Linear Stability Calculations with M3D-C1

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GENERAL ATOMICS

Motivation

- **Use of M3D-C1 allows study of:**
  - Diverted geometries
  - Non-ideal effects on ideal modes
    - Resistivity
    - Two-fluid effects
    - Gyroviscosity
  - Non-ideal modes
    - RWMs, tearing modes
  - Boundary effects
    - Resistive walls

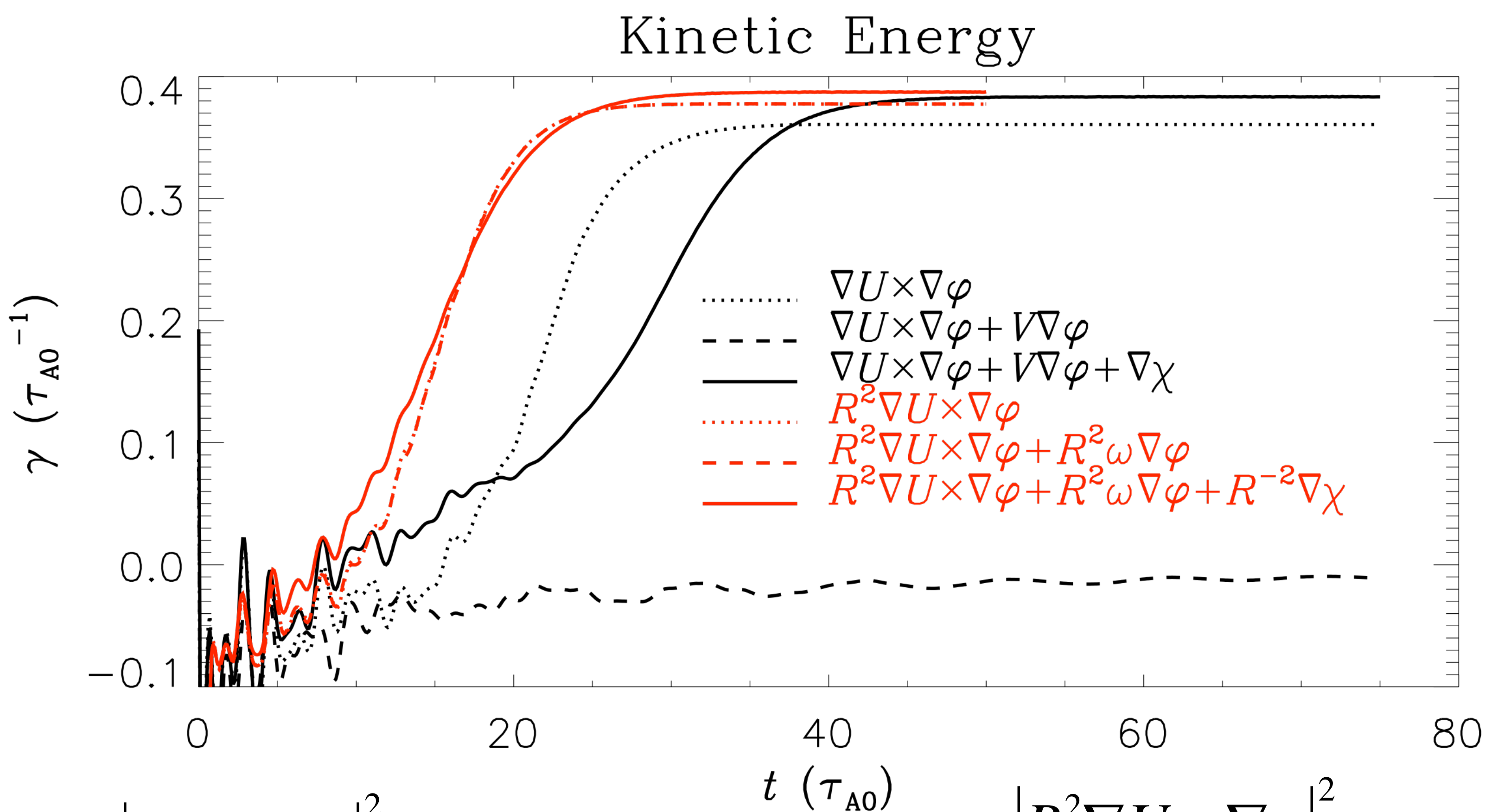
Method

- **M3D-C1 has been extended to included linear non-axisymmetric equations**
- **Nonlinear code (relatively) easily adapted to linear equations**
  - REAL → COMPLEX
  - $\partial_\varphi \longrightarrow in$
- **New coding to allow non-rectangular boundaries; EFIT, GATO, TOQ equilibria**
- **Vacuum region = resistive plasma**

New Velocity Form

- **Old form:** $\vec{u} = \nabla U \times \nabla\varphi + V\nabla\varphi + \nabla\chi$
  - *U* advects, but does not compress, *n* and *p*
- **New form:** $\vec{u} = R^2\nabla U \times \nabla\varphi + R^2\omega\nabla\varphi + R^{-2}\nabla\chi$
  - *U* advects, but does not compress, RB_ϕ
- **Using the "new form," the most unstable eigenmode should have** $\left|R^2\nabla U \times \nabla\varphi\right| >> \left|R^{-2}\nabla\chi\right|$
- **Full equations using both velocity forms have been implemented**

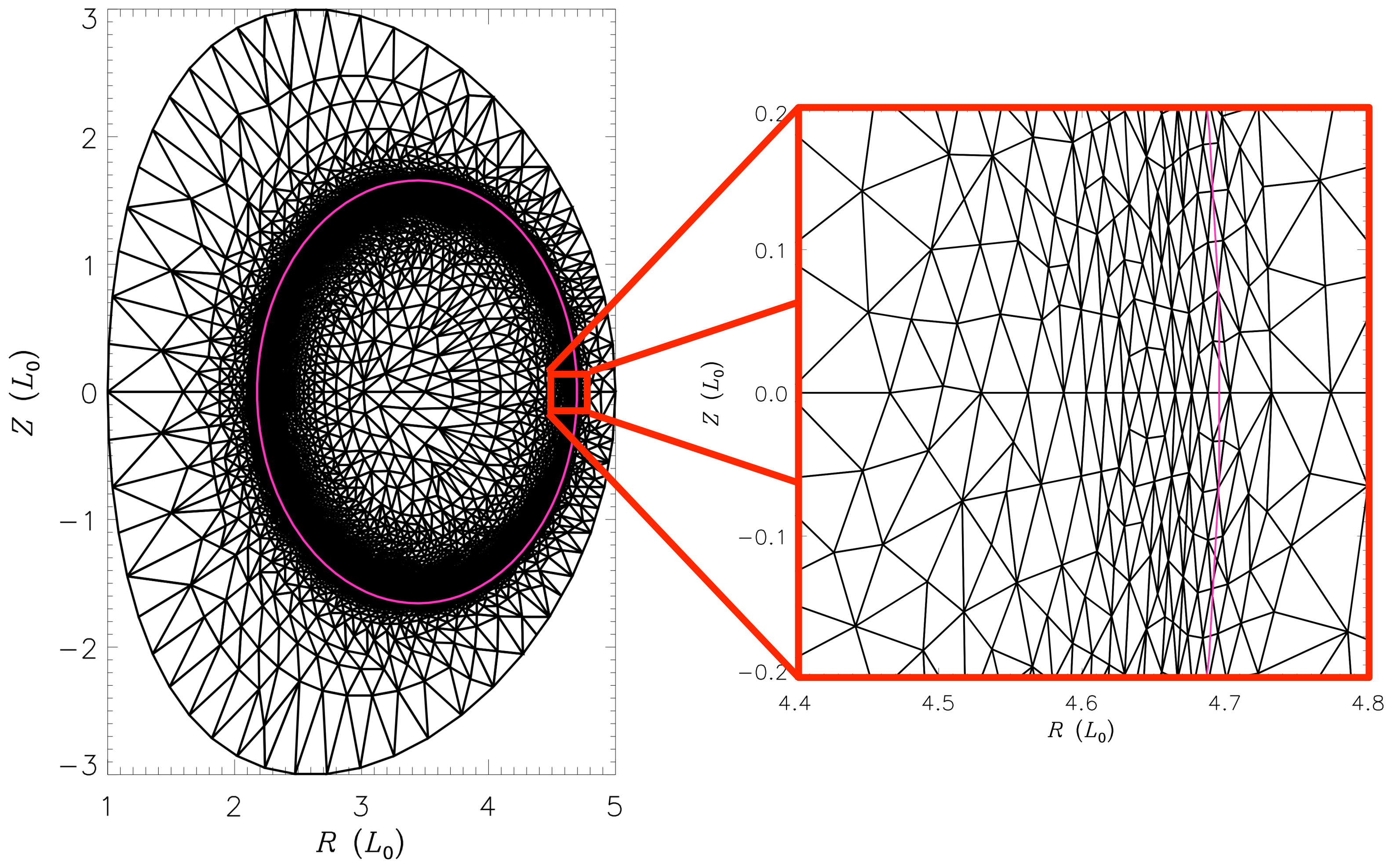
Comparison of Velocity Forms



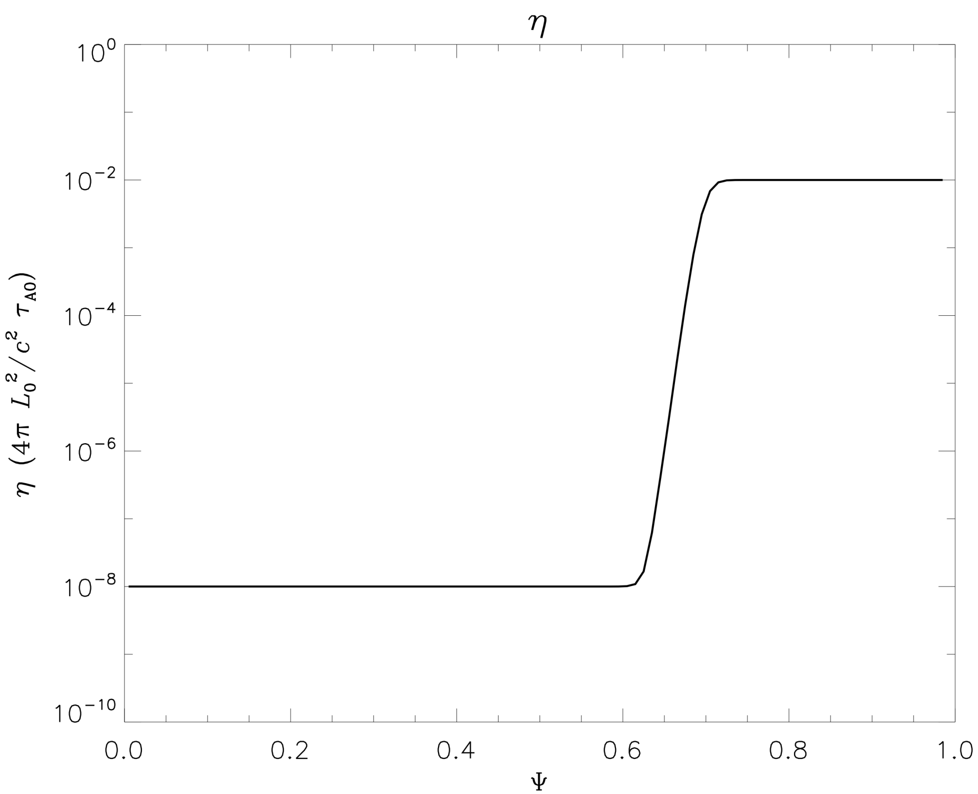
$$\frac{|\nabla U \times \nabla \varphi|^2}{|\nabla \chi|^2} \approx 80$$

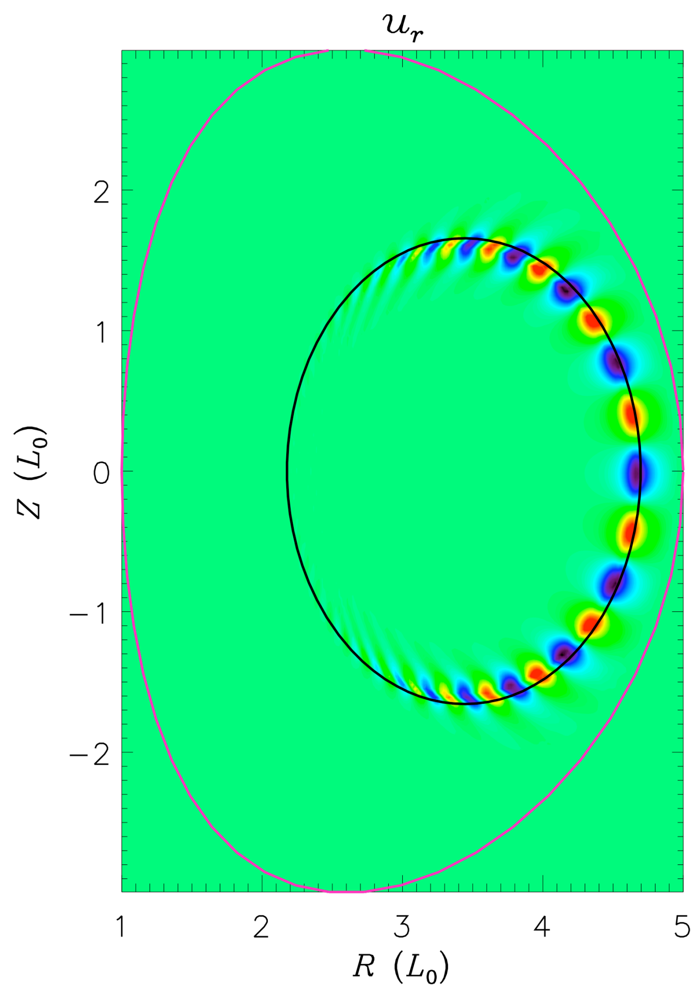
$$\frac{|R^2 \nabla U \times \nabla \varphi|^2}{|R^{-2} \nabla \chi|^2} \approx 2000$$

Benchmarks: dbm18: Mesh



Benchmarks: dbm18: Equilibrium & Eigenmode

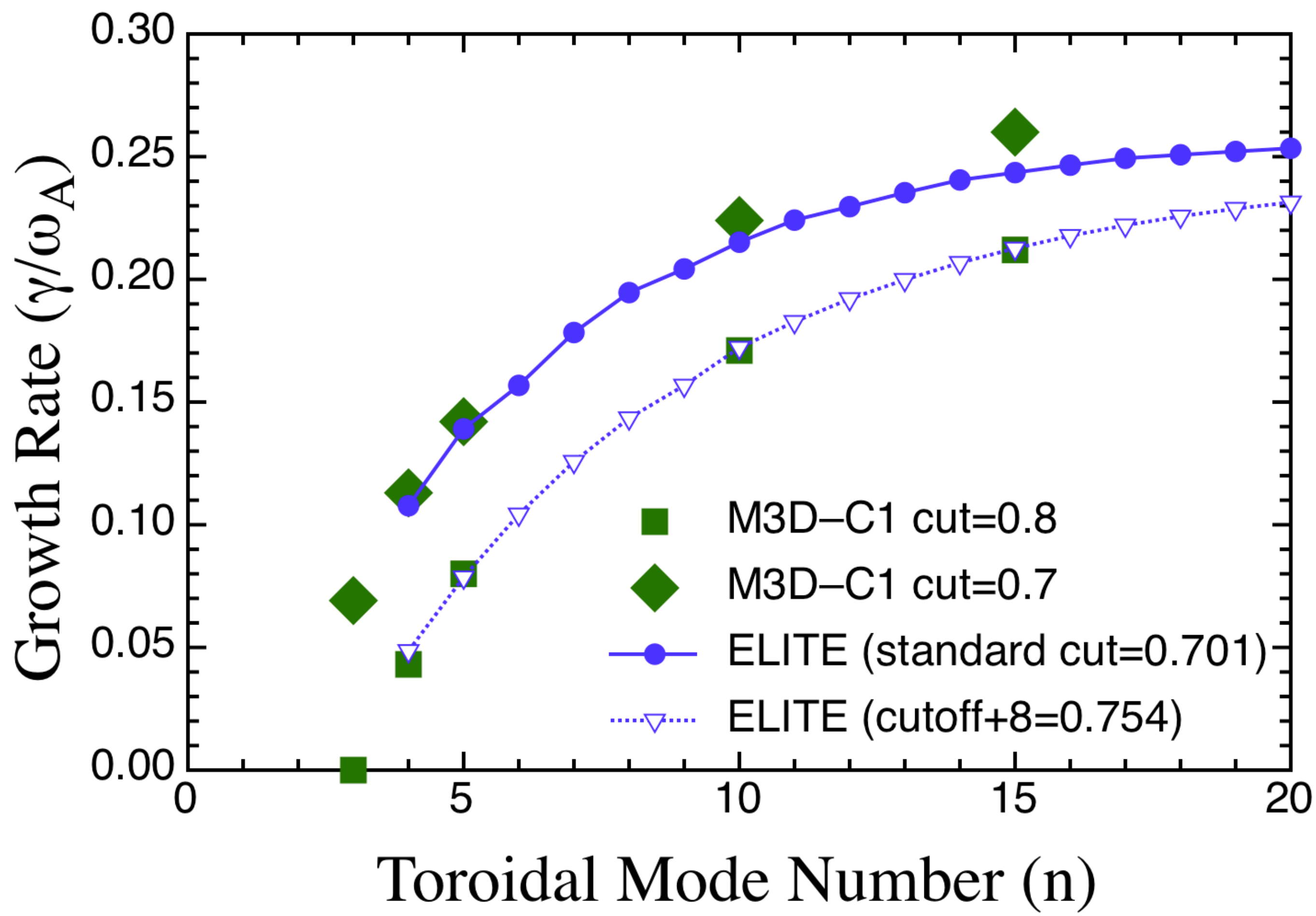




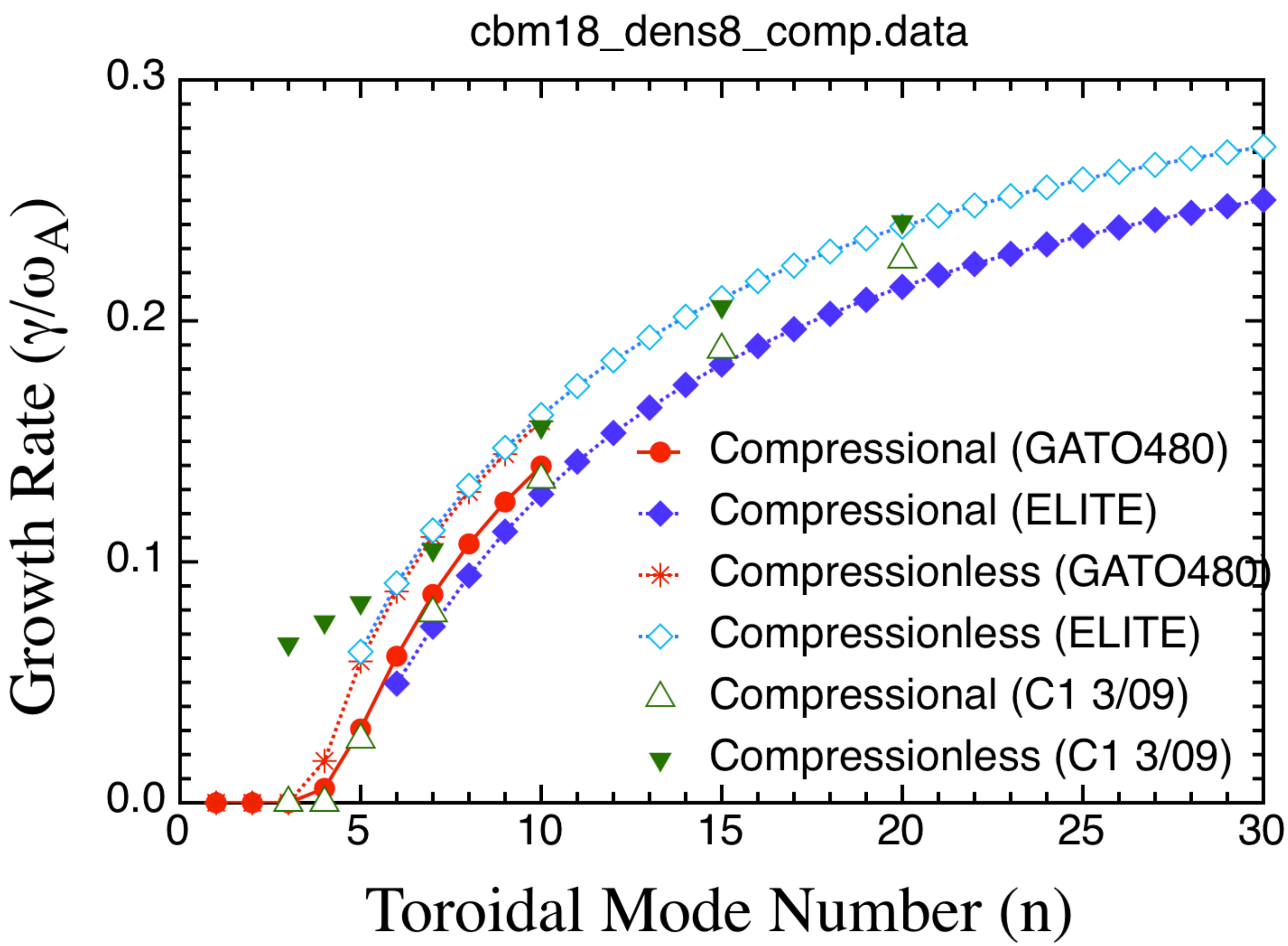
$$\frac{\Delta W_\eta}{\Delta \Psi} = 0.01$$

Benchmarks: dbm18

dbm18_comp.data



Benchmarks: cbm18-dens8

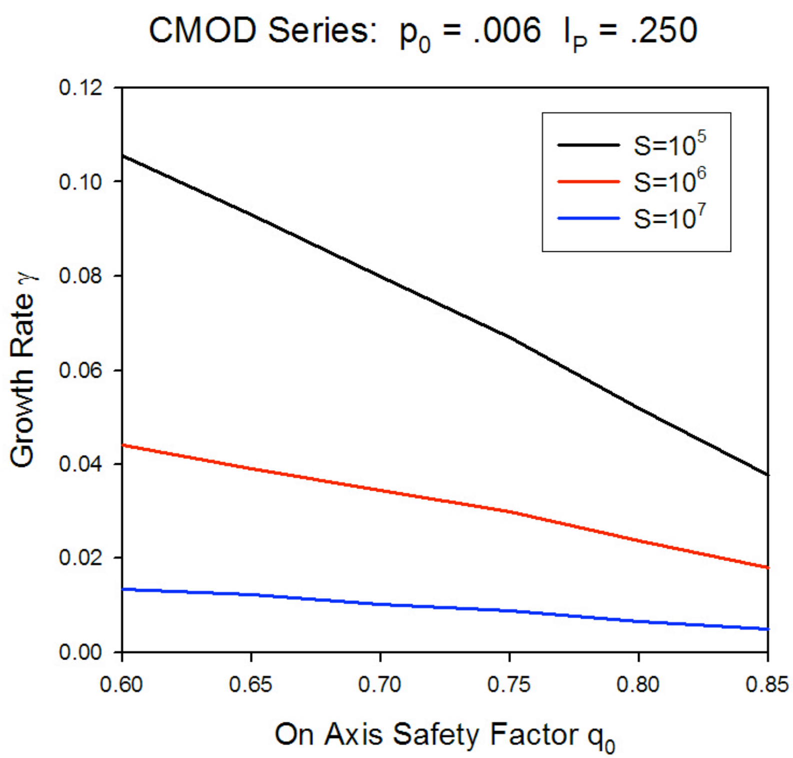


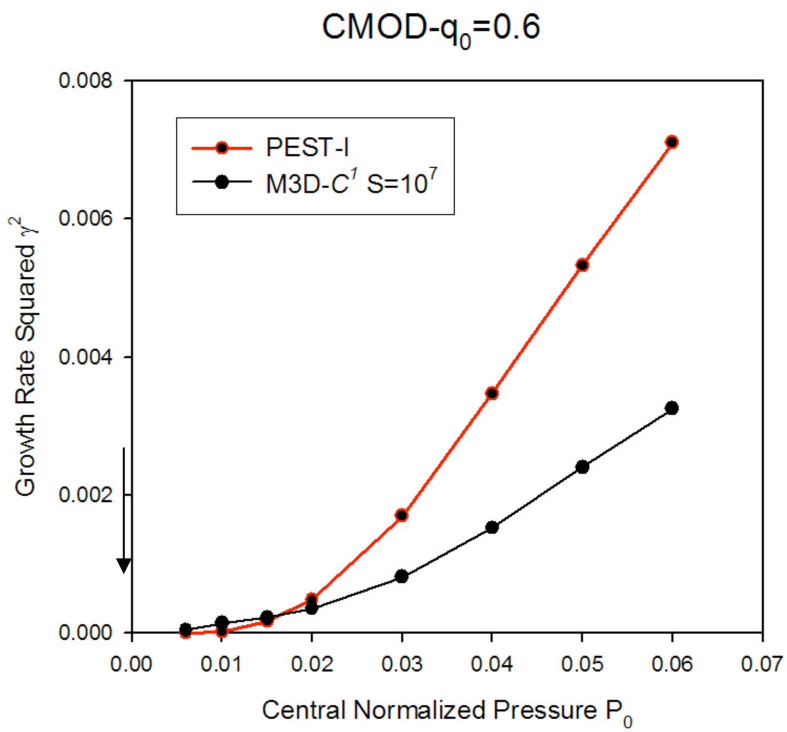
N=1 Resistive Internal Kink Mode in CMOD

CMOD is stable to ideal MHD n=1 mode at operating point of P_0/B^2 = .006

Ideal MHD stable even down to q_0 = 0.6. Why does it exhibit sawteeth?

The resistive internal kink is unstable, but at a much lower growth rate. Can this explain the sawtooth crash?





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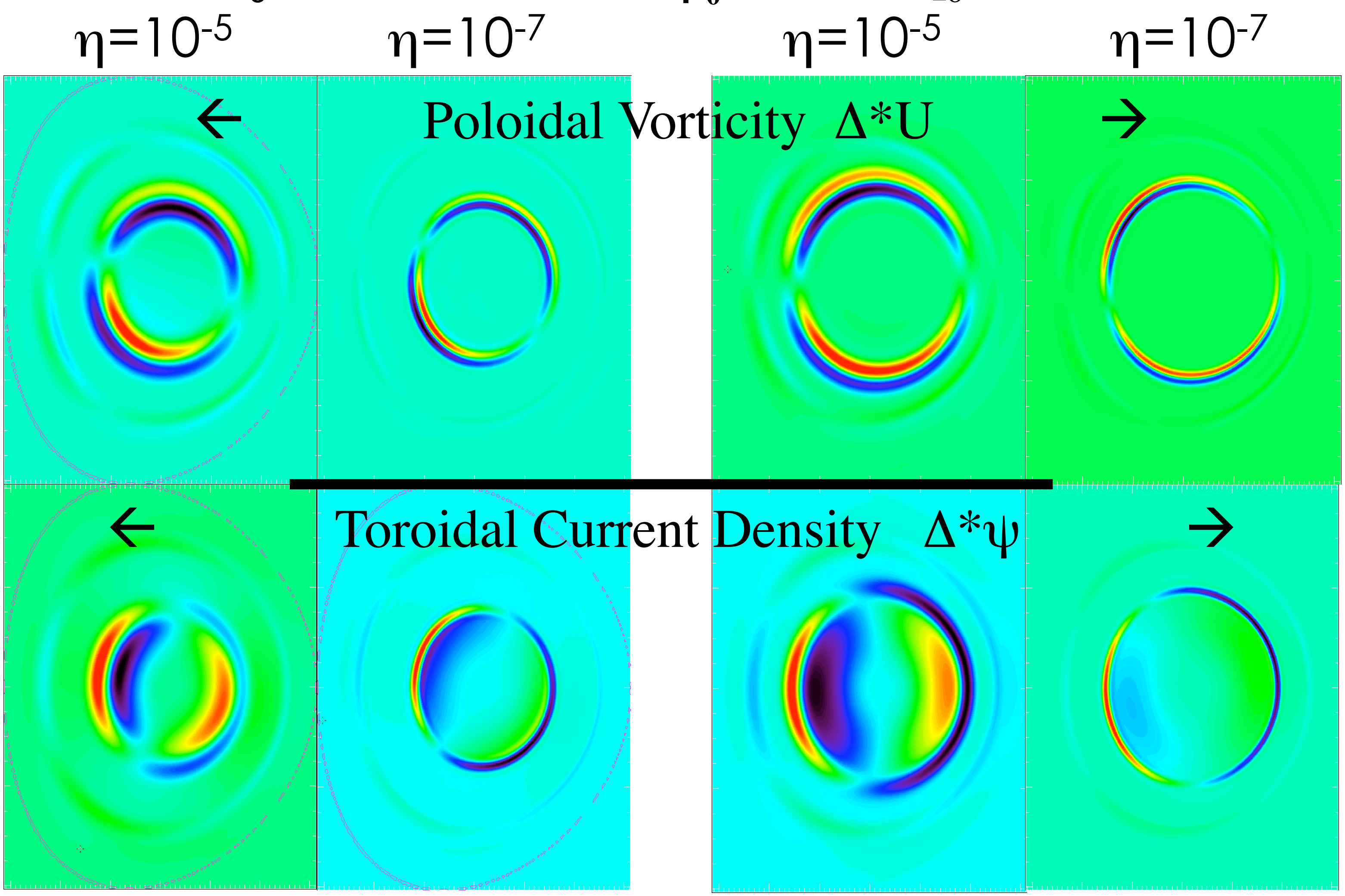
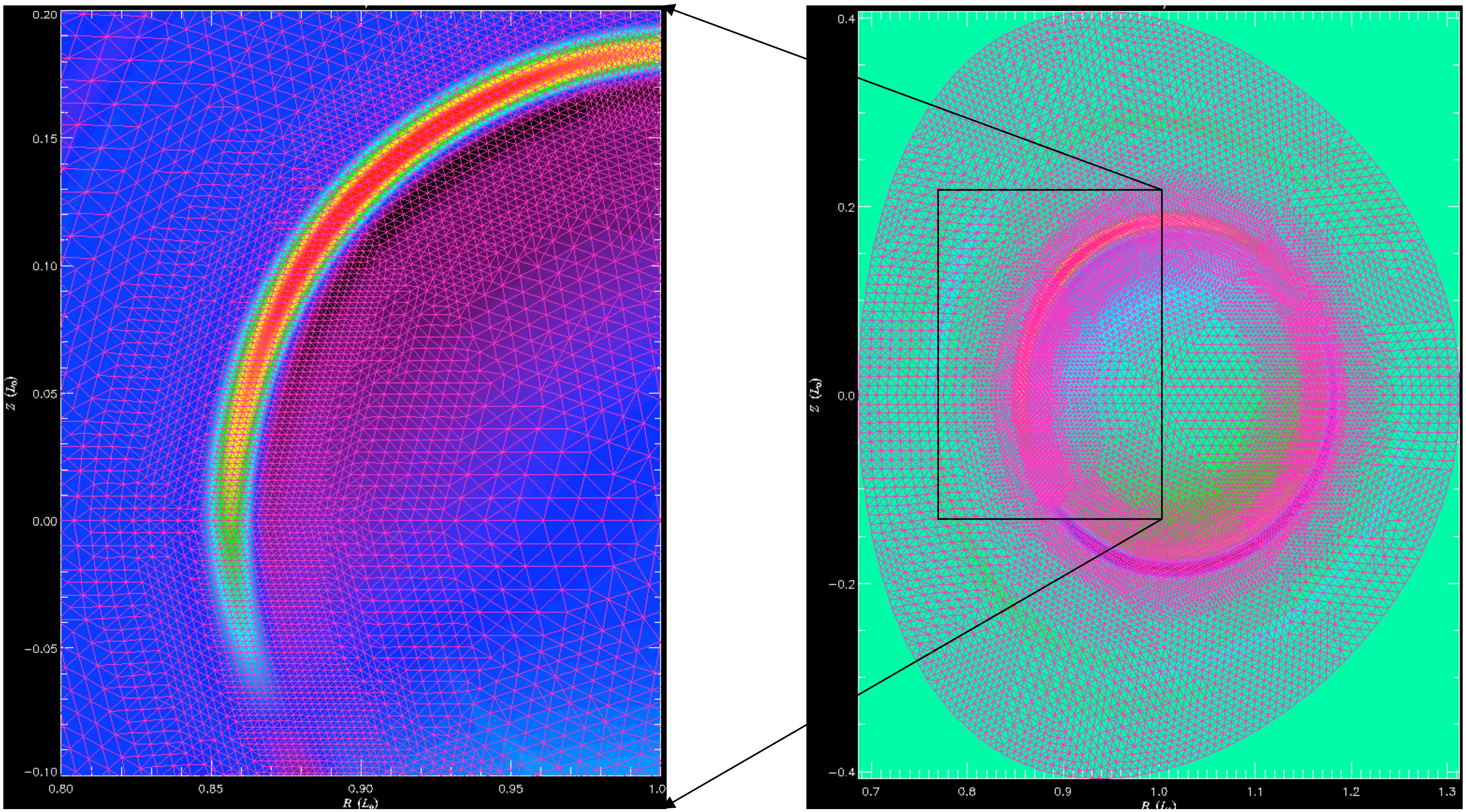
N=1 Resistive Internal Kink Mode in CMOD

$q_0=0.85$ **CMOD: $\beta_0=.006$** $q_0=0.60$



N=1 Resistive Internal Kink Mode in CMOD with $S=10^7$

Close-up | Perturbed Current with Mesh



Conclusions

- **Linear capability for M3D-C1 for full equations is now implemented**
- **Ideal benchmarks show good agreement**
- $\vec{u} = R^2 \nabla U \times \nabla \varphi$ **velocity form is best for linear instabilities in tokamak geometry**
- **Future work:**
  - Apply to more realistic equilbria
  - Benchmark non-ideal effects
  - RWMs
  - Linear response to error fields