Simulations of Energetic Particle Modes In Spherical Tokamaks and Stellarators

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Outline

- Introduction
- Particle/MHD Hybrid Model
- Energetic Particle-driven Modes in STs

Introduction

- The M3D code solves a full set of single fluid MHD or two-fluid equations plus energetic ion species treated as particles.
- Previously, M3D code had been applied to problem of nonlinear saturation of TAEs, stabilization of internal kink and excitation of fishbone.
- Recently, M3D hybrid code has been extended to full 3D geometry applicable for spherical tokamaks and stellarators. The code has been parallelized via MPI.
- In this work, M3D is applied to energetic ion-driven Alfven modes in NSTX plasmas and stellarators.

Particle/MHD Hybrid Model

$$\rho_b \frac{d\mathbf{v}_b}{dt} = -\nabla P_b - (\nabla \cdot \mathbf{P}_h)_\perp + \mathbf{J} \times \mathbf{B}$$

$$\mathbf{J} = \nabla \times \mathbf{B}$$

$$\frac{\partial \mathbf{B}}{\partial t} = -\nabla \times \mathbf{E}$$

$$\mathbf{E} + \mathbf{v}_b \times \mathbf{B} = \eta \mathbf{J}$$

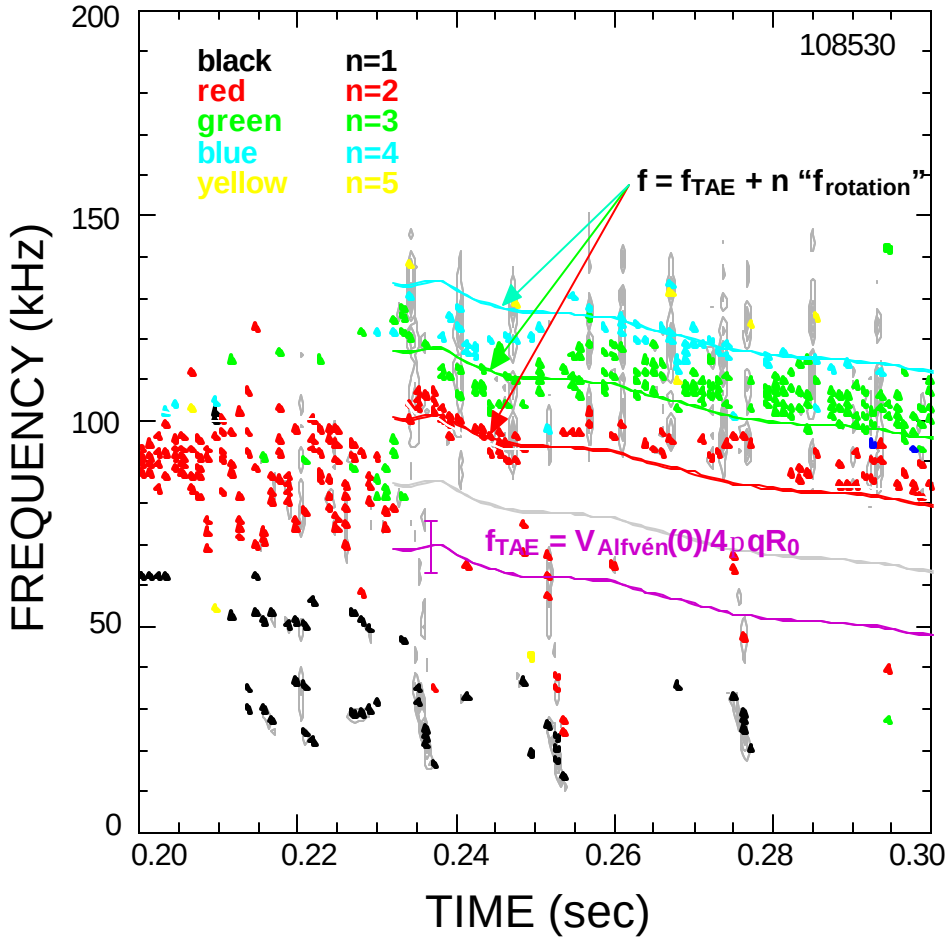
Energetic Particle-driven Modes in Spherical Tokamaks

- In the NBI-heated NSTX plasmas, beam-driven modes were observed with mode number n=1~5 and frequencies similar to TAE's.
- The M3D code is used to simulate these modes for experimental parameters. Unstable TAEs are excited in the simulations with frequencies similar to the observed values.

E. Fredrickson

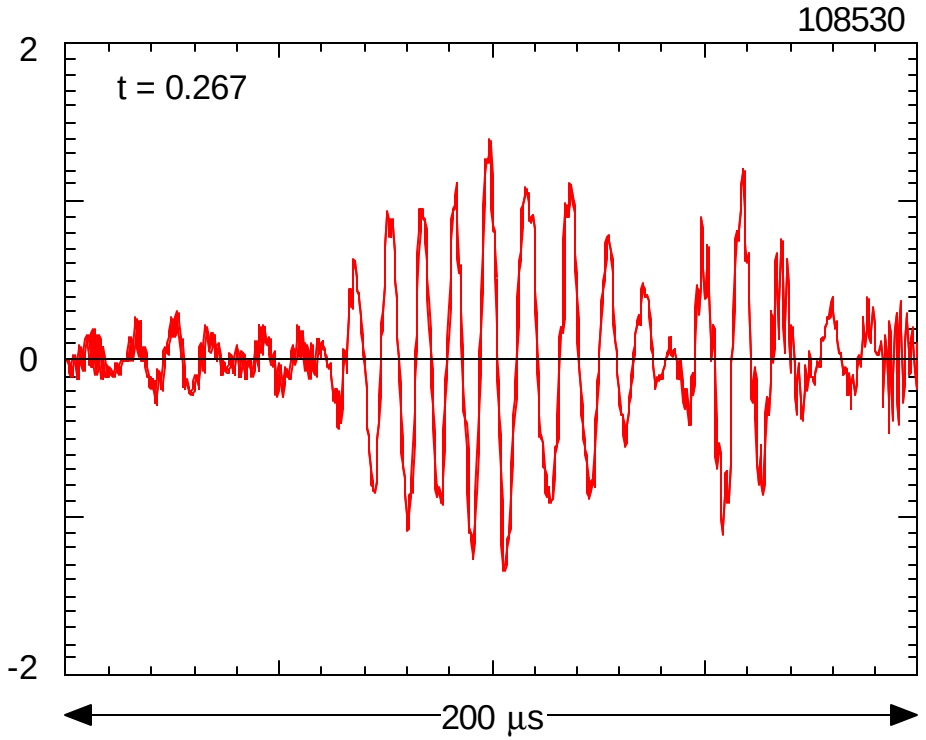
The bursting modes are in the TAE frequency range (NSTX)

- Multiple modes burst at the same time.
- Toroidal mode number, n, ranges from 2 - 5 with the dominant mode being n=2 or 3.
- Mode frequencies in reasonable agreement with expected TAE frequencies.

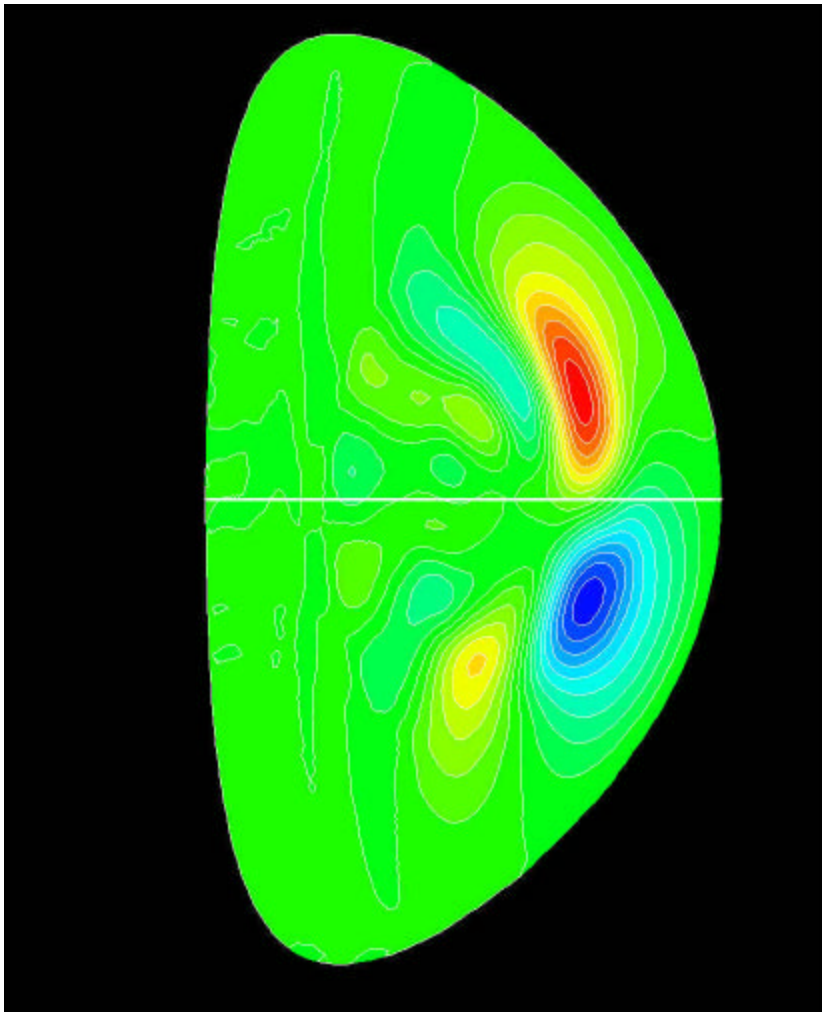


The final mode growth and decay is very fast

- Some of the mode amplitude modulation represents "beating" of the multiple modes.
- Mode growth and decay times are approximately 50 - 100 μs.



The simulation of an NSTX plasma show unstable TAEs consistent with observations



- NSTX shot #108530 at t=0.267sec;
- The calculated n=2 TAE mode frequency is 73 kHz which is close to the experimental value of 70 kHz (assuming 15kHz toroidal rotation)

N=1 and N=3 Modes in NSTX