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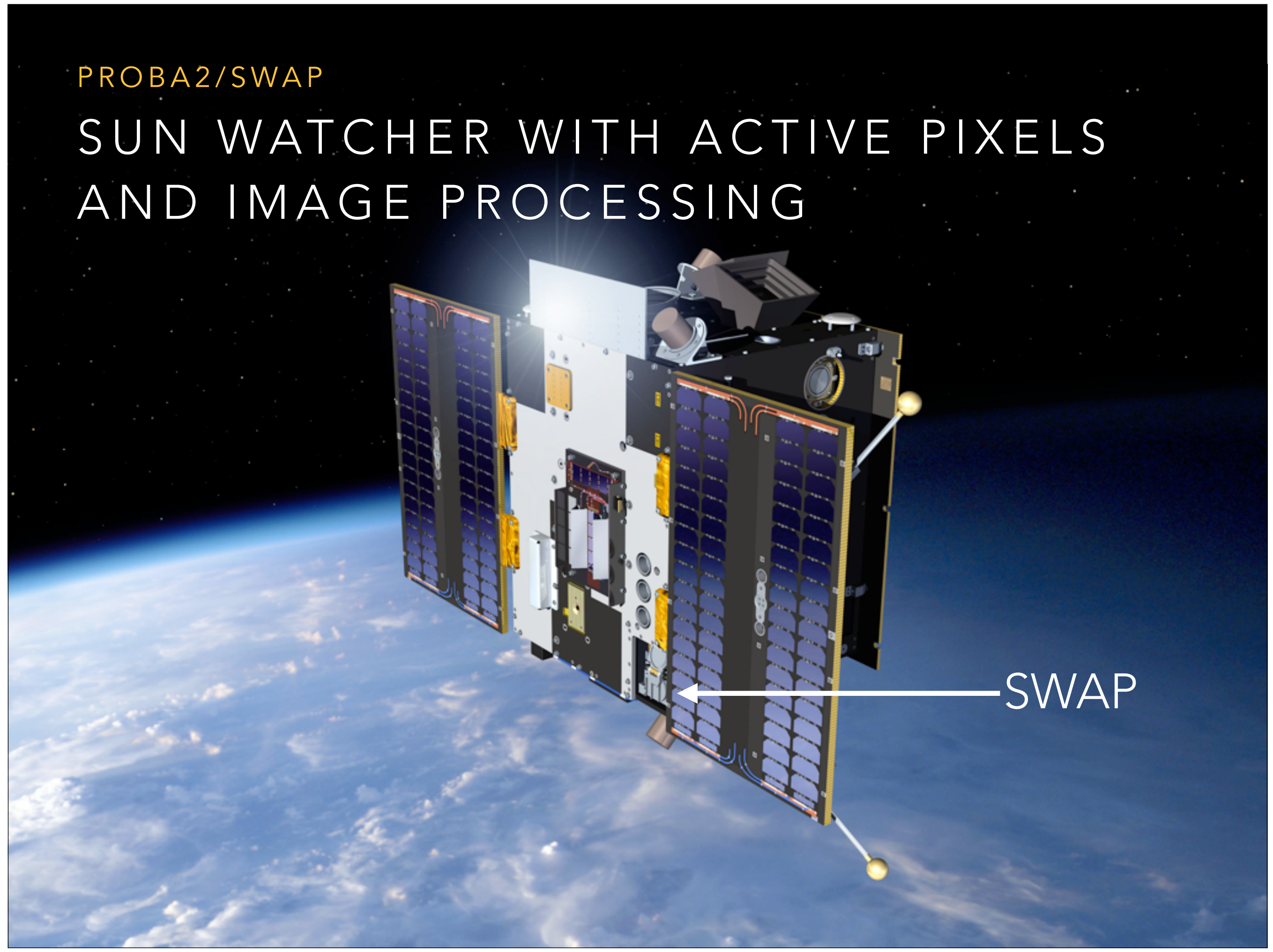
TRIENNIAL EARTH-SUN SUMMIT
INDIANAPOLIS, INDIANA ☀ 30 APRIL 2015

PROBA2/SWAP OBSERVATIONS OF THE UNUSUAL ACTIVITY OF AR12192

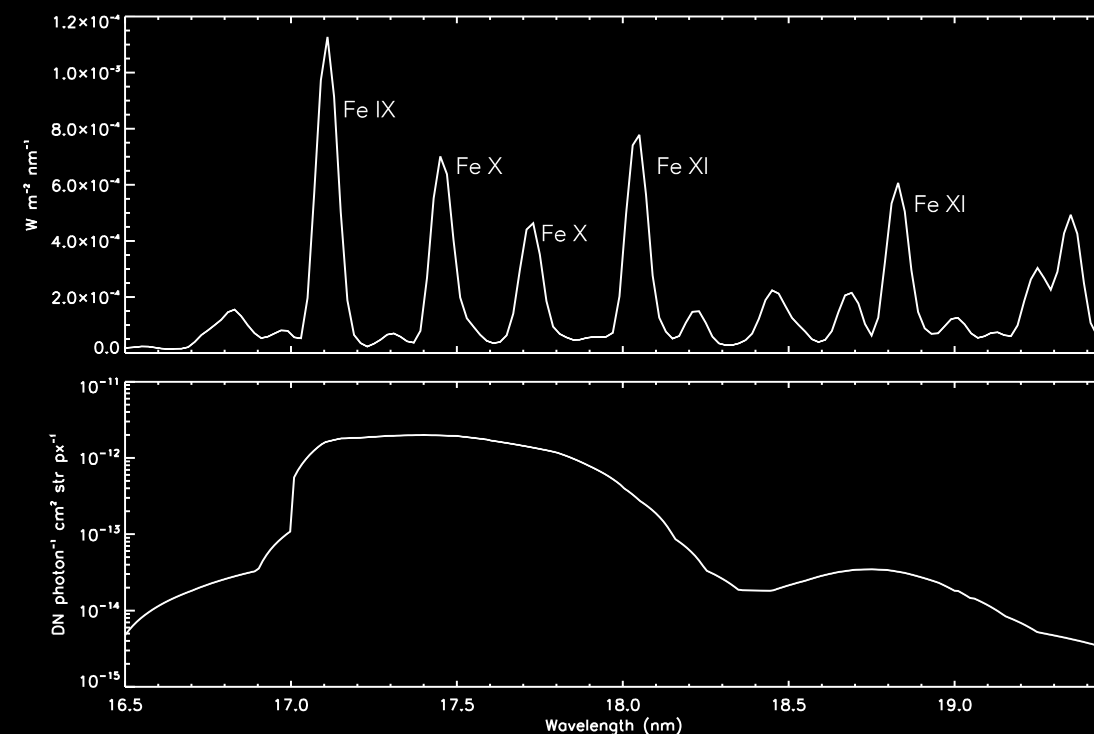
A BRIEF INTRODUCTION TO PROBA2/SWAP



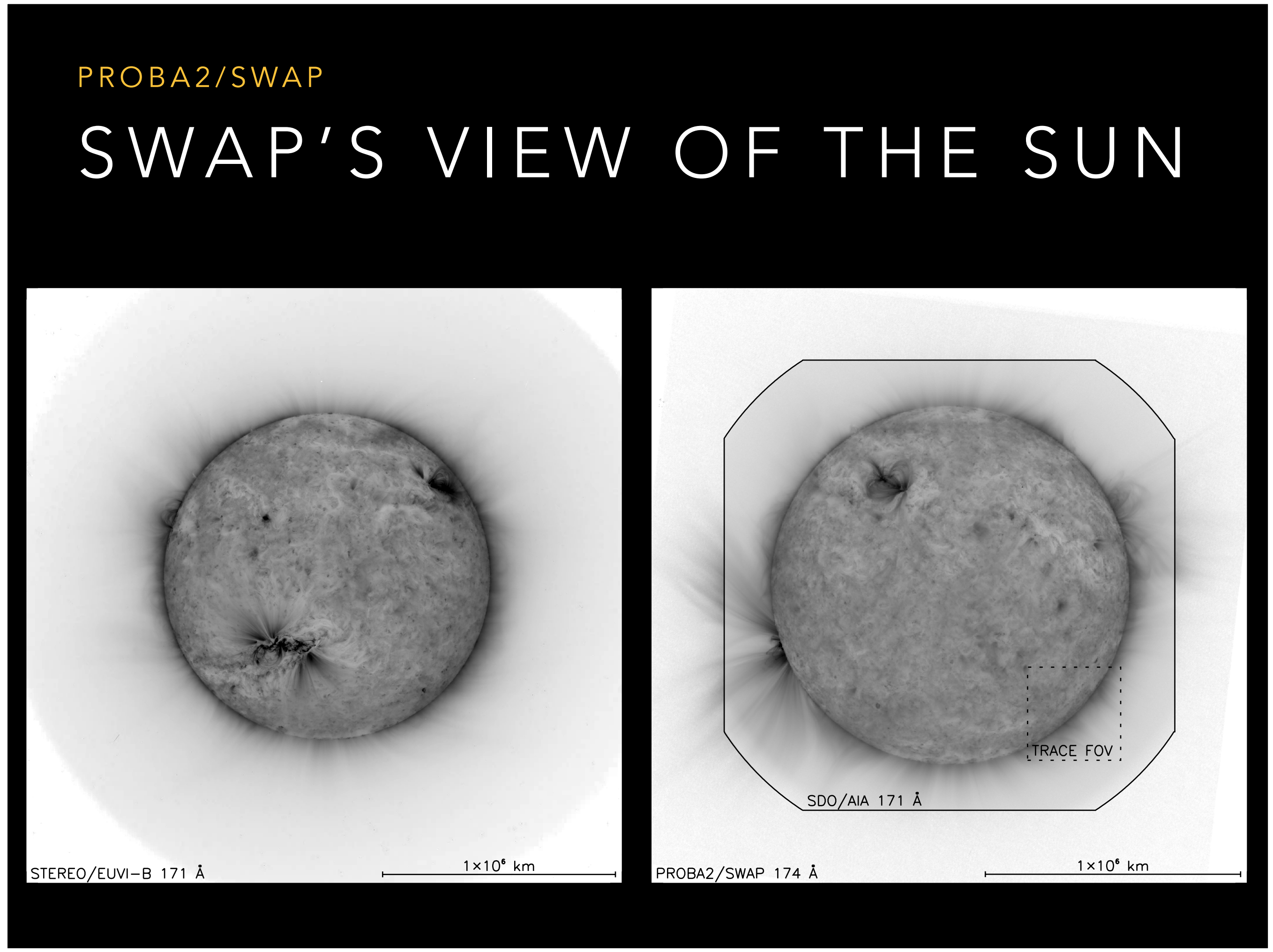
PROBA2 is the second of ESA's Project for On-Board Autonomy missions, a washing machine-sized spacecraft that hosts SWAP and three other science instruments: LYRA, a radiometer, and two plasma instruments. It also hosts 17 technology demonstrations.

PROBA2/SWAP

SWAP RESPONSE



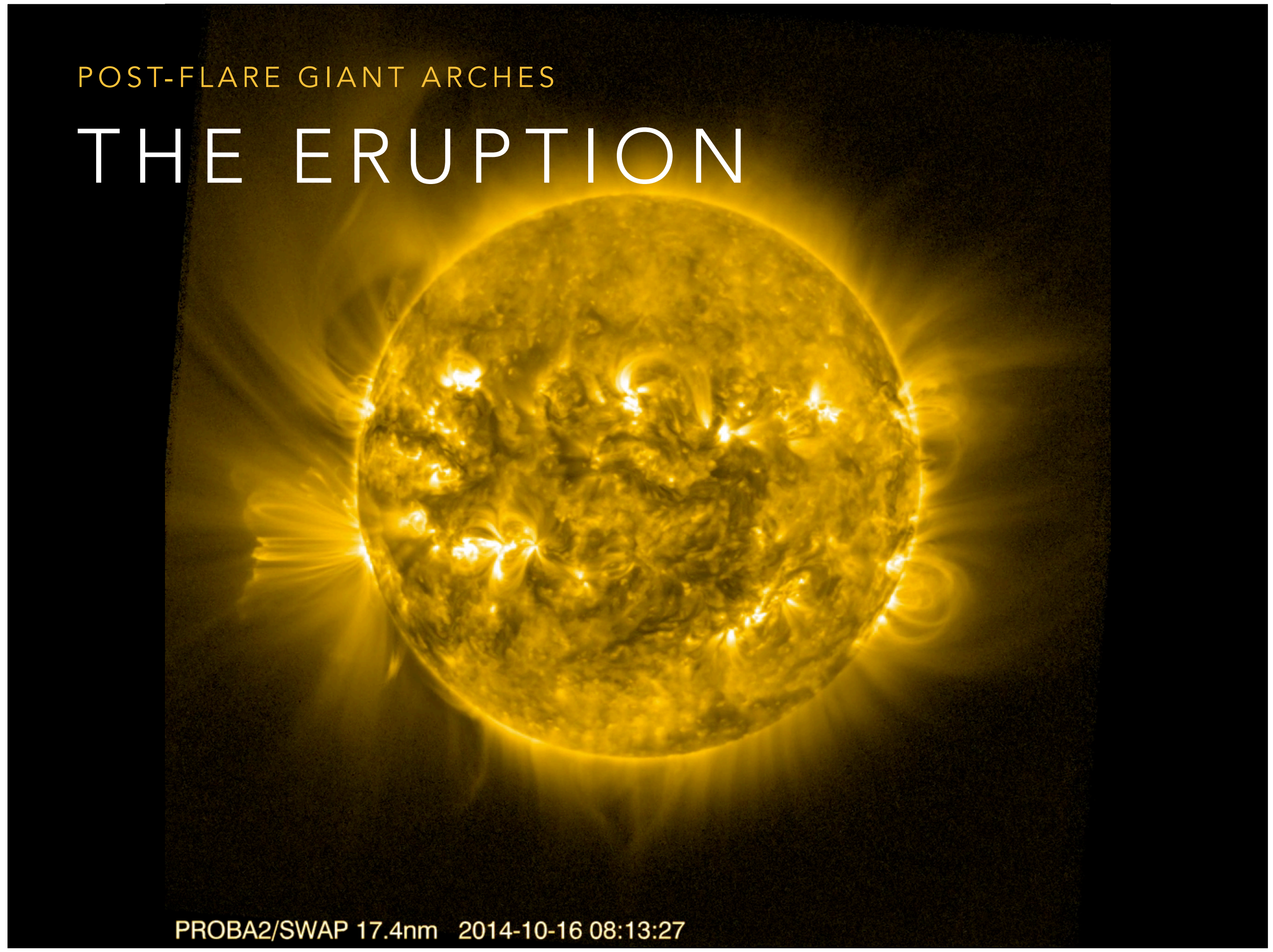
Spectral response peaks around 17.4 nm and the passband includes mainly lines of FeIX and FeX. Temperature response is between 0.8 and 1 MK.



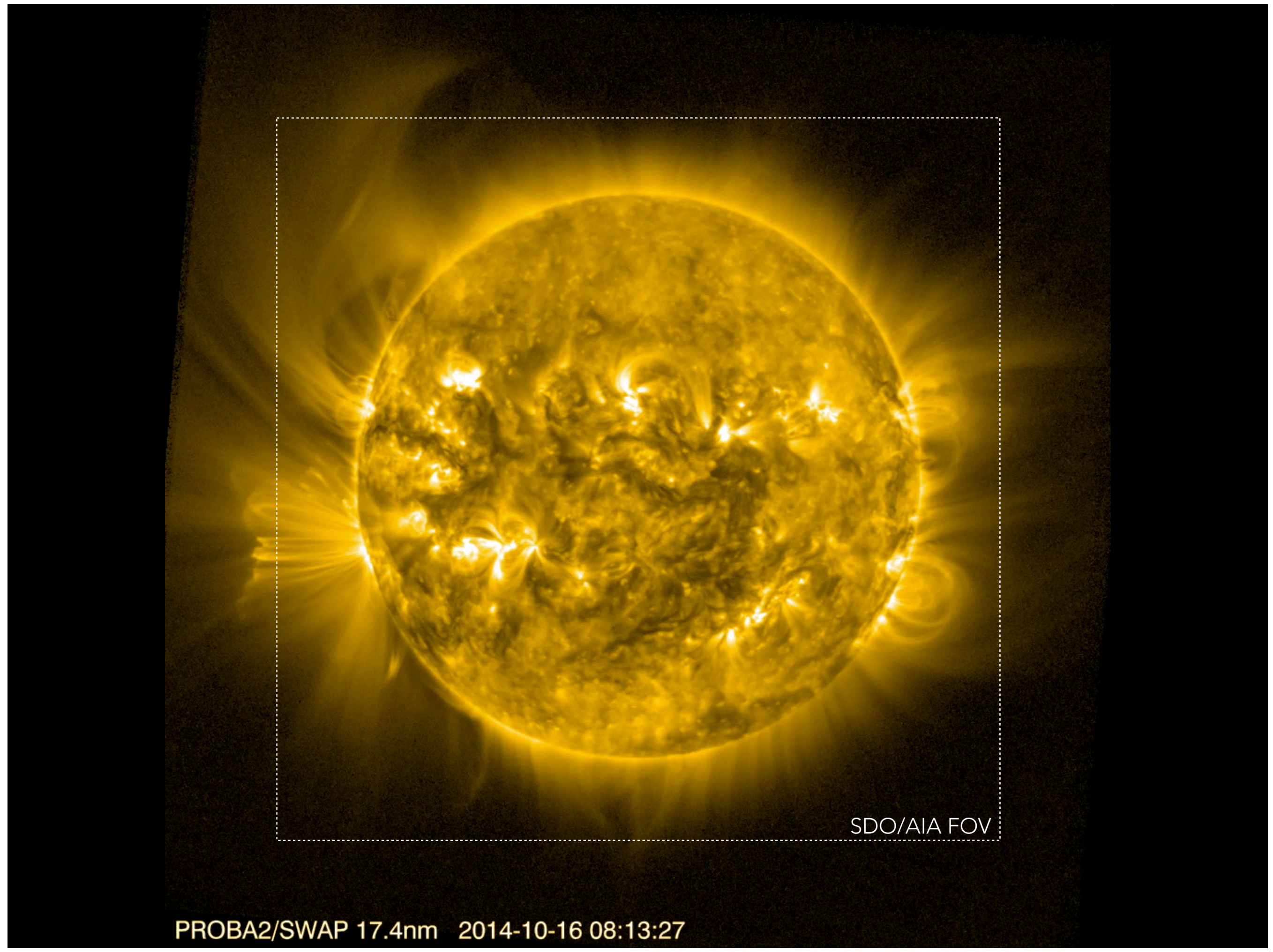
SWAP's field-of-view is comparable to the FOVs of the EUVI imagers on STEREO. Early in the solar cycle we saw only a few structures extending to large heights in the FOV. SWAP can also off-point to make ultra-wide mosaic images, which I'll come back to later.

OBSERVATIONS OF POST-FLARE GIANT ARCHES

We reported on these post-flare giant arches in an ApJ Letter. They occurred on the east limb in October 2014.



Starting October 14 AR 12192 produced a very long-duration M2.2 flare that gave birth to a huge set of post-eruptive loops. The loops grew so large that they extended well beyond the AIA field-of-view.



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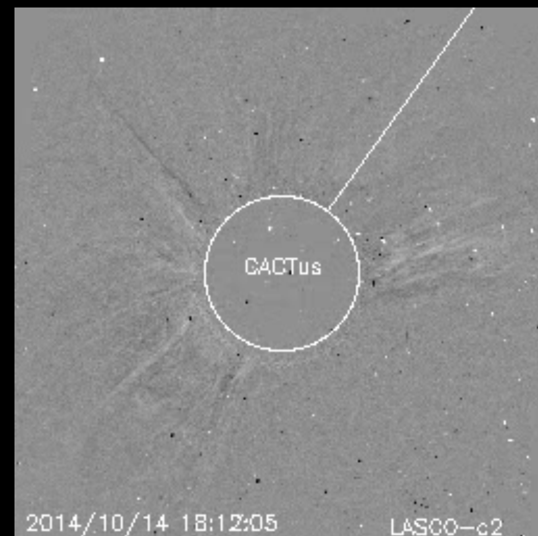
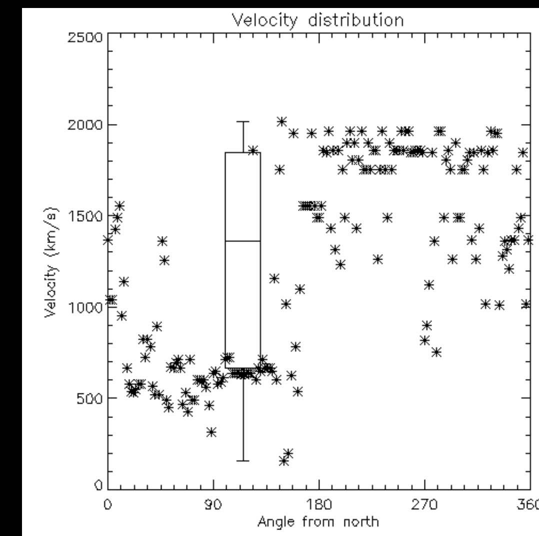
POST-FLARE GIANT ARCHES

THE ERUPTION





CACTus CME Velocity: 1360 km/s

This eruption was associated with a large, fast CME as reported by the CACTus CME detector.

POST-FLARE GIANT ARCHES

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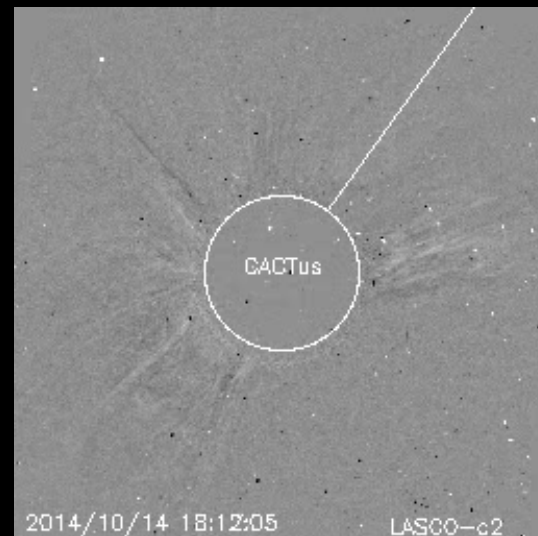

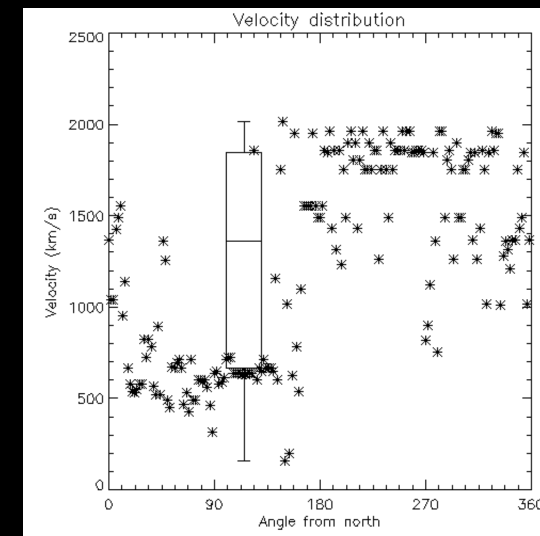

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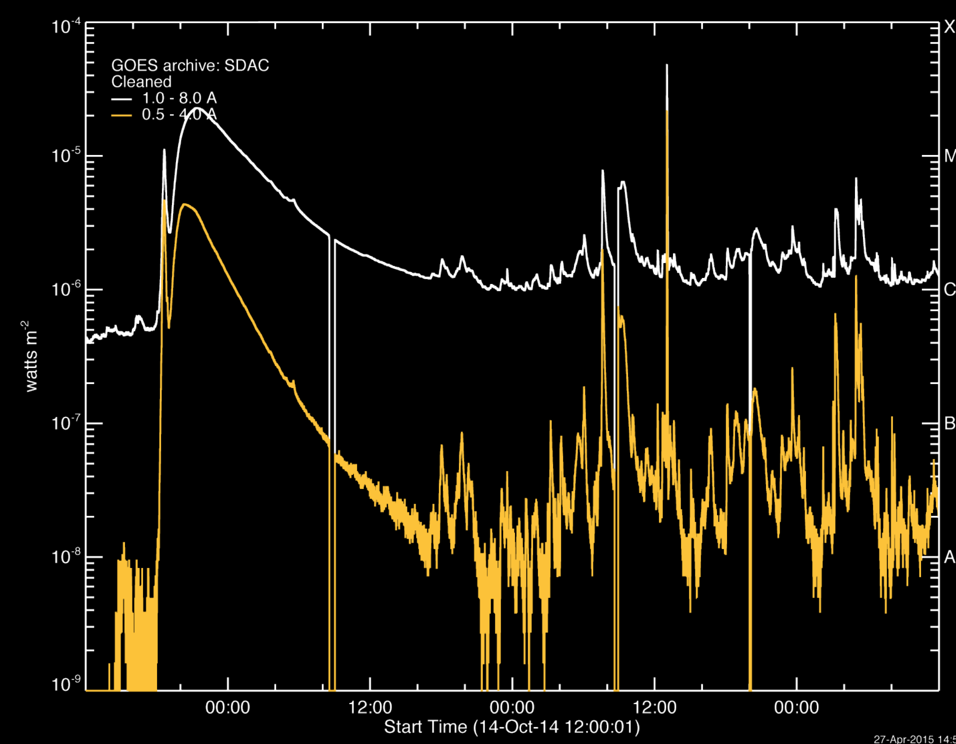
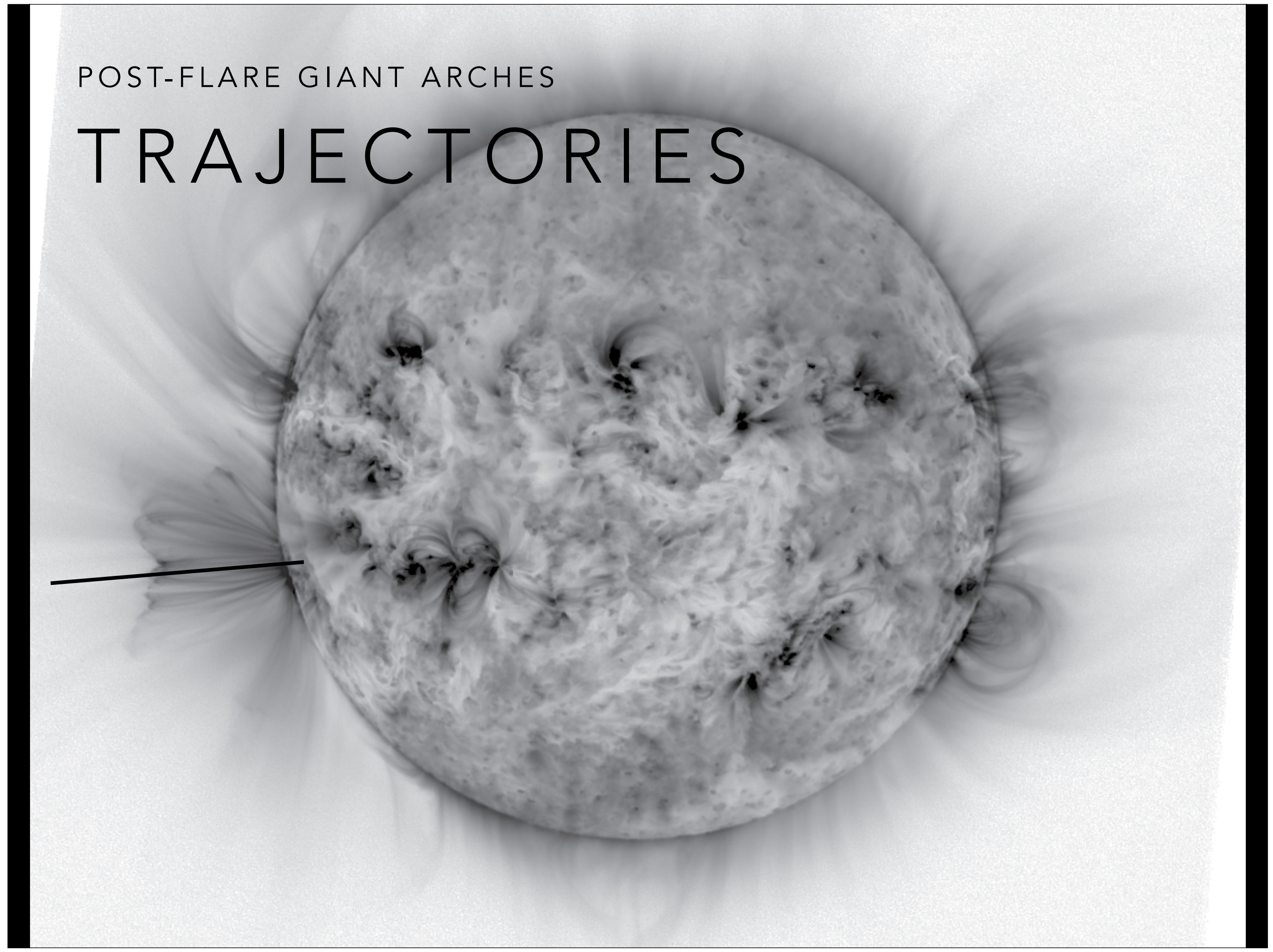
POST-FLARE GIANT ARCHES

GOES LIGHT CURVE



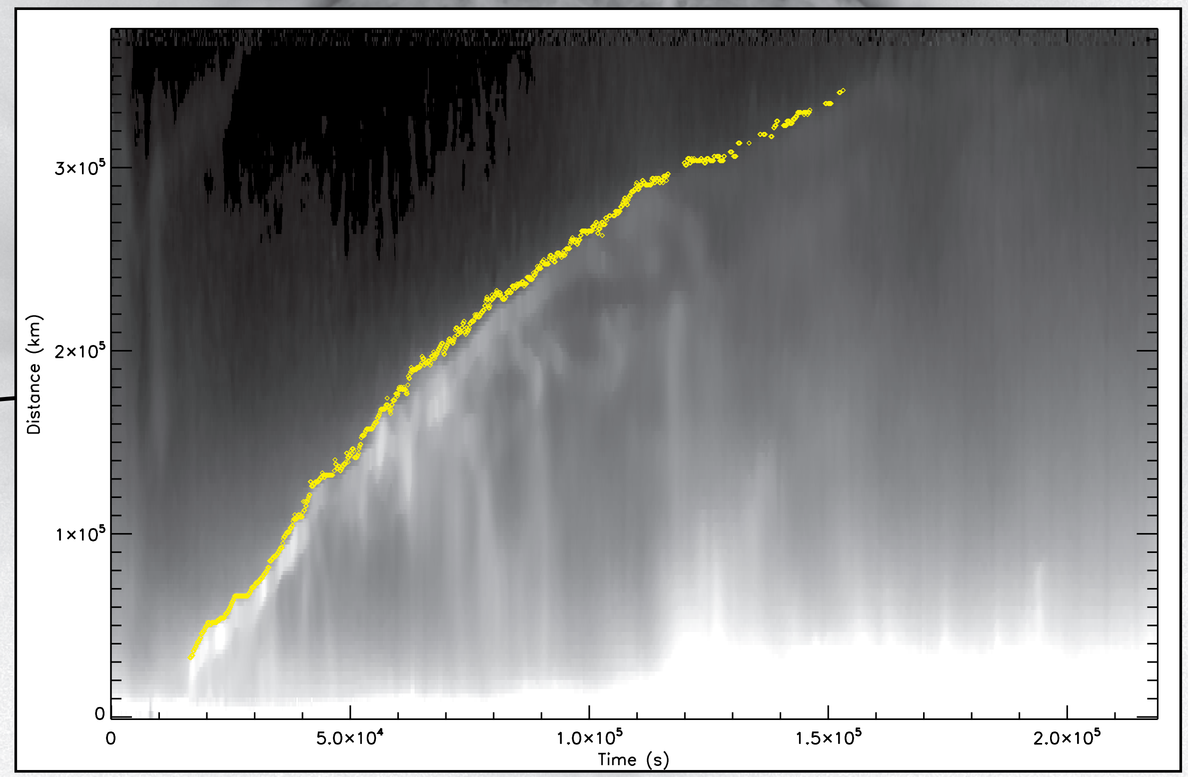
The GOES x-ray irradiance was double-peaked, probably because the footpoints of the eruption were occulted. As the post-eruptive loops grew, they became bright in GOES. The x-ray event extended for more than a day.



We tracked the growth of the loops generated during this event by taking a cut across them and using an automated algorithm to track the brightness peak.

POST-FLARE GIANT ARCHES

TRAJECTORIES



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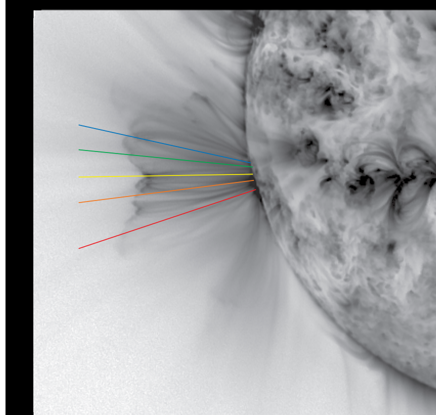
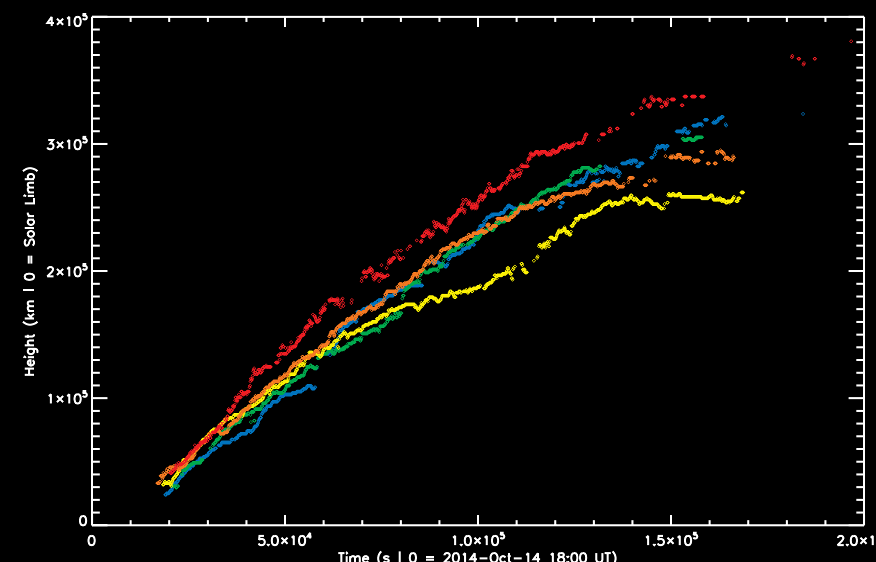
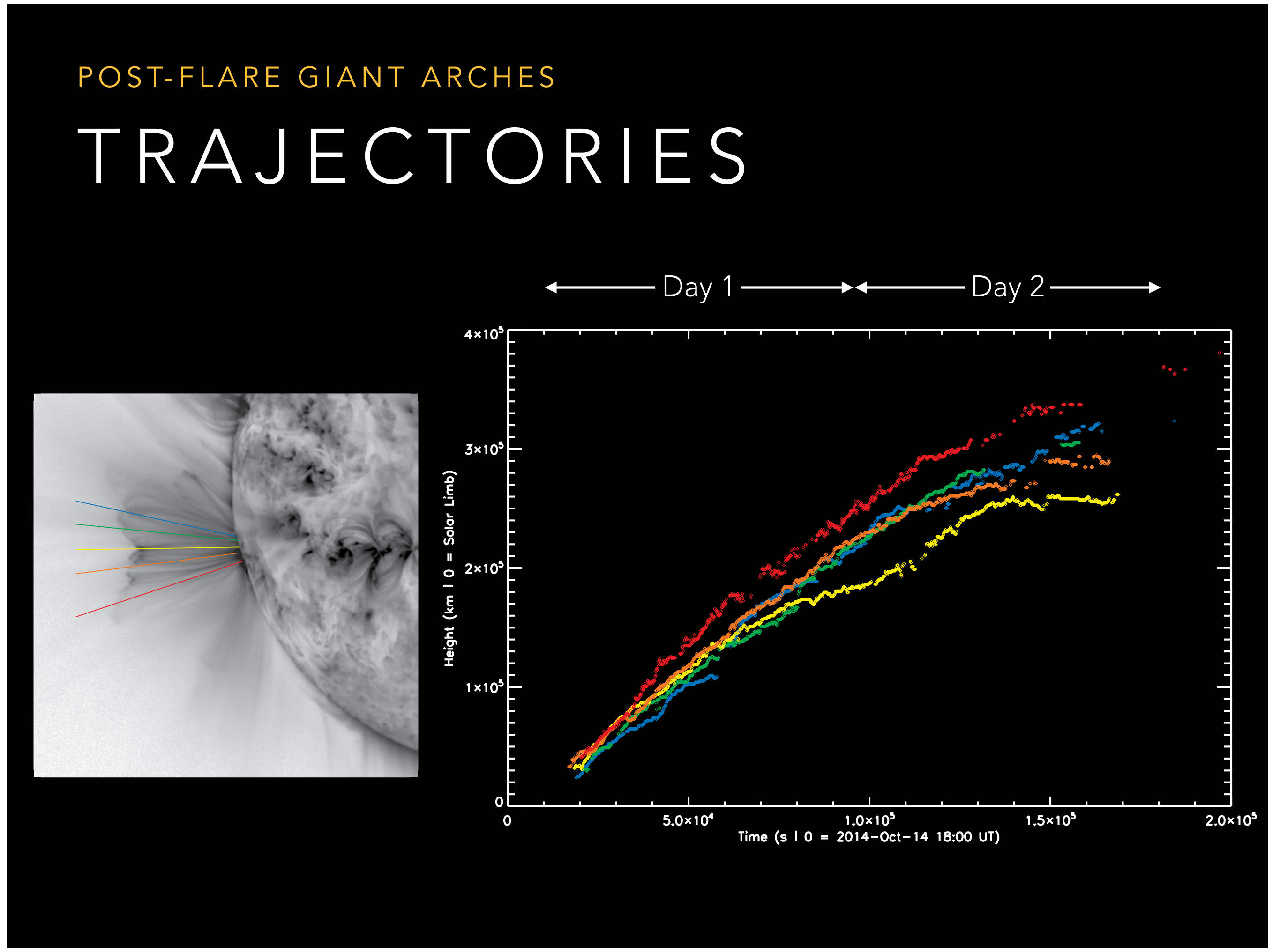




The growth rates varied over the whole arcade, but loops reached heights between 200 and 400 thousand km over two days of growth. The speeds of growth were a few km/s.



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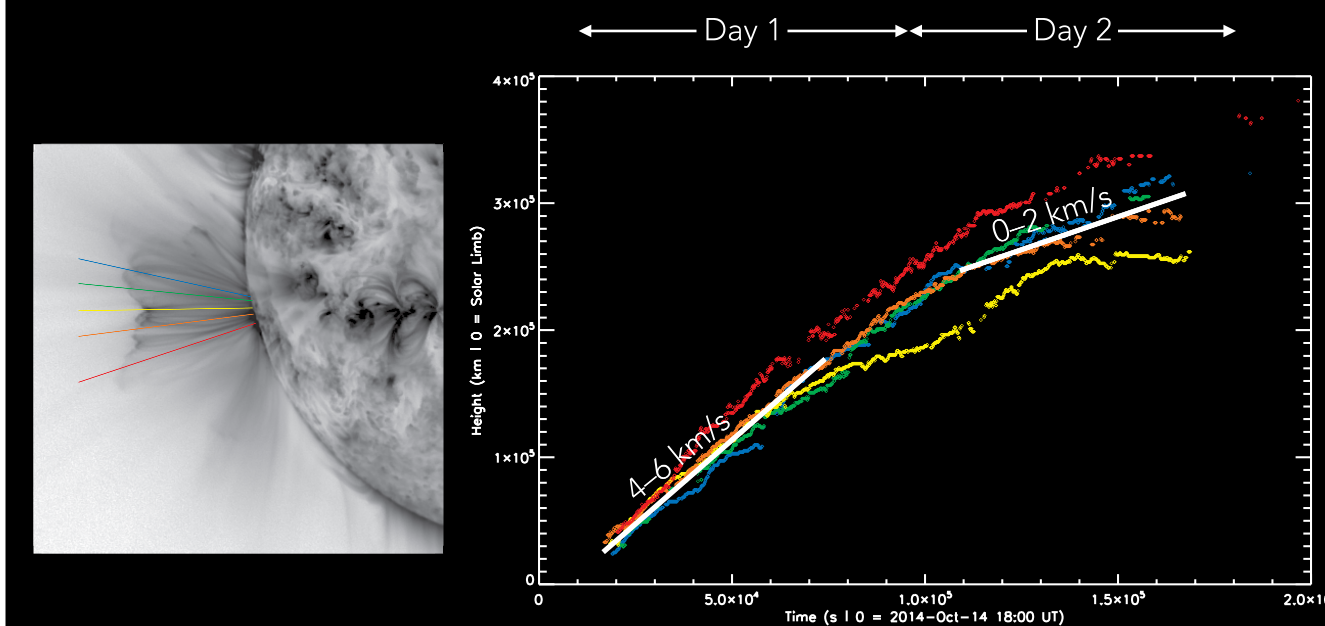

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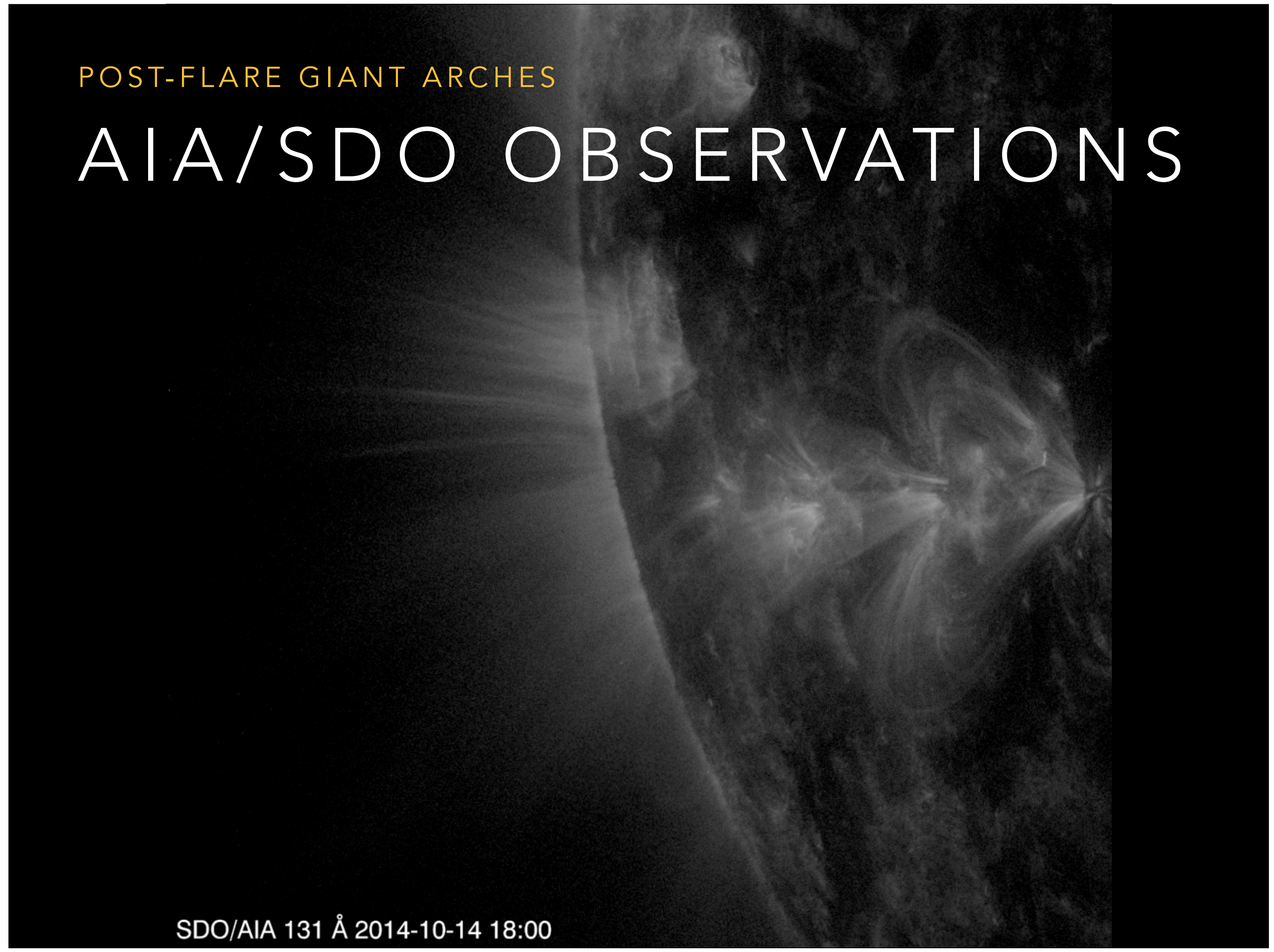
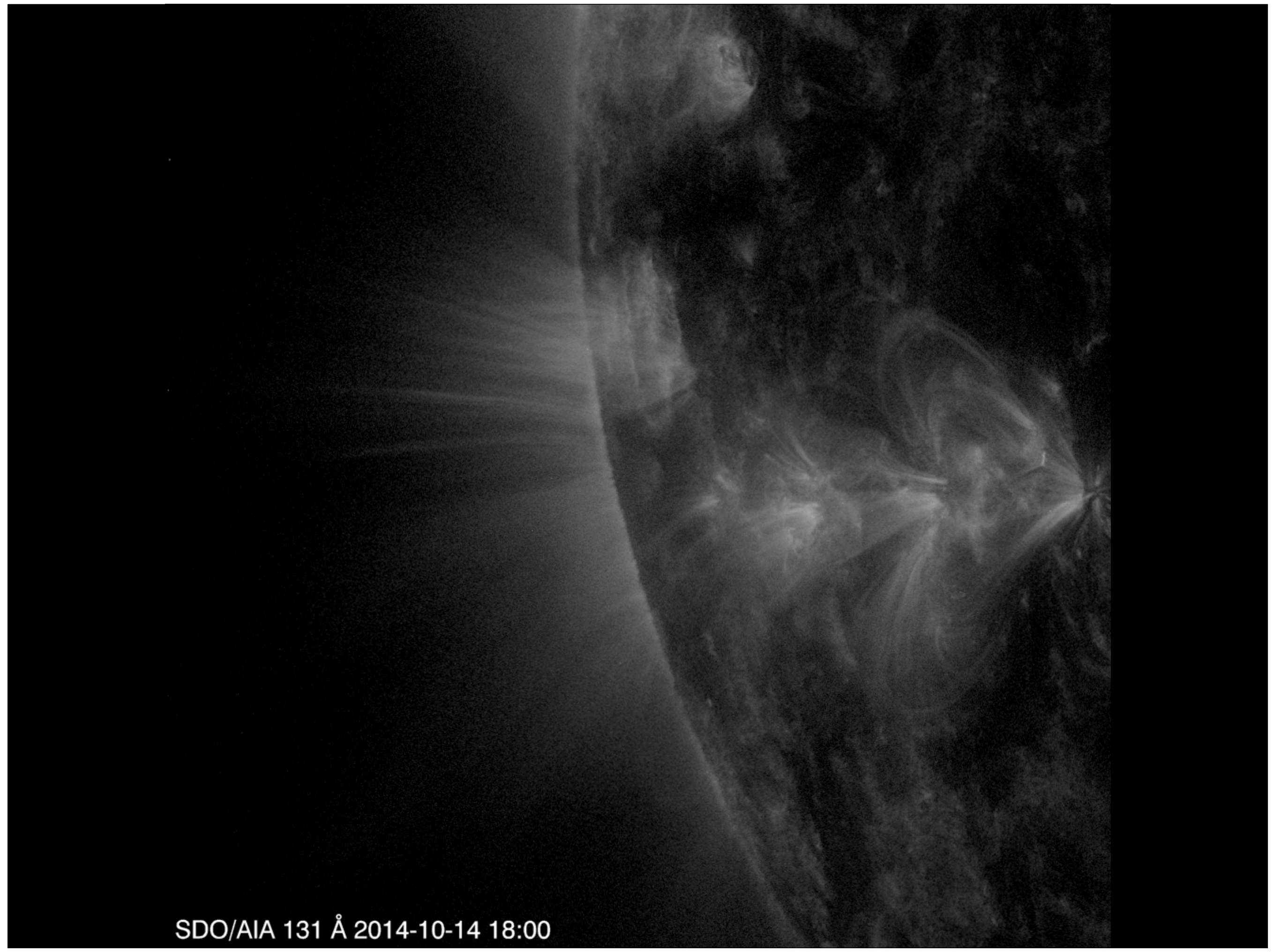


During the eruption SDO/AIA observed a large region of hot, diffuse plasma above the post-flare loop system. It's hard to see in this movie, but it was quite dynamic.



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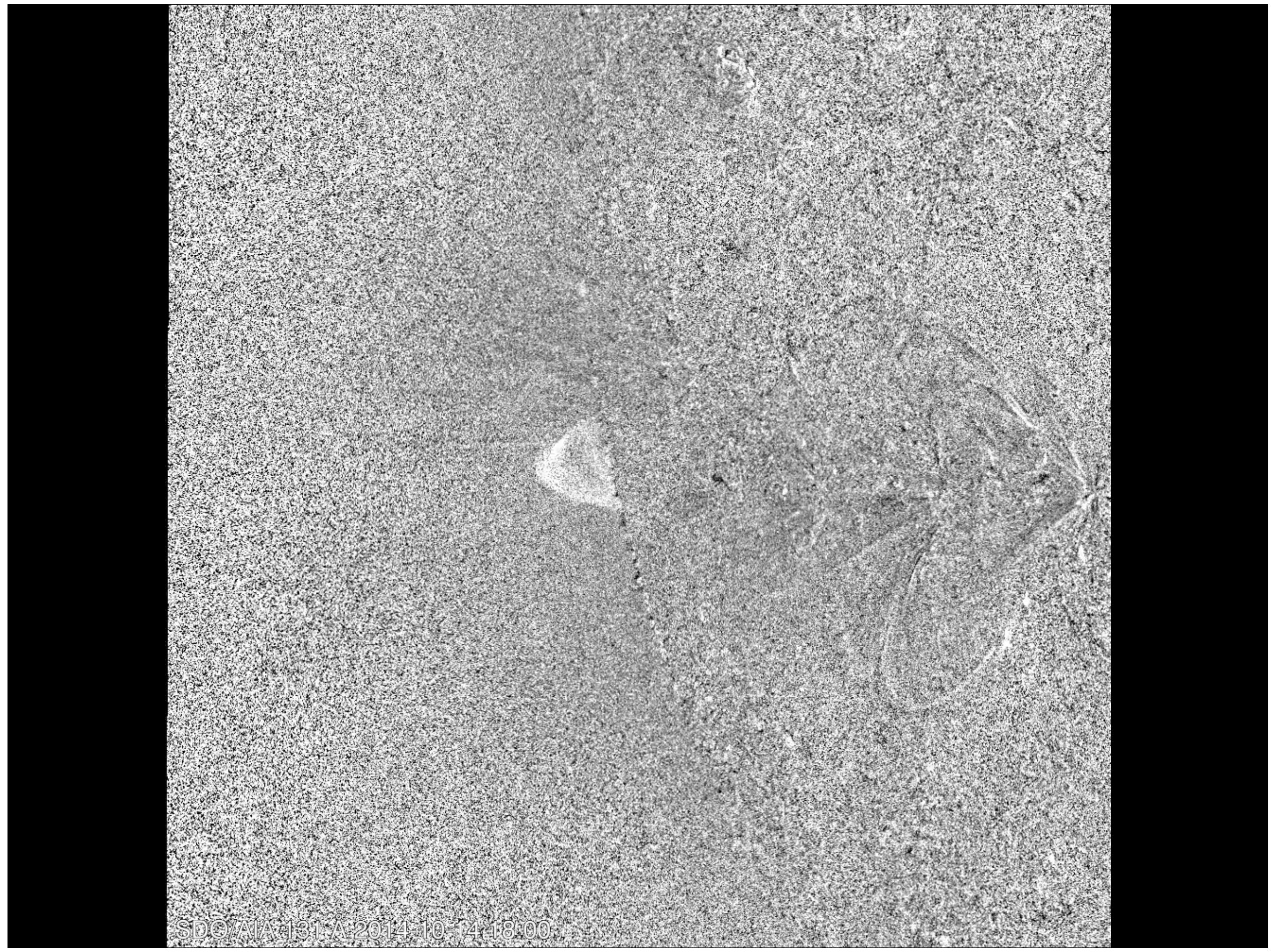
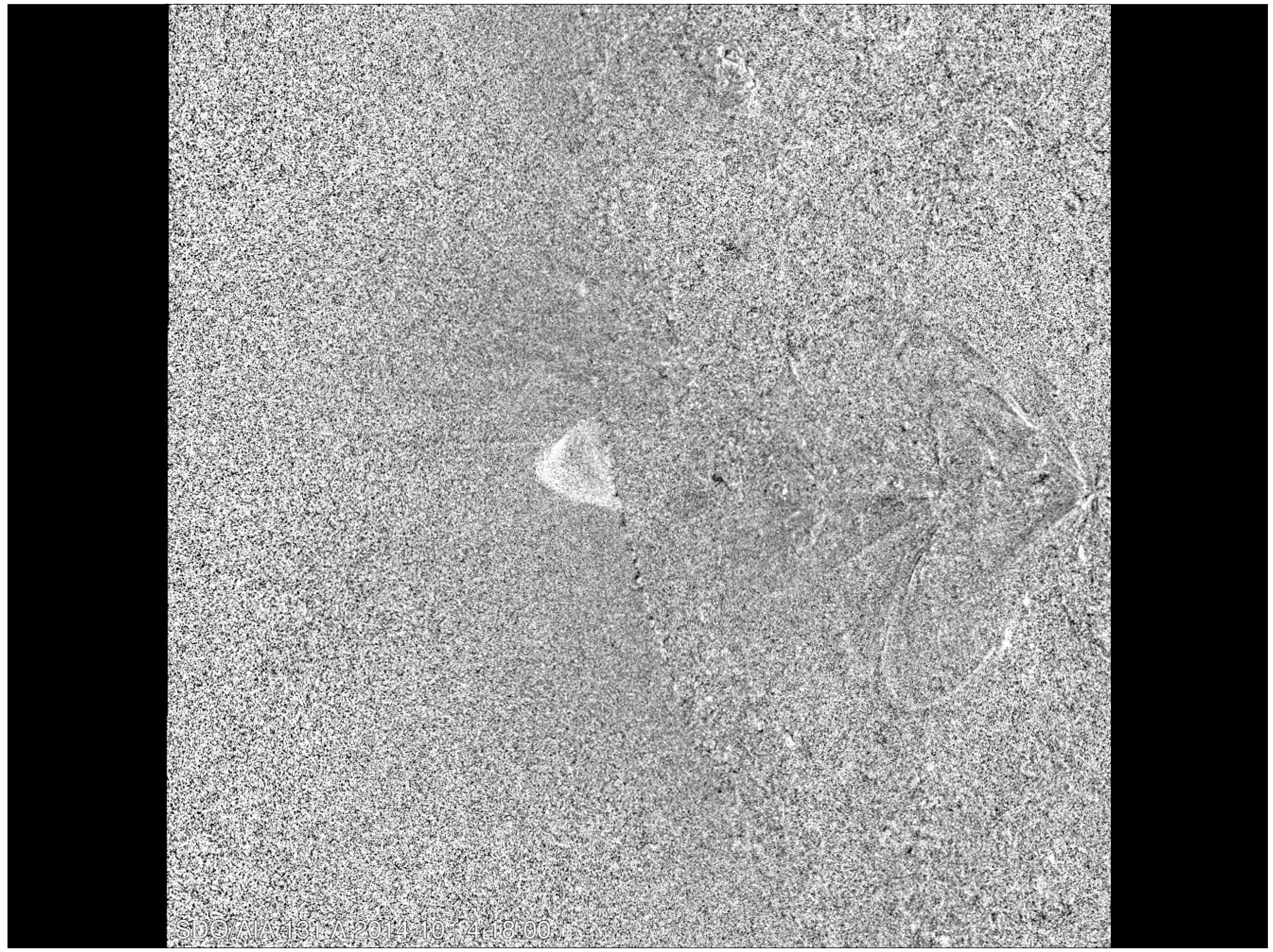


So we made a running-difference movie instead. The inflowing material and shrinking loops seen in the hot lines in the AIA 131Å passband are classic signs of magnetic reconnection.



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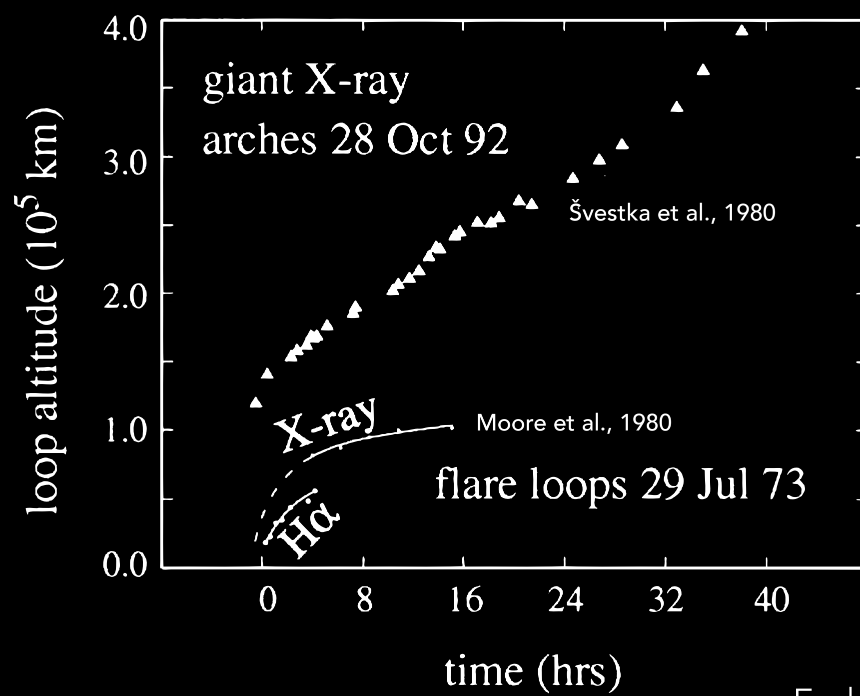
POST-FLARE GIANT ARCHES

IMPLICATIONS



Forbes & Lin, 2000

Svestka reported on similar structures seen in X-rays, which he called “Post-Flare Giant Arches”. He wondered if reconnection could be responsible for their growth. Unlike most post-eruptive loops, whose growth stops after a few hours and which rarely reach heights above 100,000 km, they grow to large heights over several days.

POST-FLARE GIANT ARCHES

IMPLICATIONS

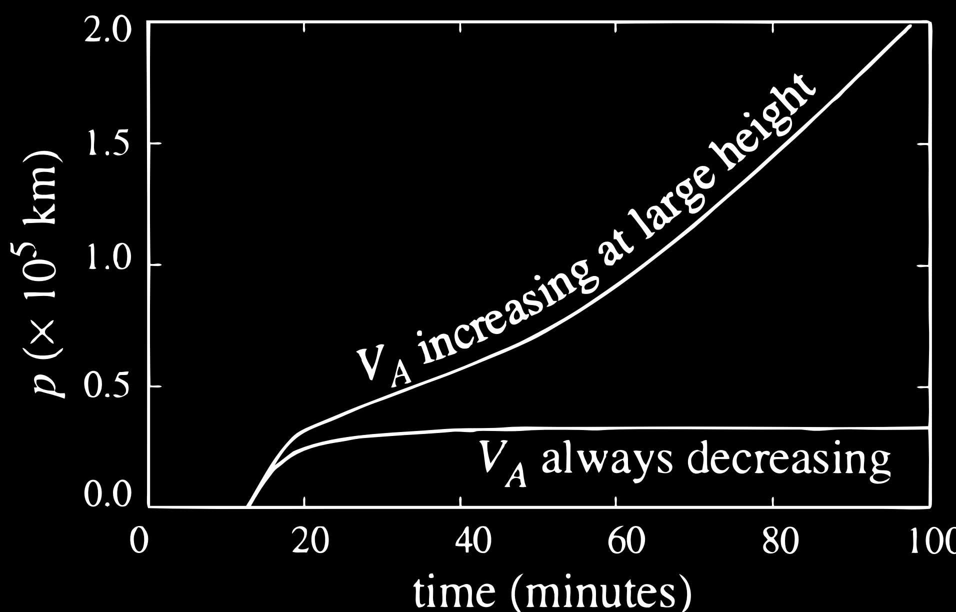
$$V_A = \frac{B}{\sqrt{\mu\,\rho}}$$

Alfvén Speed ∝ Reconnection Rate

Svestka wondered if reconnection could be responsible for their growth, given that the reconnection rate is proportional to the Alfven speed, which, in turn, is: v_A = B/(μ rho)^1/2. But there is another term in the equation that can come into play.

POST-FLARE GIANT ARCHES

IMPLICATIONS

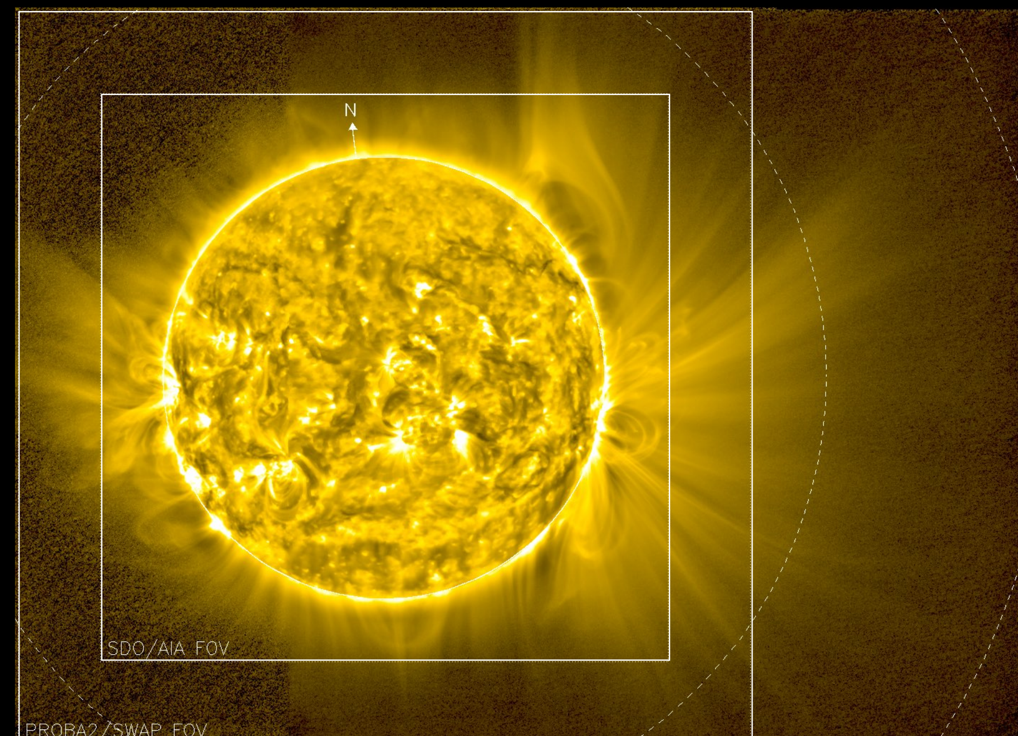


Forbes & Lin, 2000

Forbes and Lin argued that there is a pretty plausible argument for reconnection's role in these loops. If the density falls fast enough to balance any decrease in the magnetic field, the Alfvén speed can increase at large height. Using their analytic eruption model they showed that in this case, the reconnection can runaway and the post-eruptive loops system can grow to large heights.

POST-FLARE GIANT ARCHES

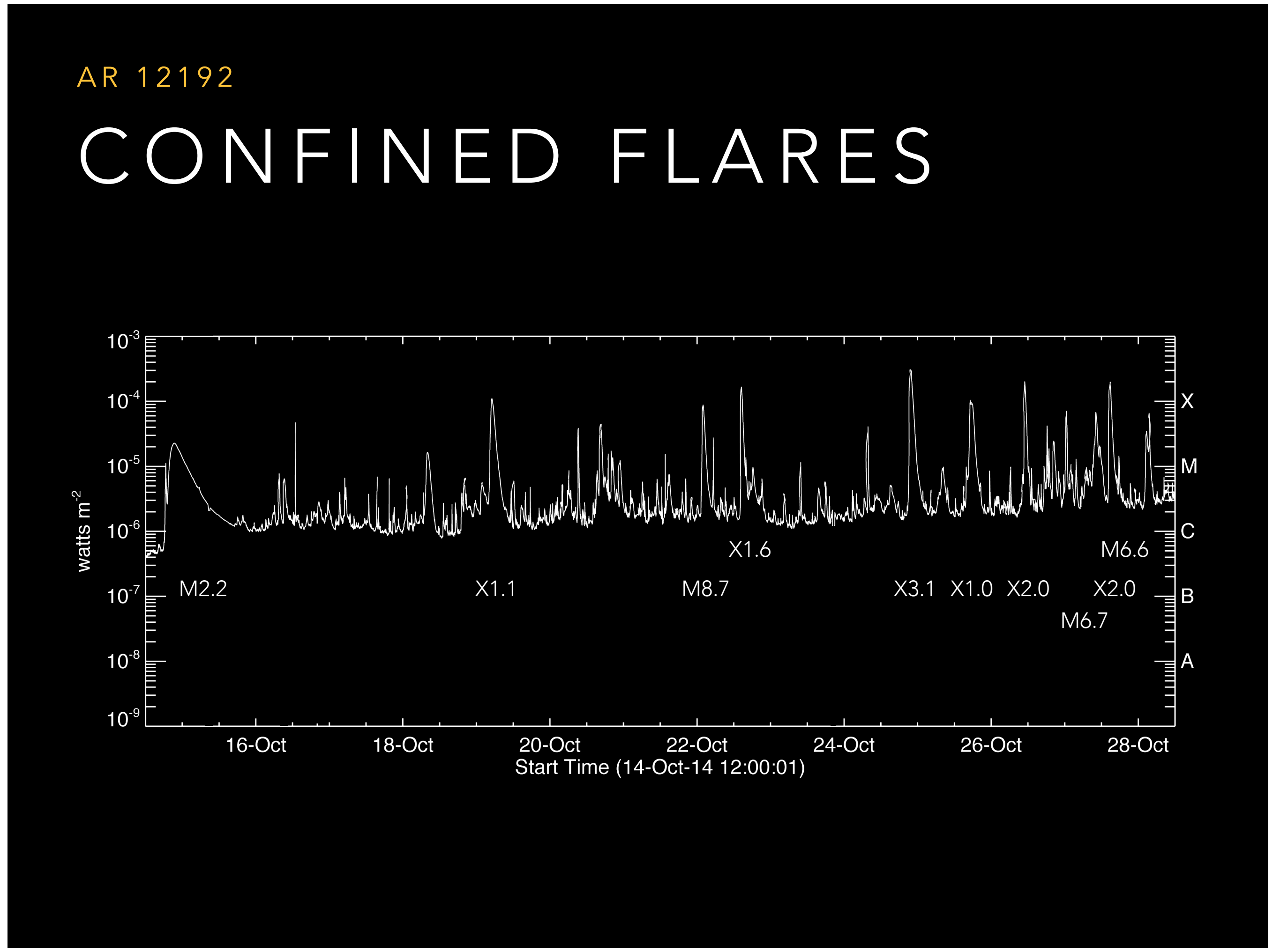
AR 12192 (LATER)



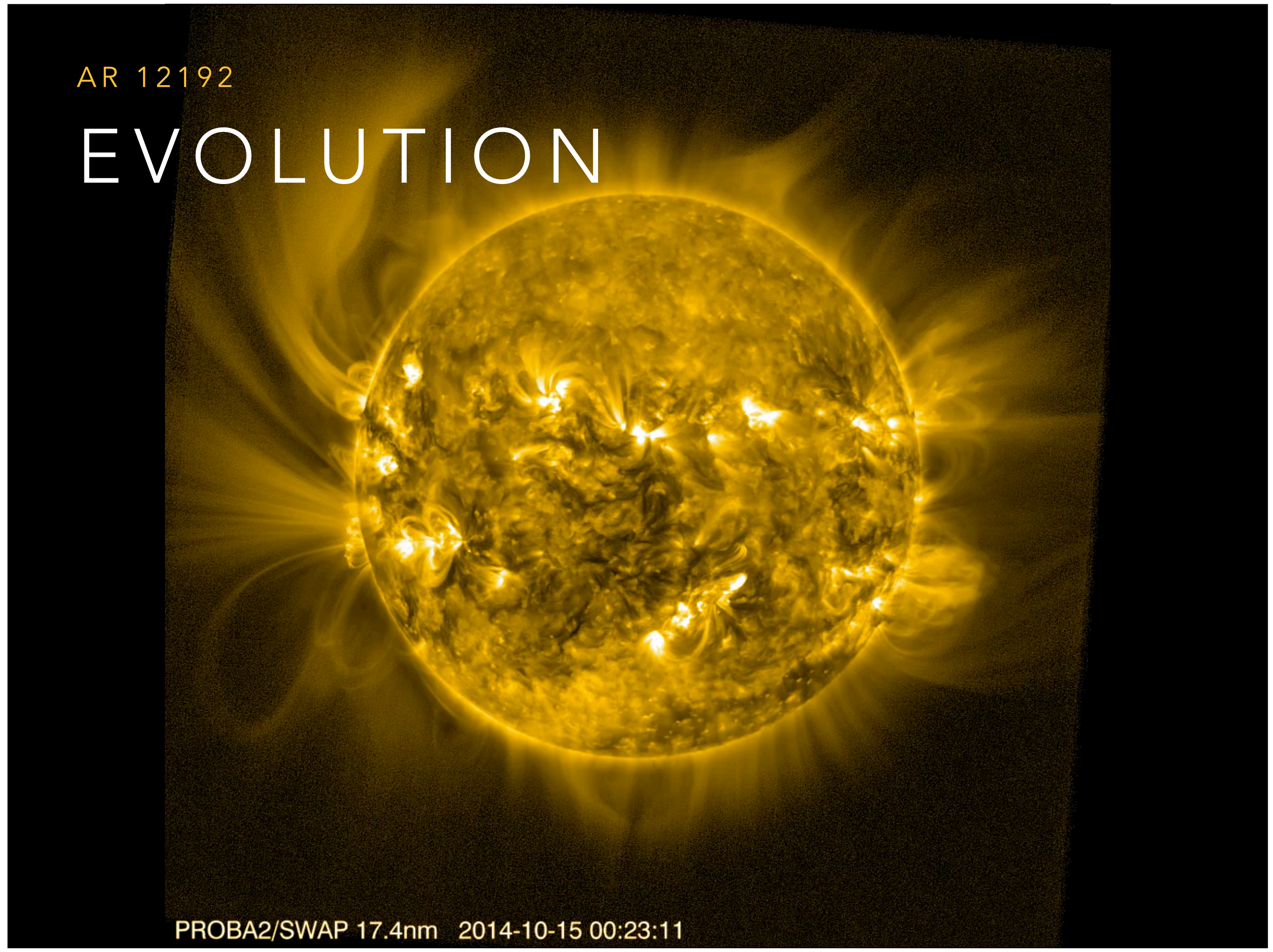
Much later in its evolution it was associated with a massive region of open field. Does that tell us anything? Maybe, maybe not, but we wonder if the large, open field region could be evidence of large-scale density outflow.

ACTIVE REGION 12192

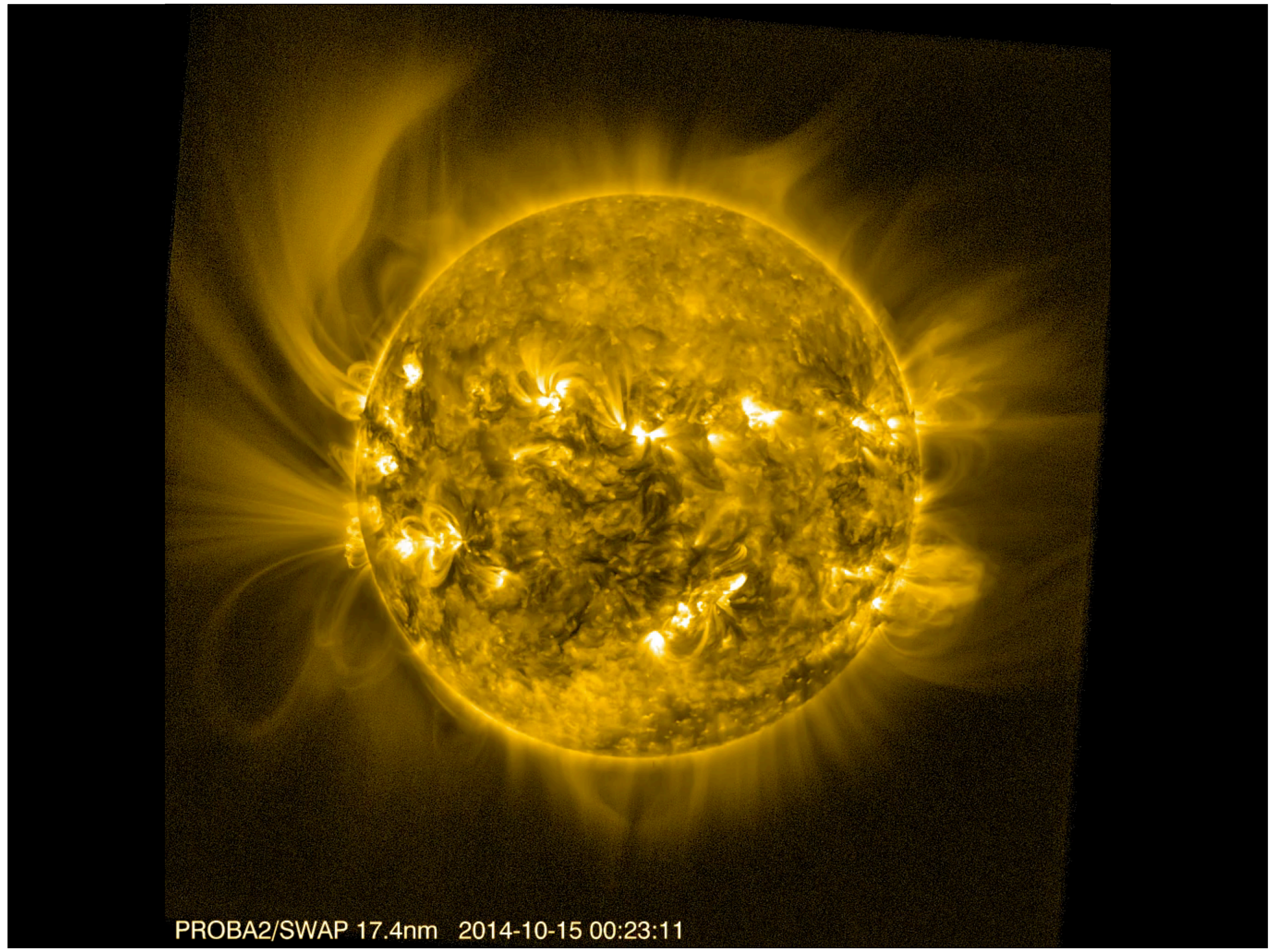
In addition to this event, AR 12192 produced many other unusual flares. Can we say something about them?



After our event, AR12192 produced at least nine flares above M5, but none of these were associated with a CME.



We can watch this region over the long term using SWAP and see how the large-scale magnetic field associated with it evolves. This region was associated with a massive set of dipolar loops that were practically as large as the sun itself.



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The PFSS of this region a little later shows the dipolar field I’m talking about very clearly.

Comparing to the real observations, we can see this field. We can see the region is intense, but any erupting structure would have a hard time breaking through this highly potential field system and erupting. Most eruptions from this region came from weak flares near the edges of the region.

AR 12192

FREE ENERGY

			AR 12192	AR 11429	AR 11158	Unit	Type*
Flare and CME†		Flare index	2335	1295	592		
		Major flares	15	7	3		
		Event	SOL2014-10-24T21:41	SOL2012-03-07T00:24	SOL2011-02-15T01:56		
		Location	S21W21	N18E31	S20W10		
		GOES class	X3.1	X5.4	X2.2		
		Duration	66	38	22	min	
		CME	No	Halo	Halo		
Low corona‖	Overlying	$B_h(42)$	220±8	61±7	42±0	G	I
		$B_h(42)/B_h(2)$	**0.35±0.04**	**0.06±0.00**	**0.05±0.00**		I
		Critical height	77±1	34±0	42±1	Mm	I
	Energy	E_p	152.8±0.2	20.9±0.1	8.8±0.0	10^{32} erg	E
		E_f	4.5±0.0	10.6±0.0	2.5±0.0	10^{32} erg	E
		E_f/E_p	**0.03±0.00**	**0.51±0.02**	**0.28±0.01**		I

Sun *et al.*, 2015

They compared the eruptions from this region to other similar active regions. They found that, although the fields are strong and there is plenty of energy to drive flares, the critical height for eruptions is very large and the ratio of free to potential energy is very low. Eruptions were energetically impossible. What role did our event play in generating these large dipolar fields?

CONCLUSIONS

1. The **Post-Flare Giant Arches** associated with the October 14 eruption were generated by magnetic reconnection.

2. Despite its size, AR 12192 could not produce CMEs because of the **massive, highly potential dipolar fields** overlying it.

3. Why the October 14 event *did* produce a CME — and its role in the evolution of AR12192 — is an interesting but **unanswered** question.

It would be very interesting to know either what was special about our event, or whether our event played a role in setting up the conditions that dictated the dynamics of the rest of the non-eruptive flares later on.