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Response of micro-fluctuation and ion heat transport to MHD island dynamics in multi-scale turbulence simulation

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Micro-instabilities, for instance the ion temperature gradient (ITG) mode at the ion-scale, are generally excited in an ideal MHD equilibrium. Various instabilities with different driving force have been intensively investigated in a stationary MHD equilibrium to build the plasma stability theory so far. Here we address the property of the micro-instabilities and their nonlinearity in a dynamical MHD equilibrium, for example, typically with a magnetic island in the Rutherford stage of the nonlinear tearing mode.

Direct simulations based on gyro-fluid model are performed to understand the response of micro-scale fluctuation and transport to the magnetic island dynamics with individual driving force for resistive tearing mode and micro-turbulence versus ITG in an initial ideal MHD equilibrium. The results reveal the collapse of ion temperature island while the magnetic and density islands survive, then subsequently a new short wave-length micro-instability induced by the magnetic island (referred to as MITG) in multi-scale turbulence. Most interestingly, different from usual instability occurring in a stationary equilibrium, this novel one results from the multi-scale nonlinear interaction in which all zonal modes (the zonal field/current for the island formation, zonal temperature and density for profile modification and the zonal flow for fluctuation stabilization.) are involved dynamically. The quasi-steady-state turbulence behaves with intermittent ion transport in the case with steeper temperature gradient and the transport is enhanced by the MITG instability. The results may helpfully understand the experimental observation of ion temperature profile peaking inside a magnetic island [1].

[1] K. Ida, et al, Plasma Conference 2011, 25F05, Kanazawa, Nov.22-25, 2011