JOHNS HOPKINS
UNIVERSITY

Understanding and Predicting Microtearing Instabilities in the ST

K. Tritz, D. Stutman, L. Delgado-Aparicio, M. Finkenthal

Department of Physics & Astronomy, Johns Hopkins University

Presented at:

ReNeW
Theme V: Optimizing the Magnetic Configuration
March 16-19, 2009
Princeton Plasma Physics Laboratory

JOHNS HOPKINS UNIVERSITY

Understanding Transport and Turbulence Important for Predicting Performance of Future Devices

Predict:

Confinement, Profiles, Stability, ...

Understand:

Thermal Transport

electron heat transport*

**TAP Tier 1 priority*

Momentum Transport

Particle Transport

Measure:

Turbulence

High-k: ETG

microtearing

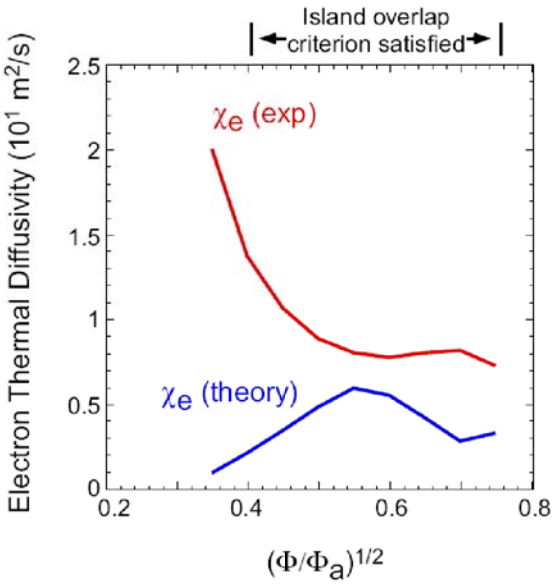
Low-k: ITG/TEM

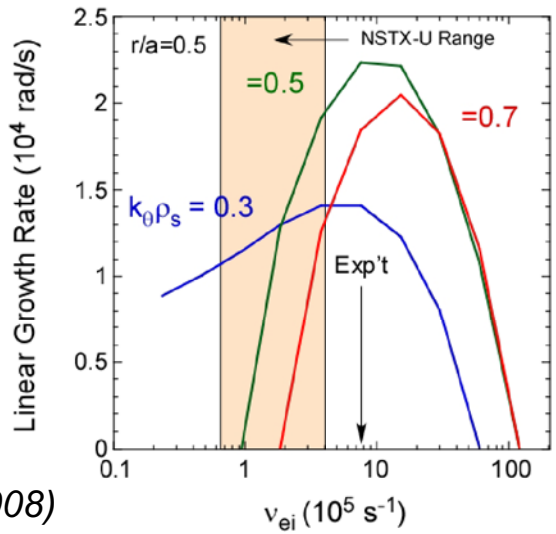
Other mechanisms:

EPMs (GAE, CAE, ...)
Stochastic heating
MHD
...

- Why specifically focus on microtearing turbulence?

Microtearing Turbulence May Play Important Role in Electron Thermal Transport on ST Devices





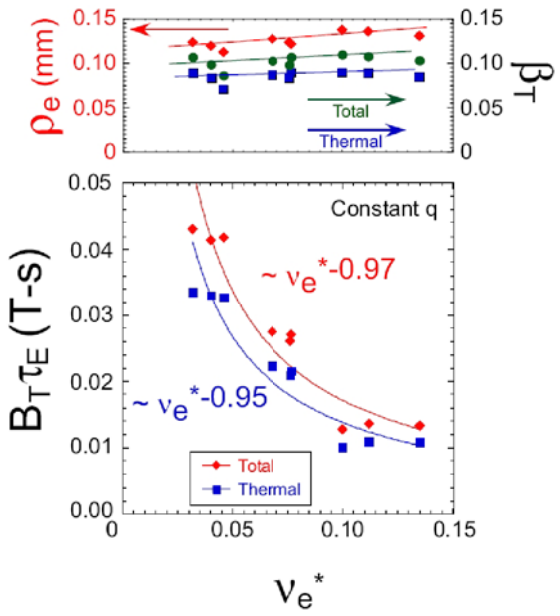
Wong PoP (2008)

- Analytic theory predicts microtearing transport close to TRANSP inferred values for r/a > 0.5 in NSTX H-modes
- Modes may be stabilized at lower collisionality, but depends on profiles (*Kotschenreuther, Nucl. Fus. 2000*)
- Picture similar in MAST, numerical calculations indicate differences from theoretical models (*Applegate, PPCF 2007*)

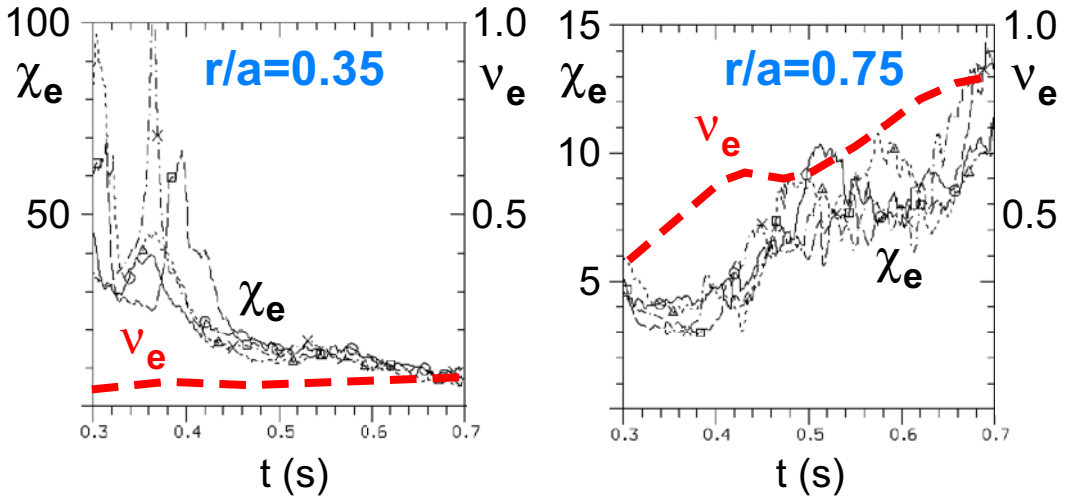
JOHNS HOPKINS UNIVERSITY

Strong Dependence of Confinement on Collisionality Supports Role of Microturbulence in Transport

NSTX



TRANSP calculated ν_e, χ_e in 4MW repeatable discharges



- Scaling of confinement as ν_e^{-1} suggests magnetic transport dominant

- TRANSP: χ_e trends with ν_e in outer plasma (r/a > 0.5) consistent with location of microtearing instability from theory, linear gyro-kinetic calculations

JOHNS HOPKINS
UNIVERSITY

Microtearing Turbulence Research Lags ETG, ITG/TEM Efforts

- ITG/TEM & ETG modes have been measured successfully and compared to non-linear calculations (important, should continue)
- Microtearing theory/simulation advances needed to improve understanding
  - Linear stability codes can predict microtearing modes, growth rates
  - Linear gyrokinetic stability calculations show differences with theoretical models
  - Non-linear simulations are computationally intensive, convergence issues
- Present ST devices lack microtearing diagnostics
  - Direct measurements of microtearing magnetic fluctuations are challenging
  - Non-magnetic (and indirect) measurements of microtearing require comparisons to non-linear simulations/synthetic diagnostics for interpretation

JOHNS HOPKINS UNIVERSITY

Magnetic Fluctuation Diagnostics Face Difficulties Detecting Microtearing Instabilities

Diagnostics must measure (for NSTX typ. H-mode)

- $dB/dt \sim 10^{-3}$
- $k_\theta \rho_s \sim 0.1\text{-}1$
- BW ~ 10's of kHz
- $\Delta r \sim 1$ cm

MSE diagnostic: can measure dB/dt, but lacks sensitivity at required bandwith

Polarimetry: used successfully on MST, but broad density profile of ST will prevent spatial localization

Cross-polarization scattering: uses RF mode conversion to measure magnetic fluctuations, $kp_s > 10$ more suited to ETG

Heavy ion beam probe: sensitivity to other quantities (e.g. electric potential) complicates interpretation, challenging to build/implement - may be best solution for measuring microtearing dB/dt on ST

JOHNS HOPKINS
UNIVERSITY

Non-magnetic Measurements Must be Coupled to Simulations

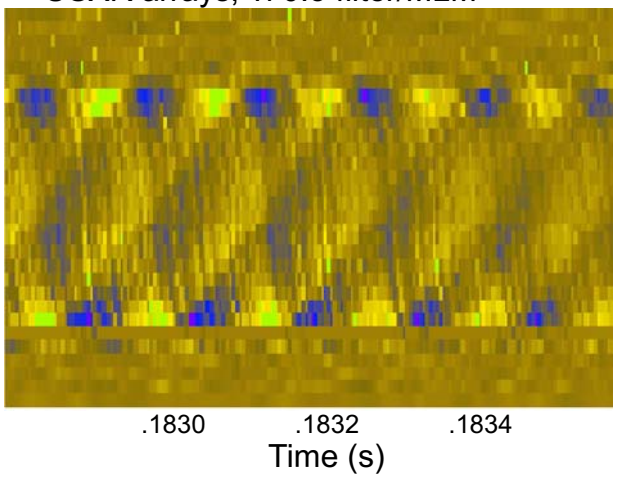
- Microtearing fluctuations may affect other plasma quantities (T_e, n_e, ...)

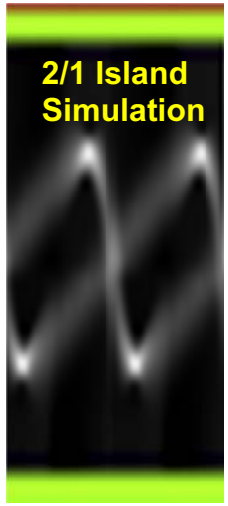
Example: possible microturbulent fluctuations observed with Soft X-ray imaging

30 radially viewing, poloidal chords

radial localization from line emission:
carbon emission shell near pedestal top

high m/n structures ~50-80kHz
overlaying 2/1 5kHz island





- General fluctuation diagnostics may observe microtearing (e.g. BES, SXR, ...)
  - combinations may allow isolation of n_e, T_e fluctuations

- Indirect measurements may also detect microtearing presence (PHA)

- Making connection to transport theory requires validation of codes
  - non-linear codes predict measurements from synthetic diagnostics for comparison

JOHNS HOPKINS
UNIVERSITY

Proposed Microtearing Turbulence Research (sub-) Thrust

Develop physics-based understanding of microtearing modes, specifically how they manifest at low aspect ratio.

- understand role of magnetic, ExB shear on mode stabilization
- understand effects of ν, β, β', and operation at low A

obtained by...

Translating fluctuation measurements into knowledge about microtearing induced electron thermal transport

- implement diagnostic(s) necessary to measure fluctuations (B, n_e, T_e)
  - HIPB?, BES, SXR imaging, also PHA
- advance non-linear codes to provide synthetic measurements for validation
  - GEM code nearly there, others?

Goal: predicting microtearing transport for future devices