Study of microtearing mode in NSTX with GEM code

J. Chowdhury [1], Y. Chen[1], W. Wan[1], S. E. Parker[1],

J. M. Canik[2], W. Guttenfelder[3], D. R. Smith[4]

1. CIPS, University of Colorado at Boulder, Boulder, CO 80309, USA

2. Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

3. Princeton Plasma Physics Laboratory, Princeton, NJ 08540, USA

4. University of Wisconsin-Madison, Madison, WI 53706, USA

Work supported by: DOE SciDAC Edge Physics Simulation Center

55th Annual Meeting of the APS Division of Plasma Physics,

November 11-15, 2013, Denver, Colorado

Microtearing (MT) mode: introduction

- MT modes are electromagnetic, sensitive to collisionality, characterized by even parity in $A_{\|}$, and driven by electron temperature gradient
- Although, earlier MT modes were believed to be important only for spherical tokamaks both in core and edge (Guttenfelder *et al.* POP 19(2012), Applegate *et al.*, PPCF 49 (2007), Dickinson *et al.*, PPCF 55 (2013), Canik *et al.* NF **53** 2013), recent results have indicated that they can equally affect the electron thermal loss in conventional tokamaks (Moradi *et al.*, NF 53 (2013)), Doerk *et al.*, POP 19 (2012)).

The objective of present work is to carry out a gyrokinetic study of the MT mode for NSTX parameters using GEM (*Y. Chen, S. E. Parker, JCP(2003), JCP(2007)*).

- As a first step, we will use flux tube model of GEM to reproduce some of earlier results in the core;
- In the second step, we will use global GEM to study MT mode in the edge pedestal region;

The simulation model in GEM code

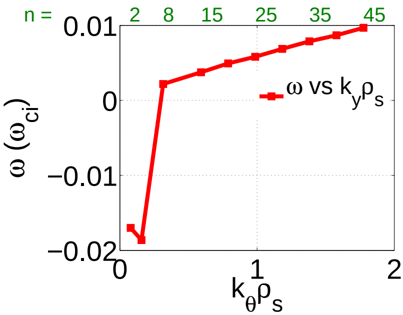
- Global electromagnetic code, with full kinetic electron physics
- Uses δf gyrokinetic simulation model based on particle in cell method
- Uses $p_{||}$ formulation, split weight scheme for electrons, high β Ampere algorithm,
- Field line following coordinates:
  - Cover $0 < \theta < 2\pi$
  - Can be used as radially local (flux tube) and global
  - Arbitrary size toroidal section
- Includes collisions and equilibrium flow
- Arbitrary shape tokamak equilibrium
- Can include upto two impurity species

Parameters used in GEM for NSTX core:

(Guttenfelder *et al.* Phys of Plasmas 19, 022506 (2012) and Moradi *et al.*, Nucl. Fusion 53 (2013) 063025)

Parameter Name	GEM inputs
r/a, R_0/a	0.6, 1.52
m_i/m_{proton}, m_{imp}/m_{proton}	2, 12
q_{imp}/e, q_i/e	6, 1
$T_e(KeV)$	1.006
$T_i(KeV)$	0.946
n_{imp}/n_e	0.064
T_e/T_i, T_{imp}/T_i	1.064, 1.0
R/Lne	-1.2616
R/Lni	5.5766e-1
$R/Lnimp$	-4.18
R/LTe	4.1344
R/LTi	3.5872
$R/LTimp$	3.5872
ρ^*	0.0074
Z_{eff}	2.91
q	1.68
$\hat{s} = rdlnq/dr$	1.73
Shafranov shift $\triangle$	-0.0
κ (elong)	1.72
$\hat{s}_\kappa$ (selon)	0.0
δ_0 (tria)	0.12
s_{δ_0}	0.0
β_e	0.024
$\gamma_E(a/c_s)$, $\nu^*_{ei}(a/c_s)$	0.0, 1.0
$\nu^*_{ei}(\omega_{ci})$, $c_s/a(\omega_{ci})$	$7.05e^{-3}$, $7.05e^{-3}$
No. ion species, $k_\theta \rho_s$	2, 0.98 (n=25)

Real frequency and growth rates versus $k_\theta \rho_s$



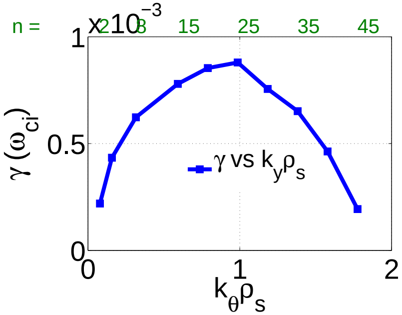


Figure: **Real freq (left) and growth rates (right) vs $k_\theta \rho_s$, for $\nu_e = 1.0$, and $\beta = 0.024$**

- Real frequency increases with $k_\theta \rho_s$
- Growth rate increases initially with $k_\theta \rho_s$; however at higher $k_\theta \rho_s$, the growth starts decaying. Subject to FLR effect?
- At very low $k_\theta \rho_s$, the dominant mode appears to be in the ion diamagnetic direction; with ballooning parity.

Real frequency and growth rates versus collision frequency

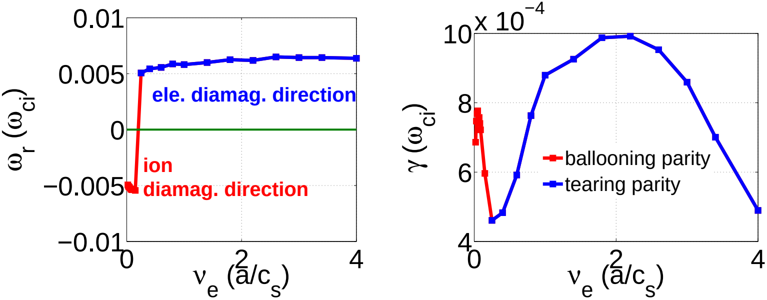


Figure: **Real freq (left) and growth rates (right) vs collision frequency for $n = 25$, $k_\theta \rho_s = 0.986$**

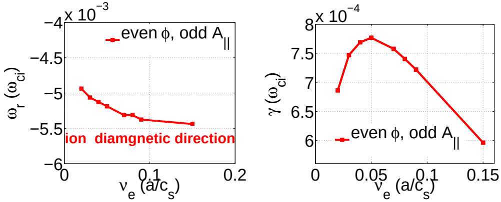


Figure: **Close up of Real freq (left) and growth rates (right) vs collision freq in the low ν_{ei} range, where the mode exhibits ballooning parity**

Mode structures for ballooning (even ϕ_{xz}) and tearing (even $A_{\|,xz}$) parity modes for two collision frequencies $\nu_e = 0.01$, and $\nu_e = 0.1$

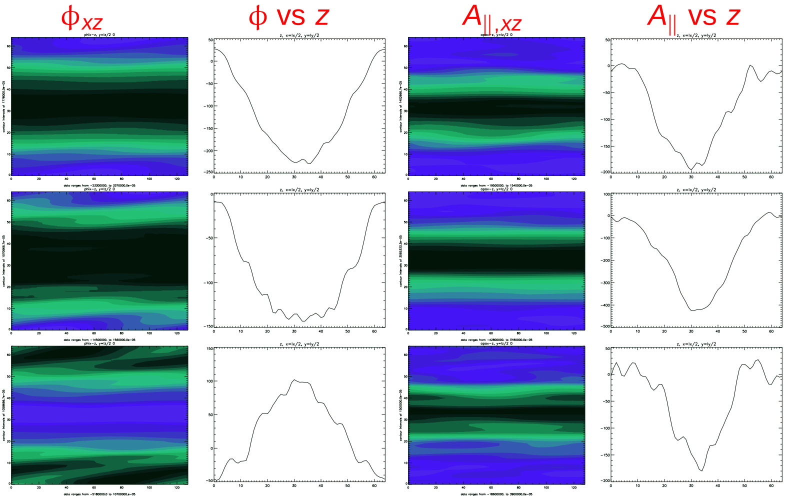


Figure: **Left two panels:** ϕ **for** $\nu_e = 0.01$. ϕ_{xz} **is even for Ballooning Parity mode**
Right two panels: $A_{\|}$ **for** $\nu_e = 1.0$. $A_{\|,xz}$ **is even for Tearing Parity mode**

Few Points To Be Noted

- Real frequency is weakly dependent on collision frequency
- At lower collision frequency the real frequency is in the ion diamagnetic direction, at higher collision frequency the real frequency rotates toward electron diamagnetic direction.
- Growth rate increases initially with collision frequency; however at higher collision frequency, the growth starts decaying again.
- At lower collision frequency the mode structure has ballooning parity characterized by even ϕ_{xz} while at higher collision frequency the mode structure has even parity characterized by even $A_{||,xz}$.

Real frequency and growth rates versus β

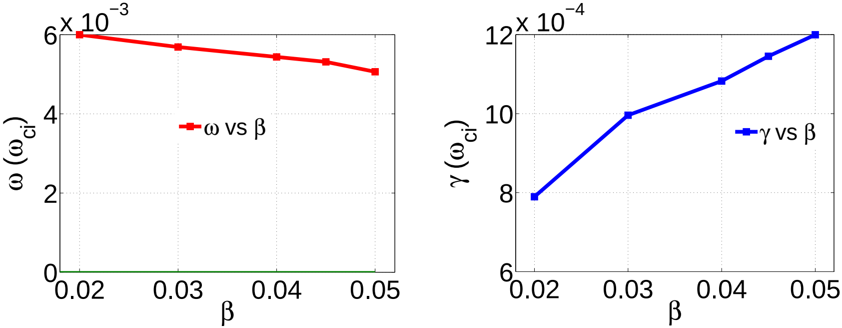


Figure: **ω_r (left) and γ (right) vs β, for $\nu_e = 1.0$, and $n = 25$, $k_\theta \rho_s = 1.0$**

- Real frequency is weakly dependent on β,
- Growth rate increases virtually linearly with β,
- At very low β, the dominant mode appears to be in the ion diamagnetic direction; with ballooning parity.

Growth rate versus electron temperature gradient

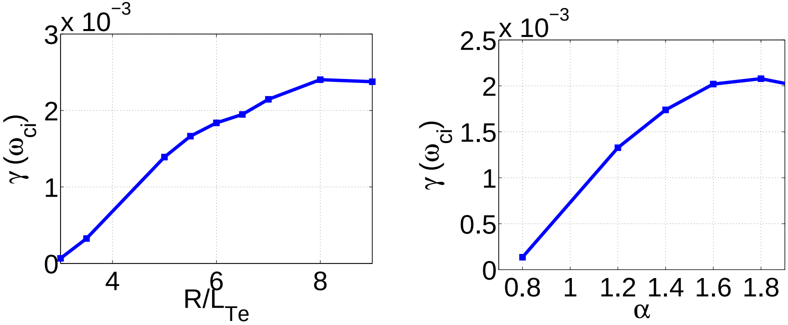


Figure: **Left: Only R/L_{Te} is varied keeping R/L_{Ti} and R/L_{Tc} constant; Right: R/L_{Te}, R/L_{Ti} and R/L_{Tc} are varied simultaneously by multiplying a factor α**

The mode is destabilized by the electron temperature gradient.

Growth rate versus ion temperature gradient

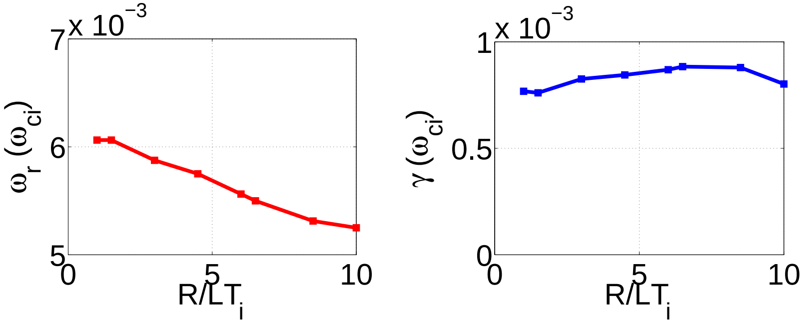


Figure: **Only R/L_{Ti} is varied keeping R/L_{Te} and R/L_{Tc} constant**

The ion temperature gradient has virtually no effect on MT mode destabilization.

Growth rate versus electron density gradient

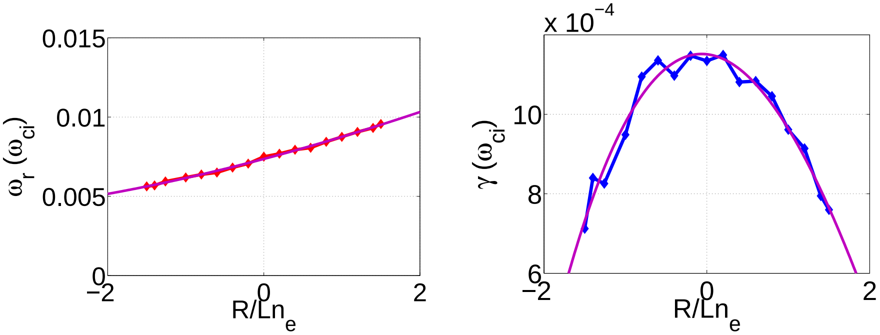
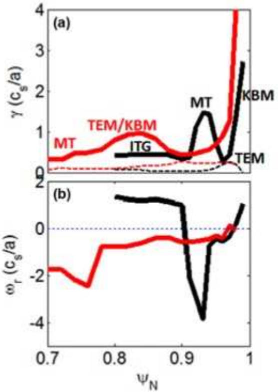


Figure: **Real frequency and growth rates versus R/L_n**

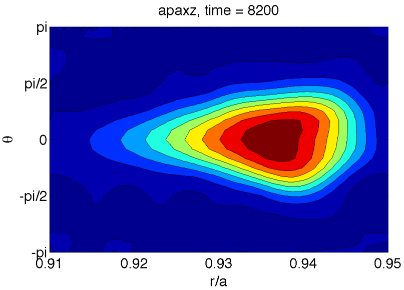
- Real frequency increases virtually linearly w.r.t. R/L_{ne},
- Growth rate decreases with increasing R/L_{ne}.

Global GEM observes MT mode at NSTX edge

Canik et al., Nucl. Fusion 53, 113016 (2013), GS2 simulation: MT at *ψN=0.93* for *kθρs≤1*.



Global GEM simulation results sees MT at *kθρs=1.*



All results are consistent with GS2:

- *γ=1.63 Cs/a; ω=4.0 Cs/a*, in electron direction
- Collision is slightly stabilizing.
- Microtearing is the dominant instability at this regime.

Even-parity mode dominates in lower-*k* regimes.

Conclusions

We have carried out a linear gyrokinetic analysis of the MT mode in the core and edge of NSTX using flux tube and global GEM.

- Main conclusions from our flux tube analysis for core (in conformity with earlier results)
  - The MT mode is the dominant instability at higher collision rate with even $A_{||}$; at lower collision rate, the dominant instability has real frequency along ion diamagnetic drift direction with ballooning parity
  - The growth rate increases almost linearly with increasing β; driving mechanism is the temperature gradient of electrons; ion temperature gradient has very weak effect on the mode
  - Preliminary studies show that density gradient of electrons stabilizes the mode.
- First global gyrokinetic study for edge MT mode in NSTX. For the given parameters global GEM observes MT mode at NSTX edge.

Future work

- Nonlinear studies will be carried out to study the contribution of microtearing mode to anomalous transport of electrons. Effect of equilibrium and perturbed shear will be investigated.
- A global linear and nonlinear gyrokinetic simulation with GEM for the edge microtearing mode will be initiated.