Multi-scale interaction between micro-turbulence and macro-MHD

A. Ishizawa and N. Nakajima

National Institute for Fusion Science, Toki 509-5292, Japan
ishizawa_at_dss.nifs.ac.jp

Mutual interactions among micro-turbulence, macro-MHD, and zonal flow are investigated by numerically solving a reduced set of two-fluid equations. We consider a situation that a current driven macro-MHD instability arises in a quasi-equilibrium including micro-turbulence and zonal flow. Because a macro-MHD instability is destabilized when there arises one or more resonant q surfaces where the safety factor q is equal to a small rational number, while micro-instabilities can arise even if there is no integer q surfaces. Thus, micro-turbulence almost always exists before destabilization of macro-MHD instability. In order to examine this situation we carried out a three-dimensional numerical simulation of a reduced set of two-fluid equations and investigated mutual interaction between micro-turbulence and macro-MHD mode (double tearing mode) [1,2]. In the simulation micro-instabilities (kinetic ballooning mode) are destabilized and grow at first, and then they saturate and turbulent state is formed. We found that the excitation of macro-mode by the energy transfer from micro-turbulence is different from macro-MHD instability because the spatial profile of the former is significantly different from the spatial profile of double tearing mode. The energy transfer from micro-turbulence to macro-mode is similar to the energy transfer from micro-turbulence to zonal flow [2]. The macro-mode is a part of turbulence in the turbulent state. After a certain period of time, then, the induced macro-mode by the turbulence becomes eigen function of double tearing mode and grows up with magnetic reconnection, in the case that the equilibrium has free energy of macro-MHD instability such as a current density gradient [1]. When the free energy is small the double tearing mode saturates, and then we have a new quasi-equilibrium including not only the micro-turbulence and zonal flow but magnetic islands [3]. The magnetic reconnection of double tearing mode is caused by non-ideal effect due to turbulent mixing of magnetic flux at the resonant surfaces [3]. The effect of zonal flow produced by micro-turbulence on the stability of double tearing mode is not clear [4], while the zonal flow shear is suppressed by the appearance of double tearing mode as implied in Ref. [1]. Finally we discuss the effect of tearing mode on micro-turbulence. The appearance of magnetic islands due to tearing mode violate ballooning structure of micro-turbulence and also flatten the temperature profile inside the separatrix of magnetic islands, and thus the tearing mode reduces the amplitude of micro-turbulence [5].

[1] A. Ishizawa and N. Nakajima, Physics of Plasmas, 14, 040702 (2007).
[2] A. Ishizawa and N. Nakajima, Nuclear Fusion, 47, 1540 (2007).
[3] A. Ishizawa and N. Nakajima, to appear in "Theory of Fusion Plasmas", AIP Conference Proceedings of Joint Varenna-Lausanne International Workshop (2008).
[4] A. Ishizawa and N. Nakajima, Physics of Plasmas, 15, 084504 (2008).
[5] A. Ishizawa and N. Nakajima, 22nd IAEA FEC, TH/P8-16 (2008).