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Generation of Electrostatic Solitary Wave Structures Through Wave breaking Process and Their Dynamics in Plasmas

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Wave breaking is a ubiquitous nonlinear phenomenon in plasmas that is followed by a sudden drop of wave amplitude after a wave steepening. Detecting such a process with the help of spacecraft is practically challenging in space plasma environments. We perform fluid and particle-in-cell simulations of the generation of ion acoustic solitary waves (IASWs) through wave breaking [Kakad and Kakad, 2016; Kakad et al, 2017a; Kakad et al, 2017b]. Our simulations demonstrate that a long wavelength perturbation (IDP) in electron and ion equilibrium densities generate two long wavelength IASWs that break and further evolved into multiple short wavelength stable solitary wave structures as shown in Fig.1 [Kakad and Kakad, 2016; Kakad et al, 2017b]. From the detailed analysis of the simulation output, we accomplish the novel criteria to identify steepening and breaking of the IASWs based on the ponderomotive potential and ponderomotive frequencies of electrons and ions. These new proxies show similar characteristics in both fluid and PIC simulations. Our particle-in-cell simulation demonstrates local electron acceleration in the course of wave breaking and during multiple interactions of the IASWs [Kakad et al, 2017a]. The new criteria for identifying steepening and breaking of waves will be useful in studying the wave breaking process in space and laboratory plasmas.

References:

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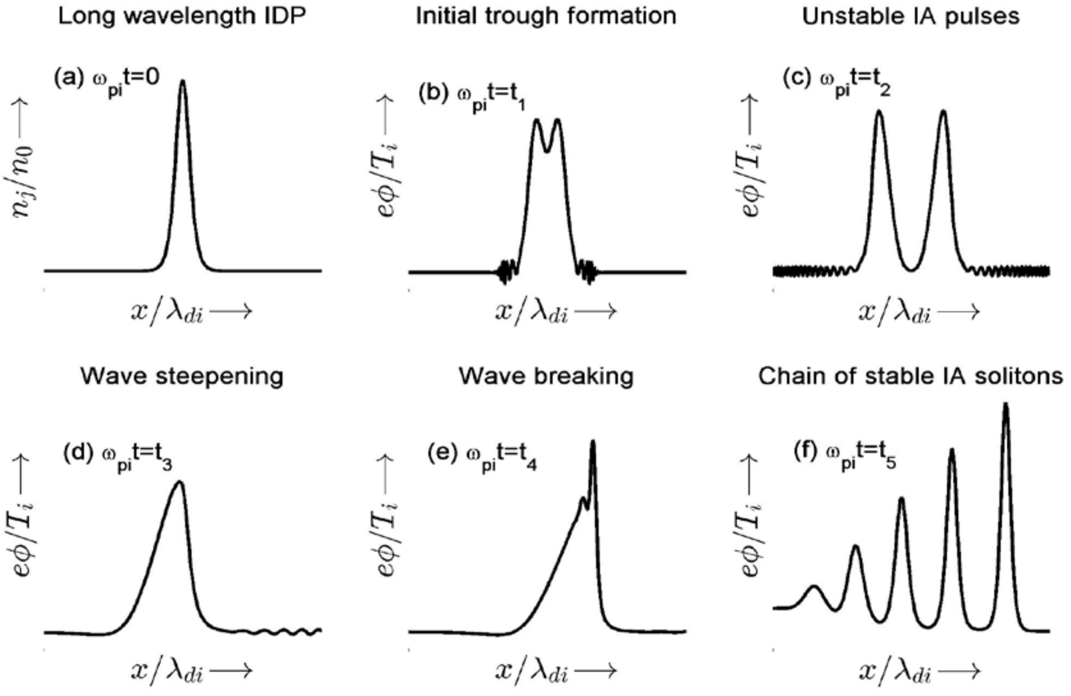

Fig. 1: Schematic diagrams illustrate some of the stages during the evolution of chains of multiple IASWs through wave breaking in the fluid simulation. (a) The perturbed densities $n_j(x)$ in the simulation at $\omega_{pi}t=0$. (b) The perturbation introduces the finite electrostatic potential in the system. The formation of trough observed at the top of this potential pulse at $\omega_{pi}t=t_1$. (c) Two long wavelength IASW pulses along with the Langmuir wave packets are formed in the system at $\omega_{pi}t=t_2$. (d) The trailing edge of both pulses steepens at $\omega_{pi}t=t_3$. One of such pulse is shown in this panel. (e) After steepening, the IASW pulse breaks at $\omega_{pi}t=t_4$. At this stage, the short wavelength pulses developed at the topside of the IASW pulses. (f) The short wavelength pulses later evolved into stable IASW structures [Kakad and Kakad, 2016].