Profile-turbulence interactions, MHD relaxations and transport in tokamaks

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In this paper we present recent results of extensive computational studies using the CUTIE Ref[1], global, electromagnetic, two-fluid turbulence code applied to the elucidation of the evolution of tokamak mesoscale structures on long (ie., resistive) time-scales. Attention is focussed on examples relating to typical data drawn from the Rijnhuizen Tokamak Project (RTP), and the JET experiments. These studies reveal the key roles played by the synergetic effects, due on the one hand to spontaneously generated or externally driven flows, and, on the other hand to current redistribution caused by bootstrap and dynamo effects in the electron channel. Central to the model is the idea of profile-turbulence interactions. The examples will include, on and off-axis sawteeth in Ohmic and ECH heated conditions, outward heat pinches, edge relaxations, transport barrier dynamics during shallow and deep pellet injections. These simulations show that the low mode number part of the turbulent fluctuation spectrum is excited (and maintained) by an inverse cascade[2], even if one starts with high mode numbers. These relatively long wavelength modes are associated with low order rational values of q, and play a key role in the tendency of the system to 'self-organize'. Firstly, they generate fine-scale, intermittent turbulence through nonlinear and toroidal mode couplings and give rise to secondary instabilities (direct cascade). Secondly, they imply corrugated fluxes due to fast radial variation in amplitude, and nonlinear, dissipative, cross-phase relations. These fluxes react on profiles and determine the local gradients of both magnetic and electric fields, which in turn, control the turbulence in a relaxation process. The paper will review the basic features of the model and the assumptions used in the simulations. It will also seek to clarify the nature of the MHD relaxations found and how they appear to organize the radial electric field and the safety factor profiles. Where appropriate, comparisons are made with experimental data. An outline is given of recent developments to the model attempting to incorporate advanced features like tight-aspect ratio, high betas and rapid rotation in the next generation code CENTORI which takes CUTIE as its point of departure but allows very high speed parallel supercomputers to be used.

[1]A. Thyagaraja, P.J. Knight and N. Loureiro, *Eur. J. Mech. B/Fluids*, **23**, 475 (2004).
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