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Simulation-based interpretation of Langmuir probe measurements (I)

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Owing to their relative simplicity, Langmuir probes are the instrument of choice to infer the density and temperature in space and laboratory plasma experiments. The interpretation of probe characteristics, that is, the collected current as a function of bias voltage, is practically always based on theoretical models amenable to analytic solutions, and capable of producing fast solutions under real-time experimental conditions. Several theoretical probe models have been developed over the years corresponding to plasma conditions under various limiting cases including collisionless unmagnetized plasma, low or high density plasma, strongly collisional plasma, and strongly magnetized plasma. Analytic models also assume isolated probes in a spatially uniform background, far from any other material object. Unfortunately these analytic models, while useful as fast and effective interpretation tools, cannot account for physical processes or experimental conditions which affect the measurements of characteristics in actual experimental conditions. Ideally, a preferred solution would rely on computer models capable of accounting for actual non-ideal measurement conditions, such as weakly magnetized plasma, Debye lengths comparable to size of the probe, plasma inhomogeneity, and the proximity of objects responsible for deflecting or obstructing particle to be collected. Such numerical models however, require considerable computing resources, which renders them inapplicable under real-time experimental conditions. This is the case in laboratory experiments, as well as in satellite on-orbit conditions. A solution would consist of using computer models, capable of accounting for the actual conditions under which lab or space measurements are made, to compute probe characteristics, and create a library of solutions over expected ranges of plasma parameters. Given this solution library, it would be possible to infer plasma parameters such as the density and temperature, directly from measured characteristics by using an adapted multivariate regression algorithm. In this talk, preliminary results are presented using solution libraries constructed from a combination of synthetic results obtained analytically, and numerically from kinetic simulations. The applicability of the method is discussed, with a particular attention to space-borne Langmuir probe measurements.

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