Edge Turbulence and SOL Transport in Tokamaks*

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Experimental results from various tokamaks (DIII-D, Alcator C-Mod, NSTX, JET, TCV, Tore Supra) and other devices (TORPEX, PISCES, etc) in the last ten years are uncovering a new paradigm of edge/scrape-off layer (SOL) transport. Results indicate that radial transport is highly intermittent throughout the SOL, resulting in fluctuation levels of ~100%, exhibiting plasma filaments that are generated near the LCFS and travel at speeds of circa 1 km/s into the SOL and shows robust, universal, behavior such as increasing normalized fluctuation levels, skewness and kurtosis as the distance from the LCFS increases. The filaments are elongated along the magnetic field and, poloidally, have a size that varies with magnetic field, but is of the order of 1-2 cm in most devices. These characteristics are consistent across plasma conditions, such as collisionality and L and H mode, and devices, and are likely due to interchange instability. In H-mode, the intensity or frequency of the intermittency is observed to decay by factors of 2-5 but it still results in significant plasma-wall contact. The intermittent flux is small (20% of the total) compared to edge localized mode (ELM)-mediated transport at low collisionality, but eventually overtakes (70% of total) it at high collisionality due to increasing inter-ELM transport and a concommitant reduction in the ELM size. The radial transport itself is poloidally asymmetric, peaking in the low field side, i.e. ballooning in character by factors of 2-5, causing a pressure asymmetry in the SOL. This pressure asymmetry and classical terms, such as Pfirsch-Schlueter currents are found to drive strong SOL flows that are distributed differently than the traditional divertor sink-driven flows. The radial transport is found to increase by orders of 2-5 with collisionality in the SOL, which can be manipulated by changing either density or temperature or geometrically by changing the connection length. Comparison of the experiments with a variety of numerical (ESEL, BOUT) and analytical models (D'Ippolitto, Krashenninikov, Fundamenski, etc.), has been done successfully, suggesting the source of the transport and various scaling with plasma parameters. In particular, the scaling of intermittency with collisionality and magnetic field have been reproduced as well as many details of the filament dynamics in the SOL. Experiments have also found that divertor detachment reduces sheath dissipation and increases radial transport darmatically, as predicted by theory.

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