REACTORS WITH STELLARATOR STABILITY AND TOKAMAK TRANSPORT

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Since the W7-AS and LHD stellarator experiments exceeded theoretical β limits, the ARIES_CS study has been considering more realistic simulations that use the NSTAB code. The problem may be that force balance and stability are lost across islands if the equilibrium equations are not in conservation form.

There are compact stellarators with either two or three field periods that are good candidates for a reactor. In the case of two periods eight modular coils have been found to reconstruct a magnetic field in the plasma meeting most of the requirments of the design.

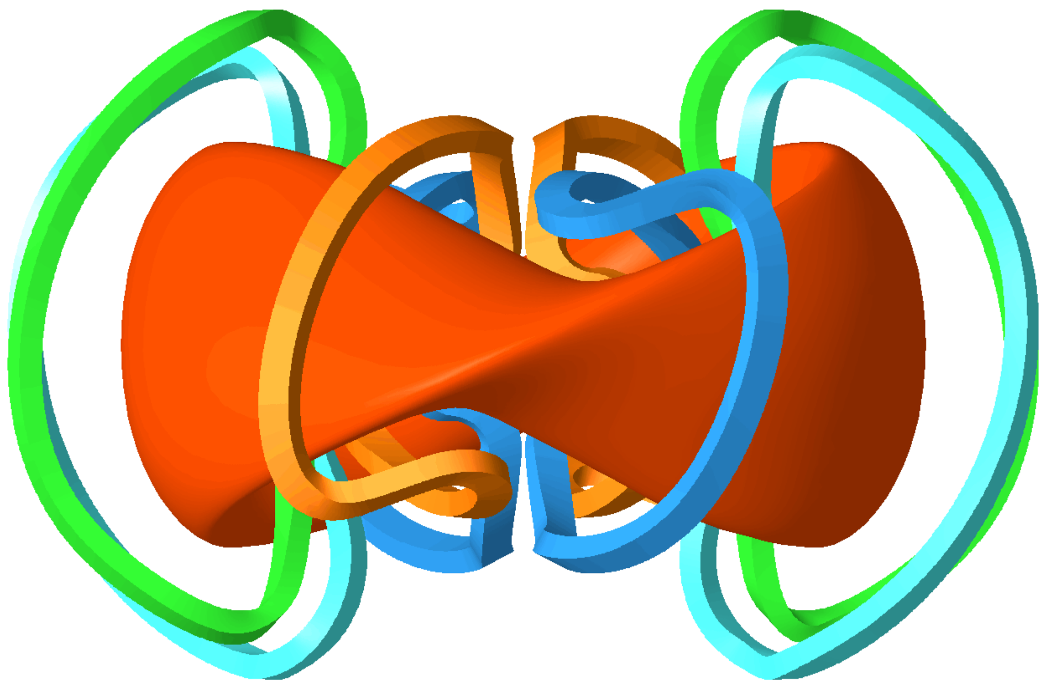
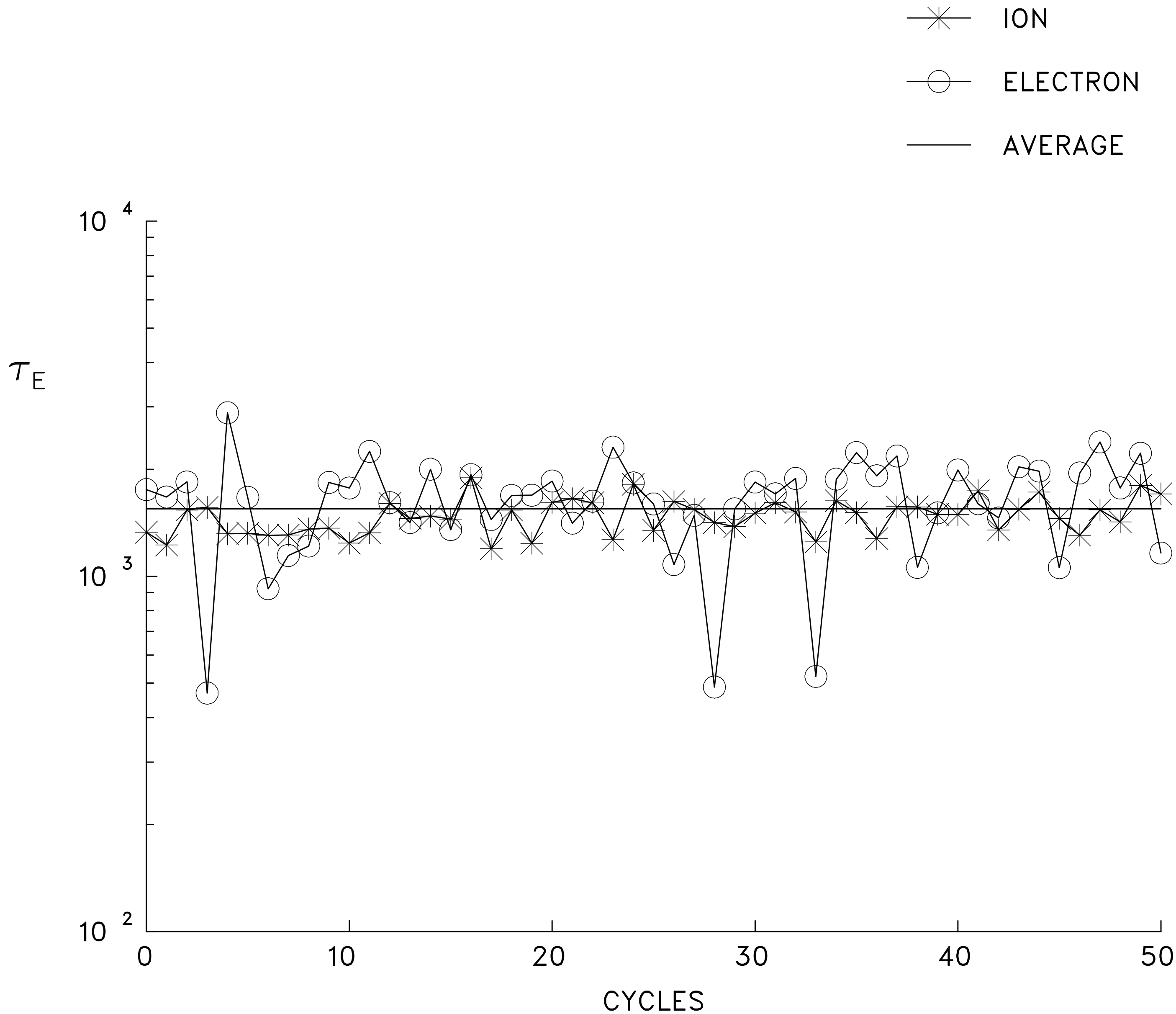


Diagram of a two field period stellarator with $A = 2.5$ designed by running the NSTAB equilibrium code. Eight moderately twisted modular coils needed to produce the external field are shown. This configuration is a candidate for the ARIES_CS reactor study. Maintenance seems to be feasible through ports between each pair of coils. (Courtesy of Tak-Kuen Mau and Tsueren Wang.)



Iterations to quasineutrality in a Monte Carlo computation of the energy confinement time τ_E, measured in milliseconds, for an NCSX reactor with major radius 7.2 m and plasma radius 1.6 m at conditions with average $T = 15\,\mathrm{keV}$, $n = 2 \times 10^{14}\,\mathrm{cm}^{-3}$, and $B = 6.5\,\mathrm{T}$. The magnetic spectrum has good quasiaxial symmetry, and the radial electric field rises to a potential level twice as big as the temperature.

$$\int\int\int[\frac{1}{2}B^2 - p(s)]\,dV \;=\; \text{minimum}$$

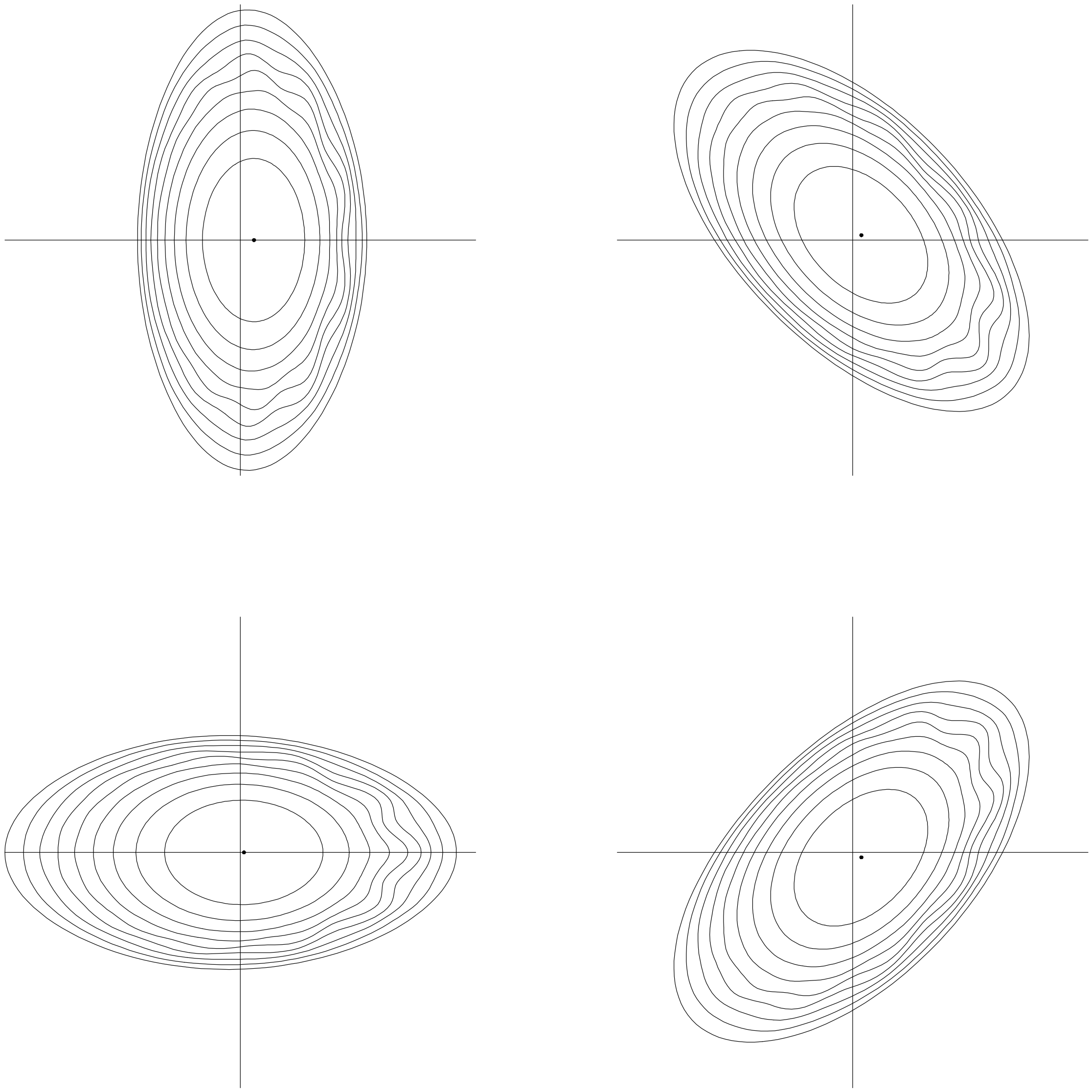
$$\nabla\cdot\mathbf{B} \;=\; 0\,, \quad \nabla\cdot[\mathbf{B}\,\mathbf{B} \;-\; (B^2/2 \,+\, p)\,\mathbf{I}] \;=\; 0$$

$$\mathbf{B} = \nabla s \times \nabla\theta = \nabla\phi - \zeta\nabla s\,, \quad \mathbf{J} = \nabla s \times \nabla\zeta$$

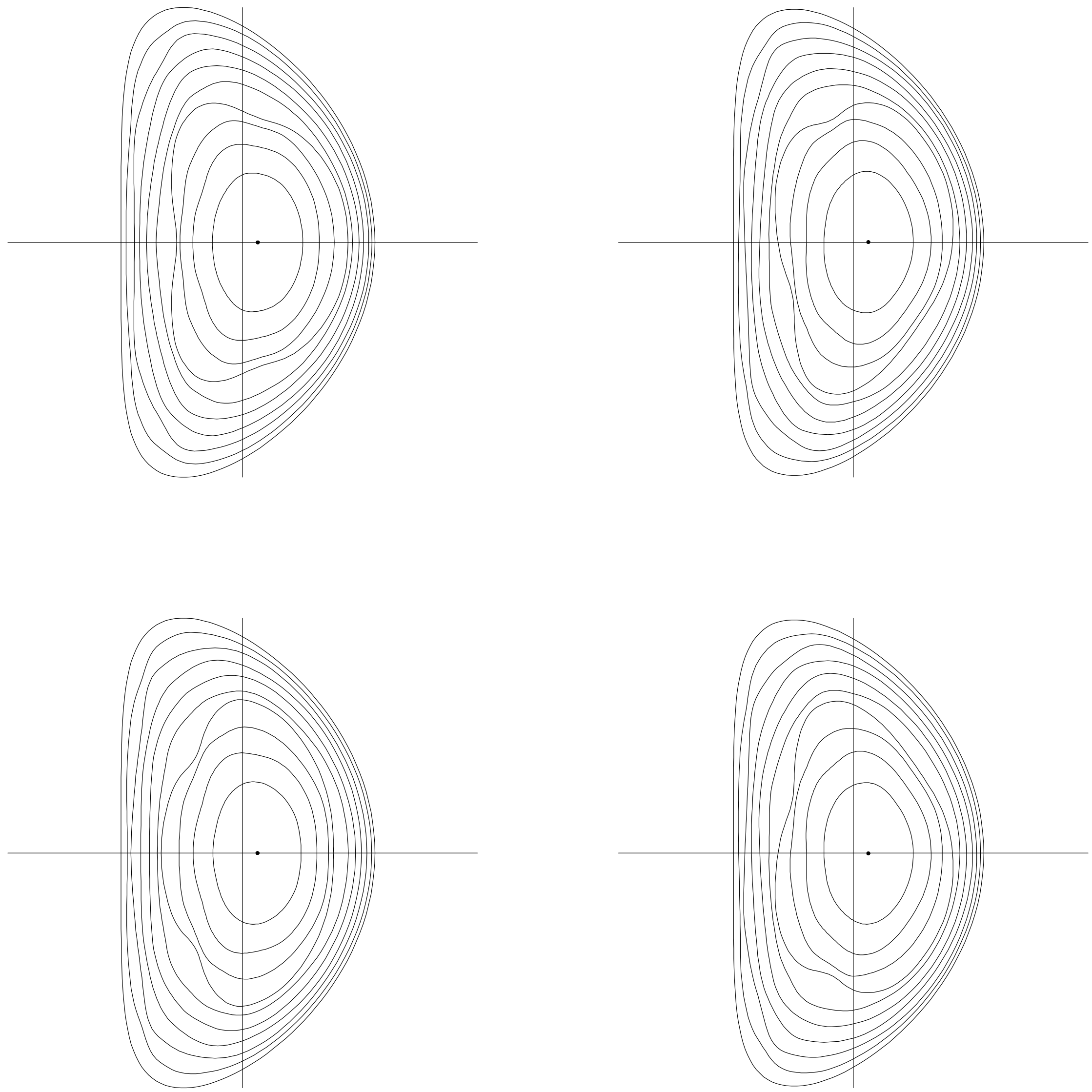
$$\frac{1}{B^2} = \Sigma\, B_{mn}\cos(m\theta - [n - \iota m]\phi)$$

$$\zeta = p'\,\Sigma\,\frac{B_{mn}}{n - \iota m}\sin(m\theta - [n - \iota m]\phi)$$

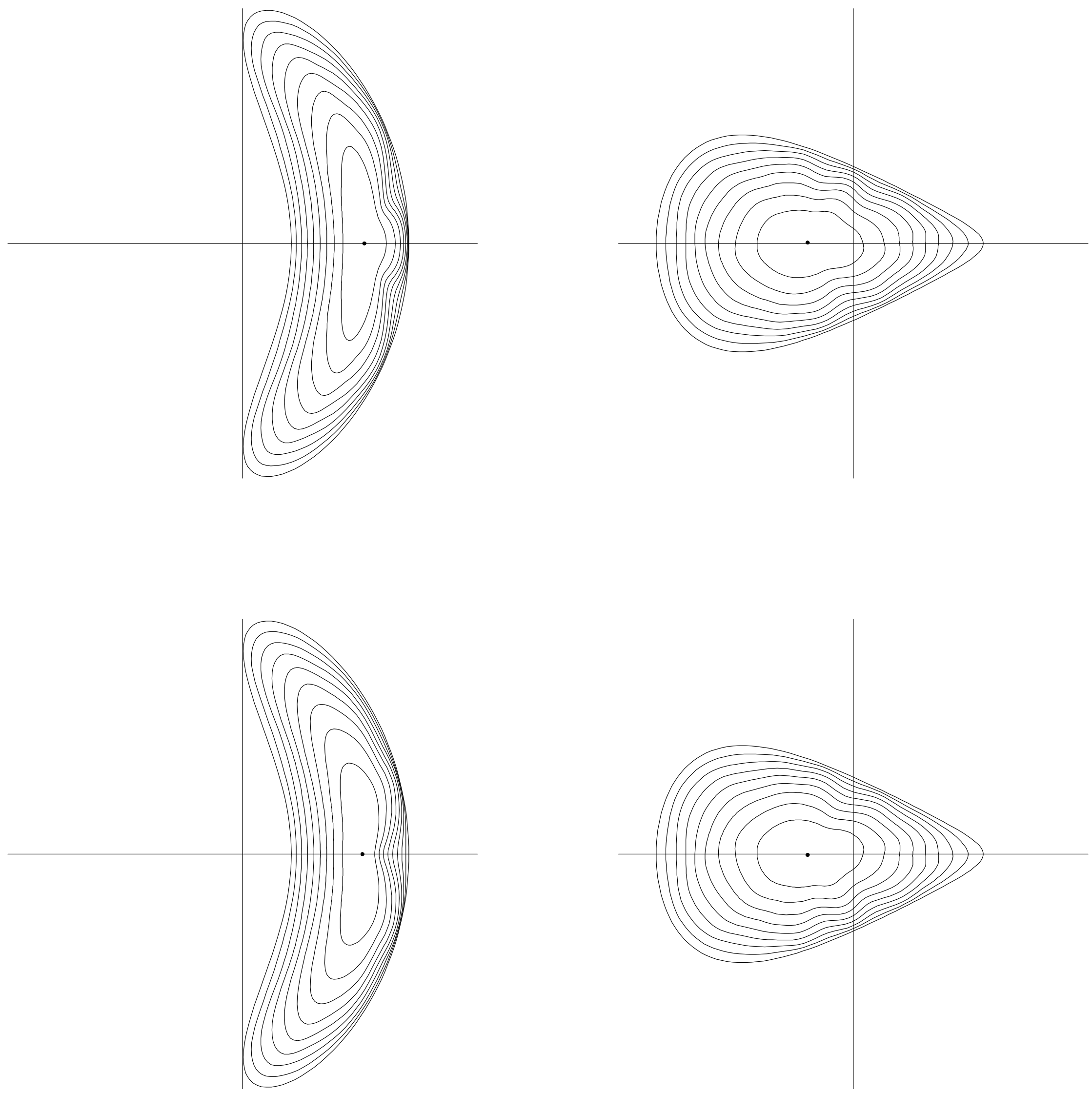
$$(\Psi_x^2)_x = \eta\,\Psi_{xxx}, \Psi(-1) = \Psi(1) = 0, \Psi_x(-1) = 1$$



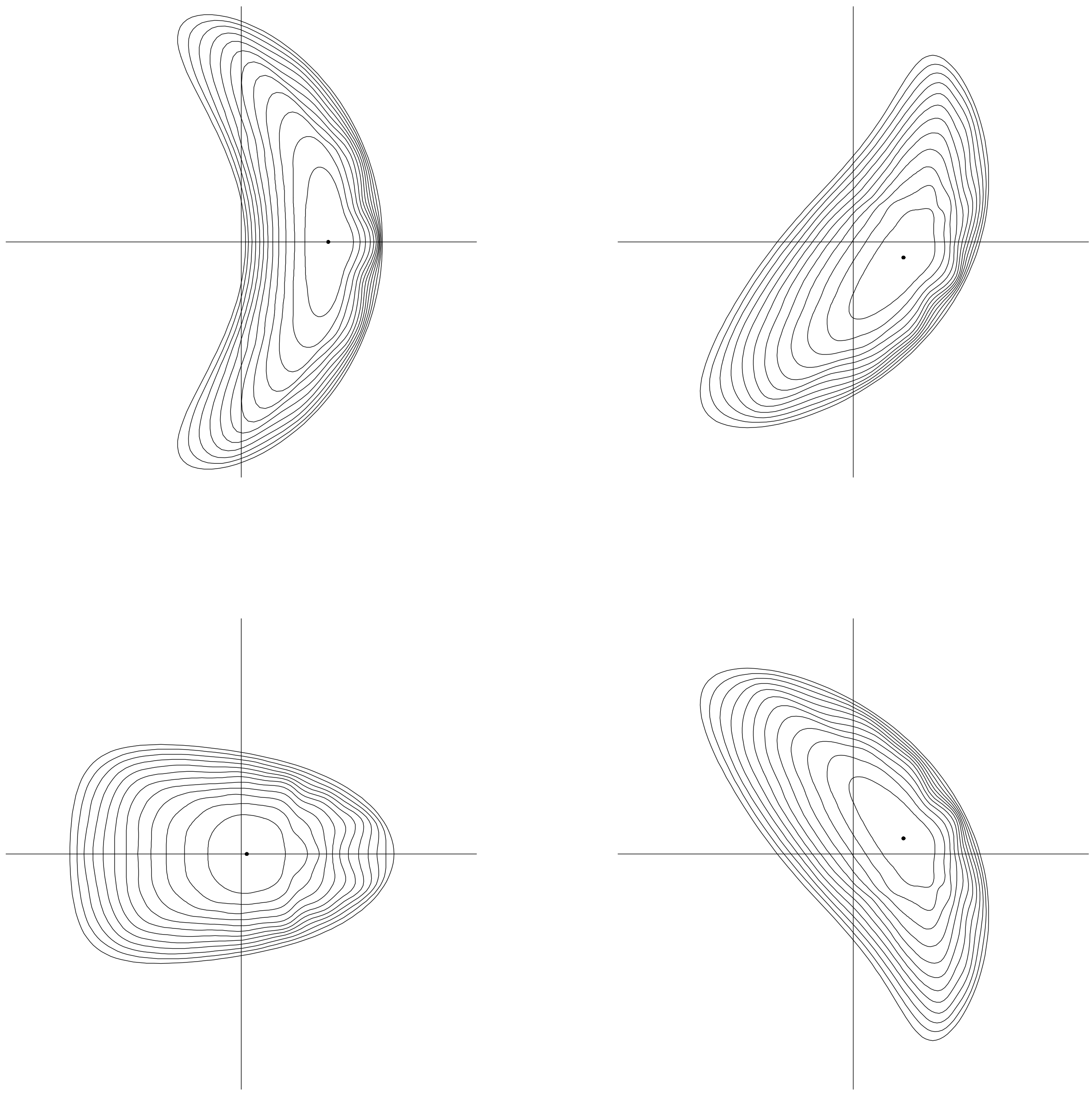
Poincaré map of the flux surfaces at four cross sections over one field period of a bifurcated LHD equilibrium at $\beta = 0.04$ with the magnetic axis shifted inward to a position with major radius $R = 3.6$ m. For a broad pressure profile $p = p_0(1 - s^2)$, this exceptionally accurate solution has magnetic surfaces with ripple suggesting that it is only marginally stable. At these conditions a similar plasma was observed in the experiment.



Four cross sections of the flux surfaces over half the torus of a bifurcated DIII-D equilibrium at $\beta = 0.05$ with $p = p_0(1 - s^{1.1})^{1.1}$ and with net current bringing the rotational transform into the interval $0.9 > \iota > 0.3$. There is a large $m = 3,\ n = 2$ magnetic island at $\iota = 2/3$ in the solution. The calculation suggests that an advanced tokamak reactor like this might be subject to disruptions and loss of α particles.



Four cross sections of the flux surfaces over two field periods of a bifurcated MHH2 equilibrium at average $\beta = 0.06$ with pressure $p = p_0(1 - s^{1.1})^{1.1}$ and with net current bringing the rotational transform into the interval $0.65 > \iota > 0.45$. A low order ballooning mode appears in the solution, which has an obvious asymmetry.



Four cross sections of the flux surfaces over the full torus of a bifurcated equilibrium in a simulation of the NCSX at $\beta = 0.06$ with a peaky pressure profile $p = p_0(1 - s^{1.2})^{1.8}$ and with net current bringing the rotational transform into a range between 0.4 and 0.7. A visible ballooning mode in the magnetic surfaces shows that a stability limit on β may have been reached. This calculation is sensitive to the choice of profiles.