A Conceptual Model for the Nonlinear Dynamics of Edge Localized Modes in Tokamak Plasmas*

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High performance magnetically confined toroidal plasmas, such as those required for the operation of a tokamak based fusion power plant, suffer from a troubling type of repetitive edge instability known as Edge Localized Modes (ELMs). Although ELMs are a common feature of high confinement tokamak plasmas, there are significant gaps in our understanding of how these instabilities scale with the geometry of the plasma and operating conditions expected in large tokamaks required for the generation of fusion power. Thus, there is an urgent need for a model that can be tested with experimental data from smaller existing devices.
In this talk, we present a conceptual model describing the topological evolution of the magnetic separatrix in a tokamak plasma with a dominant lower hyperbolic point, along with the nonlinear dynamics of the ELM instability prescribed by this evolving separatrix topology [1]. The model invokes a feedback amplification mechanism that causes the stable and unstable invariant manifolds of the separatrix, comprising a homoclinic tangle, to grow explosively as the topology of the manifolds unfolds. The amplification process is driven by the rapid growth of field-aligned helical currents that flow through relatively short edge plasma flux tubes connecting the high heat flux divertor target plates located on both sides of the plasma. These currents produce magnetic fields that couple to the separatrix and modify its global topology. As the lobes of the separatrix tangle grow with increasing current, their area of intersection with the divertor target plates increases along with the size of the flux tubes connecting the divertor targets on the high and low field sides of the plasma. This increases the magnitude of the current flowing in the short flux tubes causing an increase in the local magnetic stochasticity that connects the pedestal region to the short flux tubes. This increases the parallel heat flux to the divertor target plates, which completes the feedback loop. Numerical simulations have shown that the model is qualitatively consistent with measurements of the currents flowing between the target plates and camera images of the heat flux patterns on the walls near the low field side target plate. In addition, the model suggests that by using external non-axisymmetric magnetic coils to force higher order separatrix bifurcations ELMs can be supressed. All of these aspects of the model will be discussed along with examples of the simulation results and comparisons to experimental data.

[1] T. E. Evans, et al., J. Nucl. Mater. **390-391** (2009) 789.

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