

# Magnetic Reconnection in Three Dimensions

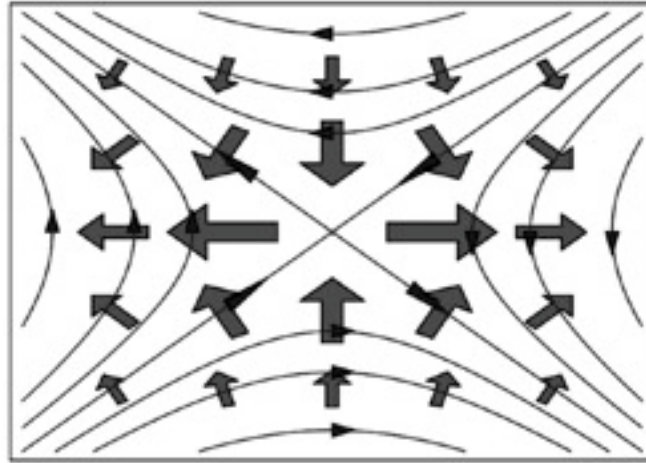


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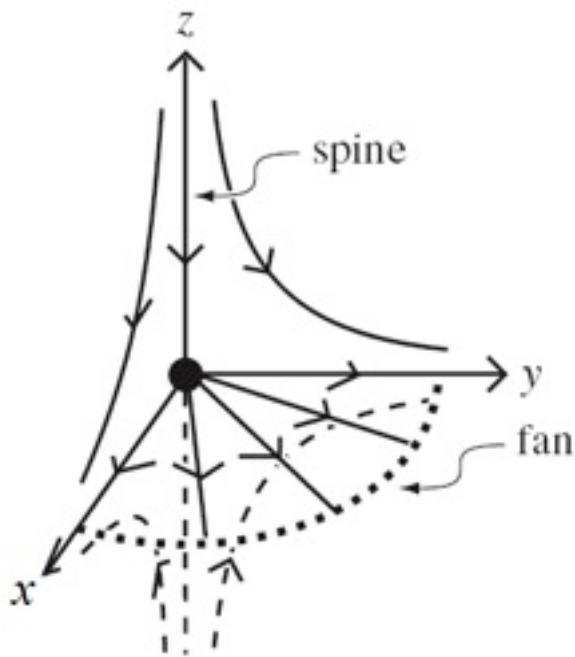
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# 2D Reconnection



- occurs only at an X-point
- field-lines cut and rejoin at single location
- solution in ideal region governs reconnection rate
- classification as fast or slow depending on  $R_m$

# 3D Reconnection

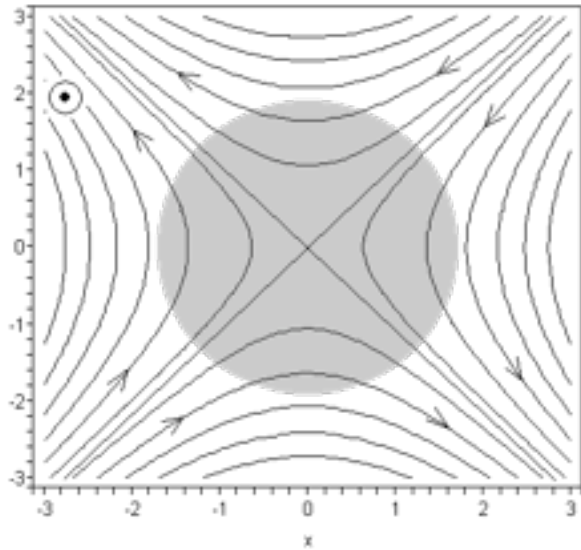


- with null-points
  - *separator, fan, spine*
- without null-points
- 3D  $\leftrightarrow$  non-ideal region bounded in 3D

no distinguished field line:

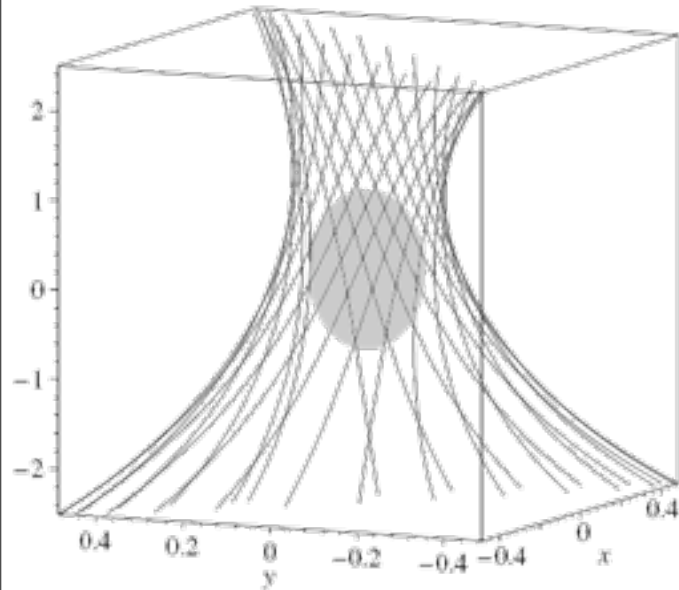
reconnection location depends on current concentration

# Analytical 3D Non-Null Reconnection Model



X-point field +  
uniform third component

$$\begin{aligned}\mathbf{E} + \mathbf{v} \times \mathbf{B} &= \eta \mathbf{j} \\ (\mathbf{v} \times \nabla) \mathbf{v} &= -\nabla p + \mathbf{j} \times \mathbf{B} \\ \nabla \times \mathbf{E} &= \mathbf{0} \\ \nabla \times \mathbf{B} &= \mathbf{0} \\ \nabla \times \mathbf{v} &= \mathbf{0}\end{aligned}$$



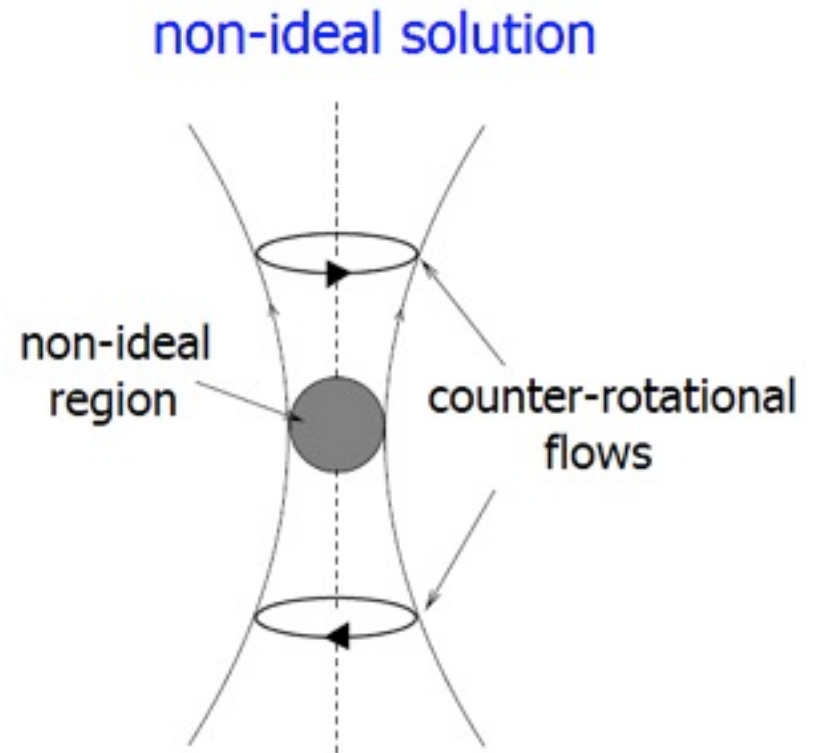
- expansion scheme
  - assume  $M_e < 1$
- localised non-ideal region
- solve for a wide variety of solutions

# Implications of Ohm's Law

- decompose into

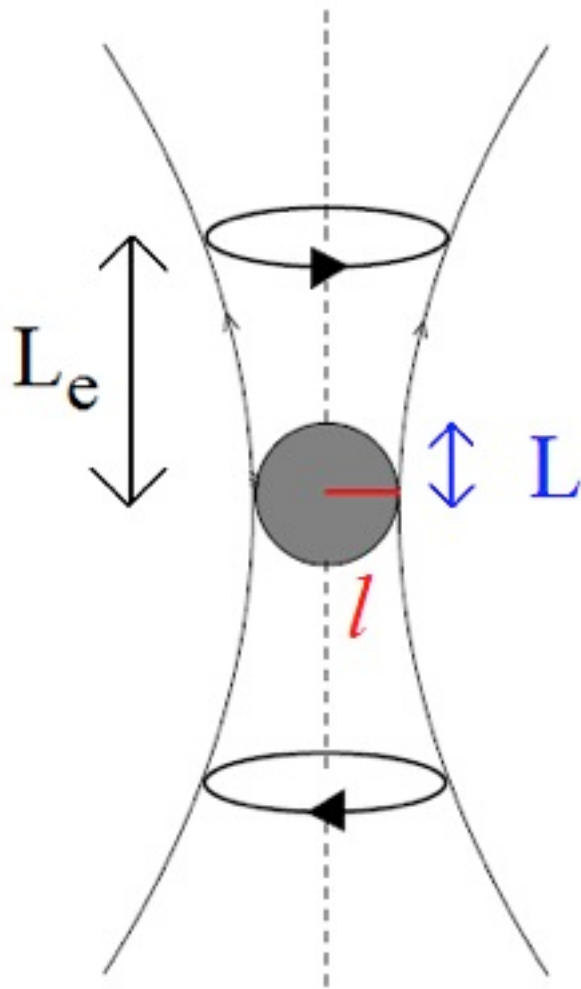
$$\mathbf{E}_{non-id} + \mathbf{v}_{non-id} \times \mathbf{B} = \eta \mathbf{j}$$

$$\mathbf{E}_{ideal} + \mathbf{v}_{ideal} \times \mathbf{B} = \mathbf{0}$$



- some coupling but *strength* and *profile* of ideal and non-ideal solutions *largely independent*.

# Non-Ideal Solution



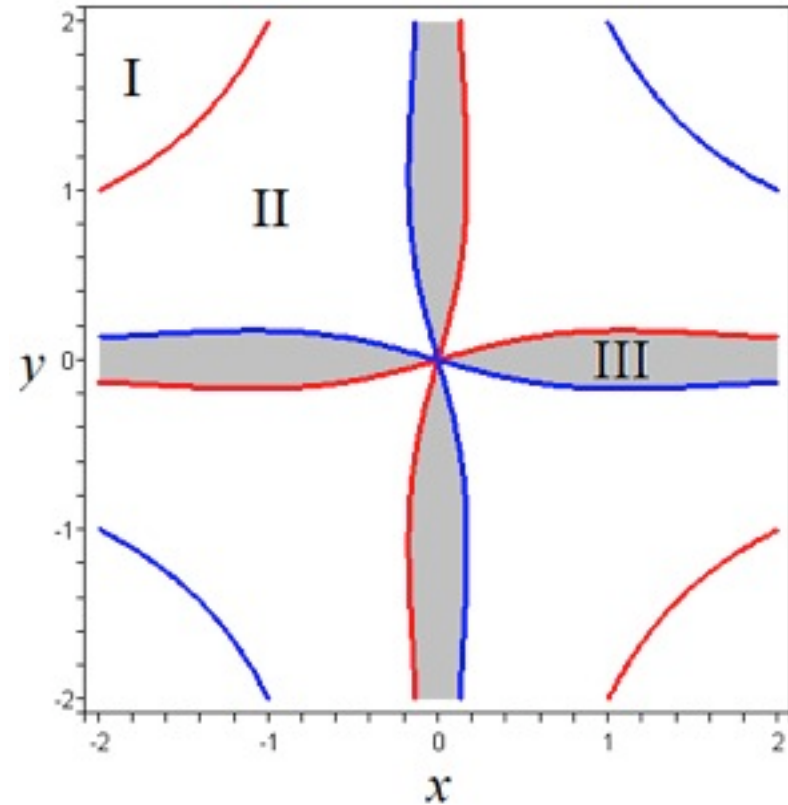
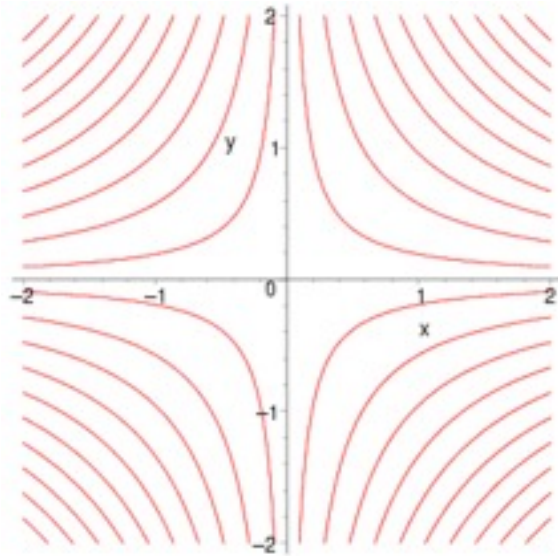
- Affects only field lines linking non-ideal region.
- Continuous change of field-line connectivity.
- Governs reconnection rate

$$M_e \sim \frac{\sqrt{\pi}}{\sqrt{2}} \frac{1}{R_{me}} \frac{L_e}{L} \frac{L}{l} g$$

(  $g$  geometric factor for field)

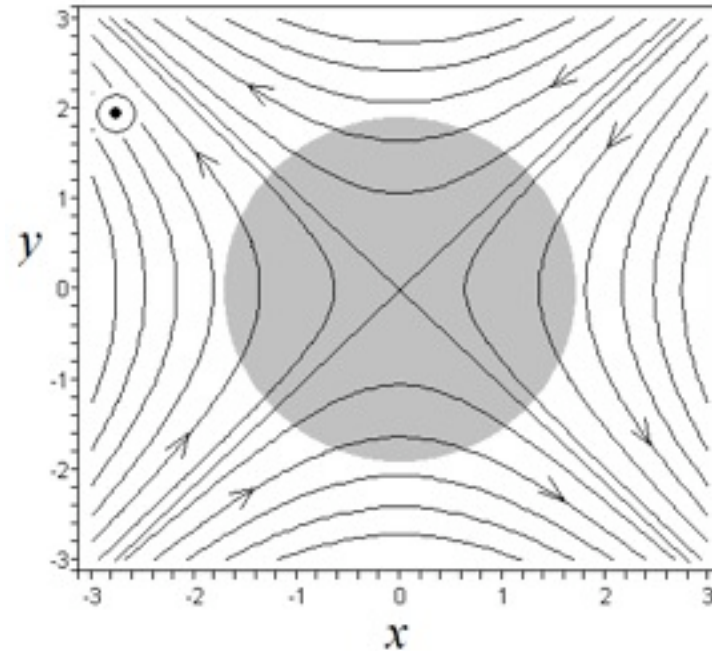
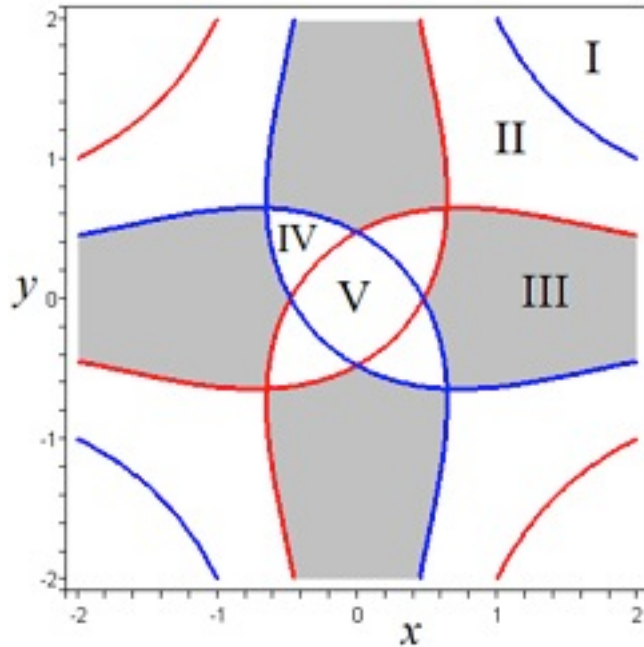
- fast/slow in 3D?

# + Ideal Solution



- wide range of flows
- stagnation flows  $\rightarrow$  reconnection effect global
- similar behaviour to classical 2D reconnection

# Link: Ideal and Non-Ideal Solution



- continuous transition between states
- no direct relation between the ideal flow and reconnection rate

# Conclusions

- Far greater variety of reconnection events in 3D than in 2D.
- Problem of distinguishing reconnection from other non-ideal processes.
- In 3D the solution outside the non-ideal region does not directly govern the reconnection rate.
- No simple dependence of reconnection rate on  $R_m$