9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Nonlinear waves in the Saturnian magnetosphere

Kuldeep Singh[1] and Ioannis Kourakis[1]

[1] Department of Mathematics, Khalifa University of Science & Technology, Abu Dhabi, UAE

e-mail (speaker): singh.kdeep07@gmail.com

Investigating nonlinear waves within planetary magnetospheres is vital for advancing our understanding of space plasma dynamics and the underlying processes governing wave-particle interactions in these vast, often unpredictable environments. Planetary magnetospheres like those of Earth, Jupiter, and Saturn engage in distinct interactions with solar wind and intrinsic magnetic fields, producing diverse plasma wave phenomena. Among these, nonlinear electrostatic solitary waves (ESWs) are particularly impactful, playing a central role in the transfer of energy and momentum within space plasmas and influencing plasma dynamics at various scales.

This talk will present findings on the occurrence, characteristics, and implications of ESWs observed across different magnetospheric regions. Our analysis shows that the unique characteristics of these localized waveforms correlate well—in magnitude with bipolar electric field pulses detected by multiple spacecraft missions, reinforcing the link between simulation/theoretical predictions and observational data [1-4]. Leveraging an advanced fluid simulation framework alongside rigorous theoretical modeling, we delve into the conditions necessary for the formation, propagation, and stabilization of solitary waves across various planetary environments.

In addition to enhancing our understanding of magnetospheric plasma behavior, the ability to simulate and analyze solitary wave behavior across diverse planetary bodies enriches our grasp of space plasma physics and strengthens our predictive capabilities for future spacecraft missions. Fig. 1 depicts the evolution of dust acoustic mode in the Saturnian magnetospheric plasma. This work ultimately sheds light on the intricate physics governing space plasmas, emphasizing the importance of nonlinear structures in various magnetospheric plasma environments [1-4].

Acknowledgments

The authors acknowledge the financial support from Khalifa University of Science & Technology via CIRA (Competitive Internal Research) grant CIRA-2021-064/8474000412.

References

[1] K. Singh, A. Kakad, B. Kakad, I. Kourakis, Astronomy and Astrophysics 666, A37 (2022).

[2] K. Singh, S.S. Varghese, F. Verheest, I. Kourakis, Astrophysical Journal 957, 96 (2023).

[3] K. Singh, F. Verheest, I. Kourakis, Astrophysical Journal 966, 203 (2024).

[4] K. Singh, S.S. Varghese, N.S. Saini, I. Kourakis, Astrophysical Journal 971, 25 (2024).

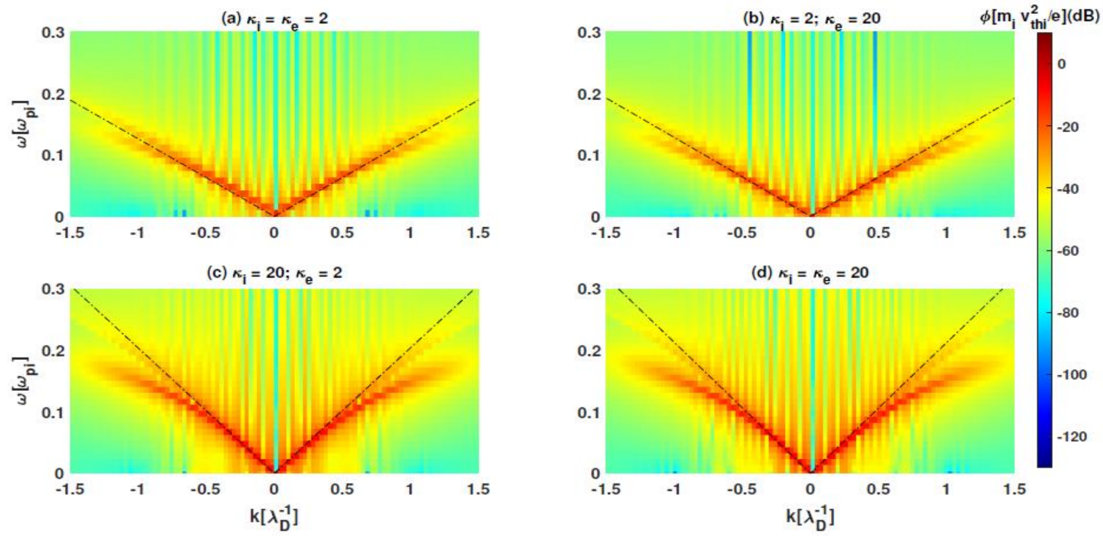

Figure 1. Frequency-wavenumber ($\omega - k$), based on the simulation runs for different values of the suprathermal indices of electrons and ions (κ_e and κ_i). The dashed black lines are plotted from the linear dispersion relation.