The Eruption from a Sigmoid Active Region on 2005 May 13

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SHINE 2006, Zermatt, Utah

Motivation

- Major event: 2B/M8.0 long duration flare with a fast halo CME and an intense geomagnetic storm.

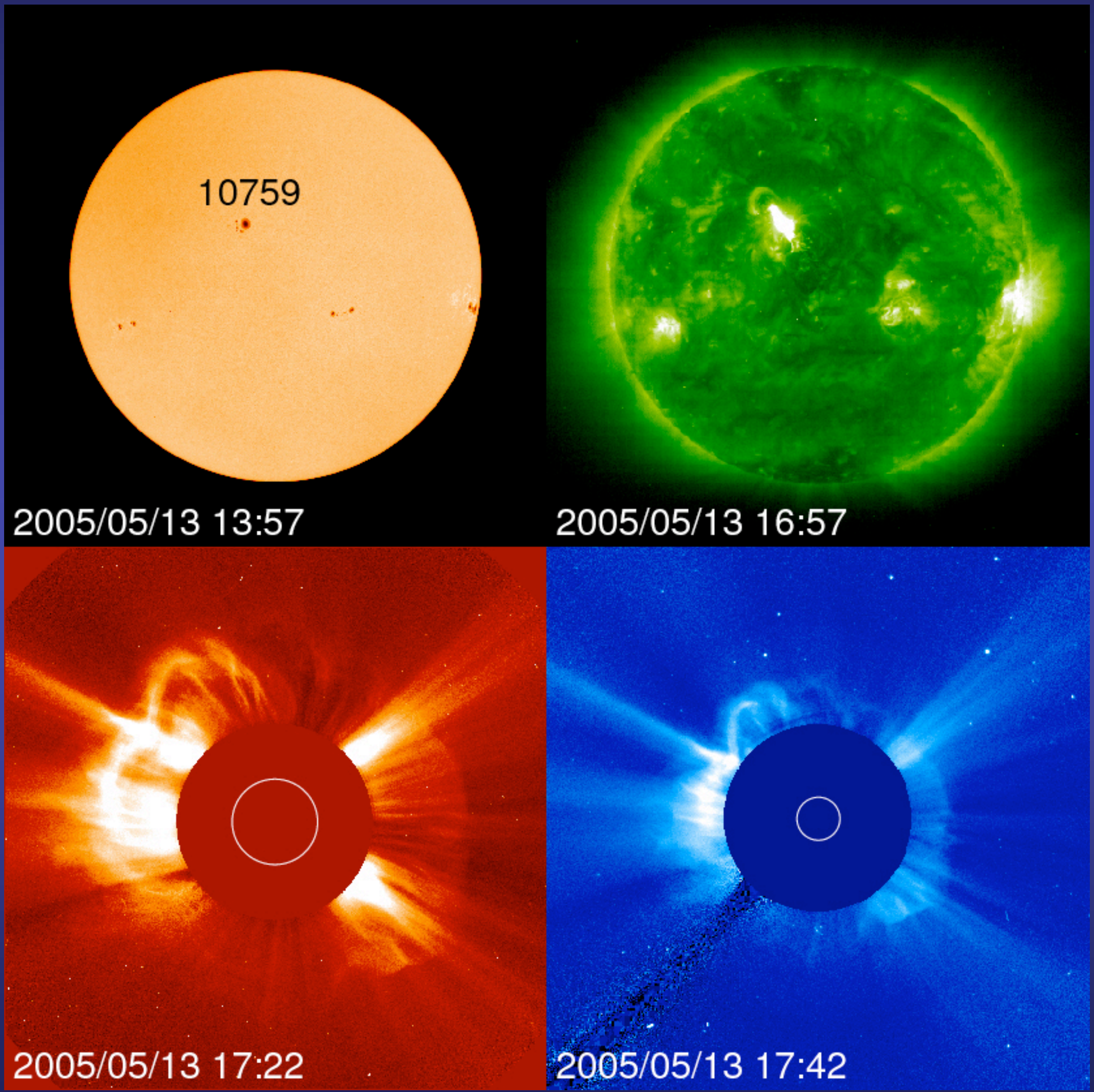
- Many characteristics of this event (e.g., position, magnetic configuration, sigmoidal appearance, flare duration, coronal dimming, and association with a CME and ICME) are strikingly similar to those of the well-studied 1997 May 12 eruption (one of the ***SHINE campaign events***), with more key data available. It is therefore essential to continue these focused, event oriented ***SHINE*** studies.

This talk concentrates on the solar properties of the CME and related phenomena (one of the ***SHINE*** goals), while another effort (V. Yurchyshyn, C. Liu, V. Abramenko, and J. Krall 2006, SolPhys, in revision) is being made in simulating the CME and ICME using EFR model that provides a good match to the observed MC.

What's in this talk

- Data sources
- Evolution of sigmoidal fields
  1. background 2. Obs. In TRACE 3. Obs. In GOES/SXI
- Flare core emission
  1. TRACE 1600A ribbon 2. RHESSI hard X-ray sources
- Large-scale activities
  1. Type II radio burst and precursor
  2. Moreton wave
  3. Coronal dimming
  4. CME
- Height-time analysis and conclusion

Event Data



BBSO:
1"/pix fulldisk Hα, 0".6/pix hi-res Hα, 0".6/pix vector magnetograms, 0".6/pix hi-res Ca IIK with 1-min cadence

OSPAN:
1"/pix fulldisk Hα and wings (± 0.4 Å) with 1-min cadence

TRACE:
1600 Å with 3-sec cadence, 171 Å before and after flare

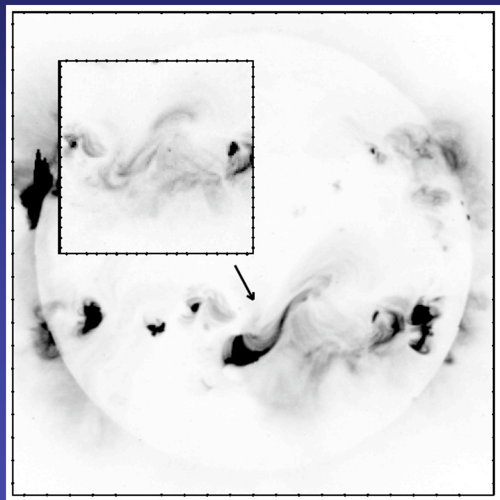
GOES12-SXI:
5"/pix P_THN_B SXR with 1-3 min cadence

RHESSI

SOHO/EIT, LASCO, MDI

OVSA, Phoenix, Potsdam, GBSRBS, WIND

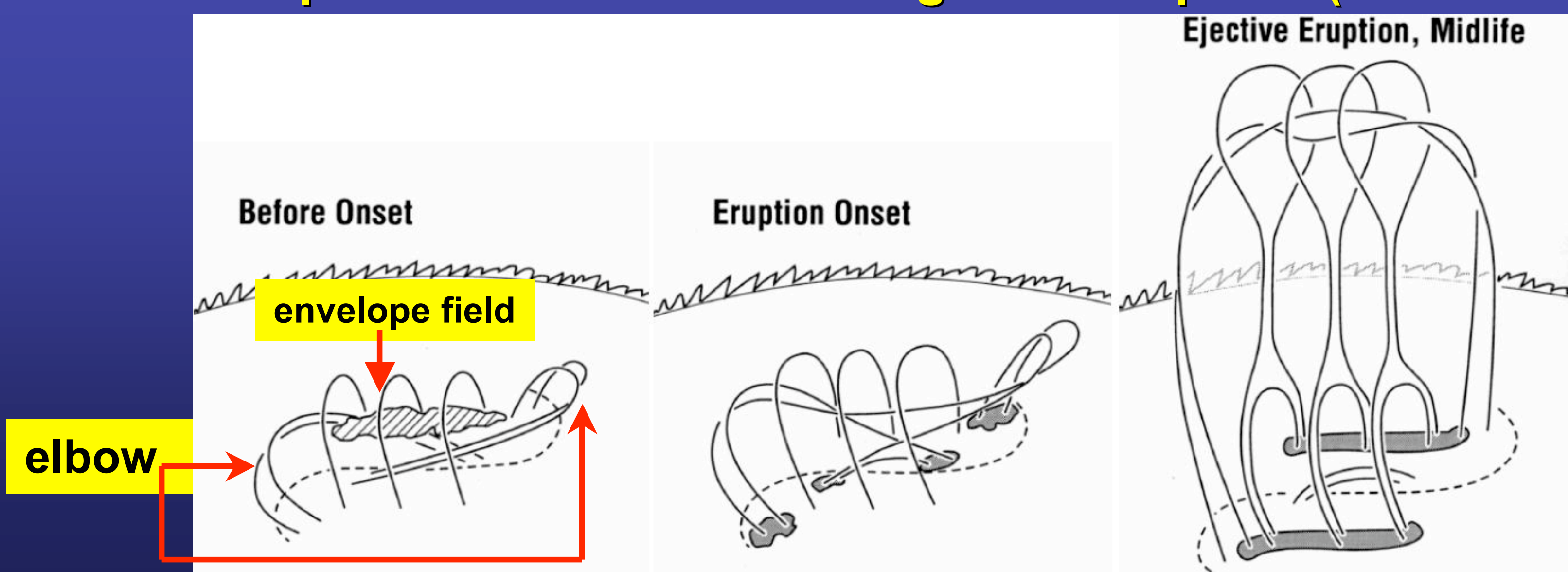
Coronal Sigmoid Structures



Glover et al. (2001)

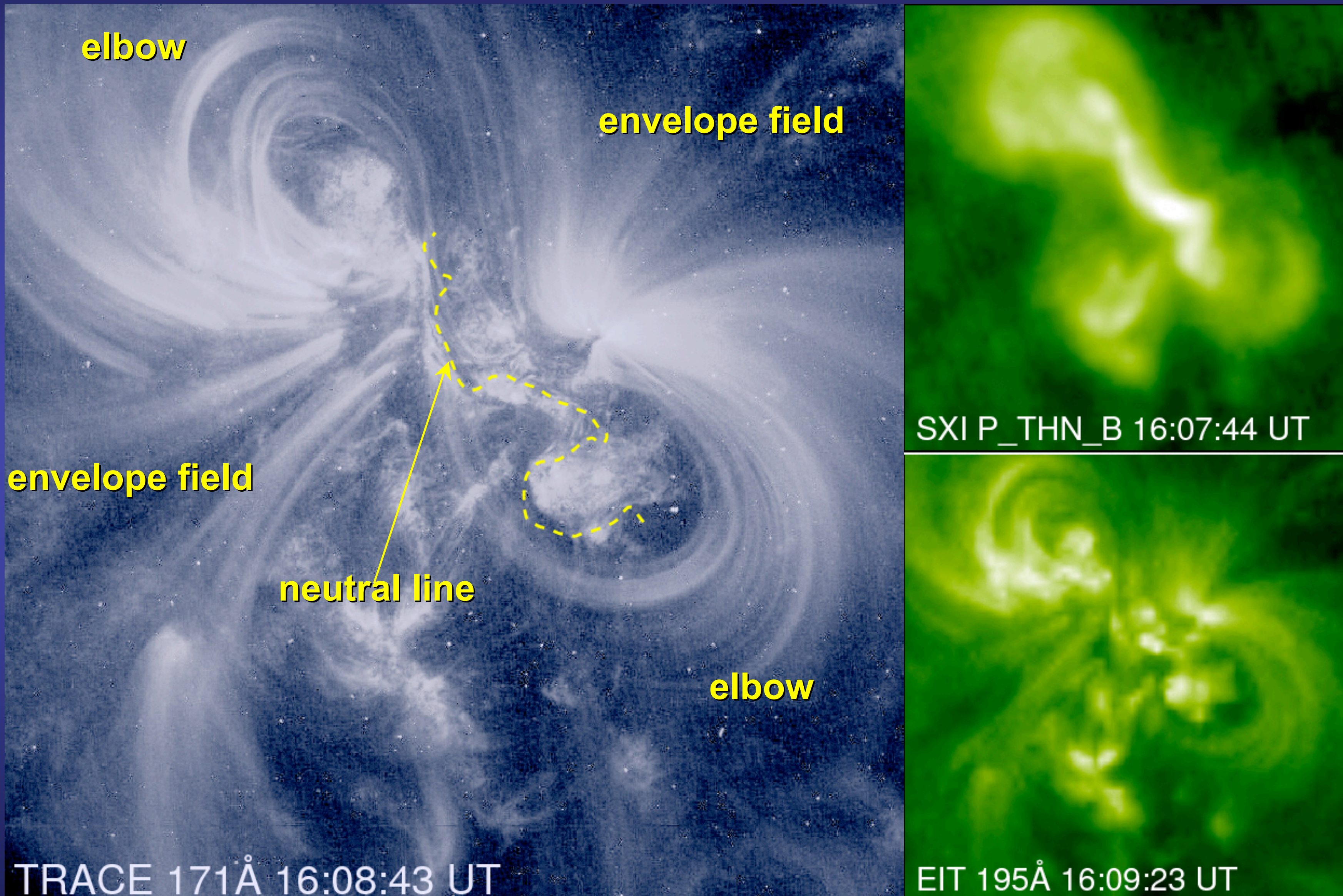
Sigmoidal loops, shaped like an S or inverse S, had long been observed by the soft X-ray telescope (SXT) on board Yohkoh (e.g., Rust and Kumar, 1996). Hudson et al. (1998) first observed a relationship between a sigmoid shape before a CME and a cusp or arcade shape afterwards. It is now believed that sigmoid loops have a higher probability of erupting into a CME (Canfield et al. 1999; Hudson et al. 1998).

Standard eruption model tailored to sigmoidal bipoles (Moore et al. 2001)



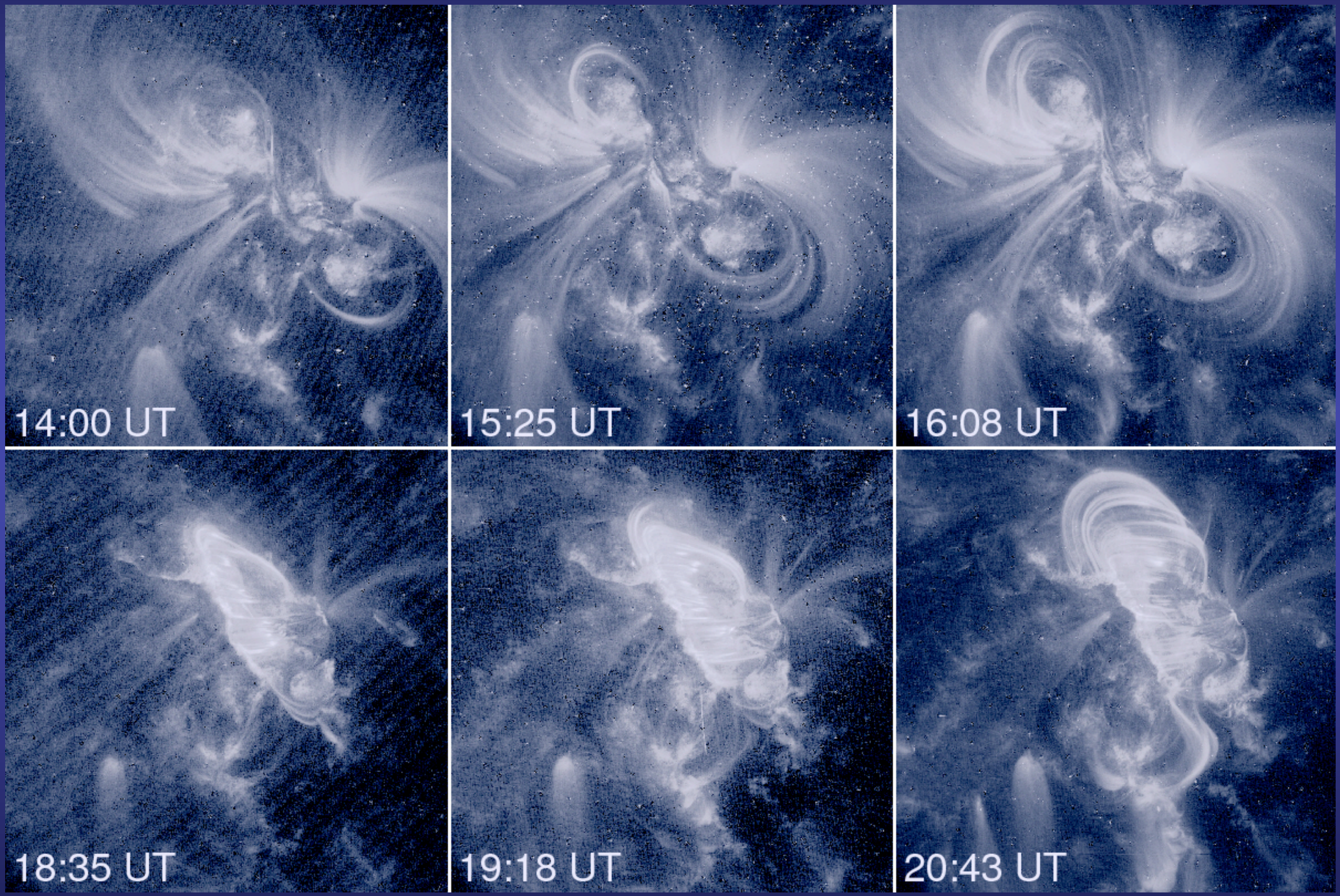
Sigmoid on 2005 May 13

(is observed clearly in TRACE as well as in SXI and EIT)

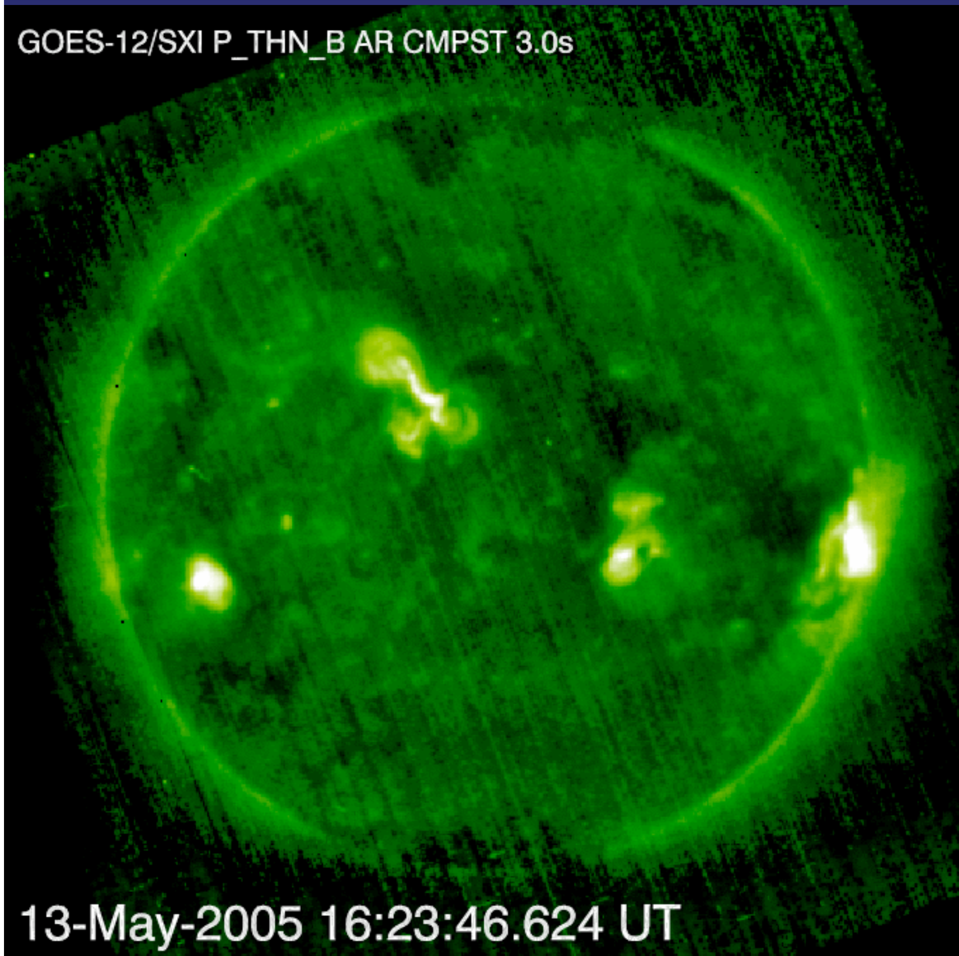


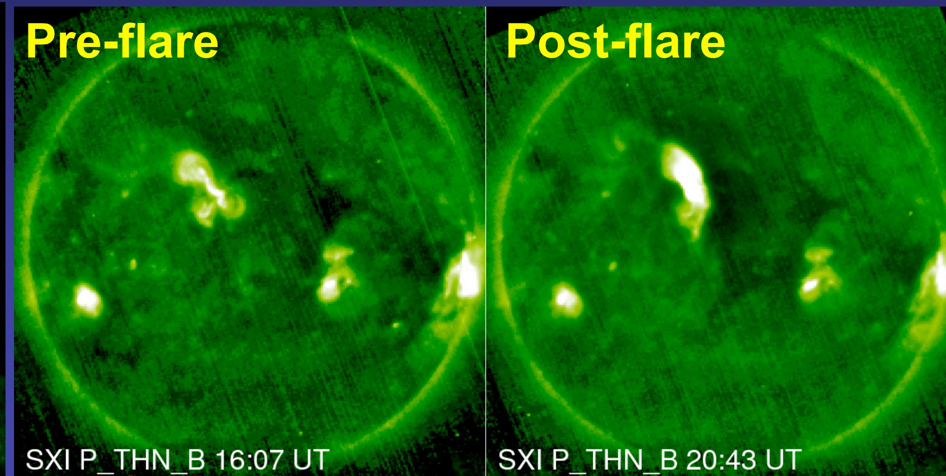
Evolution of the Sigmoid (1)

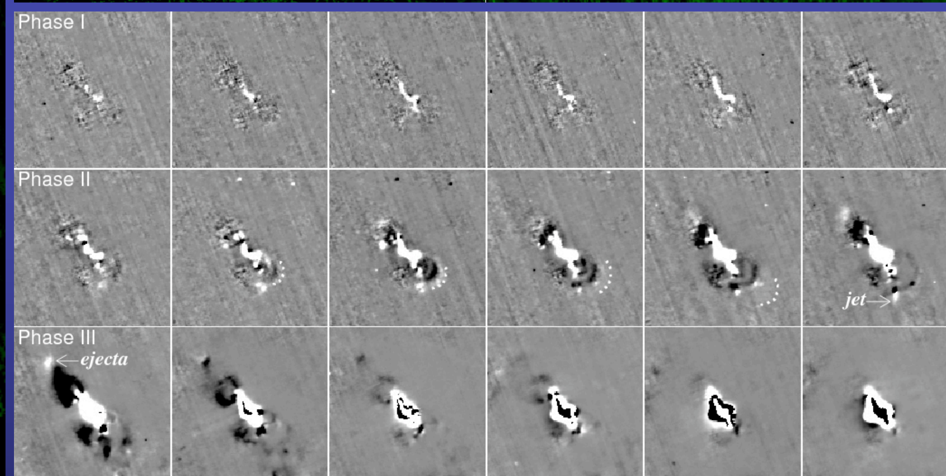
(TRACE 171 Å)



Evolution of the Sigmoid (2)
(GOES12-SXI)

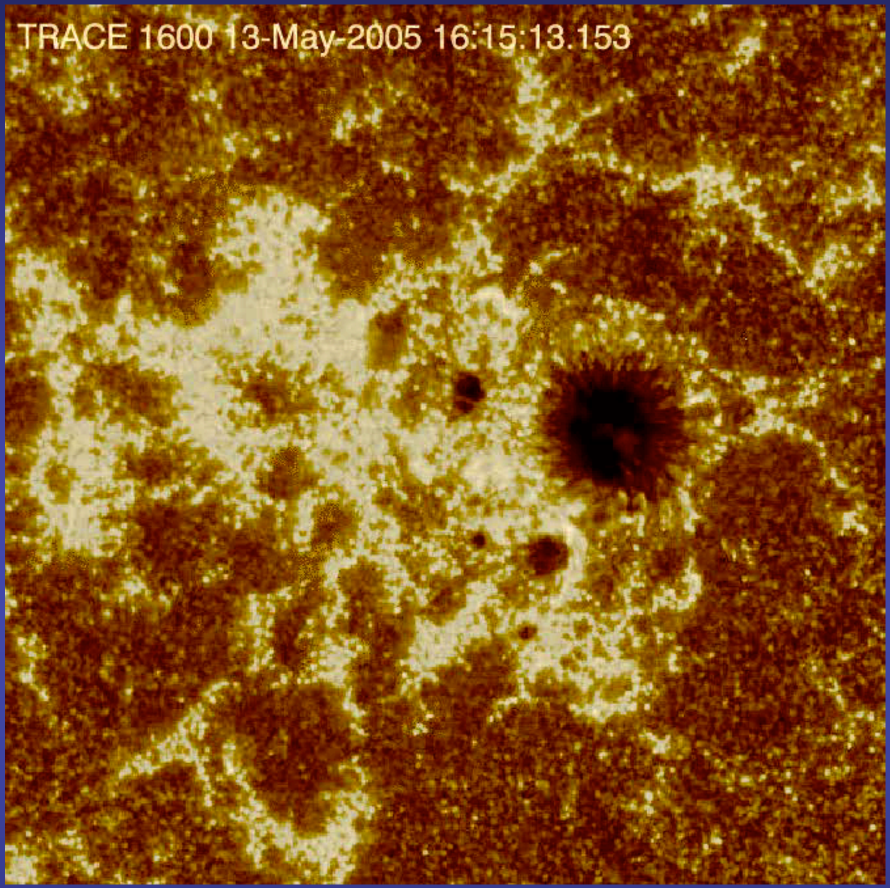


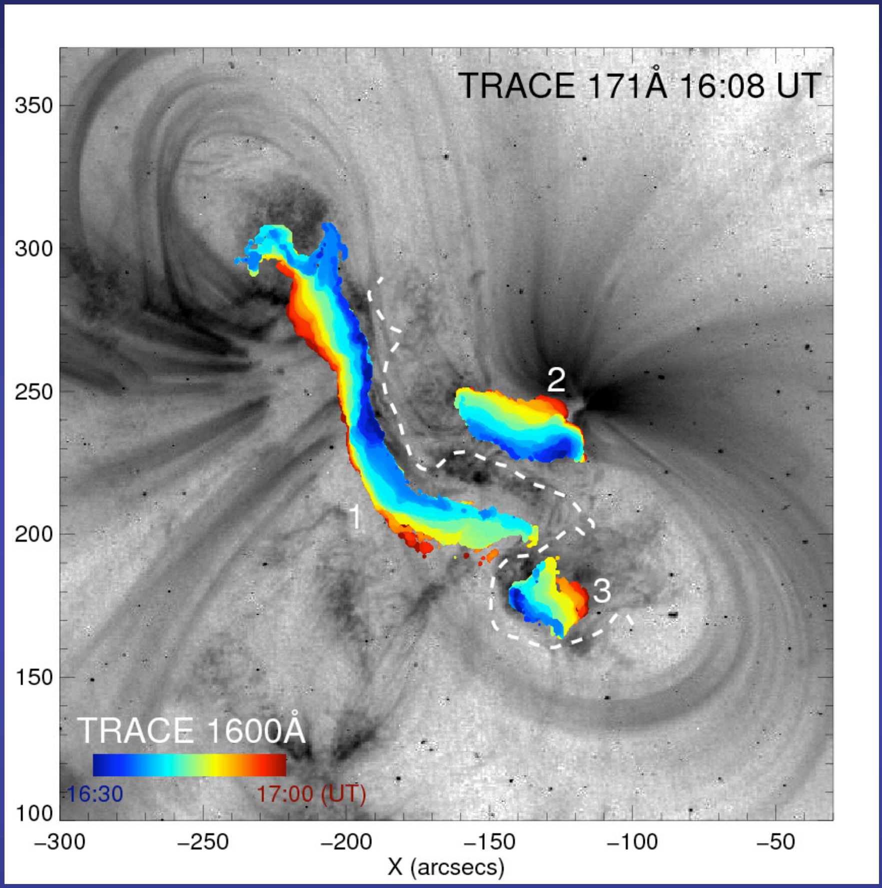




Core brightening → Loop expansion → Eruption → Flare arcade / Cusp

Flare Emissions in the Core Region (1)

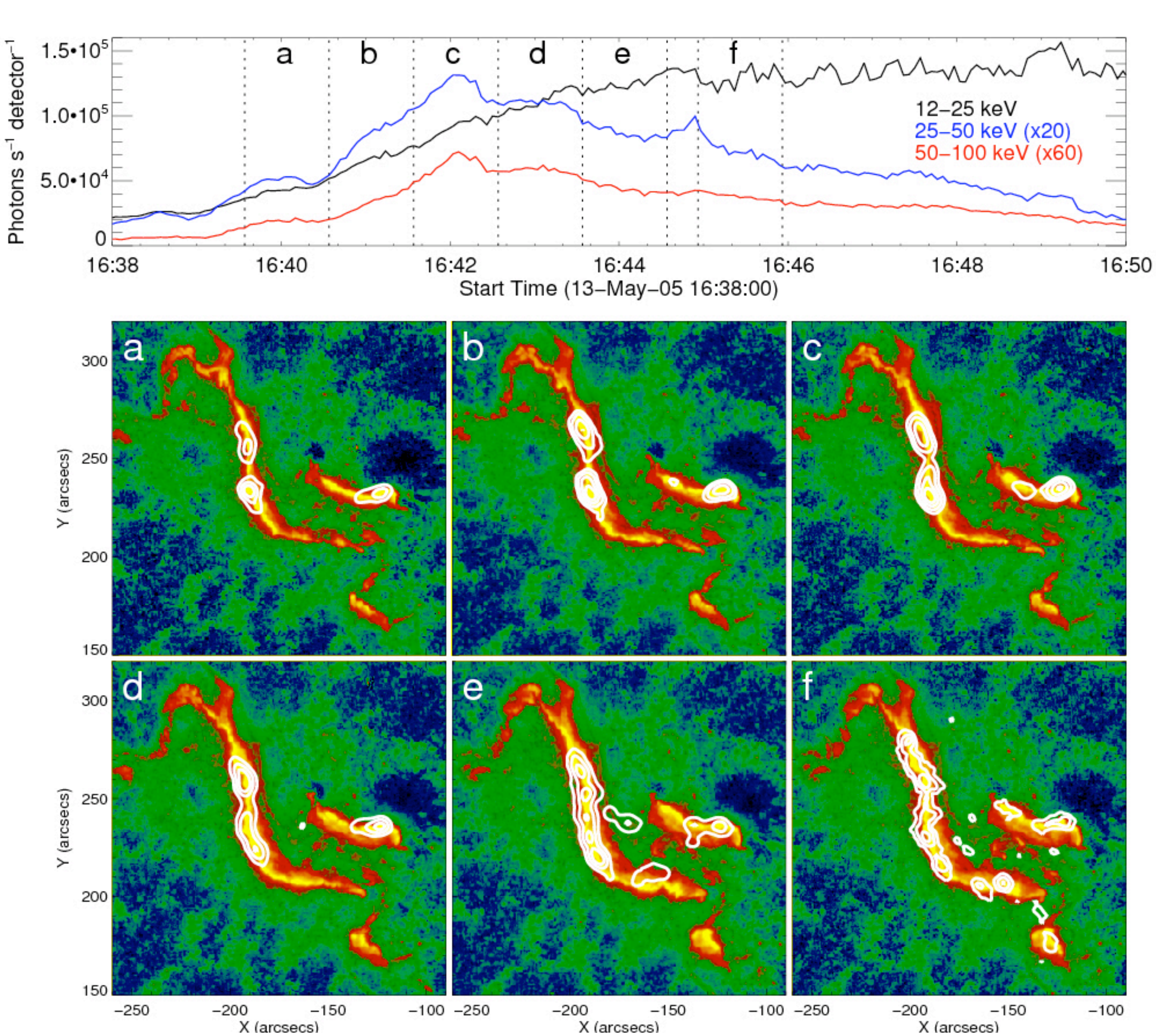




By registering the successive flare ribbon positions onto the magnetogram, we measure the change in magnetic flux to derive the **magnetic reconnection rate R** — the rate at which magnetic flux is brought into the magnetic reconnection region.

According to Qiu et al. (2004), R is timely correlated with the mass acceleration.

Flare Emissions in the Core Region (2)



Background: TRACE 1600 Å images
White Contours: RHESSI 25-50 keV HXR sources

Before and at the flare maximum (a,b,c): **footpoint-like hard X-ray sources** formed at the sigmoid footpoints.

After the flare maximum (d,e,f): the hard X-ray kernels **become elongated to occupy most of ribbon area**.

This "footpoint-to-ribbon" transformation of the hard X-ray source might be related to the "sigmoid-to arcade" transformation of the magnetic field configuration in this event.

Large-Scale Activities 1: Type II Radio Burst

Solar Geophysical Data Online

S O L A R   R A D I O   E M I S S I O N
Spectral Observations

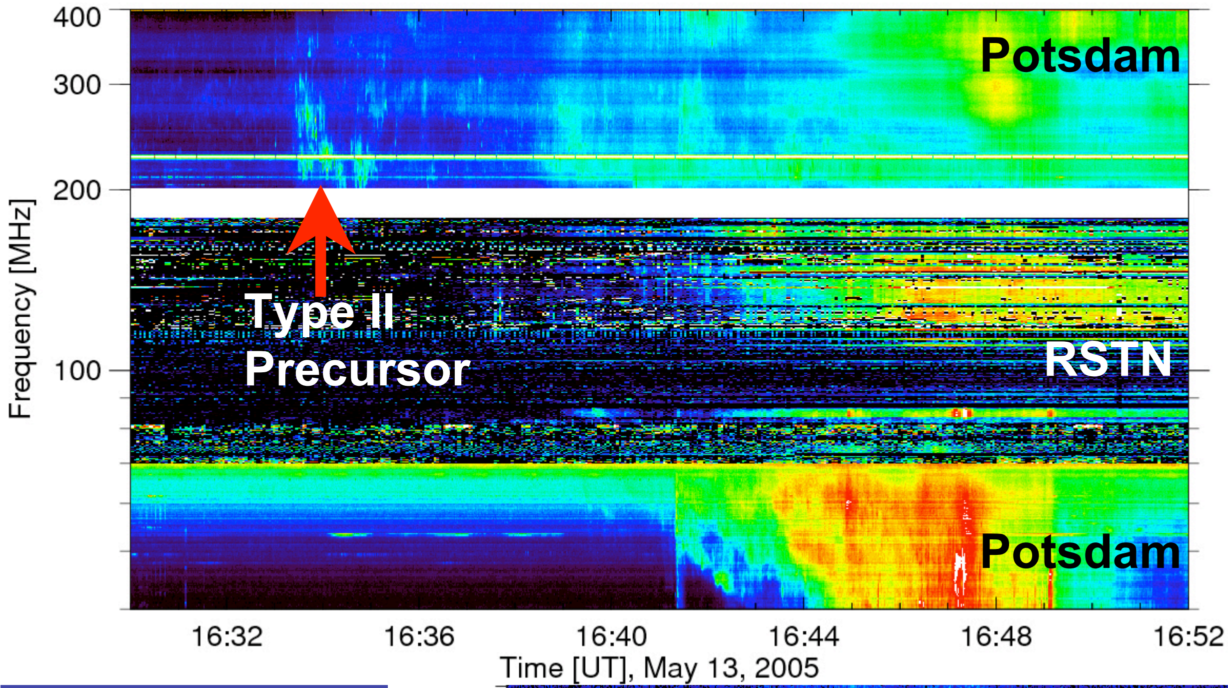
99
May 05

MAY 2005

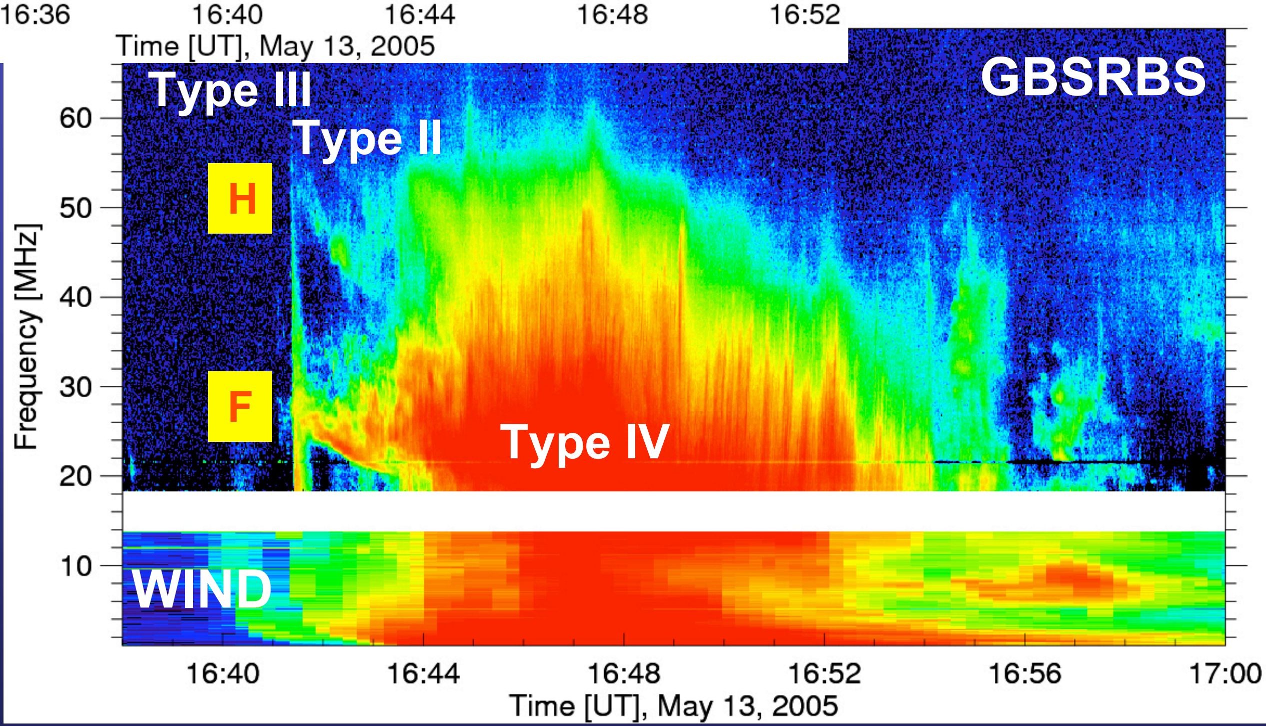
OBSERVATION Day	Start (UT)	End (UT)	Sta	EVENT Start (UT)	End (UT)	Spectral Class	Event Remarks	Int (1-3)	FREQUENCY Lower (MHz)	Upper (MHz)	Remarks
13	0435	1723	ONDR	0658.1	0659.3	DCIM	G	1	2000X	4500X	
			ONDR	0658.3	0700.2	DCIM	G	1	800X	2000X	
			SVTO	0757.0	0757.0	III		1	25	58	
			SVTO	0906.0	0906.0	III		1	25	75	
			SVTO	0932.0	0932.0	III		1	25	40	
			SGMR	1210.0	1210.0	III		1	30	63	
			SGMR	1427.0	1643.0	III	N	1	30	53	
			SVTO	1439.0	1559.0	III	N	1	25	65	
			ONDR	1628.3	1723.1U	DCIM	GG,FS	3	800X	2000X	
			SVTO	1632.0	1733.0	IV		1	25	180	
			ONDR	1632.3	1639.3	DCIM	G	2	2000X	4500X	
			POTS	1633	1828 U	IV	FS	3	40X	600U	
			POTS	1638	1650	II	F,SH	2	40X	350U	
			SVTO	1641.0	1641.0	III		1	25	153	
			SVTO	1641.0	1652.0	II		3	25	81	ESS 1349
			SGMR	1643.0	1645.0	II		3	30	67	ESS 1171
			PALE	1644.0	1655.0	II		1	25	180	ESS 1419
			SGMR	1645.0	2057.0	IV		3	30	180	
			PALE	1703.0	2058.0	IV		1	36	180	
			PALE	1952.0	1952.0	III		1	25	141	
			SGMR	1952.0	1953.0	III		1	30	150	

Possible Type II and IV Radio Bursts Observed by Wind/WAVES in 2005

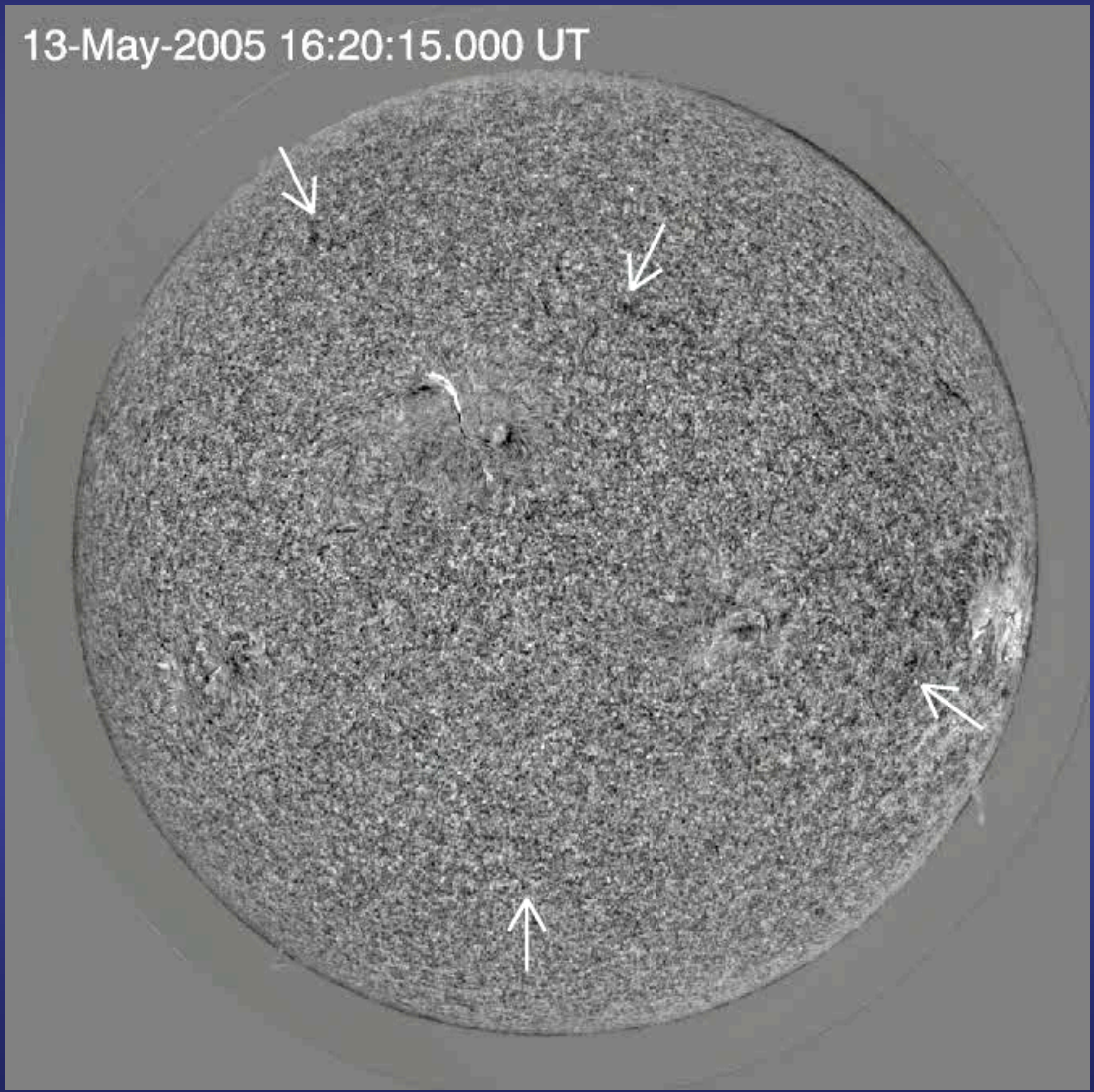
No.	Start Time		Stop Time		Freq Range (kHz)	Comments	Dyn Spec
19.	20050513	1700	20050515	0210	5000-40	Major sun to Earth event	S,S



Type II precursor (Klassen et al.1999) is simultaneous with the first hard X-ray peak and soft X-ray loop expansion, which may signify the earliest energy release and the onset of shock formation in the low corona.



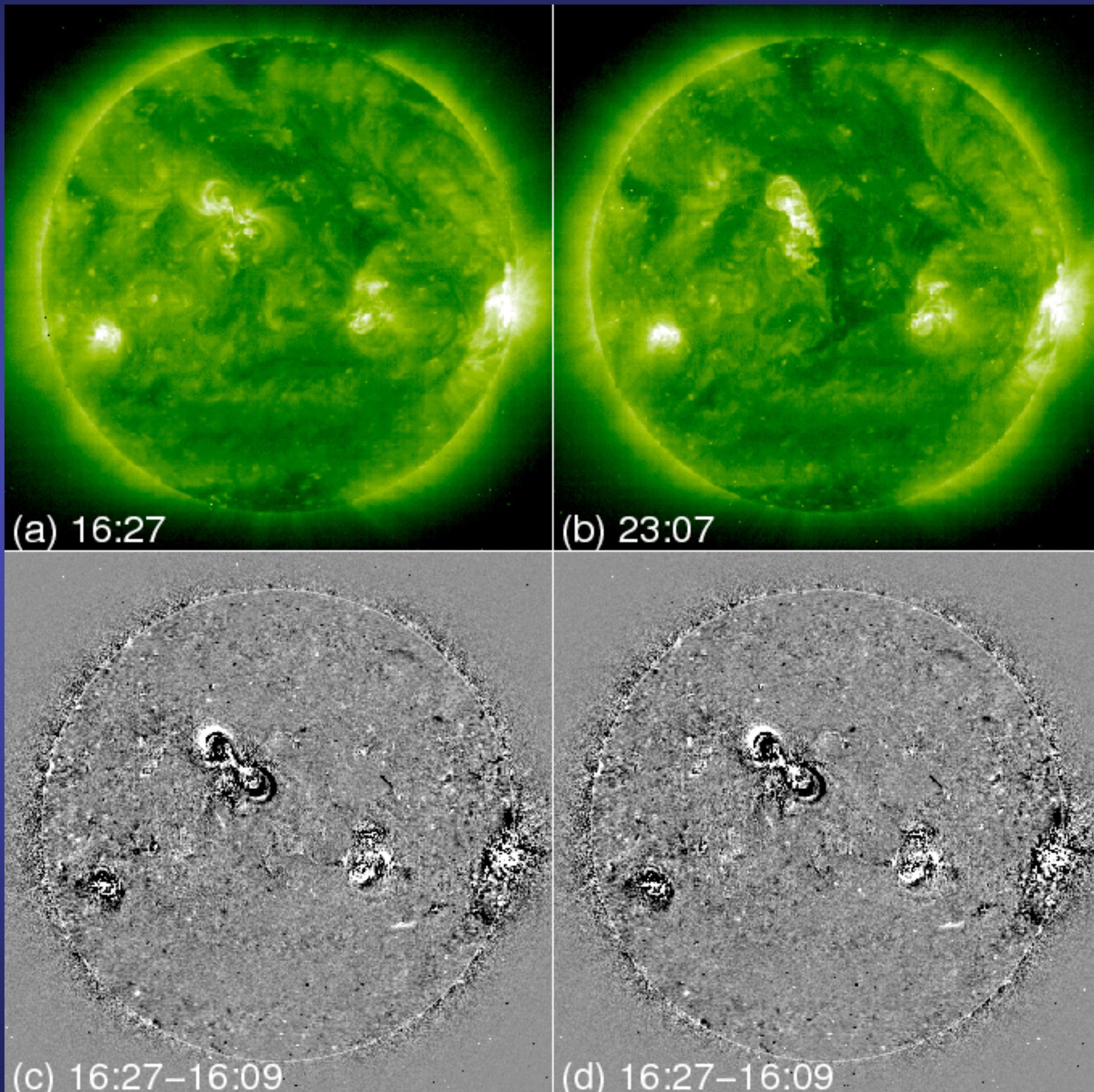
Large-Scale Activities 2: Moreton Waves in Hα



- **OSPAN 1-min cadence Hα red-wing images subtracted by blue-wing images**

- **Moreton waves are found to propagate southward. However, several oscillation of quiescent filaments (*pointed by arrows*) are observed around solar disk, on the way of (invisiable) Moreton wave propagation (Smith & Harvey 1971).**

Large-Scale Activities 3: Coronal Dimmings in EIT

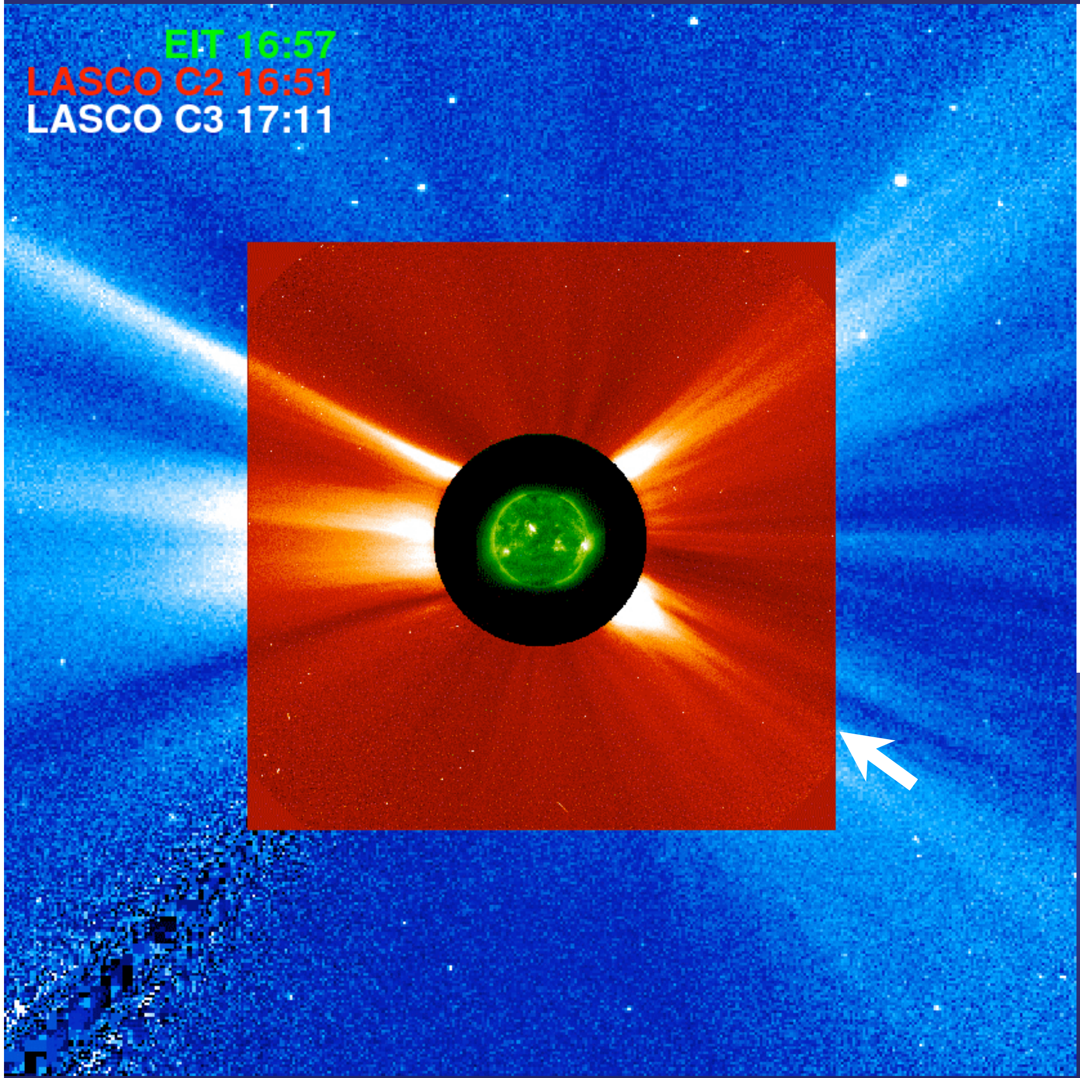


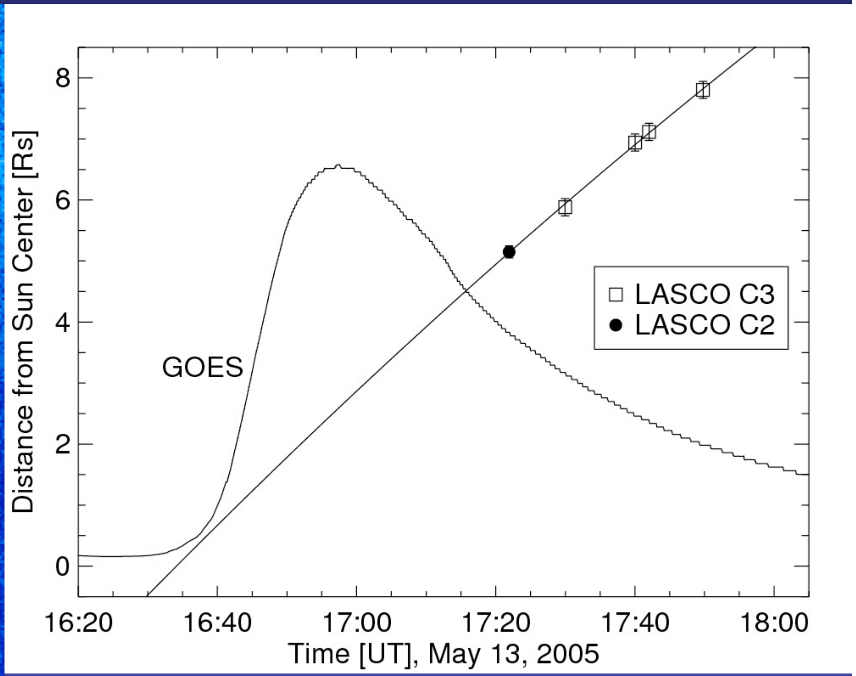
- (a) EIT 195 Å sequence
- (b) EIT post-flare image
- (c) EIT running difference
- (d) EIT fixed difference

- ❖ Global disturbance
- ❖ EIT waves

After the flare, new coronal holes formed NE and SW of the active region following the eruption of the sigmoidal fields

Large-Scale Activities 4: CME in LASCO

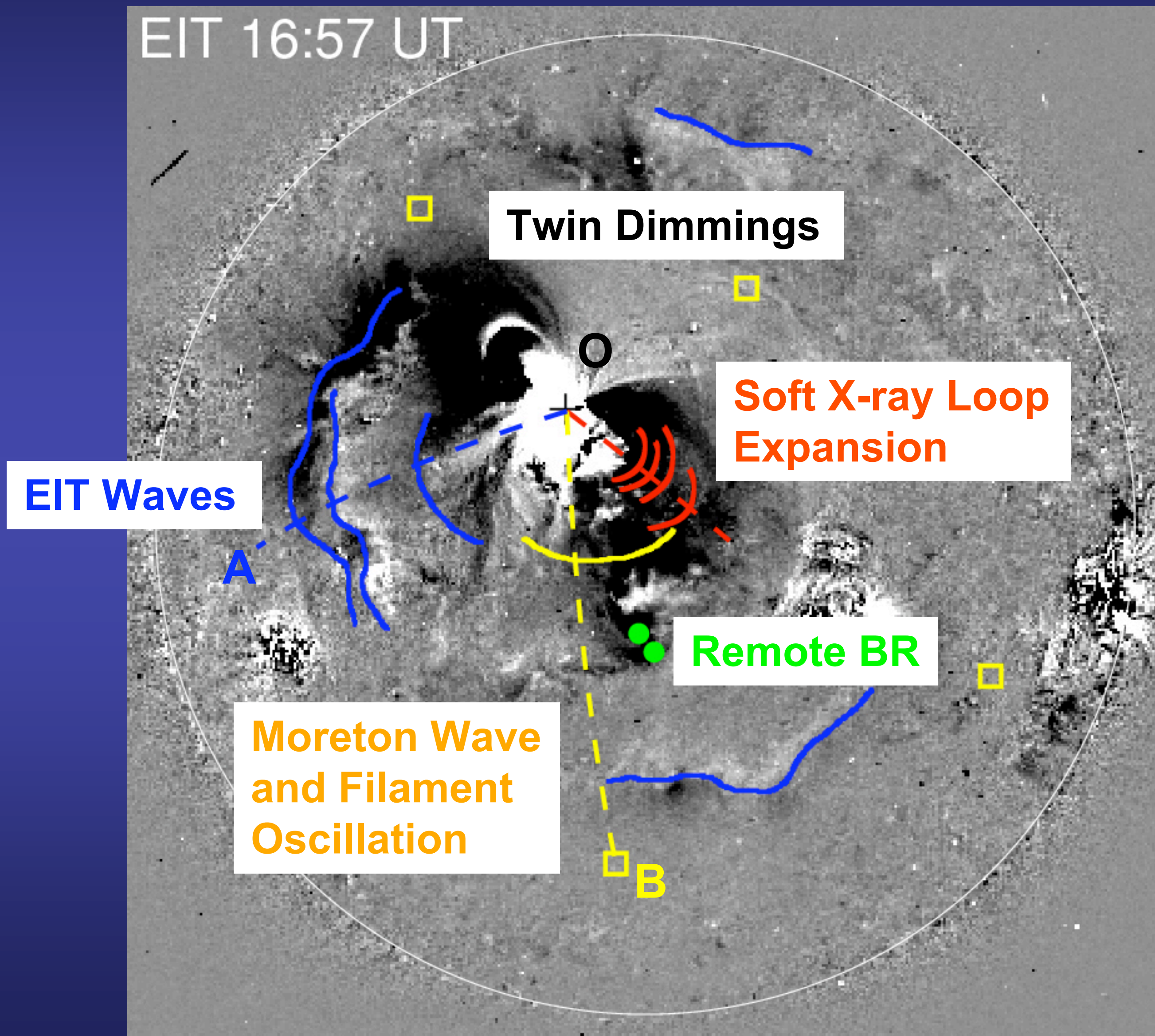




Measured position angle: 238 deg

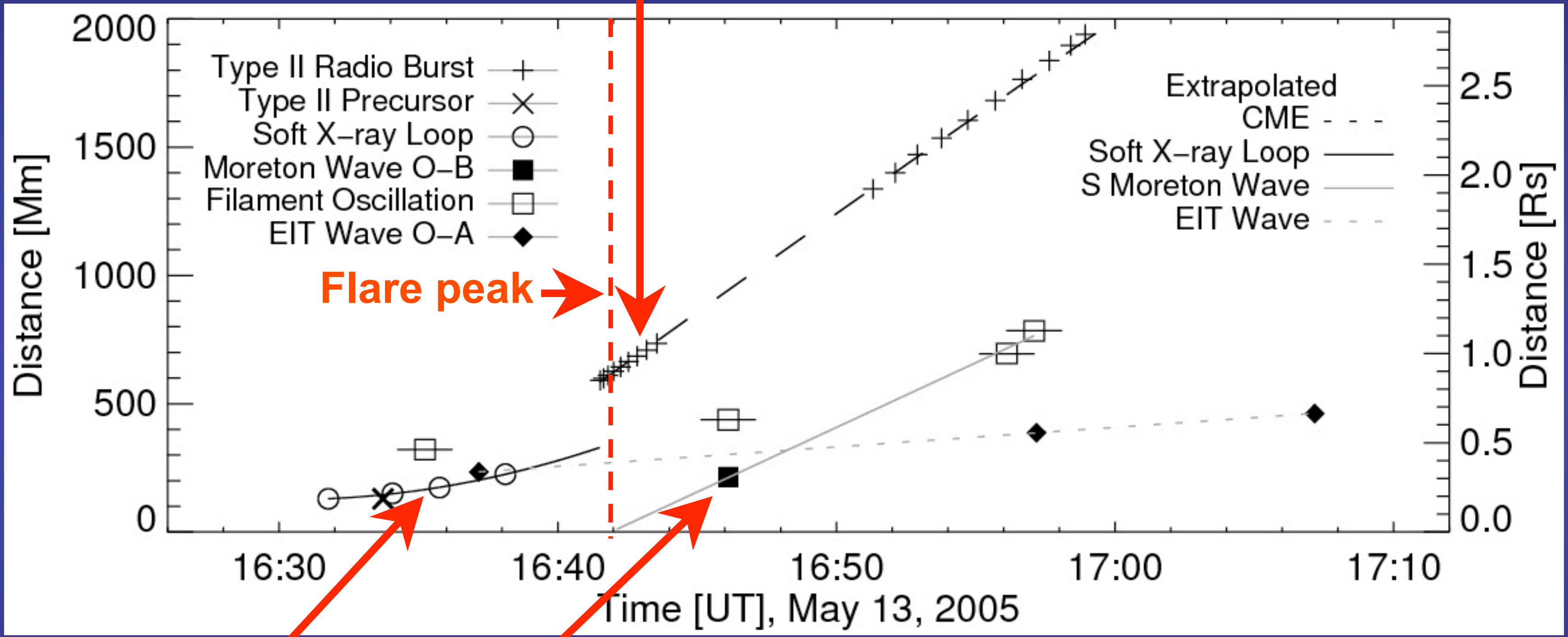
Averaged speed of the leading edge: ~1100 km/s

Summary of Large-Scale Activities



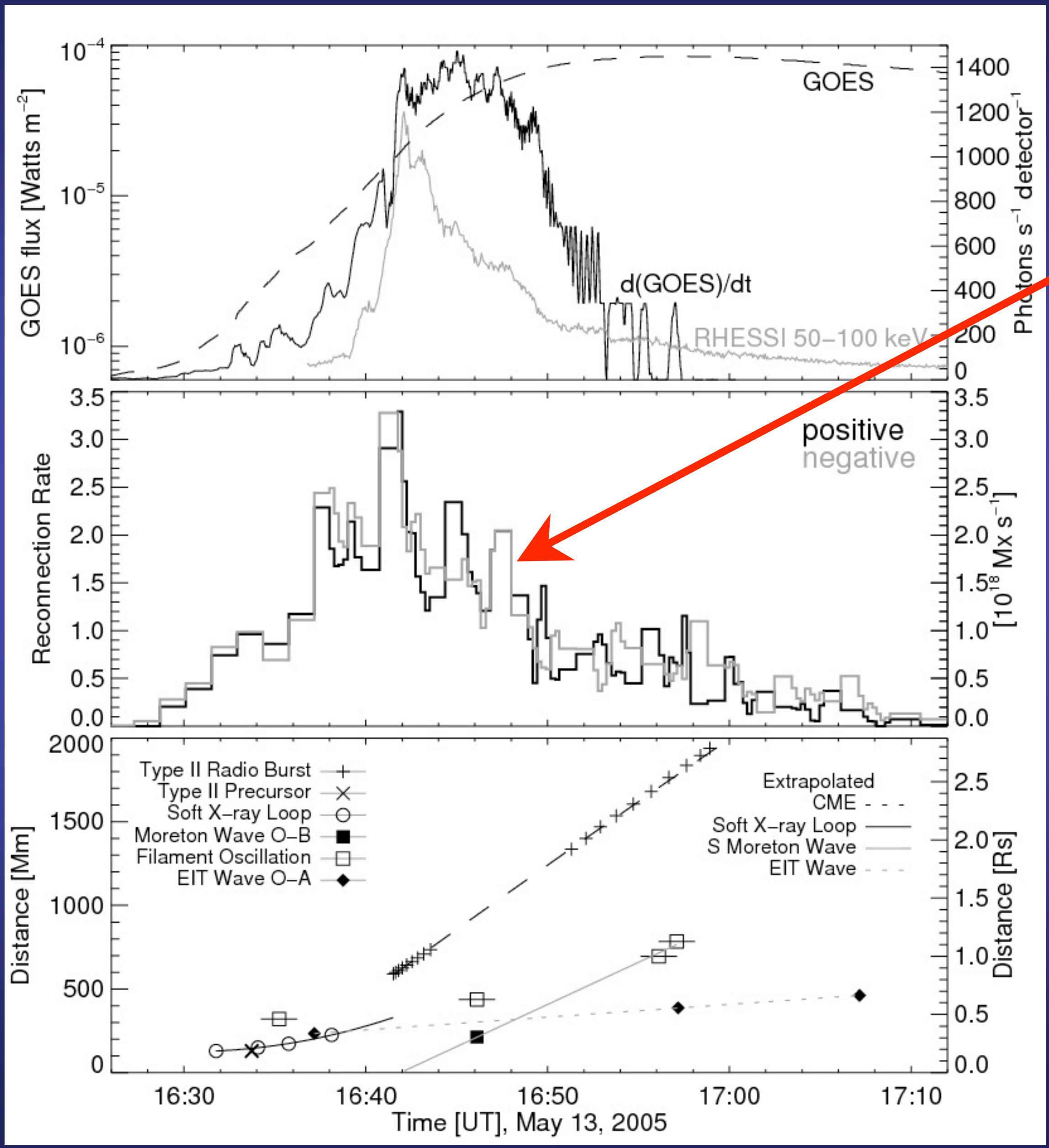
Time-Distance Diagram (1)

- **Type II radio burst** (~1300 km/s) and **CME** (~1100 km/s) have similar evolution after the flare impulsive phase



- **Soft X-ray loop expansion** (~250 km/s) has a similar height with the **type II precursor**, suggesting the earliest onset of shock formation
- **Moreton wave** (~840 km/s) was initiated at the flare peak time, most probably with a blast wave origin

Time-Distance Diagram (2)



The rate of magnetic reconnection in the low corona is temporally correlated with the evolution of flare nonthermal emissions in hard X-rays, with its peak time coincident with the maximum of flux rope acceleration.

(cf. Qiu et al. 2004)

Main Conclusions

The 2005 May 13 M8.0 event shows how eruption occurs from the sigmoidal fields.

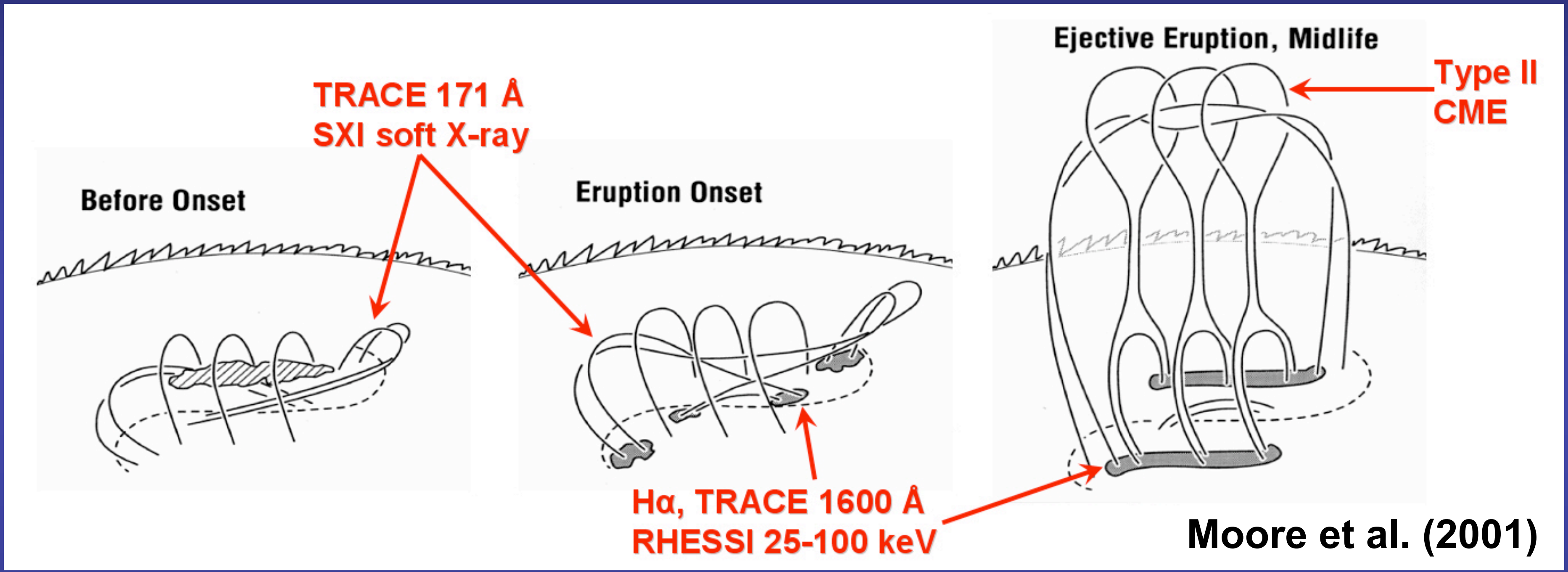
- The reconnection starts from the sheared core region of sigmoidal loops and the flux rope formed after reconnection begins to rise and expand.

- As the magnetic reconnection reaches its maximum, the flux rope abruptly accelerates and the envelope field lines are opened, which leads to long lived post-flare reconnection.

- The type II precursor indicates a shock initially formed in the low corona in association with the soft X-ray loop expansion at ~16:34 UT.

- The rapid eruption of the flux rope started at the flare maximum, simultaneous with the peak of the magnetic reconnection and the occurrence of type II radio burst.

We conclude that this event well fits into the standard bipolar eruption (tether-cutting) model



More key data available (e.g., BBSO vector magnetogram and flow field)

⟶ **future *SHINE* campaign event?!**