# A model of a 3-D fusion plasma equilibria fully consistent with the existence of field-line chaos

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The particles in a magnetically confined fusion plasma are (to a good approximation) confined to magnetic field lines, which spiral around within a toroidal volume. If the plasma is axisymmetric, the field lines lie within an infinite set of nested toroidal 'flux surfaces' and as a result the plasma tends to stay tied to the surfaces. If the toroidal plasma is geometrically deformed, flux surfaces begin to break up and, while some field lines still draw out a toroidal shape, other field lines wander chaotically within a toroidal volume, meaning the plasma tied to these field lines is no longer confined.

Our group is developing a model which relaxes the plasma energy within potentially chaotic regions, using the surviving flux surfaces as separating barriers.[1] Such a model is the first variational magnetohydrodynamic model to reconcile the coexistence of confinement and chaos in a way fully consistent with nonlinear Hamiltonian dynamics theory.

Crucial in the development of such a model is the ability to predict which flux surfaces are most likely to survive so they can be used as separating surfaces. There is more to the problem however, when an annular volume of magnetic field line chaos is predicted the pressure in that area must be constant, and so for the equilibrium to have a non-trivial pressure profile, pressure discontinuities must exist at the separating flux surfaces.[2][3] There exists a Hamiltonian formulation of the magnetic field that can be used to predict when configurational perturbations destroy flux surfaces.[4] Additionally, the above mentioned pressure discontinuity condition that must be satisfied on flux surfaces also have a Hamiltonian formulation.[5]

Both (potentially) chaotic Hamiltonians interact in a very complicated way. Although both the geometrical perturbations and the pressure loading tend to destroy flux surfaces, there do exist solutions where field lines can reform flux surfaces at a pressure higher than is usually allowed. There is evidence that the surfaces become critical just as they are about be to be destroyed, and at this point it has a fractal structure. Further, there is evidence that some field lines, ones that are in the same 'universality class' may approach the edge of chaos in the same way.

## References

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