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Ion accelerations due to two approaching flow fronts: Application to high-energy ion production in the magnetotail

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In some cases, high-energy ions ($\sim$ MeV) are observed in the magnetotail during disturbed time of the magnetosphere. Such ions, however, cannot be produced by the duskward electric field in flows due to the limitation of the dawn-dusk scale length of the flows in the magnetotail. We propose that such high-energy ions can be produced if there exist two flow fronts which approach together by ExB drift. Namely, some ideal ions are repeatedly reflected by the two fronts and accelerated to high energies exceeding the energy given by the product of the duskward electric field and dawn-dusk scale length of the flows.

By performing spatially 1-D (2-D in velocity) test particle simulations where we assumed a couple of approaching ExB-drift flows, we have confirmed the production of high-energy ions as well as the change of the energy spectrum of ions associated with the acceleration. The simulation result shows that such high-energy ions are produced with scale length shorter than the magnetotail diameter. Furthermore, we find that the maximum energy of the accelerated ions depends on the distance of the two flow fronts and the dawn-dusk scale lengths of the flows. If the dawn-dusk scale length is infinite, the energy spectrum of accelerated ions is well fitted by the analytically calculated spectrum. Our simulation results and analytical calculation indicate that the distance and dawn-dusk scale length of two flow fronts can be estimated from the observations of electromagnetic field and flow speed, the maximum ion energy and the change of the energy spectrum of ions in the magnetotail, where such two approaching flow fronts commonly exist.

Keywords: magnetotail, high-energy ion, substorm