Study of the Flare Triggering Process using SDO Data

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1. Motivation & Introduction

*** Motivation ***

To elucidate the trigger mechanism of solar flares, and advance the predictability of flare occurrence.

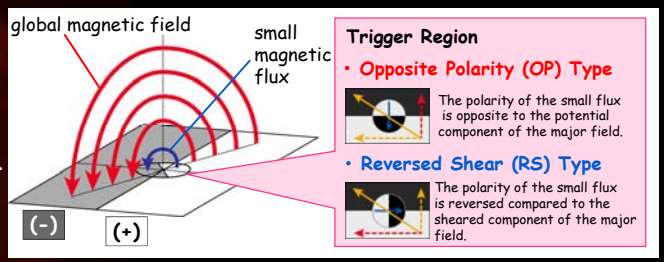
*** Theoretical Model *** (c.f. Poster 4b-218)

Kusano+[2012] proposed a new flare trigger model using numerical simulations.

1. Internal reconnection between large-scale sheared magnetic field and small magnetic field can trigger solar flares. The "flare trigger field" should exist in the center of the initial flare kernels that appeared as sheared ribbon.
2. The conditions of flare occurrence are characterized by two parameters:
   - The shear angle of the global magnetic field of the active region
   - The azimuthal angle of the small scale triggering flux
3. Small magnetic fluxes appearing on the polarity inversion line (PIL) can trigger solar flares, if they form either Opposite Polarity or Reversed Shear types of magnetic structure.

*** Observational Verification using Hinode/SOT data ***

Bamba+[2013] analyzed four major flares observed by Hinode/SOT, and confirmed that the observed signatures strongly support Kusano's flare trigger model. (→ Fig. 1)



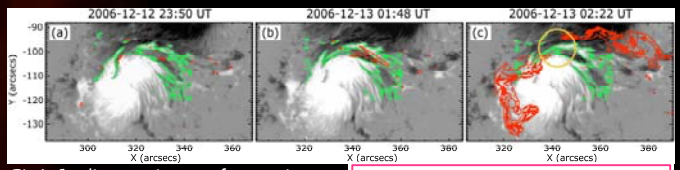


Fig.1: Co-alignment images of magnetic structures and chromospheric emissions before the X3.4 flare onset (13 Dec. 2006), obtained by Hinode.

Background : LOS magnetic field (NFI/Stokes-V/I in Fe-line) (white=positive, black=negative)
Green lines : PILs
Red contour: contours of chromospheric emission (BFI/Ca-line)

There is a small bipole structure indicated by the yellow circle in panel (c) at the center of the sheared ribbon. Transient brightenings in the chromosphere are seen on the local PIL of the bipole before the flare onset, as in panel (b).

2. Data Analysis

*** Data Sets ***

- HMI LOS magnetograms
  wavelength: 6173 Å (Fe I)
  spatial resolution: 1"
  cadence: 45 sec.
- HMI vector magnetograms (SHARP)
  wavelength: 6173 Å (Fe I)
  spatial resolution: 1"
  cdence: 12 min.
- AIA filtergrams
  wavelength: 1600 Å , 304 Å , 171 Å
  spatial resolution: 1.5"
  cadence: 12 sec.

*** Analysis Method ***

(1) We superposed an AIA image and LOS magnetogram at each time, and investigated the correlation between the brightenings on each layer and the magnetic structures.

(2) We indicate the vector strength, the difference between the potential and transverse field vectors with color, and investigated the non-potentiality along the PILs in the active region.

*** Event List ***

No.	Start time	AR	class
1	2011-02-15 01:44:00	11158	X2.2
2	2011-03-09 23:13:00	11166	X1.5
3	2011-09-06 22:12:00	11283	X2.1
4	2012-03-07 00:02:00	11429	X5.4
5	2012-03-07 01:05:00	11429	X1.3

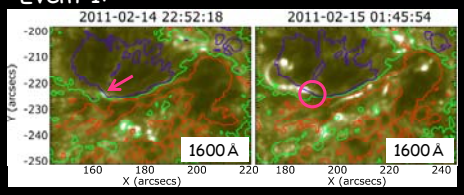
→ Where is the "flare trigger region" for each event ??
Are the observed signatures consistent with Kusano's flare trigger model ??

3. Results

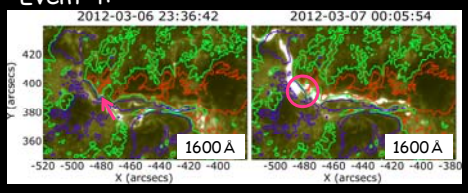
Background : AIA image (1600 Å ,171 Å ,304 Å)
Green lines : PILs
Red contour : strong magnetic field (+500G)
Blue contour : strong magnetic field (-500G)

*** Simple Case ***

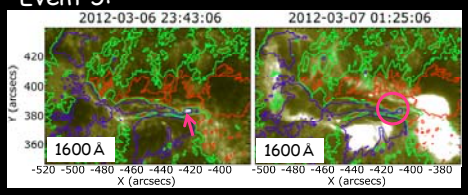
- Event 1:



- Event 4:

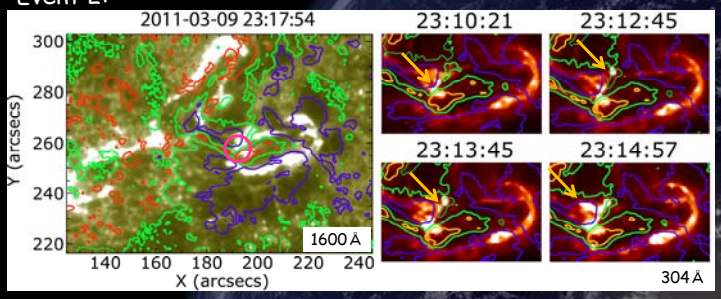


- Event 5:



*** Complicated Case ***

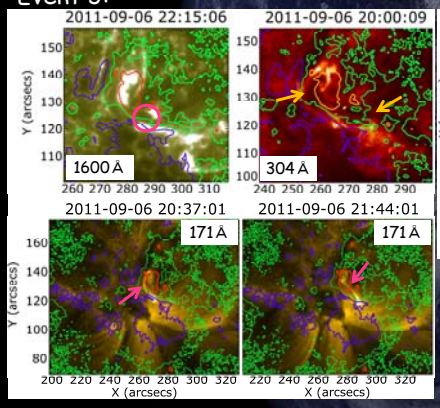
- Event 2:

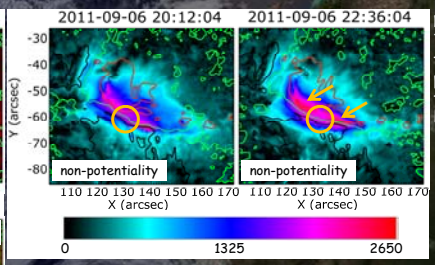


In case of Event 2 and 3, we could not specify the trigger region easily, because we could not see clear brightenings in the AIA 1600 Å images.

However, we can specify the trigger region using the temporal evolution of the brightenings and filament structure in 304 Å, and faint coronal loop structures in AIA 171 Å.

- Event 3:





Non-potentiality map. The vector strength, the difference between potential and transverse field vectors, is high lighted in color.

The non-potentiality is strengthened on both sides of the trigger region, after the flare onset, in all the events. It suggests that the horizontal magnetic field is strengthened by the magnetic reconnection which causes the flares, and it is consistent with Kusano's numerical simulation. (c.f. Poster 1b-339)

4. Summary

We can specify the "flare trigger region" using high cadence and multiple wavelength data obtained by AIA and HMI, even if the magnetic structure is too complicated and there are no clear brightenings in the AIA 1600 Å images. The temporal evolution of the non-potentiality maps are consistent with Kusano's numerical simulation, and these non-potentiality maps may be used to identify the "flare trigger region".