The Relationship Between Sigmoids and Filaments and Verification of their Automatic Detection

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Outline

- What is the Heliophysics Events Knowledgebase?
- Why is it Necessary?
- What is a Filament?
  - Advanced Automatic Solar Filament Detector
- What is a Sigmoid?
  - Sigmoid Sniffer
- How are they Related?
- What Did I Do?
- Results
- Conclusions

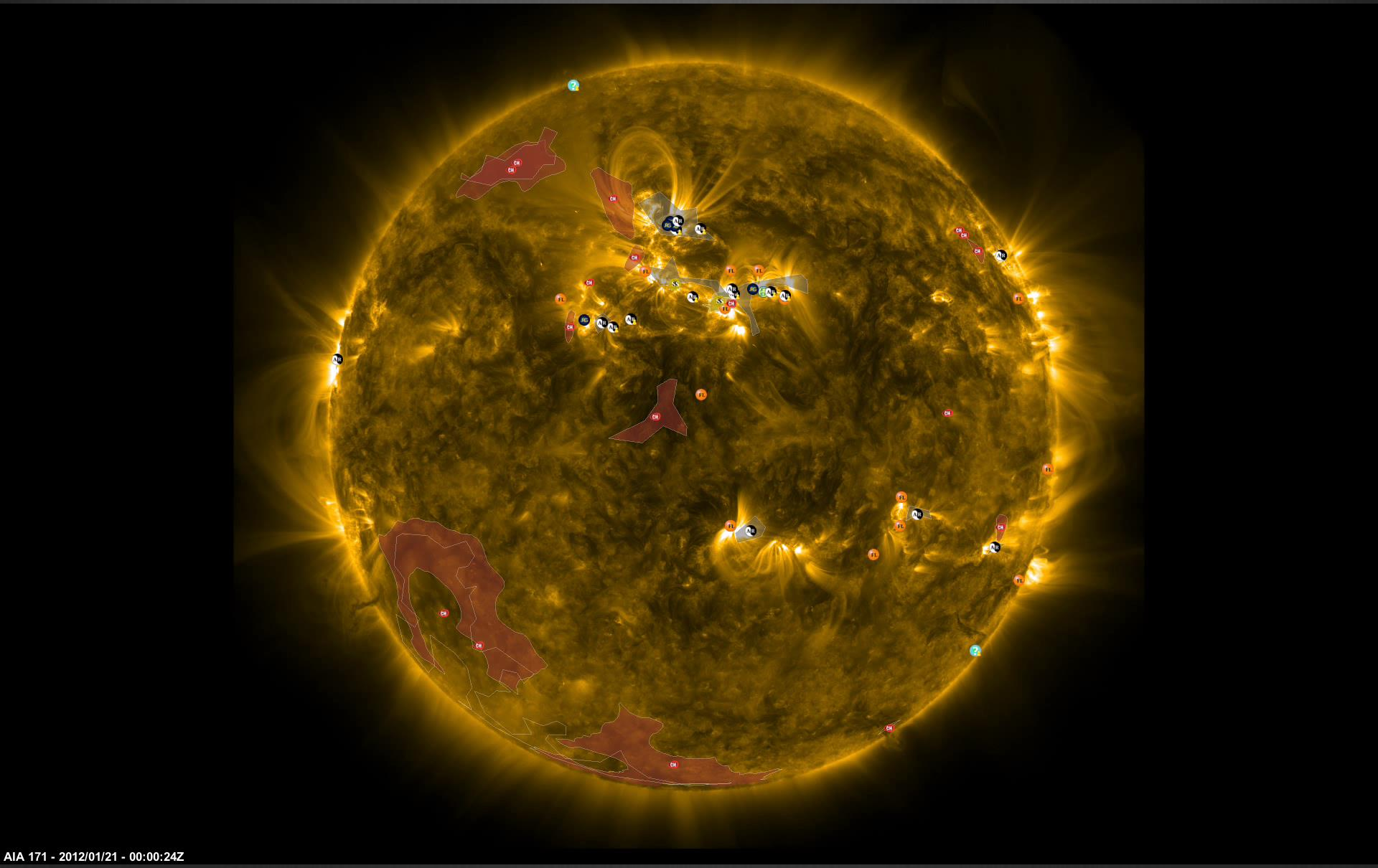
SDO Computer Vision

- Solar Dynamics Observatory (SDO) launched in February 2010
- "Trainable feature detection module based on a generalized image-classification algorithm"
- Created to keep up with the SDO data stream, while detecting, analyzing, and tracing numerous phenomena

(Martens et al., SoPh. 2012)

Heliophysics Events Knowledgebase

- Created by the Lockheed Martin Solar & Astrophysics Laboratory
- Catalogs the SDO Computer Vision module's data
- Useful, digestible form of information to facilitate scientific discovery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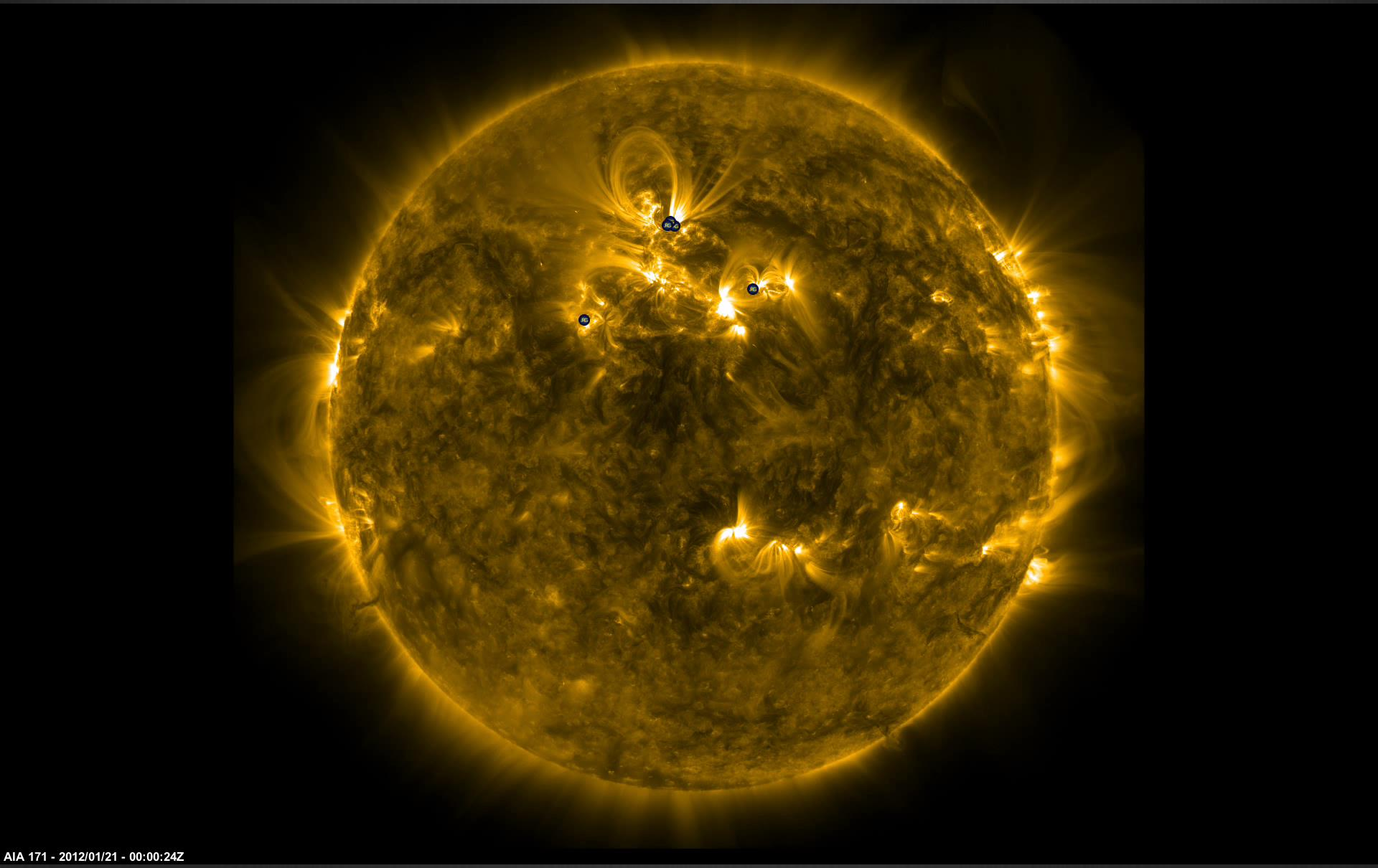
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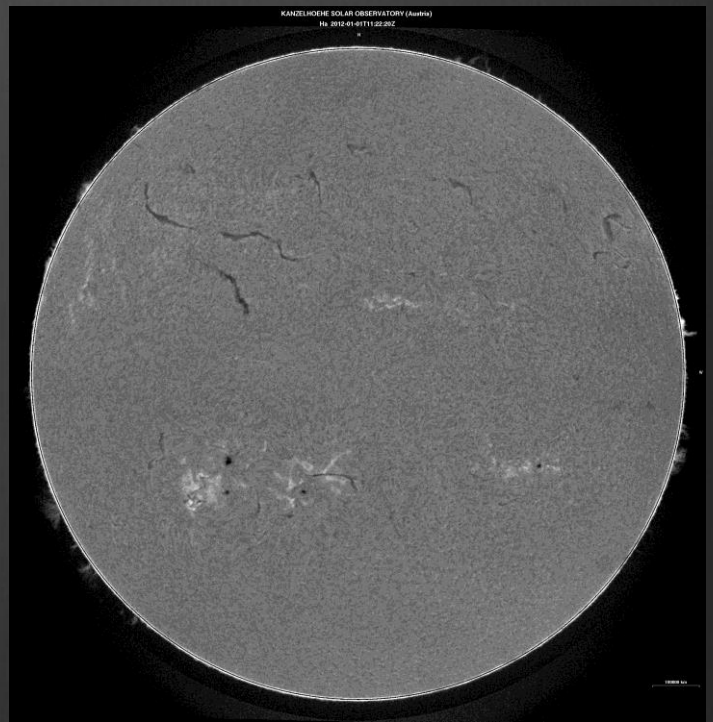
What is a Filament?

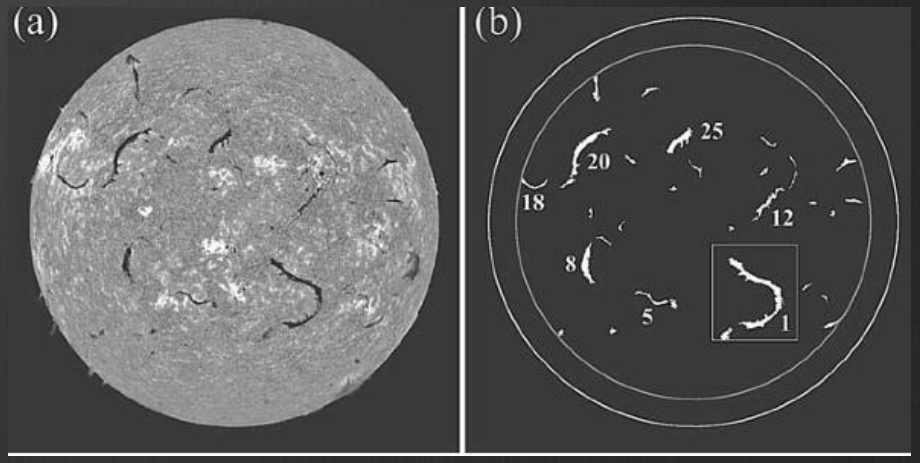
- Dense, cool plasma suspended in the hot corona
- Called prominences when seen on the solar limb
- Thought to be supported by twisted magnetic flux ropes

(Bernasconi, Rust, and Hakim, SoPh. 2005)



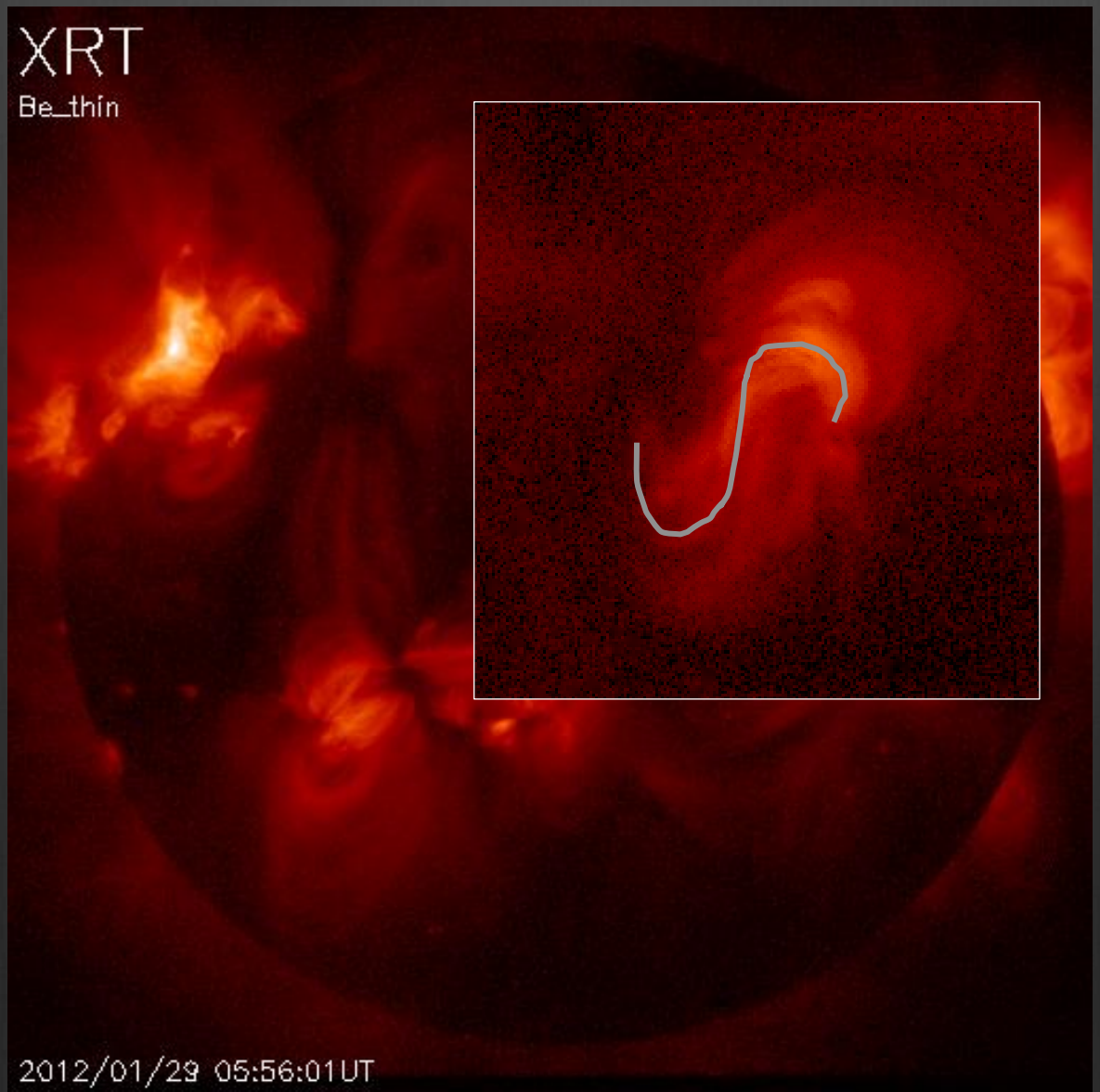
Advanced Automated Filament Detection and Characterization Code

- Accesses full disk Hα images from ground based telescopes and identifies all dimmings
- Determines chain code for the outer shape and spine for all positively identified filaments
- Compares the location of newly detected filaments to previous ones in order to track across the disk
- Active about twice a day

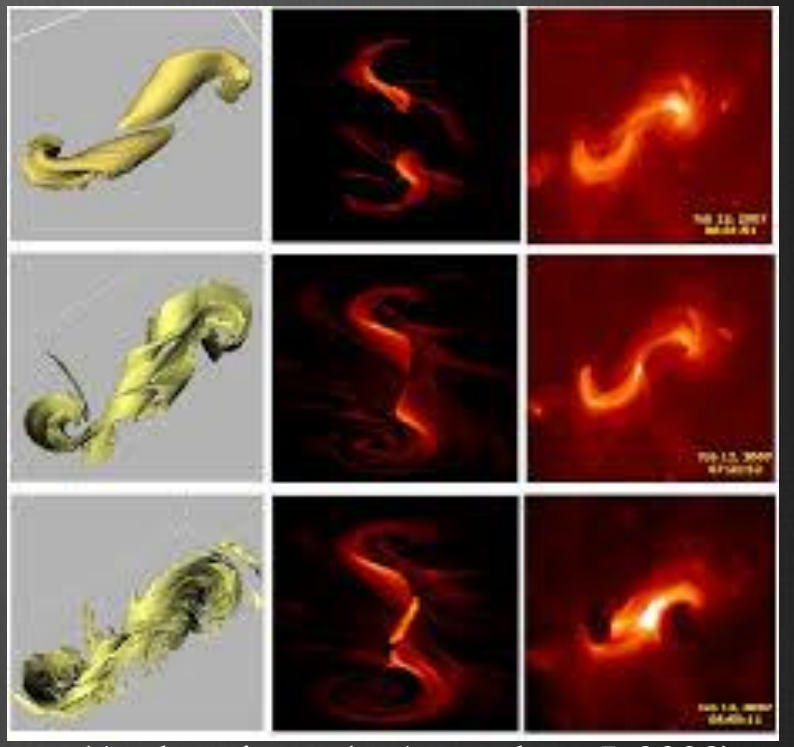


(Bernasconi, Rust, and Hakim, SoPh. 2005)

What is a Sigmoid?



Sigmoids



(Archontis et al., Astrophys. J. 2009)

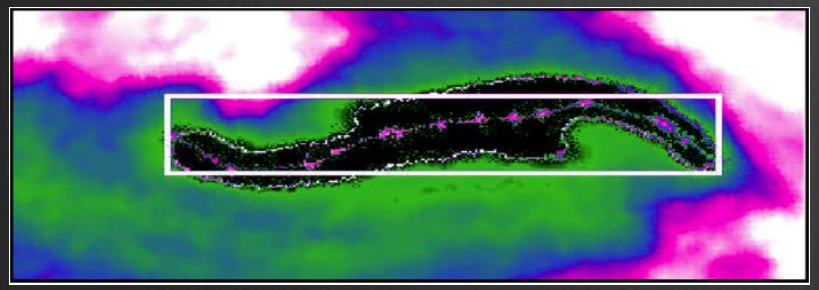
- Thought to be signatures of unstable coronal magnetic flux structures
- Believed to be two ‘J’ shaped structures
- Active regions with sigmoidal structures have a 70% greater chance of eruption than non-sigmoidal ones
- Current research focuses on how sigmoids can evolve from a stable to unstable configuration

(Rust and Kumar, Astrophys. 1996)

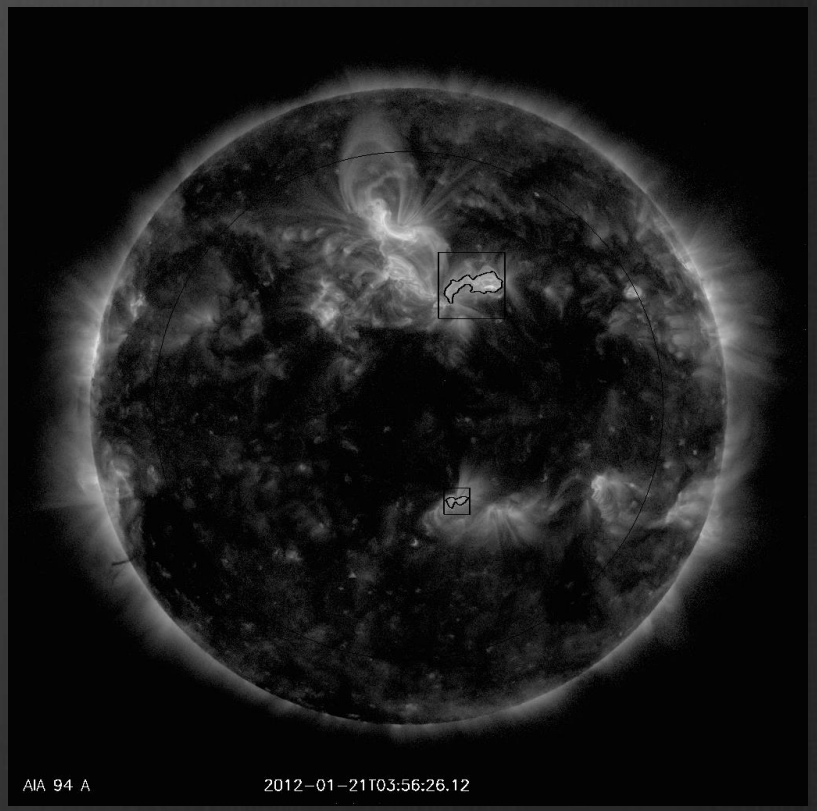
(Canfield, Hudson and McKenzie, SoPh. 1999)

Sigmoid Sniffer

- Searches X-ray, 94Å, 131Å, 211Å, and 335Å images for persistent bright structures
- Matches to idealized ‘S’ shapes
- Cross-correlated with the filament identification module
- Tracks across the disk



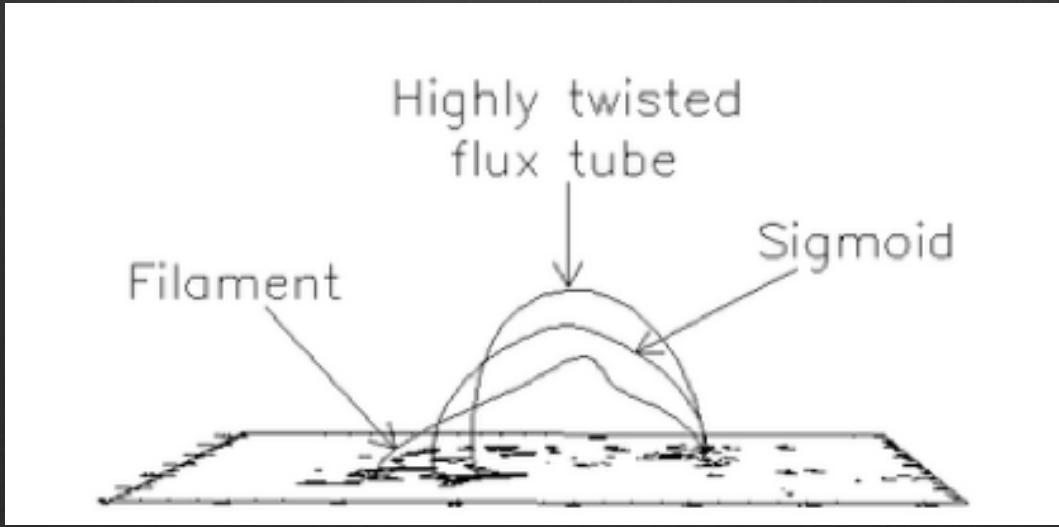
(Martens et al., SoPh. 2012)



How are they Related?

- Sigmoids and filaments are both related to eruptive events, especially CMEs
- Close spatial association and similar topological structure
- Believed that the twisted flux rope, which supports both features, caused the explosive events

(Régnier and Amari, A&A 2004)



Automated Relationship

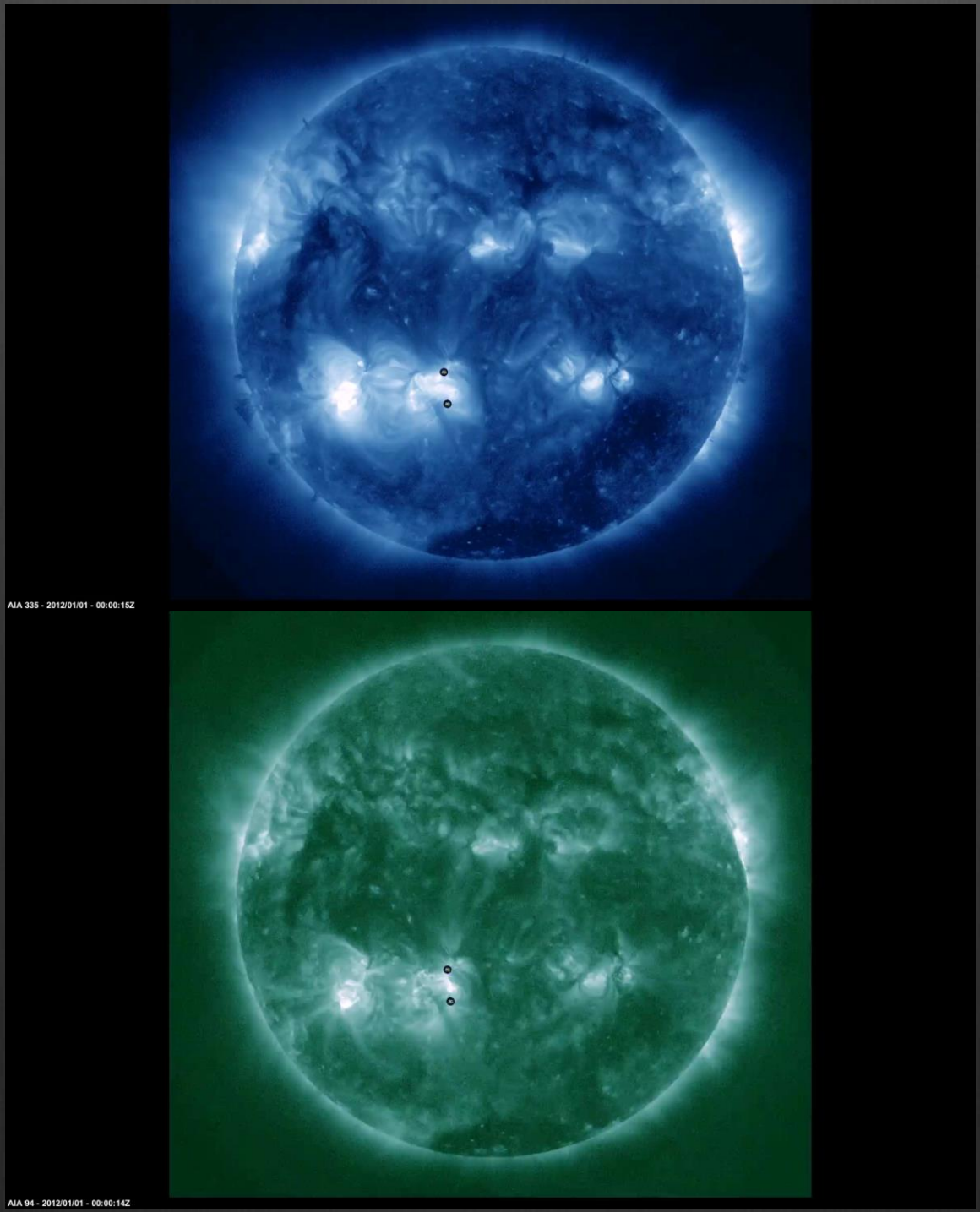
If	Then	Conditional Probability
Sigmoid	Filament	0.3285
Filament	Sigmoid	0.0798

(Martens, et al., Proceedings of IAU Symposium 300, 2014)

- Expected to be much higher correlation

What Did I Do?

- HEK Movies
- Identified Filaments
- Identified Sigmoids
- Flares
- Conditional Probabilites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AIA 94 - 2012/01/01 - 00:00:14Z

Identifying Filaments

- Recorded presence of HEK AAFDCC icons in each active region and total number on the solar disk twice a day for each day
- Observed Hα images from Big Bear Solar Observatory and Kanzelhöhe Solar Observatory and counted filaments in each active region and total number twice a day for each day
- Compared automatically detected filaments to my observed filaments

		6:00		18:00			
Date	Active Region	AAFDCC	Manual	AAFDCC	Manual	Total AAFDCC	Total Manual
20120103	11386	No	No	No	No	33	36
	11388	Yes	Yes	Yes	Yes		
	11389	Yes	Yes	Yes	Yes		
	11390	No	No	No	No		
	11391	No	No	No	No		
	11392	No	No	No	No		

Filament Contingency Table

		Manual	Manual	
		Yes	No	Total (Automated)
AAFDCC (Automated)	Yes	95	8	103
AAFDCC (Automated)	No	68	233	301
	Total (Manual)	163	241	404

Identifying Sigmoids

- Recorded presence of HEK Sigmoid Sniffer icons in each NOAA numbered active region twice a day for each day
- Verified detections by observing full disk XRT images, 94Å, and 335Å AIA data twice per day
- Compared my own manual detections to the Sigmoid Sniffer

		6:00		18:00	
Date	Active Region	Sigmoid Sniffer	Manual	Sigmoid Sniffer	Manual
20120103	11386	No	No	No	No
	11388	Yes	Yes	Yes	No
	11389	Yes	Yes	No	Yes
	11390	No	No	Yes	Yes
	11391	No	No	No	No
	11392	No	No	No	No

Sigmoid Contingency Table

		Manual	Manual	
		Yes	No	Total (Automated)
SS (Automated)	Yes	50	43	93
SS (Automated)	No	20	301	321
	Total (Manual)	70	344	414

Skill Scores

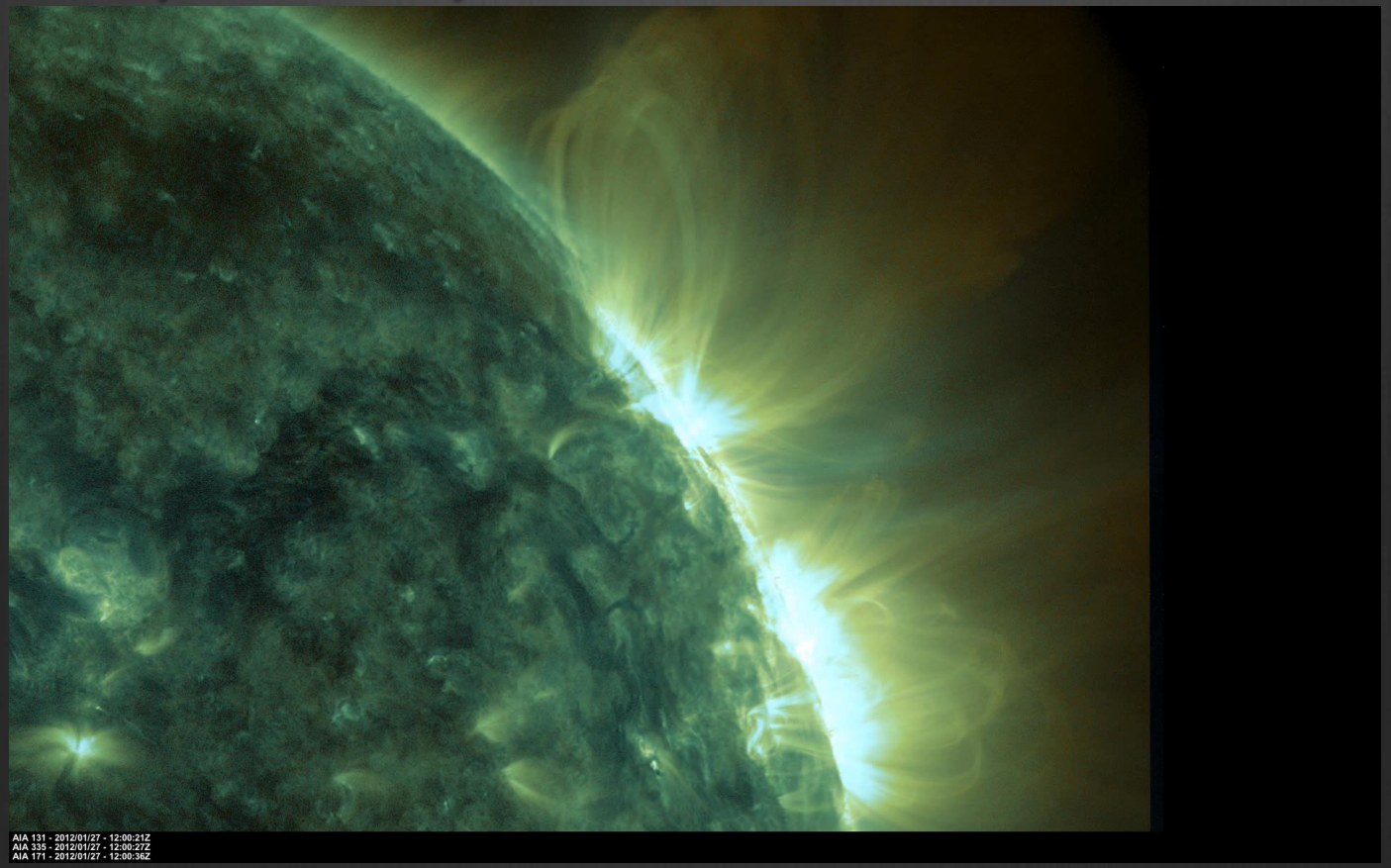
- Accuracy - fraction of correct observations
- Bias Score - how does frequency of automated positives compare to frequency of manual positives
- Success Ratio – fraction of automated positives that were manual positives
- Probability of Detection – what fraction of manual positives were correctly identified by the module
- Heldke Skill Score (Cohen's k) – accuracy of automated module relative to random chance

Comparisons

Module	Skill Score	Value	Perfect Score
AAFDCC	Accuracy	0.81	1
SS	Accuracy	0.85	1
AAFDCC	Bias Score	0.63	1
SS	Bias Score	1.33	1
AAFDCC	Success Ratio	0.92	1
SS	Success Ratio	0.54	1
AAFDCC	Probability of Detection	0.58	1
SS	Probability of Detection	0.71	1
AAFDCC	Heldke Skill Score	0.58	1
SS	Heldke Skill Score	0.52	1

Flares

- Recorded NOAA detected flares for each active region for each day twice a day



Size 2 Conditional Probabilities

If	Then	Probability
Manual Sigmoid	Manual Filament	0.69
Automated Sigmoid	Manual Filament	0.57
Manual Sigmoid	Automated Filament	0.43
Flare	Manual Filament	0.34
Manual Filament	Automated Sigmoid	0.33
Automated Sigmoid	Automated Filament	0.31
Automated Filament	Manual Sigmoid	0.29
Manual Filament	Manual Sigmoid	0.29
Automated Filament	Automated Sigmoid	0.28
Flare	Automated Sigmoid	0.18
Flare	Automated Filament	0.16
Automated Filament	Flare	0.16
Manual Filament	Flare	0.15
Automated Sigmoid	Flare	0.14
Manual Sigmoid	Flare	0.10
Flare	Manual Sigmoid	0.10

Size 3 Conditional Probabilities

If	Then	Probability
Manual Sigmoid, Flare	Manual Filament	0.71
Automated Sigmoid, Flare	Automated Filament	0.23
Automated Filament, Flare	Automated Sigmoid	0.25
Manual Filament, Flare	Manual Sigmoid	0.20
Manual Sigmoid, Manual Filament	Flare	0.10
Automated Sigmoid, Automated Filament	Flare	0.10
Flare	Manual Sigmoid, Manual Filament	0.07
Manual Sigmoid	Manual Filament, Flare	0.07
Flare	Automated Sigmoid, Automated Filament	0.04
Automated Sigmoid	Automated Filament, Flare	0.03
Automated Filament	Automated Sigmoid, Flare	0.03
Manual Filament	Manual Sigmoid, Flare	0.03

Conclusions

- Sigmoid Sniffer
  - Over-identifies
    - Misses fainter, larger sigmoids
  - Possibly due to brightness filter and interaction with AAFDCC
- AAFDCC
  - Under-identifies
    - Misses smaller filaments
  - Possibly due to sunspot elimination techniques

Conclusions

If	Then	Conditional Probability
Martens Sigmoid	Martens Filament	0.33
Automated Sigmoid	Automated Filament	0.31
Manual Sigmoid	Manual Filament	0.69
Martens Filament	Martens Sigmoid	0.08
Automated Filament	Automated Sigmoid	0.28
Manual Filament	Manual Sigmoid	0.29

(Martens, et al., Proceedings of IAU Symposium 300, 2014)

- HEK may not be the most reliable source
- Combination of frequency of identifications and the direction of the error lead to the very small correlation seen between sigmoids and filaments in HEK data

Acknowledgements

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