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Simulation Study on Generation Mechanism of Electron/Ion Holes in Space Plasmas

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In recent spacecraft observations, it has been found that a variety of coherent potential structures exist along magnetic field lines of various regions of the magnetosphere. We assume that some of coherent potential structures are electron holes and ion holes corresponding to positive solitary potentials and negative solitary potentials, respectively.

We performed one-dimensional electrostatic particle simulations of the Buneman instability, which occurs when beams of electrons and ions have a relative drift velocity. We used the real ion/electron mass ratio and performed simulations with boundaries are periodic boundaries and open boundaries. We varied thermal velocities of electrons and ions, and found that nonlinear evolution are mainly classified into two potential structures. One is an electron hole, other one is an ion hole. It is also found that electron holes and ion holes coexist and interfere with each other under some conditions.

In the present study we first calculated linear growth rates and phase velocities in order to study dependence of the instability on the thermal velocities of ions and electrons in detail. The difference of nonlinear evolutions depends not only on the thermal velocities of beams but also on the maximum growth rate and the phase velocity of the waves at the initial stage. Especially, the phase velocity is an important parameter which determines characteristics of interaction between the waves, electrons and ions. It affects the final states of nonlinear evolutions significantly.

The electron holes are generated through coalescence of waves generated at the initial state. This mechanism is the same as found in a two-stream electron instability or bump-on-tail instability. On the other hand, the generation mechanism of ion holes is different from that of electron holes. At first, a double layer potential is formed at some local position in the system. A negative potential becomes gradually bigger at the boundary of the layer. Finally, the potential grows to trap ions, resulting in an ion hole in the velocity phase space of ions.

The ion hole is unstable and disappears after a time. New double layer potential is generated at other local position after the disappearance, then an ion hole appears again. The process repeats in the simulation system. While the negative potential exists, some electrons are reflected by the potential and excite a two-stream instability with non-reflected electron. We will present detail analyses of electron and ion dynamics related to the generation of double layers and ion holes.