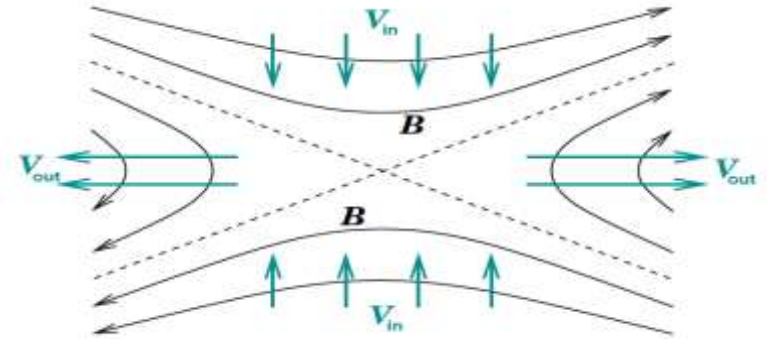
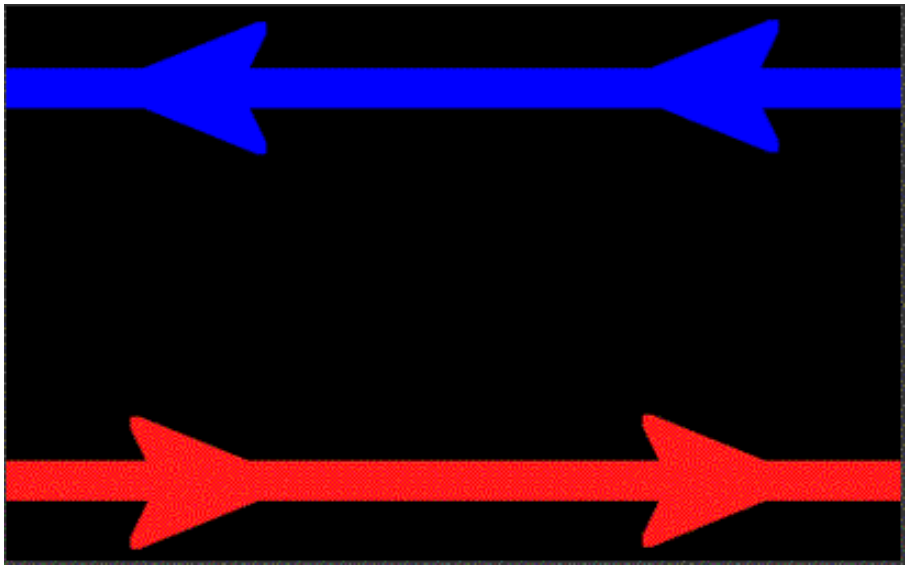
Introduction: Magnetic Reconnection

- **Magnetic reconnection** is a rapid rearrangement of magnetic field topology



- Reconnection often results in violent release of magnetic energy and its conversion to:
  - electron and ion heating
  - bulk kinetic energy
  - non-thermal particle acceleration



Magnetic Reconnection in Nature

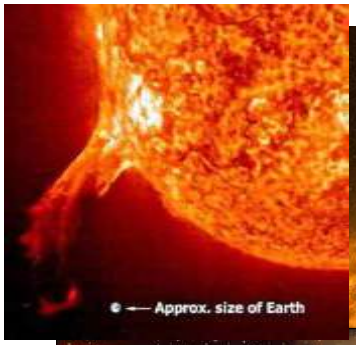
Out of this world applications:

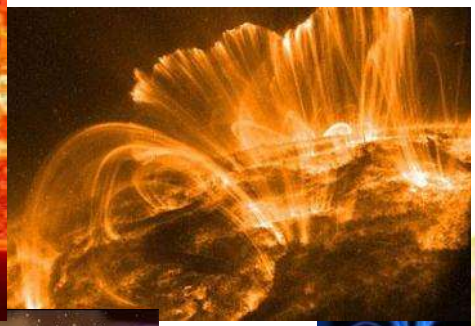
- **Solar corona:**
  - solar flares;
  - coronal heating/nanoflares.
- **Earth magnetosphere:**
  - day side/magnetopause;
  - magnetotail.
- **Astrophysics:**

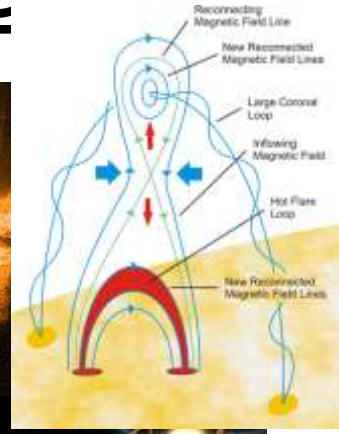
- interstellar medium;
- magnetic star-disk interaction;
- pulsar magnetospheres/wind/PWN;
- accretion disk coronae (ADC);
- black hole (AGN, blazar) jets;
- Gamma-Ray Bursts (GRB);
- magnetar flares.

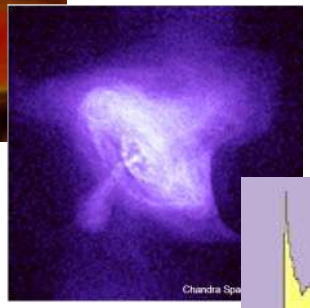
- **Laboratory:**

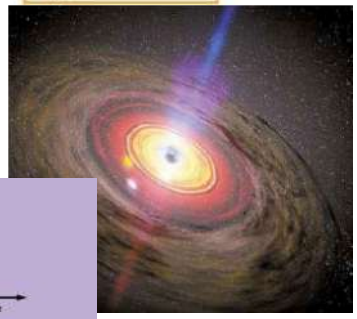
- magnetic fusion (tokamaks);
- dedicated lab experiments.

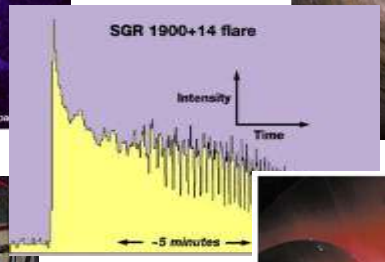


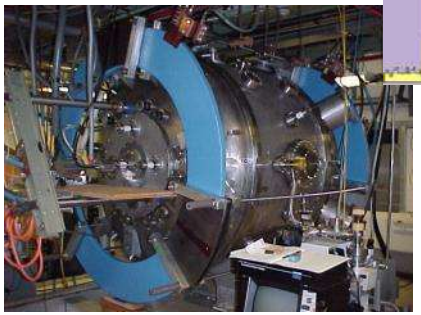


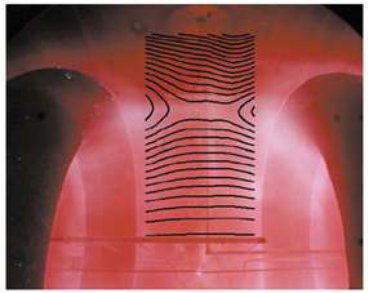












Reconnection in MHD Turbulence: statistics of current sheets and intermittency of energy dissipation.

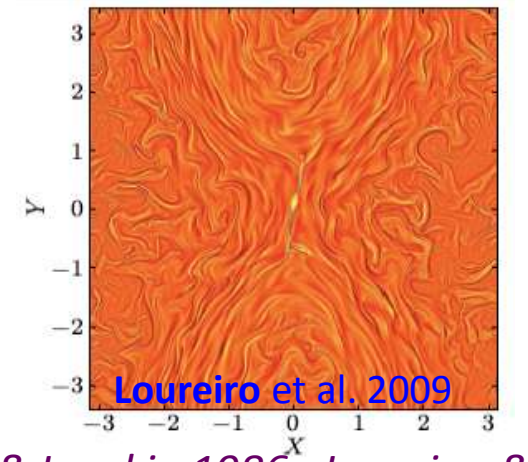
Dmitri Uzdensky (Univ. Colorado)

- **Magnetic reconnection** and **turbulence** are two of the most important and well studied space/astrophysical plasma processes.
- In real systems, these processes occur simultaneously & interact with each other.
- Two principle issues:
  - Effect of externally imposed turbulence on *large-scale* magnetic reconnection.
  - Role of *small-scale* reconnection in energy dissipation in plasma turbulence.

Reconnection in turbulent cascade

Servidio et al. 2009, 2010, 2011, etc., Uritsky et al. 2010

Turbulent Reconnection

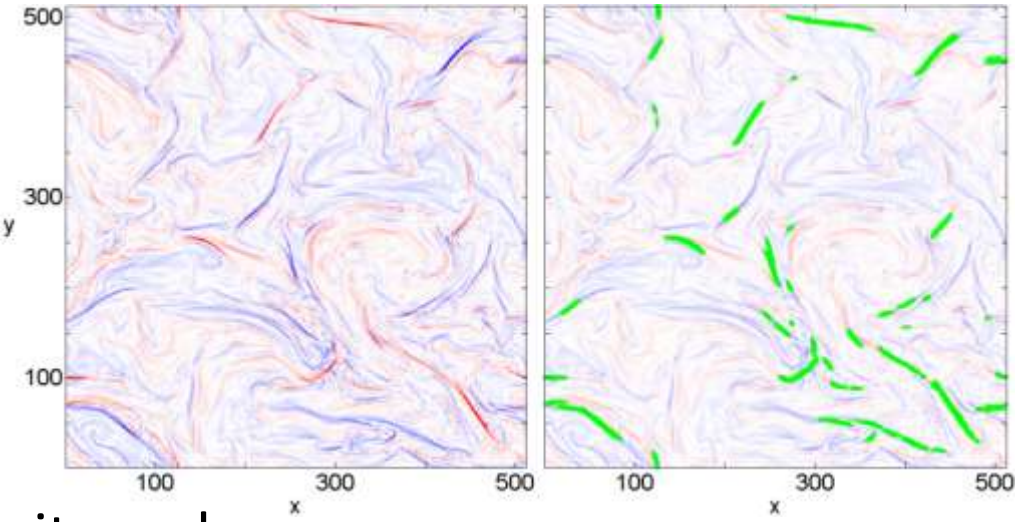


Matthaeus & Lamkin 1986; Lazarian & Visniac 1999; Kim & Diamond 2001; Kowal et al. 2010, …

I. Current Sheets in 3D reduced-MHD Turbulence

(Zhdankin et al. 2013)

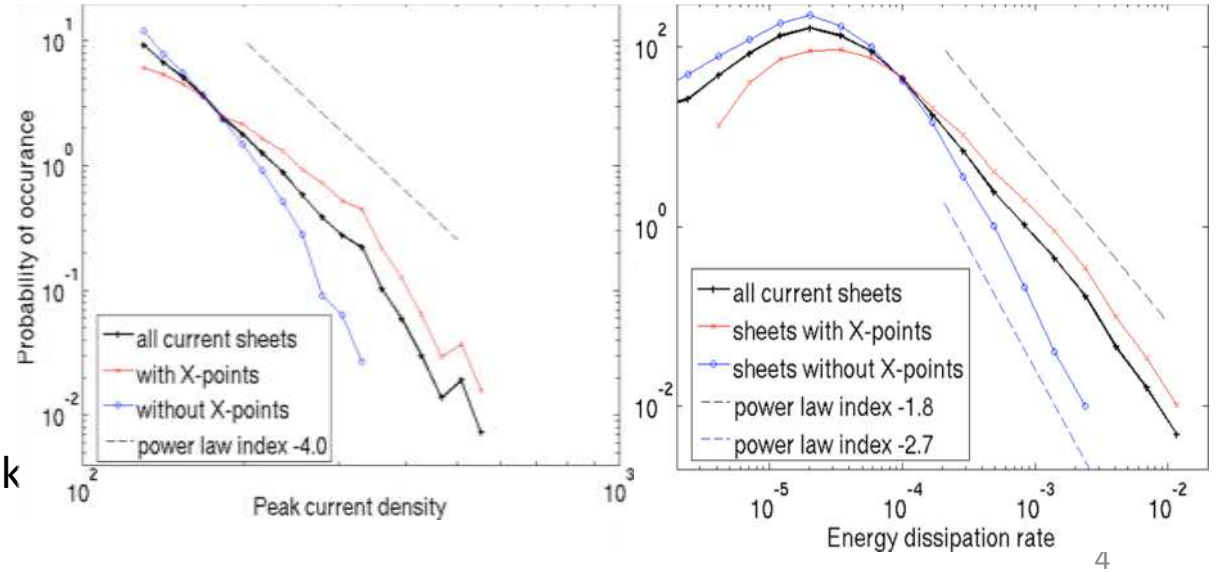
(c.f., Servidio+ '09,'10; Uritsky+ '10)



Developed diagnostic algorithms that:

- identify intense current sheets (CSs);
- measure CS 3D dimensions, peak current densities, dissipation rates, etc;
- analyze statistical properties of CSs.

Distributions of peak current density and energy dissipation rate:



Intense CSs occupying 1% of volume account for 25% of total energy dissipation!

Astrophysical implications:

thermodynamics of systems with **prompt radiative cooling:**

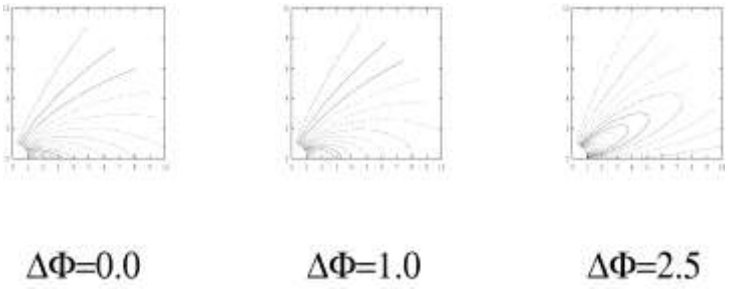
e.g., accretion flows, accretion disk coronae, ISM, galaxy clusters…

II. Current-Sheet Formation and Reconnection Onset

- **Reconnection onset -** important problem.

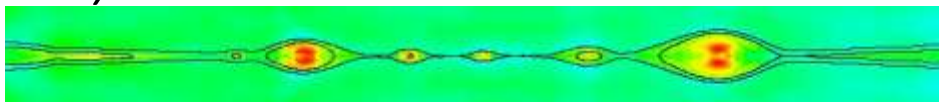
- Reconnection requires a thin current sheet (CS) → (ideal-MHD) **current sheet formation problem**.

- Most numerical reconnection studies start with an already developed thin long laminar CS.



(Uzdensky et al. 2002)

- But thin reconnecting CSs are unstable to very fast secondary tearing instability *(Loureiro+'07)* → cannot form in the first place!


(Loureiro+ 2012)

- As a CS is formed gradually by some ideal-MHD process, it should automatically transition to plasmoid-dominated reconnection regime!

Analysis of linear and nonlinear (Rutherford and X-point collapse) development of resistive-MHD tearing instability of a time-dependent forming CS, shows *(Uzdensky & Loureiro 2013, in prep.)*:

- dominant fastest-growing tearing mode is the longest (kL ~1);
- produces 1-2 large plasmoids in immediate aftermath of CS formation.