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Simulation and Theory of Long Range Frequency Sweeping of TAE Modes[1]

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Toroidal Alfven eigenmode (TAE) excited by energetic particles is extensively observed in magnetic fusion. Frequently, the wave frequency is found to sweep in the TAE gap and even penetrate into the continuum. To achieve more realism than a chirping model based on the bump-on-tail instability, TAE wave equation reduces to a Volterra integral equation which couples to currents from energetic particles. The code enables tracking of the chirping signals arising from the resonant interaction in phase space. A down-chirping signal produced by clumps eventually enters the Alfven continuum, whereupon the mode amplitude and chirping rate both increase more rapidly. In contrast, the up-chirping signal never penetrates the continuum. An adiabatic theory (ADT) quantitatively produces the simulation's down-chirping dynamics including an explosive response in the continuum. ADT for the up-chirping signal reproduces the simulation until its frequency approaches the upper continuum. Two extrinsic dissipation models are employed that generally give similar results, though for frequencies near the upper gap/continuum boundary, there is a dependence on the dissipation models. The hole smoothly vanishes as it goes into the continuum in ADT for both models. However, simulations show that the hole suddenly disintegrates before reaching the upper continuum for one case and smoothly decays for the other. The discrepancy for the hole's decay is apparently explained from the calculation of an adiabatic validity parameter that implies that the hole's disintegration takes place when the adiabatic condition breaks down as the upper continuum is approached. Ongoing improvements to TAE modeling takes into account the spatial profile variation of mode structure. The most significant disparity between newest Hamiltonian and an older simpler one occurs near continuum tips where there is the possibility that topological change in the phase space may emerge. Two major qualitative results of this theory: chirp penetration into the lower continuum with enhancement of the field amplitude but with no chirp penetration into the upper continuum, has been observed in the MAST experiment.

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