Study on the triggering Process of Solar Flares based on Hinode/SOT Observations

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0. Problem & Motivation

Interplanetary disturbances associated with solar flares sometimes impact terrestrial environments and infrastructure. Therefore, understanding the flare triggering conditions is important not only from a solar physics perspective but also for space weather forecasting. However, the underlying mechanism of flare onset remains elusive.

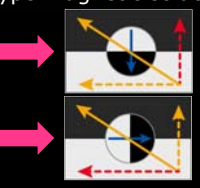
→ **Motivation : To reveal the trigger mechanism of solar flares, and advance the predictability of flare occurrence.**

1. Introduction ~Our Flare Trigger Model~

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

1. The internal reconnection between large-scale sheared magnetic field and small magnetic field can trigger solar flares. The "flare trigger field" exist at the center of initial flare kernels appeared as sheared ribbon.
2. The conditions of flare occurrence are characterized by following two parameters;
   - The sheared angle of global magnetic field of active region: θ
   - The azimuthal angle of small scale triggering flux: φ
3. The small magnetic fluxes appearing on the polarity inversion line (PIL) can trigger solar flares, if it forms either the Opposite Polarity (OP) type or the Reversed Sheared (RS) type magnetic structures.

- **Opposite Polarity (OP) Type**
  The polarity of small flux is opposite to the potential component of major field.
- **Reversed Shear (RS) Type**
  The polarity of small flux is reversed to the sheared component of major field.



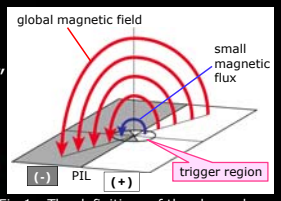


Fig.1 : The definitions of the sheared angle θ and the azimuthal angle φ.

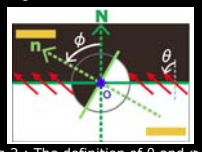


Fig.2 : The definition of θ and φ on the observational images.

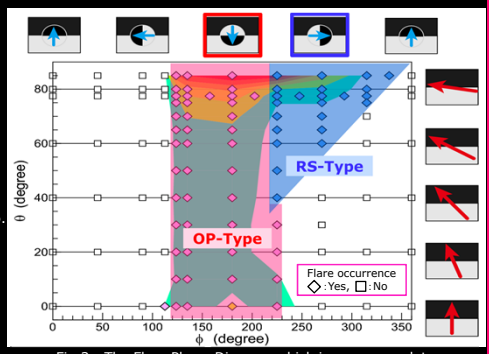


Fig.3 : The Flare Phase Diagram which is summary plot of numerical simulations (Kusano+ [2012]).

2. Data sets

- Period : October 2006 ~ July 2011
- Flare magnitude ≥ M5.0-class

Event No.	Date	Start time	Active region	X-ray class
1	13-Dec-2006	02:14 UT	10930	X3.4
2	14-Dec-2006	22:07 UT	10930	X1.5
3	13-Feb-2011	17:28 UT	11158	M6.6
4	15-Feb-2011	01:44 UT	11158	X2.2

- Instrumentation

	Filter magnetograph(NFI)	Filtergraph(BFI)
Wavelength	6303Å(Fe I), 5896Å(Na D)	3968Å(Ca II H)
Pixel size	0.16"	0.108"

3. Analysis & Results

3-1. Method

We superpose Ca-line emission contour and PIL on filter magnetograms in order to investigate following issues on four major flares;

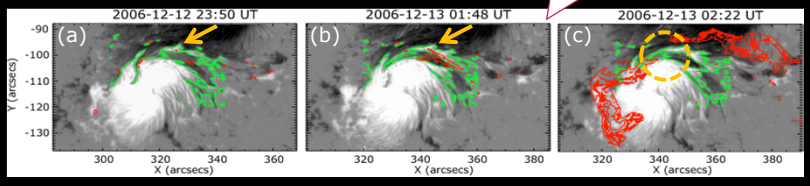
- Where is the "triggering region" ?
- Which is flare trigger type ? (OP- or RS-Type ?)
- What degree the shear angle of θ and azimuthal angle φ are ?

→ θ is measured as the mean angle between global PIL and vector magnetic field around trigger region. Φ is measured as the angle between global PIL of active region and local PIL of trigger region.

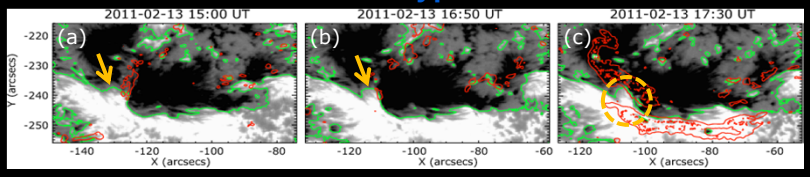
3-2. Results: the location of trigger regions and flare trigger types

Background : Line-of-sight magnetic field white=positive black=negative
Green lines : Polarity inversion line
Red contour: Ca-line emission

Event 1: **Opposite Polarity Type**



Event 3: **Reversed Shear Type**



- The initial flare kernel has sheared structure like the simulation results, and it is supposed that the trigger region locates around yellow-colored dashed-circles (c).
- We can identify the small magnetic structures a few hours before the flare onset (a), and these small structure slowly grew up and formed OP- or RS-type configurations and Ca-line emission was observed to brighten on the PIL of trigger regions (b).

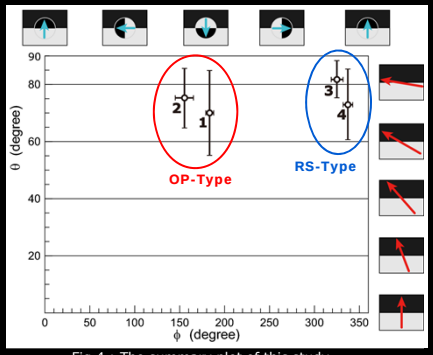


Fig.4 : The summary plot of this study on the Flare Phase Diagram.

- From the measurement of the shear angle θ and the azimuthal angle φ, we can classify all the flares into either OP- or RS-types as shown in Fig. 4.

4. Discussion

The flare is not immediately occurred even if the magnetic structure satisfied the geometrical conditions for OP- or RS-Types. What is the crucial parameter for timing of flare occurrence?

→ We investigate the temporal evolution of positive magnetic flux and Ca-line intensity before the Event 1 flare onset.

There are three increasing phases of the magnetic flux, and Ca-line intensity tends to increase after the magnetic flux increased.

It is suggested that the amount of small magnetic flux is important for triggering flares.

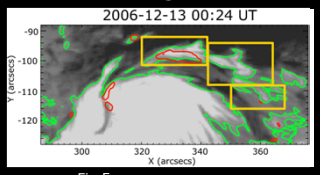


Fig.5 :
The regions in which we calculated positive magnetic flux and Ca-line intensity. The total value is plotted on Fig.6.

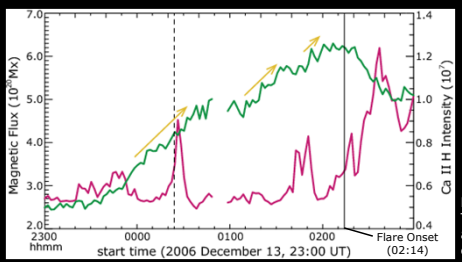


Fig.6 :
Time profiles of positive magnetic flux at the trigger region and Ca-line emission intensity at the FOV of Fig.5.

In case of other events, the critical magnetic flux which can trigger the flares are different. It is suggested that the critical amount of triggering flux depends on the pre-existing flux ropes in the flaring region.

5. Summary

- We can find that all the flares had the "flare-trigger regions", and they can be classified to either OP- or RS-types as shown in Fig.4. These results are well consistent with the trigger model which proposed by *Kusano+* [2012].
- Not only the configurations of small scale magnetic flux but also the amount of small magnetic flux is important for triggering flares.

References: **Bamba+[2013]**, Kusano+[2012]