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 \( \nu_i \times B / B \) 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 (\( \tilde{n} \times E \)) 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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