Observation of reverse shear Alfvén eigenmodes in Alcator C-Mod and their modeling with NOVA

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Introduction
The phase contrast imaging (PCI) diagnostic has observed reverse shear Alfvén eigenmodes (RSAEs) during the current ramp with early ICRF heating.

The ideal MHD code NOVA has been used to model the RSAE frequency evolution with good accuracy. The addition of geodesic acoustic coupling terms has improved the results significantly.

The intermittent behavior of some modes is suggestive of strong continuum interaction.

The contribution of $\rho_{\min}$ to the eigenmode structure, and the damping rate by consequence, is unknown. If this information can be determined experimentally or inferred from the frequency measurement then the parameter space will be reduced from 2-D ($q_{\min}, q_0$) to 1-D ($q_{\min}$).

The frequency chirping characteristics are approximated by the $q_{\min}$ dependent equation

$$f(t) = \frac{1}{2\pi} \left[ \frac{m}{q_{\min}} - \frac{n}{q_0} \right] + f_0$$

Reverse Shear Alfvén Eigenmodes
RSAEs are a class of ideal MHD modes that exist in the presence of a q profile with reverse shear near the core.

They are destabilized by resonant interaction with fast particles, from ICRF heating, beams, or alphas.

In Alcator C-Mod RSAEs are seen only during the current ramp phase with early ICRF heating.

There is evidence that higher power ICRF, 5MW compared to 3MW, delays the onset of the RSAEs by about 20 ms. This can be explained by the decreased resistivity of the plasma at higher temperatures, creating a slower current penetration.

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The Analysis
Modes are excited by fast particle resonance and damped by various means, including collisional, radiative, Landau and continuum damping.

Continuum interaction is a source of strong damping. The following analysis is done under the assumption that the primary damping mechanism is continuum interaction. Damping increases with mode amplitude at the point of interaction.

The $n=1$ mode marked in the spectrogram below is a good mode for this analysis since it shows intermittent behavior which may be a sign of significant continuum interaction. The analysis looks at values of $q_{\min}$ in the set (1.85, 1.90, 1.75, 1.70) with 0.01 ≤ $q_0 - q_{\min}$ ≤ 0.20 and $\rho_{\min}$ fixed at 0.33.

Phase Contrast Imaging
The Phase Contrast Imaging (PCI) diagnostic measures line integrated electron density fluctuations.

Digitizers are capable of 5 MHz frequency resolution. During the ramp-up experiments, the PCI system on C-Mod was set up to measure $n_{e,\min}$ in the range 0.5 cm$^{-1}$ to 8 cm$^{-1}$.

PCI has 32 channels along the major radius covering about 12 cm through the core.

Measured signal intensity is proportional to the magnitude of the density fluctuations.

References