Nonlinear force-free field extrapolation calculation for inferring solar colona magnetic fields

Report Number: R24EU0912
Subject Category: Space and Astronautical Science
URL: https://www.jss.jaxa.jp/en/ar/e2024/26957/

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Abstract

Our study focuses on understanding of the mechanism responsible for the occurrence of the solar flares. We derive 3D magnetic field structure in the corona by performing a 3D magnetohydrodynamics simulation using vector magnetic field maps mainly acquired with the Hinode spacecraft. We investigate 3D magnetic field structure formed in the solar atmosphere responsible for the occurrence of solar flares.

Ref. URL: http://www.isas.jaxa.jp/home/solar/solarPlasma/whatsSolarPlasma.html

Reasons and benefits of using JAXA Supercomputer System

The aim to use JAXA supercomputer is to estimate chromospheric and colonal 3D magnetic fields from the spatial distribution of magnetic field vectors observed at the solar surface (photosphere). We use force-free field modeling based on three-dimensional magnetohydrodynamics simulations, requiring computer resource. Usage of calculation results is to search 3D magnetic fields distribution before flare and the area where energetic magnetic fields easy to expand explosively. Thanks to high-spec supercompution resource, we can investigate a variety of magentic fields data with different time siries in a short time.

Achievements of the Year

Unstable states of the solar coronal magnetic field structure result in various flarebehaviors. We compared the confined and eruptive flares that occurred1 under similar magnetic circumstances in the active region 12673, on 2017 September12, using the twist number, decay index, and height of magnetic field lines to identify observational behaviors of the flare eruption. We investigated the parameters from the magnetic field lines involved in an initial energy release, which were identified from the positions of the core of flare ribbons, i.e., flare kernels. The magnetic field lines were derived by nonlinear force-free field modeling calculated from the photospheric vector magnetic field. The twist number of all the magnetic field lines in the confined flare was

below 0.6; however, the twist number in seven out of twenty-four magnetic field lines in the eruptive flare was greater than 0.6. These lines were tall. It is found that the decay index is not a clear discriminator of the confined and eruptive flares. Our study suggests that some magnetic field lines in the kink instability state may be important for eruptive flares, and that taller magnetic field lines may promote flare eruption.

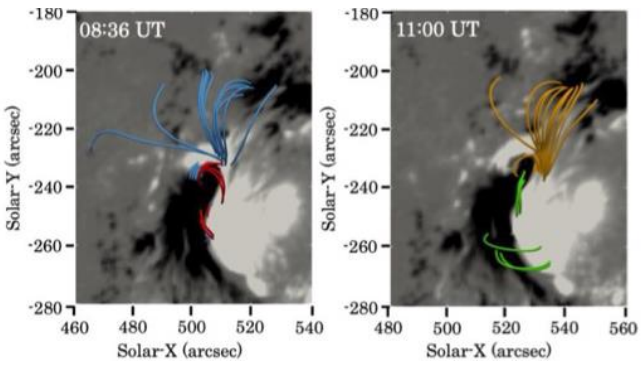

Fig. 1: Magnetic field lines obtained by nonlinear force-free magnetic field modeling. The magnetic field lines (colored lines) involved in the initial energy release from the position of the flare ribbon core are shown on the solar surface magnetic field map (black and white indicate the magnetic field polarity). Left: confined flare, right: eruptive flare.

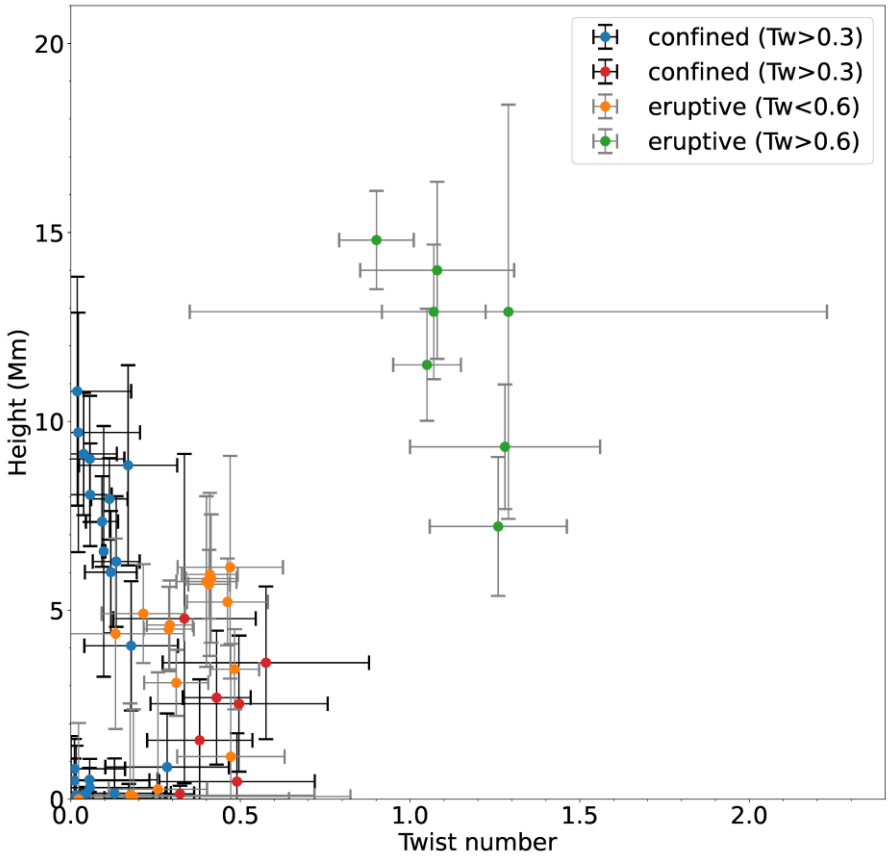

Fig. 2: Twist number and height of the magnetic field lines involved in the initial energy release. We obtained that the twist number of 7 of the 24 magnetic field lines in the eruptive flare is greater than 0.6 and that these field lines are also tall.

Publications

- Peer-reviewed papers

Teraoka,1K, Yamasaki, D., Kawabata,, Y., Imada, S., and Shimizu, T. “Observational Comparison Between Confined and Eruptive Flares: Magnetohydrodynamics Instability Parameters in a Similar Magnetic Configuration,” 2025, The Astrophysical Journal, 983, 126

doi: https: /10.3847/1538-4357/adc12d

- Oral Presentations

Teraoka, K., et al. "Observational Comparison of Coronal Magnetic Field Parameters Between Confined and Eruptive Flares in the Similar MFR Configuration", Hinode-17 / IRIS-15 / SPHERE-3 meeting, 22-27 July 2027, Bozeman, MT, U.S.A.

Usage of JSS

Computational Information

Process Parallelization Methods	MPI
Thread Parallelization Methods	N/A
Number of Processes	16
Elapsed Time per Case	3.5 Hour(s)

JSS3 Resources Used

Fraction of Usage in Total Resources[*1](%): 0.00

Details

Computational Resources		
System Name	CPU Resources Used (core x hours)	Fraction of Usage[*2](%)
TOKI-SORA	0.00	0.00
TOKI-ST	0.00	0.00
TOKI-GP	0.00	0.00
TOKI-XM	0.00	0.00
TOKI-LM	0.00	0.00
TOKI-TST	0.00	0.00
TOKI-TGP	0.00	0.00
TOKI-TLM	0.00	0.00

File System Resources		
File System Name	Storage Assigned (GiB)	Fraction of Usage*2 (%)
/home	10.00	0.01
/data and /data2	2,450.00	0.01
/ssd	0.00	0.00

Archiver Resources		
Archiver Name	Storage Used (TiB)	Fraction of Usage*2 (%)
J-SPACE	0.00	0.00

*1: Fraction of Usage in Total Resources: Weighted average of three resource types (Computing, File System, and Archiver).

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.

- **ISV Software Licenses Used**

ISV Software Licenses Resources		
	ISV Software Licenses Used (Hours)	Fraction of Usage*2 (%)
ISV Software Licenses (Total)	0.00	0.00

*2: Fraction of Usage：Percentage of usage relative to each resource used in one year.