Electron Transport by the EXB-Driven Ion Acoustic Instability in a Hall Thruster Based on r-z Multi-Fluid Simulations with Hall2De

Alejandro Lopez Ortega and Ioannis G. Mikellides

A Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, 91109
*e-mail: Ioannis.G.Mikellides@jpl.nasa.gov

After several years of effort with the r-z code Hal2De the spatial variation of the anomalous collision frequency needed in Ohm's law to produce the observed thruster behavior has now been isolated for a lab Hall thruster called H6. This numerical solution was used recently to test the validity of a first-principles model of the anomalous transport in these devices. The model was based on the hypothesis that the Electron Cyclotron Drift Instability (ECDI) excites ion acoustic turbulence that, in turn, enhances the effective collision frequency in these devices. We found that an idealized model of the ECDI with Maxwellian velocity distributions for electrons and singly-charged, main-beam, cold ions was insufficient to explain the expected variation of the anomalous collision frequency. When warm ions (~0.5-3 eV) were accounted for, the ECDI model in the channel interior appeared more promising but failed by orders of magnitude in the near plume region due to the much higher Landau damping of the ion acoustic waves there. We concluded that either (a) one or more processes allow the ECDI instability to remain uninhibited by classical Landau damping or, (b) that a different instability (or instabilities) altogether, also insusceptible to Landau damping, is/are active in this region. Part I of this presentation provides a brief overview of this work which, in part, led to the effort presented in Part II.
In Part II, we first explore the possibility that the discrepancies between the "theoretical" and "needed" growth rates are due to waves of different wave-lengths grow, that saturate and decay at different locations in the plasma. Here we also account for the anomalous heating produced by the ion acoustic instability. We conclude that these two mechanisms cannot decrease the growth rate to values that would be required to self-consistently produce an anomalous collision frequency profile similar to expected profile. We finally present the hypothesis that in the acceleration region, the waves of the ion-acoustic instability do not produce additional drag of the electrons in the azimuthal direction. We justify this assumption by comparing the energy associated with the electron azimuthal drift with the energy carried by the waves. Full self-consistent simulations that account for this hypothesis produce results that agree remarkably well with the expected solution.