§3. Statistical Characteristics of Dynamics and Field Structure on Magnetized Plasmas

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Turbulence in magnetized plasmas is spatially inhomogeneous. Recently, temporal inhomogeneity is widely recognized as one of essential properties of plasma turbulence[1,2]. According to these recent theoretical and experimental achievements, the new concept is being required that plasma turbulence has intrinsically probabilistic characteristics. Not only plasma turbulence, the statistical characteristics of magnetic field structure in toroidal plasmas have been found to have significant impacts on confinement. The stochastization of magnetic flux surfaces is recently identified by the characteristics of heat pulse propagation[3].

A paradigm shift of turbulent transport of plasma from local and linear picture to non-local and non-linear one has been established. This research aims at disseminating new paradigm shift from deterministic picture to probabilistic one. We clarify statistical characteristics of dynamics and field structure of magnetized plasmas through cooperation between LHD and linear device experiments.

Linear Device Experiment: In the PANTA, spontaneous transitions of turbulence are investigated by changing the neutral gas pressure or the magnetic field strength. With a magnetic field strength of B = 0.09 T and high neutral gas pressure conditions (P_n ~ 0.40 Pa), a large amplitude coherent fluctuation accompanied by higher order harmonics, which is regarded as a drift solitary wave, is seen. When the neutral gas pressure is lowered to an intermediate value (P_n ~ 0.27Pa), the PANTA shows a transition region, where the shape of the fluctuation spectrum switched spontaneously between two states. Finally, at low neutral gas pressure conditions (P_n ~ 0.13Pa), a broad fluctuation spectrum is observed that had been associated with a streamer structure in the LMD-U. It has now been discovered, that a transition region can also be observed for a pressure between the intermediate and the low neutral gas pressure condition (at P_n ~ 0.16 Pa). In this regime, transitions are observed for the equilibrium profile as well as for the fluctuation spectrum. Figure 1 shows conditional averaged two-dimensional power spectral density before and after transitions. The dominant fluctuating mode is changed from (m, f) = (2, 6.7 kHz) to (1, 2.3 kHz). Conditional averaged temporal evolution of fluctuation power demonstrated that a mode propagating in the ion diamagnetic direction starts to change after transitions[4].

LHD Experiment: The long-range mode has been discovered in LHD[4]. Spatiotemporal evolution of the quasi-periodic structural of the long-rage mode is one of key issues to understand the transient transport. However, the long-range mode is buried in (or comparable in power to) background fluctuations. The quasi-periodic structural of the long-rage mode is reconstructed by using phase-tracking conditional averaging technique. In this technique, wavelet analysis is applied to detect the temporal change of period of the fundamental mode and signals are averaged over each period with similar period length[5]. It is found that the waveforms are not simple sinusoidal waves, but show distorted waveforms[6]. The waveforms are changed in time as shown in Fig. 2.

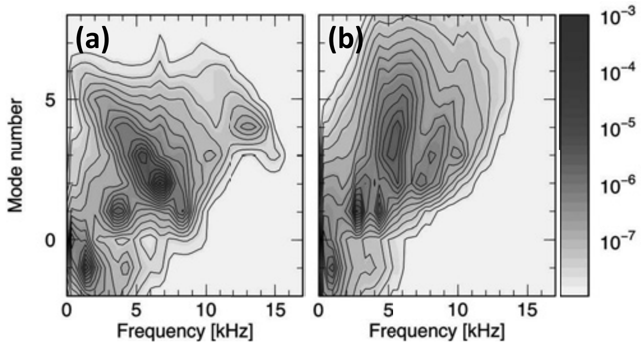

Fig. 1 Conditional averaged two-dimensional power spectral density before (a) and after (b) transitions.

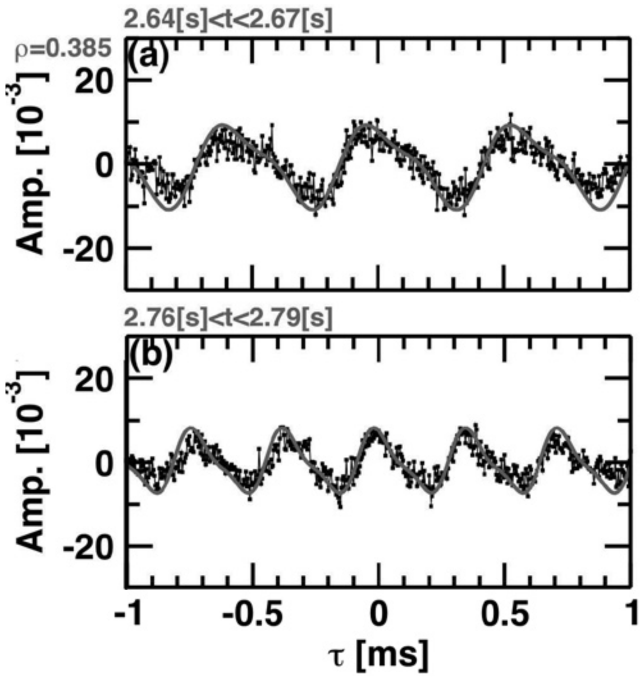

Fig. 2 Reconstructed periodic non-sinusoidal waveform (black curves) at two different time windows. Bi-spectrum-filtered signals are also shown (red bold curves).

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