# Gyrokinetic particle simulations of ITG modes and zonal flows with canonical and local equilibrium distributions

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Nonlinear electrostatic global gyrokinetic simulations of ITG modes including their interaction with $E \times B$ zonal flows in tokamak geometry [1] are examined for different choices of the initial distribution function $f_{\mathrm{init}}$ and of the decomposition $f = f_0 + \delta f$. In Particle-In-Cell schemes with $\delta f$ ansatz the $\delta f$ part of the distribution is discretized with randomly chosen markers in phase space [2] and this information is used to obtain the perturbed density, while the $f_0$ contribution is treated analytically thus contributing to substantially reduce the numerical statistical noise. The model used is collisionless gyrokinetic ions and adiabatic electrons on magnetic surfaces. The magnetic configuration is axisymmetric. Choosing a local Maxwellian, $f_{\mathrm{LM}}(\psi, \epsilon)$, for $f_{\mathrm{init}}$ and for $f_0$, the initial electric field is zero. However, $f_{\mathrm{LM}}$ is not a constant of motion ($df_{\mathrm{LM}}/dt|_{unperturbed} \neq 0$) and a $n = 0$ potential builds up in a timescale of the order of the particle transit time. In small systems with temperature gradients this $n = 0$ field is strong enough to suppress ITG modes. In the standard $\delta f$ scheme the variation of $f_{\mathrm{LM}}$ along unperturbed orbits is often neglected [2] and the $n = 0$ initial build up is avoided. The aim of this paper is to examine other options. Choosing a canonical Maxwellian, $f_{\mathrm{CM}}(\psi_0, \epsilon, \mu)$ for $f_{\mathrm{init}}$, where $\psi_0$ is the canonical toroidal angular momentum, and a local Maxwellian $f_{\mathrm{LM}}$ for $f_0$, a $n = 0$ potential is created at $t = 0$ which can be strong enough to keep the ITG modes from growing. As the amplitude of this $n = 0$ field is directly related to the difference between $f_{\mathrm{CM}}$ and $f_{\mathrm{LM}}$, hence between $\psi$ and $\psi_0$, it is of the order of the poloidal gyroradius over the equilibrium gradient length. In order to avoid the problem of these “spontaneous” (and probably unphysical) $n = 0$ fields, we examine different options for the choice of $f_{\mathrm{init}}$ and $f_0$, requiring that the initial state should satisfy both a gyrokinetic equilibrium condition $f_{\mathrm{init}} = f(\psi_0, \epsilon, \mu)$ and the quasineutrality equation with vanishing electric fields. Both standard $\delta f$ and direct $\delta f$ schemes [3] are used and are shown to be equivalent.

**Acknowledgements.** We thank Drs S.J. Allfrey, A. Koenies, Y. Idomura, J.P. Graves for stimulating discussions. Work partly supported by the Swiss National Science Foundation.

## References

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