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ELMs, Magnetic X-points, and Chaotic Fields[1]

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Edge Localized Modes (ELMs) in a magnetically confined plasma are shown to be a new type of nonlinear plasma instability, in which a coherent plasma structure couples to part of a chaotic magnetic field. Numerical simulation using the M3D code [1] provides a detailed picture. Toroidal magnetic fields can be described as Hamiltonian systems. Under small perturbations, a plasma boundary magnetic surface containing an X-point splits into two, defined asymptotically by the limits of the field lines traced infinitely in each direction. The limiting surfaces overlap to form a homoclinic tangle [2]. The steep pressure gradient near the edge of an H-mode fusion plasma drives ballooning-type plasma instabilities, aligned along the equilibrium magnetic field. These can couple nonlinearly to the "unstable" magnetic surface that ripples the equilibrium boundary. Fingers of plasma grow outwards, above and below the midplane on the outboard side, and the alternating low density regions may penetrate deep into the plasma. The field becomes chaotic over the affected region. Field lines are contained for many toroidal transits, but develop significant radial excursions. Many are eventually lost through the X-point region. The original magnetic boundary is preserved. Over several hundred Alfvén times the plasma heals back towards the original shape, but with relaxed profiles of density and temperature. A complex nonlinear interaction between the plasma instability and a magnetic homoclinic tangle leads to distinct stages in the ELM crash, that are similar to experimental observations. This new picture may help to explain the large range of ELM and ELM-free behavior seen in experiments and suggests a re-examination of H-mode edge confinement and the L-H transition.

[1] W. Park, et al., *Phys. Plasmas* **6** 1796 (1999).
[2] T. Evans, et al,, *J. Phys. Conf. Series* **7** 174 (2005).

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