The role of zonal flows and predator-prey oscillations in triggering the formation of edge and core transport barriers

L. Schmitz,[1] L. Zeng,[1] T.L. Rhodes,[1] J.C. Hillesheim[2] W.A. Peebles,[1] R.J. Groebner,[3] K.H. Burrell,[3] G.R. McKee,[4] Z. Yan,[4] G.R. Tynan,[5] P.H. Diamond,[5] J.A. Boedo,[5] E.J. Doyle,[1] B.A. Grierson,[6] C. Chrystal,[5] M.E. Austin,[7] W.M. Solomon,[6] and G. Wang[1]

[1]University of California Los Angeles, Los Angeles, California 90095-7799, USA
[2]EURATOM/CCFE Fusion Association, Abingdon, Oxon OX14 3DB, UK
[3]General Atomics, PO Box 85608, San Diego, California 92186-5608, USA
[4]University of Wisconsin-Madison, Madison, Wisconsin 53706, USA
[5]University of California San Diego, 9500 Gilman Dr., La Jolla, California 92093-0417, USA
[6]Princeton Plasma Physics Laboratory, Princeton, New Jersey 08543-0451, USA
[7]University of Texas-Austin, Austin, Texas 78712, USA

Corresponding author: lschmitz@ucla.edu

Abstract. We present direct evidence of low frequency, radially sheared, turbulence-driven flows [zonal flows (ZFs)] triggering edge transport barrier formation preceding the L- to H-mode transition via periodic turbulence suppression in limit-cycle oscillations (LCO), consistent with predator-prey dynamics. The final transition to ELM-free H-mode occurs after the equilibrium $\boldsymbol{E}\times\boldsymbol{B}$ flow shear increases due to ion pressure profile evolution. Zonal flows are also observed to initiate formation of an electron internal transport barrier (ITB) at the $q=2$ rational surface via local suppression of electron-scale turbulence. Multi-channel Doppler Backscattering (DBS) has revealed the radial structure of the ZF-induced shear layer and the $\boldsymbol{E}\times\boldsymbol{B}$ shearing rate, $\omega_{E\times B}$, in both barrier types. During edge barrier formation, the shearing rate lags the turbulence envelope during the LCO by 90º, transitioning to anti-correlation (180º) when the equilibrium shear dominates the turbulence-driven flow shear due to the increasing edge pressure gradient. The time-dependent flow shear and the turbulence envelope are anti-correlated (180º out of phase) in the electron ITB. Limit cycle oscillations with time-reversed evolution dynamics (transitioning from an equilibrium-flow dominated to a ZF-dominated state) have also been observed during the H-L back-transition and are potentially of interest for controlled ramp-down of the plasma stored energy and pressure (normalized to the poloidal magnetic field) $\beta_\theta = 2\mu_0 n\left(T_e+T_i\right)\big/B_\theta^2$ in ITER.

PACS No.: 52.35.Ra, 52.25.Fi, 52.55.Fa, 52.70.Gw