# Simulations of microturbulence in magnetised plasma with heat sources using a delta-f gyrokinetic approach with an evolving background Maxwellian

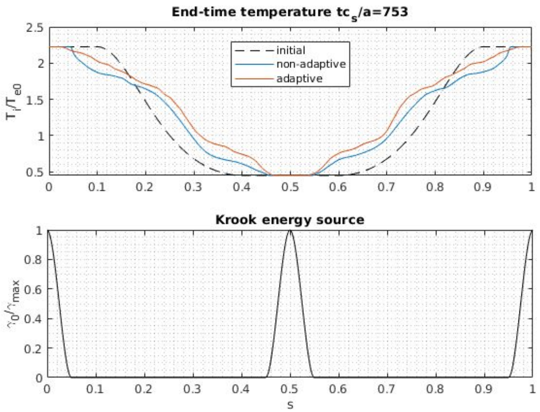
Code: **GKengine**

- Delta-f PIC
- Single species, adiabatic electrons
- Electrostatic, sheared slab
- Fields represented by B-splines

N. Ohana et al, J. Phys.: Conference Series **775** 012010 (2016)

Strong gradient to simulate plasma edge:

$$\kappa a = 4.00$$




## Time-dependent background temperature:

$$\begin{aligned}\vec{Z} &= (\vec{R}, v_\parallel, \mu)\\ f(t,\vec{Z}) &= f_0(t, X, v_\parallel, \mu) + \delta f(t, \vec{Z})\\ f_0(t, X, v_\parallel, \mu) &= \frac{n_0(X)}{[2\pi T_{i0}(t,X)]^{3/2}} \exp\left(-\frac{m v_\parallel^2/2 + \mu B(X)}{T_{i0}(t,X)}\right)\end{aligned}$$

## Krook source and conservative noise control:

$$\begin{aligned}f_{00} &= f_0(0, X, v_\parallel, \mu)\\ f &= f_{00} + \delta f + (f_0 - f_{00})\\ \frac{\mathrm{d}\delta f}{\mathrm{d}t} &= -\frac{\mathrm{d}f_0}{\mathrm{d}t} - \gamma_0(x)(f_0 - f_{00} + \delta f) - \gamma_1 \delta f\end{aligned}$$

B.F. McMillan, Phys. Plasmas **15**, 052308 (2008)

## Quasi-neutrality equation:

$$\begin{aligned}&\frac{e n_0}{T_e}(\phi - \bar{\phi}) - \nabla_\perp \cdot \left(\frac{n_0}{B\Omega_i}\nabla_\perp \phi\right)\\ &= \frac{1}{2\pi}\int \delta f(t, \vec{x} + \vec{\rho}_L(\mu,\alpha), v_\parallel, \mu) J \,\mathrm{d}\mu\, \mathrm{d}v_\parallel\, \mathrm{d}\mu +\\ &\quad \frac{1}{2\pi}\int \{f_0 - f_{00}\}(x + \rho_L(\mu)\cos\alpha, v_\parallel, \mu) J \,\mathrm{d}\mu\, \mathrm{d}v_\parallel\, \mathrm{d}\mu\end{aligned}$$

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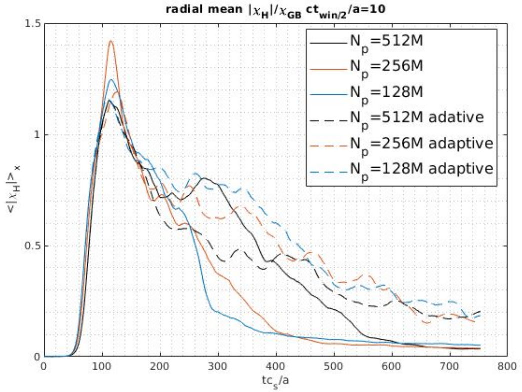


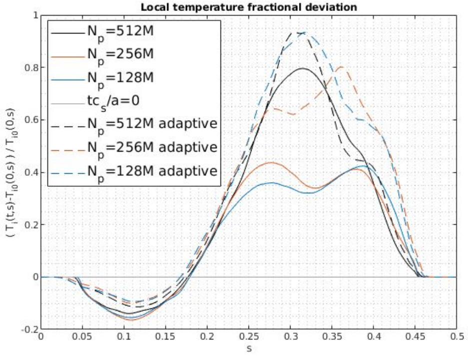

Non-adaptive case: Drop in heat flux and diffusitivity due to noise, leading to negligible residual values

Background temperature relaxation equation:

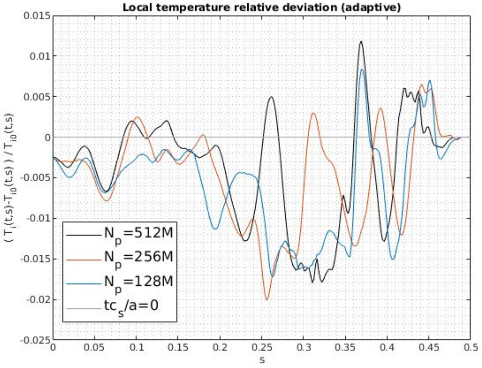
$$\frac{3}{2}n_0(x)T_{i0}(t,x) = \frac{3}{2}n_0(x)T_{i0}(0,x) + \sum_b \xi_b(t)\Lambda_b(x)$$

$$\frac{\partial}{\partial t}\left(\frac{3}{2}n_0(x)T_{i0}(t,x)\right) = \alpha_E\left\langle\int\left(\frac{mv_\parallel^2}{2}+\mu B\right)\delta f(t,\vec{Z})J\,\mathrm{d}v_\parallel\,\mathrm{d}\mu\right\rangle$$

S. Brunner et al, Phys. Plasmas. **6**, 4505 (1999)




Adaptive cases give converged larger final temperature change




Temperature relative deviation remains low for adaptive cases

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Fourier decomposition on the B-spline coefficients of the RHS of the quasi-neutrality equation allows for SNR diagnostics

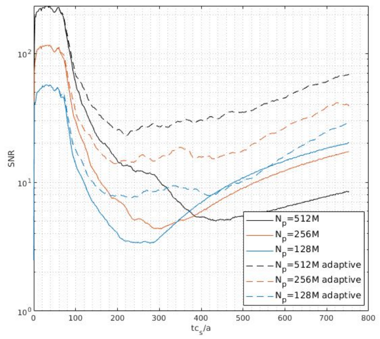
Physical modes satisfy: $\Delta m \in |nq(s) - m|$

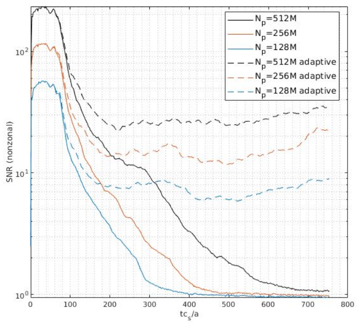
$$\text{noise} = \frac{\Sigma^{N_s} \Sigma_{(m,n)\in\mathcal{F}_2} |b_i^{(m,n)}|^2}{\Sigma^{N_s} \Sigma_{(m,n)\in\mathcal{F}_2}}$$

$$\text{signal} = \frac{\Sigma^{N_s} \Sigma_{(m,n)\in\mathcal{F}} |b_i^{(m,n)}|^2}{\Sigma^{N_s} \Sigma_{(m,n)\in\mathcal{F}}}$$

B. F. McMillan et al, Comp Phys Comm. **181**, 715 (2010)

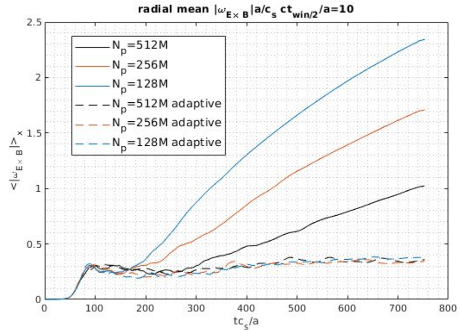
SNR with and without the zonal mode, which noise accumulates, under adaptive scheme:

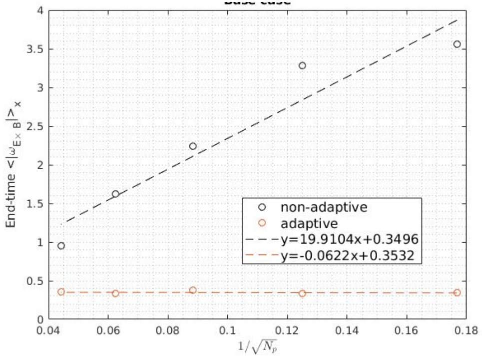



$$\omega_{E\times B} \sim -\frac{\mathrm{d}^2\phi}{\mathrm{d}x^2} \times \hat{b}$$

Noise leads to increased shearing rate, which in turn suppresses turbulence:

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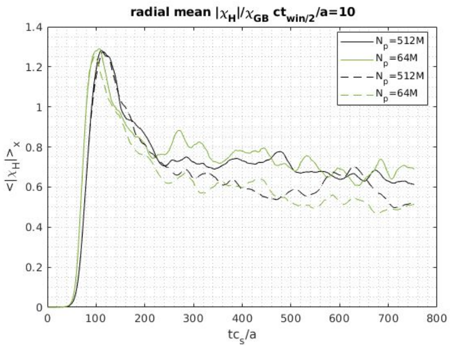
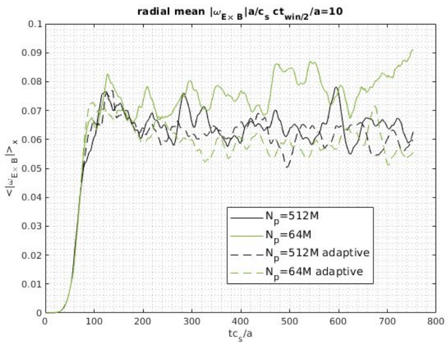
To better simulate conditions at plasma edge with high fluxes, disabling the flux-surface-averaged potential in the electron adiabatic response reduces shearing rate, and thus increases turbulence levels:

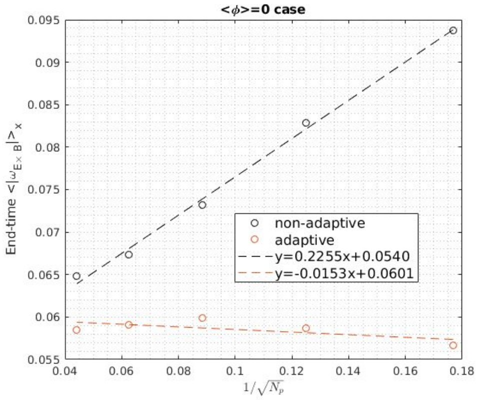
Heat diffusivity:




Shearing rate:




Simulations are less sensitive to marker numbers in general, but shearing rate increases when marker number decreases




D. R. Hatch et al, J. Plasma Physics. **80**, 531 (2014)

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