Overview of turbulence stabilization by electromagnetic effects and fast ions

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Since the experimental discovery a decade ago that ion stiffness is significantly reduced by increasing NBI and/or ICRH power in JET L-mode discharges, and its subsequent explanation by means of gyrokinetic simulations as due to non-linear electromagnetic (e.m.) stabilization associated with pressure gradients (including thermal and suprathermal components), several new results have been achieved on this topic, both experimentally and theoretically. In both JET and ASDEX-Upgrade evidence has been found that these mechanisms are at the basis of improved ion confinement and T_i peaking in high power Hybrid scenarios. They have also been shown responsible of an anti-gyroBohm mass dependence of core transport if the fast ion population is different with different main ion species. An additional mechanism linked to a purely fast ion driven resonant linear electrostatic (e.s.) stabilization has been found in JET high ICRH power discharges and very recently used in ASDEX-Upgrade to design pulses with improved T_i peaking. On DIII-D a similar stabilizing effect on ITGs was found when including e.m. effects and fast ions in gyrokinetic simulations of plasmas with NBI power and torque scans. Significant progress has been achieved in the physical understanding of these stabilizing effects and work is still in progress to better understand the extrapolability to ITER conditions. The linear e.s. stabilization is due to a wave-particle resonance mechanism when the fast ion magnetic drift frequency is close enough to the linear frequency of the wave, and is therefore predicted to vanish at the high energies of α-particles, but could be used optimally in all devices with ICRH fast ions. The non-linear e.m. stabilization is a complex phenomenon involving 3-wave coupling amongst the unstable ITG, the zonal flows and a marginally stable mode (e.g. the Kinetic Ballooning Mode for the thermal beta stabilization or the Toroidal Alfven Eigenmode for the suprathermal beta stabilization) which gets non-linearly destabilized and acts as mediator boosting nonlinear saturation mechanisms. This mechanism is expected to be effective also in ITER, particularly in scenarios with flat central q profile, like the Hybrids. One caveat is that most theoretical results have been so far obtained with gyrokinetic flux-tube simulations, and in the case of very energetic fast ions their reliability in addressing this physics may be questionable. Therefore a verification activity using global gyrokinetic simulations has recently started. A major development that is still ahead in time would be the inclusion of the non-linear e.m. effects in existing quasi-linear models, in order to properly predict plasma profiles in regimes where these effects are important.

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