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巨視的なMHDモードと微視的乱流の相互作用

Interaction between large scale MHD mode and micro-turbulence

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Complexity of anomalous transport mechanisms in magnetic fusion plasmas does not only originate from various drift wave instabilities and MHD activities due to the complex geometry and non-homogeneity, but also results from highly nonlinear interaction among these fluctuations. Recent experimental observations in tokamaks have shown some evidences [1,2]. For example, Iinetrnal Transport Barriers (ITBs) are often formed along the low order rational q surfaces; nonlocal transport occurs in the discharges with peripheral fueling or heating. And MHD activities are also diagnosed accompanying with suddenly occurring small-scale fluctuations, showing the secondary excitation. Such phenomena are speculated as a consequence of nonlinear interaction among macroscopic MHD activities and microscopic drift waves.

Here, we performed direct numerical simulations of multi-scale multi-mode MHD and micro-turbulence at ion gyro-radius scale based on gyrofluid model. We focus on the nonlinear evolution of both MHD magnetic island and micro-turbulence in a dynamically interacting system involving all zonal mode components. Here we report the progress on the understanding of nonlinear interaction mechanism with two remarkable findings: (1) A novel short wavelength ITG instability induced by a MHD magnetic island as a consequence of the breakdown of the frozen-in magnetic field law. The new instability is identified to be characterized by a substantial lower stability threshold and a global structure propagating in the ion diamagnetic drift direction. (2) A magnetic island seesaw oscillation due to the interaction with micro-turbulence. A minimal model is proposed to numerically illustrate the seesaw mechanism. It is identified that fluctuating electromagnetic (EM) torque due to the polarization current produced by the micro-turbulence may drive the island seesaw in the case with full reconnection. Such mechanisms offer new insights in understanding complex nonlinear interaction among multi-scale and multi-mode fluctuations in fusion plasmas [3,4].

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