M3D Status and Plans

M3D Project

W. Park et al., Phys. Plasmas **6,** 1796 (1999)
http://w3.pppl.gov/~wpark/pop_99.pdf

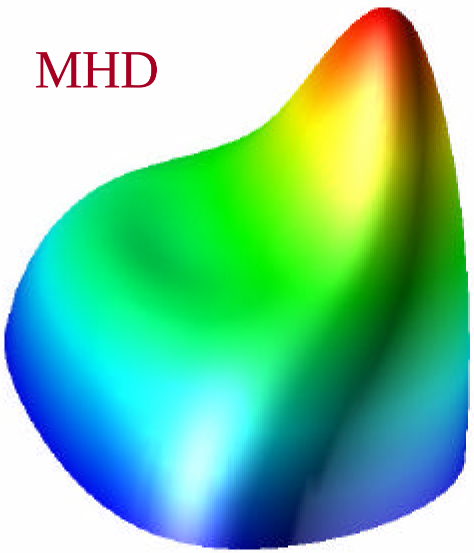
Multilevel 3D Project for Plasma Simulation studies.

MPP code using MPI.

Physics	Geometry & Hardware	State
MHD 2 Fluids Gyrokin. Hot P./MHD Gyrokin.Ion/Fluid Elect. ….	Tokamaks, ST's,… Stellarators,… Resistive Shell External coils	Equilibrium Linear Nonlinear

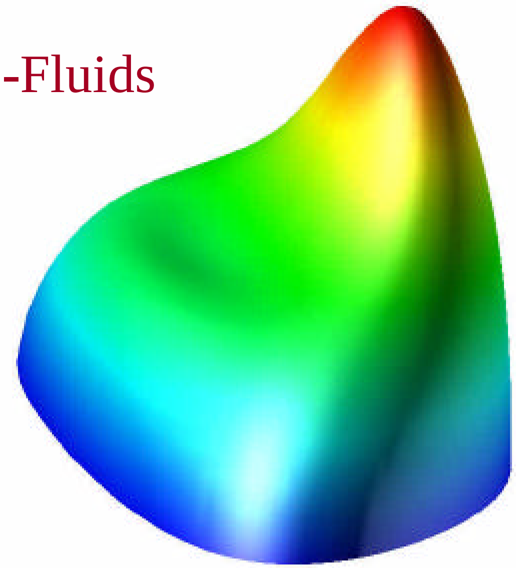
Density profile dependence on Physics model

MHD



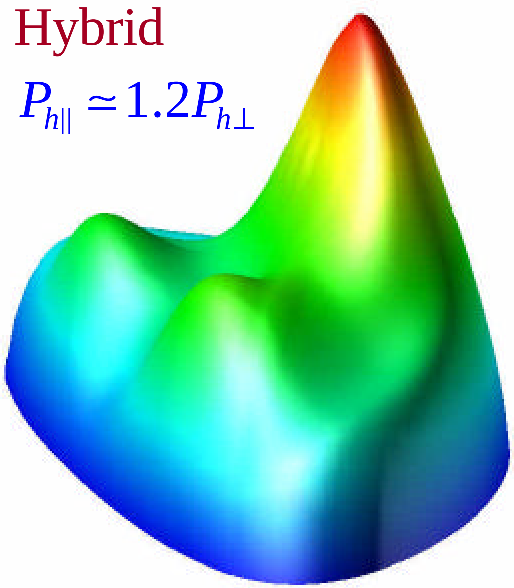
M_A=0.2
Sh=0.3
ρ_{max}=1.1
ρ_{min}=0.5
RelSh=1

Two-Fluids



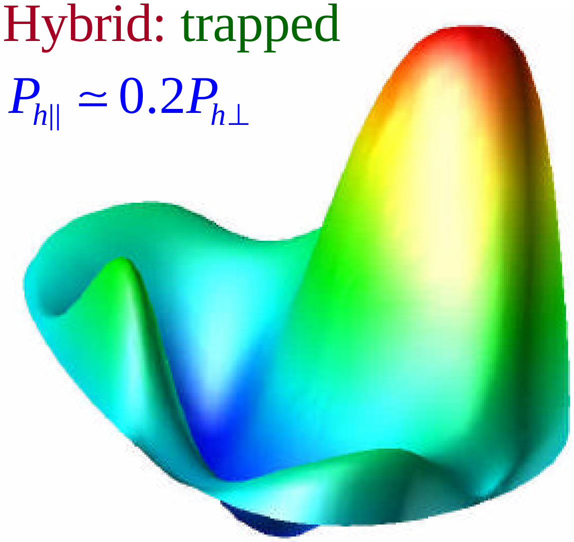
M_A=0.2
Sh=0.3
ρ_{max}=1.1
ρ_{min}=0.5
RelSh=1

Hybrid
$P_{h\|} \simeq 1.2 P_{h\perp}$

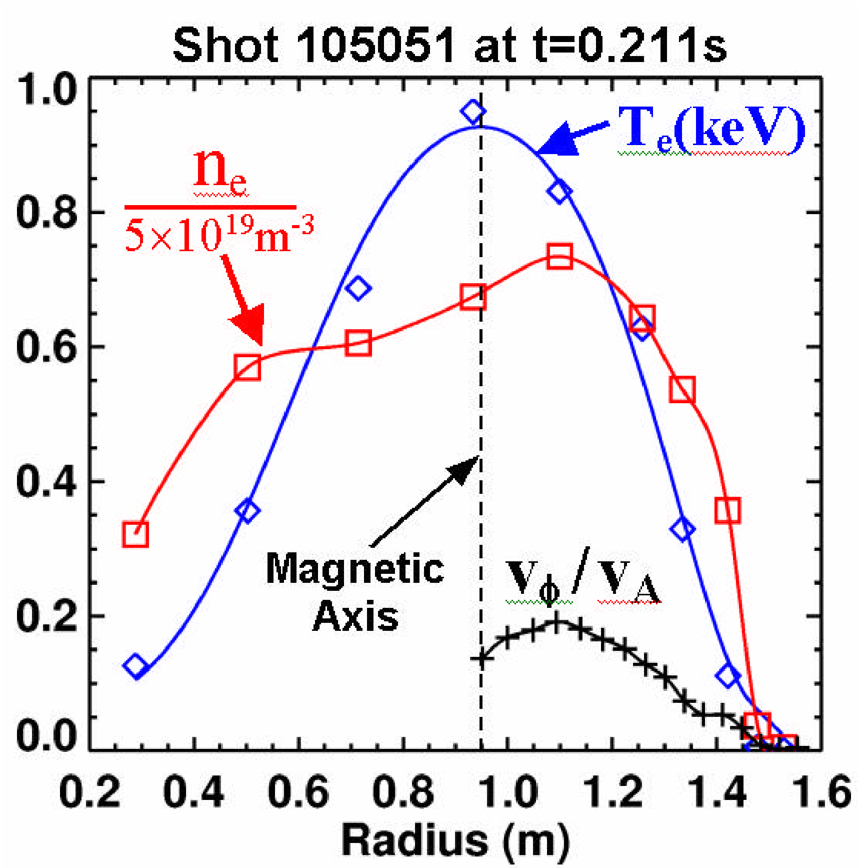


M_A=0.2
Sh=0.3
ρ_{max}=1.2
ρ_{min}=0.5
RelSh=0.8

Hybrid: trapped
$P_{h\|} \simeq 0.2 P_{h\perp}$



M_A=0.2
Sh=0.3
ρ_{max}=1.8
ρ_{min}=0.15
RelSh=1.9

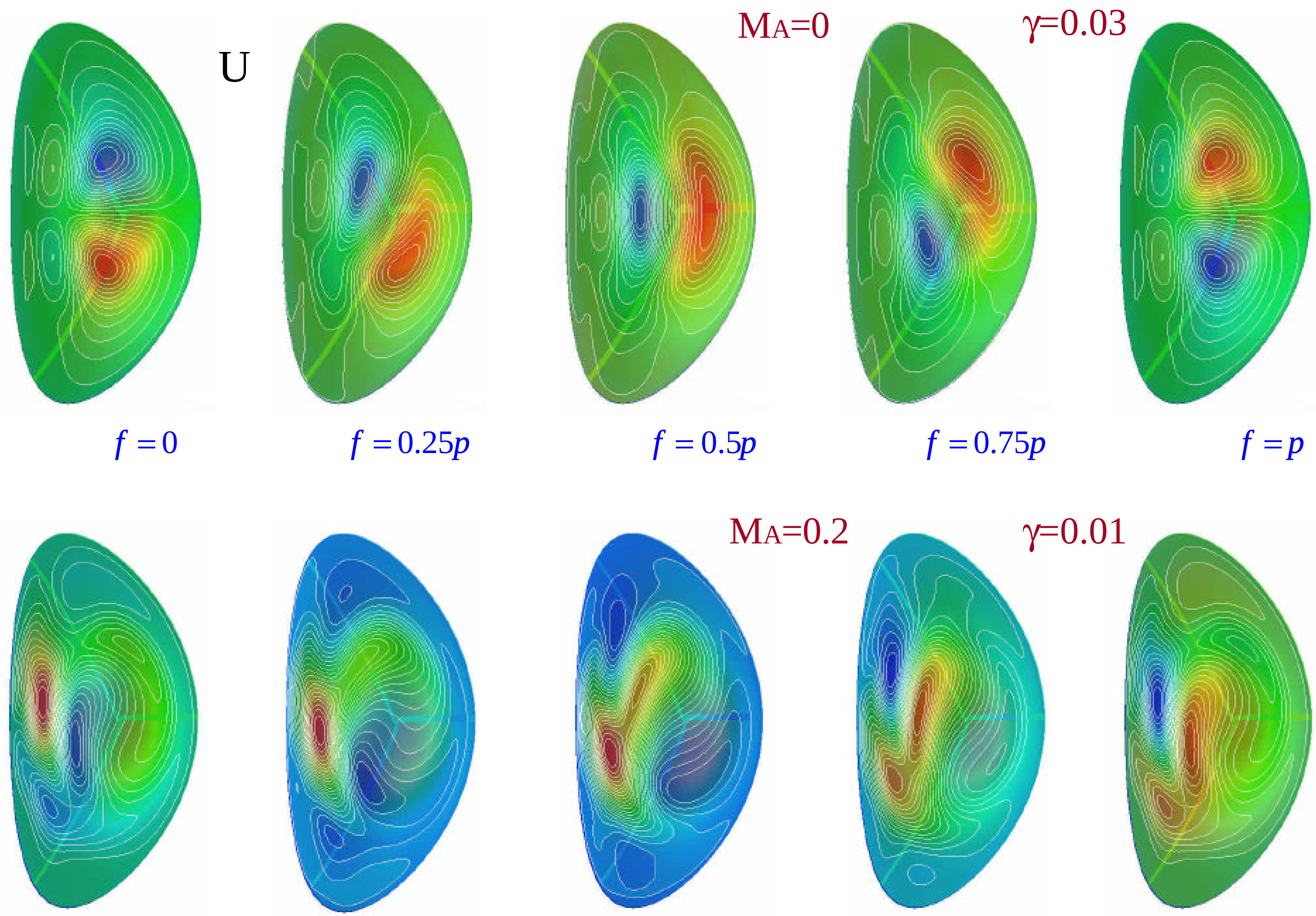


Relative shift of *r*

$$\frac{R\partial r}{r\partial R} = \frac{2M_A^2}{b}$$

Hot particle centrifugal force
~ Bulk plasma

Linear Eigenmodes: shear flow reduces growth rate

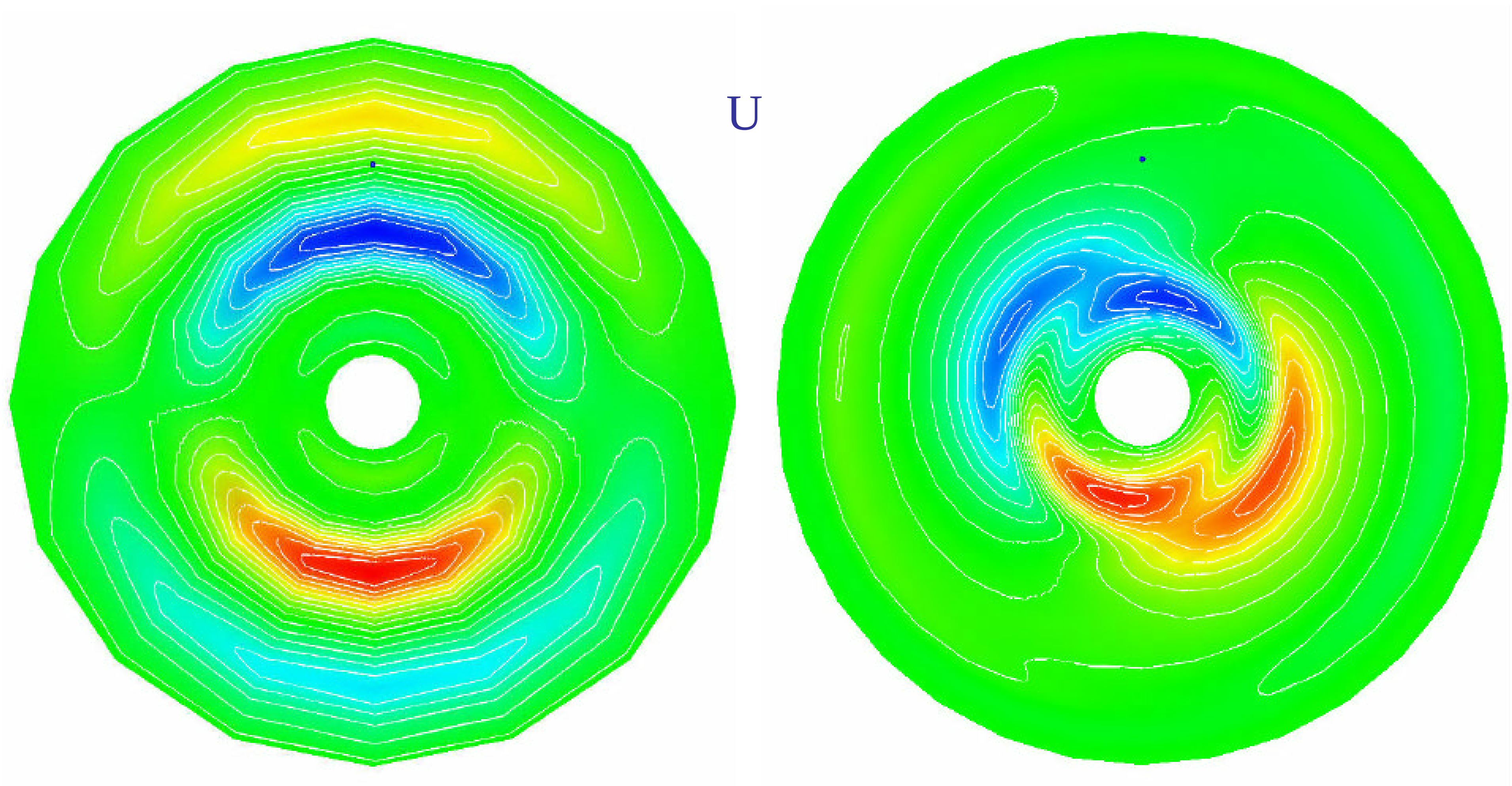


Linear Eigenmodes

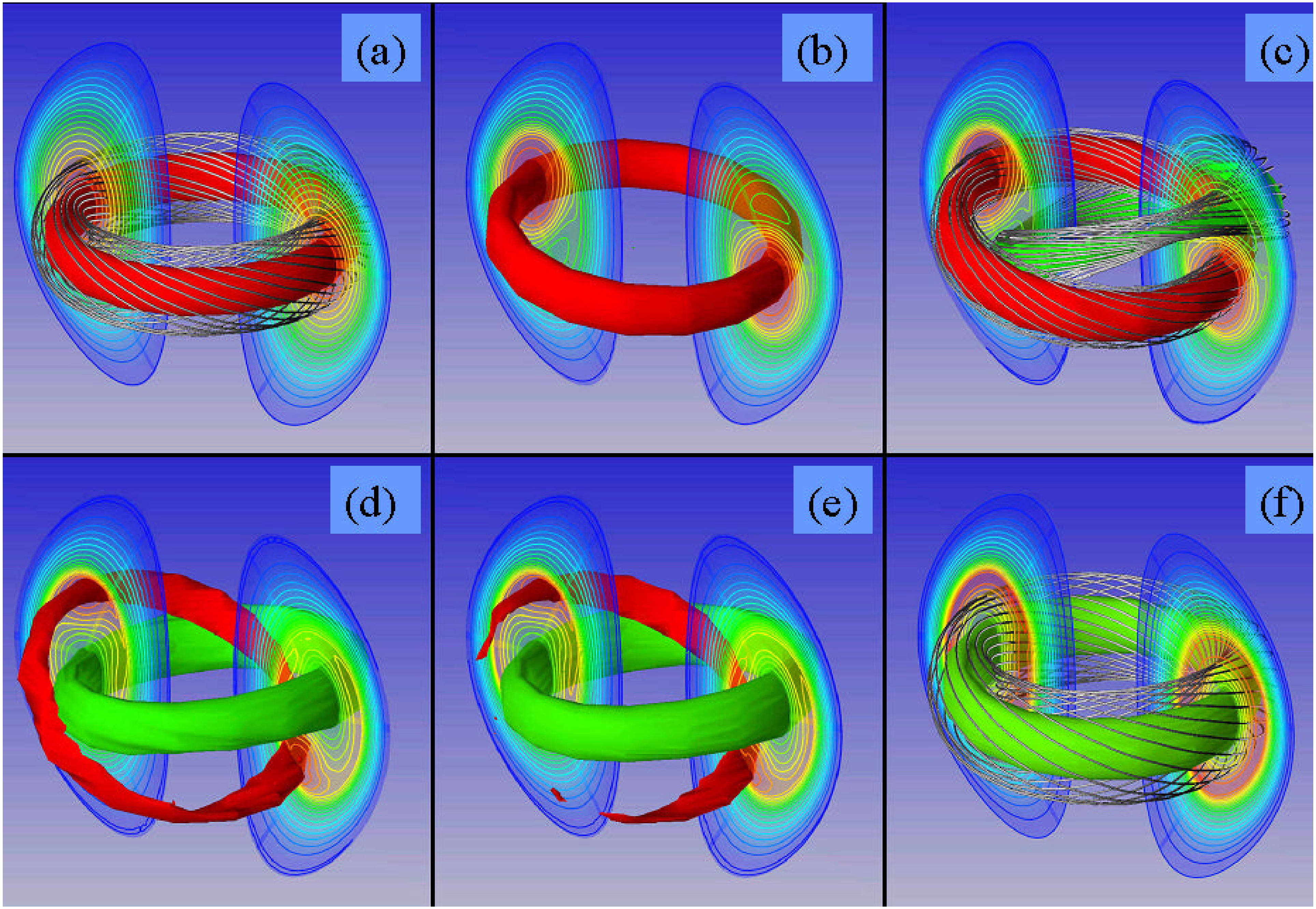
Top view on the mid-plane

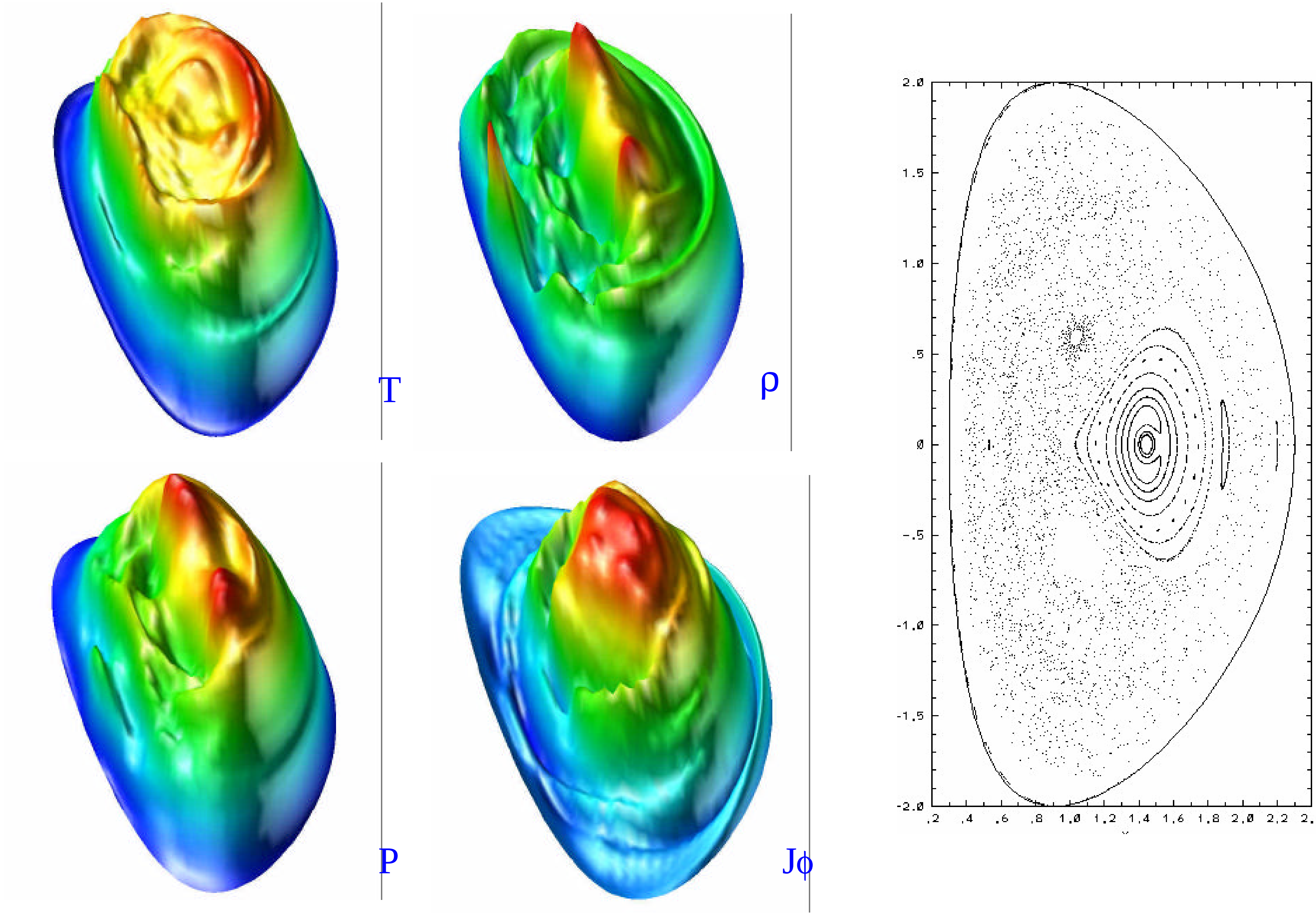
$M_A=0$
$\Omega_m=0$

With shear flow: $M_A=0.2$
Rotating mode: $\Omega_m=0.13$



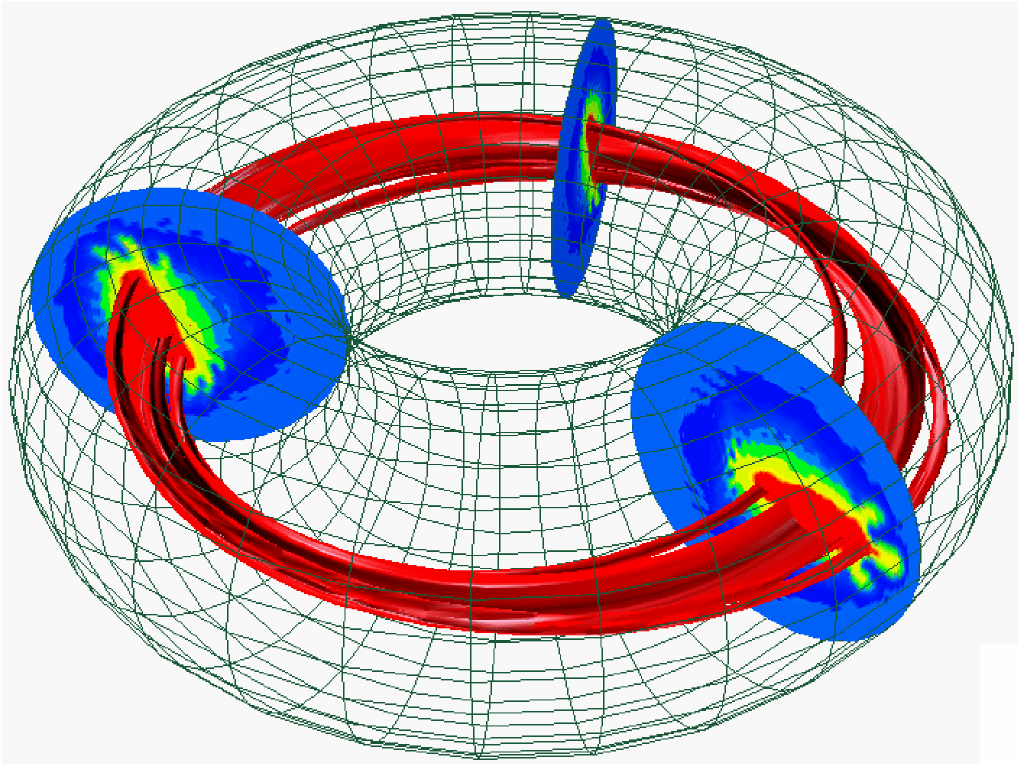
Nonlinear Evolution without strong flow: similar to a sawtooth crash



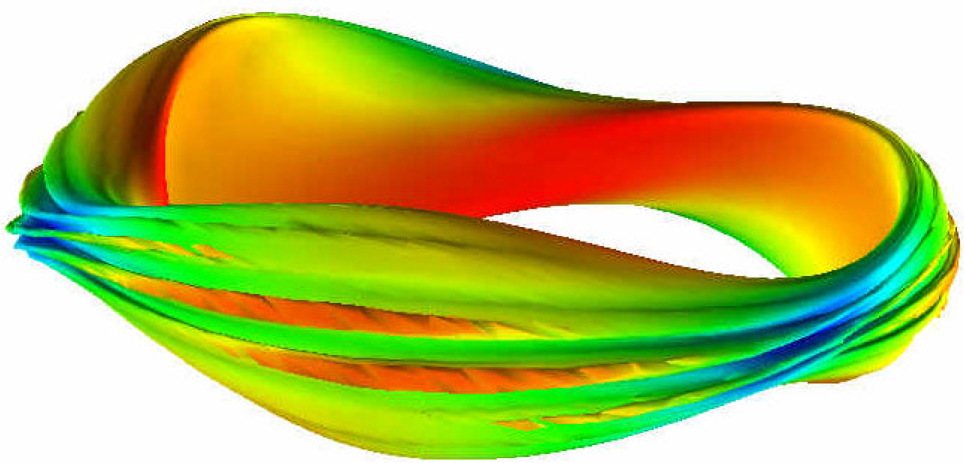

T
ρ
P
Jϕ
2.0
1.5
1.0
.5
0
-.5
-1.0
-1.5
-2.0
.2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8 2.0 2.2 2.4

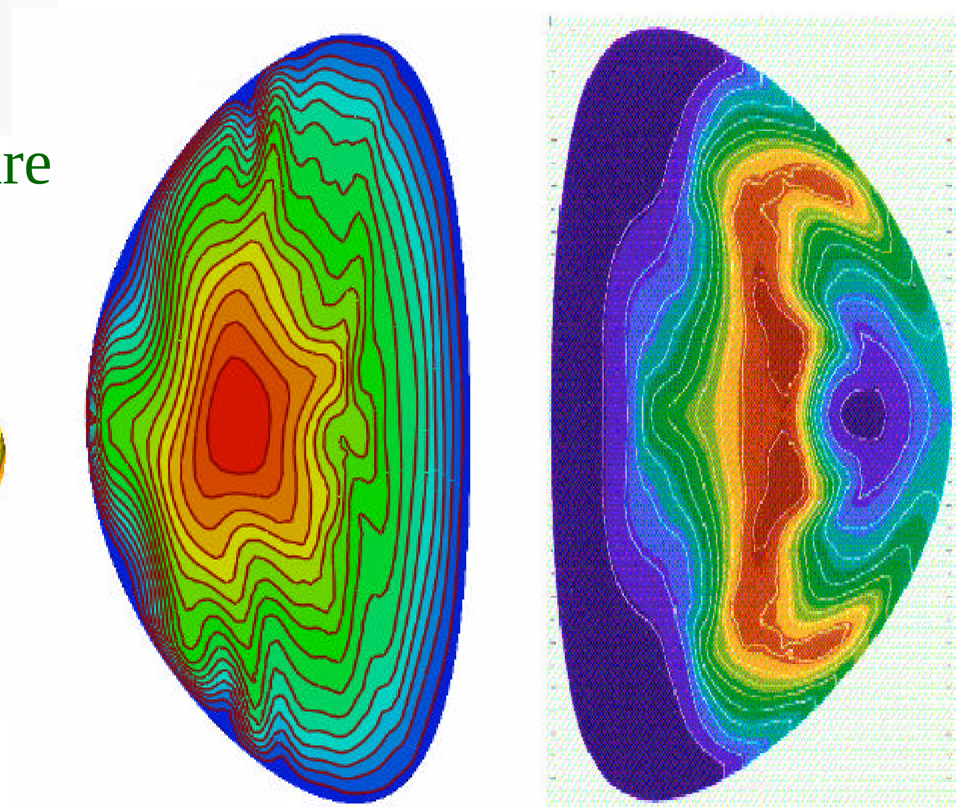
IRE : Disruption

•Stochasticity as shown before.
•Localized steepening of pressure driven modes as shown here.

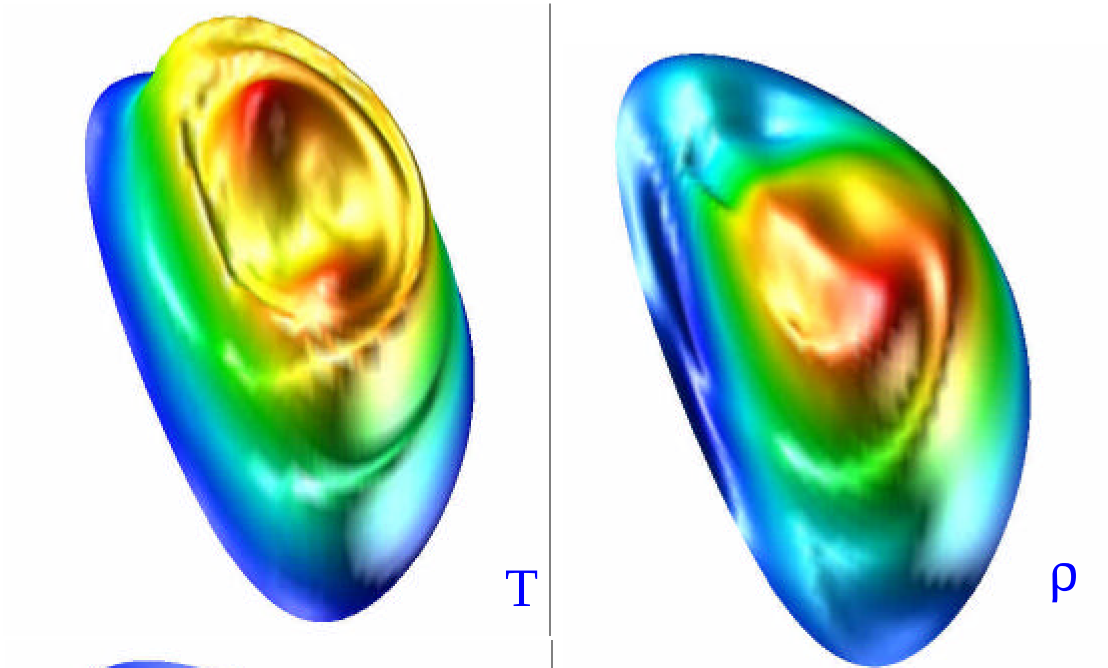


Pressure



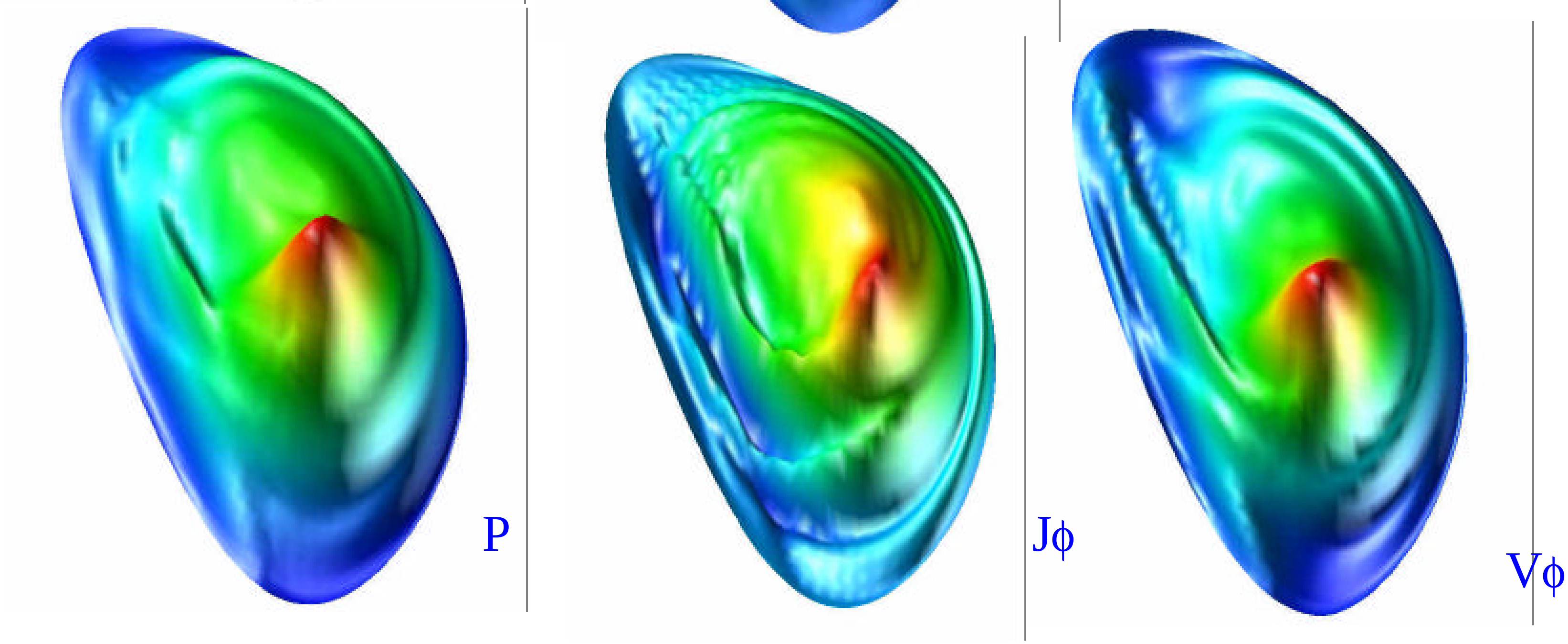


Nonlinear Evolution with peak rotation of M_A=0.2

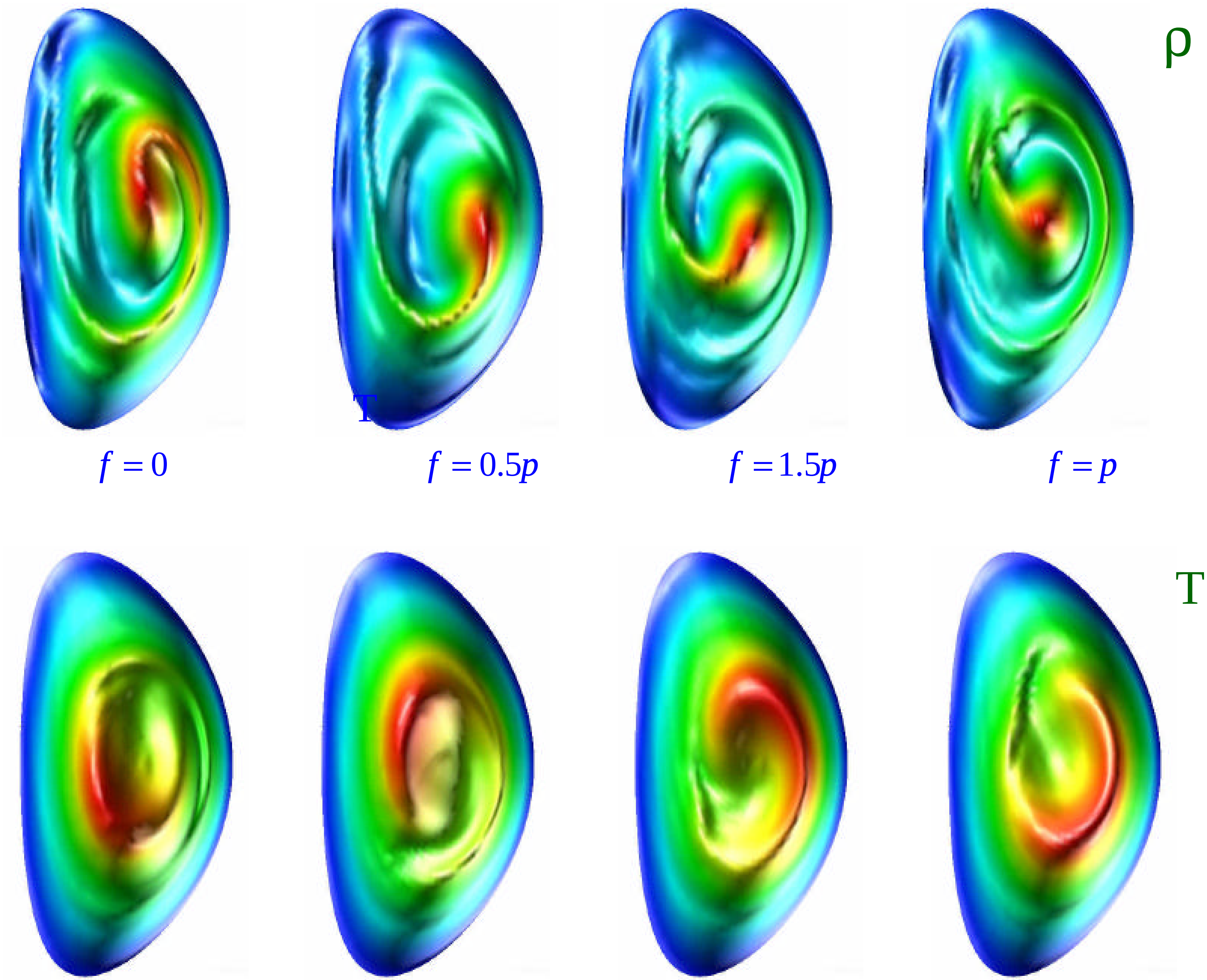


Vϕ profile evolves
with reconnection

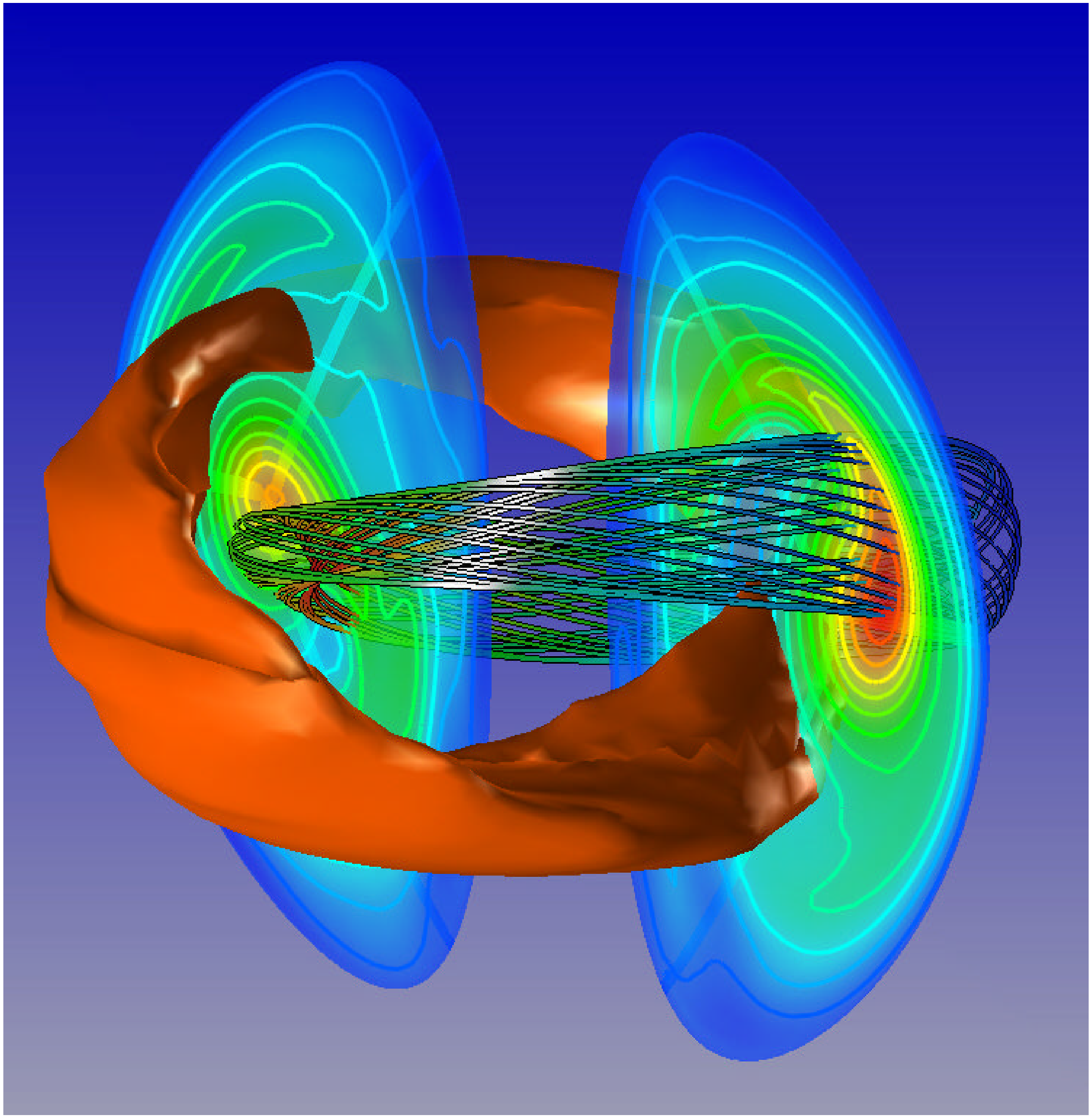
Momentum source rate
is an important factor



ρ (P) and T out of phase



Saturated steady state with strong sheared flow



B Field line
in the island
Density (Pressure)
contours
Temperature
isosurface

Pressure peak inside the island together with shear flow causes the mode saturation.

EPM (BAE) is excited at high beta in Hybrid simulations

More coupling to sound wave due to stronger curvature and high beta.

May explain experimental data.

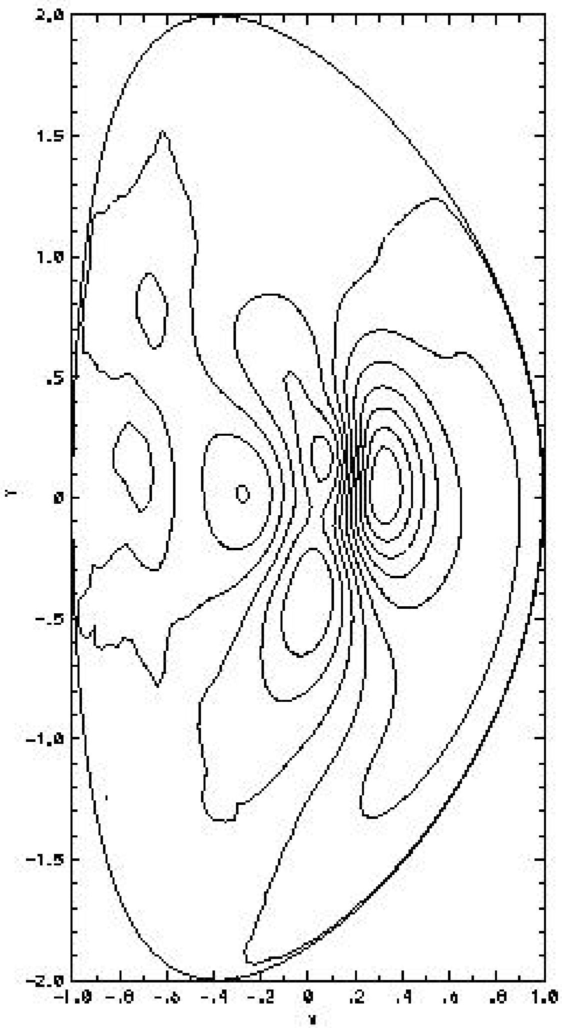
TAE

total=3.8%

h=3.8%

=0.327

=0.013



BAE

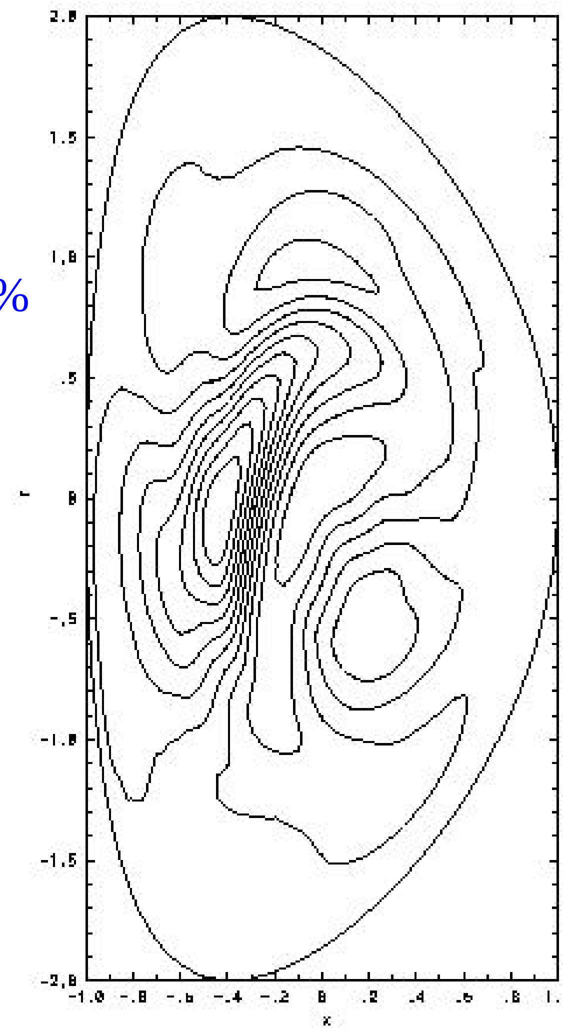
total=28%

h=3.8%

=0.067

=0.007

U



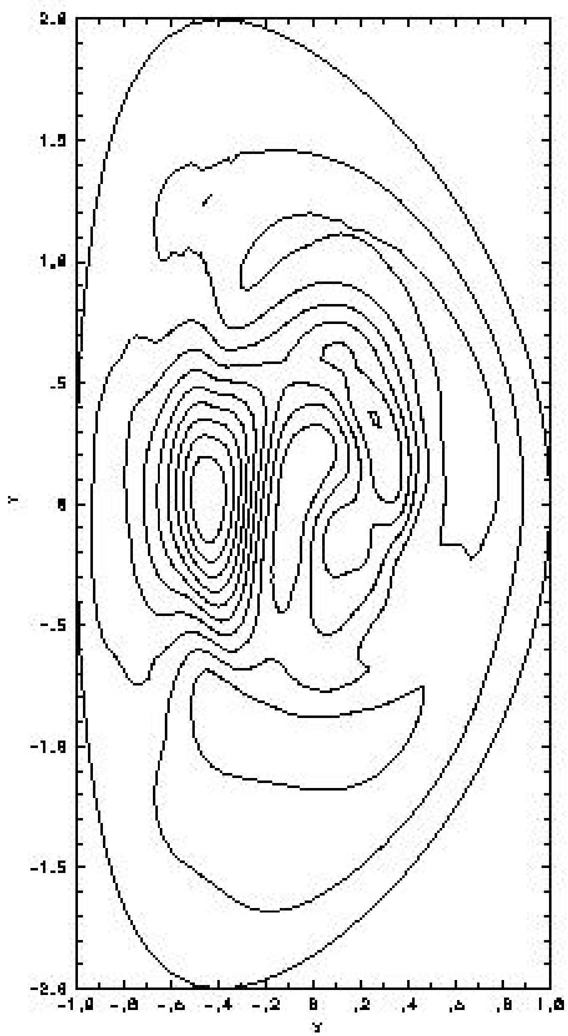
BAE changes to TAE when Γ is set to zero

BAE

Γ=1.666

=0.05

=0.003

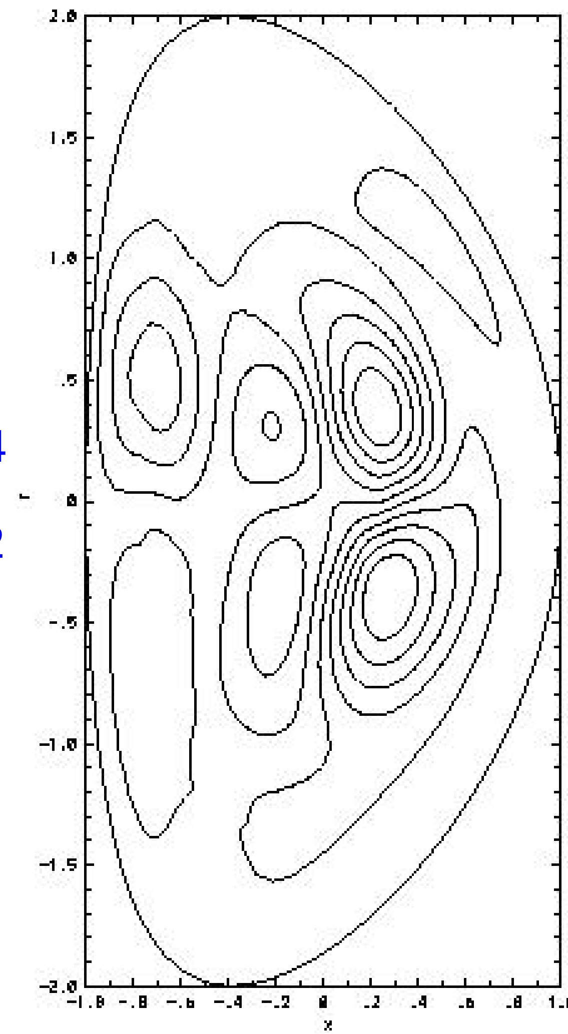


TAE

Γ=0

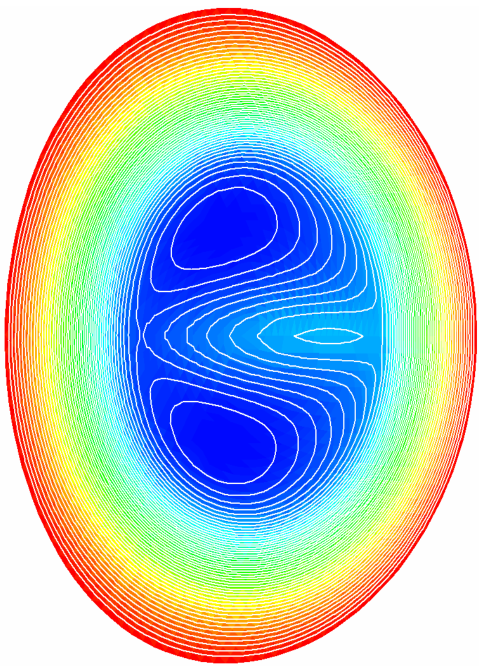
=0.24

=0.02

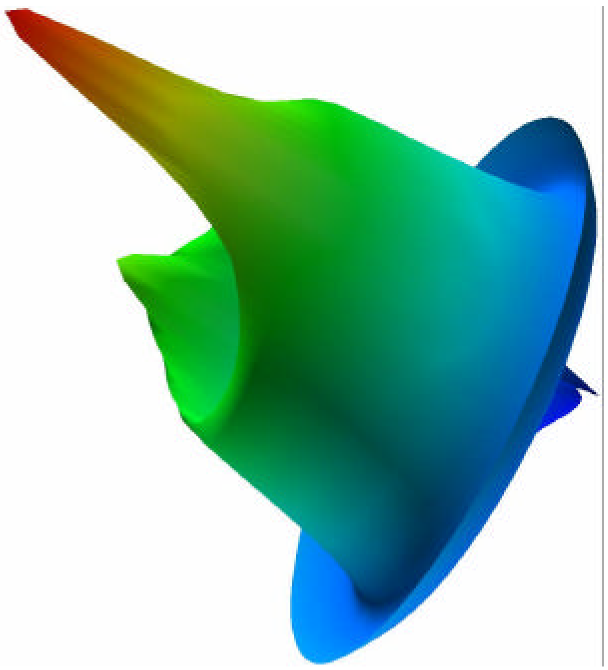


Current Hole phenomena

- Off-axis current drive applied
- Central current density was clamped by axisymmetric sawteeth



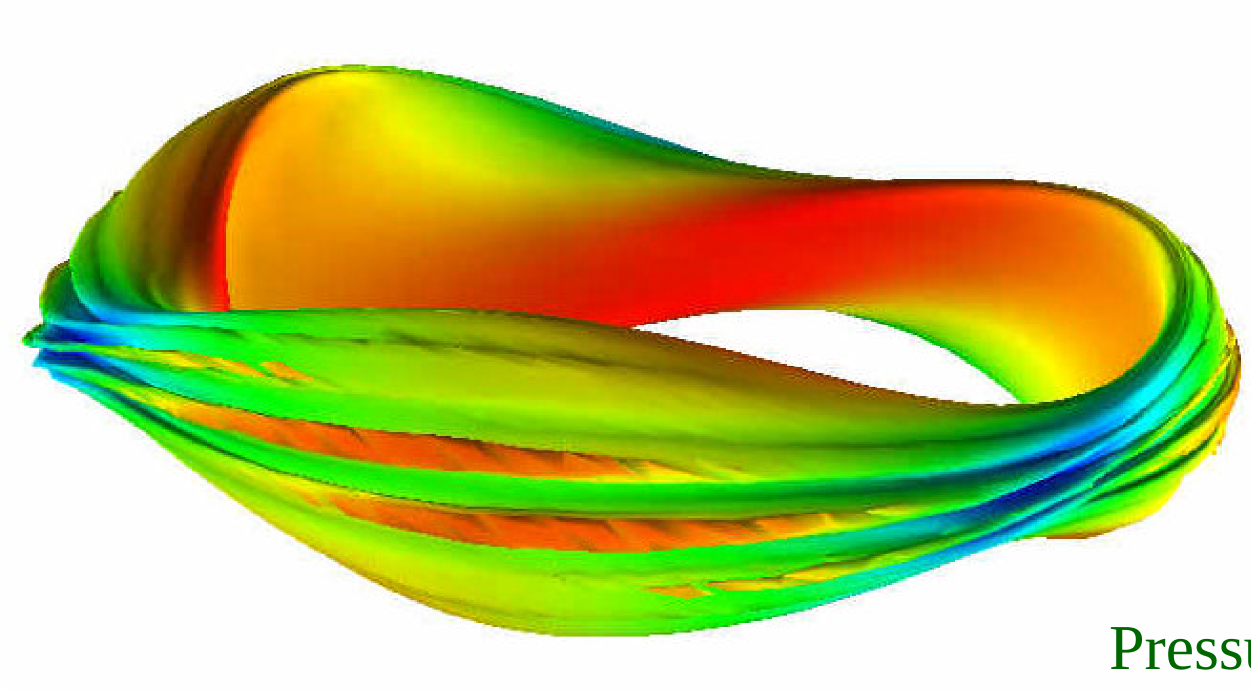
Poloidal flux,
$t = 22.5\, t_A$



Toroidal current density,
$t = 22.5\, t_A$

Stellarator nonlinear ballooning mode

At β=8%, disruption can occur due to localized steepenings of pressure driven modes.



Pressure

Two-fluid effects seem to stabilize the resistive modes. May explain the absence of resistive modes in experiments.

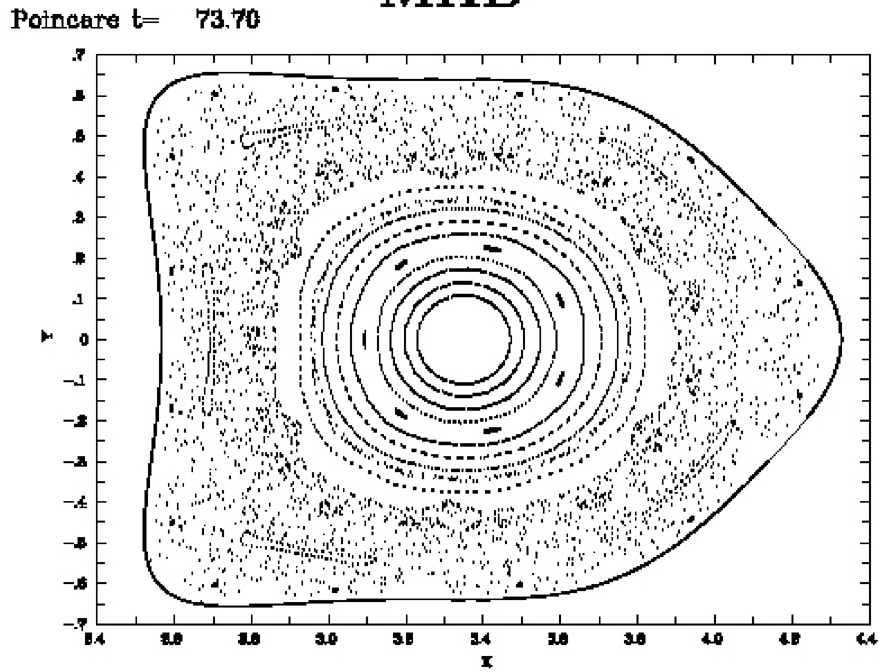
$h = c/(\ \ _{pi}R)$

$^{*}\ \ _{A} = hn(\ \ _{p}a/2qL_{p})$

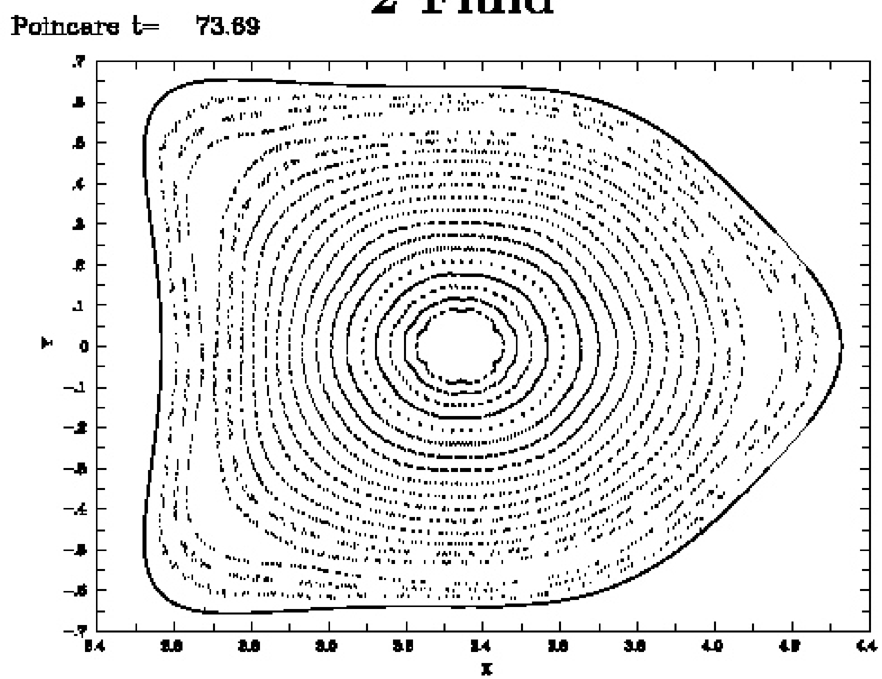
β=4%

ω* stabilization is more effective for higher *n* modes which tend to be dominant in stellarators. This may also give substantially higher ideal beta limit.

MHD



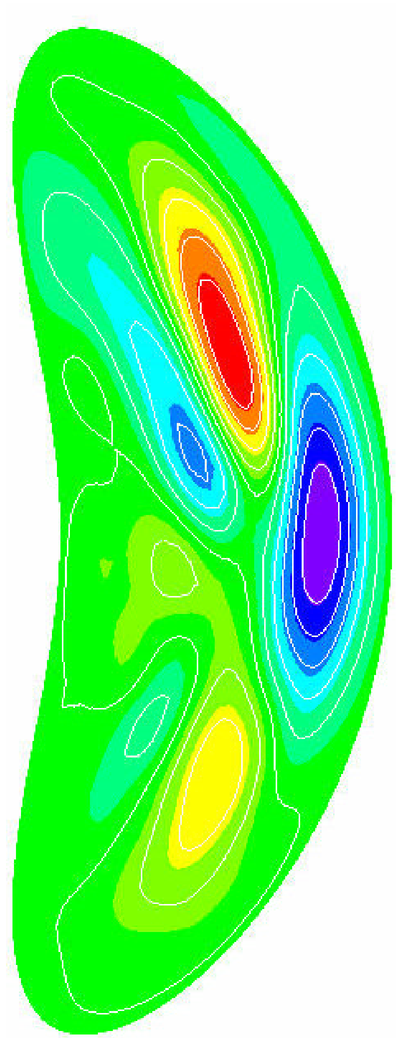
2 Fluid



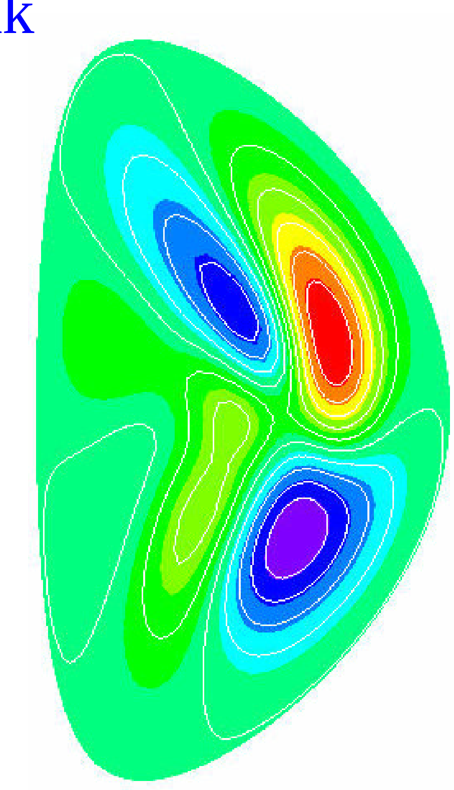
TAE Modes in Stellarators in Hybrid simulations

A 2-period QAS stellarator case is compared
to the case when the 3D shape is suppressed.

Stellarator



Tokamak



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Summary

- Continue simulation studies of NSTX using MHD, Two-fluid (ω*, Hall, NC), and Particle/Fluid hybrid models.
- Better parallel efficiency, more efficient numerical methods, such as dynamic meshes,…

  Ion collisions. Better electron fluid closures; NC, Landau.
- Resistive wall and coils: CHI, RWM, Feedback.
- For EFIT initial condition, would like to have more accurate profiles especially the q profile.

  For comparison of modes, would like to have high digitation rate local measurements, such as EBW.