Kinetic Studies of Magnetized Plasma Sheaths and Progress on a Continuum Gyrokinetic Code for Fusion Edge Simulations

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The kinetic study of plasma sheaths is critical, among other things, to understanding the deposition of heat on divertor targets, sputtering, and contamination of the plasma with detrimental impurities. In this work we will report on (1) kinetic studies of magnetized sheaths, performed with a version of the continuum code `Gkeyll` that solves the Vlasov-Poisson equations (not gyrokinetics) including a static magnetic field, and (2) on extension of the gyrokinetic version of `Gkeyll` from previous 1D SOL tests [3] to our first 3D+2V simulations in a simplified SOL geometry. The code uses novel versions of the finite-element Discontinuous Galerkin (DG) scheme that conserve energy in the continuous-time limit (or with implicit time-stepping). In the Vlasov-Poisson code, the fields are computed from a Poisson equation, transitioning smoothly to a quasi-neutral Ohm's law away from the sheath. This allows treating the bulk plasma region with spatial cells significantly larger than the Debye length (Debye length is well resolved in the sheath itself) and time-steps larger than the plasma as well as the electron cyclotron frequency.

Building on the work of Chodura and others on the magnetic pre-sheath (MP), and the recent effort[1] to design MP boundary conditions for use in turbulence simulations in the cold-ion limit, we will characterize magnetized sheaths in tokamak relevant magnetic geometries, including the effects of Secondary Electron Emission (SEE) and sputtering. `Gkeyll` allows treating each plasma species kinetically, allowing for fully kinetic simulations with hot plasma ions and various impurity species. The fundamental behavior of the sheath is modified by the presence of the magnetic field, which adds new scales to the problem, as well as alters the behavior of the emitted electrons by confining them in tight gyro-orbits near the wall[2]. In this work, we will extend previous studies to magnetized sheaths with warm ions, and include SEE and ion sputtering. Further, these studies with the Vlasov-Poisson version of `Gkeyll` will be used to determine a parameterized boundary condition for use in gyrokinetic simulations of plasma edge physics.

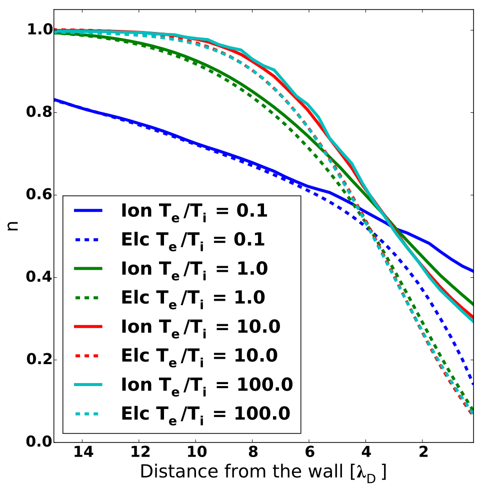

Figure 1: `Gkeyll` simulation of classical sheath. Electron and ion number densities in the Debye Sheath (DS) region with varying electron-ion temperature ratio, T_e/T_i.

[1] Loizu, J., Ricci, P., Halpern, F. D., & Jolliet, S. (2012), "Boundary conditions for plasma fluid models at the magnetic presheath entrance," Physics of Plasmas, 19(12), 122307.

[2] T. Stoltzfus-Dueck, A. Hakim, E. L. Shi, G. W. Hammett, "Secondary-electron emission effects in a 1D ELM model studied with `Gkeyll`", American Physical Society, Div. Plasma Physics Conf., Savanna, Georgia, 2015

[3] E.L. Shi, A. H. Hakim, G. W. Hammett, Phys. Plasmas 22, 022504 (2015)