How reconnection within a current sheet can release energy stored over the global corona — insights from a toy model

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*I am not Michael Bareford
Energy storage – e.g. from emergence

FCE: lowest energy without changing flux $P1-N2$ (DWL 1996)

$\nabla \times \mathbf{B} = 0$

cf. Heyvarts, Priest & Rust 1977
Energy release via reconnection

**Energy release:** breaking topological constraint on P1-N2 flux: access to lower energy state.

Transfer (reconnect) flux $\Delta \Phi$ through current sheet

$\Delta \Phi$: flux difference between field & potential

Energy difference

$\Delta W_M \sim I \Delta \Phi$

(DWL & Magara 2004)
\[ W_M = \frac{1}{8\pi} \int d\Phi \int B \, dl \]

\[ \delta W_M \sim \delta \Phi B w \]

\[ \delta W_M \sim \delta \Phi B \Delta L \]

A Morsel of Reconnection

Dissipation negligible if \( w << \Delta L \)
Many Morsels Make a Meal

Reconnection enables shorter field lines = lower energy

$$\delta W_M \sim \delta \Phi B \Delta L \quad B \Delta L \sim B h \sim I$$

Ampère

$$I \sim \frac{\Delta \Phi}{L}$$

local current/flux relation

$$\Delta W_M = \int I \ d(\Delta \Phi) = \frac{1}{L} \int \Delta \Phi \ d(\Delta \Phi) = \frac{1}{2} I_0 \Delta \Phi_0$$

Local flux transfer will release all stored free energy

Bozeman 7/9/13
Where is the energy stored?

Not in current sheet

cf. magnetic field from wire

\[ \Delta W_M = \frac{1}{8\pi} \int |\mathbf{B} - \mathbf{B}_0|^2 d^3x \]

\[ \mathbf{B}_{np} = \mathbf{B} - \mathbf{B}_0 \sim I \]
The puzzle so far

• lack of reconnection
  ➔ equilibrium w/ current sheet (CS)
• reconnection at CS =
  E-field localized to dissipation region in CS
• E-field releases stored magnetic energy
  does not dissipate/thermalize it
• global field must change in response to
  decreasing current of sheet (current/flux relation)

1) How does local flux x-fer create global change?
2) What form does the converted energy take?
1) Assume perturbation is small — linear perturbation
2) Reconnection via resistivity* `switched on’ at t=0
3) Solve linearized MHD equations

* Diffuses current, does not reduce it
Azimuthal decomposition of $\delta B$ about X-point

$\Delta W_M (m \geq 2) = 0.27I^2 \sim 10\% \Delta W_M$

90\% of free energy from $m=0$ mode — i.e. net current (equiv. wire)

Consider dynamics of $m=0$ mode only
Linear response to diffusion

FMS rarefaction front: converts $W_m$ to KE

NB: $m=0$ pert. to $J(x,y)$
$\Leftrightarrow m=2$ pert. To $B$ and $v$

Net current carried by FMS front
Current carried upward by FMS front

Reflection plays significant role
The front and its reflection

á la WKB

Not reflected: 85%

Reflected: 15%

Much more reflection at lower frequencies (100% at $\omega=0$)

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Bozer
Results/Conclusions

• 5% of energy dissipated **directly** by reconnection **E** field (i.e. ohmic dissipation)
• 95% converted initially to **KINETIC ENERGY** energy by FMS wave front
  • 55% reflected repeatedly* – dissipated at X-point after time ~ ln(S) \( \tau_A \)
    (see Craig & McClymont 1991, Hassam 1992)
• 40% propagates ever upward as FMW

Toy model suggests 95% of flare energy problem **cannot** be studied using local (\( \mu \)-physics) models

*lower \( \omega \) favored by each reflection – results in more efficient reflection each time (DWL & Tarr 2012)