

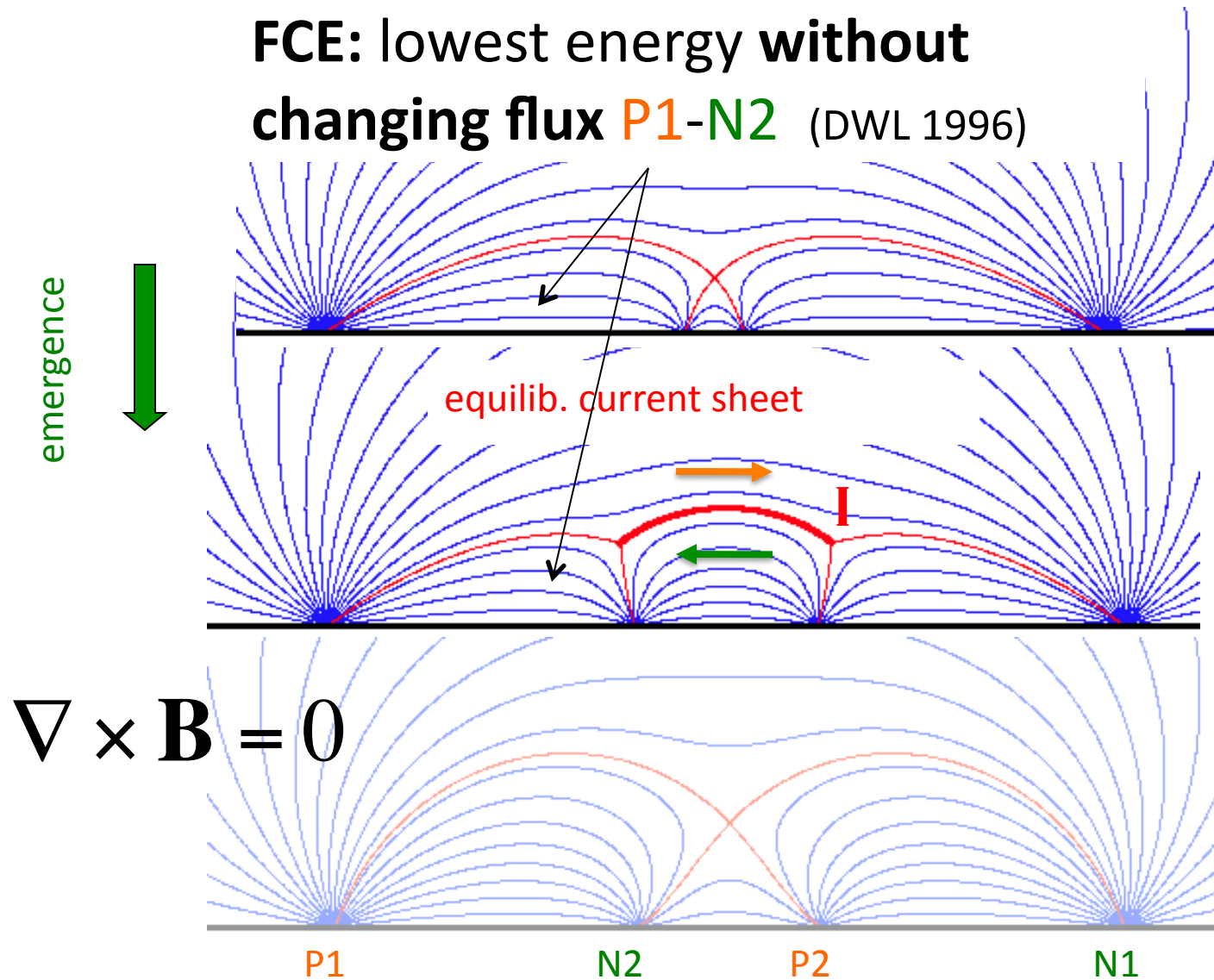
How reconnection within a current sheet can release energy stored over the global corona — insights from a toy model

Dana Longcope,* MSU

Thanks: Eric Priest, Lucas Tarr

Energy storage – e.g. from emergence

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



cf. Heyvarts, Priest & Rust 1977

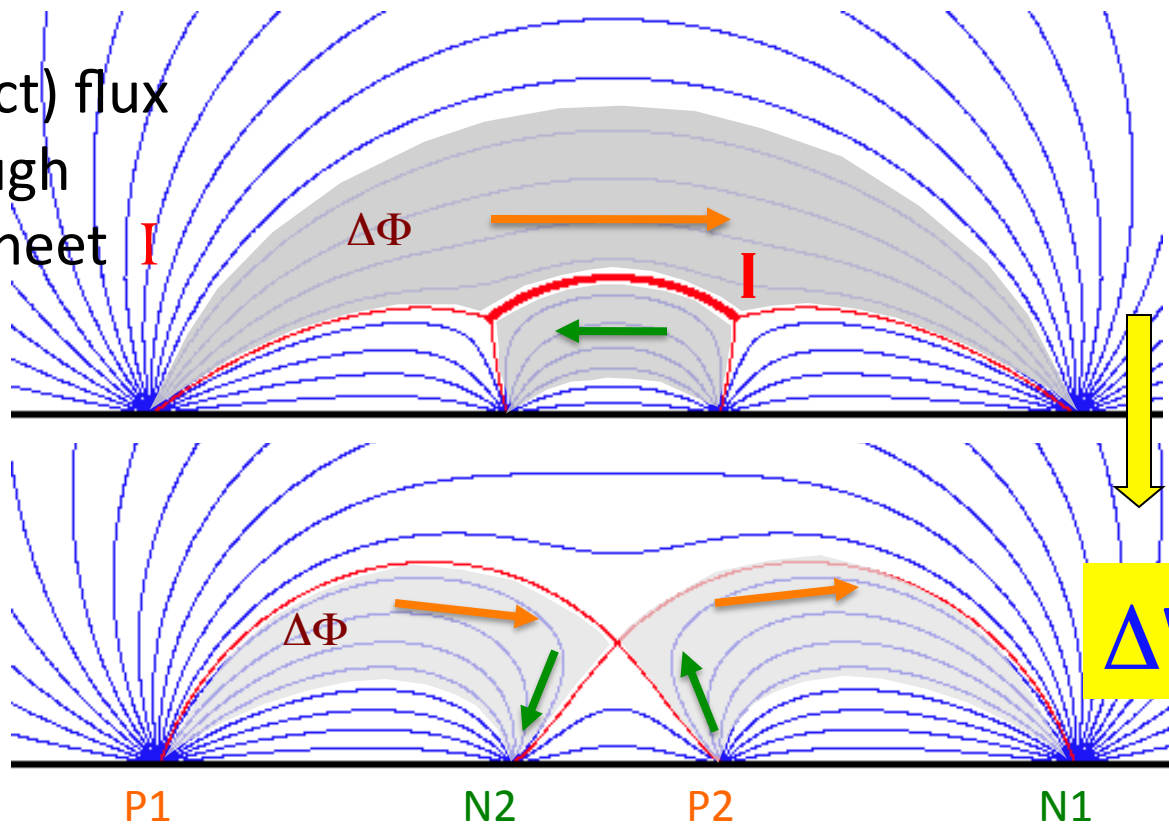
Energy release via reconnection

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

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

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

Energy
difference



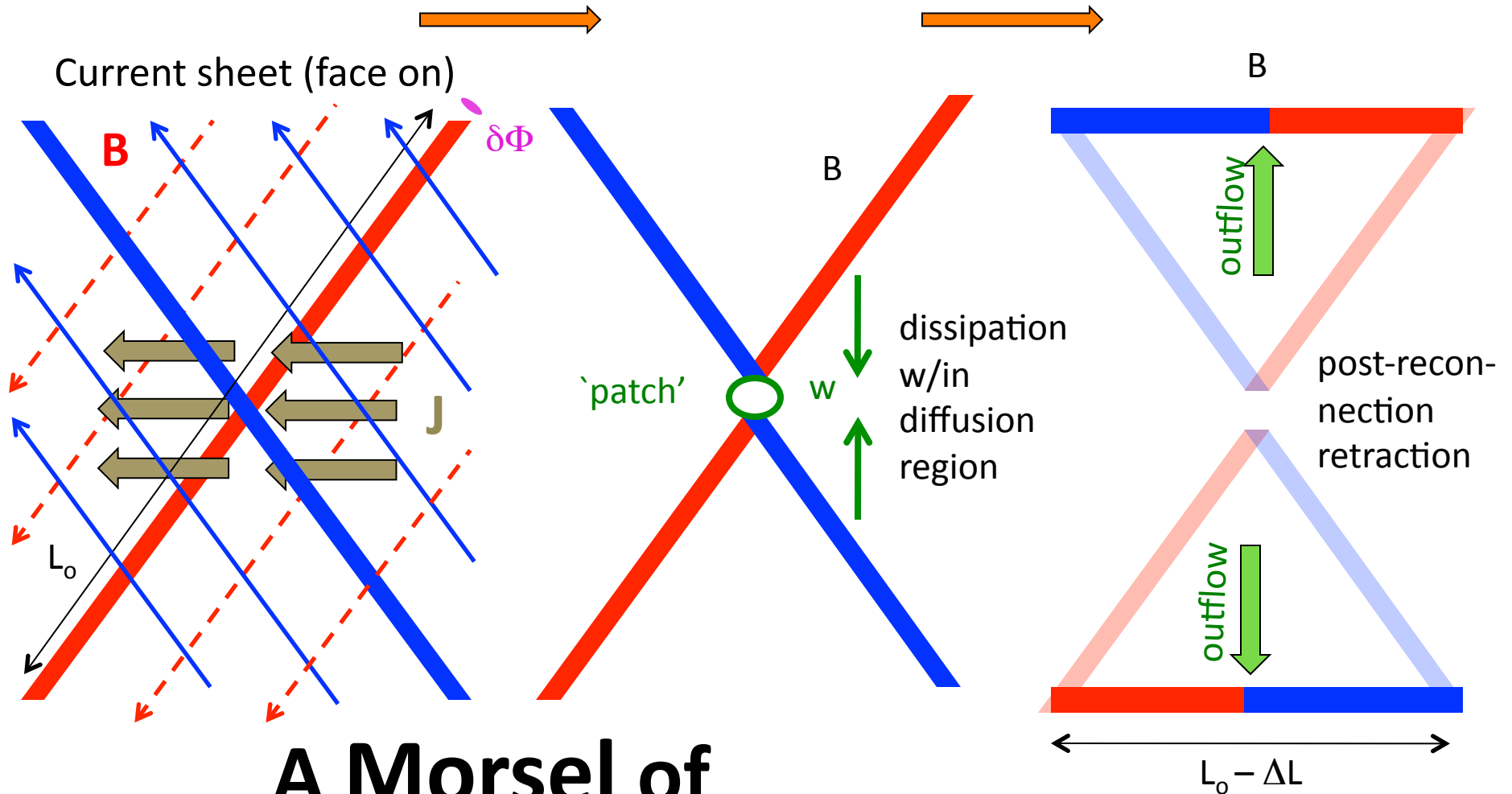
$$\Delta W_M \sim I \Delta\Phi$$

(DWL & Magara 2004)

$$W_M = \frac{1}{8\pi} \int d\Phi \int B d\ell$$

$$\delta W_M \sim \delta\Phi B w$$

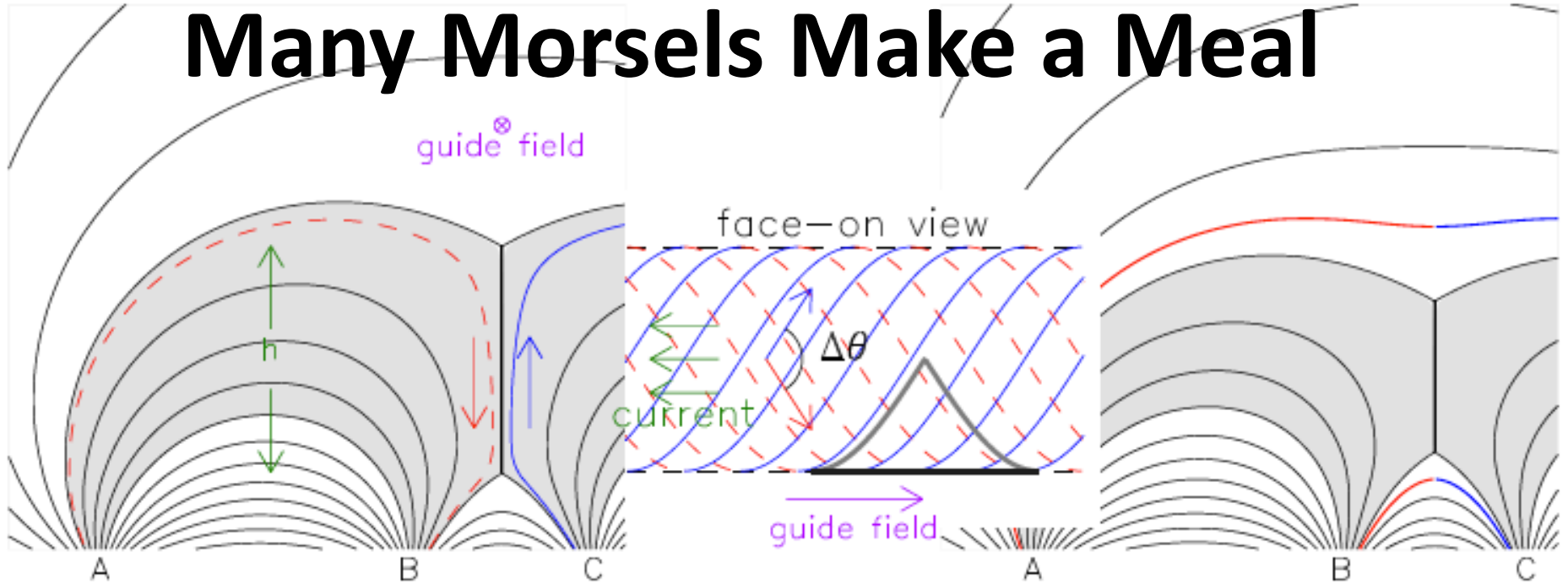
$$\delta W_M \sim \delta\Phi B \Delta L$$



A Morsel of Reconnection

Dissipation negligible if $w \ll \Delta L$

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

$$\delta W_M \sim I \delta\Phi$$

basic E&M

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

current/flux
relation

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

Local flux transfer will release **all** stored free energy

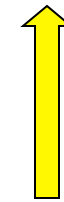
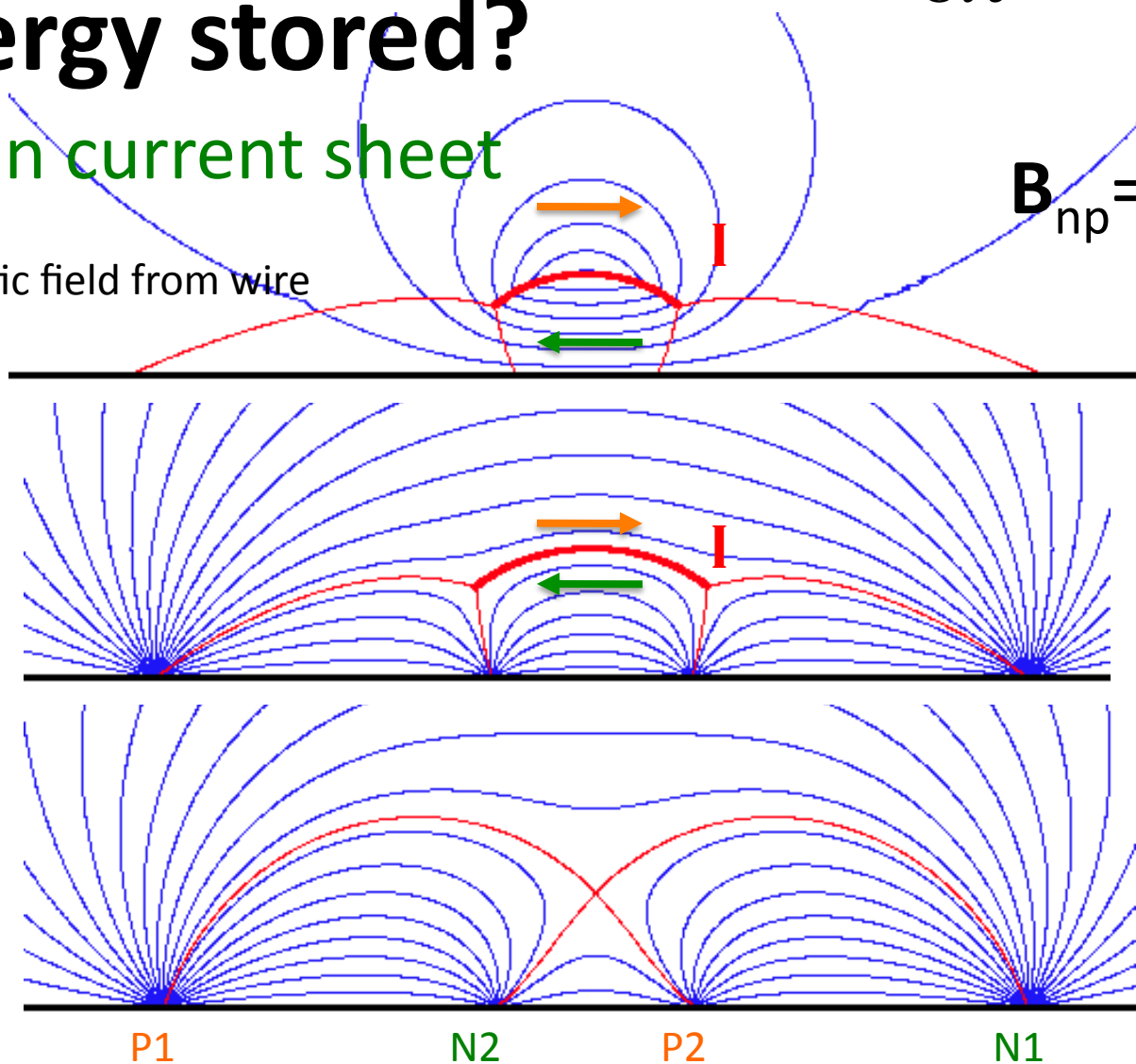
Where is the energy stored?

Not in current sheet

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

$$\mathbf{B}_{np} = \mathbf{B} - \mathbf{B}_0 \sim \mathbf{I}$$

cf. magnetic field from wire



\mathbf{B}

\mathbf{B}_0

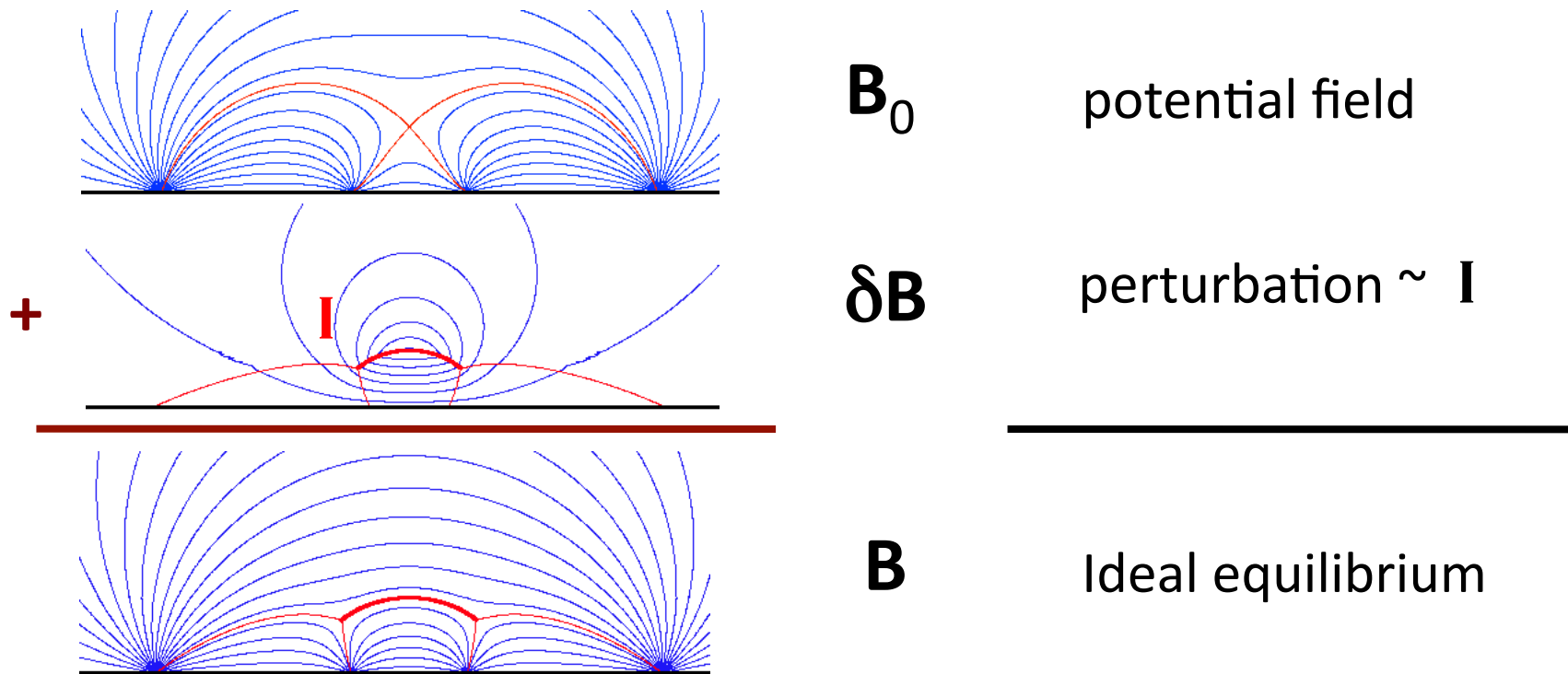
The puzzle so far

- 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?

Insight from a toy model

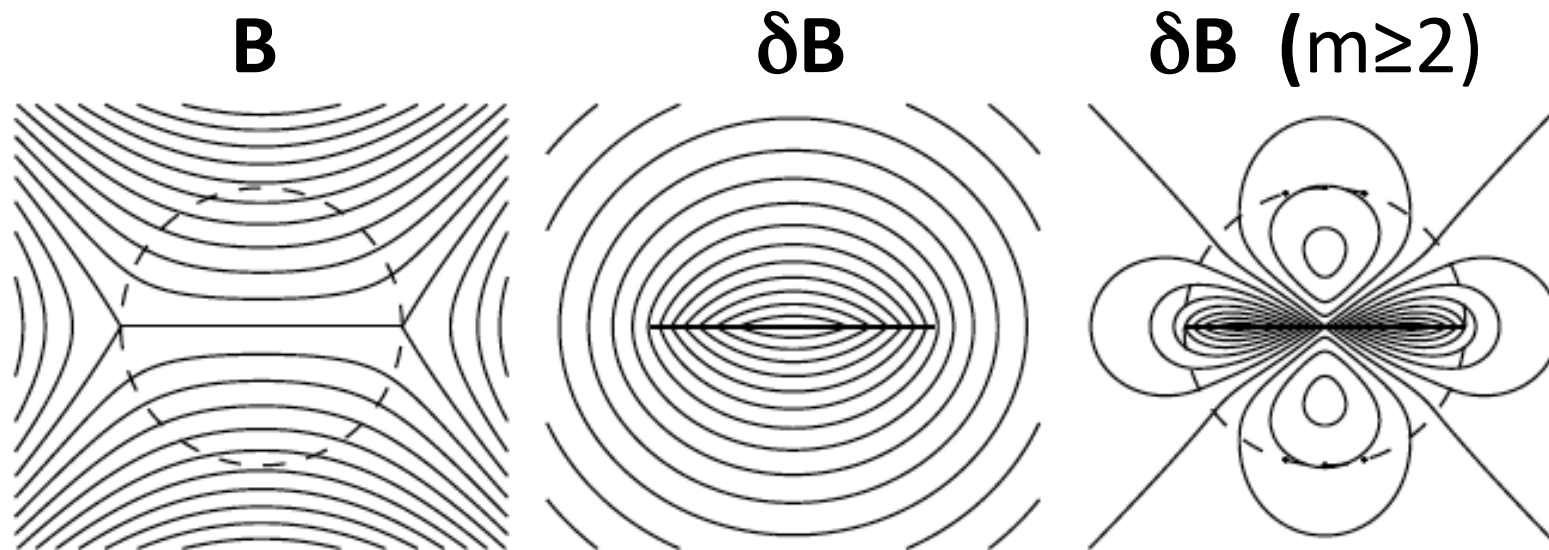
(DWL & Priest 2007, DWL & Tarr 2012)



- 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 $\delta\mathbf{B}$ about X-point



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

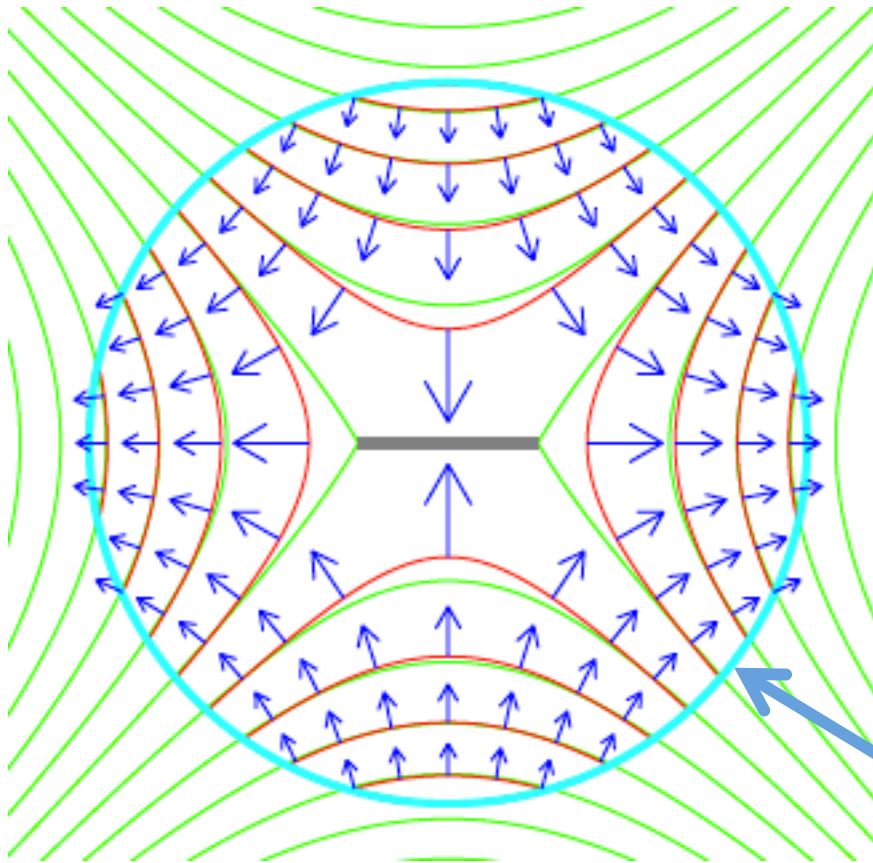
90% of free energy from $m=0$ mode
— i.e. net current (equiv. wire)

Consider dynamics of $m=0$ mode only

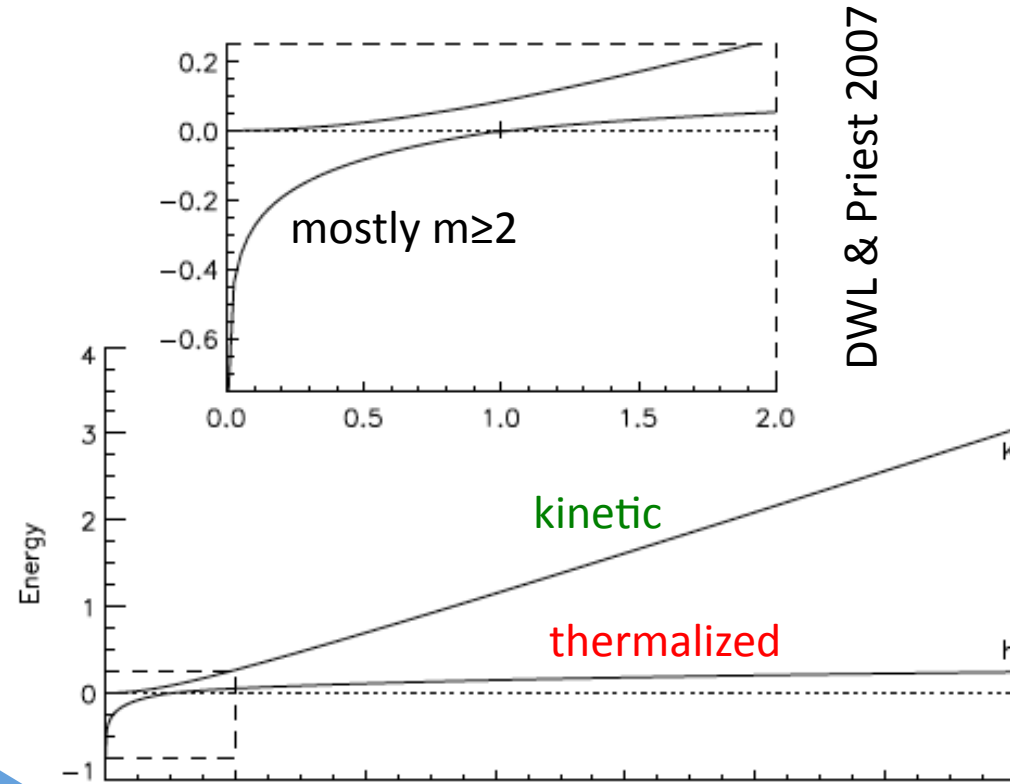
DWL & Tarr 2012

Linear response to diffusion

FMS rarefaction front: converts W_M to KE



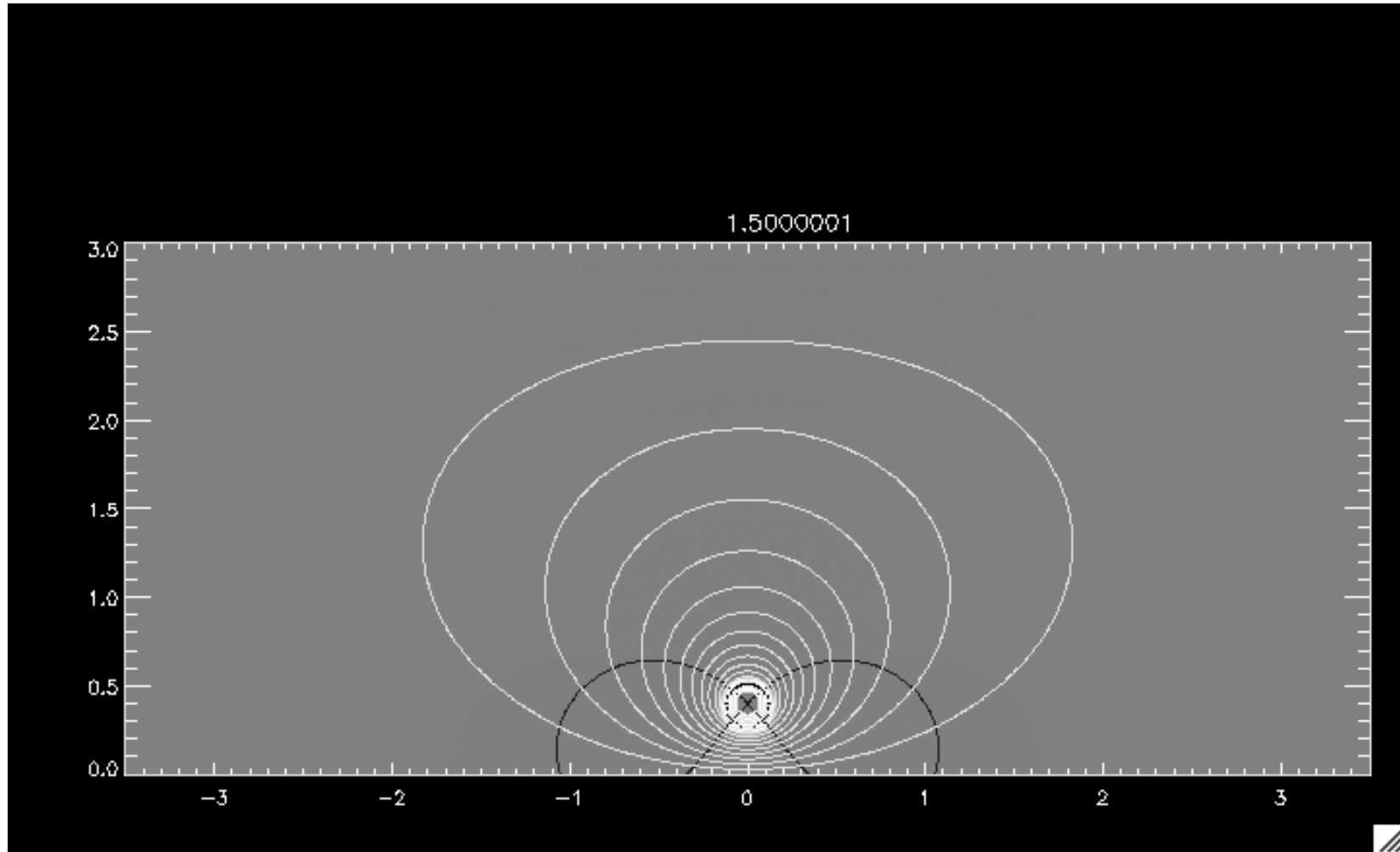
NB: $m=0$ pert. to $J(x,y)$
 \Leftrightarrow $m=2$ pert. To \mathbf{B} and \mathbf{v}



DWL & Priest 2007

Net current carried by FMS front

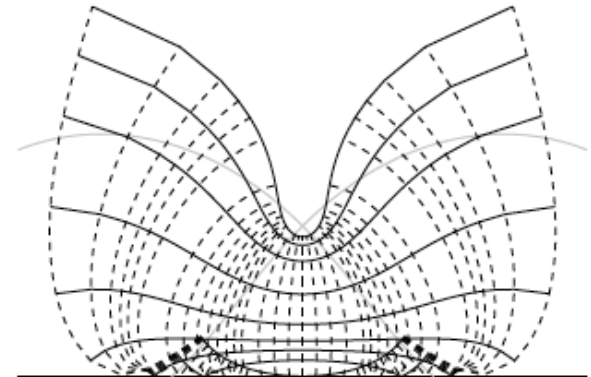
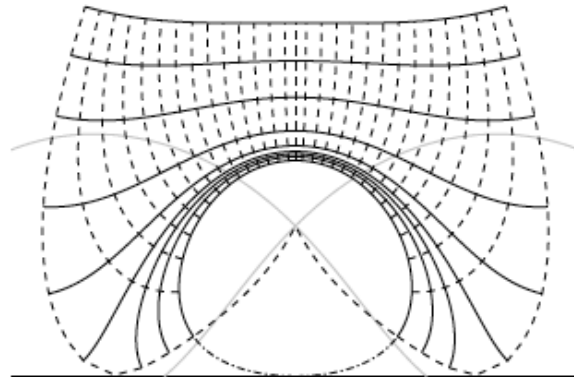
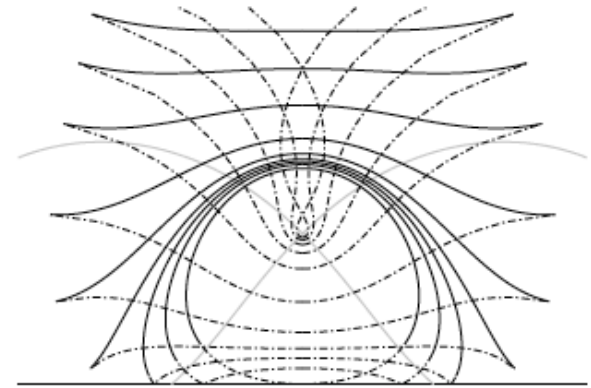
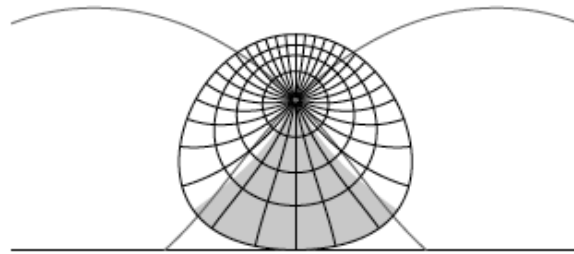
Current carried upward by FMS front



Reflection plays significant role

The front
and its
reflection

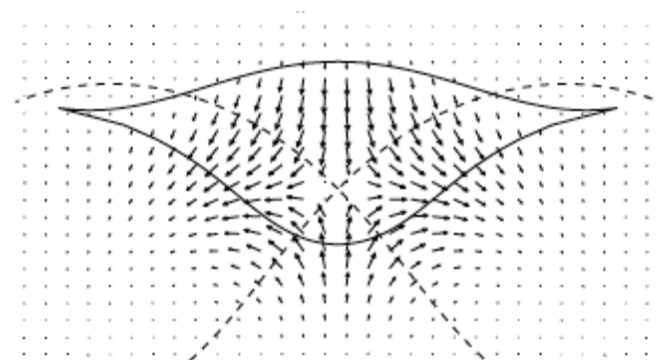
à la WKB



Not reflected: 85%

Reflected: 15%

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



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 $\sim \ln(S) \tau_A$
(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 (μ -physics) models

*lower ω favored by each reflection – results in more efficient

SPD 201 reflection each time (DWL & Tarr 2012)