

The poloidal distribution of electrostatic zonal flow drive in strongly shaped tokamaks

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Developing a physics-based understanding of confinement, including both transitions between confinement states and zonal flow (ZF) dynamics, requires detailed validation. Due to the limited poloidal coverage of experimental turbulence measurements, a missing but important piece is a theoretical estimate for the poloidal distribution of the nonlinear turbulence-flow interaction, and its dependency on macroscopic equilibrium parameters. Through spectral energy transfer functions, which appropriately weigh contributions from three-wave coupling, we obtain such an estimate directly from gyrokinetic flux-tube simulations. In previous work [1] a strong correlation between the envelopes of turbulent activity and the nonlinear coupling was observed for circular plasma shaping. With integrated diagnostic capabilities introduced in the GS2 release 8.2.0 [2], we uncover a non-trivial dependence on plasma shaping of both the ZF drive and the turbulent activity, thus breaking their degeneracy. Our study encompasses a wide range of shaped axisymmetric equilibria, including ones with up-down asymmetry. A common trend emerges, namely the ZF drive distribution develops multiple poloidal maxima which are aligned with those of poloidal curvature. This leads to the surprising implication that the ZF drive can be relatively weak at the outboard mid-plane, where the turbulent fluctuations are strongest and where the relevant turbulence diagnostics are located on most tokamaks.

References

- [1] S. N. Biggs-Fox, Thesis, University of York, 2022
- [2] M. Barnes *et al.*, GS2 v8.2.0, 2024