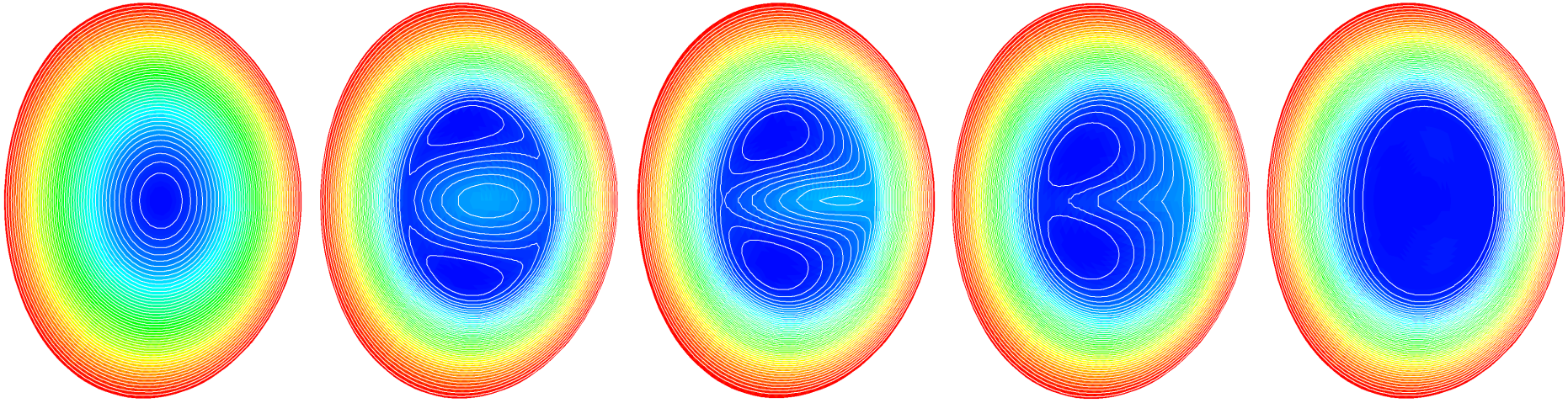
Previous M3D Study of Current hole with negligible β

Result: *n*=0 reconnection (axisymmetric sawtooth).

Breslau et al. (to appear Phys.Plasmas 2003)

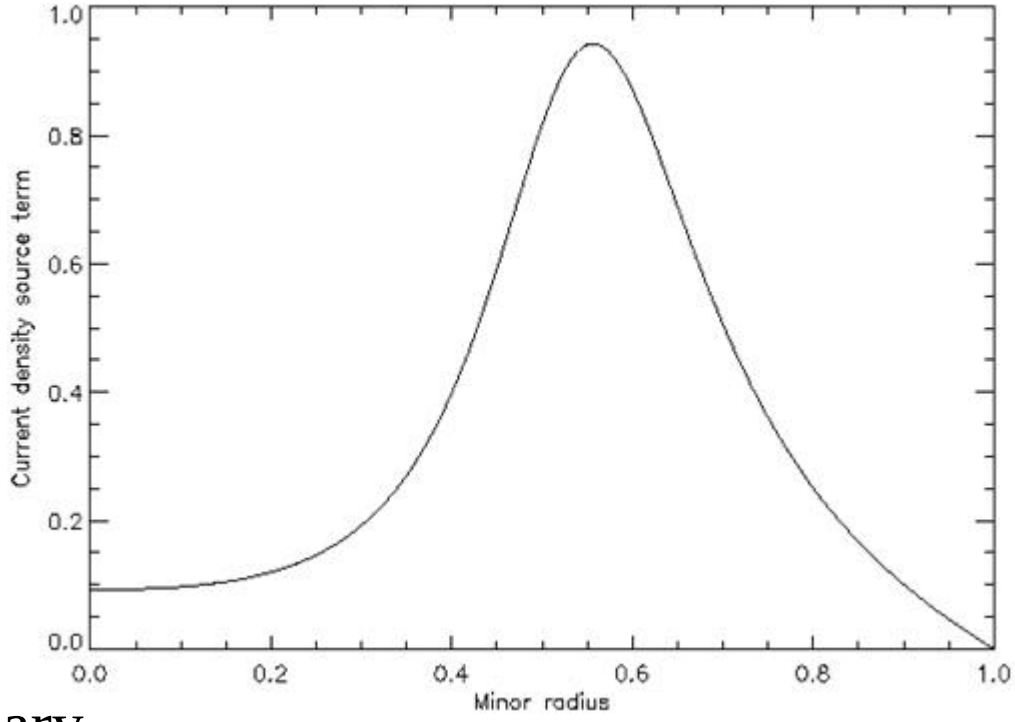
Poloidal flux contours:



The Analytic Current Drive Term

$$J_{CD}(r) = c_1 + c_2 r^2 \left[\frac{1 - c_3 r^2}{c_4^2 + (r - c_5)^2} \right]$$

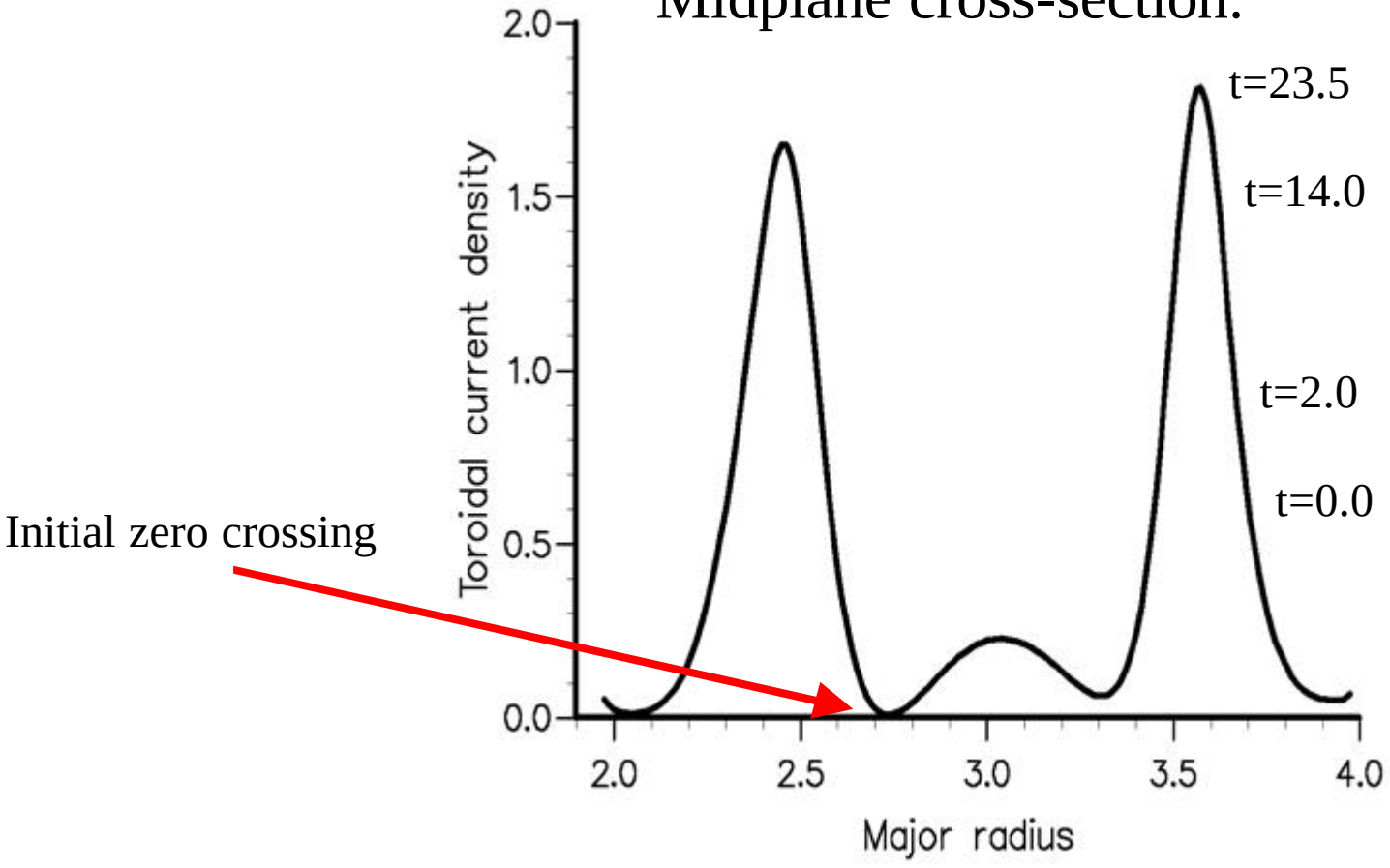
c_1=0.092
c_2=0.1003
c_3=1.214924
c_4=0.15
c_5=0.54



Drive term is finite on axis, peaked off-axis, zero at boundary.

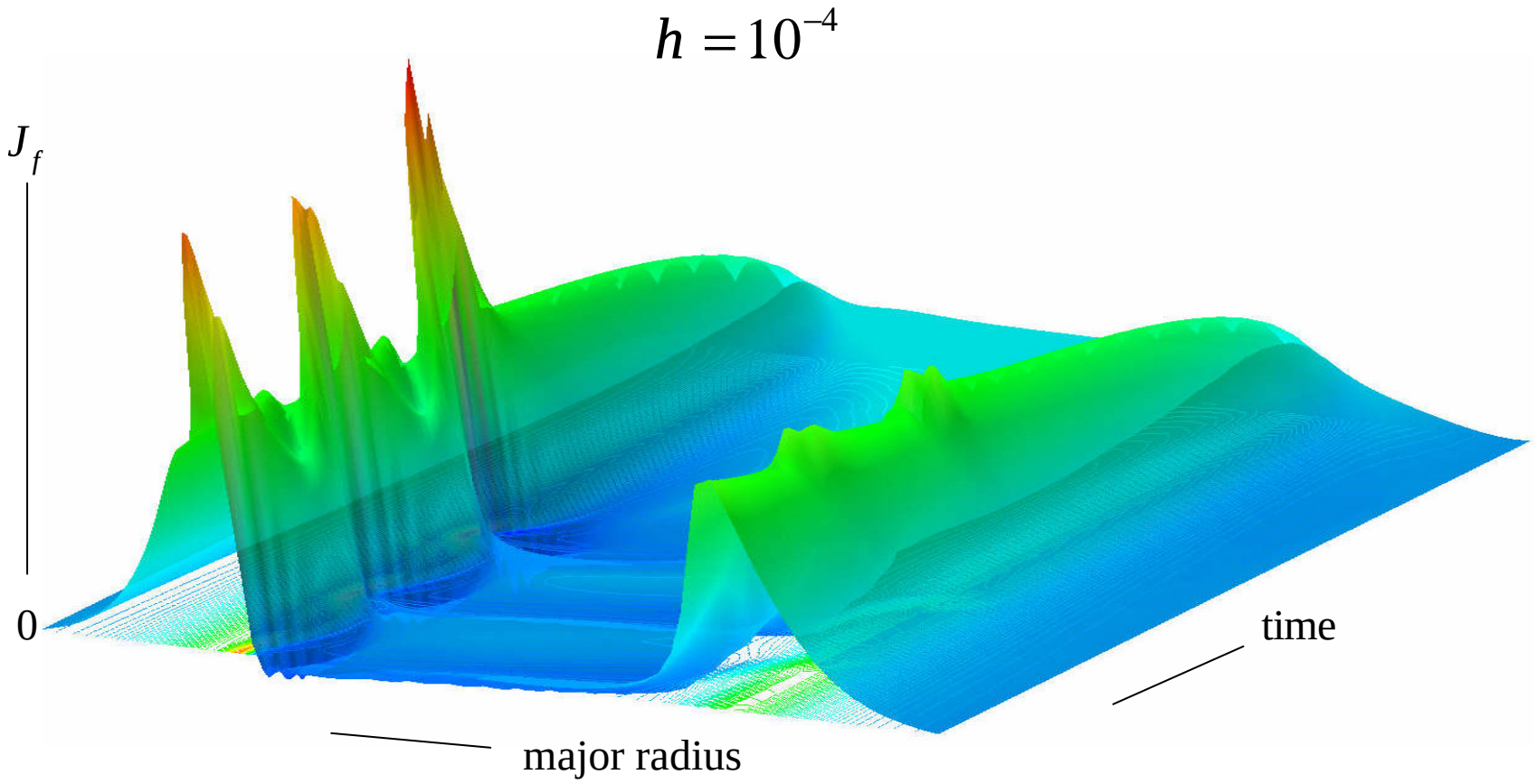
Current Goes Negative Off-Axis First

Midplane cross-section:



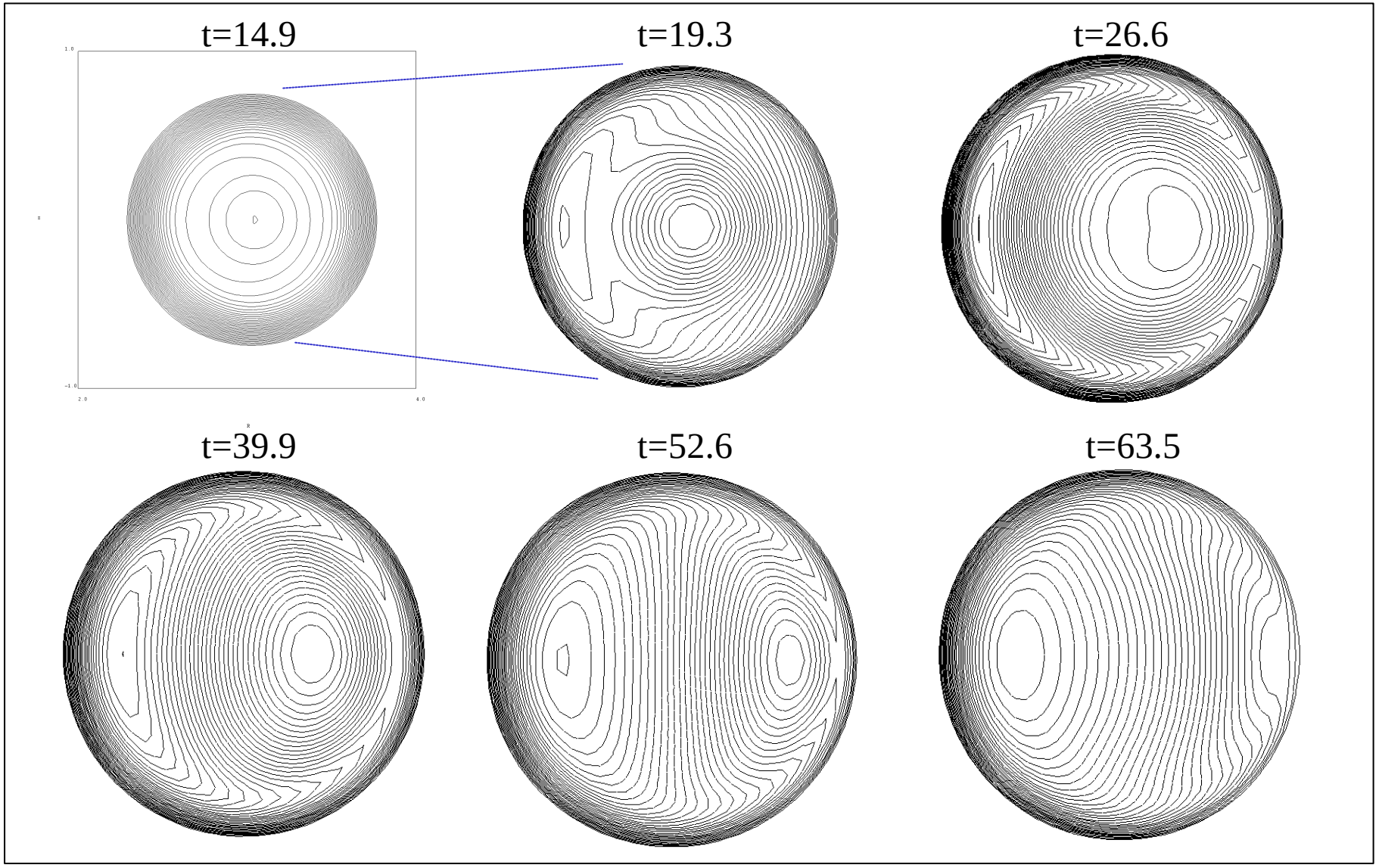
- $q=\infty$ surface appears soon afterward, when **net current** enclosed by surface is zero.

Current Density History at Midplane



- Repeated n=0 reconnection events keep current clamped near zero in core region.

Reconnection with Circular Cross-Section is Pure m=1



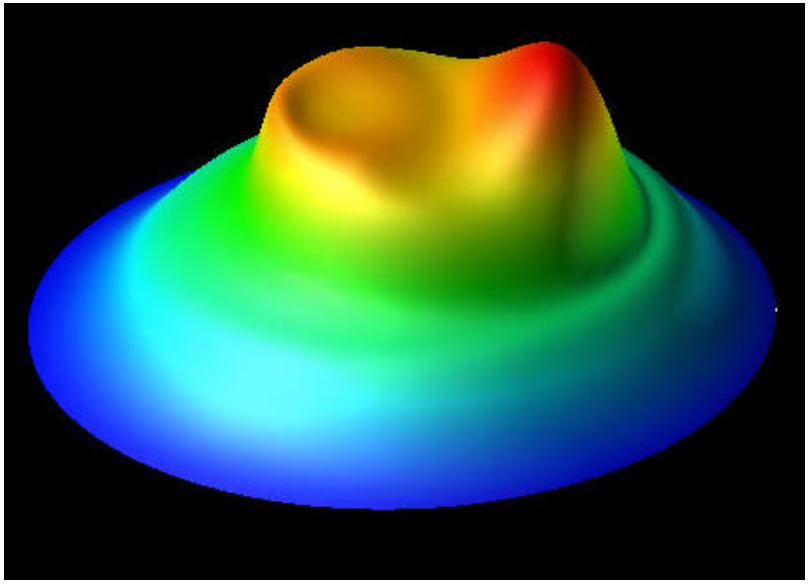
Finite β effects

MHD

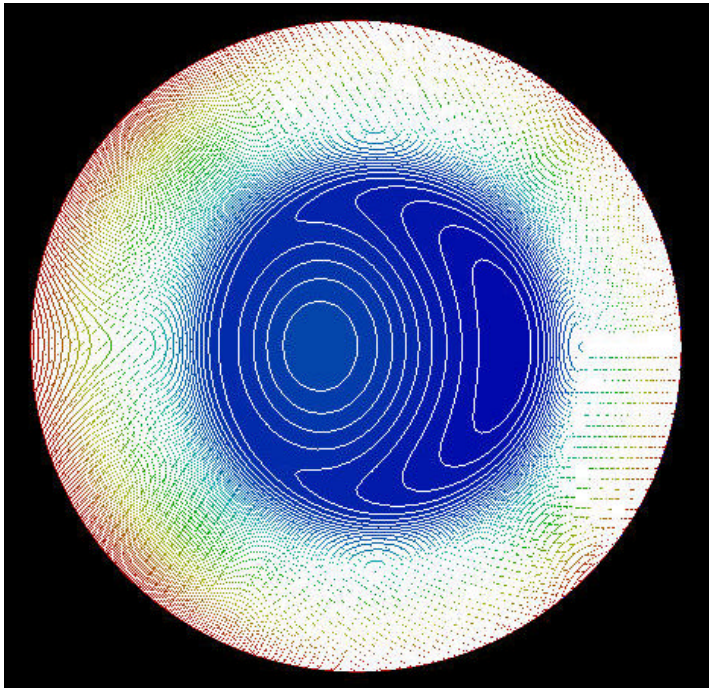
With a peak β of 1 %, the n=0 sawtooth mode can saturate due to pressure peaking in the island.

The physical reason is analogous to similar n=1 mode saturation cases. A complete reconnection would mean the high pressure island region moving inbord, which is energetically unfavorable.

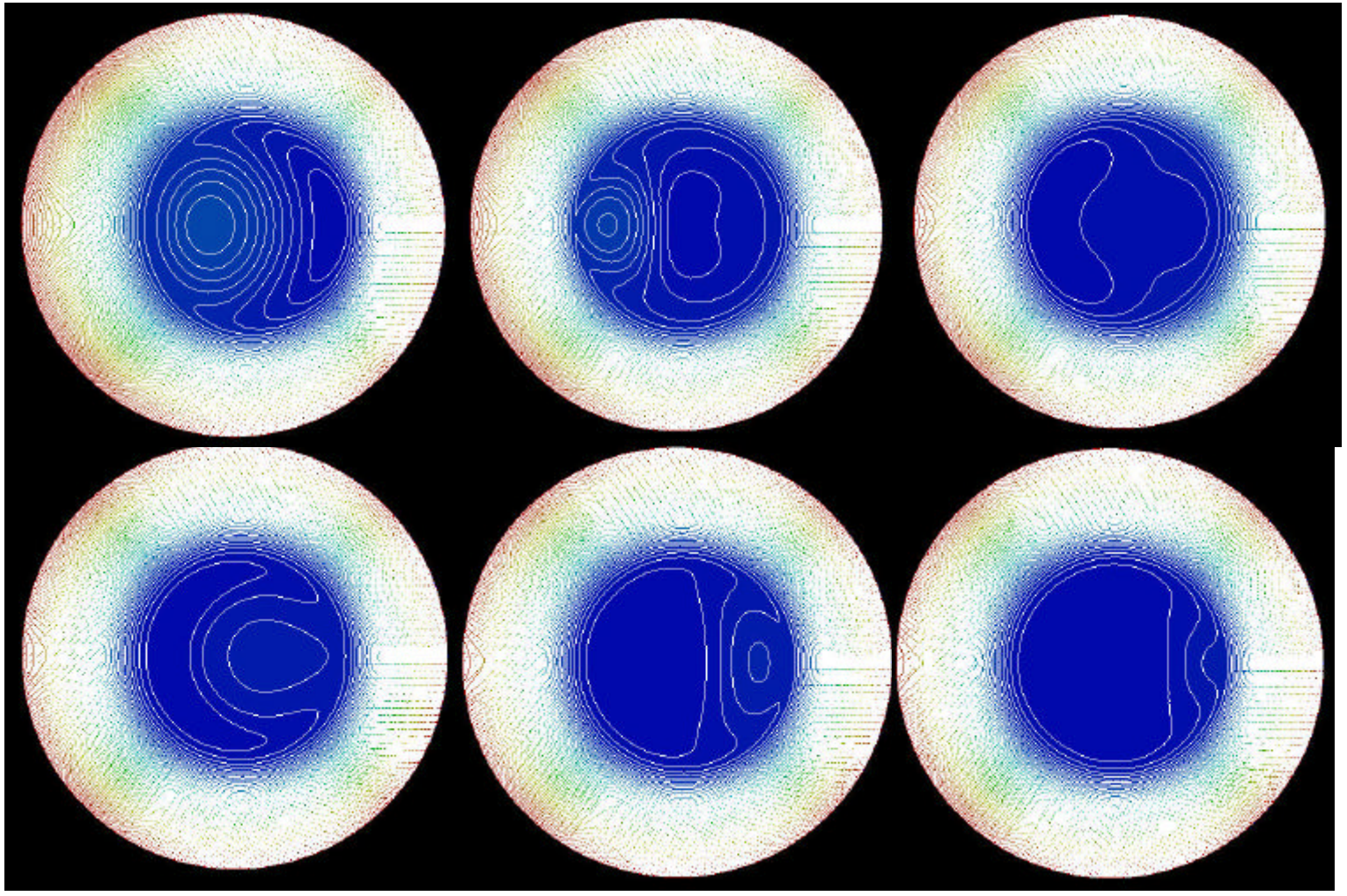
Pressure



Flux



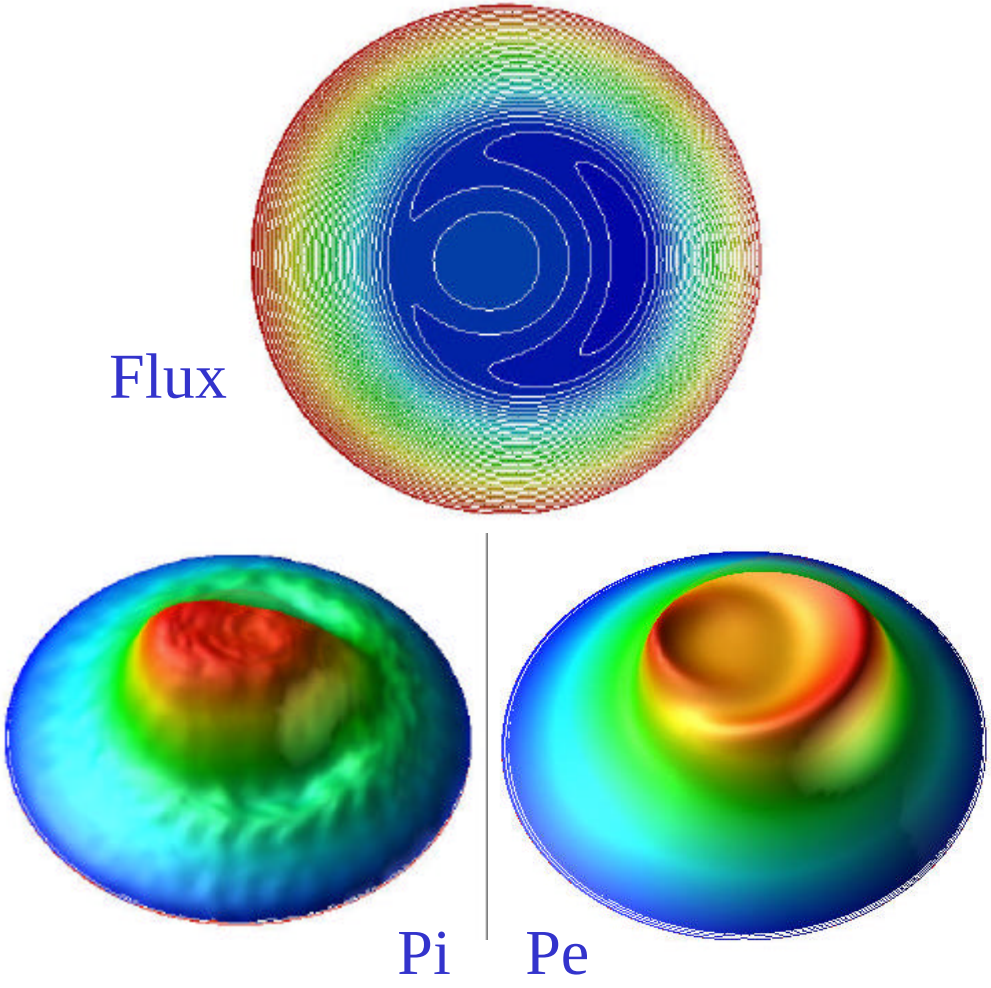
When the pressure is reduced, the state went through complete reconnections, showing that the saturation is in fact due to finite β effect.



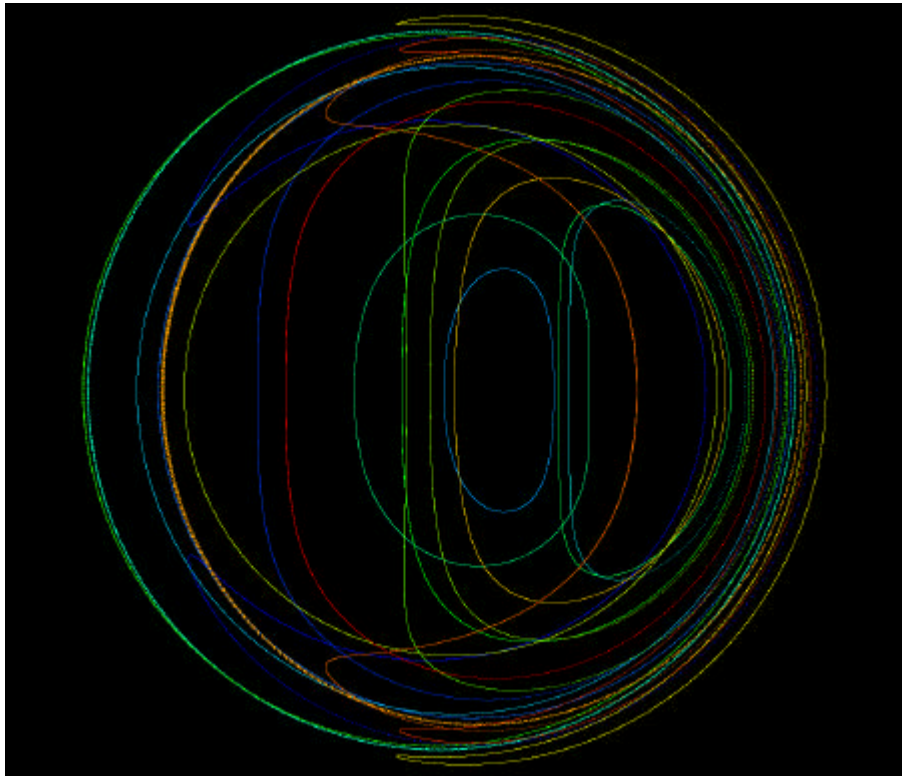
Flux

Ion-drift kinetic particles/MHD

Similar behavior as MHD, i.e., saturation due to pressure peaking in the island.



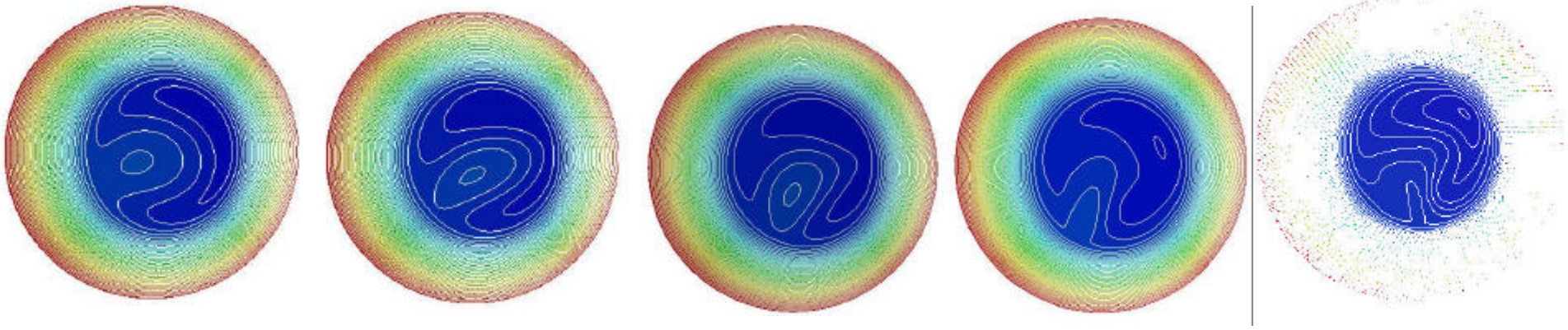
C.f., ion orbits with E=0



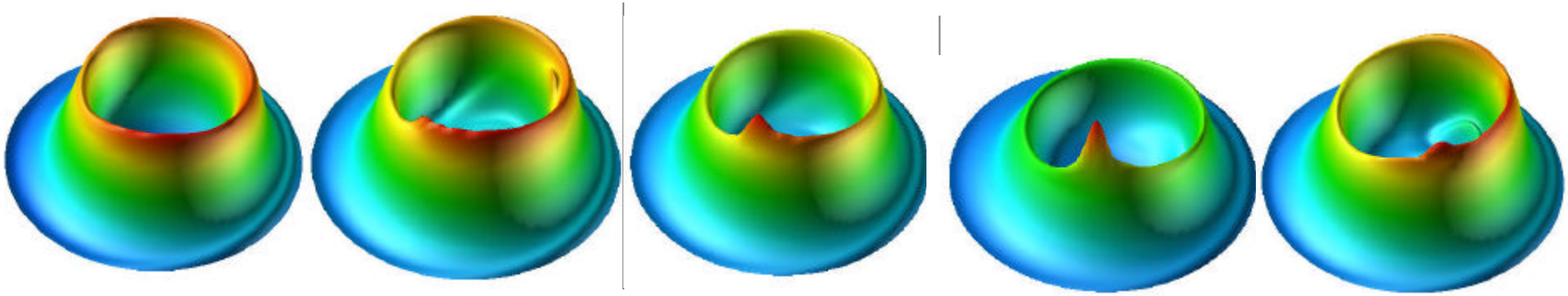
Two-Fluids

The mode rotates in ω^*_i direction and eventually goes through complete reconnection with Pe~Pi.
(With Pe=0.9 P_{tot}, it rotate in ω^*_e direction.)

Flux



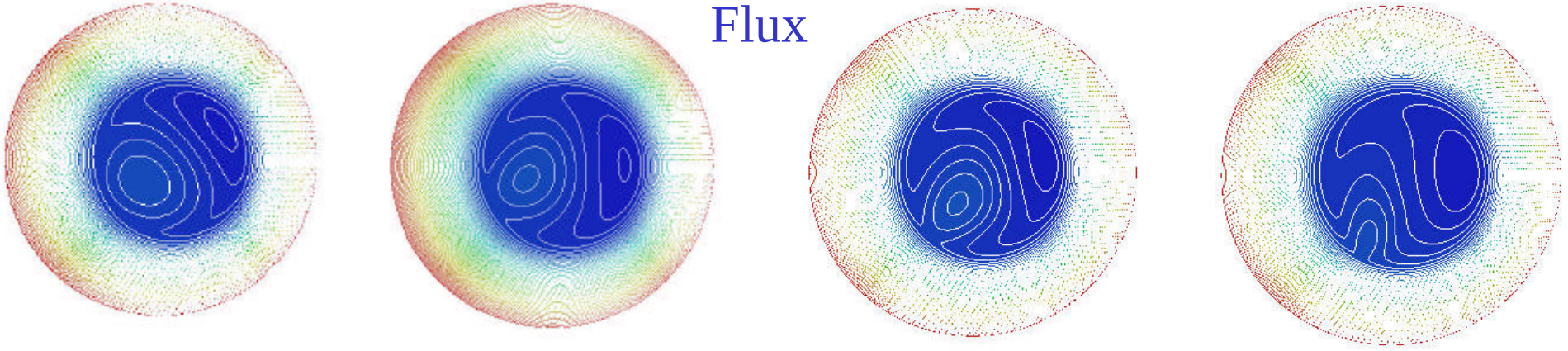
Toroidal current



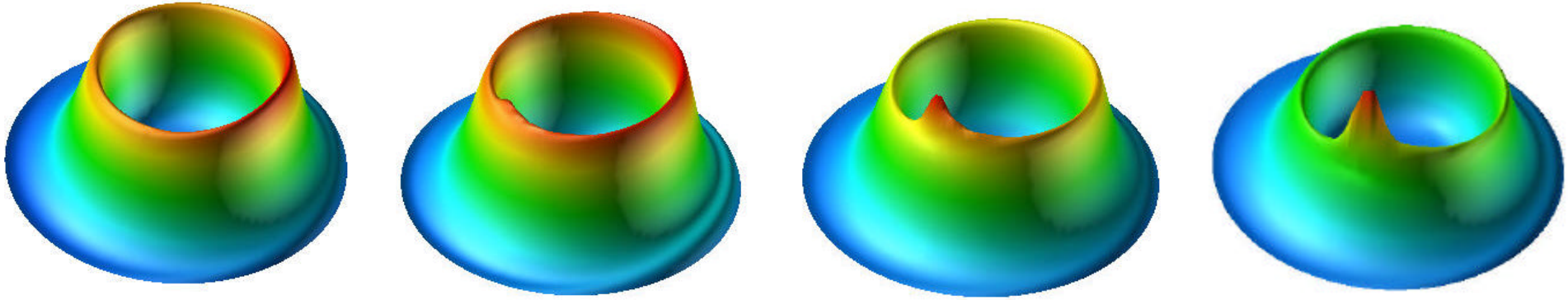
MHD with an initial rotation of the mode is sufficient to induce a fast reconnection.

This indicates that the initial rotation due to ω_{*i} is all that is needed for complete reconnection for the two-fluid case.

Flux

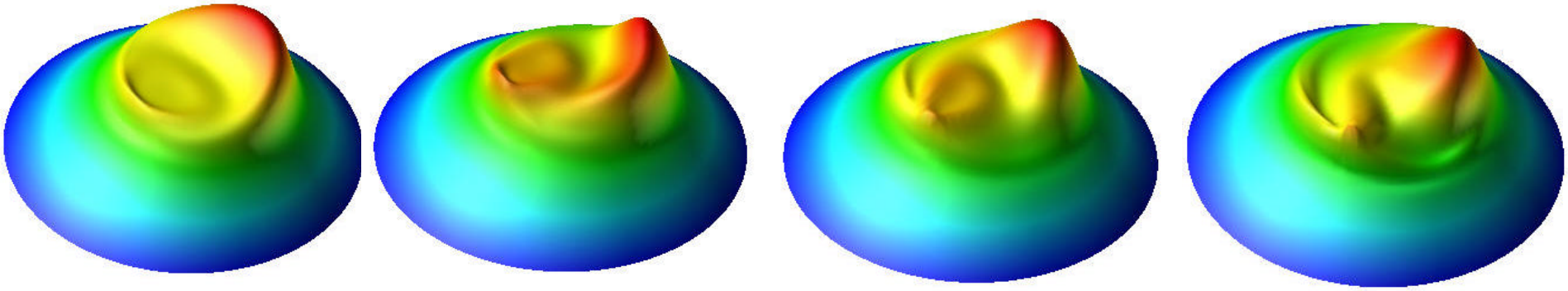


Toroidal current

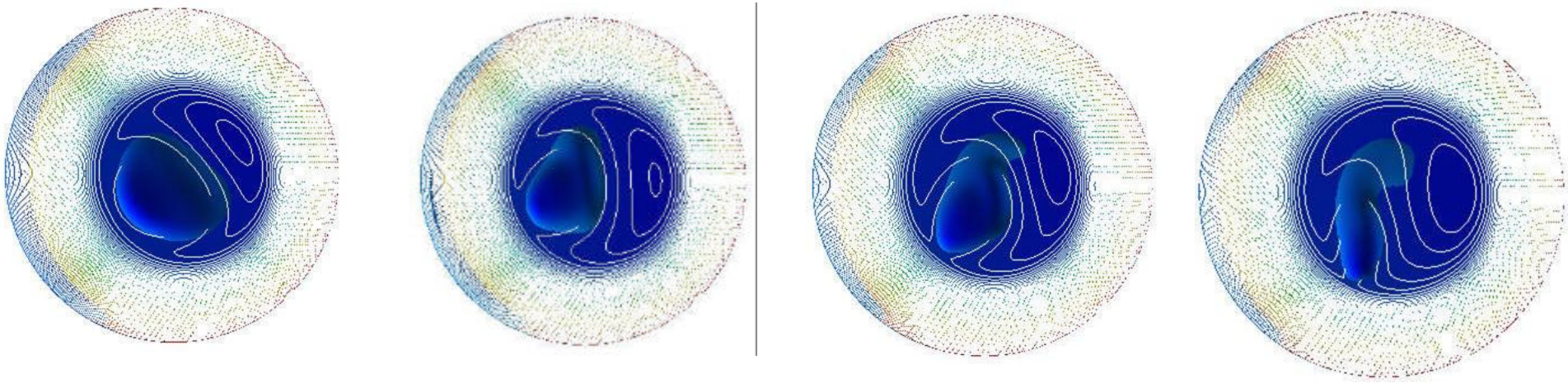


Pressure peak in the ilsand remains intact.
The negative current still disappears through a fast reconnection

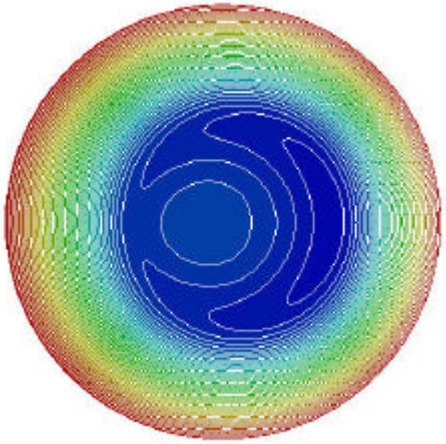
Pressure



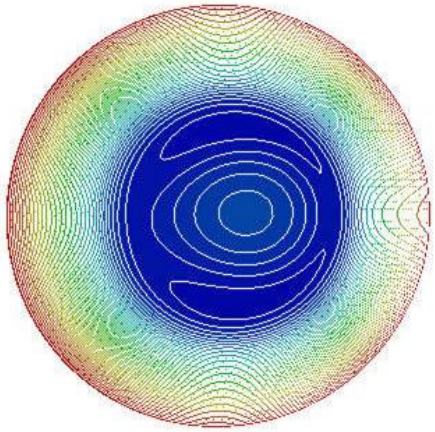
Flux with negative current

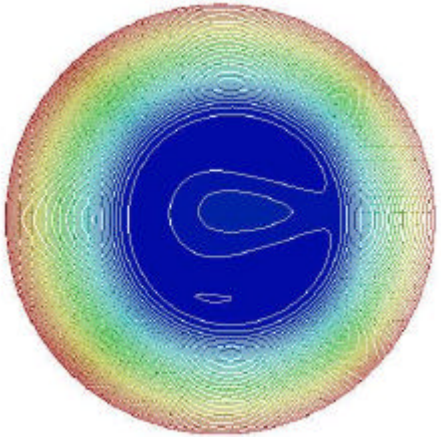


Longer time behavior Ion-drift kinetic particles/MHD

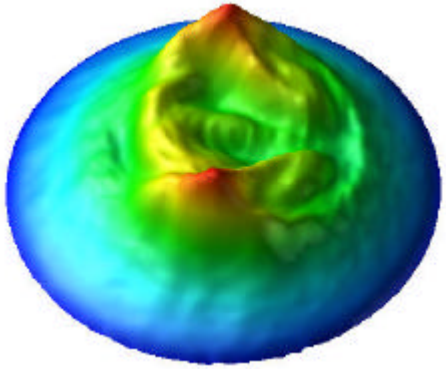


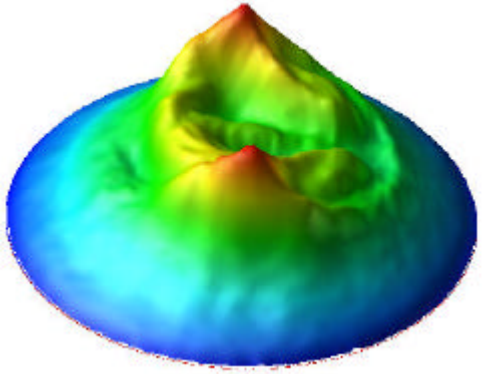
Flux



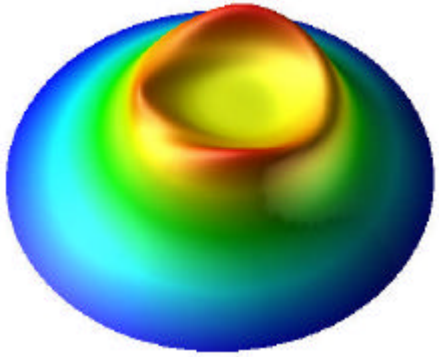


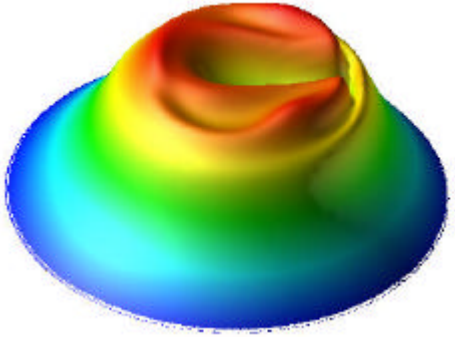
Pi





Pe





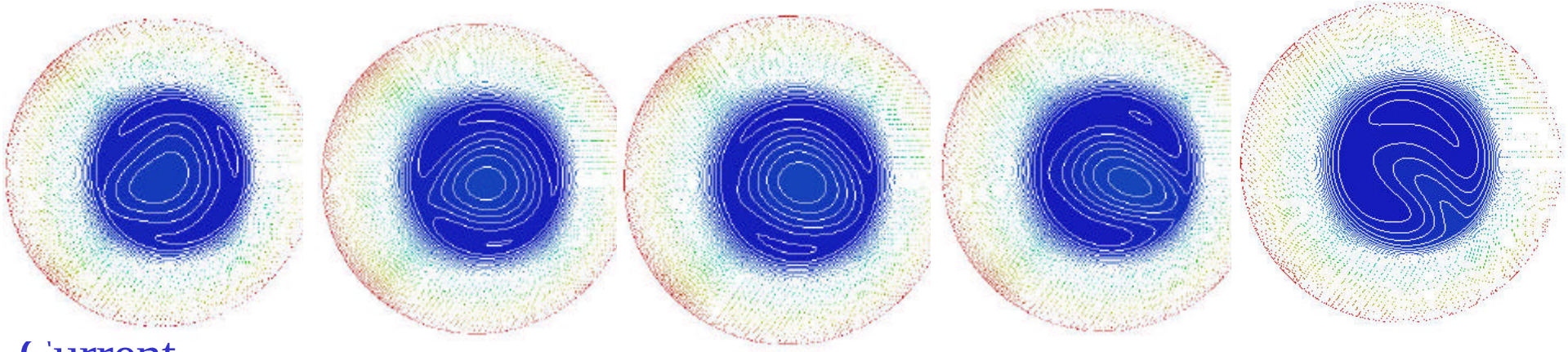
In a resistive time scale, topology changes and then, fast reconnection occurs.

Longer time behavior Two-fluids

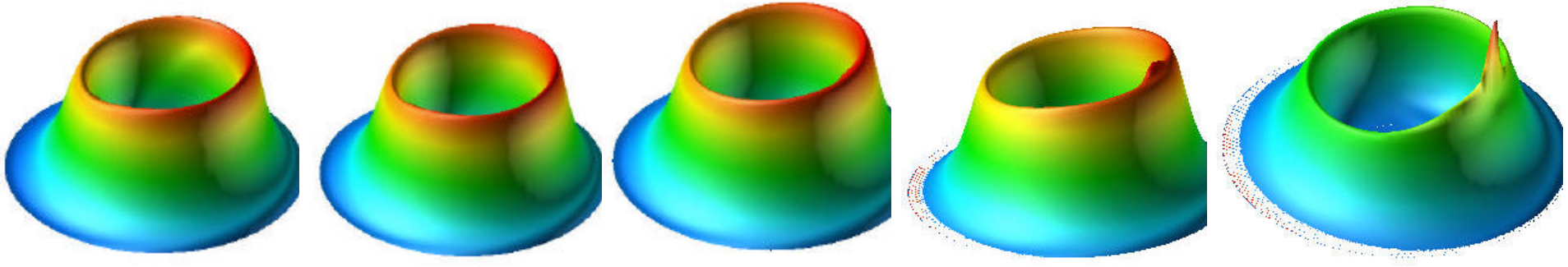
Successive crashes.

The following shows the next crash.

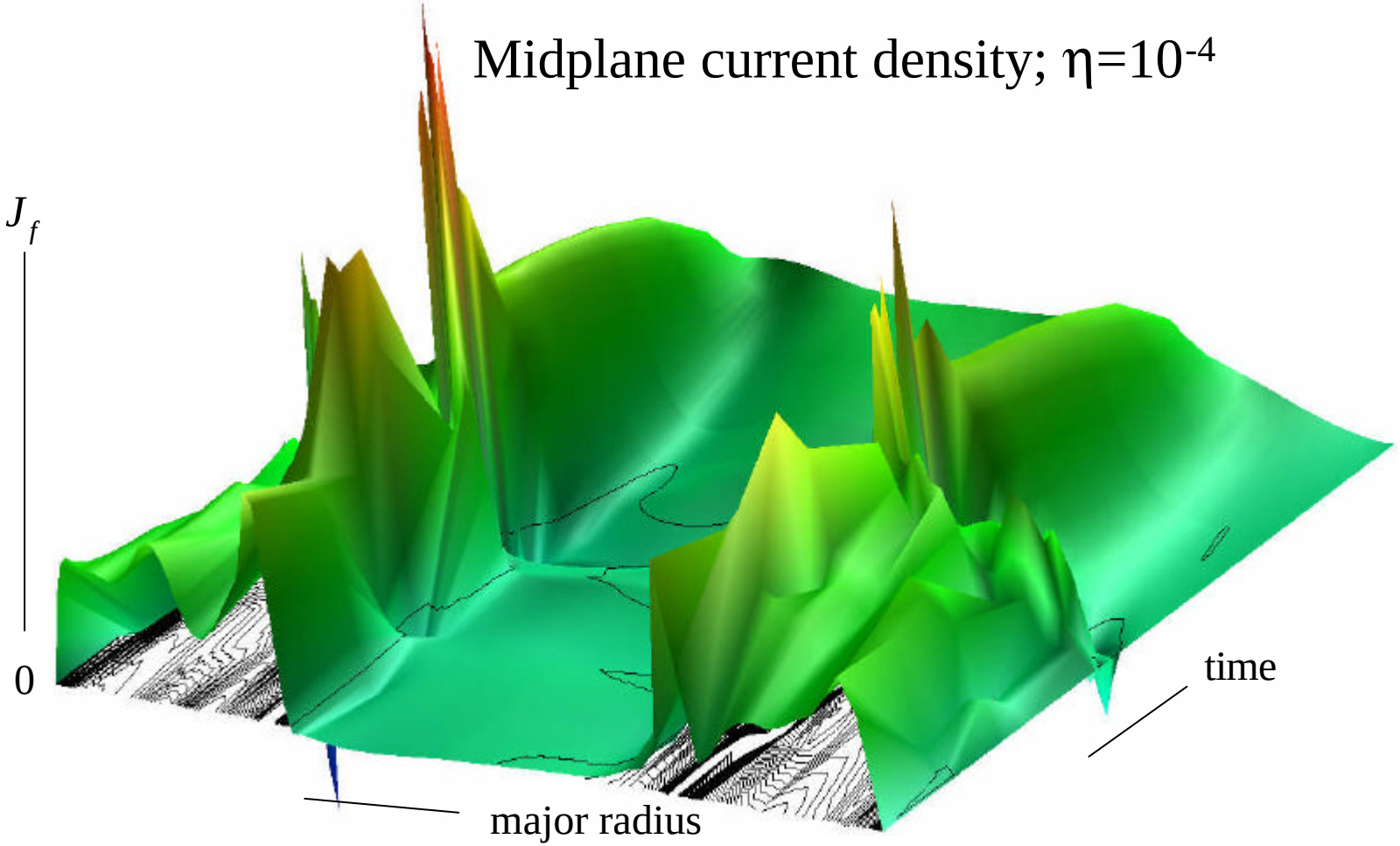
Flux



Current



Axisymmetric Sawtooth Persists in 3D



- n=0 reconnection still flattens current profile.
- Higher *n* modes develop as well.

Summary

- Breslau et al. found that n=0 sawteeth prevents current going substantially negative inside a current hole, for negligible β cases.

- Beta effects on current hole evolution

  With peak β of 1%, both MHD, and drift-kinetic-ion-particle/MHD gave mode saturation due to pressure peaking in the m=1 island.

  However, two-fluid model gives complete reconnection with mode rotation to ω*i direction.

  MHD with some initial mode rotaion resulted in a similar complete reconnection as the two-fluid case, indicating the mode rotation is the essential cause of the complete reconnection in the two-fluid case.

  For a longer time scale, the two-fluid model gives successive crashes.