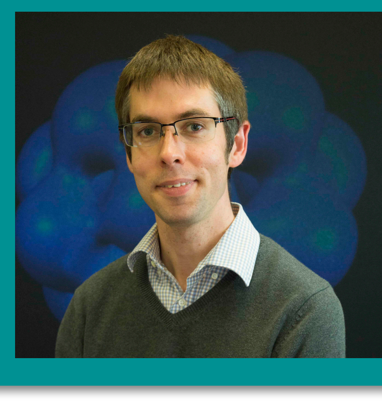
REVISITING TAYLOR RELAXATION

Anthony Yeates (anthony.yeates@dur.ac.uk), **Long Chen** (Durham University, UK)
Alexander Russell, Gunnar Hornig (University of Dundee, UK)



We are using resistive-MHD simulations to probe the self-organization of turbulently relaxing magnetic fields.

Understanding the fundamental relaxation process is important for predicting energy release in solar/stellar coronal heating and confined solar flares.

CLASSIC TAYLOR HYPOTHESIS [1]

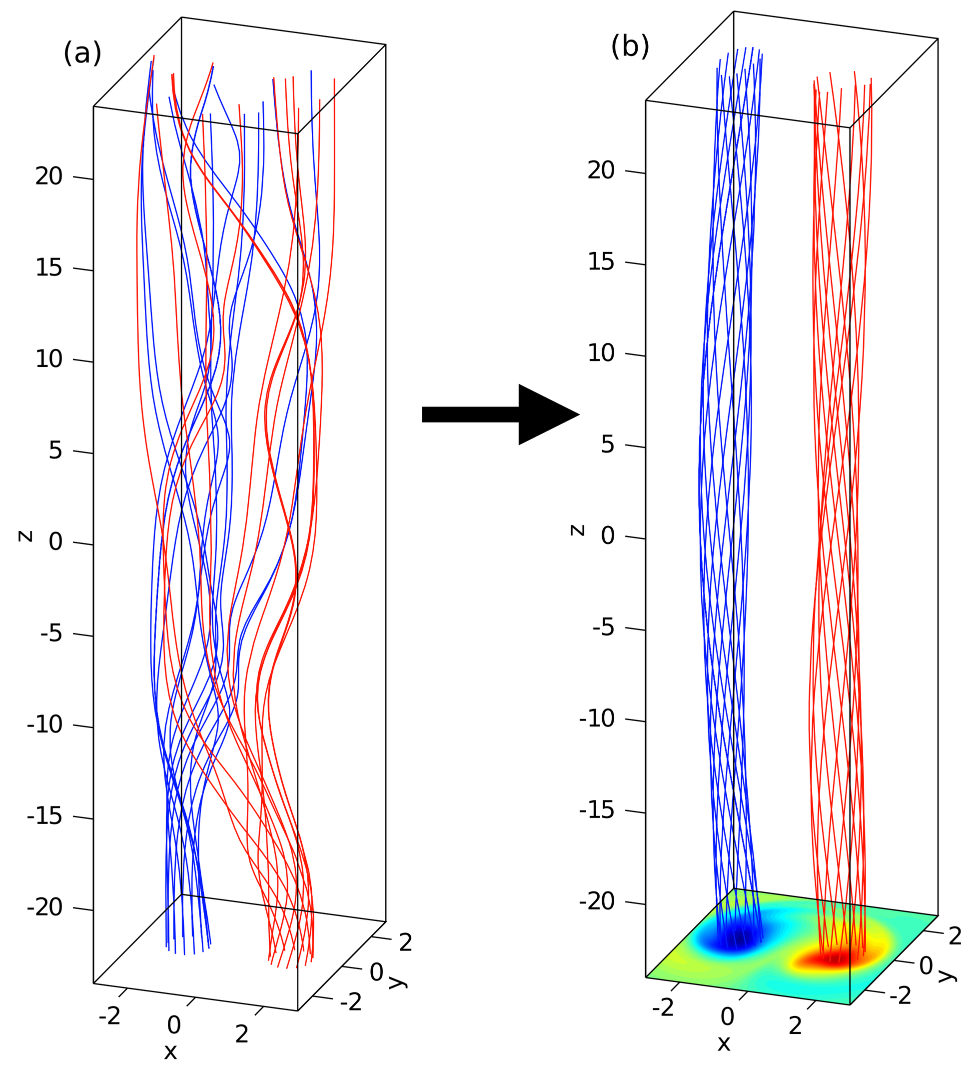
If the only constraints are total magnetic flux and helicity, the minimum-energy state is a **linear force-free field**

$$\nabla \times \boldsymbol{B} = \lambda_0 \boldsymbol{B} \quad \text{where } \lambda_0 = \text{constant}.$$

NUMERICAL SETUP

Lare3D [2] is used to solve the (unforced) resistive-MHD equations, starting from an initially braided magnetic field [3] that is resistively unstable.

- Ideal gas with low plasma-beta.
- Line-tied boundary conditions.
- Typical resolution: 640x640x480 grid with Lundquist number $S=10^4$.
- The qualitative results are the same for $S=2\times10^4$ or 10^3 (resistive "smoothing" dominates for lower S), and even for higher plasma-beta.

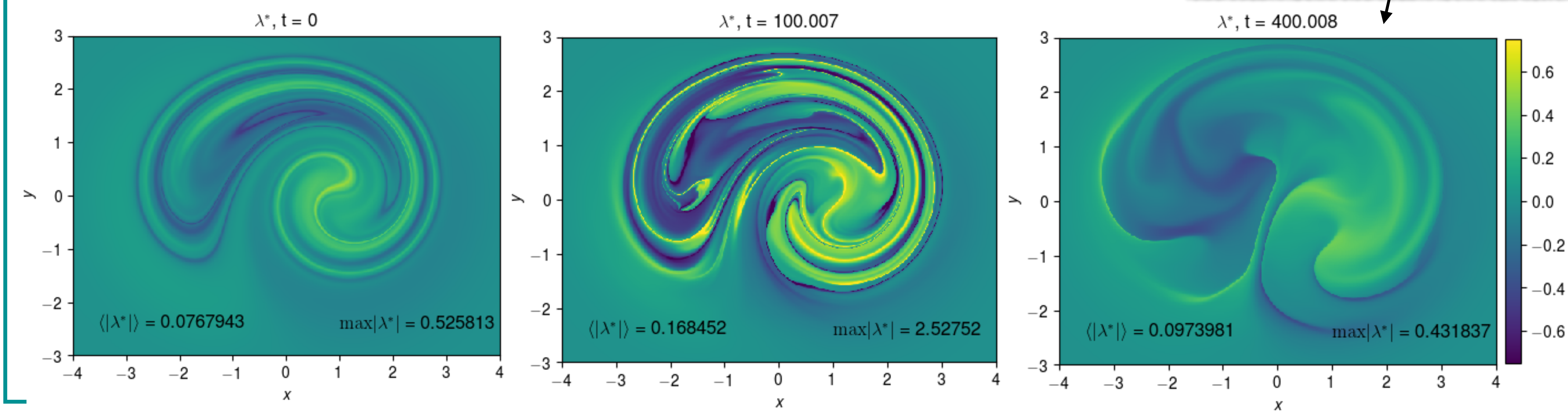


RESULTS

1. In contrast to the classic Taylor prediction, the relaxed state is *nonlinear* force-free.

We quantify the departure from linear force-free by the field-line average $\lambda^*(L) = \frac{1}{L}\int_L \frac{\nabla \times \boldsymbol{B}\cdot\boldsymbol{B}}{B^2}\,\mathrm{d}l.$

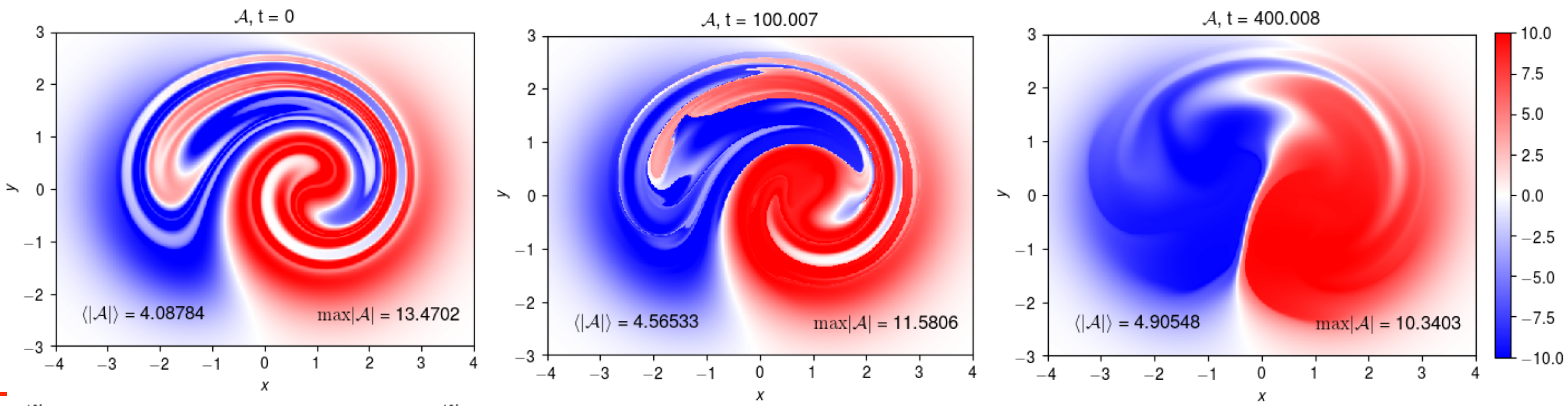
Relaxed state has clearly non-uniform λ^*, even within each flux tube.

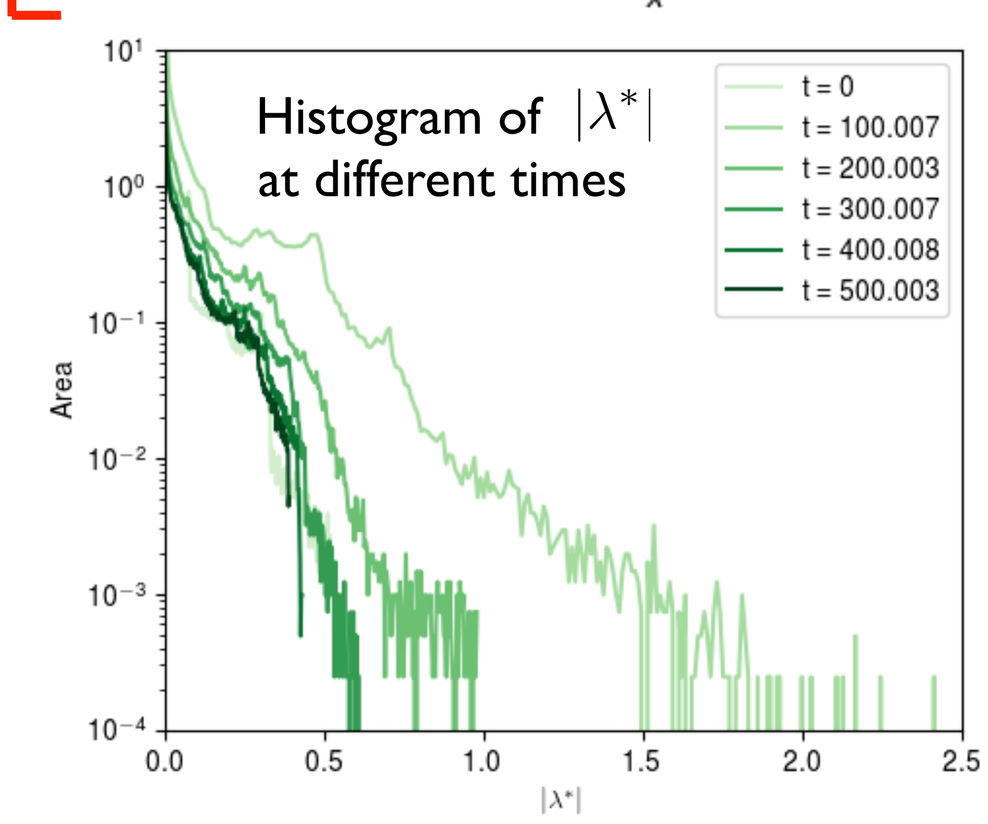


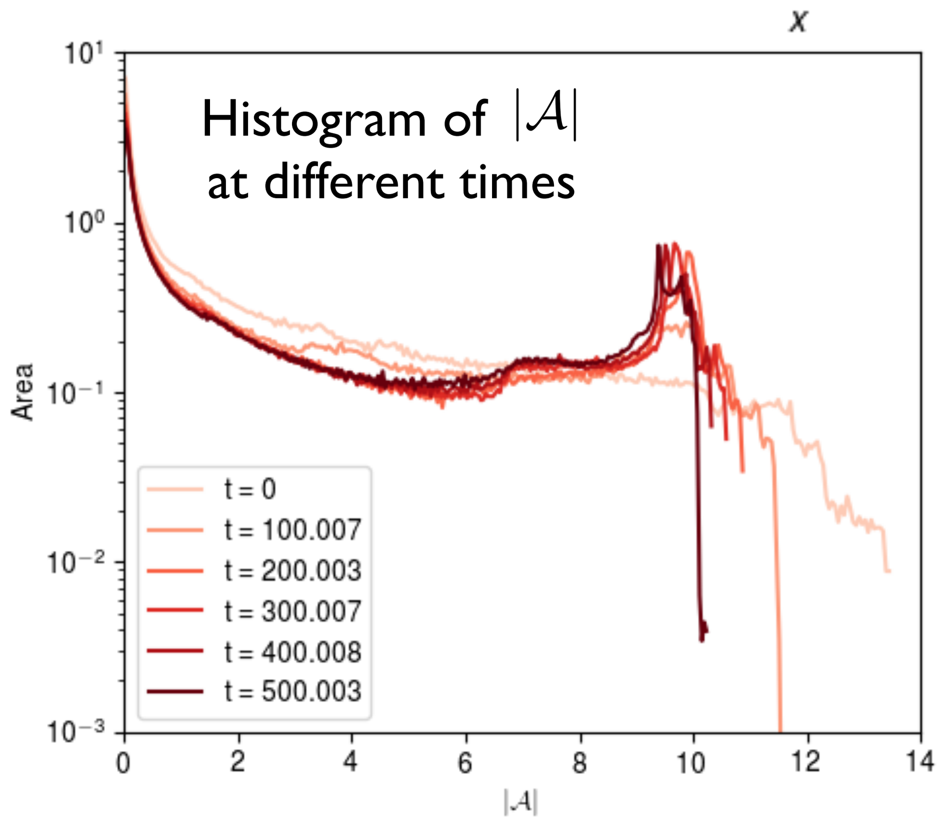
2. However, we do observe a local "flattening" of field line helicity within each tube.

In our line-tied system, **field line helicity** $\mathcal{A}(L) = \int_L \boldsymbol{A}\cdot\mathrm{d}\boldsymbol{l}$ [4] would be invariant for every field line in an ideal evolution.

Taylor [1] conjectured that the individual line helicities are destroyed by the reconnection. Indeed they can change rapidly at a given footpoint position. However, the dominant behaviour is not a removal of field line helicity but rather a **flattening**/uniformization within regions of opposite sign:







Our recent analysis of the evolution equation [5] shows that the preservation of line helicity arises from the thinness of current sheets.

But the mechanism underlying the flattening remains to be explained.

References

[1] Taylor, *PRL* **33**, 1139 (1974).
[2] Arber et al., *J Comp Phys* **171**, 151 (2001).
[3] Pontin et al., *PPCF* **58**, 054008 (2016).
[4] Berger, *A&A* **201**, 355 (1988).
[5] Russell et al., *PoP* **22**, 032106 (2015).

paper in preparation

LEVERHULME TRUST
Science & Technology Facilities Council