# Confinedness of an X3.1 class solar flare occurred in NOAA 12192: Analysis from multi-instruments observations

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## Abstract

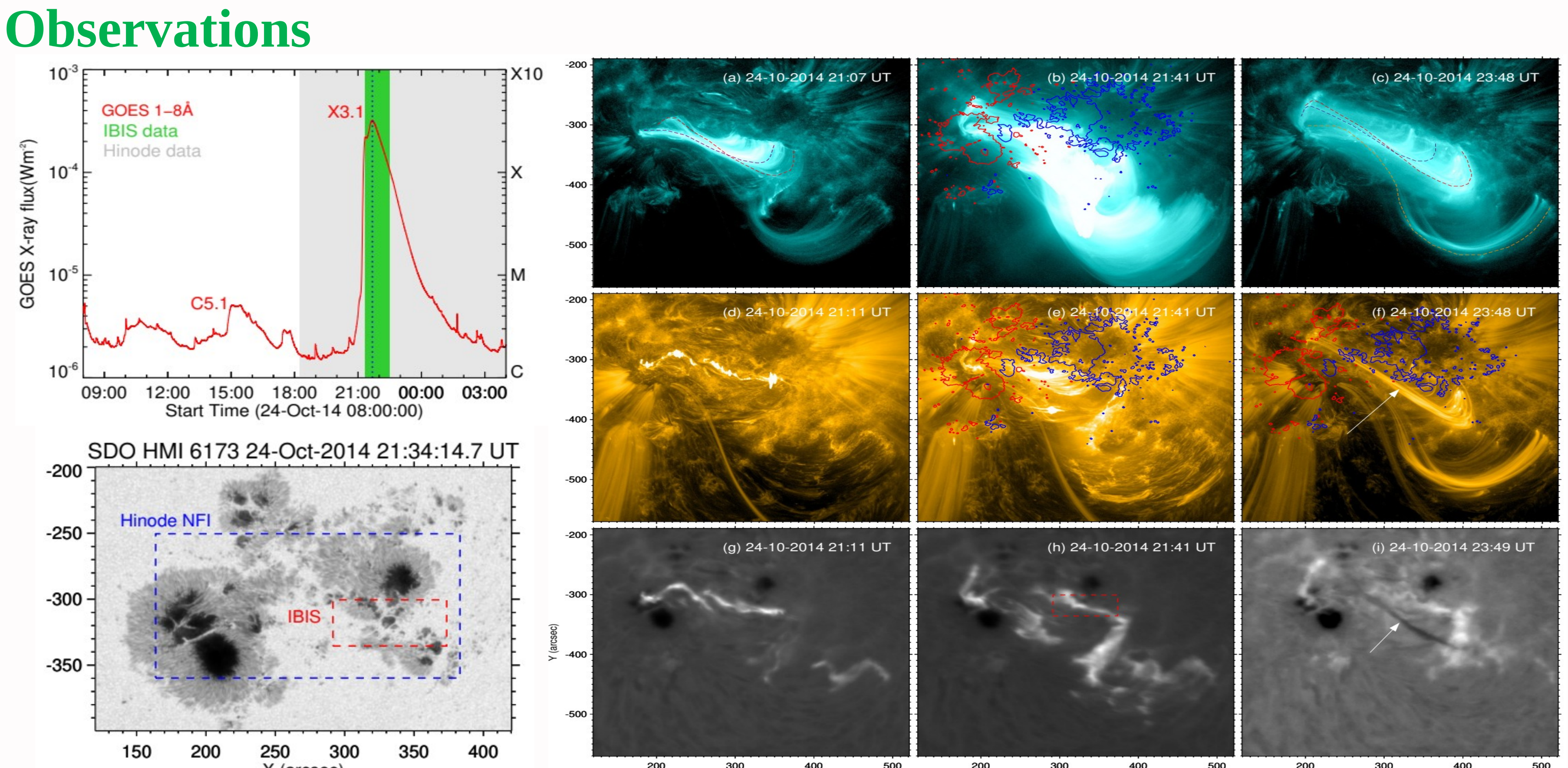
The non-association of coronal mass ejections with high energetic flares is sparse. For this reason, the magnetic conditions required for the confinedness of major flares is a topic of active research. Using multi-instrument observations, we investigated the evolution and effects of confinedness in an X3.1 flare, which occurred in active region (AR) 12192. The decrease of net fluxes in the brightening regions, near the footpoints of the multi-sigmoidal AR in photosphere and chromosphere, indicative of flux cancellation favouring tether-cutting reconnection (TCR), is observed using the magnetic field data acquired by HMI/SDO and SOT/Hinode, respectively. The analysis of spectropolarimetric data obtained by the Interferometric Bidimensional Spectrometer (IBIS) over the brightening regions suggests untwisting of field lines, which further supports TCR. Filaments near polarity inversion line region, resulted from TCR of low lying sheared loops, undergo merging and form an elongated filament. The temperature and density differences between footpoints of the merged filament, revealed by DEM analysis, caused streaming and counter-streaming of plasma flow along the filament and unloads at its footpoints with an average velocity of ≈ 40 km $s^{-1}$. This results in decrease of mass of the filament (density decreased by > 50%), leading to its rise and expansion outwards. However, due to strong strapping flux, the filament separates itself instead of erupting. Further, the evolution of non-potential parameters describes the characteristics of confinedness of the flare. Our study suggests that the sigmoid-filament system exhibits upward catastrophe due to mass unloading, but gets suppressed by strong confinement of external poloidal field

## Introduction

The association of flares and CMEs has been studied quite extensively and is still an active research topic. The AR 12192 is one of the largest, flare prolific and CME poor ARs of solar cycle 24. This AR produced about 35 major non-eruptive flares (29 M-class and 6 X-class) and one eruptive flare (M 4.0) during its disk passage from 18 to 29, October 2014.

Many studies were conducted on the X3.1 confined flare event, the strongest amongst the flare series. Past observational and simulation studies could successfully explain the formation of post-flare less sheared core field and stableness against kink instability, but they did not explain the formation of the observed filament and its rise motion during the long duration X3.1 flare event. Owing to the peculiar qualities and rareness of the event, we carried out a comprehensive analysis to investigate the evolution, cause and properties of confinedness of the X3.1 flare using spectropolarimetric imaging data, magnetograms and filtergrams corresponding to different layers of the solar atmosphere obtained by multi-instruments, on board different space-and ground-based telescopes.

## Observations



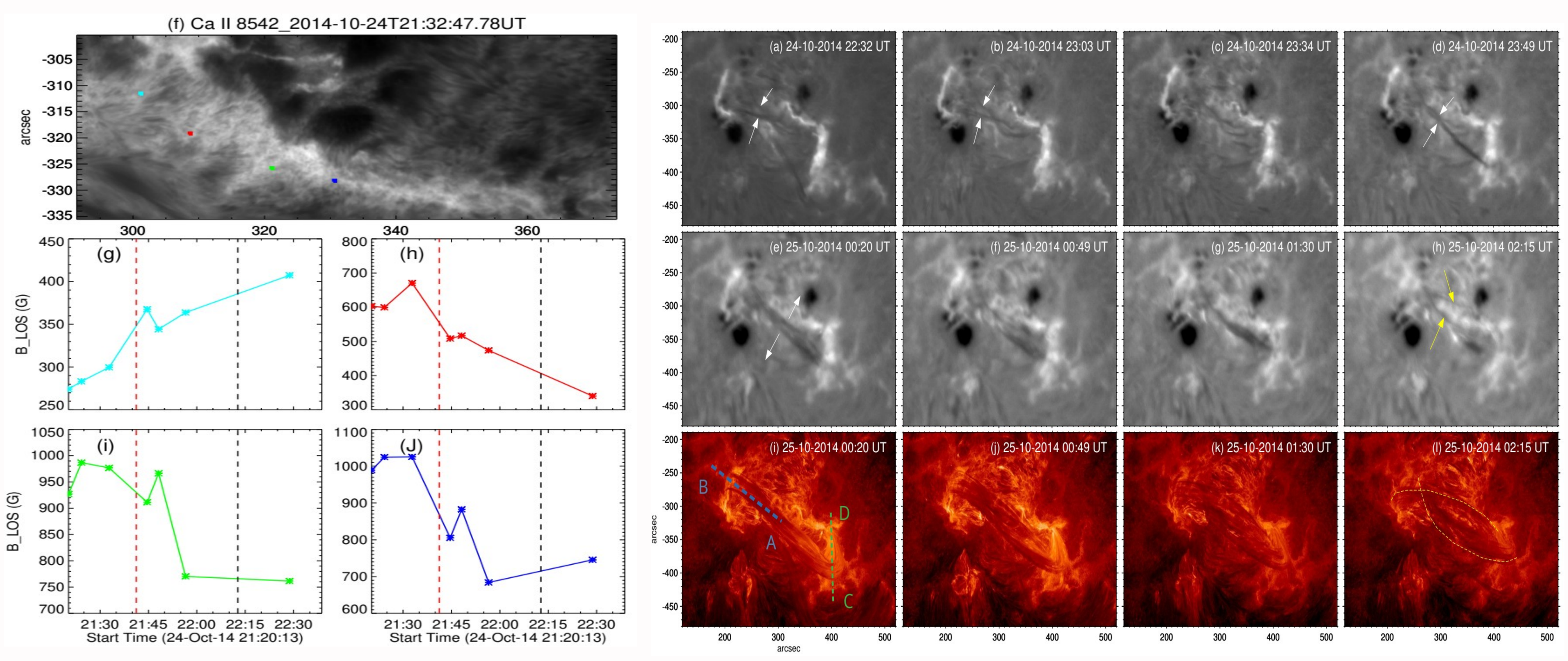

* The X3.1 flare was of long duration, lasting for 5 - 6 hours and occurred at a heliocentric angle of μ = 0.9.

* The AR holds multi sigmoidal structures prior to the start of the flare. Magnetic reconnection during the flare, brought out minimum morphological changes to the pre-flare coronal sigmoidal structures, but the appearance of filaments underneath these sigmoids was observed.

* Motivated by these observations, we studied the dynamics and non-eruptiveness of filamental structures and the mechanisms responsible for it using the data obtained from SDO, IBIS, GONG and Hinode instruments.

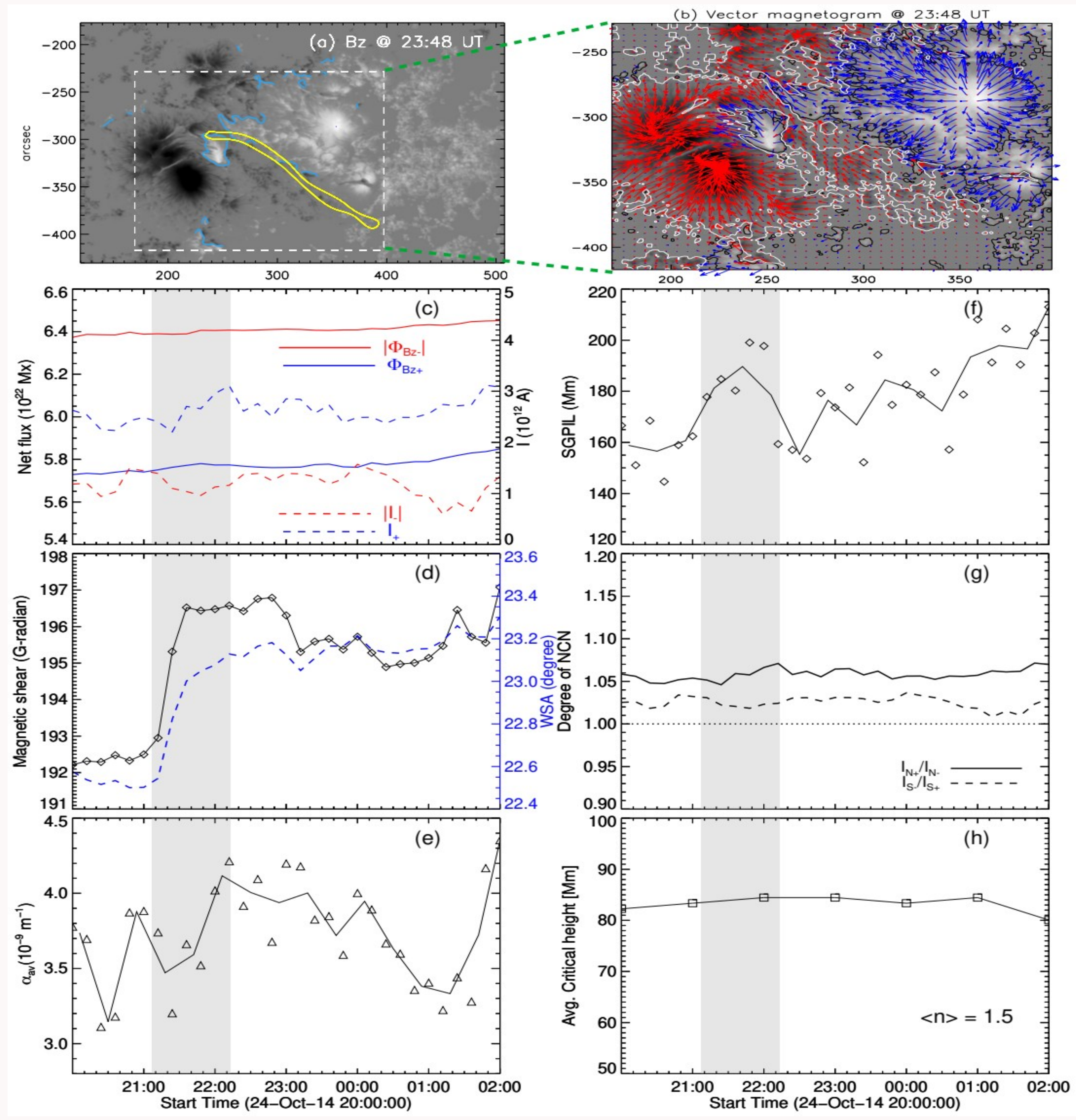
## Data analysis

* Study of B_LOS value and flux variations near initial flare brightening regions at both photospheric and chromospheric heights were carried out using IBIS, Hinode and HMI/SDO data (evidences for TCR).




* Differential Emission Measure (DEM) analysis were carried out on sigmoid-filamental structure to understand its mass-unloading process.

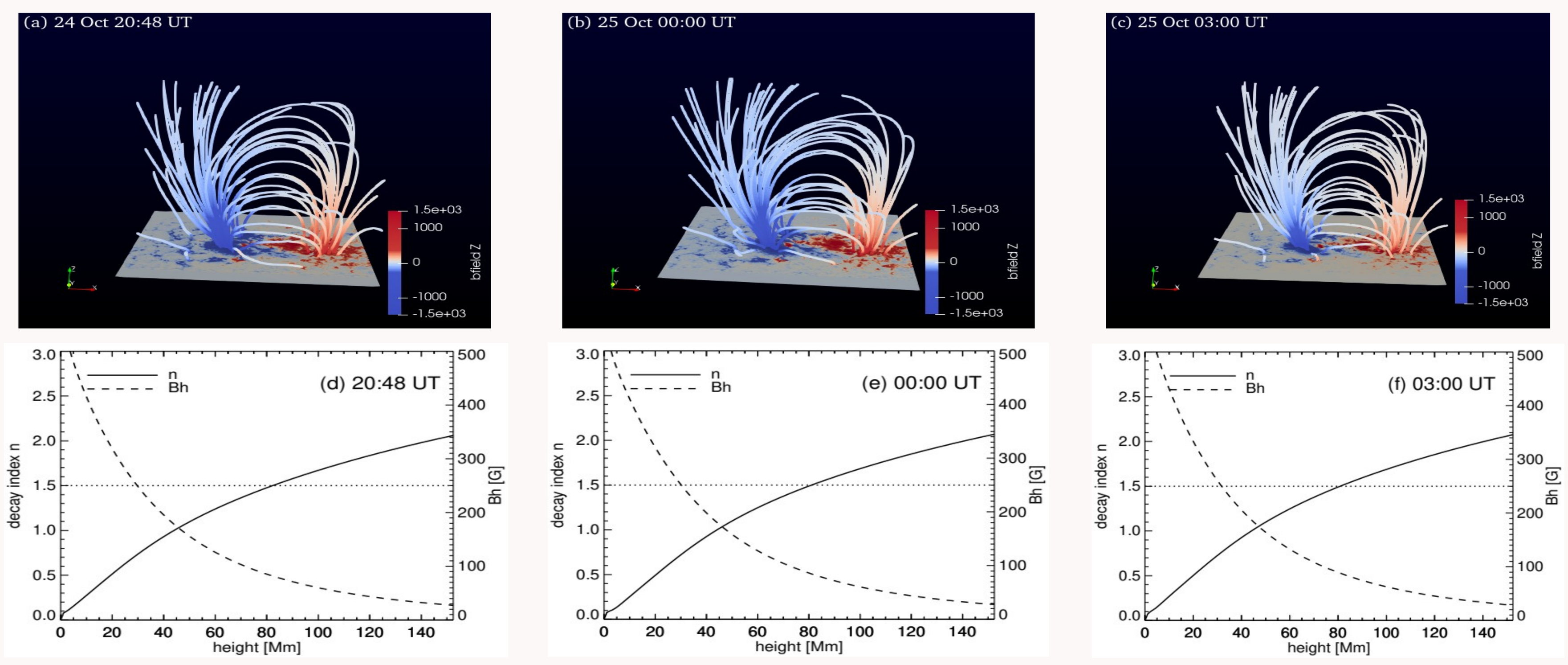
## Magnetic non-potentiality and confinedness




Automated Strong Gradient Polarity Inversion Line (SGPIL) traced in blue curves and contour of filament in yellow is overplotted on Bz in (a). (b) Vector magnetogram. (c) Net flux and current evolution. (d) Magnetic shear and WSA. (e) $\alpha_{avg}$ evolution (f) SGPIL (g) Degree of NCN signifying full current neutralization (NCN≈1) and (h) Average critical heights, when $n = n_c \geq 1.5$, over the filament channel. The gray shaded region indicates the time duration of the flare as recorded by GOES.

## Prominent cause for confinement of X3.1 flare:

The downward Lorentz force provided by the strapping field, a component of potential field running nearly perpendicular to the axial direction of filament.




PFSS configuration of AR 12192 at different time instances, from pre-flare time (20:48 UT) to end time (3:00 UT), of X3.1 flare. The unvarying potential field configuration provides the robust confinement throughout the flare. Decay index, n, reaches 1.5 at about 80 Mm above the photosphere.

## Main results :

1. Our study provides evidence for "mass-unloading" as an eruption driver and suggests that a modification of gravitational force due to reduction in mass may influence the stabilization of flux ropes.
2. The distribution of fragmented SGPIL in the flaring area and the full current neutralization (NCN=1), both indicate absence of robust flux rope along PIL. However, we observed the appearance of sigmoid-filament structure along the main PIL and its dynamics of rise and expansion. Thus, the main contribution to the confinedness of X3.1 flare should be the stronger inward directed force from background field and not the weaker outward driving force from the inner non-potential magnetic field.
3. The confinedness of the X3.1 event is due to the net downward Lorentz force contributed mainly by the strapping field with the possible contribution from non-axisymmetry of the filament.

## Contact

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