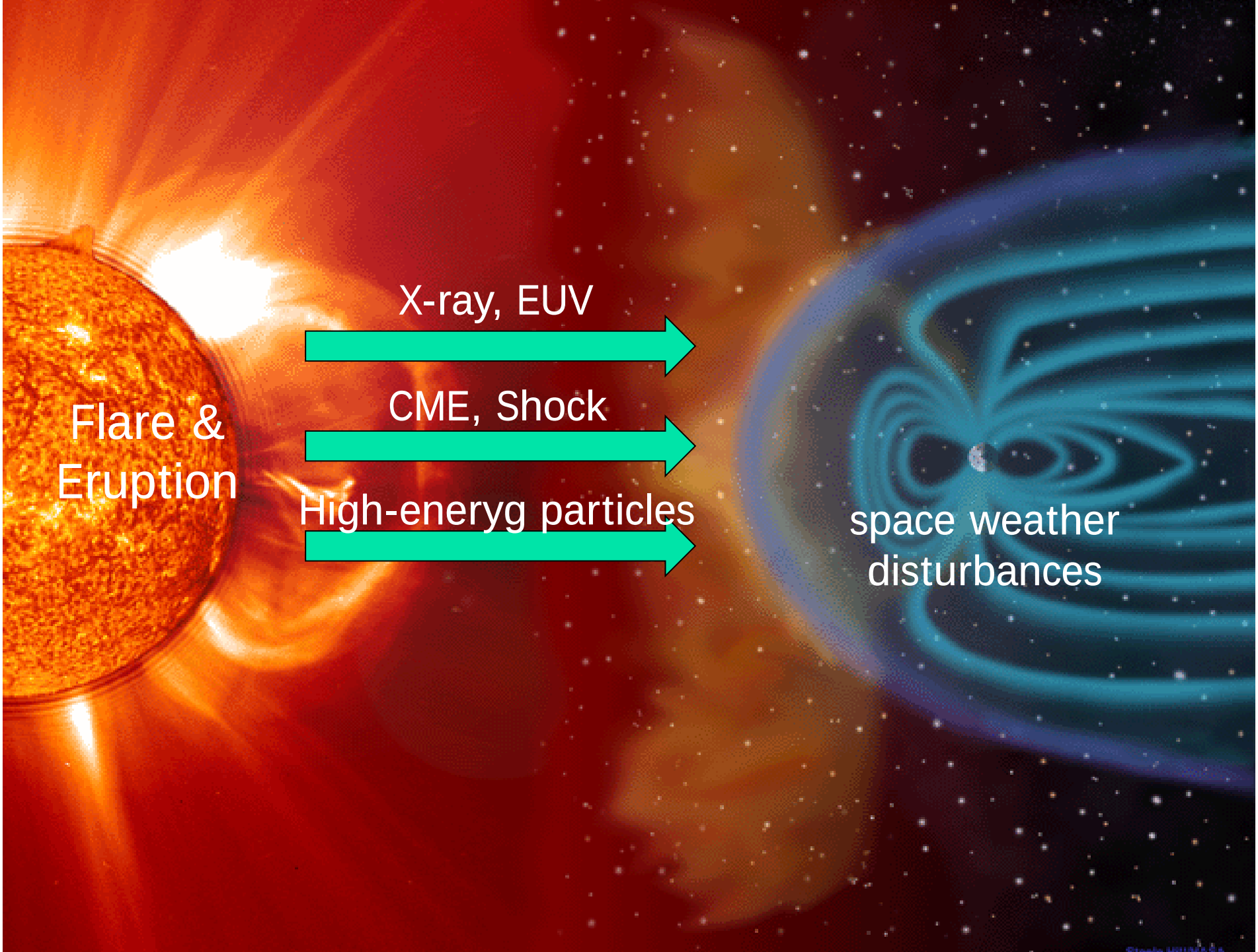

Flare &
Eruption
X-ray, EUV
CME, Shock
High-eneryg particles
space weather
disturbances

Solar-C Science Meeting
Takayama, Hida, 11 Nov, 2013

Will Solar-C be able to contribute the prediction of solar eruption?

Kanya Kusano

Solar-Terrestrial Environment Laboratory
Nagoya University

Outlook

- Introduction
  - Prediction of solar eruption as a Solar-C science objective.
- Current status of the prediction of solar eruption
- What determines the onset of solar eruptions?
  - Comparative study between simulation and observations
- Strategy of prediction in Solar-C era.

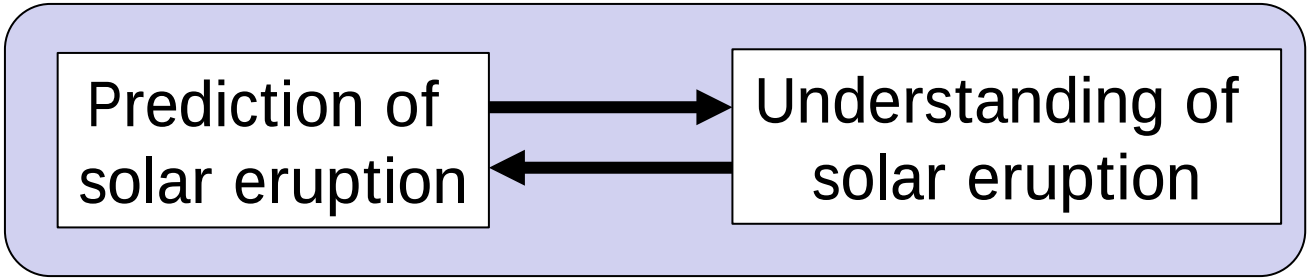
Scientific Objectives of Solar-C

- High-resolution 3D magnetic field
- Magnetic reconnection
  (fundamental physical processes)
- Chromospheric and coronal heating
- Origin of solar wind
- Solar activity prediction (prediction of solar eruption)

Empirical prediction ⟸ current stage of s/w prediction

Vs.

Physics-based prediction



- Halley's prediction of the comet's return (1758)

- Einstein's prediction of the apparent bending of light (1919)

Current Status of Flare Prediction

- Crown 2012 “Validation of NOAA Flare Prediction for Cycle 23” Space Weather

Contingency Table for X-class Flares Prediction with the lead time of one-day

Prediction \ Obs.	Yes	No
Yes	50	67
No	52	31315

50/(50+67)
~43% of flares was predicted.

50/(50+52)
~49% of predictions was success.

Skill Score
=(50-67)/(50+52)
=−0.17

Empirical Prediction

- McIntosh Classification

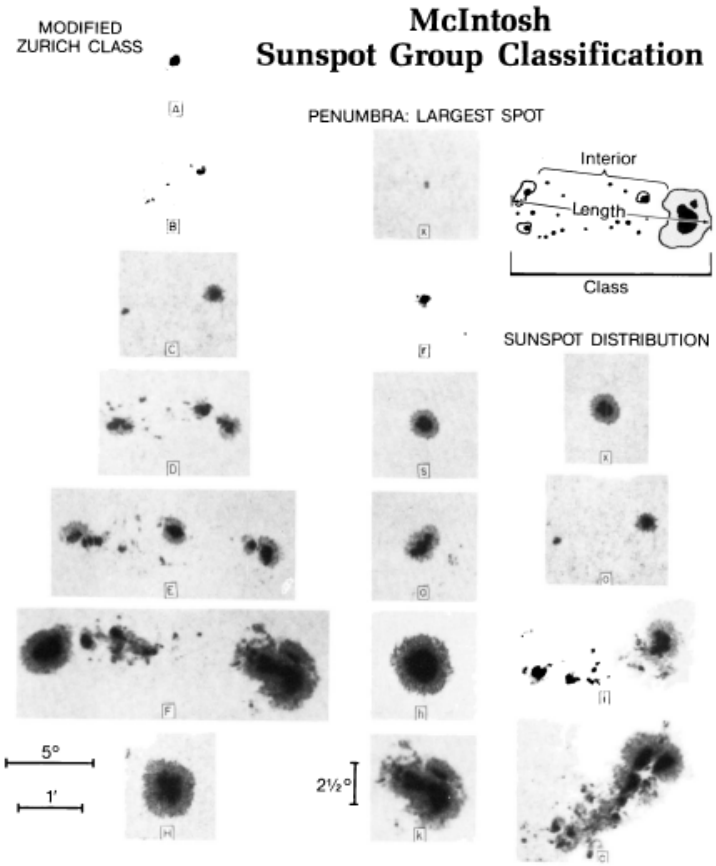


Fig. 1. The 3-component McIntosh classification, with examples of each category.

McIntosh 1990

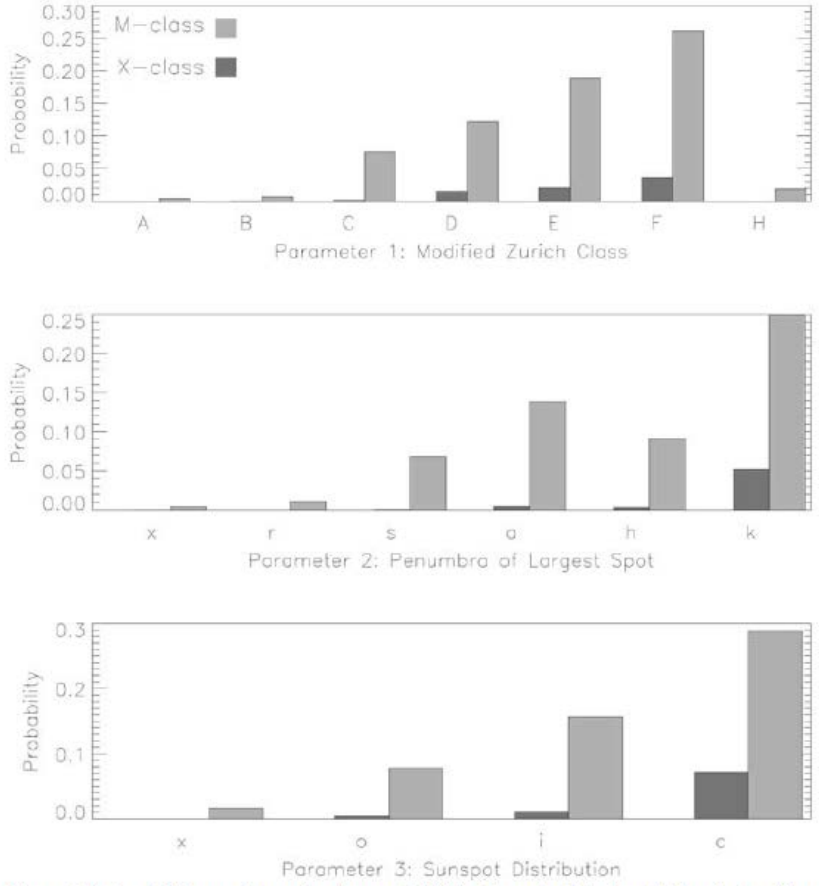


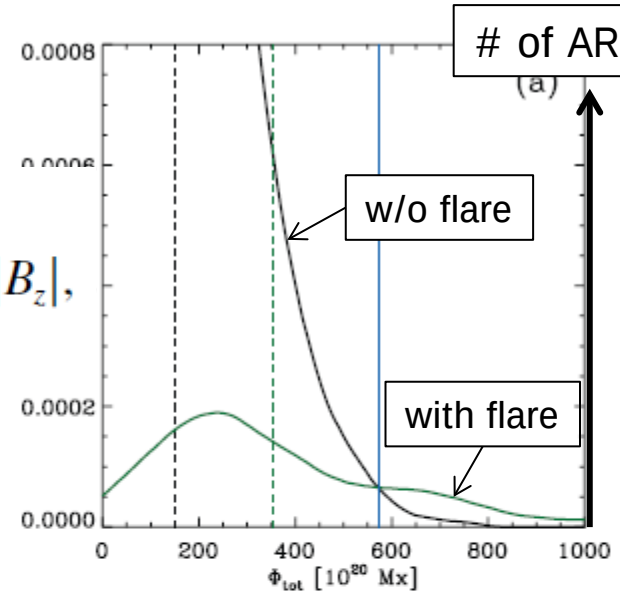
Figure 4. Derived 24-hour active-region flare probabilities for each of the three McIntosh classification parameters using Poisson statistics.

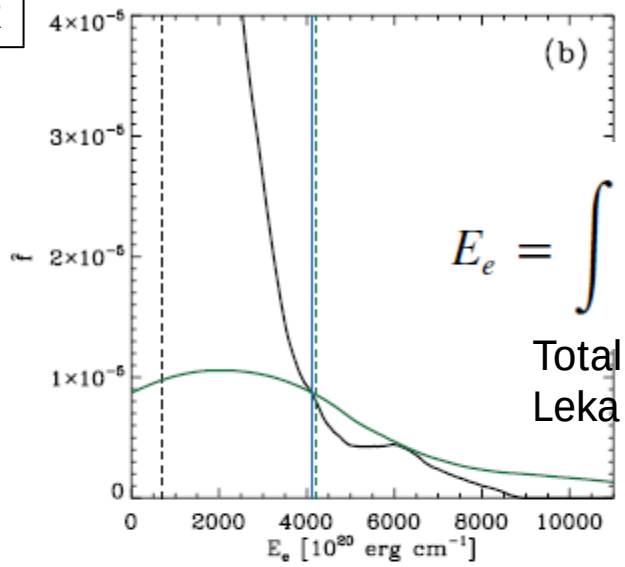
Gallacher, Moon, Wang 2002 Sol. Phys.

Discrimination Analysis

Barnes and Leka 2008
(M&X class within 1d)

$$\Phi_{\rm tot} = \int d^2x\ |B_z|,$$

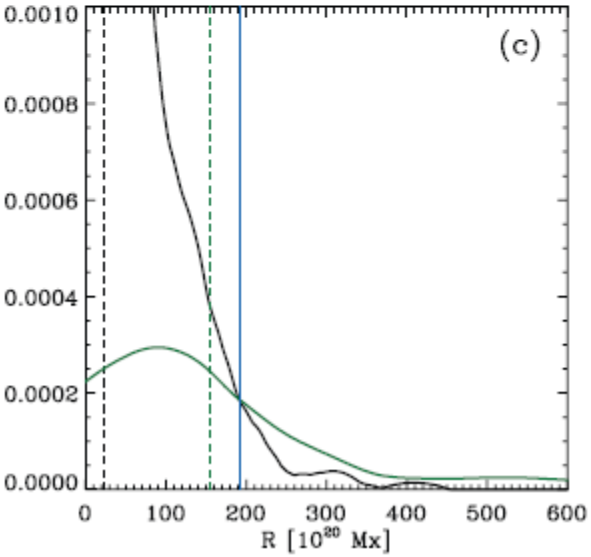


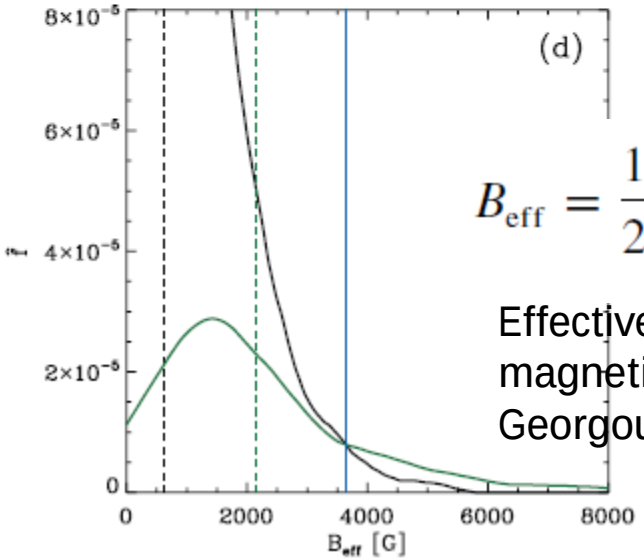


$$E_e = \int d^2x\,(\boldsymbol{B} - \boldsymbol{B}_p)^2,$$

Total excess energy
Leka & Barnes 2003

R: unsigned flux over the high-gradient polarity-separation lines
Schrijver 2007



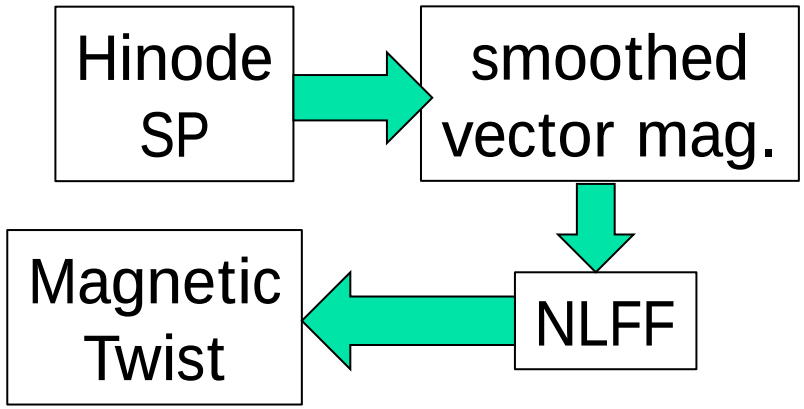


$$B_{\rm eff} = \frac{1}{2}\sum_{i\neq j}\frac{\psi_{ij}}{|\boldsymbol{x}_i - \boldsymbol{x}_j|^2},$$

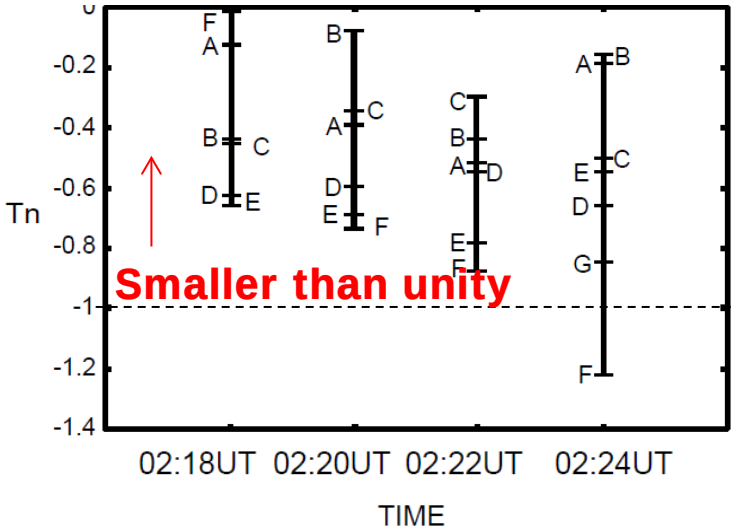
Effective connected magnetic field
Georgoulis & Rust 2007

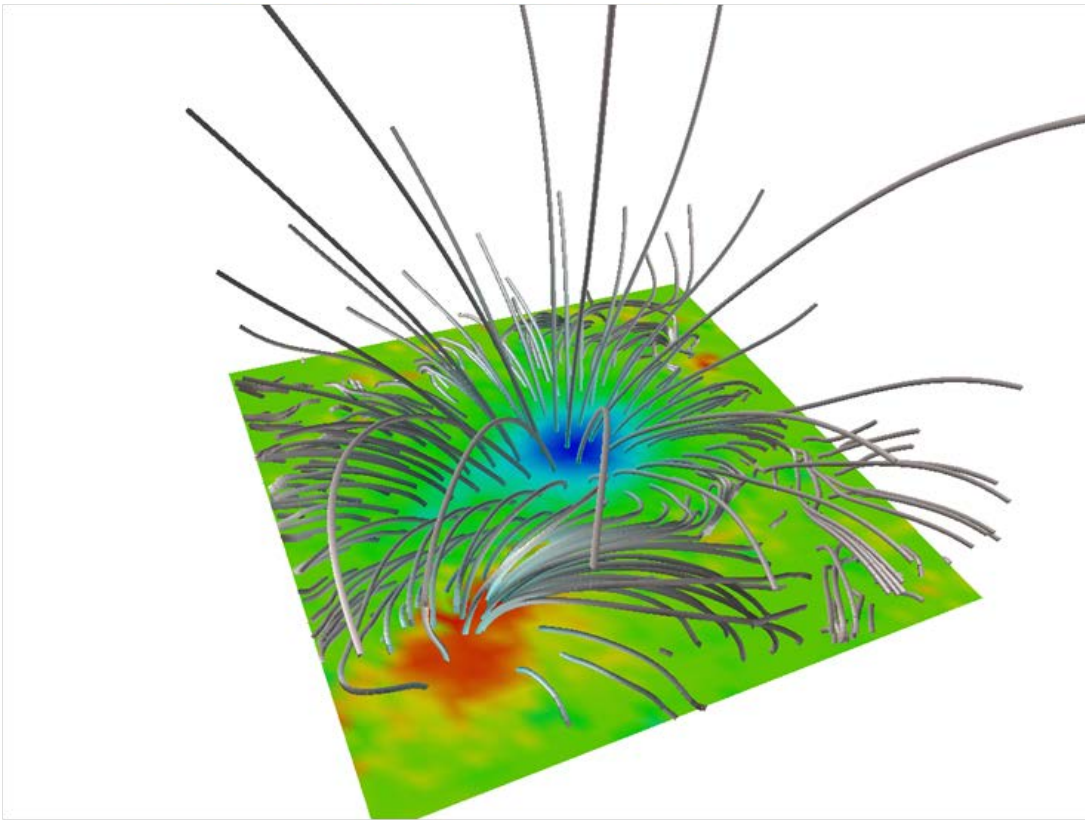
NLFFF Model Analysis

Inoue, Kusano et al. ApJ 2011



$$T_n = (4\pi)^{-1} \int_{field\ line} \alpha \ dl$$





fairly stable even in pre-flare state !

Prediction is difficult, because

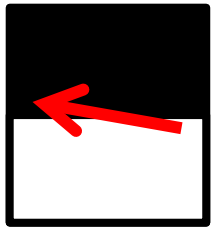
many kinds of large-scale magnetic parameters (e.g. total magnetic free energy) and the 3D NLFFF model cannot provide the sufficient information to predict the onset of large flare.

- The limited capability implies that there is some hidden parameters to determine the flare-productivity.

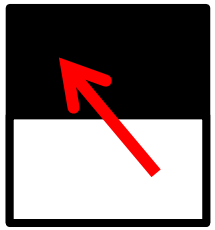
The clarification of the hidden parameters should be the important subject of Solar-C, because it is likely to be related to small magnetic feature.

Ensemble 3D MHD Simulation

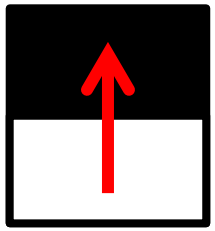
Kusano et al. 2012 ApJ



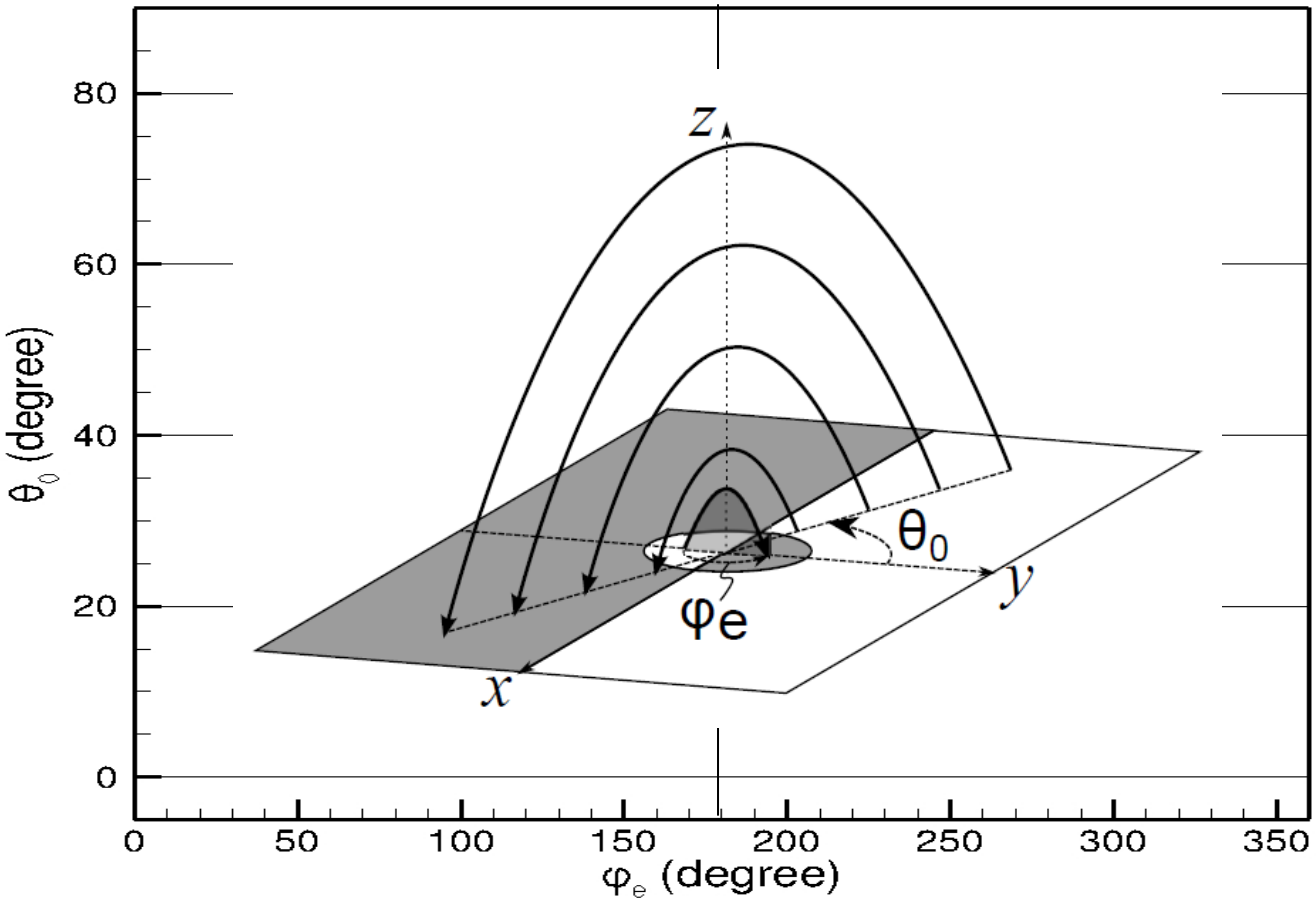
strong shear



weak shear



potential field



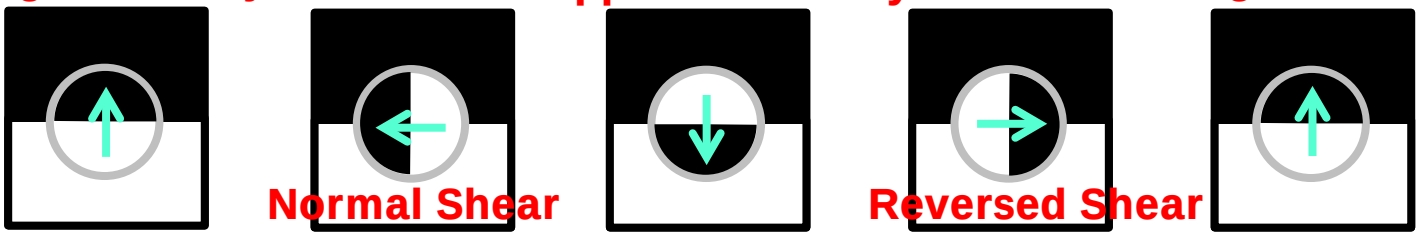
Right Polarity

Normal Shear

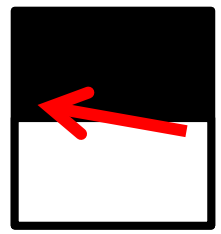
Opposite Polarity

Reversed Shear

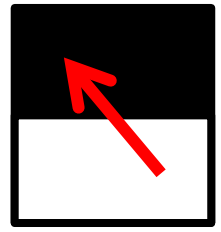
Right Polarity



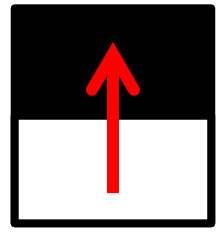
Simulation Results



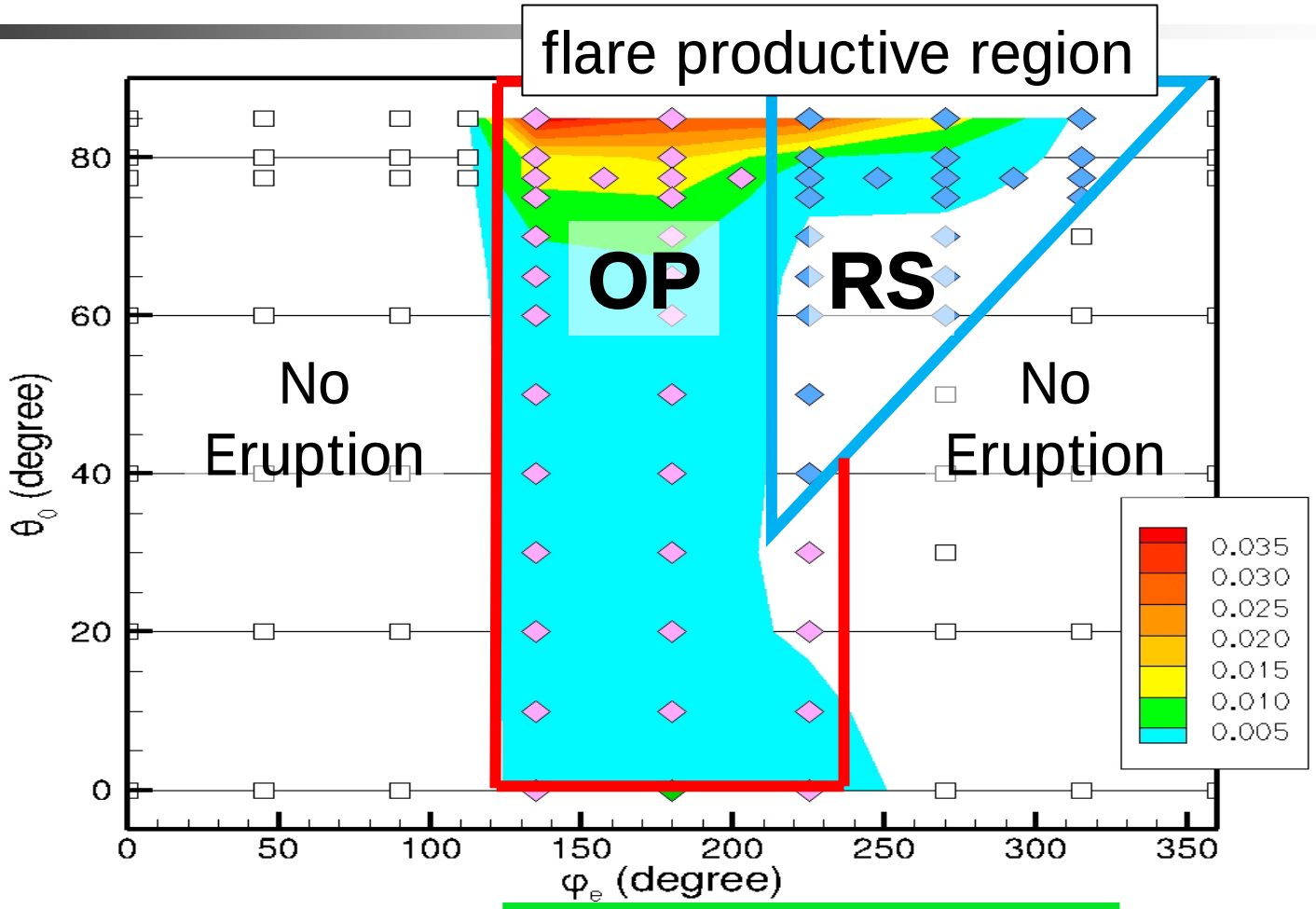
strong shear

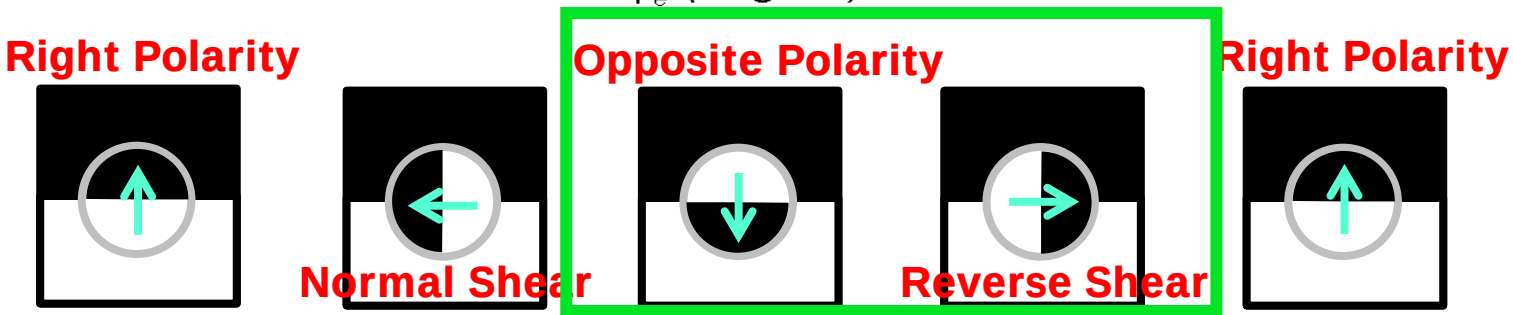


weak shear

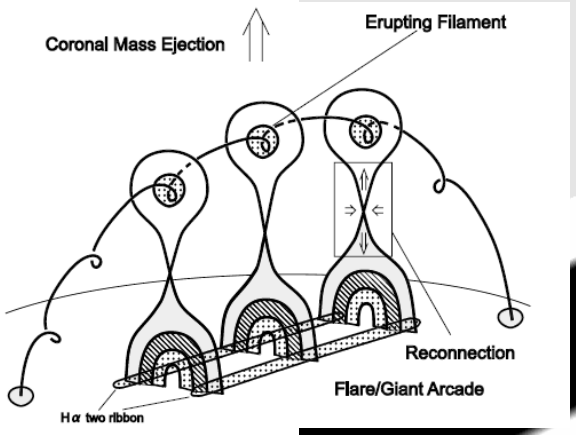


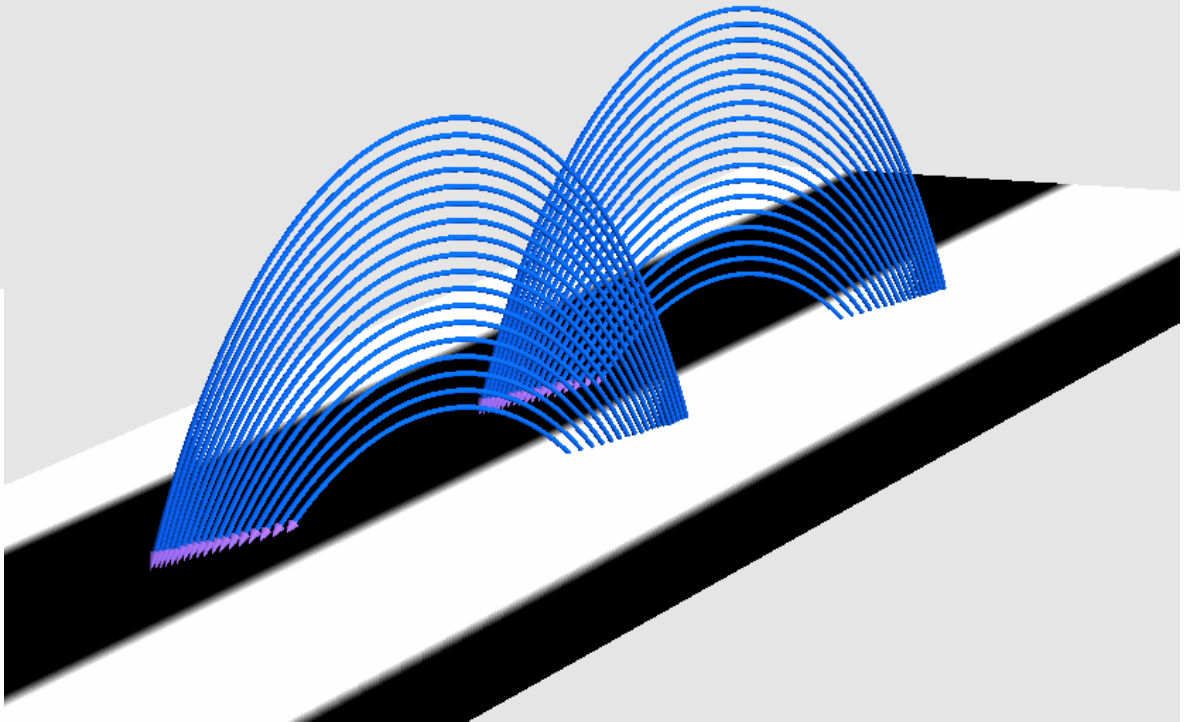
potential field

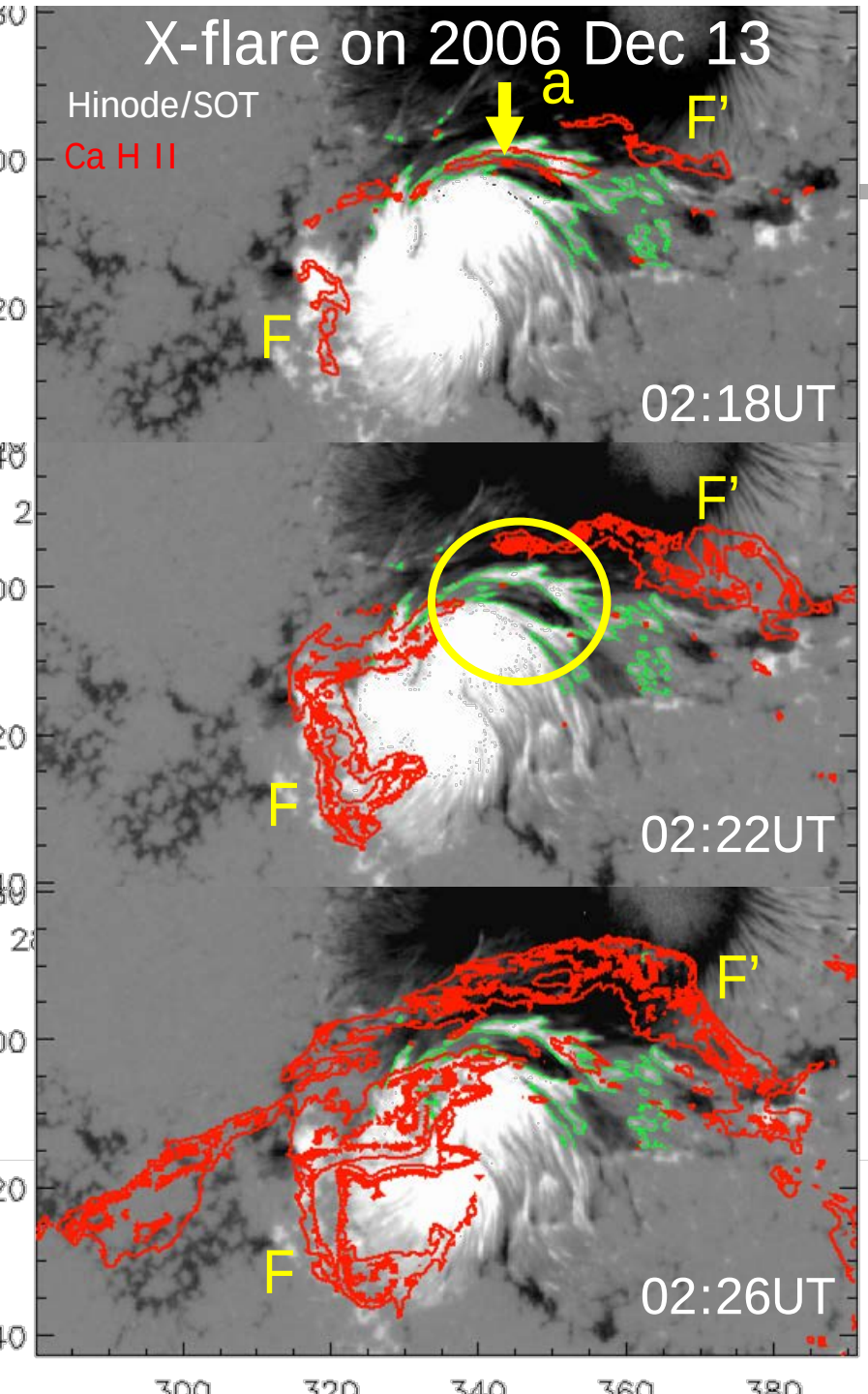




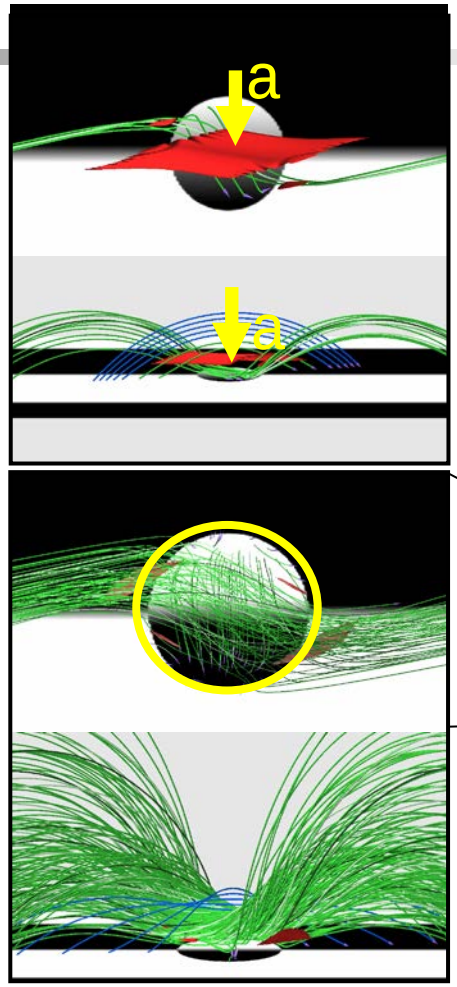
Eruption-induced Reconnection

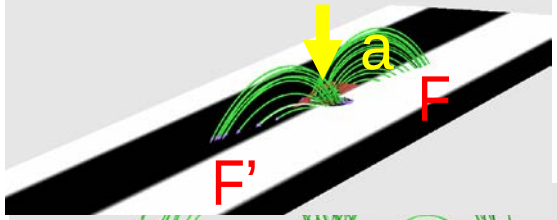


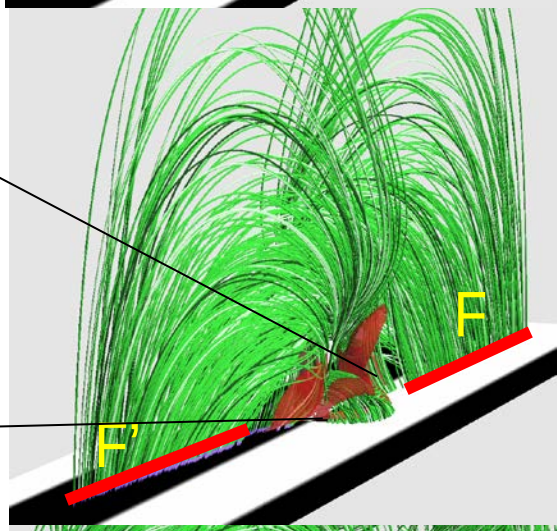


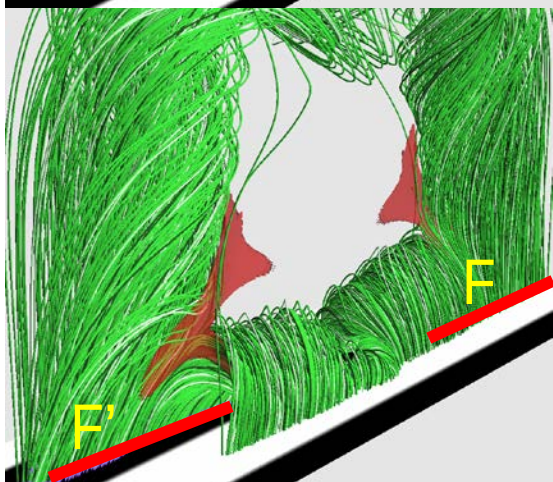


Opposite Polarity type perturbation

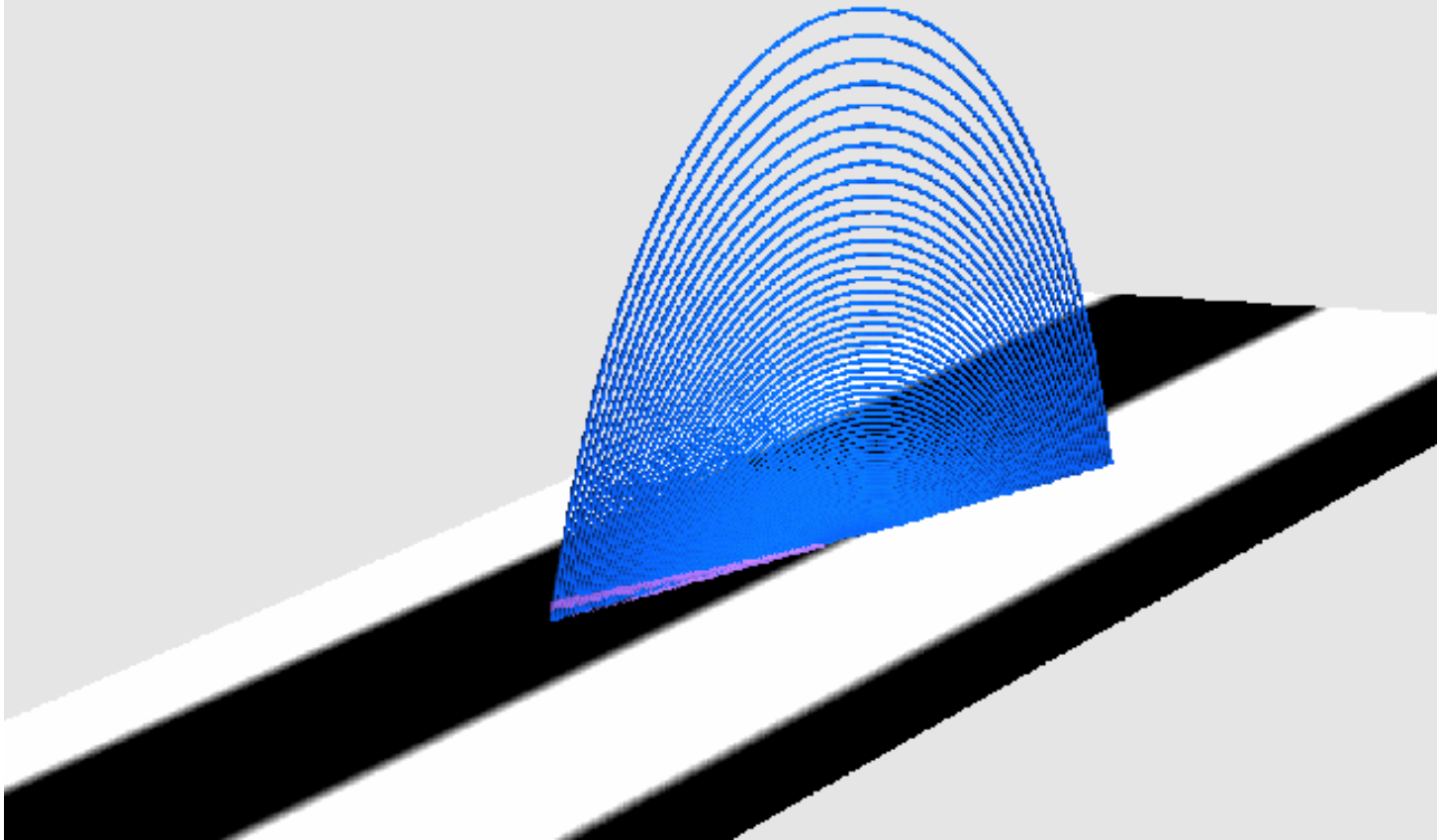




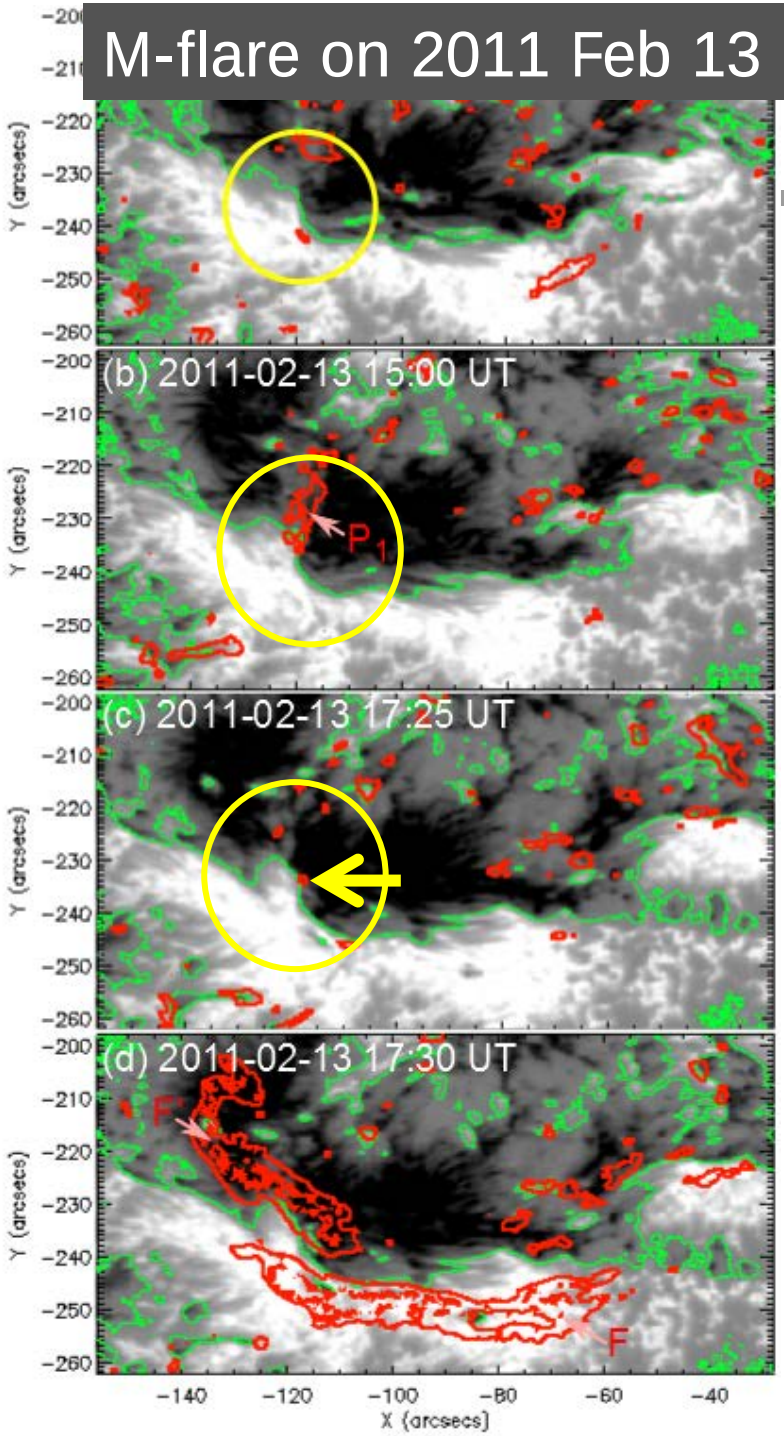




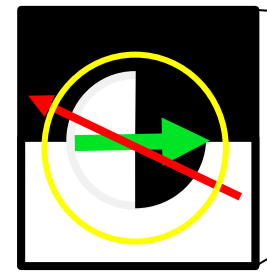
Reconnection-induced eruption



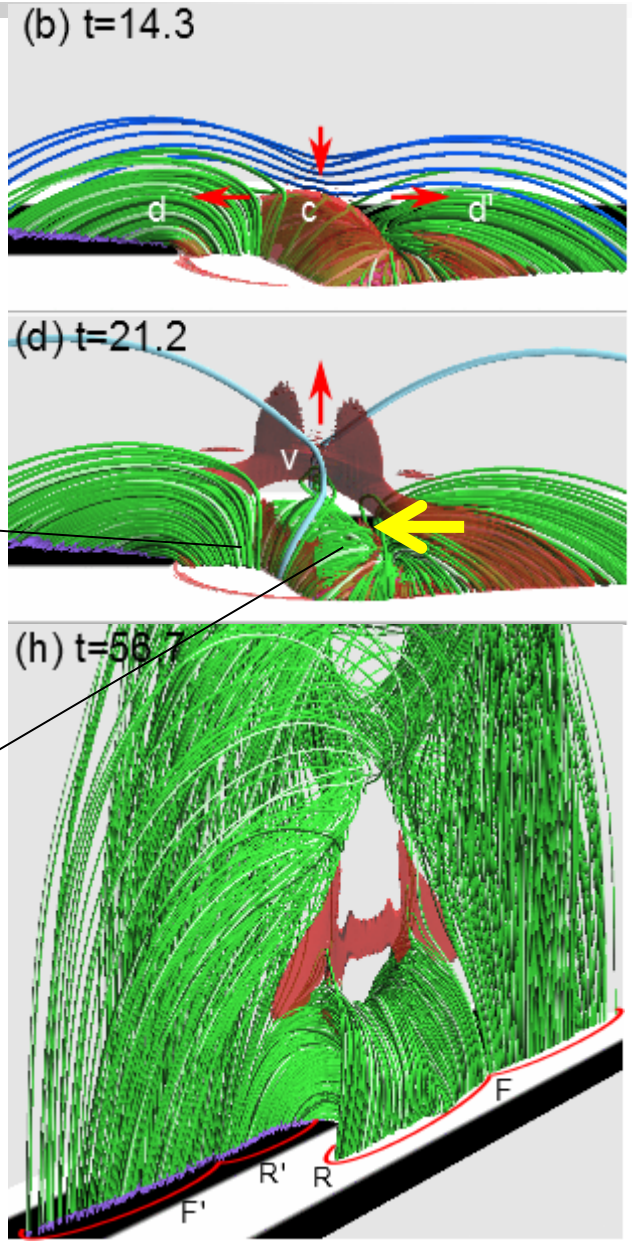
M-flare on 2011 Feb 13



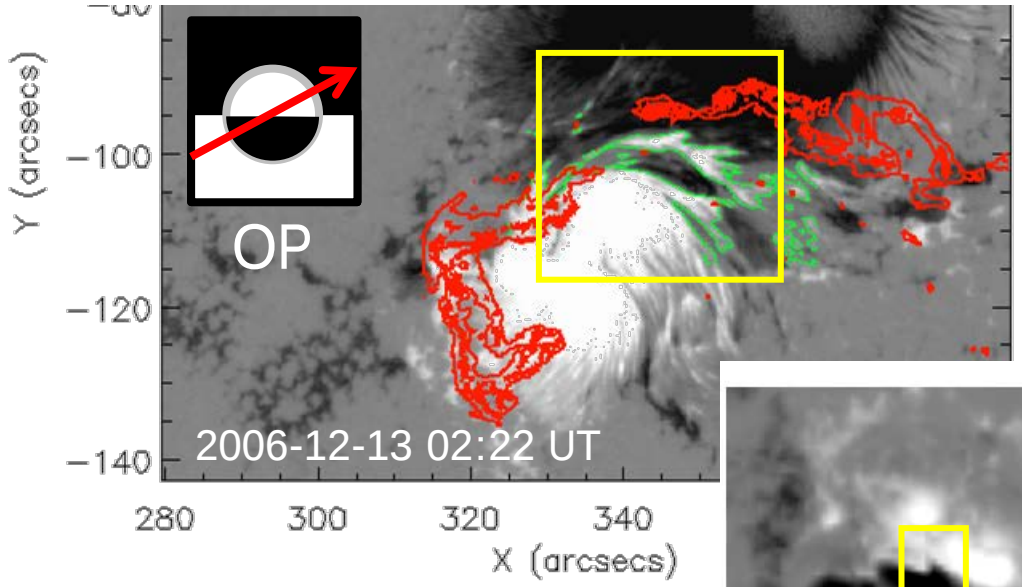
Reversed-Shear type perturbation

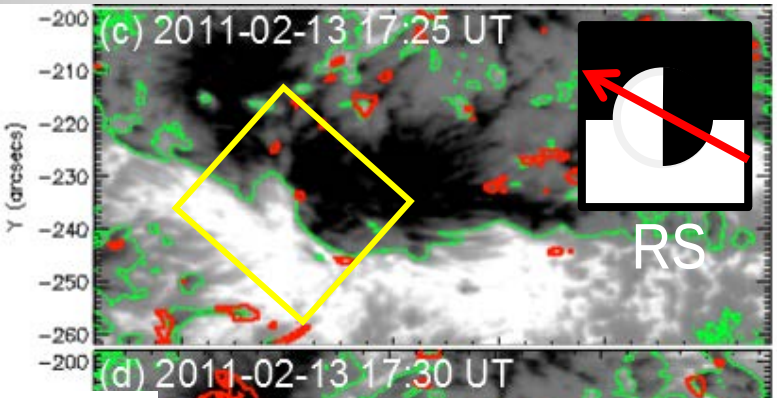


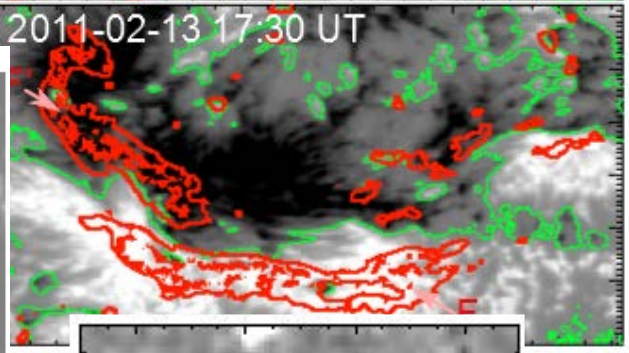
RS configuration

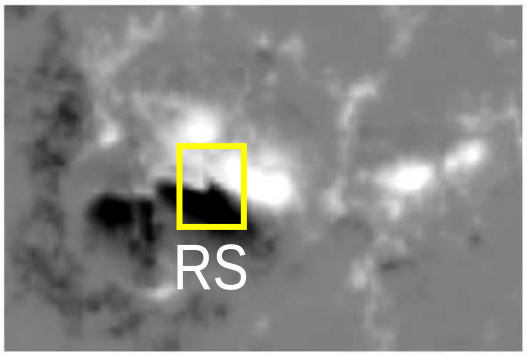


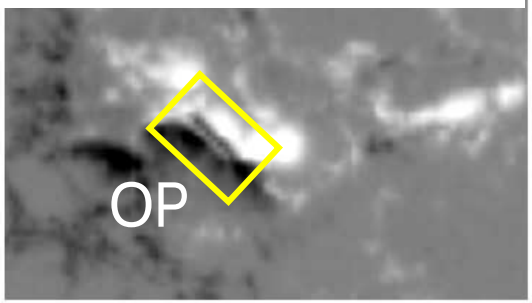
PIL Structures Triggering Flares

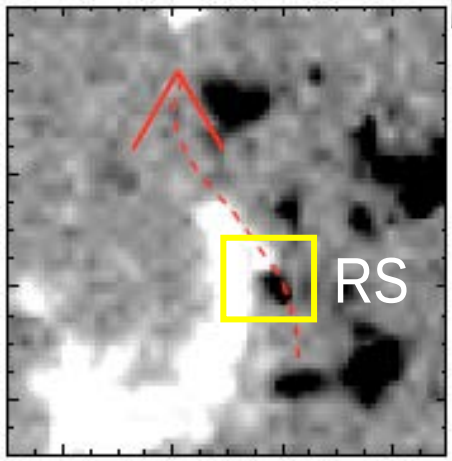


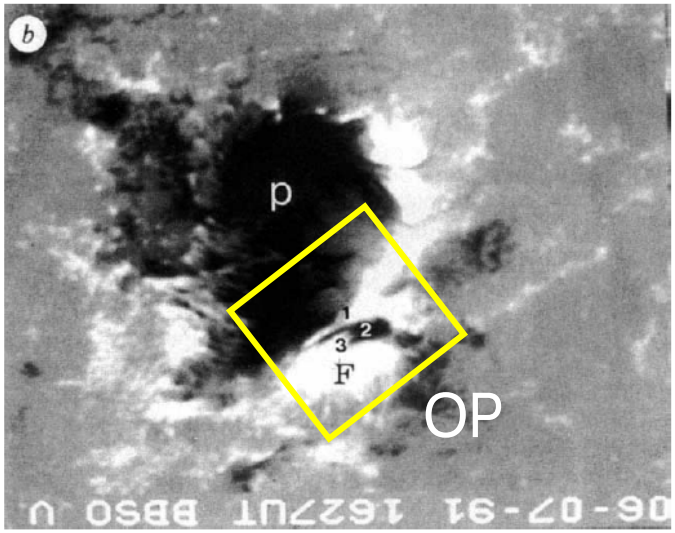












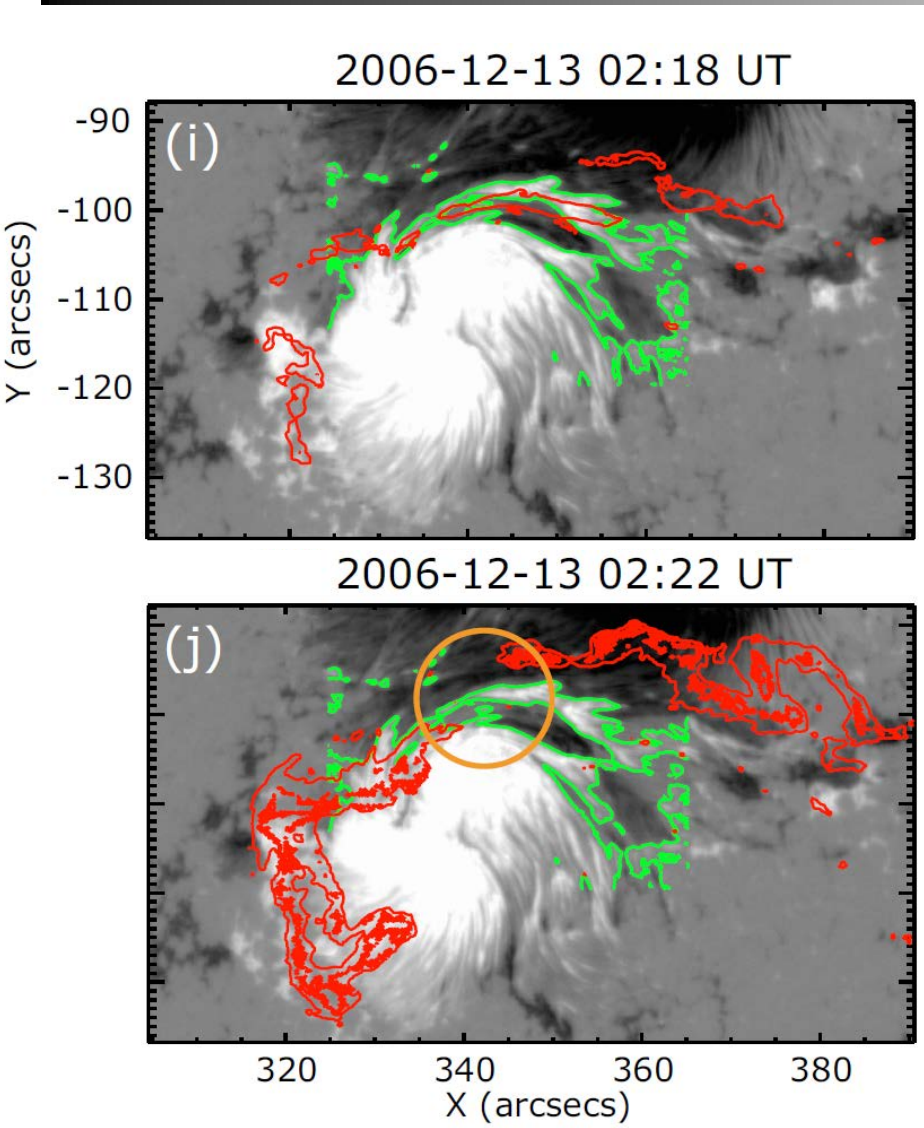
Zirin and Wang 1993

Kurokawa, Wang & Ishii 2002

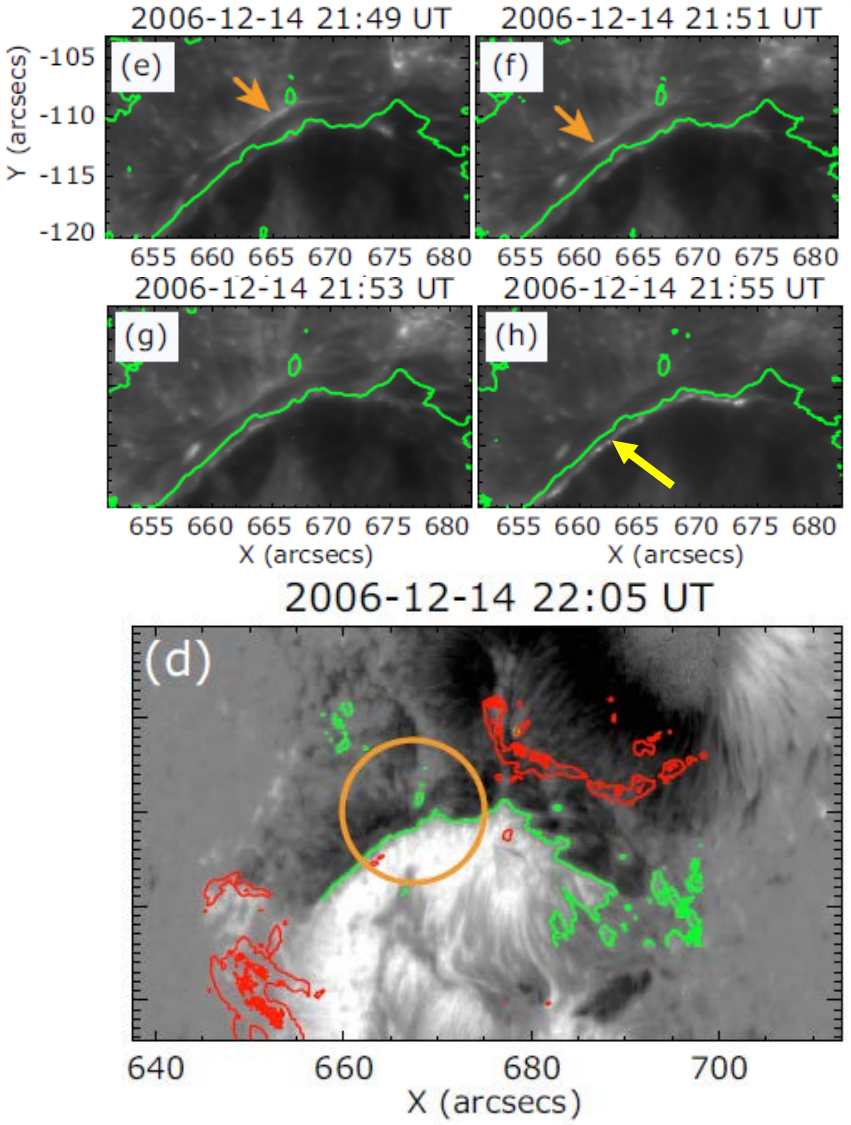
Green, Kliem & Wallace 2011

Bamba et al. 2013 ApJ
Poster S4-P-12

Two X-flares in AR10930

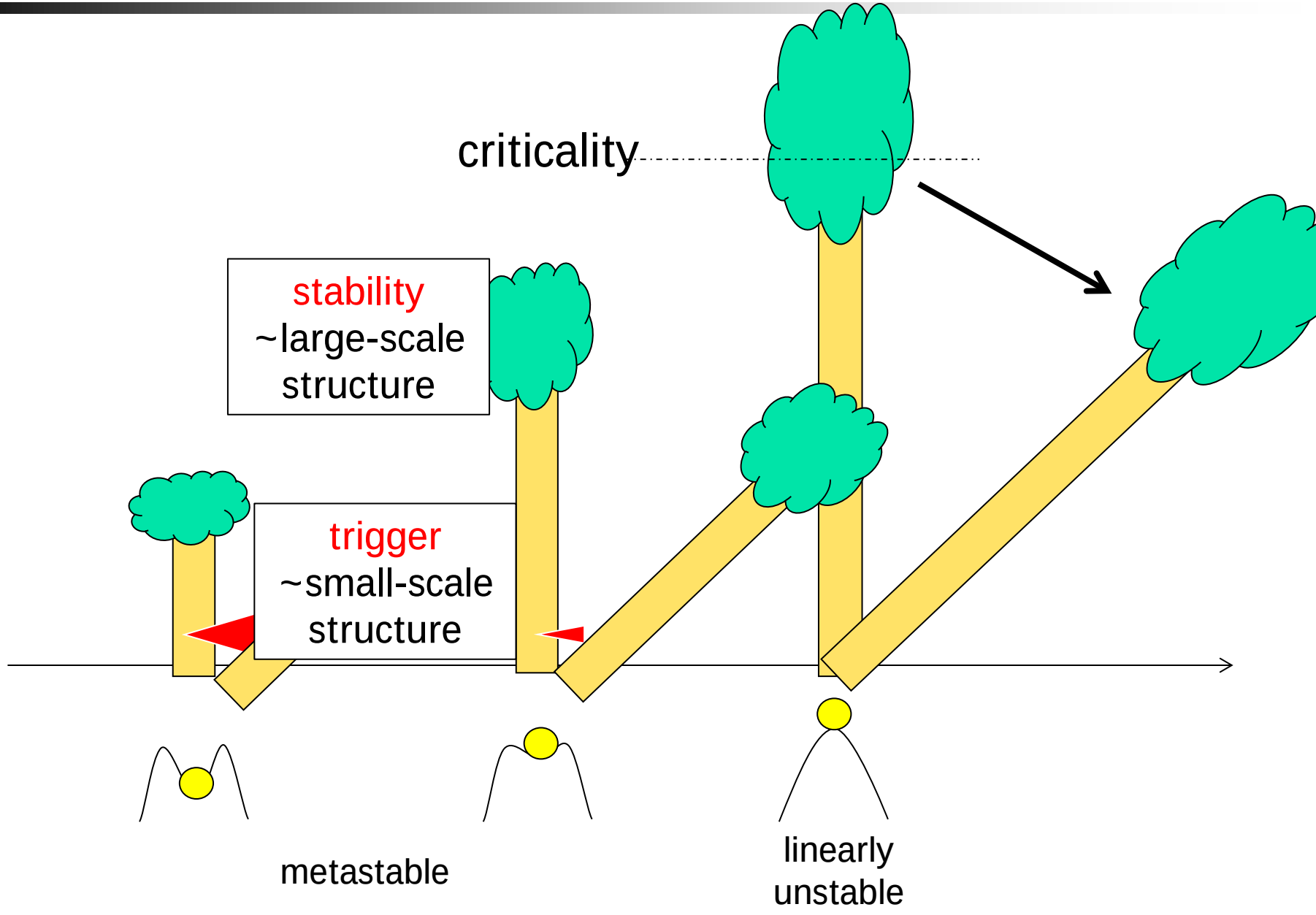


X3.4 class flare

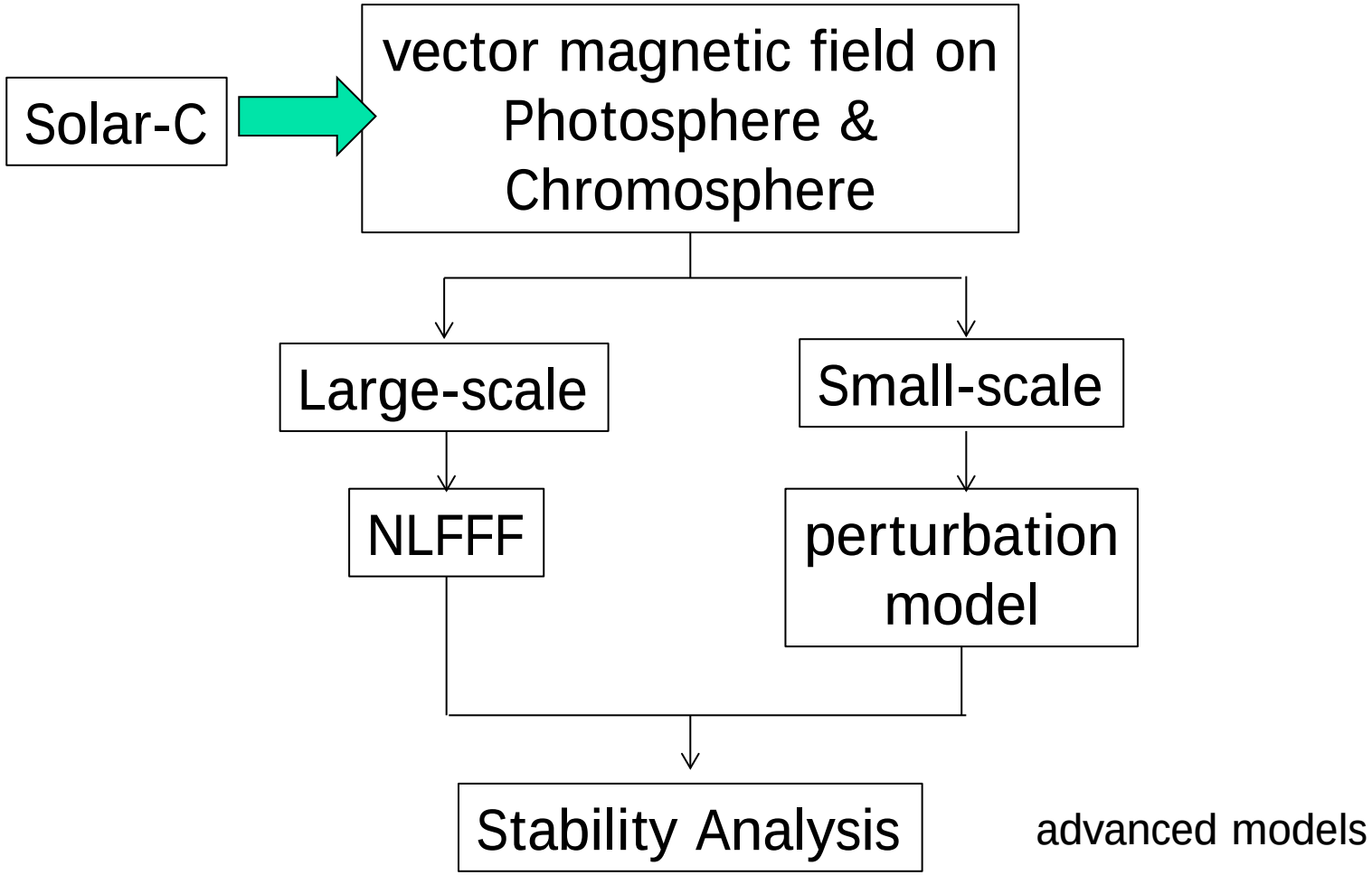


X1.5 class flare

Destabilizing metastable state



Strategy



3D magnetic field measurement with Solar-C will first enable the physics-based prediction of solar eruption.