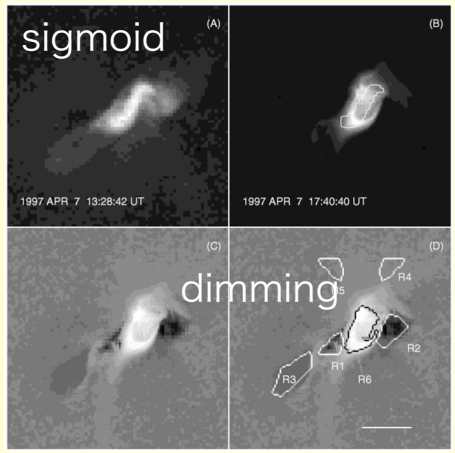
Accompanying phenomena of CMEs

Sigmoid, Dimming

Sterling & Hudson (1997)

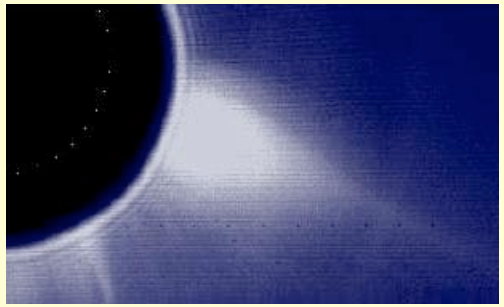
Canfield et al. (1999)



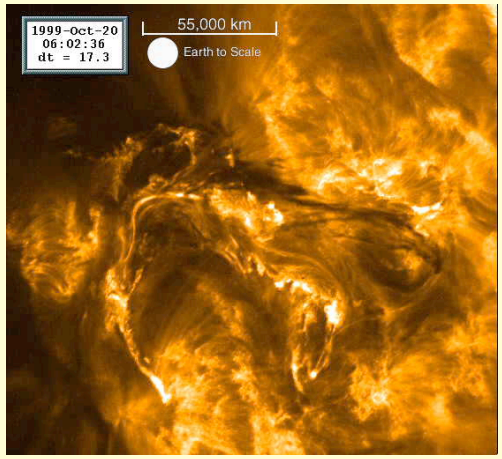
Yohkoh

Helmet Streamer

SMM

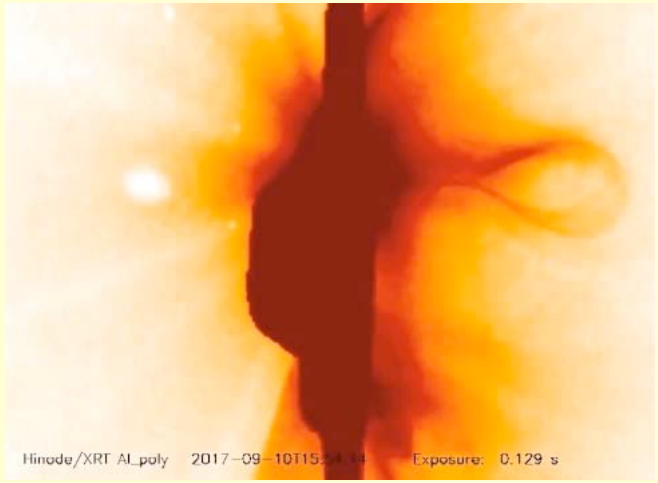


Prominence/filament eruption



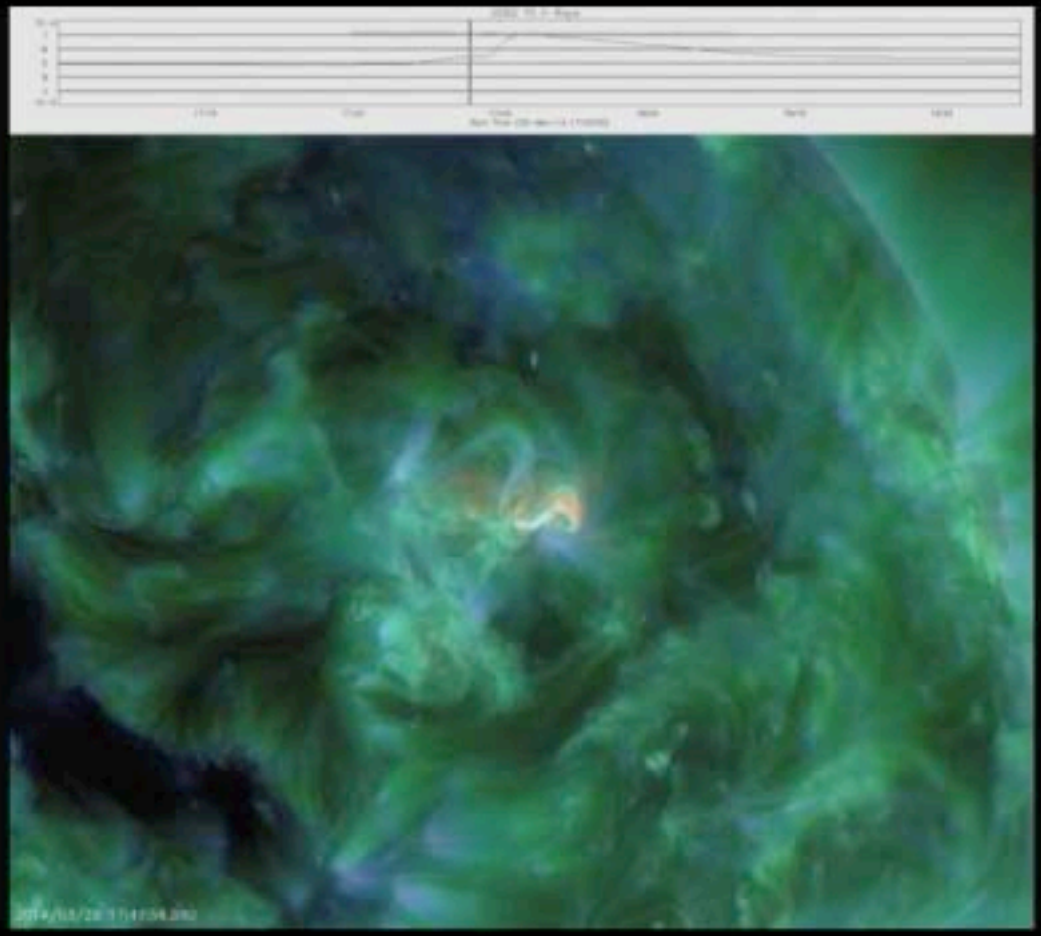
TRACE

Flare



Hinode

An X-class flare accompanying a CME (29 March, 2014)

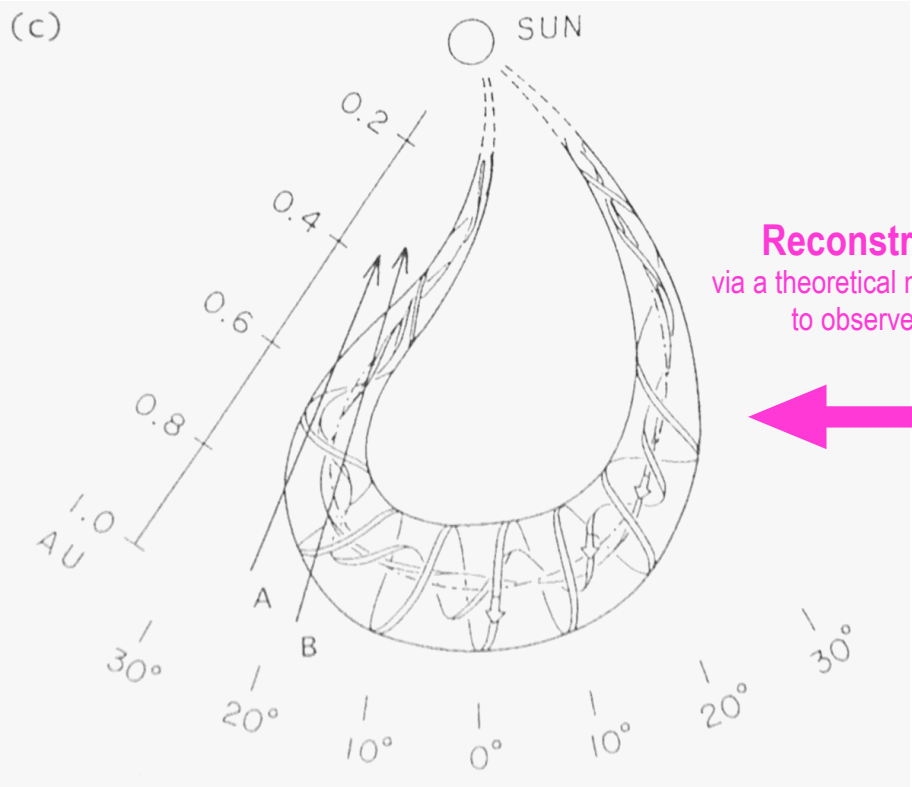


Sigmoid appeared just before the onset of the flare.

SOHO, SDO

ICME (Interplanetary CME)

CME traveling through the interplanetary space



Helical magnetic structure of an ICME

Marubashi (2000)

Reconstruction
via a theoretical model applied to observed data

In-situ observation

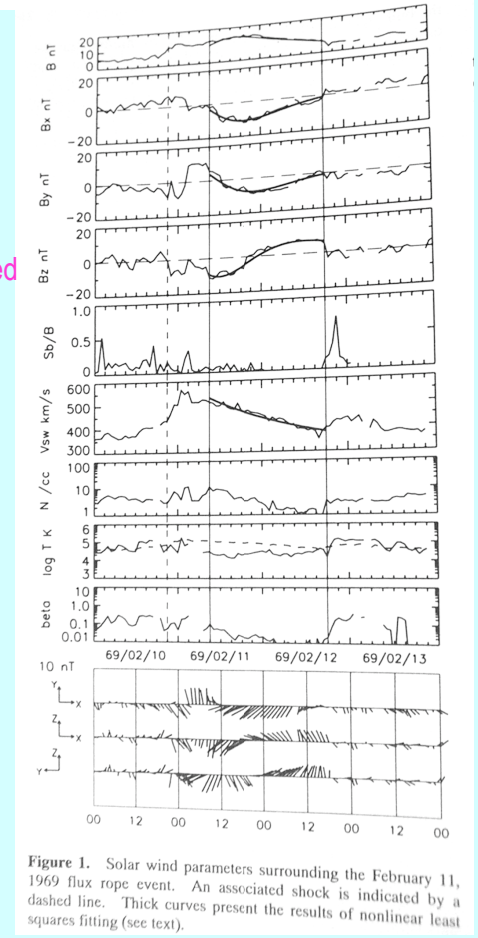
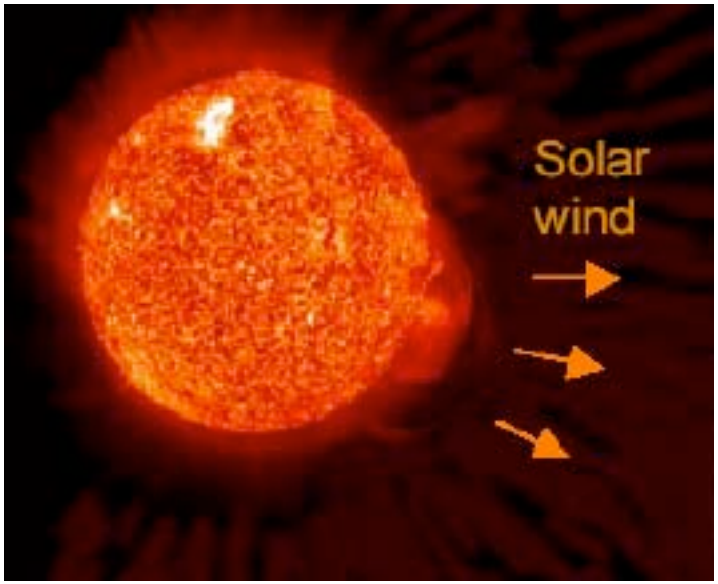


Figure 1. Solar wind parameters surrounding the February 11, 1969 flux rope event. An associated shock is indicated by a dashed line. Thick curves present the results of nonlinear least squares fitting (see text).

Solar wind...

it is **an outflow driven in the solar atmosphere**, where **gas pressure** and **magnetic field** may play important roles.



Brief history:

1859... R. Carrington found a flare on the Sun (he supposed an energy flow from the Sun).

1913... K. Birkeland predicted flows of electrons and positive ions from the Sun.

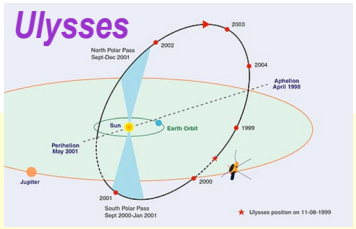
1919... F. Lindemann suggested that both electrons and protons come from the Sun.

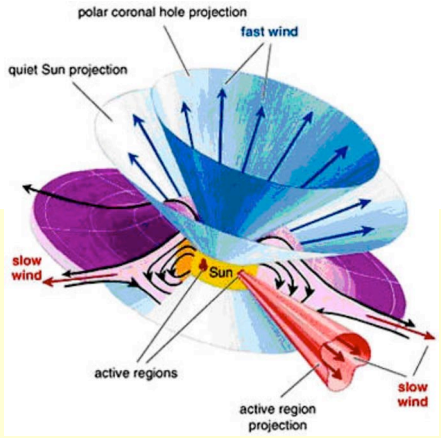
1950s... S. Chapman suggested that a coronal plasma should extend over the orbit of the Earth.

1951... L. Biermann investigated tails of comets and postulated that the Sun emits a steady stream of particles pushing the tails away from the Sun.

1958... E. Parker developed a hydrodynamic model of solar wind.

Properties of solar winds





Components: **electrons, protons**

Energy: **10 ~ 100 ev** **(1 ev ~ 10^4 K for thermal plasma)**

Speed (near the Earth): **400 km/s** (*slow wind* $1.5\times10^{6}\ K$, coronal composition)

750 km/s (*fast wind* $8\times10^{5}\ K$, photospheric composition)

(c.f. escape velocity: 618 km/s, coronal thermal velocity: 150 km/s)

Source region: **low latitude**, from **closed-field region** (**slow wind**)

high latitude, from **open-field region** (**fast wind**)

Mass flux (loss rate of mass): $\dot{M} \sim 10^{12}$ g/s ($\sim 10^{-14}\ M_\odot$ / yr) $\longleftrightarrow$ $M_\odot \sim 2\times10^{33}$ g

Angular momentum flux (loss rate of angular momentum):

$\dot{J} \sim 7\times10^{29}$ g cm^2/s^2 ($\sim 10^{-11}\ J_\odot$ / yr) $\longleftrightarrow$ $J_\odot \sim 2\times10^{48}$ g cm^2/s