On the Formation of Ion Acoustic Waves and Double Layers in the Electron Foreshock Region

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Large amplitude electrostatic waves have been observed in the electron foreshock region upstream from the planetary bow shocks, interplanetary shocks, and the solar wind termination shock. The observed electrostatic waves include electron acoustic waves, ion acoustic waves, and double layers. Based on the linear instability analysis, only the electron acoustic waves are expected to be found in the electron foreshock region. Since the electron acoustic waves are electron-time-scale phenomena, but the ion acoustic waves and the double layers are ion-time-scale phenomena, it is in need of a reliable cross-scale simulation code to simulate the cross-scale evolution of the nonlinear electrostatic waves in the electron foreshock region. A low-noise Vlasov simulation code is developed to simulate the cross-scale evolution of the electrostatic waves and the potential jumps in the collisionless plasma. Our simulation results indicate that the boundary between hot and cold electrons always leads to formation of electrostatic potential jump. Depending on the propagation speed of the potential jump with respect to the ambient ions, the potential jump can turn into an electrostatic shock, or a contact discontinuity, or a double layer. Our simulation results indicate that the gentle potential gradient in the upstream foot region of an electrostatic shock can accelerate electrons and result in ion-electron two-stream instability. The large-amplitude ion acoustic waves generated by the ion-electron two-stream instability can lead to localized electron heating, which can modify the electron temperature profile and turn the ion acoustic wave into a double-layer-like structure in the upstream region of the electrostatic shock. A comparison between the simulation results and observations will be addressed.

Keywords: Shock Wave; Double Layer; Ion Acoustic Wave; Electron Acoustic Wave; Electron Foreshock; Vlasov Simulation;