



Modeling of the Plasma Response to Resonant Magnetic Perturbations with the NIMROD Code

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- Goals: understand response of plasma to external perturbations
- Computational formulation
- Numerical benchmarking

Brief summary of boundary condition work



- Implementation of resistive wall boundary conditions requires matrix-vector multiply:

$$\chi(w) = M(w, w') B_n(w')$$

- This required new infrastructure in NIMROD
- As a way of testing this new infrastructure, been performing simulations of Taylor problem

The experimental reconnection regime is closer to the case of slow “field penetration”



- Intrinsic plasma time scales:**

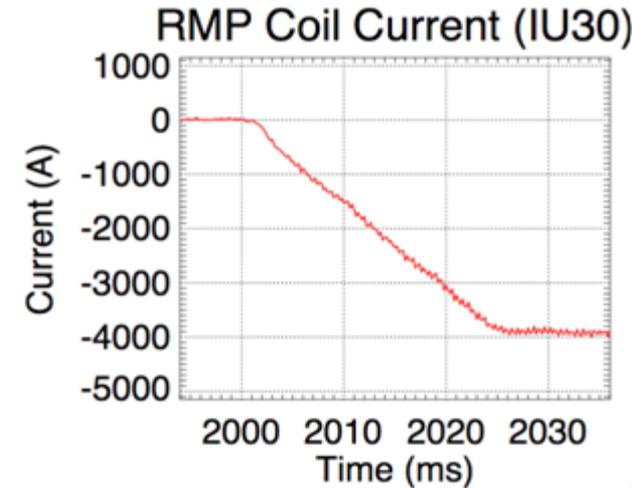
Alfven time: $\tau_A = R/V_A \sim 10^{-8}-10^{-6}$ s

Resistive diffusion: $\tau_R = r^2 \mu_0/\eta_{||} \sim 1-10^2$ s

Viscous diffusion: $\tau_V = r^2 \rho/\eta_0 \sim 10^{-1}-1$ s

Reconnection time: $\tau_{rec} \sim \tau_A^\mu \tau_R^\nu \sim 10^{-3}-10^{-2}$ s
where $1 > \mu, \nu > 0$

Intrinsic ordering $\tau_A \ll \tau_{rec} \ll \tau_V, \tau_R$



- Different reconnection regimes depend on the perturbation speed**

$\tau_{RMP} \sim 20-30$ ms = time scale for application of external perturbation

Forced reconnection: $\tau_{RMP} \ll \tau_{rec}$ e.g., nonlinear ELM reconnection

Field error penetration: $\tau_{rec} < \text{or} \ll \tau_{RMP}$ **slow external perturbation**

Slab model provides a good test case for reconnection: “Taylor’s problem”



1. Stable sheared slab at $t=0$
2. Perturb boundary on time scale τ_{RMP}
3. Island forms at center

Symmetric (even parity) perturbation removes rippling & twisting modes

The slab model is well studied both analytically & computationally. A sampling:

Hahm and Kulsrud, PF 28, 2412 1985.

- Analytic studies of forced reconnection

Wang and Bhattacharjee, PFB 4, 1795 1992.

Ma, Wang, and Bhattacharjee, PP 3, 2427 1996.

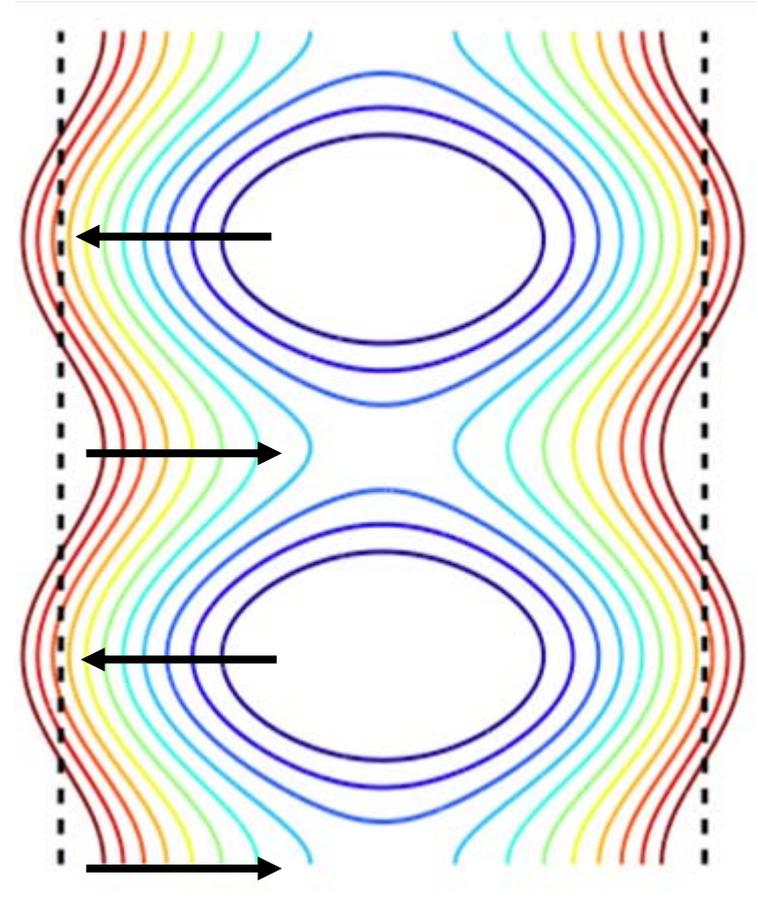
- Analytic studies of forced reconnection with flow
- Numerical studies of forced reconnection with flow

Fitzpatrick, PP 11, 937 2004.

- Analytic studies of forced reconnection with Hall MHD

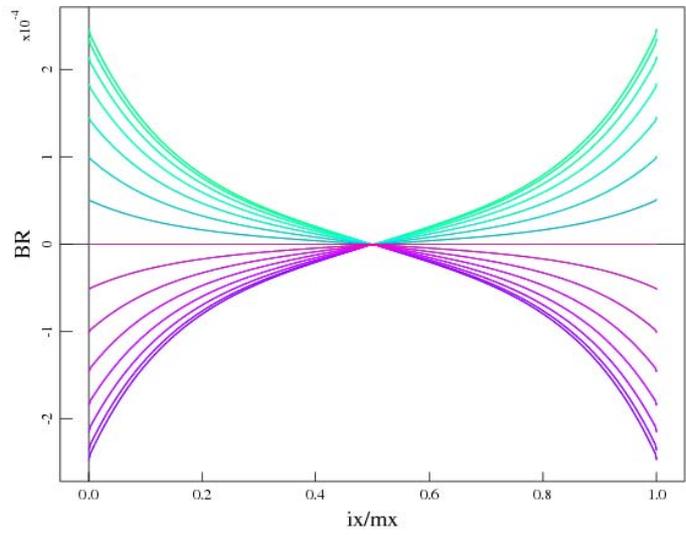
Fitzpatrick, PP 10, 1782 2003.

- Extended problem to study field-error penetration problem

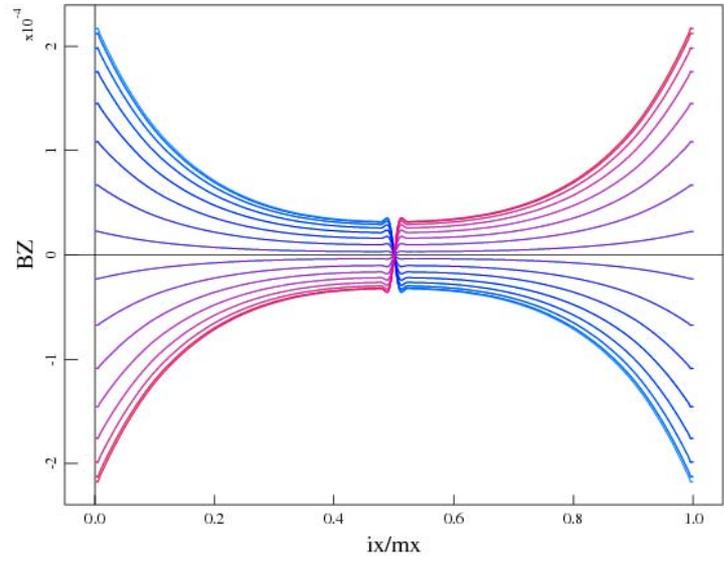


Magnetic field equation formulations work well for having flux enter the plasma

Re Br vs. i

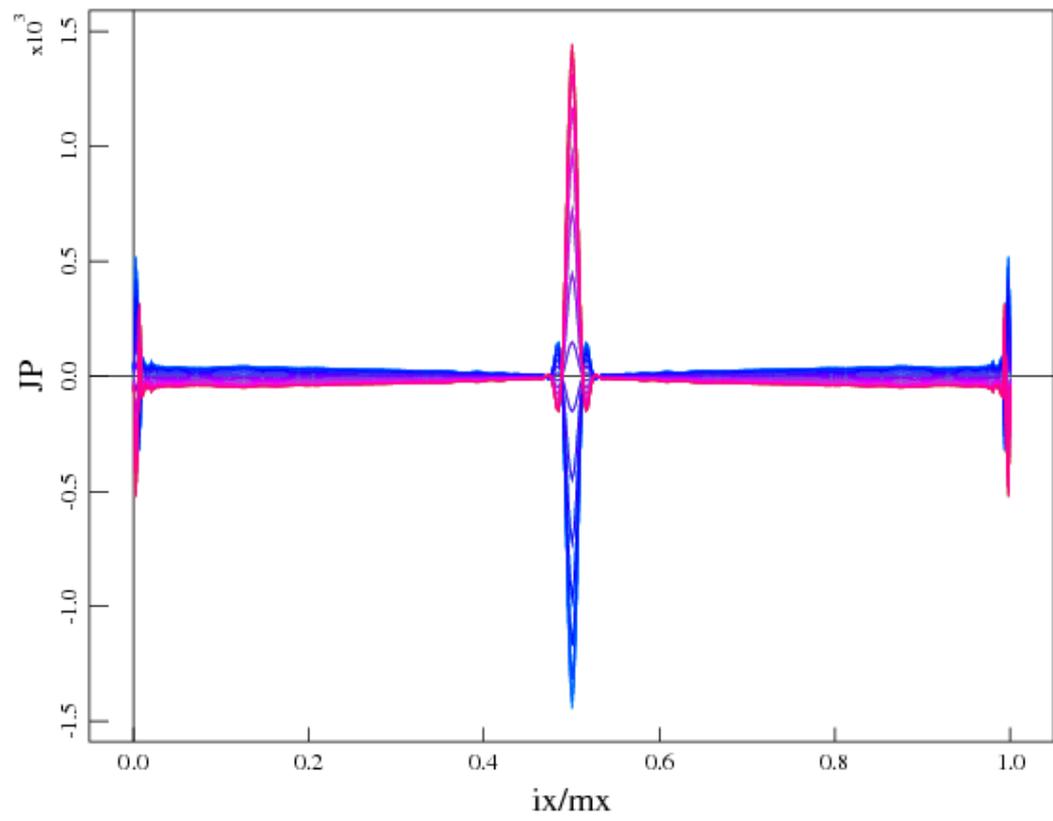


Re Bz vs. i

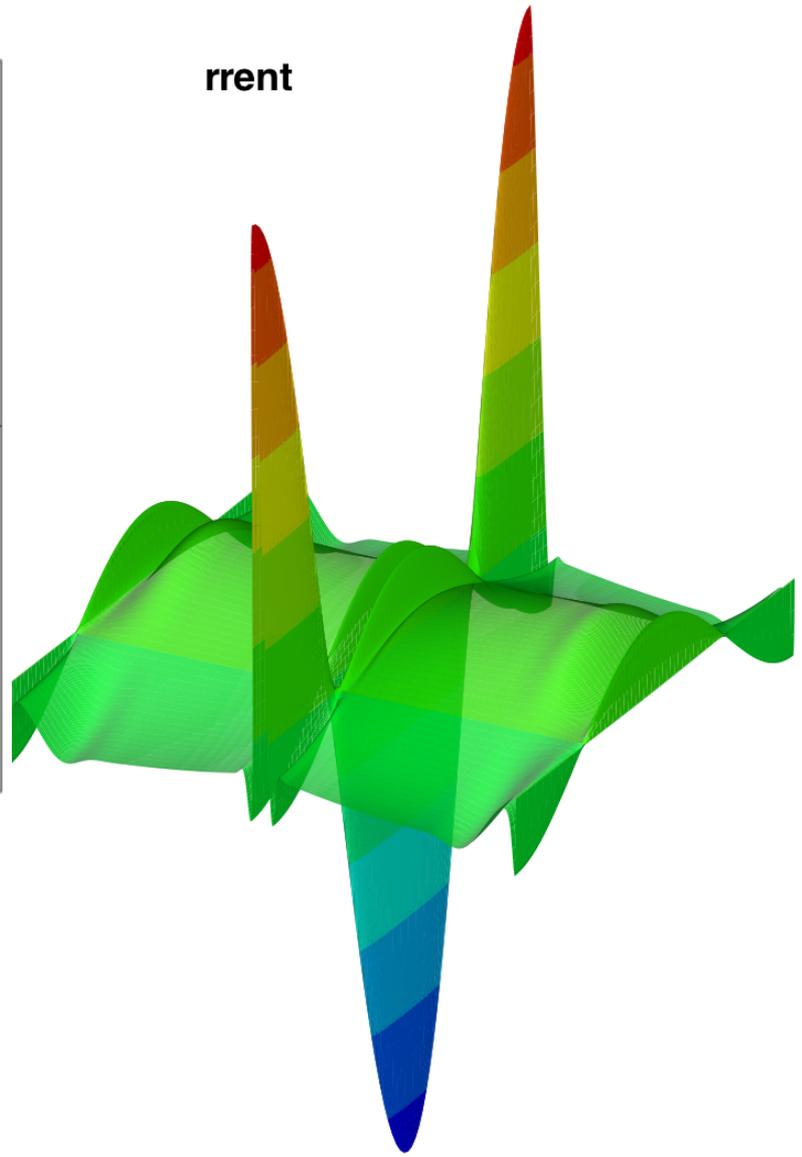


Nice Current Sheet Forms

Re Jphi vs. i



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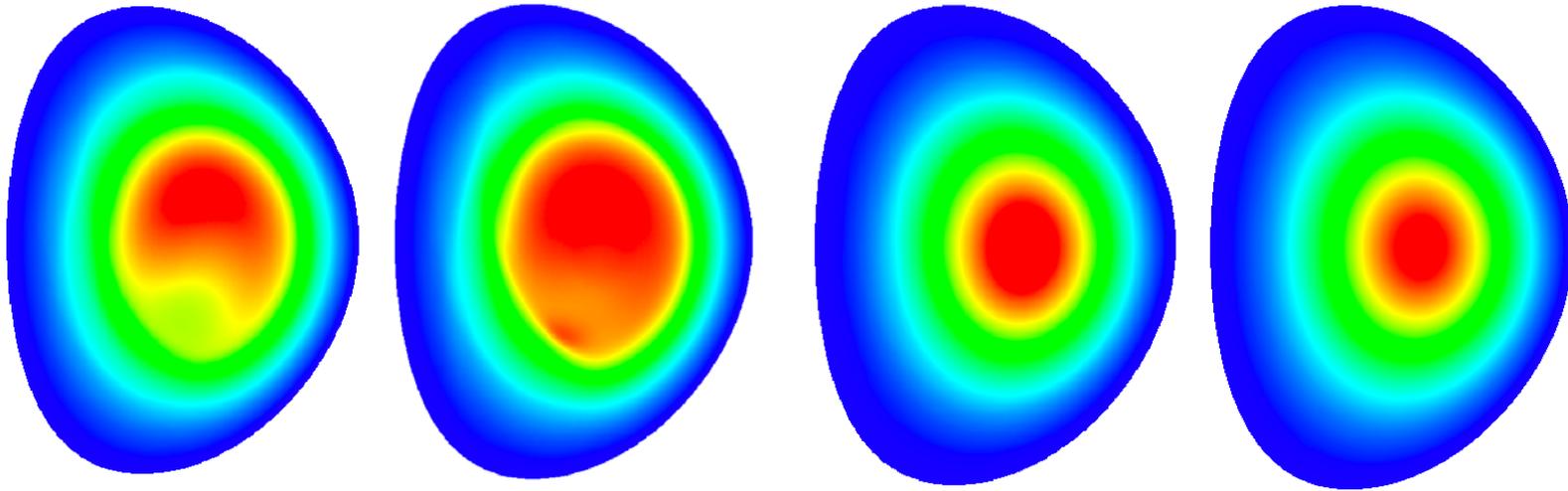


Benchmarking/code plans



- **Quantitative comparisons on this case, and with:**
 - Forced reconnection with flow
 - Error field penetration
 - Two-fluid results
- **Extend to include effects more relevant to experiments**
 - Multiple rational surfaces
 - Rapidly varying equilibrium profiles

Visit plugin used in proposal preparation is becoming Visit standard



From CEMM Proposal

- **Tech-X has developed a Visit HDF5 reader**
 - Developed as SBIR project that collaborated with CEMM (FSML)
 - Will become standard HDF5 reader for Visit as of version 1.6.2 (not just CEMM codes)
 - As capabilities advance, we will have to add HDF5 attributes to enable additional capabilities (e.g., time sequences)