NON-LINEAR DAMPING OF SURFACE ALFVÉN WAVES DUE TO UNITURBULENCE

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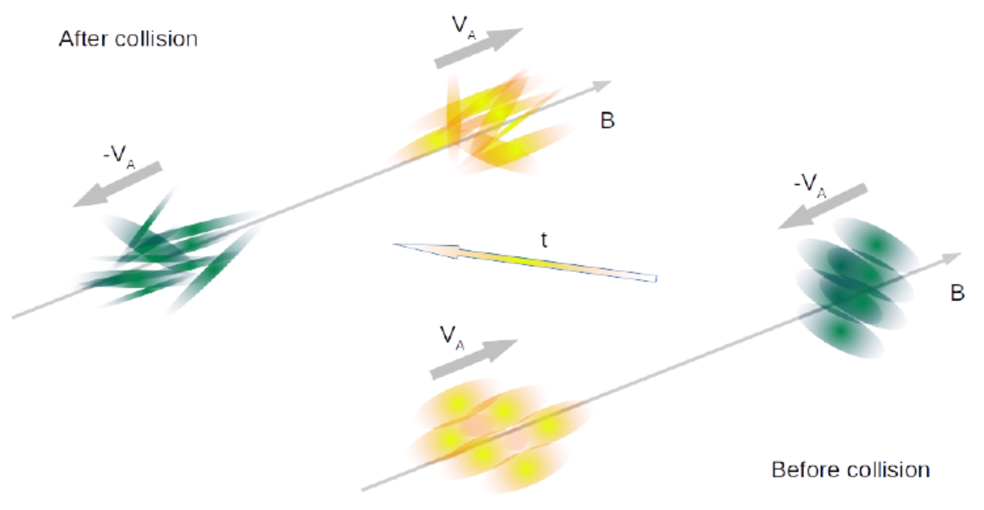
MHD turbulence

(Marsch & Tu 1989; Zhou & Matthaeus 1989)

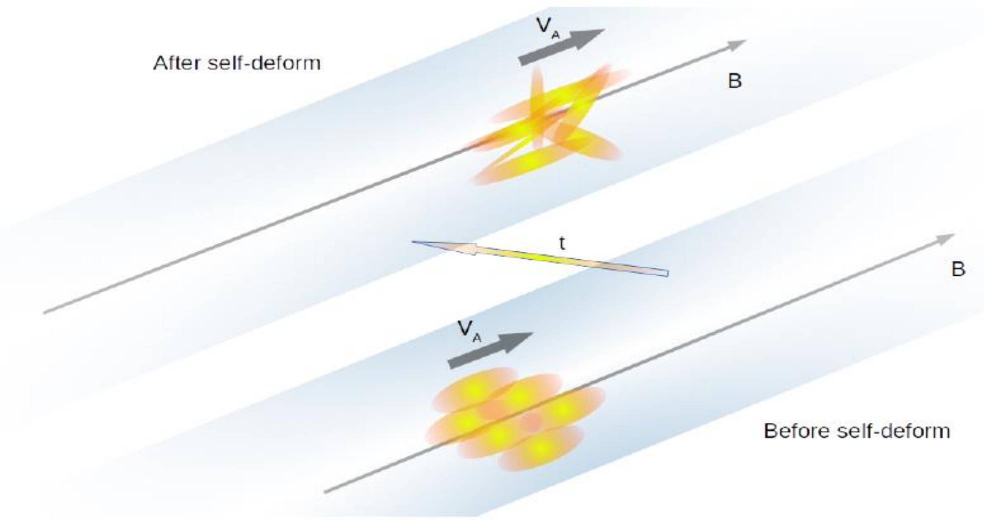
- Main idea was that two **counterpropagating** waves should generate turbulence



Uniturbulence

(Magyar, Van Doorsselaere, Goossens 2017, 2019)

- This generates turbulence by **co-propagating** waves, which is termed as '**Uniturbulence**'

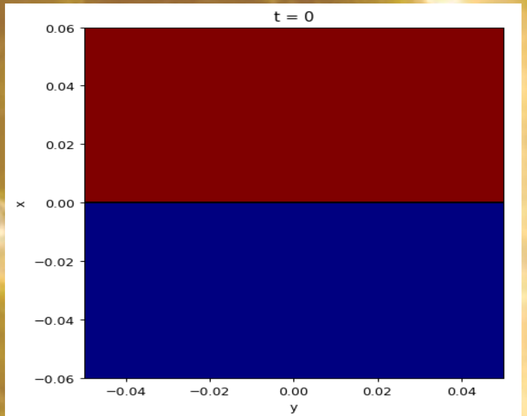


	MHD turbulence		Uniturbulence	
	Upward	Downward	Upward	Downward
z^-	✓		✓	
z^+		✓	✓	
	counterpropagating		co-propagating	

Van Doorsselaere et al. 2020 (Space Science Reviews)

ANALYTICAL MODEL FOR UNITURBULENT DAMPING OF SURFACE ALFVEN WAVES

- Incompressible MHD equations;
  - Background magnetic field along z axis
  - no background flow



- **Piece–wise constant density** $\begin{cases}\rho_l\,, & \text{if} \quad x \le 0\\ \rho_r\,, & \text{if} \quad x > 0\end{cases}$

- Energy dissipation rate: $\epsilon^{\pm} = \vec{z}^{\pm} \cdot \nabla w^{\pm}$, using Ëlsasser variables: $\vec{z}^{\pm} = \vec{v} \pm \vec{B}/\sqrt{\mu\,\rho}$

- Calculating the energy density average over the cross-section and over the period

- Damping time: $\tau = \frac{\langle w \rangle}{\langle \epsilon \rangle} = \frac{3\sqrt{10}}{5\,V\,k_y}\,\frac{\zeta+1}{\zeta-1}$

Van Doorsselaere et al. 2020 (Space Science Reviews)

NUMERICAL SETUP

- 3D ideal MHD simulations using the code MPI-AMRVAC

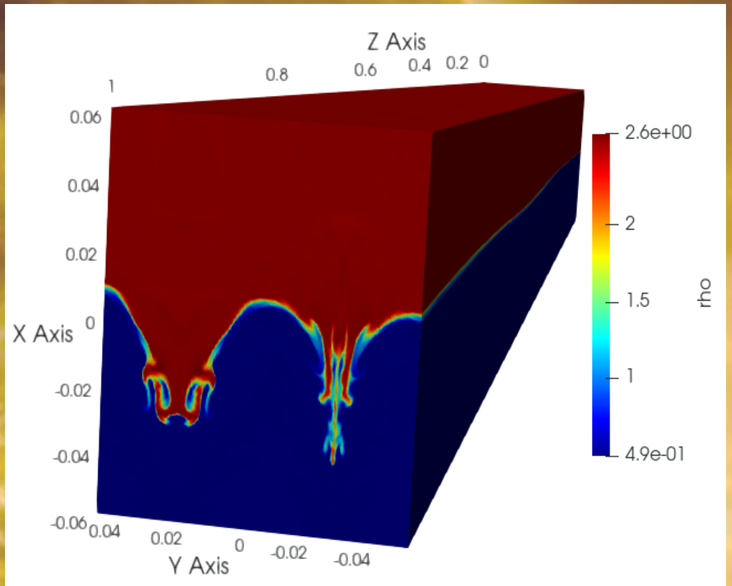
- BC at bottom of z : $v(x,t) = V\,cos(\omega\,t)\,sin(k_y\,y)$ driver

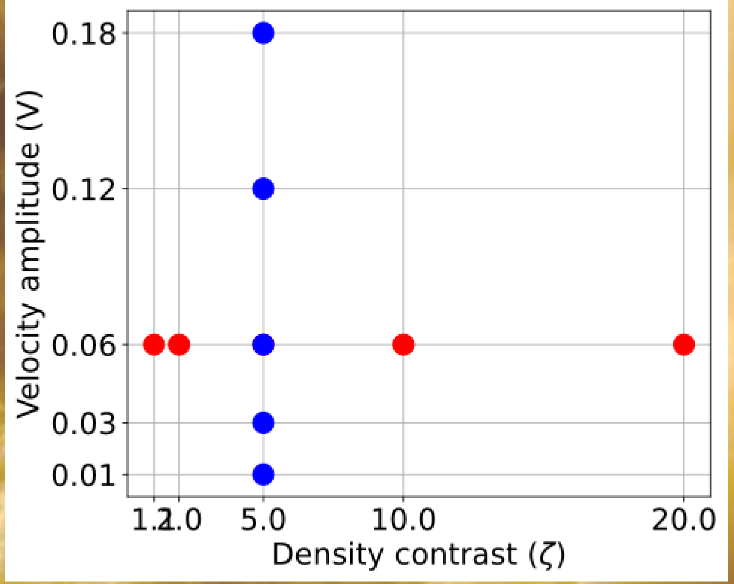
- Density: varying discontinuously at $x = 0$:

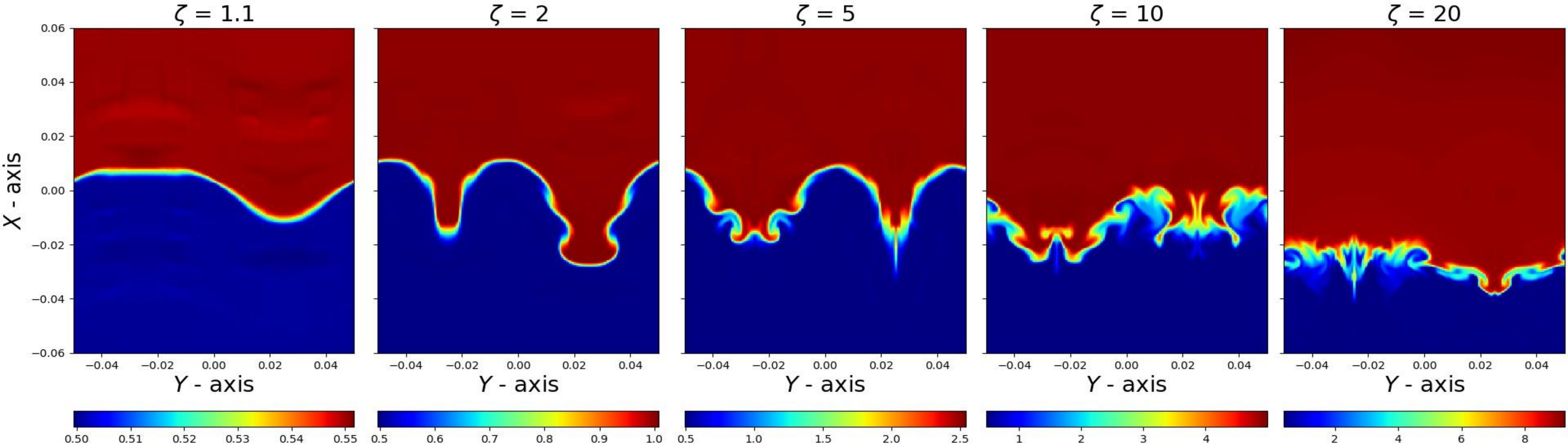
$$\rho_l = 0.5, \qquad \rho_r = 2.5$$

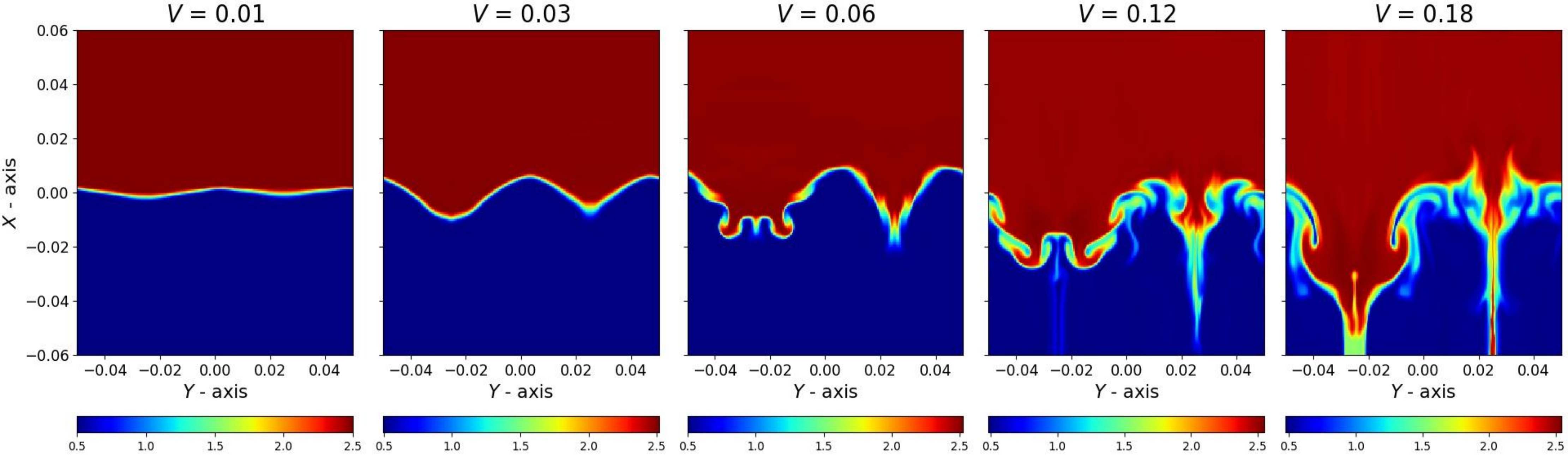
- Different cases considered for varying two parameters:

  Density contrast (ζ) & Velocity amplitude (V)

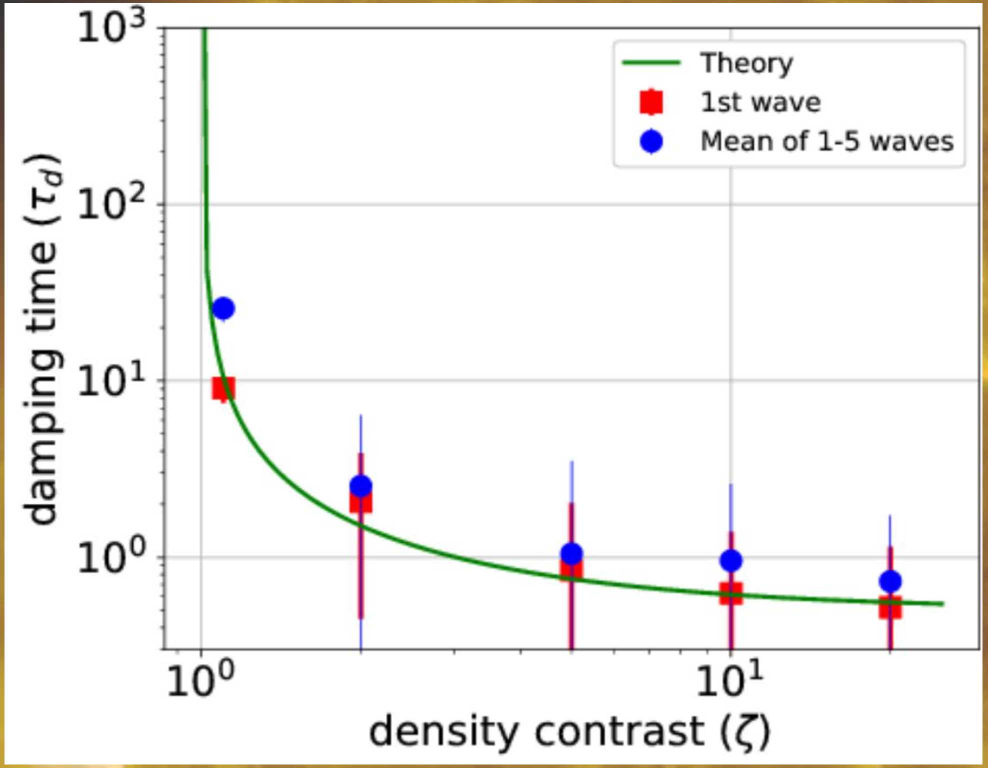


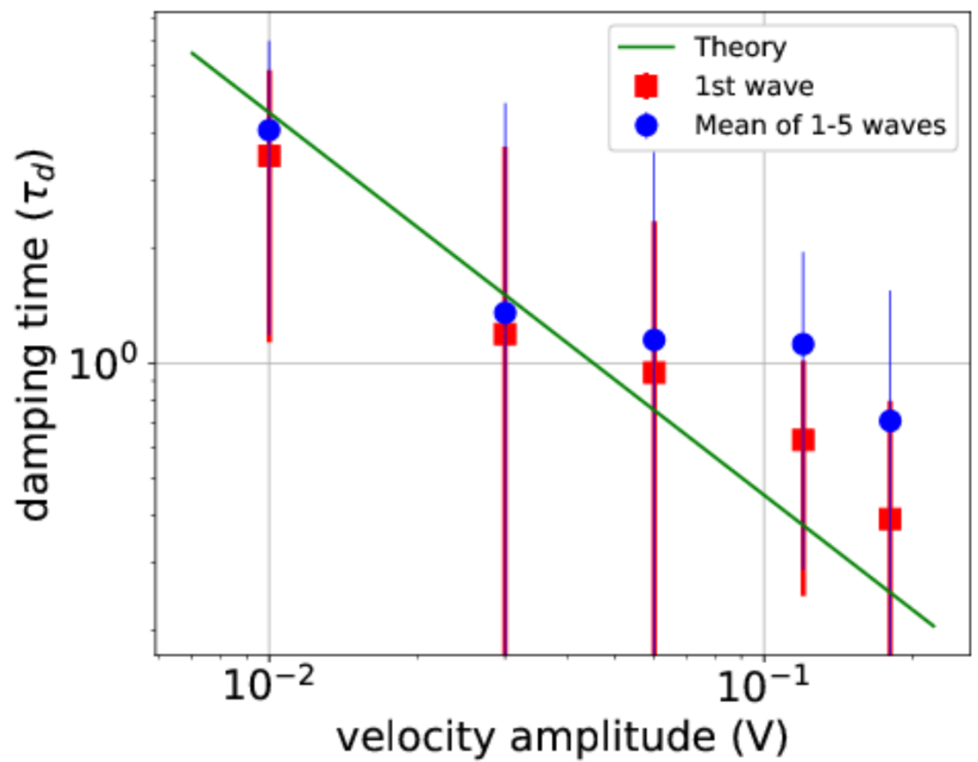



$\zeta = 1.1$
$\zeta = 2$
$\zeta = 5$
$\zeta = 10$
$\zeta = 20$
X - axis
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.04 −0.02 0.00 0.02 0.04
Y - axis
0.50 0.51 0.52 0.53 0.54 0.55
0.5 0.6 0.7 0.8 0.9 1.0
0.5 1.0 1.5 2.0 2.5
1 2 3 4
2 4 6 8


$V = 0.01$
$V = 0.03$
$V = 0.06$
$V = 0.12$
$V = 0.18$
X - axis
0.06
0.04
0.02
0.00
−0.02
−0.04
−0.06
−0.04 −0.02 0.00 0.02 0.04
Y - axis
0.5 1.0 1.5 2.0 2.5

NUMERICAL RESULTS





a) $\zeta = 1.1, \quad 2, \quad 5, \quad 10, \quad 20$

b) $V = 0.01, \quad 0.03, \quad 0.06, \quad 0.12, \quad 0.18$

SUMMARY

- **Plasma inhomogeneity leads to uniturbulence**
- **constructed analytical model for uniturbulence evolution in surface Alfvén waves**
- **found expressions for damping time**
- $$\tau = \frac{3\sqrt{10}}{5\,V\,k_y}\,\frac{\zeta+1}{\zeta-1}$$

Cylindrical:

$$\tau = \frac{2\sqrt{5}\,\pi\,R}{V}\,\frac{\zeta+1}{\zeta-1}$$

Van Doorsselaere et al. 2020, ApJ

- **Analysed numerical models to check analytical expressions for damping**
  - **Numerical proof of our theoretical model**
  - **As the numerical results match with the theory in a planar geometry, it approves that it will also be correct for the cylindrical case**

Thank you for your attention