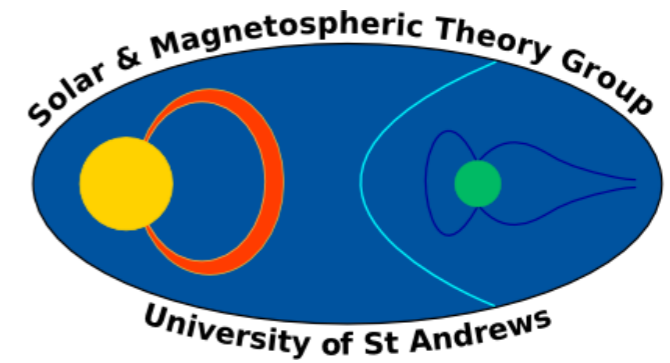




University of
St Andrews



Effects of dissipation and magnetic twist on the formation of the KHI in oscillating coronal loops

Thomas Howson

Ineke De Moortel

Patrick Antolin



Science & Technology
Facilities Council

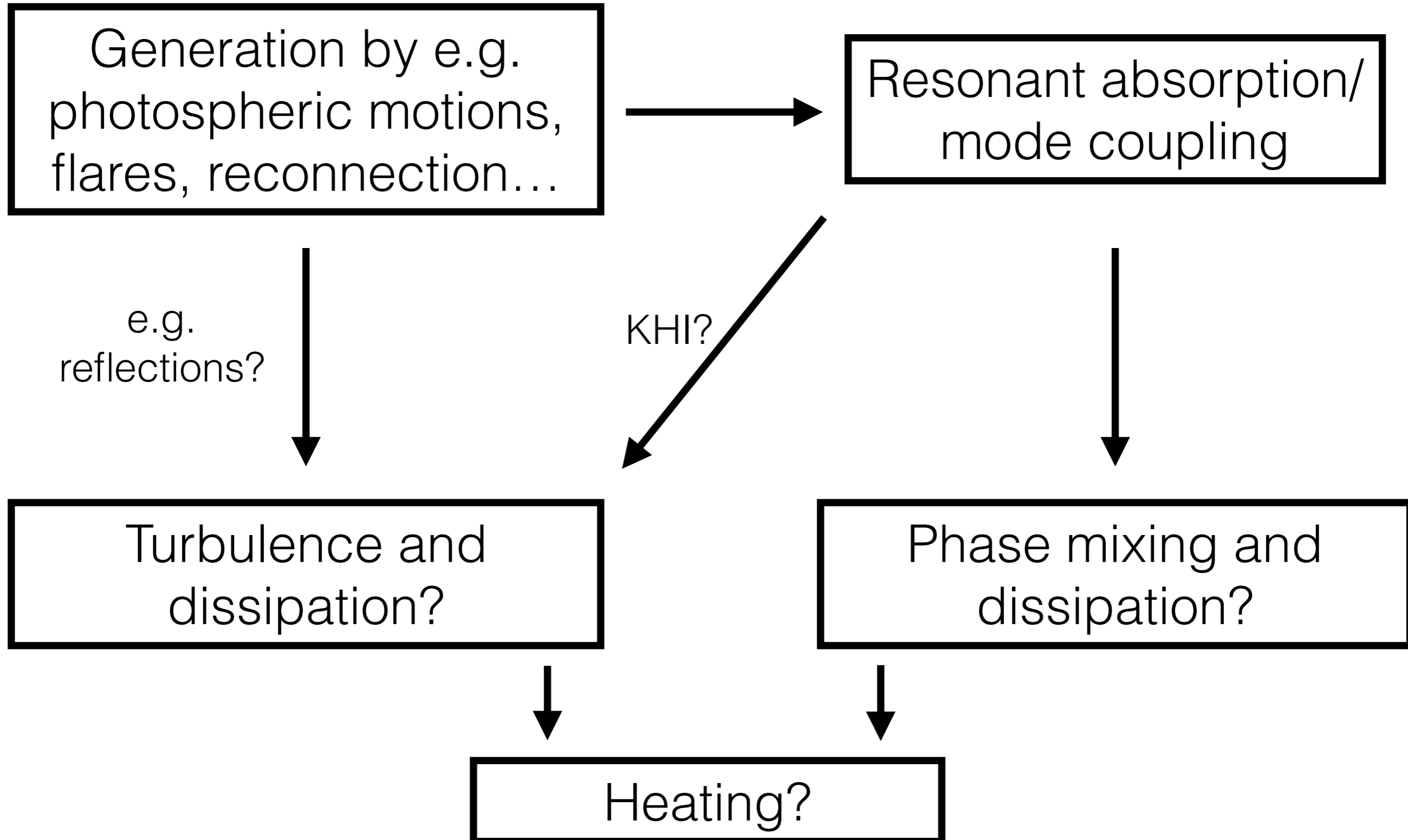


European Research Council
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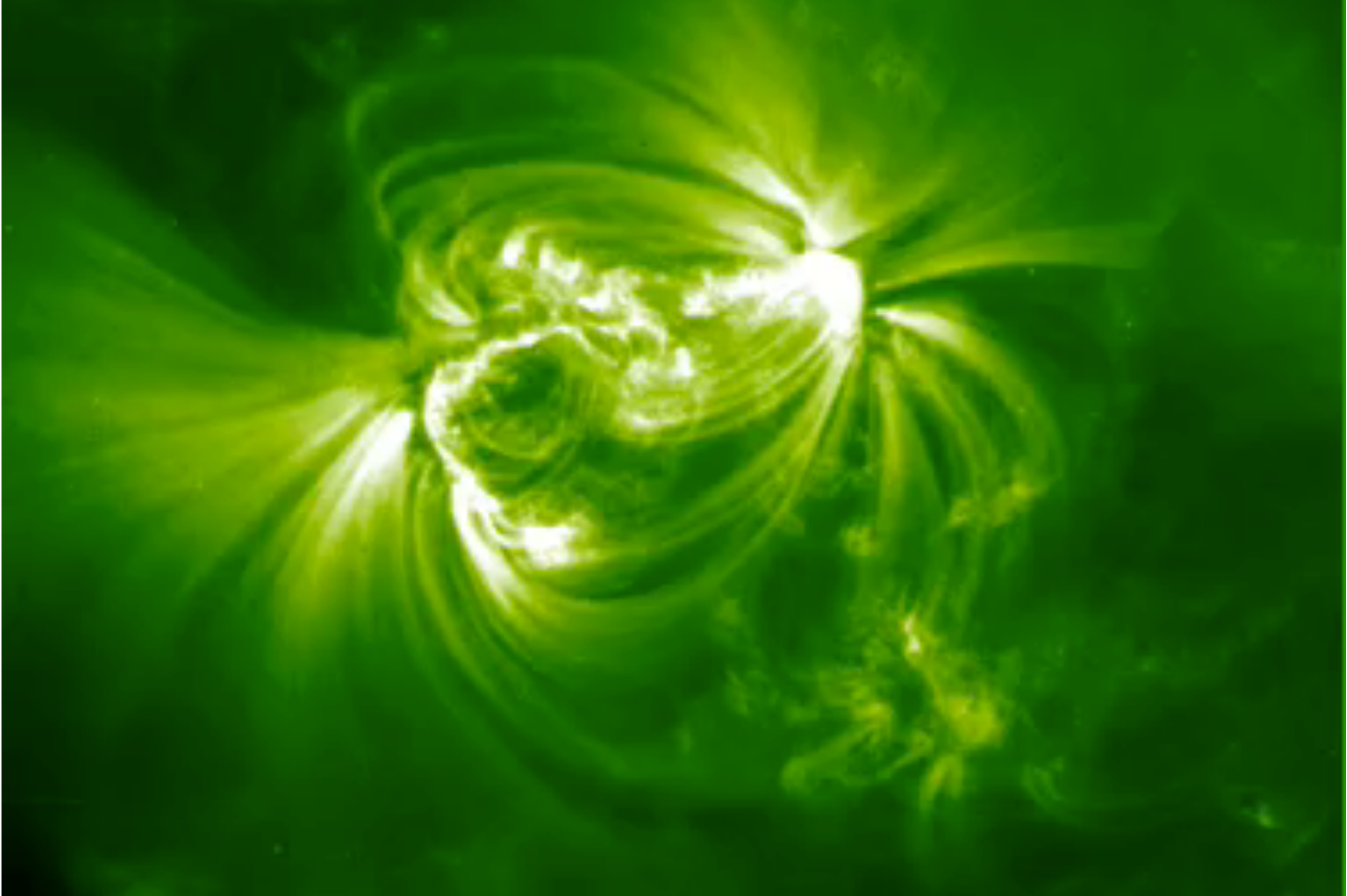


Coronal Wave Energy

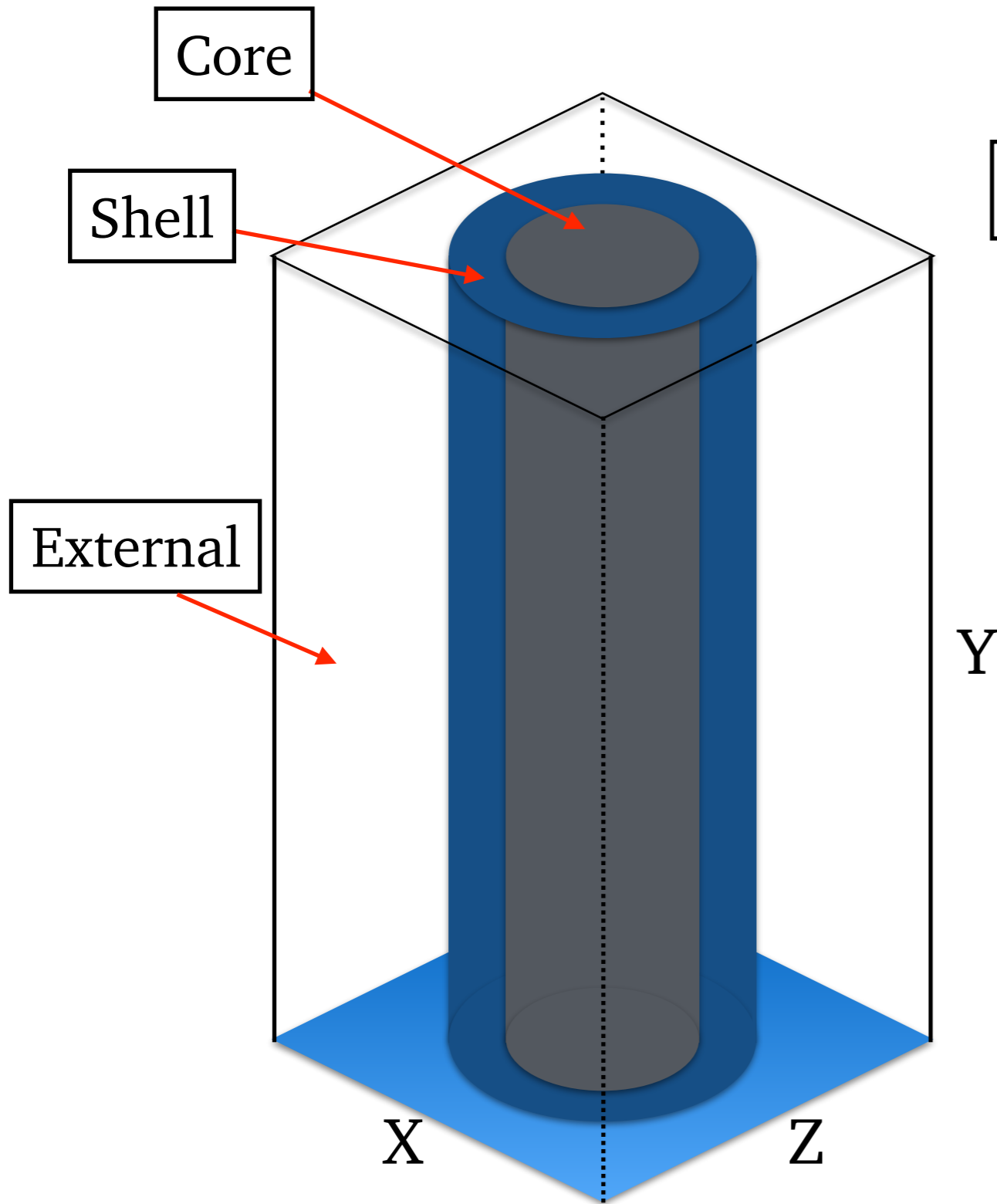
Need to generate small length scales!



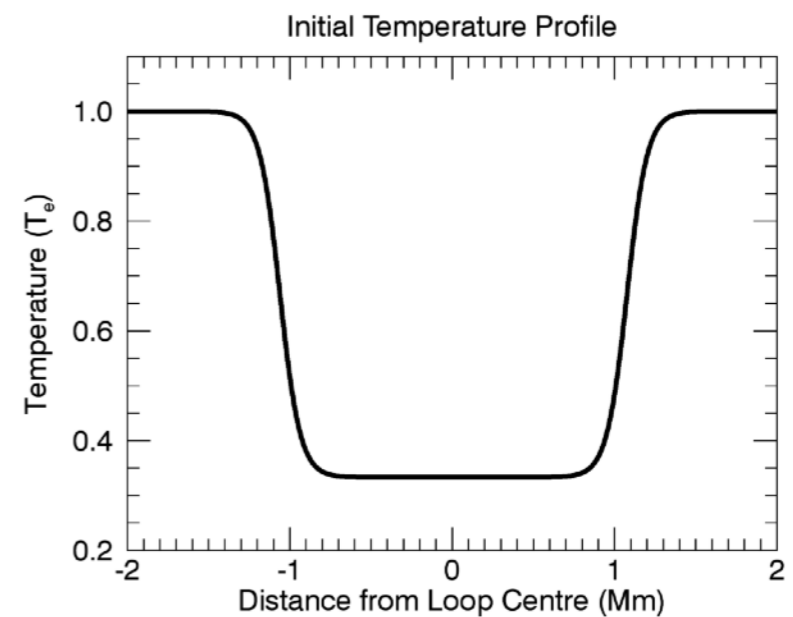
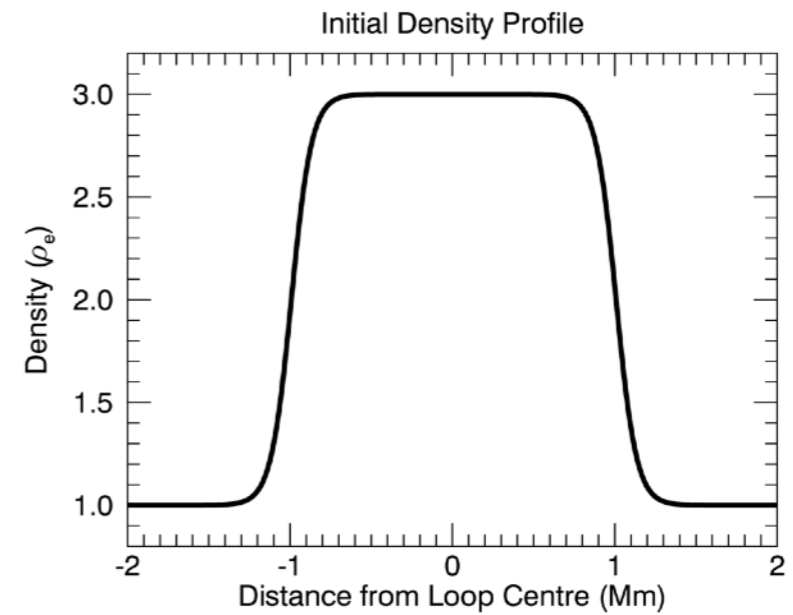
14-Jul-98 12:40:15



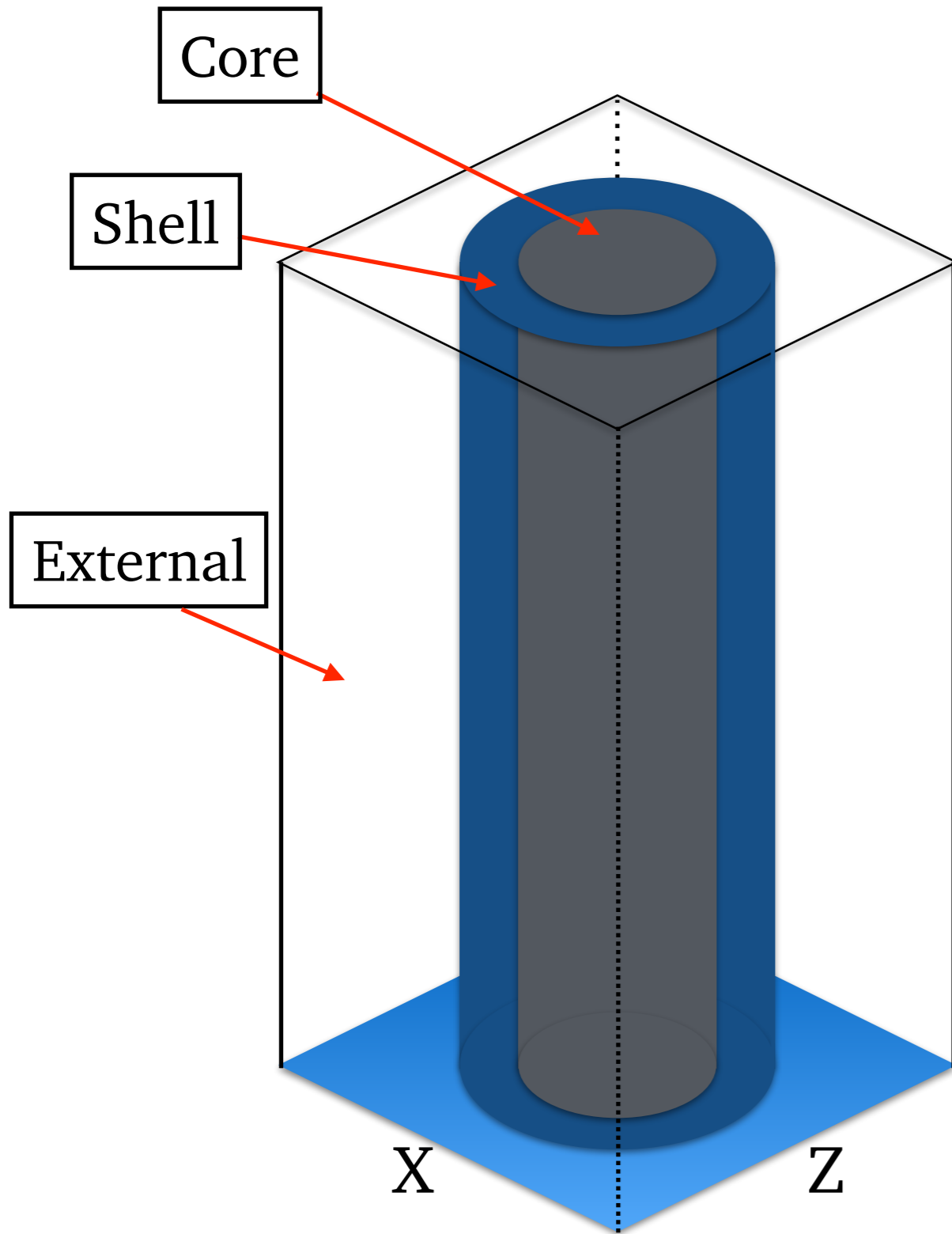
Our Model



Straight, dense magnetic flux tube



Our Model



Straight, dense magnetic flux tube



Initial perturbation



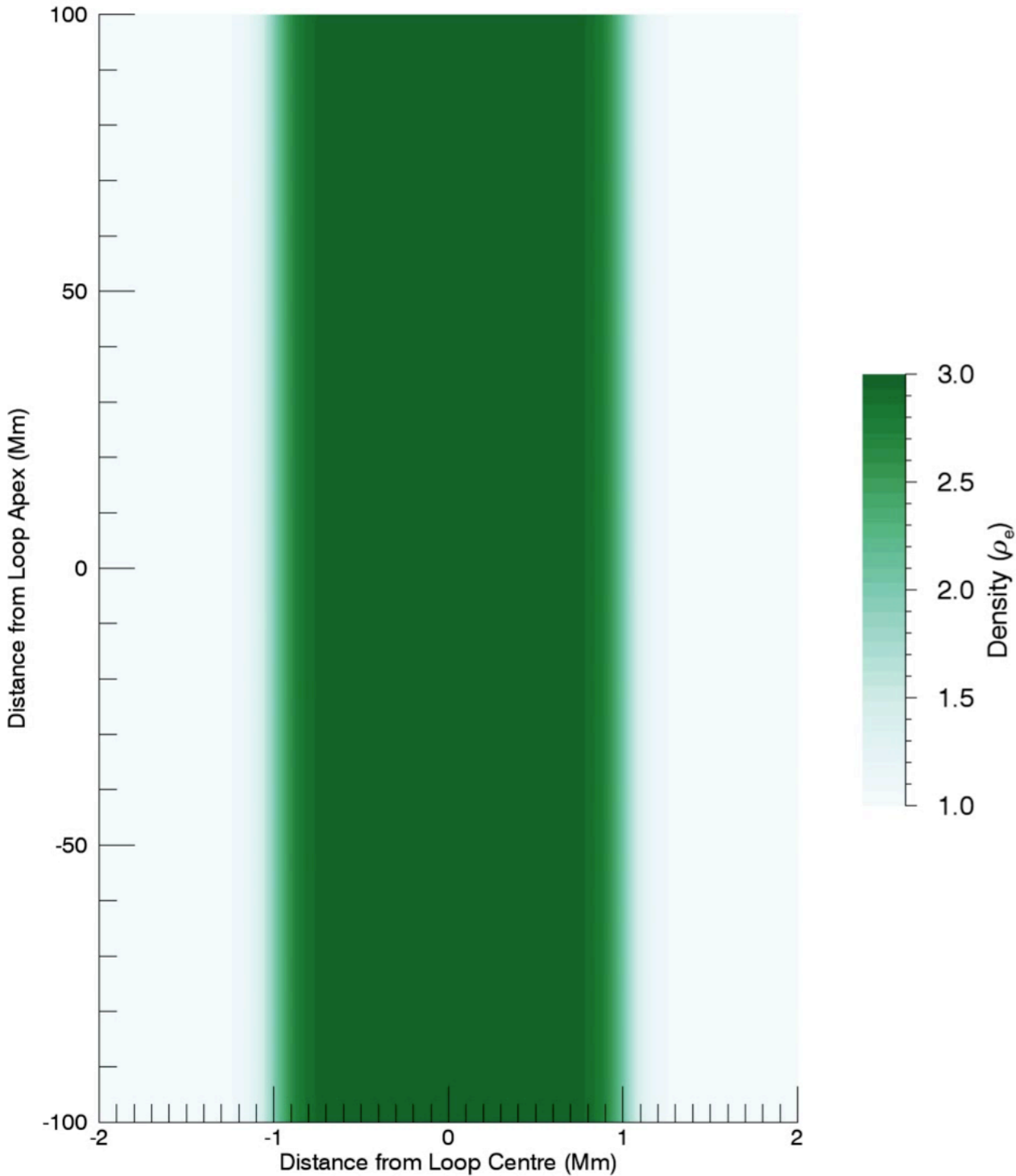
Generates standing wave



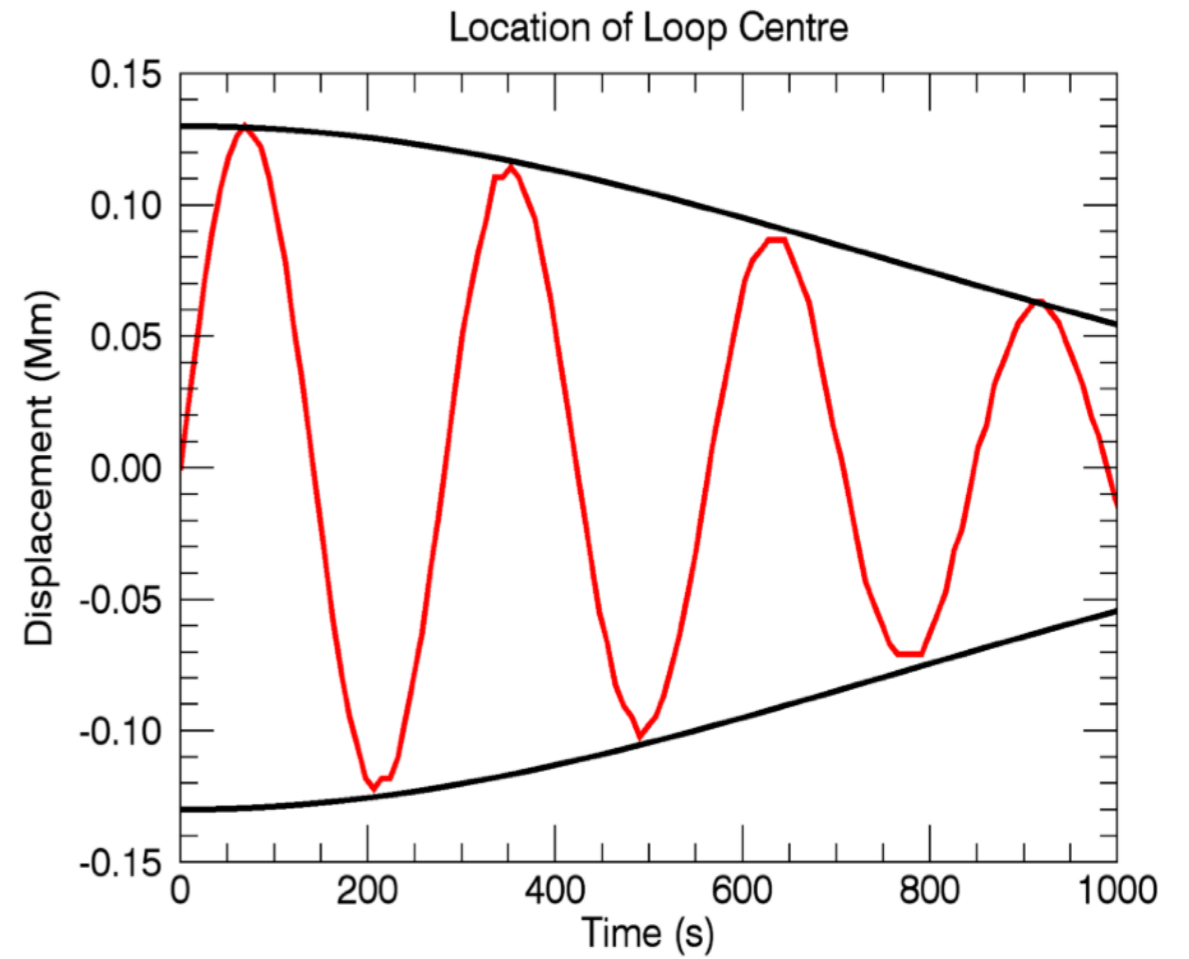
Lare3D, dissipation & magnetic
twist parameter studies

Kink Wave

Vertical Density Profile 000 s



Vertical Cross-Section



Standing kink wave.

Antinode at 'apex'.

Wave damping occurs but
no dissipation.

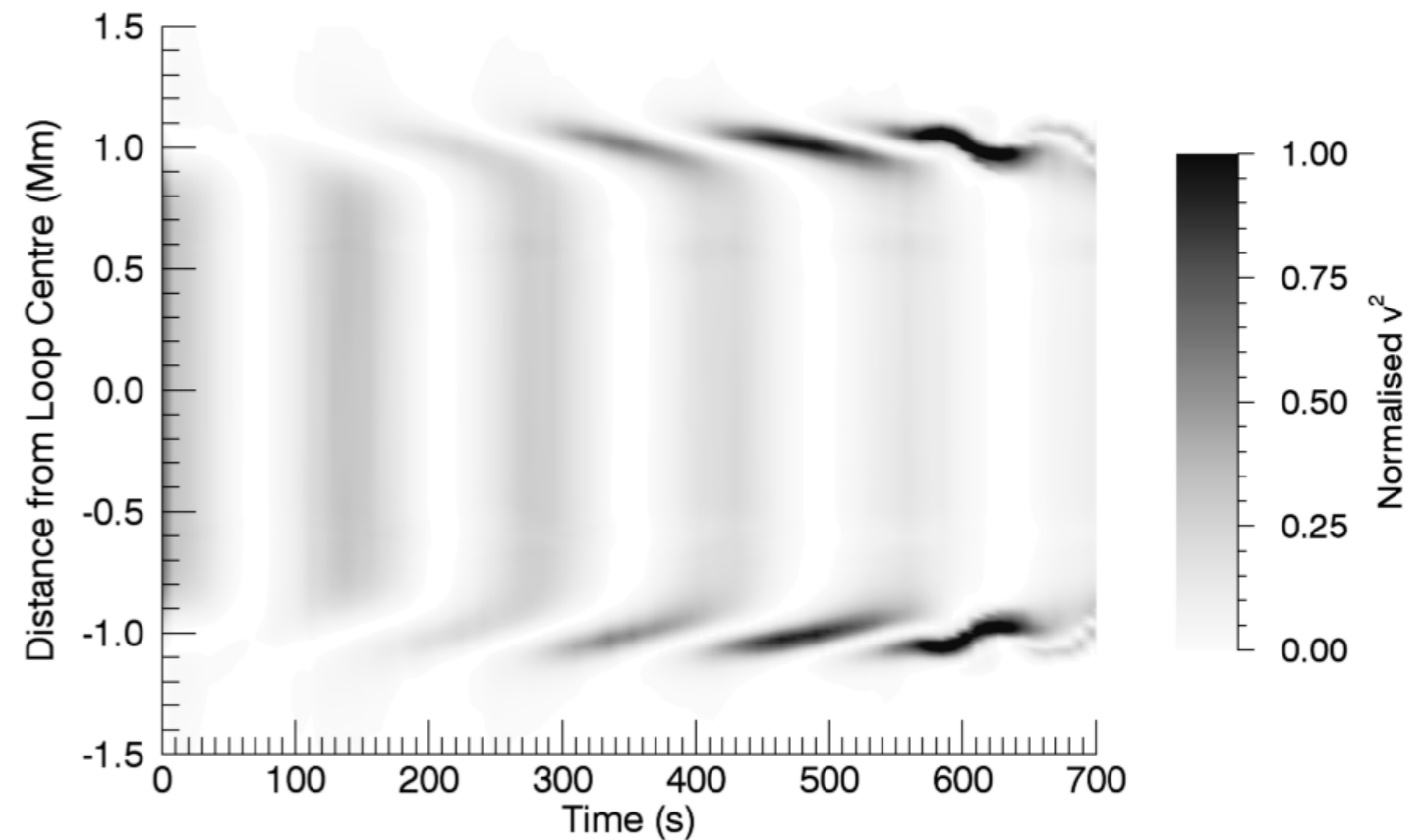
Gaussian damping profile.

Resonant Absorption & Instability

Initial velocity profile concentrated in loop core.

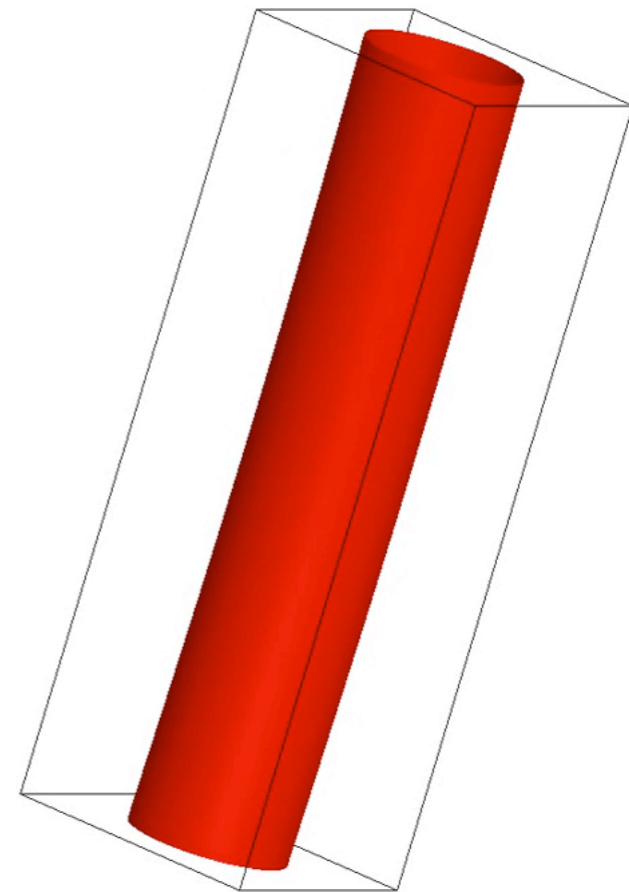
Resonant absorption creates flows within the loop shell - subject to **phase mixing**.

Creates large velocity shear within the loop
→ **K-H instability**.



Isosurface:

$$\rho = 2$$

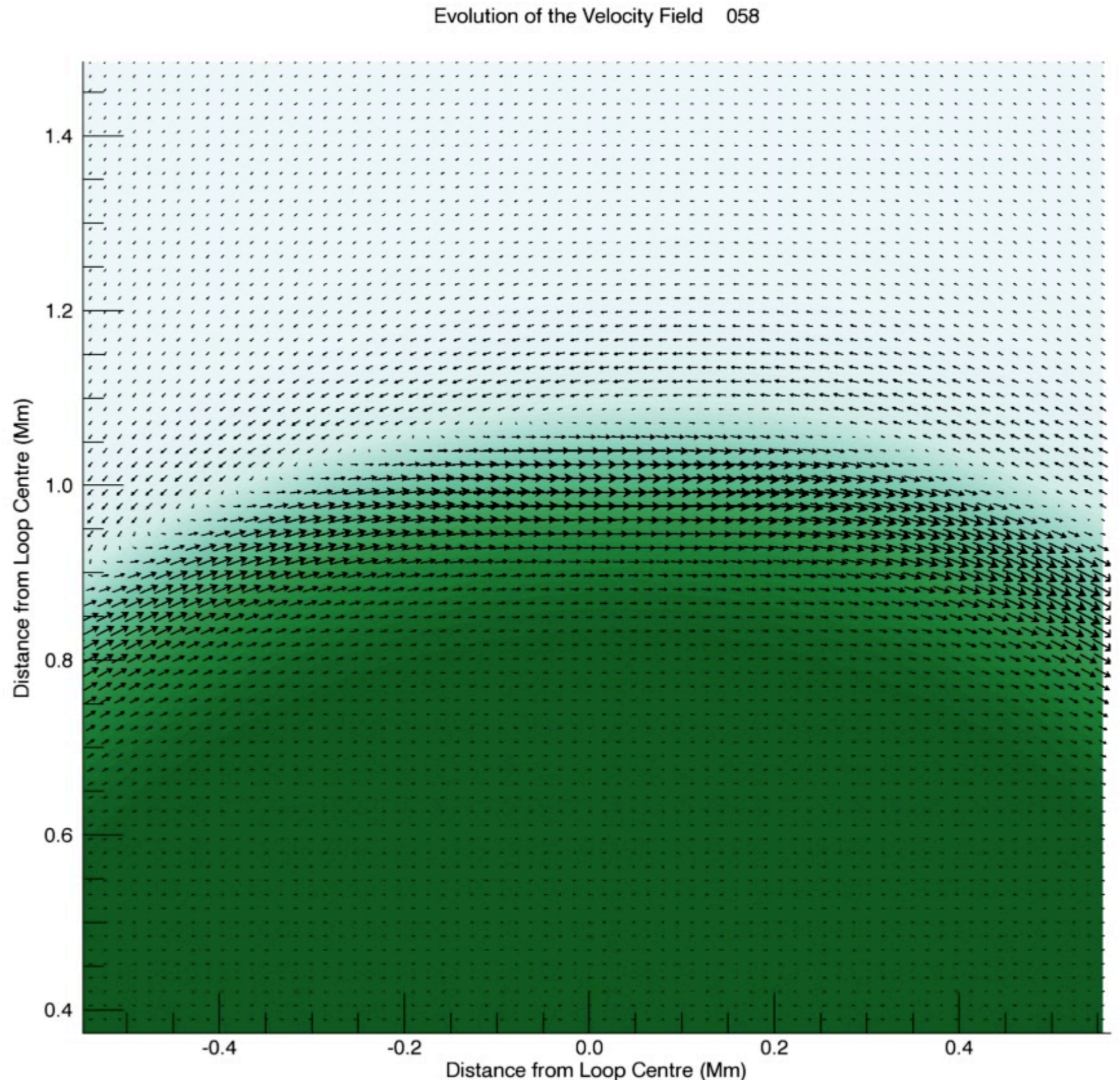


Density Evolution

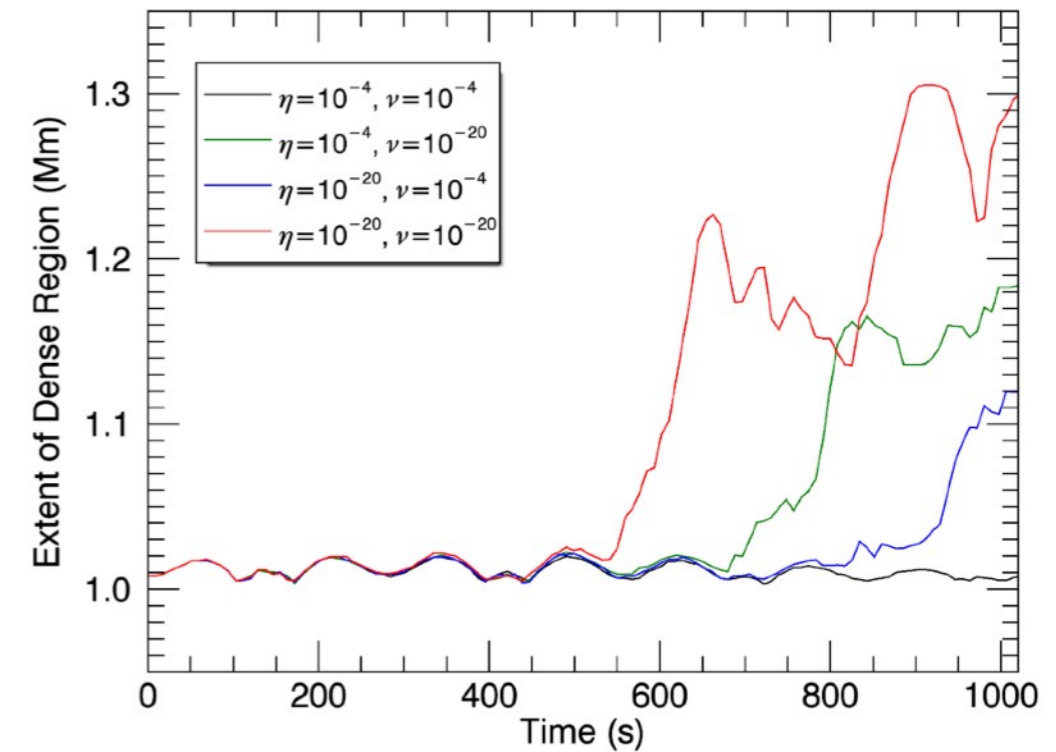
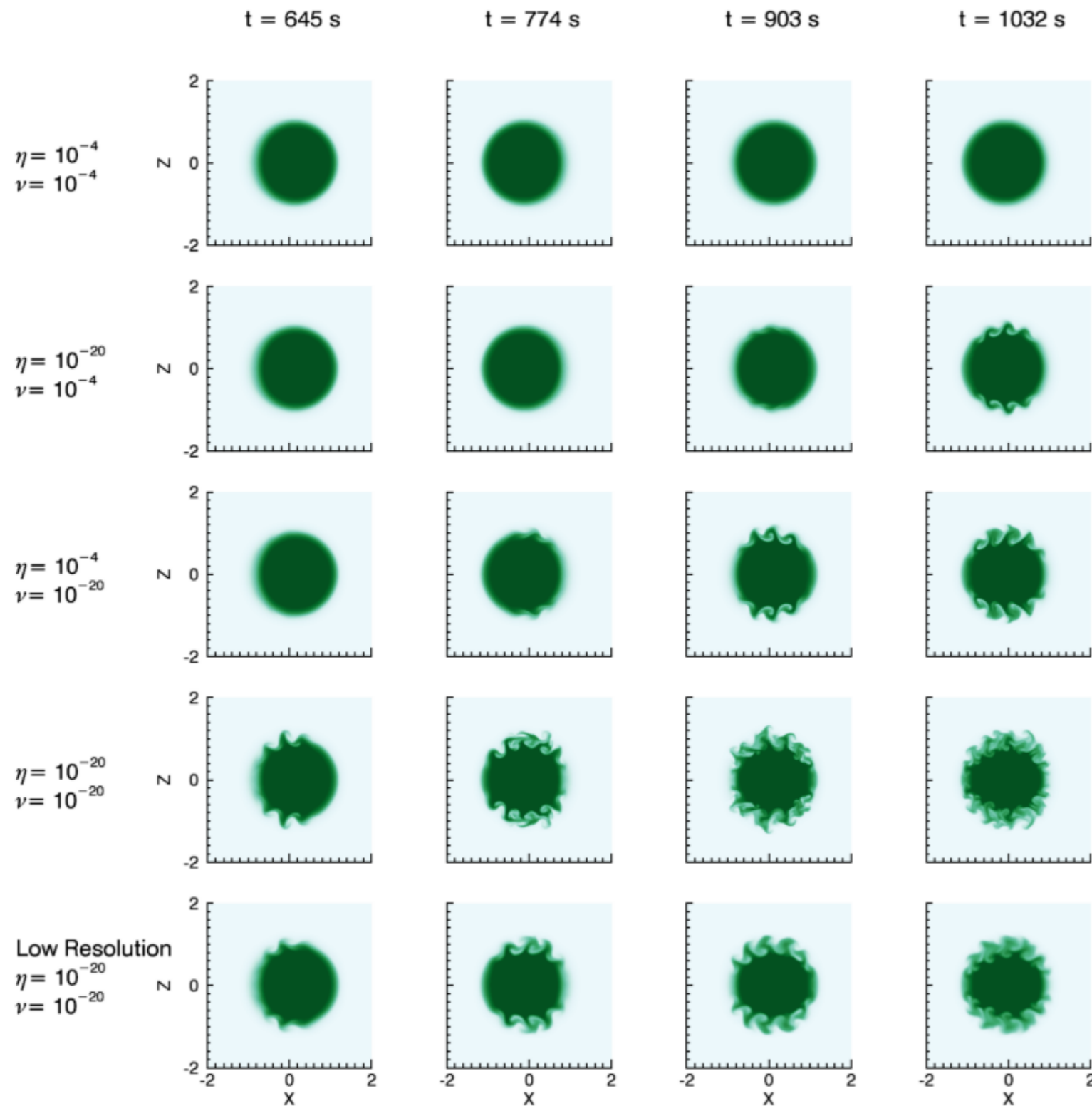
Deformation of density profile caused by KHI.

Resonant layer changes - modifies subsequent resonant absorption.

Progression of KHI affected by dissipation (and numerical resolution).



Dissipation Dependence



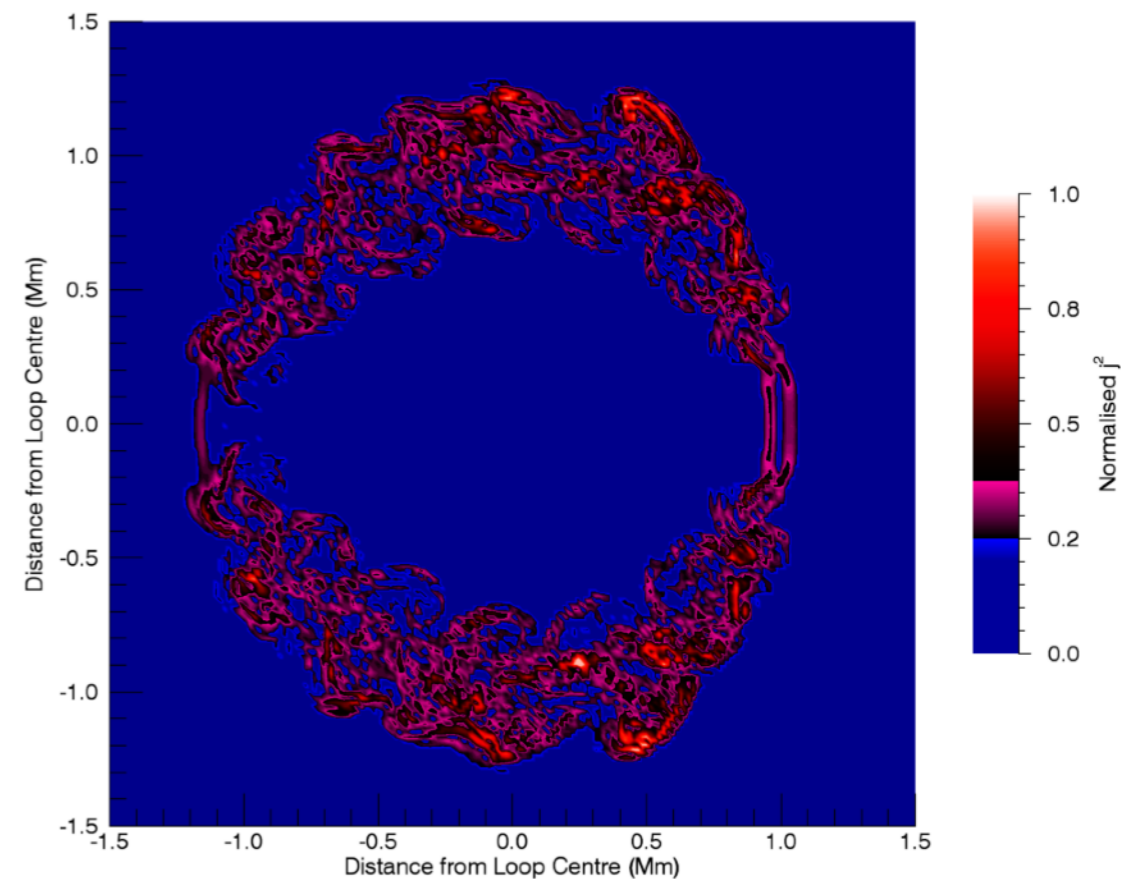
Large transport coefficients suppress the instability.

Viscosity has a larger effect than resistivity.

Ohmic heating at Loop Apex

KHI generates small scales in magnetic field.

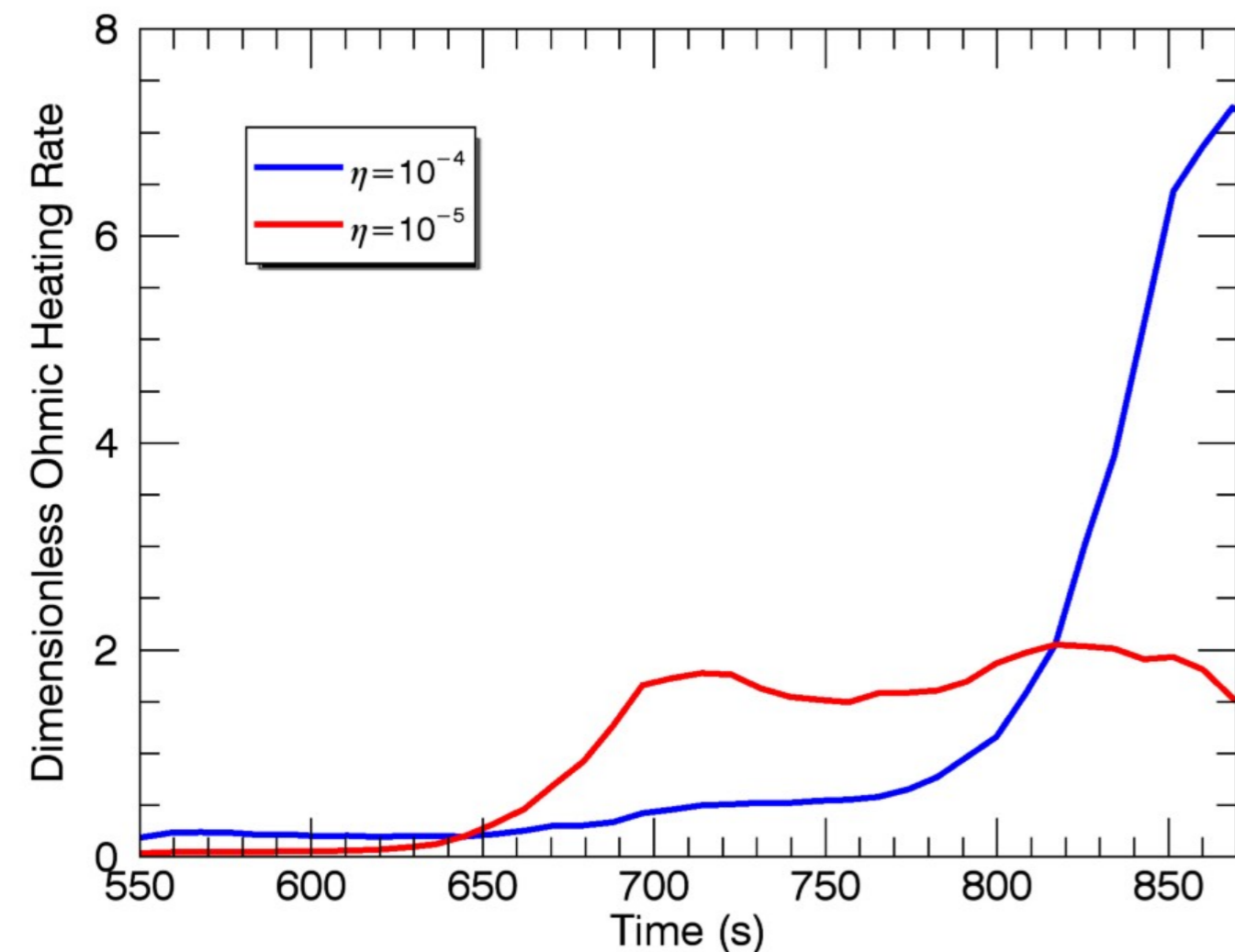
Currents form in boundary layer.



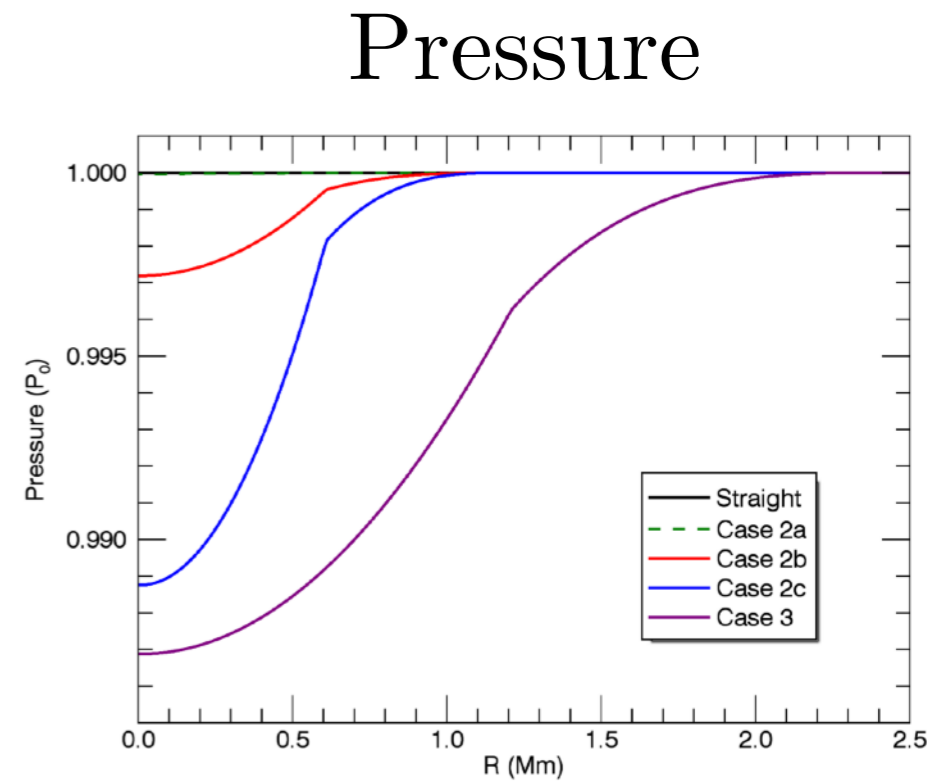
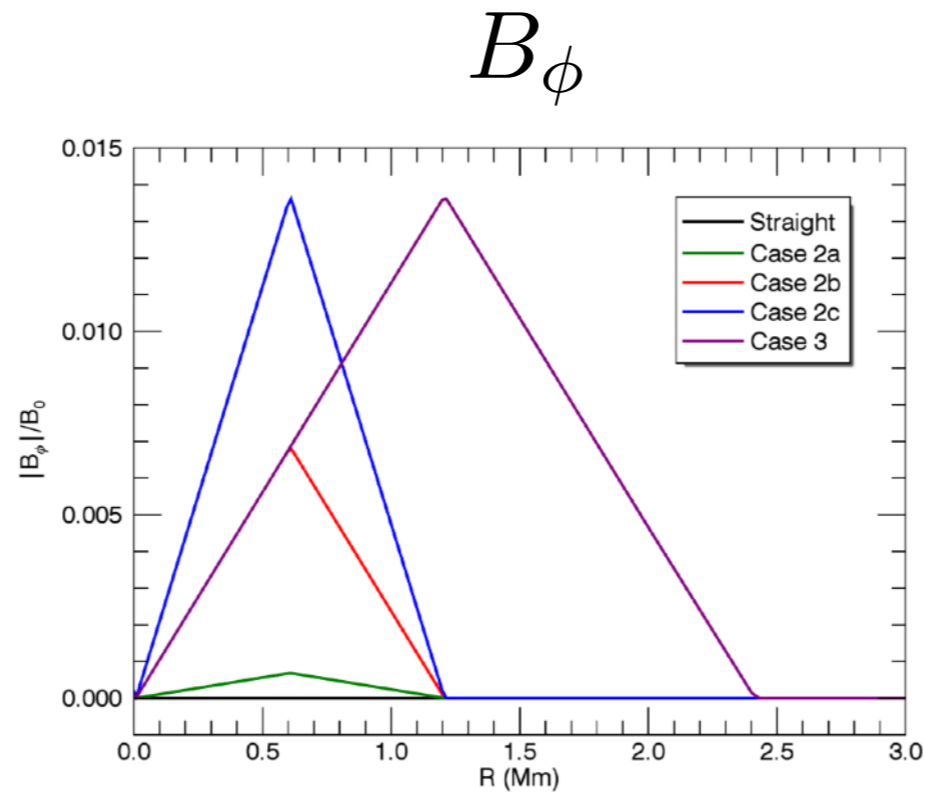
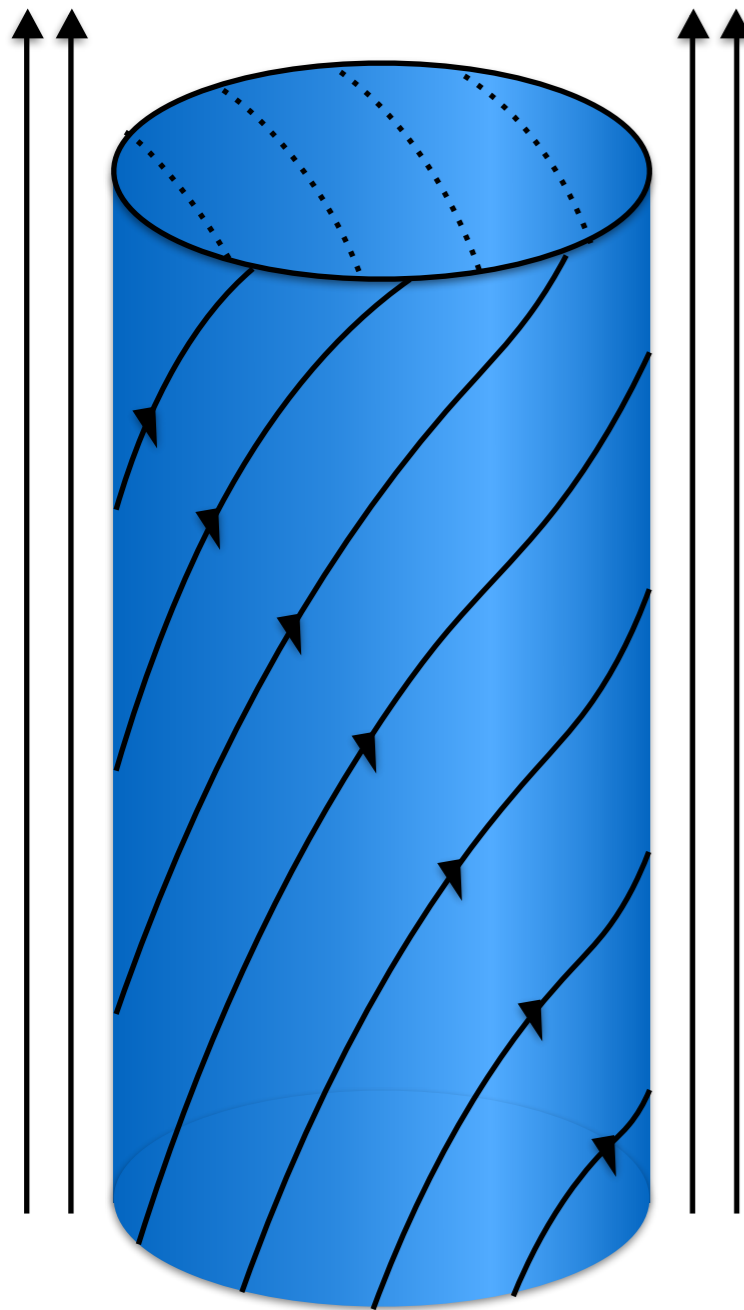
Initial kinetic energy converted into heat.

Larger resistivity causes greater rate of heating once KHI occurs.

Observe **earlier heating** in cases with **lower resistivity**.



Twist: Initial Setup



Azimuthal magnetic field.

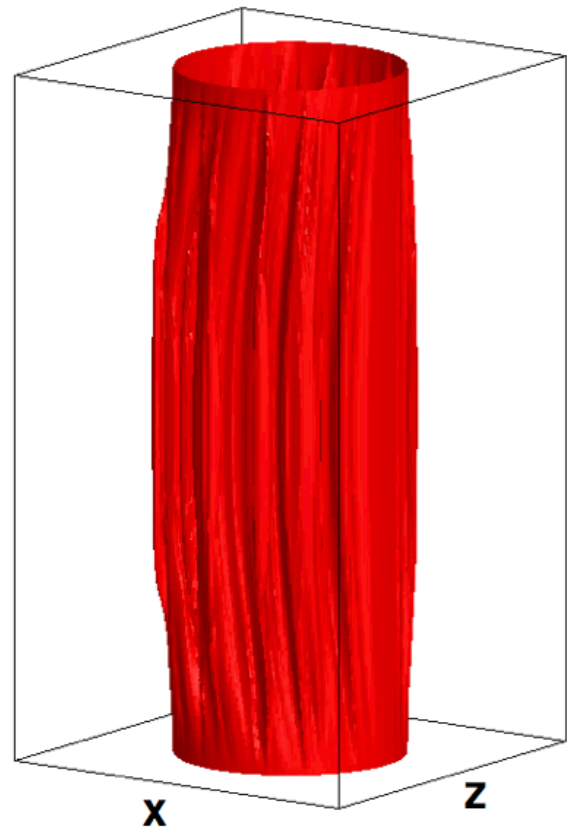
Tension force balanced by gas pressure.

Same density, new temperature.

τ	Case 2 Angle ($^\circ$)	ψ	Case 3 Angle ($^\circ$)
0.1	0.39	1.0	78
1.0	39		
2.0	78		

Nature of Vortices

Straight



Twisted



Increasing twist reduces density deformation.

Most unstable mode now inclined.

Straight vs helical vortex formation.

Larger in straight field case.

Increasing Twist

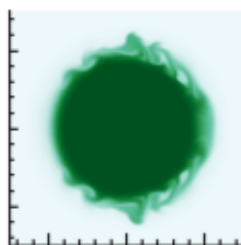
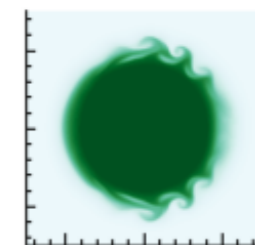
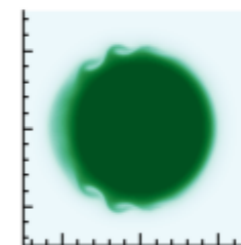
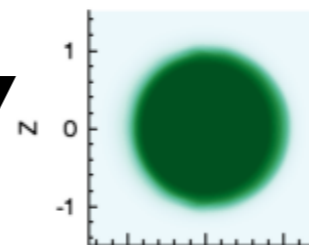
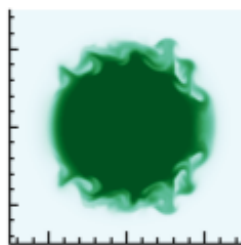
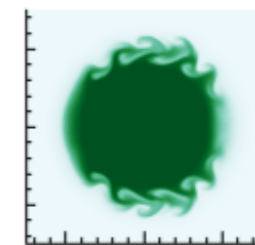
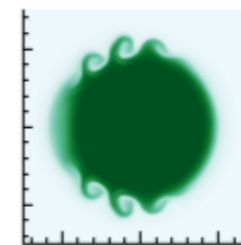
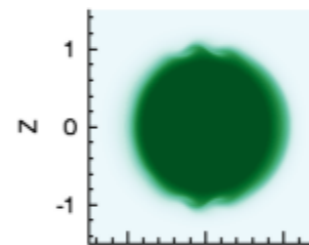
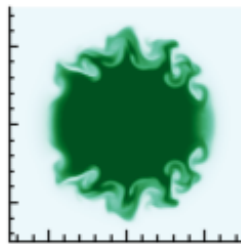
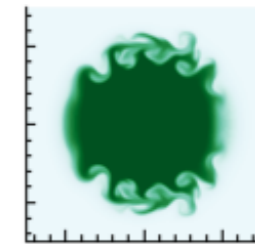
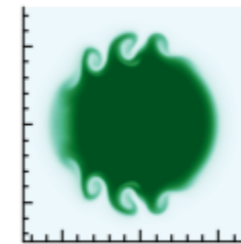
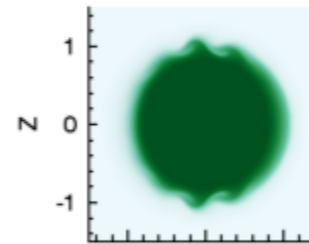
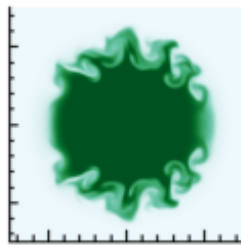
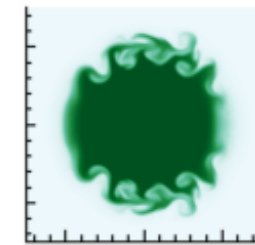
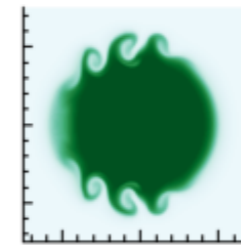
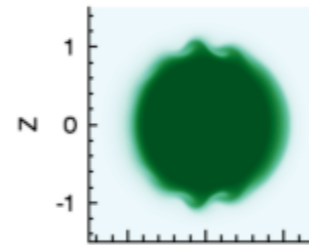


t = 602 s

t = 688 s

t = 774 s

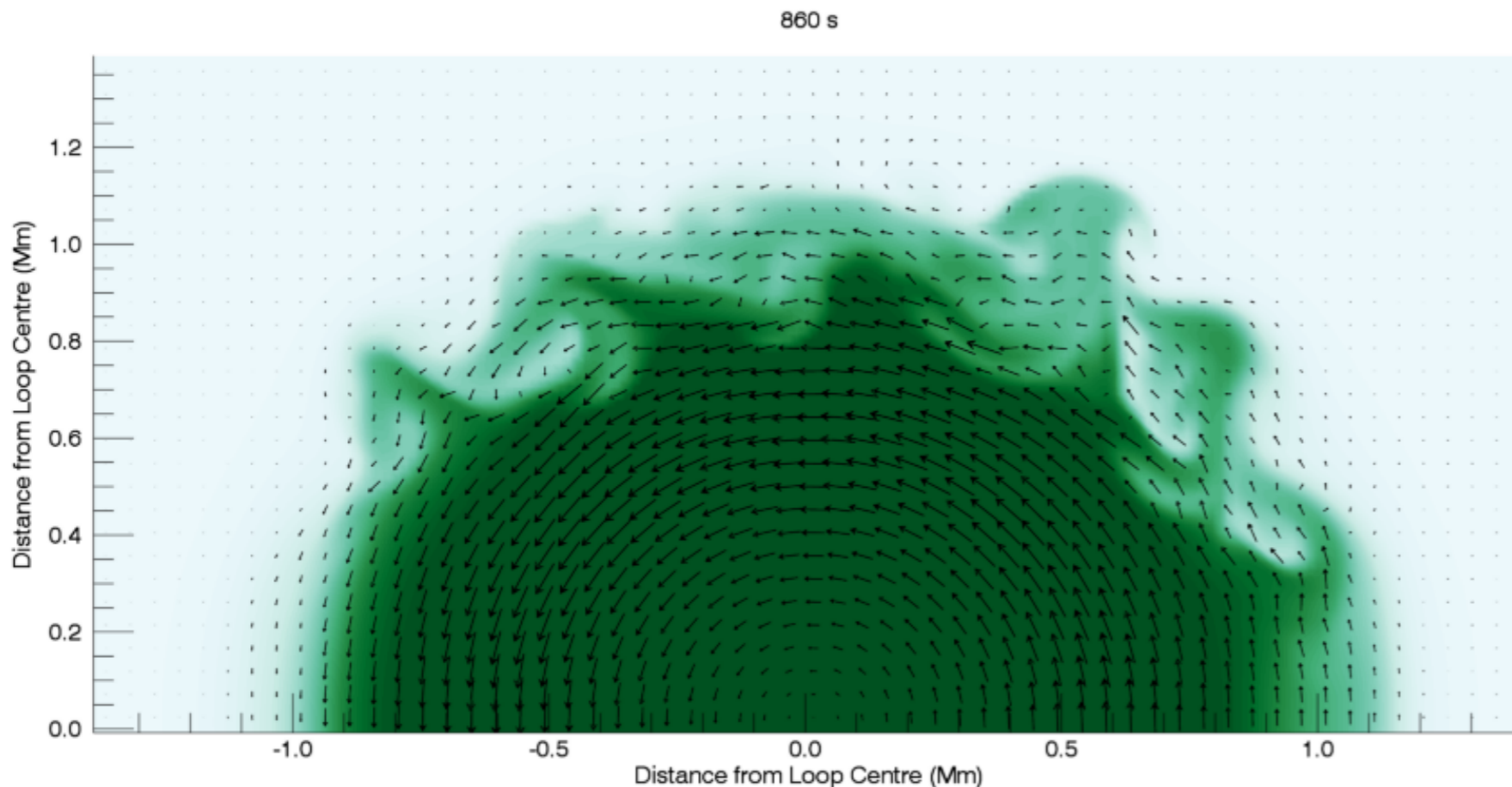
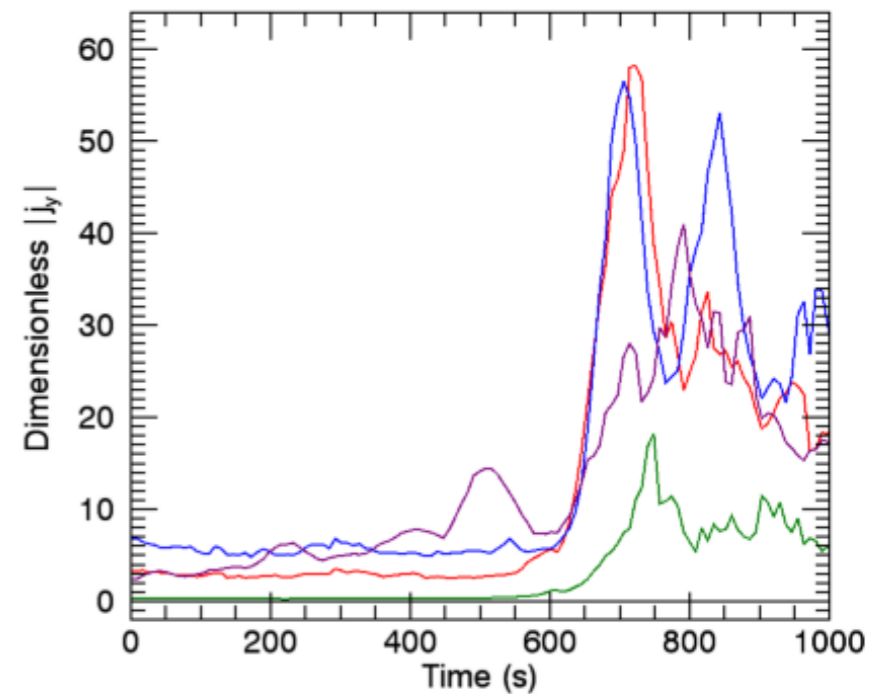
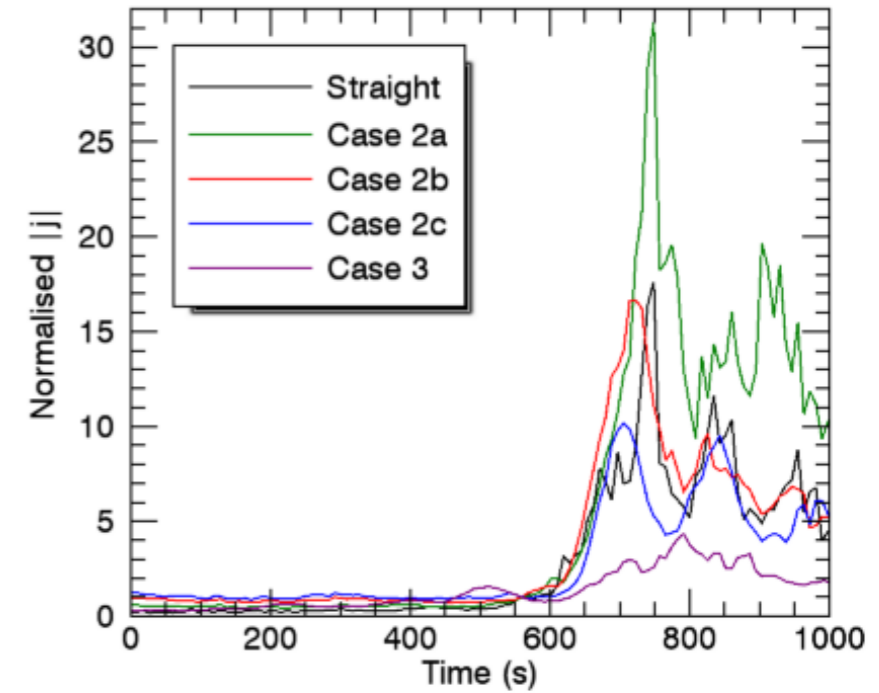
t = 860 s



Current Formation

In straight case, KHI currents are horizontal.

Large loop aligned currents even in weakly twisted case.



Conclusions

Resonant absorption generates Alfvén waves in boundary of loop.

Induces **velocity shear** which becomes unstable to KHI.

Instability generates small scales in density and velocity and magnetic fields.

Dissipation stabilises loop. Can produce **heating sooner with lower dissipation.**

Magnetic twist also reduces density deformation but instability is **more energetic with increased twist.**

Density Evolution

Deformation of density profile caused by KHI.

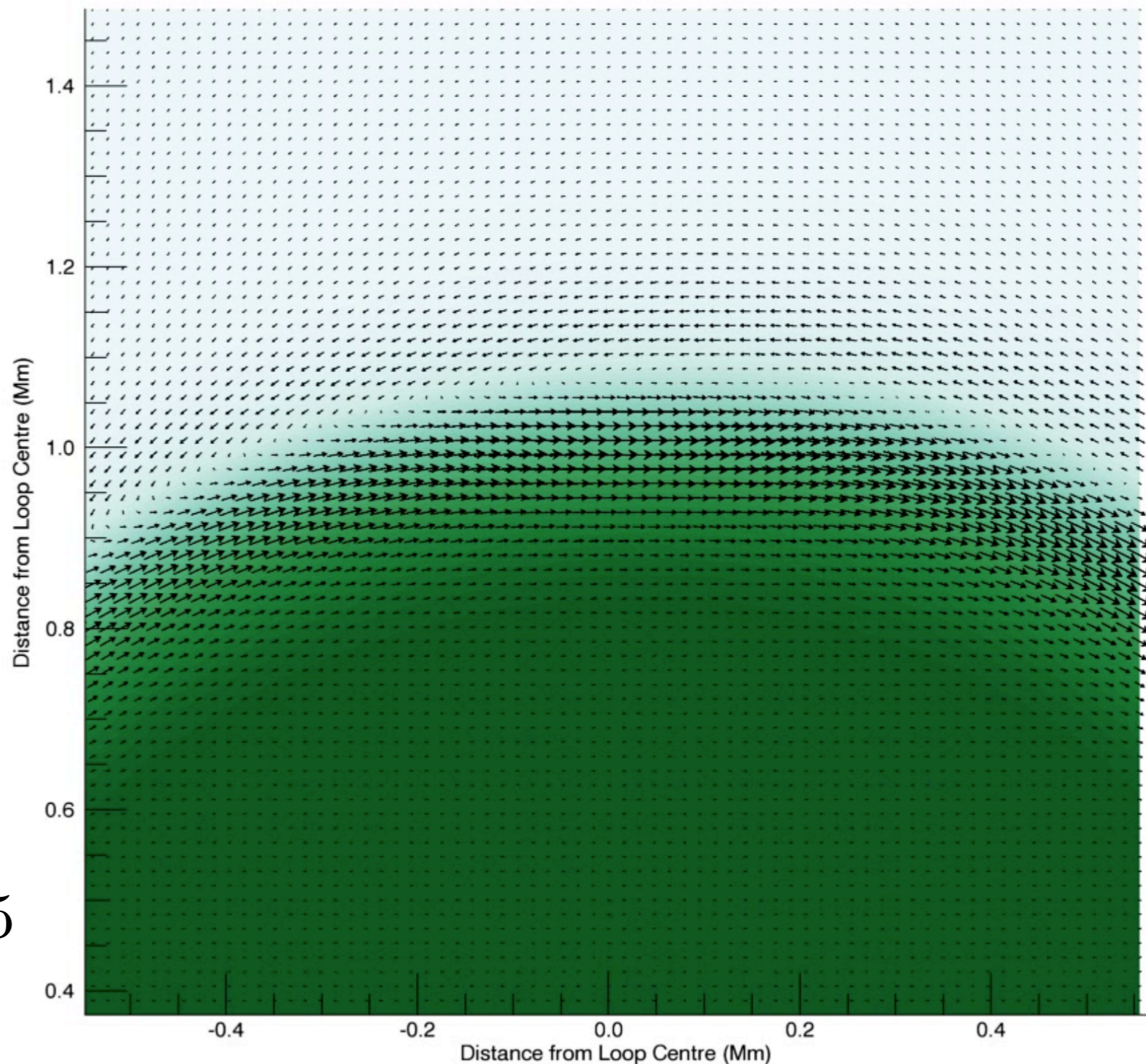
Resonant layer changes - modifies subsequent resonant absorption.

Forms when:

$$\Gamma_{KH} \approx \frac{1.7V_0}{4\omega_A L_{ph}} \approx 0.5$$

Allan & Wright (2010), Terradas et al. (2016)

Evolution of the Velocity Field 058

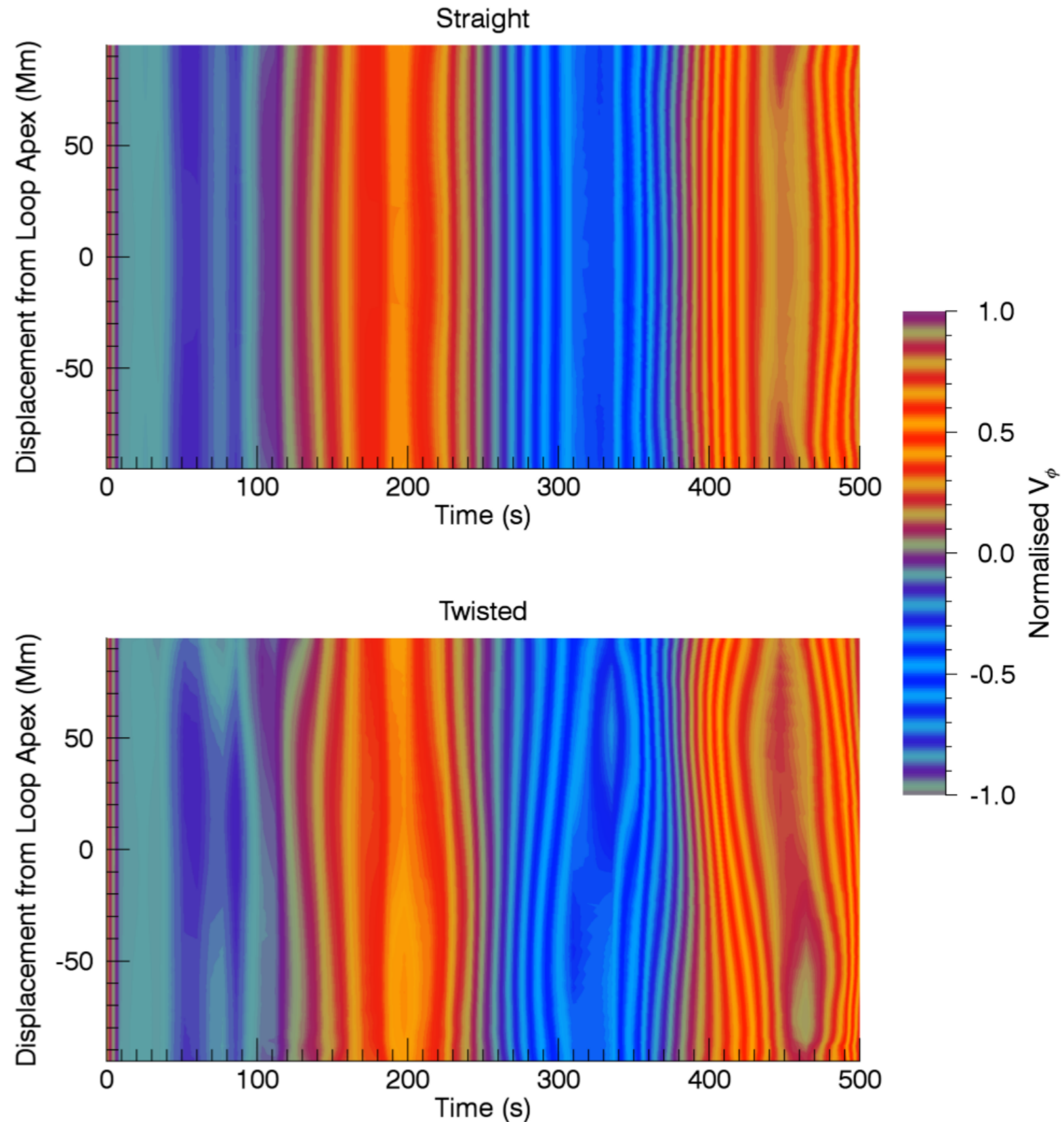


Additional Harmonics

Azimuthal field introduces new harmonics.

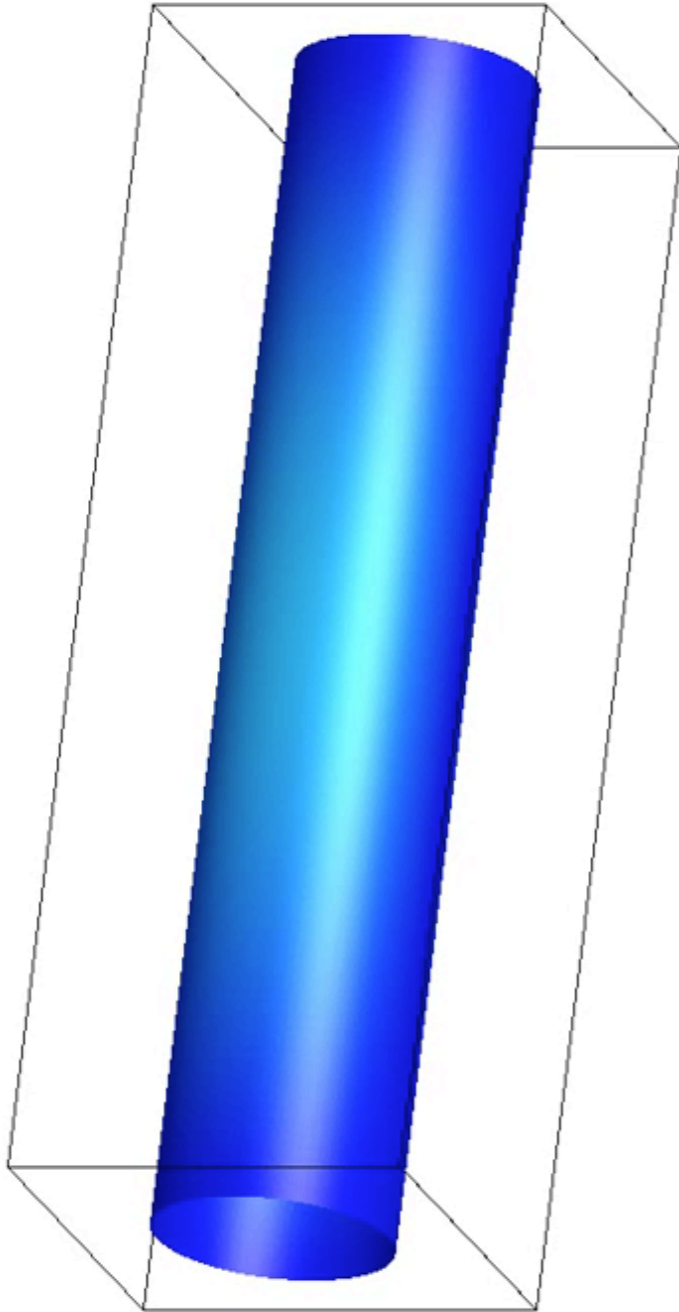
Alfvén waves affected by new tension direction in field lines.

Vertical asymmetry.

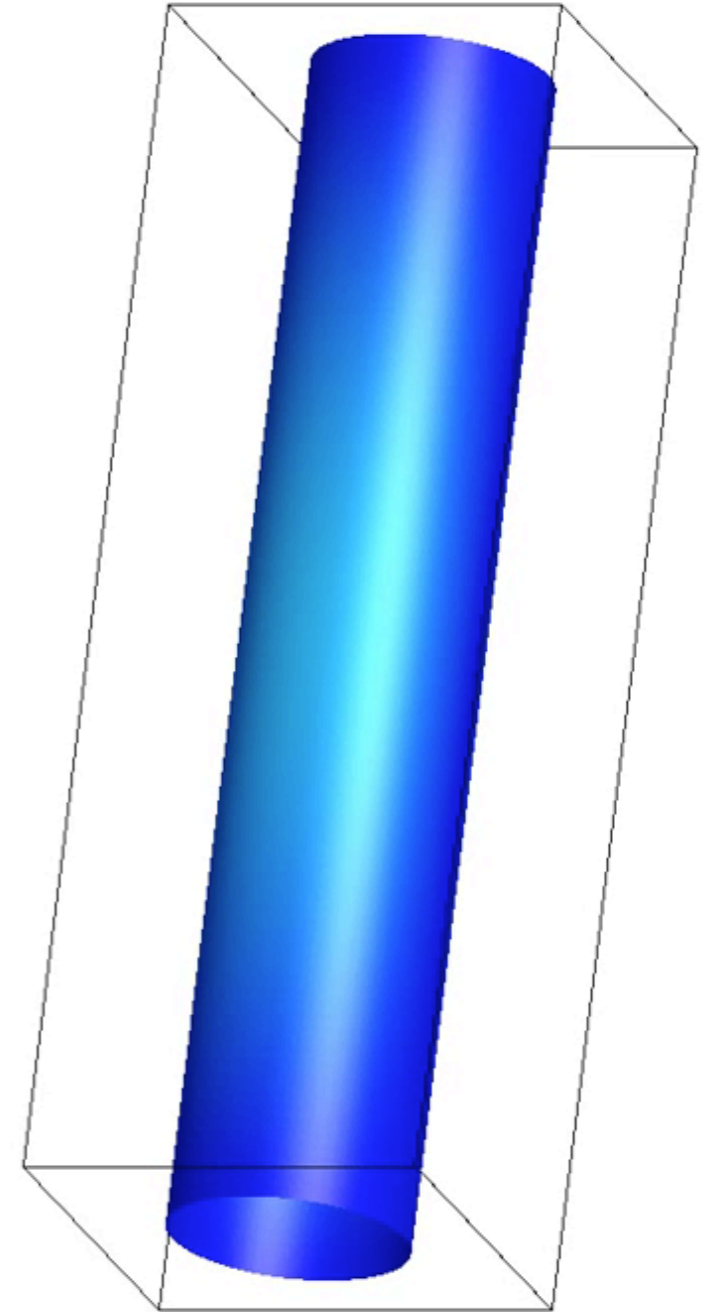


Velocity Comparison

Straight



Twisted

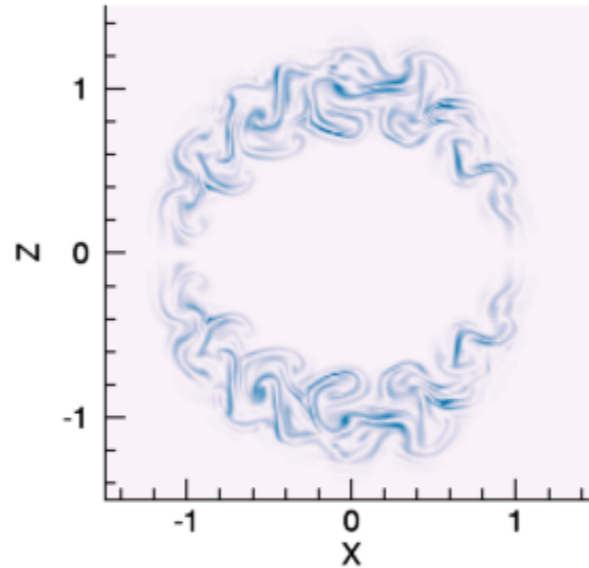
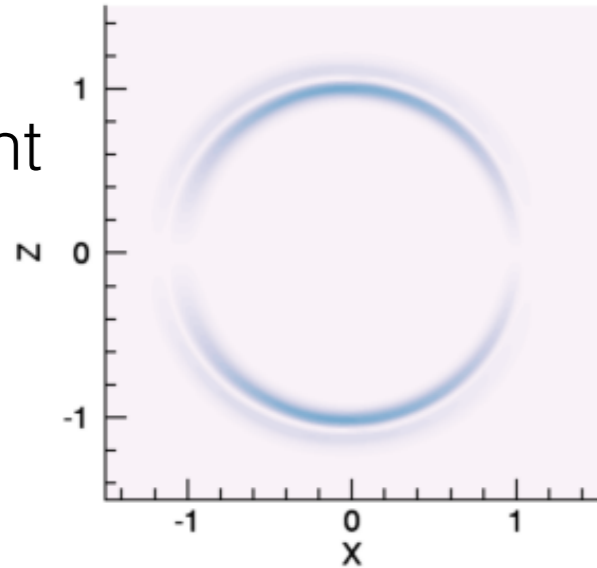


Vorticity

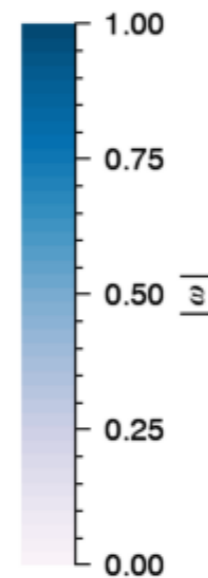
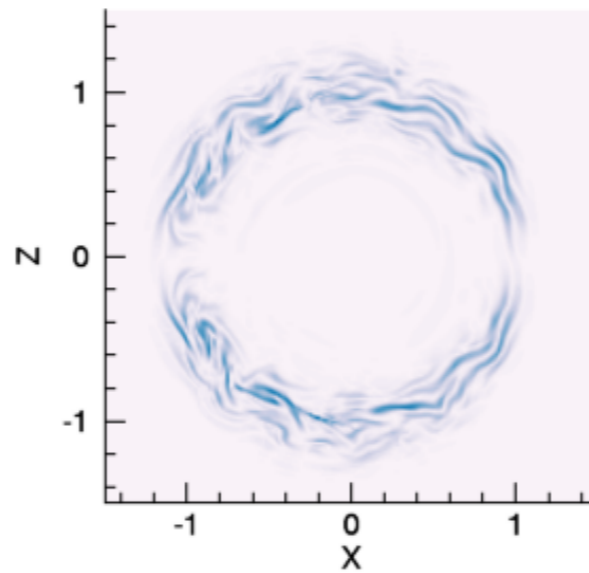
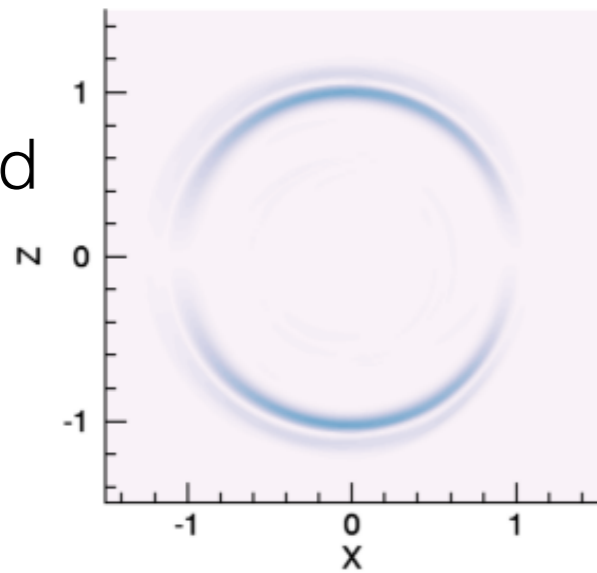
t = 420 s

t = 990 s

Straight



Twisted



Alfvén waves associated with vorticity prior to KHI.

‘Turbulent’ region more extended in straight case.

Vortices at least as energetic in twisted case.