University of Maryland update

- People
- Research highlights
- Questions for the Hidden Symmetries group & collaboration ideas

People

University of Maryland stellarator personnel

(both Simons- & DOE-funded)

Departures

- Patrick Kim, Rahul Gaur, Stefan Buller to Princeton.
- Alan Kaptanoglu to NYU.

Arrivals

- Todd Elder (split 50/50 between Maryland & IPP-Greifswald)
- Rory Conlin

University of Maryland stellarator personnel

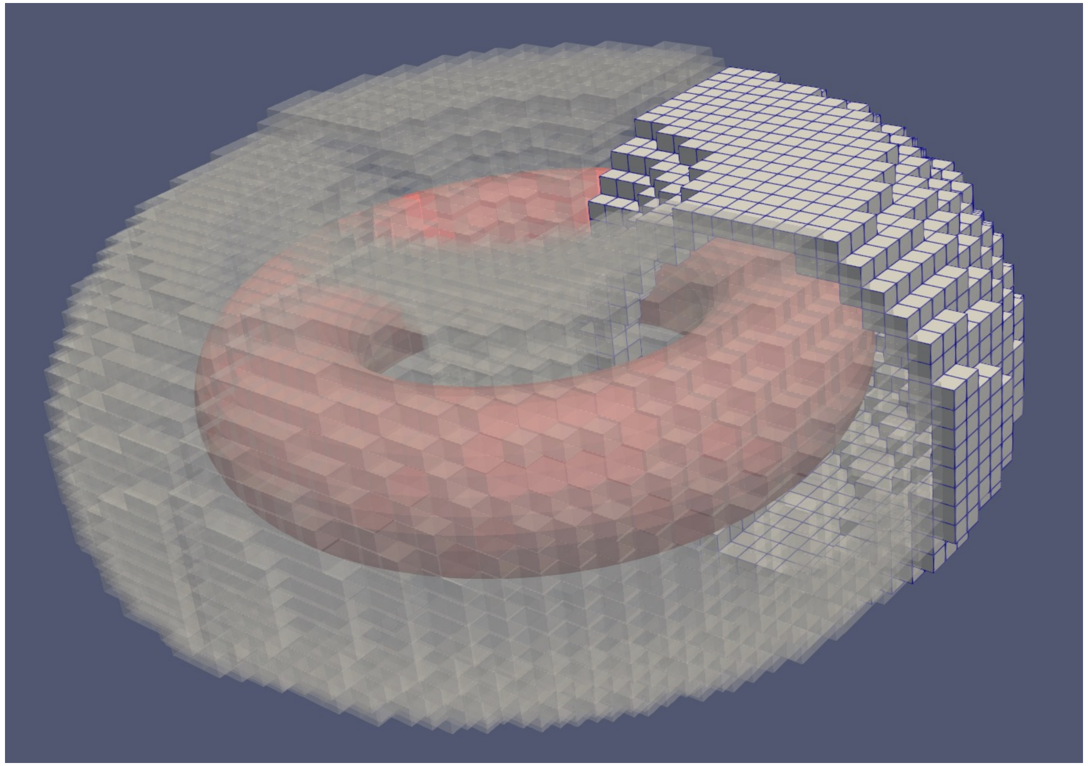
(both Simons- & DOE-funded)

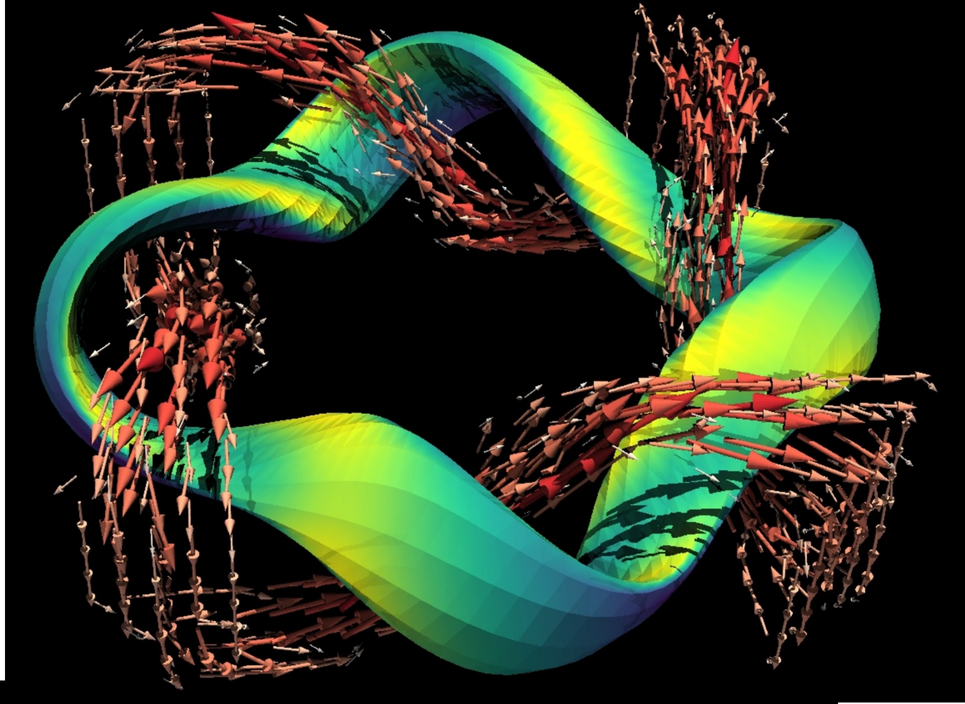
- Tom Antonsen (professor): adjoint methods, coil self-fields/forces.
- Bill Dorland (professor): GX gyrokinetic code.
- Todd Elder (postdoc): divertors.
- John Kappel (PhD student): limits on coil-to-plasma distance.
- Byoungchan Jang (PhD student): physics-informed neural networks, loss landscapes.
- Siena Hurwitz (PhD student): calculating & optimizing coil **I** x **B** forces & max |B| in coil.
- Alex Wiedman (undergraduate): coils for QH, near-axis expansion.
- Mustafa Khan (undergraduate): finite element modeling for coil forces.
- Matt Landreman (research scientist): supervising.

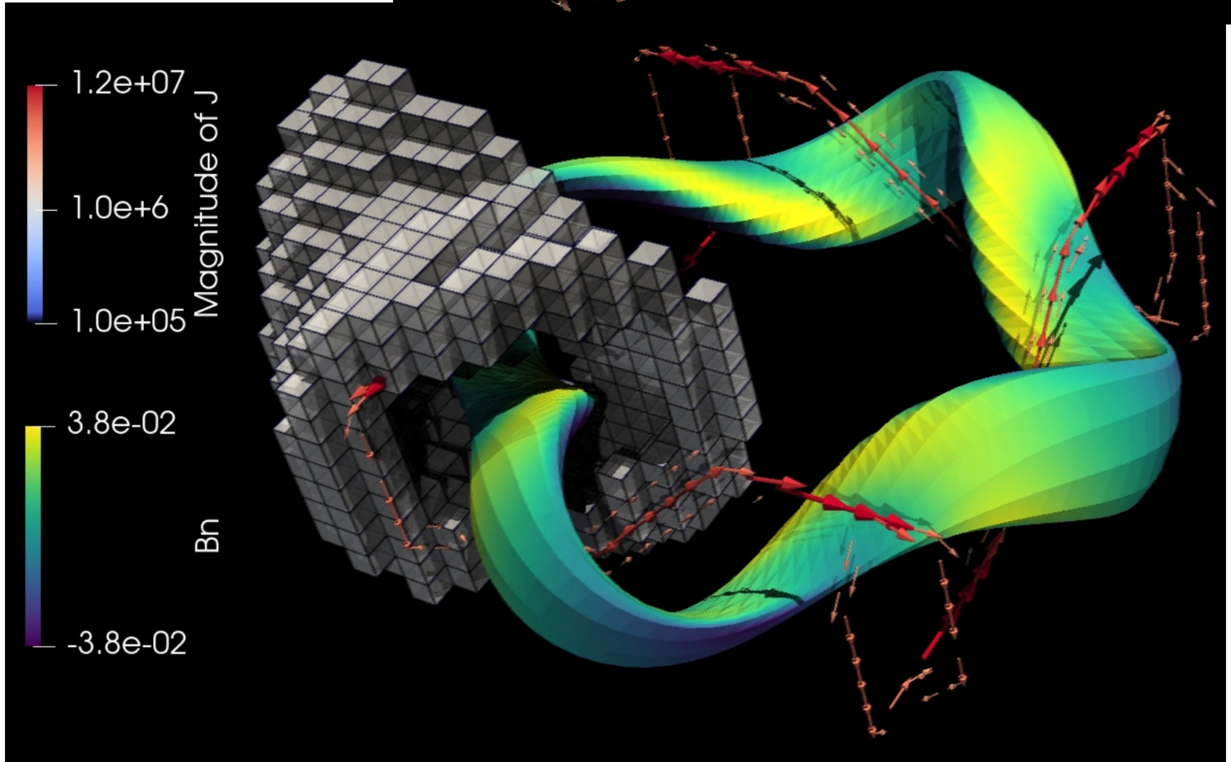
Research highlights

Coil topology optimization: "current voxels"

Alan Kaptanoglu, Gabriel Langlois - *Computer Methods in Applied Mechanics and Engineering* 418A, 115504 (2023)





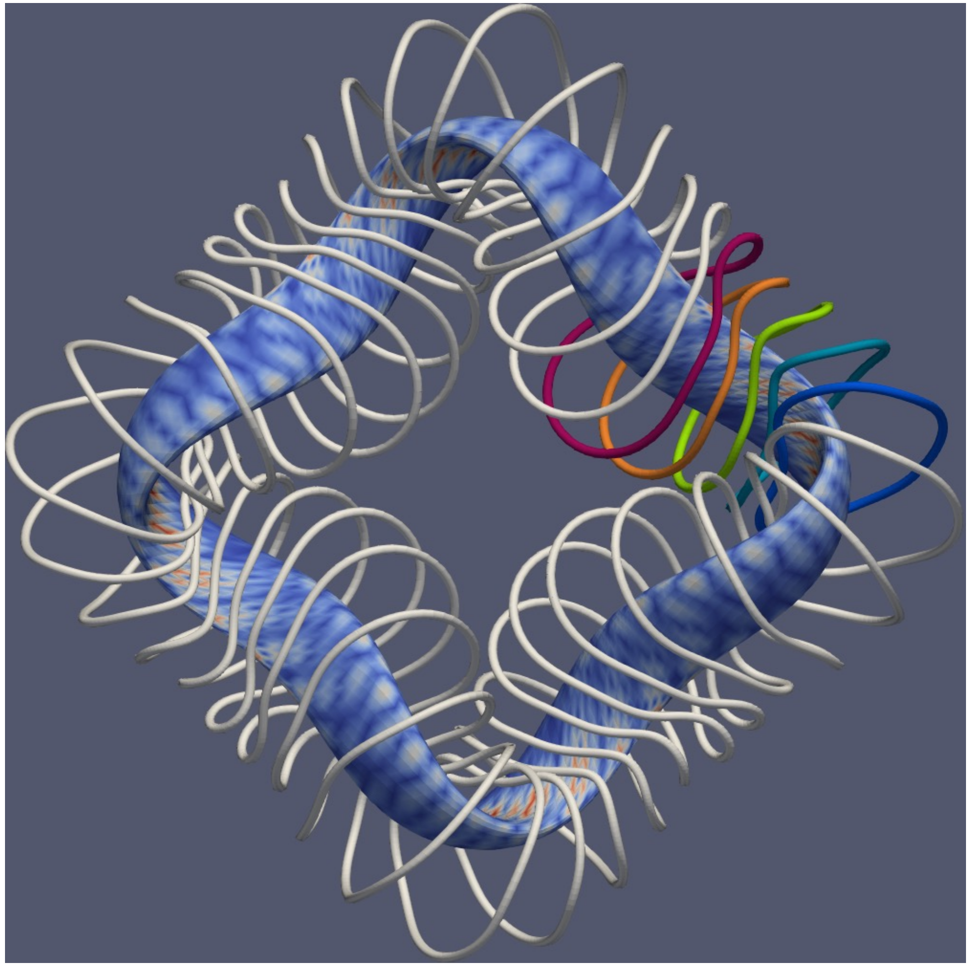


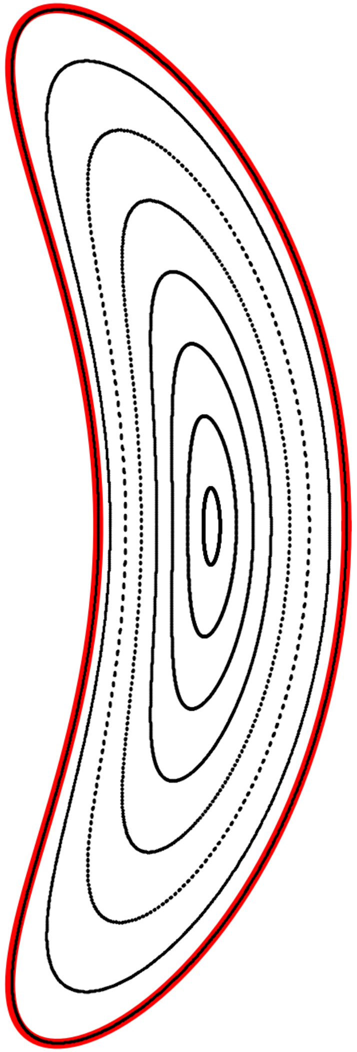
Minimize objective:

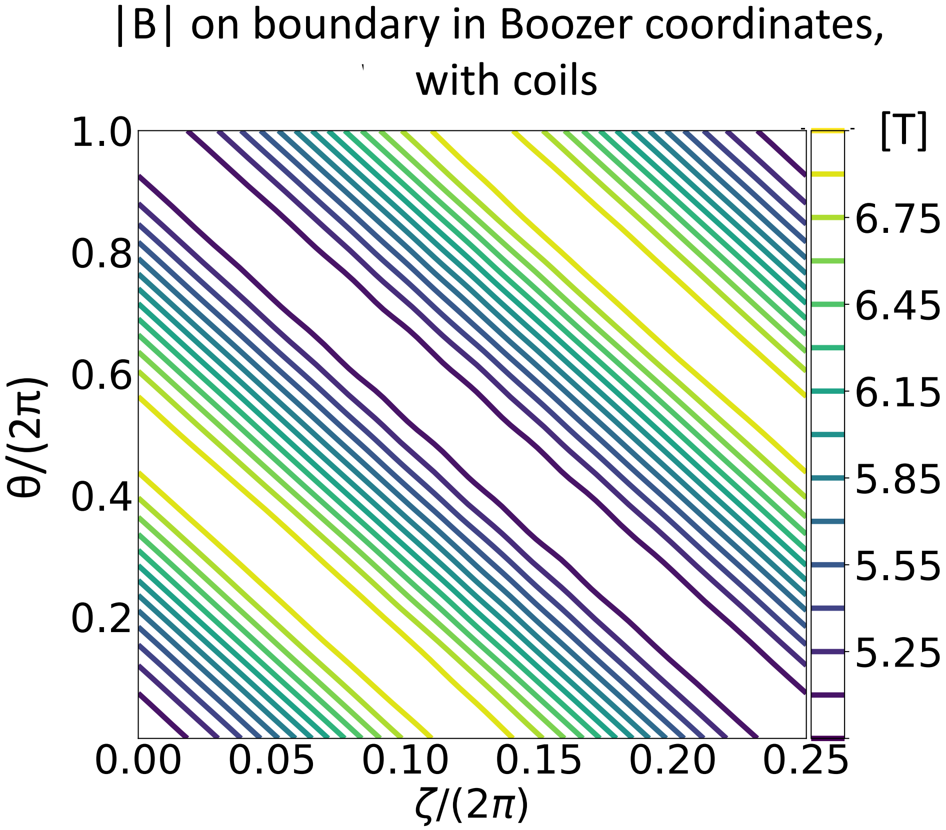
$$f = \underbrace{\int_{plasma\ surf} (\boldsymbol{B} \cdot \boldsymbol{n})^2}_{\text{Match target B}} + \underbrace{\int_{voxels} \lambda \|\boldsymbol{J}\|_2^2 + \eta \|\boldsymbol{J}\|_0}_{\text{Regularization}}$$

Precise quasi-helical symmetry can be produced with coils

Alex Wiedman & Stefan Buller, arXiv:2311.16386





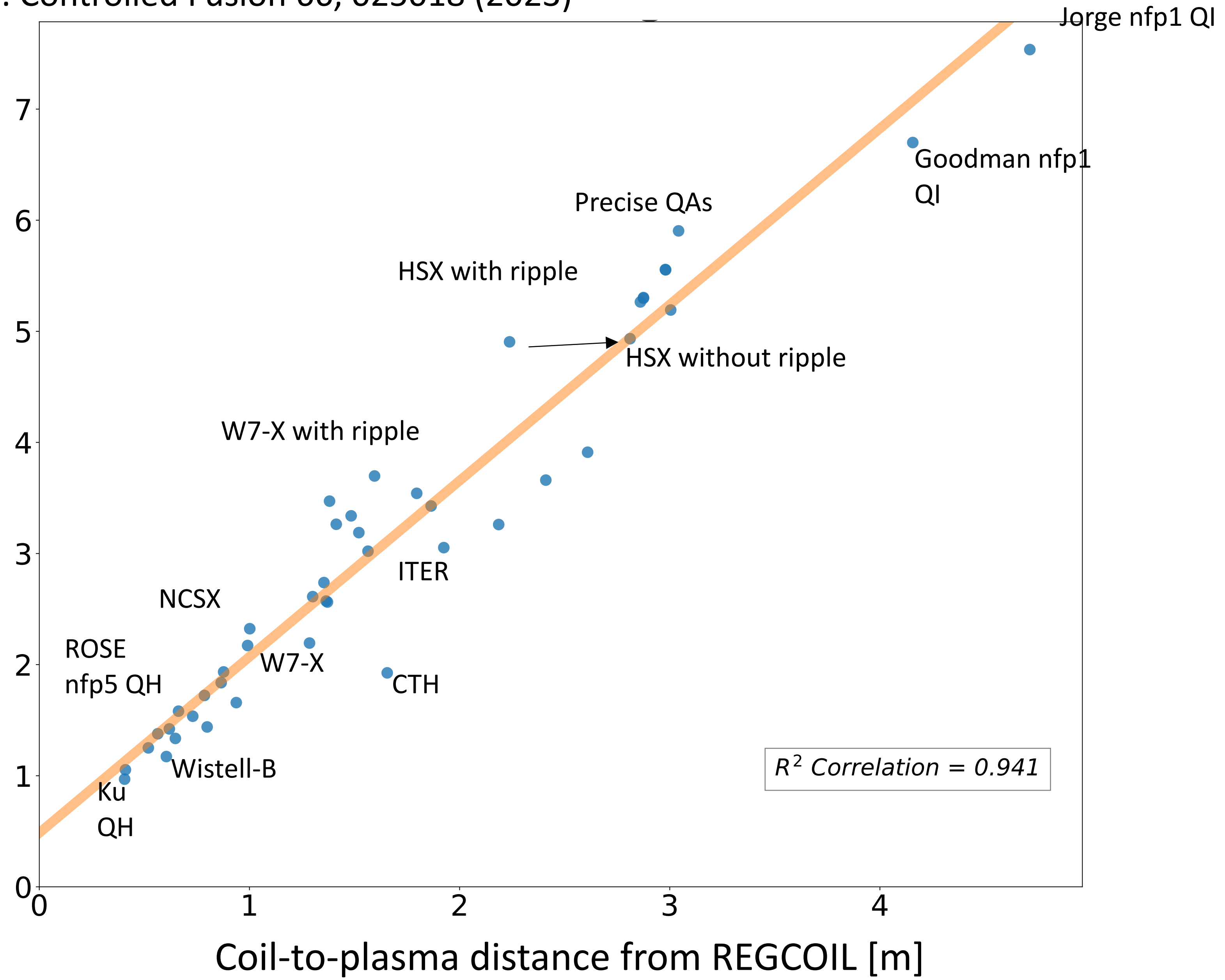


The maximum coil-to-plasma distance is the minimum scale length in B

John Kappel, Plasma Phys. Controlled Fusion 66, 025018 (2023)

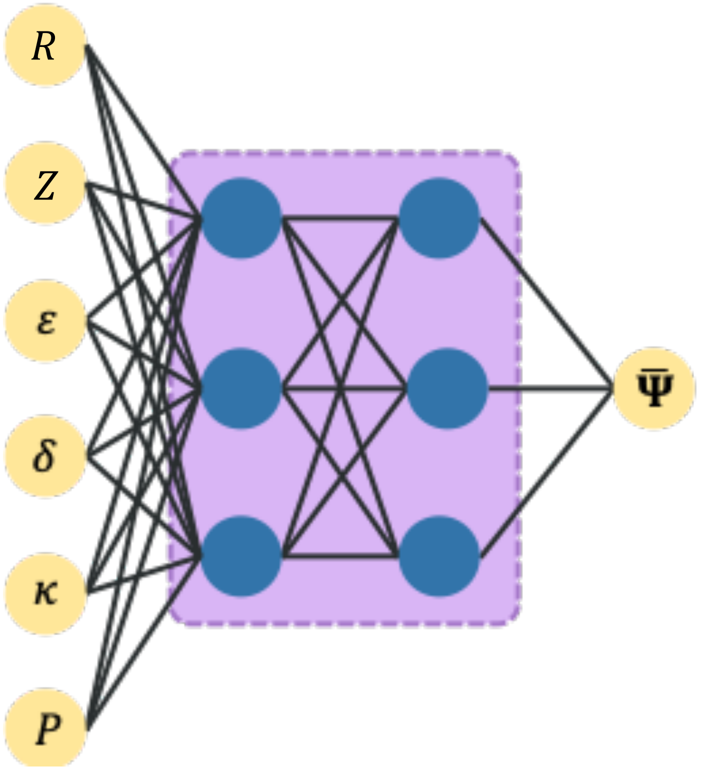
B scale length

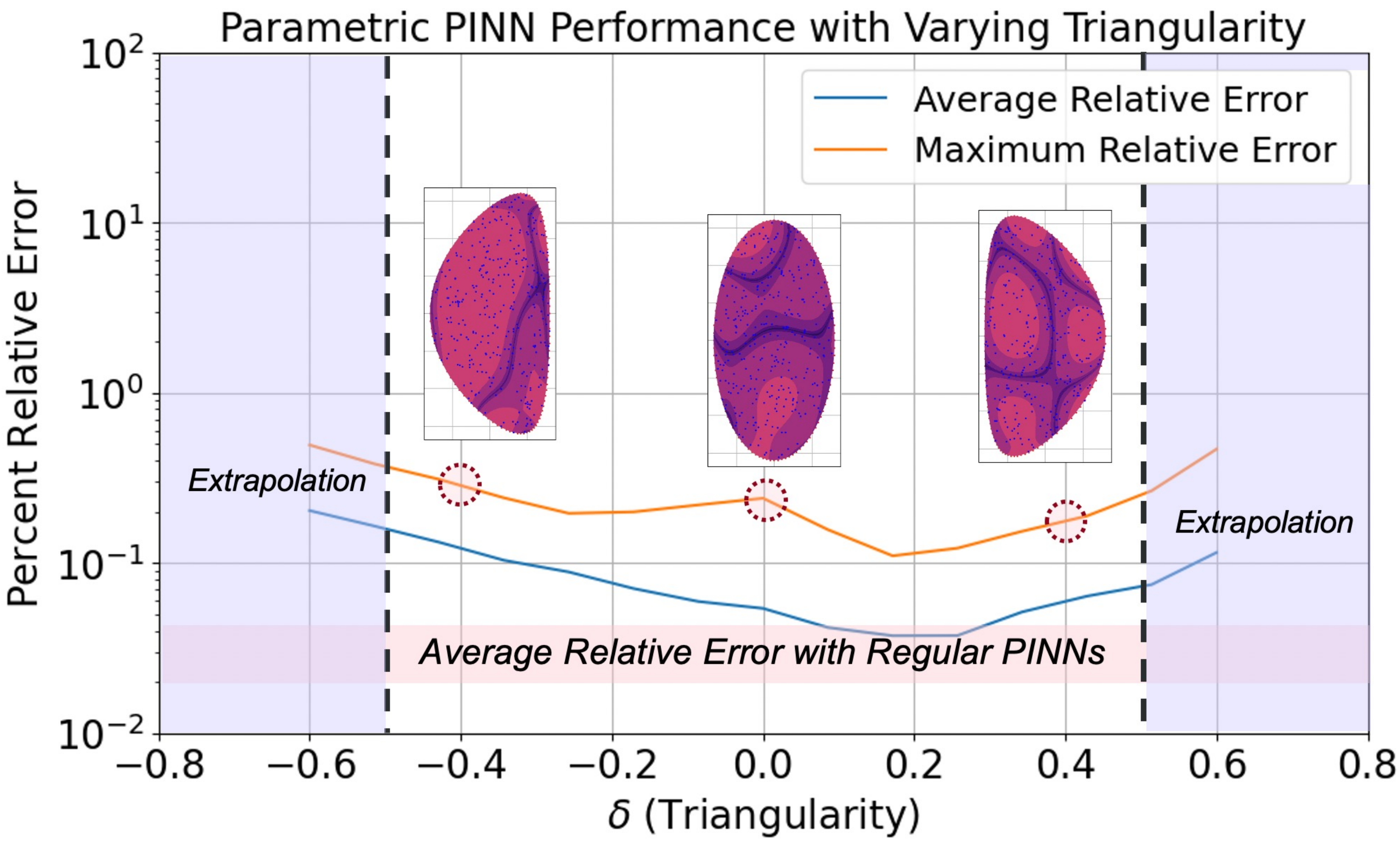
$$\min \frac{\sqrt{2}B}{\|\nabla \boldsymbol{B}\|_F} = L_{\nabla \boldsymbol{B}} \text{ [m]}$$



Physics-informed neural networks for MHD equilibrium

Byoungchan Jang, Alan Kaptanoglu, et al, arXiv:2311.13491 (2023), to appear in Physics of Plasmas.





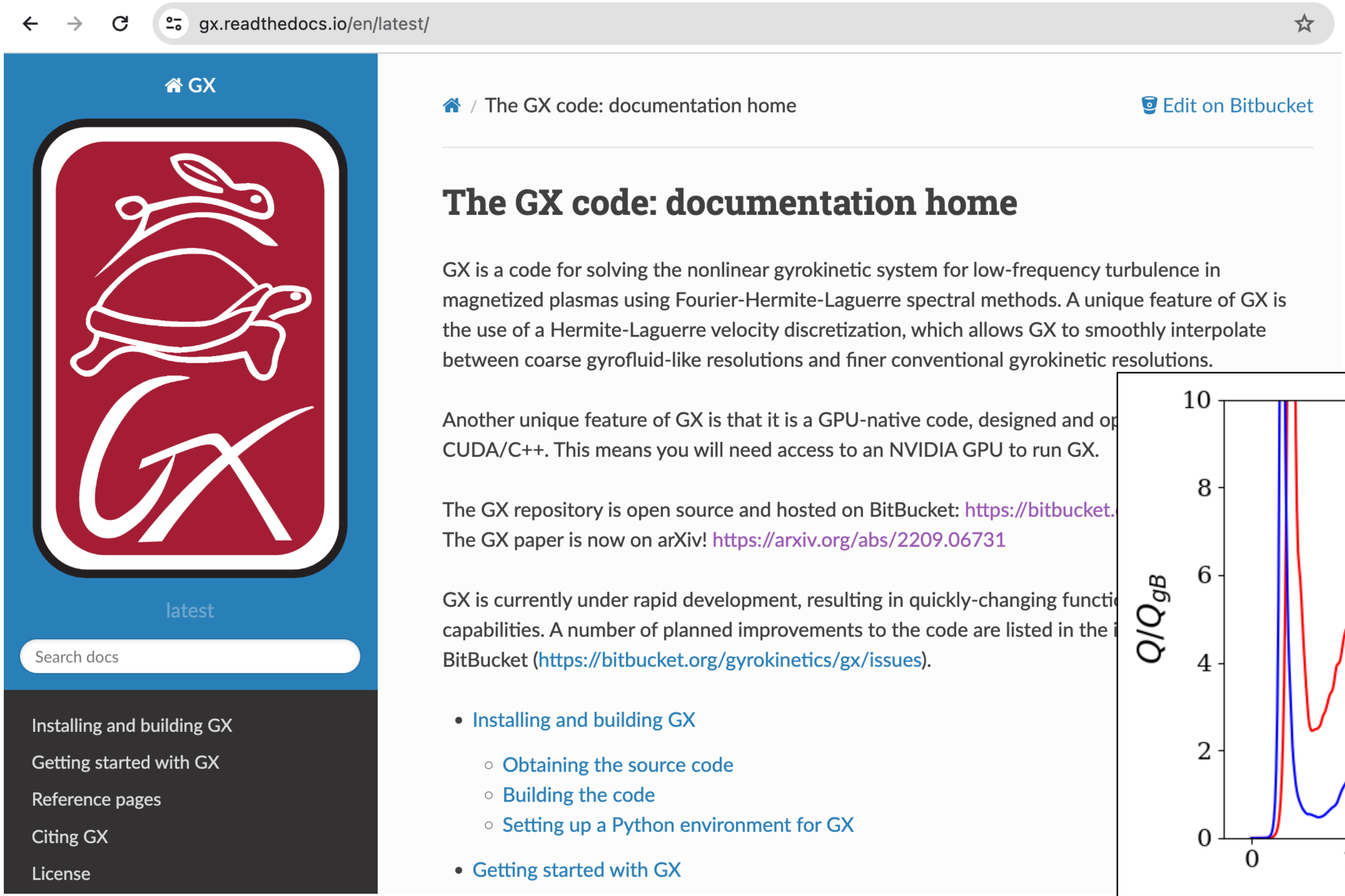
Gyrokinetic modeling & optimization for stellarators with GX, Trinity3D

See Noah Mandell talk on Wednesday – with Bill Dorland, Patrick Kim, et al

Mandell et al, arXiv:2209.06731,

Kim et al, arXiv:2310.18842,

To appear in J. Plasma Physics


gx.readthedocs.io/en/latest/

GX

latest

Search docs

- Installing and building GX
- Getting started with GX
- Reference pages
- Citing GX
- License

The GX code: documentation home — Edit on Bitbucket

The GX code: documentation home

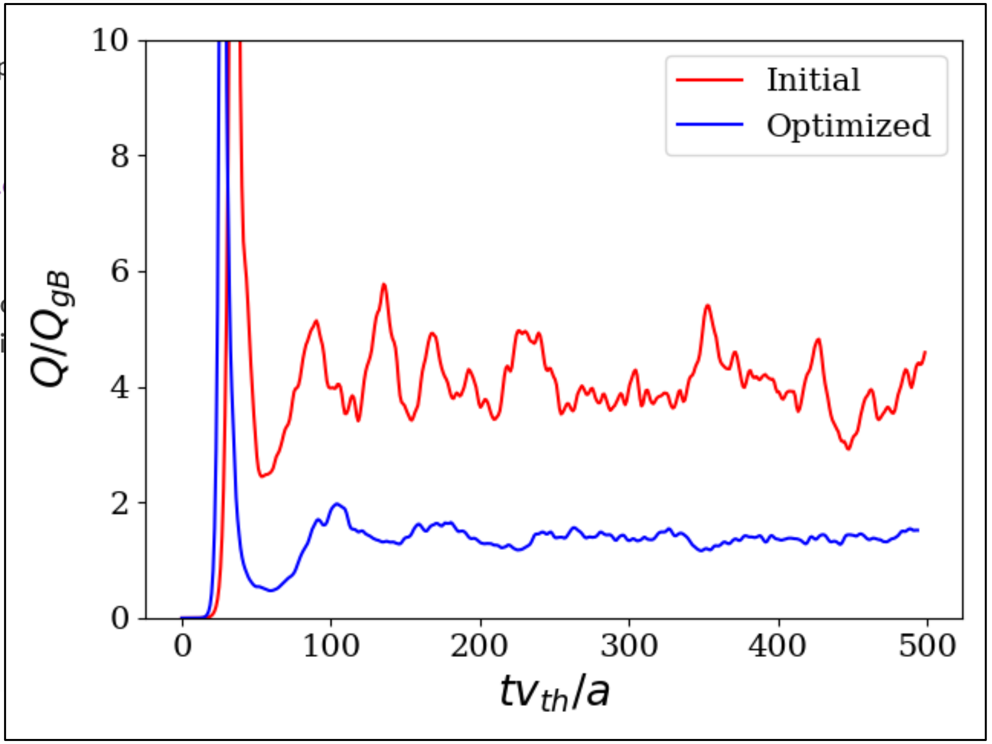
GX is a code for solving the nonlinear gyrokinetic system for low-frequency turbulence in magnetized plasmas using Fourier-Hermite-Laguerre spectral methods. A unique feature of GX is the use of a Hermite-Laguerre velocity discretization, which allows GX to smoothly interpolate between coarse gyrofluid-like resolutions and finer conventional gyrokinetic resolutions.

Another unique feature of GX is that it is a GPU-native code, designed and op
CUDA/C++. This means you will need access to an NVIDIA GPU to run GX.

The GX repository is open source and hosted on BitBucket: https://bitbucket.
The GX paper is now on arXiv! https://arxiv.org/abs/2209.06731

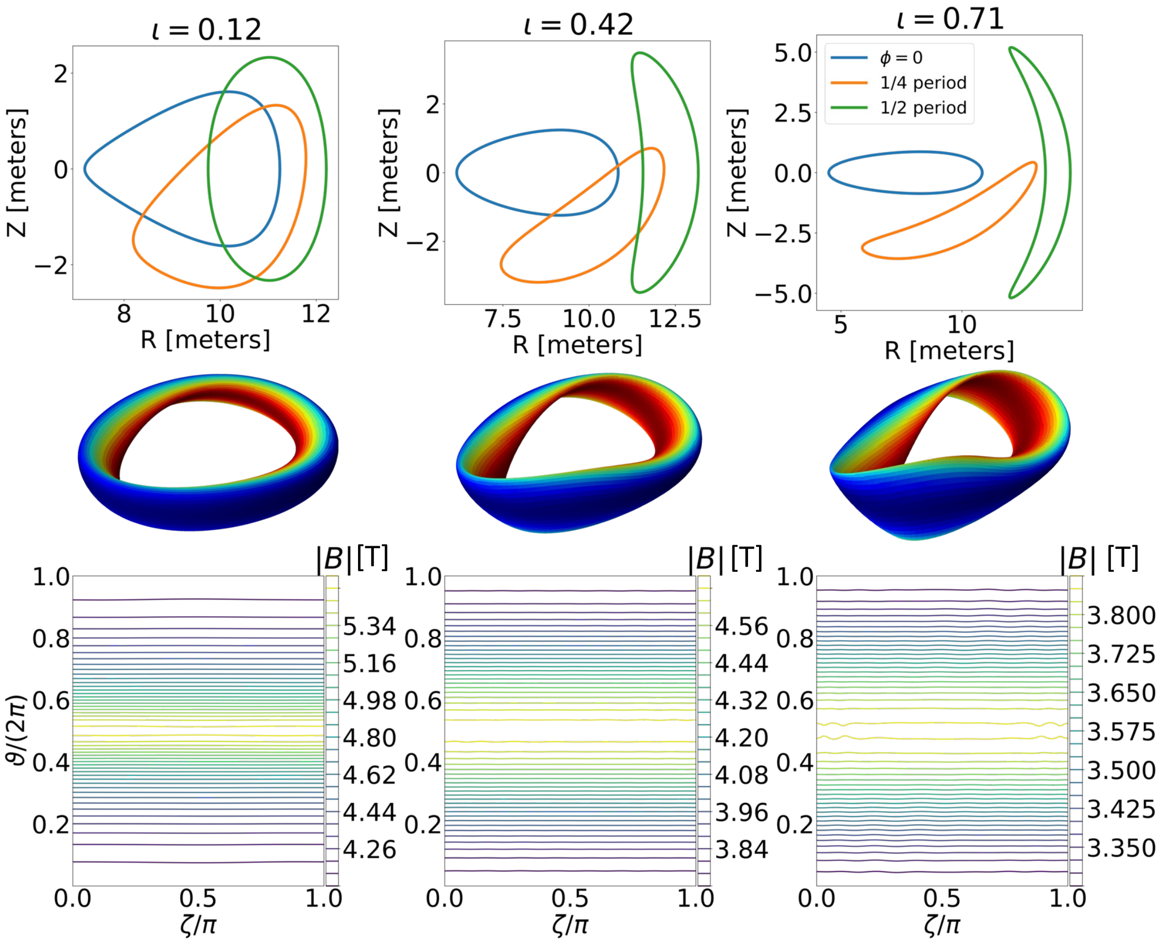
GX is currently under rapid development, resulting in quickly-changing functi
capabilities. A number of planned improvements to the code are listed in the i
BitBucket (https://bitbucket.org/gyrokinetics/gx/issues).

- Installing and building GX
  - Obtaining the source code
  - Building the code
  - Setting up a Python environment for GX
- Getting started with GX

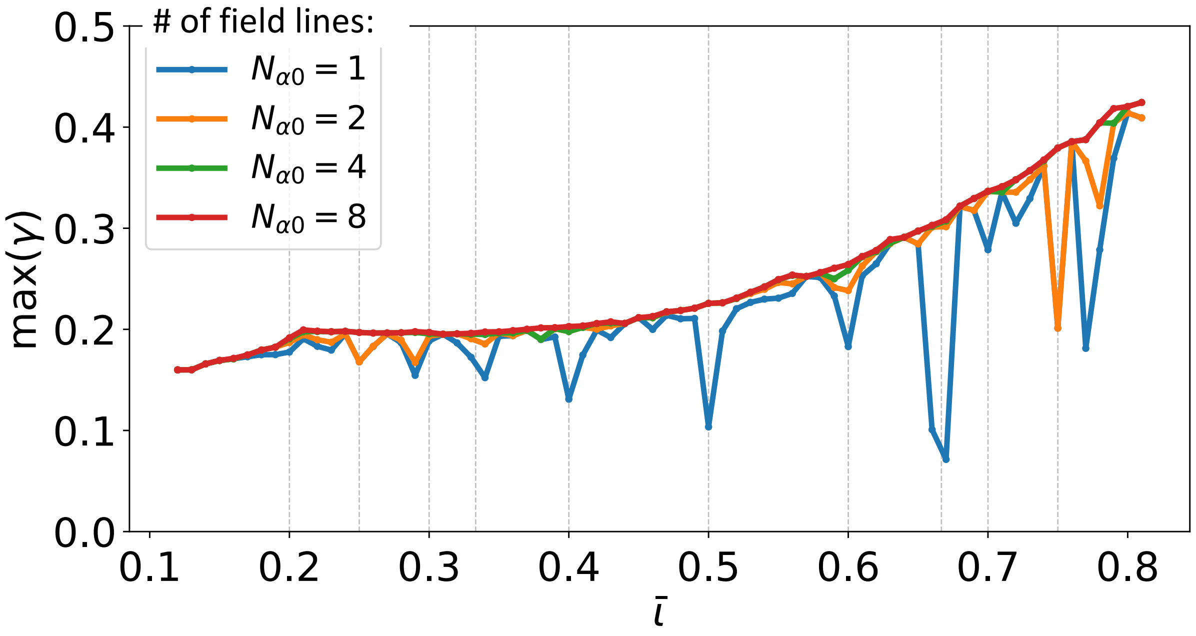


Trends with iota and shear in quasi-axisymmetric stellarators

Stefan Buller et al, arXiv:2401.09021 (2024)



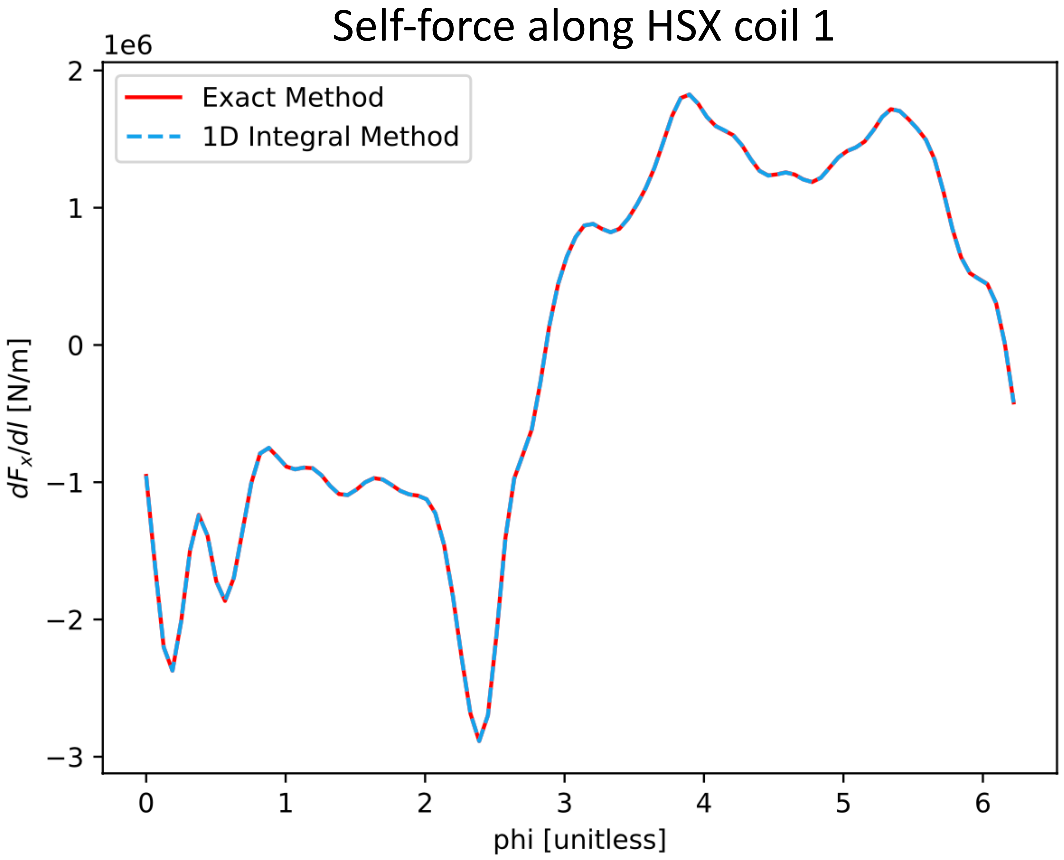
ITG growth rate dips at rational ι unless you include multiple field lines per surface

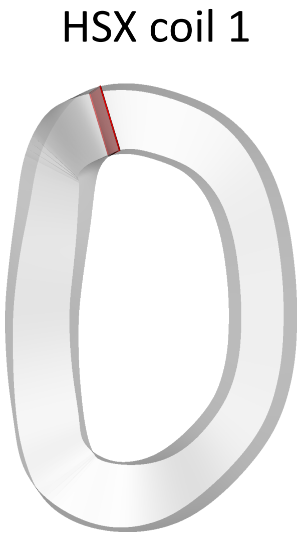


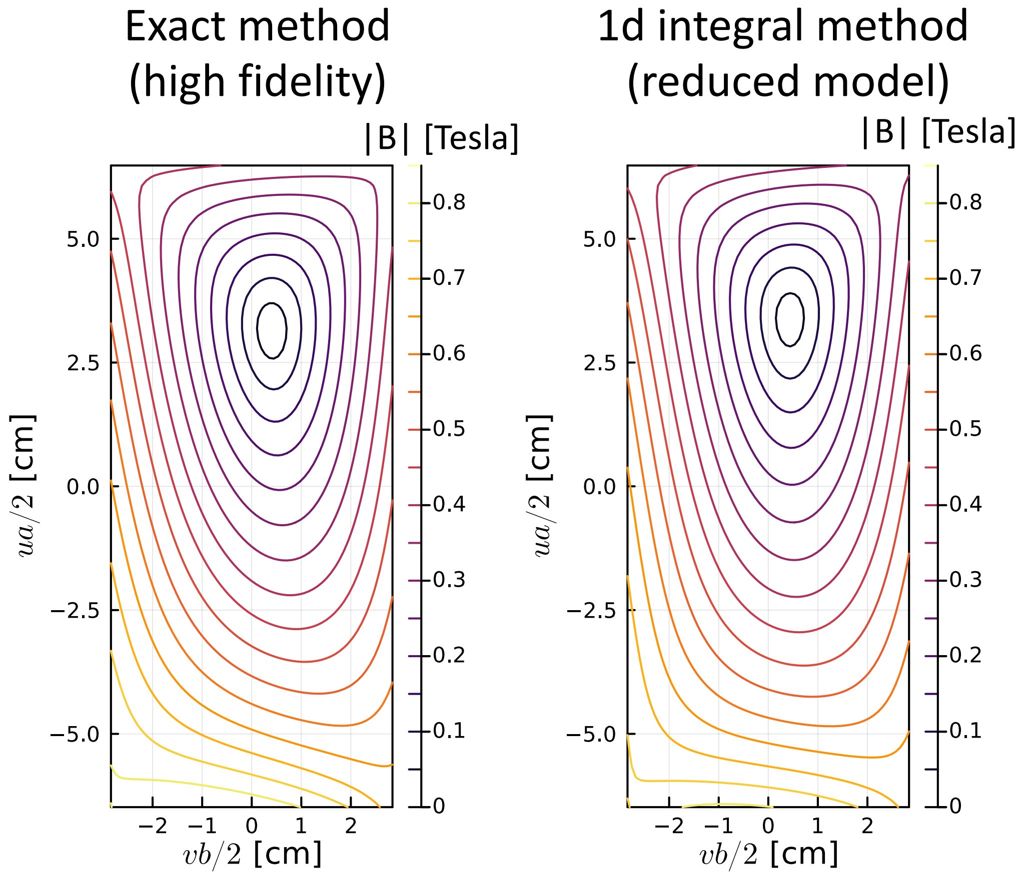
Efficient & accurate calculation of coil self-fields and self-forces

Siena Hurwitz, Tom Antonsen, arXiv:2310.09313, arXiv:2310.12087 (2023)

$$\mathbf{B}_{reg}(\mathbf{r}) = \frac{\mu_0 I}{4\pi} \int \frac{d\tilde{\mathbf{r}} \times (\mathbf{r} - \tilde{\mathbf{r}})}{\left(|\mathbf{r} - \tilde{\mathbf{r}}|^2 + \Delta\right)^{3/2}}$$







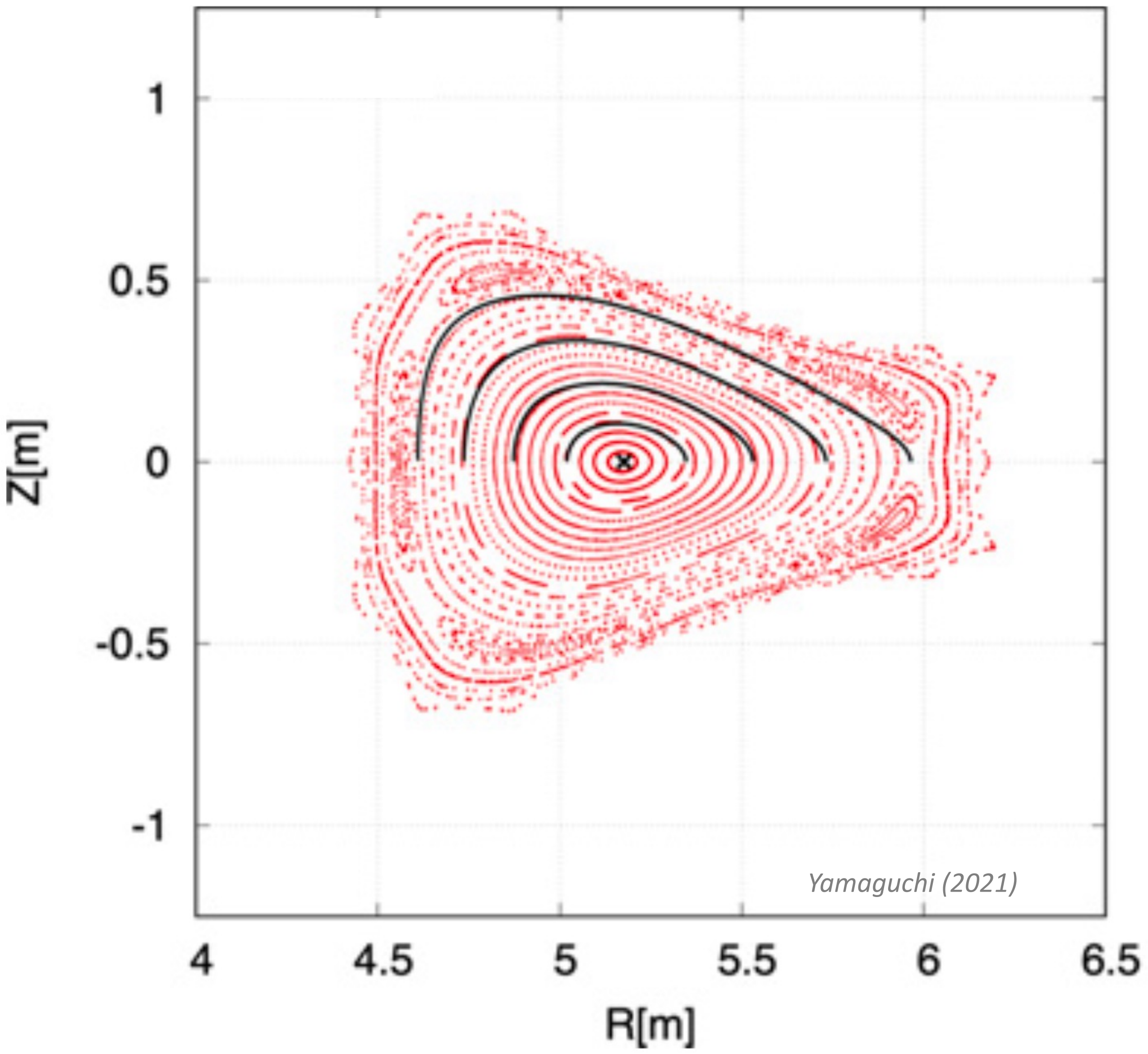
Questions for the Hidden Symmetries group

Research questions for the Hidden Symmetries group

PDEs & MHD

- Can anything be proved about 3D solutions of $\min \int d^3x \, \|\boldsymbol{J}\times\boldsymbol{B} - \nabla p\|^2$, subject to good surfaces existing? $\min \int d^3x \left(\|\boldsymbol{J}\times\boldsymbol{B} - \nabla p\|^2 + \lambda J_{||}^2\right)$? $\min \int d^3x \, \|\nabla\times\boldsymbol{B}\|^2$?

- Instead of MHS, is there a regularized PDE of the form $\boldsymbol{J}\times\boldsymbol{B} = \nabla p + \epsilon$ that is analytically free of singularities and convenient numerically?

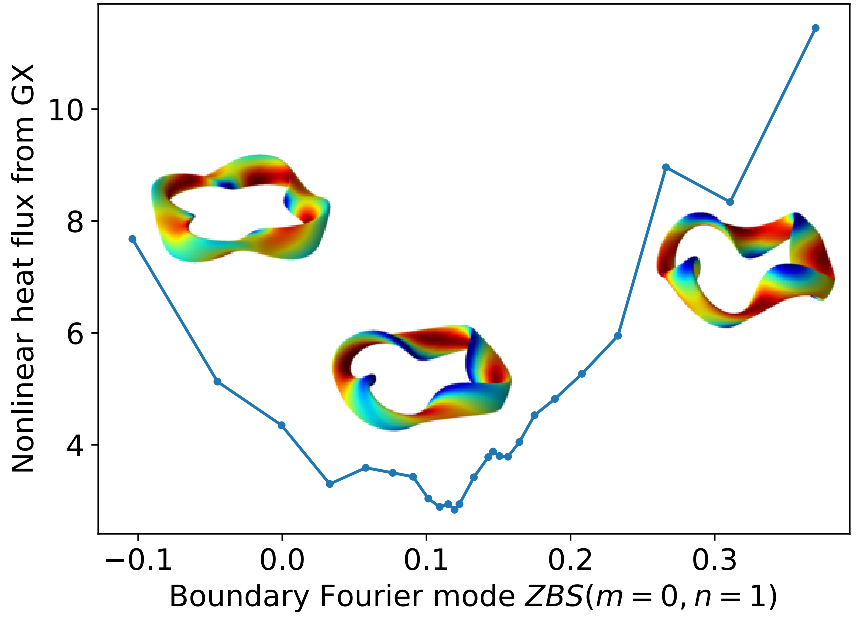


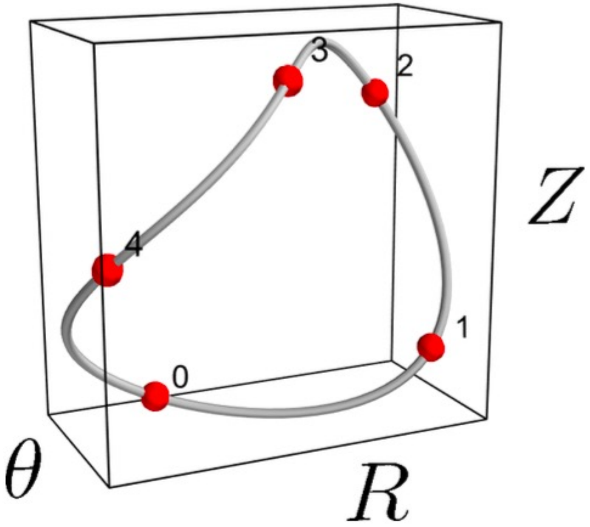
Yamaguchi (2021)

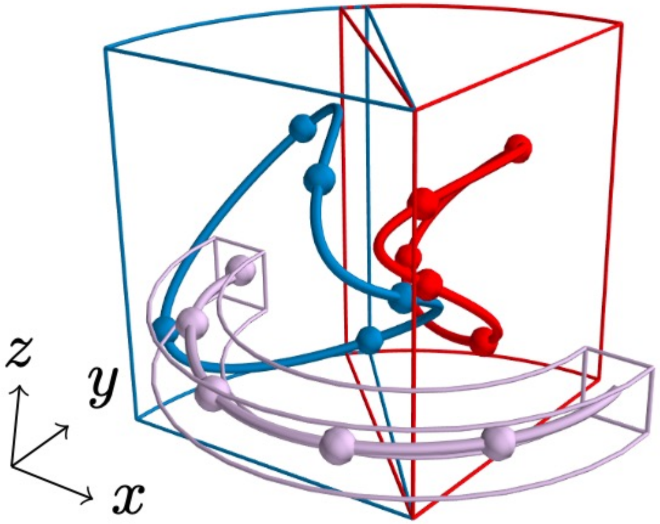
Research questions for the Hidden Symmetries group

Optimization

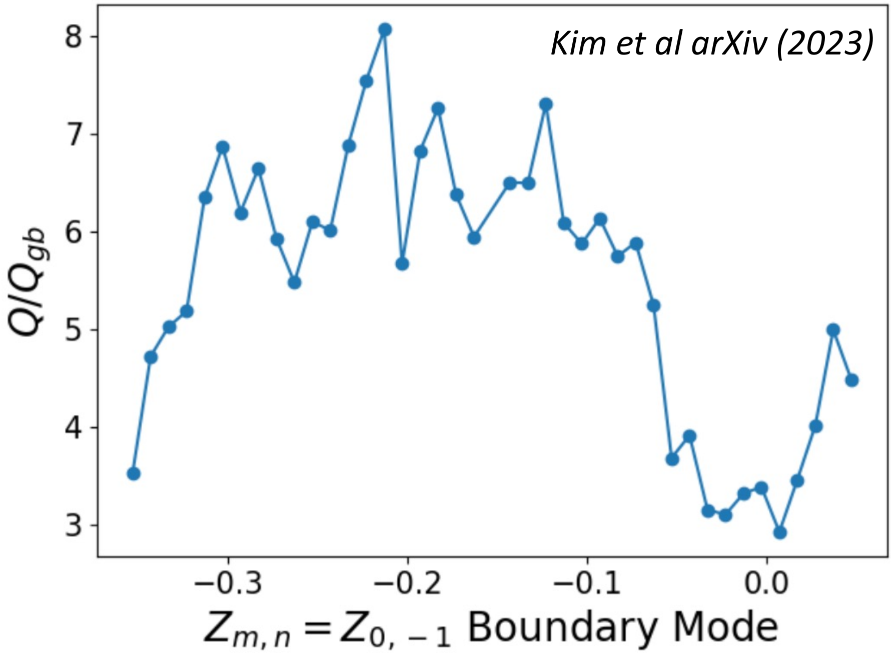
- For expensive & non-smooth objectives (turbulence, directly following orbit losses), what are efficient algorithms for finding surrogates and optimizing?
- What are effective ways to do *global* optimization for curve & surface shapes?







Giuliani arXiv (2023)



Kim et al arXiv (2023)

Research questions for the Hidden Symmetries group

Dynamics & Divertors

- Field structures relevant to a divertor: periodic field lines, residues, separatrices, (un)stable manifolds / tangles, turnstiles, cantori, $|\nabla\psi|$, others?
- How can these structures be controlled to tune connection length, make divertor more closed, & robust to perturbations?
- Can we formulate cost functions like $\int_{surf}(\boldsymbol{B}\cdot\boldsymbol{n})^2$ or residues to control the field outside the closed surfaces in a useful way?