# Comparative studies of nonlinear ITG and ETG dynamics

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The present work demonstrates that the crucial difference in nonlinear dynamic behaviors of ion temperature gradient (ITG) instabilities with respect those of electron temperature gradient (ETG) modes, stands in the particle response to zonal flows (ZF). On the one hand, for ITG, massless electron response imposes that the lowest order zonal density fluctuation vanishes; on the other hand, for ETG, the ion response is adiabatic, due to $k_\perp \rho_i \gg 1$, even for $n = m = 0$. The main consequence of these different behaviors is that the specular symmetry between ITG and ETG, which holds linearly, is nonlinearly broken. This results into two main facts, *i.e.*, that the ZF polarizability is much lower for ITG [1] than for ETG [2, 3] and that the dominant Drift Wave - Zonal Flow (DW-ZF) interaction is due to E $\times$ B nonlinearity for ITG, while ETG are characterized by the usual Hasegawa-Mima nonlinear coupling [4].

Based on these facts, the paradigm model for ITG, presented here, assumes that different DW interactions on the shortest non-linear time scale are mediated by ZF, which is spontaneously generated by ITG via modulational instability [5]. The resulting coherent model demonstrates turbulence spreading [6] to be the cause of transport scaling with system size [6, 7, 8]. The non-linear saturated state can be either coherent, with limit cycles, or chaotic, depending on proximity to marginal stability [9]. Meanwhile, ZF spontaneous generation is the weakest nonlinear dynamics for ETG, which saturate via nonlinear toroidal couplings that transfer energy successively from unstable modes to damped modes preferably with longer poloidal wavelengths [2, 3]. The ETG turbulence is dominated by nonlinearly generated radial streamers, but both fluctuation intensity and transport level are independent of the streamer size [2, 3]. Nonlinear Gyrokinetic particle simulations indicate that typical ETG transports are smaller than those of experimental relevance [2, 3].

## References

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