Experimental Measurement of Non-linear Coupling and Energy Transfer in Plasma Turbulence in a Hall Effect Thruster*

Zachariah A. Brown and Benjamin A. Jorns

University of Michigan, Aerospace Engineering (brownzac@umich.edu)

Hall thrusters are a form of crossed-field plasma device commonly employed for in-space electric propulsion. A strong magnetic field confines the lighter species of the plasma, electrons, which ionize the propellant, while an applied electric field accelerates the ions down-stream. Ideally, the electrons would be confined by the magnetic field, serving as an efficient ionization source. However, it has been found experimentally that electrons can cross field lines in these devices at rates orders of magnitude higher than can be explained by classical collision effects.

To date, no self-consistent model has been developed for this anomalous electron transport. This lack of understanding about Hall thruster plasma dynamics precludes predictive modelling and forces designs to be validated with lengthy and expensive physical testing. The prevailing theory to explain anomalous electron transport supposes that a strong azimuthal plasma instability develops in the Hall thruster that can knock electrons across magnetic field lines. The instability is known as the E X B electron drift instability (EDI), due to the plasma turbulence gaining energy from the electrons' high E x B drift velocity [1].

Recent particle-in-cell simulations have demonstrated that this wave driven transport is strongest due to oscillations at long wavelengths that develop from a non-linear energy cascade from the initial, small wavelengths [2]. Using the analysis technique of Ritz [3], we experimental show that this theorized non-linear effect does occur in these devices. Furthermore, these non-linear effects dominate the linear mechanisms in regards to the spatial evolution of the spectral content and interaction with the electron transport.

References

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