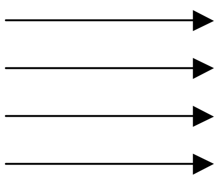
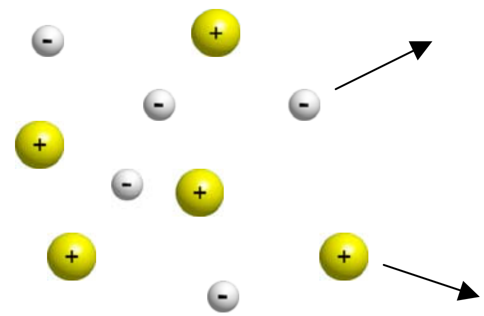
What is Magnetic Reconnection?

Magnetic Energy → **Kinetic Energy**



$$\frac{B^2}{8\pi}$$



$$\frac{mV^2}{2}$$

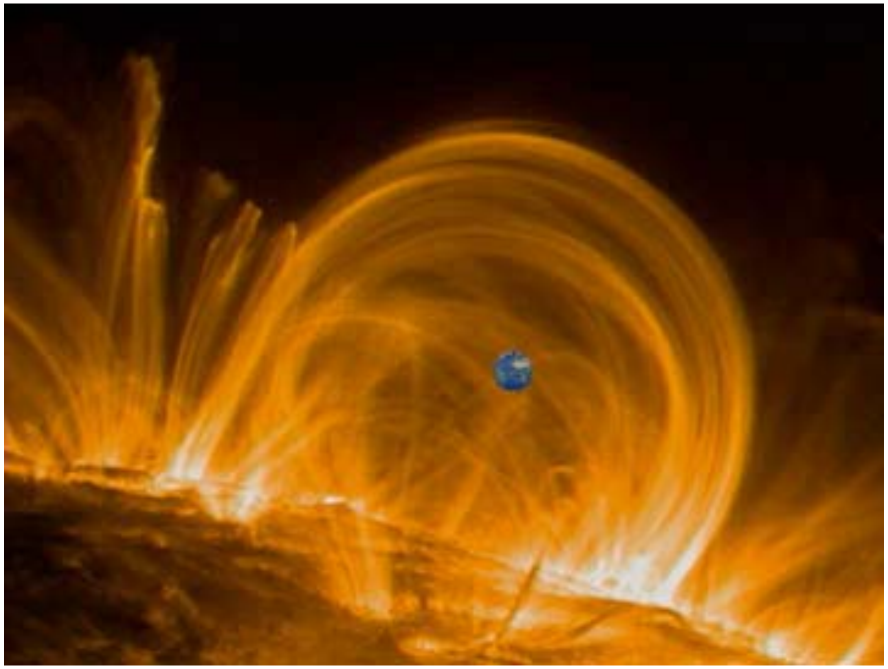
Many applications →

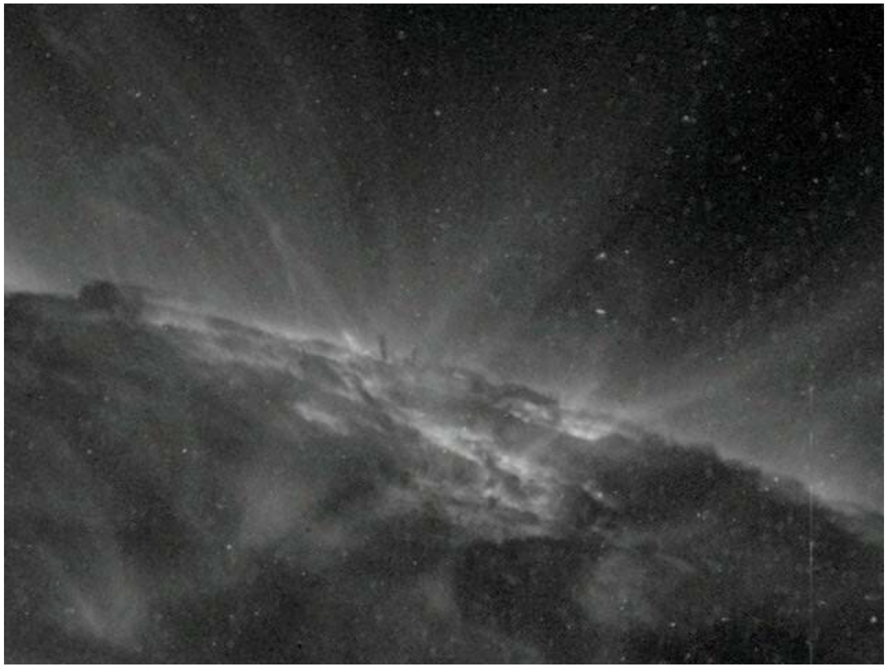
Space Plasmas

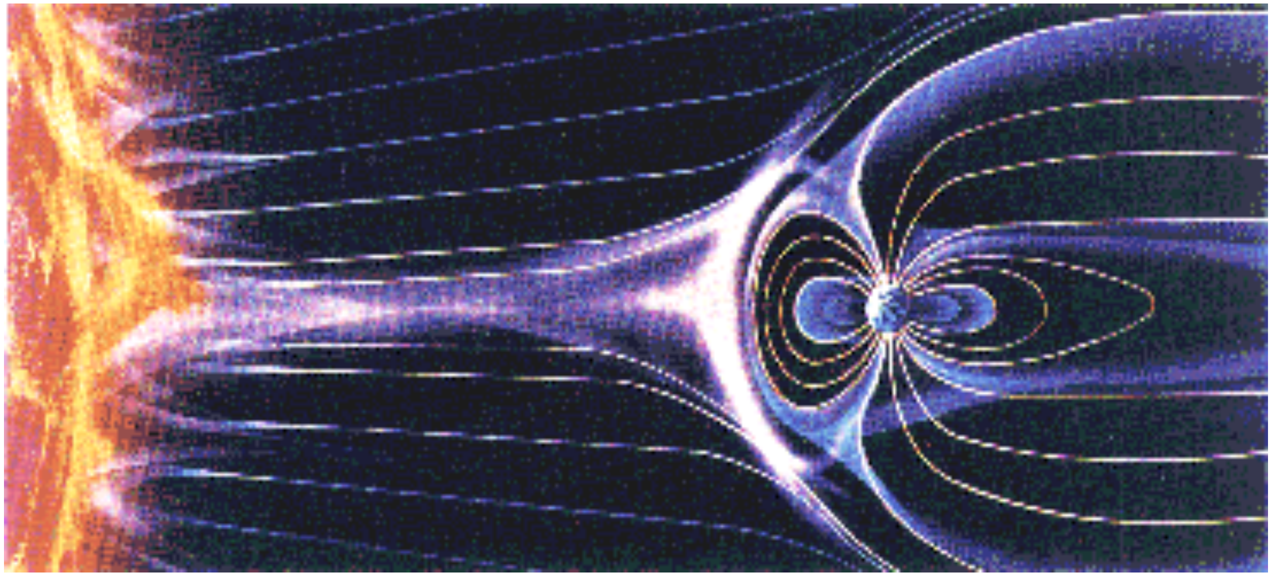
Laboratory Experiments

Astrophysical Plasmas

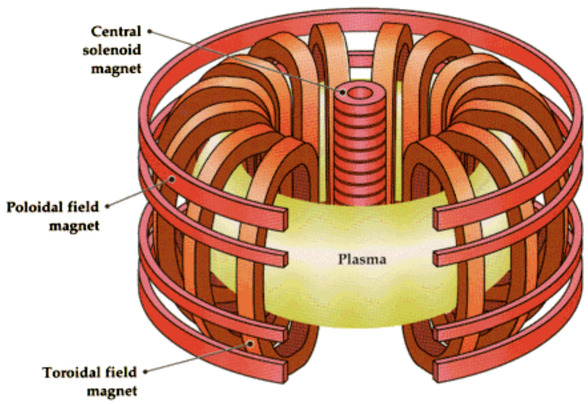
Reconnection in Space Plasmas

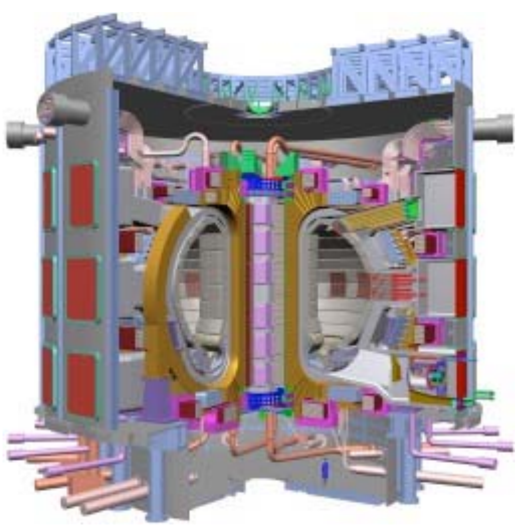


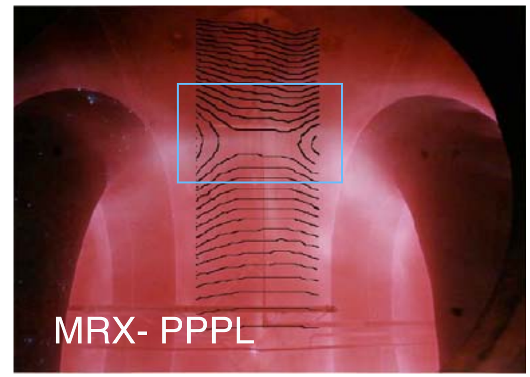


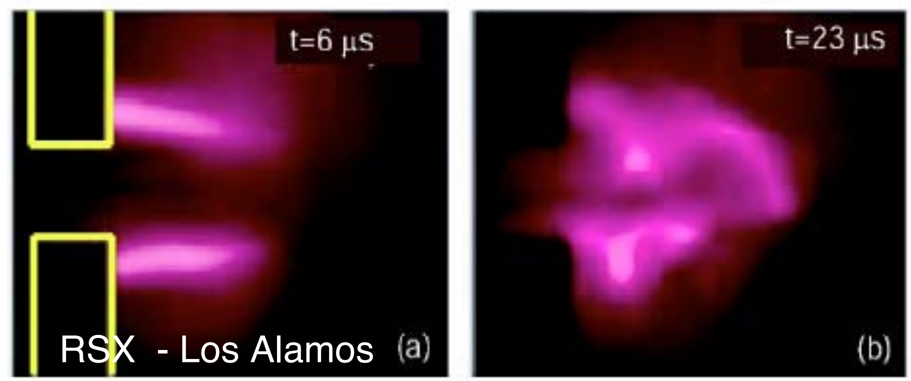


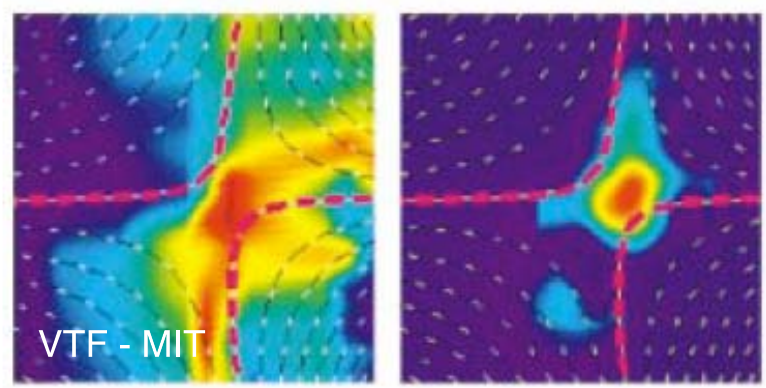
Reconnection in Laboratory Plasmas





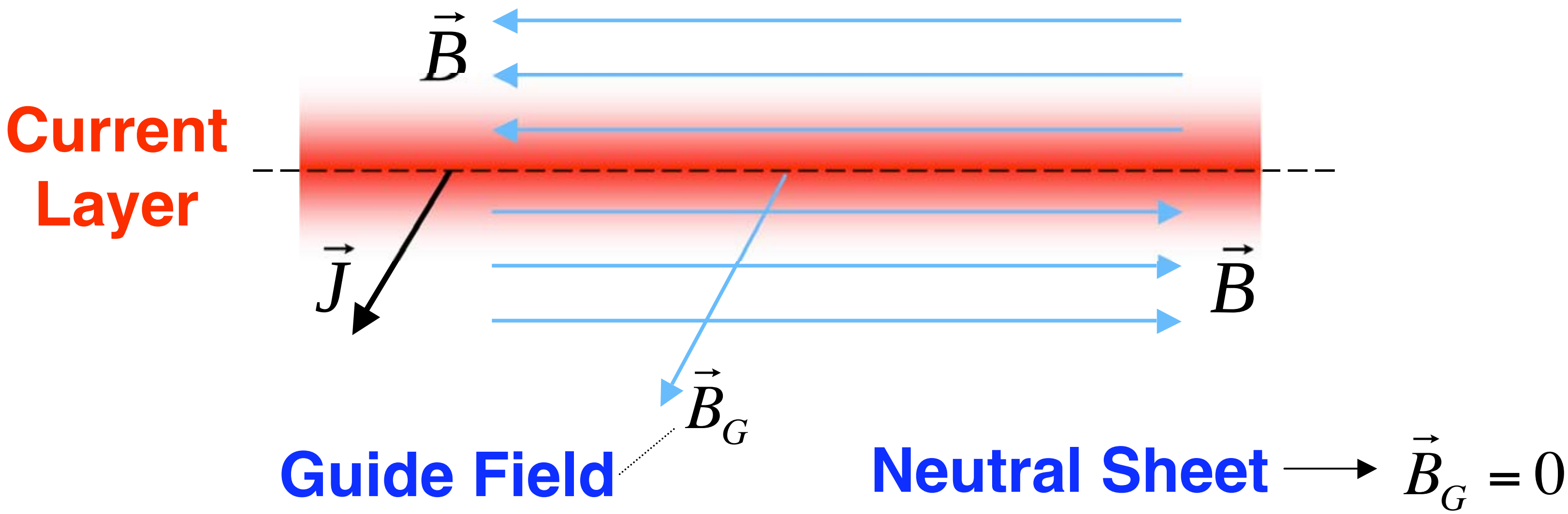






What is a Current Sheet?

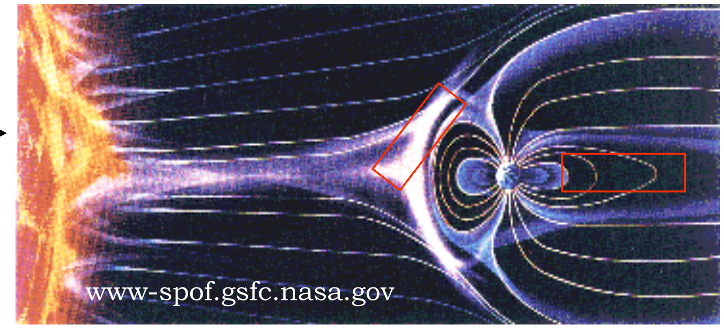
Current layer + corresponding field reversal



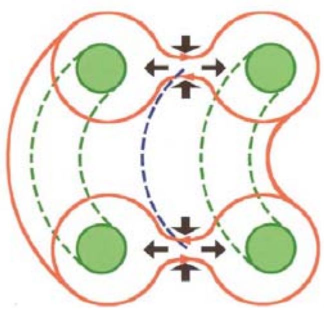
SciSearch Database
"current + sheet" → ~ 10,000 papers since 1960

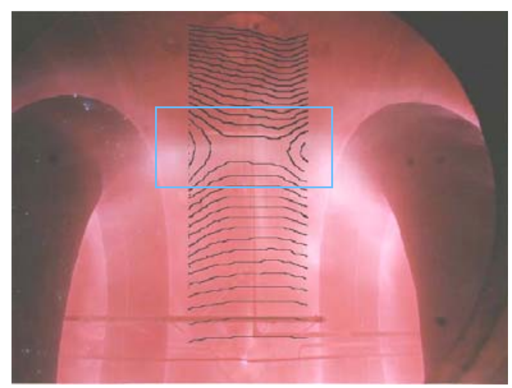
Examples of Current Sheets

- Magnetotail
- Magnetopause



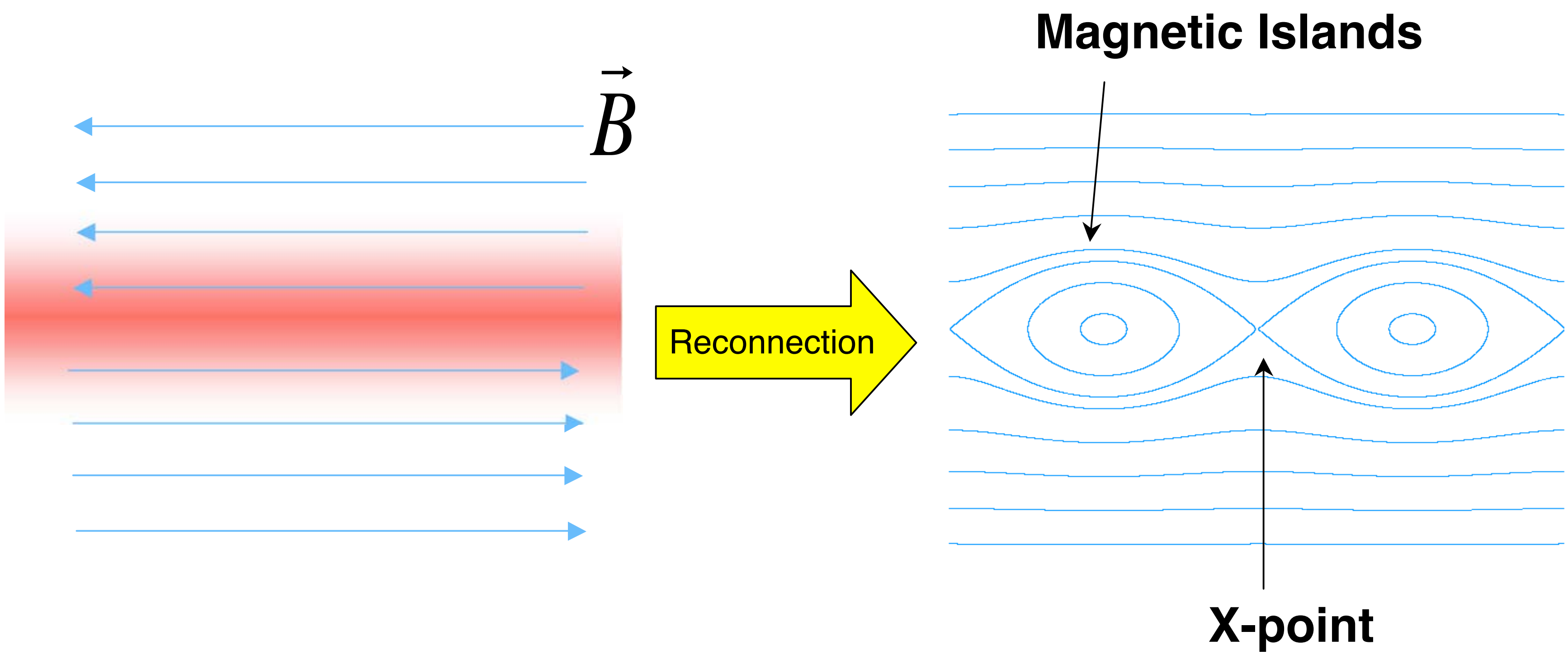
- Heliospheric current sheet
- Plasma tail of comets
- Solar flares & prominences
- Simple geometry to study magnetic reconnection
- Laboratory plasmas – MRX experiment at PPPL



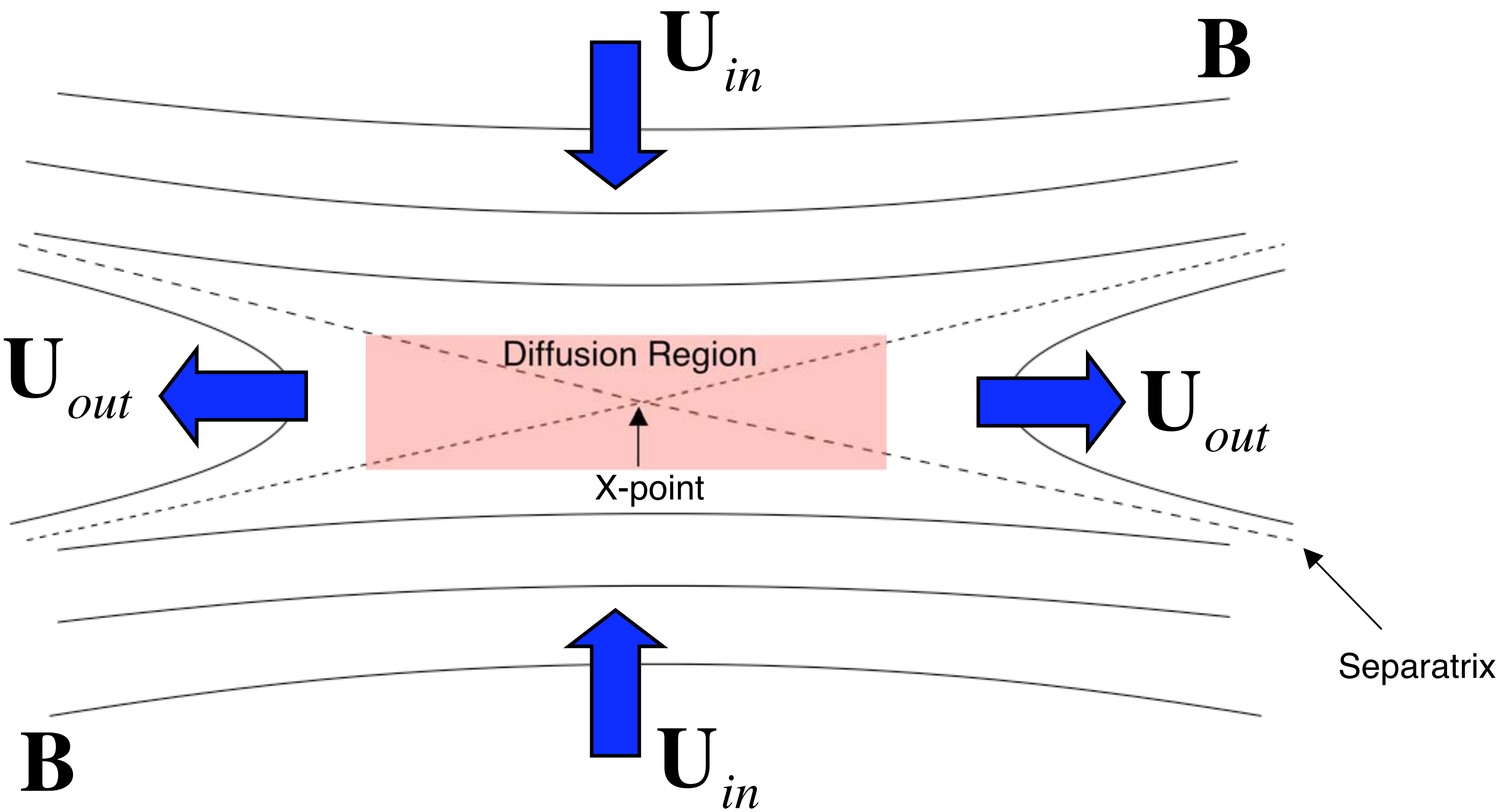


Figures courtesy of Hantao Ji (PPPL)

Topological Consequences



More Terminology



Collisional vs Collisionless Reconnection

$$\nu \propto \frac{n}{T^{3/2}}$$

Magnetotail Parameters

$T_e \sim 1\ \text{keV} \quad T_i \sim 6\ \text{keV}$

$n \sim 1\ \text{cm}^{-3} \quad B \sim 20\ \text{nT}$

$\text{L} \sim 1000\ \text{km}$

$\longrightarrow$

$\nu_e \sim 10^{-9}\ \text{sec}^{-1} \quad \Omega_{ci} \sim 1\ \text{sec}^{-1}$

$\frac{\text{V}_{\text{the}}}{\nu_e L} \sim 10^{10} \quad \frac{\rho_i}{L} \sim 1$

Questions for Collisionless Regime:

1. **How does reconnection proceed so rapidly in collisionless regimes?**

2. **How does it get started in the first place?** ⇨ **Onset problem**

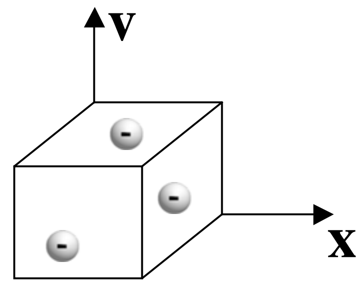
What equations describe a plasma?

$$\frac{\partial f_s}{\partial t} + \mathbf{v} \bullet \frac{\partial f_s}{\partial \mathbf{x}} + \frac{q_s}{m_s}\left(\mathbf{E} + \frac{\mathbf{v} \times \mathbf{B}}{c}\right) \bullet \frac{\partial f_s}{\partial \mathbf{v}} = 0$$

Vlasov

$\varepsilon = 0$

$f_s(\mathbf{x}, \mathbf{v}, t) \rightarrow$ Number of particles / Unit volume of phase space



Small Parameter $\longrightarrow \varepsilon = \dfrac{1}{n\lambda_D^3} \sim 10^{-6} \rightarrow 10^{-12}$

Maxwell's Equations

$$\rho = \sum_s q_s \int f_s \, d\mathbf{v}$$

$$\mathbf{J} = \sum_s q_s \int \mathbf{v} \, f_s \, d\mathbf{v}$$

$$\nabla \bullet \mathbf{B} = 0 \qquad \nabla \times \mathbf{B} = \frac{4\pi}{c}\mathbf{J} + \frac{1}{c}\frac{\partial \mathbf{E}}{\partial t}$$

$$\nabla \bullet \mathbf{E} = 4\pi\rho \qquad \nabla \times \mathbf{E} = -\frac{1}{c}\frac{\partial \mathbf{B}}{\partial t}$$