GTS simulations of global gyrokinetic turbulence and associated transport in NSTX

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in collaboration with

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PPPL

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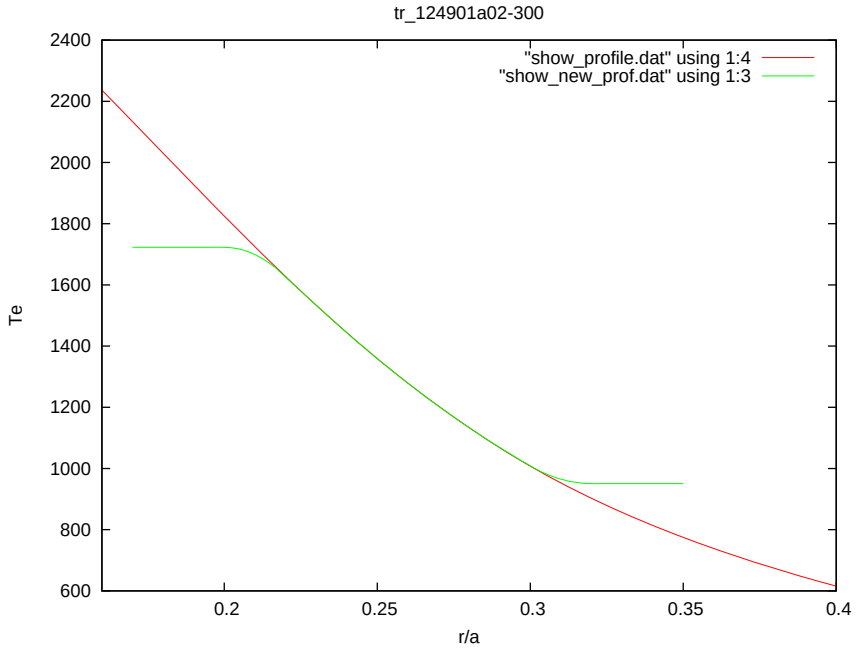
GTS main physical and numerical features

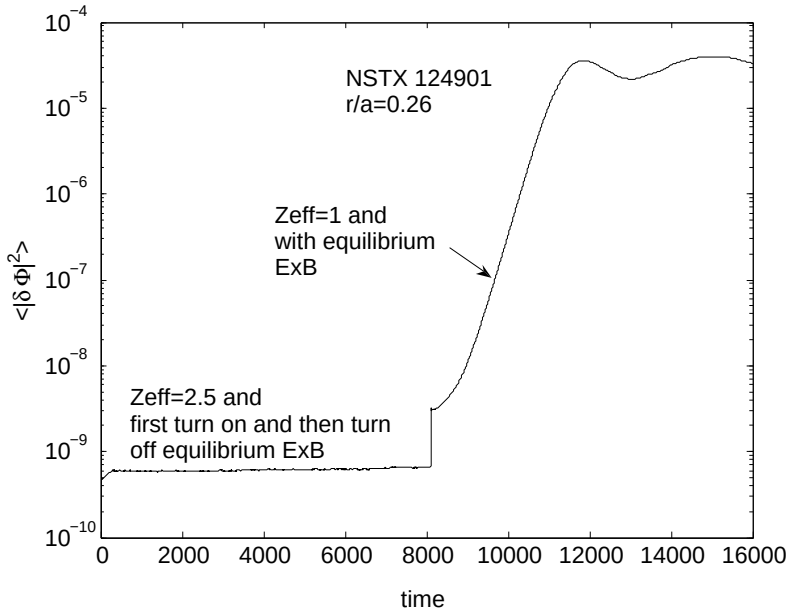
- Gyrokinetic Tokamak Simulation (GTS) code: generalized gyrokinetic simulation model; PIC approach
- Global simulation
- Shaped cross-section; experimental profiles; consistent rotation and equilibrium $\mathbf{E} \times \mathbf{B}$ flow; linear Coulomb collisions; $\cdots$
- Interfaced with MHD equilibrium codes and TRANSP data base
- Interface with neoclassical simulation via GTC-NEO
- Kinetic(electrostatic) electrons via split-weight scheme

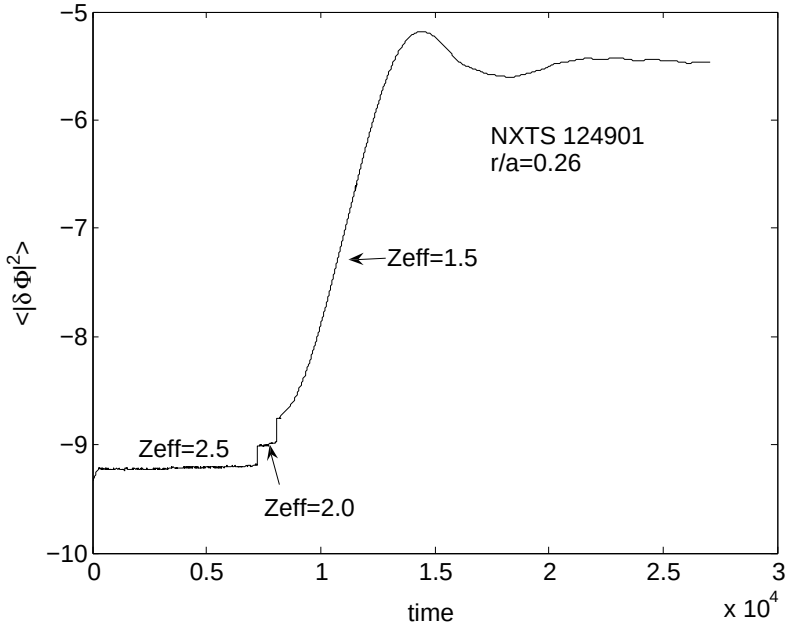
ETG simulation model, parameters, domain ...

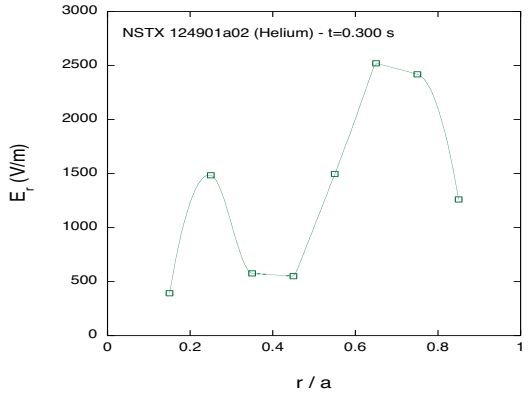
- adiabatic ions (neglecting coupling with low-k fluctuations)
- global simulation covers full toroidal and poloidal domain; typically $0.17 \leq r/a \leq 0.35$ in radial direction ($\sim 600\rho_e$)
- current simulations use artificial mass ratio: $m_e/m_i = 1/100$
- working gas is Helium; Z_{eff}



Effects of equilibrium E × B shear flow and Z_{eff} on ETG instability

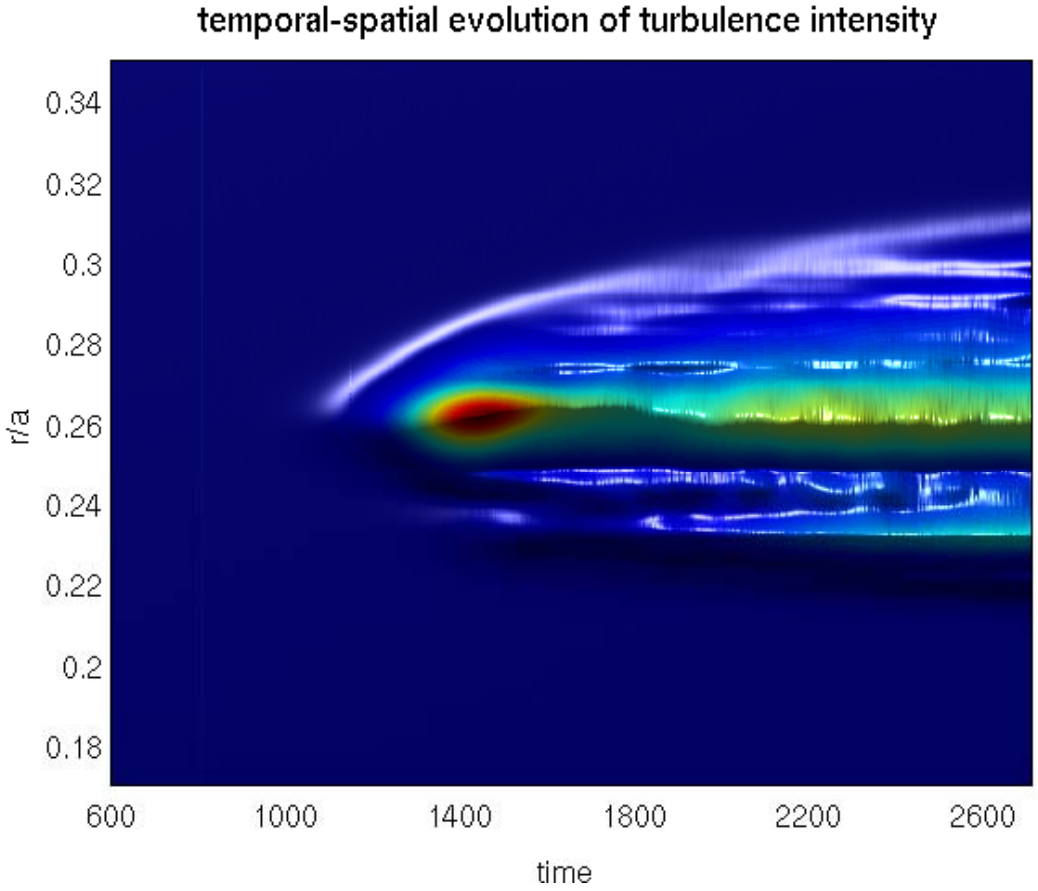






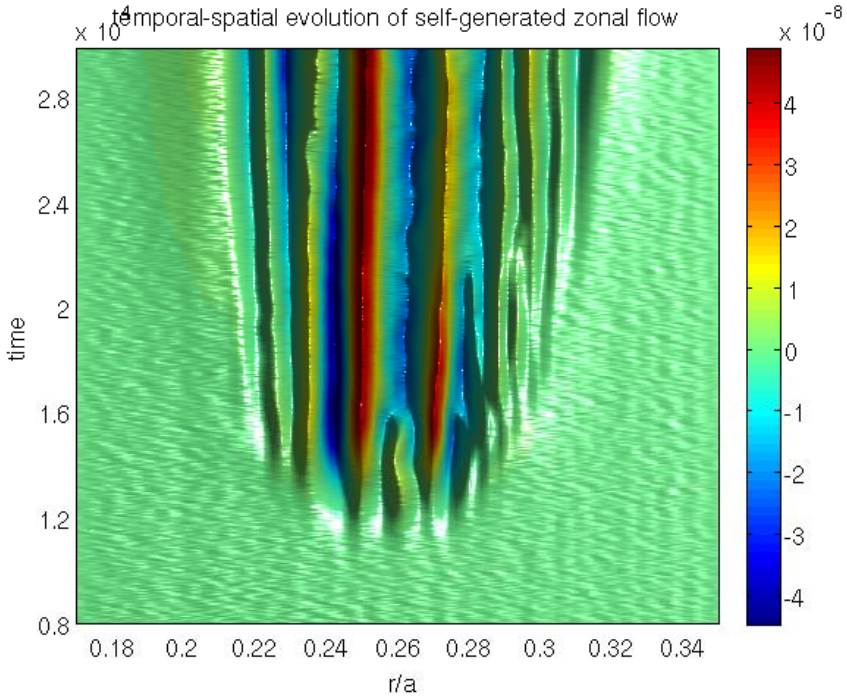
- equilibrium ExB shear flow seems to be a minor player
- strong impact of Z_{eff} on ETG threshold
  - stabilized for $Z_{eff} > 2$ with and w/o Er
  - unstable for $Z_{eff} = 1.5$ with and w/o Er

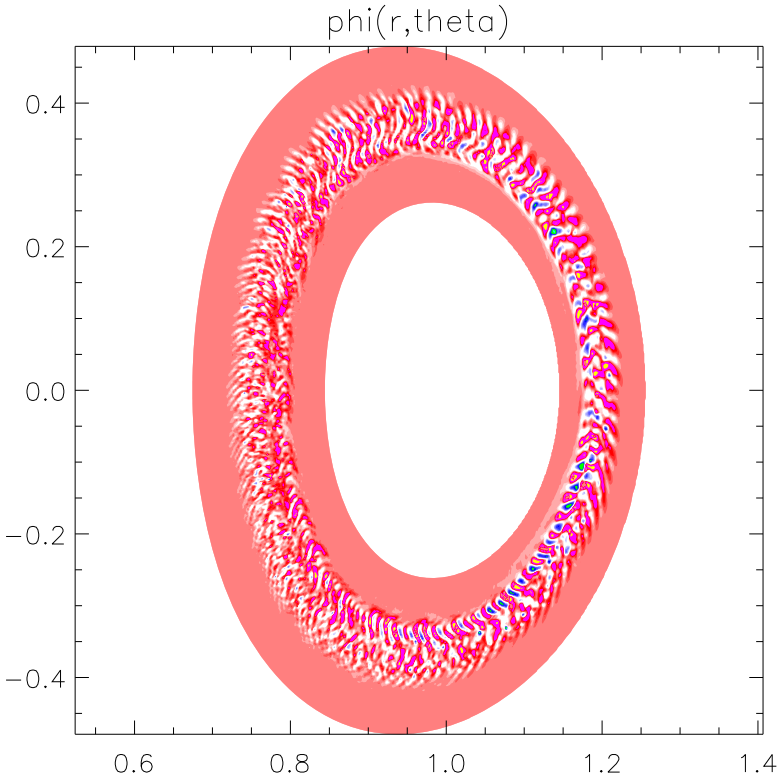
ETG turbulence spreading and bursting



- turbulence spreads mainly in outward direction (spreading may be less significant with real electron mass)
- reversed magnetic shear ($r/a < 0.25$) not only suppresses ETG instability but also blocks turbulence spreading

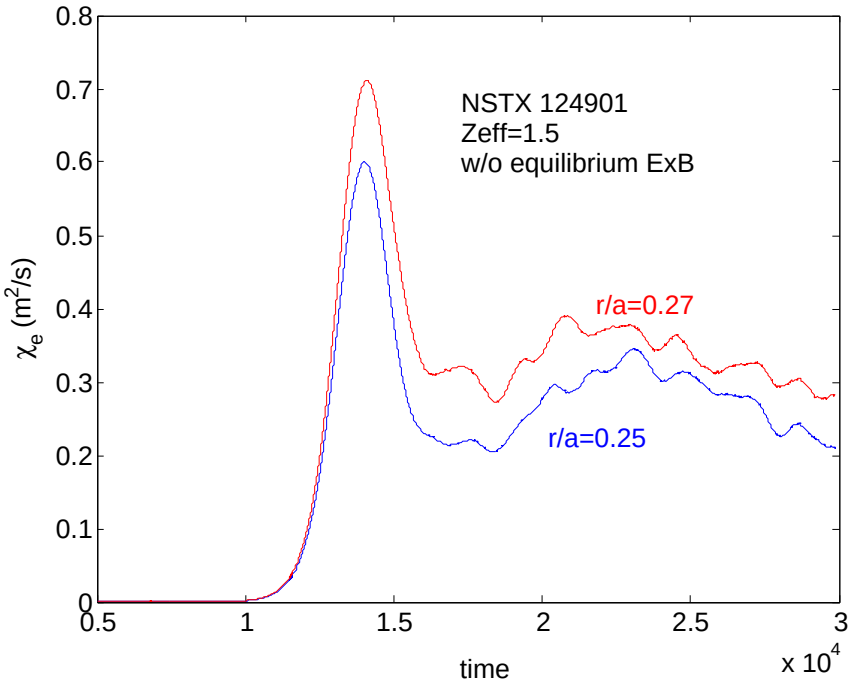
Effect of self-generated zonal flows

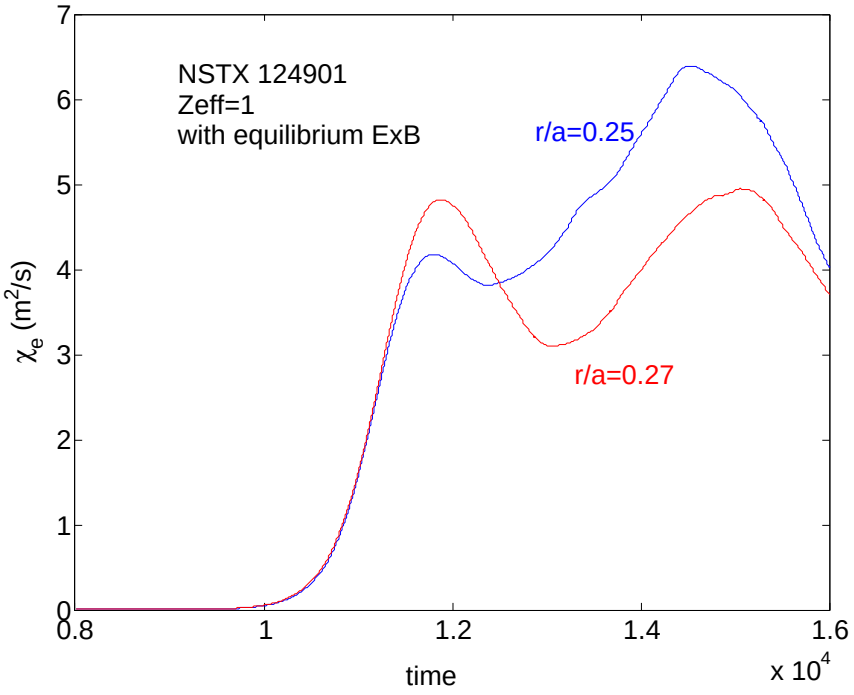




- nonlinear zonal flow generation is observed, HOWEVER, in contrast to ITG case:
- it shows much finer radial scale
- it is too weak to break up streamers
- it contains much less energy than turbulence

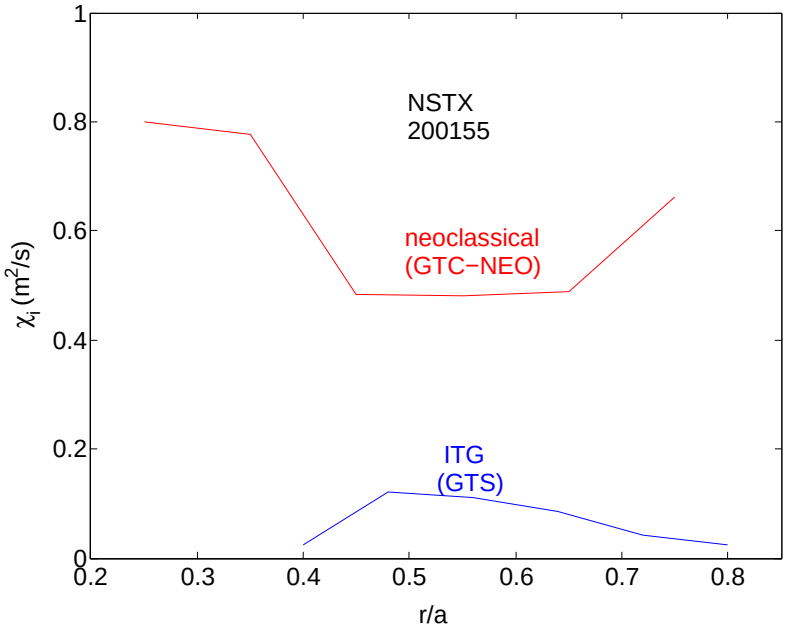
ETG driven electron heat transport in NSTX

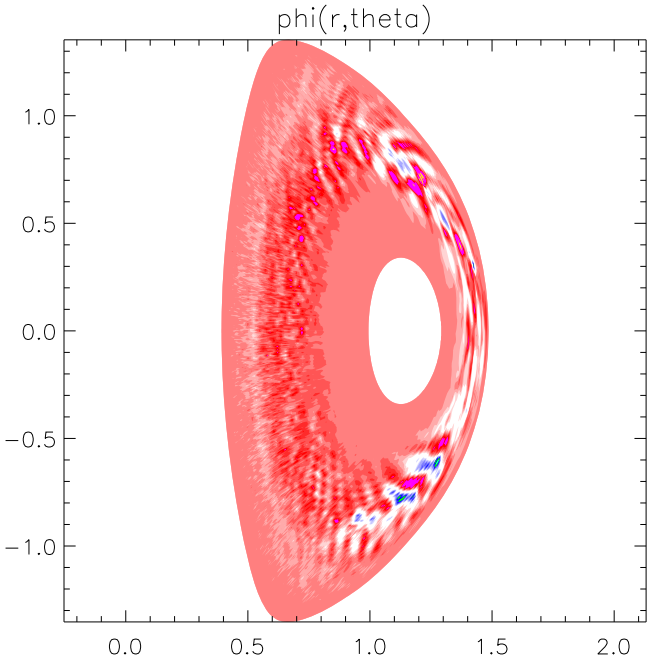


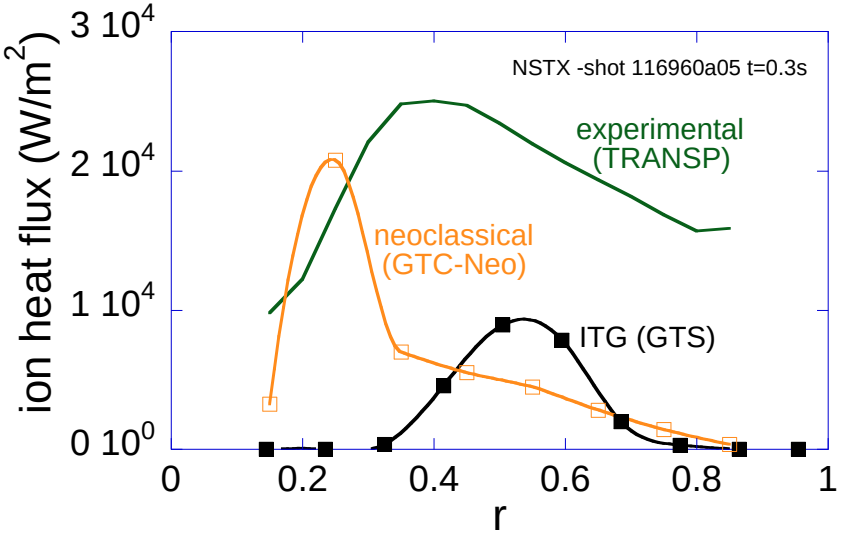


- there is a good chance for $\chi_e^{ETG} \gg \chi_i^{ITG}$ for NSTX
- in strong drive case, ETG may drive significant electron heat transport

ITG is a minor player in NSTX transport







- Even without equilibrium ExB flow shear suppression, ITG turbulence makes insignificant contribution to ion energy transport in NSTX (possibly including NSTX upgrade) – key factors may be related to size scaling

Summary

- Global ETG simulations of NSTX discharges are a huge challenge because of extremely high resolution required for electron-scale fluctuations
- Z_{eff} has strong impact on ETG instability, while equilibrium $\mathbf{E} \times \mathbf{B}$ seems to be minor player
- Streamers can be sustained in nonlinear saturation stage while zonal flows are generated
- In the case of strong drive, ETG may drive large electron heat transport in NSTX
- ITG turbulence makes insignificant contribution to ion heat transport in NSTX even without equilibrium $\mathbf{E} \times \mathbf{B}$ flow shear suppression
- Real electron mass ETG simulations are scheduled on 250TF Jaguar at ORNL