XGC Linearized E & M fluid electron equations + Poisson solver
4 field fast waves - verification

$$\begin{bmatrix} 0 & 0 & 0 & B_0 \nabla_{\|} \dfrac{1}{eB_0} \\ 0 & 0 & \nabla_{\|} & -\eta = 0 \\ M & 0 & -\dfrac{n_0 m_i}{B^2} \nabla_{\perp}^2 & 0 \\ 0 & -\nabla_{\perp}^2 & 0 & \mu M \end{bmatrix} \begin{bmatrix} n_1 \\ A \\ \phi \\ J \end{bmatrix} + \begin{bmatrix} \dfrac{\partial}{\partial t} n_1 \\ \dfrac{\partial}{\partial t} A \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

New fully implicit MHD PETSc solver

- Hybrid fluid electron version of XGC1: electron MHD
- Simplified fast wave version of equations
- Used to verify: see growth mode (d/dz φ term) while jumping over fast wave (d/dz J term)

$$\begin{bmatrix} \varepsilon & 0 & 0 & B_0\nabla_\parallel \frac{1}{eB_0} \\ 0 & \varepsilon & \nabla_\parallel & -\eta \\ M & 0 & -\frac{n_0 m_i}{B^2}\nabla_\perp^2 & 0 \\ 0 & -\nabla_\perp^2 & 0 & \mu M \end{bmatrix} \begin{bmatrix} n_1 \\ A \\ \phi \\ J \end{bmatrix} + \begin{bmatrix} \frac{\partial}{\partial t} n_1 \\ \frac{\partial}{\partial t} A \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Solver implemented – testing now

- Implemented fully implicit time integrator of reduced equations
  - All terms moved to LHS w/ explicit matrix implementations
- Fast wave demands fully implicit
  - Slow wave terms are complicated but will be done matrix free with XGC1 code and moved to RHS
- Using PETSc's Field split solver: use optimal, scalable and robust, algorithms (eg, Schur complement solver
  - Implemented direct solver for verification
  - And scalable iterative method – it works but we have artificial viscosity
- To do:
  - Verify: see growth mode, reduce artificial viscosity terms (ε) as needed
  - Optimize solvers. Use more complex and robust approximate solvers (eg, Schur complement based) as needed