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Excitations of Cylindrical and Spherical Pinned Solitons in a Flowing Dusty Plasma Medium: Experimental and Simulations Studies

Prasanta Amat[1], Krishan Kumar[2], Pintu Bandyopadhyay[1], and A. Sen[1]
[1] Institute for Plasma Research, A CI of HBNI, Bhat, Gandhinagar, Gujrat, India, 382428,
[2] West Virginia University, Morgantown, West Virginia 26506, USA
e-mail (speaker): prasanta.amat@ipr.res.in

Excitations of nonlinear structures, ahead of a solid object, in a fluid are spectacular phenomena that have been known for some time in hydrodynamics These nonlinear excitations get triggered in the upstream direction when the solid object either moves through a stationary medium or the fluid moves over a stationary object with supersonic velocity. Over the past few years, comprehensive experimental studies have been performed to investigate the excitations of precursor and pinned solitons in a dusty plasma medium [1, 2, 3]. In this work, we report the experimental and simulation studies of the excitations of cylindrical and spherical pinned solitons in a flowing dusty plasma medium. The experiments are performed in an inverted Π-shaped dusty plasma experimental (DPEx) device [4]. A DC glow discharge Ar plasma is created between a circular anode and a tray-shaped cathode and the dusty plasma is formed using micron-sized Kaolin particles. For the excitations of cylindrical and spherical solitons, the cylindrical and spherical charged objects are placed on the cathode, and the dust fluid is made to flow over these charged objects with supersonic velocity using a single gas injection technique [5].

For a particular range of supersonic velocities, the nonlinear cylindrical (or spherical) stationary structures are excited in front of the object and remain attached to it (hence called pinned solitons). A space-time diagram is shown in Fig. 1, confirming that the generated wavefronts remain stationary in the laboratory frame or pinned in the fluid frame. It is also found that the soliton parameter, namely, the product of amplitude and square of the width of the soliton, remains constant over time. A 3D molecular dynamics simulation is carried out with Yukawa interparticle interaction and has the equilibrium parameters close to experimental values for providing a strong first principles foundation to our experimental observations.

References

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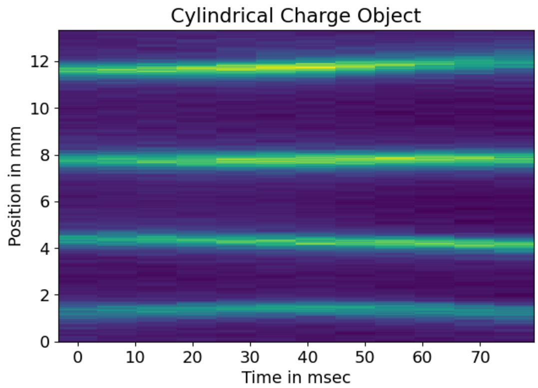

Fig. 1: The periodogram plot of pinned solitons. The intense lines indicate the spatio-temporal evolution of solitons. Each line remains parallel to the time-axis essentially confirming that the solitons are pinned in nature.