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Nonlinear Precursor Waves from a Moving Charged Object in a Plasma

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1 Extended Abstract

A charged object moving in a plasma can excite a trailing wake of electrostatic or electromagnetic waves much like a boat moving on the surface of a lake creates wake structures behind it. However, a fast moving boat traveling more rapidly than the phase velocity of the surface water wave can also emit nonlinear waves ahead of it in the form of *precursor* solitons or shock structures. Such a phenomenon of fore-wake excitations has been widely studied in hydrodynamics and precursor structures have also been experimentally observed in a number of laboratory studies of model ships being towed in a channel [1, 2, 3]. In principle, a similar phenomenon can also occur in a plasma medium when the charged object moves at a supersonic velocity (e.g. with respect to the ion acoustic speed, Alfven speed etc) and one can expect to see nonlinear structures moving ahead of the object. The conditions for such excitations exist naturally in many space plasma situations, e.g. the interaction of the supersonic solar wind component with the earth or moon, the fast streaming of space craft or charged debris objects interacting with the plasma in the ionosphere etc. Recently a proof-of-principle laboratory experiment observed the excitation of upstreaming dust acoustic solitons when a dusty plasma was made to flow supersonically over a stationary electrostatic potential hill [4]. The experimental results have been well validated by model calculations based on a forced Korteweg-de Vries (fKdV) equation [4] as well as fluid [5] and molecular dynamic simulations [6]. In this talk, the basic concept of nonlinear precursor waves and a review some of these past theoretical and experimental works related to this idea will be presented, followed by a discussion on some potential applications of precursors such as for Space Situational Awareness (SSA) purposes [7]. The basic idea is that multiple emissions of precursor solitons by moving space debris in the ionosphere can create a cloud of plasma irregularity that may be easily detectable from the earth and act as a tracking aid for the debris. The conditions for the excitation of electrostatic (ion-acoustic) as well as electromagnetic (magneto-sonic) structures in the LEO region will be delineated and their relative merits discussed. The possibility of identifying such structures in existing ionospheric satellite data as well as the feasibility of detecting them in a laboratory setup will also be presented.

References

[1] D. B. Huang *et al*, "Ships moving in the transcritical range", *Proc. Conf. on Behavior of Ships in Restricted Waters*, **2**, Varna, Bulgarian Ship Hydrodynamics Center, pp. 26-1-26-10 (1982).

[2] Akylas, T. R., "On the excitation of long nonlinear water waves by a moving pressure distribution", *J. Fluid Mech.*, **141**, 455-466 (1984).

[3] S.-J. Lee, G. T. Yates, and T. Y. Wu, "Experiments and analyses of upstream advancing solitary waves generated by moving disturbances", *J. Fluid Mech.*, **199**, 569 (1989).

[4] Surabhi Jaiswal, P. Bandyopadhyay, and A. Sen, "Experimental observation of precursor solitons in a flowing complex plasma", *Phys. Rev. E*, **93**, 041201(R) (2016).

[5] Sanat Kumar Tiwari and Abhijit Sen, "Wakes and precursor soliton excitations by a moving charged object in a plasma", *Phys. Plasmas*, **23**, 022301 (2016).

[6] Sanat Kumar Tiwari and Abhijit Sen, "Fore-wake excitations from moving charged objects in a complex plasma", *Physics of Plasmas*, **23**, 100705 (2016).

[7] Abhijit Sen, Sanat Tiwari, Sanjay Mishra, and Predhiman Kaw, "Nonlinear wave excitations by orbiting charged space debris objects", *Advances in Space Research*, **56**, 429âĂŞ435 (2015).