Nonlinear coherent structures from linearly stable modes in stellarator TEM turbulence

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Nonlinear gyrokinetic simulations of density-gradient-driven trapped-electron-mode (TEM) turbulence in the Helically Symmetric eXperiment predict integrated heat fluxes that are compatible with experimental observations in the corresponding density range [Faber et al., PoP 2015]. Zonal flows develop in the quasi-stationary turbulent state, consistent with saturation physics of density-gradient-driven TEM in tokamaks. However, the usual eddy-shearing mechanism, measured by the shearing rate, is too weak to account for flux suppression, suggesting the more powerful energy dissipation by zonal-flow-catalyzed transfer to stable modes. An additional feature of the turbulence, a low-frequency, long-wavelength, radially localized coherent structure develops that significantly enhances flux levels at low wavenumbers.

Following recent work on the contribution of subdominant ion-temperature-gradient modes to stellarator turbulence [Pueschel et al., PRL 2016], analysis of the subdominant TEM spectrum shows that the coherent structure is associated with nonlinearly destabilized ion-propagating modes. The interplay between the dominant TEM, the zonal flows and the coherent modes paints a complicated picture, with the stable ion modes excited to finite-amplitude fluctuations by zonal-flow-mediated nonlinear energy transfer from the dominant TEM, thus simultaneously aiding in TEM saturation and causing additional heat and particle transport. The very complex linear eigenspectrum, which includes clusters of related unstable or stable modes, depends on the choice of flux tube on a given flux surface; this choice, however, has only a moderate effect on the integrated transport.