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(I) The century old Langmuir probe inference problem: Beyond analytic approximations with machine learning techniques.

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The inference of basic plasma parameters such as density and temperature, is a century old problem, starting with the seminal work of Tonks and Langmuir in the early 1900. Several theories have been developed to determine probe characteristics; that is, collected currents as a function of bias voltage, under diverse laboratory and more recently, space plasma conditions. The advantage of the resulting theoretical analytic characteristics, is that they enable relatively simple algorithm, making it possible to infer plasma parameters quickly, with modest computing resources. On the downside however, all theories rely on simplifying assumptions in order to make the solution of the probe characteristic problem analytically tractable. In actual plasma, these assumptions are typically not all satisfied, which results in errors and uncertainties which are often difficult to quantify. A solution to this predicament would consist of using computer simulations to determine probe characteristics under more realistic conditions, and from there, infer parameters of interest. A direct use of simulations is unfortunately not practical, because of the large computing resources (days to months of computing on supercomputers, depending on the complexity of the system) required to determine a single characteristic. An alternative to the direct simulation approach is to use simulations to pre-compute probe, and more generally particle sensor responses in a range of relevant plasma conditions, and construct a solution library consisting of probe collected currents with, for example, corresponding plasma density, temperature, flow velocity, or ion effective mass. This synthetic solution library in turn can be used to train regression models from which inferences with quantifiable uncertainties. Examples are presented where such models are constructed and applied to in different situ space plasma measurements.

Primary author: Prof. MARCHAND, Richard (University of Alberta)

Presenter: Prof. MARCHAND, Richard (University of Alberta)

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