is the boundary between the sling-shot current with large stress and the Harris-type current sheet with less stress. Further, induced flows toward the current sheet center around the boundary may enhance the formation of the magnetic neutral line and the efficiency of the magnetic reconnection.