First Direct Evidence of Main Ion Flow Triggering the L-H Transition*


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Simultaneous measurements of main ion flow (via main ion CER), $E \times B$ flow, and turbulence level $\tilde{n}/n$ (via Doppler backscattering) during transitions characterized by extended limit cycle oscillations (LCO [1]), show for the first time that the initial (transient) turbulence collapse [Fig. 1(a)] preceding the L-H transition is caused by turbulence-generated main ion flow and $E \times B$ opposing the equilibrium (L-mode) edge plasma $E \times B$ flow related to the edge ion pressure gradient. The formation dynamics of edge transport barriers is crucial for understanding the physics basis of the empirical L-H transition power threshold scaling, and for confidently extrapolating auxiliary heating requirements to burning plasmas. Figure 1(b) shows that the $v_i \times B/B$ contribution to the $E \times B$ velocity peaks as fluctuations are first suppressed. Fig. 1(c) shows that the $E \times B$ shearing rate $\omega_{E \times B}$ reverses at this time. The correlations between turbulence envelope, main ion flow, and pressure-gradient driven flow, and their detailed spatio-temporal evolution have been measured. The main ion poloidal velocity lags $\tilde{n}$ early in the LCO, consistent with turbulence-driven poloidal ion flow [Fig. 1(d)]. As the LCO evolves, the periodic reduction in edge turbulence and edge transport enables a gradual increase (and periodic modulation) of the edge pressure gradient and ion diamagnetic flow. During the final phase of the LCO the pressure gradient diamagnetic flow) dominates the mean flow $E \times B$ shearing rate, which becomes sufficiently large to sustain fluctuation suppression and secure the LCO-H-mode transition. A two-predator, one-prey model, similar to a previously developed model [2] but retaining opposite polarity of the turbulence-driven and pressure-gradient-driven $E \times B$ flow, captures essential aspects of the transition dynamics, and is consistent with the direction of the ($\tilde{n}$, $E_z$) limit cycle observed in DIII-D and recently in JFT-2M. The scaling of the L-LCO transition threshold power and LCO frequency with edge plasma density, collisionality, and $q_{95}$ will be presented.


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