Final Report

UC San Diego Contributions to the Edge Plasma Simulation (EPSI) Project

DOE-SC0008689
Period of Performance:
1 August 2012 – 31 July 2017

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December 2017

Abstract:

UCSD participated as an experimental collaborator in the EPSI Project, led by Dr. C.S. Chang from PPPL. As a part of our work, we carried out several experiments on the ALCATOR C-MOD tokamak device, aimed at unraveling the "trigger" or cause of the spontaneous transition from low-mode confinement (L-mode) to high confinement (H-mode) that is universally observed in tokamak devices, and is planned for use in ITER. Our approach first focused on studying the evolution of turbulence-zonal flow coupling in L-mode, as the heating power was increased towards the threshold for the L-H transition. This work showed that this coupling became more intense as the threshold was approached. It also showed that turbulence coupling to a side-band, finite frequency mode known as the geodesic acoustic mode (GAM). Second, we then studied the turbulence-zonal flow coupling evolution during a fast L-H transition. This work showed that, just before the L-H transition, the coupling to the zonal flow became strong enough that the flow extracts all of the kinetic energy out of the turbulence. This then results in a collapse of the turbulence amplitude, which then shuts down the rapid rate of heat loss at the boundary of the plasma. As a result, the edge density and temperature gradients rapidly (< 1msec) build up. These steep edge pedestal gradients then "lock in" the strong sheared flow, and maintain the turbulence suppression, allowing the H_mode state to be sustained. In a third experimental paper, we showed that this picture can help explain why the H-mode is more easily accessed when the grad-BxB drift direction points towards the X-point of the divertor. Finally, we collaborated with Dr. Chang's group and carried out the first-ever full-f gyrokinetic simulation of the L-H transition. This work confirmed the key role that turbulence-zonal flow coupling plays in initiating the transition. It also provided evidence that fast ion orbit loss plays a secondary, but important, role in navigating the plasma into the steady-state H-mode state.

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1. Cziegler, I., et al., *Nonlinear transfer in heated L-modes approaching the L-H transition threshold in Alcator C-Mod.* Nuclear Fusion, 2015. **55**(8).
2. Cziegler, I., et al., *Zonal flow production in the L-H transition in Alcator C-Mod.* Plasma Physics and Controlled Fusion, 2014. **56**(7).
3. Cziegler, I., et al., *Turbulence Nonlinearities Shed Light on Geometric Asymmetry in Tokamak Confinement Transitions.* Physical Review Letters, 2017. **118**(10).
4. Chang, C.S., et al., *Fast Low-to-High Confinement Mode Bifurcation Dynamics in a Tokamak Edge Plasma Gyrokinetic Simulation.* Physical Review Letters, 2017. **118**(17).
5. Tynan, G.R., et al., *Recent progress towards a physics-based understanding of the H-mode transition.* Plasma Physics and Controlled Fusion, 2016. **58**(4).