Formation and dynamics of solitary waves in plasmas

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Solitary waves are small-scale structures in plasma that represent holes in the electron/ion phase space or density enhancements and depletions, depending on whether they are Bernstein-Greene-Kruskal (BGK) structures generated by a beam, two-stream, or kinetic Buneman type of instability or an electron/ion acoustic mode generated by an electron/ion acoustic instability. They are abundantly occurred as an isolated or series of localized bipolar electric field pulses with significant parallel components to the background magnetic field and are detectible in high-resolution electric field measurements. These waves can efficiently accelerate low-energy electrons up to keV energies [1], which makes them as one of the vital components of particle acceleration.

The fluid and kinetic models are frequently used to investigate the formation and dynamics of solitary waves observed in the laboratory [2] and space plasmas [3]. While a fluid treatment offers macroscopic processes involved in their generation [4, 5], a kinetic treatment provides the possibility of microscopic plasma behaviour [6, 7] including the wave-particle interactions [8, 9]. We present a detailed insight into the solitary waves through the novel theories of electron holes [7, 8] and ion holes [9] in thermal and nonthermal plasmas. Furthermore, we review the recent fluid and kinetic simulations that can describe the formation and dynamics of the solitary waves in plasma. These simulations have revealed that the wave breaking process is responsible for the generation of series of solitary waves [4, 5]. Allowing multiple interactions between the solitary waves, we find the local electron acceleration in plasma [10], which is a new mechanism proposed for particle acceleration in plasma.

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