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Theoretic studies of low-frequency shear Alfvén waves in reversed shear tokamak plasmas

Ruirui Ma[1,4], W.W. Heidbrink[2], Liu Chen[2,3,4], Fulvio Zonca[4,3] and Zhiyong Qiu[3,4]
Southwestern Institute of Physics, [2] Department of Physics and Astronomy, University of California, [3] Institute for Fusion Theory and Simulation, School of Physics, Zhejiang University, [4] Center for Nonlinear Plasma Science and C.R. ENEA Frascati
e-mail (speaker): rrma@swip.ac.cn

The linear properties of the low-frequency shear Alfvén waves such as those associated with the beta-induced Alfvén eigenmodes (BAEs) and the low-frequency modes observed in reversed-magnetic-shear DIII-D discharges are theoretically investigated and delineated based on the theoretical framework of the general fishbone-like dispersion relation (GFLDR) [1,2]. By adopting representative experimental equilibrium profiles, it is found that, even though both modes are predominantly of Alfvénic polarization, the low-frequency mode is a reactive unstable mode with weak coupling to the energetic particles, while the BAE involves a dissipative instability due to resonant excitation by the energetic ions. Thus, the low-frequency fluctuation is more appropriately called low-frequency Alfvén mode (LFAM). Moreover, the ascending frequency spectrum patterns of the experimentally observed BAEs and LFAMs can be theoretically reproduced by varying the minimum of the safety factor (as shown in Figure 1), and also be well interpreted based on the GFLDR [3]. The present analysis illustrates the solid predictive capability of the GFLDR and its practical usefulness in enhancing the interpretative capability of both experimental [4] and numerical simulation results [5].

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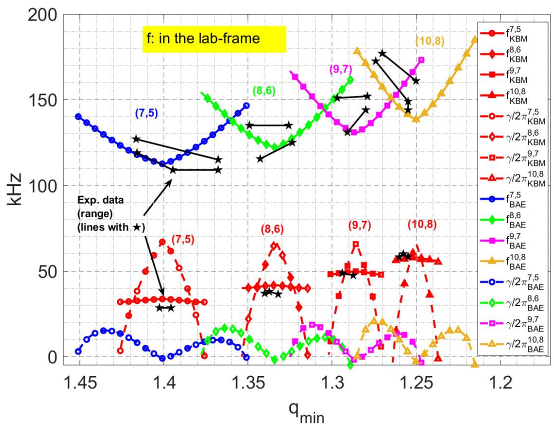

Figure 1. Dependence of mode frequencies (solid curves with markers) and growth rates (dashed curves with markers) on q_{min} of the KBMs (red curves) and the BAEs (blue, green, purple and orange curves) for different (m,n). The experimentally observed frequencies are also shown. For the BAE, since the modes span a range of frequencies, the lines indicate the upper and lower limits of the unstable bands; for the LFAM, the experimental frequency variation is < 0.5 kHz. In the abscissa, the experimentally measured $q_{min}(t)$ fit shown in Fig. 8 of Ref. 4 is used to convert time to q_{min}, with an associated uncertainty of $q_{min} \approx 0.01$. In the ordinate, the theoretical lab-frame frequency incorporates a Doppler shift to the calculated plasma-frame frequency of nf_{rot}, with an associated uncertainty of ~ 0.5n ~ kHz.