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Overview of Gyrokinetic Studies on Electromagnetic Turbulence

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Recent results on electromagnetic turbulence from gyrokinetic studies in different magnetic configurations are overviewed, showing the characteristics of electromagnetic turbulence and
transport in situations where it is both expected and unexpected, and showing how it is affected by equilibrium magnetic field scale lengths. Ballooning parity ion temperature gradient (ITG) turbulence is found to produce magnetic stochasticity and electron thermal transport through nonlinear excitation of linearly stable tearing parity modes. The process is governed by nonlinear three-wave coupling between the ITG mode, the zonal flow, and the damped tearing parity mode. A significant electron thermal flux scales as beta squared, consistent with magnetic flutter. Above a critical beta known as the nonzonal transition, the magnetic fluctuations disable zonal flows by allowing electron streaming that effectively shorts zonal potential between flux surfaces. This leads to a regime of very high transport levels. A consideration of the residual flow in the presence of magnetic flutter confirms the disabling effect on zonal flows. Tearing parity microtearing modes become unstable in the magnetic geometry of spherical tokamaks and the RFP. They yield a growth rate in NSTX that requires finite collisionality, large beta, and is favored by increasing magnetic shear and decreasing safety factor. In the RFP, a new branch of microtearing with finite growth rate at vanishing collisionality is shown from analytic theory to require the electron grad-B/curvature drift resonance. However, when experimental MST RFP discharges are modeled gyrokinetically, the turbulence is remarkably electrostatic, showing trapped electron mode turbulence, large zonal flows, and a large Dimits shift. Analysis of the effect of the RFP's shorter equilibrium magnetic field scale lengths shows that it increases the gradient thresholds for instability of trapped electron modes, ITG and microtearing. The stronger magnetic shear increases the beta threshold for kinetic ballooning mode (KBM) instability. This in turn increases the thresholds for magnetic activity, including the nonzonal transition.

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