Zonal Flow — Drift Wave Interactions in 2D 2-Fluid ITG

P.G. Ivanov\textsuperscript{1,3}, A.A. Schekochihin\textsuperscript{1,2}, A.R. Field\textsuperscript{4}

\textsuperscript{1} Rudolf Peierls Centre for Theoretical Physics, University of Oxford, 1 Keble Rd, Oxford OX1 3NP, UK
\textsuperscript{2} Merton College, Oxford OX1 4JD, UK
\textsuperscript{3} St John’s College, Oxford OX1 3JP, UK
\textsuperscript{4} EURATOM/UKAEA Fusion Association, Culham Science Centre, Abingdon, Oxon OX14 3DB, UK

It is believed that most of the heat transport in tokamak plasmas is caused by turbulence. Numerical simulations have shown that turbulence in tokamaks is regulated by the interaction of 3 different phenomena — shear of the mean plasma flow, zonal flows (ZF) and drift waves (DW) \cite{1, 2}. The latter represent wave-like fluctuations in the plasma, driven by gradients in the background plasma parameters — density, temperature, etc. Zonal flows are Larmor-scale shear flows in the poloidal direction (around the smaller radius of the torus), which are generated nonlinearly by the drift-wave turbulence itself.

We aim to find an analytical description of the nonlinear interaction of ZFs and DWs and the phenomena resulting thereafter — the Dimits shift \cite{1} and the recently discovered state dominated by coherent structures \cite{3}. Our equations are obtained by taking density and temperature moments of the electrostatic gyrokinetic equation in an appropriate cold ion limit ($T_i \rightarrow 0$) and large collisionality expansion $v_i \gg \omega \sim v_i k_{\parallel}^2 \rho_i^2$. The resulting system of two PDEs is shown to exhibit both a linear ion-temperature-gradient instability, driven by a background magnetic field and temperature gradients, a nonlinear (secondary) instability towards the development of strong zonal flows, as well as the break-up of the ZF-dominated state (tertiary instability). We present analytical results on both the linear and nonlinear behaviour of the system, together with numerical validations.

References