Coherent Potential Structures Induced by Electron/Ion Beam Instabilities in Plasmas

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We performed electrostatic particle simulations with beams of electrons and ions.
In the presence of beams of electrons and ions with a relative drift velocity, there occurs the Buneman instability.
We varied thermal velocities of electrons and ions, and found that nonlinear evolutions of the instability are very different depending on these parameters. A large sinusoidal potential is formed initially by the instability, and it traps the electrons and ions, depending on the magnitude of the potential and the thermal velocities of beam electrons and beam ions. Trapping of electrons and ions leads to formation of isolated potentials called electron holes and ion holes, respectively.

Recent spacecraft observations show that a variety of coherent potential structures exist along the magnetic field lines in various regions of the magnetosphere. In order to find possible generation mechanisms of these potential structures, we performed electrostatic particle simulations with beams of electrons and ions.
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We varied thermal velocities of electrons and ions, and found that nonlinear evolutions of the instability are very different depending on these parameters. A large sinusoidal potential is formed initially by the instability, and it traps the electrons and ions, depending on the magnitude of the potential and the thermal velocities of beam electrons and beam ions. Trapping of electrons and ions leads to formation of isolated potentials called electron holes and ion holes, respectively. Under some conditions both electron and ion holes coexist, and they interfere each other. We classify the final states of these nonlinear evolutions, and clarify the necessary conditions for them.
Next we performed another set of simulation runs assuming two ion beams and one electron beam. The interaction of two streaming ion beams generates large potential structures, which traps the electron beam. In addition to the competing processes between electron and ion holes, we found a case where large potential structures are formed as a result of strong coupling of electron and ion holes.
A variety of coherent potential structures can result from these electron/ion beam instabilities in a simple model of one-dimensional electrostatic system with periodic boundaries. Their spatial structures and stability can be different depending on the dimensions and boundaries of the simulation system.