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EX/P7-17: The Role of Zonal Flows and Predator-Prey Oscillations in the Formation of Core and Edge Transport Barriers

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Understanding the formation dynamics of core and edge transport barriers is crucial for extrapolating present tokamak performance to burning plasma regimes. We present here direct evidence of low frequency Zonal Flows (ZF) reducing electron-scale turbulence in an electron internal transport barrier (ITB) at the q=2 rational surface, and periodically suppressing ITG-scale turbulence via a predator-prey cycle near the separatrix, triggering edge barrier formation. Multi-channel Doppler Backscattering (DBS) has revealed strong similarity of the radial structure of the ZF-induced double shear layer, the ratio of ExB shearing rate omega_{ExB} to turbulence decorrelation rate Delta omega_D, and the phase shift between turbulence envelope and time-dependent flow shear in both barrier types. Electron-scale (k_theta rho_s ˜3) turbulence suppression by localized ZF shear (Delta r ˜ 4 rho_s ˜ 1.5–2 cm) has been directly observed for the first time in an electron ITB. Both steady-state and oscillating ZF components with a broad frequency spectrum (f_{ZF} ≤ 5 kHz) are found; ZF shear and density fluctuation amplitude are anticorrelated. In plasmas near the L-H transition threshold power, ZFs are observed to trigger edge barrier formation via limit cycle oscillations at/inside the separatrix, with a 90° phase lag of the ZF with respect to the density fluctuation envelope, characteristic of predator-prey oscillations. These observations are in qualitative agreement with a 0-D Lotka-Volterra model. Turbulence reduction due to ZF shearing is first observed when the turbulence decorrelation rate decreases sharply at or before ZF onset and the increasing ZF shearing rate locally surpasses the decorrelation rate. Above threshold, ZFs are observed as short transients preceding the transition, and executing only part of one limit cycle period. The "final"transition to H-mode with sustained turbulence/transport reduction is shown to be linked to increasing equilibrium flow shear due to the increasing ion pressure gradient. Limit cycle oscillations during the H-L back-transition, recently observed in DIII-D, are potentially important for ITER as a tool for controlled reduction of beta_theta during current ramp-down. This work was supported in part by the U.S. Department of Energy under DE-FG02-08ER54984, DE-FG03-01ER54615, DE-FC02-04ER54698 and DE-AC02-09CH11466.

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