

Experimental Signatures of Homoclinic Tangles in Poloidally Diverted Tokamaks

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In a poloidally-diverted tokamak plasma containment device, the core plasma region is magnetically isolated from the containment vessel walls by the creation of an axisymmetric separatrix. The region near the separatrix, the boundary and pedestal region, is particularly sensitive to the onset of magnetic field stochasticity due to small non-axisymmetric resonant perturbations [1]. Calculations of the primary separatrix structure show that the amount of stochastic magnetic flux escaping from the boundary layer and its distribution on plasma facing surfaces is intimately related to the topology of homoclinic tangles formed in the perturbed system [2]. Non-resonant homoclinic tangles appear in the primary separatrix of the system above a relatively low threshold in error field strength. The threshold level depends on a variety of equilibrium shape parameters. Based on modeling that does not include the response of the plasma, the area of the homoclinic lobes scales linearly with the amplitude of an externally imposed perturbation field [3]. Since these lobes (or manifolds) set the boundaries that prescribe how stochastic field line trajectories are organized i.e., how field lines from the inner domain of the unperturbed separatrix mix and are transported to plasma-facing vessel surfaces such as divertor target plates and protruding baffle structures, and since plasma heat and particles are conducted efficiently along the field lines, they are of significant practical interest for high power tokamak experiments.

Experimental measurements of heat and particle flux distributions on plasma facing surfaces sometimes show split peak patterns that are consistent with the presence of large homoclinic tangles. These split peak patterns have a variety of complex behaviors and are often observed during so-called locked modes and other types of edge instabilities. They are also observed when perturbation fields from MHD control coils are pulsed on during a plasma discharge. Numerical modeling of the perturbation field from the MHD control coils shows that the homoclinic tangles produced by the coils are not large enough to produce the splitting patterns seen in most cases. Nevertheless, there is a clear correlation between the coil pulses and the appearance of the split profiles. These results suggest the presence of a plasma amplification mechanism that enhances the size of the non-resonant homoclinic tangles.

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