Saturation Physics in Negative- and Positive-Triangularity Plasmas

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Strong shaping of tokamak flux surfaces provides an avenue by which turbulence characteristics can be influenced in tokamak plasmas. Once particularly pertinent shaping parameter is the triangularity δ, which in recent years has received special attention in the context of inward-pointing triangular shapes, or negative $\delta < 0$. Here, characteristics of microinstabilities as well as their saturation properties are analyzed in both positive-δ and negative-δ configurations.

The potential benefits of finite δ are captured in gyrokinetic simulations of ion-temperature-gradient-driven modes. Linearly, substantial negative $\delta \lesssim 0.5$ leads to a reduction in growth, as local (along the field line) magnetic shear dis-aligns the eigenmode from the region of bad curvature. At large positive $\delta \gtrsim 0.5$, the local shear forces the mode to finite radial wavenumber k_x, reducing transport efficacy. This picture is confirmed by nonlinear simulations, which additionally show that while zonal flows are stronger at positive δ, their impact in saturation is comparable regardless of triangularity sign due to higher saturation efficiency at negative δ.

The impact of finite β is studied for a pair of TCV discharges at $\delta < 0$ and $\delta > 0$. Notably, $\delta > 0$ exhibits lower fluxes due to lower normalized equilibrium gradients, and profile flips – where pressure gradients from one discharge are combined with the magnetic geometry of another – are used to ensure comparability. It is found that both the $\delta > 0$ and the $\delta < 0$ discharges are near-marginal to decorrelation of field lines: a very moderate increase in β leads to a substantial boost in field-line stochasticity and ensuant zonal-flow erosion [1]. A key consequence is the proximity to a regime of extreme profile stiffness. Notably, even cases where electromagnetic stabilization ensures that the system locally sits below the nonlinear critical gradient, intermittency can still lead to decorrelation. In select cases, transition to a high-flux state is only temporary, and instead a zonal-flow-dominanted attractor is eventually reached.

References

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