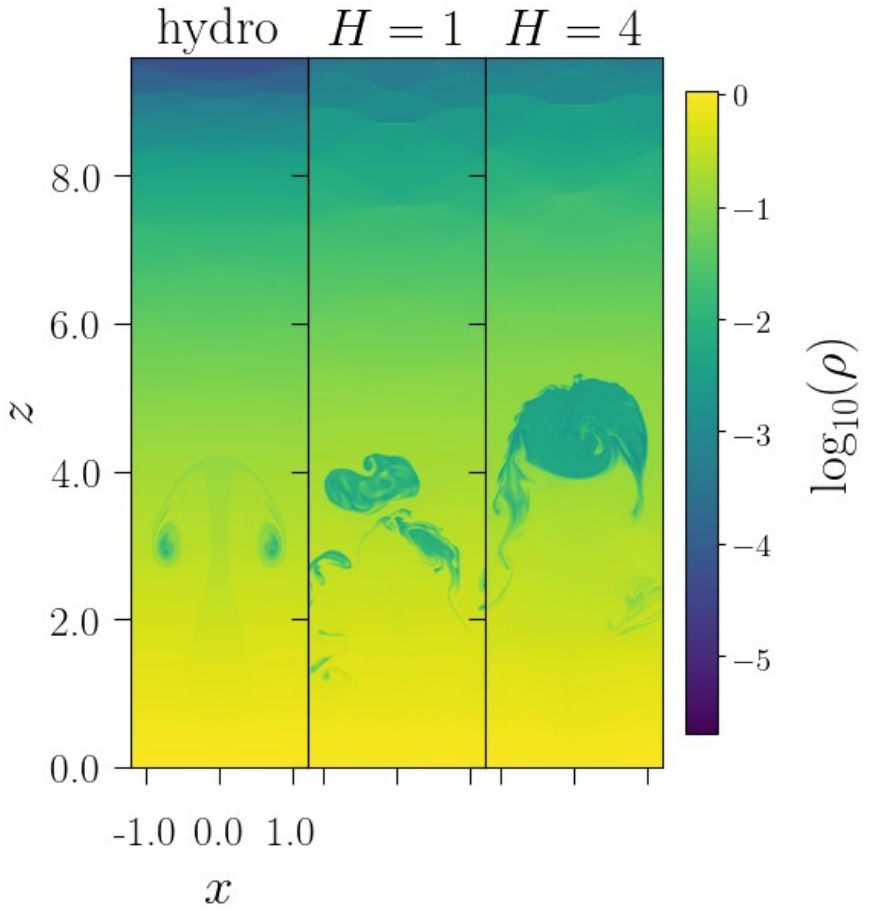
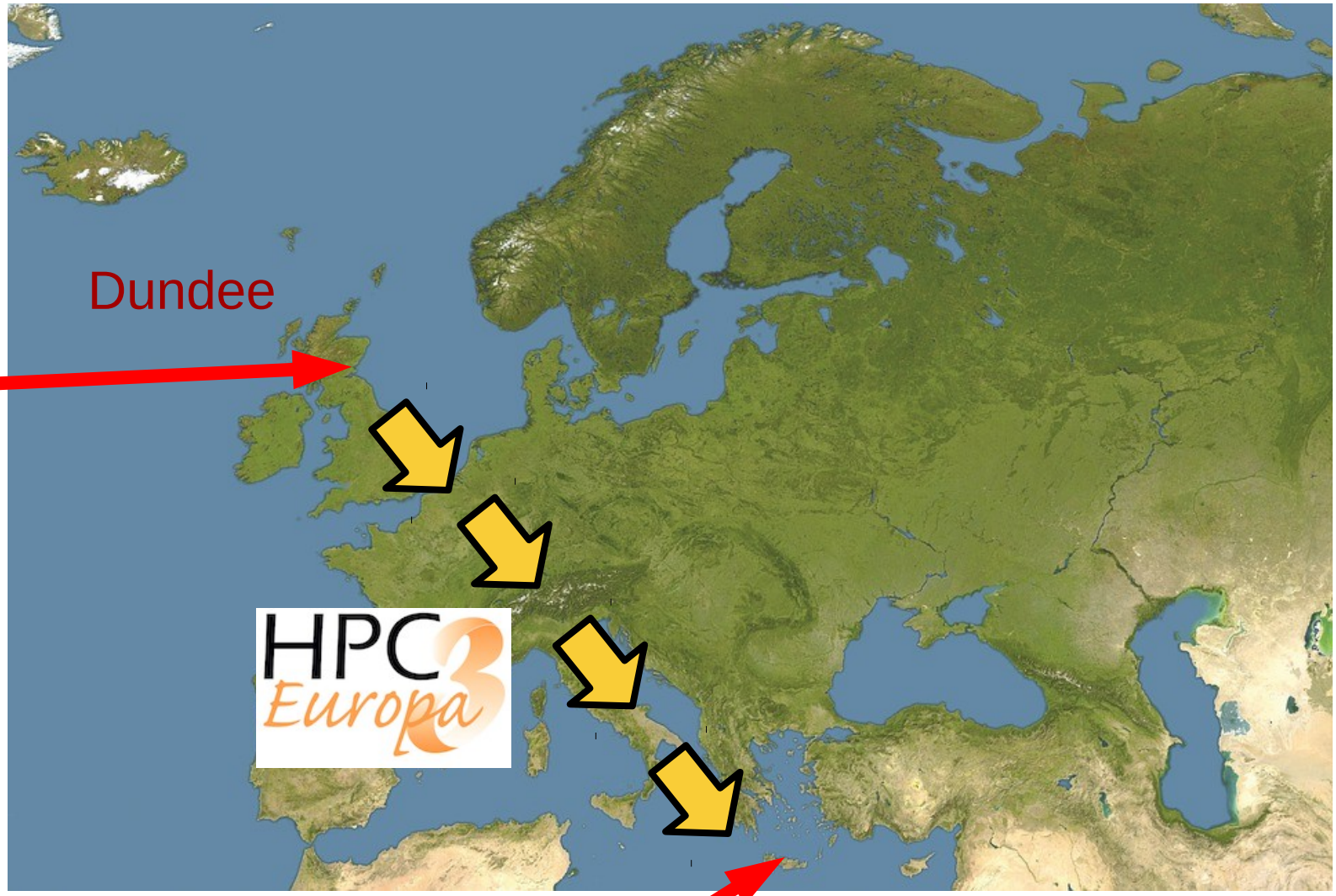
Stabilizing effect of magnetic helicity on magnetic cavities in the intergalactic medium.

Simon Candelaresi, Fabio Del Sordo



Collaboration



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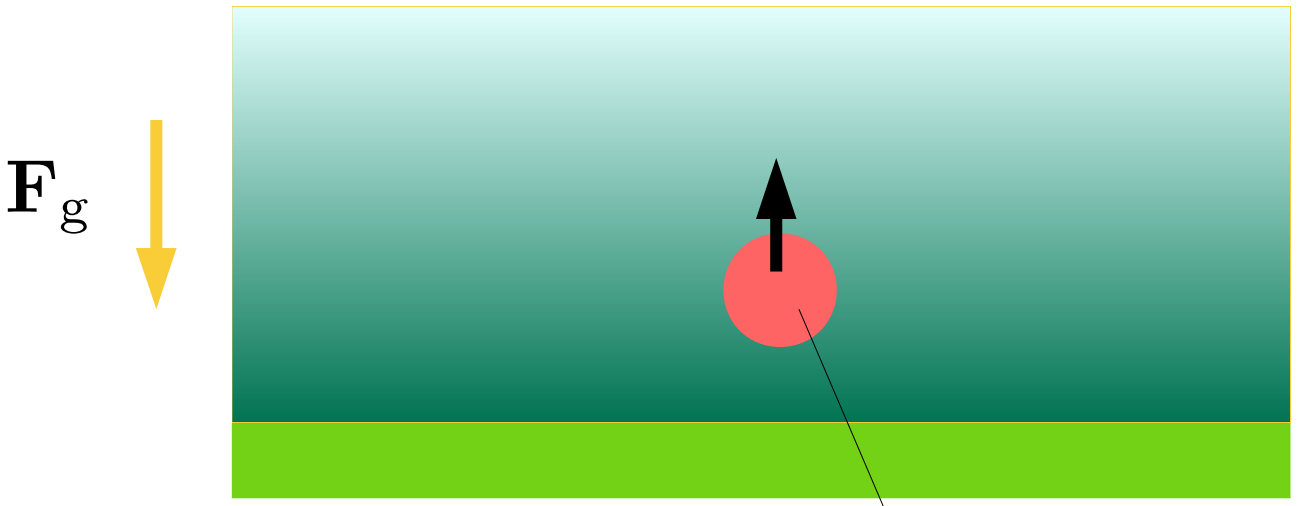
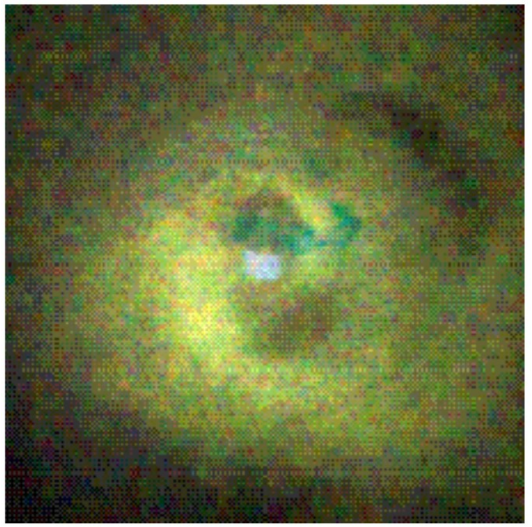
Intergalactic Bubbles

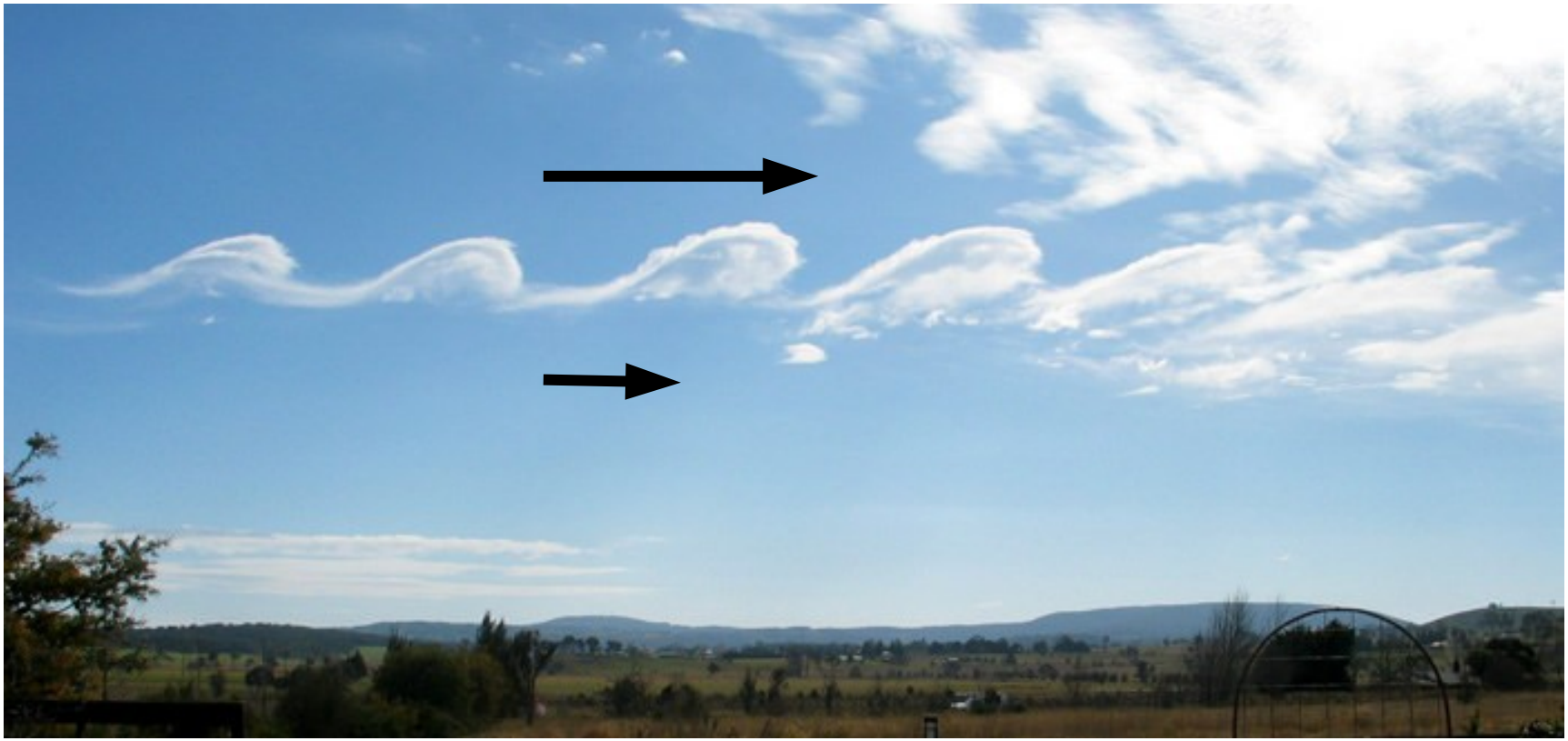




(Fabian et al. 2000)

- Bubbles rise buoyantly through density difference.
- Bubbles' age is several tens of millions of years.

Kelvin-Helmholtz Instability



(GRAHAMUK/Wikimedia Commons)

- Bubbles should get disrupted.
- What is the reason for their stability?

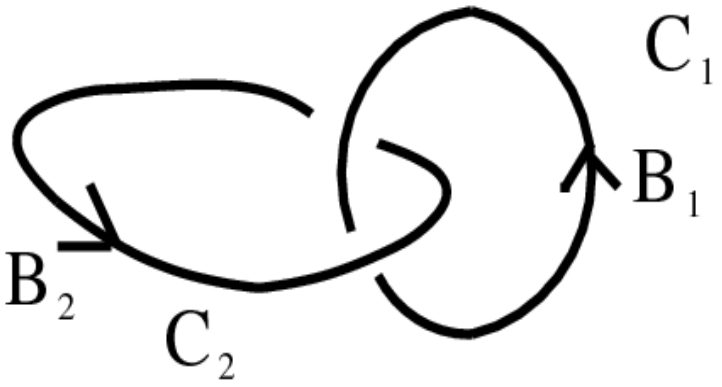
Magnetic Helicity

Measure for the topology:

$$H_{\mathrm{M}} = \int_V \boldsymbol{A} \cdot \boldsymbol{B} \, \mathrm{d}V = 2n\phi_1\phi_2$$

$$\boldsymbol{\nabla} \times \boldsymbol{A} = \boldsymbol{B} \qquad \phi_i = \int_{S_i} \boldsymbol{B} \cdot \mathrm{d}\boldsymbol{S}$$

$n =$ number of mutual linking



(Moffatt 1969)

Conservation of magnetic helicity:

$$\lim_{\eta \to 0} \frac{\partial}{\partial t} \langle \boldsymbol{A} \cdot \boldsymbol{B} \rangle = 0 \qquad \eta =$$ magnetic resistivity

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Can a helical magnetic field stabilize the bubbles?

Numerical Experiments

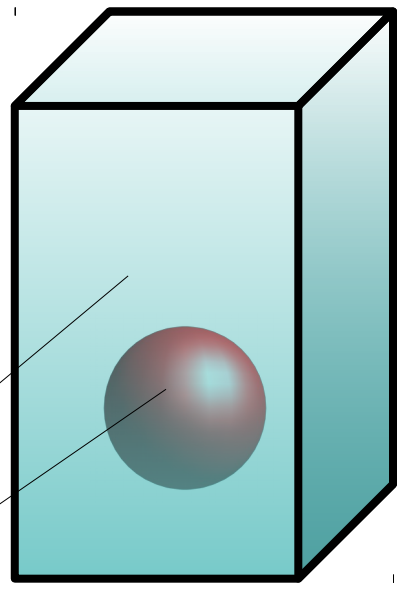
Full resistive magnetohydrodynamics simulations with the PencilCode.

$$\frac{\partial \mathbf{A}}{\partial t} = \mathbf{U} \times \mathbf{B} + \eta \nabla^2 \mathbf{A}$$

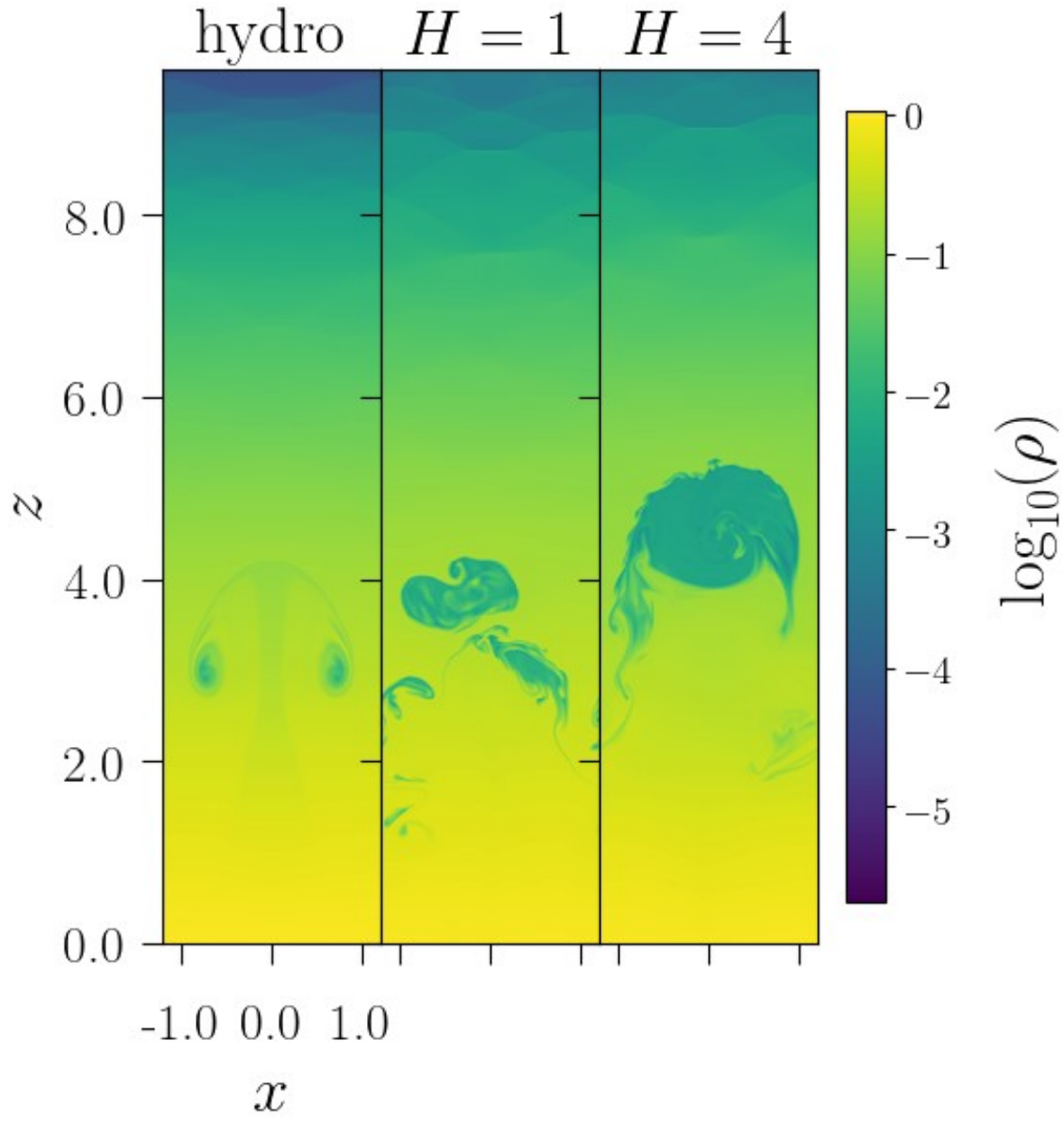
$$\frac{\mathrm{D}\mathbf{U}}{\mathrm{D}t} = -c_\mathrm{S}^2 \nabla \left(\frac{\ln T}{\gamma} \ln \rho \right) + \mathbf{J} \times \mathbf{B}/\rho - \mathbf{g} + \mathbf{F}_\mathrm{visc}$$

$$\frac{\partial \ln T}{\partial t} = -\mathbf{U} \cdot \nabla \ln T - (\gamma - 1) \nabla \cdot \mathbf{U} + \frac{1}{\rho c_V T} \left(\nabla \cdot (K \nabla T) + \eta \mathbf{J}^2 + 2\rho\nu \mathsf{S} \otimes \mathsf{S} + \zeta \rho (\nabla \cdot \mathbf{U})^2 \right)$$

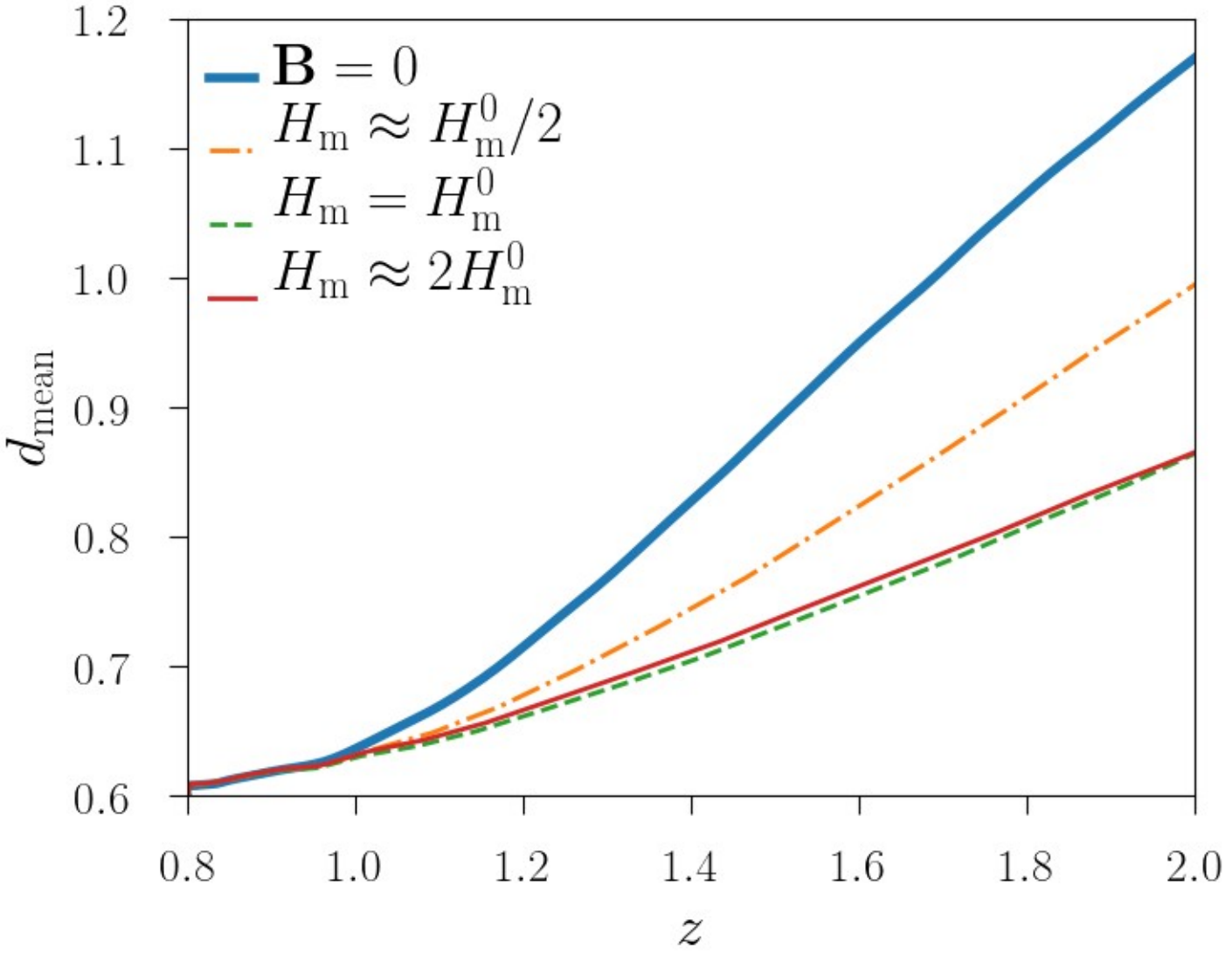
$$\frac{\mathrm{D} \ln \rho}{\mathrm{D}t} = -\nabla \cdot \mathbf{U}$$



Bubble Coherence



Bubble Coherence



Helical magnetic fields can stabilize the bubbles.

Conclusions

- Intergalactic bubbles are very stable.
- Magnetic helicity leads to stability at small magnetic energy.
- Combined expertise between Heraklion and Dundee.

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