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Electromagnetic turbulence suppression by energetic particle driven modes

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Transport due to plasma turbulence determines the energy content and thus the performance of a tokamak reactor. A recent striking observation in experiments [1,2] and numerical gyrokinetic simulations [3] is the particularly interesting link between the presence of fast particles and a substantial improvement of energy confinement. These findings are intriguing in view of reactor-grade plasmas, which will naturally contain a high fraction of fast ions. The underlying physics has been shown to be rather complex. Besides the possibility of a linear resonant stabilization of the ion temperature gradient (ITG) modes due to fast ions in particular circumstances [4], micro-turbulence, axisymmetric zonal flows and energetic particles driven modes, such as Toroidal-Alfvén-eigenmodes (TAE) strongly interact via nonlinear mode coupling. A detailed analysis based on gyrokinetic GENE simulations has shown for the first time a clear and coherent picture of the role of energetic particles in nonlinear electromagnetic plasma scenarios [5]. A new approach based on a frequency-spectral decomposition of the free-energy balance reveals that fast ions lead to a reduction of the heat fluxes through the excitation of marginally stable Alfvén modes in the frequency range of TAEs, which (i) deplete the energy content of the turbulent (ITG) modes and (ii) can act as an additional mediator for an increased zonal-flow activity. In particular, an increased zonal-flow activity mediated by high-frequency modes with relatively low wavelength has been observed in different simulation setups corresponding to both ASDEX Upgrade and JET discharges with improved ion energy confinement. The details of the coupling processes are clarified.

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