The global distribution of magnetic helicity in the solar corona

Durham University

Anthony Yeates

with thanks to
Gunnar Hornig (Dundee), **Chris Lowder, Marcus Page** (Durham)

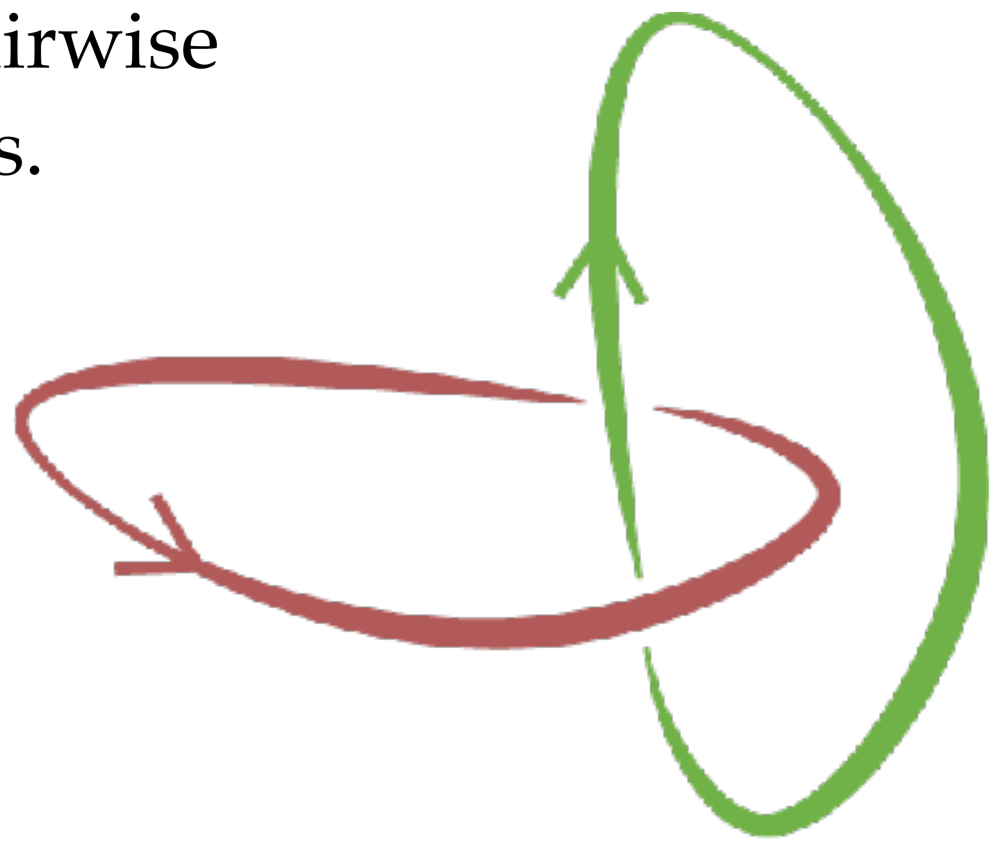
National Astronomy Meeting, Hull, 06-Jul-2017

Aim

To identify **where** magnetic helicity is stored in the corona.

Magnetic helicity is a volume integral that measures the average pairwise linking of magnetic field lines.

$$H = \int_V \boldsymbol{A} \cdot \boldsymbol{B} \, \mathrm{d}V$$



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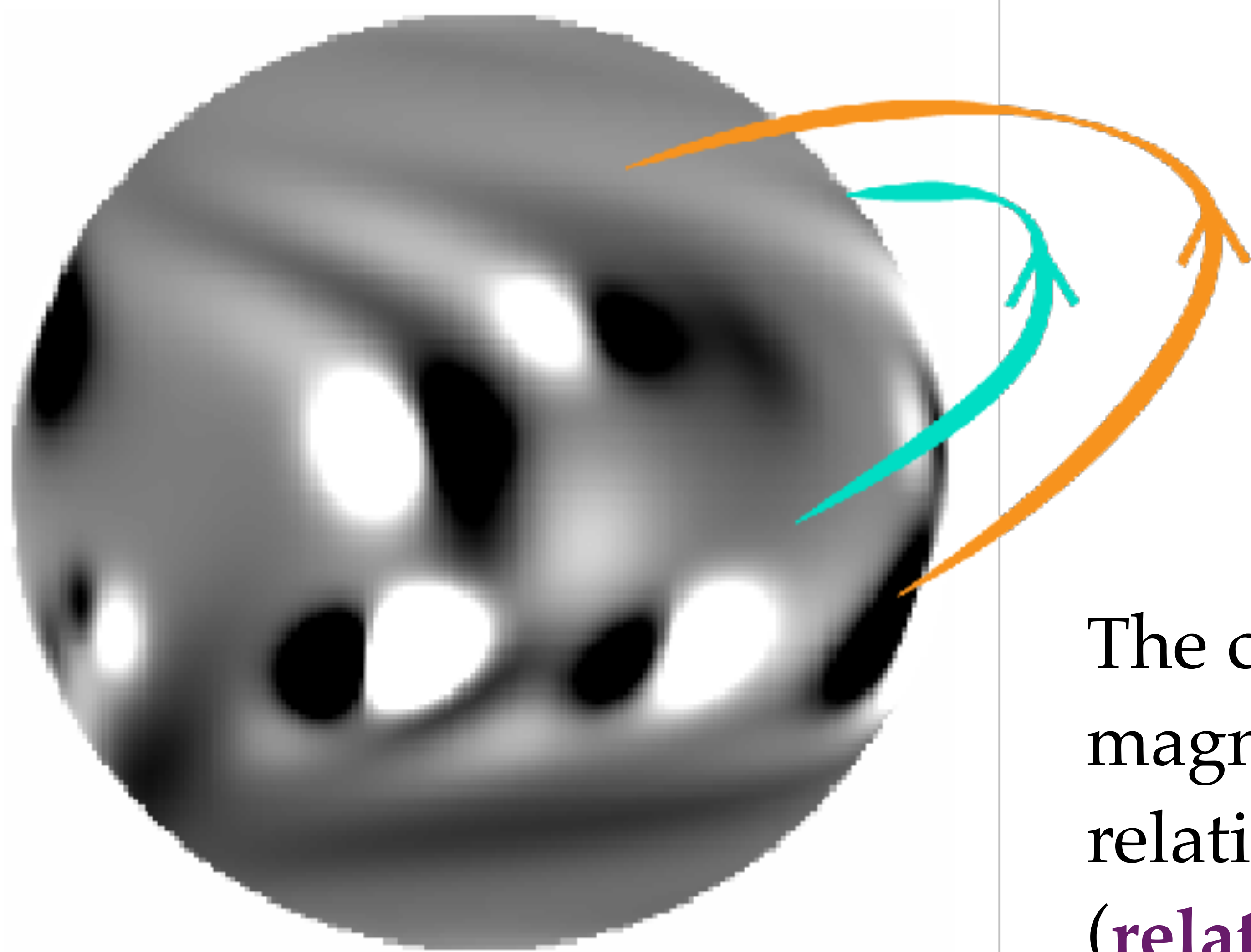
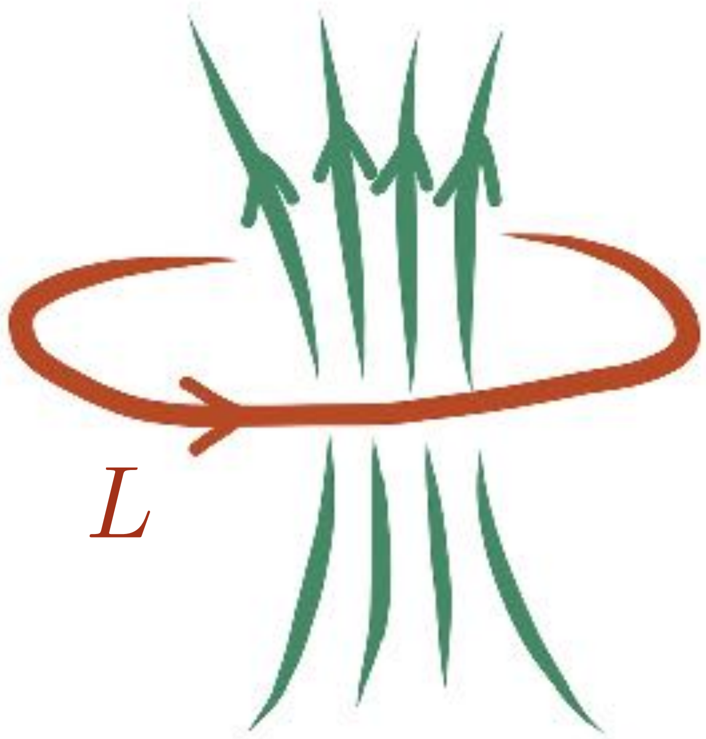


The concept extends to non-closed magnetic field lines if you specify relative connection of end-points (**relative helicity**).

The ideal tool



The magnetic flux through a closed magnetic field line is invariant in ideal magnetohydrodynamics.

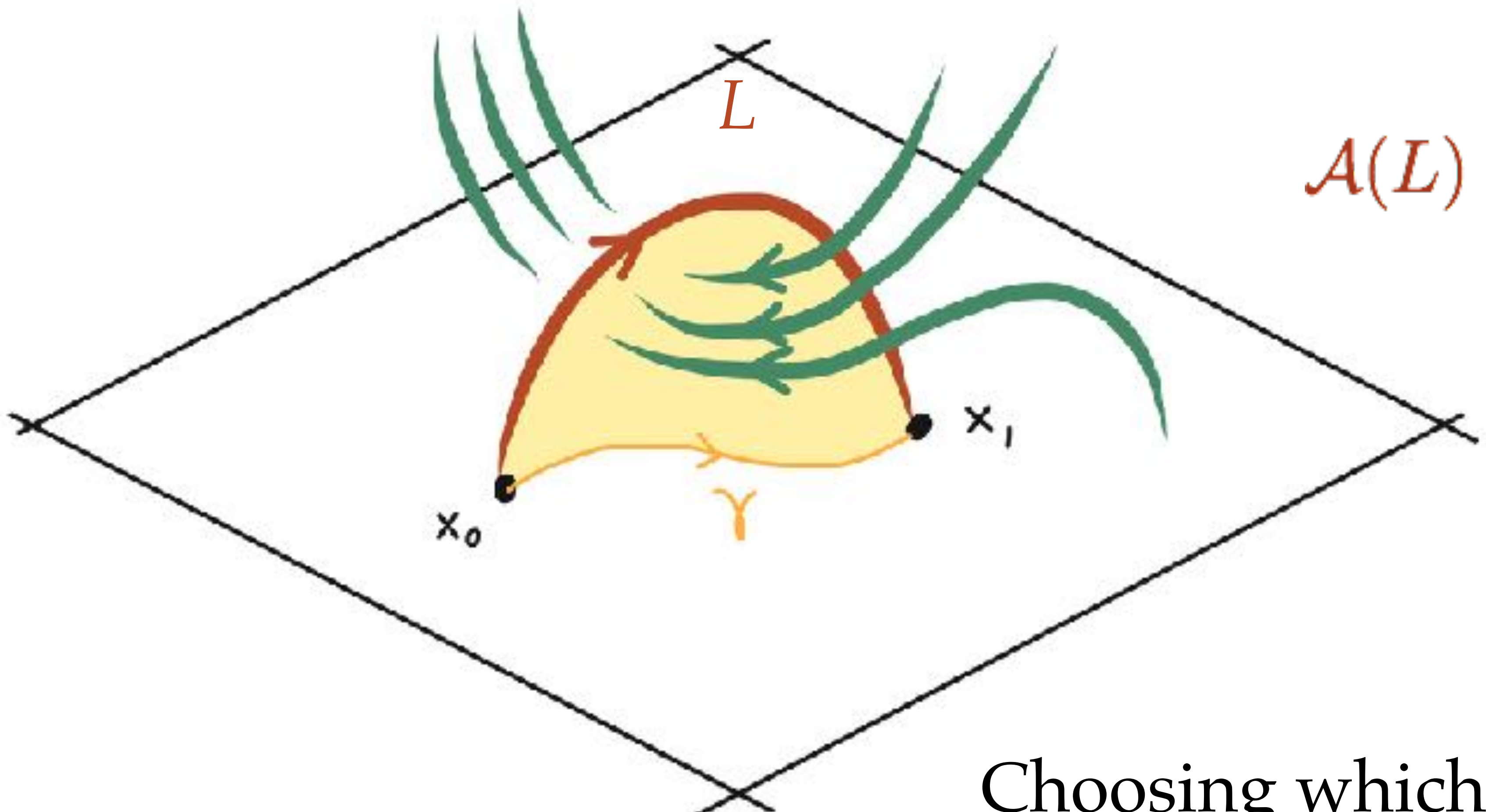
$$\mathcal{A}(L) = \int_{S(L)} \boldsymbol{B} \cdot \boldsymbol{n} \, \mathrm{d}S = \oint_L \boldsymbol{A} \cdot \mathrm{d}\boldsymbol{l}$$

$$\boldsymbol{B} = \nabla \times \boldsymbol{A}$$

We call $\mathcal{A}$ the **field line helicity**.

The ideal tool

If L ends on the boundary, $\mathcal{A}$ is still the flux through a suitable surface. This is invariant if the footpoints are fixed.

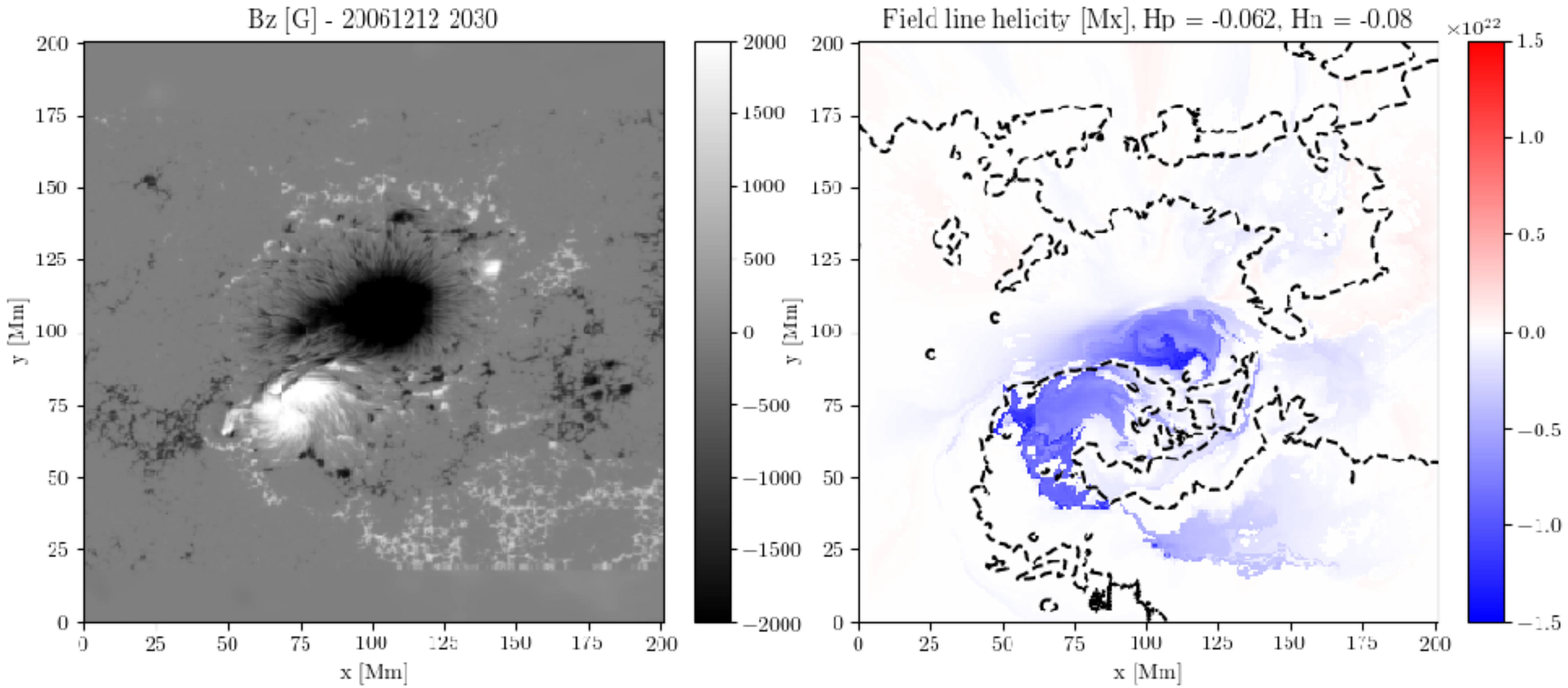


$$\mathcal{A}(L) = \int_L \boldsymbol{A} \cdot \mathrm{d}\boldsymbol{l}$$

Choosing which curve γ to complete the loop is equivalent to choosing the gauge of **A** on the boundary, or to choosing the reference field in relative helicity.

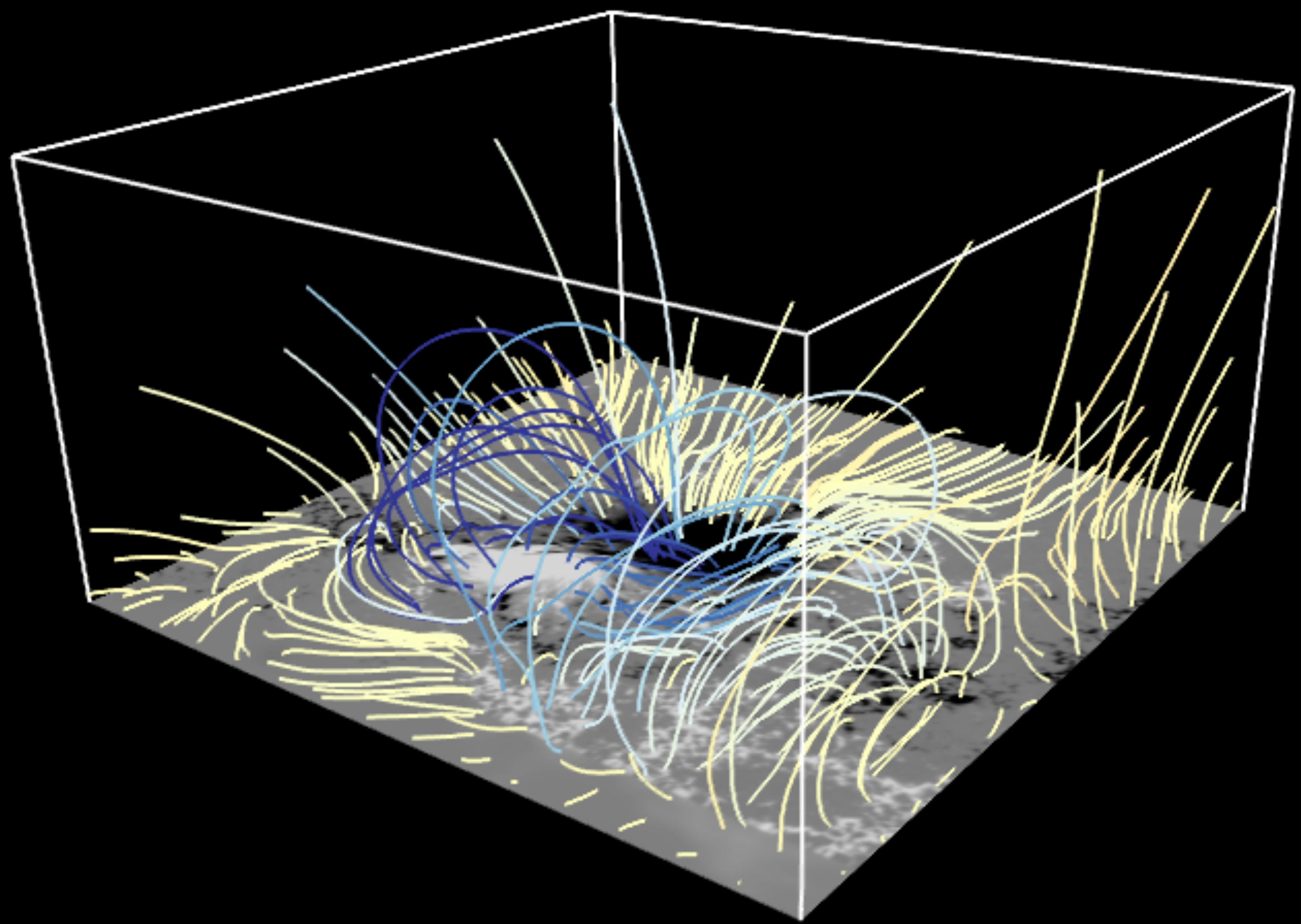
Example: NLFFF for AR 10930

Extrapolation by Mike Wheatland based on *Hinode*/SOT magnetogram.
(best performing method in Schrijver et al., *ApJ* 2008)

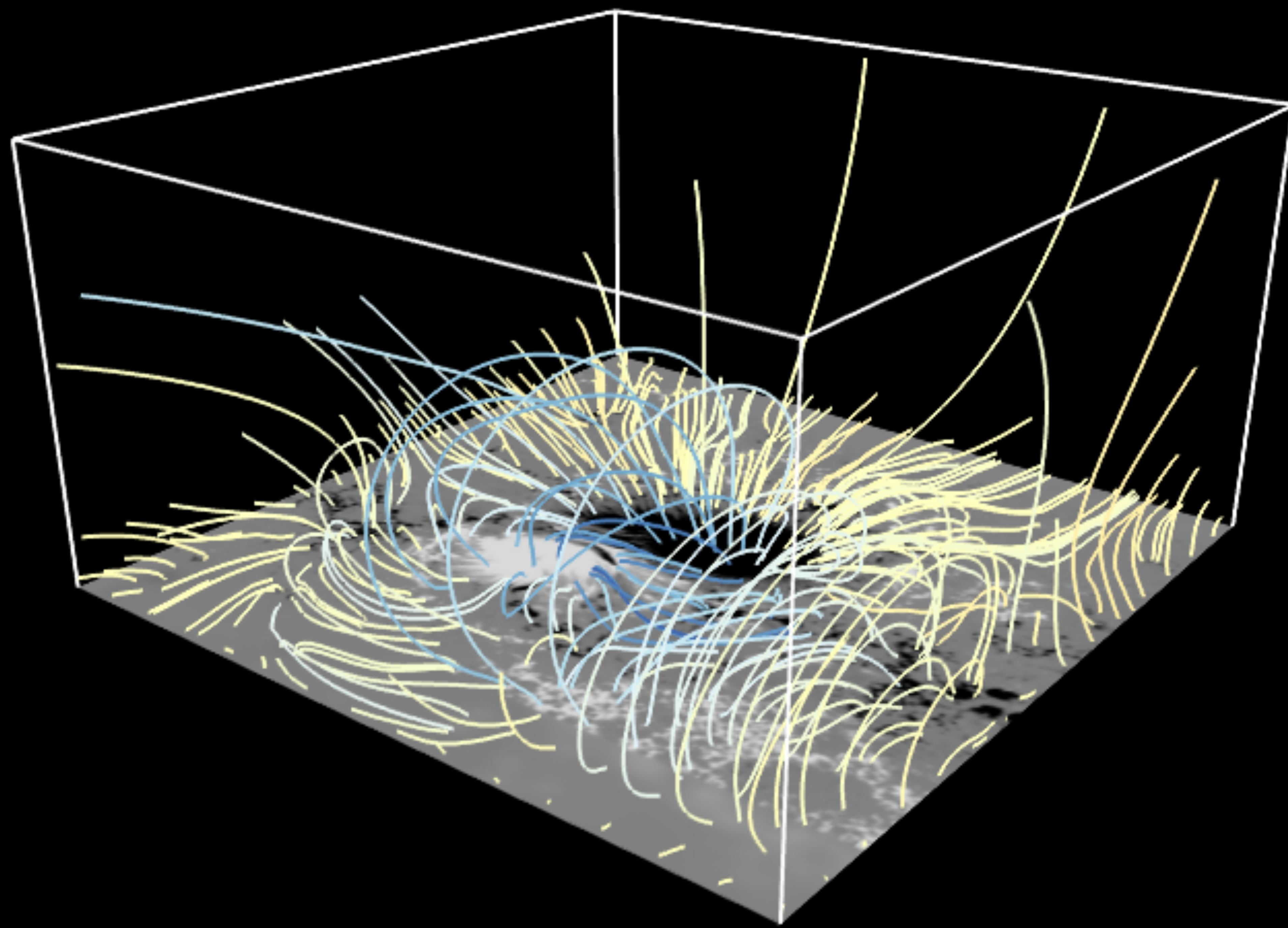


Field line helicity reveals footpoints of the sheared arcade.

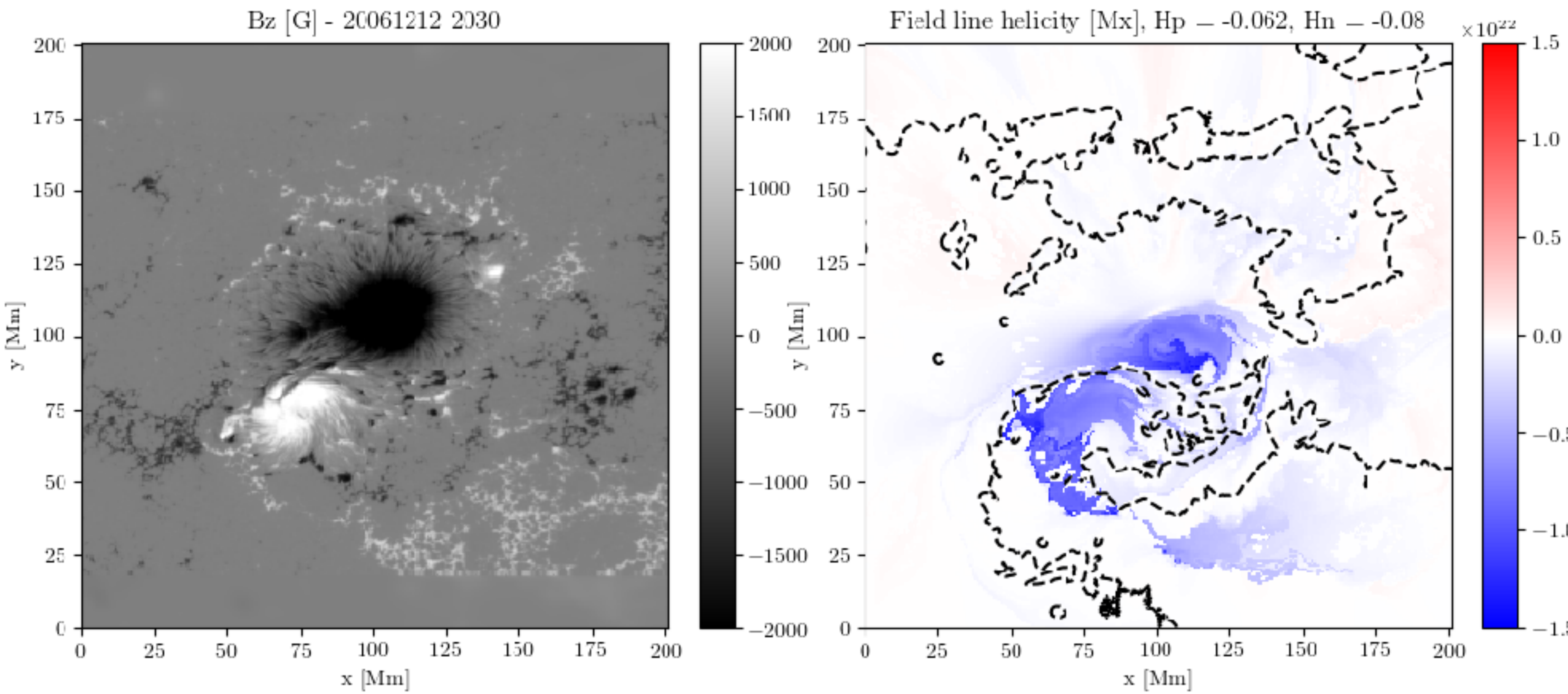
before the flare…



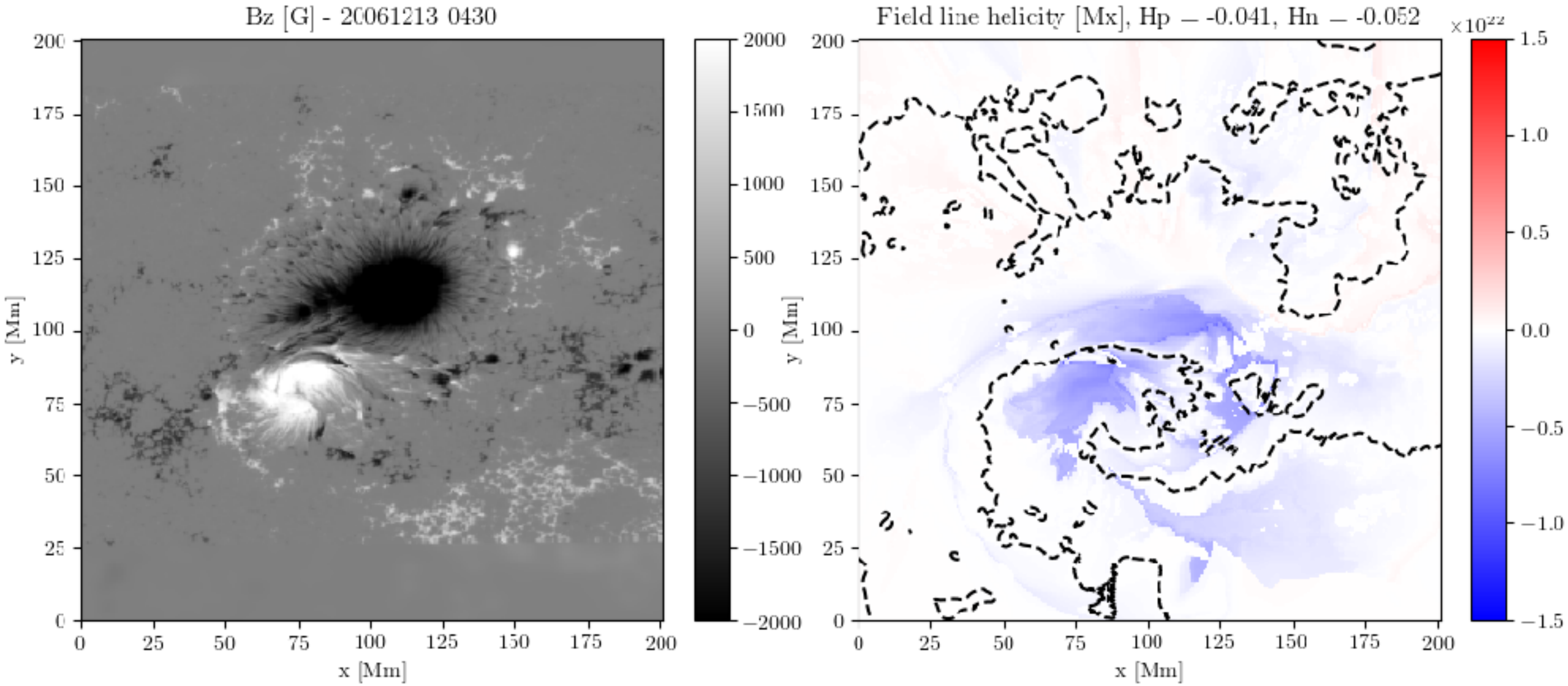
after the flare…



before the flare…

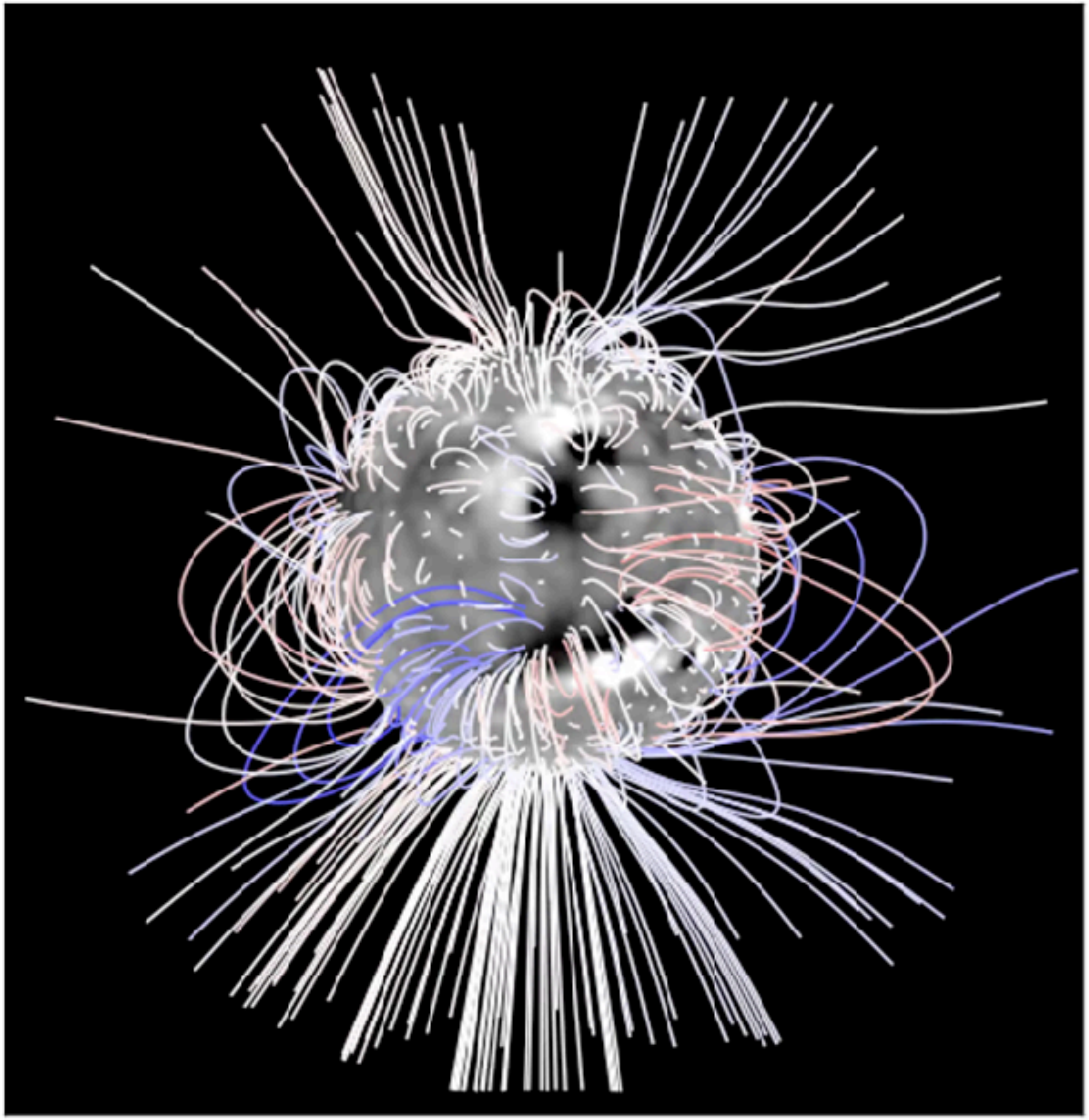


after the flare…



Significant *local* decrease in helicity during the flare.

Example: global magneto-frictional model

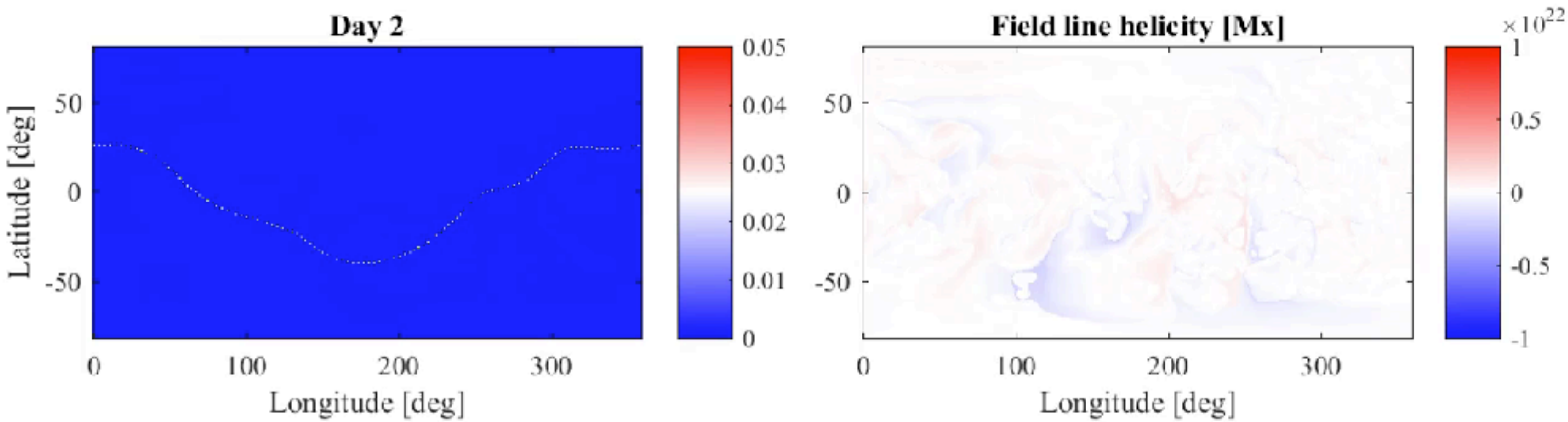


Field line helicity reveals the concentration of helicity above photospheric neutral lines.

Yeates & Hornig, *A&A* 2016

Example: global magneto-frictional model

Outer boundary: **Inner boundary:**



Field line helicity can identify flux ropes and eruptions…

Conclusions

- **Field line helicity** reveals the distribution of magnetic helicity within the corona.
- Useful tool both within active regions and globally, e.g. for identification of magnetic flux ropes [next talk!]

More details

- Evolution of field line helicity in **global corona**:
  Yeates & Hornig, *A&A* **594** A98 (2016).
- Evolution of field line helicity **under reconnection** [neat]:
  Russell, Yeates, Hornig, Wilmot-Smith, *PoP* **22** 032106 (2015).

http://www.maths.dur.ac.uk/~bmjg46/

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