REACTORS WITH STELLARATOR STABILITY AND TOKAMAK TRANSPORT (SSTT)

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Because the W7-AS and LHD experiments exceeded theoretical β limits, the ARIES-CS study has been considering more realistic predictions from runs of the NSTAB code. Force balance and stability may be lost across islands when the equilibrium equations are not in conservation form.

There are compact stellarators with either two or three field periods that have good properties for a reactor. The coils for two periods look better primarily because their distance from the separatrix is smaller in units of the plasma radius. The most economical size for the reactor has not yet been determined.

Maxwell stress tensor

$$\mathbf{T} \;=\; \mathbf{B}\,\mathbf{B} \;-\; (B^2/2 \;+\; p)\,\mathbf{I}$$

MHD force balance in conservation form

$$\nabla \cdot \mathbf{T} \;=\; 0\;, \quad \nabla \cdot \mathbf{B} \;=\; 0$$

force on a closed control surface

$$\int\!\!\int \;\mathbf{T} \cdot \mathbf{N}\, dS \;=\; 0$$

example of Burgers equation in slab geometry

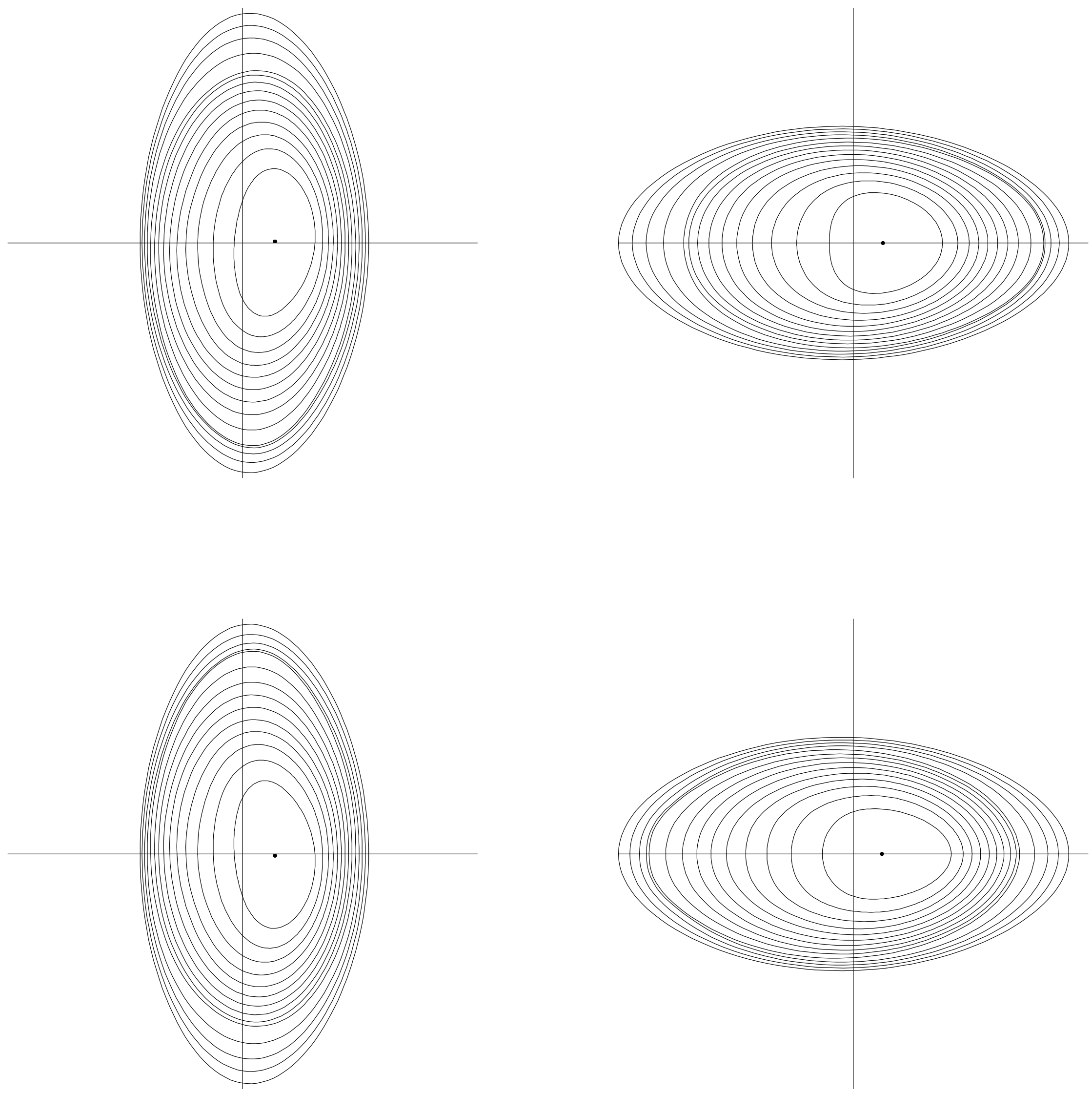
$$2\Psi_x\; \Psi_{xx} \;=\; (\Psi_x^2)_x \;=\; 0$$

conservative difference scheme

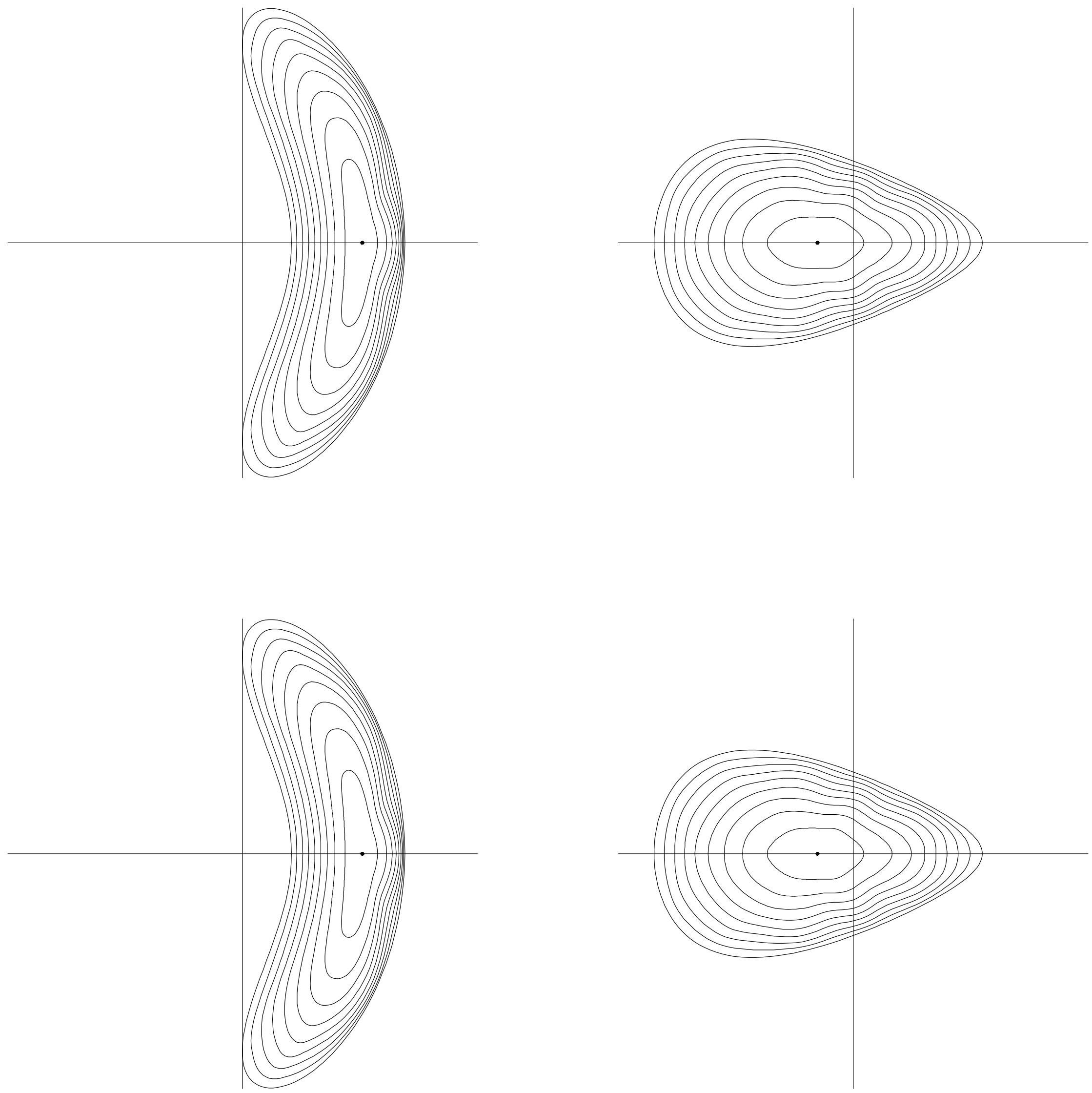
$$(\Psi_{n+1} \;-\; \Psi_n)^2 \;-\; (\Psi_n \;-\; \Psi_{n-1})^2 \;=$$

$$\epsilon\,\left(\Psi_{n+1} - 3\Psi_n + 3\Psi_{n-1} - \Psi_{n-2}\right)$$

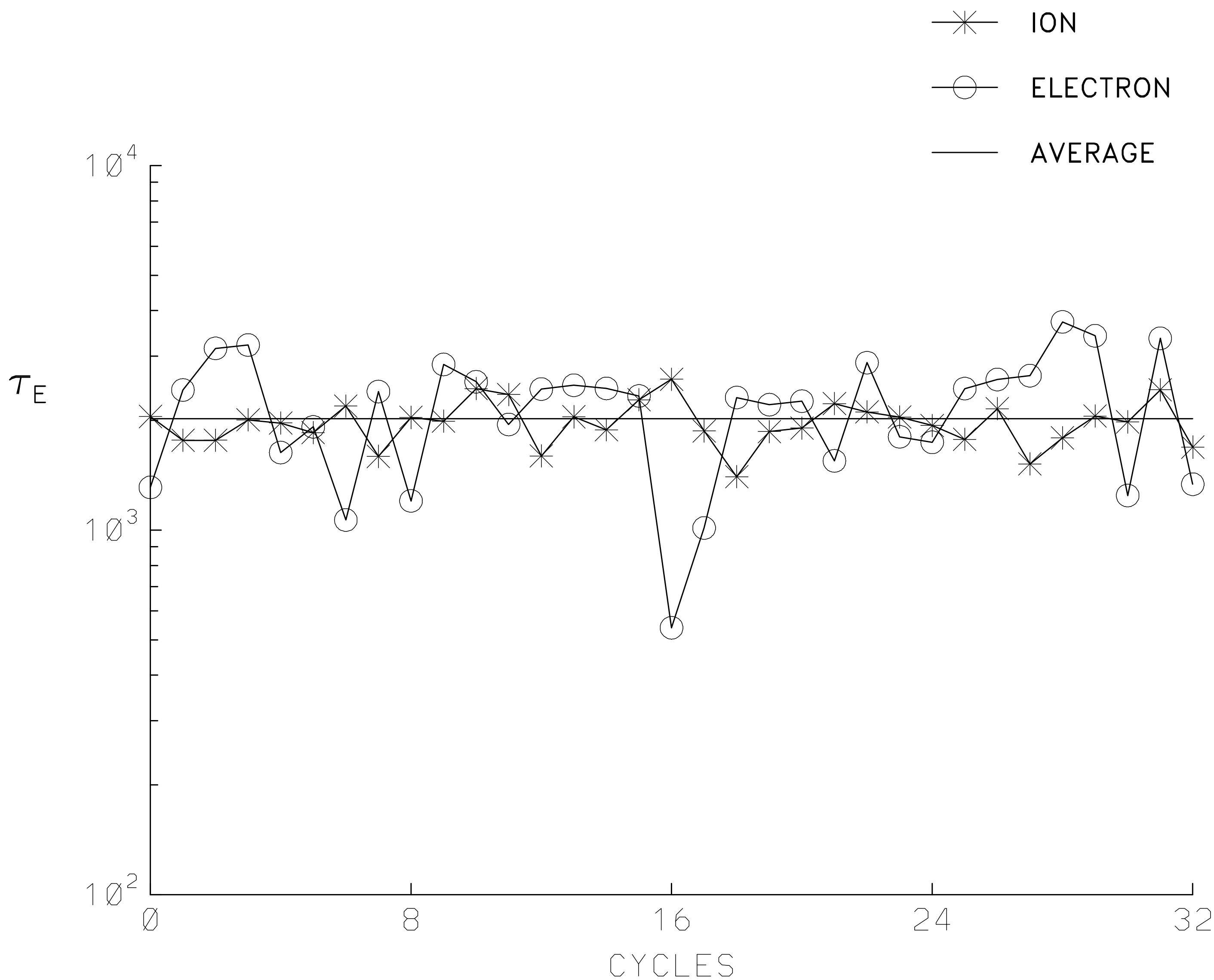
correct jump calculation



Poincaré map of the flux surfaces at four cross sections over the full torus of a bifurcated LHD equilibrium at $\beta = 0.032$ with the magnetic axis at a position with plasma radius $R = 3.6$ m. For a standard pressure profile $p = p_0(1 - s)$ the global $m = 1,\ n = 1$ mode of this solution is linearly unstable, but nonlinearly stable. This NSTAB calculation was performed using harmonics of degree up to 24 in the poloidal angle and up to 120 in the toroidal angle.



Four cross sections of the flux surfaces over two field periods of a bifurcated SSTT 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 $0.64 > \iota > 0.44$. A low order ballooning mode appears in the solution, and its structure does not change much when the mesh is refined.



Iterations to quasineutrality in a Monte Carlo computation of the energy confinement time τ_E, measured in milliseconds, for an SSTT reactor with major radius 7 m and plasma radius 2 m at efficient conditions with average $T = 20\,\text{keV}$, $n = 1.4 \times 10^{14}\,\text{cm}^{-3}$, and with $B = 6\,\text{tesla}$. The magnetic spectrum has excellent quasiaxial symmetry, and the radial electric field rises to a potential level two times as big as the temperature.

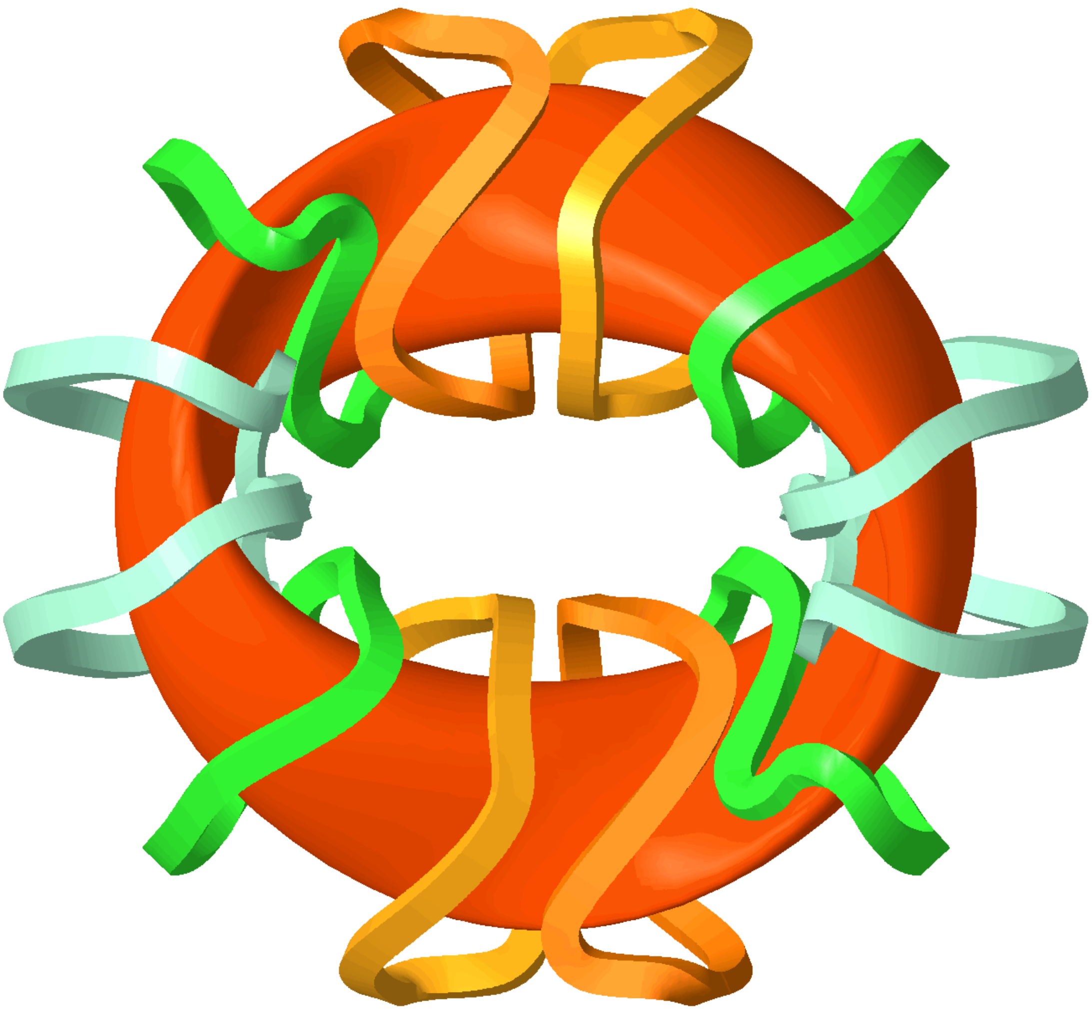
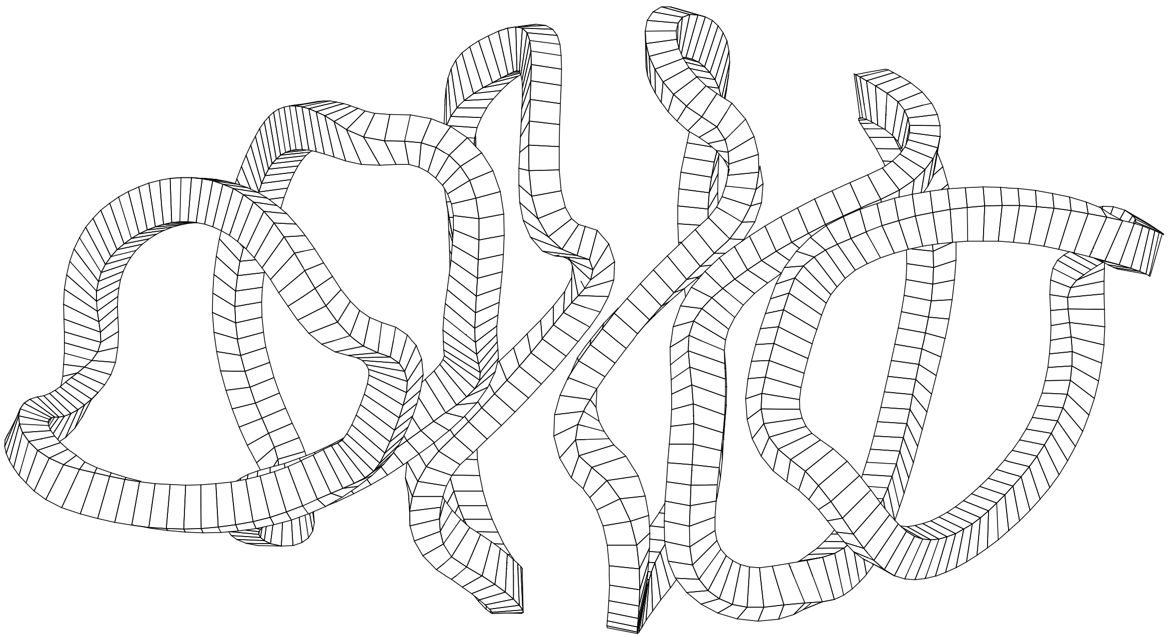


Diagram of an MHH2 stellarator with $A = 3.5$ designed by running the NSTAB equilibrium code. Only half of the twelve moderately twisted modular coils needed to produce the external field are shown. This configuration is a candidate for the stellarator reactor study being conducted at UCSD. Maintenance seems to be feasible through ports between each pair of coils. (Courtesy of Tak-Kuen Mau and Tsueren Wang.)



Asymmetric view of 6 out of 18 modular coils for the KG3 stellarator in a vacuum magnetic field given by the Biot-Savart law. Parameters have been adjusted to provide ample space around each coil, and the aspect ratio of the plasma is 4.5. The low number of coils generates significant ripple in the magnetic field.