The Role of Zonal Flows and Predator-Prey Oscillations in the L-H and H-L Transition*

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Understanding the trigger and power threshold of the L-H transition is critical for extrapolating present tokamak performance to burning plasma regimes. We present here direct experimental evidence of low frequency Zonal Flows (ZFs) in the form of limit cycle oscillations (LCO), initiating turbulence reduction preceding the L-H transition [1] near the power threshold in low to medium density plasmas ($1.8 \times 10^{19}\,\mathrm{m}^{-3} \leq \langle n \rangle \leq 3.5 \times 10^{19}\,\mathrm{m}^{-3}$). These LCOs, with a 90° phase lag of the ZF with respect to the density fluctuation envelope $\tilde{n}/n$ [Fig. 1(a,b)], exhibit characteristics typical of predator-prey oscillations. Periodic turbulence suppression is observed in a narrow radial layer at/inside the separatrix when the shearing rate locally exceeds the turbulence decorrelation rate. The ZF initially propagates radially inwards, later transitioning to a standing wave pattern. The detailed spatio-temporal evolution of the $E \times B$ shear layer and turbulence characteristics including the radial correlation of flow with density turbulence and their respective phasing is examined. The "final" H-mode transition (characterized by sustained turbulence/transport reduction) is shown to be linked to increasing equilibrium flow shear due to the increasing ion pressure gradient after the initial turbulence reduction. Both features are consistent with the two predator/one prey model of the L-H transition [2], with ZF $E \times B$ shear initiating transient turbulence suppression. Limit cycle oscillations were also recently observed in the L-H back-transition, showing similar predator-prey characteristics, and a hysteresis in onset heating power at H-LCO transition and the LCO-L transition. Back-transition LCOs are potentially important for controlled rampdown of β_θ in ITER, to achieve a "soft landing" of the discharge without vertical displacement events.

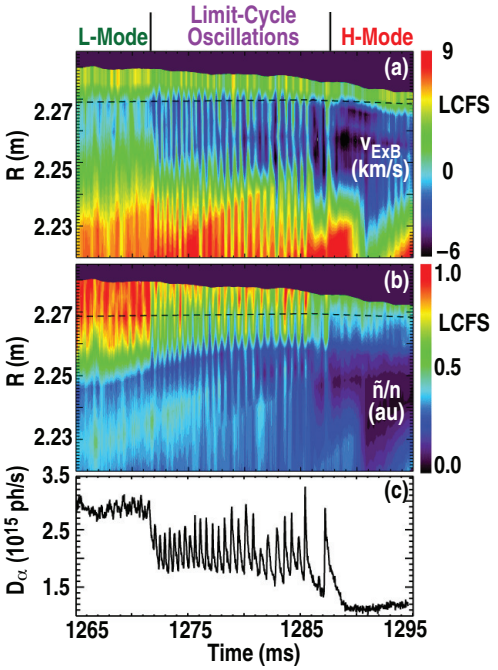

Figure 1: (a) $E \times B$ velocity, (b) rms density fluctuation level $\tilde{n}/n$, (c) D_α recycling light during the transition from L-mode through the LCO phase to H-mode.

References

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