H-Mode Transitions and Limit Cycle Oscillations From Mean Field Transport Equations

G.M. Staebler

General Atomics, PO Box 85608, San Diego, California 92186-5608, USA

The momentum transport of the mean field ExB toroidal and ion poloidal velocities are modeled with both collisional and turbulent contributions to the transport equations [1–3]. It will be shown that there are both normal one-step L/H transitions to suppressed turbulence [2] and newly discovered limit cycle oscillations, from the momentum equations, without the aid of oscillations driven by turbulent zonal flows [4,5]. The results will be compared with recent high resolution measurements [6-8] of L/H transitions and limit cycle oscillations, or dithering transitions, that have given unprecedented detail of the dynamics and spatial structure of the plasma velocities and turbulence.

A particular case with limit cycle oscillations of the two dimensional momentum transport system is shown in Fig. 1 for the normalized potential fluctuation amplitude (a) and the shear in the mean field ExB velocity (b). These model plots compare well with the measurements of the density fluctuations and ExB velocity shear in Ref. [7]. It should be noted that the measurements of the ExB velocity in Ref. [7] are time averaged over an interval (100 μs) that is 50 times the measured correlation time (2 μs) of the density fluctuations so these should be considered as measurements of the mean (i.e. low frequency compared to the turbulence) ExB velocity by definition. In this simulation the diamagnetic velocity is slowly ramped up to induce the transition from the L-mode (early) to the final H-mode (late). For different parameters this model can give one-step L/H transitions. The potential fluctuations [Fig. 1(a)] are suppressed when the ExB shear [Fig. 1(b)] is high and are high when the shear is low. For more general cases, that evolve plasma density, temperatures and the two momentum equations, there can be a phase shift between the potential fluctuation amplitude and the ExB velocity shear, as observed in experiments [7,8]. The phase shift is due to the linear growthrate dependence on temperature and density gradients.

The new limit cycle oscillations are an intrinsic property of the momentum equations and are not driven by oscillating external sources or the intermittency of the turbulence. For a range of parameters, there is a finite frequency for the instability of the momentum transport system caused by the ExB velocity shear suppression of the turbulence and limit cycle oscillations occur as in Fig. 1. The range of parameters of the model where oscillations are found will be compared with experimental data.

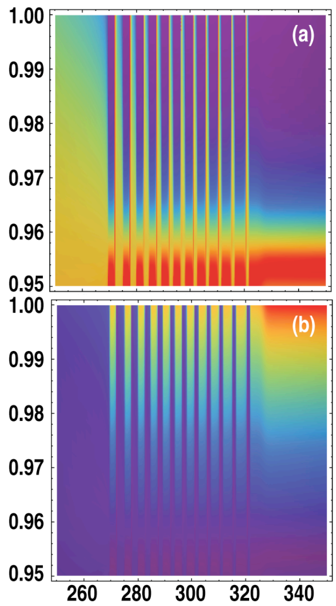

Fig. 1. Time histories (ms) for the region $0.95<x<1.0$ showing normalized potential fluctuation amplitude (a) and ExB velocity shear (b). (Rainbow scale from violet to red is 0 to 1.)

This work was supported by the US Department of Energy under DE-FG02-95ER54309.

[1] V. Rozhansky and M. Tendler, Phys. Fluids B**4**, 1877 (1992).
[2] G.M. Staebler, *et al.*, Phys. Plasmas **1**, 909 (1994).
[3] G.M. Staebler, *at al.*, Phys. Rev. Lett. **110**, 055003 (2013).
[4] Eun-jin Kim and P.H. Diamond, Phys. Rev. Lett. **90**, 185006 (2003).
[5] K. Miki, *et al.*, Phys. Plasmas **19**, 092306 (2012).
[6] G.D. Conway, *et al.*, Phys. Rev. Lett. **106**, 065001 (2011).
[7] L. Schmitz, *et al.*, Phys. Rev. Lett. **108**, 155002 (2012).
[8] J. Cheng *et al.*, Phys. Rev. Lett. **110**, 265002 (2013).