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Magnetic island as turbulence spreading barrier in toroidal plasma

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Magnetic island is a closed magnetic flux surface bounded by a separatrix, isolating it from the rest of the space with nested magnetic flux surface. The separatrix is called X-point, while the center of the magnetic island is called O-point. The magnetic island is identified by the flattening of temperature at the O-point due to a lack of heat flux not due to the enhancement of transport. The magnetic island has been found to play a role in transport barrier [1, 2] because of the low thermal diffusivity inside magnetic island [3]. Because the locally driven turbulence is negligible due to the flattening of the profile, the turbulence inside the magnetic island is dominated by the spreading turbulence. Therefore, the magnetic island is an ideal region in the plasma for turbulence spreading study in the experiment.

Recently, turbulence spreading [4] from X-point to O-point of the magnetic island has been identified in experiment [5]. Fig.1 shows the response of electron temperature and turbulence amplitude to the heat pulse propagating from outside the magnetic island. The turbulence increases after the increase of temperature due to the heat pulse at X-point, but the turbulence at O-point increases before the temperature rise by the heat pulse. This result indicates the fast turbulence propagation from X-point to O-point of the magnetic island and is an evidence of turbulence spreading.

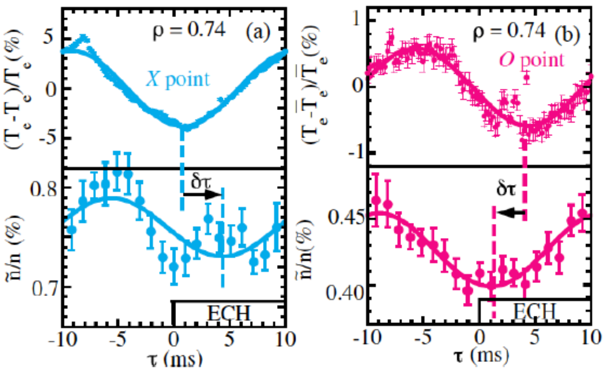

Fig.1. Time evolution of electron temperature and density turbulence in the (a) X-point and (b) O-point of the magnetic island at ρ = 0.74 as a response to heat pulse propagating from outside the magnetic island [5].

Turbulence spreading decreases with increasing ExB flow shear [6], which is often observed at the boundary of magnetic island [7]. The interplay between the penetration of turbulence spreading into magnetic island and ExB flow shear at the boundary of magnetic island causes the bifurcation of turbulence and transport states inside magnetic island [8]. Fig.2(a) shows the contour of relative modulation amplitude of electron temperature in space and time during the transition from high accessibility ($\tau < 0$) to low accessibility ($\tau > 0$) magnetic island and Fig. 2(b) shows the back transition from low accessibility to the high accessibility magnetic island at O-point. Because the heat pulse propagation is accelerated by the turbulence which is spreading from outside the magnetic island, The region of the low relative modulation amplitude imply that turbulence spreading is also low level. The transition to the low accessibility state (shallow heat pulse penetration) clearly indicates that the turbulence spreading is shielded at the boundary of magnetic island due to the ExB flow shear which usually appears at the boundary of the magnetic island.

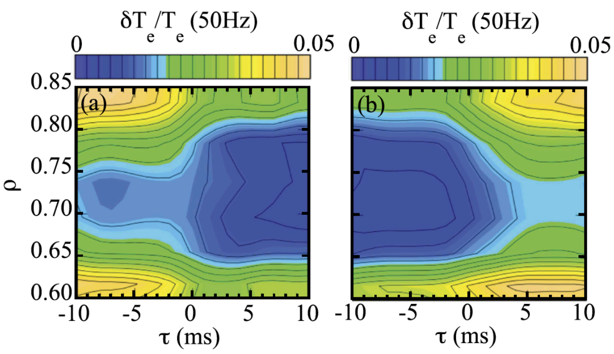

Fig. 2. Contour of relative modulation amplitude of electron temperature in space and time during the (a) forward transition from high accessibility state (deeper heat pulse penetration) to low accessibility state (shallow heat pulse penetration) and (b) backward transition at O-point of magnetic island [8].

This transport bifurcation is in contrast to the transport bifurcation at the plasms edge, where the interplay between the locally driven turbulence and ExB flow shear due to mean flow and zonal flow is important. In this presentation, the role of magnetic island on turbulence and transport, especially as a barrier of turbulence spreading, is discussed. The idea of turbulence spreading barrier gives a new insight to the space coupling of turbulent transport in magnetic fusion plasma.

References

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