# PhD project outline and risk analysis

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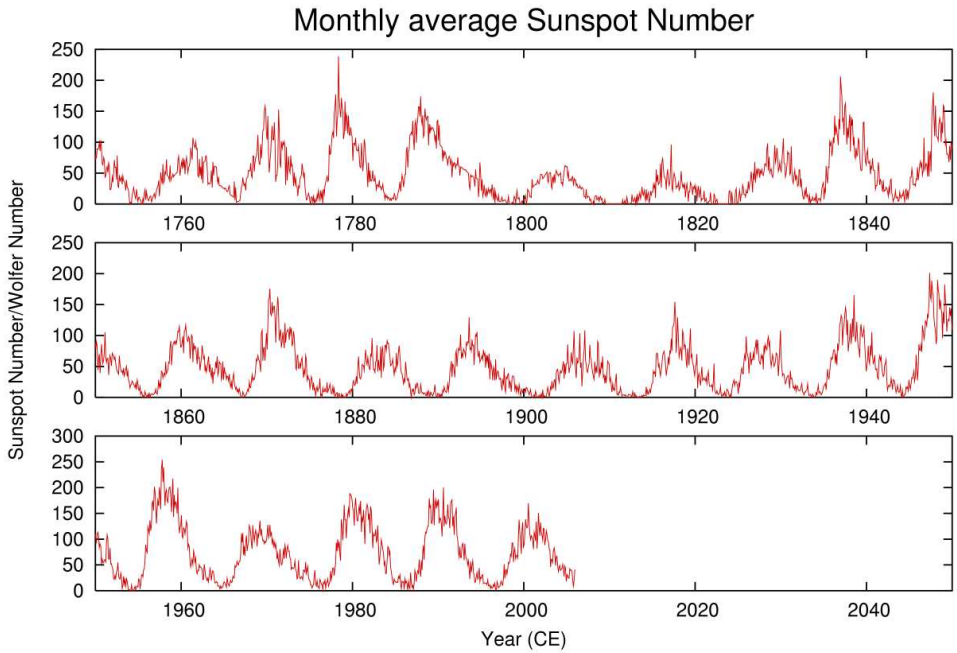
# Overview

1. Motivation
2. Past and current work
3. Future work and outline
4. Risk analysis

# Motivation

- Solar cycle




- Solar winds: destruction of satellite, heazard for astronauts
- Solar weather forecast
- 1d mean field simulation $\longrightarrow$ global sun simulation (DNS)

# Past and current work

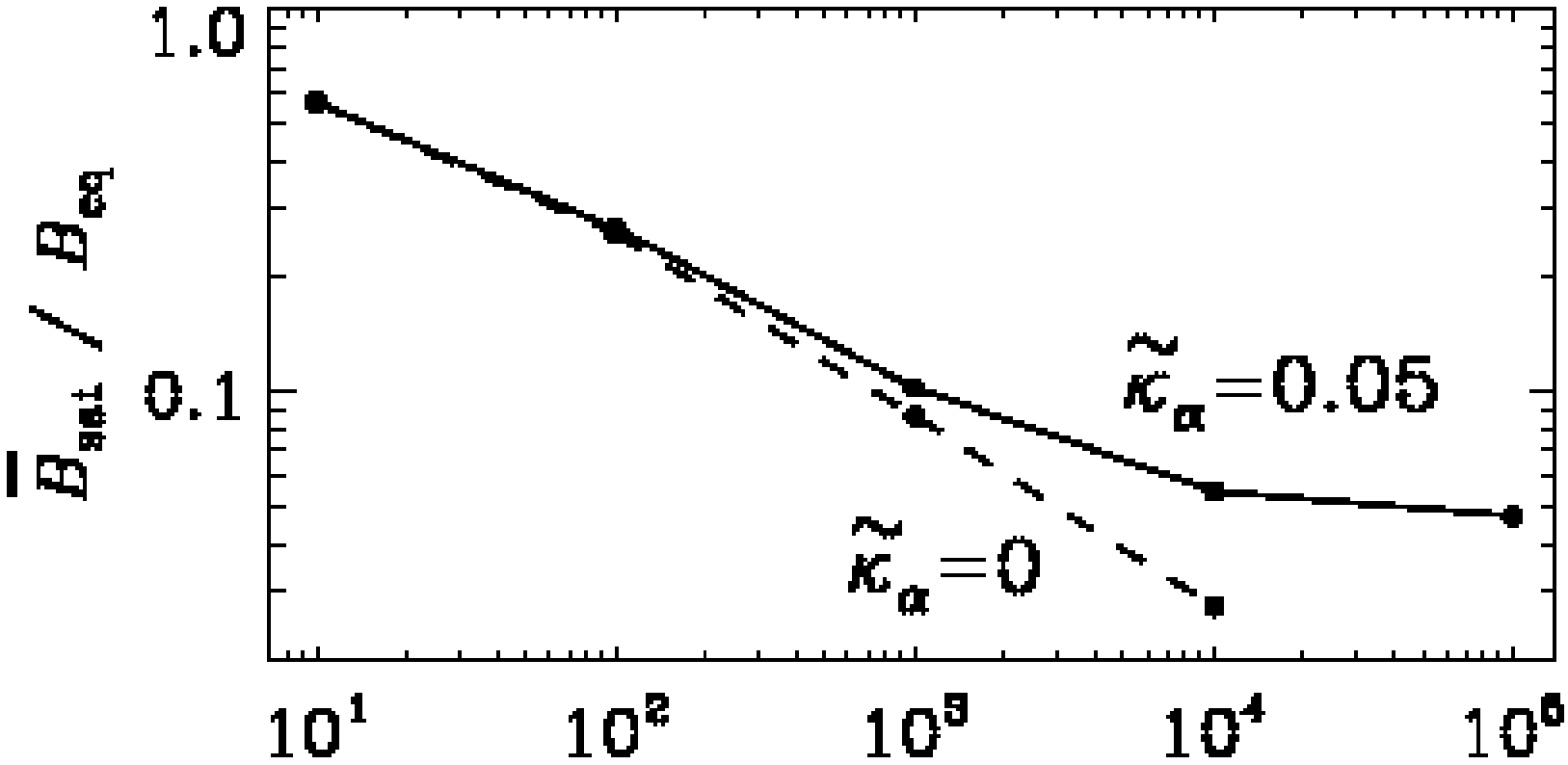
## Mean field simulations

Axel Brandenburg and Piyali Chatterjee (MNRAS)

**One dimensional mean field dynamo**

Question: Is magnetic helicity hindering dynamos ('alpha quenching')?

Answer: Yes. Remove it or let it diffuse through the equator.



# Past and current work

## Topological aspects

Fabio Del Sordo and Axel Brandenburg (PhysRevE)

**Topological aspects**

Question: Does the topology change the dynamics?

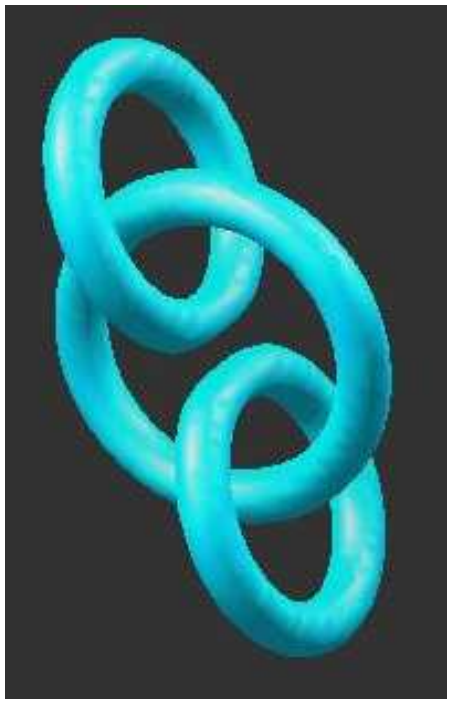
Answer: Depends on the helicity.

$$\begin{aligned} H_m &= \int \mathbf{A} \cdot \mathbf{B} \\ &= 2\alpha\phi_1\phi_2 \end{aligned}$$

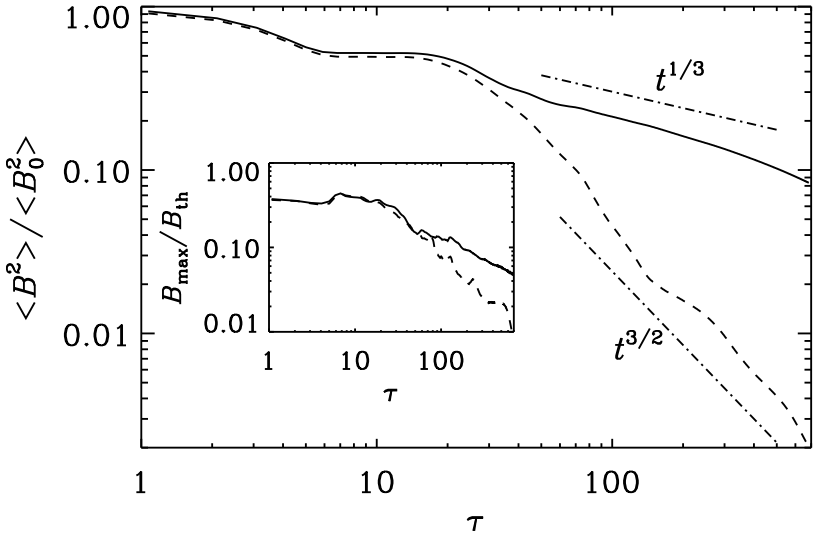
# Past and current work

## Topological aspects

3 flux rings:



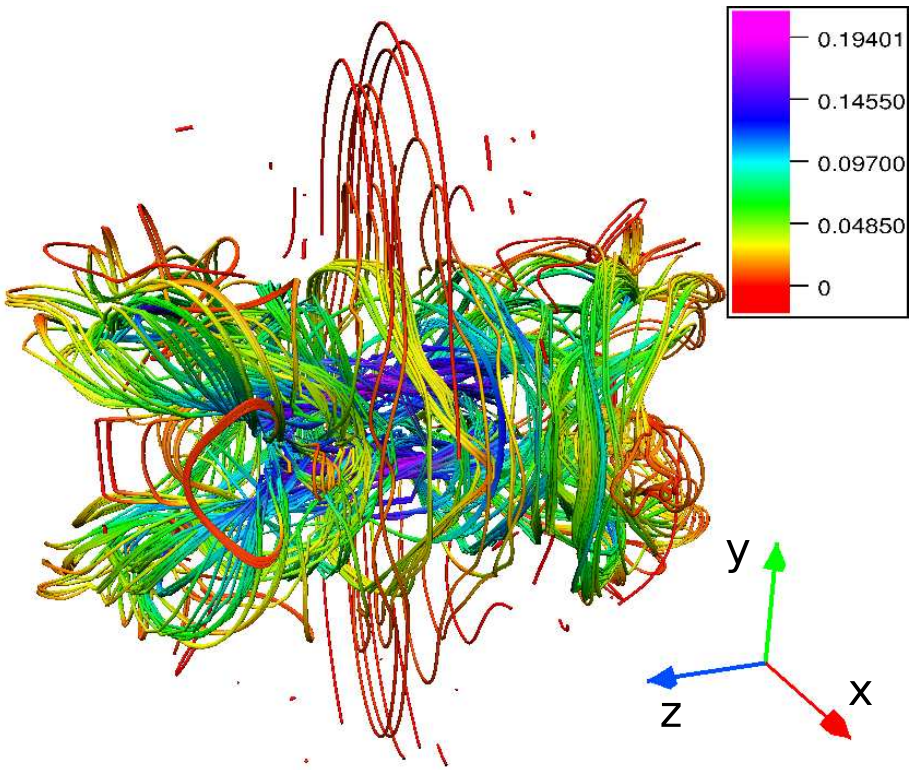
Result: Magnetic energy decays slower with helicity.



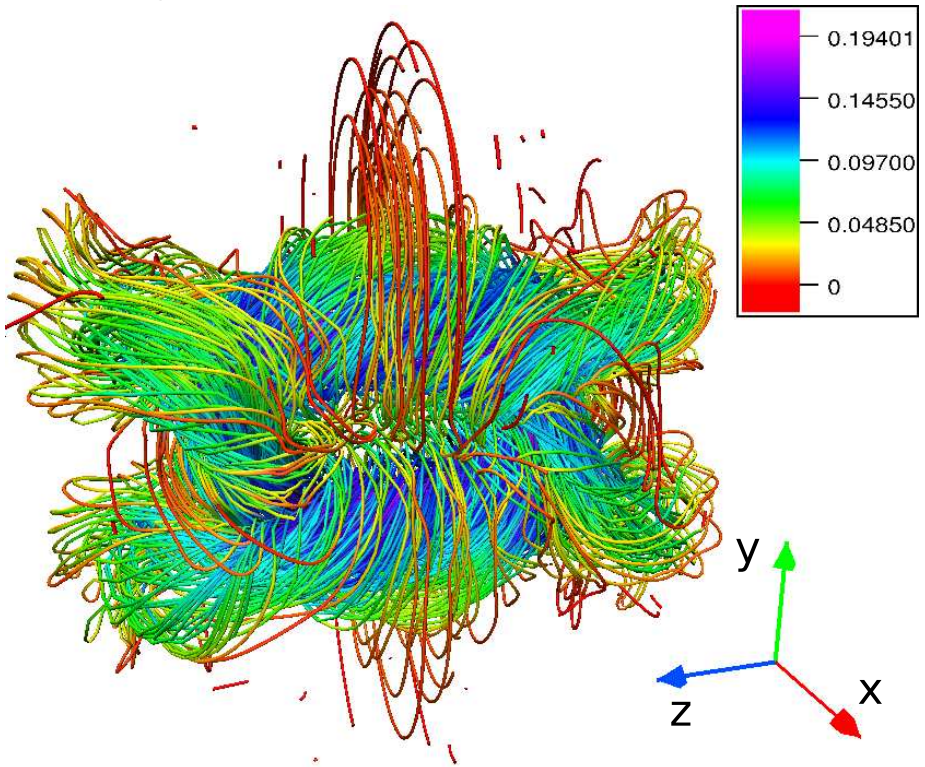
# Past and current work

## Topological aspects

helicity $= 0$




helicity $= 2$



# Past and current work

## Gauge invariance

Dhrubaditya Mitra, Piyali Chatterjee, Reza Tavakol and Axel Brandenburg (AN)

**Gauge invariance of magentic helicity fluxes in DNS**

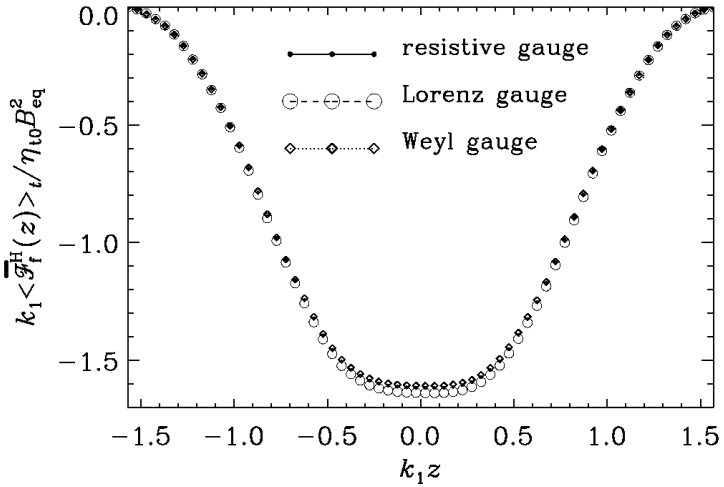
Magnetic helicity density $\mathbf{A} \cdot \mathbf{B}$ is gauge dependent.

| | |
|---|---|
| Weyl gauge | $\Psi = 0$ |
| pseude-Lorenz gauge | $\nabla \cdot \mathbf{A} + \frac{1}{c_s^2} \frac{\partial \Psi}{\partial t} = 0$ |
| resistive gauge | $\Psi = \eta \nabla \cdot \mathbf{A}$ |

# Past and current work

## Gauge invariance

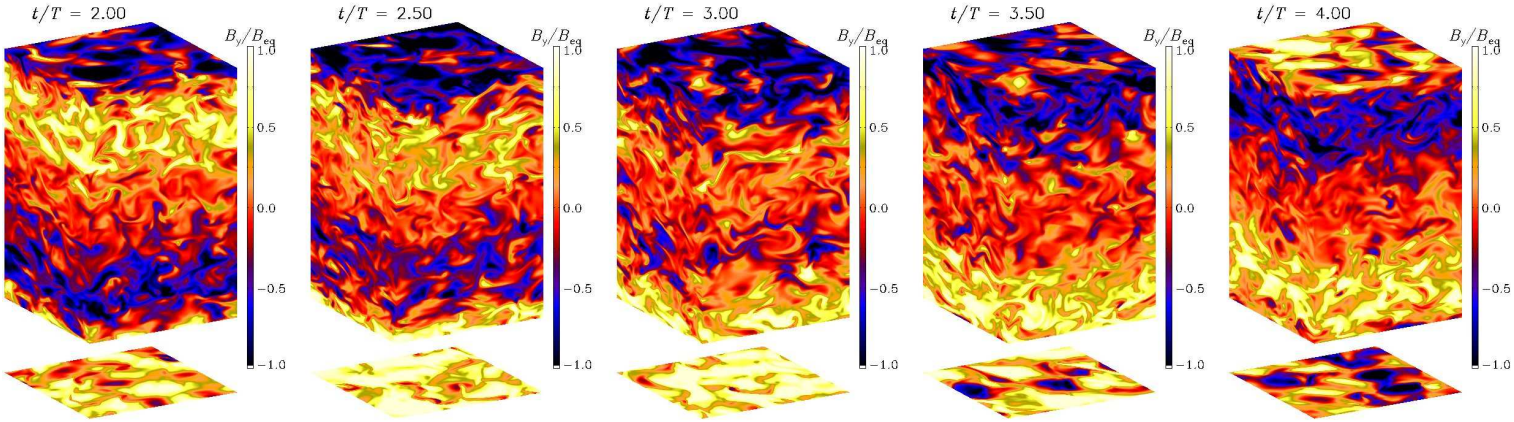
Result: Averaged magnetic helicity fluxes are independent of the gauge.



# Past and current work

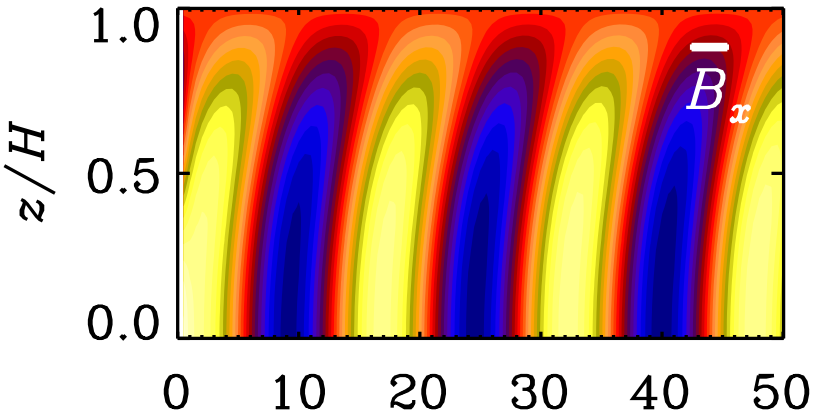
## Gauge invariance

Polarity reversal DNS:

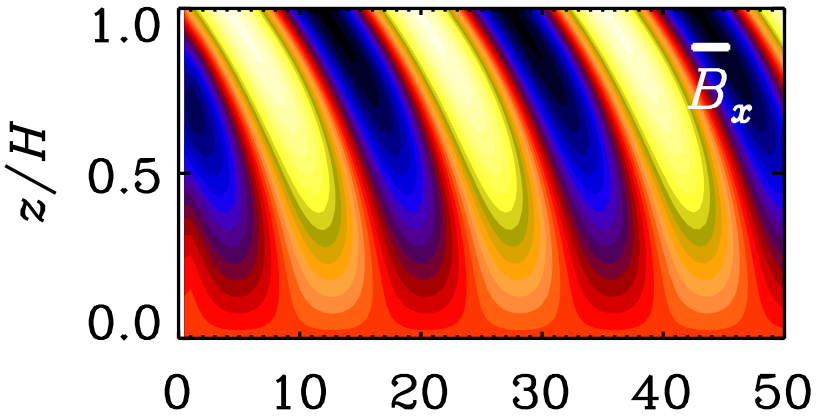



Polarity reversal mean field:

vertical field condition, S

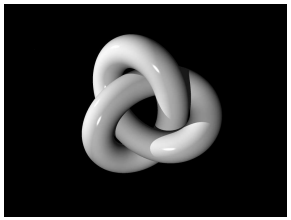



perfect conductor, A



# Future work and outline

- linking number $\Leftrightarrow$ helicity
  higher order topological invariants $\Leftrightarrow$ ?



- Vishniac-Cho magnetic helicity flux (shear)
- simulate the sun
- solar wind
- migrate simulations to GPUs (CUDA)

# Collaboration

- Dhrubaditya Mitra (London)
- Reza Tavakol (London)
- Piyali Chatterjee (Stockholm)
- Fabio Del Sordo (Stockholm
- Axel Brandenburg (Stockholm)

# Risk analysis

- Dependecne on aviable processing capacity.

# Thanks!

Thanks!