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Electrostatic Solitary Waves in Space Plasmas: Recent Advancements and Applications in Planetary Magnetospheres

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This presentation aims to provide an overview of the current state of the art in research related with the formation and dynamics of electrostatic nonlinear structures in Space plasmas. Some of the topics to be covered include *electrostatic solitary waves* in non-Maxwellian Space (dusty) plasmas [1], supersolitons [2,3] and extreme wave events (freak waves) [4]. 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. Certain recent results [5-8], focusing on the interpretation of *E*-field waveforms observed in planetary magnetospheres, will be presented.

Localized electrostatic structures in Space plasmas are typically manifested in observations as bipolar E-field pulses, accompanied by co-propagating pulse-shaped localized density excitations. Asides the "standard" bipolar waveforms that were e.g. recently detected in MAVEN data from Mars's induced magnetosphere [5,9], these may feature different, rather counter-intuitive profiles, such as supersolitary waves [2, 3] and flat-top solitary waves [6, 8].

I shall focus on the distinction among different types of electrostatic structures and how it depends critically on the plasma composition, i.e. taking into account the multi-ion plasma environment present e.g. in the Martian upper layers of the magnetosphere, in addition to the coexistence of different electron populations with nonthermal distribution, originating from interactions with the solar wind [6, 8] or created by various electron acceleration mechanisms. The role of negative ions, in particular, will be shown to be crucial in determining the polarity of electrostatic structures, as well as the influence of suprathermal electrons on the morphology of nonlinear waves.

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References

[1] I. Kourakis, S. Sultana and M.A. Hellberg, Plasma Phys. Cont. Fusion, **54**, 124001 (2012).
[2] Frank Verheest, Manfred A. Hellberg and Ioannis Kourakis, Phys. Plasmas (AIP) **20**, 012302 (2013).
[3] Steffy S. Varghese, Kuldeep Singh & Ioannis Kourakis, Fundamental Plasma Physics, **10**, 100048 (2024).
[4] I. S. Elkamash, B. Reville, N. Lazarides & I. Kourakis, Chaos, Solitons and Fractals, **188**, 115531 (2024).
[5] Bharati Kakad, Amar Kakad, Harikrishnan Aravindakshan and I. Kourakis, Astrophysical Journal, **934**, 126 (2022).
[6] Steffy Sara Varghese, Kuldeep Singh and Ioannis Kourakis, Scientific Reports **12**, 18204 (2022).
[7] Kuldeep Singh, Steffy Varghese, N. S. Saini and Ioannis Kourakis, Astrophysical Journal, **971**, 25 (2024).
[8] Steffy Varghese, Kuldeep Singh, Frank Verheest and Ioannis Kourakis, Astrophysical Journal, **977**, 100 (2024).
[9] Scott. A. Thaller et al, J. Geophys. Res. (Space Physics), **127** (7), e2022JA030374 (2022).