A Comparative Study of the Eruptive and Non-Eruptive Flares Produced by the Largest Active Region of Solar Cycle 24

Ranadeep Sarkar & Nandita Srivastava
Udaipur Solar Observatory, Physical Research Laboratory, Udaipur, India

AR 12192 was the largest active region (AR) of Solar Cycle 24. The most peculiar aspect of this AR was that it produced six X-class flares during its disc-passage in October 2014, but none of them were associated with CMEs. Only one CME was produced by this AR, during an M4.0-class flare that occurred away from the core region on 24 October. Several studies have reported that the energetic flares are accompanied by an abrupt, downward vertical Lorentz-force change. However, the flare-related photospheric magnetic-field and Lorentz-force changes in the case of confined flares are poorly studied. Thus, AR 12192 gave a unique opportunity to verify and extend the above results for several confined flares produced by it. In this work, we examine the flare related changes in morphological and magnetic characteristics associated with both the confined and eruptive flares produced by AR 12192.

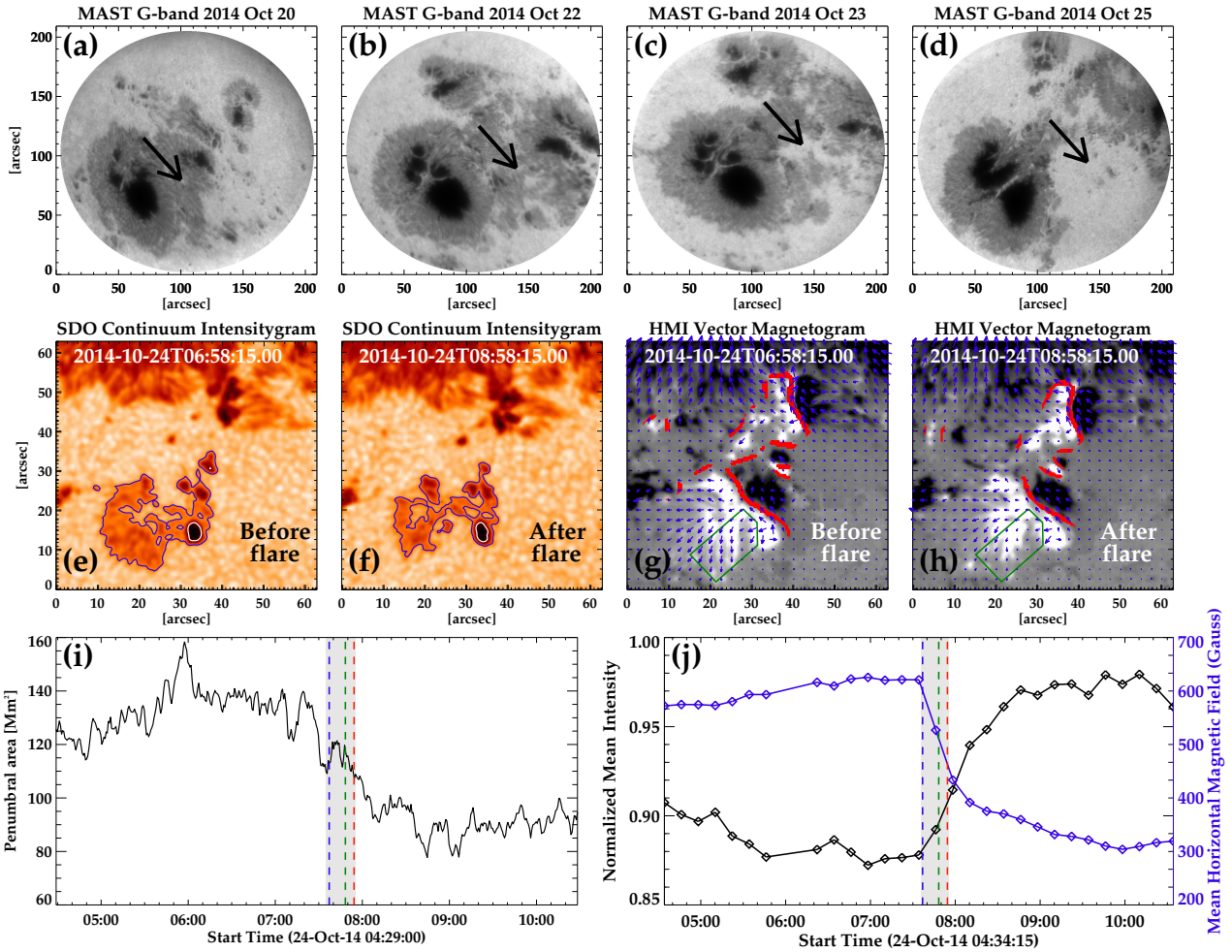

Figure 1: *(a)-(d): G-band images of AR 12192 taken from Multi Application Solar Telescope (MAST) at the Udaipur Solar Observatory. (i): The areal variation of the contoured penumbral region shown in (e) and (f). (j): The black-solid line represents the temporal variation of normalized intensity and the blue-solid line represents the variation of transverse magnetic field calculated within the green bounded box shown in (g) and (h).*

Analyzing the vector magnetograms obtained from Helioseismic Magnetic Imager (HMI) on board the Solar Dynamics Observatory (SDO), within a time-window of six hours centering each of the eruptive and four confined flares of our dataset, we have found that the integrated transverse magnetic flux near the polarity inversion line (PIL), increased permanently for all the cases. Importantly, the

change in mean horizontal magnetic field during the eruptive flare has been found to be about 135 Gauss, whereas for the confined flares it ranges from about 15 to 35 Gauss only. During each of the flares, the radial component of the Lorentz force underwent a large and abrupt downward change, range from 0.3×10^{22} to 2.6×10^{22} dyne. Noticeably, the change in Lorentz force per unit area for the eruptive flare was about 4040 dyne/cm^2, which is almost three times larger than the maximum change (1390 dyne/cm^2) found in the four confined cases.

AR 12192 underwent significant morphological changes during its disc passage from 17-30 October 2014. G-band images from the Multi-Application Solar Telescope (MAST) of Udaipur Solar Observatory/PRL, for four different days (Figure 1) depict the gradual decay of penumbral area near the core region (marked by black arrows) of AR 12192 where all the confined X-class flares occurred. Besides the gradual change, we have also found flare-related abrupt penumbral area decay (Figure 1(e),(f),(i)) away from the PIL of the source region of eruptive M4.0-class flare on 24 October 2014. Importantly, this rapid decay in penumbral area was associated with the permanent decay in horizontal magnetic field. The mean horizontal magnetic field, decreased permanently by almost half of its initial value from about 600 to 300 Gauss (Figure 1(j)) within less than half an hour during this eruptive flare.

From the study of the extrapolated magnetic field, we have found that the critical decay index (1.5) for the onset of torus instability was achieved at a higher height (52 Mm) over the non-eruptive core region of AR 12192, whereas this critical height was comparatively lower (35 Mm) over the eruptive part of the AR. Our comparative study of both the eruptive and non-eruptive flares produced by AR 12192 suggests that, although the flare-related permanent and abrupt changes in photospheric magnetic field and Lorentz forces are a common feature in large flares, the magnitude of those changes is smaller in the case of the confined flares compared to the eruptive ones.

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