Dynamics of the L-H and H-L Transitions, and Implications for the Pedestal

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We examine the dynamics of the L→H and H→L transitions, with attention on:

i.) the transition physics influencing and limiting the pedestal width

ii.) the strength of the hysteresis of the H→L back transitions

Regarding (i), simple models suggest that for a ∇P driven electric field shear bifurcation, the basic scale of the pedestal is inexorably tied to the particle fueling depth, which is the neutral penetration depth. Three different approaches to a more rigorous analysis (in context a two field model) of the H-mode barrier width all ultimately suggest that the barrier forms in the region of L and H phase coexistence, with a scale set by a Maxwell-type construction. This problem has certain degeneracies, which can be removed by a hyper-diffusion regularization scheme. There is no hysteresis. A promising way to more accurately calculate power threshold of L-H transition is to retain pressure profile curvature effects in the electric field shear. This allows us to determine when a transition actually occurs within the interval of possible transitions (mode co-existence criterion above). It is shown to occur at the lower end (in heating power) of the co-existence range. This softens threshold requirements. A testable consequence of this approach is that the model predicts that transitions may occur in regimes of flat density.

To further explore the dynamics of possible transition scenarios a time dependent zero-dimensional model of L-H transition is studied. The dynamical system consists of three equations coupling the drift wave turbulence level, zonal flow speed and the pressure gradient. The mean shear velocity is slaved to the pressure gradient. The bursting behaviour characteristic for predator-prey models of the drift wave - zonal flow interaction is recovered near the transition to the quiescent H-mode (QH). It occurs as strongly nonlinear relaxation oscillations arising from a Hopf bifurcation (limit cycle) of an intermediate (between the L and H modes) fixed point. The system remains at the QH-mode even after the heating rate is decreased below the bifurcation point (i.e., hysteresis, sub-critical bifurcation) but the basin of attraction of the QH-mode shrinks rapidly with decreasing power. The shrinkage of the H-mode basin of attraction with respect the back-transition suggests that the hysteresis at the H-L transition may be less than what is often thought.