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サブストーム発生時のプラズマシートにおける酸素イオンの加速と輸送過程
Oxygen ion acceleration and transport in the near-Earth plasma sheet during an isolated substorm

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Rapid enhancements of energetic ions during a substorm are one of the unsolved issues in the inner magnetospheric research (<7 Re). Previously, two distinct processes have been suggested to explain the enhancements. The first one is transport from the near-earth plasma sheet, and the other one is local acceleration. To test the both process, we performed test particle simulation under the electric and magnetic fields that are self-consistently obtained by the global MHD simulation developed by Tanaka et al. (2010, JGR). Oxygen ions are released in the lobe region with an interval of 1 minutes. The distribution function in the lobe is assumed to be drifting Maxwellian. The temperature is assumed to be 20 eV, the density is 105 cm-3, and the parallel velocity is given by the MHD simulation. In total, a few hundreds of millions of particles are traced. Each test particle carries the real number of particles in accordance with the Liouville theorem. After tracing particles, we reconstruct 6-dimensional phase space density of the oxygen ions, as well as the directional differential number flux so as to be able to make a direct comparison with in-situ satellite observations. Just after a substorm onset, the differential flux of the ions is rapidly enhanced in the energy range from 50 to 150 keV at radial distance R greater than 7 on the nightside in the equatorial plane. The region of the enhanced flux propagates duskward, then to dayside because of grad-B and curvature drift of the ions. We also plotted energy versus time spectrograms of the differential flux at a fixed position to make a direct comparison with the CRRES satellite observation. At 7.2 Re and at 22.4 MLT, the ion flux is suddenly enhanced about 10 minutes after the onset. The enhancement appears first at 120 keV, followed by lower energy as time proceeds. The energy-time dispersion is similar to that observed by CRRES [Fu et al., 2002]. The steepness of the energy-time dispersion depends on the source location of the ions. After a while, a high energy ion flux appears first, followed by that at lower energies. This is a called a drift echo, arising from the ions that encircled the Earth by the grad-B and curvature drift. We will discuss the acceleration processes in more detail, the role of pre-existing ions, and the total kinetic energy of the oxygen ions and its dependence on the source distribution function in terms of the ring current development.

Reference:

Fu, S. Y., Q. G. Zong, T. A. Fritz, Z. Y. Pu, and B. Wilken, Composition signatures in ion injections and its dependence on geomagnetic conditions, J. Geophys. Res, 107(A10), 1299, doi:10.1029/2001JA002006, 2002.

Tanaka, T., A. Nakamizo, A. Yoshikawa, S Fujita, H. Shinagawa, H. Shimizu, T. Kikuchi, and K. K. Hashimoto, Substorm convection and current system deduced from the global simulation, J. Geophys. Res. 115, A05220, doi:10.1029/JA014676, 2010.