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Simulating Multi-Needle Langmuir Probe Instrument Performance for Improved Design

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Langmuir probes have played a significant role in in-situ plasma measurements for near-Earth space missions for space plasma research. Traditional Langmuir probes employ voltage sweeps to obtain a current-voltage characteristic, providing information about physical parameters such as ion and electron density and temperature. However, the increasing demand for higher sampling rates in recent space missions has driven the development of the multi-needle Langmuir probe (m-NLP) instrument. The m-NLP instrument utilizes multiple fixed-bias cylindrical probes that directly derive electron density from the collected current, utilizing probes with different biases [1, 2].

Interactions between moving objects and the surrounding plasma can disturb the local plasma environment, leading to the formation of plasma wakes and the potential for measurement errors [e.g., 3-5]. This study uses simulation studies to investigate the interaction between the m-NLP instrument and the surrounding plasma. Previous research has demonstrated that the extension of plasma wakes up to 15 Debye lengths behind a single positively biased probe in subsonic plasma flow [6]. Here, we present the examination of the interaction between the m-NLP instrument and the surrounding plasma using test-particle modeling (Figure 1) and particle-in-cell simulations (Figure 2) [7]. By studying the resulting plasma wake structures arising from the presence of the m-NLP instrument, our findings contribute to an improved understanding of this interaction, mainly focusing on the effects on the collected current.

References

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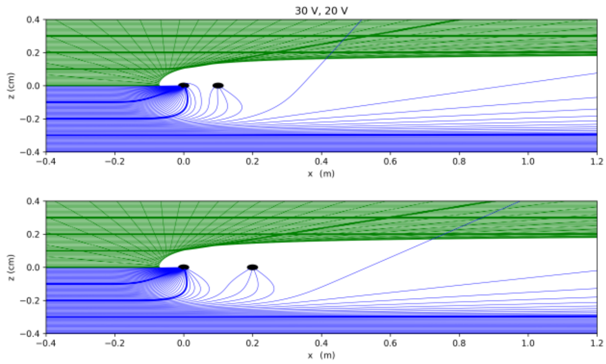

Figure 1 Particle trajectories of protons (green curves) and electrons (blue curves) obtained from test-particle simulations for the 30V-20V case.

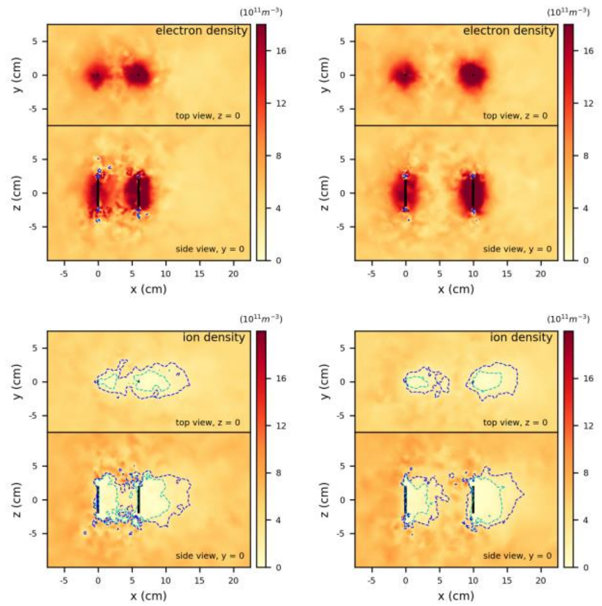

Figure 2 Spatial profiles of electron density (top panels) and proton density (bottom panels) obtained from PIC simulations for the 30V-20V case.