Statistical Properties of Solar Filament Eruptions

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Solar filaments

- Filament (absorption in H-alpha)
- Prominence (emission in H-alpha)

(it's what happens to filaments at the limb)
• Cool material suspended in the concave upward “dips” of a twisted magnetic field
Filament environments

Active Region

Intermediate

Quiet Sun

Polar Crown

McCauley et al. SolPhys, 2015
External triggers


Mass Draining
Mass drains, B force overcomes g force

Emerging Flux
Emerging B-field disrupts overlying B-field

Flux Cancellation
Cancelling B-field disrupts overlying B-field
flux rope stability

Decay index of overlying field determines stability

\[ n = -\frac{d(\ln B)}{d(\ln h)} \]

Critical value >1-2, depending on solar conditions

MHD instabilities


kink instability

torus instability

Kink instability has a faster speed

Torus instability has a larger critical decay index
Data sources

**H-alpha data**
- Big Bear Solar Observatory
- Kanzelhöhe Solar Observatory

**Global H-alpha Network**

**Extreme ultraviolet data**
- Atmospheric Imaging Assembly (AIA) on the Solar Dynamics Observatory
Meta-data sources

Heliophysics Event Knowledgebase
https://www.lmsal.com/isolsearch
**Meta-data sources**

CfA Filament Eruption Catalog

904 filament eruptions observed by SDO between 06/2010 and 09/2014

http://aia.cfa.harvard.edu/filament/
statistical investigations

kinematics of filament eruptions

eruption kinematics

McCaulley et al.
SolPhys, 2015
Onset height increases with latitude

McCauley et al.
SolPhys, 2015
Connection with CMEs

McCabe et al.
SolPhys, 2015
eruption velocity and location
Decay index decreases with latitude, explaining higher onset heights at high latitudes.

Many eruptions have a decay index of <1, indicating that an external mechanism rather than an ideal instability is the trigger.
Twist and writhe

Twist: Rotation about an axis

Many filament eruptions exhibit some form of twist

Writhe: Rotation of the axis

Writhe is less common, but may be misclassified as twist in some cases

McCauley et al. SolPhys, 2015
Twist vs. no twist

Twisted eruptions are more likely to be faster (like the kink instability) and have higher onset heights.

No noticeable difference in decay index.

McCauley et al. SolPhys, 2015
Why do filaments erupt?
Aggarwal, A.*, Schanche, N., Reeves, K. K., Kempton, D., Angryk, R.  
(Submitted to ApJS)
HEK filament tracking algorithm (Bernasconi, Rust, and Hakim, 2005) records each filament instance, but we need to associate instances as filaments rotate across disk.

**Filament properties:**
- Center position
- Polygon shape
- Bounding box
- Length
- Tilt
- Chirality
- Number of barbs
Filament tracking

Tracking algorithm (Kempton et al. 2015) associates filament instances into tracks
Eruption matching

Eruption center within a filament polygon within +/- 12 hours

Filament polygon intersects eruption bounding box within +/- 12 hours
Filament properties:

area (mean, stdev, skew, slope)
length (mean, stdev, slope)
L/W (mean, stdev, slope)
tilt (mean, stdev, skew, slope)
chirality (mean, stdev, skew, slope)
# barbs (mean, stdev, skew, slope)
latitude (mean)
Anderson Darling Test

Change in Length

- Frequency distribution of Change in Length (cm/day) for erupting and non-erupting cases.
- Mean for erupting: 1.3e+08
- Mean for non-erupting: 1.4e+09

Average Latitude

- Frequency distribution of Average Latitude (arcsec) for erupting and non-erupting cases.
- Mean for erupting: 36
- Mean for non-erupting: -75

Probably a solar cycle effect
Random forest

decision tree

random forest

many trees

Random forest

Forests of 25 trees give a ~60% accuracy. Better than guessing randomly at 49%.
Feature importance

Random Forest

AD Test

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<th>Feature</th>
<th>$A^2$</th>
<th>p-value</th>
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Possible trigger mechanism

Filaments that get smaller are more likely to erupt

Mass draining is a possible triggering mechanism
Conclusions

- Polar crown filaments have higher eruption onset heights, possibly due to lower decay indexes
- Eruptions with twist have faster speeds and lower onset heights, implicating a kink instability
- Twist in filament eruptions does not seem to be related to magnetic asymmetry
- Parameters such as filament length and area tend to decrease before an eruption, implicating mass draining as a trigger