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Ion Loss as an Intrinsic Momentum Source in Tokamaks[1]

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A series of coupled experiments in DIII-D and simulations provide strong support for the kinetic loss of thermal ions from the edge as the mechanism for toroidal momentum generation in tokamaks. Measurements of the near-separatrix parallel velocity of D^+ with Mach probes show a 1-2 cm wide D^+ parallel velocity peak at the separatrix reaching 40-60 km/s, up to half the thermal velocity, always in the direction of the plasma current. The magnitude and width of the velocity layer are in excellent agreement with a first-principle, collissionless, kinetic computation of selective particle loss due to the loss cone [1] including for the first time the measured radial electric field, E_r in steady state. C^{6+} rotation in the core, measured with charge exchange recombination (CER) spectroscopy is correlated with the edge D^+ velocity. XGC0 computations [2], which include collisions and kinetic ions and electrons, show results that agree with the measurements, and indicate that two mechanisms are relevant: 1) ion orbit loss and 2) a growing influence of the Pfirsch-Schluter mechanism in H-mode gradients. The inclusion of the measured E_r in the loss-cone model [1] drastically affects the width and magnitude of the velocity profile and improves agreement with the Mach probe measurements. A fine structure in E_r is found, still of unknown origin, featuring large (10-20 kV/m) positive peaks in the SOL and at, or slightly inside, the separatrix of low power L- or H-mode conditions. This high resolution probe measurement of Er agrees with CER measurements where the techniques overlap. The flow is attenuated in higher collisionality conditions, consistent with a depleted loss-cone mechanism.

[1] J.S. deGrassie et al., Nucl. Fusion **52**, 013010 (2011).
[2] C.S. Chang et al., Phys. Plasmas **11**, 5626 (2004).

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