Particle trapping and ponderomotive processes during breaking of ion acoustic waves in plasmas

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The recent fluid simulation revealed that the ponderomotive potentials and ponderomotive frequencies of electrons and ions can be used as proxies to identify the steepening and breaking of the ion acoustic solitary waves (IASWs) in plasma. However, the behavior of these proxies may get modified in the presence of kinetic effects such as particle trapping. In the present study, we performed one-dimensional particle-in-cell (PIC) simulations to examine the effects of the kinetic processes on the behavior of these proxies at the breaking of IASWs in plasma. The electron and ion equilibrium densities were superimposed by long-wavelength Gaussian type perturbation, which initially evolves into two IASW structures. These structures are observed as two phase space vortices due to the trapping of electrons in the ion acoustic (IA) potentials. The IASW structures grow due to the steepening of their trailing edges, and later they break to form a chain of IA phase space vortices. Each of these vortices is associated with bipolar electric field resulting positive potential structure. We estimated the amplitude, width and the phase speed of the IASWs at their breaking process to examine their link with the trapping velocity. In addition, we computed the electron and ion ponderomotive potentials and frequencies from the PIC simulations to verify their applicability in identifying wave breaking limit, under the kinetic regime. The present study shows that the behavior of the ponderomotive potential during the IA wave breaking process is similar to the one which is proposed through fluid simulations. We find that IA wave breaking occurs when the maximum trapping velocity of the electron (Vtrap+Vs) exceeds its thermal velocity. A present simulation study shows that both maximum electron trapping velocity and ponderomotive potential can be used to identify the IA wave breaking processes in plasmas.