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TURBULENCE DRIVEN BY PHASE-MIXED TORSIONAL ALFVÉN WAVES IN NONUNIFORM CORONAL LOOPS

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Introduction

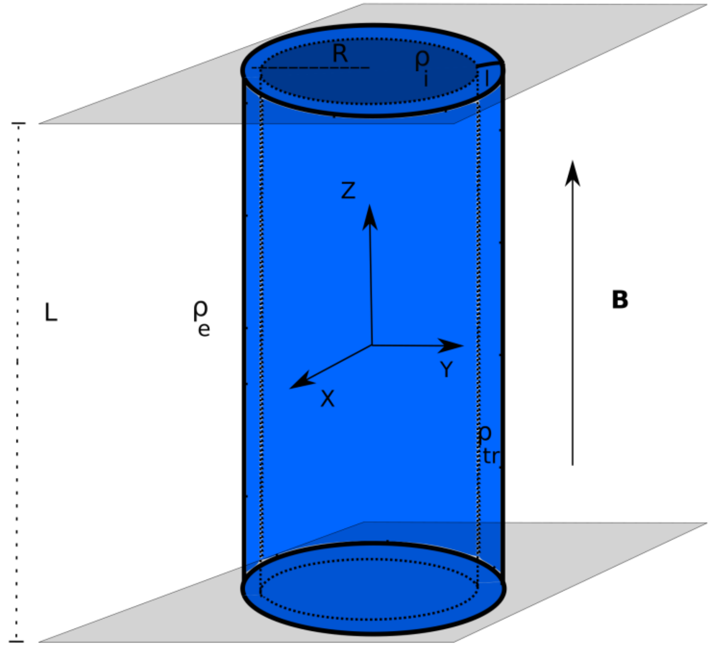
- High-resolution observations have shown the existence of torsional Alfvén waves during solar flares (Aschwanden and Wang 2020), and at coronal heights (Kohutova et al 2020).

- Moreover, Soler et al 2021 have shown that these waves can transport enough energy to balance radiative losses at coronal heights through resonances with a coronal loop.

- Few works have studied numerically nonlinear torsional Alfvén waves in a coronal loop (e.g., Shestov et al 2017, Guo et al 2019). However, kink waves have been studied extensively (e.g., Terradas et al. 2008, Antolin et al. 2014,2015, Magyar and Van Doorsselaere 2016, Howson et al. 2017, Antolin and Van Doorsselaere 2019).

- We aim to investigate numerically the nonlinear evolution of torsional Alfvén waves in a simple configuration mimicking a coronal loop.

Numerical model



- We considered a cylindrical, radially inhomogeneous, and straight magnetic flux tube. The tube ends are line-tied at two rigid walls representing the solar photosphere.

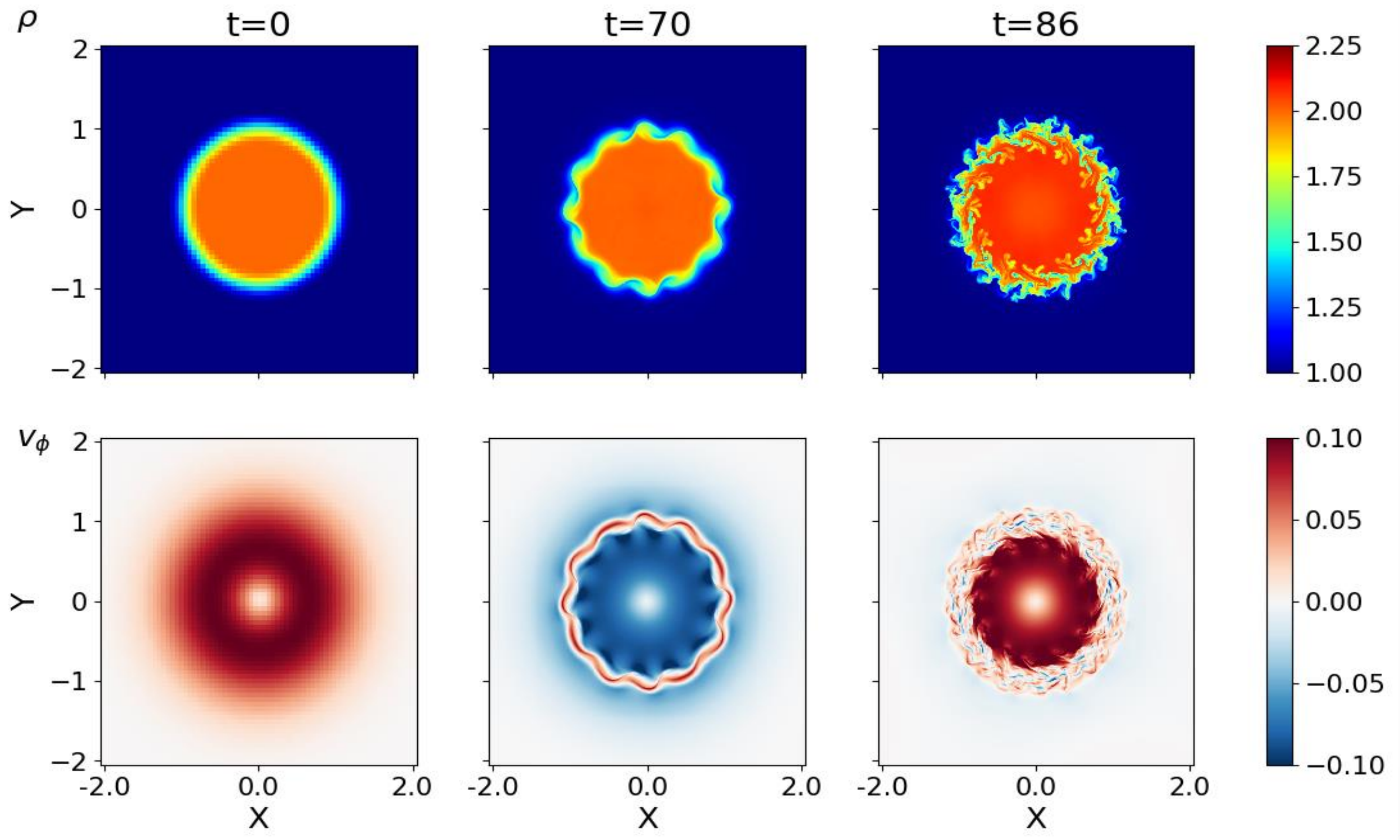
- The 3D ideal MHD equations are numerically solved with the PLUTO code (Mignone et al 2007) that uses finite volumes and adaptive mesh refinement (Mignone et al 2012).

- On the 0^{th} level, we used a uniform grid of 100x100x100 cells. We used 4 levels of refinement, so the largest effective resolution is 1600x1600x1600.

- A standing torsional Alfvén wave is excited with a prescribed amplitude.

Cross sectional cut

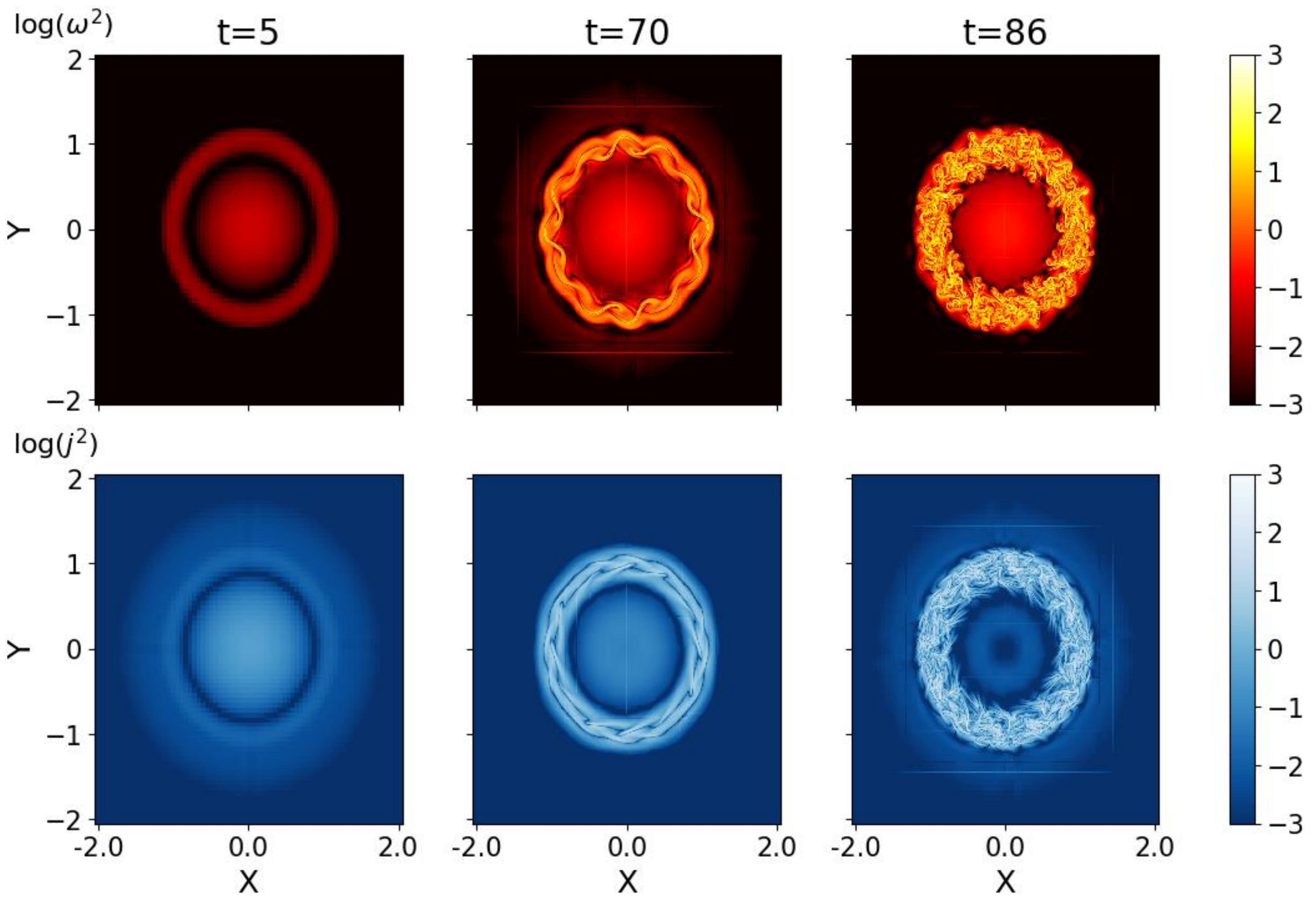
Azimuthal shear flows can trigger Kelvin-Helmholtz instability (Heyvaerts & Priest 1983, Browning & Priest 1984)



An animation of both panels is available.

Vorticity and current density

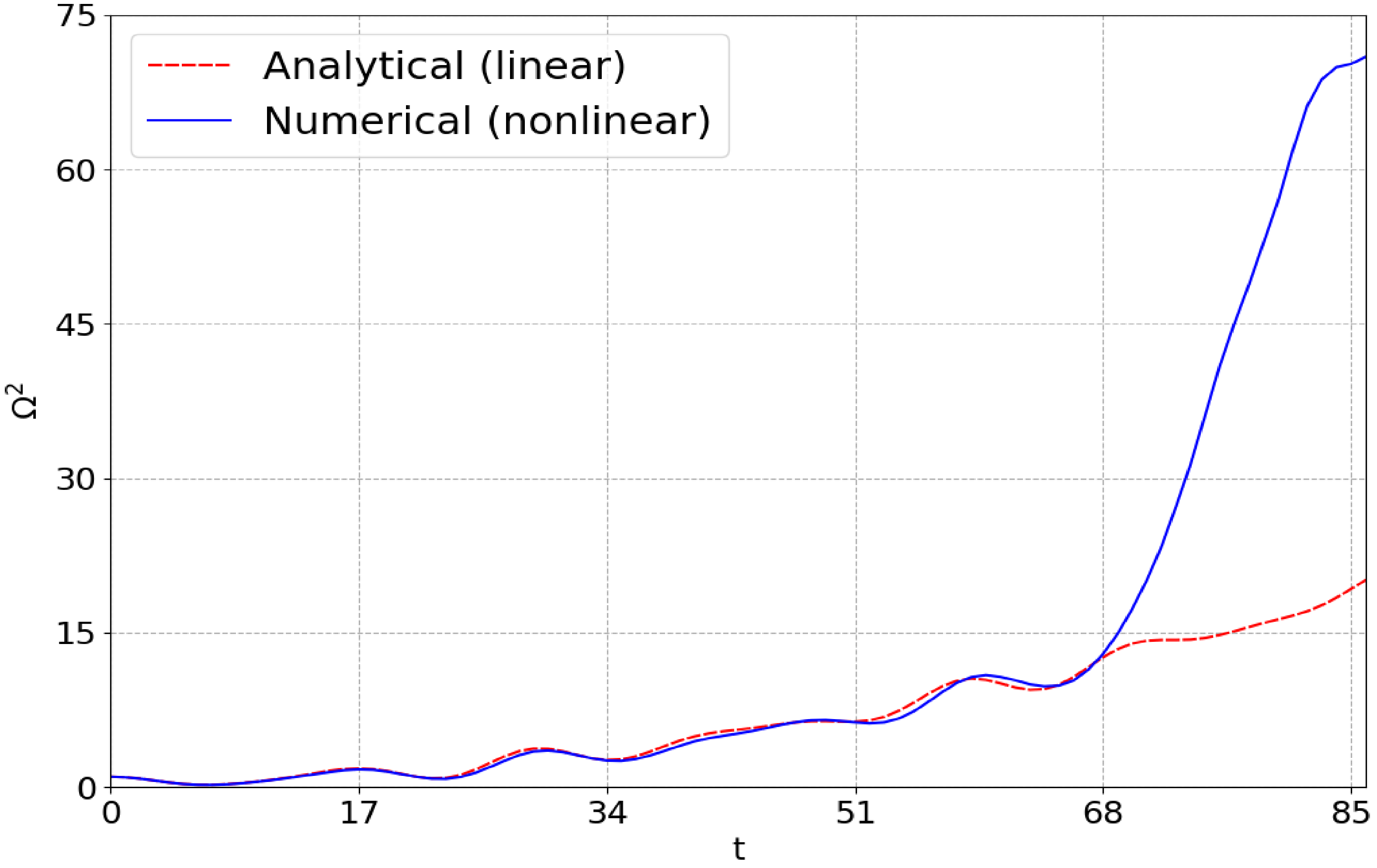
Kelvin-Helmholtz instability and turbulence generates incredibly fine structures



An animation of both panels is available.

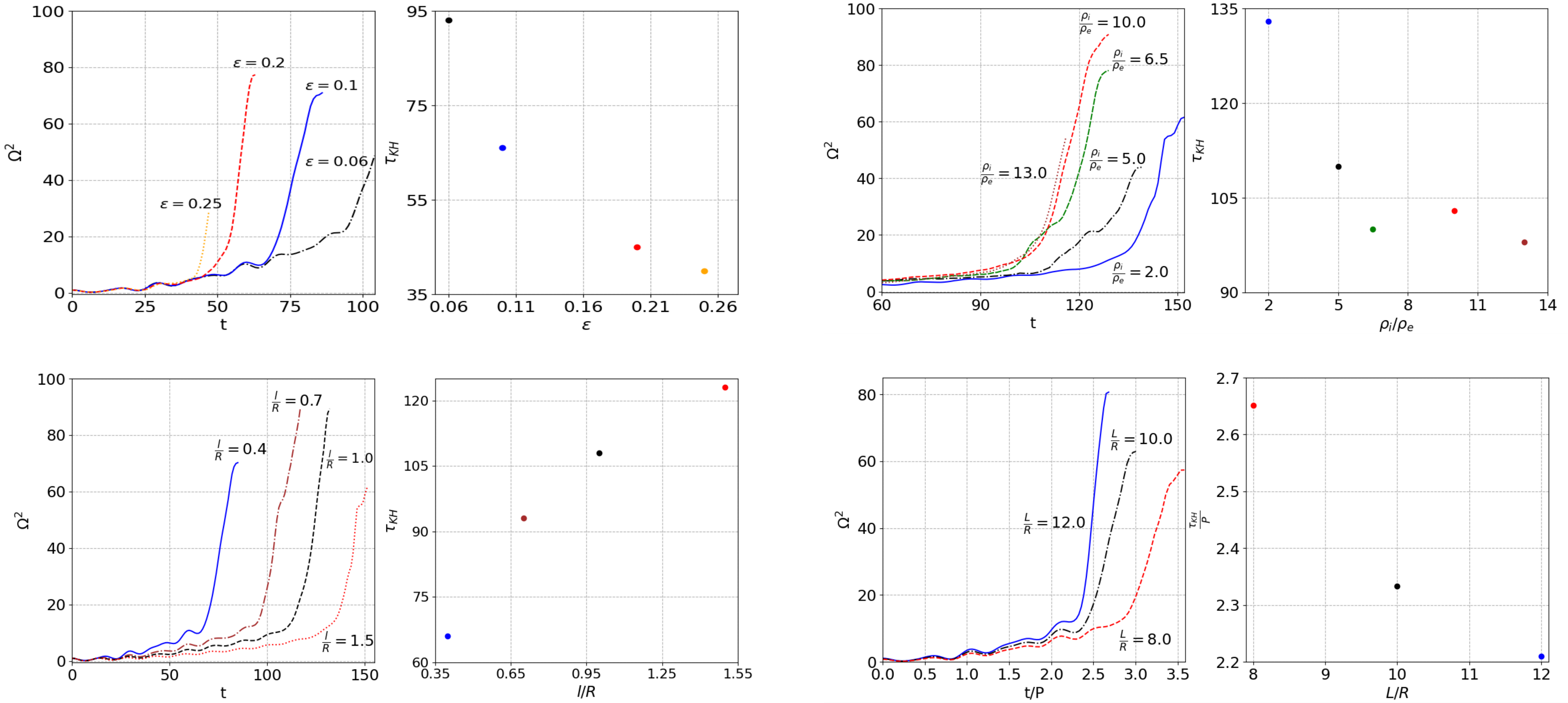
Evolution of vorticity squared

Quantifying the onset of the Kelvin-Helmholtz instability



Parameter study

The change of trend in the vorticity indicates the global onset of the Kelvin-Helmholtz instability



Conclusions

- Phase-mixed torsional Alfvén waves can generate turbulence through Kelvin-Helmholtz instability (KHi)
- KHi triggered after few periods of torsional oscillations
- The huge increase in vorticity evidences an impact of KHi in the whole flux tube
- Turbulence and KHi speed up the growth of small scales initiated by phase-mixing
- Linear theory greatly underestimates the generation of small scales