

# Direct Imaging of a Classical Solar Eruptive Flare

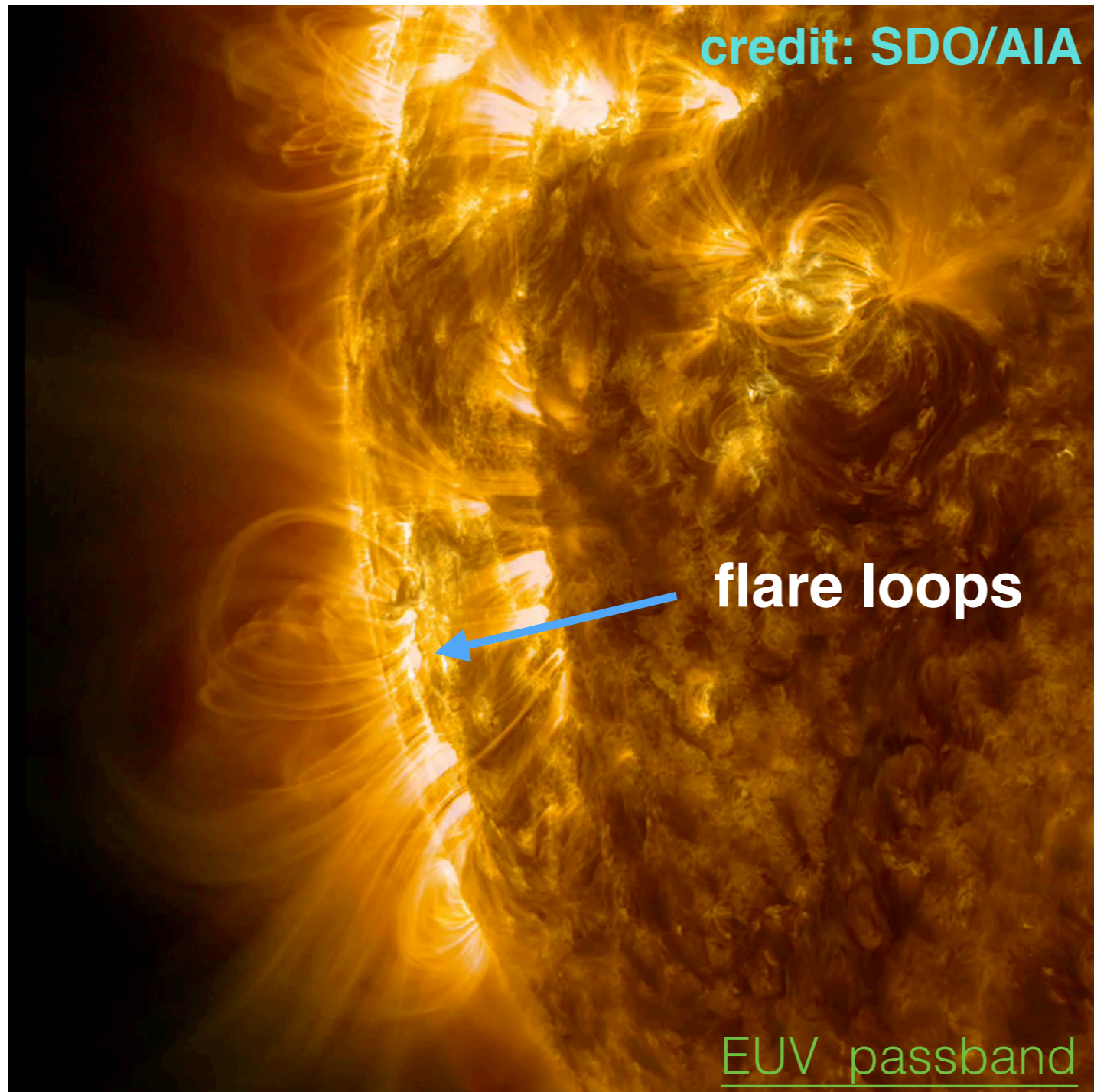
**LI, Ying (李瑛)**

X. Sun, M. D. Ding, J. Qiu, & E. R. Priest

October 18, 2016

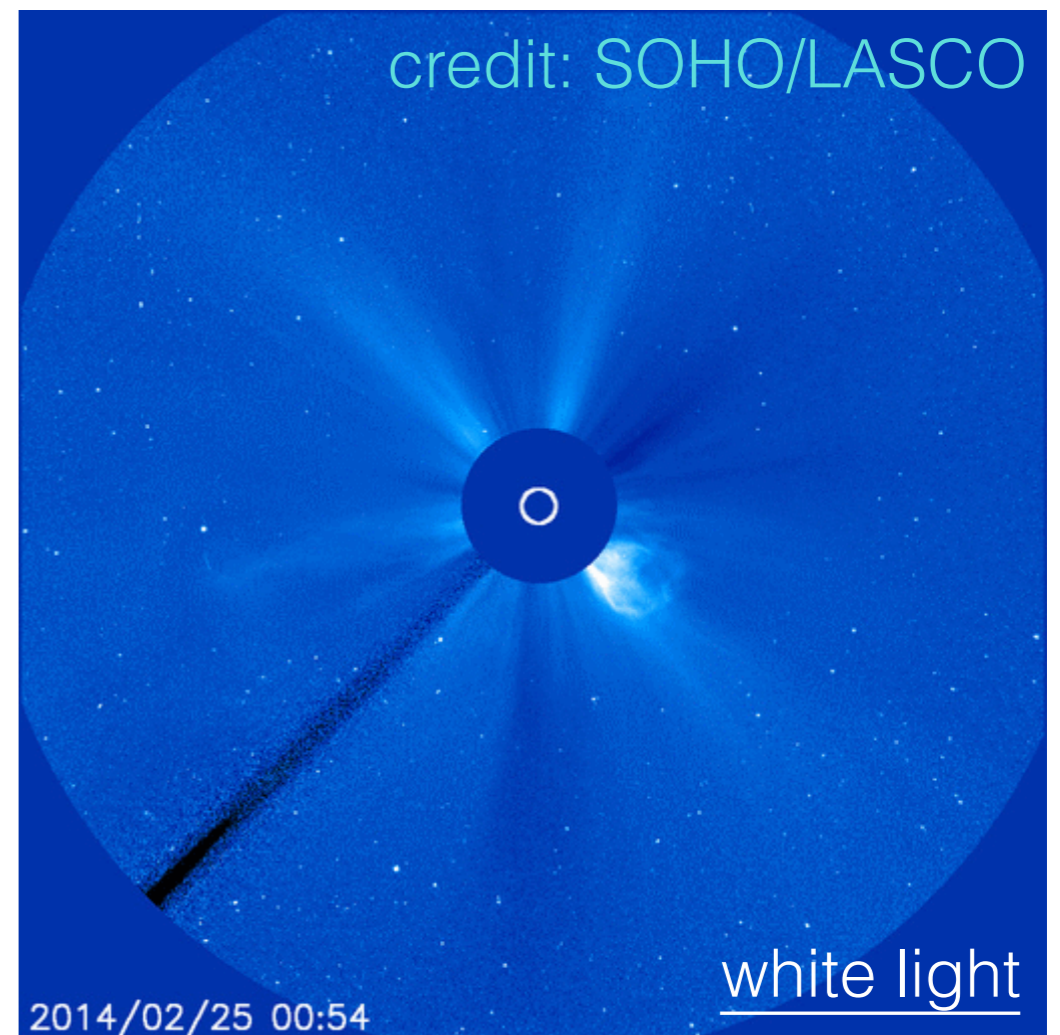
# solar flare

a sudden brightening in the solar atmosphere



# eruptive flare

accompanied by a coronal mass ejection (CME)

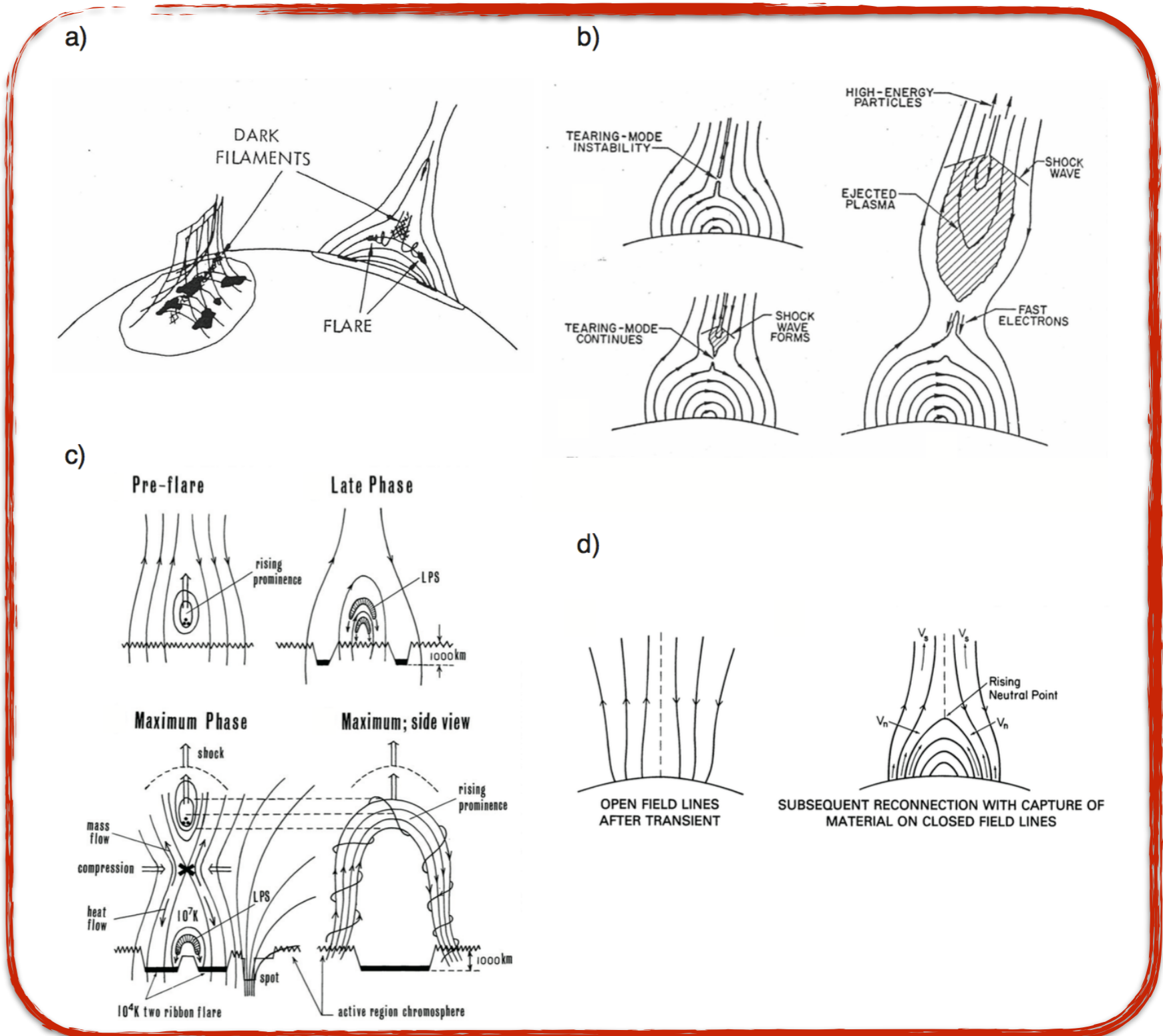


the most popular model for typical eruptive flares —  
**the standard solar flare model (CSHKP)**

flare loops  
 & two ribbons

**magnetic  
 reconnection**

plasmoid  
 structure

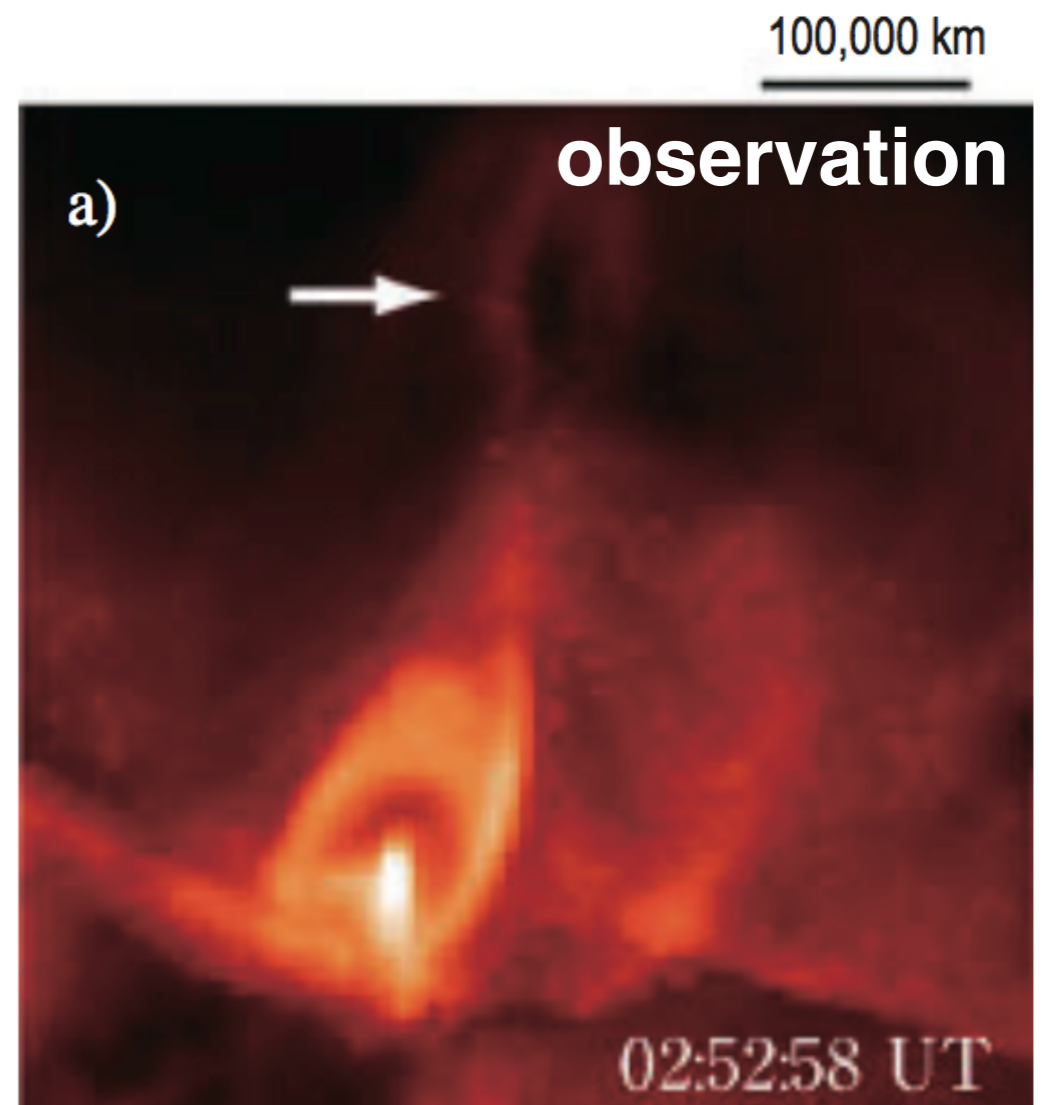
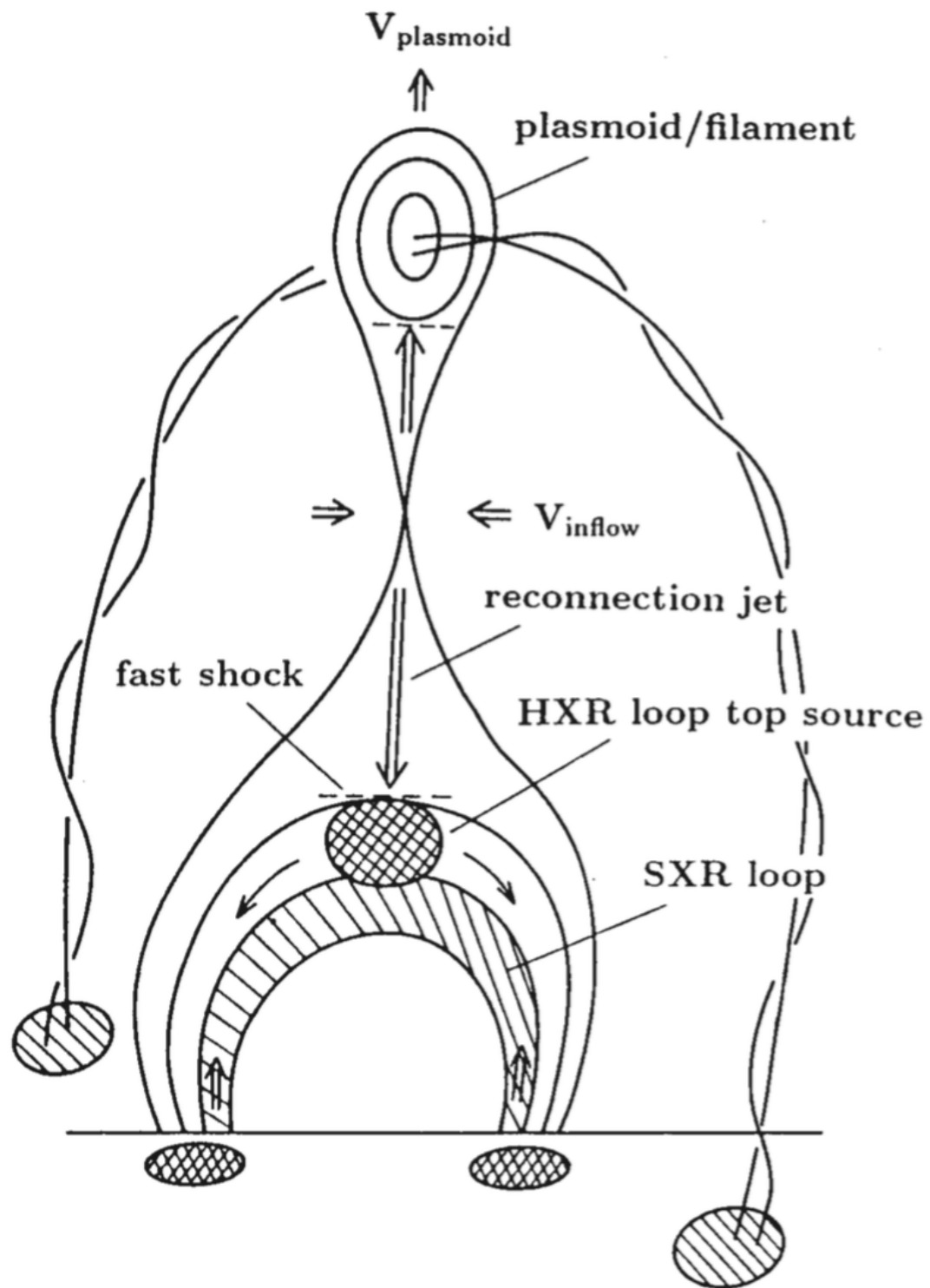


**Figure 2:** Phenomenological models for flares based on magnetic reconnection. Lines with arrows on them indicate magnetic field lines. (a) Carmichael (1964), (b) Sturrock (1966), (c) Hirayama (1974), (d) Kopp and Pneuman (1976).

# a modified version (Shibata & Magara 2011)

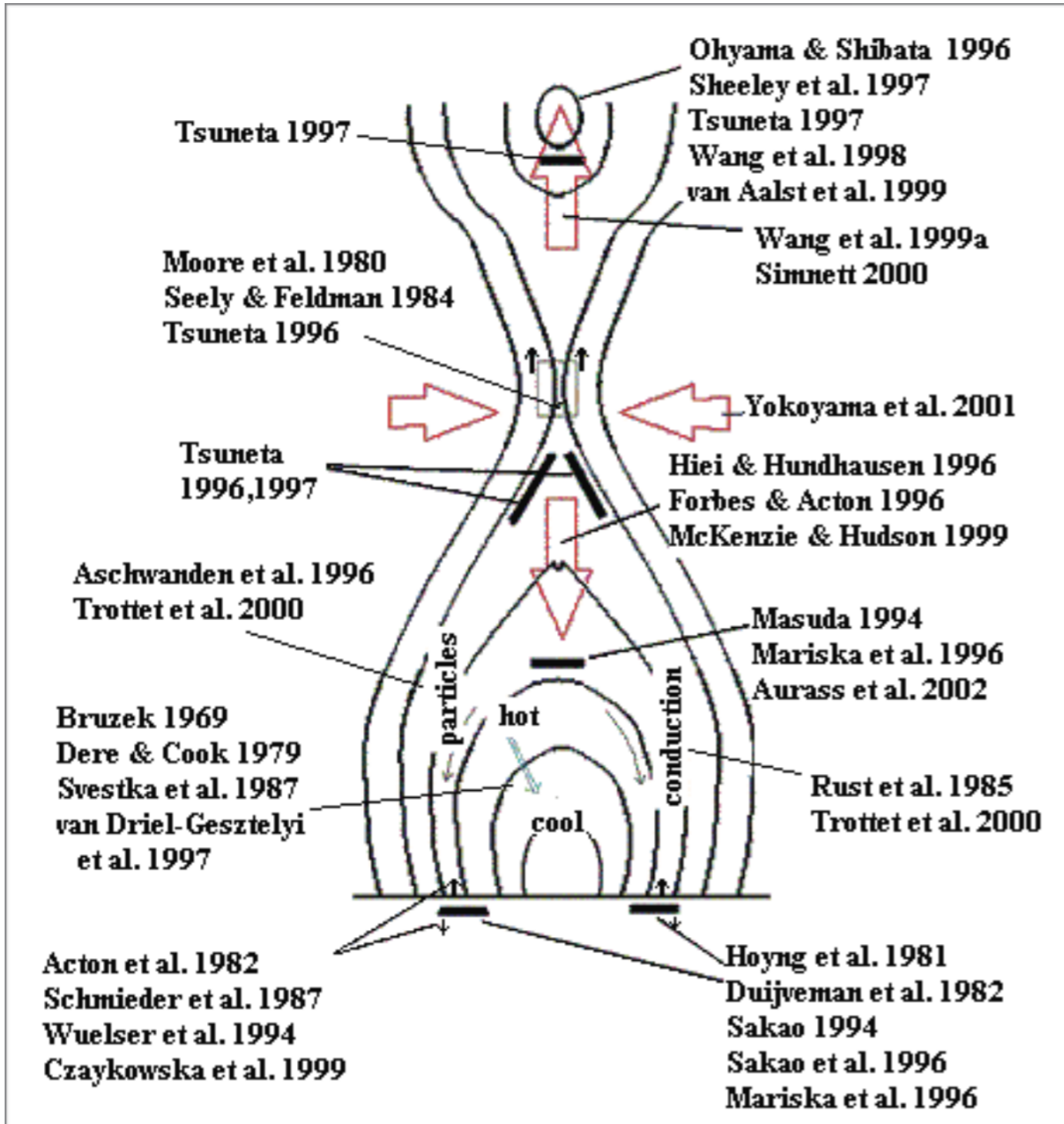
## key elements

- magnetic flux rope (plasmoid/twisted)
- **magnetic reconnection** (X-structure)
- flare loops & ribbons (brightenings)

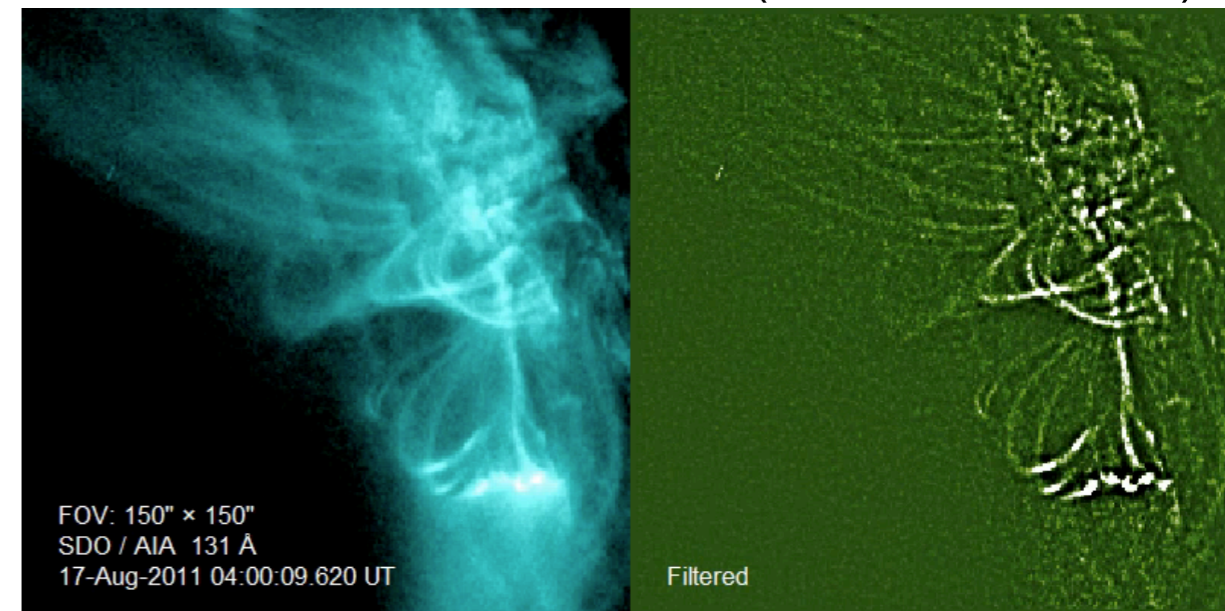


# efforts to prove magnetic reconnection

(Su et al. 2013)

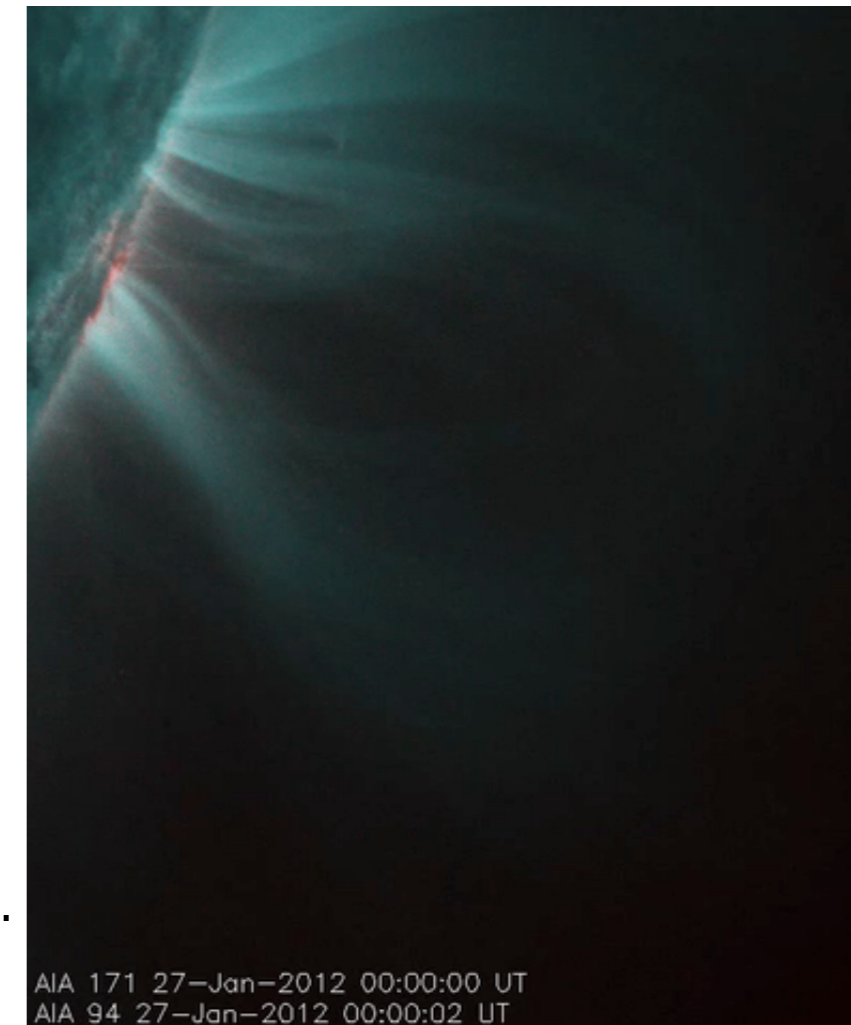


(compiled by David McKenzie)



SDO/AIA

limb events



(Sun et al. 2015)

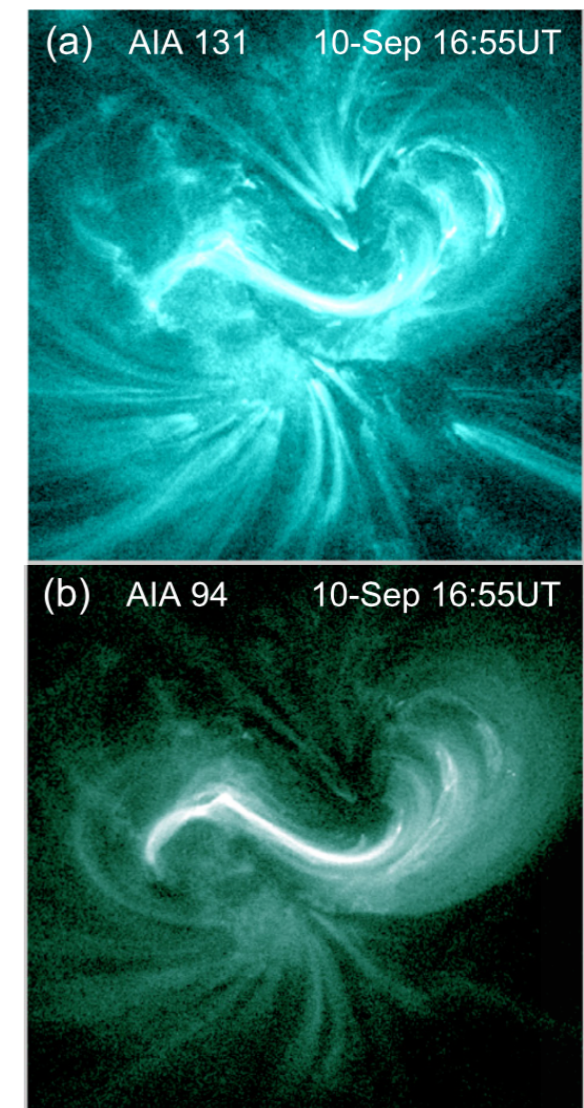
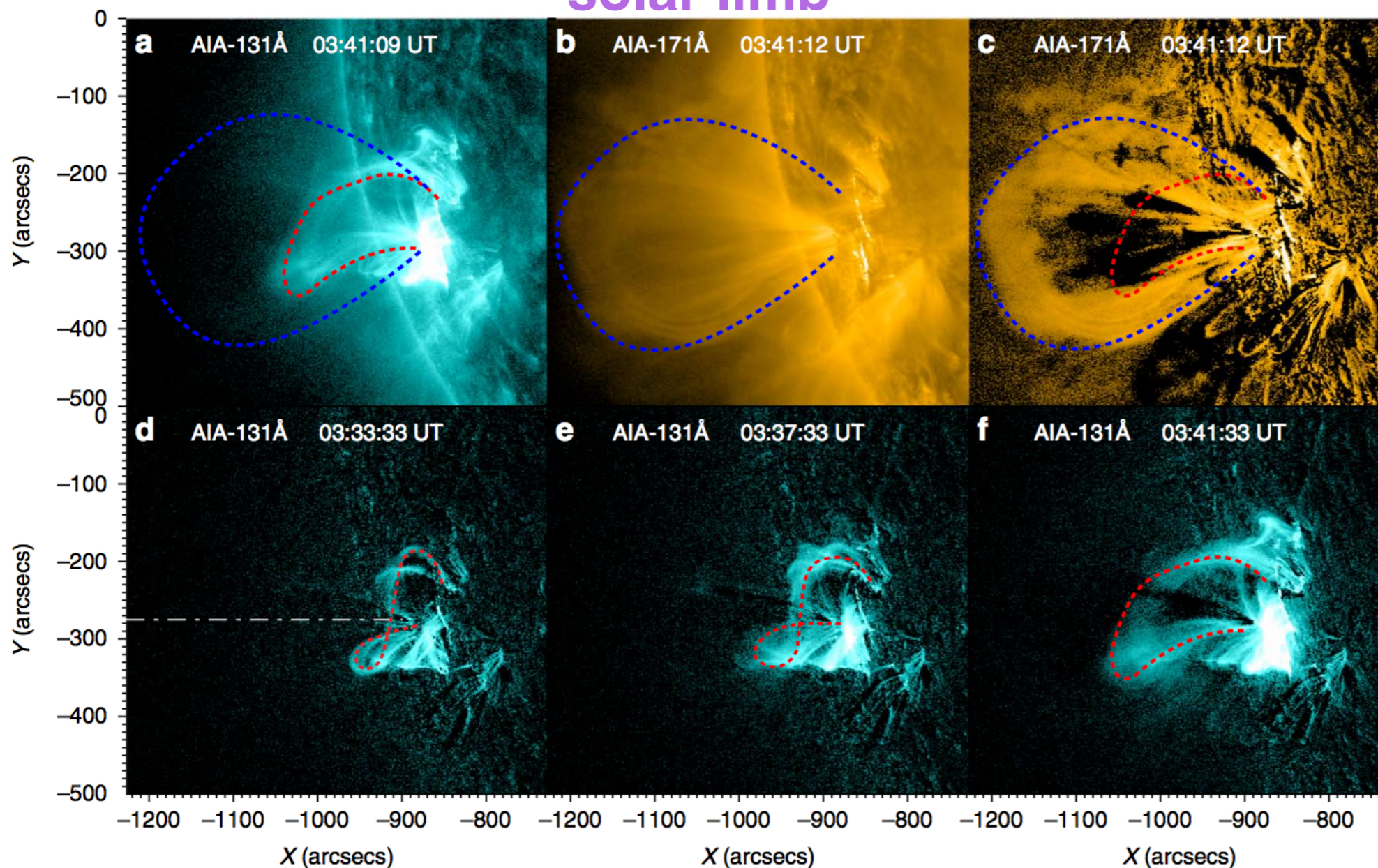
# evidence for magnetic flux rope

**hot channel** (AIA 131,  $\sim 10$  MK): **twisted rope/sigmoid structure**

**cool channel** (AIA 171,  $\sim 0.6$  MK): **bubble-like/cavity structure**

## solar limb

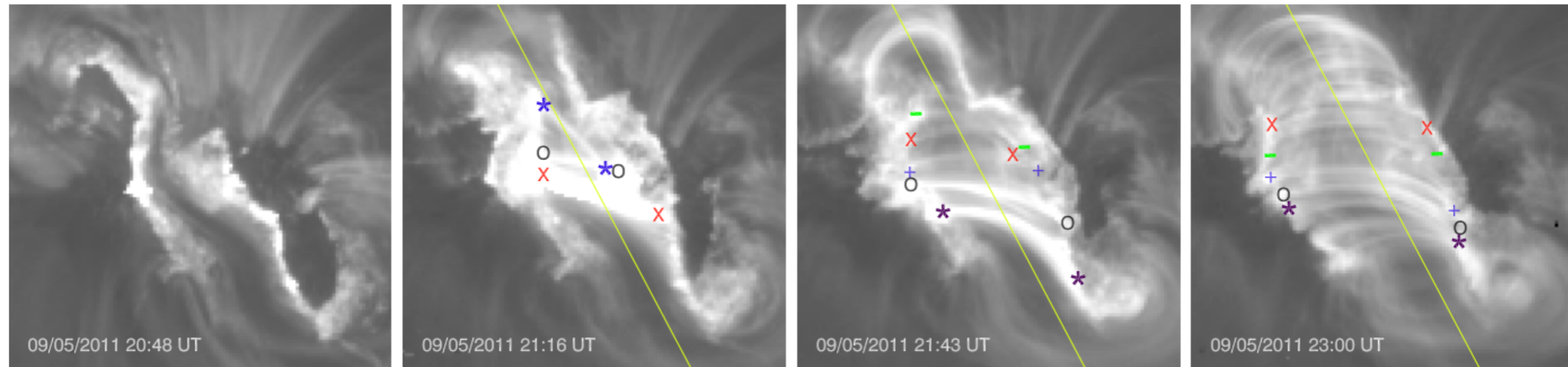
## solar disk



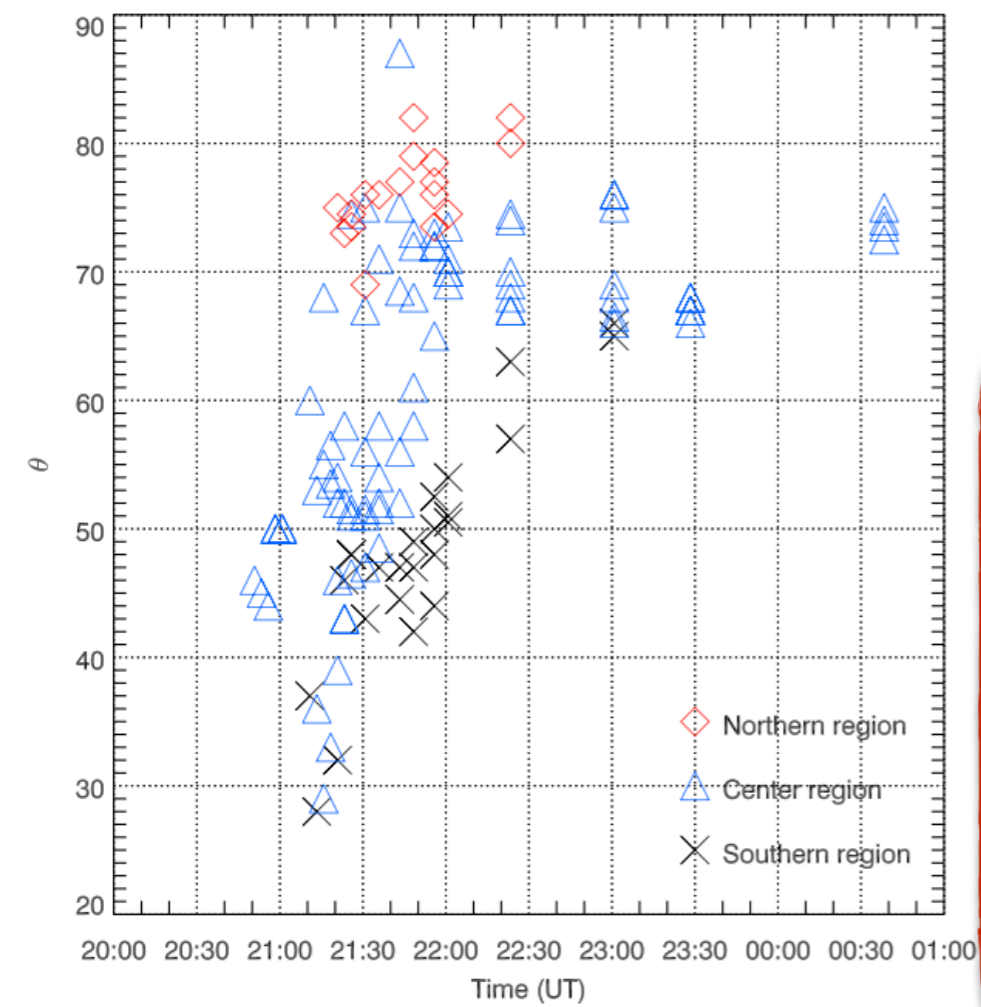
(Zhang et al. 2012)

(Cheng et al. 2015)

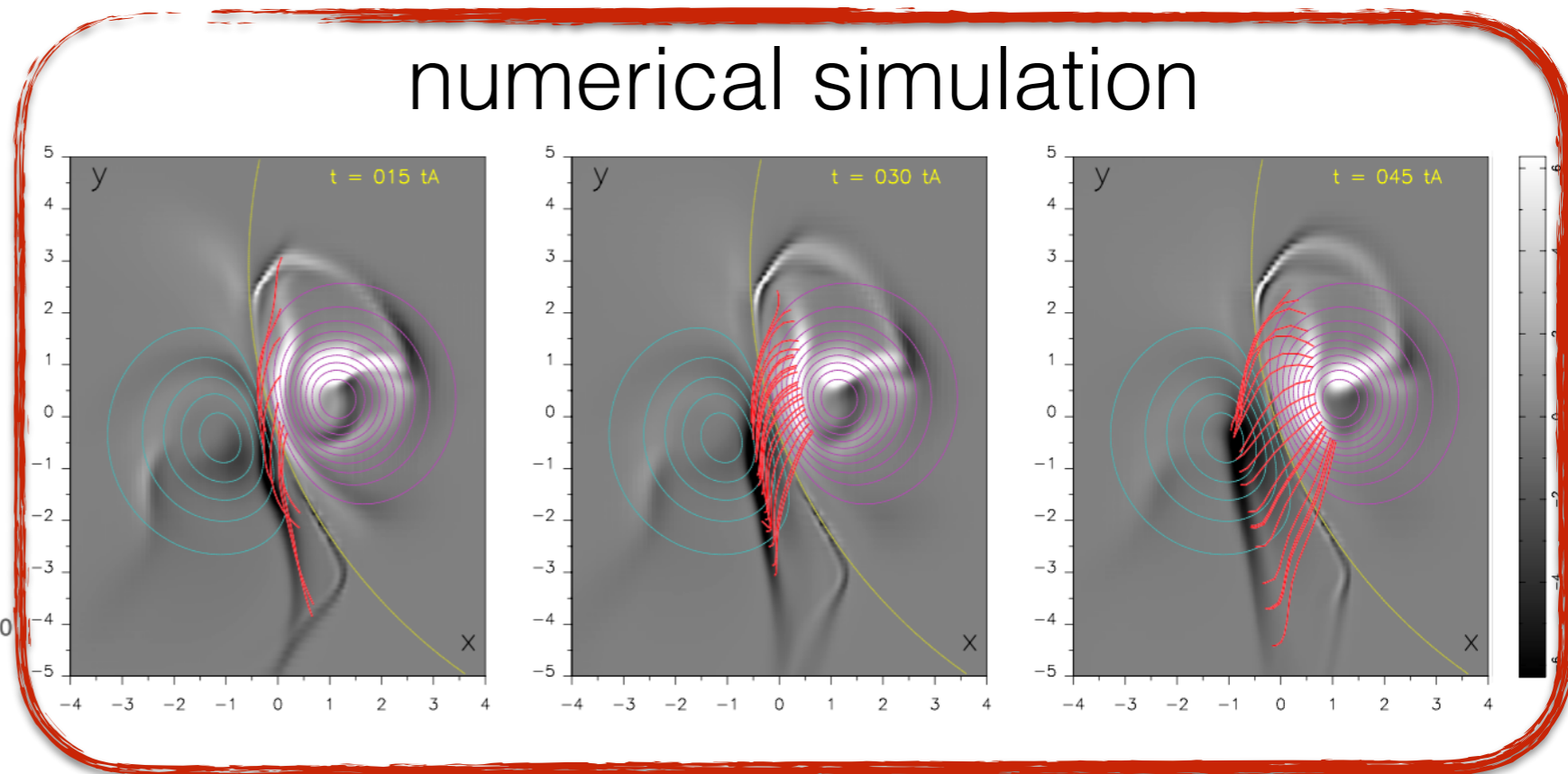
# flare loop/ribbon evolution



strong-to-weak shear transition



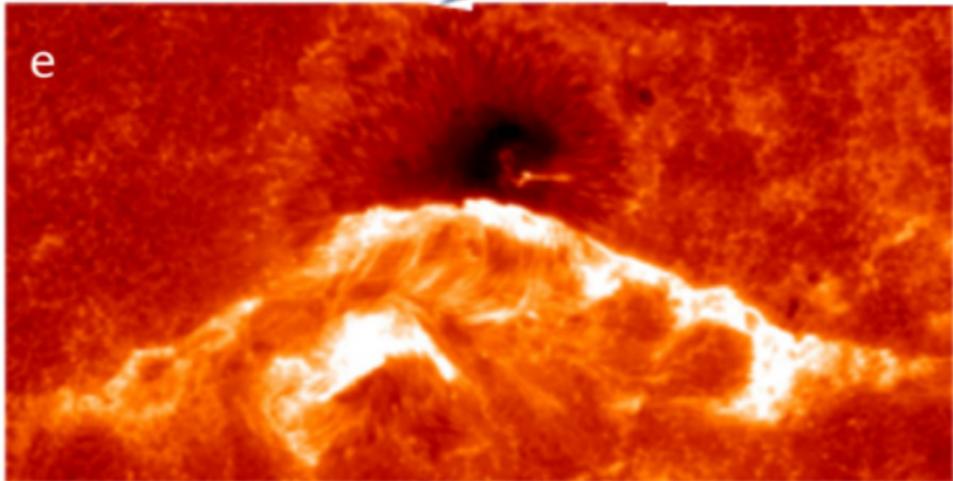
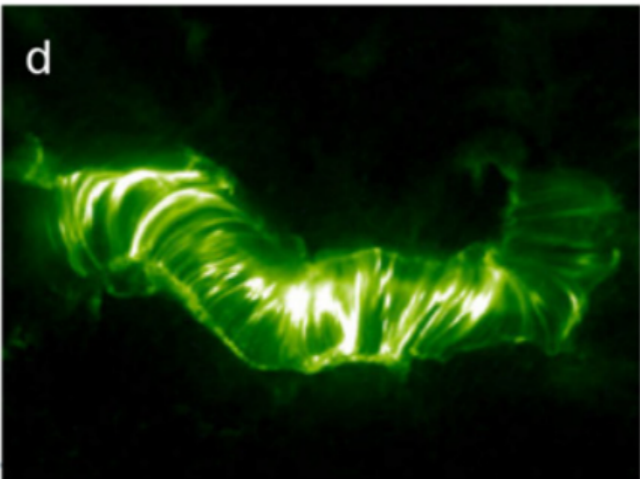
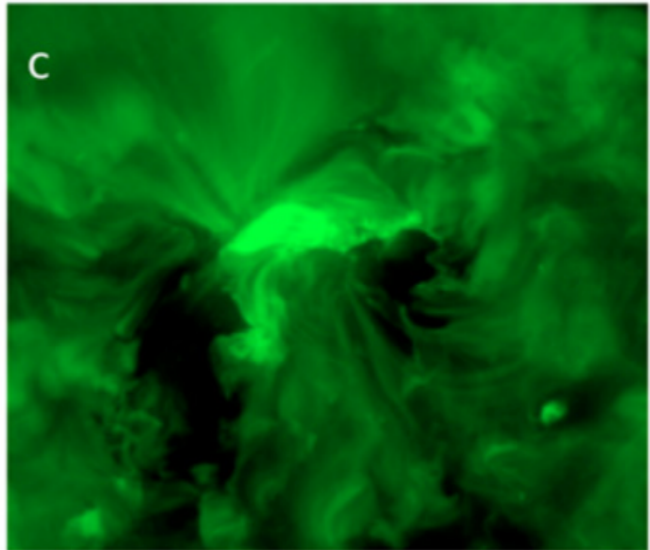
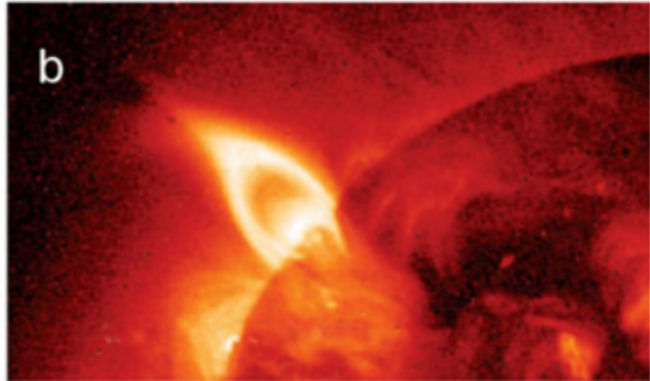
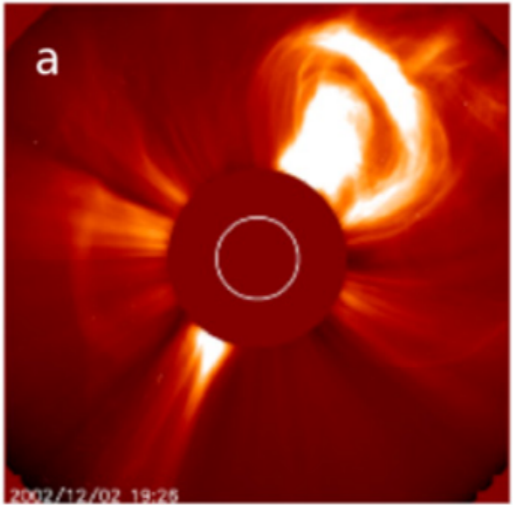
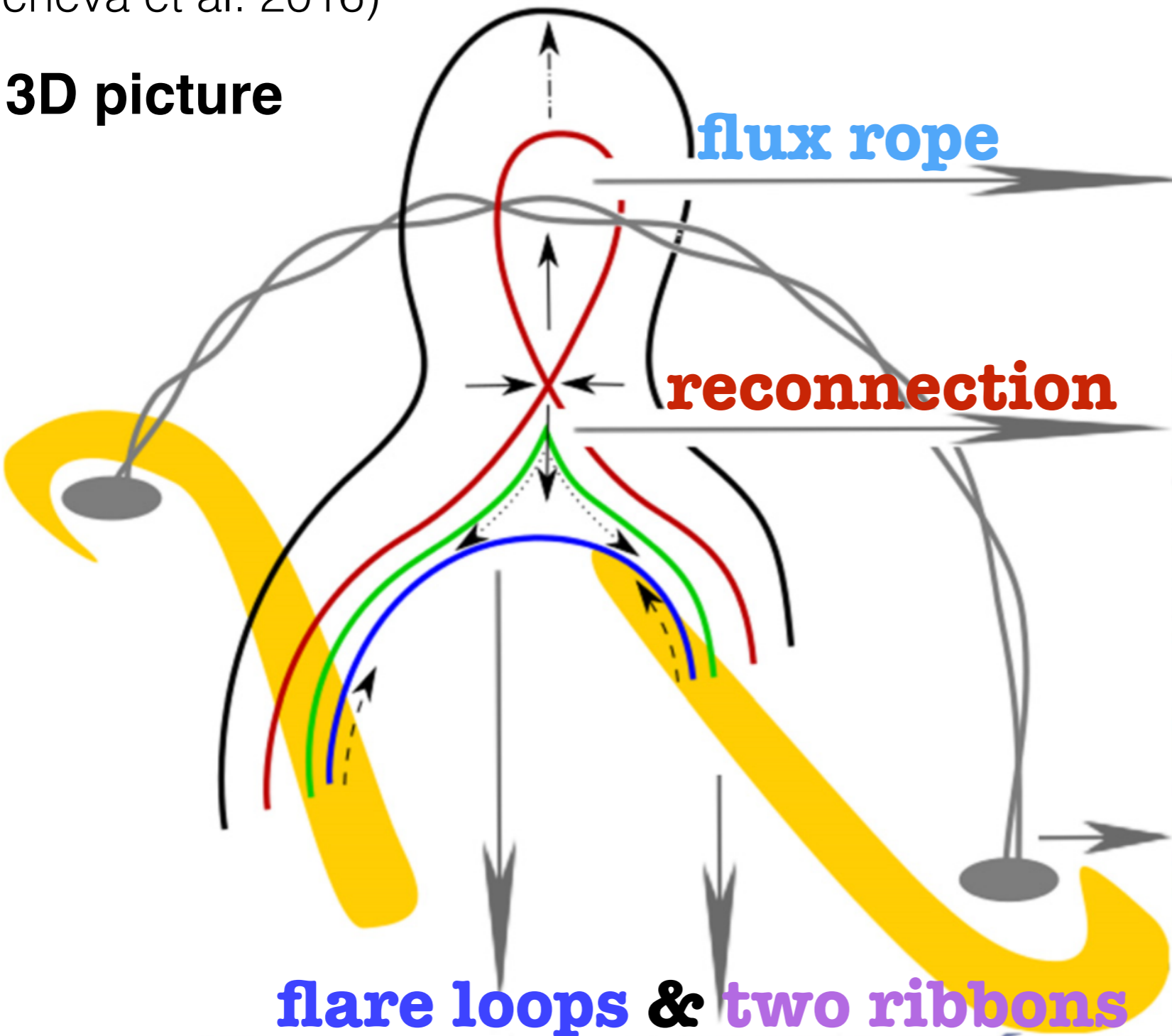
numerical simulation



(Aulanier et al. 2012)

(Savcheva et al. 2016)

# 3D picture



**different events  
on the disk/limb**



**piece together almost all the key elements  
into a SINGLE eruptive event (on the disk)**

**to study the key processes**

in particular, **magnetic reconnection**

& **magnetic flux rope (MFR) eruption**

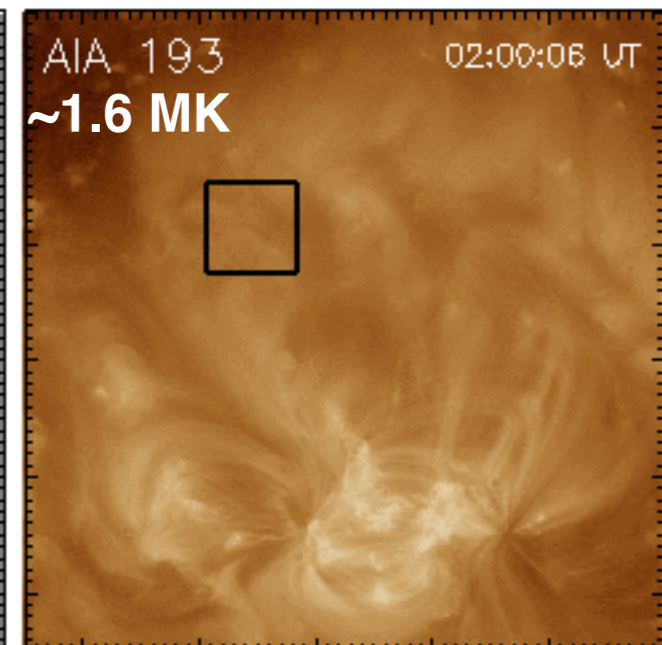
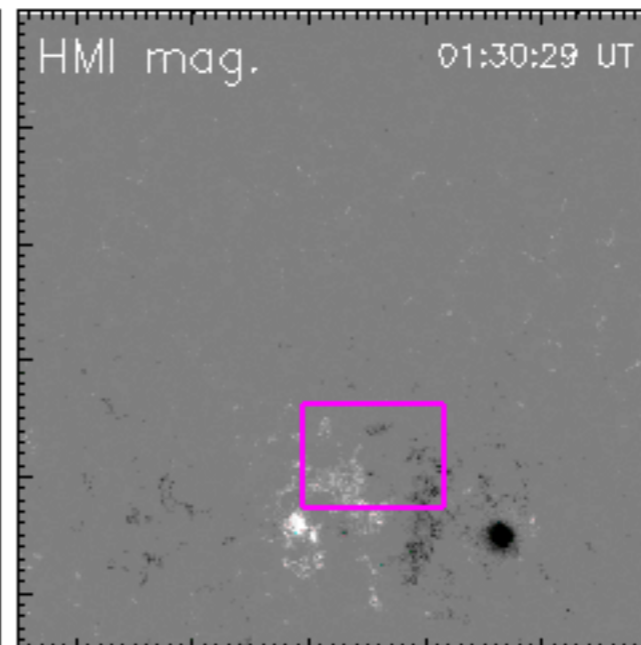
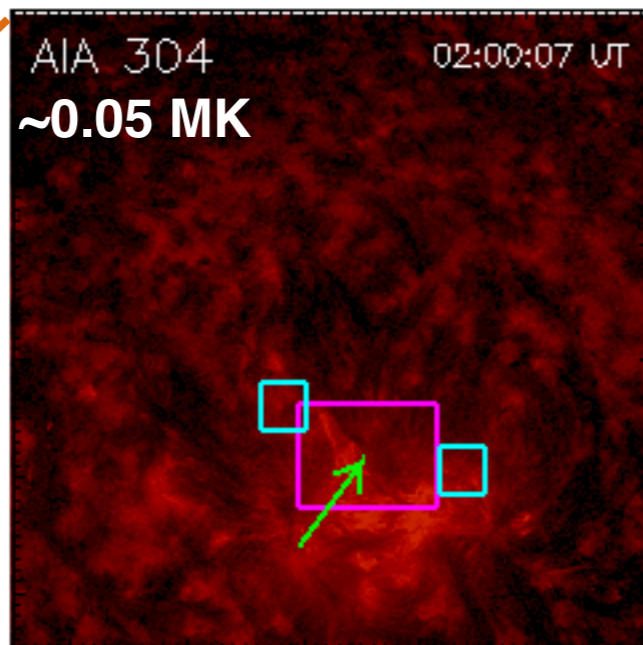
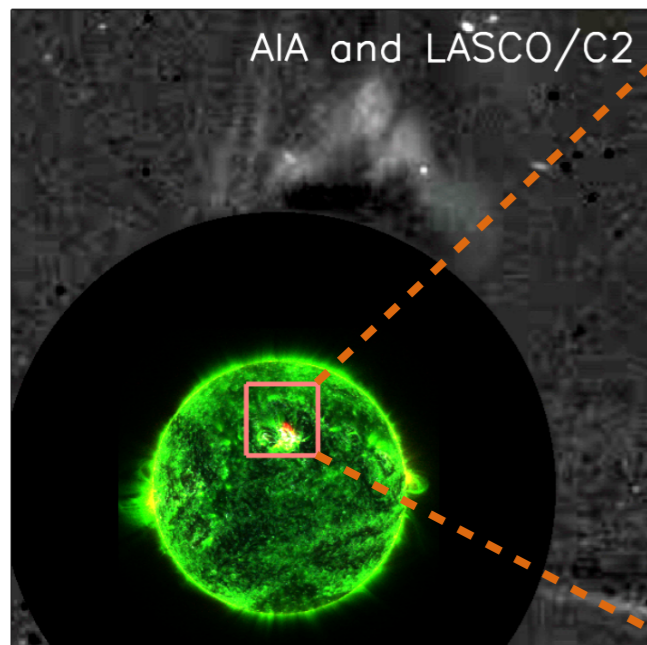
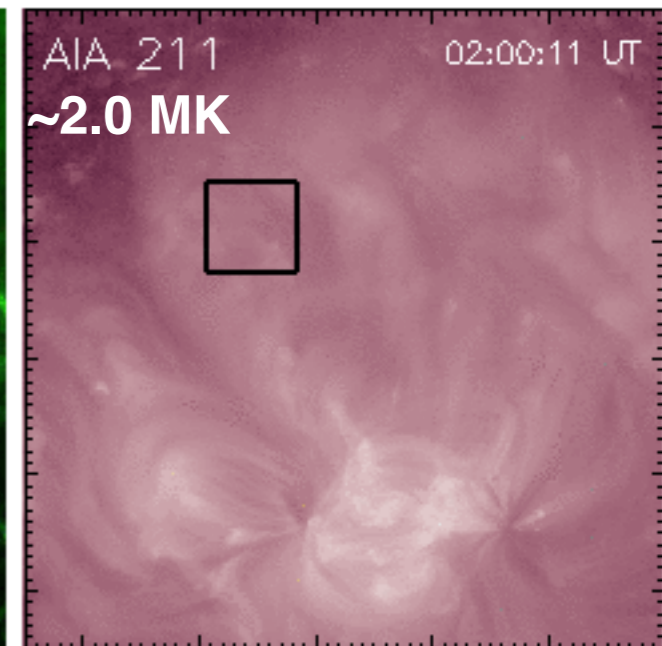
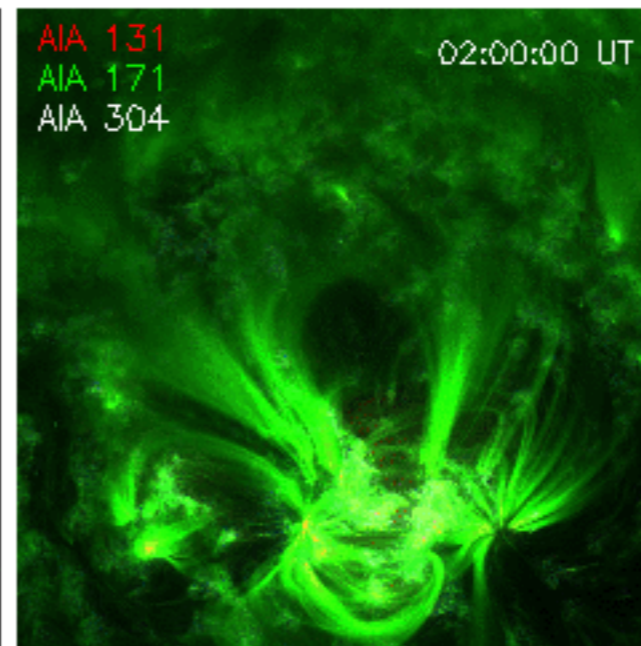
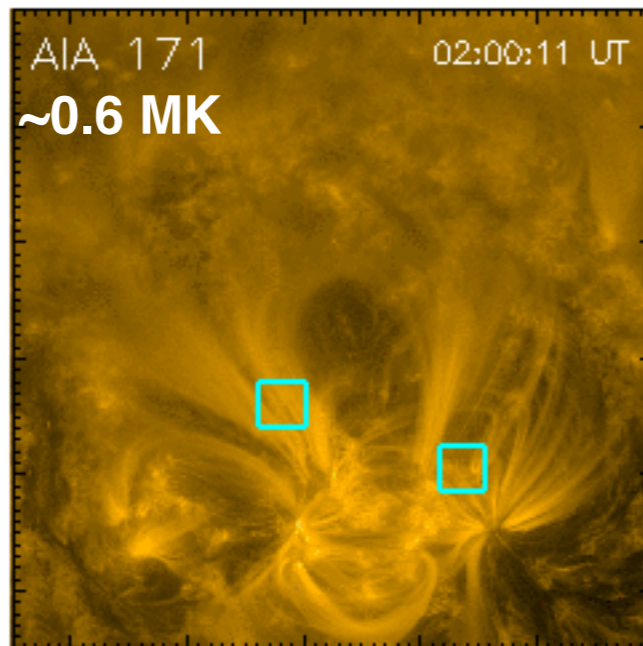
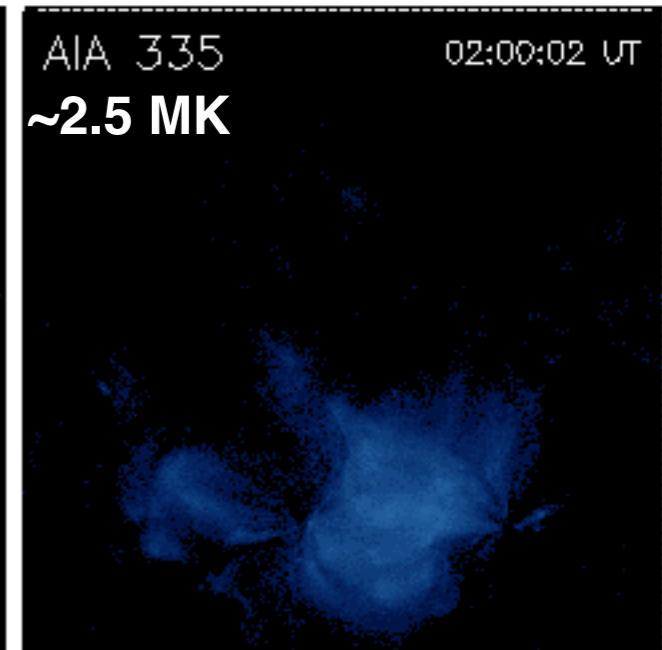
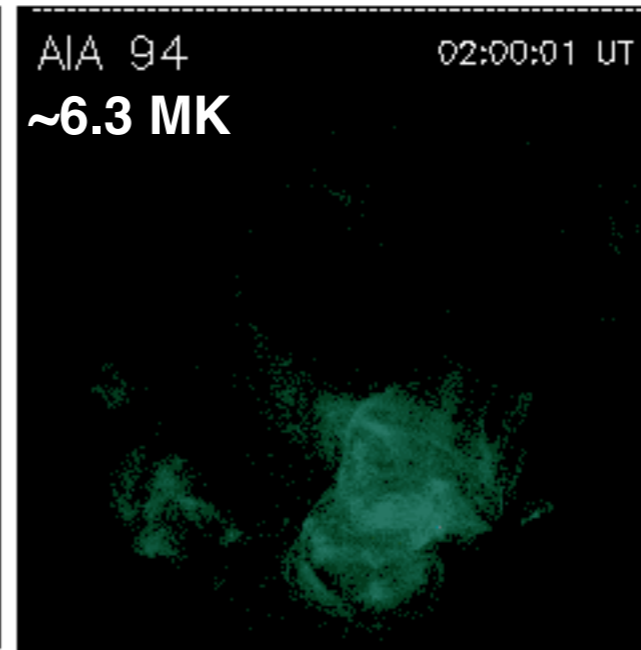
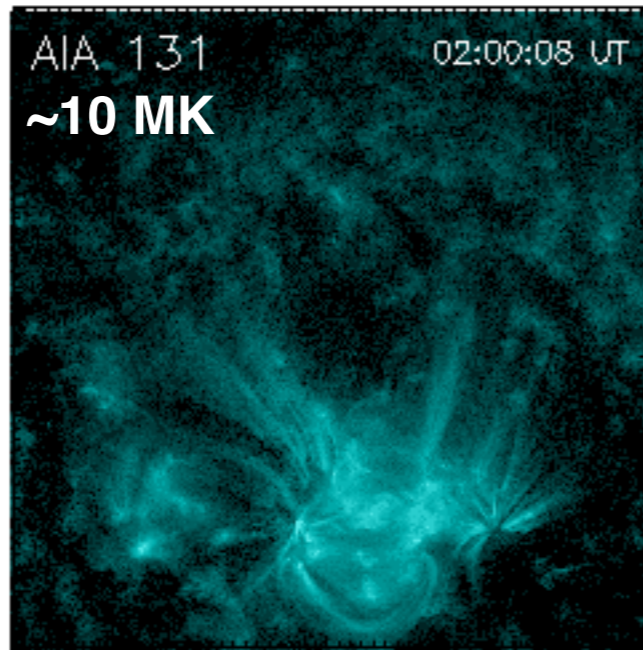
*from both the coronal and chromospheric layers*

a C1.1 flare  
observed  
by SDO/AIA

**magnetic  
reconnection**

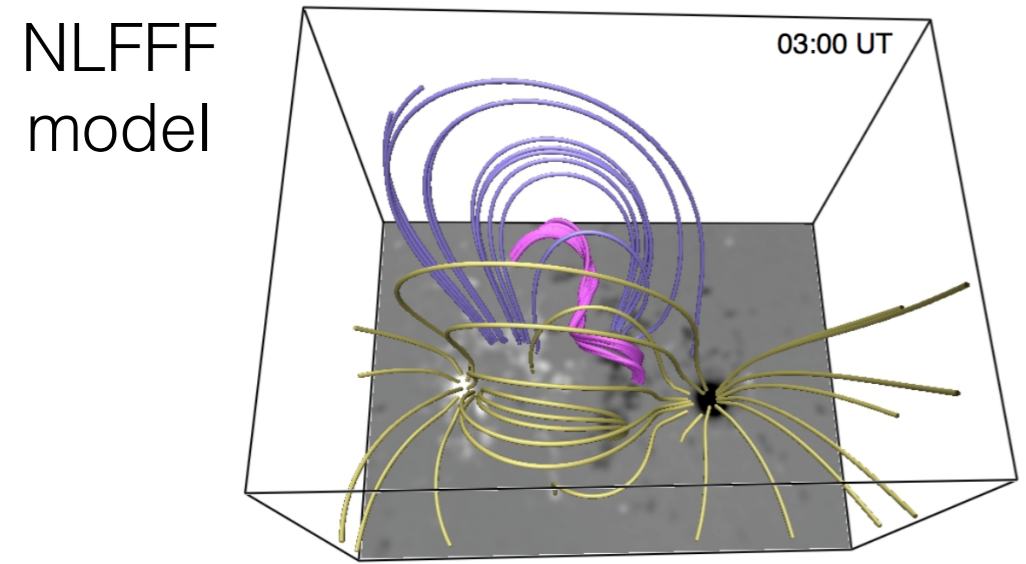
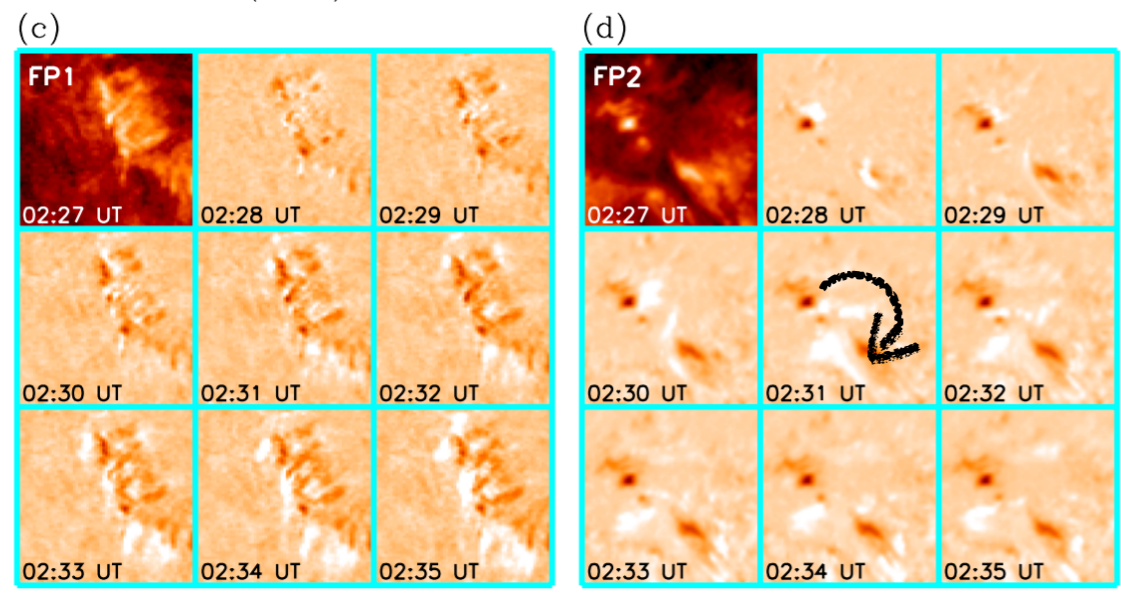
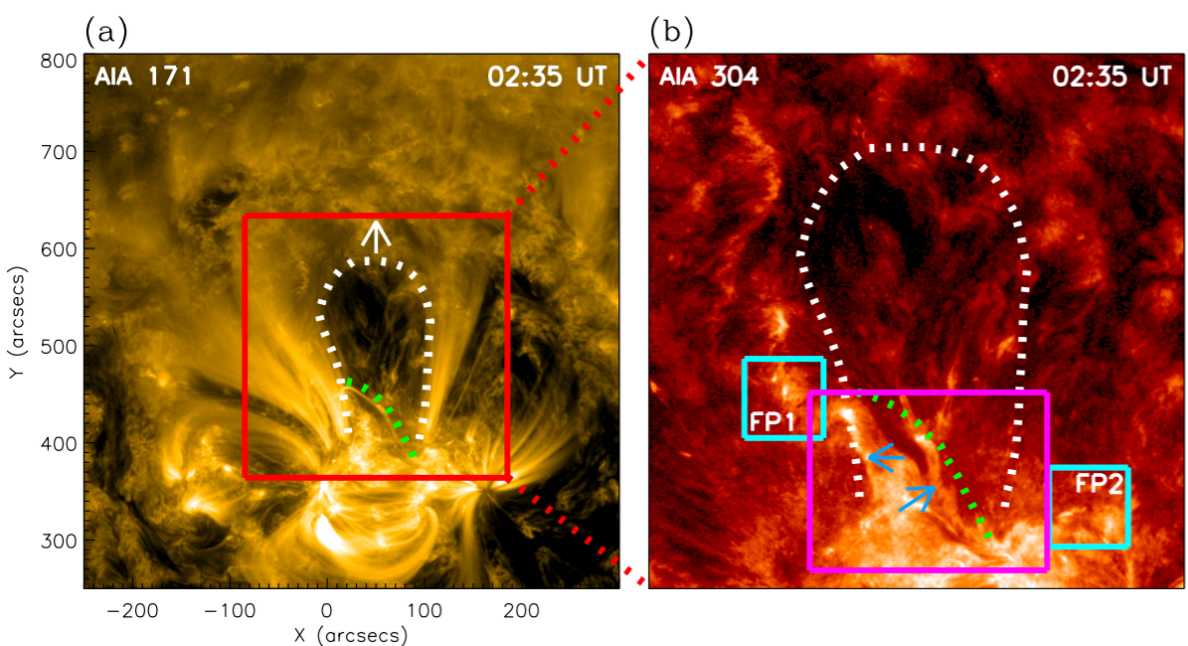
**magnetic  
flux rope**

**flare loops  
& ribbons**



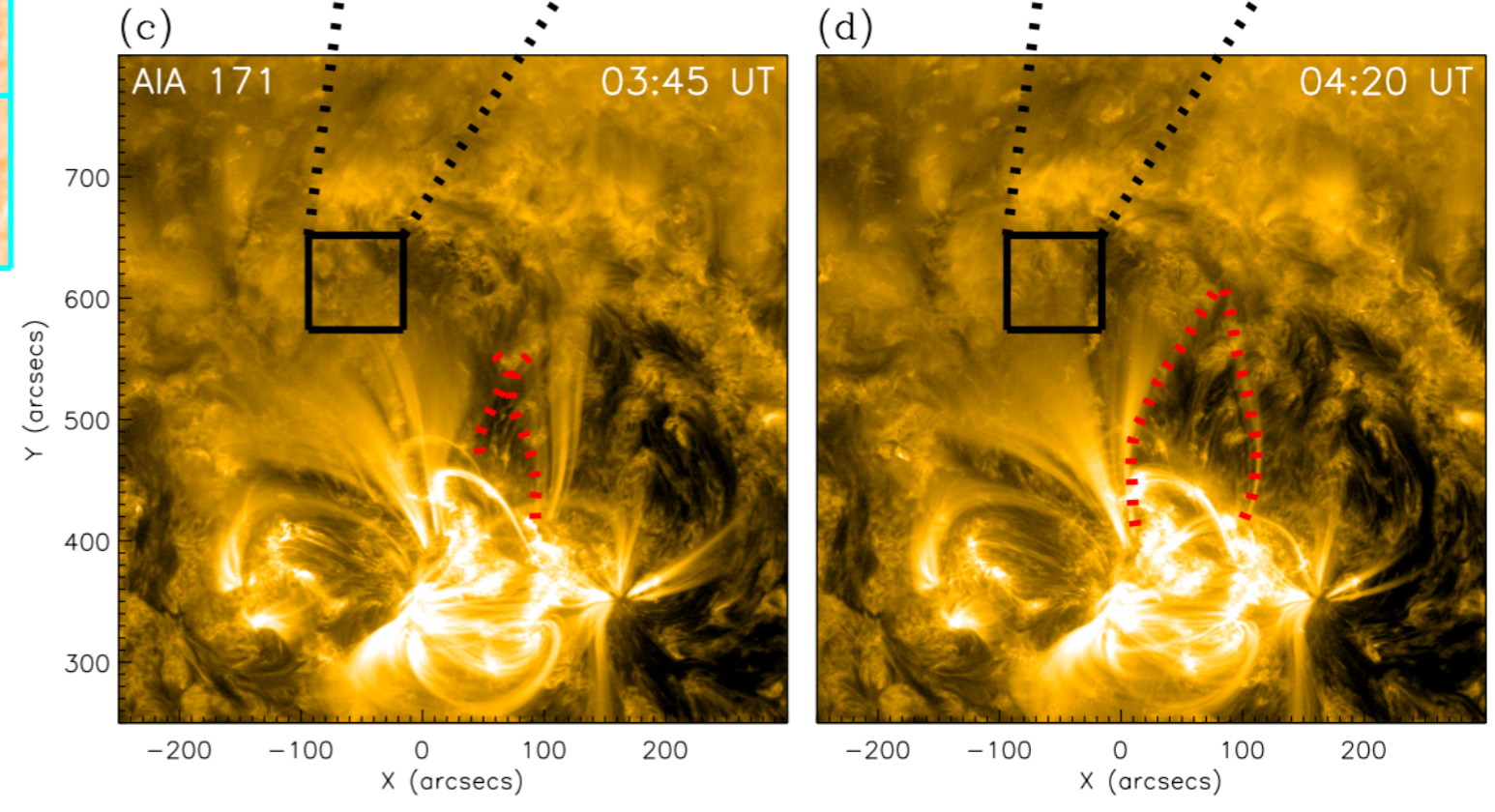
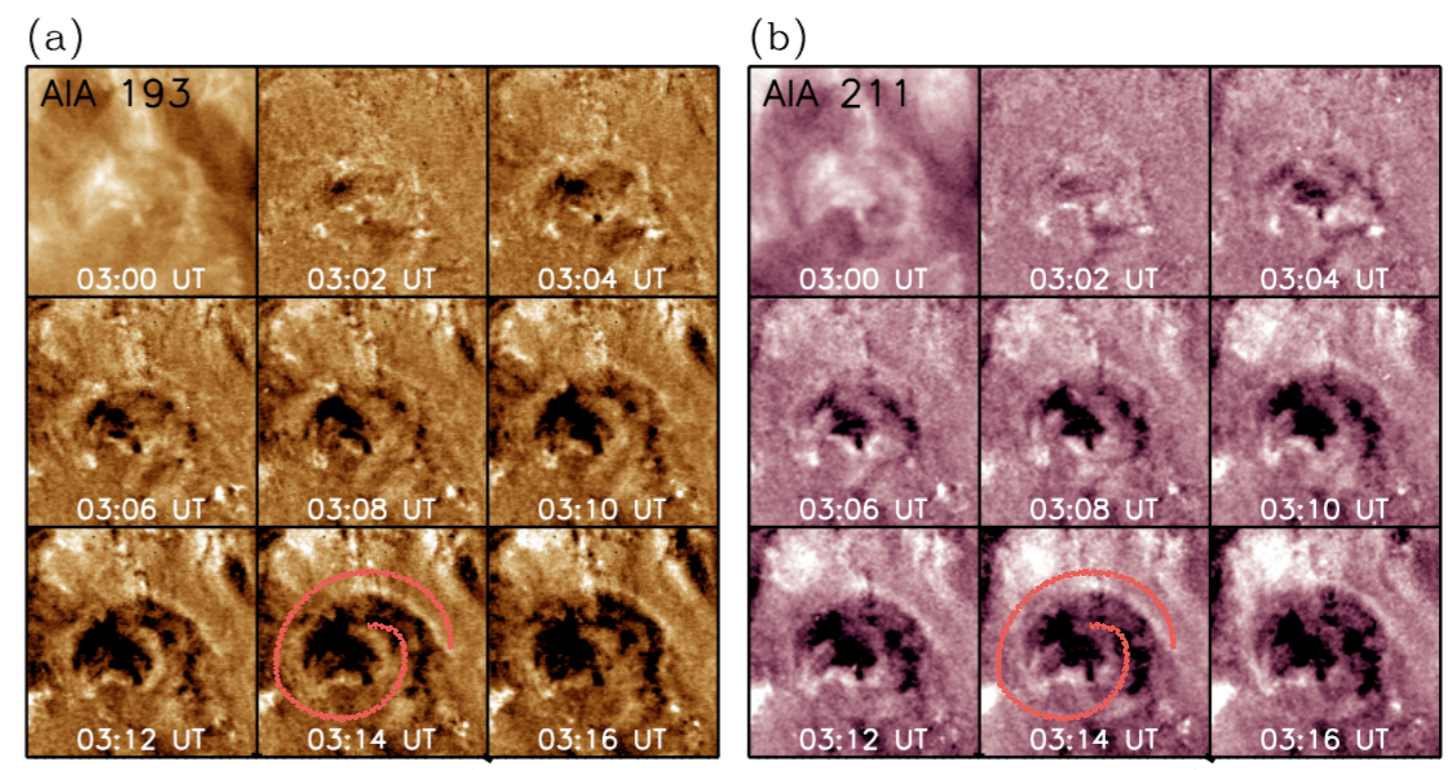
# preflare features

- MFR cavity & swirling hooks
- bright arches & faint ribbons

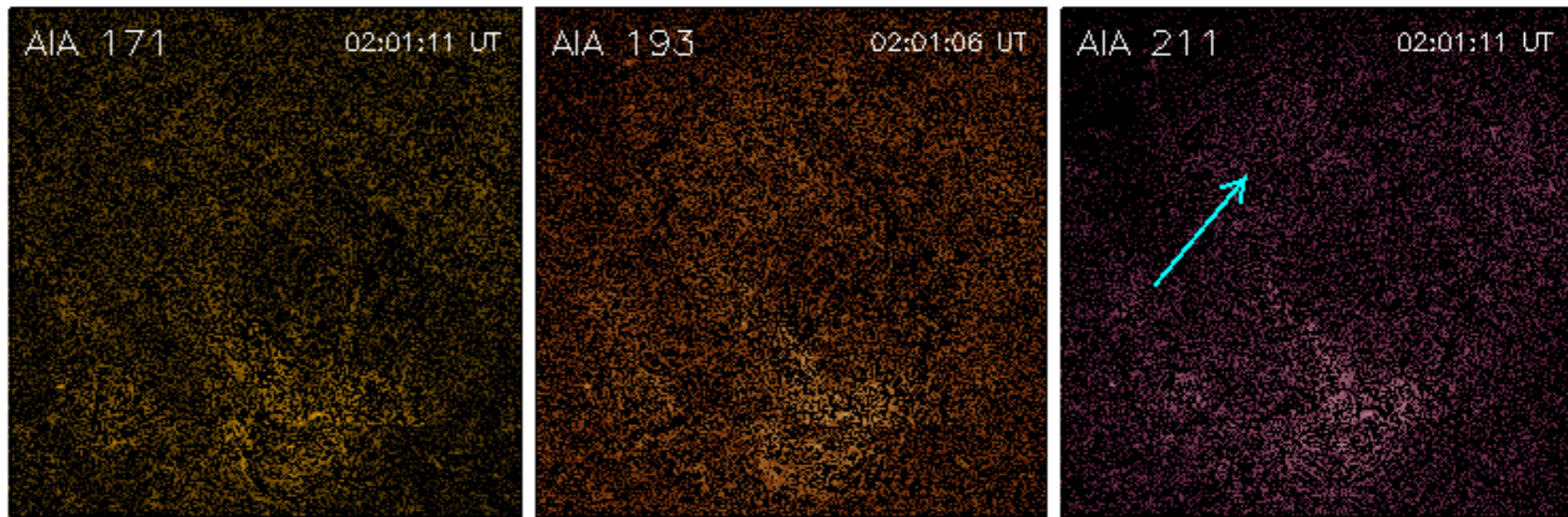


# flaring features

- helical structures at AIA 193 and 211
- X-type magnetic reconnection at 171



# rise and eruption of magnetic flux rope



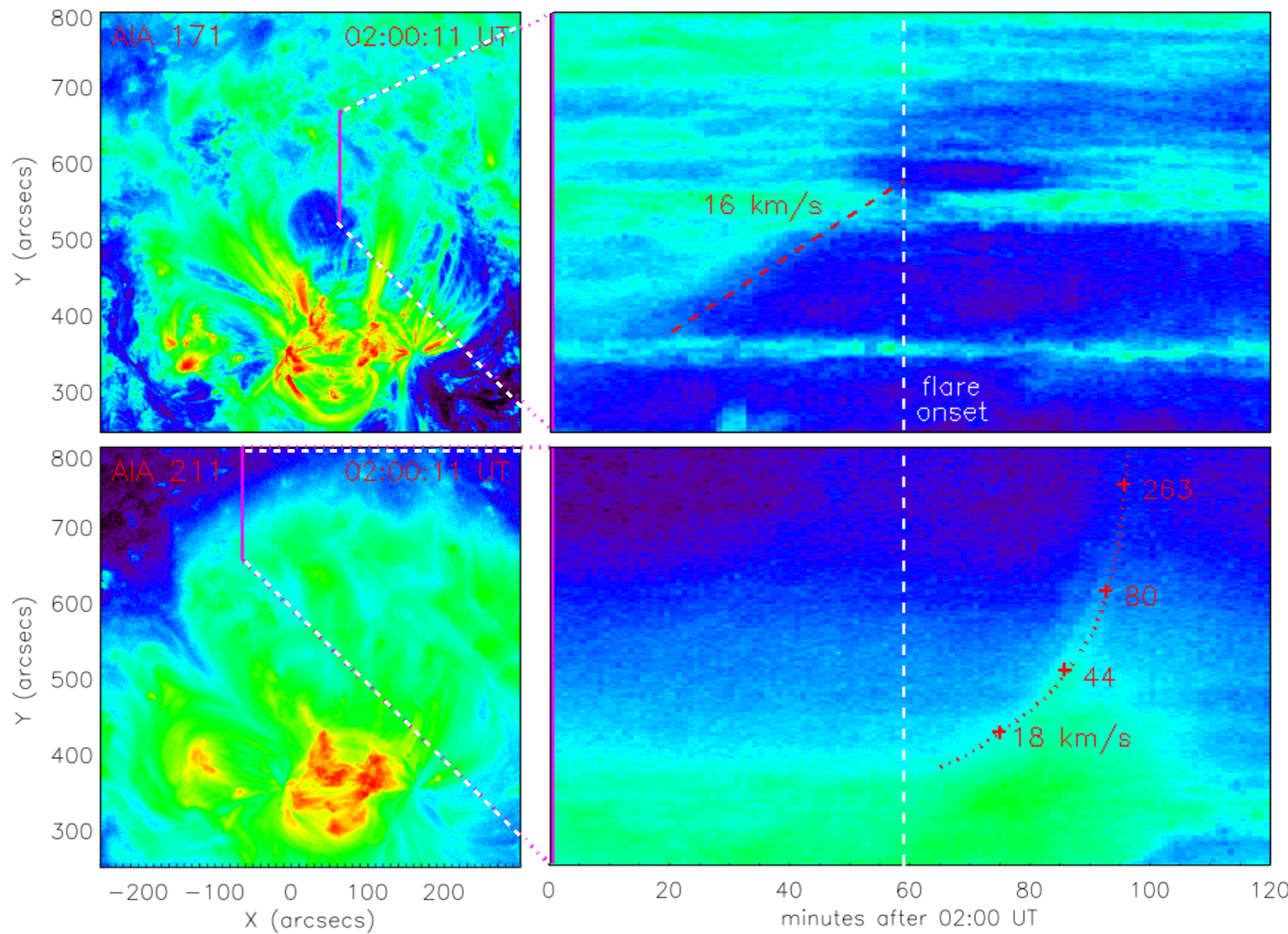
## two stages:

(before/after flare onset)

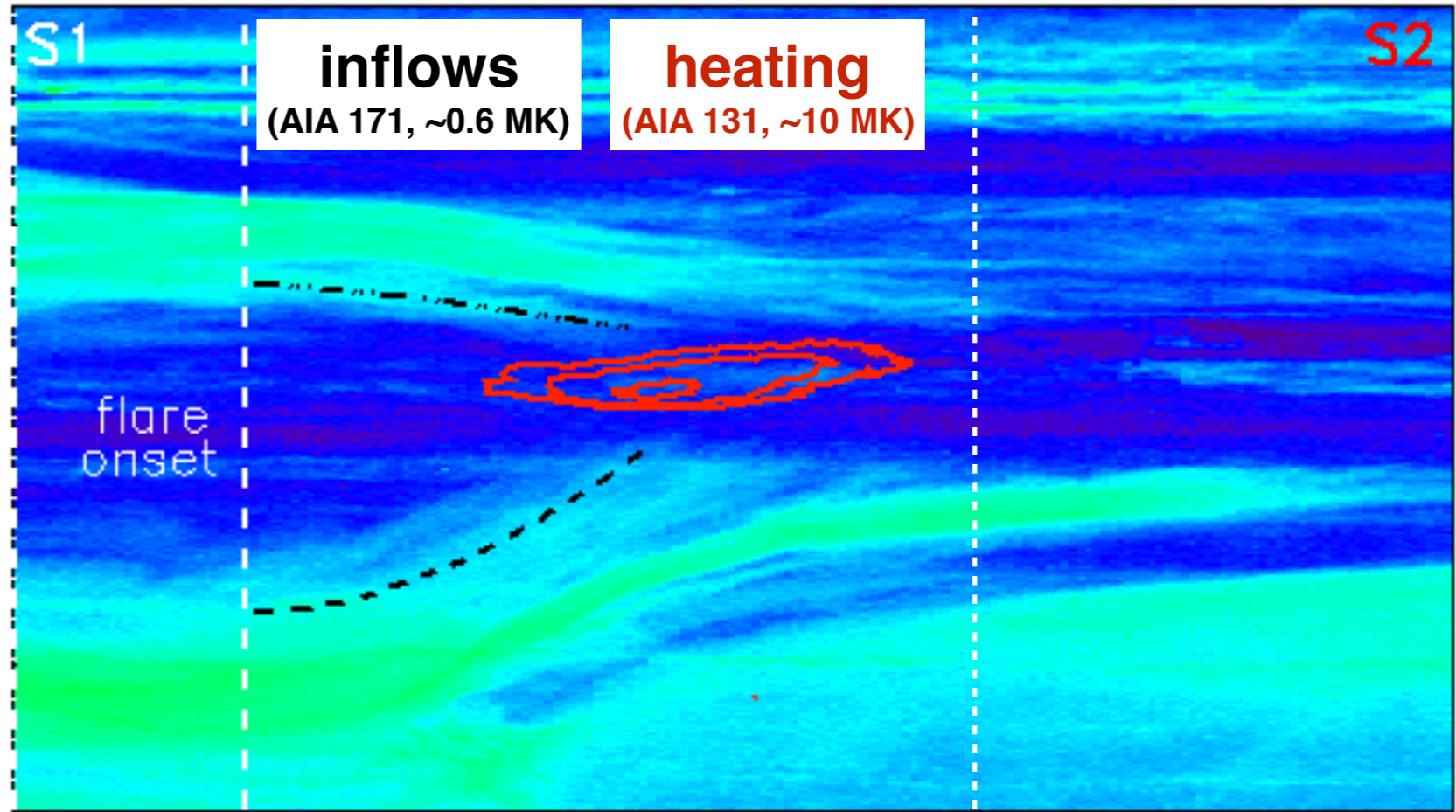
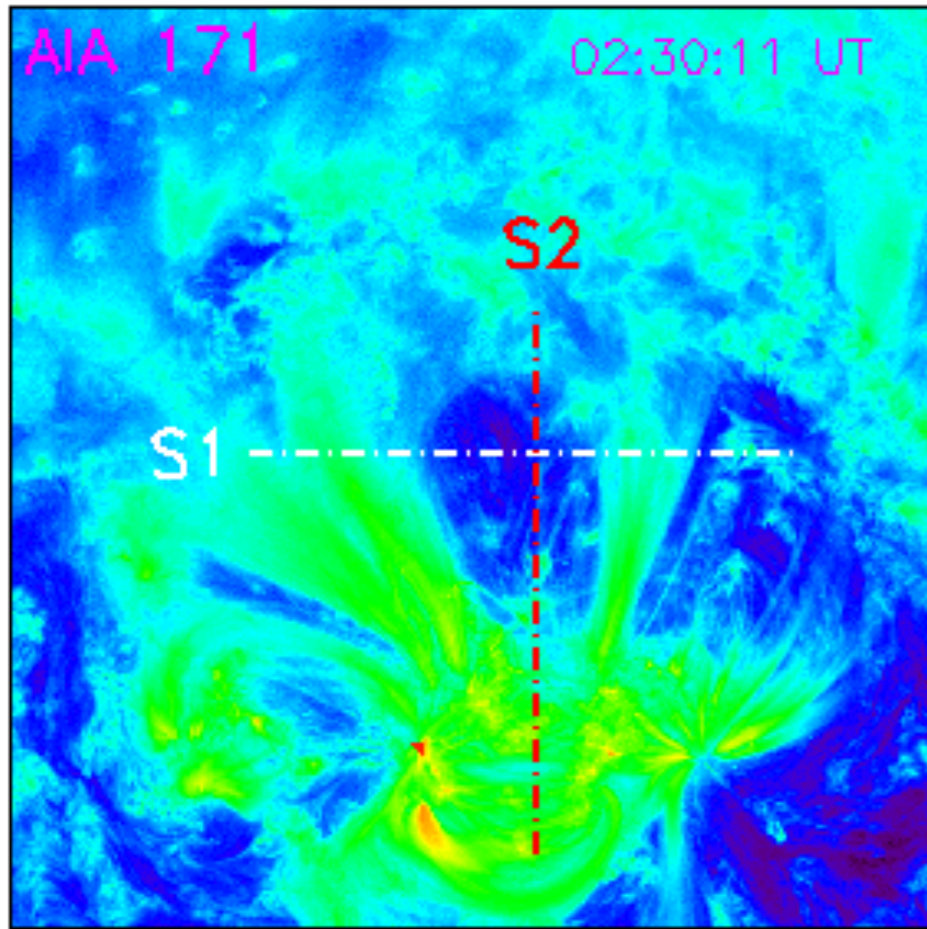
- slow rise

( $\sim 36$  Mm  $\rightarrow$   $\sim 75$  Mm;  
torus instability  $\sim 60$  Mm)

- acceleration  
(or eruption)



# solid evidence for **magnetic reconnection**



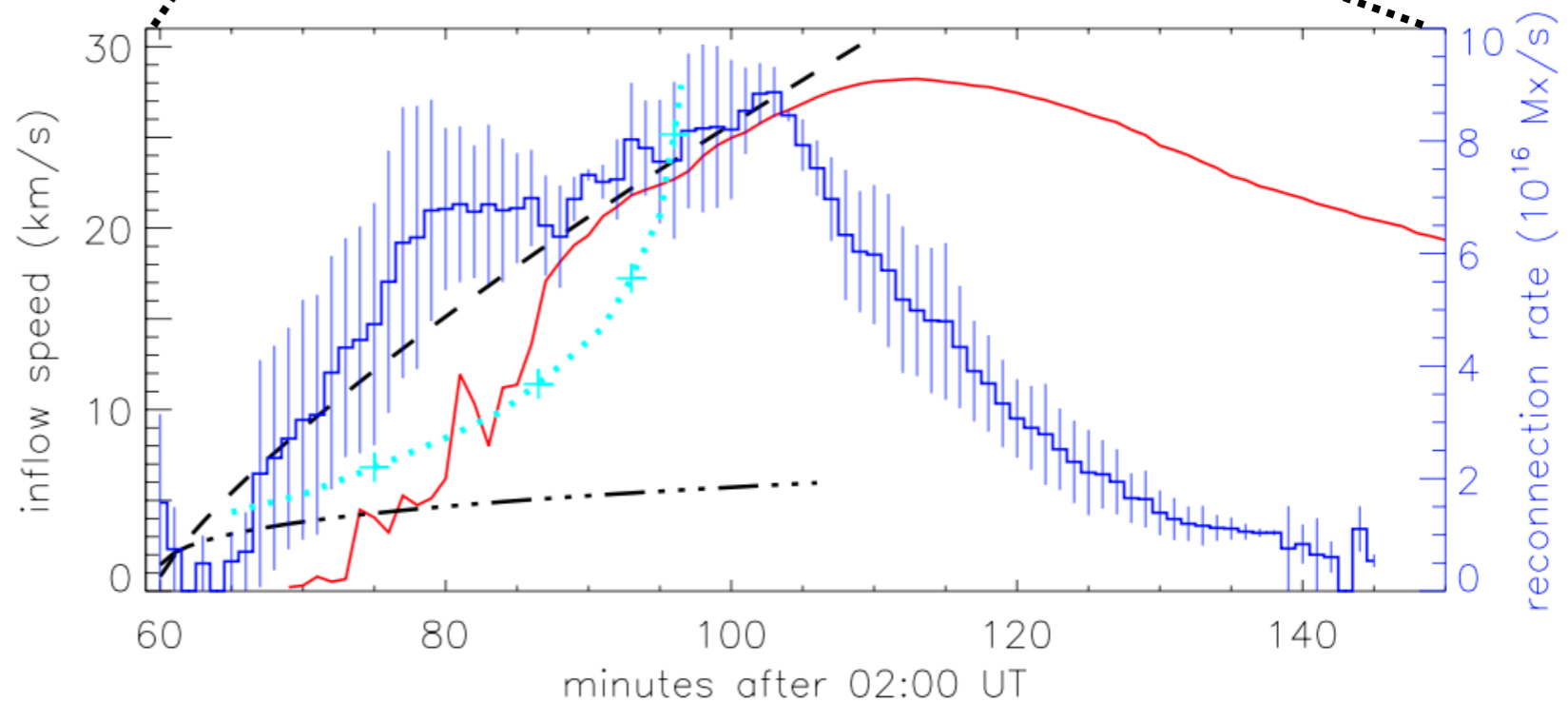
inflow speeds:

~5-30 km/s

reconnection flux rate:

~ $9 \times 10^{16}$  Mx/s

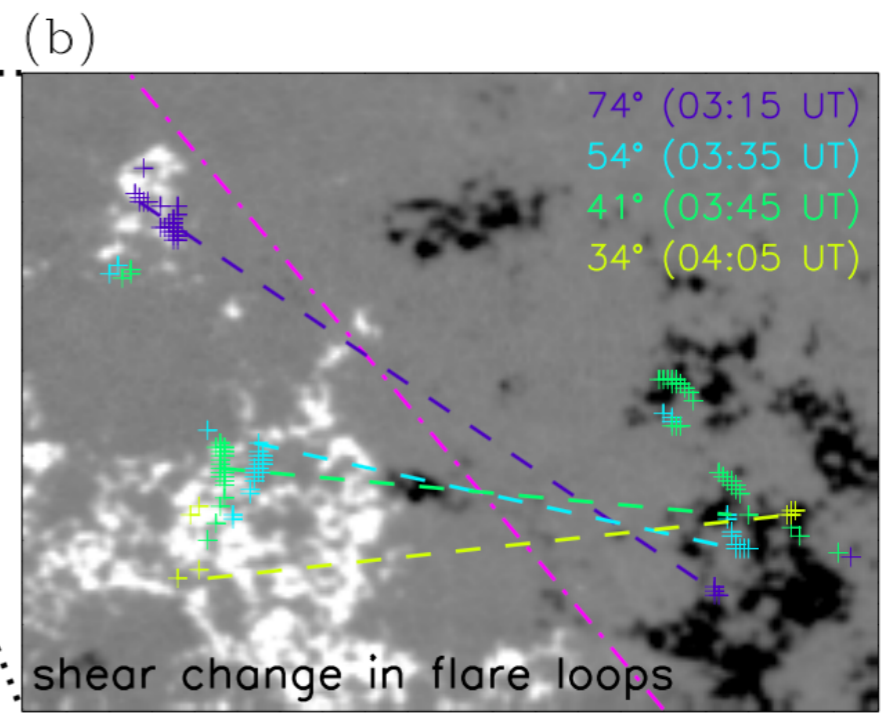
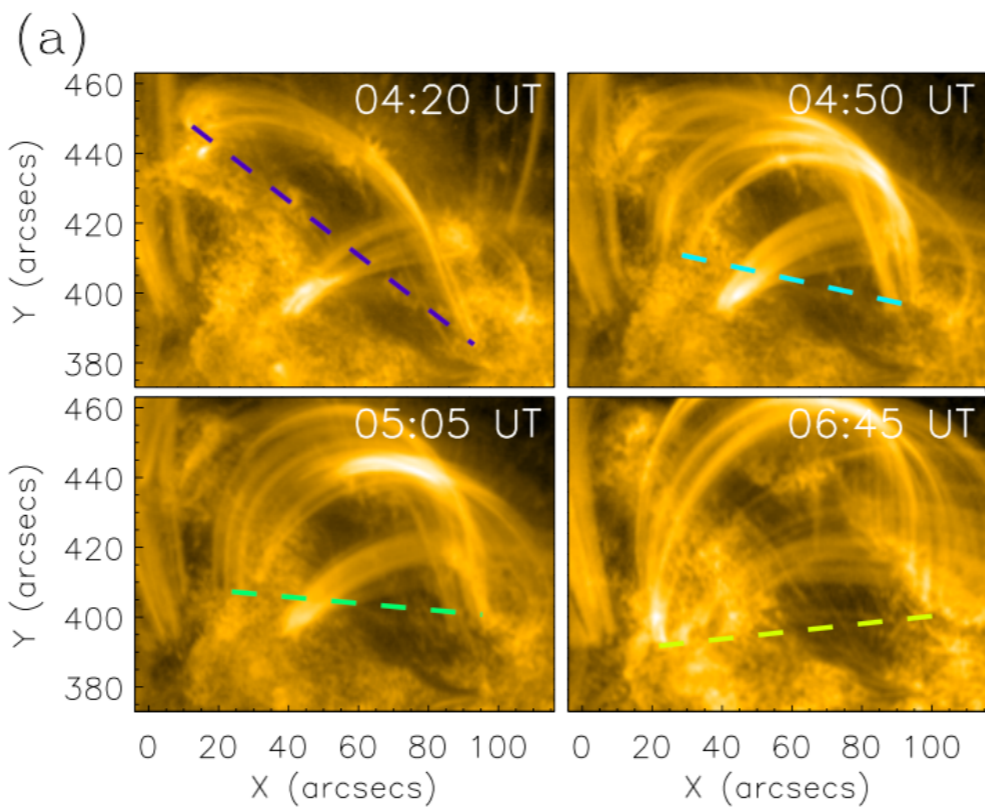
correlated with hot emission  
(& flux rope acceleration)



# evolution of flare loops & two ribbons

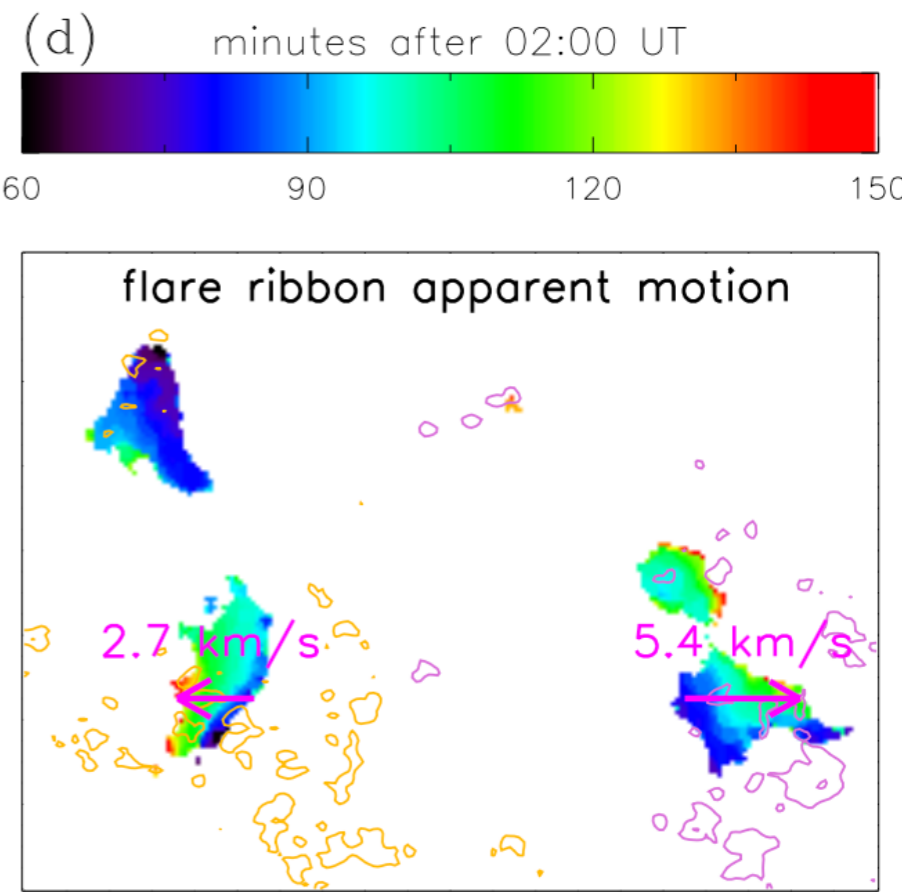
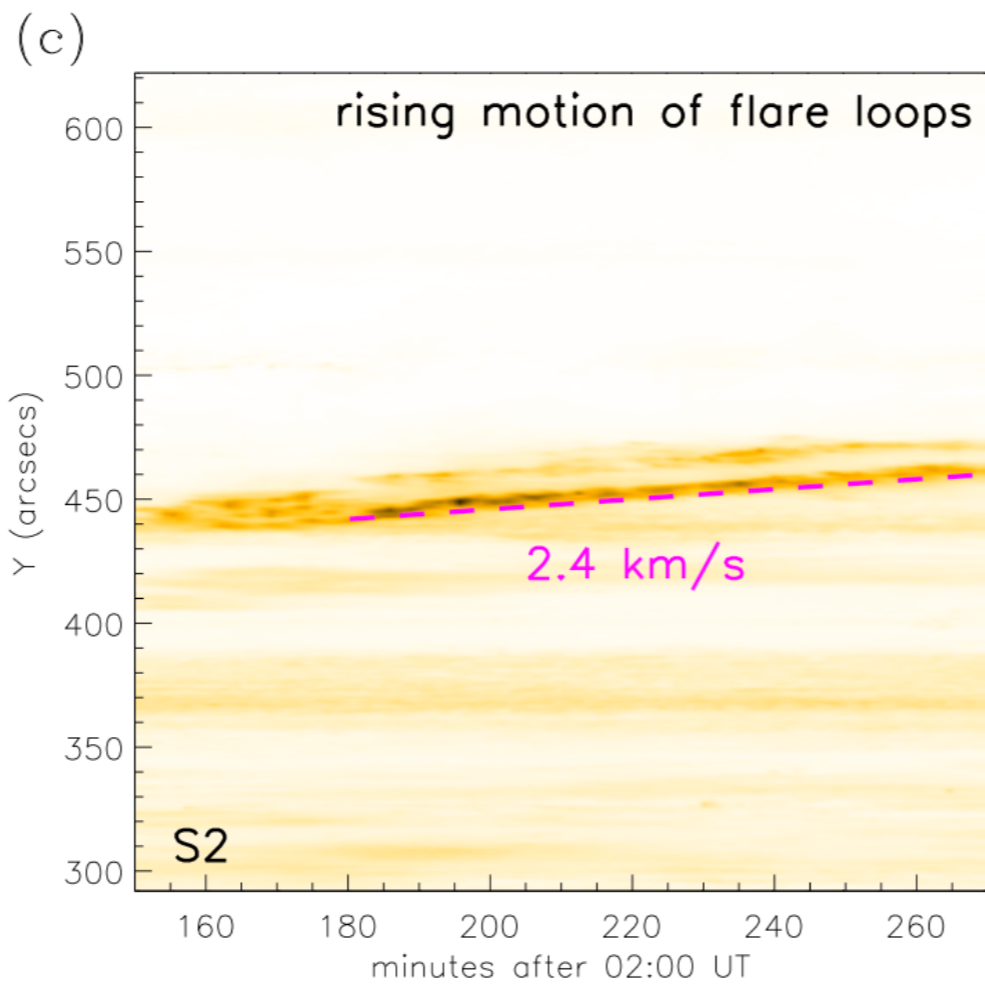
**strong-to-weak  
shear transition**

**shearing  
(3D-type)**



**apparent rising  
separating**

**(2D-like)**



# Summary

We have presented **a comprehensive set of observations** for an eruptive flare.

The SDO/AIA images exhibit **clear rise and eruption of an MFR**, and **solid evidence for magnetic reconnection** in different phases from both corona and chromosphere.

**Weak reconnection starts before the flare onset.** It may help the MFR to rise slowly.

Strong reconnection occurs in the rise phase. The reconnection rate grows with the MFR acceleration, shown as increasing inflow speeds and hot emissions.

The flare loops show mostly a strong-to-weak shear variation in the early phase, while they mainly show an apparent rising motion in the later phase: 3D to 2D reconnection.

The joint effect of **magnetic reconnection** and **torus instability of the MFR** likely leads to the final eruption of the event.

**The End!**

**Thanks for your attention!**