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Electromagnetic gyrokinetic turbulence in high-beta helical plasmas

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Gyrokinetic simulation of electromagnetic turbulence in finite-beta plasmas is important for predicting the performance of fusion reactors. Whereas in low-beta tokamaks the zonal flow shear acts to regulate ion temperature gradient (ITG) driven turbulence, it has often been observed that the kinetic ballooning mode (KBM) and, at moderate-beta, the ITG mode continue to grow without reaching a physically relevant level of saturation. The corresponding problem in helical high-beta plasmas, the identification of a saturation mechanism for microturbulence in regimes where zonal flow generation is too weak, is the subject of the present work. This problem has not been previously explored because of numerical difficulties associated with complex three-dimensional magnetic structures as well as multiple spatio-temporal scales related to electromagnetic ion and electron dynamics [1]. The present study identifies a new saturation process of the KBM turbulence originating from the spatial structure of the KBM instabilities in a high-beta Large Helical Device (LHD) plasma. Specifically, the most unstable KBM in LHD has an inclined mode structure with respect to the mid-plane of a torus, i.e. it has finite radial wave-number in flux tube coordinates, in contrast to KBMs in tokamaks as well as ITG modes in tokamaks and helical systems. The simulations reveal that the growth of KBMs in LHD is saturated by nonlinear interactions of oppositely inclined convection cells through mutual shearing, rather than by the zonal flow shear. The mechanism is quantitatively evaluated by analysis of the nonlinear entropy transfer.

[1] A. Ishizawa, et.al., Nuclear Fusion 53, 053007 (2013).