First evidence of Alfvén wave activity in KSTAR plasmas

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We report on first evidence of wave activity during neutral beam heating in KSTAR plasmas: 40 kHz magnetic fluctuations with a toroidal mode number of $n = 1$.\textsuperscript{[1]} Our analysis suggests this a beta-induced Alfvén eigenmode (BAE) resonant with the $q = 1$ surface. A kinetic analysis, when coupled with electron temperature measurements from electron cyclotron emission and ion/electron temperature ratios from crystallography, enables calculation of the frequency evolution, which is in agreement with observations. Complementary detailed MHD modelling of the magnetic configuration and wave modes supports the BAE conclusion, by locating an $n = 1$ mode separated from the continuum in the core region. Figure 1 shows magnetic oscillations of discharge #4220, with overlay of the kinetic accumulation frequency $\omega_{\text{CAP}}$, and a global mode BAE mode.

We have also computed the threshold to marginal stability for a range of ion temperature profiles. These suggest the BAE can be driven unstable by energetic ions when the ion temperature radial gradient is sufficiently large. Figure 2 shows candidate ion temperature profiles with core temperature matching crystallography data from neighbouring discharge #4229, as well as the corresponding profile of $\eta_i/\eta_{ic}$, where is $\eta_{ic}$ is the critical value of $\eta_i = (\partial \ln T_i/\partial \ln n_i)$ necessary for ion thermal excitation. For sufficiently high radial temperature gradient and/or sufficiently high ion temperature, the Alfvénic ion temperature gradient driven mode instability threshold will be approached, or possibly even exceeded, in the region where the mode amplitude is large, and so the mode can become unstable, due to a combination of energetic and thermal ion kinetic effects. Our findings suggest that mode existence could be used as a form of inference for temperature profile consistency in the radial interval of the mode, thereby extending the tools of MHD spectroscopy


Fig. 1: Magnetic spectrogram of #4220 with evolution of $\omega_{\text{CAP}}$ (red) and BAE (black) from overlaid (red).

Fig. 2: (a) Possible ion temperature profiles (solid) with core temperature matching crystallography data from discharge #4229, and (b) corresponding profile of $\eta_i/\eta_{ic}$. In both panels the dashed line corresponds to a possible Ohmic ion temperature profile, with $\tau=T_e/T_i$ taken from discharge #4229 prior to NBI heating. In (b) the light line is $\zeta$, of the BAE.