Gyrokinetic simulations of ITG turbulence with GYSELA 5D

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The gyrokinetic description of turbulence allows one to investigate the impact of wave-particle resonances on the transport level, as well as a rigorous treatment of the dynamics of zonal flows, which are known to contribute to the turbulence saturation. Various numerical approaches can be envisaged to tackle the problem. The GYSELA-5D code is based on a semi-Lagrangian scheme, which takes benefit from both the Eulerian and PIC approaches, and considers the full distribution function, allowing for the self-consistent treatment of equilibrium and fluctuations. It models the electrostatic toroidal branch of the Ion Temperature Gradient turbulence with adiabatic electrons in a global geometry.

Initialising the system with a distribution function constant on magnetic flux surfaces leads to the development of large-scale poloidal E×B flows. They result from the vertical charge imbalance due to the curvature and grad-B drifts. Up-down asymmetric geodesic acoustic modes (GAMs) are shown to develop first, linearly in time. The proportionality coefficient scales like ρ_*^2, where $\rho_*=\rho_i/a$ is the ratio of the ion Larmor radius over the minor radius. Also, the saturation time of such modes is approximated analytically, allowing for the estimation of their saturation level. Especially, it is found that the velocity shear induced by such modes can compete with the linear growth rate of the instability at large enough ρ_*, potentially preventing the onset of turbulence. These analytical results well agree with numerical simulations. Conversely, as noticed in previous works, a Maxwellian depending on the motion invariants only constitutes a stationary equilibrium at vanishing electric field. In this case, the fluid drift velocities are recovered up to the first order in ρ_*.

In the linear regime, the eigenmodes exhibit the characteristic ballooned and radially elongated shape, with growth rates and real frequencies in agreement with published results. Also, an initial poloidal flow is observed to decay towards the residual level predicted theoretically, with a transitory oscillatory regime governed by the GAM frequency. Finally, for the first time regarding gyrokinetic full-f codes, the turbulent transport level is satisfactorily benchmarked against the CYCLONE test case at $\rho_*=5.10^{-3}$, while it is significantly larger when zonal flows are artificially suppressed.