TH/2-6Ra: Gyrokinetic Studies of Nonlocal Properties of Turbulence-driven and Neoclassical Transport

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TH/2-6Rb: Long Time Simulation of Microturbulence in Fusion Plasmas

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Outline and Conclusions

- Particle noise effects in PIC turbulence simulations have been studied using GTC and GEM codes.

  Noise effects were found to be negligible with sufficient particles

- Influence of global (radially nonlocal) dynamics on neoclassical transport in spherical tori has been examined using the GTC-Neo code

  Significantly improved agreement with experiments found

- Numerical experiments on turbulence spreading were performed using GTC code with shaping and ExB shear

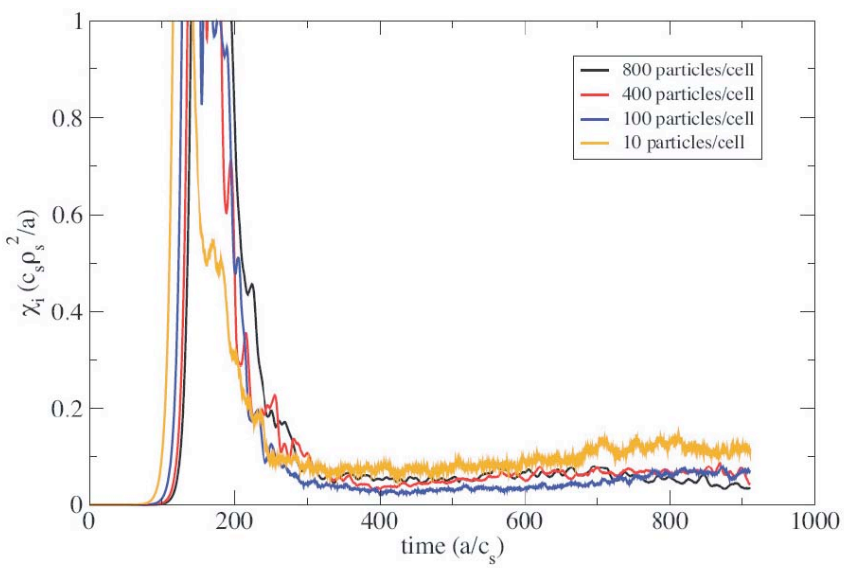
  Roles of nonlinear mode coupling, linear toroidal coupling, and self-generated zonal flows are elucidated

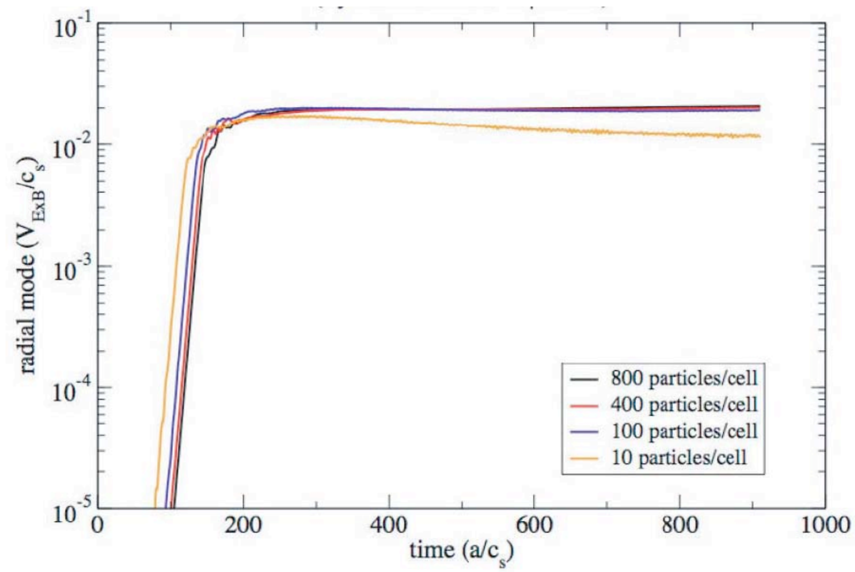
  ω_{ExB} profile controls the spatio-temporal evolution of turbulence spreading through a transport barrier

Convergence in ITG Simulations using GTC

- Convergence: does numerical resolution affect physics?
- Two possible contributing factors to non-convergence

  Particle Noise (PIC) Velocity Space Resolution (Vlasov, PIC)
- Simulations using CRAY X1E at ORNL
- Saturated values of thermal diffusivity & zonal flow amplitude are virtually constant for 10-800 particles per cell





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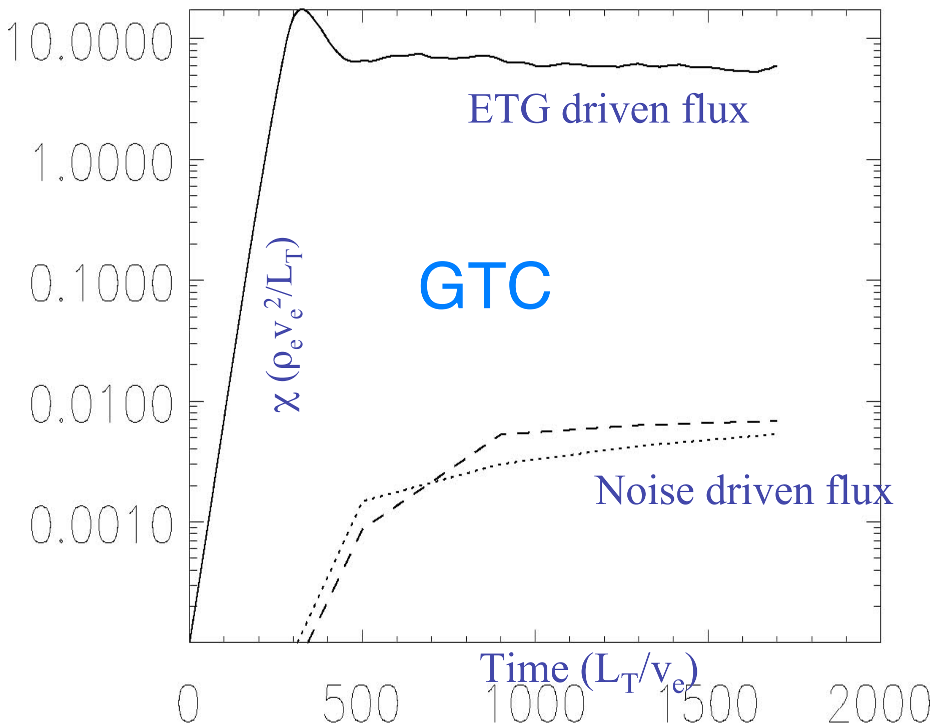
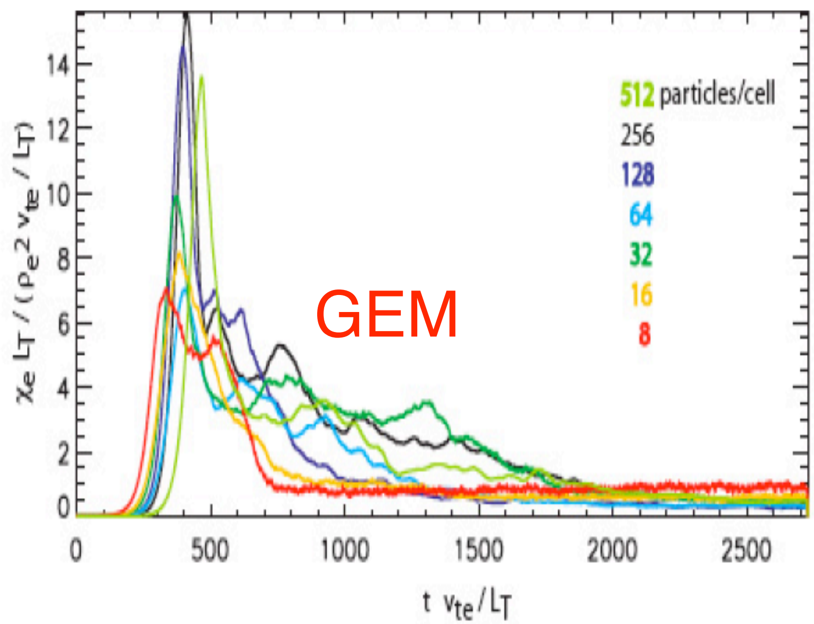
Convergence in ETG Simulations [Lin, Parker]

- Flux driven by particle noise is 1000 times smaller than ETG flux in global GTC simulation: noise does not affect ETG physics
- GTC: 4×10^{10} particles, 10000 time steps using ORNL Cray XT3, 6400 compute cores
- Benchmark with flux-tube GEM simulations showing similar trend: Cyclone weak case: R/L_T=5.3, s=0.78, q=1.4





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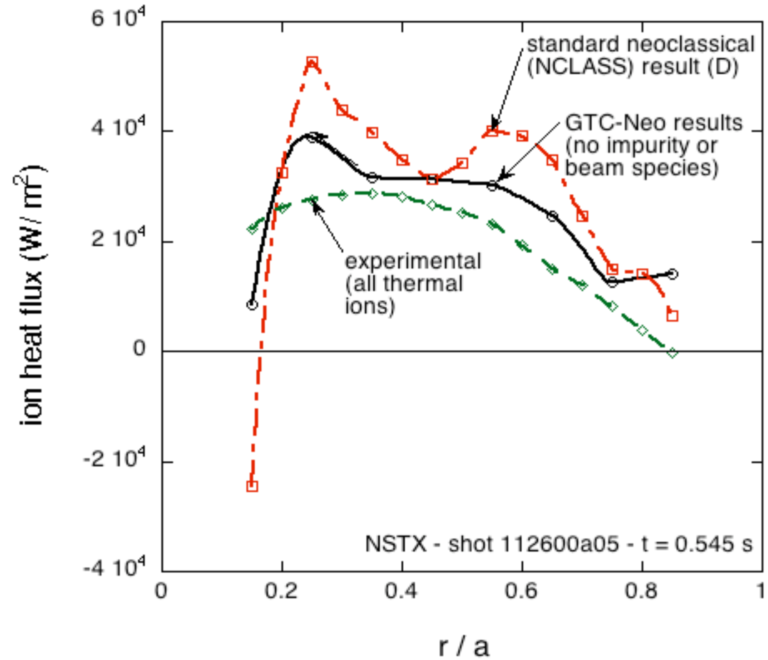
GK Simulations of Nonlocality in Neoclassical Transport

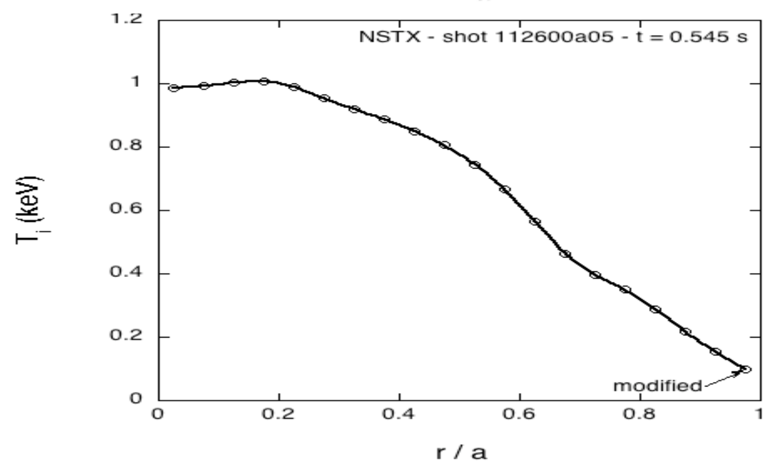
- GTC-Neo global Gyrokinetic PIC Code calculates neoclassical fluxes, E_r and J_b for realistic equilibrium and profiles
- Includes large orbits, momentum, energy, and number conserving collisions
- Benchmarked against Standard Theory

- Near the axis, in particular in ST's, nonlocal effects can be significant due to large orbits

- GTC-Neo simulation with nonlocal effects can bring calculated ion heat flux closer to the experimental value

  [Wang et al., PoP 13, 082501 (2006)]





Turbulence Spreading can affect Size Scaling

- **Global Toroidal ITG Eigenmode**

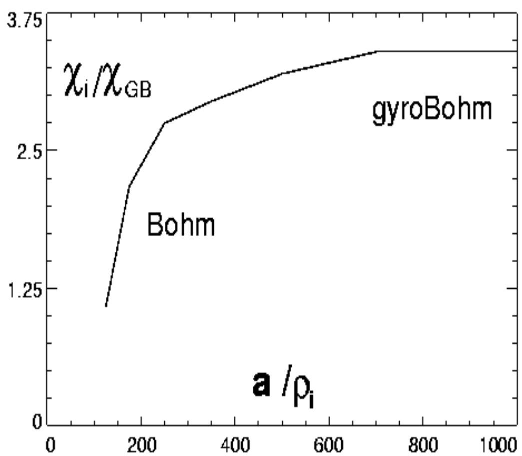
  Bohm Scaling ?

- **Shearing by Zonal Flows**

  GyroBohm scaling ?

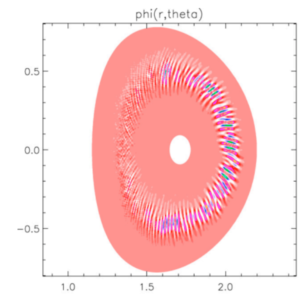
- **Turbulence spreading**

[Hahm, Diamond, Lin, et al., PPCF '04, PoP'05]
[Chen, Zonca, White, PRL '04, PoP '05][Waltz et al., PoP '05]
[Gurcan et al., PoP '05] [Yagi et al., PPCF '06]

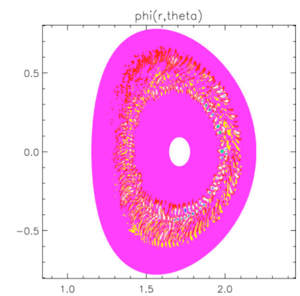


Deviation
from
GyroBohm ?

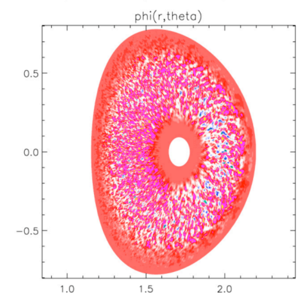
[Lin, et al., PRL '02]



t=150 L_T/v_{ti}



t=210 L_T/v_{ti}



t=1260 L_T/v_{ti}

Density fluctuations from a GTC simulation of ITG turbulence in a shaped plasma [Wang, *et al.,* PoP 13, 092505 (2006)]

Spreading is enhanced by NL coupling, reduced by ZFs

- Linear Toroidal Coupling leads to convective propagation with $V_s = C_s\rho_i/R$
[Garbet, Laurent, Samain et al., NF ‘94]

- Nonlinear Mode Coupling (w/o Zonal Flows)

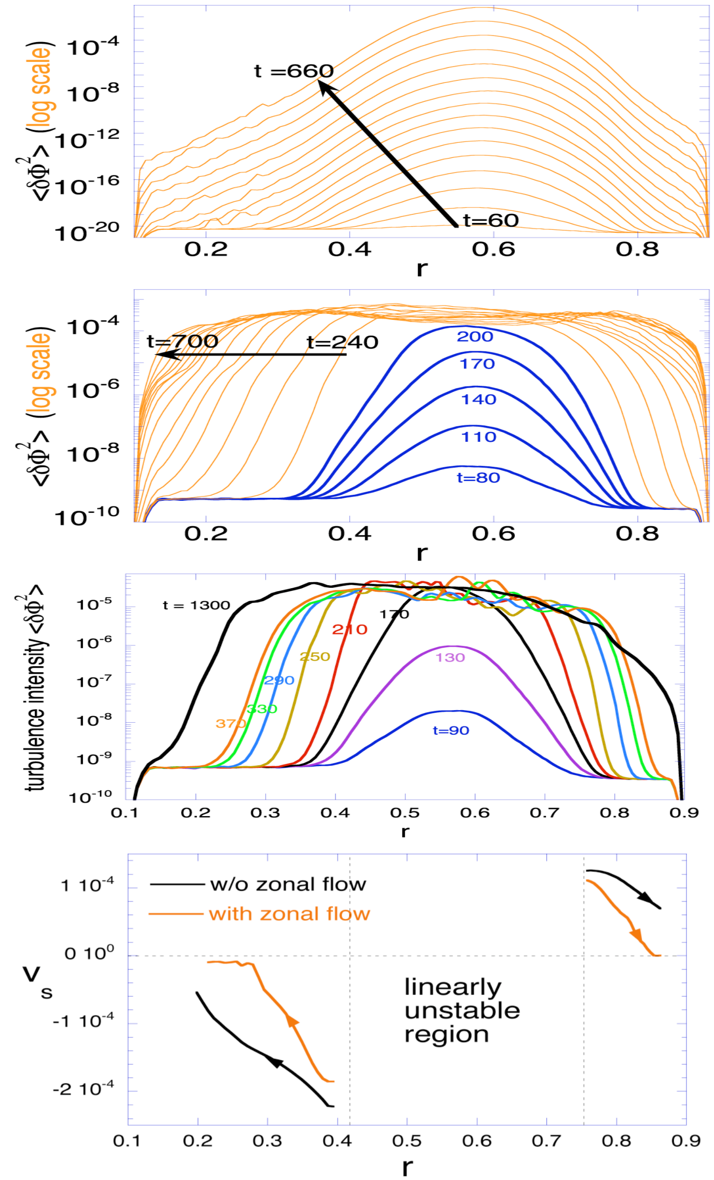
faster propagation,

convective in strongly unstable zone
[Gurcan, Diamond, Hahm et al., PoP ‘05]

subdiffusive in weakly stable zone
[Hahm, Diamond, Lin et al., PPCF ‘04]

- With Zonal Flows:

reduction of turbulence intensity leads to slower and less turbulence spreading

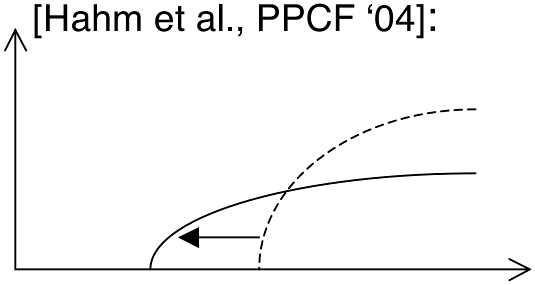


Turbulence Spreading through a Transport Barrier

- Non-zero fluctuations and anomalous transport observed in linearly stable zone of JT-60U reversed shear plasma [Nazikian et al.,PRL '05]

- Place E x B shear layer next to linearly unstable zone as a barrier

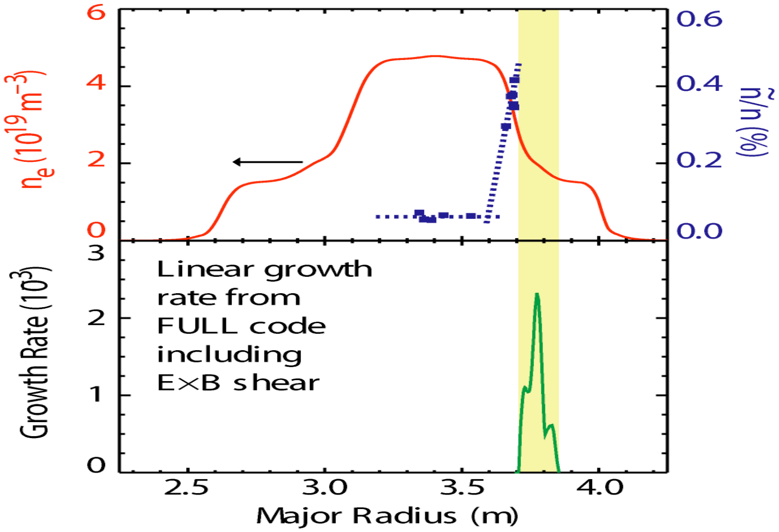
- From nonlinear diffusion model [Hahm et al., PPCF '04]:

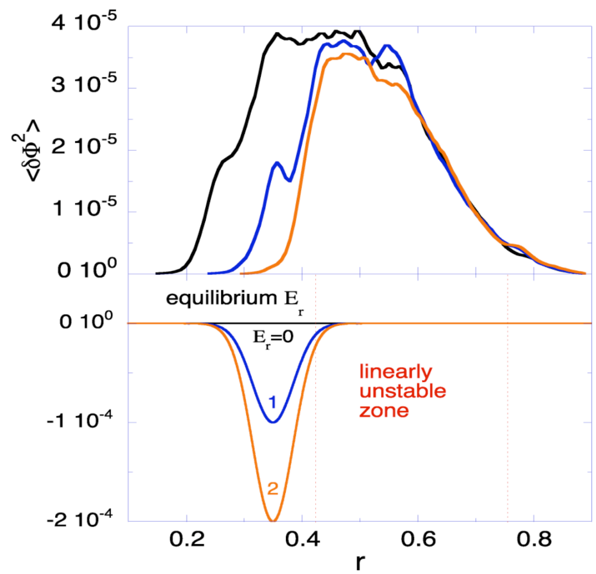


$\Delta / V_s \sim 1/|\gamma|' \Delta$ $\quad\Rightarrow\quad$ $\Delta \sim (V_s / |\gamma'|)^{1/2}$

ω_{ExB} increases $|\gamma'|$

Look for ω_{ExB} effects on V_s





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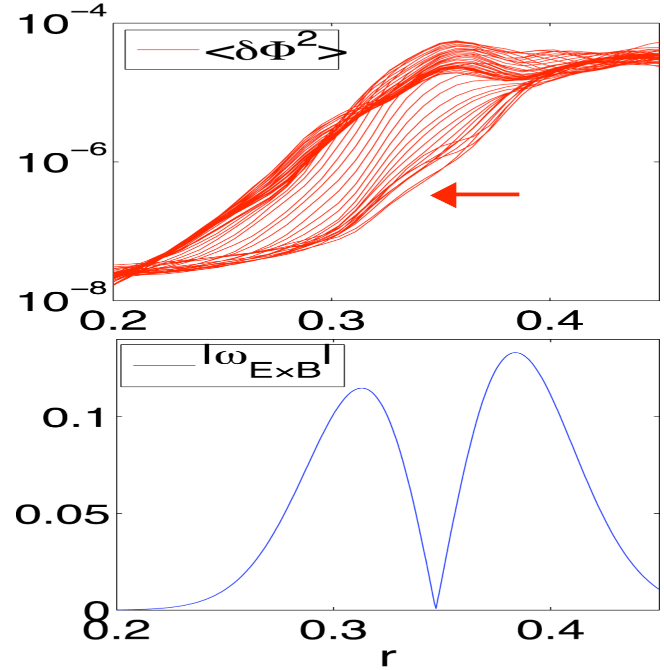
Spreading Speed is controlled by Local Value of ω_{ExB}

- Spatio-temporal evolution of front propagation:



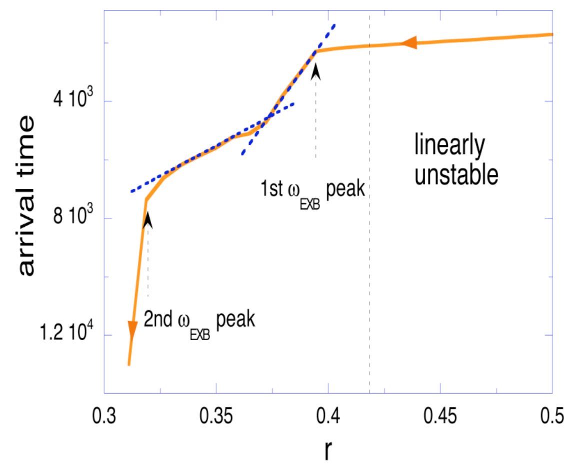
V_s increases with fluctuation intensity
[Hahm et al., PPCF '04, Gurcan et al., PoP'05]

ω_{ExB} (not E_r) reduces fluctuation intensity locally

⇒ ω_{ExB} decreases V_s locally

$\Delta \sim (V_s / |\gamma'|)^{1/2}$

Rough agreement in trend



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[For details, Posters Wednesday AM: TH/2-6Rb by Lee et al., TH/P2-8 by Lin et al.,]

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