A Generalised Flux Function for 3D Reconnection

Anthony Yeates

with

Gunnar Hornig (Dundee)

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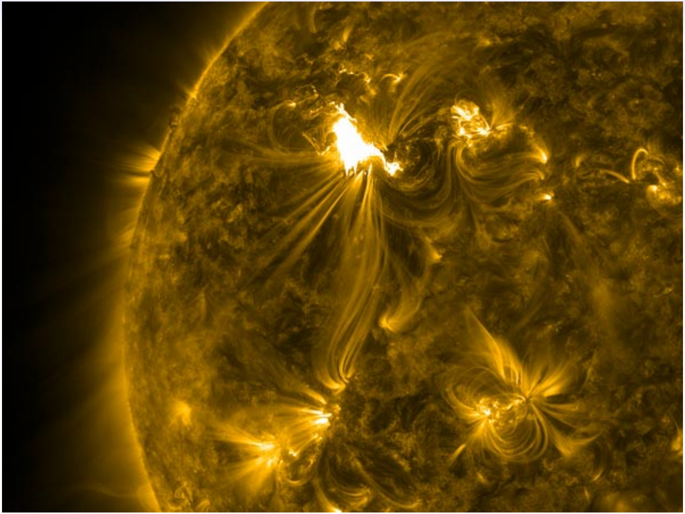
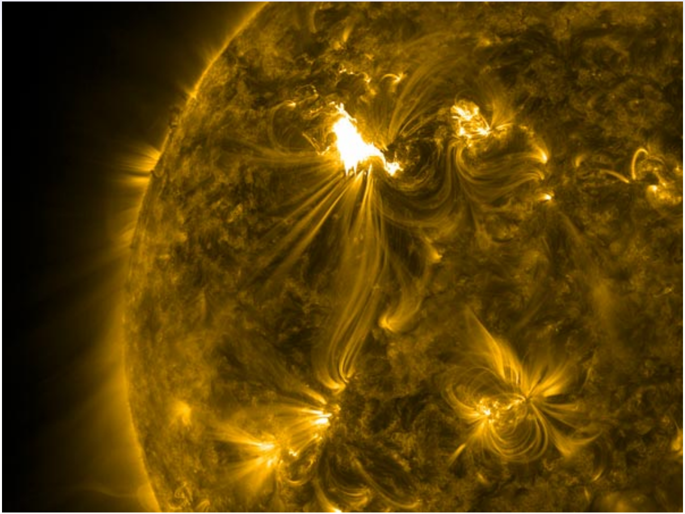
RAS National Astronomy Meeting 2012, Manchester

Durham University



SDO/AIA, 6th March 2012

Magnetic reconnection: the change of connectivity of magnetic field lines in a non-ideal plasma.

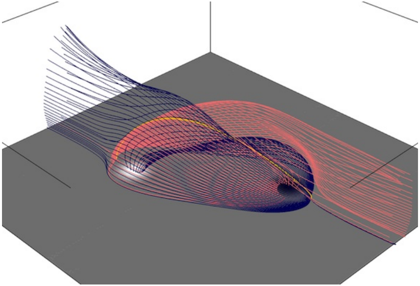


SDO/AIA, 6th March 2012

Magnetic reconnection: the change of connectivity of magnetic field lines in a non-ideal plasma. ****Can occur anywhere in 3D****

Magnetic field partitions

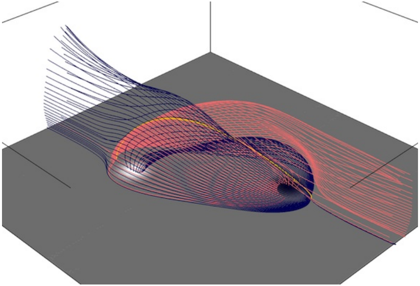
- 3D magnetic skeleton



[Parnell, Haynes & Galsgaard, *JGR* 2010]

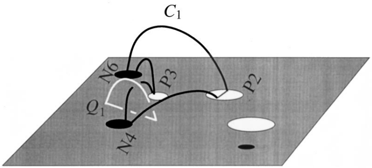
Magnetic field partitions

- 3D magnetic skeleton



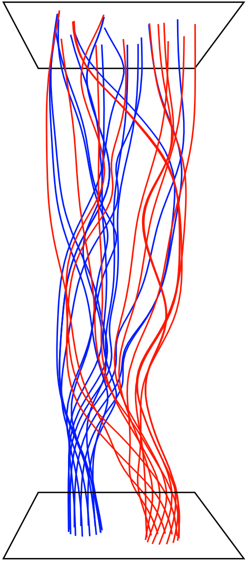
[Parnell, Haynes & Galsgaard, *JGR* 2010]

- Boundary connectivity



[Longcope, *ApJ* 2001]

How to partition a flux tube?



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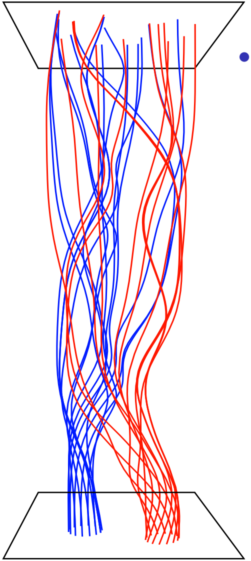
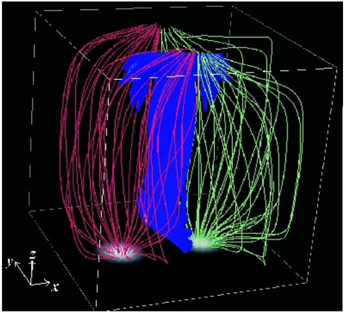
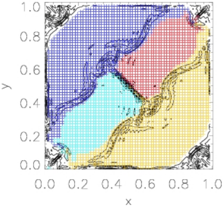


- Sometimes by boundary connectivity (**toroidal** fluxes):





[Wilmot-Smith & De Moortel, *A&A* 2007]

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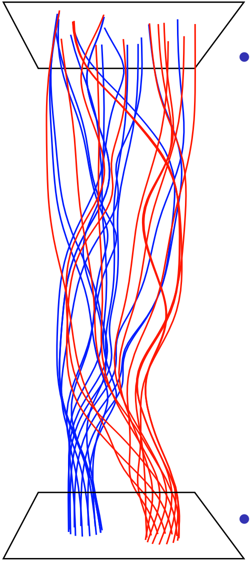

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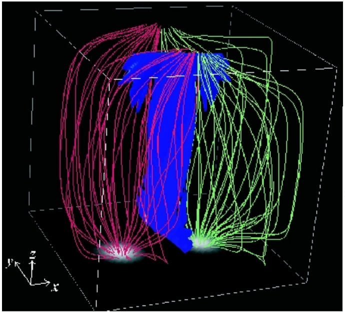
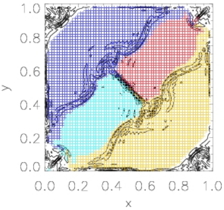
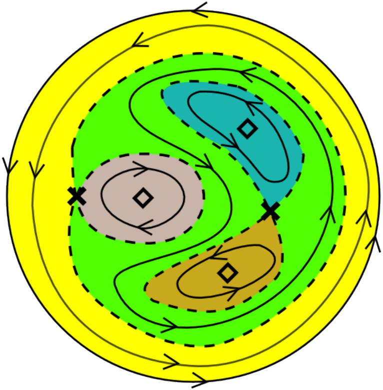




[Wilmot-Smith & De Moortel, *A&A* 2007]

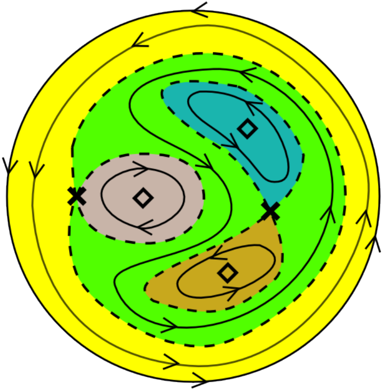
- What about **poloidal** (horizontal) fluxes?

Poloidal fluxes in 2D



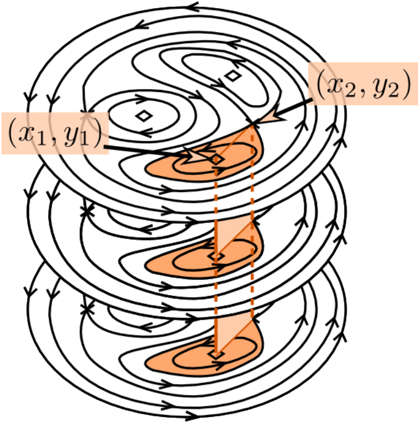
$$\mathbf{B}(x, y) = \nabla \times \left[A(x, y)\mathbf{e}_z\right]$$

Poloidal fluxes in 2D

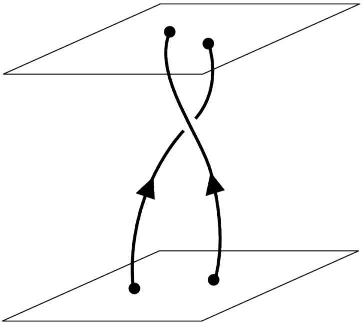


$$\mathbf{B}(x,y) = \nabla \times \left[A(x,y)\mathbf{e}_z\right]$$

$$\Phi = \int \mathbf{B}\cdot d\mathbf{a} = \oint \mathbf{A}\cdot d\mathbf{l}$$
$$= A(x_1,y_1) - A(x_2,y_2)$$

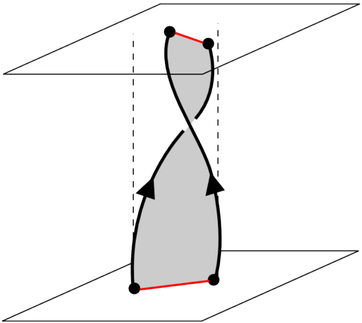


Generalised flux function



Generalised flux function

$$\mathcal{A}(x,y) = \int_{(x,y)}^{\mathbf{F}_1(x,y)} \mathbf{A} \cdot d\mathbf{l}$$



Generalised flux function

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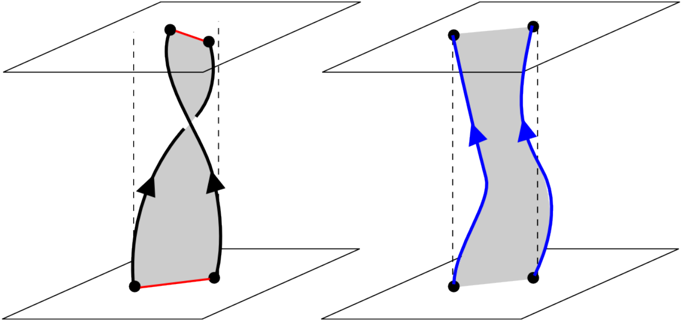

- $\mathcal{A}$ values at periodic points are **topological fluxes**.

Generalised flux function

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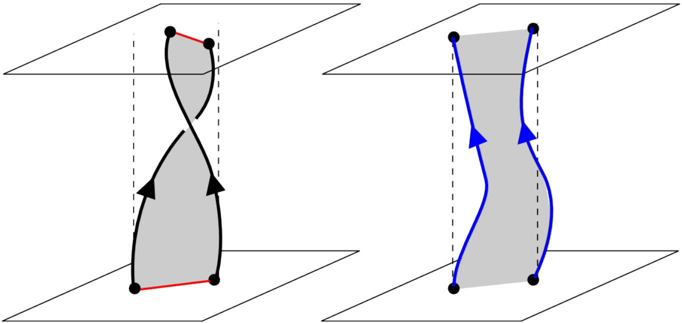
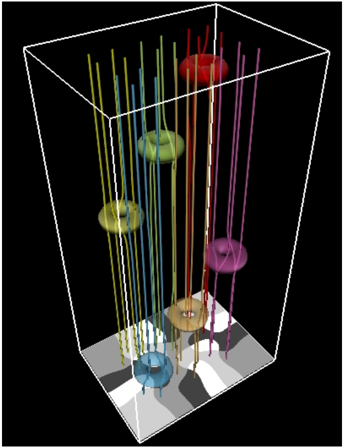
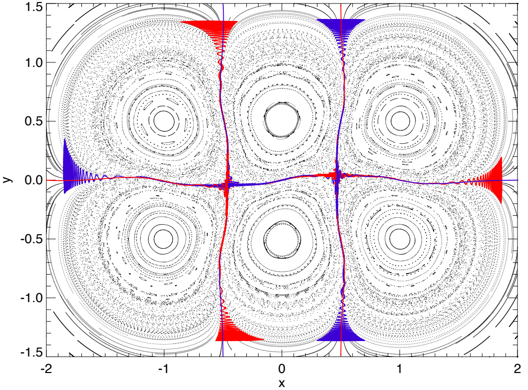


- $\mathcal{A}$ values at periodic points are **topological fluxes**.
- Gauge transformation $\mathbf{A} \to \mathbf{A} + \nabla\psi$ gives
  $\mathcal{A}(x,y) \to \mathcal{A}(x,y) + \psi\Big|_{(x,y)}^{\mathbf{F}_1(x,y)}.$

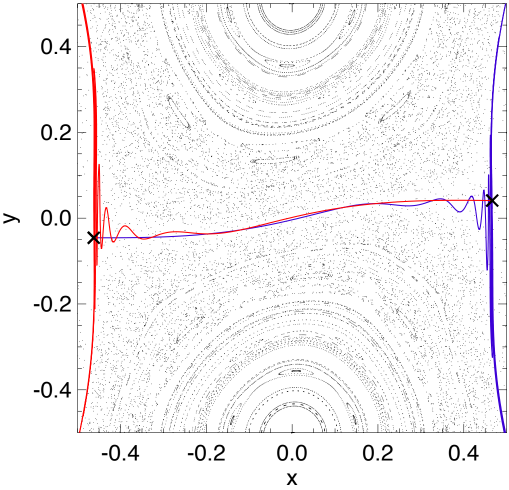
Example

- Flux tube with six twist regions:





Example



- (Un)stable manifolds calculated with method of [Krauskopf & Osinga, *J Comp Phys* 1998].

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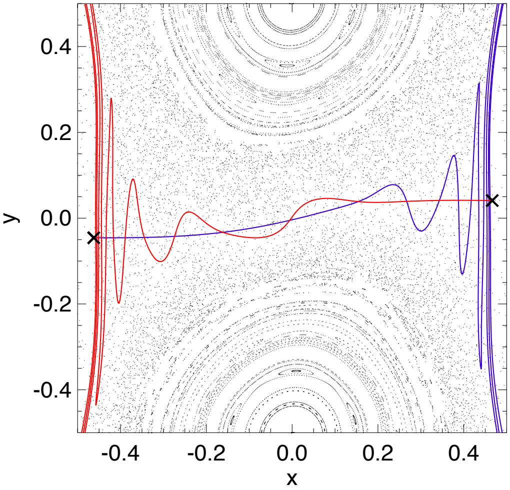

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Conclusion

- **Partition** of poloidal fluxes in a non-zero flux tube.
- **Measured** by generalised flux function $\mathcal{A}(x, y)$ at periodic points.
- **Well-defined** measure of global reconnection.

Further details

- Yeates & Hornig, *Phys Plasmas* **18**, 102118 (2011).

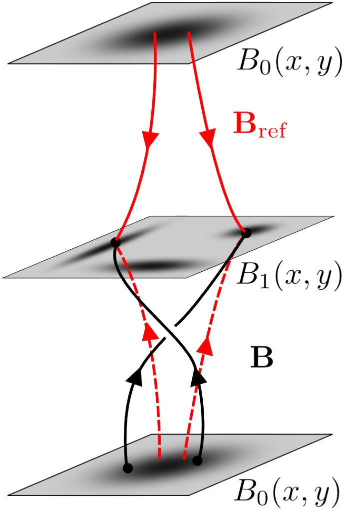
Future:

- Measure reconnection in numerical relaxation simulations.
- Partition could be refined using higher period orbits.

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

APPENDICES

Non-periodic flux tubes



- Define topological fluxes with respect to a reference field.
- Suggest to choose the unique potential field.