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

Inagaki, S., Itoh, S.-I., Fujisawa, A. (Kyushu Univ.),
Itoh, K., Yamada, H.

A paradigm shift of turbulent transport of plasma from local and linear picture to non-local and non-linear one has been established[1,2]. According to the recent theoretical and experimental achievement, the new concept is being required that plasma turbulence has intrinsically probabilistic characteristics and a magnetic field configuration bifurcates topologically.

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:** Intermittent pulse events have been observed in the periphery of the linear cylindrical plasmas produced in Plasma Assembly for Nonlinear Turbulence Analysis (PANTA). The argon plasma with a length of 4 m and a radius of $a$ = 5 cm is produced with a 7 MHz radio frequency source operated at 3 kW of power. The magnetic field is 0.09T and a relatively low filling gas pressure of 0.8 mTorr for this study. The 32 azimuthal and 3 radial probes measure spatiotemporal structure of ion saturation current fluctuations. A massive structure, like a blob, propagates in the radial direction. Inside the plasma ($r<a$) the fluctuations show turbulence-like or 'random' characteristics, while signals become pulse-like, and more structured, and the pulse width becomes narrower in outer radii. A quasi-Gaussian probability density function (PDF) in the core changes to a non-Gaussian one at $r$ ~ 6 cm. The spatiotemporal evolution of the structure with non-Gaussian PDF can be deduced by evaluating the 2D correlation between 32 probes of the azimuthal probe array and 3 probes with each radial distance of 5 mm. Using these probes, 32 × 3 = 96 pairs of correlations can be analyzed simultaneously. The correlation shows that, in the inner region of $r$ = 6 cm, a structure with azimuthal mode number $m$ = 2 rotates in the electron diamagnetic direction. In the outer region of $r$ = 6 cm an $m$ = 1 structure, like a cloud, rotates oppositely in the ion diamagnetic direction. Based on the assumption that the rigid-body structure rotates with a constant angular frequency in the ion diamagnetic direction, the structure can be reconstructed[3]. Figure 1 shows an example of such reconstruction. The 2D structure of blob-like event is important for understanding of the physics of the turbulence-driven transport.

**LHD Experiment:** Heat pulse propagation experiment in LHD has been recognized to be a useful tool to study the topology of the magnetic surfaces. A new wavelet analysis method is used to study heat pulse propagation in plasma where magnetic shear is temporally changed. The wavelet transform is applied to estimate the time evolution of the phase delay in heat pulse propagation with a fine temporal resolution. The phase delay structure directly reflects the magnetic field topology. The method is examined by taking an exemplary heat pulse propagation in the LHD. Various wavelet parameters are tested as shown in Fig. 2 and the parameter region where relevant results are obtained is identified[4]. Using of data in linear device experiments, convergence study is also performed.

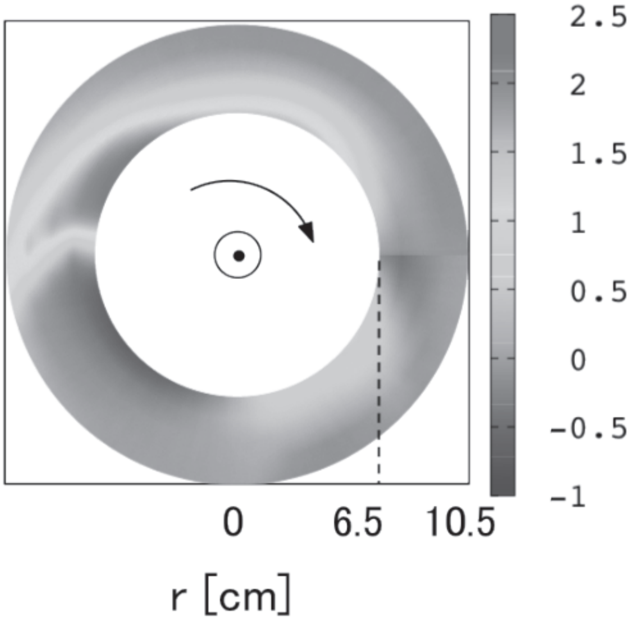

Fig. 1 Reconstructed image of a spatial structure of a pulse event.

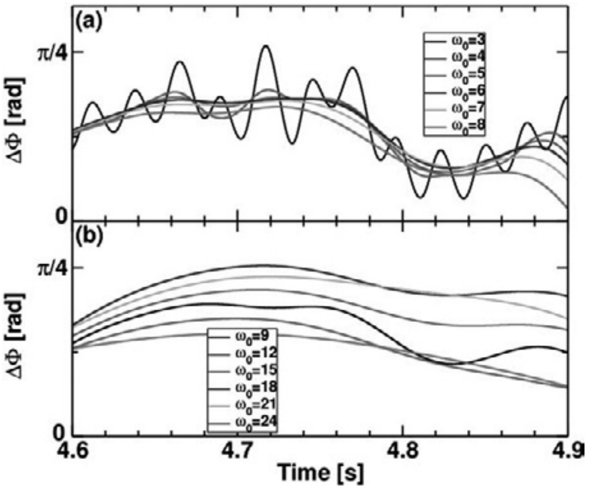

Fig. 2 Wavelet phase difference with various wavelet parameters in regions (a) 3 ≤ $\omega_0$ ≤8 and (b) 9 ≤ $\omega_0$ ≤ 24, where $\omega_0$ is the normalized frequency.

[1] S.-I.Itoh, J.PlasmaFusionRes.**86** (2010) 334
[2] S. Inagaki et. al., Phys. Rev. Lett. **107** (2011) 115001
[3] N. Ohyama, A. Fujisawa, S. Inagaki et. al., Plasma and Fusion Research **7** (2012) 1201025
[4] T. Kobayashi, S. Inagaki et. al., Plasma Phys. Control. Fusion **53** (2011) 095012