Exploration of Alfvén Eigenmode physics via active antenna excitation in JET Deuterium, Tritium, and DT plasmas

P2a.107

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Alfvén Eigenmode Active Diagnostic (AEAD)

- 2 sets of 4 toroidally spaced antennas in JET [1,2]
- Independent power/phase: <10 A, $|n| < 20$ [3]
- Scan frequency range $f \sim 25$ - 330 kHz (NEW!)
- Actively resonate with *stable* Alfven Eigenmodes
- Fast magnetic coils measure response and… [4]
  - Resonant frequency $f_0 = \omega_0/2\pi$
  - Total damping rate $\gamma < 0$
  - Toroidal mode number n

→ Compare f_0, γ, n with theory and modeling

→ Predict AE stability of future fusion devices

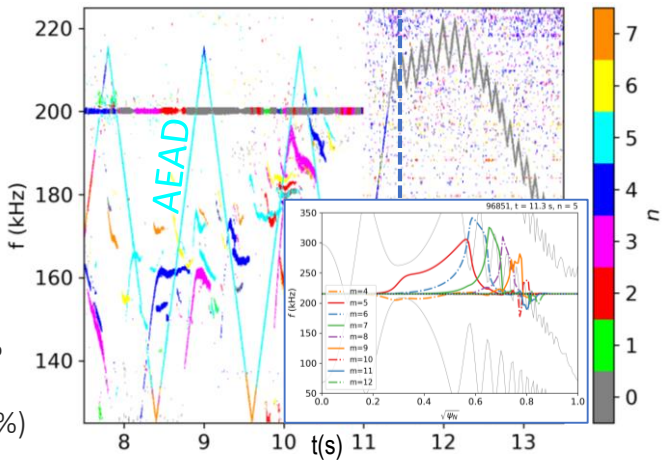
Summary and Outlook

- Thousands of AE stability measurements in JET D, T, and DT plasmas; many yet to be explored
- NOVA-K simulations match experiment well in two novel plasma scenarios:
  1. Stability transition: unstable-to-stable
  2. DT-alpha bump-on-tail instabilities
- Radiative, continuum, and electron Landau damping are dominant in these cases
- Future analysis: simultaneous measurements of un/stable AEs [5] also achieved in DT plasmas

TAE stability transition: unstable-to-stable

- RSAEs destabilized by NBI + RF in JPN 96851 [6,7] with non-monotonic safety factor profile
- After 11 s, AEAD tracks stable AE in real-time with normalized damping rate $-\gamma/\omega_0 \sim 1\% \pm 0.1\%$
- Hybrid kinetic-MHD code NOVA-K [8-10] identifies n = 4,5 TAEs at correct frequencies at 10.6 s & 11.3 s
- (Note: q-profile lowered at 11.3 s to achieve q < 1)
- NOVA-K calculates similar damping rate ~1% ± 0.1%

→ Radiative (0.7%), continuum (0.1%), and electron Landau (0.1%) damping, even from RF fast ions (0.2%)

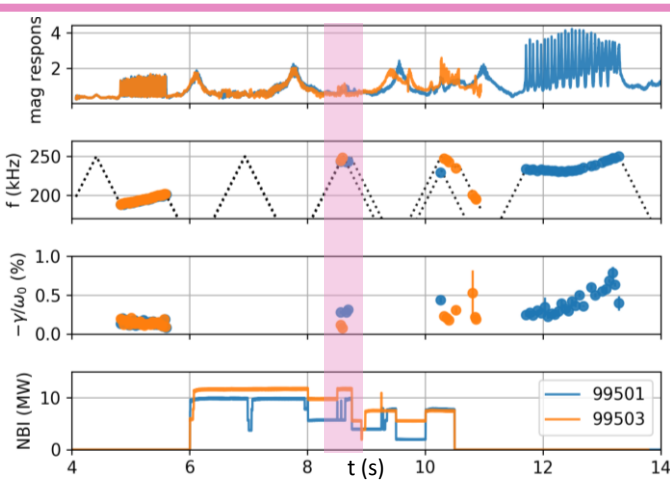


AE stability measurements in T & DT plasmas

- 4000+ stable AEs measured in 100+ T and 200+ DT plasmas (10% of T data with f > 250 kHz)
- Strong correlation of γ/ω_0 with edge safety factor/ magnetic shear and non-ideal parameter [11,12]

→ Continuum and radiative damping

- Alpha bump-on-tail (BOT) instabilities [13,14] investigated in JPN 99501/3 via NBI modulation
- Stable AEs with $f \sim 245$ kHz, $-\gamma/\omega_0 \sim 0.1\%$ - 0.3% consistent with edge EAEs ($\sqrt{\psi_N} > 0.6$) in NOVA-K, but little interaction with alphas (0.02%, no BOT)



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This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 — EUROfusion). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

Supported by US DOE grants DE-SC0014264 and DE-AC02-09CH11466.