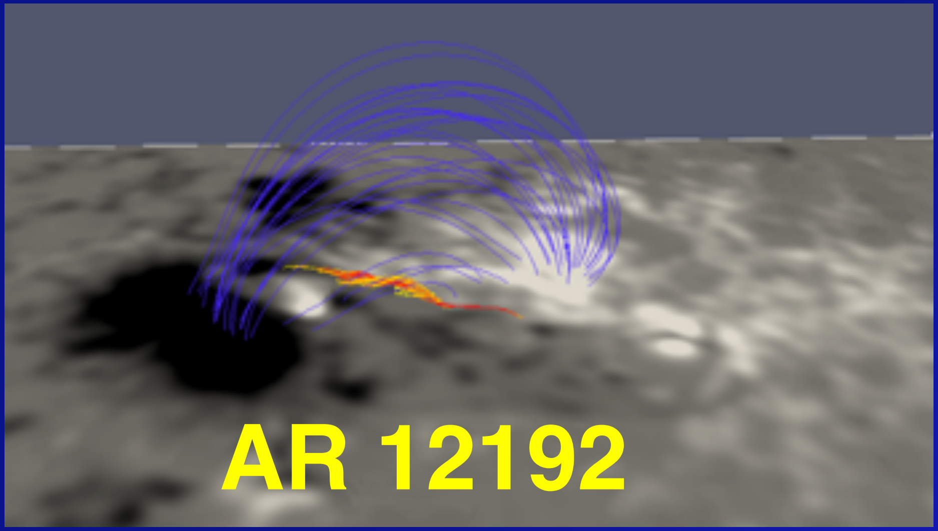
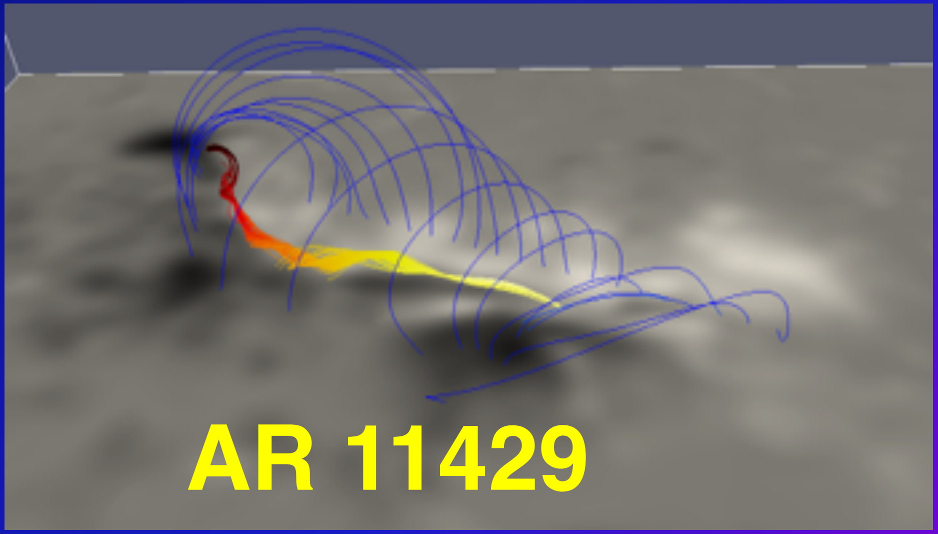
VarSITI Symposium June 06-10, 2016 Albena, Bulgaria

A Tale of Two Super-Active Active Regions: On the magnetic Origin of Flares and CMEs





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“The big-event syndrome”

- For example, Carrington event in 1859, Halloween event in 2003

- Large sunspot, big flare, fast CME
- Fast IP shock, large SEP, strong magnetic cloud
- Intense geomagnetic storm, low-latitude aurora, long-lasting radiation belt storm, ionospheric storm and many other disturbances
- Society consequences, e.g., satellite operation, communication and navigation etc

The Problem?

However, AR 12192, the largest sunspot group in solar cycle 23 and 24, was nearly CME-less, and there was no space weather consequence

Probably the most upset false-alarming in modern space weather prediction!

Why the peculiarity of AR 12192?

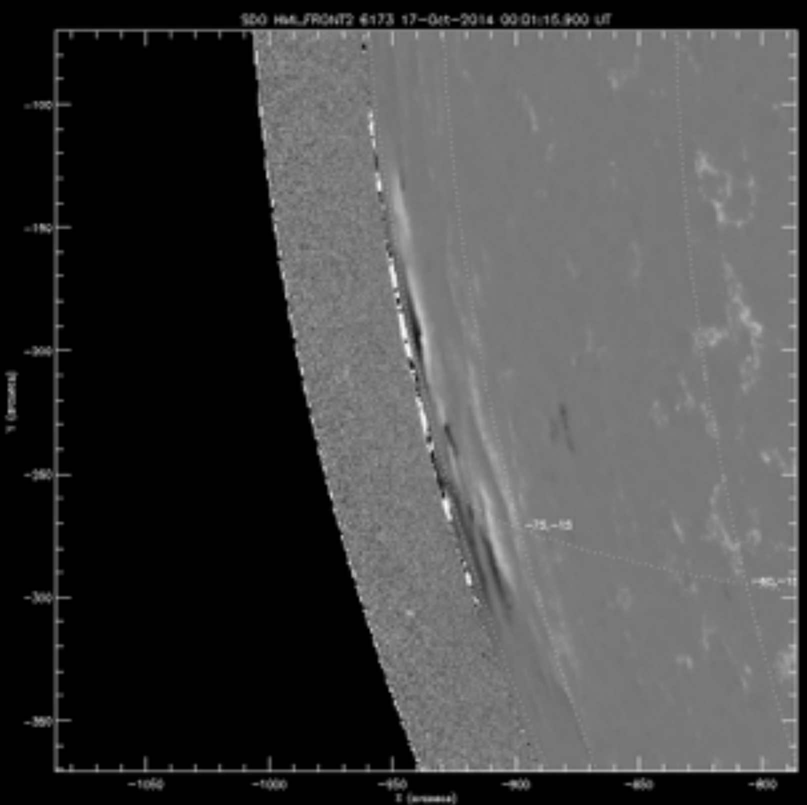
A Tale of Two ARs

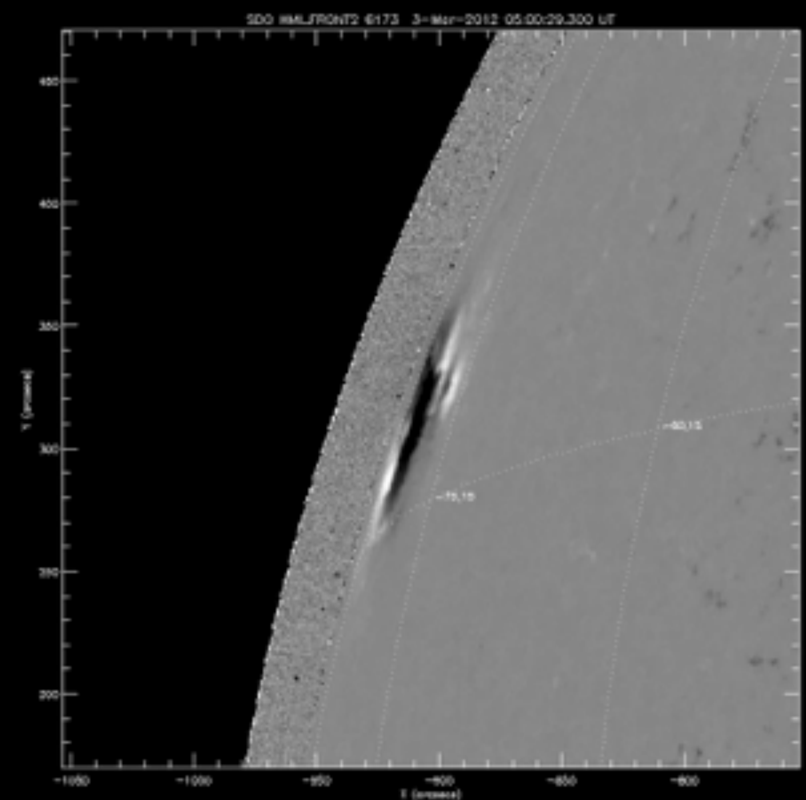
AR 12192 (October 2014) and AR 11429 (March 2012) are both super active in terms of producing multiple X-class solar flares.

However, AR 12192 had no CME, while AR 11429 was CME-rich

AR 12192 studies (Sun et al. 2015; Thalmann et al, 2015; Chen et al. 2015).

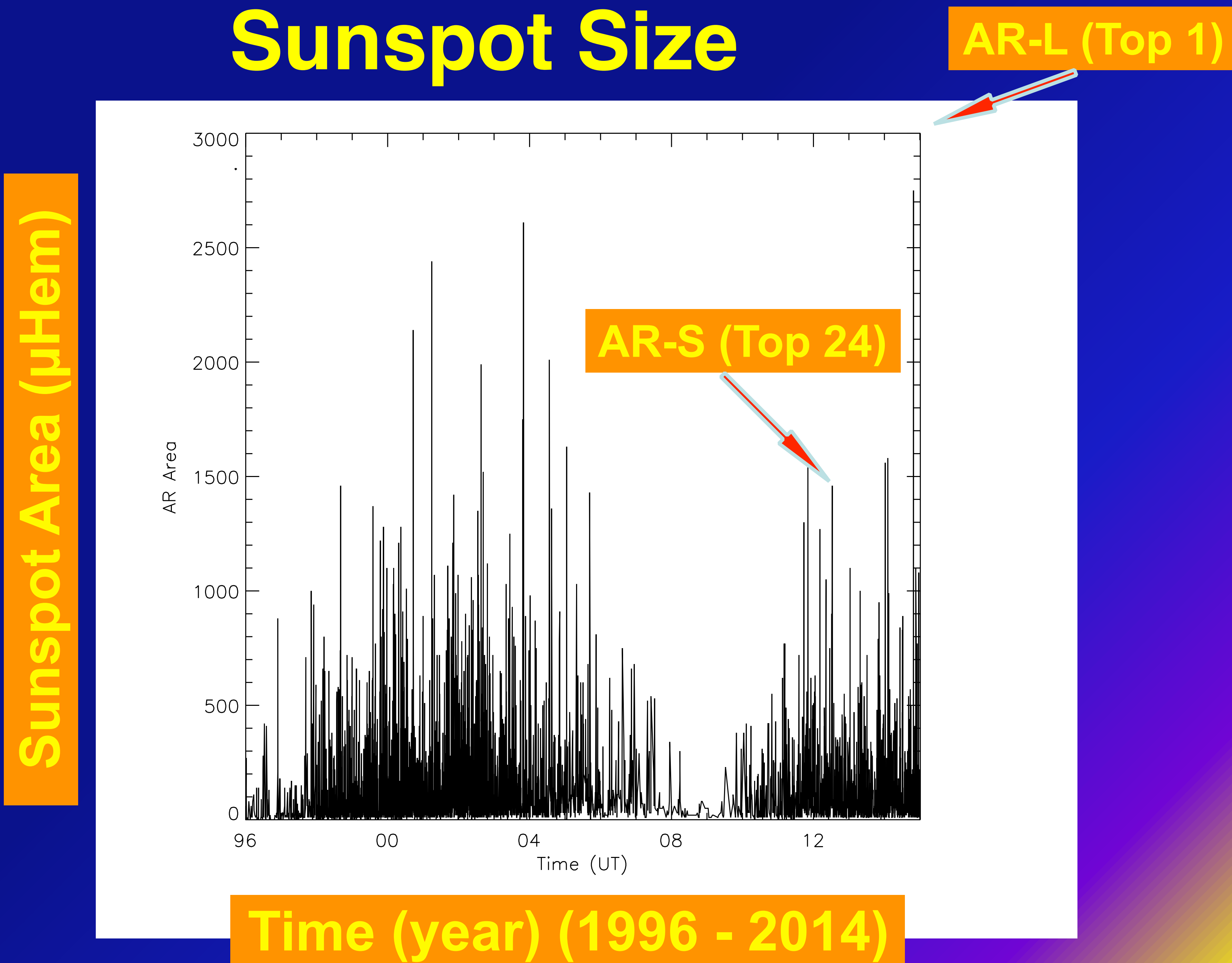
Photospheric Magnetogram



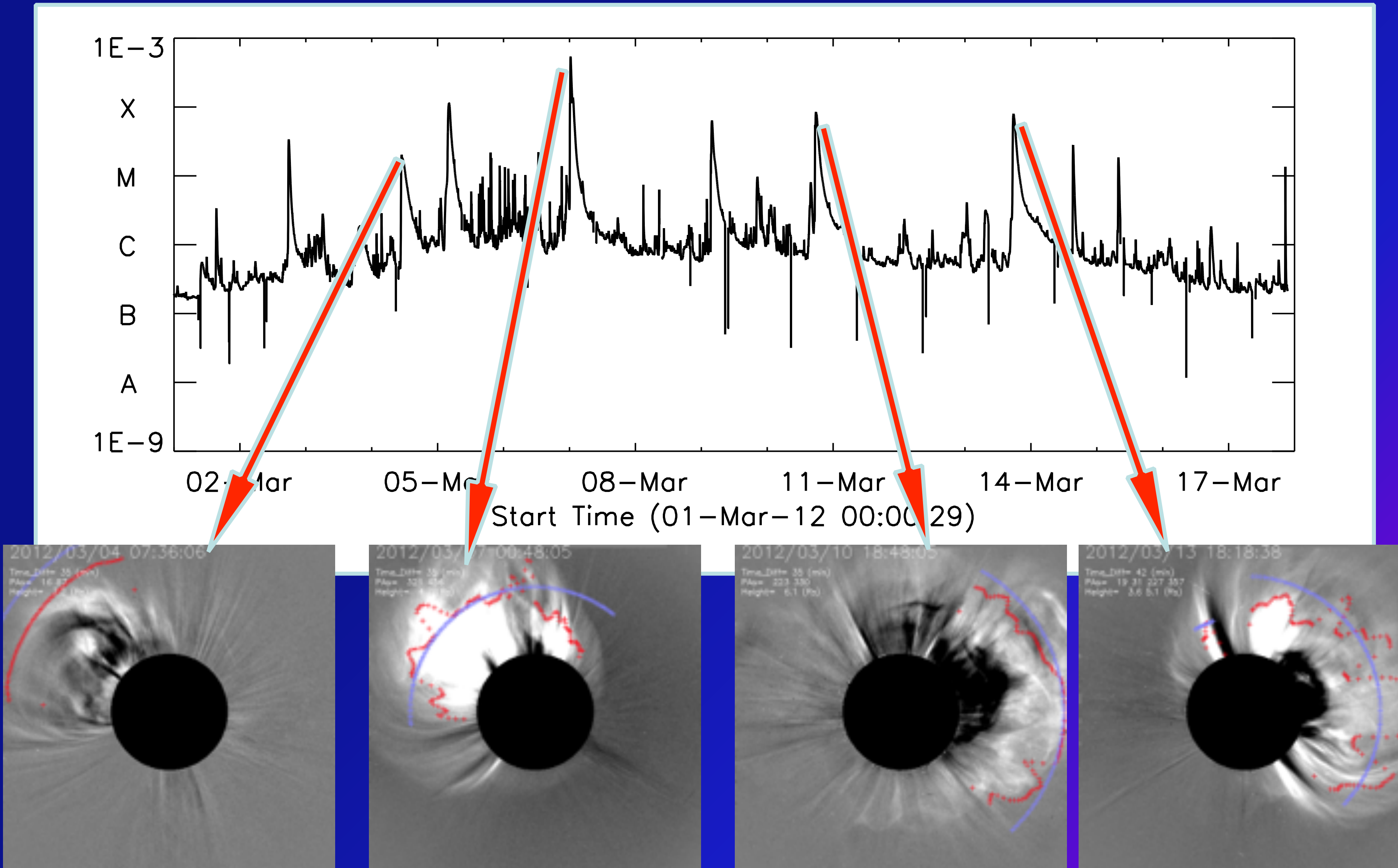


AR 12192 (L) **AR 11429 (S)**

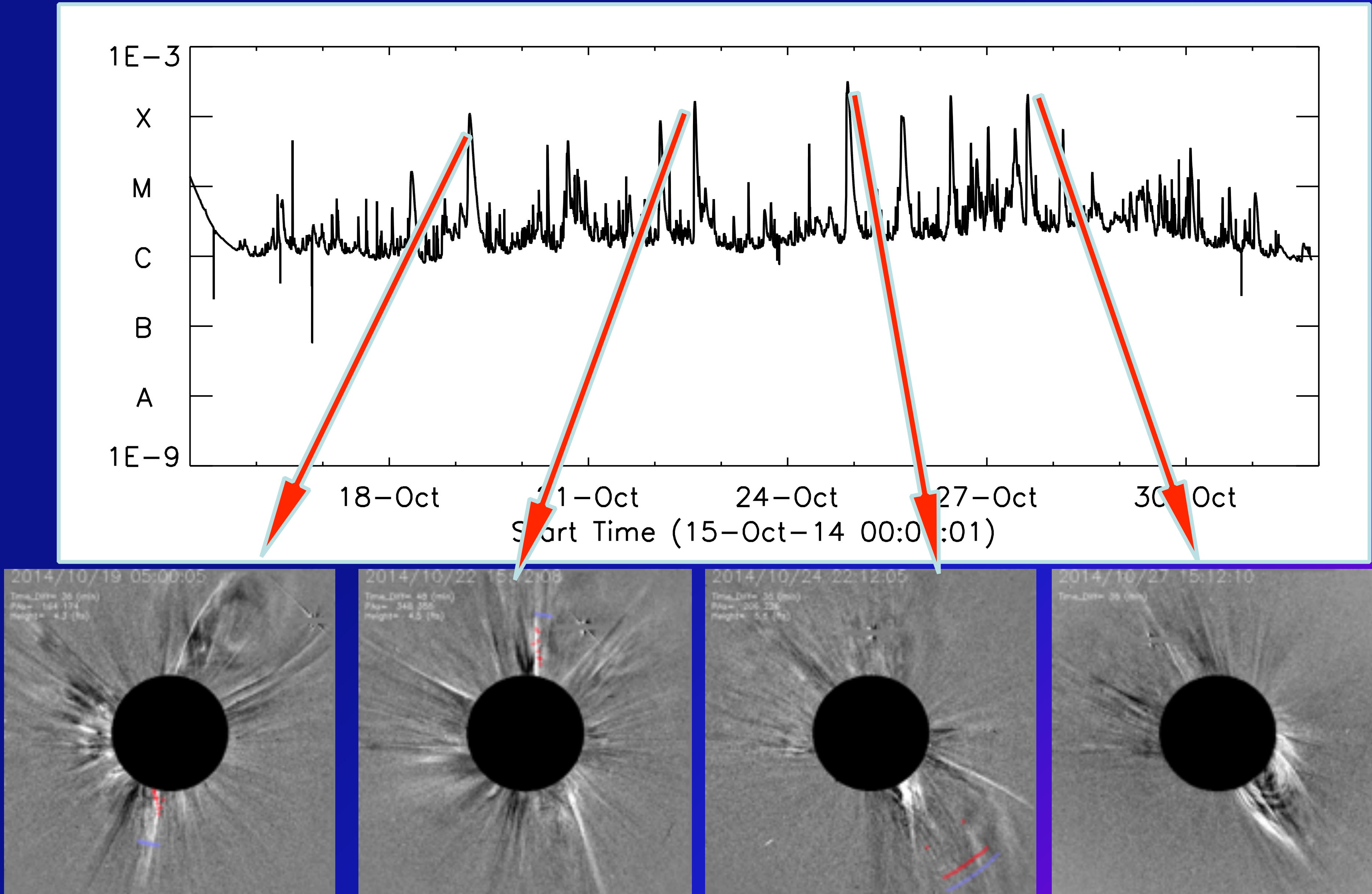
Sunspot Size



Flare - CME Activity (AR-S)



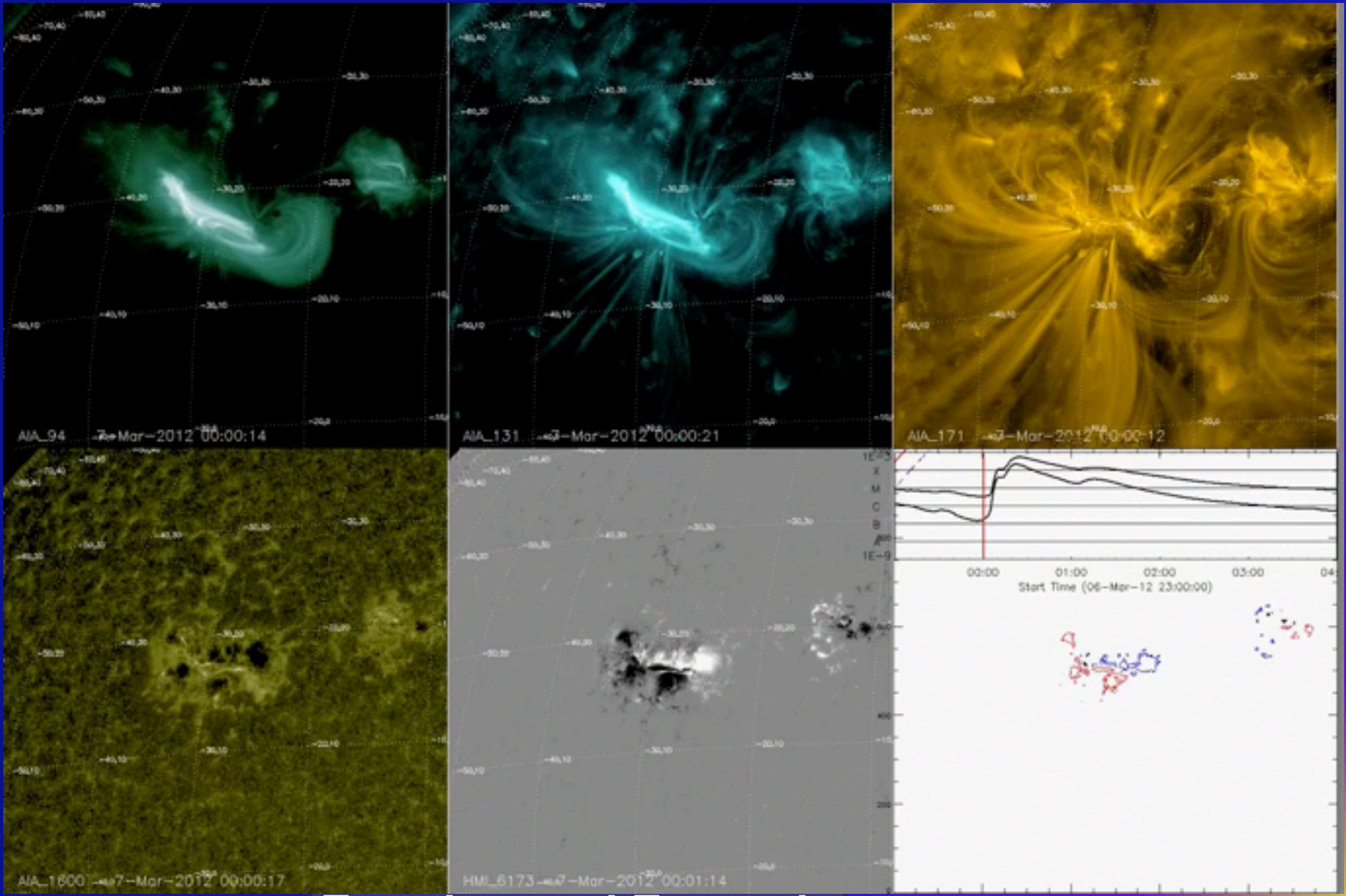
Flare - CME Activity (AR-L)



AR-L (12192) and AR-S (11429)

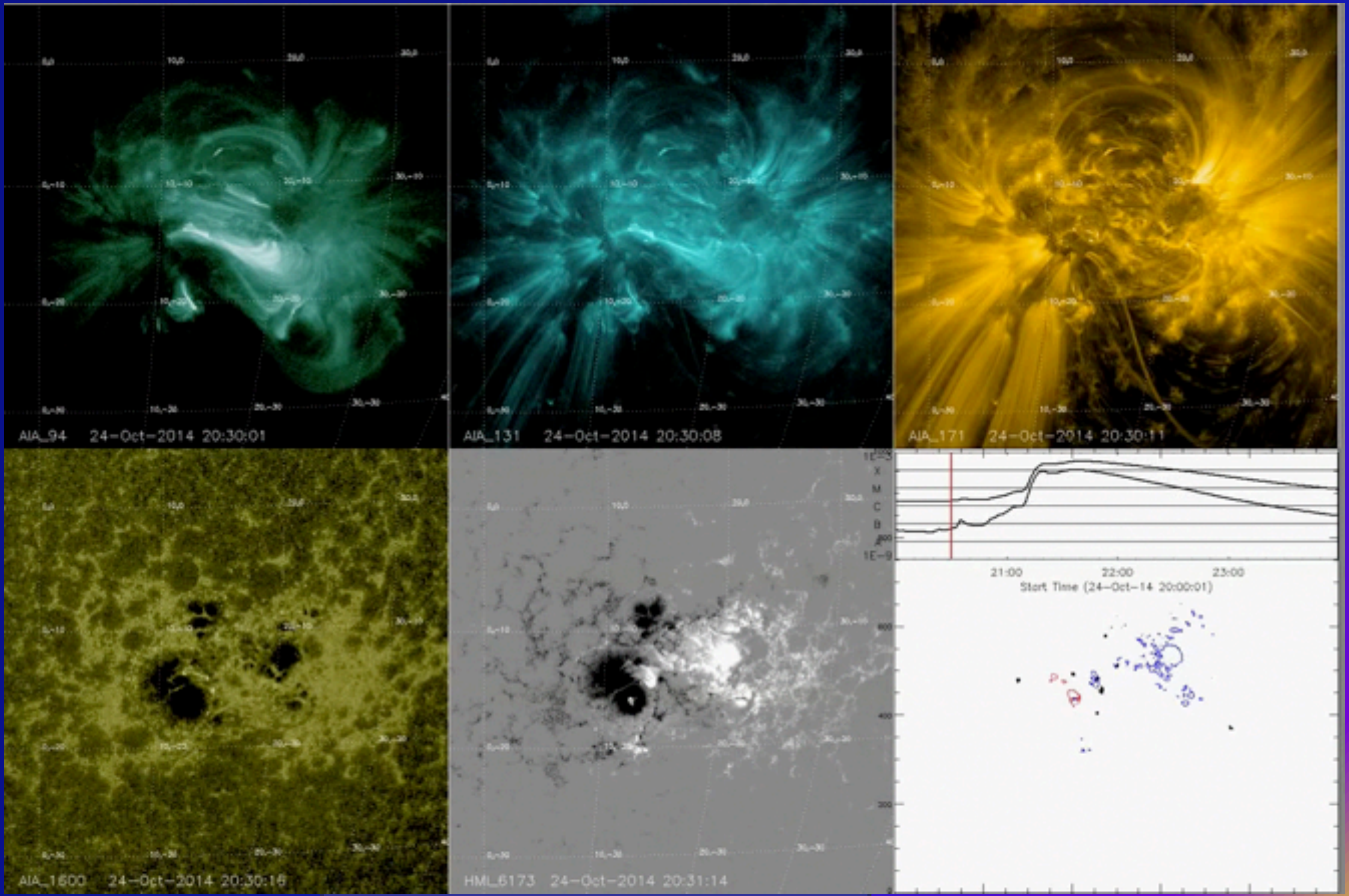
	AR 12192	AR 11429
Sunspot Size (μHem)	*2750 (Top 1)*	*1270 (Top 24)*
Flare (X/M/C)	*6 / 30 / 93*	*3 / 15 /47*
Flare Index (M1=1, X1 = 10)	*137 (Top 8)*	*92 (Top 20)*
CME	*1 (not from core)*	*9*

AR-S: 2012/03/07 X5.4 flare



Eruptive, and Erupted

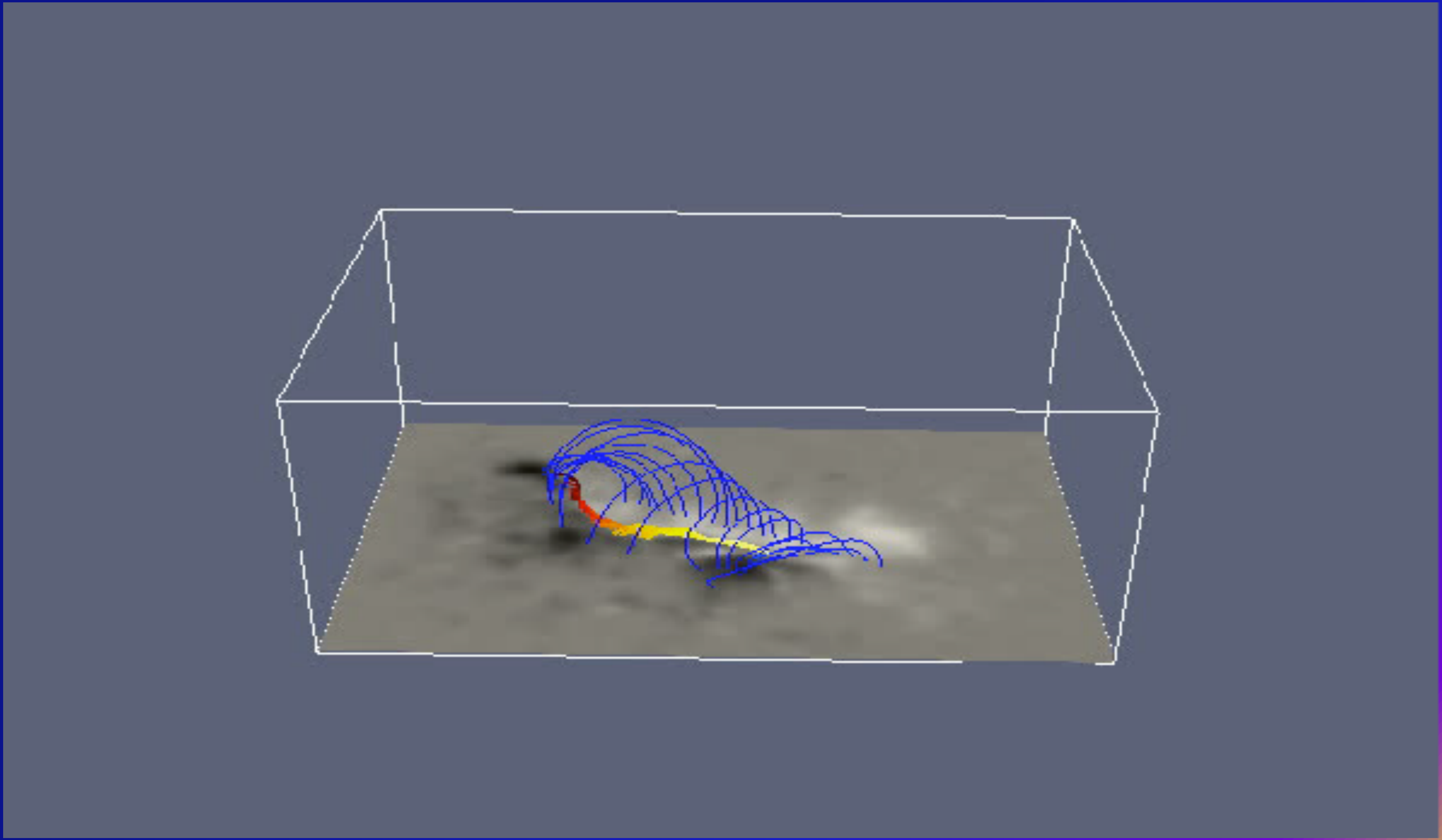
AR-L: 2014/10/24 X3.1 flare



Eruptive, but failed !

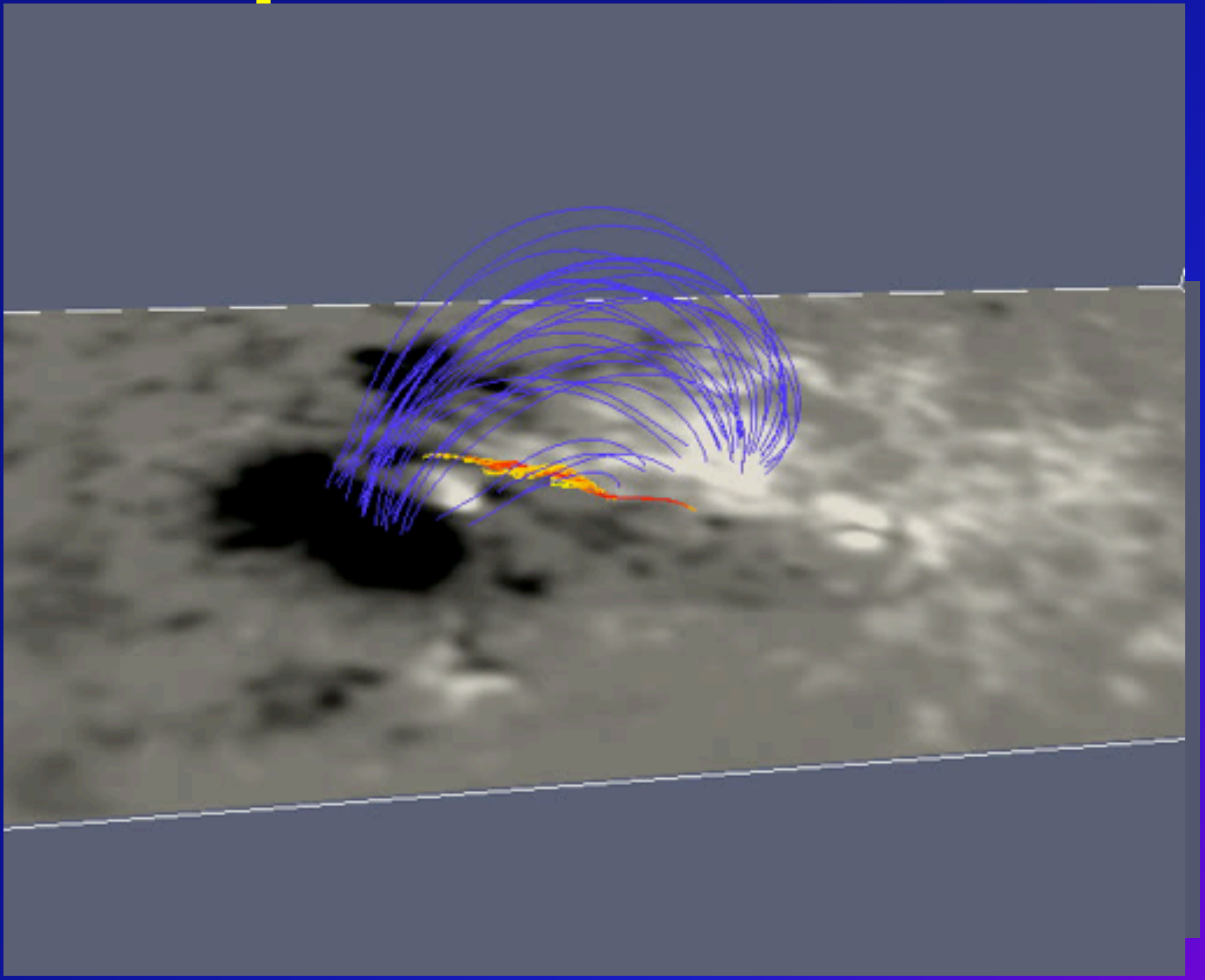
Why the peculiarity?

Photospheric and Coronal B



AR-S 11429

Photospheric and Coronal B

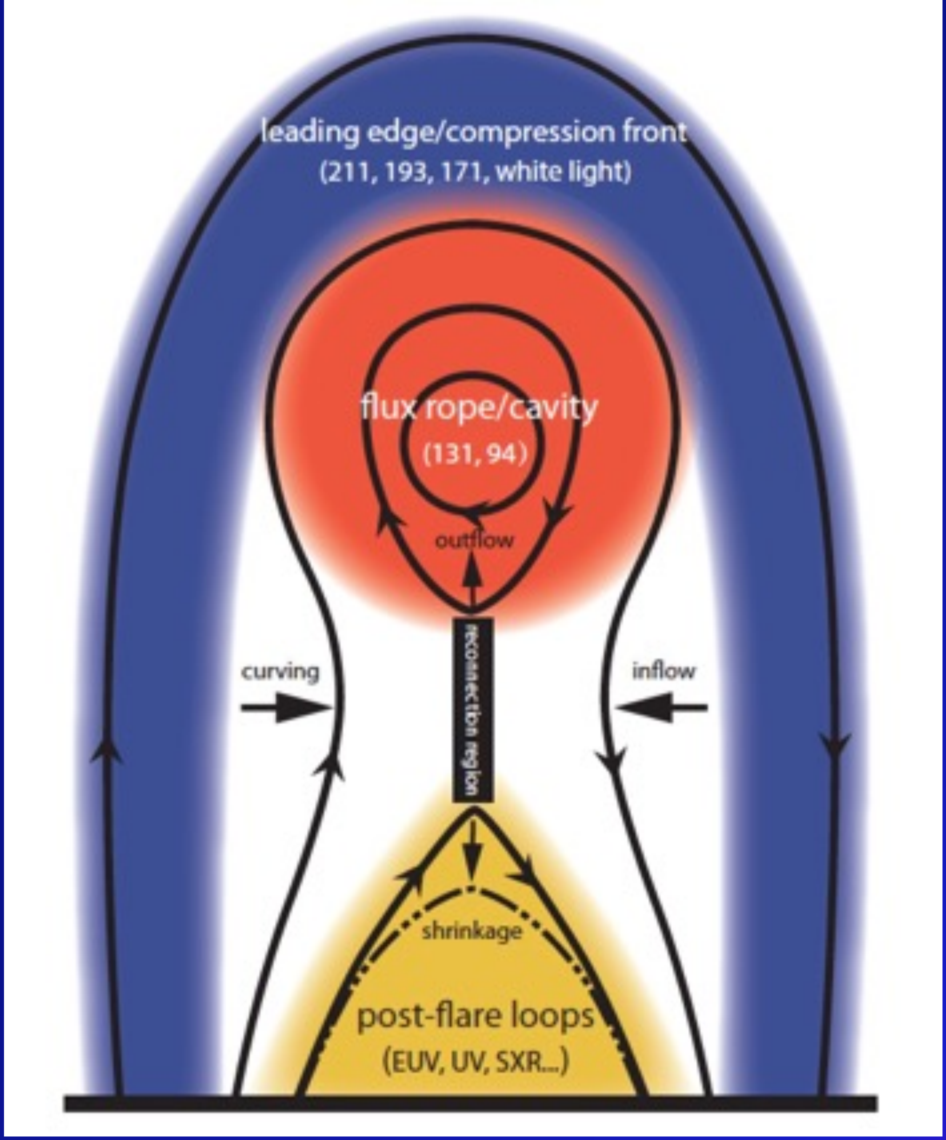


AR-L 12192

Magnetic Parameters

	AR 12192 (L)	AR11429 (S)	Ratio
Total Unsigned Flux (Mx)	16.1×10^{22}	5.1×10^{22}	3.2
Total B Energy (ergs)	13.2×10^{33}	2.3×10^{33}	5.7
log R (Schrijver 2007)	5.3	5.2	1.0
Free B Energy (ergs) (free/total %)	2.4×10^{22} (1.8%)	3.4×10^{22} (14.8%)	0.7
Flux-Height Ratio (<36Mm / >36 Mm)	2.2	4.7	0.5
Current Helicity (G^2 m^{-1}) (Sun et al. 2015)	0.72	6.74	0.1

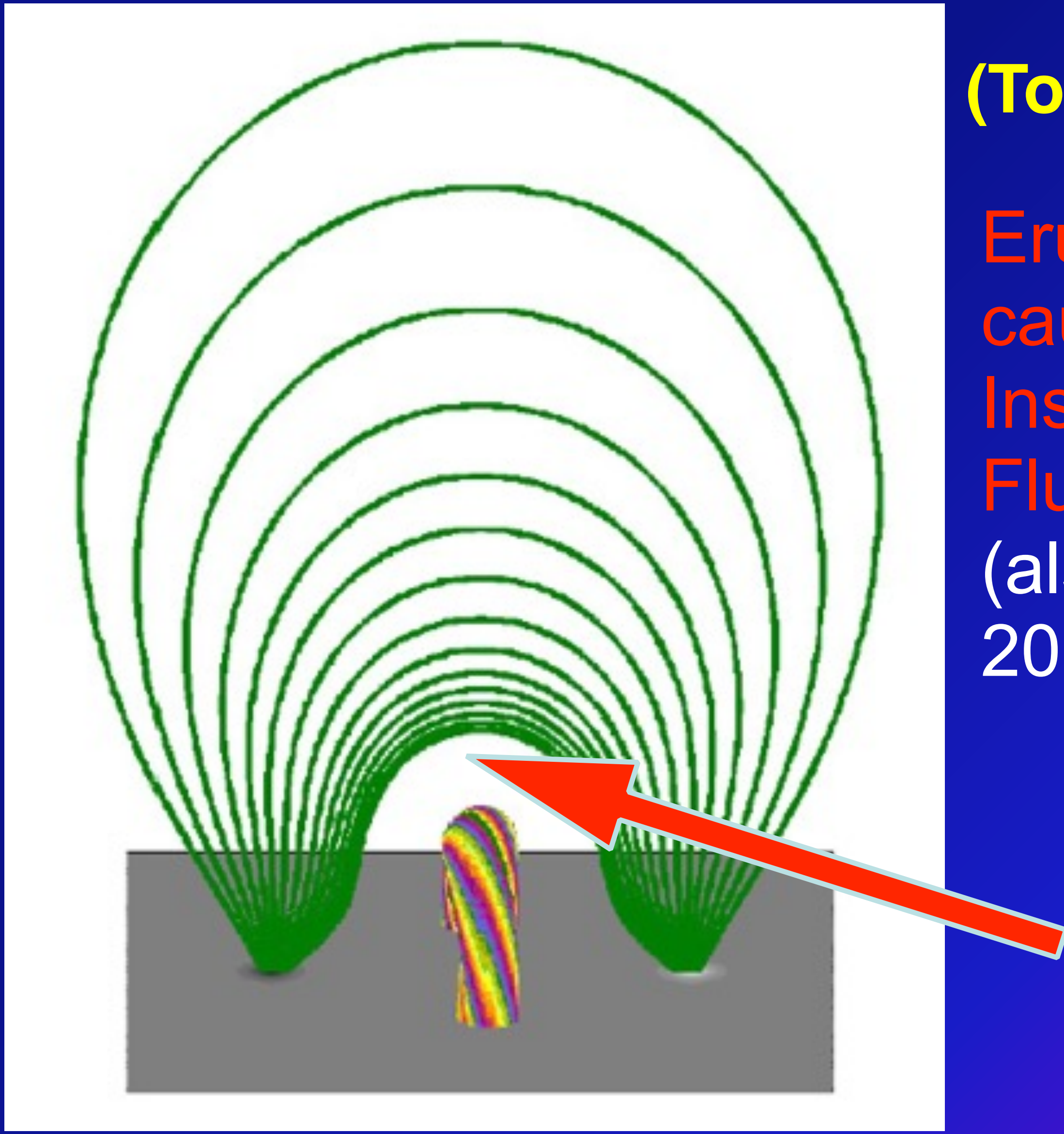
Mechanism of Solar Eruptions



(Cheng et al. 2011)

Flare is caused by magnetic reconnection in a current sheet underneath the erupting magnetic flux rope
(ref. classical CSHKP model, Priest & Forbes 2002).
However, why failed eruption?

Mechanism of Solar Eruptions



(Torok & Kliem 2007)

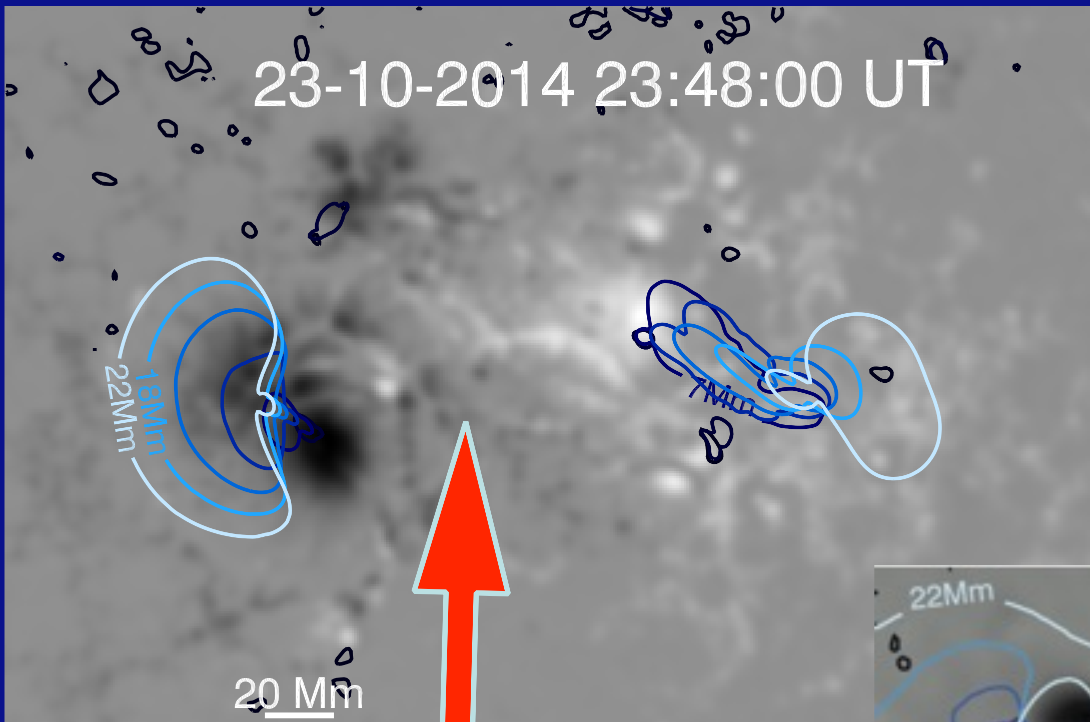
Eruption or CME is caused by the Torus Instability of Magnetic Flux Rope

(also Olmedo & Zhang 2010)

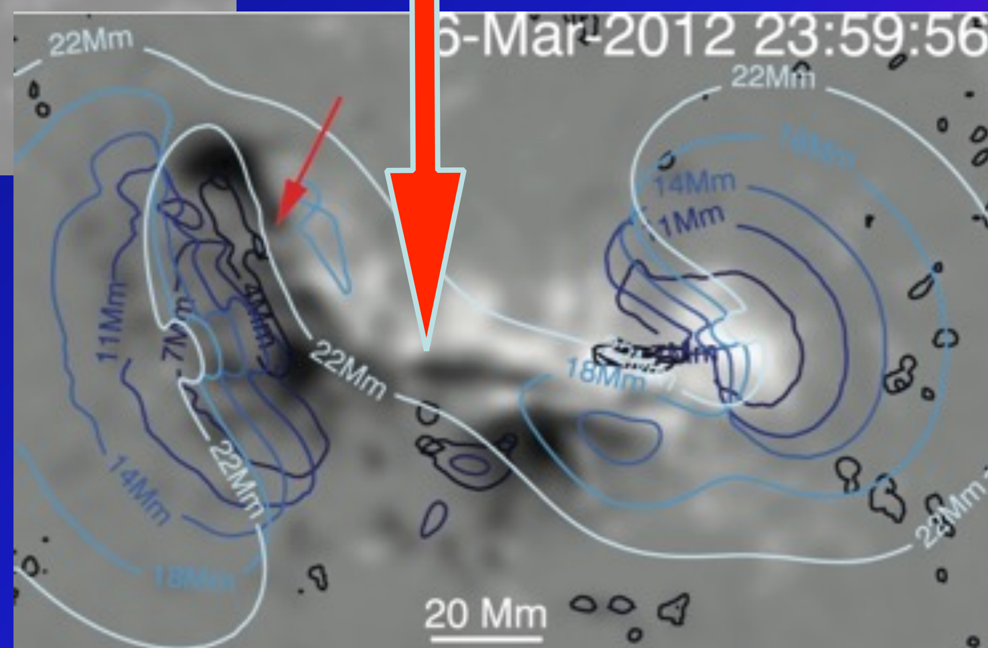
$$\frac{d \ln B_s}{d \ln Z} \geq n_{critical}$$

$$n_{critical} \approx 1.5$$

Magnetic Decay Index n_{crit}



Erupting magnetic flux rope can reach the critical height



Erupting magnetic flux rope could not reach the critical height

Conclusion

The peculiarity of the failed eruption of large solar flares in AR 12192 is caused by an excessive amount of magnetic flux in the high corona, thanks to the large-separation strong bipolar configuration. Torus instability of magnetic flux rope was not realized during the magnetic reconnection for the events in the AR.

Discussion

1. CME prediction is more difficult than flare prediction: quantitative coronal magnetic field needs to be known, by extrapolation or ideally by direct measurement in the future

2. Other types of peculiarities (Nitta; Temmer talks)
   - Stealth CME
   - Problem ICME

3. Better understanding is still needed for realistic space weather prediction starting from the Sun

Thanks