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Core Microturbulence and Edge MHD Interplay and Stabilization by Fast Ions in Tokamak Confined Plasmas

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Extensive linear and non-linear gyrokinetic simulations, including kinetic electrons, collisions, flow shear, realistic geometry, electromagnetic effects, impurities as well as perpendicular and parallel magnetic fluctuations, and linear MHD analyses performed respectively with the GENE and MISHKA codes, have shown for the first time that the large population of fast ions found in the plasma core under particular heating conditions has a strong impact on core microturbulence and edge MHD. In particular, nonlinear electromagnetic stabilization of Ion Temperature Gradient (ITG) turbulence can be very much enhanced by fast ion pressure gradients. These results can explain the improved ion energy confinement regime observed in L-mode ion heat transport studies at the JET tokamak which manifests itself as a reduction of the ion temperature stiffness and which, until now had not been reproduced by nonlinear gyrokinetic simulations.
The same effect has been shown to be important in high beta hybrid scenarios from JET and JT-60U with a large population of fast ions. Up to 4 times of lower ion heat flux for the same R/LTi is obtained in these plasmas when the fast ions contribution is taken into account. This can explain the higher core ion temperature gradients obtained in these regimes as the flow shear is found to play a much weaker role. In addition to the core transport stabilization, the fast ions have been seen to favorably impact edge transport. The high core total pressure achieved due to fast ions modifies the Shafranov-shift leading to a pedestal pressure which can increase by 10% when the extra core pressure is taken into account. Therefore, a virtuous circle starts in these plasmas when the fast ions increase the total core pressure without increasing the turbulence drive, even reducing the ITG microturbulence. This leads to an improved edge pedestal pressure by means of the increased Shafranov-shift in a manner unachievable by simple thermal pressure, which is strongly limited by microturbulence.

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