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Kinetic Understanding of Neoclassical Scrape-off Layer Physics, Comparison with Fluid Modeling, and Experimental Validation

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Simulations using the fully kinetic code XGCa were undertaken to explore the impact of kinetic effects on scrape-off layer (SOL) physics in DIII-D H-mode plasmas. XGCa is a
total-f, gyrokinetic code which self-consistently calculates the axisymmetric electrostatic potential and plasma dynamics, and includes modules for Monte Carlo neutral transport. Fluid simulations are normally used to simulate the SOL, due to its high collisionality. However, a number of discrepancies have been observed between experiment and leading SOL fluid codes (e.g. SOLPS) [1], including underestimating outer target temperatures, radial electric field in the SOL, parallel ion SOL flows at the low field side, and impurity radiation. Many of these discrepancies may be linked to the fluid treatment, and might be resolved by including kinetic effects in SOL simulations. Results presented here will address the SOL parallel ion flow discrepancy among other SOL kinetic effect findings from XGCa.

The XGCa simulation of the DIII-D tokamak in a nominally sheath-limited regime shows many noteworthy features in the SOL. The SOL ion Mach flows are at experimentally relevant levels ($Mi \sim 0.5$), with similar shapes and poloidal variation as observed in various tokamaks[2][3]. Surprisingly, the ion Mach flows close to the sheath edge remain subsonic, in contrast to the typical fluid Bohm criterion requiring ion flows to be above sonic at the sheath edge. Related to this are the presence of elevated sheath potentials, $e\Delta\Phi/Te \sim 3$–3.6, over most of the SOL, with regions in the near-SOL close to the separatrix having $e\Delta\Phi/Te > 4$. These two results at the sheath edge are a consequence of non-Maxwellian features in the ions there.

Status of benchmarking efforts to compare XGCa with fluid models, in particular the fluid code SOLPS, will be presented in the sheath-limited and medium-recycling regimes, with future plans to compare results in the high-recycling and detached regimes.

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[1] A.V. Chankin, et. al., JNM Vol. 390-391, pg. 319-324 (2009)
[2] J.A. Boedo, et. al., JNM Vol. 266-269, pg. 783-787 (1999)
[3] S.K. Erents, et. al., PPCF, Vol. 46, pg. 1757-1780 (2004)

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