The physics of trapped electron mode turbulence

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Trapped electron modes (TEMs) are considered to be a key driver of anomalous transport both in present-day experiments with strong electron heating as well as in future burning plasmas. This calls for a systematic investigation of TEM turbulence. Our present study is based on nonlinear gyrokinetic simulations with GENE, including fully kinetic ions and electrons (both trapped and passing) and employing both tokamak and stellarator geometries.

Nonlinear saturation. The first important finding is that away from the thresholds in R/L_n and/or R/L_{Te}, the turbulence does *not* saturate via zonal flow generation, in contrast to ion temperature gradient (ITG) turbulence. This can be demonstrated by zeroing out the zonal potentials, which has only little effect on the turbulence characteristics and transport levels. Instead, one finds that the transport dominating modes in the k_y spectrum resemble the respective linear microinstabilities to an amazing degree. Moreover, the action of the nonlinearity on long-wavelength TEMs is statistically equivalent to that of a diffusion operator. These results lead us to consider individual nonlinear TEMs as dressed test modes in the spirit of renormalized perturbation theory,. On this basis, a rather simple transport model can be developed which captures many features of the direct numerical simulations.

Tokamaks versus stellarators. While most linear and nonlinear studies of TEMs employ tokamak geometry, it is also very interesting to study their behavior in modern stellarators like Wendelstein 7-X. Here, the regions of large trapped particle fraction and large magnetic curvature are fairly well separated in space. Thus one might expect that TEMs are rather weak in such a device. However, although TEM turbulence tends to be somewhat less pronounced than in a tokamak, it can still induce substantial transport levels. These results are discussed together with the basic characteristics of TEM turbulence in Wendelstein 7-X and implications for other stellarators like NCSX.