Numerical simulation of plasma-wall interactions in weakly collisional plasmas

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Eulerian Vlasov codes, which solve the kinetic equation on a fixed phase-space grid, have become increasingly popular in the fusion plasma physics community. Their main advantage is the lack of random statistical noise inherent to particle-in-cell (PIC) calculations. Although they do require a somewhat larger computational effort compared to their PIC counterparts, Eulerian codes are now able to deal with problems requiring a four- and even five-dimensional phase space.

In this paper, I shall illustrate some recent applications of Vlasov codes to plasma-wall interactions and sheath formation. Indeed, a sound understanding of these issues is crucial for the correct interpretation of measurements obtained with probes, besides having important applications to tokamak edge plasmas.

Firstly, a Vlasov-Poisson code has been used to interpret experimental measurements of the ion temperature obtained with Retarding Field Analyzers (RFA). It is well-known that the presence of the RFA itself perturbs the ambient plasma, so that the measured ion distribution is distorted with respect to the unperturbed one far from the probe. This is particularly true in the presence of large plasma flows, frequently observed in a tokamak edge, which induce upstream-downstream asymmetries in the probe measurements. Our numerical calculations provide accurate results for the ion distribution function on both sides of the probe, leading to a precise estimation of the ion temperature in the unperturbed plasma. The model has subsequently been extended to include the effect of a tilted magnetic field, which is relevant to tokamak divertor physics.

Secondly, the code has been used to study the dynamics of an unmagnetized, weakly collisional Argon plasma, confined in a cylindrical chamber. Measurements of the ion temperature near the outer plates at the bases of the cylinder have yielded values of T_i that are an order of magnitude larger than those measured in the unperturbed plasma. Our numerical calculations show that such an increase in T_i is an artefact caused by the violent acceleration of the ions in the sheath that surrounds the plate. The simulations resolve the entire plasma (which is 80 cm long), both on the Debye length scale ($\sim$ 3 mm) and on the ion-neutral mean-free-path scale ($\sim$ 10 cm).