First Optimization Results with lasso

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Julia for stellarator optmization

Optimizer

- lasso.jl: currently uses Optim.jl

Geometry Interface

- PlasmaEquilibriumToolkit.jl: abstractions, coordinate transformations
- VMEC.jl
- NE3DLE.jl (near future)

Physics Analysis

- GammaC.jl
- Quasisymmetry and VMEC submodules
- PlasmaTurbulenceSaturationModel.jl
- Cobra.jl (near future w/ Bindel group from Cornell)

Visualization

- PlasmaViz.jl: nascent collection of visualization routines using Makie.jl (special thanks to Gavin Held)

Available Optimizers with Optim.jl

Gradient based

- BFGS
- L-BFGS $\Rightarrow$ used here
- Conjugate Gradient
- Gradient Descent
- N-GMRES
- O-ACCEL

Gradient-free

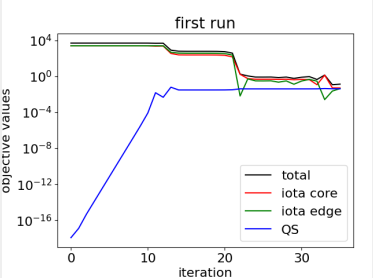
- Nelder-Mead
- Particle Swarm
- Simulated annealing

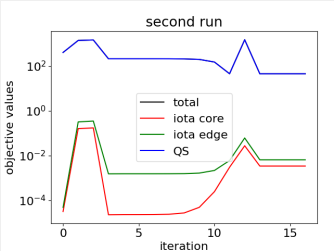
Varying QS and iota weights

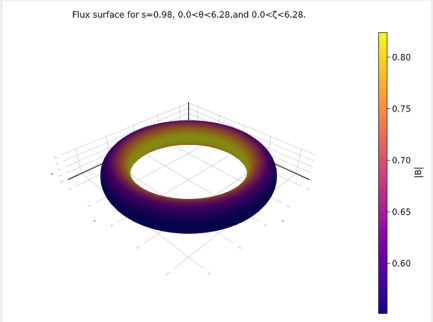
Targets: $\iota(0.3) = \iota(0.7) = 0.5$, $qs(0.5) = 0$

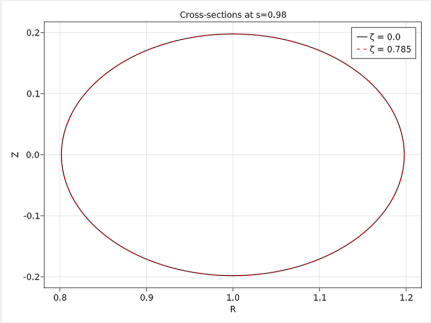
Method: Least-squares: $F = \sum_{\iota_i} \frac{(\iota_i - 0.5)^2}{\sigma_\iota^2} + \frac{qs(0.5)^2}{\sigma_{qs}^2}$

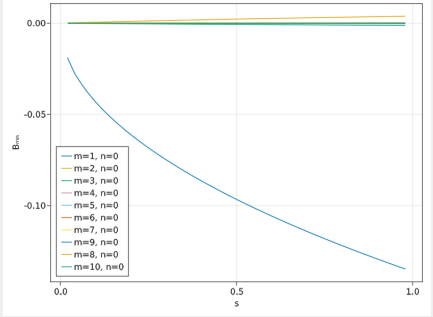
1. Allow $N = (-2, 2)$, $M = (0, 2)$ to vary, set $\sigma_\iota < \sigma_{qs}$
2. Allow $M = (-3, 3)$, $M = (0, 3)$, decrease σ_{qs} to re-emphasize quasisymmetry

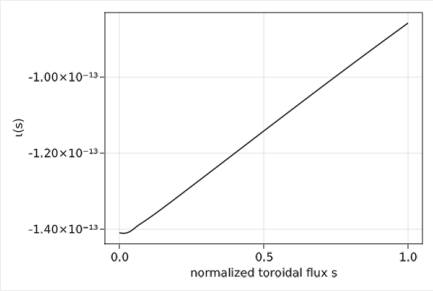


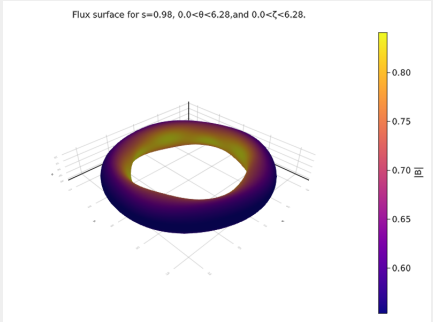


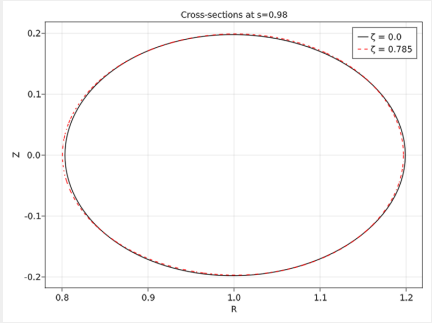

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
0.80
0.75
0.70
0.65
0.60
|B|

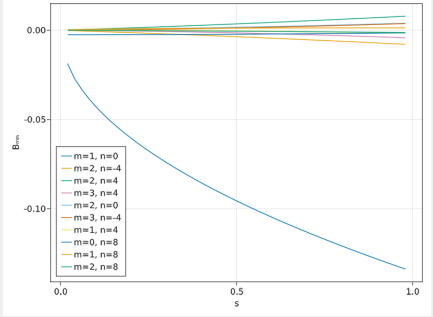

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.1
0.0
-0.1
-0.2
Z
0.8
0.9
1.0
1.1
1.2
R

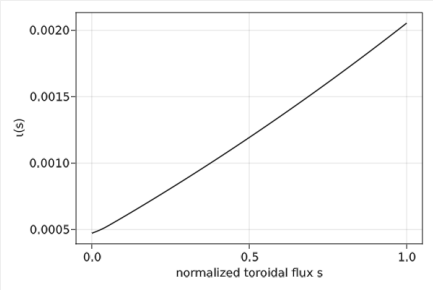

0.00
-0.05
-0.10
B_{mn}
m=1, n=0
m=2, n=0
m=3, n=0
m=4, n=0
m=5, n=0
m=6, n=0
m=7, n=0
m=9, n=0
m=8, n=0
m=10, n=0
0.0
0.5
1.0
s

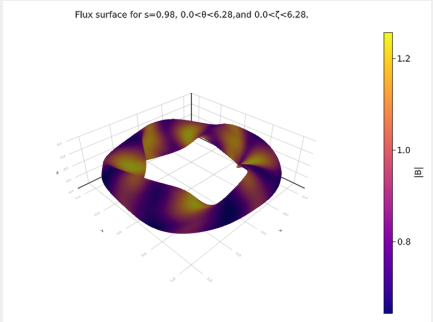

-1.00×10^{-13}
-1.20×10^{-13}
-1.40×10^{-13}
ι(s)
0.0
0.5
1.0
normalized toroidal flux s

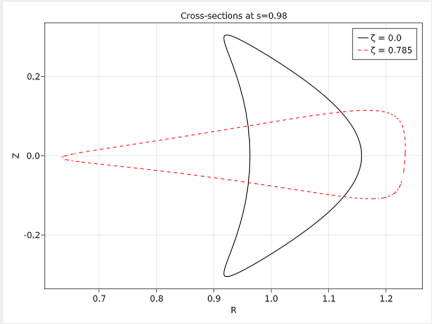

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
0.80
0.75
0.70
0.65
0.60
|B|

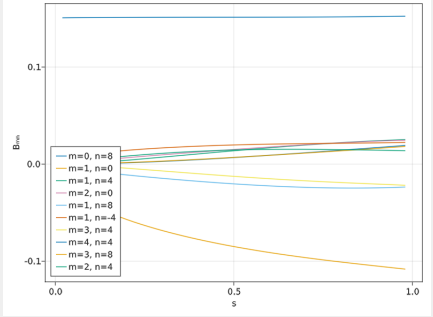

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.1
0.0
-0.1
-0.2
Z
0.8
0.9
1.0
1.1
1.2
R

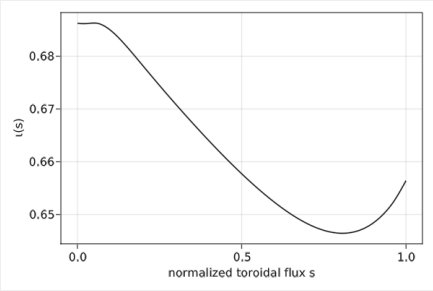

0.00
-0.05
-0.10
B_{mn}
m=1, n=0
m=2, n=-4
m=2, n=4
m=3, n=4
m=2, n=0
m=3, n=-4
m=1, n=4
m=0, n=8
m=1, n=8
m=2, n=8
0.0
0.5
1.0
s

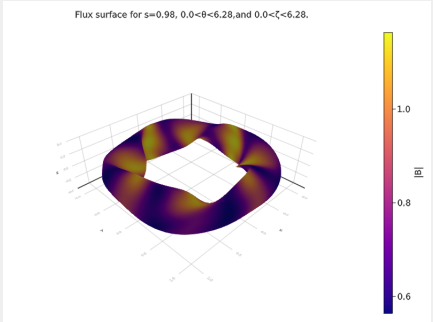

0.0020
0.0015
0.0010
0.0005
ι(s)
0.0
0.5
1.0
normalized toroidal flux s

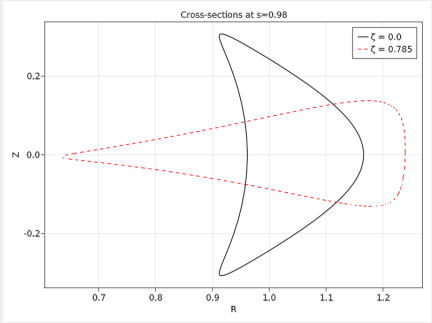

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
1.2
1.0
0.8
|B|

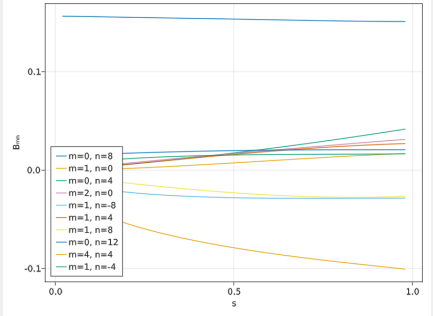

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.0
-0.2
Z
0.7
0.8
0.9
1.0
1.1
1.2
R

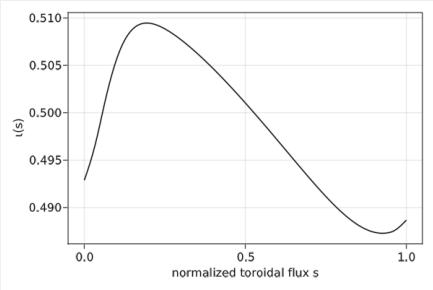

0.1
0.0
-0.1
B_{mn}
m=0, n=8
m=1, n=0
m=1, n=4
m=2, n=0
m=1, n=8
m=1, n=-4
m=3, n=4
m=4, n=4
m=3, n=8
m=2, n=4
0.0
0.5
1.0
s

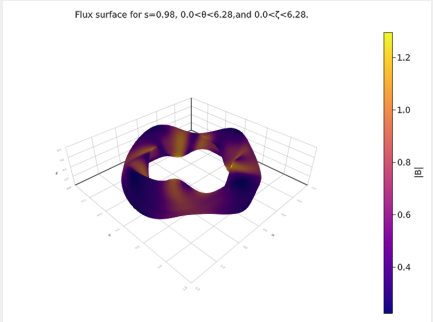

0.68
0.67
0.66
0.65
ι(s)
0.0
0.5
1.0
normalized toroidal flux s

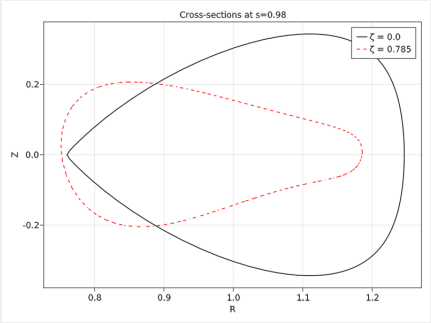

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
|B|
1.0
0.8
0.6

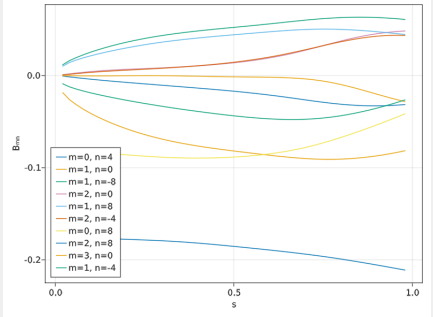

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
Z
R
0.2
0.0
-0.2
0.7
0.8
0.9
1.0
1.1
1.2

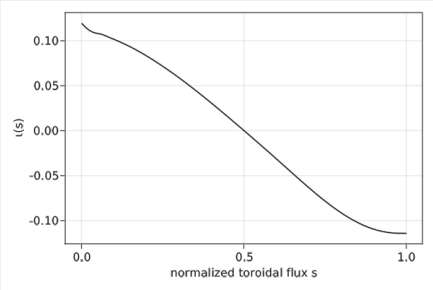

B_{mn}
s
0.1
0.0
-0.1
0.0
0.5
1.0
m=0, n=8
m=1, n=0
m=0, n=4
m=2, n=0
m=1, n=-8
m=1, n=4
m=1, n=8
m=0, n=12
m=4, n=4
m=1, n=-4

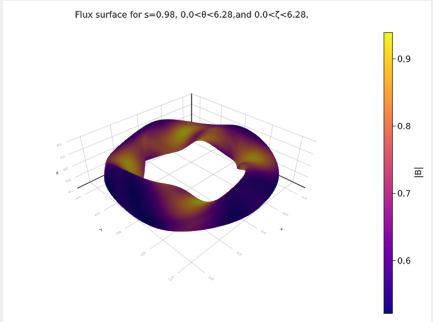

ι(s)
normalized toroidal flux s
0.510
0.505
0.500
0.495
0.490
0.0
0.5
1.0

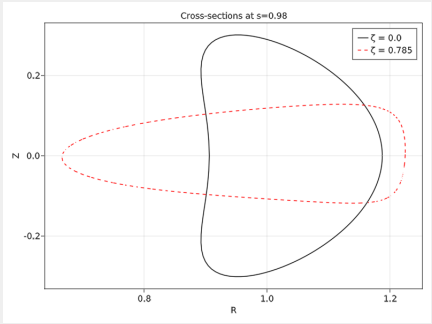

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
|B|
1.2
1.0
0.8
0.6
0.4

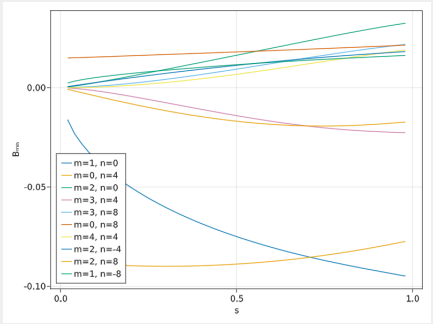

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
Z
R
0.2
0.0
-0.2
0.8
0.9
1.0
1.1
1.2

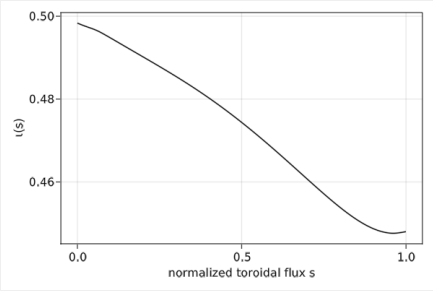

B_{mn}
s
0.0
-0.1
-0.2
0.5
1.0
m=0, n=4
m=1, n=0
m=1, n=-8
m=2, n=0
m=1, n=8
m=2, n=-4
m=0, n=8
m=2, n=8
m=3, n=0
m=1, n=-4

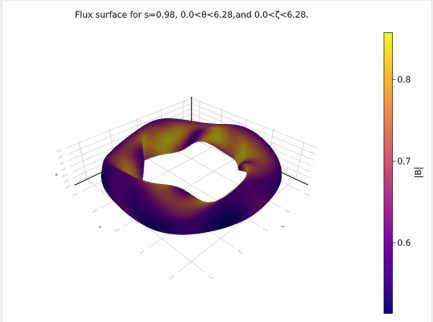

ι(s)
normalized toroidal flux s
0.10
0.05
0.00
-0.05
-0.10
0.0
0.5
1.0

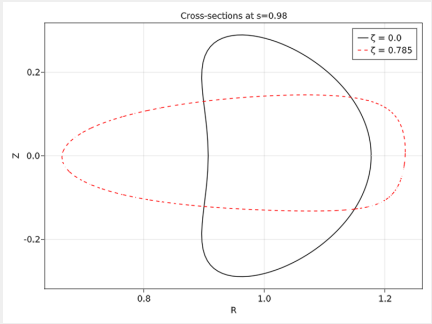

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
|B|
0.9
0.8
0.7
0.6

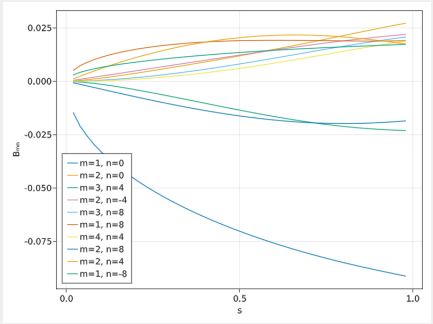

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
Z
R
0.2
0.0
-0.2
0.8
1.0
1.2

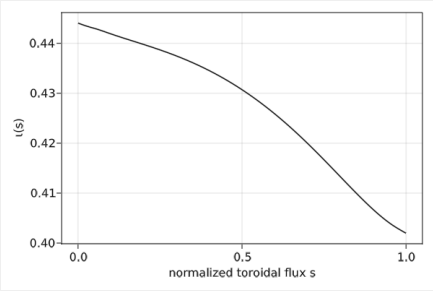

B_{mn}
s
0.00
-0.05
-0.10
0.0
0.5
1.0
m=1, n=0
m=0, n=4
m=2, n=0
m=3, n=4
m=3, n=8
m=0, n=8
m=4, n=4
m=2, n=-4
m=2, n=8
m=1, n=-8


ι(s)
normalized toroidal flux s
0.50
0.48
0.46
0.0
0.5
1.0


Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
0.8
0.7
0.6
|B|


Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.0
-0.2
Z
0.8
1.0
1.2
R


0.025
0.000
-0.025
-0.050
-0.075
B_{mn}
m=1, n=0
m=2, n=0
m=3, n=4
m=2, n=-4
m=3, n=8
m=1, n=8
m=4, n=4
m=2, n=8
m=2, n=4
m=1, n=-8
0.0
0.5
1.0
s

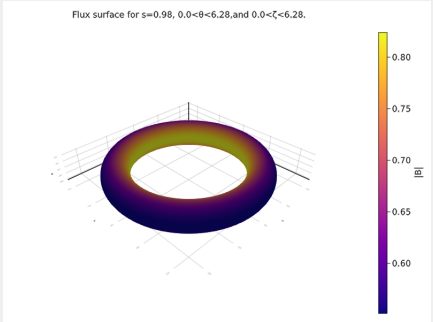

0.44
0.43
0.42
0.41
0.40
ι(s)
0.0
0.5
1.0
normalized toroidal flux s

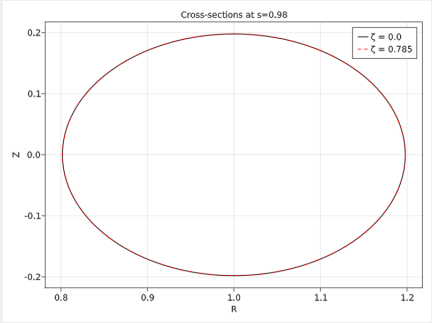
Commensurate QS and iota weights

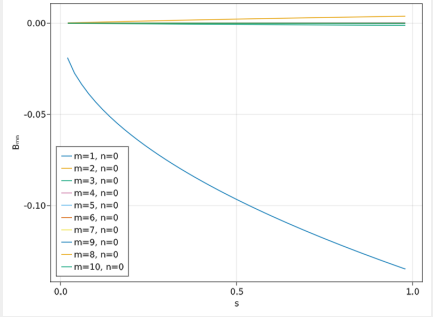
Targets: $\iota(0.1) = \iota(0.3) = \iota(0.5) = \iota(0.7) = 0.5$, $qs(0.5) = 0$

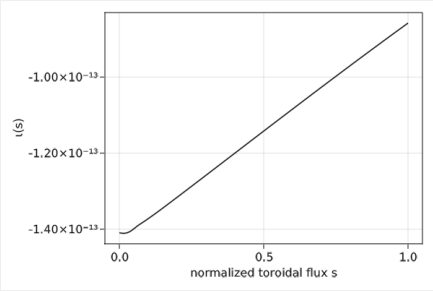
Method: Least-squares: $F = \sum_{\iota_i} \frac{(\iota_i - 0.5)^2}{\sigma_\iota^2} + \frac{qs(0.5)^2}{\sigma_{qs}^2}$

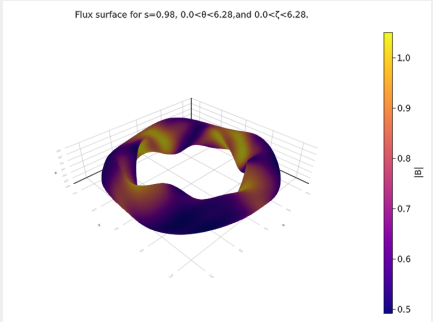
1. Allow $N = (-3, 3)$, $M = (0, 3)$ to vary, set $\sigma_\iota = \sigma_{qs} = 1$
2. Decrease $\sigma_\iota \to \sigma_\iota = 0.1 * \sigma_{qs}$ to slightly emphasis ι
3. Decrease σ_{qs} to re-emphasize quasisymmetry
4. Allow $M = (-4, 4)$, $M = (0, 4)$ to vary for more freedom

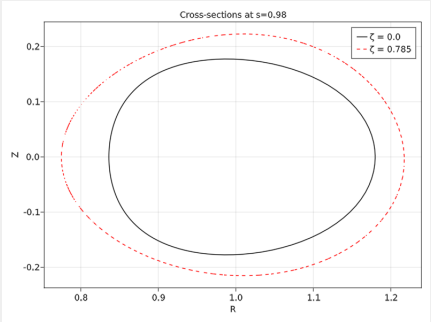

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
0.80
0.75
0.70
0.65
0.60
|B|

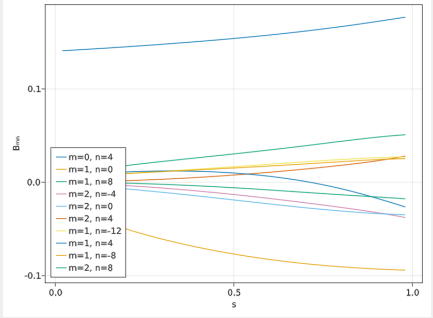

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.1
0.0
-0.1
-0.2
Z
0.8
0.9
1.0
1.1
1.2
R

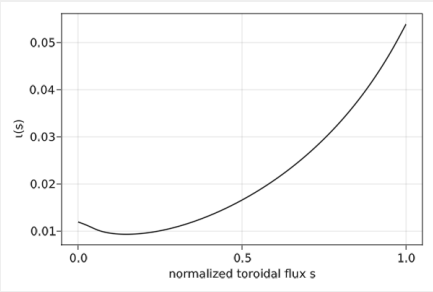

0.00
-0.05
-0.10
B_{mn}
m=1, n=0
m=2, n=0
m=3, n=0
m=4, n=0
m=5, n=0
m=6, n=0
m=7, n=0
m=9, n=0
m=8, n=0
m=10, n=0
0.0
0.5
1.0
s

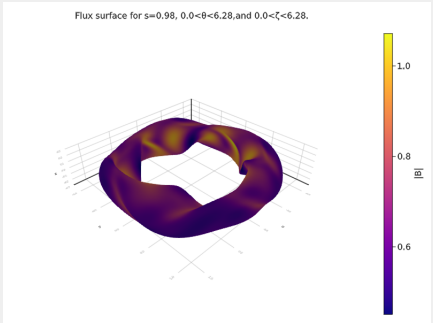

-1.00×10⁻¹³
-1.20×10⁻¹³
-1.40×10⁻¹³
ι(s)
0.0
0.5
1.0
normalized toroidal flux s

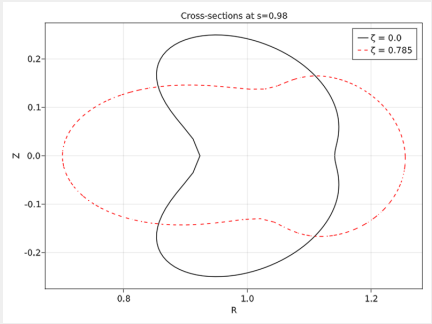

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
|B|
1.0
0.9
0.8
0.7
0.6
0.5

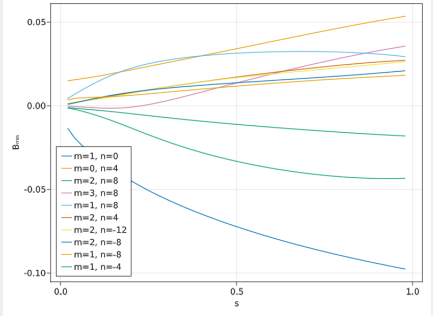

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
Z
R
0.2
0.1
0.0
-0.1
-0.2
0.8
0.9
1.0
1.1
1.2

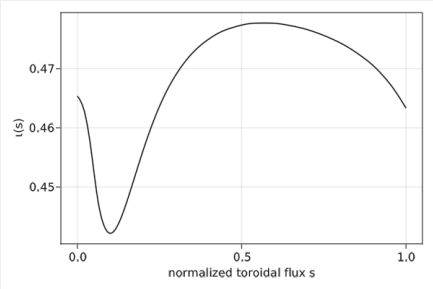

B_{mn}
m=0, n=4
m=1, n=0
m=1, n=8
m=2, n=-4
m=2, n=0
m=2, n=4
m=1, n=-12
m=1, n=4
m=1, n=-8
m=2, n=8
0.1
0.0
-0.1
0.0
0.5
1.0
s

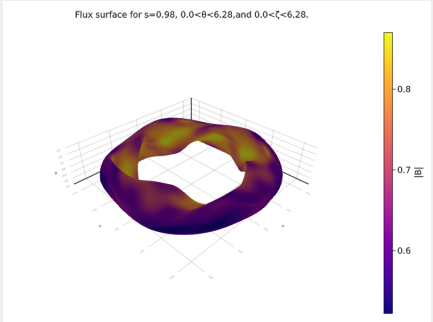

ι(s)
0.05
0.04
0.03
0.02
0.01
0.0
0.5
1.0
normalized toroidal flux s

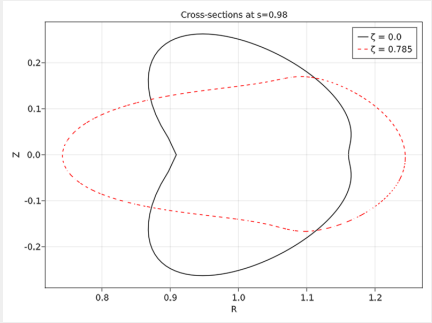

Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
1.0
0.8
0.6
|B|

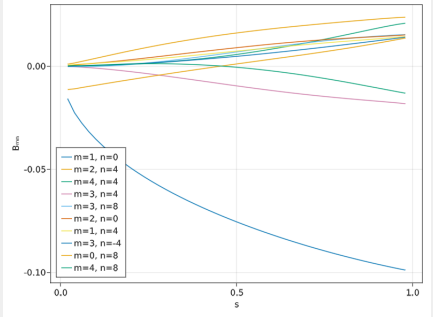

Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.1
0.0
-0.1
-0.2
Z
0.8
1.0
1.2
R

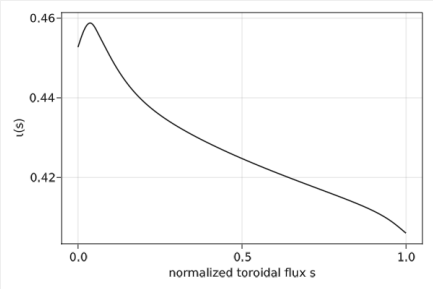

0.05
0.00
-0.05
-0.10
B_{mn}
m=1, n=0
m=0, n=4
m=2, n=8
m=3, n=8
m=1, n=8
m=2, n=4
m=2, n=-12
m=2, n=-8
m=1, n=-8
m=1, n=-4
0.0
0.5
1.0
s


0.47
0.46
0.45
ι(s)
0.0
0.5
1.0
normalized toroidal flux s


Flux surface for s=0.98, 0.0<θ<6.28,and 0.0<ζ<6.28.
0.8
0.7
0.6
|B|


Cross-sections at s=0.98
ζ = 0.0
ζ = 0.785
0.2
0.1
0.0
-0.1
-0.2
Z
0.8
0.9
1.0
1.1
1.2
R


0.00
-0.05
-0.10
B_{mn}
m=1, n=0
m=2, n=4
m=4, n=4
m=3, n=4
m=3, n=8
m=2, n=0
m=1, n=4
m=3, n=-4
m=0, n=8
m=4, n=8
0.0
0.5
1.0
s


0.46
0.44
0.42
ι(s)
0.0
0.5
1.0
normalized toroidal flux s