Large E×B Convection Near the Divertor X-Point*

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The magnetic X–point is the convergence of four regions or quadrants. The X–point quadrants of a typical tokamak divertor are: outer scrape-off layer (SOL), inner SOL, confined plasma and private region. Since each quadrant can have different plasma density, temperature and electric potential from the others, it is likely that complicated plasma physics occurs near the X–point. To date, the tokamak divertor X–point has received little experimental or theoretical study. We report measurements in all four quadrants around the X–point of a single-null-diverted L–mode plasma in the DIII–D tokamak, by Thomson scattering for electron density (n_e) and temperature (T_e) and by insertable Langmuir probes for plasma potential. Comparison between the X–point region and elsewhere on a given magnetic surface reveals locally high electric potential, electron pressure and electron density near the X–point. These potential, p_e and n_e hills exist for both directions of the toroidal magnetic field, $\mathbf{B}_T$. The potential hill drives an $\mathbf{E}\times\mathbf{B}_T$ circulation around the X–point, transporting plasma from one quadrant to the next. The circulation exchanges particles ($\approx 10^{22}$ s^{-1}), energy (≈0.25 MW) and toroidal momentum (~0.1 N) between the confined plasma and the SOL. These rates are comparable with total transport out across the separatrix and might even determine the L–mode edge transport. The p_e hill is not seen in H–mode discharges. We have been unable to measure upstream plasma potentials inside the separatrix with probes during H–mode. However, we speculate that this $\mathbf{E}\times\mathbf{B}_T$ circulation might also influence the L– to H–mode transition.

The potential hill is sustained by p_e and n_e gradients parallel to **B**, in accordance with a Maxwell–Boltzmann plasma equilibrium. The X–point p_e hill appears to be generated by a high upstream ion pressure, p_i, on both closed and open (SOL) magnetic surfaces near the separatrix, such that total pressure on a magnetic surface remains approximately constant upstream of the X–point vicinity. High upstream p_i arises from the commonly observed decoupling of T_i from T_e just inside and outside of the upstream separatrix. Downstream of the X–point, total pressure decreases along the SOL and is balanced by the inertia of plasma acceleration along **B** to the divertor targets, as usual.

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