Beyond MHD - global electromagnetic gyro-kinetic simulations in stellarators

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By performing fully non-linear, gyrokinetic, electromagnetic, realistic-electron-mass simulations in stellarator equilibria with the particle-in-cell (PIC) code EUTERPE [1], we demonstrate that turbulence and MHD as fundamentally electromagnetic phenomena can be treated on the same footing. Simulating a field period in Wendelstein 7-X, we find that ITG turbulence can drive not only zonal flows but subsequently Alfvénic modes with low poloidal and toroidal mode numbers. The excitation of modes is observed to start after the drive exceeds some threshold. Surprisingly, the driven modes grow with growth rates of twice and triple that of the driving ITG mode which we interpret as they are being forced-driven in analogy to the mechanism proposed in [2]. Scaling to the experimental density values while keeping the plasma-β fixed matches the frequencies observed in W7-X [3]. In full-torus EUTERPE simulations, we assess the importance of the vacuum-field magnetic well, which is a standard proxy of ideal-MHD stability. For this study, we use low-shear, helical-axis stellarator equilibria, that are ideal-MHD unstable against spatially extended and periodicity breaking perturbations. It will be shown that the linear phase can be successfully validated against linear ideal-MHD stability results obtained by the CAS3D code [4]. Furthermore, by indicators like the evolution of profiles or the ergodization of flux surfaces, the saturation phases of these gyrokinetic simulations demonstrate that such spatially extended instabilities can indeed be detrimental to the plasma confinement of low-shear stellarators.

References

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