# Taming chaos in the reversal region of the reversed-field pinch

A.Cravotta[1,2], G.Spizzo[1], D.F.Escande[1,3], S.Cappello[1], I.Predebon, P.Martin[1,2], L.Marrelli[1], R.B.White[4], A.Canton[1], R. Lorenzini[1], F. Auriemma[1], P. Zanca[1]

*[1]Consorzio RFX, Associazione EURATOM-ENEA sulla fusione, Padova, Italy*
*[2]Dipartimento di Fisica "Galileo Galilei", Università di Padova, Padova, Italy*
*[3]UMR 6633, CNRS-Université de Provence, Marseille, France*
*[4]Princeton Plasma Physics Laboratories, Princeton, NJ, U.S.A.*

Experimental temperature and density profiles in the multiple helicity (MH) regime of the Reversed-Field Pinch magnetic configuration (RFP) are rather flat in the core, and display a steep gradient only in the plasma edge[1]. This indicates that the core, which is characterised in MH by a high level of magnetic stochasticity, plays a minor role in plasma confinement. On the contrary, the edge is more important in determining transport properties of particles and energy. In this work this idea is backed up by numerical calculations of magnetic field lines in the edge region of the RFP. The ORBIT code[2] is used to compute magnetic field lines and related particle orbits, corresponding to the magnetic field profiles (equilibrium + perturbations) supplied by the three dimensional SpeCyl code[3].

Magnetic topology (studied through toroidal Poincaré plots) shows that $m$=1 and $m$=0 modes generate magnetic chaos in the internal region, implying poor confinement there. However these modes cooperate and produce magnetic islands localized across the reversal radius (i.e., the radial position where the axis-symmetric part of $B_z$ vanishes). These islands are transport barriers in the chaotic background. This is highlighted by computing the loss time of thermal particles deposited in the core, and collected at increasing distances towards the wall. The loss time profile shows a steep gradient starting at a typical radius smaller than that related to magnetic field reversal.

The effectiveness of this transport barrier is studied in different plasma conditions, i.e. mainly in terms of amplitude and phases of $m$=0 and $m$=1 modes. While the effect of $m$=0 mode amplitude is negative in their natural phase relation, there exists a correct phase and amplitude combination that allows for enhancing the barrier. This has been analyzed and explained using the usual Hamiltonian description of field lines, and studying a suitable canonical transformation. In particular, assuming the amplitude of $m$=0 and $m$=1 modes to be of order $\varepsilon$, it is shown that $m$=1 modes produce an $\varepsilon^2$, $m$=0 type correction to the Hamiltonian, that sums up to the $\varepsilon$ term due to $m$=0 modes. By adding an external $m$=0 perturbation, the full $\varepsilon$ and $\varepsilon^2$ $m$=0 contribution can be made to vanish, and chaos to decrease in the $q$=0 region.

This theoretical model of the RFP reversal region suggests that applying an $m$=0 external perturbation in the Padua experiment RFX-mod, by means of the new toroidal power supply system [4] and feedback control techniques, might be useful to tame chaos in the reversal region.

[1] A.Intravaia et al., Phys. Rev. Lett. 83, 5499 (1999); D.Gregoratto et al., Nucl. Fusion **38**, 1199 (1998).
[2] R. B. White and M.S. Chance, Phys. Fluids **27**, 2455 (1984).
[3] S. Cappello and D. Biskamp, Nucl. Fusion **36**, 271 (1996).
[4] V. Toigo *et al*., in 20th Symposium on Fusion Engineering (IEEE/NPSS, San Diego, USA, 2003).