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ORIGINAL ARTICLE

The electron-ion streaming instabilities driven by drift velocities of the order of electron thermal velocity in a nonmagnetized plasma

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Abstract We examine the electron-ion streaming instabilities driven by drift velocities of the order of the electron thermal velocity in a nonmagnetized plasma by using one-dimensional electrostatic particle-in-cell code which adopts an ion-to-electron mass ratio of 1600. An initial state is set up where the ion bulk speed is zero while the electrons drift relative to ions, and where electrons are much hotter. We examine in detail four runs where the drift velocity is systematically varied from lower than to larger than the electron thermal velocity. In all runs the Langmuir waves with Doppler-shifted frequencies dominate early on when streaming instabilities are too weak to discern. And then intense ion-acoustic waves or Buneman instabilities appear, which tend to be accompanied by localized electron and ion beams. Ion-acoustic modes and Buneman modes co-exist in the system when the initial drift velocity is just over the electron thermal speed. Beam modes are excited when localized beams with large enough velocities appear. In the developed stage of instabilities, the direction in which density depressions propagate is always opposite to that of the localized ion beams. When the initial drift velocity is close to the electron thermal speed, categorizing the relevant instabilities is not easy, and one needs to examine in detail the wave dispersion diagrams at various stages of the evolution of the system.

Keywords Electron-ion streaming instability · Particle-in-cell simulation

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1 Introduction

The electron-ion two-stream instability has been subject to extensive research for a long time (e.g., Bohm and Gross 1949; Buneman 1959; Kellogg and Liemohn 1960; Bernstein and Kulsrud 1961). A collective dissipation mechanism in space plasmas, the behavior of this instability is largely dictated by the relative electron-ion streaming u_0 measured in units of the electron thermal speed v_{the}. When u_0/v_{the} is sufficiently less than unity, the electron-ion instability belongs to the ion-acoustic type, whereas when u_0/v_{the} far exceeds unity, it turns into the Buneman instability, which becomes unstable when a current flows across a plasma (Yoon and Umeda 2010).

The electron-ion two-stream instability has significant bearings on such important subjects in plasma physics as anomalous resistivity, electron holes and double layers, to name but a few. For instance, in collisionless space plasmas, anomalous resistivity plays an important role for magnetic reconnections. Using a finite difference approximation to the Vlasov-Maxwell equations, Petkati et al. (2003, 2006) found that the ensemble mean of the ion-acoustic resistivity during the nonlinear regime is higher than estimates at quasi-linear saturation. In magnetic reconnections with a guide field, the Buneman instability produces electron holes, and the associated electron scattering off the holes enhances electron heating in the dissipation region (Che et al. 2009, 2010). Found