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NSTX-U

Comparison of compressional Alfvén eigenmodes in NSTX with simulation using the CAE3B eigenmode solver

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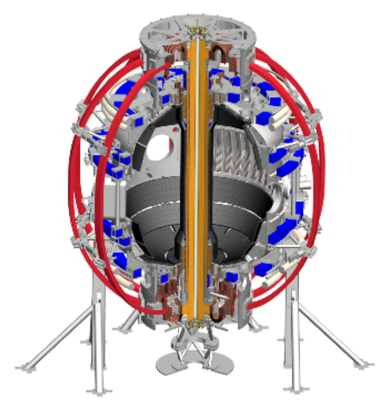
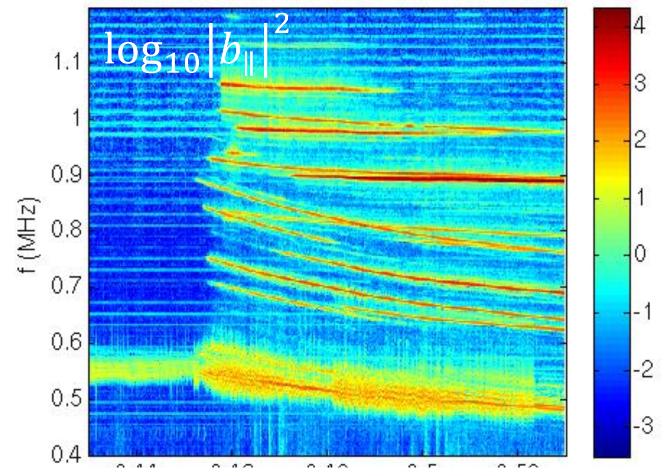


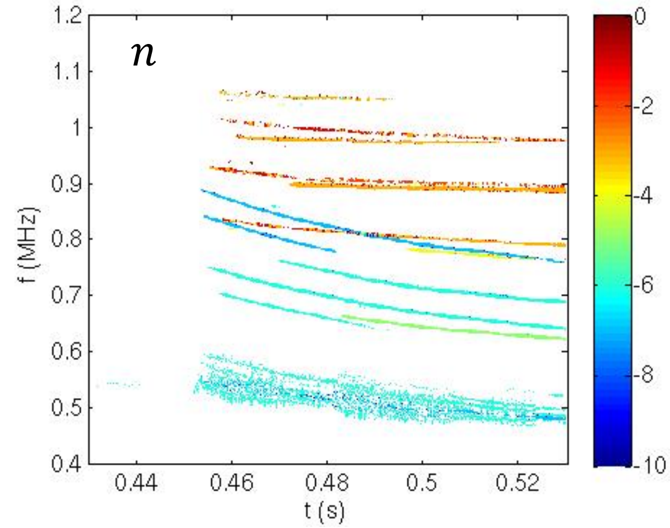
Understanding energy transport requires predictive capability for CAEs

- Compressional Alfvén eigenmodes (CAEs) may contribute to energy transport
  - Stochastization of resonant electron orbits?
  - Electromagnetic channeling of beam energy to plasma edge?
- Frequency and toroidal mode number of experimentally observed CAEs can be measured
- CAE3B eigenmode solver numerically simulates CAEs in experimental plasmas
- CAE3B simulations can be compared with observed modes in an NSTX discharge to verify the physics of CAE3B and further our understanding of CAEs

Can identify CAEs and GAEs in the NSTX with an array of edge magnetic sensing coils

Observed modes in NSTX shot 130335



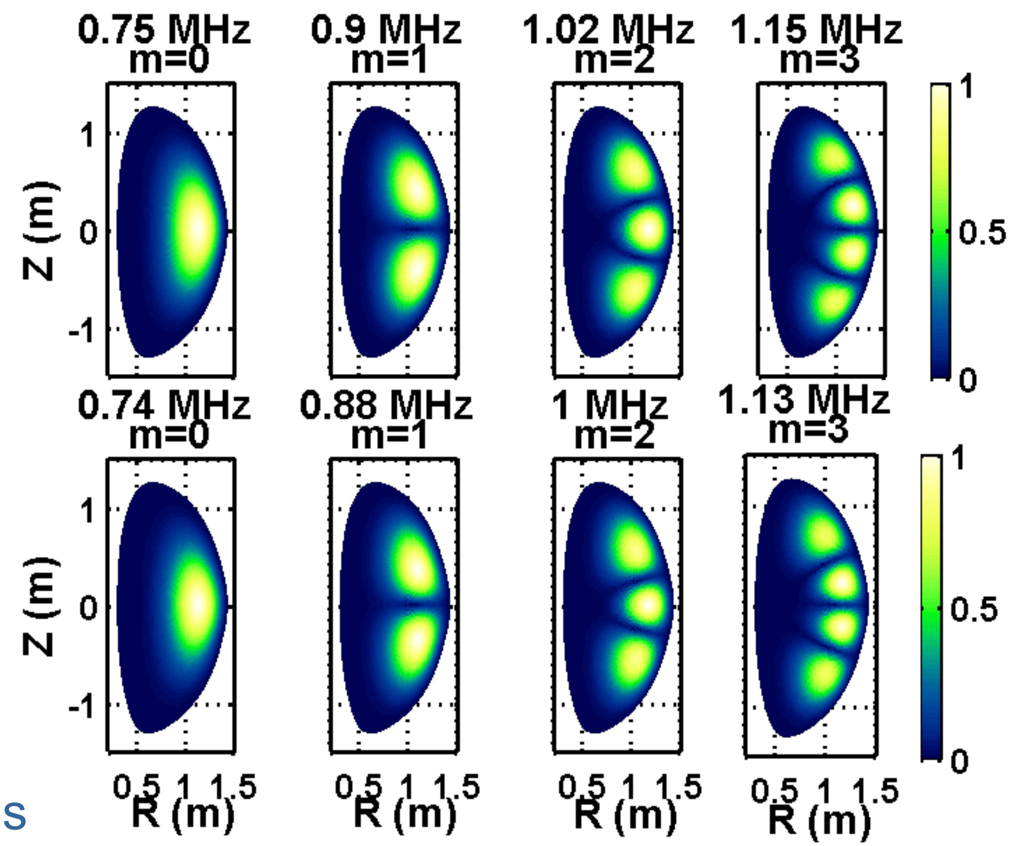


- Short-time Fourier transform of measured $b_\parallel(t)$ into $f - t$ space to identify modes
  - Regions of *high* $|b_\parallel|^2$, *narrow-band in* f and *temporally extended* are experimental modes
- CAEs and GAEs difficult to unambiguously identify by f alone
- Toroidal mode number n obtained by fitting to toroidally distributed array → facilitates identification
  - Can be complicated by incorrect or ambiguous n determination (e.g. from noise or pickup)
  - n determination analysis continues to evolve

Eigenmode solver CAE3B can be used to simulate CAEs in an NSTX plasma

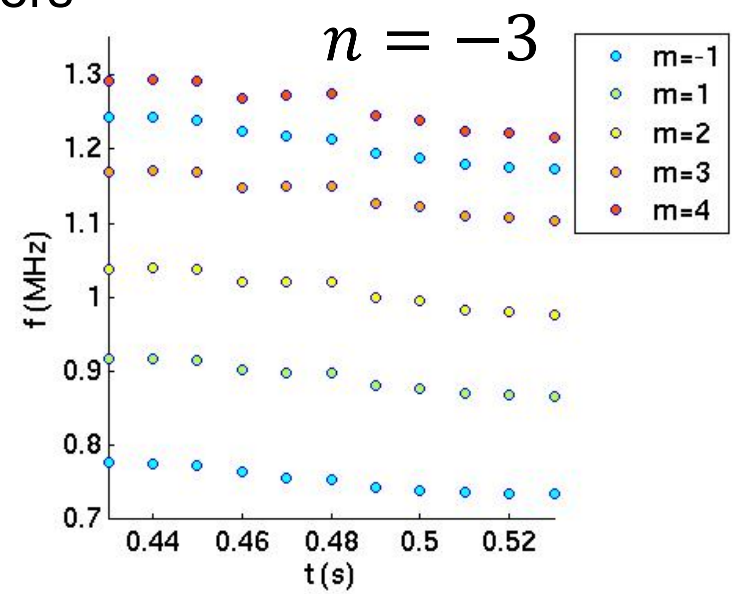
- Simulated CAEs can be compared to observed modes in the NSTX to validate the physics of CAE3B
- CAE3B assumes Hall MHD with simplified physics
  - Hall MHD keeps ion inertia effect in Ohm's law: $\frac{\omega}{\omega_{ci}} \lesssim 1$
  - Simplified boundary at edge of plasma: $b_{\|} = 0$
  - Removes coupling to shear Alfvén waves: $\frac{v_A{}^2}{\omega^2 B^2}(\boldsymbol{B} \cdot \nabla)^2 \ll 1$
- Only compare subsets of observed and simulated modes
  - Observed modes include CAEs and GAEs
  - CAE3B produces only CAEs and spurious solutions
  - CAE3B doesn't predict which CAEs are unstable

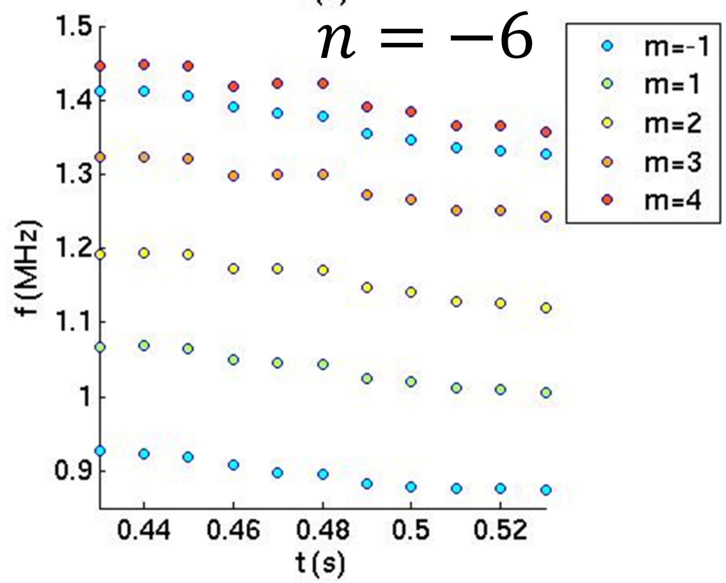
$|b_{\|}|$ of simulated CAEs, shot 130335, $n = -3$



Poloidal mode number m must be identified to track CAEs in simulation

- CAEs adiabatically evolve, conserving mode numbers → track mode over time with mode numbers
- Matching between times steps by n and s easy:
  - Simulation assumes n
  - Δf for change of $s \gg \Delta f$ for time step
- Matching between times steps by m hard:
  - Lack of poloidal symmetry complicates identification
  - Δf for change of $m \gtrsim \Delta f$ for time step
- m can be calculated by iteratively morphing plasma geometry to a circle
  - Computationally expensive
- Quick (and dirty) method for calculating m: poloidal Fourier transform of $b_{||}$; integrate over r
  - Peak in integrated spectrum gives m
  - Does not always correctly identify m
- Cross-coherency resolves misidentifications
  - $\frac{b_{t_1} b_{t_2}^*}{\sqrt{|b_{t_1}|^2 |b_{t_2}|^2}} \approx 1$ for same CAEs

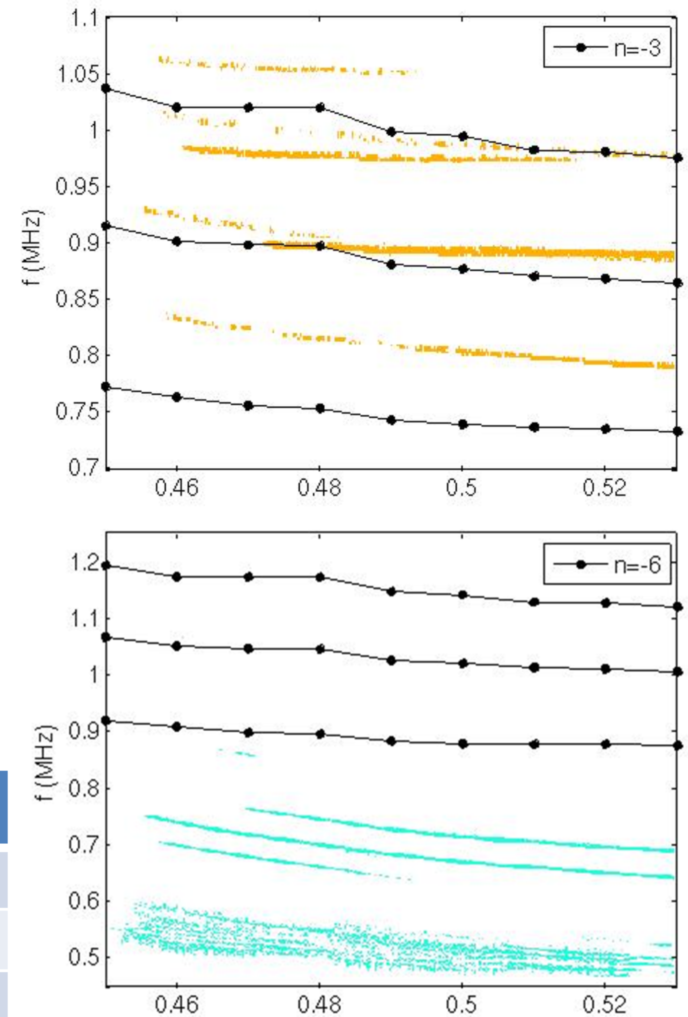




$n = -3$ observed modes probably CAEs; $n = -6$ probably GAEs

- The $n = -3$ simulated CAEs have $f(t)$ and $\min(f)$ similar to experimental modes → *probably CAEs*
- The $n = -6$ experimental modes have f too low & much higher $|\Delta f/\Delta t|$ than simulation → *probably GAEs*
- Consistent with identification of high-n, low-f modes as GAEs and vice-versa as CAEs in previous research [Crocker, NF 2013]

	$n = -3$		$n = -6$	
	CAE3B	Expt.	CAE3B	Expt.
f_{min} (kHz)	~750	~820	~900	~500
$\lvert\Delta f/\Delta t\rvert$ (kHz/ms)	~0.5-0.9	~0.1-0.7	~0.6-1.0	~1.3-1.9
Δf (kHz)	~80-150	~80	~80-150	~40



CAE3B enhances toolkit for distinguishing CAEs and GAEs in NSTX and NSTX-U plasmas

- Combination of $f(t)$ with $\min(f)$ comparison strengthens identification
  - Powerful comparison tool, but not conclusive: predicted f close but not exact
- f-spacing between modes larger in simulation than experiment; not fully understood, but some effects known
  - Plasma rotation not included in simulations here (under development)
  - Computational domain restricted to plasma for numerical reasons → boosts frequencies
- Known effects expected to influence f offset more than $\Delta f/\Delta t$
  - Rotation relatively constant in plasma considered here
  - Shape relatively constant for plasma considered here → expansion to vacuum vessel wall stretches plasma eigenmodes similarly at all times → adds f offset but changes spacing little (tested by E. Fredrickson's CAE code)

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