Topics II
Large Scale Explosions & Eruption
flares, CME, and space weather

Sub-group of NGSPM team
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Key scientific objectives

Key observations

Instrument requirements

Sub-objectives

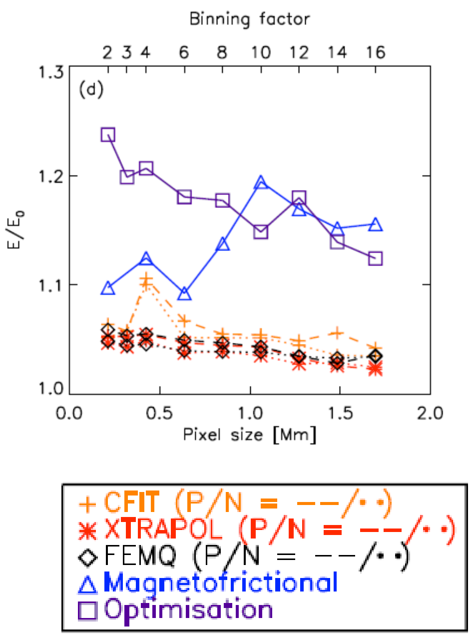
1. **Measure the energy build-up processes in flaring and CME regions**
2. **Identify the trigger mechanism of solar flares and CMEs**
3. **Clarify the mechanisms of destabilizing and erupting of the entire system**
4. **Understand the processes of fast magnetic reconnection**
5. **Understand the formation mechanism of delta sunspot**
6. **Understand the particle acceleration**

II：Mechanism of large-scale solar eruptions and algorithm for prediction

	Sub-objectives	Tasks	Key Observations	Requirements	Instruments
II-1	Measure the energy build-up processes in flaring and CME regions	II-1-1: Measure electric current configuration reaching corona below from photospheric and chromospheric magnetic fields, and evolution of magnetic free energy	･Vector magnetic fields in photosphere and chromosphere ･Wide FOV covering AR ･Continuous observation for more than several days ･Data storage of large number of ARs	Spectro-polarimetry e ~ 3×10^{-4} dx ~ 0.3” , FOV > 300” T: 5000 ~ 10^4K dt < 10min, Time span ~ 1week	SOLAR-C/SUVIT ASOT
		II-1-2: Measure development of magnetic structure of dark filament (prominence on disk) until eruption	･Vector magnetic fields of dark filament ･Wide FOV time-series photospheric vector magnetic fields	Spectro-polarimetry e ~ 3×10^{-4} dx ~ 0.3” , FOV > 300” T: 5000 ~ 10^4K dt < 10min, Time span ~ 1week	SOLAR-C/SUVIT ASOT
II-2	Identify the trigger mechanism of solar flares and CMEs	II-2-1: Observe plasma motions and fine magnetic structures interacting with surrounding fields before flare occurrence, and identify a key process to control the trigger in the majority of flares and CMEs.	･Vector magnetic and velocity fields in photosphere and chromosphere ･FOV covering AR ･Data storage of large number of events	Spectro-polarimetry e ~ 3×10^{-4} dx ~ 0.3” , FOV > 300” T: 5000 ~ 10^4K dt < 10min, Time span ~ 1week Total data period > 1 year (for > 50 events)	SOLAR-C/SUVIT ASOT

1. Measure the energy build-up

- NLFFF extrapolation



DeRosa et al. 2015 ApJ

THE INFLUENCE OF SPATIAL RESOLUTION ON NONLINEAR FORCE-FREE MODELING

	Properties	
Bin Level	Size (pixels)	Pixel Scale (Mm)
1	1129 × 837	0.106
2	564 × 418	0.212
3	375 × 278	0.318
4	282 × 209	0.424
6	187 × 138	0.635
8	141 × 104	0.847
10	112 × 82	1.06
12	93 × 68	1.27
14	80 × 58	1.48
16	70 × 52	1.69

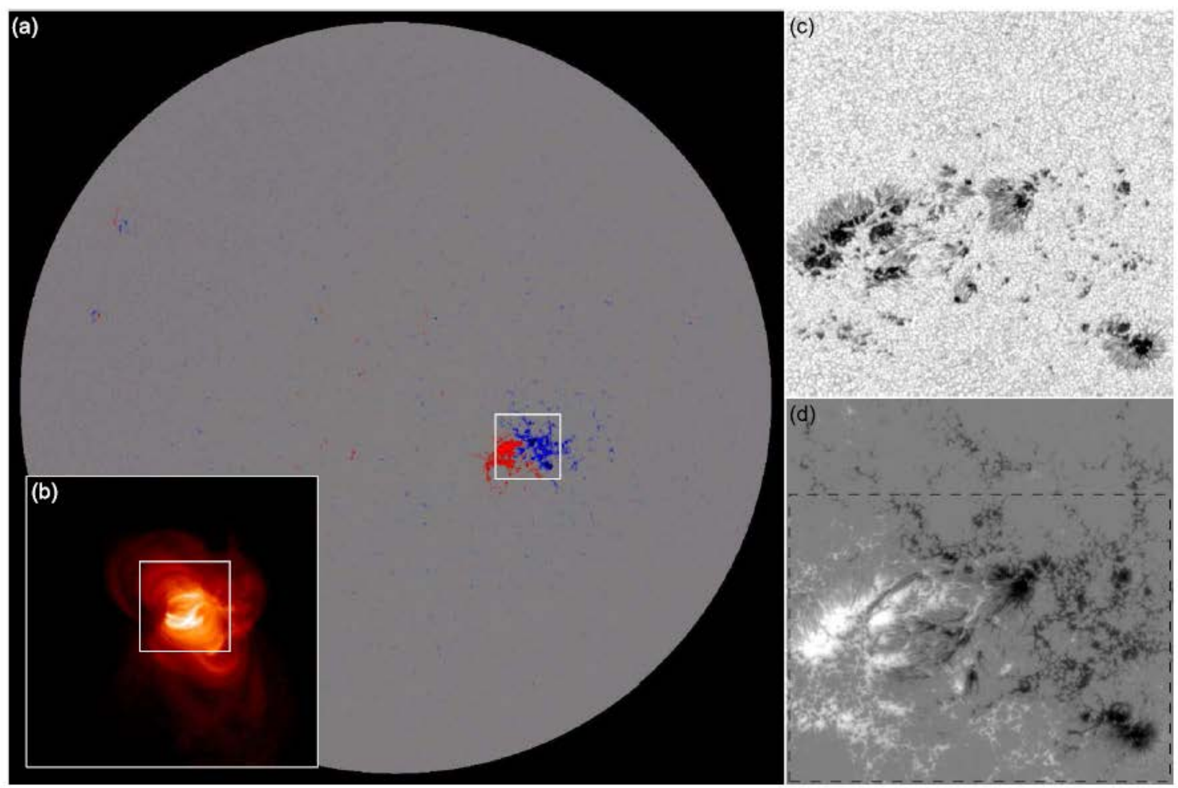
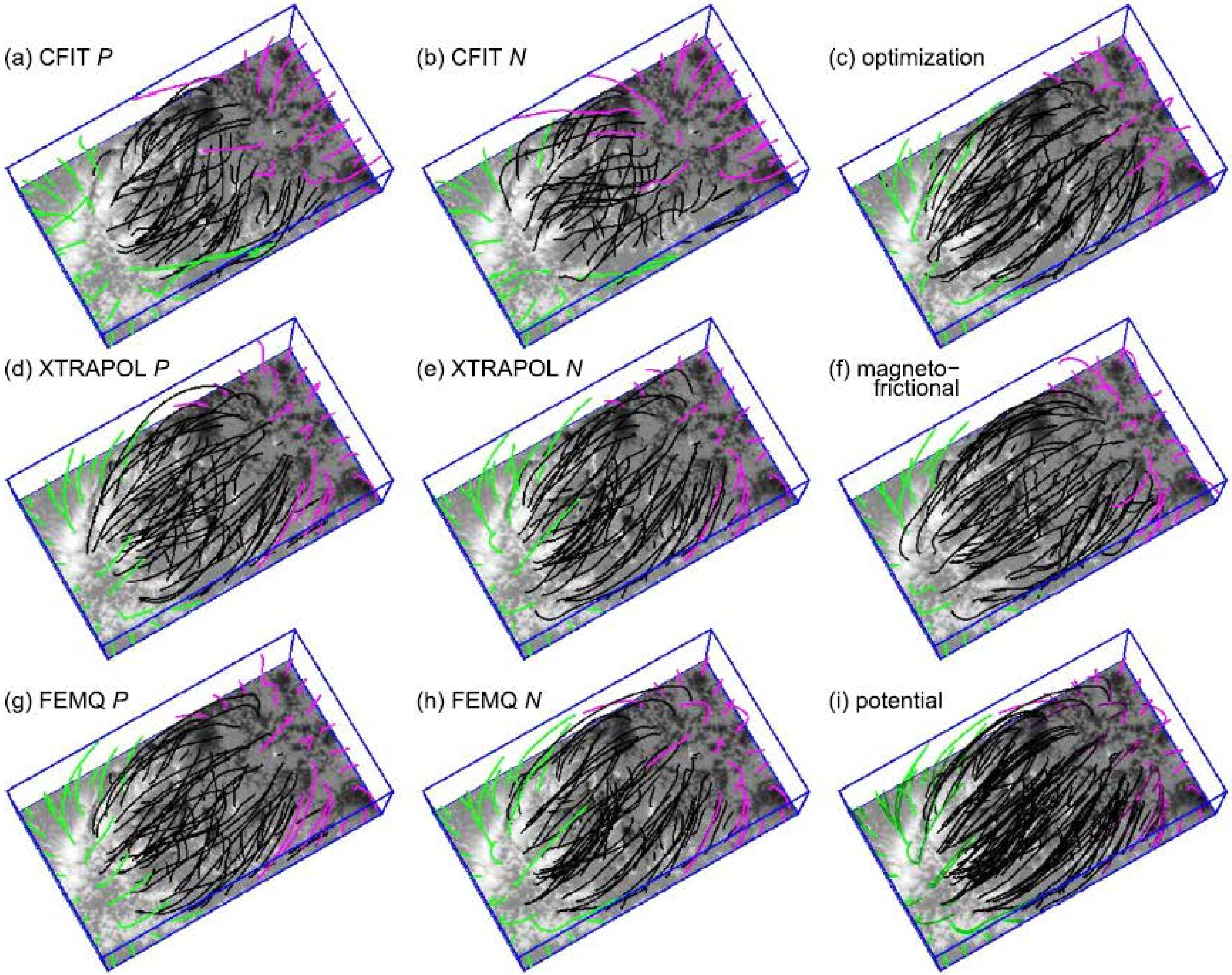


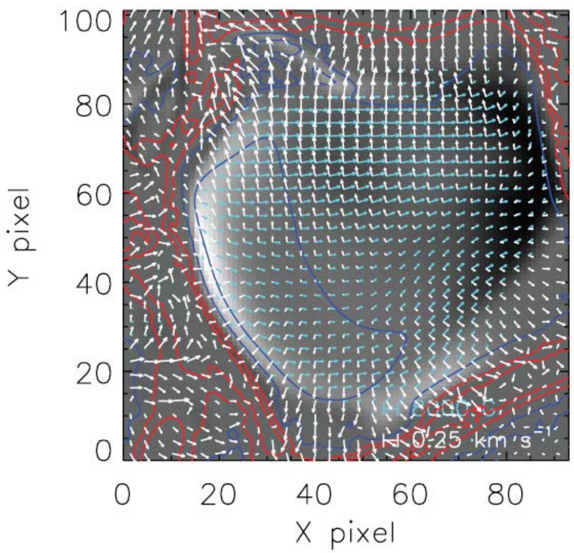
Figure 1. Images of NOAA AR 10978 on 2007 December 13. Panel (a) shows the *SOHO*/MDI full-disk magnetogram at 12:46 UT, obtained within the interval of the *Hinode* normal-map scan used in this study. The image saturates at ±1000 Mx cm^{-2}. Panel (b) shows a logarithmically scaled *Hinode*/XRT images (Ti/Poly filter) averaged over the scan interval, for context. Representative *Hinode*/SOT-SP data are shown in the two smaller panels (both 162″ × 162″) at right: panel (c) is the continuum intensity, and panel (d) shows the longitudinal magnetic field derived from the *Hinode* polarization spectra (scaled to ±1500 Mx cm^{-2}). The white boxes in

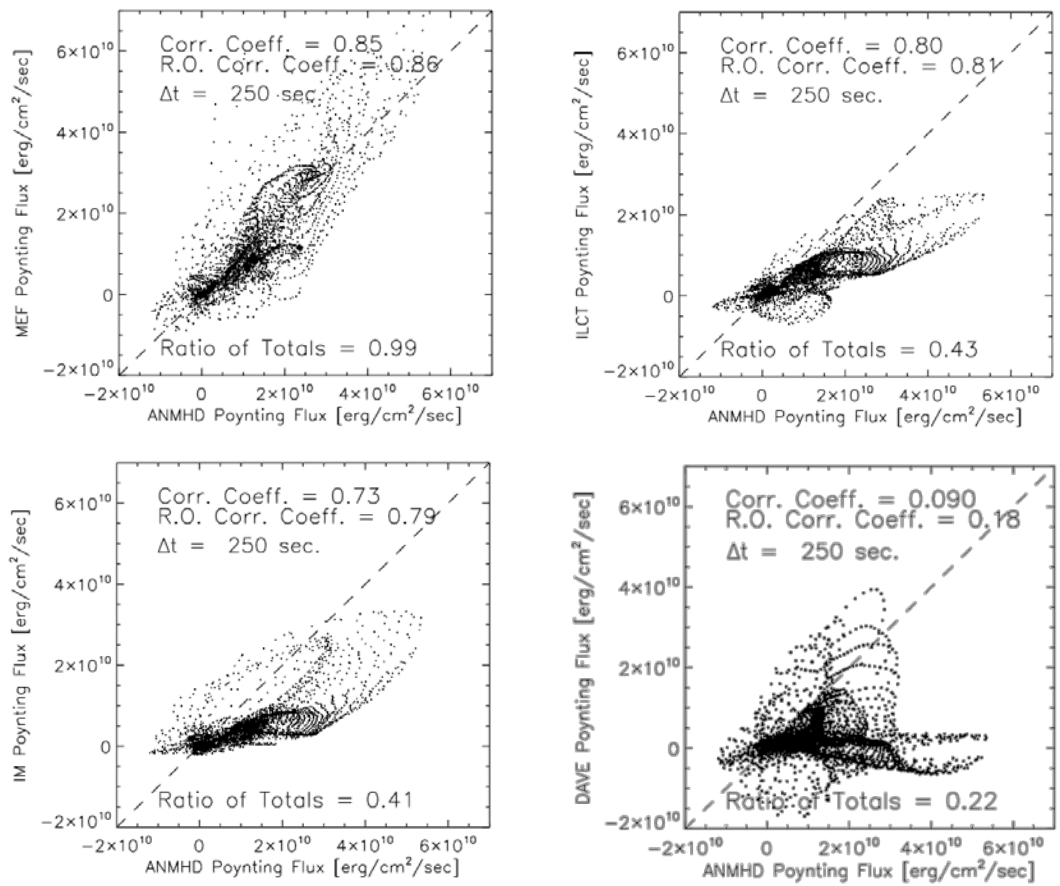

(a) CFIT P
(b) CFIT N
(c) optimization
(d) XTRAPOL P
(e) XTRAPOL N
(f) magneto-frictional
(g) FEMQ P
(h) FEMQ N
(i) potential

Measurement of Poynting Flux

- Measurement of Poynting Flux & Helicity Flux

Test of velocity inversion (Welsch et al. 2007)





II：Mechanism of large-scale solar eruptions and algorithm for prediction

	Sub-objectives	Tasks	Key Observations	Requirements	Instruments
II-1	Measure the energy build-up processes in flaring and CME regions	II-1-1: Measure electric current configuration reaching corona below from photospheric and chromospheric magnetic fields, and evolution of magnetic free energy	･Vector magnetic fields in photosphere and chromosphere ･Wide FOV covering AR ･Continuous observation for more than several days ･Data storage of large number of ARs	Spectro-polarimetry e ~ $3x10^{-4}$ dx ~ 0.3”， FOV > 300” T: 5000 ~ 10^4K dt < 10min, Time span ~ 1week	SOLAR-C/SUVIT ASOT
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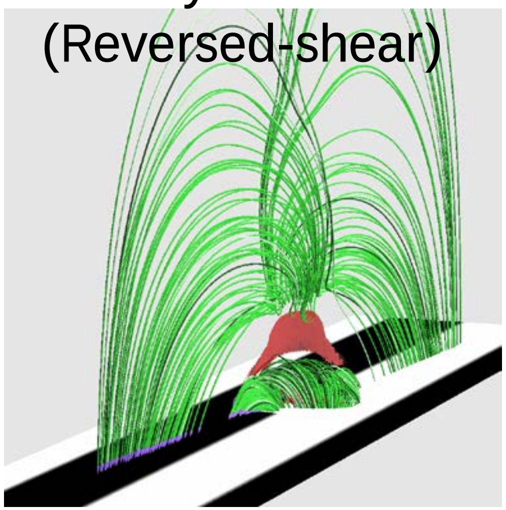
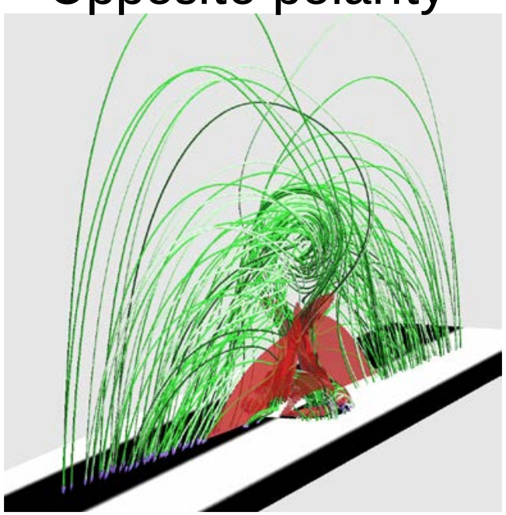
Measurement of Flare Trigger

Helicity cancellation (Reversed-shear)

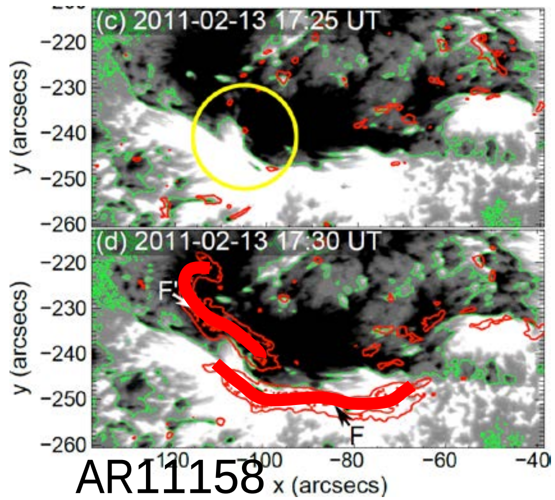


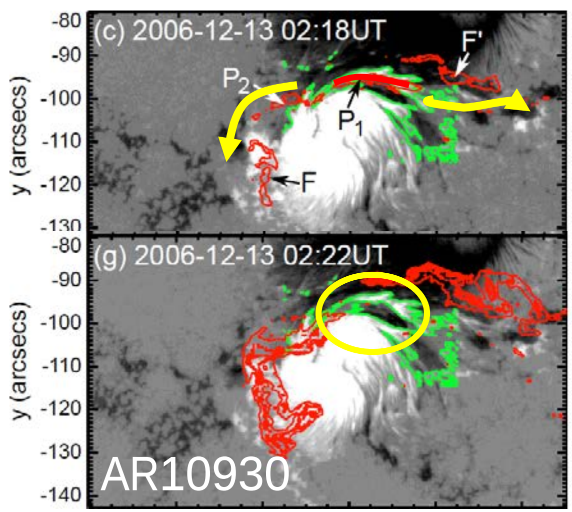
Opposite polarity



Flare Ribbon

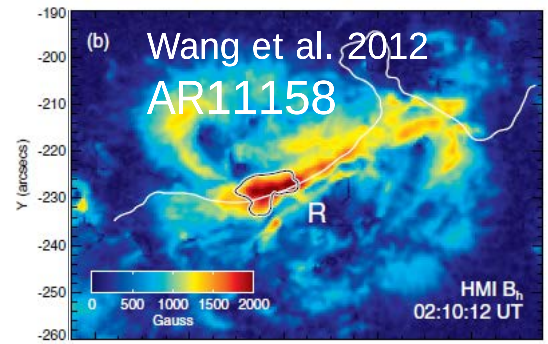
Bamba's talk (O7A25)





Change in B_h

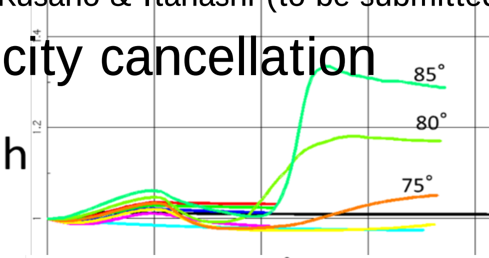
Wang 1992, Wang et al. 1994

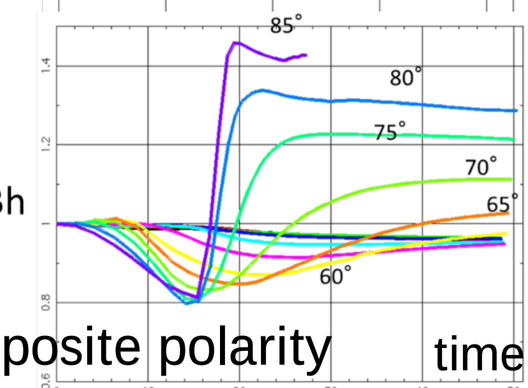


MHD Simulation

Kusano & Itahashi (to be submitted)

Helicity cancellation



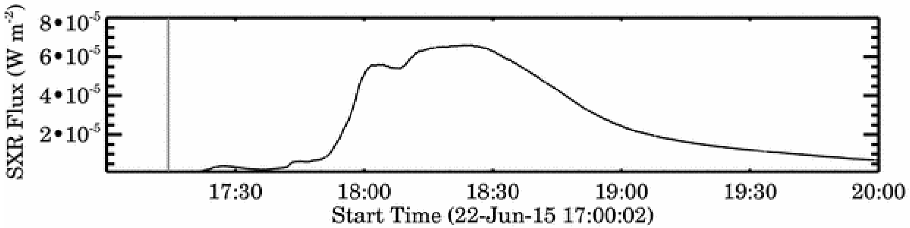


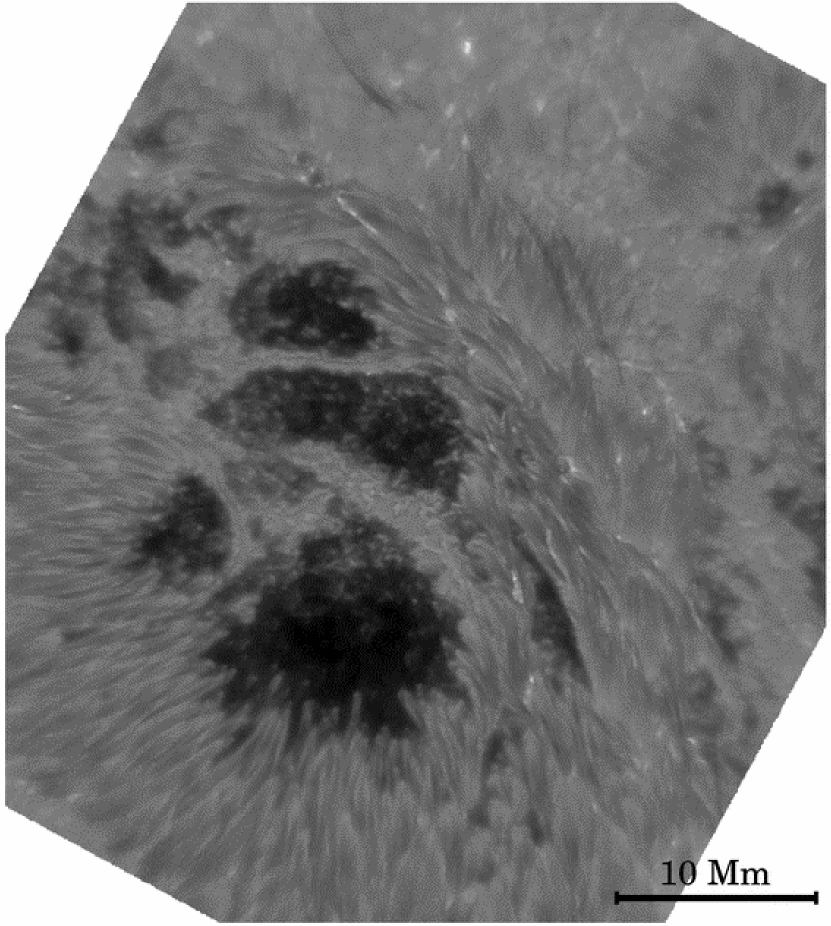
Opposite polarity

Jing et al. 2016 Nature

Unprecedented Fine Structure of a Solar Flare Revealed by the 1.6 m New Solar Telescope

High cadence &
High resolution

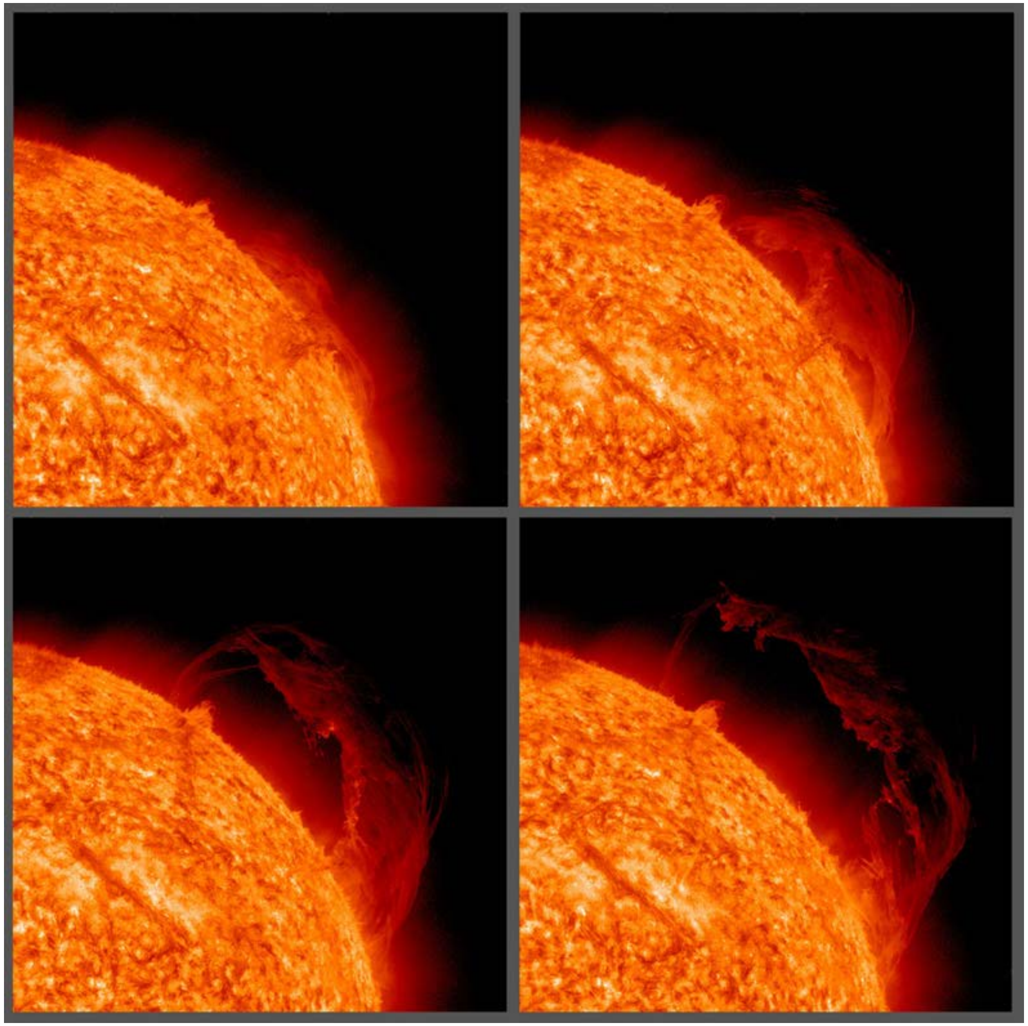


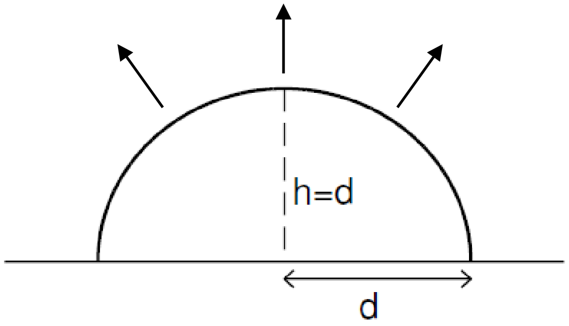


II：Mechanism of large-scale solar eruptions and algorithm for prediction

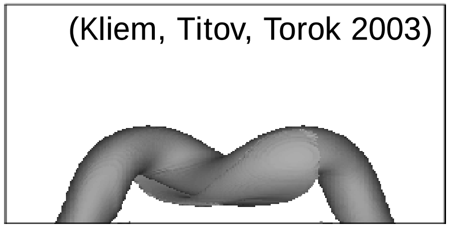
	Sub-objectives	Tasks	Key Observations	Requirements	Instruments
II-3	Clarify the mechanisms of destabilizing and erupting of the entire system	II-3-1: Identify MHD instability mode by observing dynamical changes of coronal structure and electric current system	・High-resolution coronal images, velocity fields covering AR ・Time cadence to track erupting process ・photospheric vector magnetic fields and morphological changes of chromospheric thread structures	Spectro-polarimetry e ~ $3x10^{-4}$ dx ~ 0.3", FOV > 300" T: 5000 ~ 5×10^{6}K dt < 20sec, Time span ~ 1week	SOLAR-C ASOT+coroan

Which Instability?

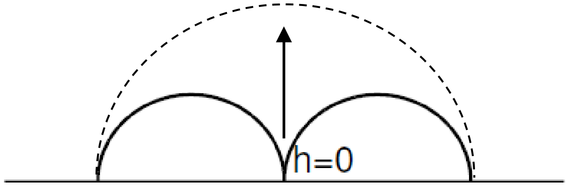




Torus Instability



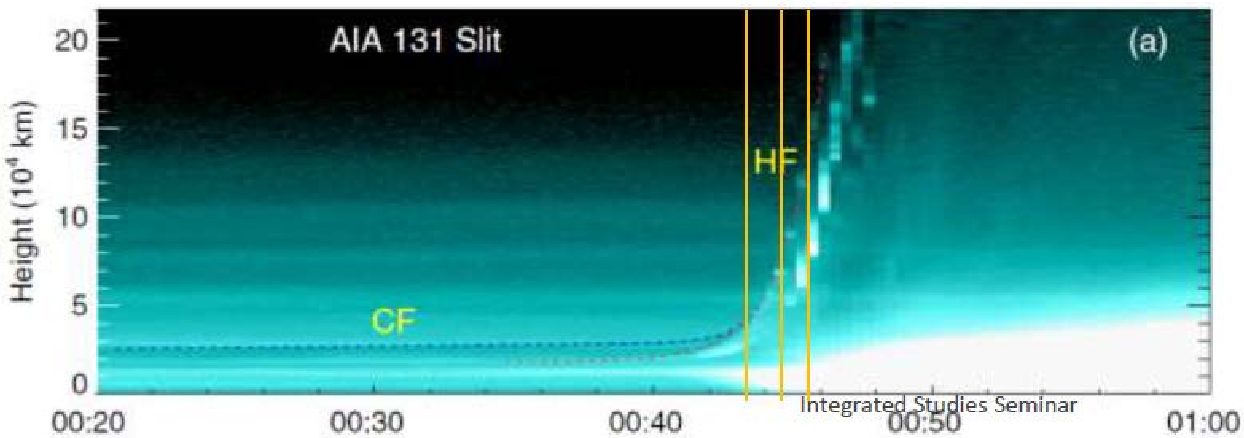
Kink Instability

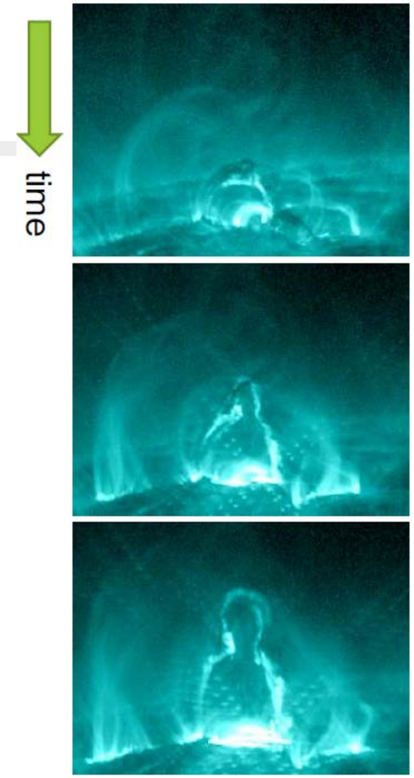


Double-arc Instability

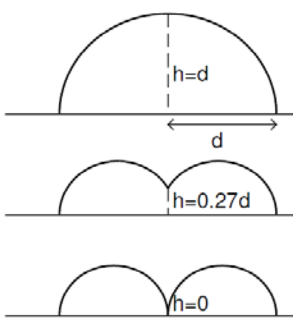
Which instability ?

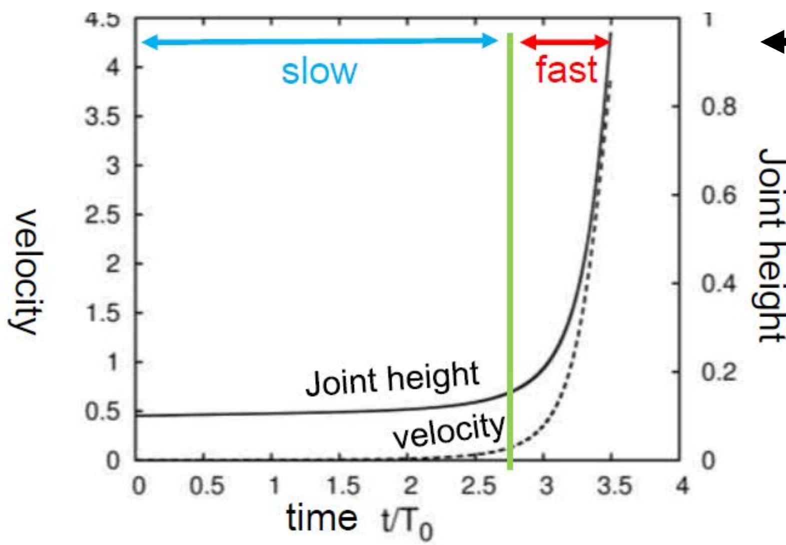
Chen et al. 2014 ApJ





Ishiguro & Kusano (to be submitted)





320km/s
25min

$$m\frac{d^2h}{dt^2}=\frac{1}{2}I^2(h)\frac{\partial L(h)}{\partial h}+I(h)\frac{\partial \Phi_{ex}(h)}{\partial h}$$

t_0~500s
V_0~80km/s

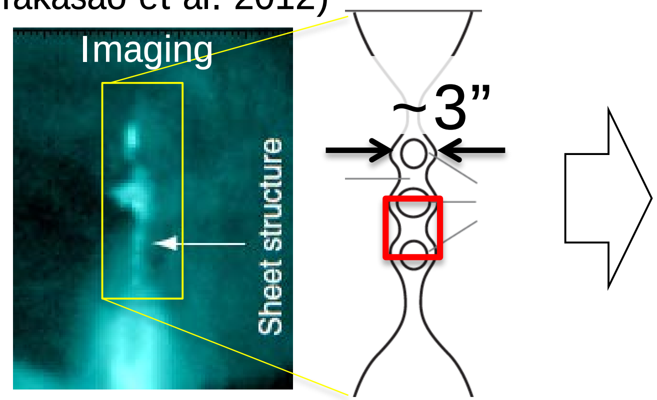
II：Mechanism of large-scale solar eruptions and algorithm for prediction

	Sub-objectives	Tasks	Key Observations	Requirements	Instruments
II-4	Understand the processes of fast magnetic reconnection	II-4-1: Observe discontinuity of chromospheric magnetic fields (current sheets)	・Vector magnetic fields of upper photosphere ~ chromosphere	Spectro-polarimetry e ~ 3x10^{-4} dx ~ 0.3” , FOV > 300” T: 5000 ~ 10^4K dt < 20sec, Time span ~ 24hr	SOLAR-C/SUVIT
		Clarify relations between the reconnection rate and the guide field in the solar chromosphere and the corona	・High-resolution coronal images, velocity fields ・Chromospheric image with chromospheric vector magnetic field ・Coronal vector magnetic field measured by Zeeman and Hanle effect or extrapolated from chromospheric and photospheric magnetic field ・FOV covering AR	Spectro-polarimetry e ~ 3x10^{-4} dx ~ 0.3” , FOV > 300” T: 5000 ~ 5×10^6K dt < ？sec, Time span ~ 1week	SOLAR-C ASOT+corona DKIST
		II-4-2: Observe growing process and motion of plasmoids in current sheets that could drive the fast magnetic reconnection	・Images and velocity fields resolving elementary structures in corona at multiple temperatures (10^5~5×10^6K) ・Time cadence capable of tracking fast motions of plasma ・Photometric accuracy capable of detecting faint structure	dx ~ 0.3” , FOV > 300” T: 5000 ~ 5×10^6K Dt < 20sec, Time span ~ 1week	SOLAR-C?EUVST&HCI
		II-4-3: Observe discontinuous structures of density and temperature associated with coronal magnetic reconnection and verify relations of shock waves and plasma heating			

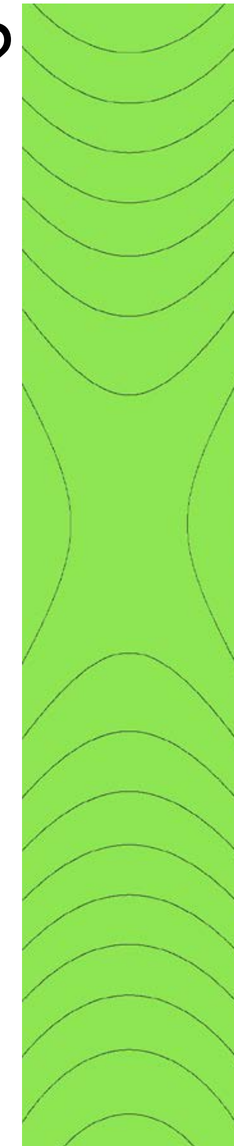
Fast Magnetic Reconnection

- What determines the reconnection rate?
  - $M \sim 10^{-2\pm1} \gg$ S–P theory ($S^{-1/2} \sim 10^{-7}$)
- What is the role of plasmoids.

(Takasao et al. 2012)



Shibayama, Kusano, et al. 2015
sporadic small-scale Petschek-type shocks



II：Mechanism of large-scale solar eruptions and algorithm for prediction

	Sub-objectives	Tasks	Key Observations	Requirements	Instruments
II-5	Understand the formation mechanism of delta sunspot				
II-6	Understand the particle acceleration		･Stokes profiles in chromospheric lines ･Continuum spectrum including Balmer jump ･Radio burst ･Gyro-synchrotron radiation ･Hard X-ray, γ-ray		