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E×B Circulation at the Tokamak Divertor X−Point[1]

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Detailed measurements by probes and Thomson scattering reveal local electric potential and electron pressure (p_e) hills near the divertor X-point in DIII-D L-mode plasmas, which give rise to a large E×B circulation of particles, energy and momentum across the separatrix. The potential hill extends from the X-point into closed magnetic surfaces (confinement surfaces), inner and outer scrape-off layers, and private surfaces (between the divertor strike points). Thus, E×B circulates plasma around the X-point, including in and out across the separatrix. The circulation is an order of magnitude more effective at removing momentum than is charge exchange with neutral atoms, a momentum removal mechanism proposed by Carreras et al. The private region convection measured in DIII-D confirms a numerical prediction by Rognlien et al., who also showed that this flow is responsible for the B_T direction sensitivity of divertor plasmas. Further modeling is in progress. The coupled p_e and potential hills are explained as consequences of an ion temperature gradient (high upstream, low near the X-point) along magnetic flux tubes stronger than the T_e gradient. The low X-point T_i might be sustained by the same E×B circulation, which convects cold ions from the divertor target plasma to the X-point. The p_e hill appears to be absent in H-mode plasmas, thus indicating absence also of the potential hill and X-point circulation. We speculate that suppression of the circulation and its transport, by uniformization of T_i on the near-X confinement surfaces, might be important for spontaneous transition from L- to H-mode. Vertical ion drift in the grad B field, as proposed by Hinton in 1985, would then lend a B_T direction sensitivity to the transition, an experimental observation whose explanation has so far been elusive.

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