Post-Flare Loop Signatures

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Post-flare giant arches are large-scale post-eruption loop systems. They were originally classified as a separate phenomena to regular post-flare loops due to their size. It was unclear how reconnection could be sustained to maintain their growth. See Švestka et al. (87, 95, 96, 97, 98).

An example of such a loop system was produced by AR 12192 at 18:30 UT on 14-Oct-2014, seen from beyond the East solar limb (See West & Seaton; 2015). The growth of the loops can be seen in Figures 1 and 2. They were associated with a CME (v=1300 kms^{-1}) and an M2.2 solar flare.

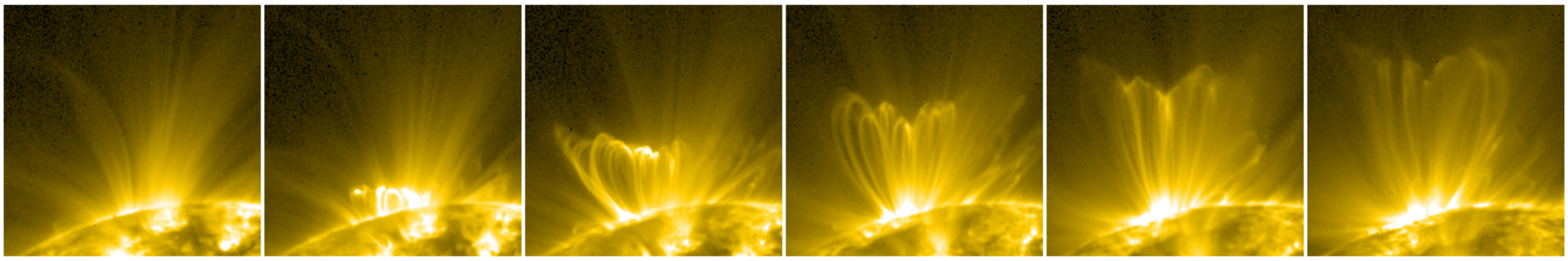

Figure1. Growth of post eruption loops observed by the SWAP EUV imager (174 Å; Fe IX/X at log T ≈ 6) on PROBA2 on 14-Oct-2014.

Evidence For Sustained Reconnection

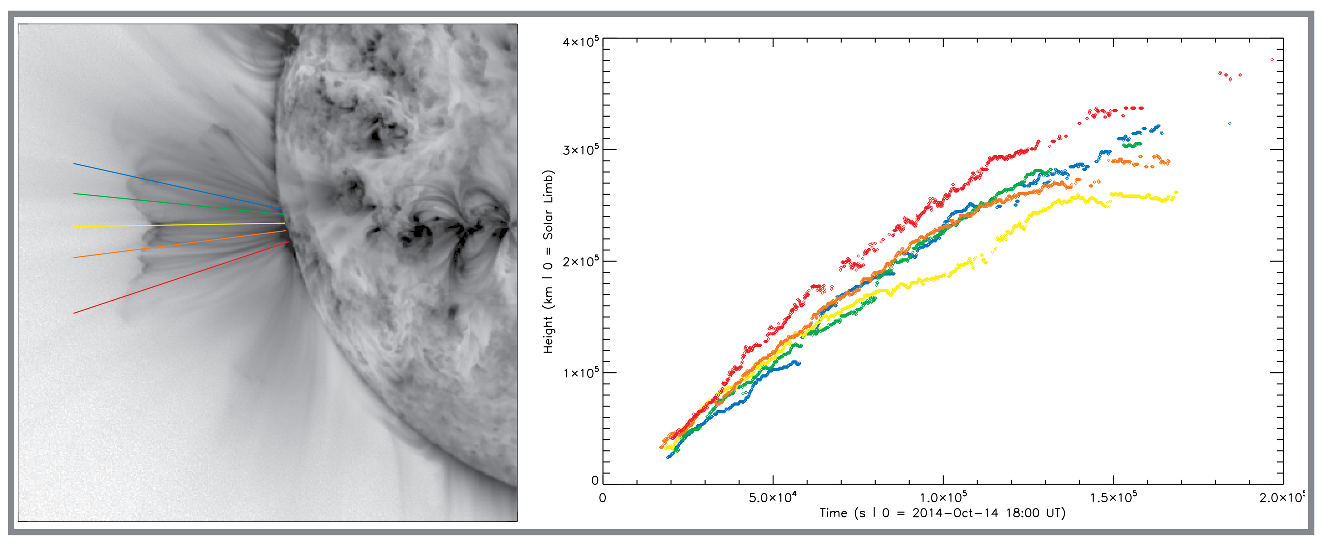

Figure 2. Growth rate of post eruption loops observed by SWAP.

A consequence of the reconnection process is the generation of hot post eruption loop arcades, which can be seen in Figures 1, 3, 5 & 6. The full extent of the loops can only be seen in EUV with SWAPs large field of view.

Seaton et al. (2017) used AIA observations to characterise the current sheet associated with a similar event. The sheet was on the order of a few thousand kilometres thick for the duration of the event, and observed to have temperatures of the order T≈8-10 MK. They estimated the reconnection rate during the event to be R≈0.004-0.007, a value consistent with model predictions.

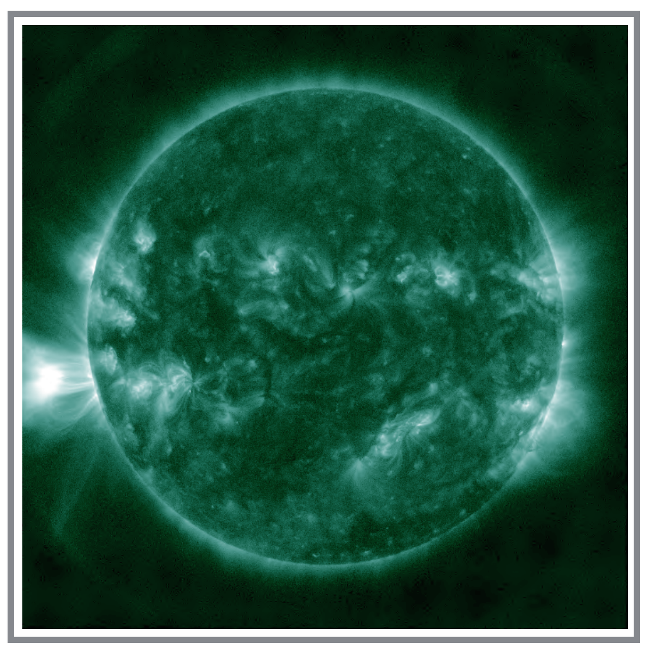

Figure 3. AIA 94 Å (T = $10^{6.8}$ K).

Growth of High Energy Structures

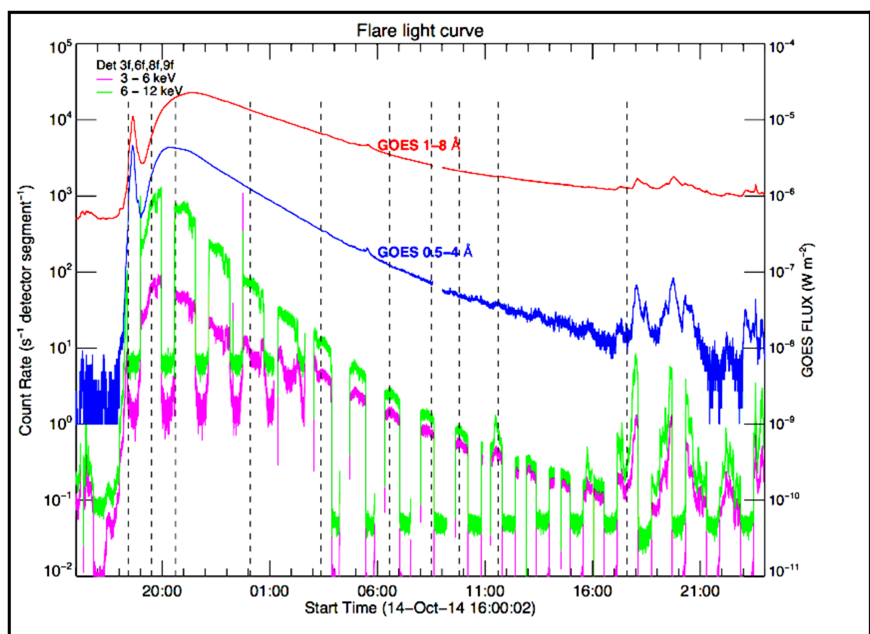

Figure 4. RHESSI 6-12 KeV & 12-25 KeV light curves

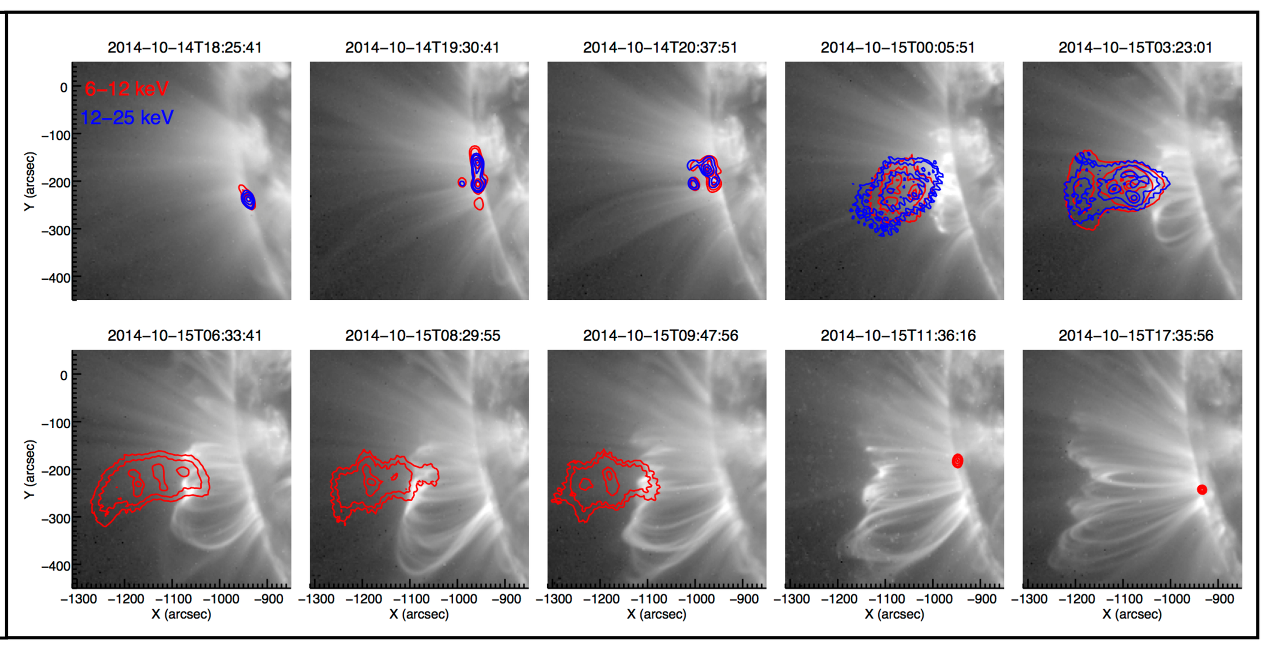

Figure 5. SWAP Observations with 6-12 KeV & 12-25 KeV RHESSI contours over plotted.

High energy signatures from the flare and subsequent post eruption reconnection (arcades) were recorded by RHESSI, which can be seen in the RHESSI light curves in Figure 4.

Particles accelerated from the reconnection region are traced by RHESSI contours (see Figure 5). The different energy bands indicate the growth of the current sheet above the reconfigured field lines ejected from the X-point.

Further High energy Signatures

The post eruption loops are also clearly evident in the hot EUV bandpasses of SDO / AIA and X-ray observations of GOES SXI. One of these hot passbands (131Å) can be seen in Figure 6 (right) next to GOES SXI (left).

In both the AIA and SXI observations we see a large region of hot, diffuse plasma above the post-flare loop system.

This plasma is restructured through magnetic reconnection, and the loops are the product of the exhaust region of the reconnection X-point.

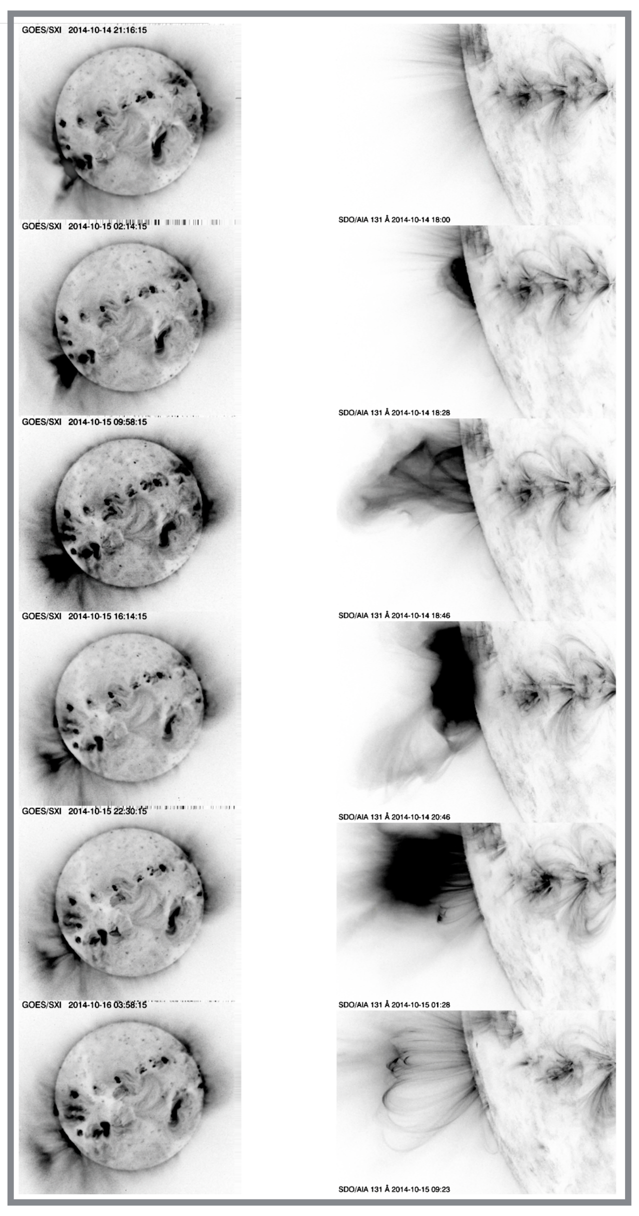

Figure 6. Observations of the post eruption loops in SXI (left) and SDO AIA 131 Å (right) observations.

Super Arcade Down-Flows

Supra-Arcade Downflows (SADs) appear to be voids created by loops (SADLs) shrinking through the fan plasma. McKenzie & Hudson 1999 - Sheeley, Warren, & Wang 2007 - Savage & McKenzie 2011 - Savage, McKenzie, & Reeves 2012 - Savage et al. 2012.
The continual shrinking loops imparts energy into the current sheet long after the flare.

The series of images in Figure 7 are made up of LASCO, PROBA2 SWAP and AIA 131Å images. Following the initial eruption, we see the post eruption loops grow out of the AIA Field of view into the SWAP Field of view.

There is clear evidence of SADs following the eruption. This is compelling evidence of ongoing reconnection following the eruption. Uniquely in this example, the SADs were observed for several days after the initial eruption and indicate ongoing fast and patchy reconnection.

Evidence of SADs are seen up to 1 week after the initial eruption!

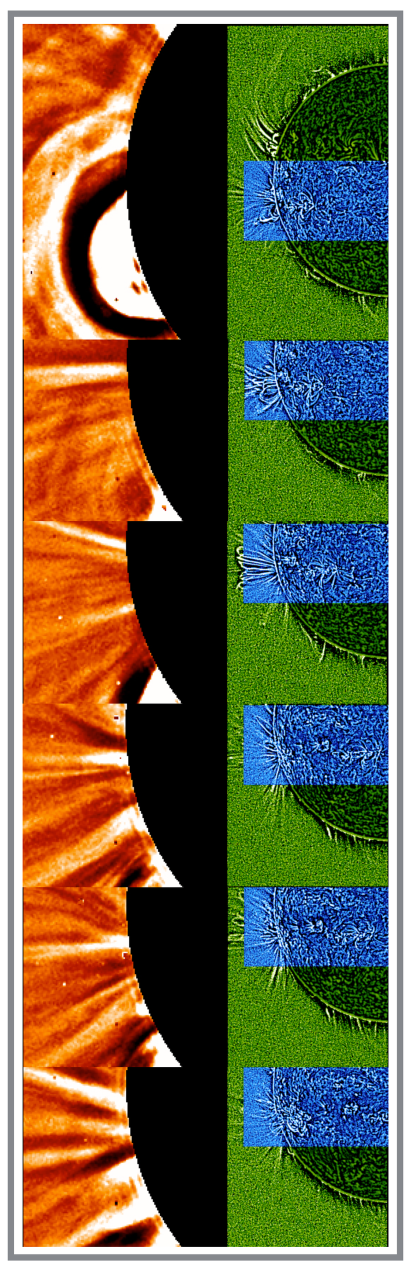

Figure 7. LASCO (orange), PROBA2 SWAP (green) and AIA 131 (blue) images of the initial eruption & CME (top), followed by the growth of the post eruption loops (moving down the page). SADs are evident in the last three frames as dark 'streaks'.

Why Are Some Loops So Large?

The observations of large post-eruption loops lead to several tantalising questions.

Why does the reconnection process cease so much earlier in most events?

Why are they so uncommon? And, correspondingly, what mechanism determines when, and at what height, reconnection is switched off, limiting the growth of such systems?

One possible explanation is that the growth of many traditional post-flare loop systems really is self-limited by the Alfvén speed in the vicinity of the erupting active region.

If the density does not fall sufficiently with height, the Alfvén speed would decrease with height and, correspondingly, the reconnection rate would drop as the height of the reconnection site increased.

In that scenario the reconnection process could be self-limited, just as Švestka originally surmised. Perhaps AR 12192 is one of the unusual active regions in which the surrounding density decreases fast enough that the Alfvén speed does not decrease significantly, allowing reconnection to proceed much longer than usual.