Model Based Investigation of Self-Consistent Closure in a Hall Thruster Model

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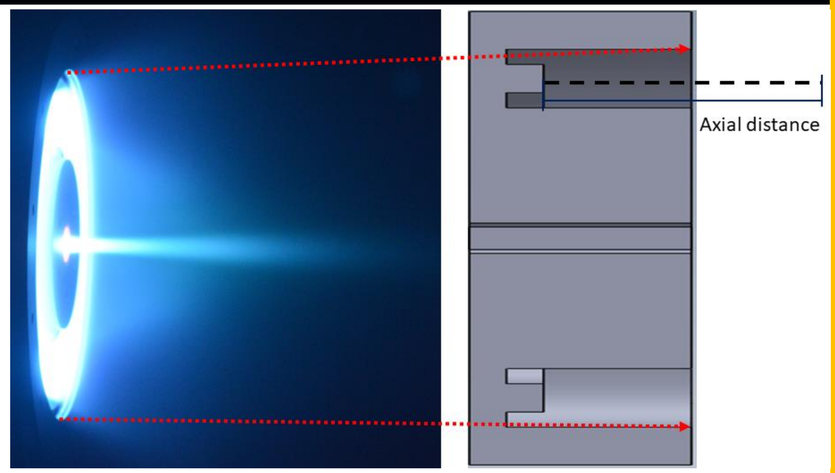
Introduction



Hall thrusters are the most widely flown form of electric propulsion. Despite their widespread use, their electron dynamics remain poorly understood with an ad-hoc "anomalous" collision frequency , ν_{an}, often included in the electron transport. For predictive models of these devices, ν_{an} must be expressed in terms of other plasma properties. A qualitative picture of electron transport based on a wave instability removing energy from electrons and depositing in ions, with the potential for neutral damping suggests that **the plasma density, neutral density, and electron temperature may be key properties for a self consistent model of anomalous transport.**

Approach

We express the anomalous collision frequency as a power law relationship between the plasma density (n_e), neutral density (n_n), electron temperature (T_e), and Coulomb logarithm ($\ln(\Lambda)$)

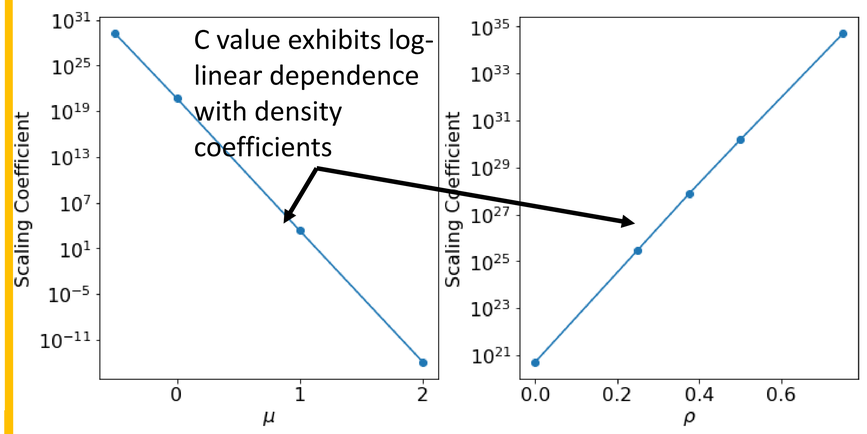
$$\nu_{an} = 2.9\,x\,10^{-12} ln(\Lambda) c \frac{n_e^{\mu}}{n_n^{\rho} T_e^{\tau}}$$

The overall scaling coefficient (c) is adjusted for each set of powers (μ,ρ,τ) until the integrated velocity error (IVR) is minimized. The IVR describes the match in the ion velocity (u_i) between the model and experimental (LIF) ion velocity values and is written as

$$IVR = \sqrt{\frac{\int_{z_u}^{z_d} \left(u_{i,model} - u_{i,LIF}\right)^2 dz}{\int_{z_u}^{z_d} u_{i,LIF}^2 dz}}$$

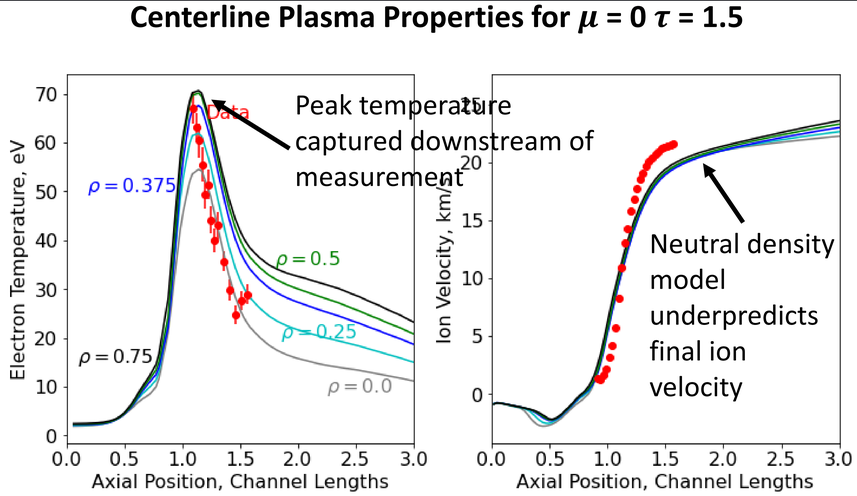
Approach Continued

Optimal c values from IVR tuning

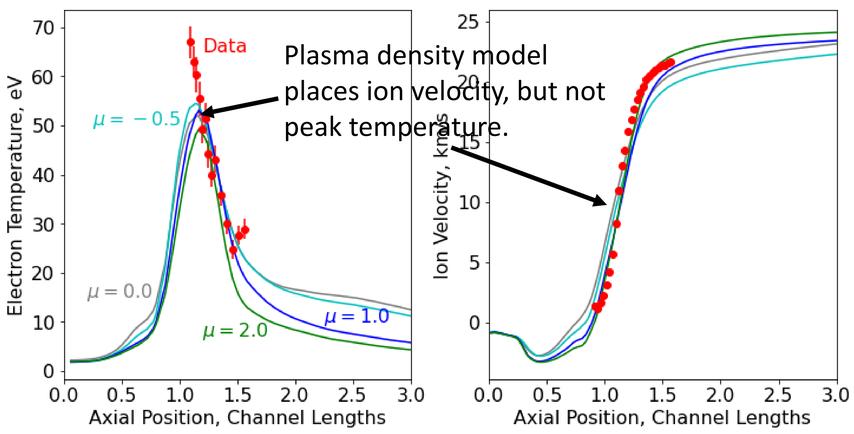


Results

Centerline Plasma Properties for $\mu = 0$ $\tau = 1.5$

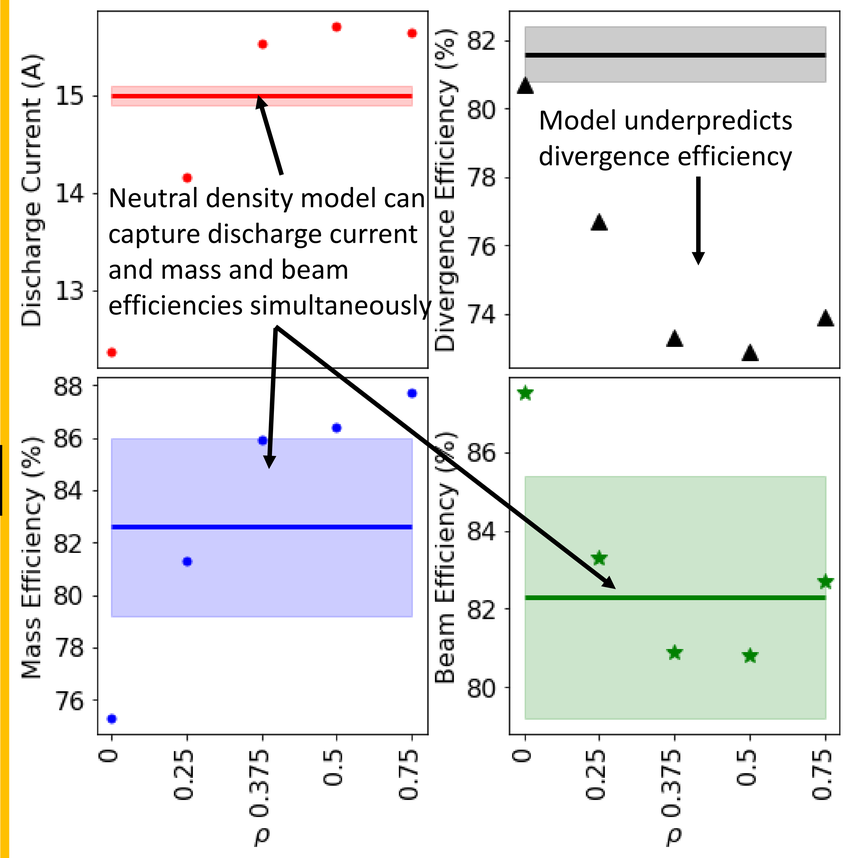


Centerline Plasma Properties for $\rho = 0$ $\tau = 1.5$



Results Continued

Global Metrics for $\mu = 0$ $\tau = 1.5$



Conclusions

1. **Dependency on neutral density is critical for capturing peak temperature and performance metrics. Suggests that neutral damping plays a role in anomalous transport**
2. **Model cannot simultaneously place ion velocity and electron temperature curves in line with experimental data**
3. **Additional dependencies are needed for a predictive model**

Acknowledgements

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