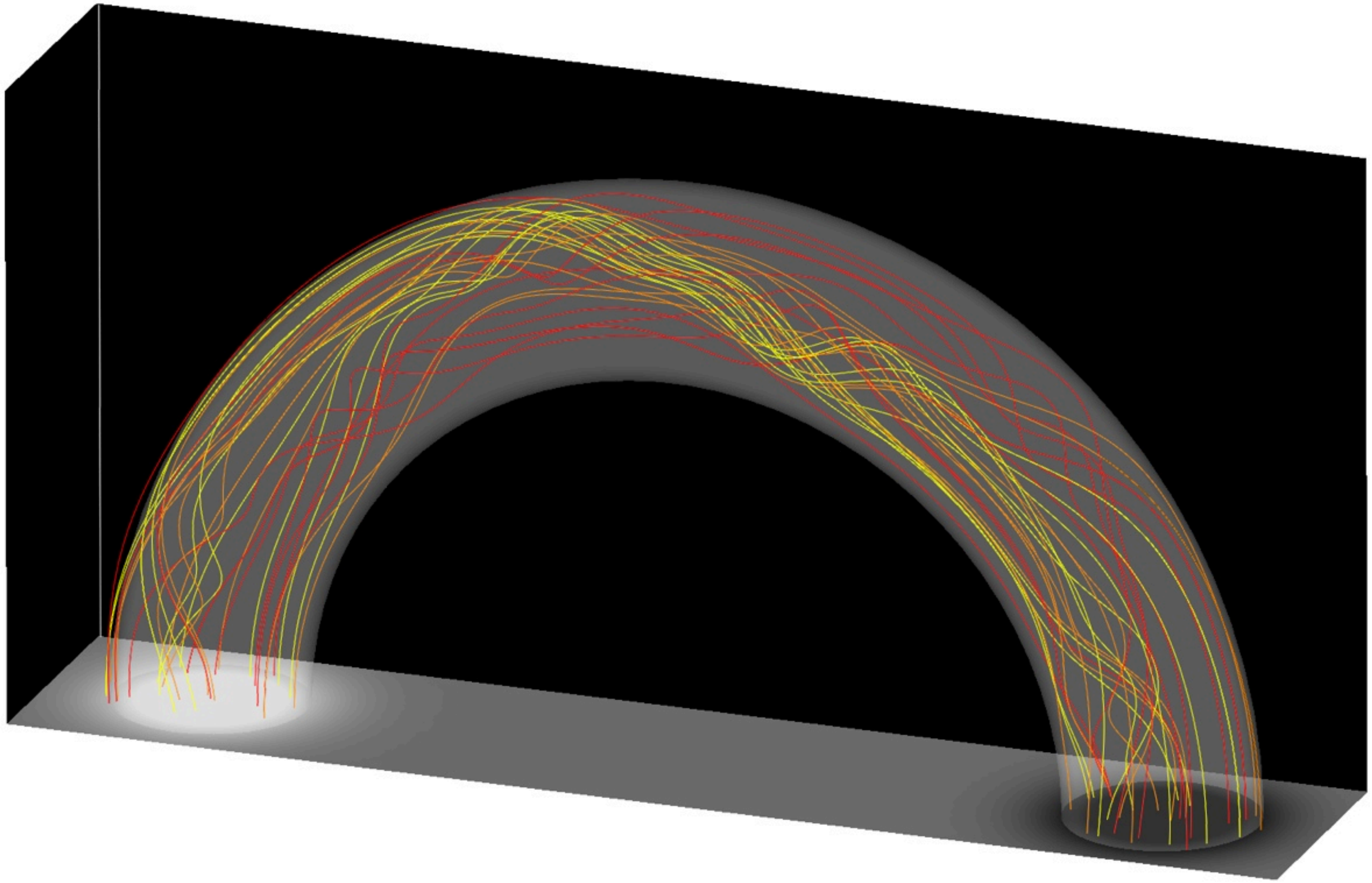
Heating of braided coronal loops



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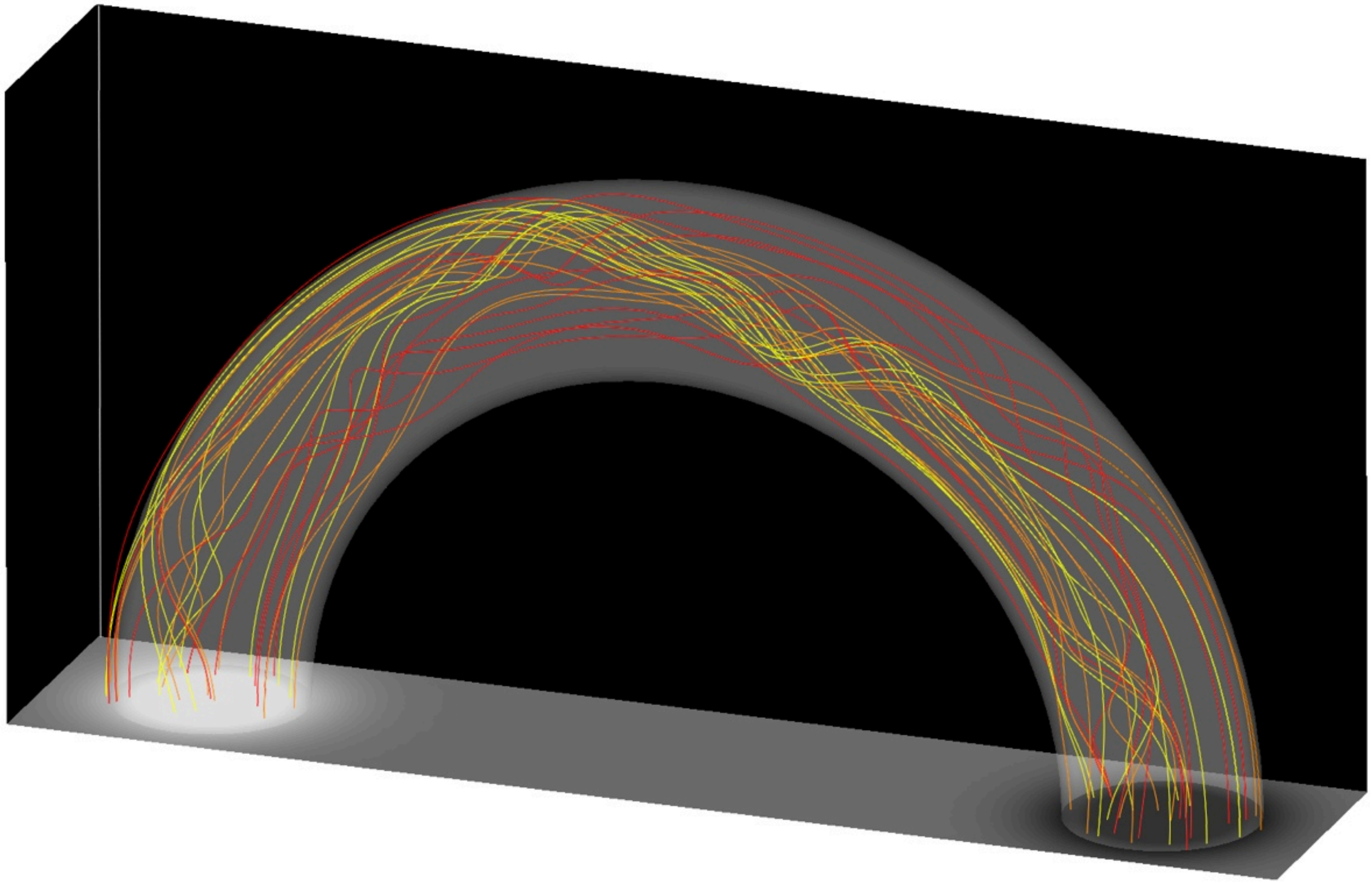
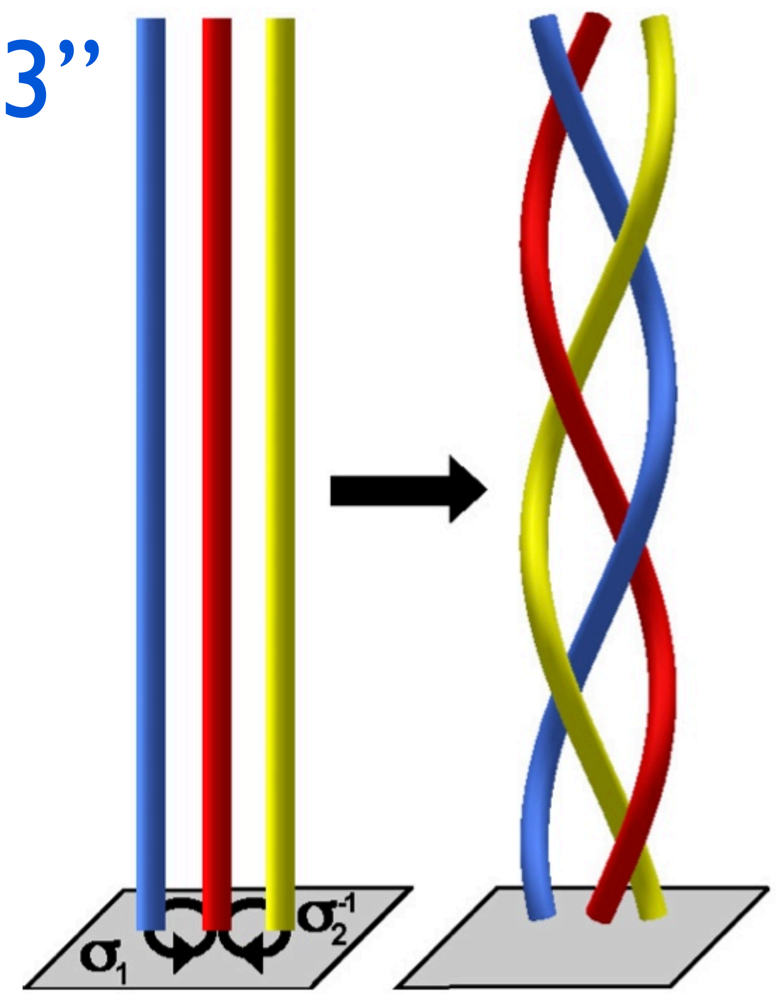
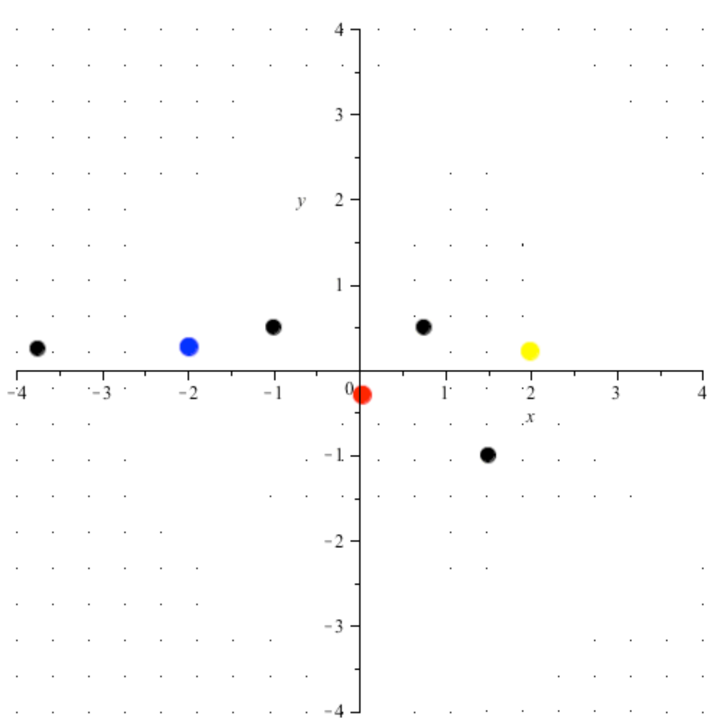


Aim: investigate how the pattern of braiding by photospheric footpoint motions affects heating of coronal loops

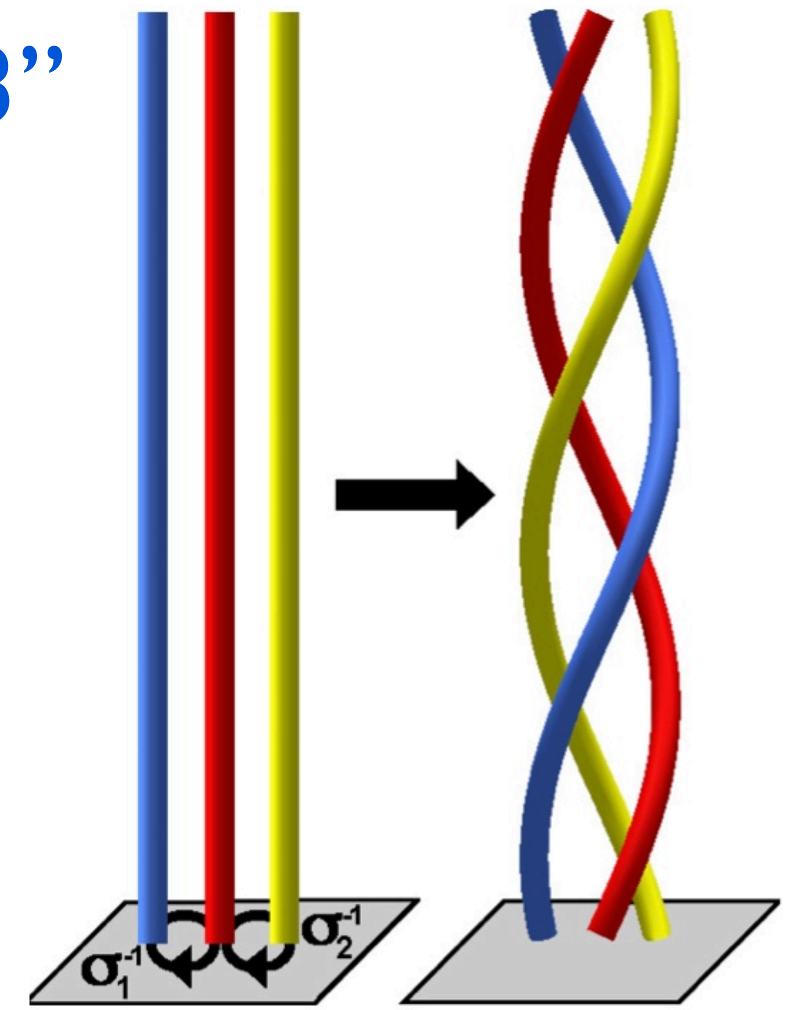
The model magnetic fields

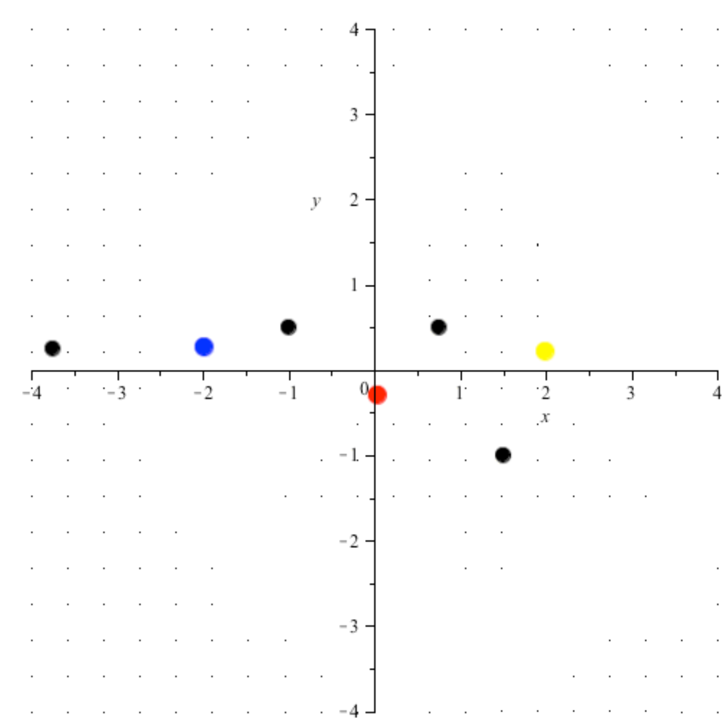
“E3”

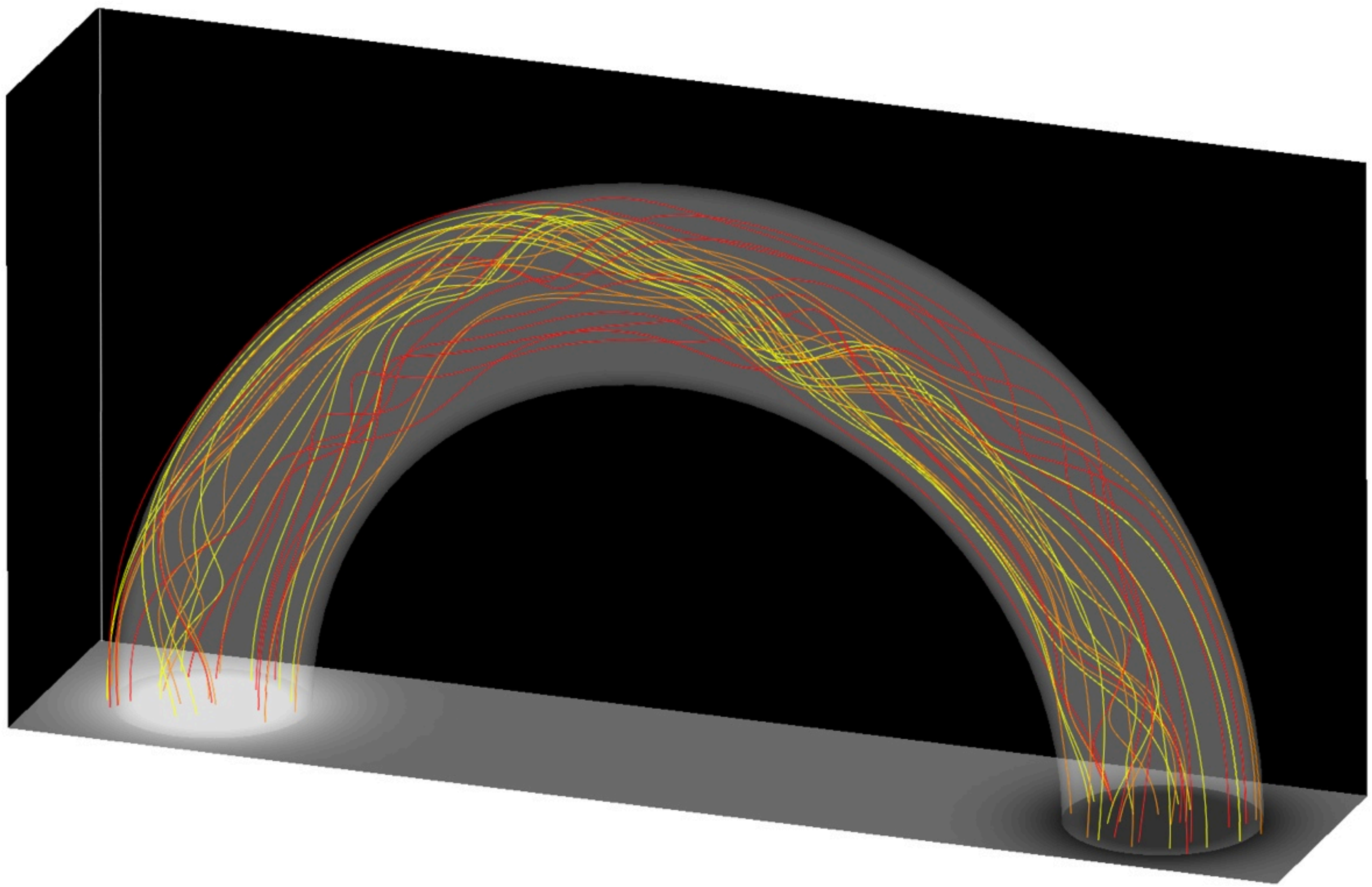


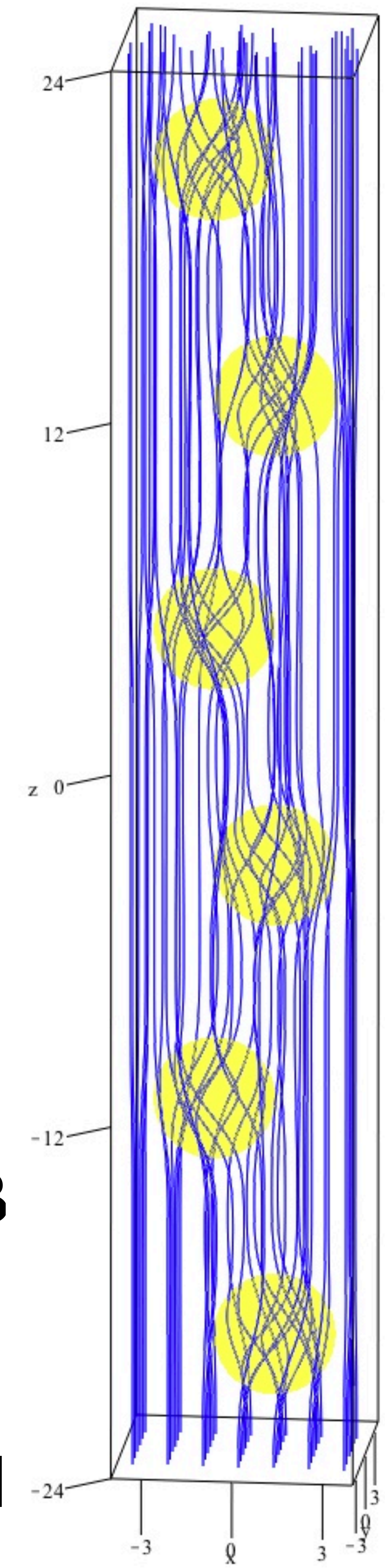


“S3”









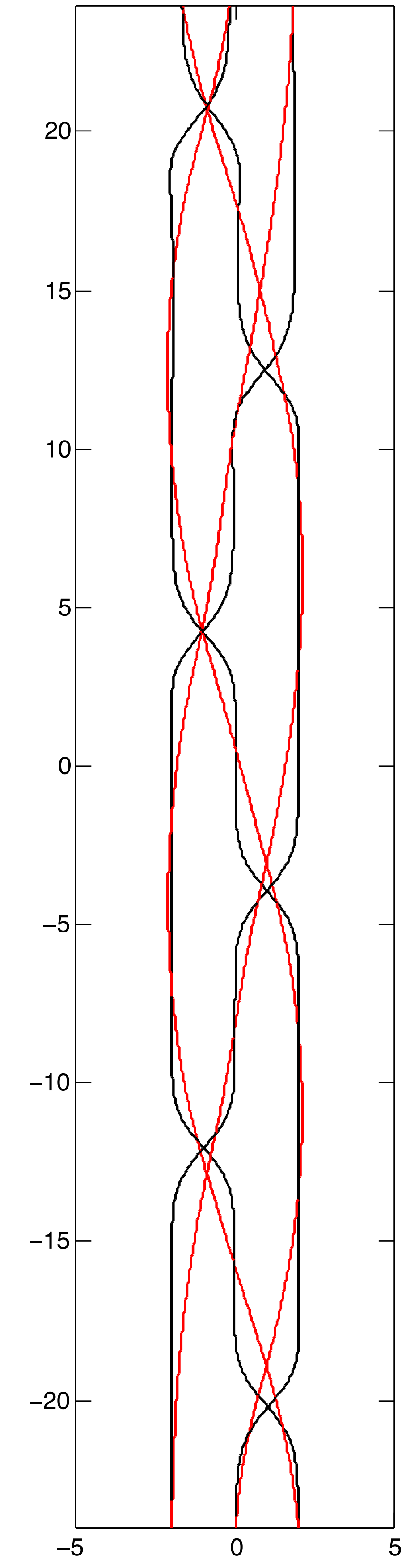
Achieved in practice by adding regions of twist to uniform B

Aspect ratio of loops is $\approx$ 1:10

Conservative approach: free energy only 3% above potential

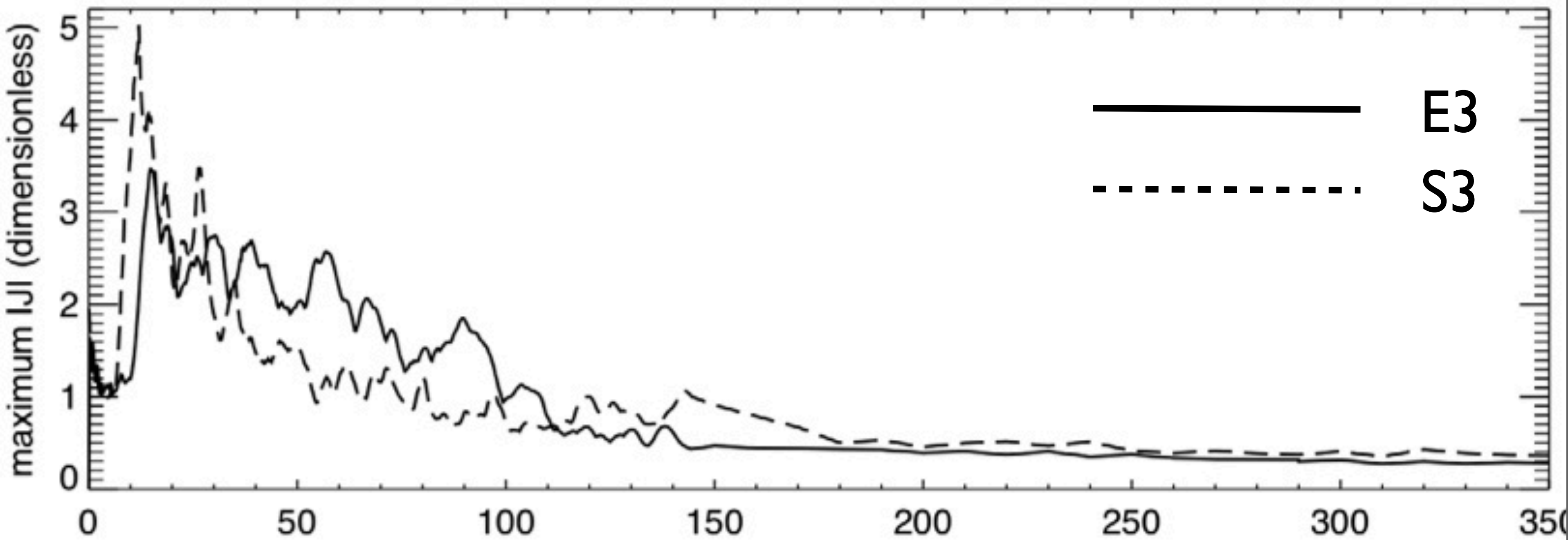
Simulation setup

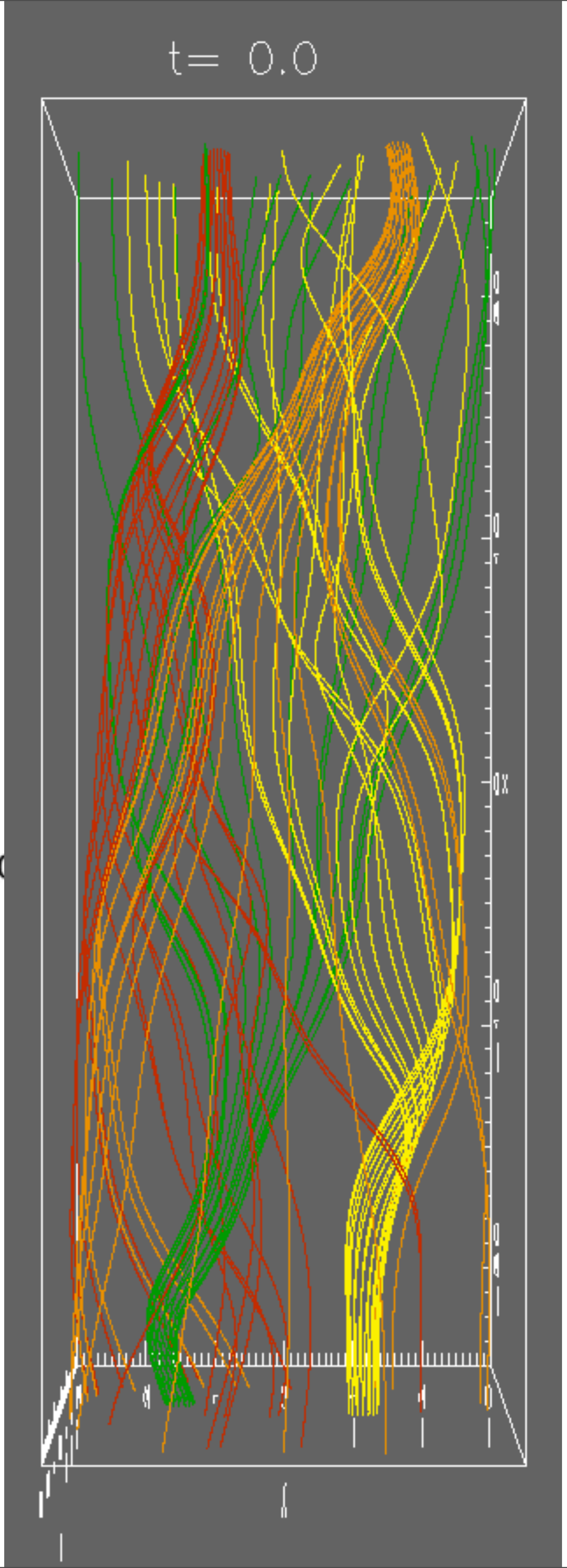
- Take field E3 or S3 and first perform an <u>ideal</u> relaxation
- Then transfer to resistive MHD code: $\underline{J}\times\underline{B}\approx 0$, and initialise with a uniform background plasma



Field lines before ideal relaxation
Field lines after ideal relaxation

Instability → relaxation



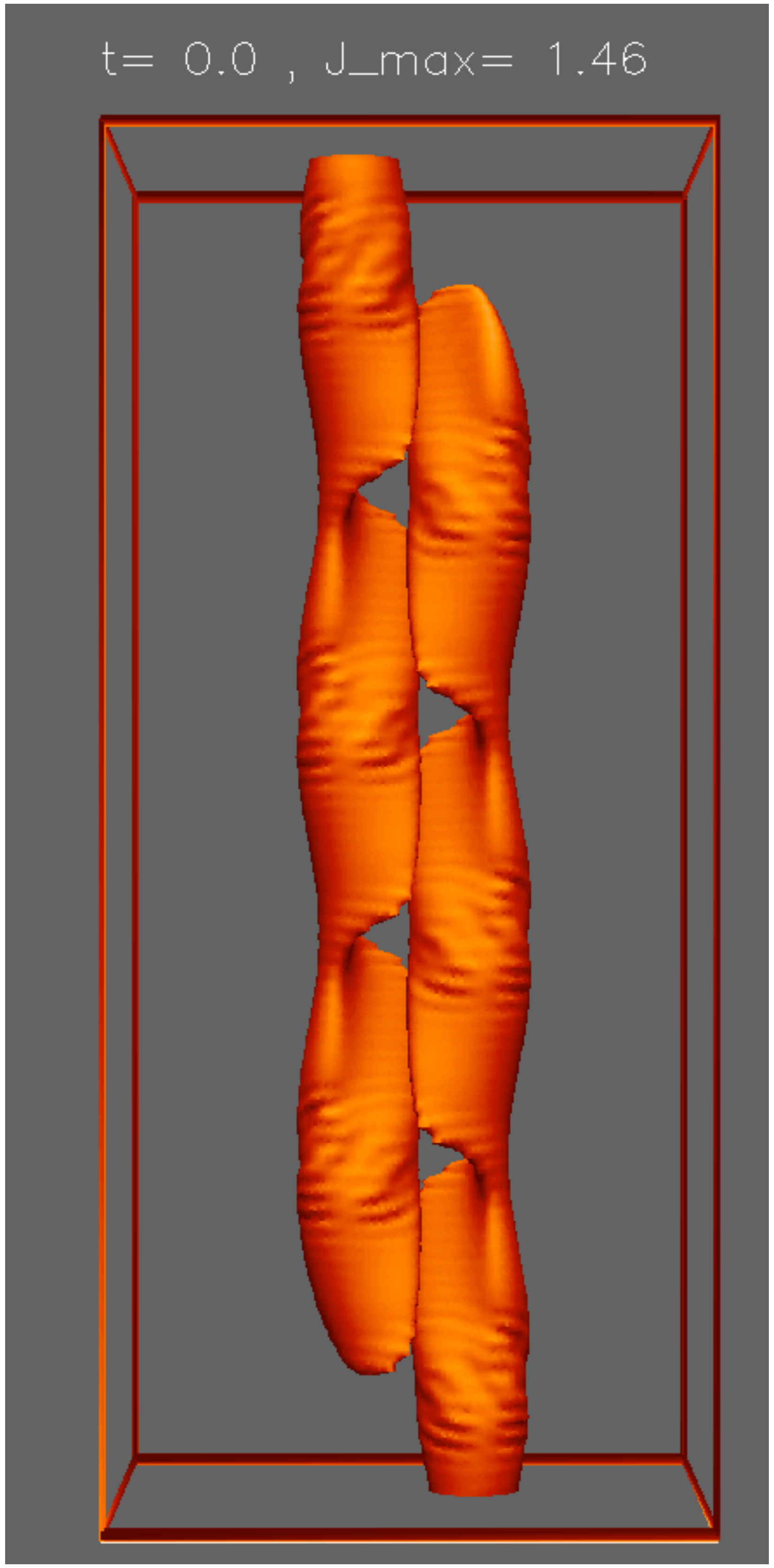


- Following an initial instability current peaks sharply in both cases
- Peak current falls off quickly for S3

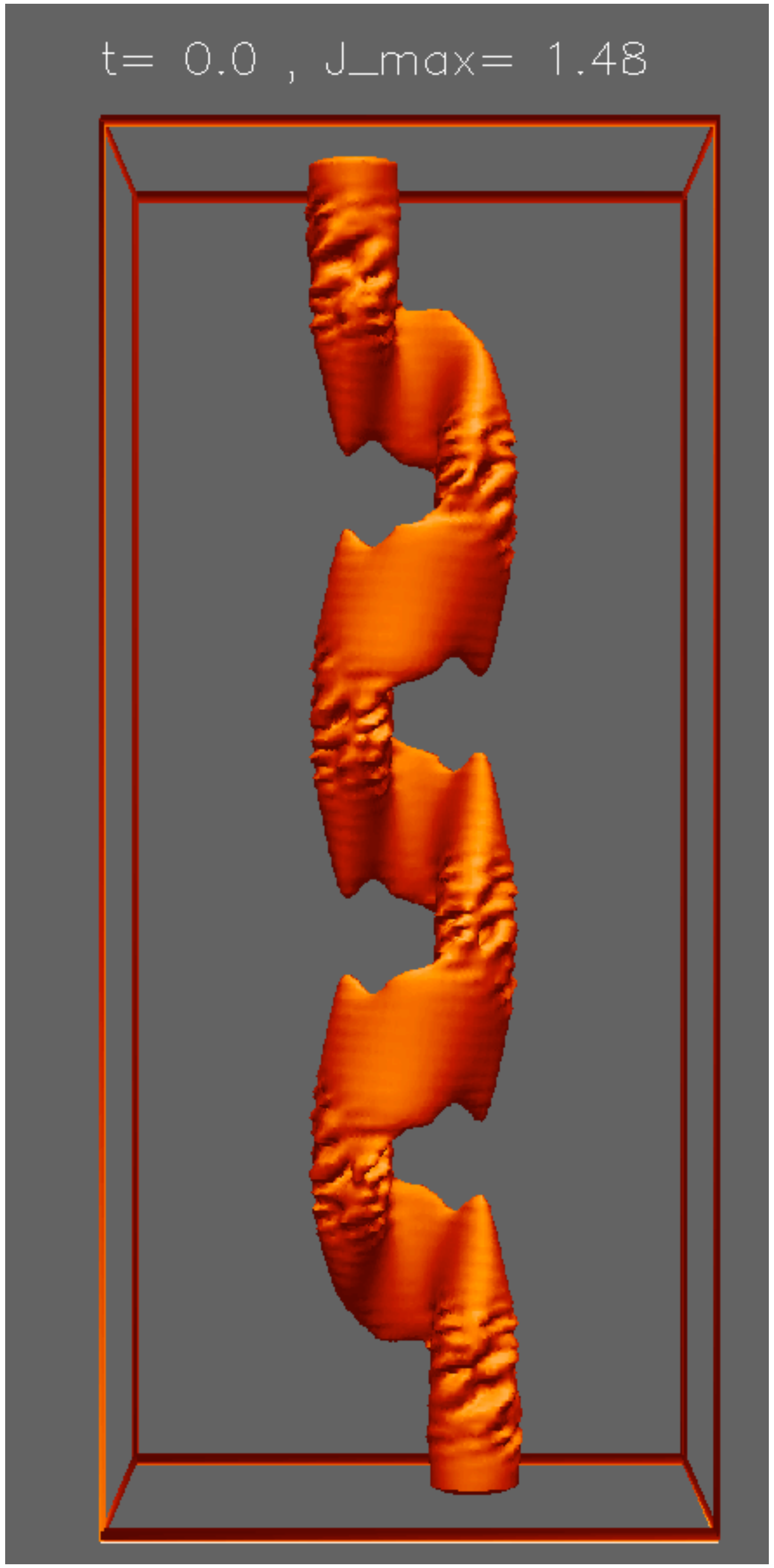
- Magnetic field 'unbraids'. E.g. E3

Current density evolution

E3

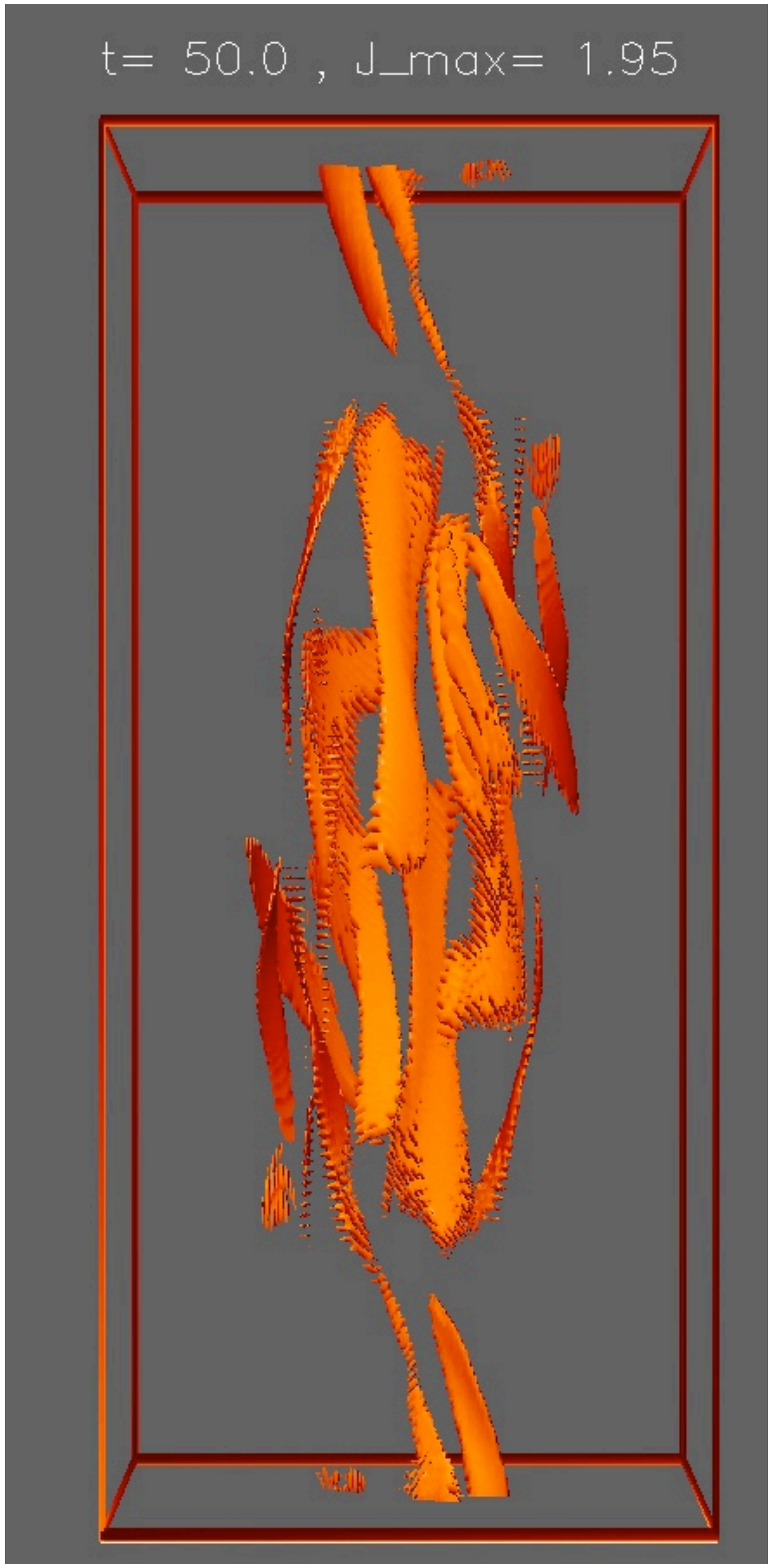


S3

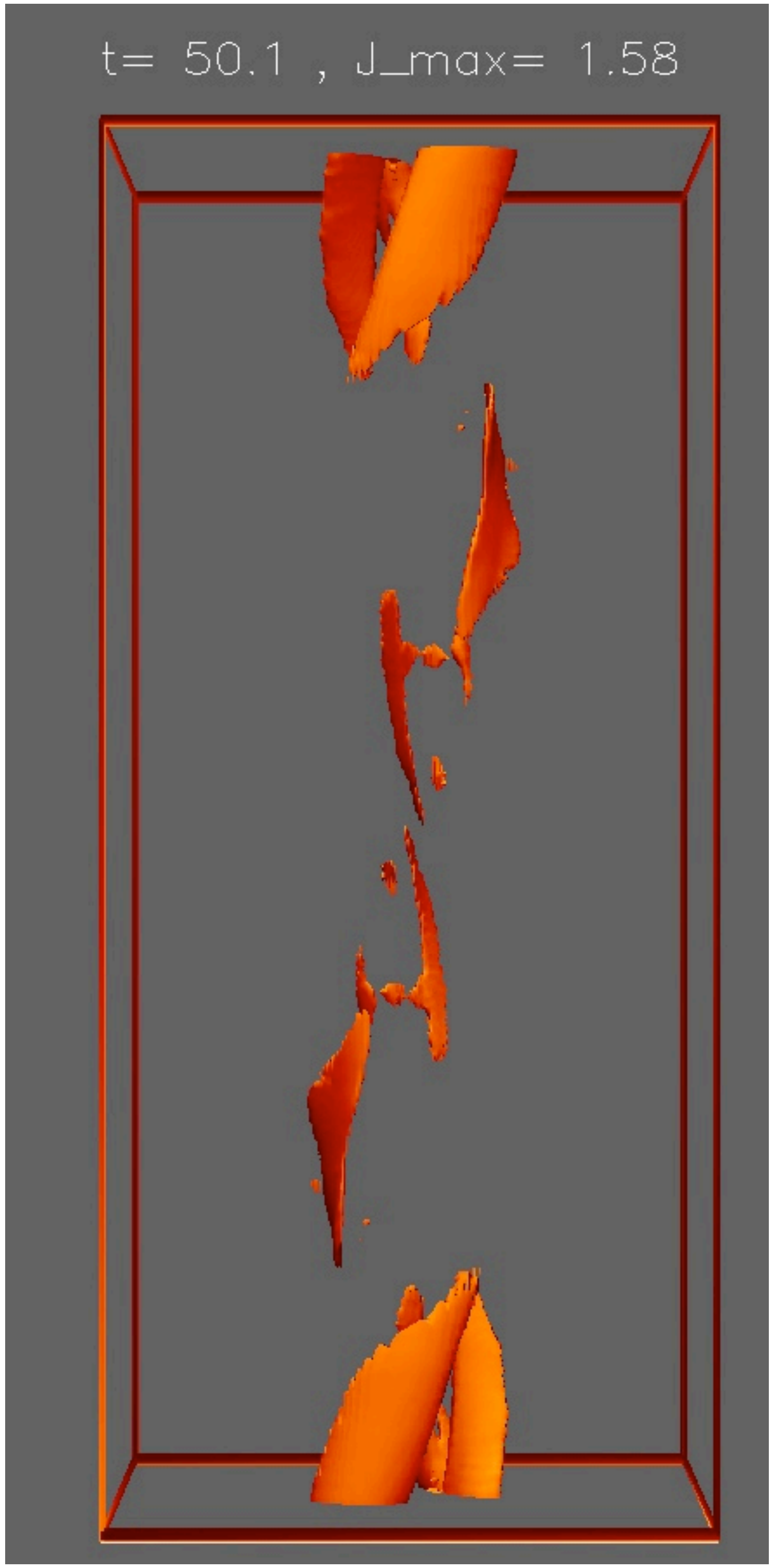


Current density evolution

E3



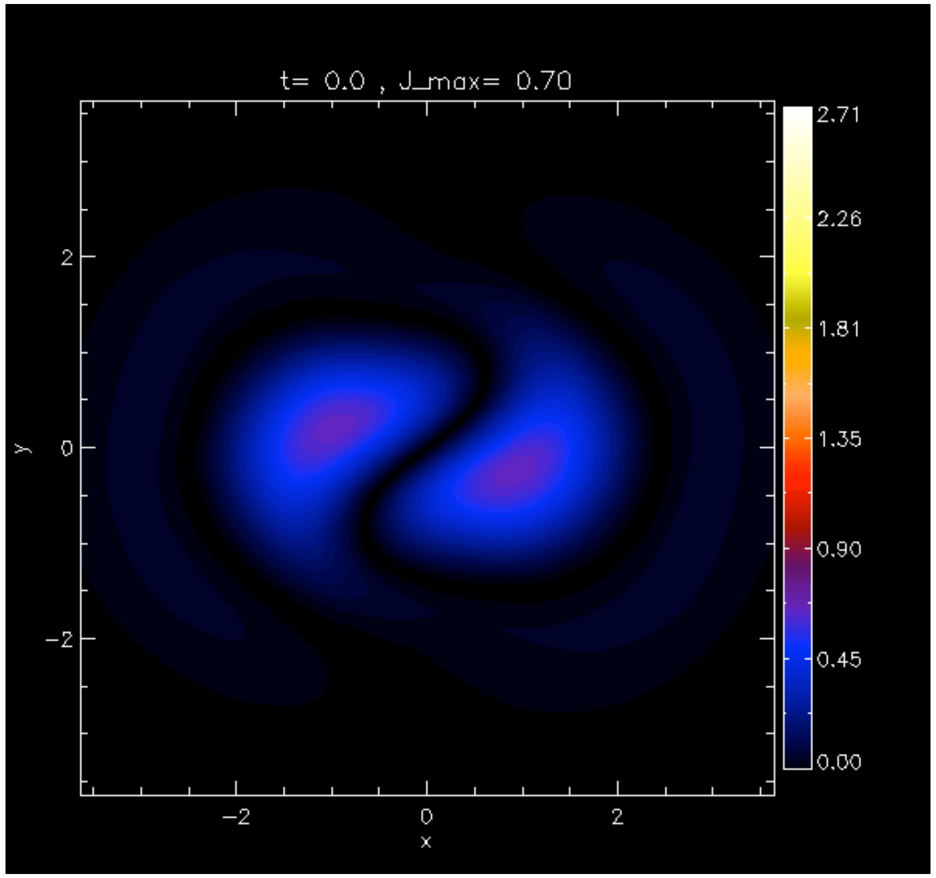
S3

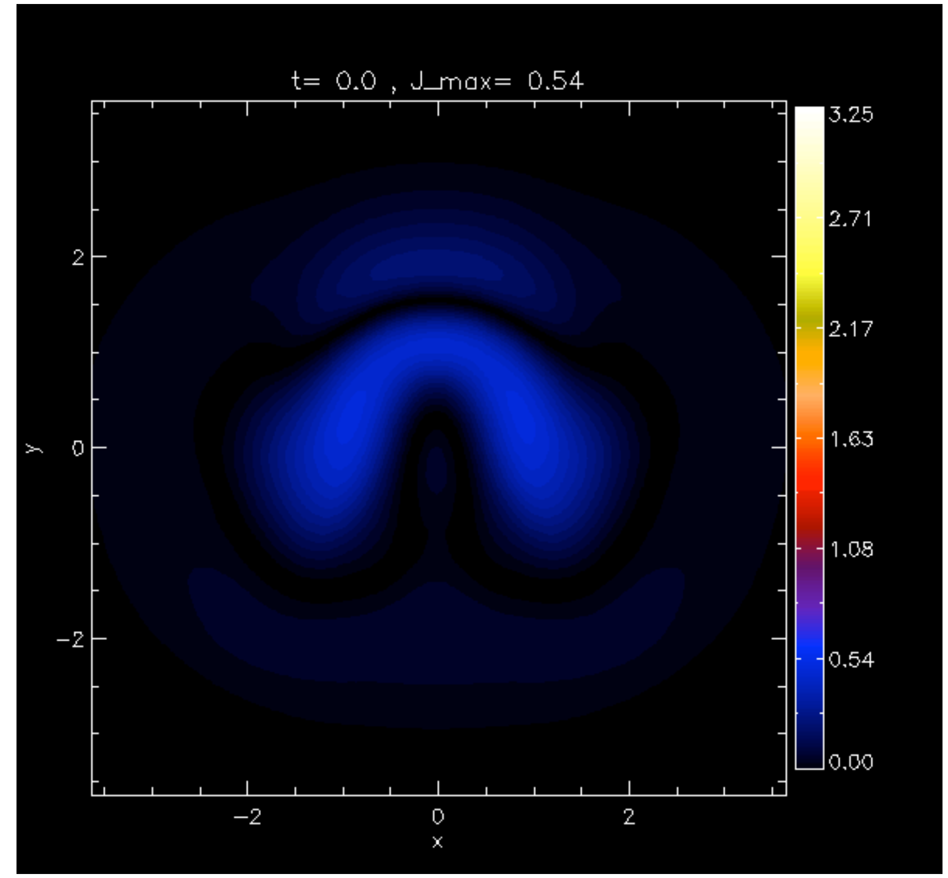


Current density in the mid-plane

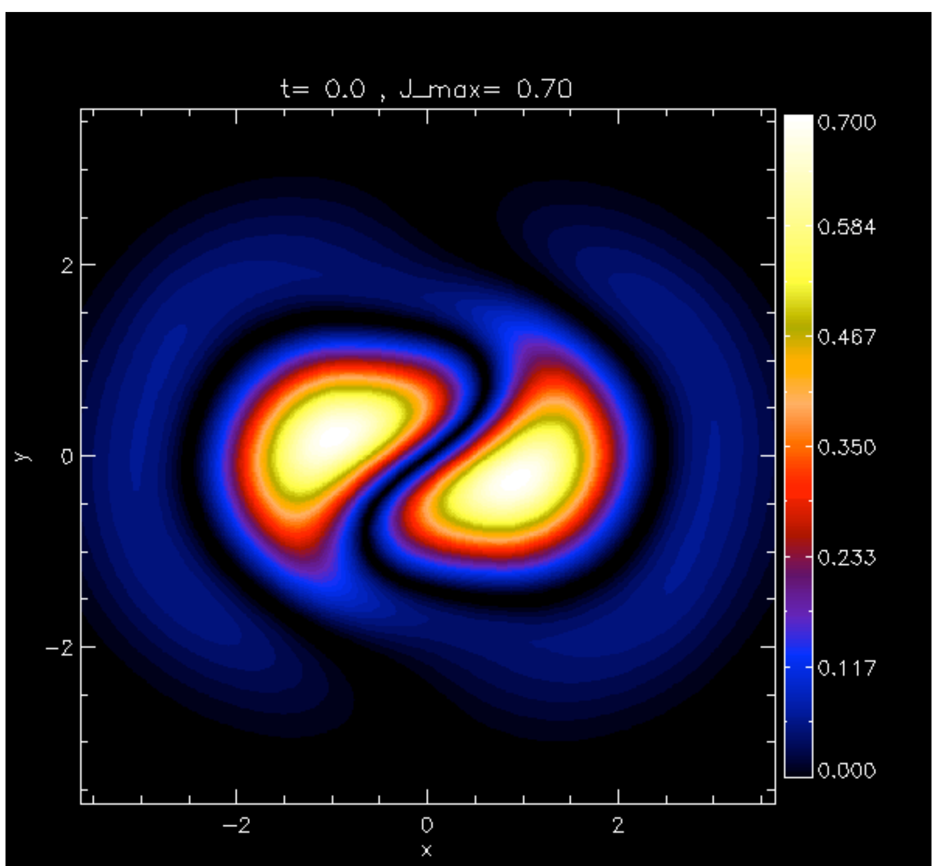
E3 | **S3**

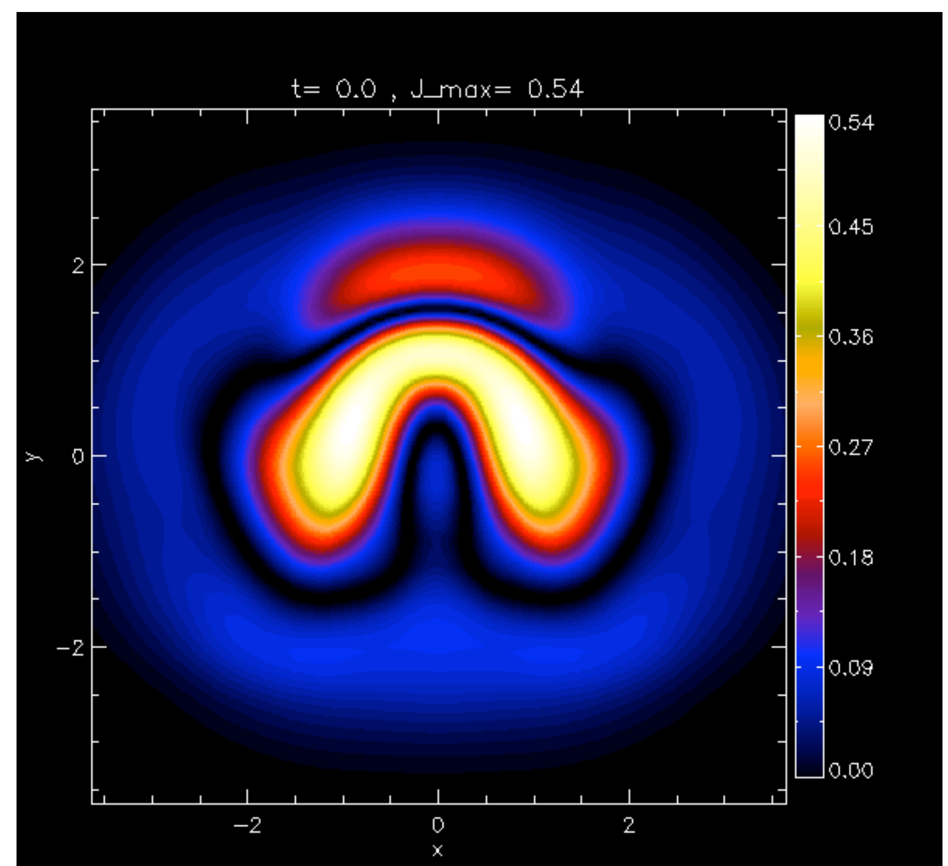
scaled





unscaled

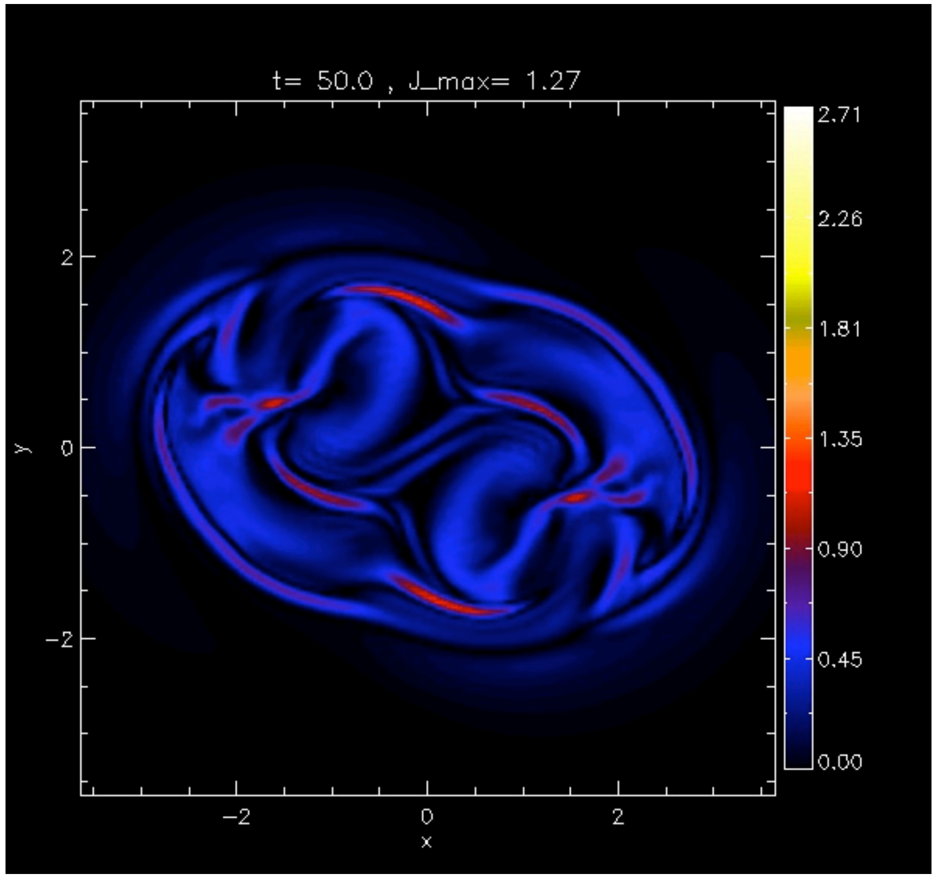


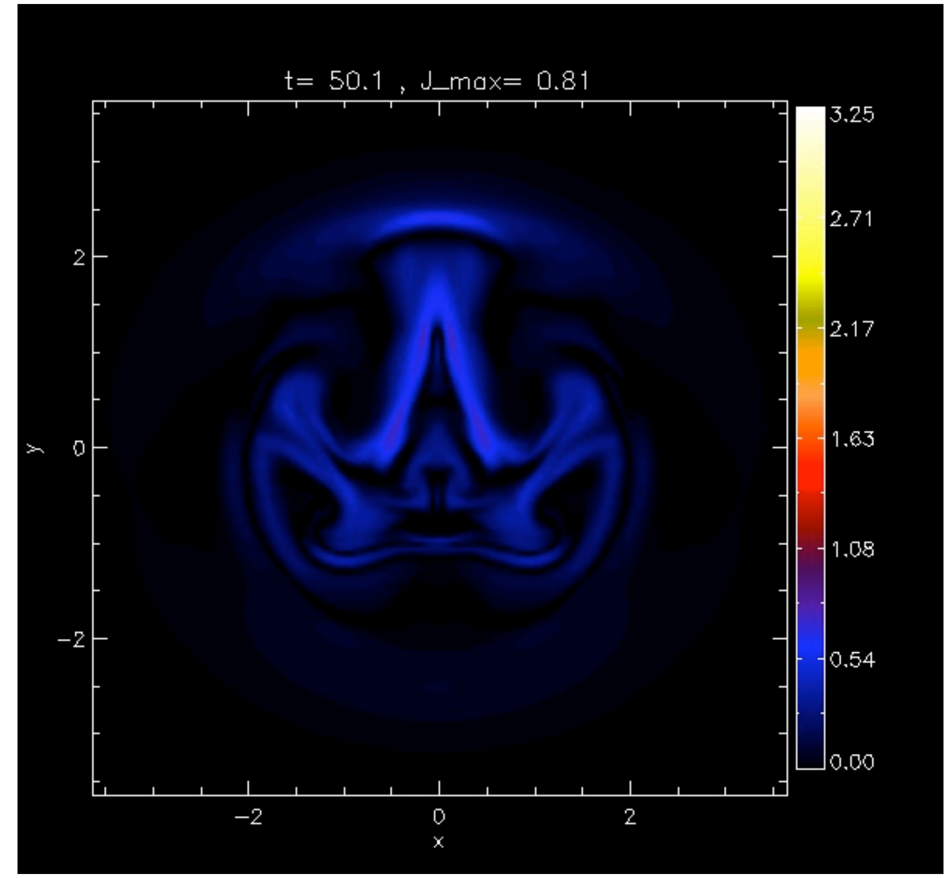


E3

Current density in the mid-plane

S3





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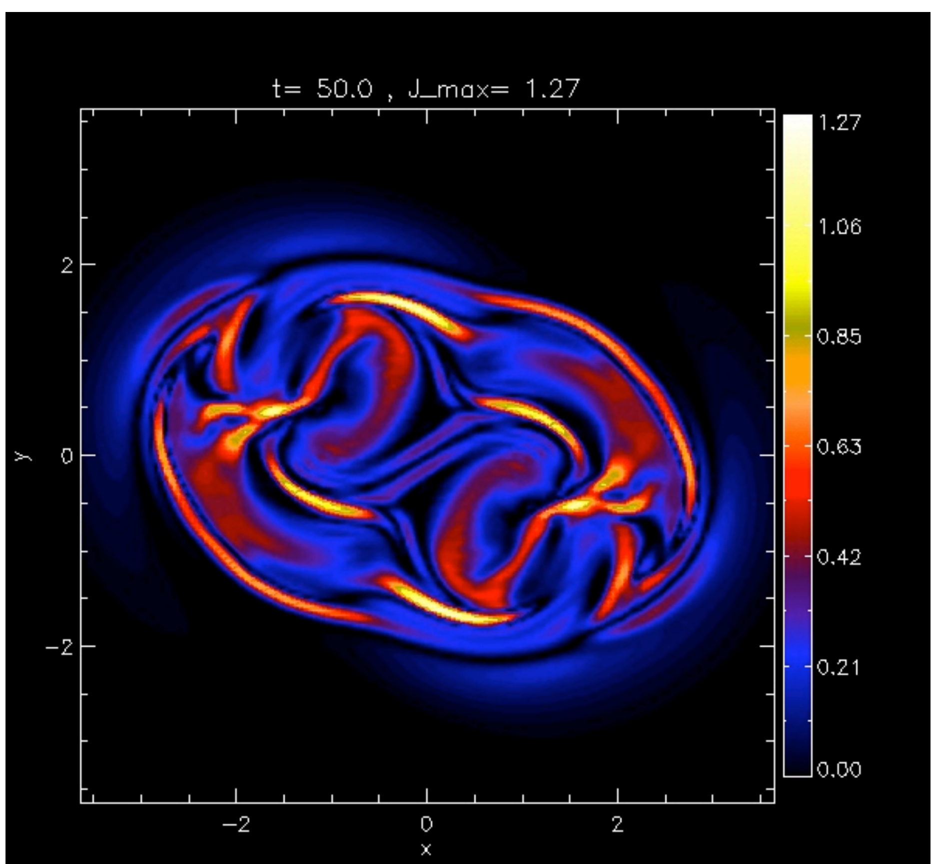
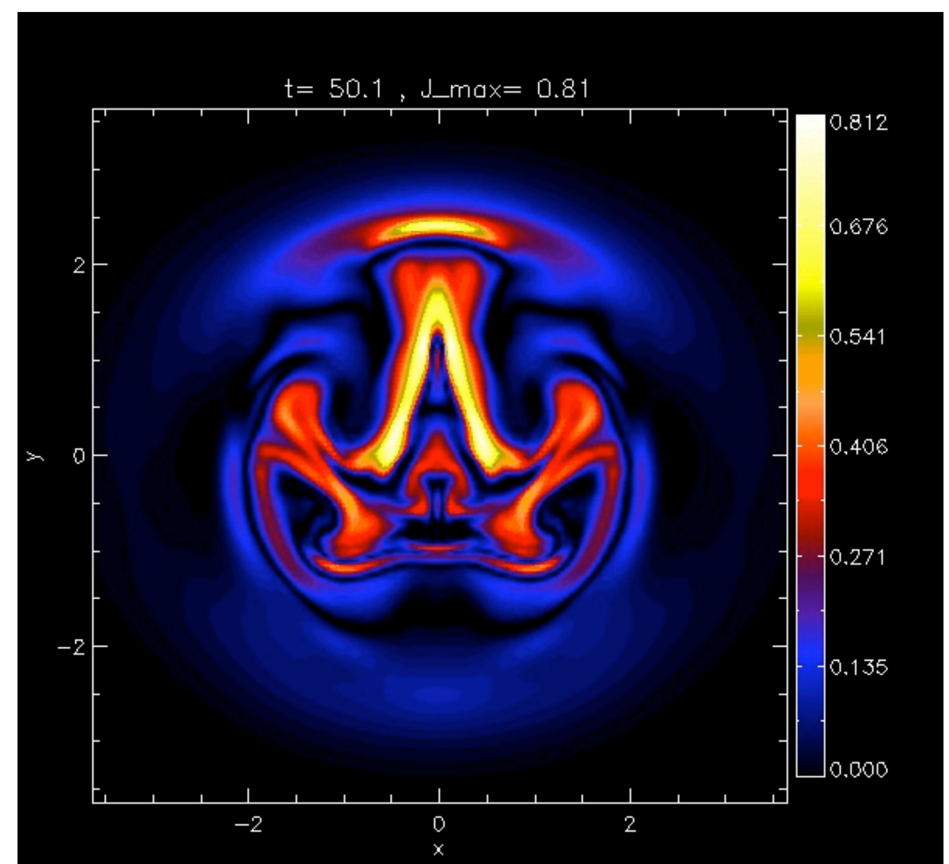




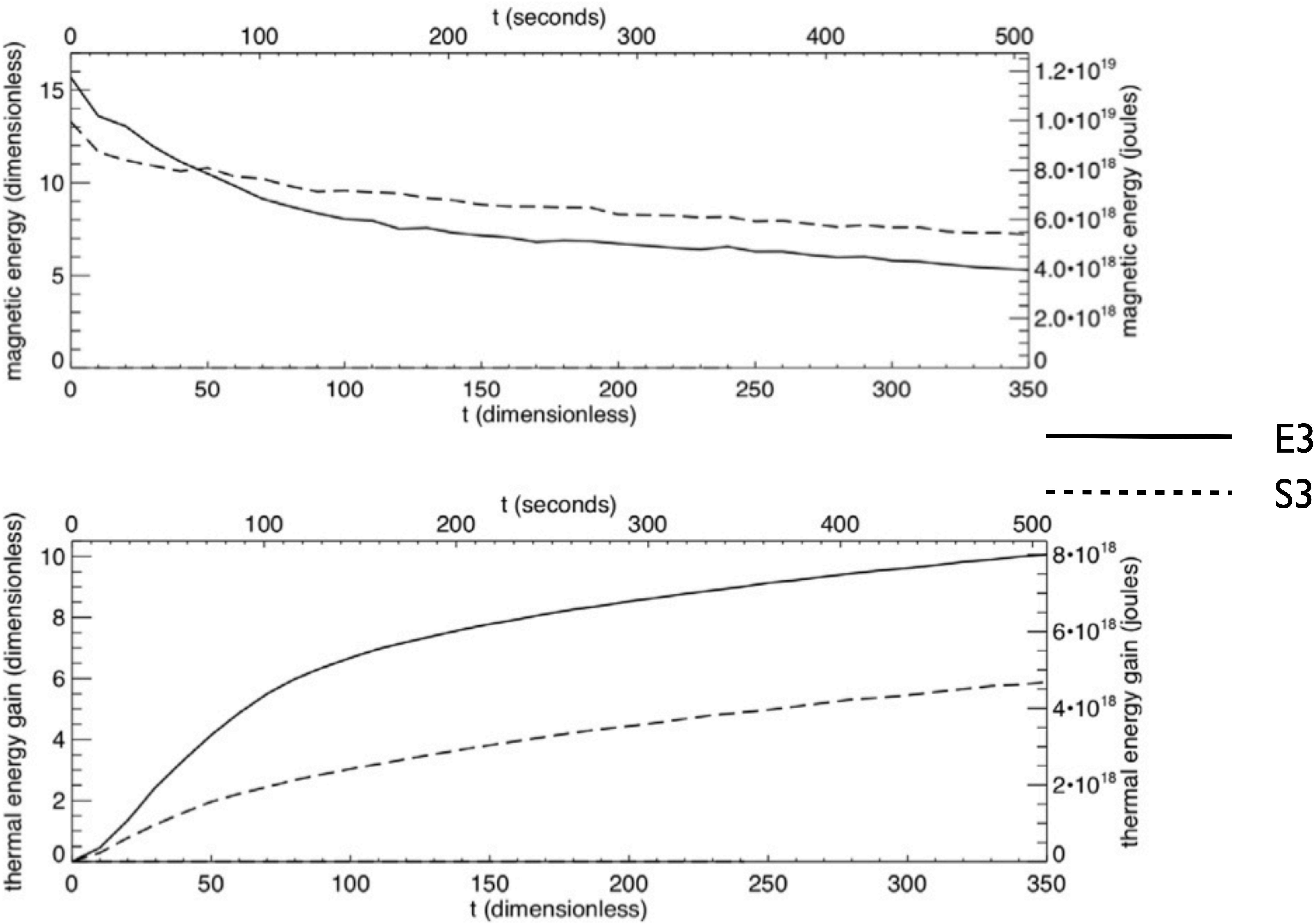
unscaled

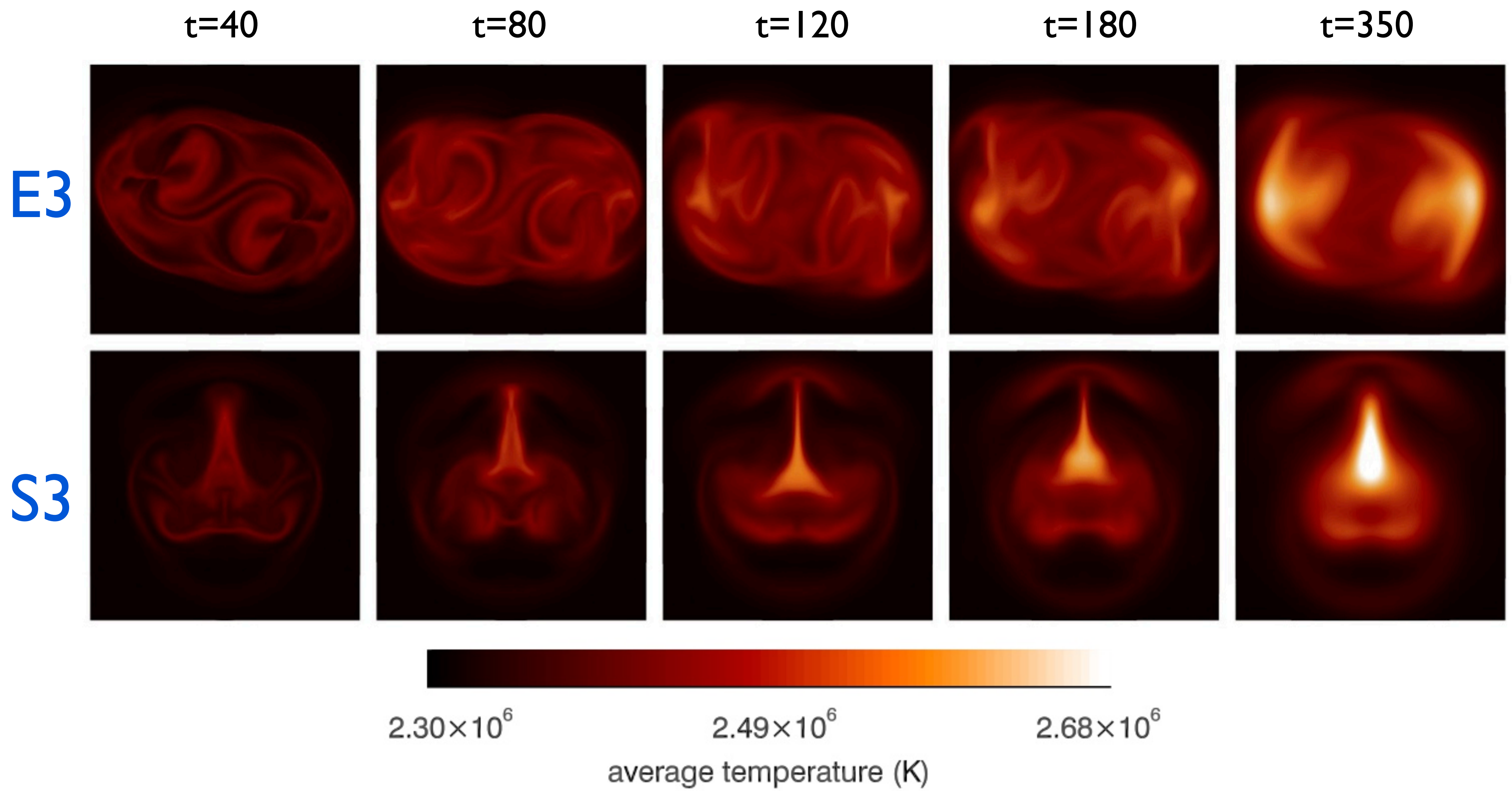
Energy / heating

- To investigate heating, make an appropriate dimensionalisation
- Parameters:
  - ✳ $B=10G$
  - ✳ $n=10^{15}\ m^{-3}$
  - ✳ $L=1$ Mm

  - ✳ $T=2.3\times10^{6}$ K
  - ✳ Loop dimensions: $6\times6\times48$ Mm
  - ✳ $t_0=1.45s$

Energy / heating

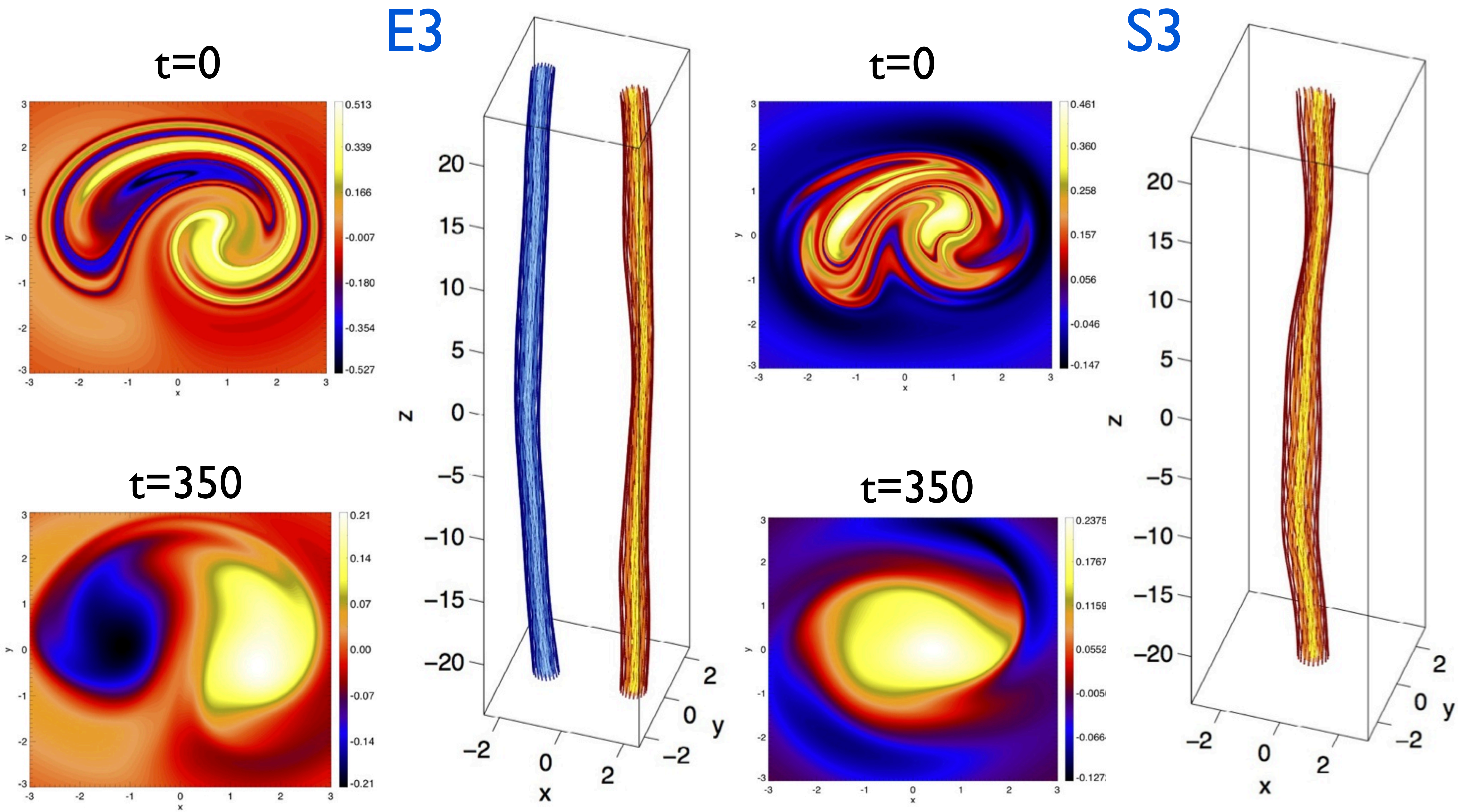




- Approx twice as much energy released for E3
- More spatially homogeneous heating for E3
- Temperature rise is modest, but so is initial free energy

Structure of final magnetic field

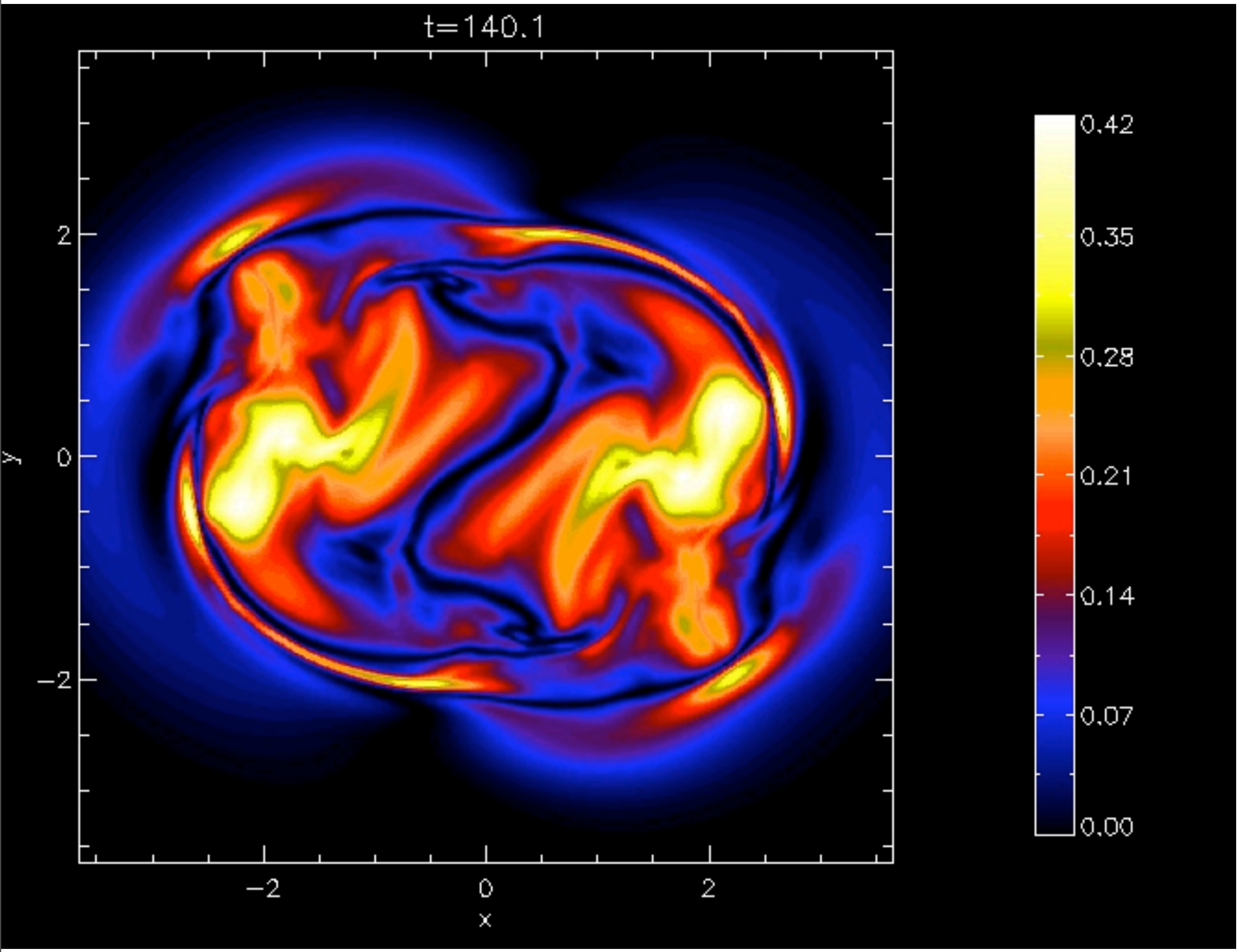
Plots: mean value of J·B/B·B along field lines



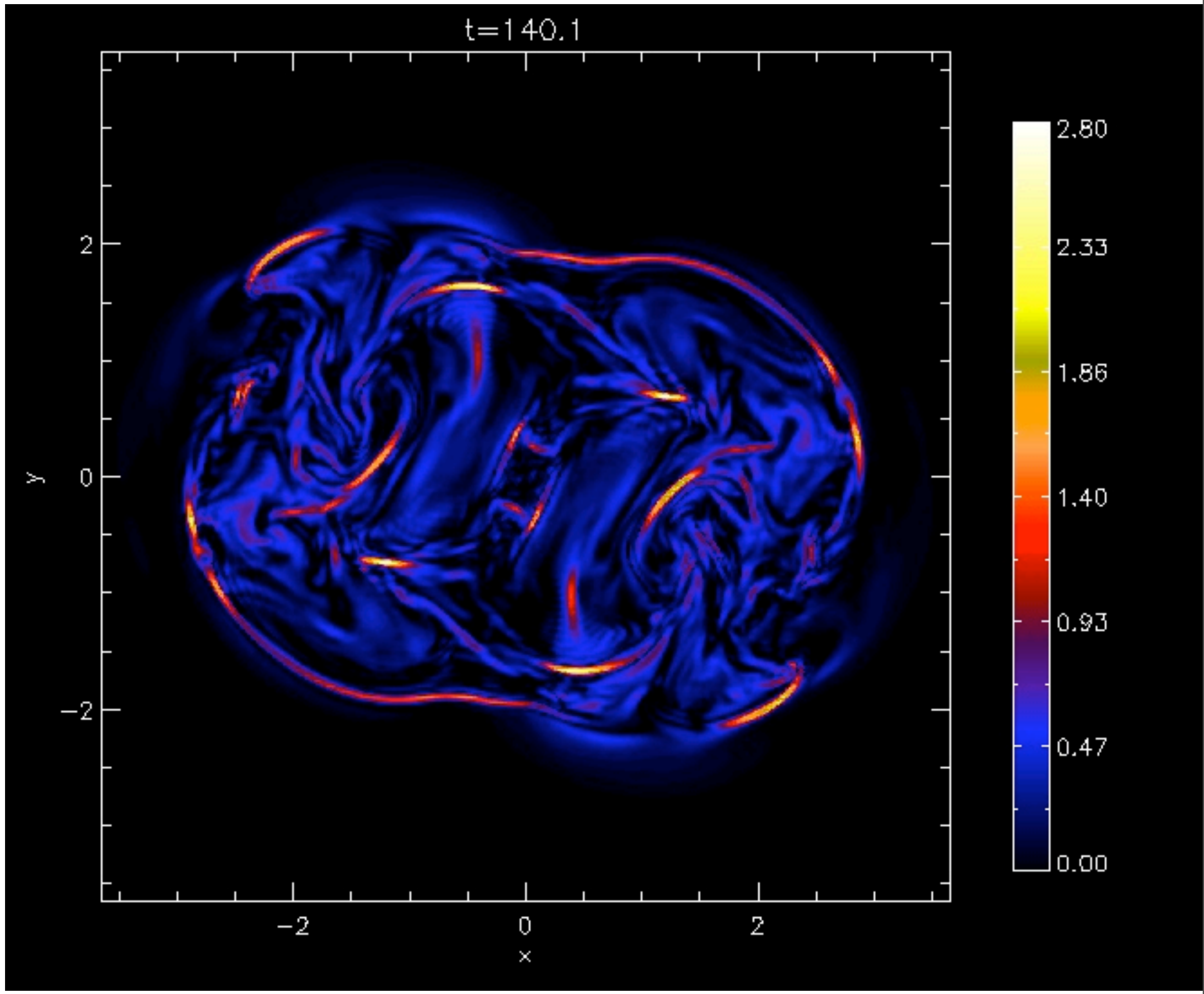
Reynolds number comparison for E3

|J| at z=0

η=10^{-3}



η=2x10^{-4}



Summary

- Resistive relaxation: B field is unbraided (E3) / untwisted (S3). Involves reconnection at multiple J sheets.
- Although "amount" of photospheric driving in the same, relaxation is more efficient for E3:
  - ✳ Current sheets fill the volume more effectively
  - ✳ More energy is released
  - ✳ Homogeneous heating of the loop
- In other words, amount and distribution of energy release dependent on pattern of driving flow.
- This can be measured by computing the "topological entropy" of the photospheric flow
- Energy release constrained by structure of B (periodic orbits)

Thanks for listening

References:

- Wilmot-Smith, A.L., Pontin, D.I., Yeates, A.R. and Hornig, G. Heating of braided coronal loops, A&A, 536, A67 (2011)
- Pontin, D.I., Wilmot-Smith, A.L., Hornig, G., Galsgaard, K., Dynamics of Braided Coronal Loops - II. Cascade to multiple small scale events, A&A, 525, A57 (2011)
- Yeates, A.R., Hornig, G. and Wilmot-Smith, A.L. Topological Constraints on Magnetic Relaxation, Phys. Rev. Lett., 105, 085002 (2010)
- Wilmot-Smith, A.L., Pontin, D.I., Hornig, G., Dynamics of Braided Coronal Loops - I. Loss of Equilibrium, A&A, 516, A5 (2010)