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On turbulence and multi-scale interactions in low and high confinement plasmas of the HL-2A tokamak

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Nonlinear interaction and multi-scale physics are crucial in the physical understanding of the turbulence and transport in complex nonlinear system of fusion plasmas. In the HL-2A tokamak, the turbulence and related transport have long been foci of intensive studies. Significant progress on the roles of electrostatic and electromagnetic turbulence in plasma transport, the effect of flows on turbulence, nonlinear interaction of multi-scale instabilities (micro-turbulence, mesoscale fluctuations, and large scale MHD activities) has been made, recently.

In HL-2A, the synchronization of geodesic acoustic modes (GAMs) and magnetic fluctuations is identified at the edge plasmas [1]. The temporal evolutions of the mesoscale electric fluctuations and the magnetic fluctuations clearly show the frequency entrainment and the phase lock between the GAM and the m/n = 6/2 magnetic fluctuations. The results indicate that GAMs and magnetic fluctuations can transfer energy through nonlinear synchronization. Such nonlinear synchronization may also contribute to low-frequency zonal flow formation, reduction of turbulence level, and thus confinement regime transitions. With correlation Doppler reflectometers, a three-dimensional spatial structure of geodesic acoustic mode (GAM) is surveyed, damping mechanisms for the GAM oscillation level were revealed [2]. By using this non disturbing microwave diagnostics, interactions among pedestal shear flows, turbulence, and the formation of the edge transport barrier have been studied [3]. The nonlinear interaction between GAM and turbulence can also be externally stimulated by supersonic molecular beam injection, which plays an important role in initiating the L-H transition.

In HL-2A H-mode plasmas, quasicoherent modes have been observed in the pedestal region, which regulate the pedestal transport [4]. In addition, a broadband electromagnetic (EM) turbulence has been observed in the edge plasma region. It is driven by the density gradient of edge self-accumulated impurities [5-7]. The nonlinear interaction is responsible for the generation of the broadband spectrum. Furthermore, the interaction between large-scale MHD modes and turbulence has been investigated in HL-2A [8-10]. The results indicate that both the perpendicular flow and the density fluctuation level are modulated by the intrinsically rotating tearing mode near the island boundary and the multi-scale interactions via the nonlinear modulation process might enhance the plasma transport. The study helps to understand the nonlinear interaction mechanisms between cross-scale instabilities and their roles in transport and confinement in magnetically confined plasmas.

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