First-principles modelling of fast-ion transport by microturbulence

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Electrostatic microturbulence is a ubiquitous and deleterious phenomenon in every current and hypothesised fusion device. However, its effects upon energetic particles have previously been thought to be small. We have recently developed an efficient method of studying these effects by post-processing local nonlinear gyrokinetic simulations. Through these analyses, we have discovered a profound effect of turbulence on the energetic particle distribution function. This affects both the plasma heating profile and the stability of Alfven eigenmodes, which are sensitive to the phase space distribution of fast particles. These are both key issues for ITER.

Our result relies upon the passive-tracer approximation. The dominant departure from the passive approximation is through dilution of the main ions by adiabatic energetic particles. We thus developed a theoretically-motivated prescription to successfully model this effect. This was benchmarked by performing full nonlinear simulations including the energetic species. We found it to be valid up to an energetic particle concentration of 20%, easily including the parameter regime of both ITER and future reactors. In order to provide a heuristic tool for quickly estimating these turbulent effects, we performed detailed analysis of our results. We show that we can, in fact, characterise the effect of turbulence on the energetic species through one dimensionless parameter. This allows an order-of-magnitude estimate to be made prior to performing any detailed calculations. Unifying all of these results, a model distribution function, which takes turbulence-induced corrections into ac- count, will also be presented. We conclude with a brief application of this to the differing behaviours of NBI- and ICRH-generated energetic particles in current experiments.