Extended MHD Calculations of Linear Interchange Mode in Spheromak Equilibria

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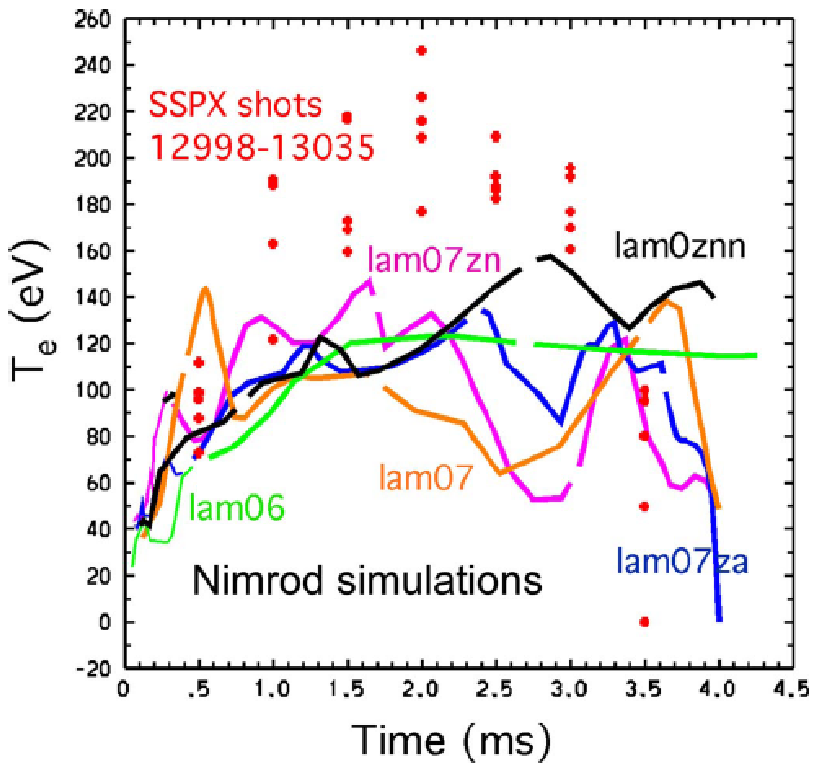
NIMROD Team Meeting

Resistive MHD simulations using NIMROD have reproduced most aspects of SSPX discharges, but consistently underestimate peak temperature.

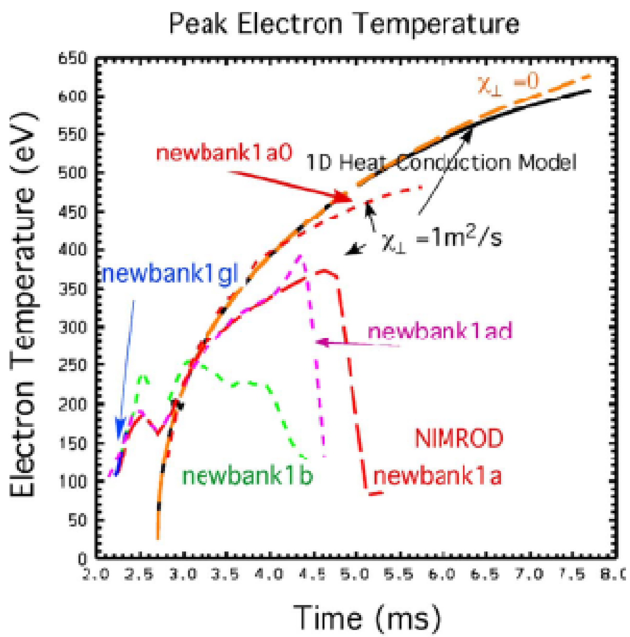
- Highest temperatures are observed during controlled decay phase when guns are turned down.
- T_e > 400eV have been observed in high performance SSPX discharges.
- Resistive MHD NIMROD simulations produce electron temperatures ~40% less than high performance discharges .



Hooper et al, POP 15, 2008

Peak temperatures observed in simulations are very sensitive to excitement of resonant MHD modes.

- MHD activity destroy good magnetic surfaces leading to increased transport.
- Axisymmetric simulations suggest that higher temperatures may be achieved if MHD modes are damped.
- Does two-fluid physics provide a strong enough stabilizing mechanism to explain the difference between simulation of experiment?
- Kinetic effects due to low collisionality may also explain the difference.



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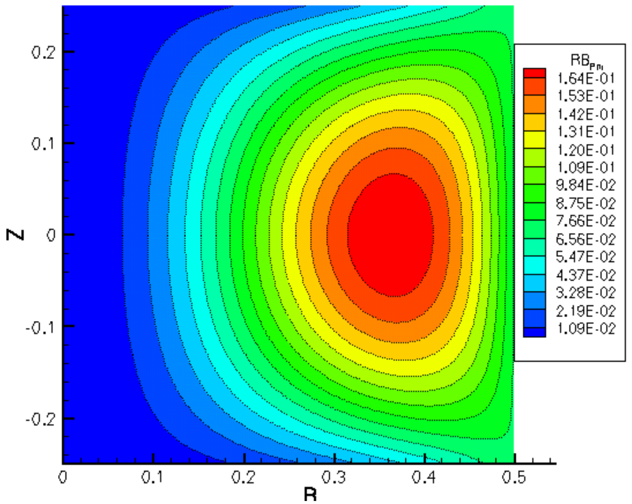
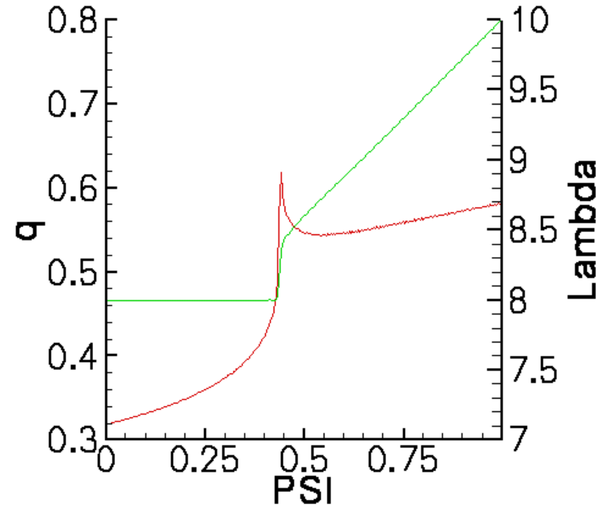
Equilibria represent controlled decay phase of high performance SSPX discharges.

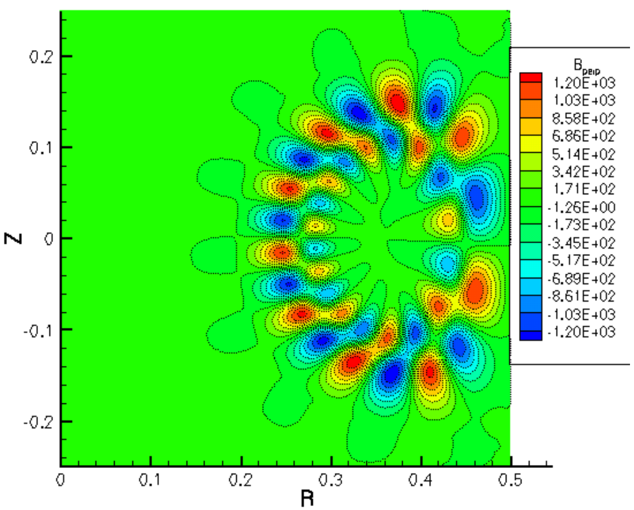
- Toroidal geometry is used in a cylindrical domain with centrally peaked pressure and current profiles.
- $S=1\times10^6$
- $\beta=10.1\%$
- $Pr_m\sim0.01$
- $\tau_A=4.78\times10^{-7}$s
- $d_i=4.6$cm
- $\rho_s=0.94$cm
- For all two-fluid simulations the full two-fluid ohms law is used with gyroviscosity.

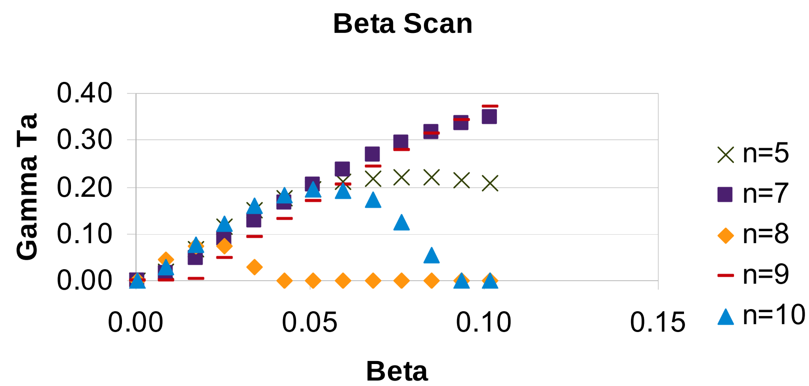


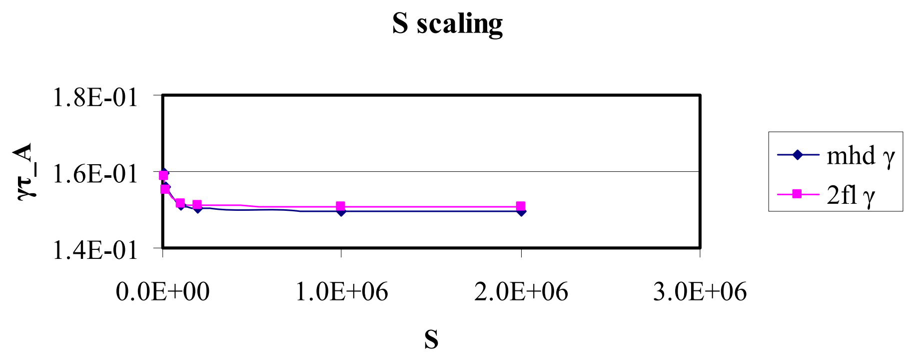


Resistive MHD scaling studies and MHD mode structure indicate Ideal Interchange modes

B_{perp}

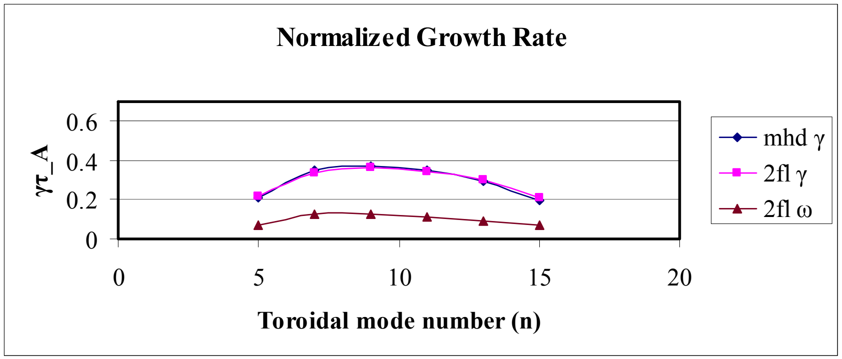


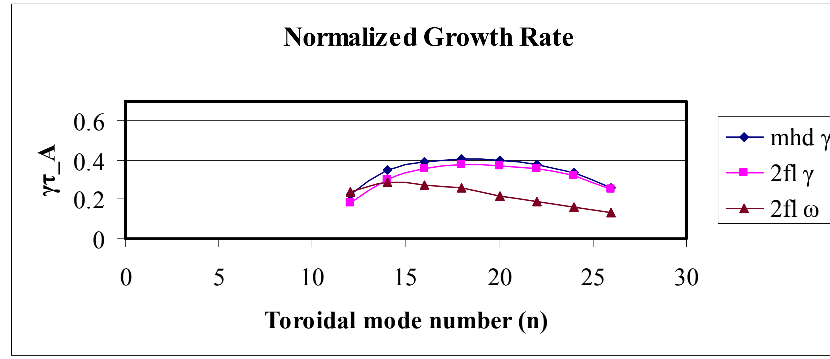


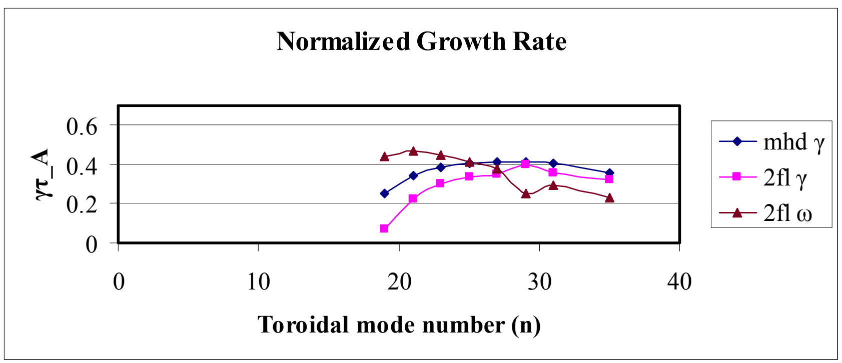


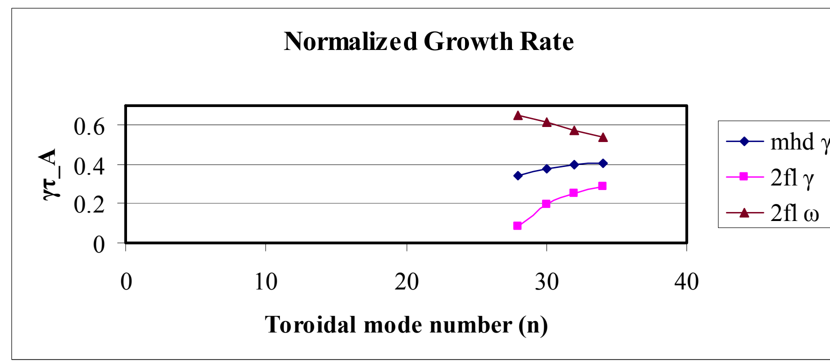
- Growth rates scale ~linearly with peak pressure.
  - As pressure is increased the q profile slowly changes and rational surfaces disappear.
- Perpendicular component of perturbed magnetic field is zero at the rational surface.
- Growth rates are insensitive to electrical resistivity at high S.

Two-fluid growth rates are damped at sufficiently high toroidal mode number.









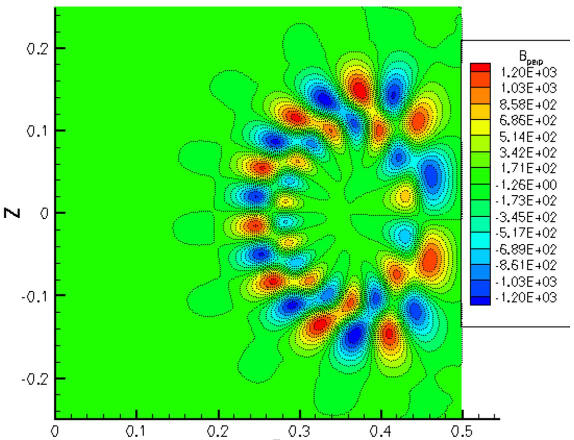
- Two-fluid physics has minimal effect of low n modes.
- Maximum dampening occurs near the magnetic axis, where the two-fluid rotation rate is maximum, when the rotation rate exceeds the MHD growth rate.

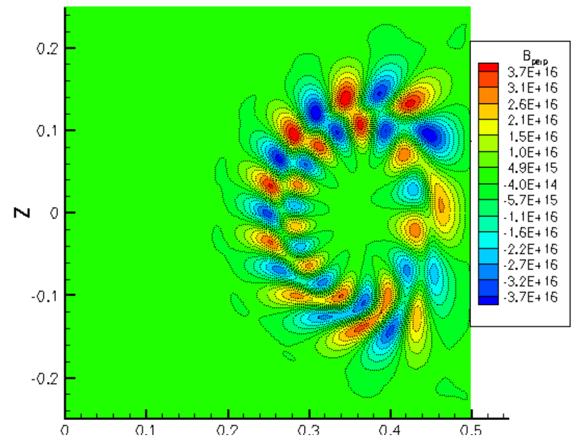
Counterclockwise rotation is evident in two-fluid mode structure (n=16 mode).

MHD

2fl

B_{perp}





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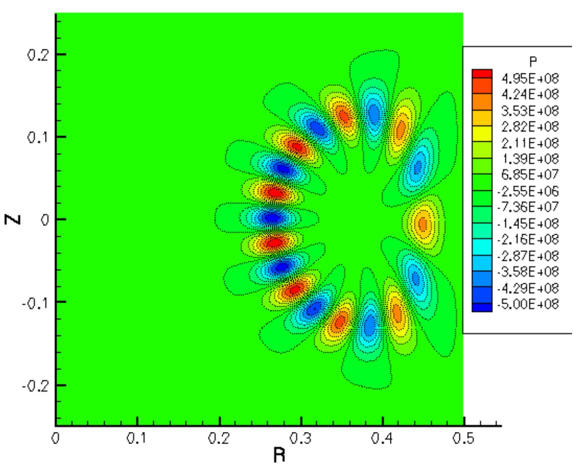
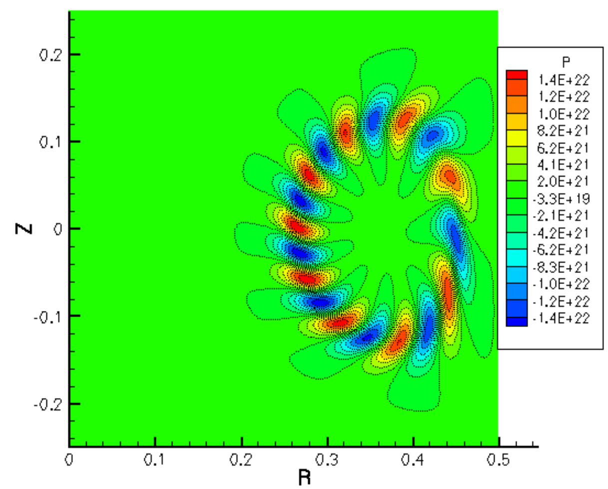
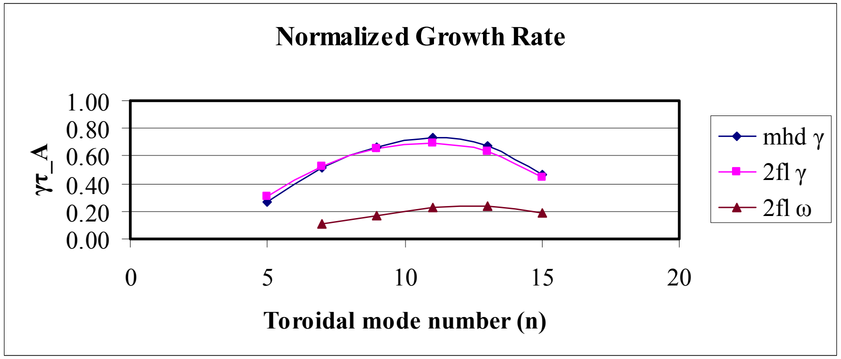
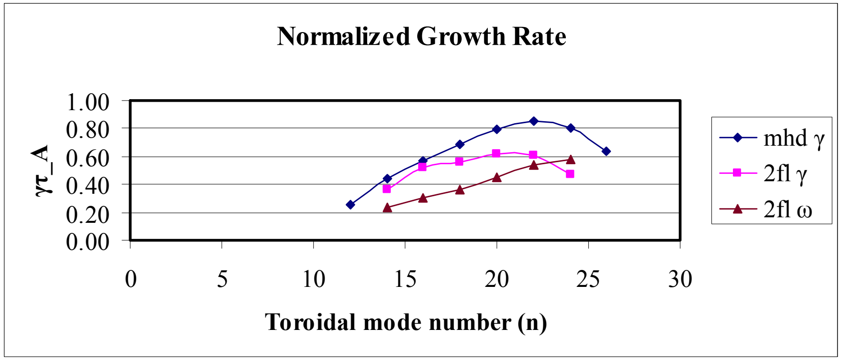




Simulations using non-uniform number density are influenced by two-fluid physics at lower n.





- Equilibrium number density is determined using (P/ρ^{γ})=constant.
- Noticeable damping is present even when two-fluid rotation rate is less than MHD growth rate.
- MHD growth rates and two-fluid rotation rates both peak near separatrix where the density is smallest.

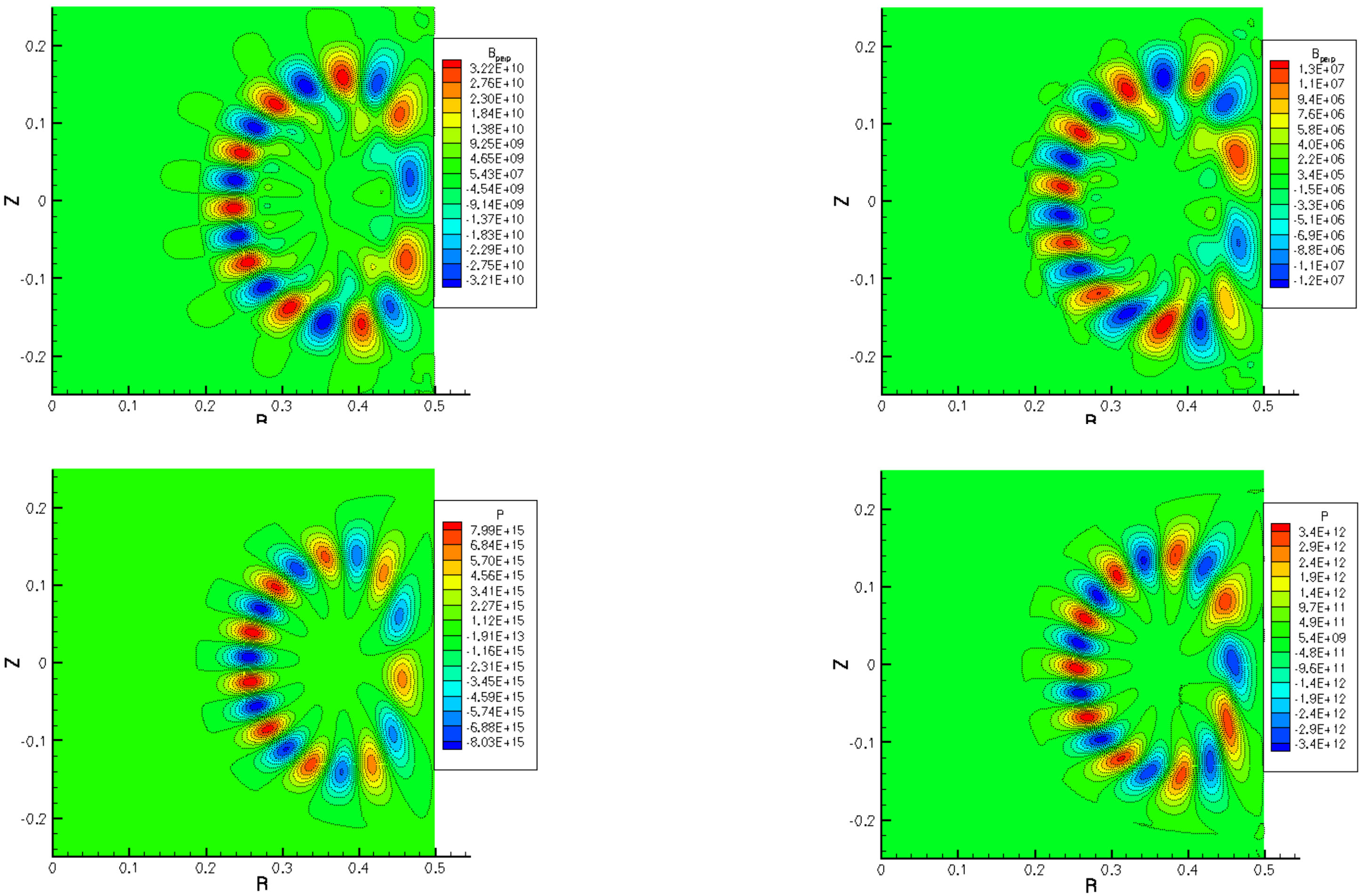
n=16 mode structure for the modified number density simulation.

MHD

2fl

B_{perp}

P



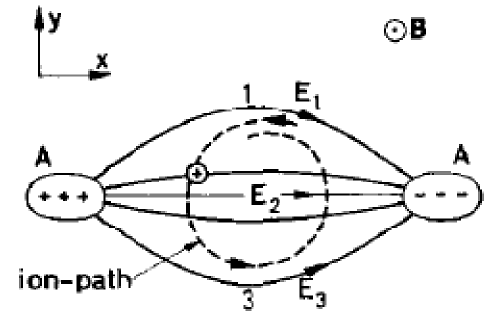
Conclusions/Future Work

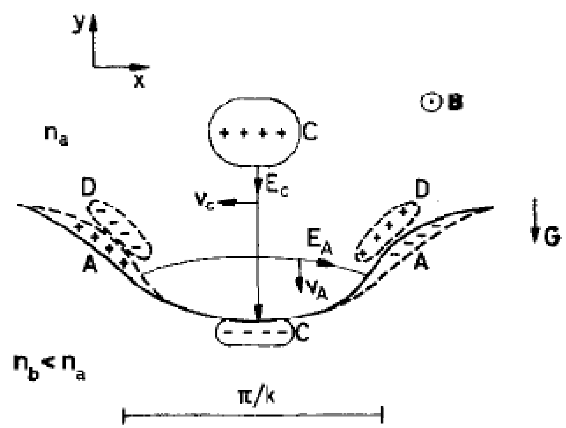
- Ideal Interchange modes are observed in simulations of spheromak equilibria.
- Two-fluid physics dampen modes at sufficiently high toroidal mode numbers.
- Dampening is most effective when the two-fluid rotation rate is comparable to or large than the MHD growth rate for constant density profiles.
- Density profile plays an important role in determining when two-fluid dampening is significant.
- Further investigate effects of number density profile on the two-fluid stabilization.
  - Trouble observing slowly growing modes due to numerical instability.
  - Isothermal equilibria.
- Incorporate diamagnetic flows into equilibrium.
- Look into the effects of different pressure profiles.
- Use a mesh representing the SSPX flux conserver.

END

FLR effects provide one mechanism for stabilization of interchange modes.

- Ion drifts are reduced in non-uniform electric fields due to a finite Larmor radius.
- In a gravitational field, ions and electrons drift in opposite fields creating a space charge (label A).
- Ion ExB drifts are reduced due to dipole like nature of E filed creating another space charge (label C).
- Ion drifts are reduced and another space charge is created (label D) that reduces the original electric field.





F.C. Hoh 1963

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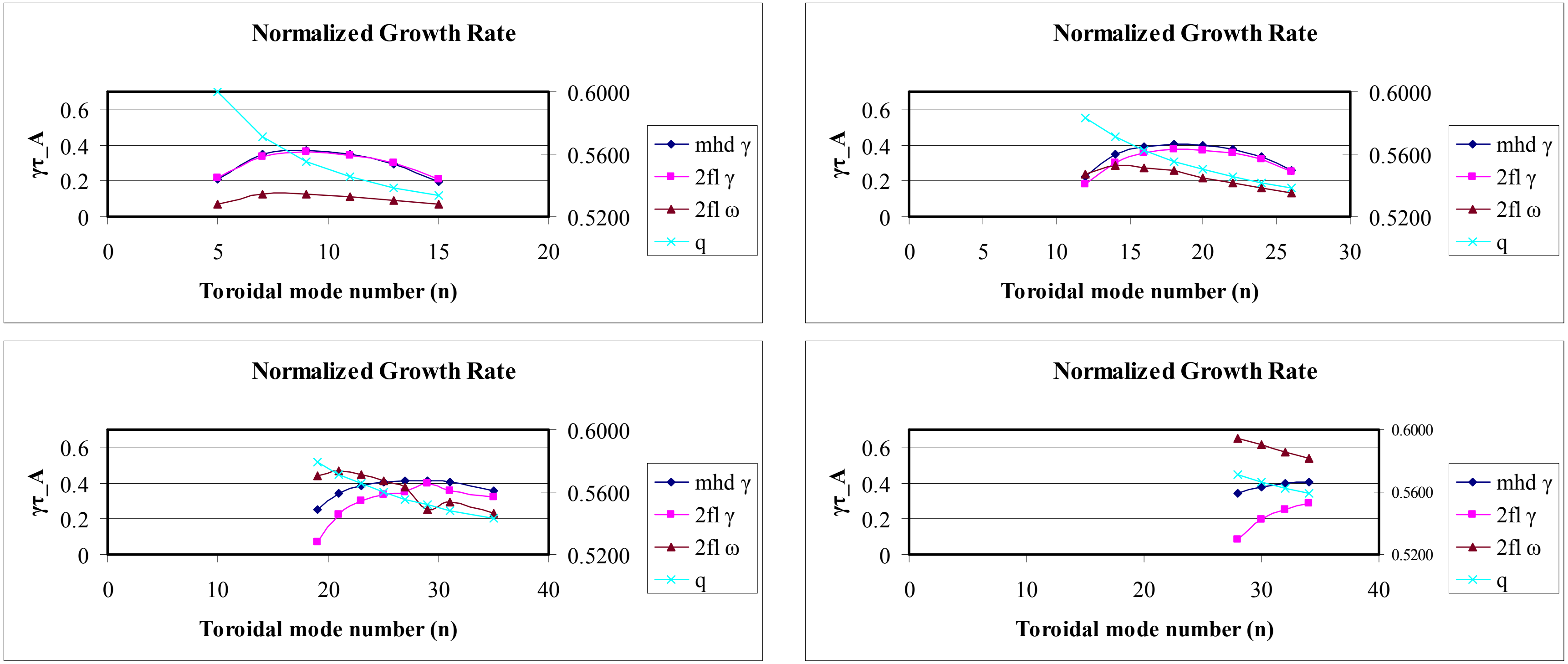

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