Julia stability calculations from CobraVmec

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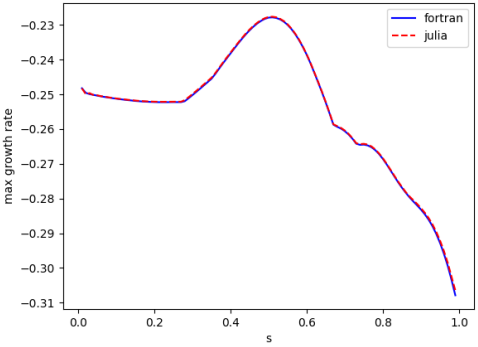
Conversion of CobraVmec into a Julia Ballooning calculation suitable for optimization

- Step 1: convert Fortran to Julia directly (done by S. Patil)
- Step 2: Replace all finite derivatives with spline functions from PlasmaEquilibriumToolkit
- Step 3: Replace Richardson scheme to find eigenvalues with canned Julia eigenvalue solver
  - We are currently here, between Step 3 and 4
- Step 4: Replace ballooning P,Q, and R with direct calculations

CobraVmec i/o

- Inputs
  - Surfaces to calculate quantities on (s in Julia, surface index in fortran)
  - Field lines to consider (given as θ and ζ values)
  - Distance along field line to travel (given as number of wells)
- Output
  - Maximum growth rate for each (s, θ, ζ) point
  - Other diagnostic info

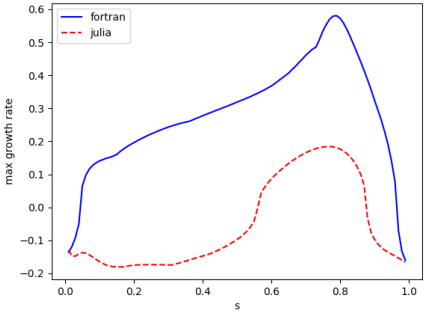
Near exact agreement between CobraVmec and Julia for zero beta case

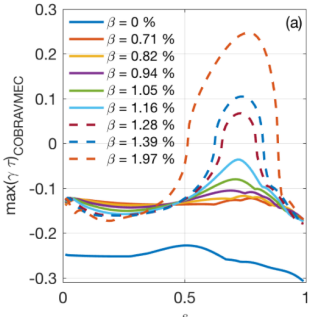


- Calculations are from exact same field lines and follow the exact same distance
- Quantities and derivatives come from spline fits
- Eigenvalue solver is a partial schur decomposition using the ArnoldiMethod package

Bug discovered in CobraVmec hampers further comparisons

- Current version of CobraVmec calculates components of B field assuming same spectral resolution as for spatial components (i.e. `mn = mn_nyq`)
- The bug has been brought to the attention of STELLOPT maintainers and developers





Implementing direct P, Q, R calculation

$$P(\theta) = \frac{1}{\sqrt{g}} \frac{1+\Lambda^2}{|\nabla\psi|^2};\ Q(\theta) = \beta' \sqrt{g} \frac{(\kappa_n + \Lambda\kappa_g)}{|\nabla\psi|};\ R(\theta)\sqrt{g}\frac{1+\Lambda^2}{|\nabla\psi|^2}$$

$$\Lambda = -\frac{|\nabla\psi|^2}{B}\left(\Theta^\alpha + q'\theta_k\right)$$

$$\Theta^\alpha = \frac{\nabla\psi\cdot\nabla\alpha}{\nabla\psi\cdot\nabla\psi};\ \theta_k = \iota' \frac{k_\psi}{k_\alpha}$$

- θ_k selects a given field line, plan to use that as input instead of θ and ζ
- Implementation and matrix construction in process