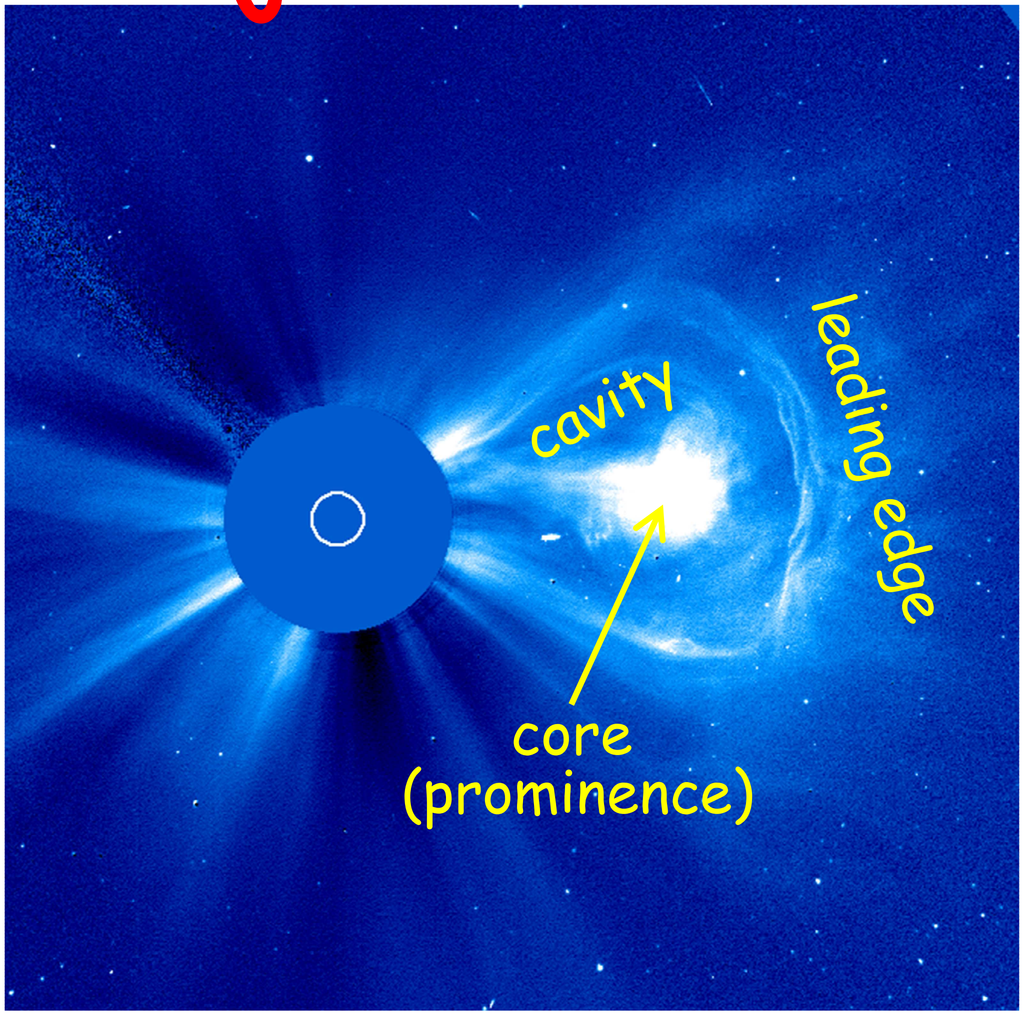
Coronal Mass Ejection

A massive (10^{14} to 10^{17} grams) burst of plasma ejected from the Sun at a speed up to 2000 km/s with a kinetic energy of >10^{32} ergs

CME eruptions are often associated with flares and filament eruptions.

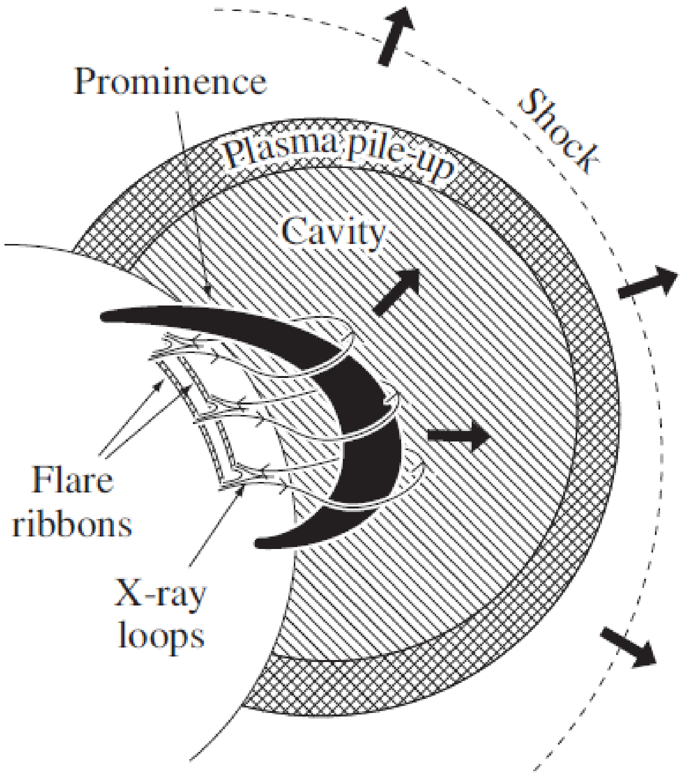
As propagating in the solar wind, a CME creates a shock wave that accelerates particles to dangerously high energies and speeds.

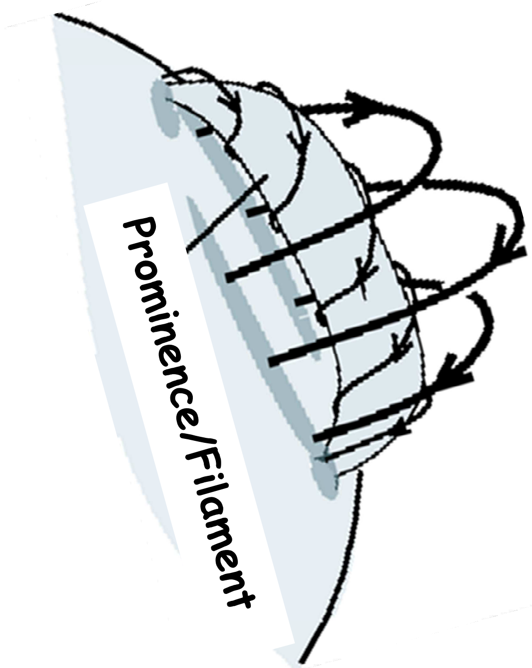


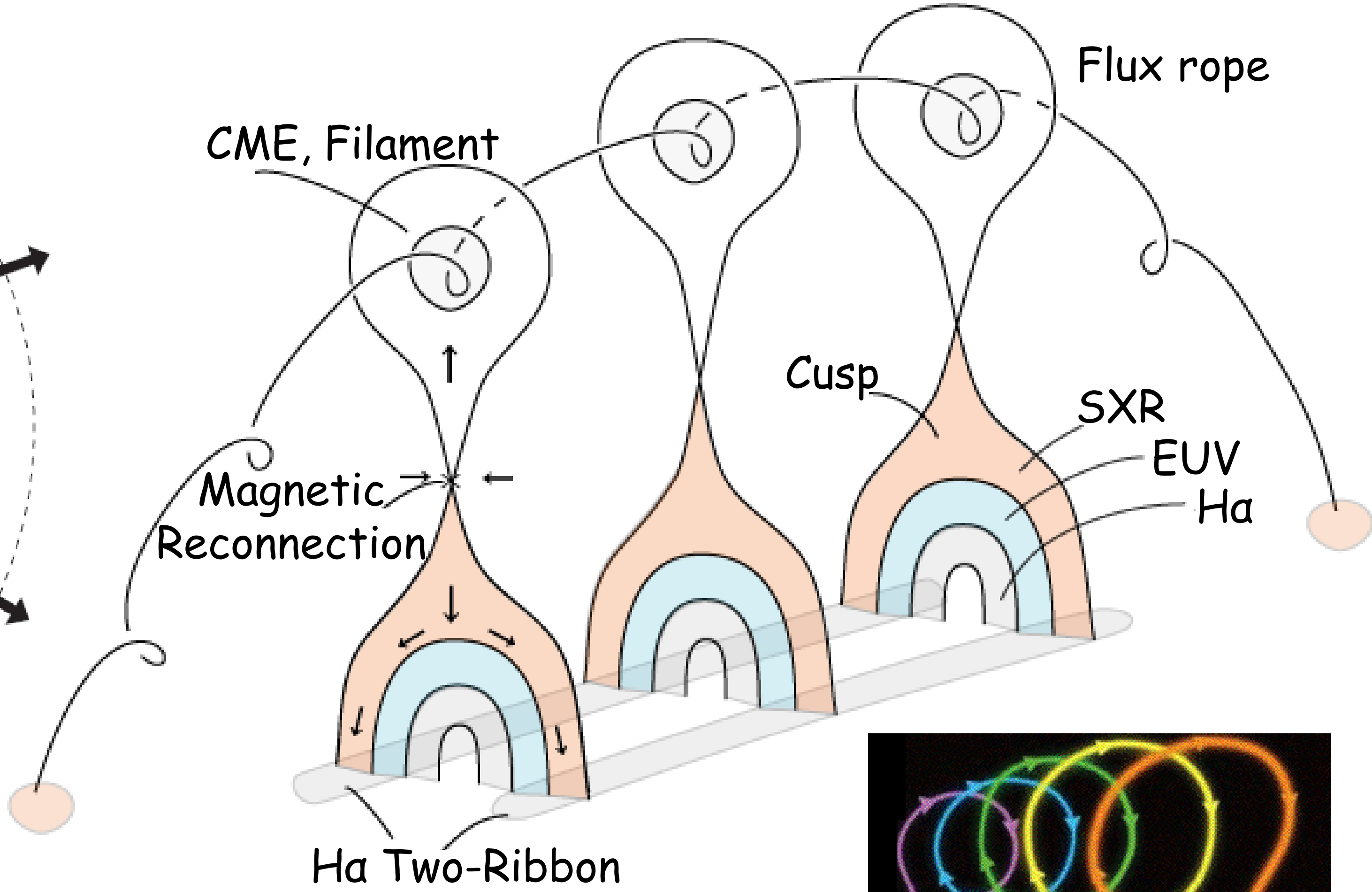
plasma embedded with magnetic fields, shock

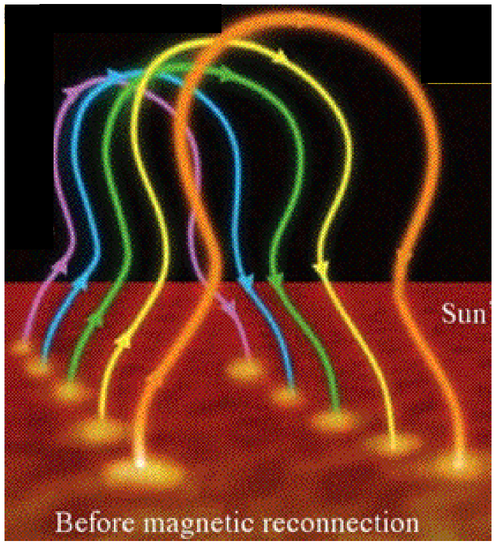
typical coronal temperature 10^6 K → sound speed: 10^2 km/s
A CME usually has a near-constant speed in the outer corona (e.g, > 2.0 Rs in C2/C3 field).

http://helios.gsfc.nasa.gov/cme.html http://www.swpc.noaa.gov/phenomena/coronal-mass-ejections









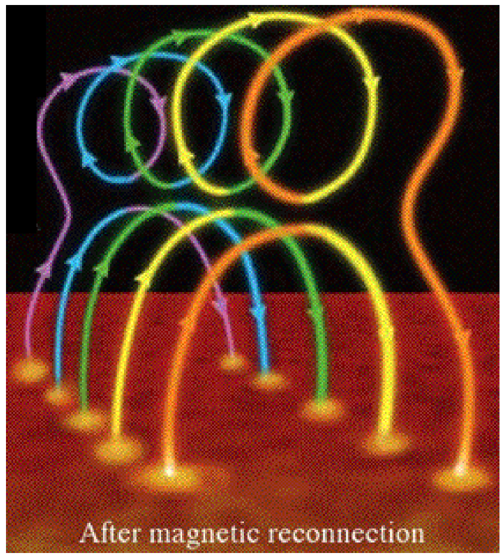
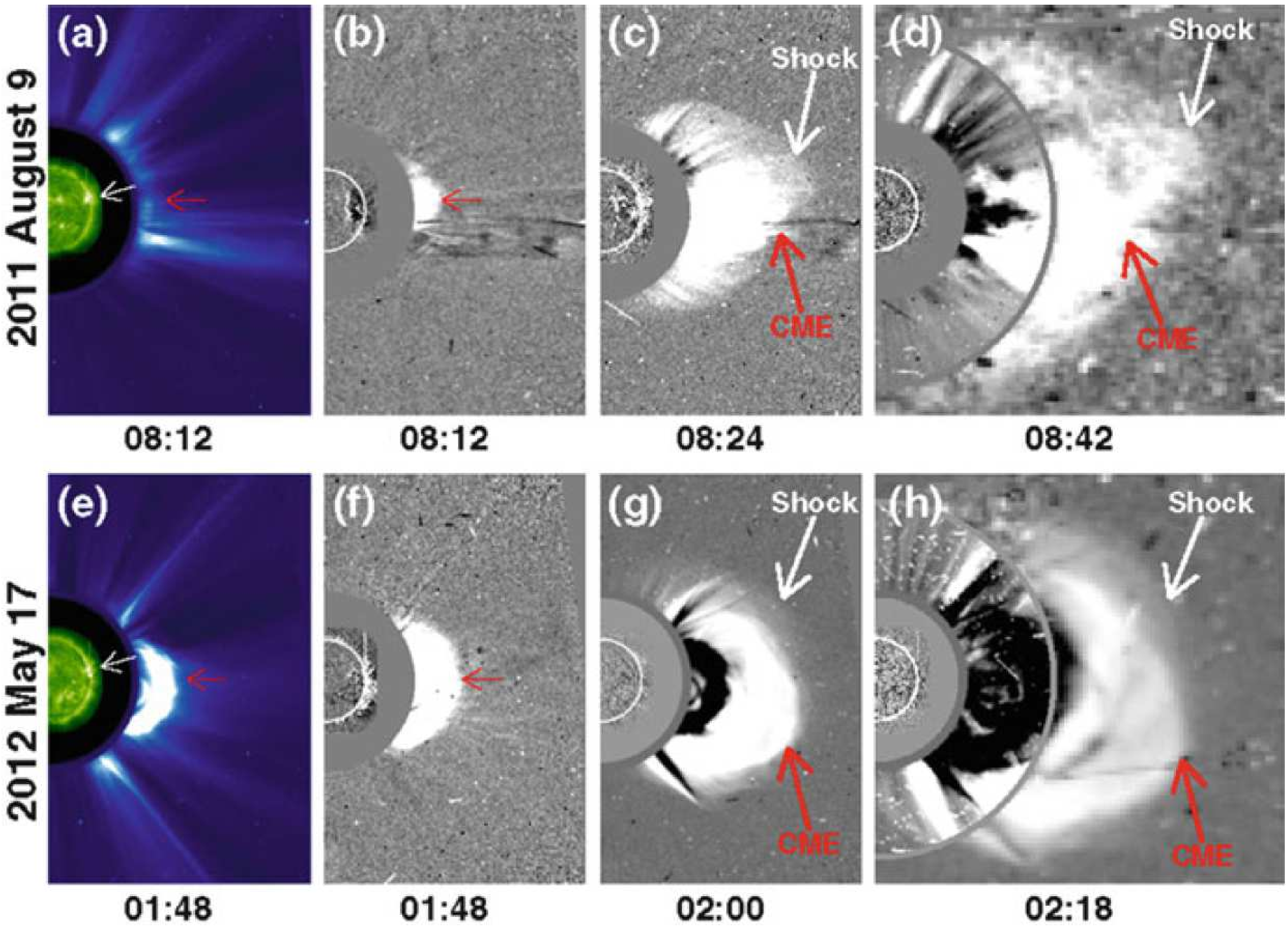


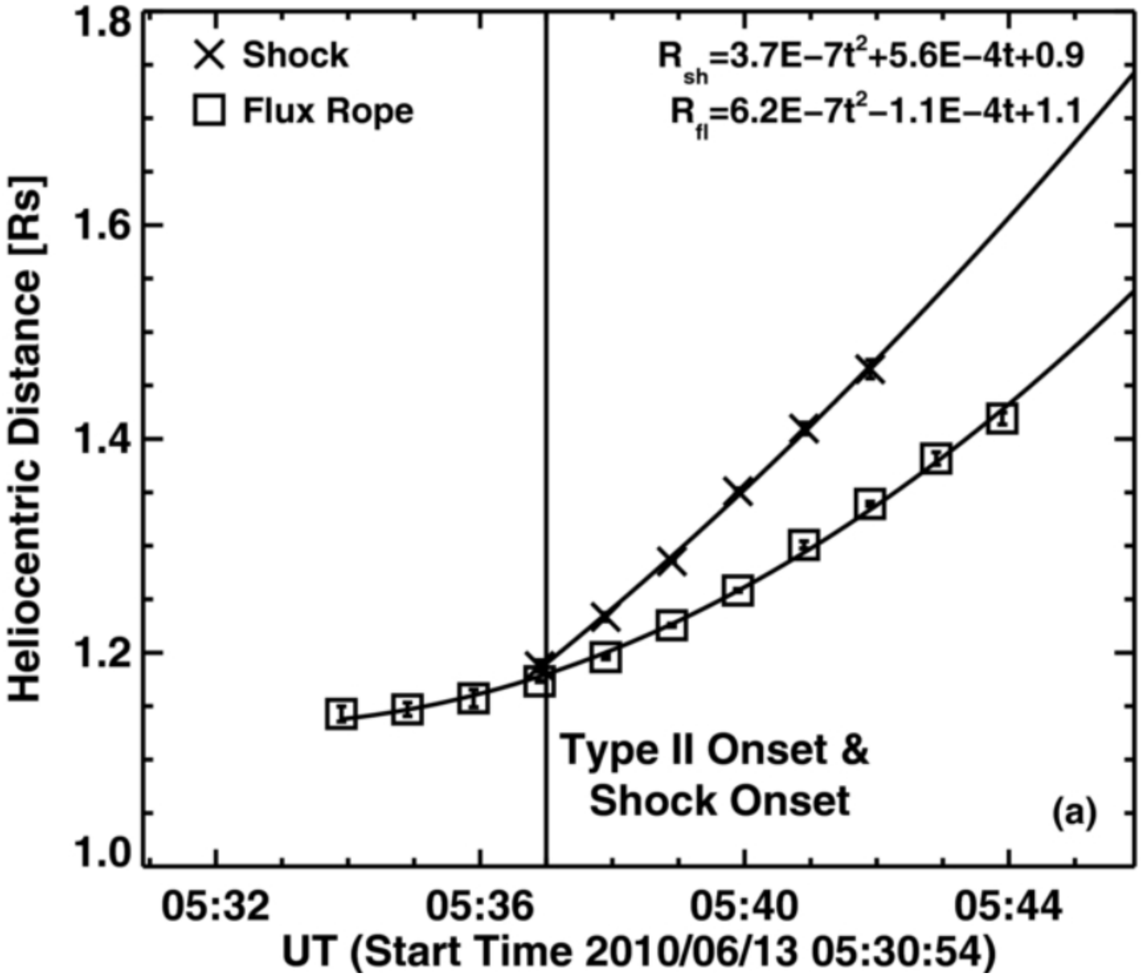
Fig. 12.1(a) in Eric Priest (2014)

http://pasj.asj.or.jp/v62/n4/620425/620425.html

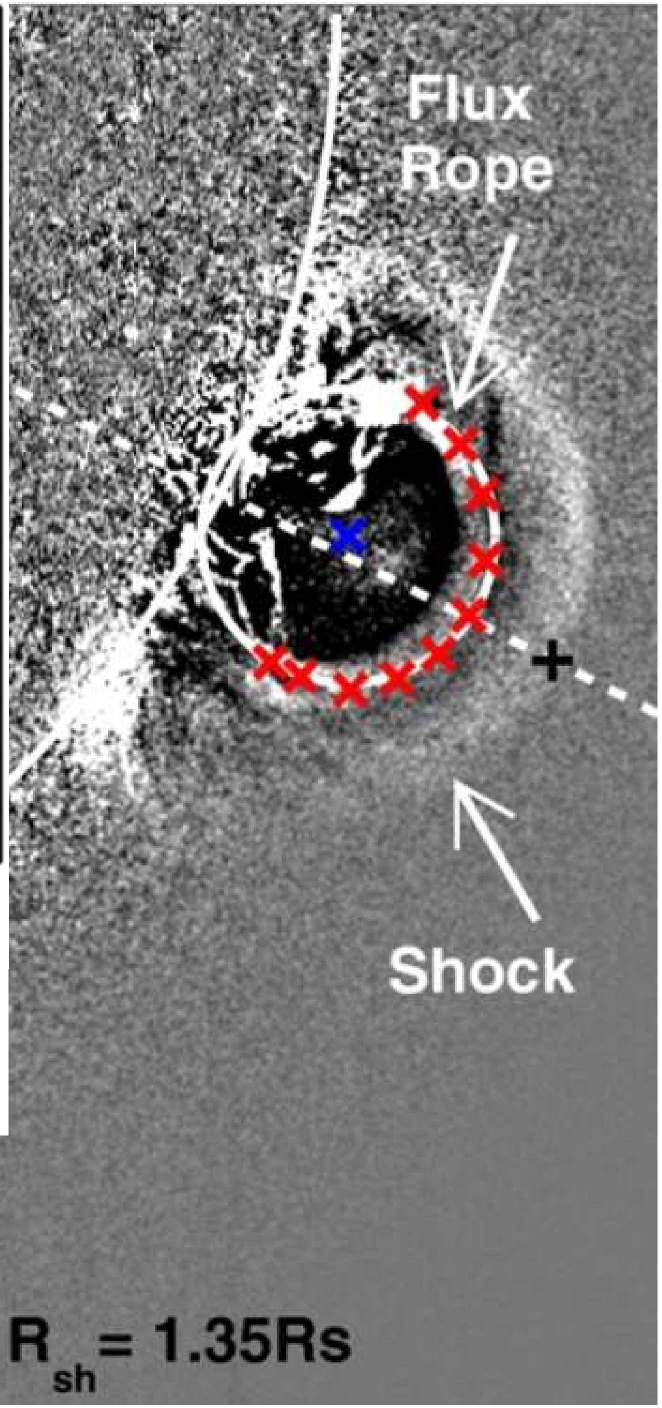


→ The shock remains closer to the CME in (h) than in (d), indicating a stronger shock (Gopalswamy et al. 2013).

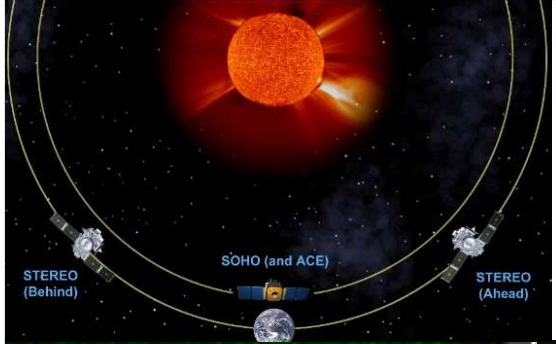
Fig. 3.5 in Donald V. Reames (2017)



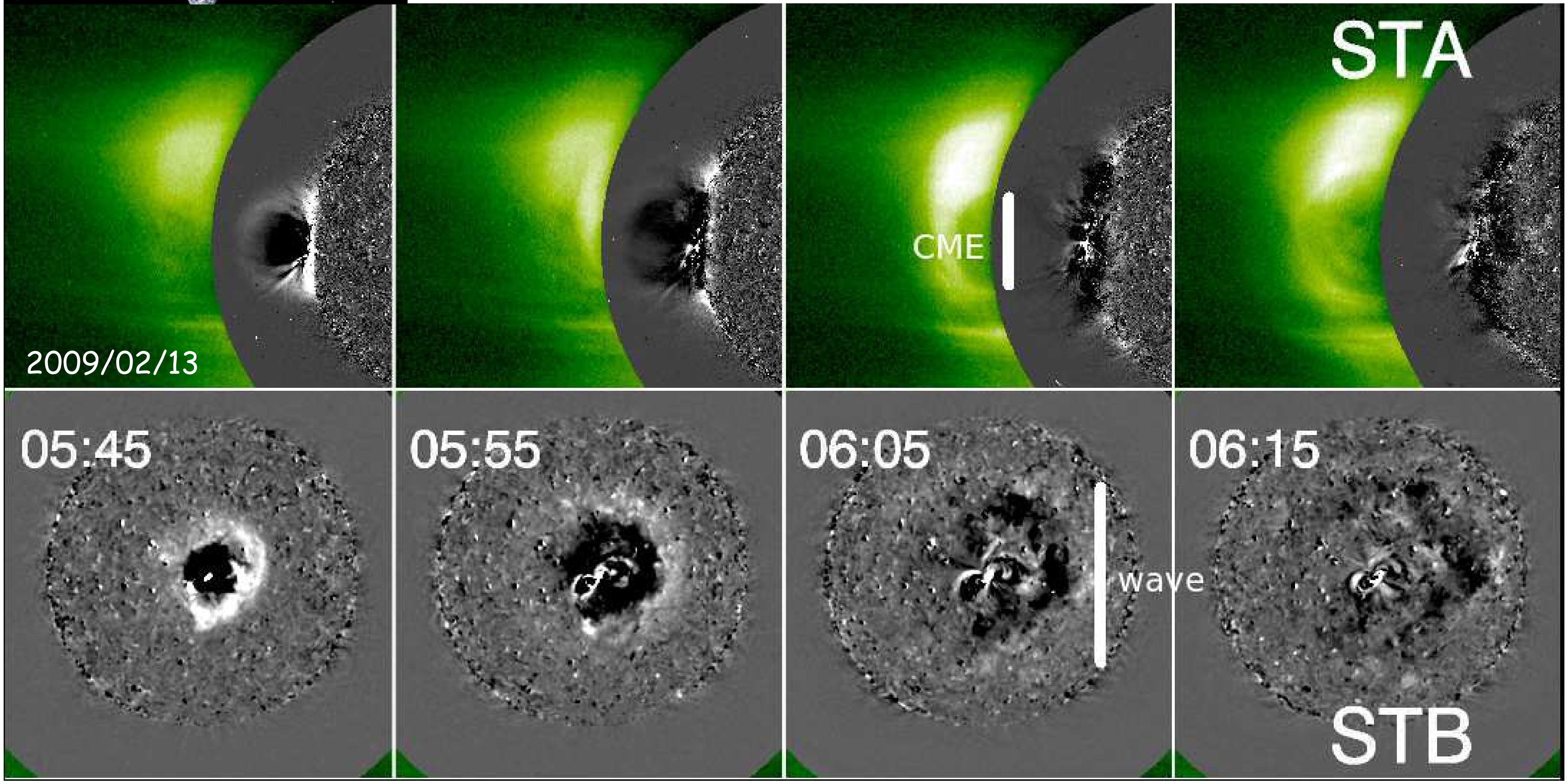
The average speeds of the flux rope and shock are 330 km/s and 644 km/s.



http://iopscience.iop.org/article/10.1088/0004-637X/744/1/72/meta

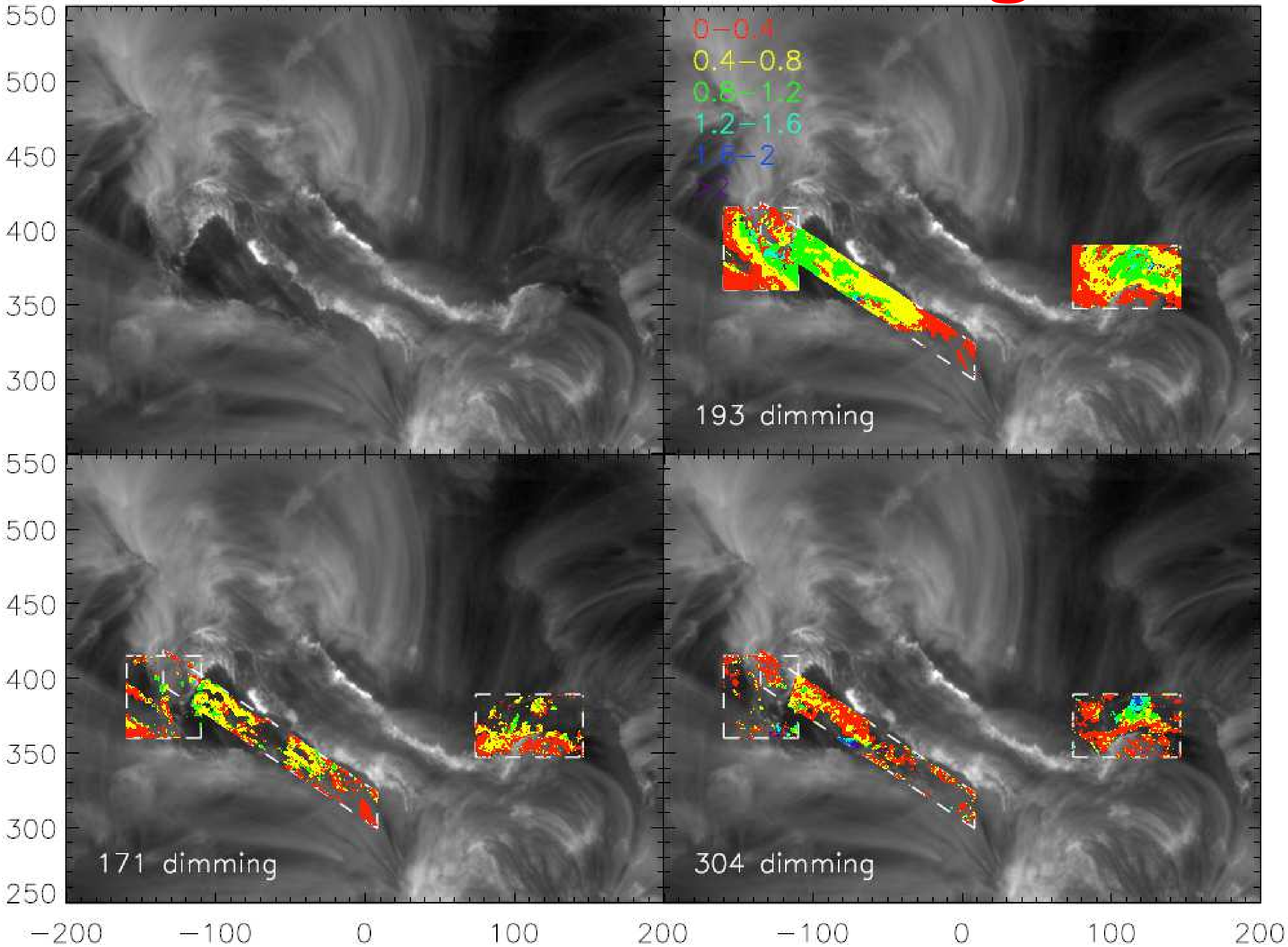


EUV Wave
(Solar Tsunami)



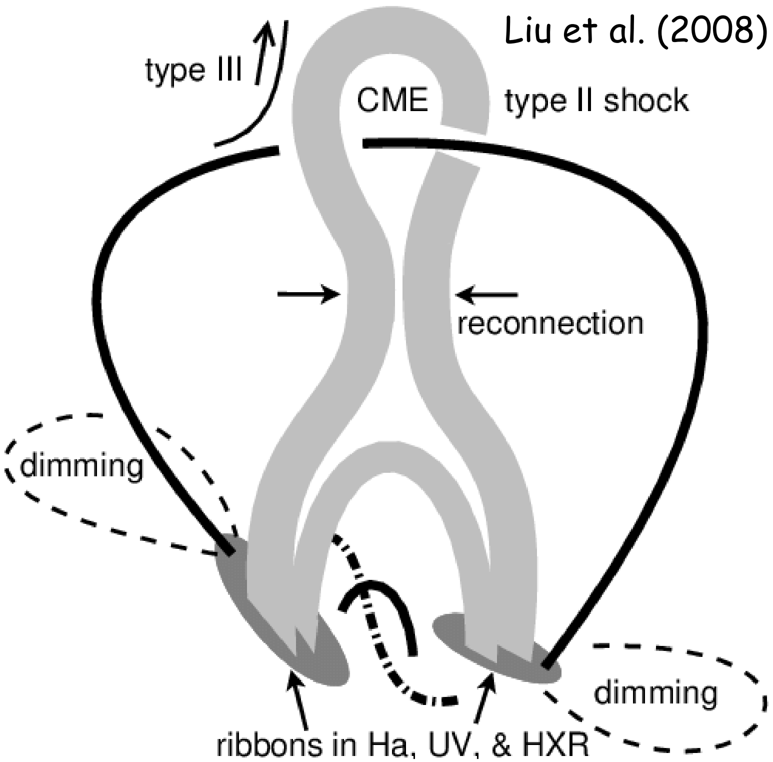
https://www.nasa.gov/mission_pages/stereo/news/solar_tsunami.html

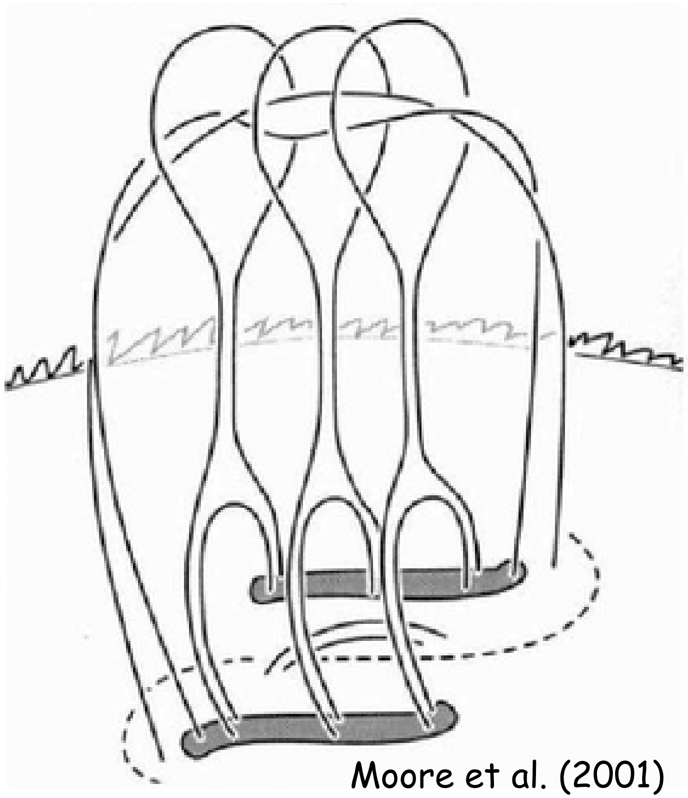
Coronal Dimming



The dimming cores, most evident in the 193 band, are seen at the ends of the two ribbons which probably map the CME feet.

Cheng & Qiu (2016)

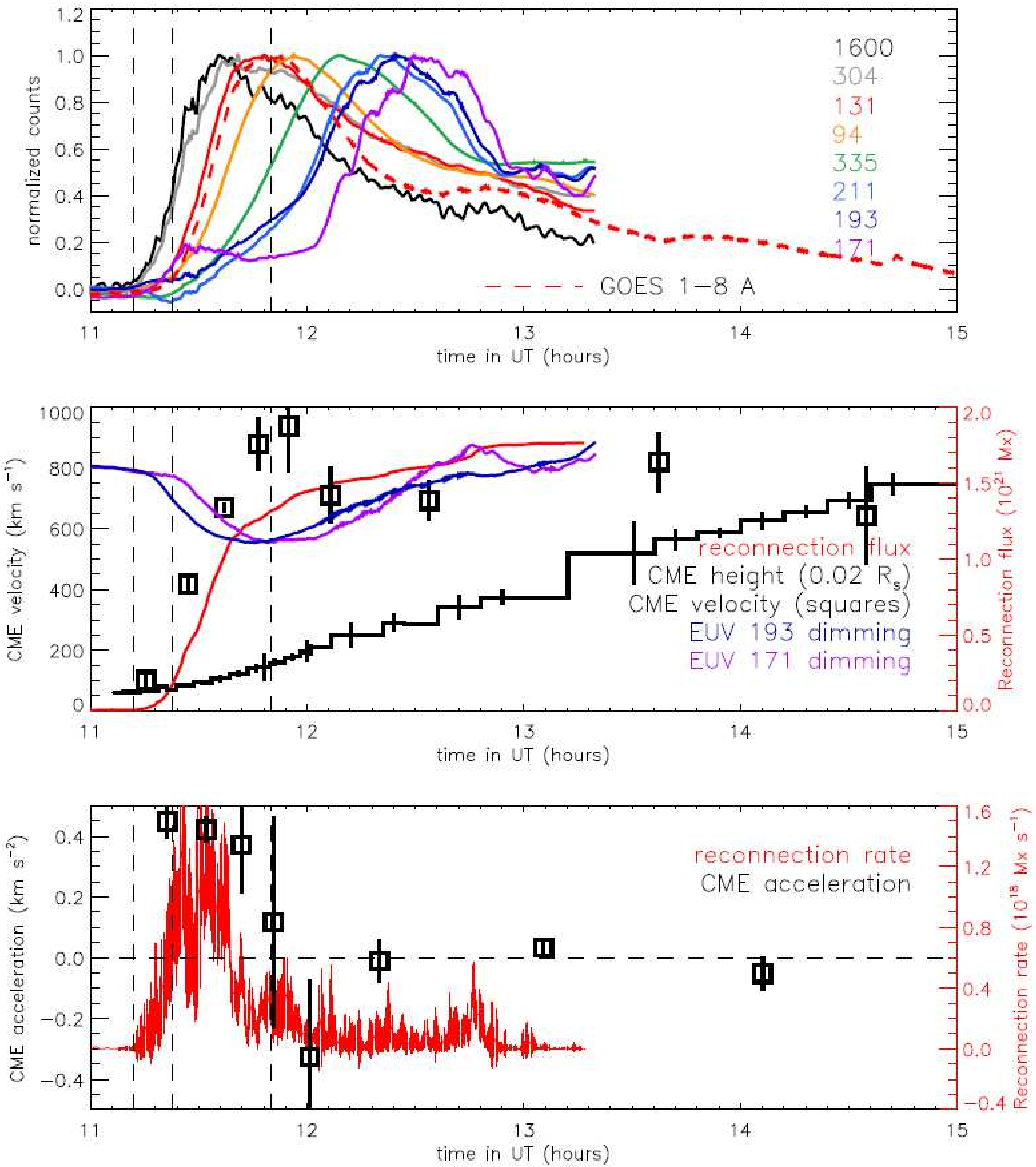




Two dimming regions are found at the opposite ends of the two ribbons, which likely map the conjugate feet of the CME. During the flare eruption, dimming along the outmost edges of one flare ribbon is also observed and followed by brightenings of flare ribbons.

This signature agrees with the standard model that the overlying coronal arcade is stretched by the erupting CME, causing coronal dimming at the feet; the arcade then reconnect and produce brightening ribbons.

Cheng & Qiu (2016)

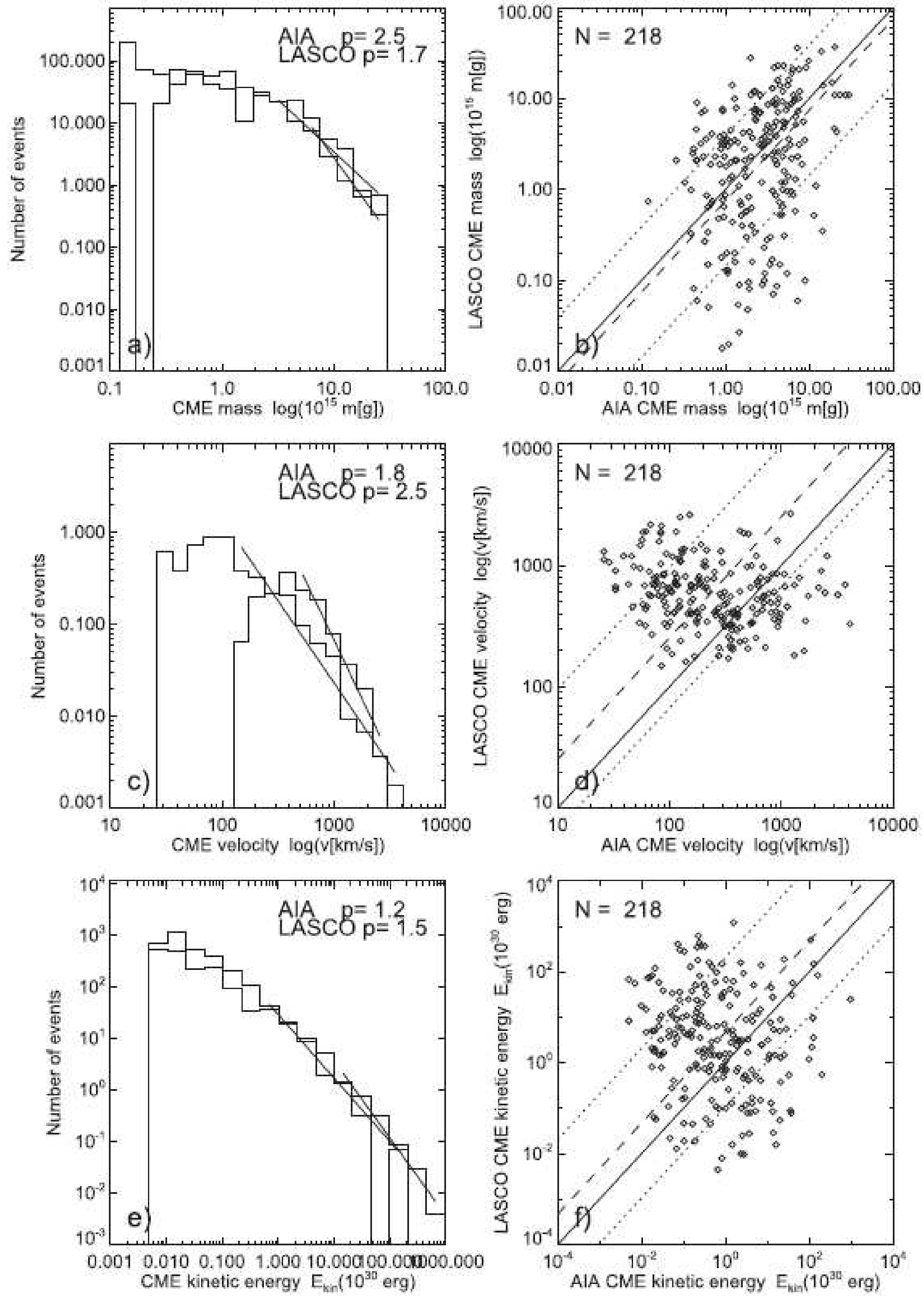


EUV 193 emission starts to decrease quickly at 5 minutes after the start of the flare reconnection and CME takeoff, whereas dimming in the 171 band starts ~5 minutes later.

The maximum dimming occurs around the GOES peak time as well as the CME velocity, and then the EUV emission in these dimming regions starts to rise as post-flare loops form in these regions.

Such timing among these events indicates that fast reconnection, CME expansion, and coronal dimming are intimately related.

Cheng & Qiu (2016)



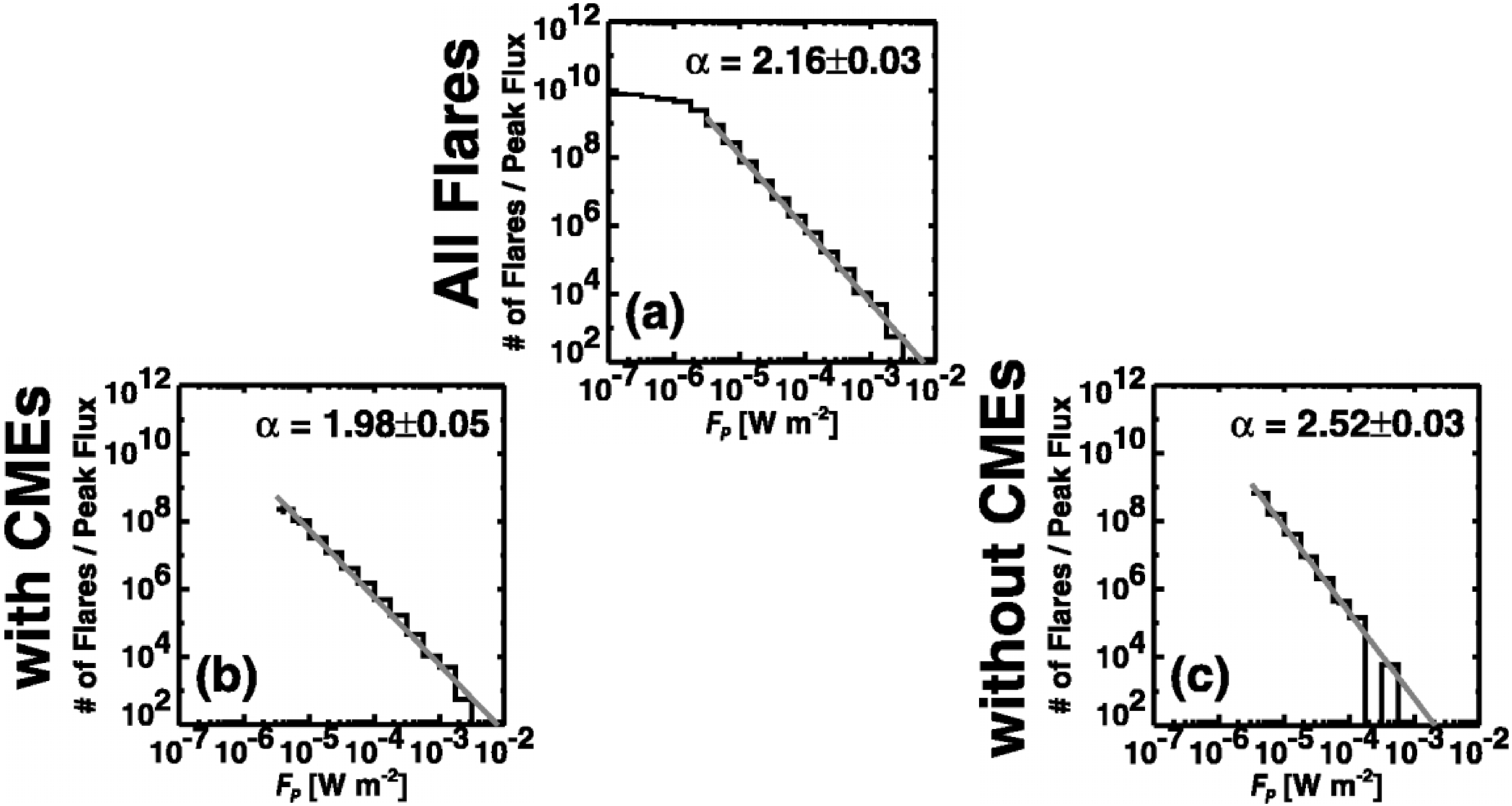
399 M- and X-class flare events observed during 2010 June – 2014 January by SDO/AIA based on the EUV dimming method.

Since the leading edges (used for LASCO) are faster than the bulk speed (for AIA), we suspect that LASCO obtains faster CME speeds than AIA, and consequently yields larger kinetic energies also.

On the other hand, LASCO detects a number of CMEs with much lower masses than AIA due to sensitivity issues in detecting whitelight polarized brightness signals.

Aschwanden (2016)

1996~2005 (98 X, 696 M, 575 C)



→ Flares without CMEs dominate at smaller energies

→ Nanoflares or microflares are a potential source for coronal heating (because no flare-released energy is used for CME eruption)

Yashiro et al. (2006)