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Mechanism of Low-Intermediate-High Confinement Transitions in Tokamaks

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Understanding the physics mechanism of low-high (L-H) confinement transitions in toroidal plasmas is essential for ensuring heating power requirements for future fusion reactors. Early experiments show that plasma may enter an intermediate phase (I-phase) with limit cycle oscillations (LCOs) of plasma parameters and pass through a slow L-H transition if heating power is close to the H-mode threshold. The triggering mechanism and conditions for L-I and I-H transitions are foci in the H-mode physics studies. Two theoretical models of LCOs were proposed and shown consistent with recent experimental observations, respectively. Here, we first report a discovery of two types of LCOs (type-Y and type-J, respectively) on HL-2A tokamak, which provides an opportunity to advance our understanding of LCO physics, and then discuss the L-I-H transition triggering mechanisms and conditions. The dynamics of the two types of LCOs observed in the experiment are analyzed in detail. Two loops of zonal flow versus turbulence and turbulence versus pressure gradient are proposed for the two types of LCOs. The conditions for the observed I-H transitions are identified to be (1) the I-phase has type-J LCOs, (2) the plasma pressure gradient scale length L_pe is less than a critical value (1.7 cm, here) and the EXB flow shearing rate is higher than a critical value (10^6 s^-1, here), and (3) the growth rate of the diamagnetic drift flow \gamma_DD is equal to or higher than the ion-ion collision frequency \nu_ii. Detailed observations, revealing L-I-H transition mechanism, will be presented.

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