Electrostatic Solitary Waves in Space Plasmas: from Fundamental Modeling to Observations

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Space plasmas have always been considered as excellent testbeds of nonlinear models, thanks to their rich dynamical behavior and a wide variety in their composition. It is an established fact by now, thanks to electric field and particle density measurements by instruments onboard various space missions, that planetary magnetospheres for instance may host localized electrostatic waveforms (solitary waves) propagating along the magnetic field lines. In their most usual form, Electrostatic solitary waves (ESWs) are a common ubiquitous occurrence in space observations [1, 2]. In planetary magnetospheres, their typical signature is a bipolar E-field structure associated with a pulse-shaped excitation in the electrostatic potential and a localized disturbance in the plasma state properties (particle density, fluid speed, pressure) moving at speeds exceeding the plasma sound speed [2, 3]. Such structures, long known to occur e.g. in the terrestrial Earth's magnetosphere [4], were recently detected in MAVEN data from Mars's induced magnetospheric region [5], among other environments.

In this lecture, I will provide an overview of the fundamental modeling of electrostatic nonlinear structures in non-Maxwellian Space plasmas [6] and will discuss the associated challenges. Topics to be covered include electrostatic solitary waves in [1-5], supersolitons [7] and flat-top solitary waves [3]. I will discuss the underlying mechanisms involved in the formation and propagation of these structures, and how these are manifested at different spatiotemporal scales in various plasma situations. In particular, I shall focus on non-Maxwellian planetary environments, where kappa-distributed electrons are observed, and on how suprathermal electrons statistics may affect the morphology and propagation characteristics of nonlinear waves.

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