# To Erupt, or not to Erupt?

## *Prediction of Solar Eruptions from HEK Filament Metadata*

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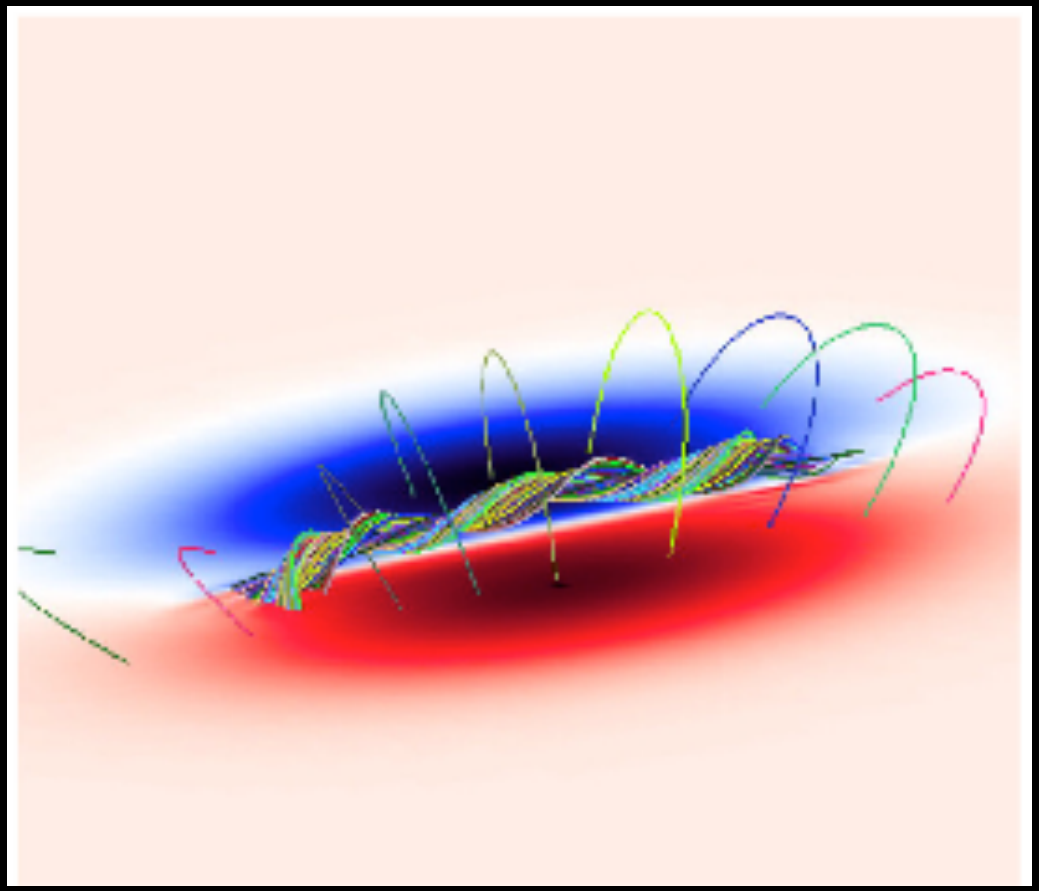
# Introduction

- Filaments are channels of dark, cool partially ionized plasma above the chromosphere
- Coronal Mass Ejections (CME's) are eruptions of solar plasma that can disturb Earth's magnetosphere
- "More than 80% of (filament) eruptions lead to a CME" (Schmieder, B.; Demoulin, P., Aulanier, G., 2013)
- Finding properties of erupting versus non-erupting filaments helps us predict CME's

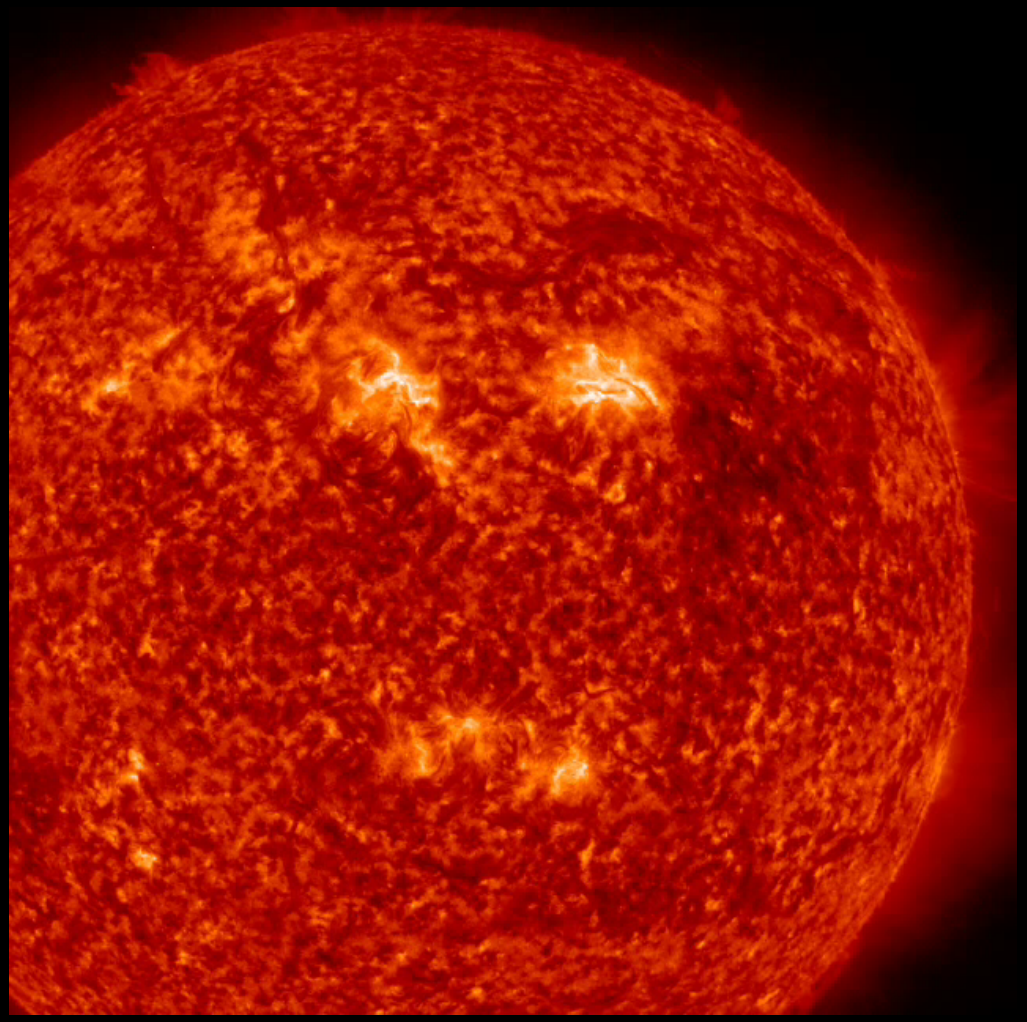
# Introduction

"Flux Rope" filament configuration



# Introduction

March 16-17 2012

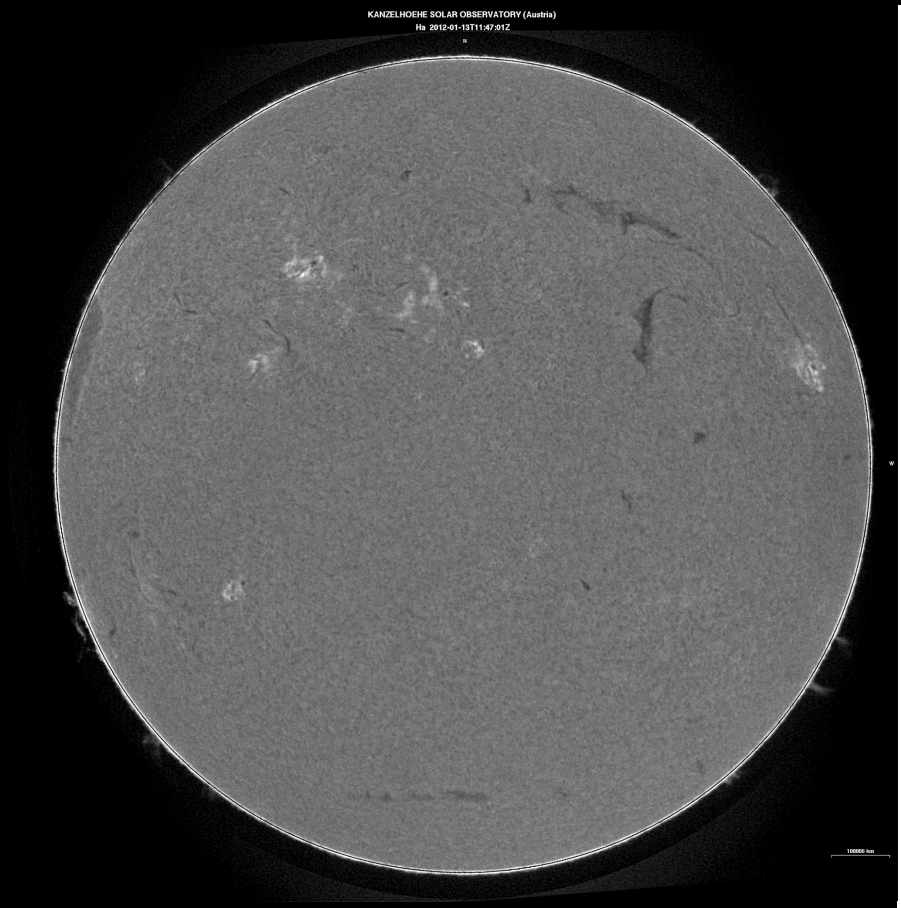


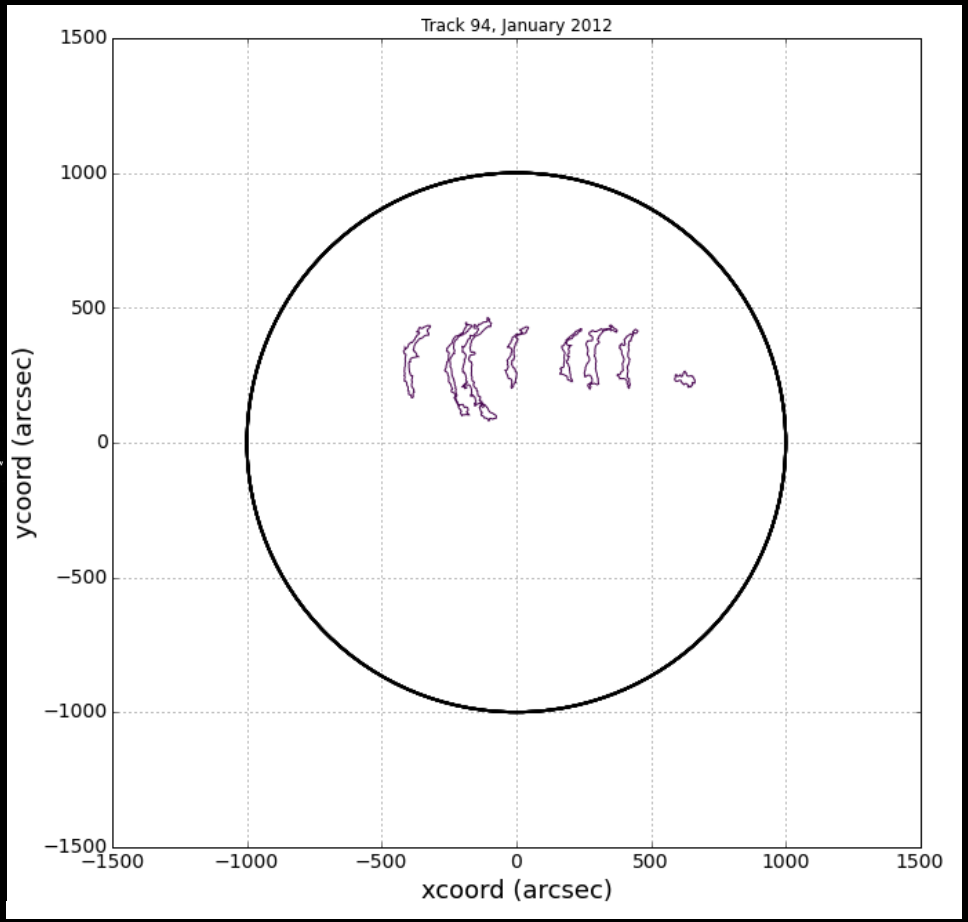
# Method

- Step 1: Associating erupting filaments correctly with eruptions
  - -Data from Heliophysics Event Knowledgebase (HEK)
  - -Filaments documented as individual instances
  - -Collaboration with Dustin Kempton at Georgia State University who tracks filaments
  - -Filament-eruption correlation algorithm based on spatiotemporal analysis
  - -Non-erupting filaments are far from an eruption in space and time

# Method

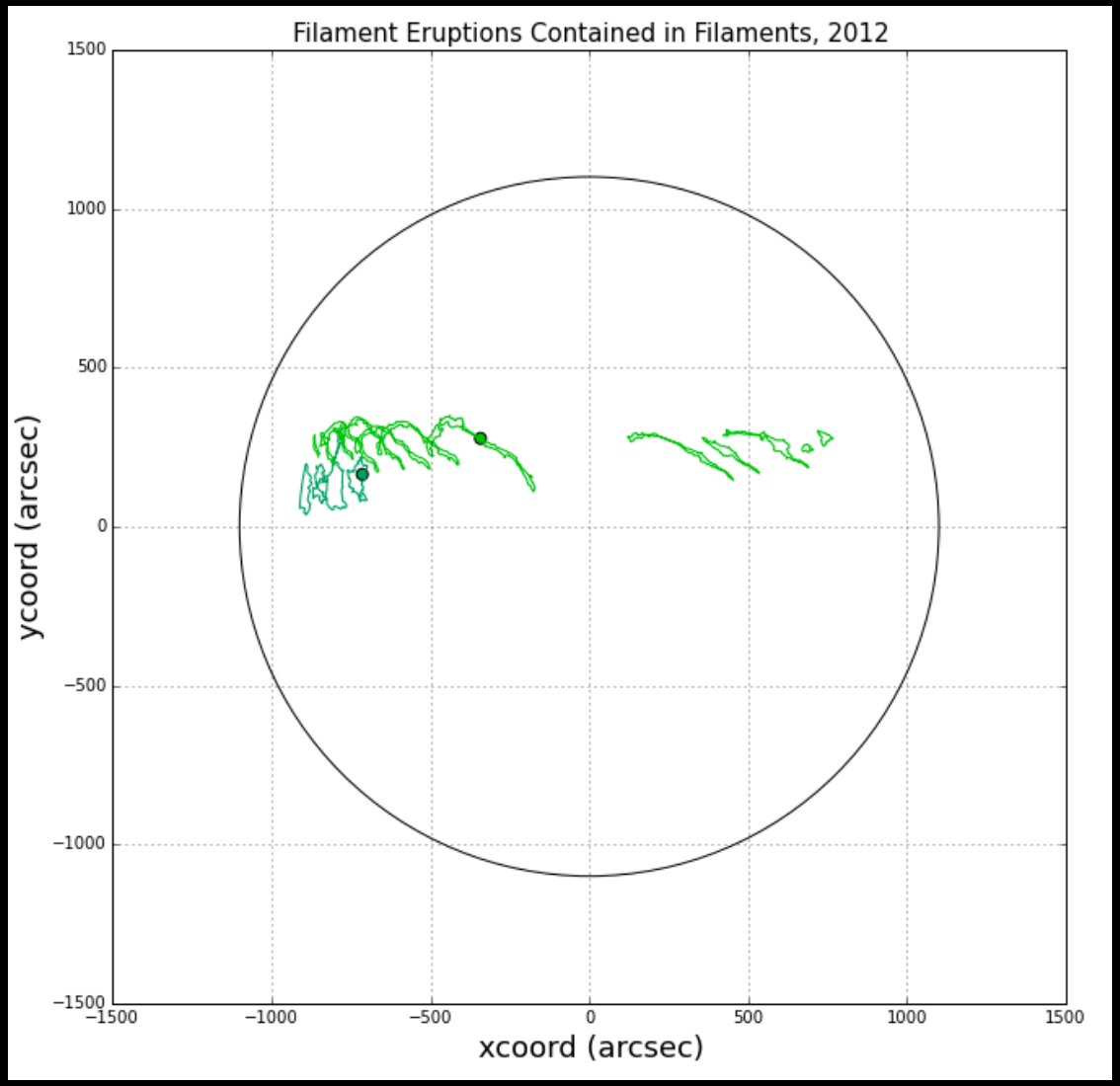
Ex. from Dustin's tracking algorithm



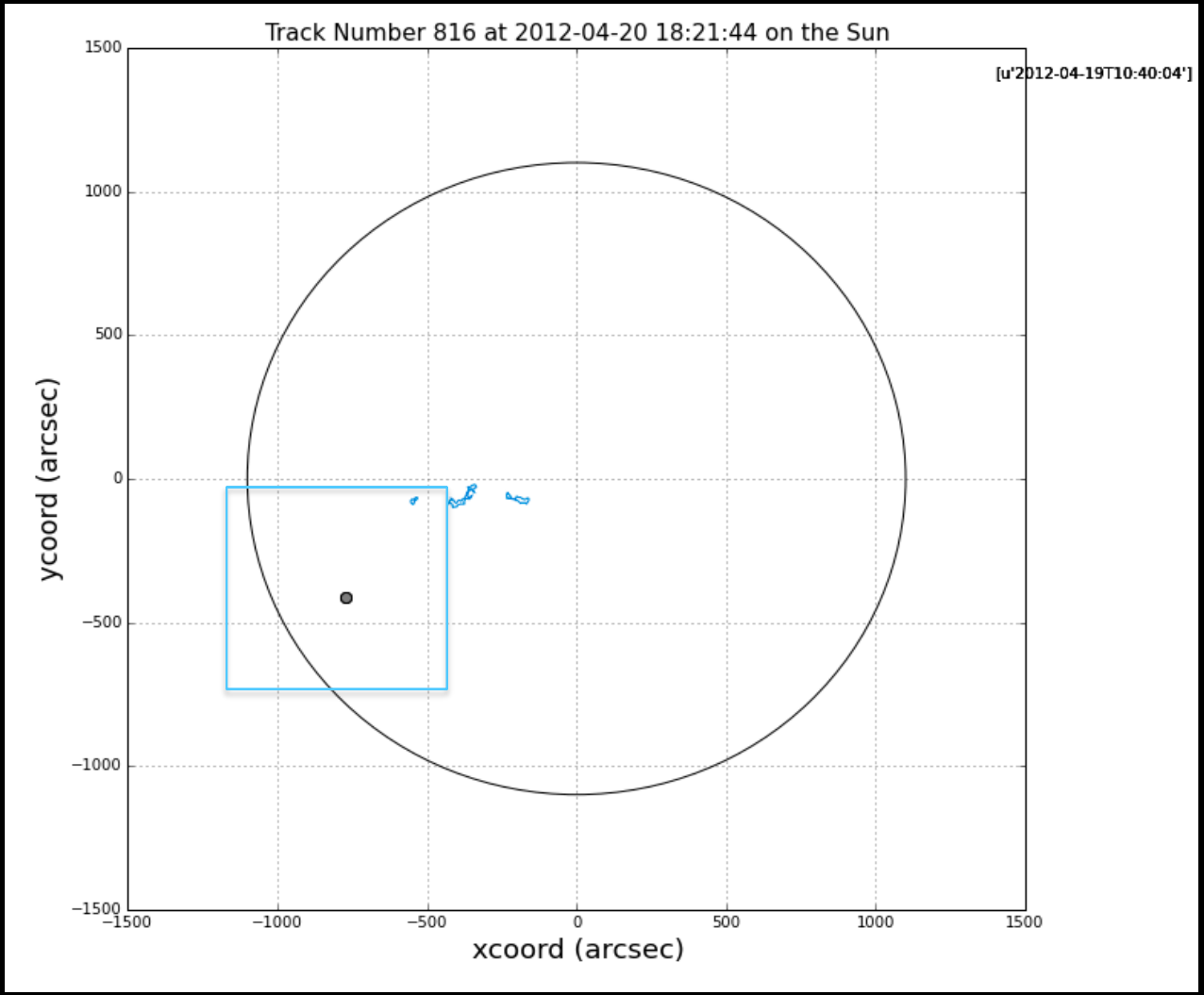
# Method

Results from correlating filaments to eruptions by +/- 12 hours and "containment"



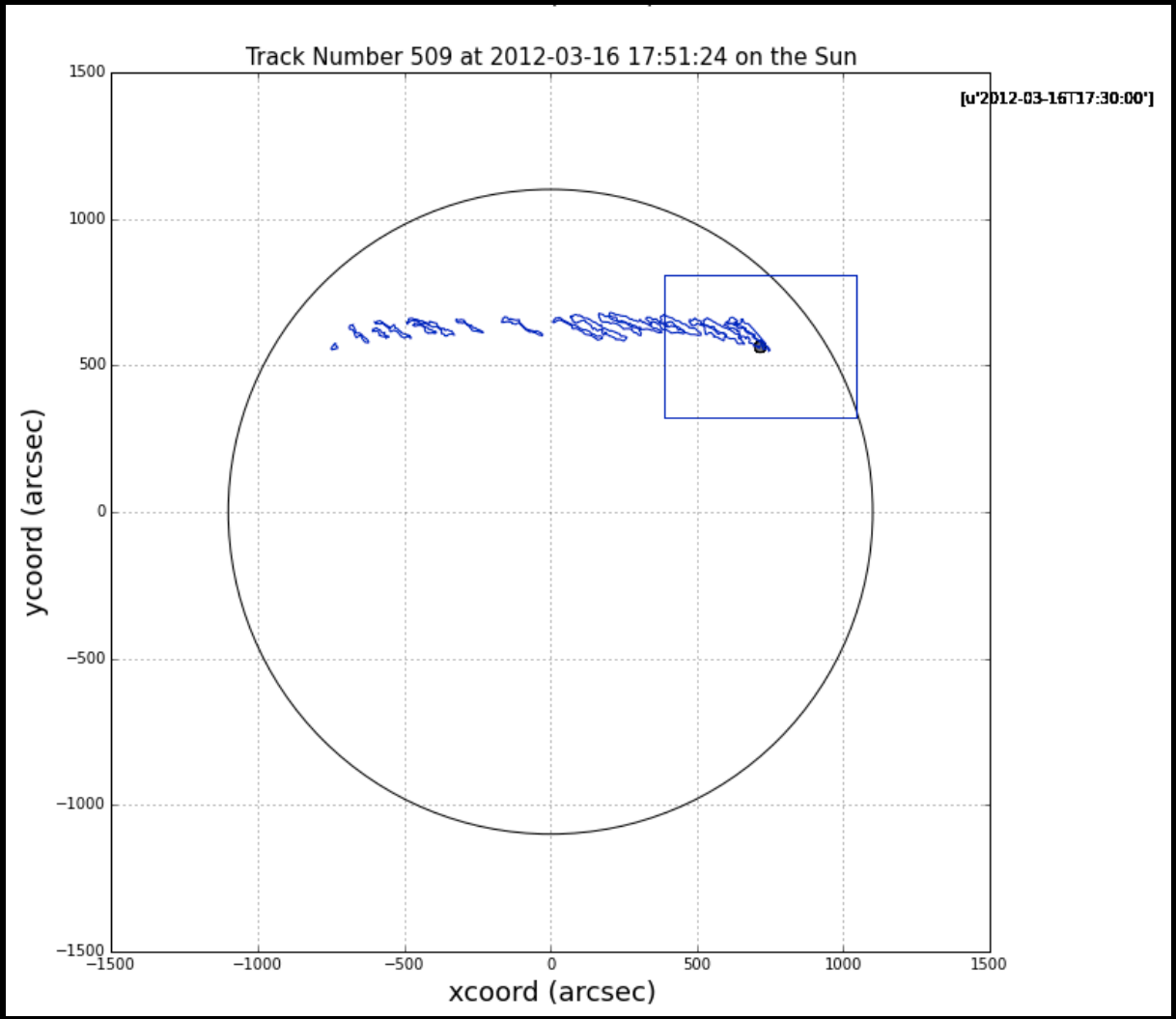
# Method

One result from correlating filaments to eruptions by +/- 12 hours and "intersection"



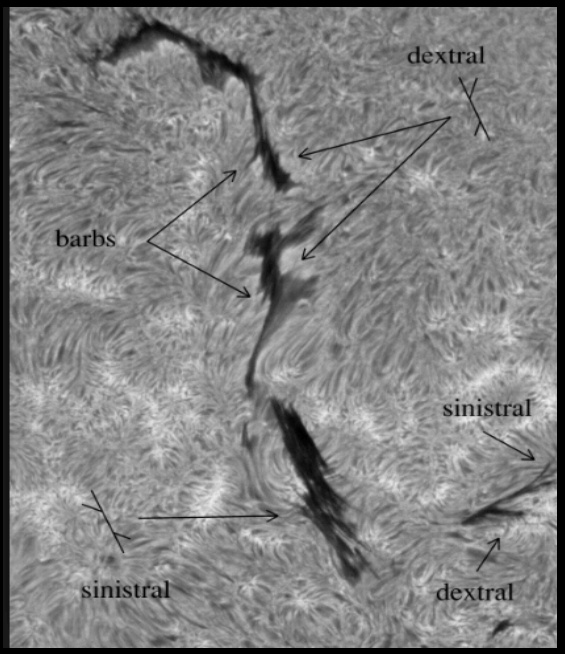
# Method

Example of an ideal track that did erupt (algorithm needed improvement)



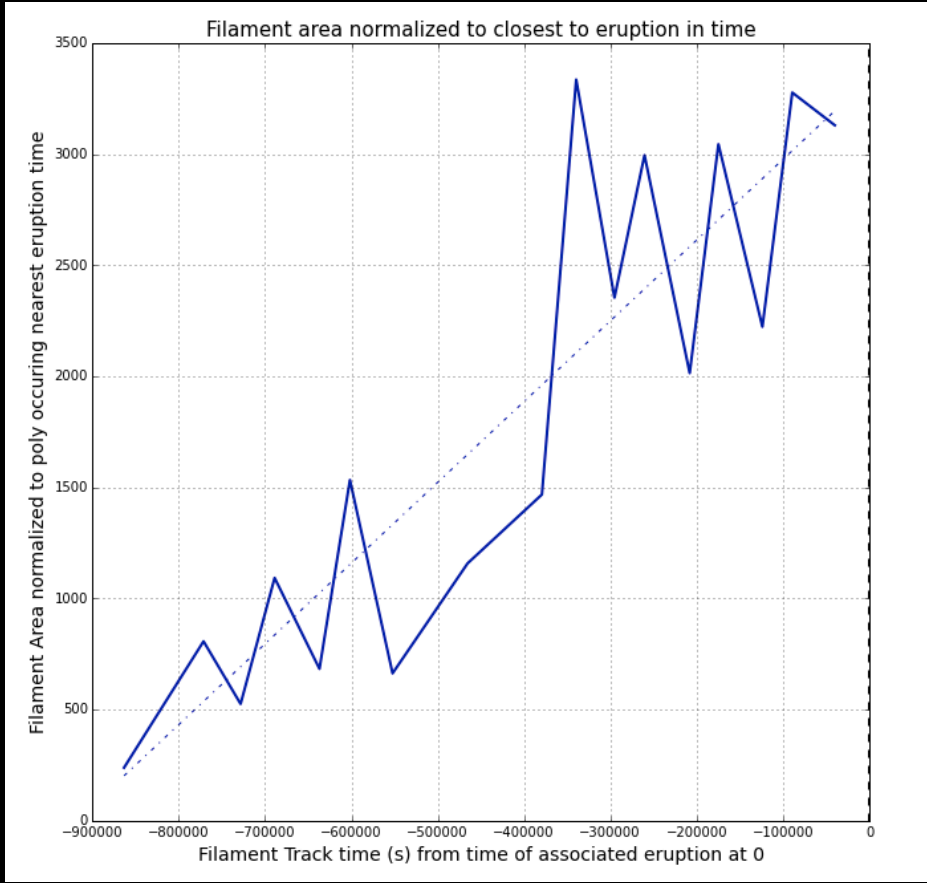
# Method

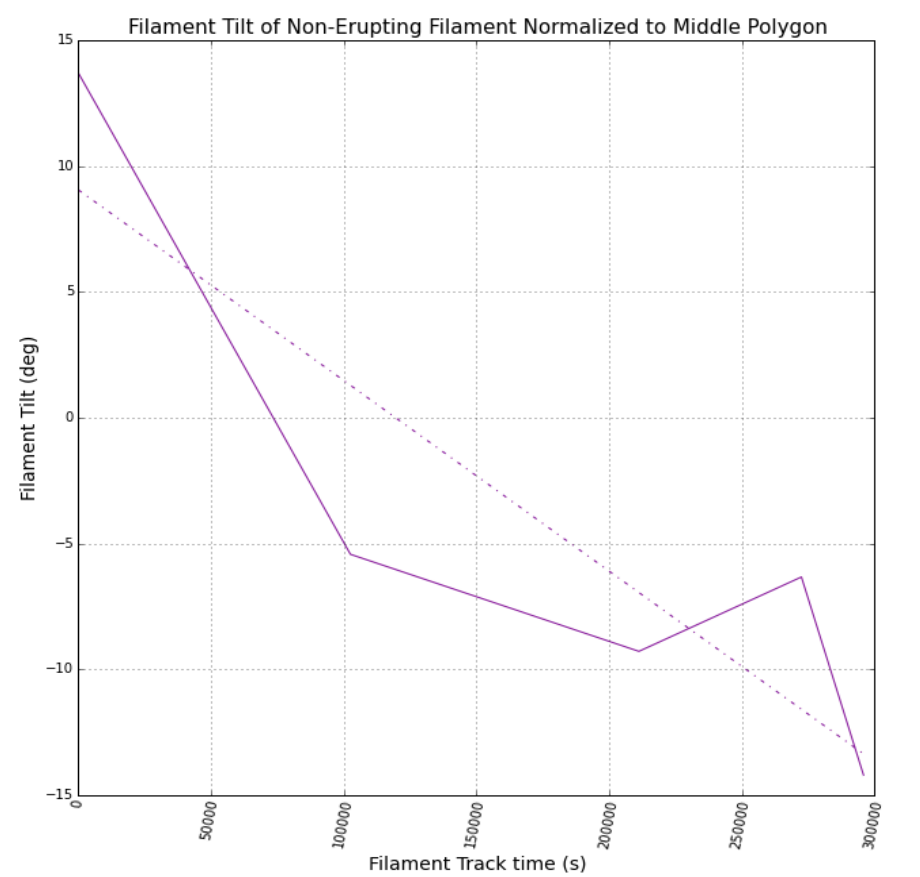
- Step 2: Working with metadata
  - -length
  - -chirality
  - -tilt
  - -area




- Average value of each parameter per track prior to eruption
- How each track evolves in time prior to eruption
- Similar analysis for non-erupting, but normalized to median polygon

# Method

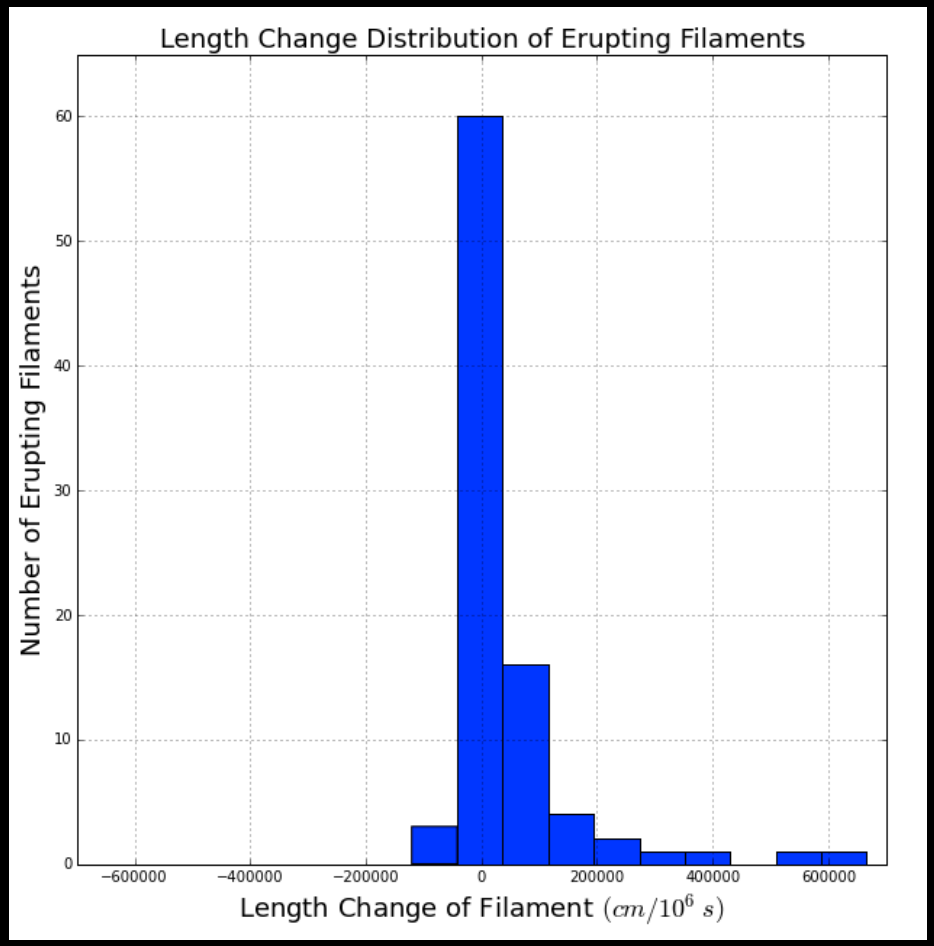

Filament area normalized to closest to eruption in time
Filament Area normalized to poly occuring nearest eruption time
Filament Track time (s) from time of associated eruption at 0
3500
3000
2500
2000
1500
1000
500
0
−900000
−800000
−700000
−600000
−500000
−400000
−300000
−200000
−100000
0

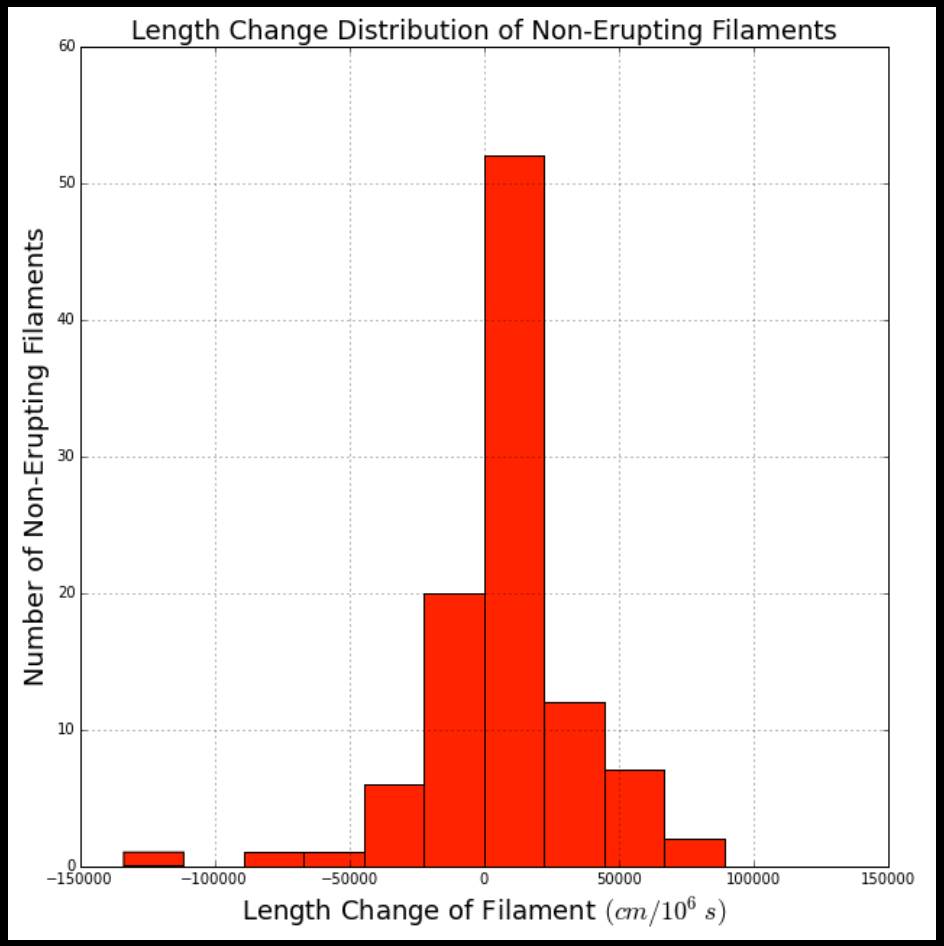

Filament Tilt of Non-Erupting Filament Normalized to Middle Polygon
Filament Tilt (deg)
Filament Track time (s)
15
10
5
0
−5
−10
−15
0
50000
100000
150000
200000
250000
300000

# Statistical Analysis

- 89 erupting, 102 non-erupting
- Plotted histograms for length, area, tilt, and chirality to compare erupting versus non-erupting data
- Two Sample Kolmogorov-Smirnov (KS) test
  - -Do two samples come from the same distribution?
  - -Want p-value $< 0.05$

# Statistical Analysis



# Statistical Analysis

- Example p-values

| **Erupting vs. Non-Erupting** | **p-value** |
|---|---|
| Avg. Length | 0.676 |
| Length Slope | 0.012 |
| Avg. Area | 0.666 |
| Area Slope | 0.003 |
| Avg. Tilt | 0.126 |
| Tilt Slope | 0.026 |
| Avg. Chiral | 0.338 |
| Chiral Slope | 0.342 |

# Preliminary Results

- Random Forest Classifier

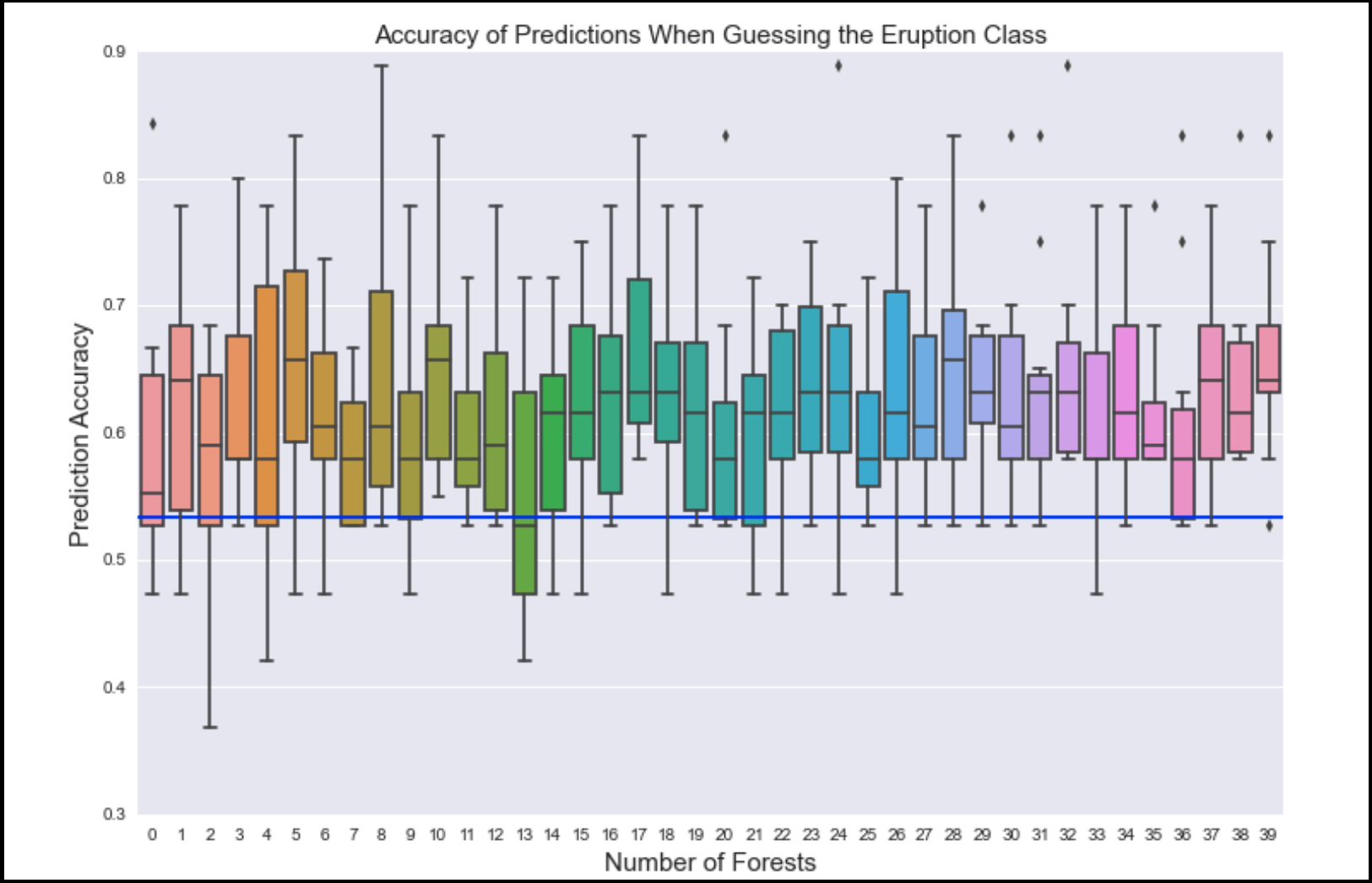
  -Program makes prediction (erupting or non-erupting) based on multiple decision trees

- Filament more likely to erupt if

  -increasing in length

  -changing in tilt with respect to equator

# Preliminary Results



# Preliminary Results

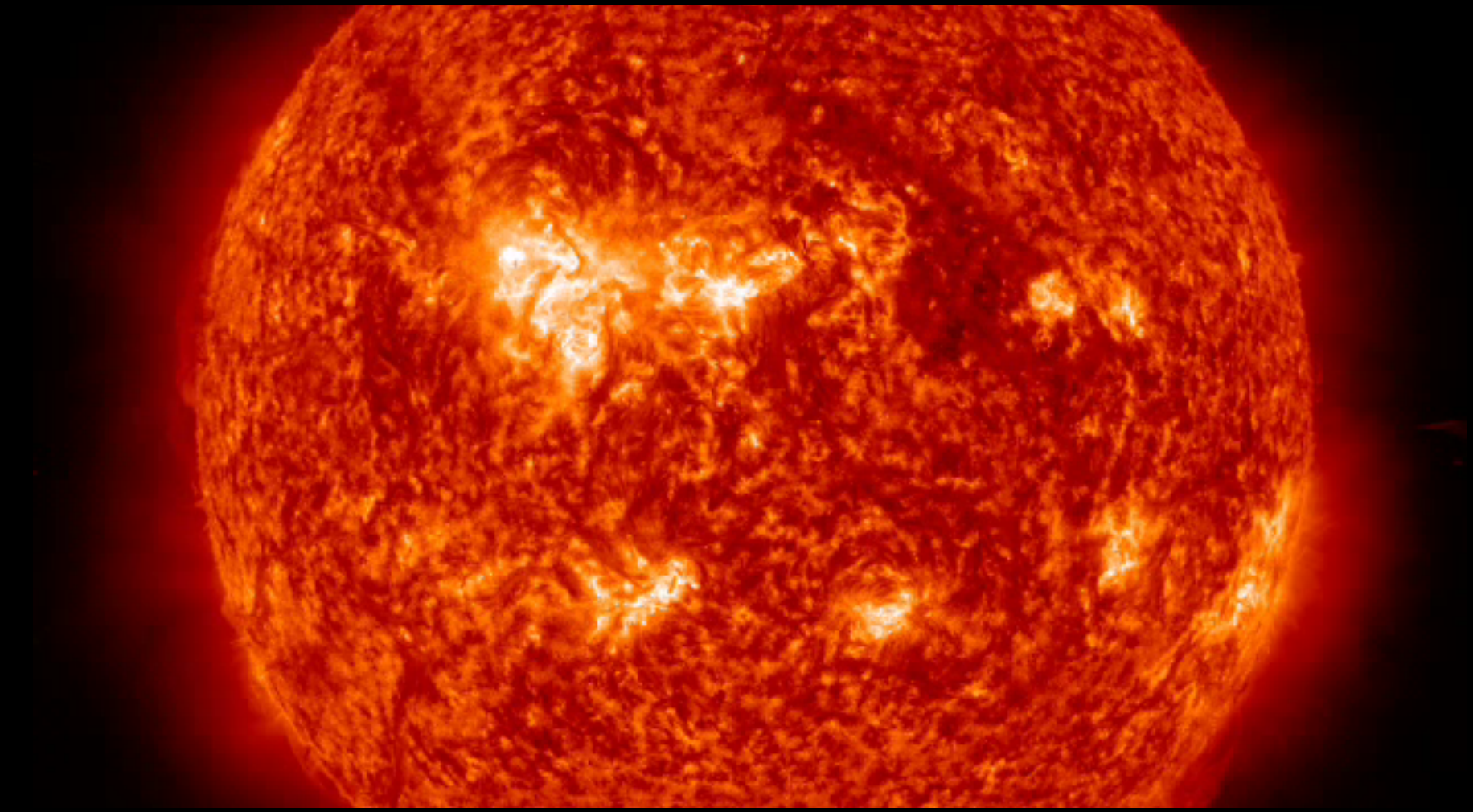
# Conclusion

From both the K-S Test and the Random Forest Classifier we found:

- Average length, tilt, and chirality were not significant when determining eruption status
- Filament **increasing in length** or **changing in tilt** is more likely to erupt

# Future Work

- Improvements on both tracking and correlation algorithms
- Analyze a larger time span (currently have a track file for 24 months)
- Look at more parameters, such as barb structure



# Acknowledgements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- My mentors: Kathy Reeves and Nicole Schanche
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- Vinay Kashyap for help on statistics
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- Everyone else in the Solar Physics group

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# References


- Schmieder, B.; Démoulin, P.; Aulanier, G., (2013) Solar filament eruptions and their physical role in triggering coronal mass ejections. Advances in Space Research, Volume 51, Issue 11, p. 1967-1980
- Parenti, S. (2014). Solar Prominences: Observations. Living Reviews in Solar Physics, 11, 1.
- Amari, T., Luciani, J.F., Mikic, Z. and Linker, J., 2000, "A Twisted Flux Rope Model for Coronal Mass Ejections and Two-Ribbon Flares", Astrophys. J. Lett., 529, L49–L52. [DOI], [ADS]. (Cited on page 46.)
- http://solarmuri.ssl.berkeley.edu/~welsch/brian/solar/glossary/glossary.html

# Questions?

# K-S Test

$$D_{n,n'} = \sup \left| F_{1,n}(x) - F_{2,n'}(x) \right|$$

Supremum value between the distribution functions of two samples

-Assumes that two samples are independent, random, and have identical distributions (p = 1.0)

-Examines single supremum, or maximum difference between two distributions

-If a difference is found, there is NO insight on the contributor of the difference

# Random Forest Classifier

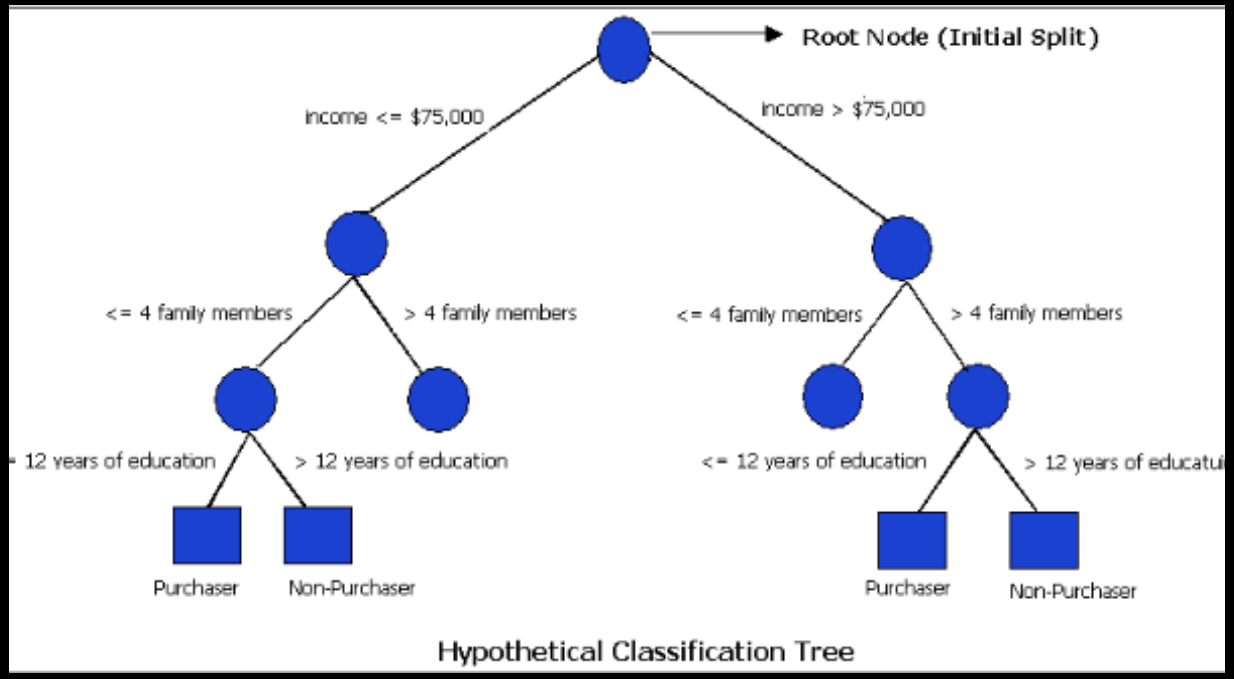
**Example of a single classification tree**

-Program classifies the data based on given parameters (in this case, purchaser or non-purchaser)

-Each tree gives a classification

-Forest chooses the classification with the most votes

-How correct was the forest?




From solver.com