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Global simulation of drift-Alfven wave instability based on kinetic-MHD hybrid model in general geometry

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Energetic particle (EP) pressure can be comparable with thermal plasmas in present-day tokamaks and future fusion reactors, of which confinement is a key issue for ignition that relies on self-heating by fusion products. However, various drift-Alfven wave (DAW) instabilities can be excited by EPs through wave-particle resonances, which in turn cause large EP transport and plasma energy loss. Therefore, evaluations of these unstable DAWs become necessary for optimizing fusion experiments, which require comprehensive treatments of EP drive and bulk plasma damping effects.

In this talk, we shall report our efforts in this aspect, namely, a new global eigenvalue code MAS is developed from scratch for studying plasma problems with wave toroidal mode number (n) and frequency (ω) in a broad range of interest in general tokamak geometry. In MAS code, the bulk plasma is described by drift-MHD model using proper closure technique for Landau resonance, as well as keeping other kinetic effects beyond MHD including diamagnetic drift, ion finite Larmor radius (FLR) and finite parallel electric field etc., which faithfully captures the continuum damping, radiative damping and Landau damping. Meanwhile, EP ion/electron based on gyrokinetic/drift kinetic models are implemented in MAS that couple with bulk plasma model non-perturbatively, and the dominant wave-particle resonances and finite orbit width (FOW) are retained for calculating EP responses to arbitrary wave length electromagnetic fluctuations. MAS has been well benchmarked with theory and other gyrokinetic and kinetic-MHD hybrid codes in a manner of adopting the unified physical and numerical framework, which covers the kinetic Alfvén wave, ion sound wave, low-n kink, high-n ion temperature gradient mode and kinetic ballooning mode. Regarding to practical application, MAS is successfully applied to model the Alfvén eigenmode (AE) activities in DIII-D discharge #159243 (figure 1), which reproduces the frequency sweeping of RSAE as shown in figure 2, the tunneling damping of TAE, and the polarization characteristics of KBAE and BAAE being consistent with former gyrokinetic theory and simulation. With respect to the key progress contributed to the community, MAS has the advantage of combining rich physical ingredients, realistic global geometry and high computation efficiency together for plasma stability analysis in the linear regime.

References

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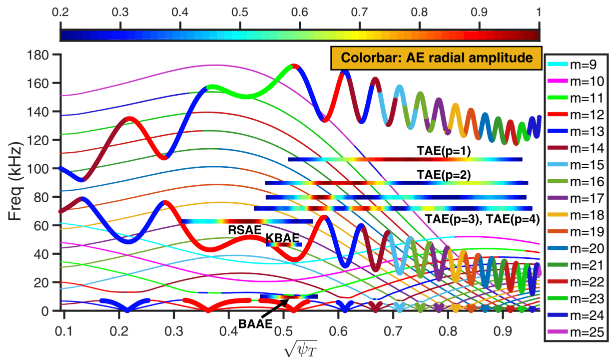

Figure 1. n=4 Alfvénic and acoustic continua for DIII-D shot #159243.The thick and thin lines represent Alfvénic and acoustic branches respectively. The colorbar represents the normalized AE radial amplitude.

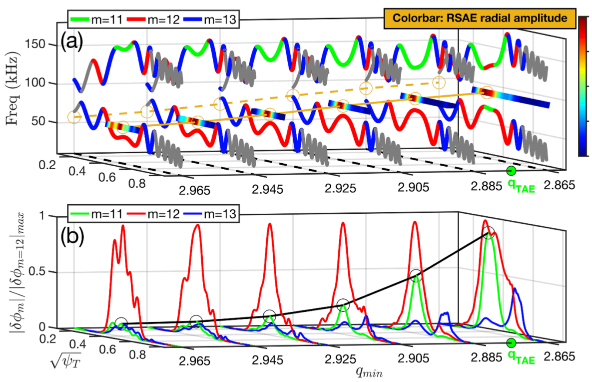

Figure 2. (a) n = 4 Alfvén continua for various qmin values. The colorbar represents the normalized RSAE radial amplitude and the yellow lines show the frequency dependence on qmin. (b) Corresponding radial profiles of poloidal harmonics $\delta\phi_m$. The black line shows the amplitude evolution of sub-dominant m=11 harmonic.The qmin threshold (i.e.q_{TAE}) of RSAE-TAE transition is shown by the green circle.