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On Nonlinear Scatterings between Drift Waves and Toroidal Alfvén Eigenmodes in Tokamaks

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Microscopic drift waves (DWs) excited by thermal plasma expansion free energy and Alfvén Eigenmodes (AEs) excited predominantly by energetic particle (EP) expansion free energy are two fundamental and, arguably, the most crucial low-frequency electromagnetic fluctuations in burning tokamak plasmas. In this talk, we will analytically investigate the fundamental mechanisms underlying the direct nonlinear interactions between DWs and AEs, and their consequences on the respective stability properties. Using electron drift wave (eDW), with no temperature gradients and trapped particle, and toroidal Alfvén eigenmode (TAE) as a paradigm model, we have analyzed the following two scattering processes; (i) a test TAE scattered off ambient eDW fluctuations, and (ii) a test eDW scattered off ambient TAE fluctuations; i.e., the "reverse" of (i). In both processes, nonlinear coupling between eDW and TAE generates microscopic kinetic Alfvén wave (KAW) upper and lower sidebands via mode coupling at the high-n KAW continuous spectrum. Here, n is the toroidal mode number. The high-n KAWs, having significant parallel electric field, are, typically, electron Landau damped quasimodes. In (i), the generation of both KAW sidebands leads to the stimulated absorption of the test TAE, and, for typical tokamak parameters and eDW fluctuation intensity, the EP-driven TAE can be significantly suppressed. However, in the "reverse" process (ii), with the ambient TAE serving as the "pump" wave, while the generation of the upper KAW sideband still corresponds to stimulated absorption, the generation of the lower KAW sideband, on the other hand, gives rise to spontaneous emission of eDW. Consequently, the stability of eDW is little affected. Implications to other types of AEs as well as indirect interactions via zonal structures will also be discussed, if time permits.

References

[1] L. Chen, Z. Qiu and F. Zonca, Nuclear Fusion 62, 094001 (2022).

[2] L. Chen, Z. Qiu and F. Zonca, submitted to Nuclear Fusion (2023)