Coronal heating problem and binary reconnection

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Coronal heating problem

- Solar corona reach temperatures of the order 2×10K whereas surface of the sun is only about 6000K.
- Unsolved problem: under what mechanism is the energy transported up to the solar corona and converted into heat within a few solar radii.
- Two leading theories:
  - Wave propagation in magneto-acoustic waves.
  - Magnetic reconnection.

Magnetic reconnection

- Refers to the phenomenon of changing in the topology of field lines i.e. breaking and reconnecting of field lines with opposite directions.
- Non-ideal term in Ohm's law can be written as $\mathbf{N} = \mathbf{E} + \mathbf{v} \times \mathbf{B}$. Evolution of magnetic field is then

$$\frac{\partial \mathbf{B}}{\partial t} = \nabla \times (\omega \times \mathbf{B})$$

.

  - 2D reconnection if $\mathbf{N} = \mathbf{u} \times \mathbf{B} + \nabla\Phi$ but $\mathbf{u}$ has a singularity.
  - 3D reconnection if $\mathbf{N} \neq \mathbf{u} \times \mathbf{B} + \nabla\Phi$.

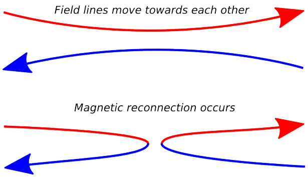

Figure: Reconnection in magnetic field lines

Helicity

- Magnetic helicity of a magnetic vector potential A where $\nabla \times \mathbf{A} = \mathbf{B}$ is defined as

$$H = \int_S \mathbf{A} \cdot \mathbf{B} \, dV.$$

- Measures the twisting and linkage of magnetic field lines in a volume.
- During reconnection, field lines naturally try to reduce their helicity - untwist themselves.

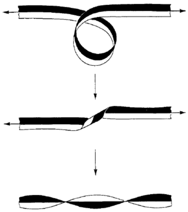

Figure: Example of stored helicity and the 'unraveling' of the field line.

Energy and heating

- It is thus this energy stored in the twisted and tangled field lines released in reconnection.
- Most of this energy is then converted into thermal energy and heats the solar corona.
- Average heating rate due to turbulent reconnection:

$$Q = \frac{M_T}{2} \sum_{\text{x-line } i} l^+ R_i c_{iAr} B_{ir}^2 (\frac{B_{ir}}{B_i})^\gamma .$$

Binary reconnection

- Theory proposed by Priest et. al characterised by binary interactions of pair of sources: in the frame of reference of one magnetic element, its corresponding pair may rotate and twist field lines - driving reconnection.
- Suggested that more likely to occur in nature given its interactions of the lowest order.
- Assumes majority of flux from one source goes to its corresponding sink.

Model

- Model magnetic elements as particles following Brownian motion.
- Constrained to a box for computation simplicity by implementation of period boundary conditions.
- Pick field line starting positions, integrate magnetic field and determine to which particle they end up: approximation of flux between sources.

Observations

- Example model with $N = 10$ particles.
- Consider the flux distribution of particle 0.

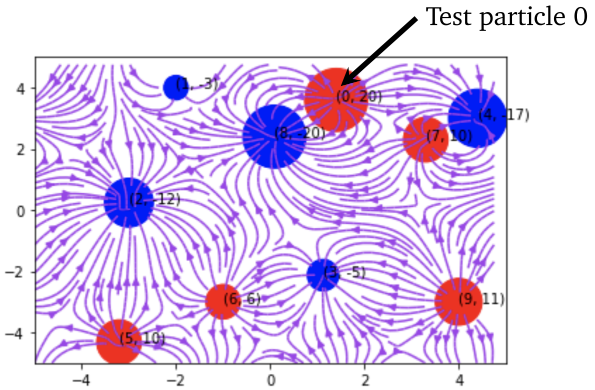

Figure: 10 particle model indexed by particle number and magnitude respectively.

Model

- Fragments initially appear in opposite polarity, equal magnitude pairs.
- As in Meyer's paper, particles may coalesce, break down, end on zero polarity.
- Is the model suitable after time evolution? Assumption needs to be tested in late time behaviour.

Thank you!

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References