Scrape-off layer flows, toroidal rotation and critical gradient phenomena in the tokamak edge

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Tokamak edge plasmas exhibit a remarkably rich set of transport phenomenology, which has only recently been explored in some detail by experiments: extreme ballooning-like transport asymmetries, near-sonic parallel plasma flows, toroidal plasma rotation that depends on magnetic topology, and behaviors that point toward critical-gradient transport dynamics near the last-closed flux surface. These observations stand in sharp contrast to the simple diffusive and/or convective transport paradigms that are often used to model the edge. Instead, transport fluxes appear to be regulated by a close coupling among all these phenomena. Evidence for critical gradient behavoir comes not only from the observations of bursty, intermittent transport in the scrape-off layer (i.e., blobs and ELMs) but also from the tendency of local pressure gradients in L- and H-mode plasmas to be clamped near a characteristic value of the MHD ballooning parameter (α_{MHD}) at fixed plasma collisionality, despite wide variations in plasma current and toroidal field. Thus, regardless of confinement regime, electromagnetic turbulence appears to play a dominate role in setting the pressure gradients at the boundary [1,2]. Ballooning-like transport is a ubiquitous feature of the tokamak edge, with recent experiments exploring the behavior in detail. Such transport asymmetries drive near-sonic parallel flows in a helical pattern that encircles the confined plasma. In response, the confined plasma can acquire a co- or counter-current toroidal rotation, depending on the location of the magnetic x-point. Interestingly, there appears to be a connection between transport-driven SOL flows, resultant toroidal rotation and the magnitude of 'critical pressure gradients' that are attained in L-mode plasmas; higher values of α_{MHD} are seen when the toroidal rotation favors the co-current direction (i.e. $B \times \nabla B$ toward the x-point) [3]. These results are reminiscent of the fact that the L-H threshold power is lower in this configuration, suggesting a further link between edge toroidal rotation and L-H transition physics [4]. Presumably, the underlying mechanisms in both cases involve flow shear near the last-closed flux surface – an area that is ripe for further experimental investigation.

†supported by U.S. Department of Energy Coop. Agreement DE-FC02-99ER54512.

[1] Nuclear Fusion **45** (2005) 1658; [2] J. W. Hughes, *et al.*, Nuclear Fusion **47** (2007) 1057;
[3] LaBombard, *et al.*, to be published in Phys. Plasmas; [4] Phys. Plasmas **12** (2005) 056111.