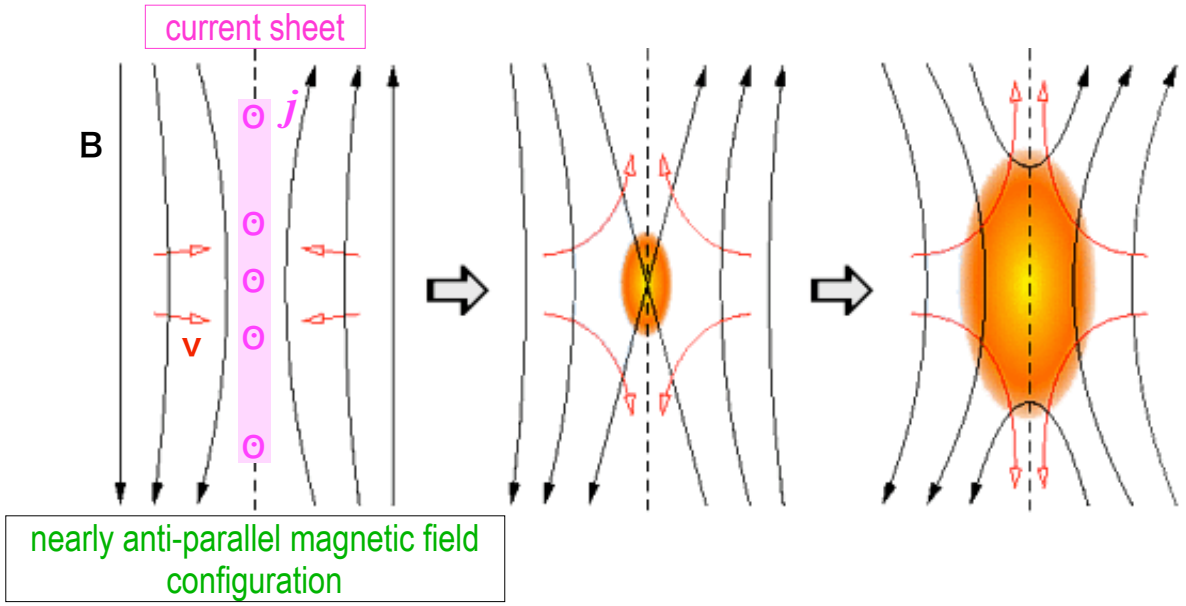
Diffusion of magnetic fields in the solar atmosphere

Magnetic reconnection

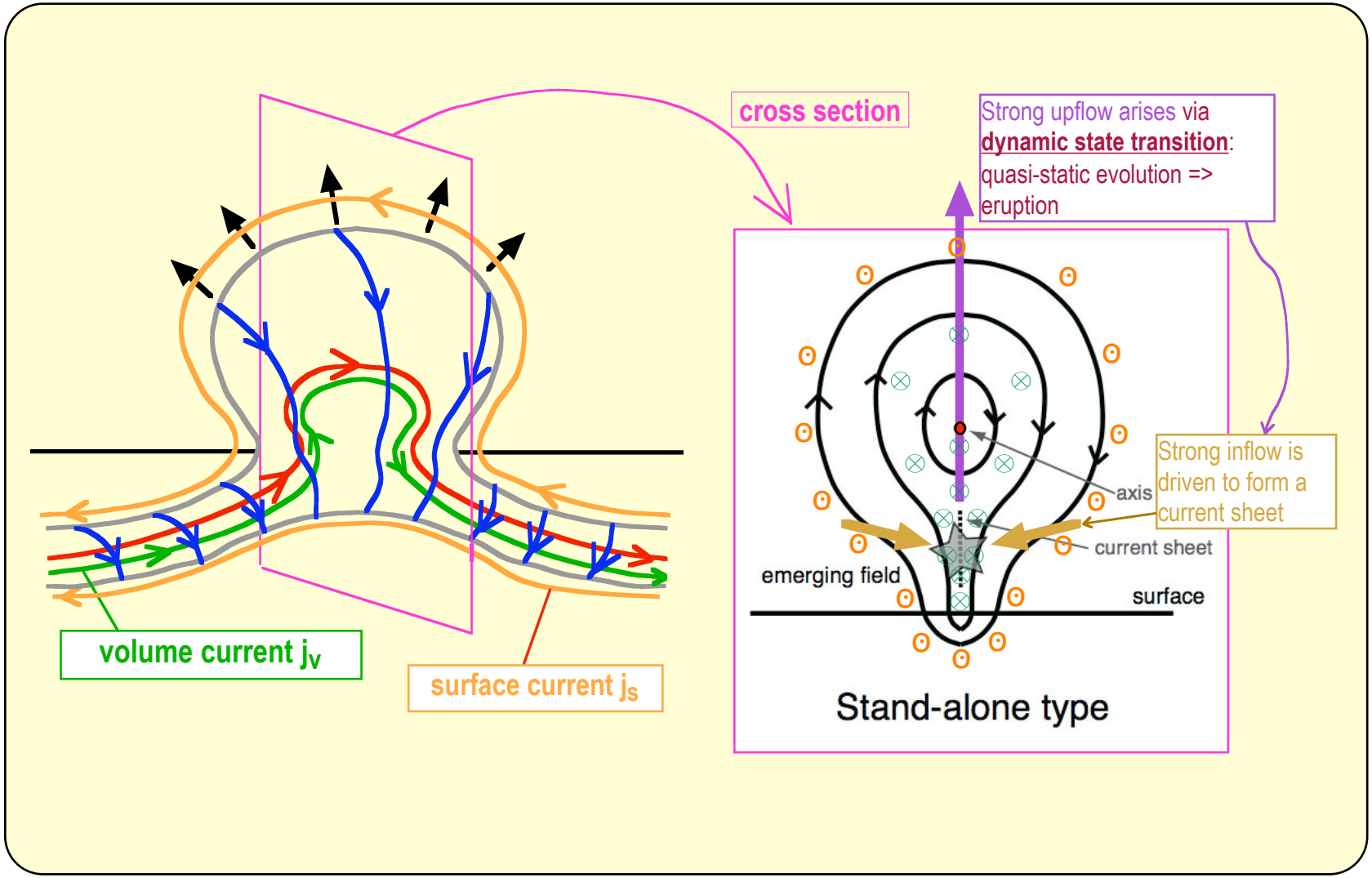
When a nearly anti-parallel magnetic field configuration exists, strong cross-field electric current flows there **(current sheet)**.



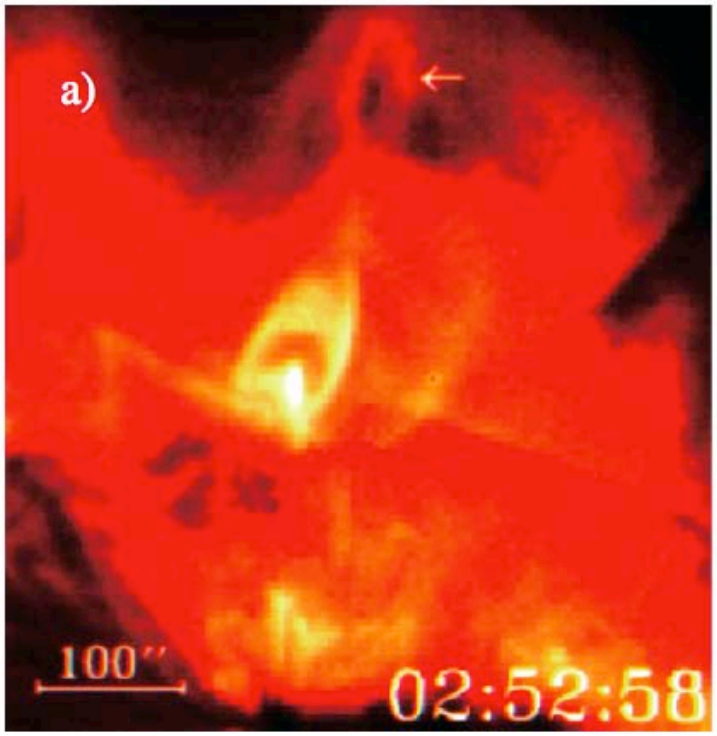
In the current sheet, energy conversion called '**magnetic reconnection**' may proceed, which efficiently converts free magnetic energy to kinetic and thermal energy.
It may also accelerate selected particles via electric field involved in the reconnection.

How is a current sheet formed in an emerging twisted flux tube?

(http://163.180.179.74/~magara/page31/Research_evolution-path.html)

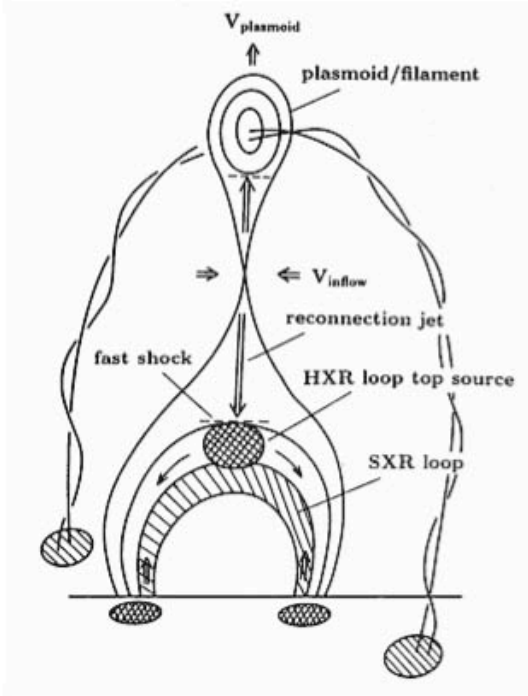


Solar flare: magnetic reconnection is expected to occur...



Observed by ***Yohkoh***

Structure of a flare

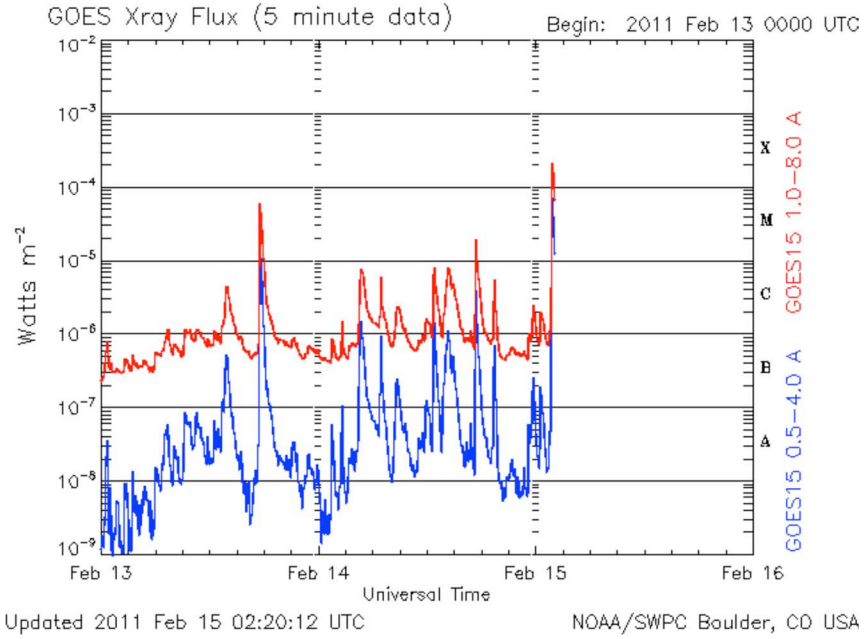


Shibata (1999)

Properties of flares

- **Spatial size: 10^4 – 10^5 km**
- **Duration: 10^3 – 10^4 sec**
- **Released energy: 10^28 – 10^32 erg/event** ⟷ $L_o \sim 4\times10^{33}$ erg/s

Classification of flares based on X-ray emission



Peak value of X-Ray flux (1 – 8 Å, W/m^2)

A	10^{-8} – 10^{-7}
B	10^{-7} – 10^{-6}
C	10^{-6} – 10^{-5}
M	10^{-5} – 10^{-4}
X	> 10^{-4}

Ejection of solar magnetic fields into the interplanetary space

Properties of CMEs

- Occurrence rate: 1 (solar minimum) ~ 3 (maximum) /day
- Average velocity: 450 km/s
  - slow CME... high latitude, gradually accelerated
  - fast CME... active region, ballistically accelerated

- Total mass loss: 10^13 – 16 g/event ⟷ solar-wind mass loss rate: 10^12 g/s

- Kinetic (mechanical) energy: 10^27 – 32 erg/event ⟷ $L_\odot \sim 4\times10^{33}$ erg/s

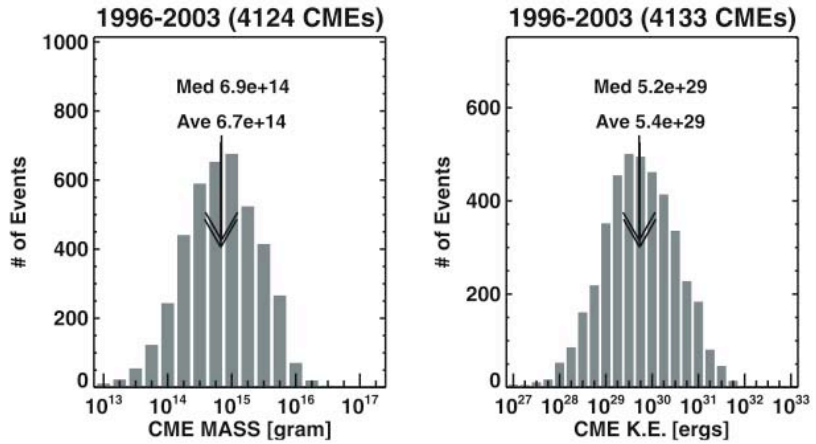


Figure 2. CME mass (left), and kinetic energy (right) of SOHO CMEs for the period 1996–2003.

Gopalswamy (2006)

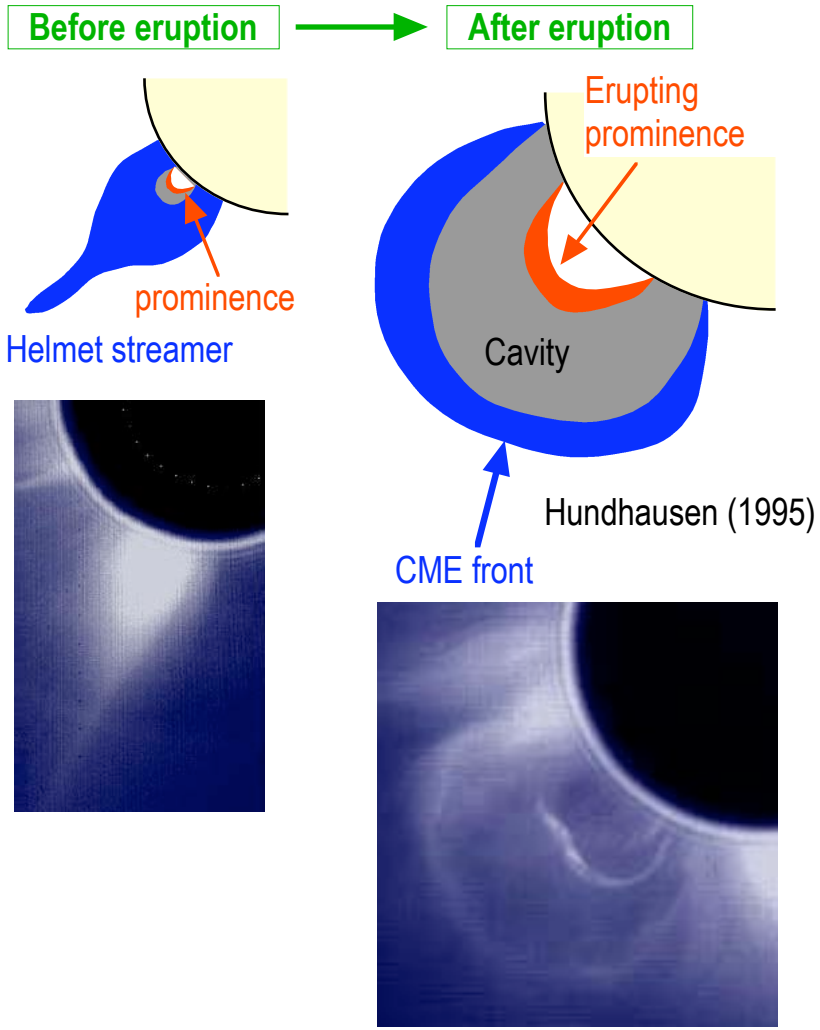
Table 1: Some Average Characteristics of Coronal Mass Ejections

	Skylab (1973-74)	Solwind (1979-80 & 1984-85)	SMM (1980, 1984-89)
Angular Size	42°	43°	47°
Speed	470 km sec^{-1}	460 km sec^{-1}	350 km sec^{-1}
Mass	—	4.0×10^{15} gm	3.3×10^{15} gm
Kinetic Energy	—	3.4×10^{30} ergs	6.7×10^{30} ergs
Potential Energy	—	—	7.1×10^{30} ergs
Mechanical Energy	—	—	1.38×10^{31} ergs

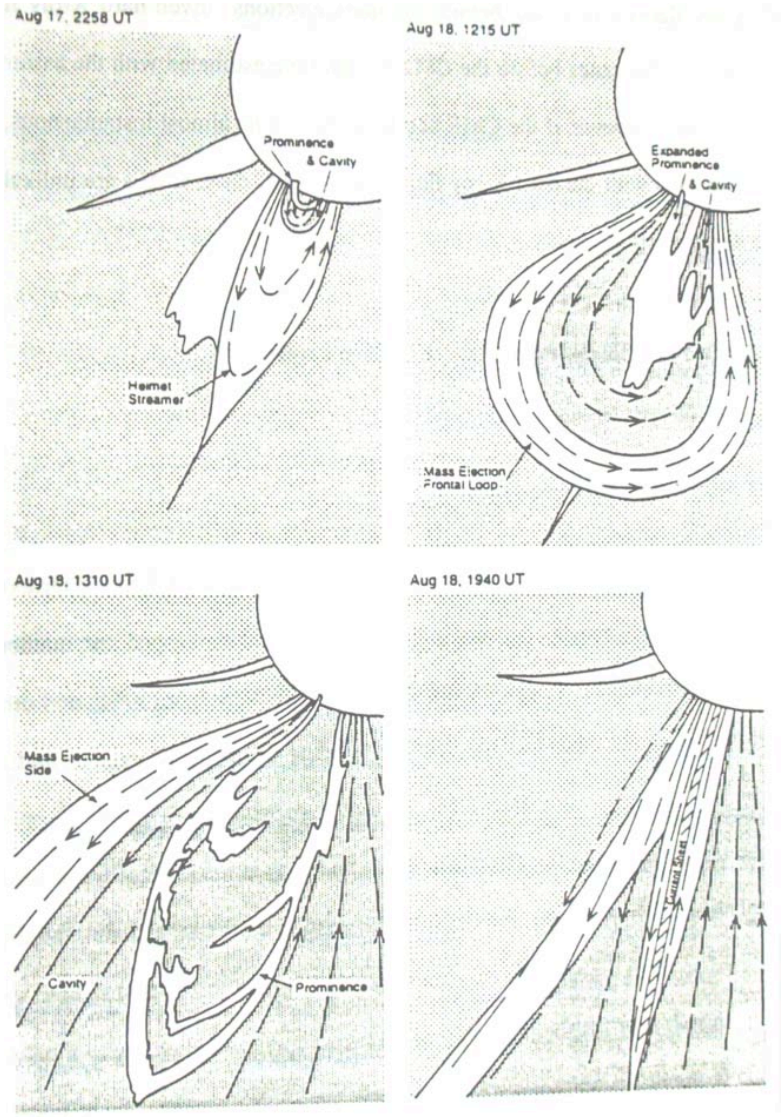
Hundhausen (2000)

Structure of a CME

Three-part structure:



Hundhausen (1995)



Choe (1995)