

# Modelling Magnetic Reconnection and Nanoflare Heating in the Solar Corona

The Coronal Heating Problem

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# Why is the corona so hot?

Two main complementary theories:

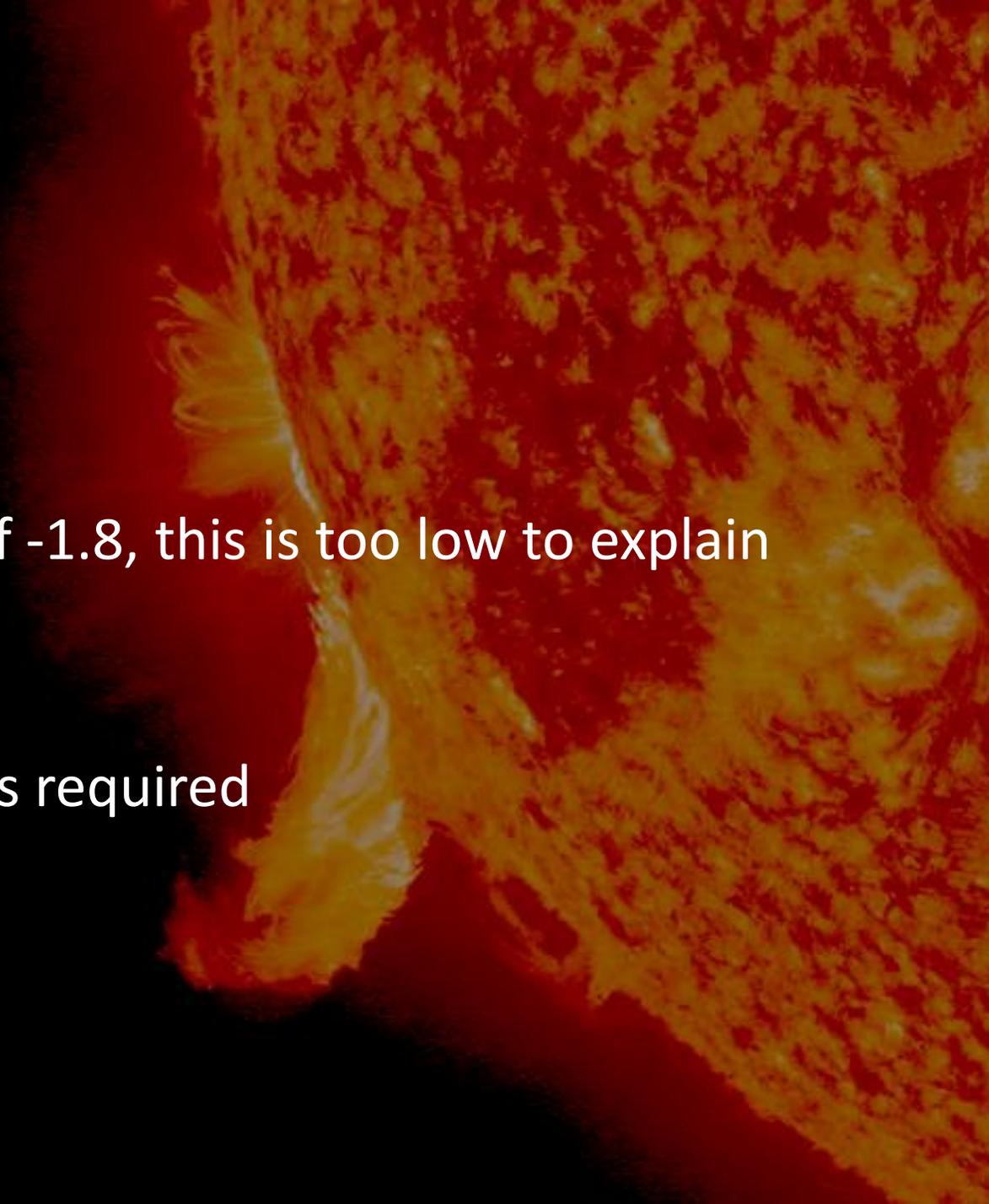
Alfvenic turbulence (1-3MK, stable heating)

Flare heating (3-10MK, rapid dynamic heating)

Nanoflare heating can be influenced by Alfvenic turbulence

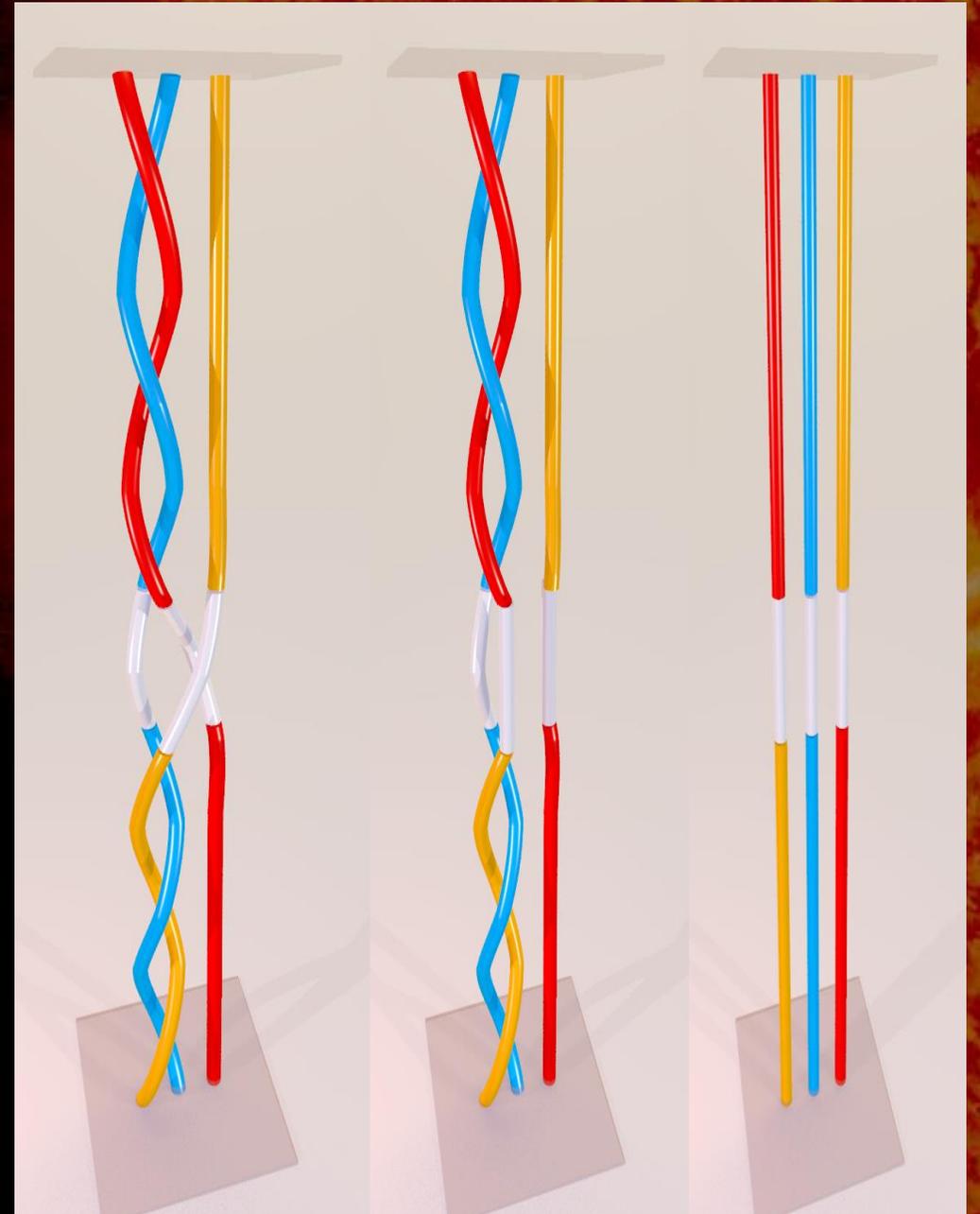
# Why Nanoflares?

- Hudson (1990) explored microflares
- Follow a power law with parameter of  $-1.8$ , this is too low to explain the observed heating
- Concluded a power law fit of over  $-2$  is required



# Magnetic Reconnection

- Removes one crossing
- Depends on critical crossing number
- Only occurs in highly stressed situations



# Magnetic Energy and Crossing Number

$$E_{\text{free}} \propto \int B_{\perp}^2 d^3x.$$

$$C_{\text{critical}} = \frac{NL}{\pi D} \tan \pi/12 \approx 0.085 \frac{NL}{D}.$$

$$E_{\text{free}} \approx \left( \frac{N\pi D^2 L}{2\mu} \right) \left( \frac{\pi C D B_{\parallel}}{NL} \right)^2 = \left( \frac{\pi^3 D^4 B_{\parallel}^2}{2\mu NL} \right) C^2.$$

B min = 381.05 Gauss

Radius = 191.7km

Length = 43.8Mm

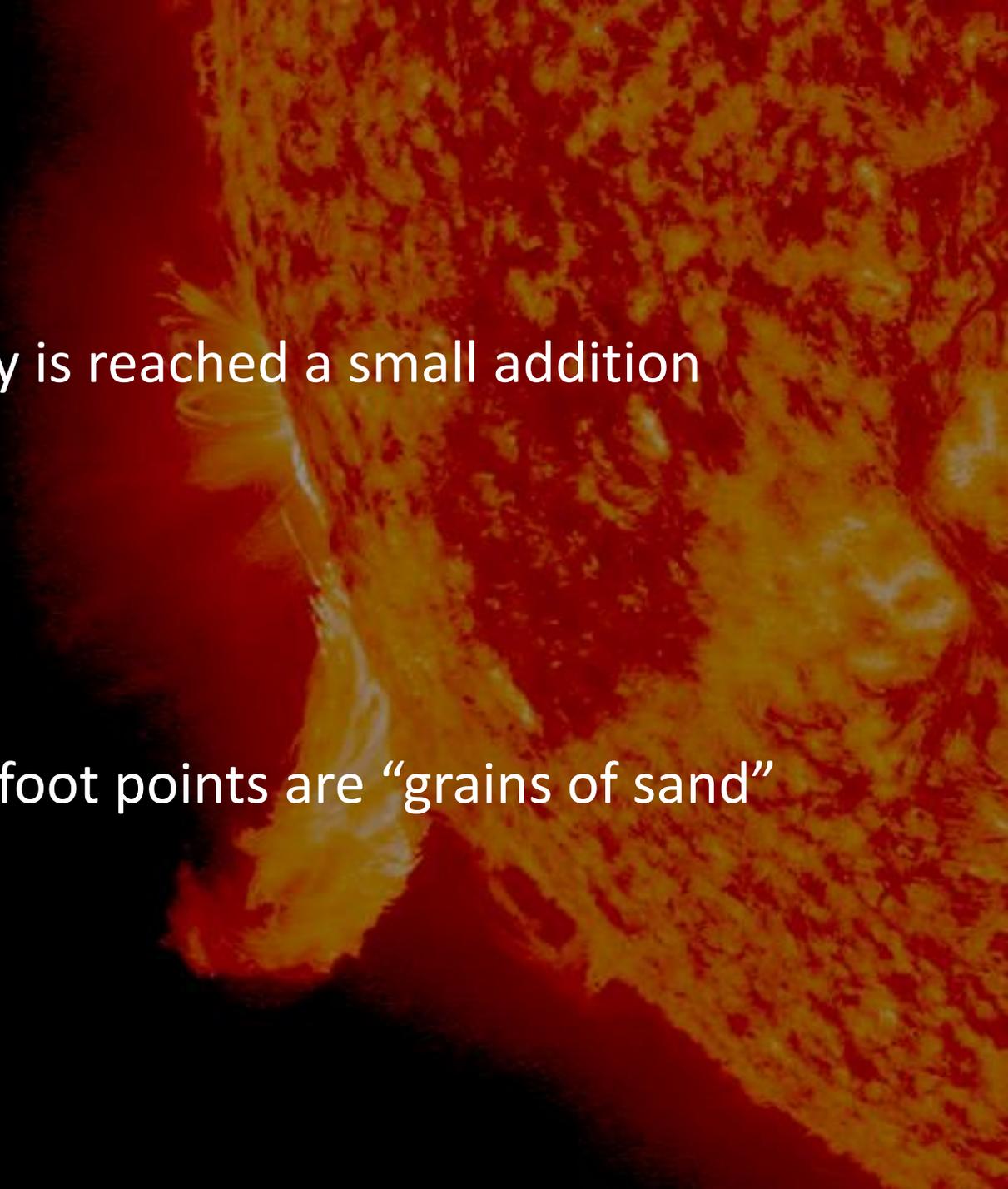


Image created using non-linear force free field fitting in CMS, HI-C data, 193 Å



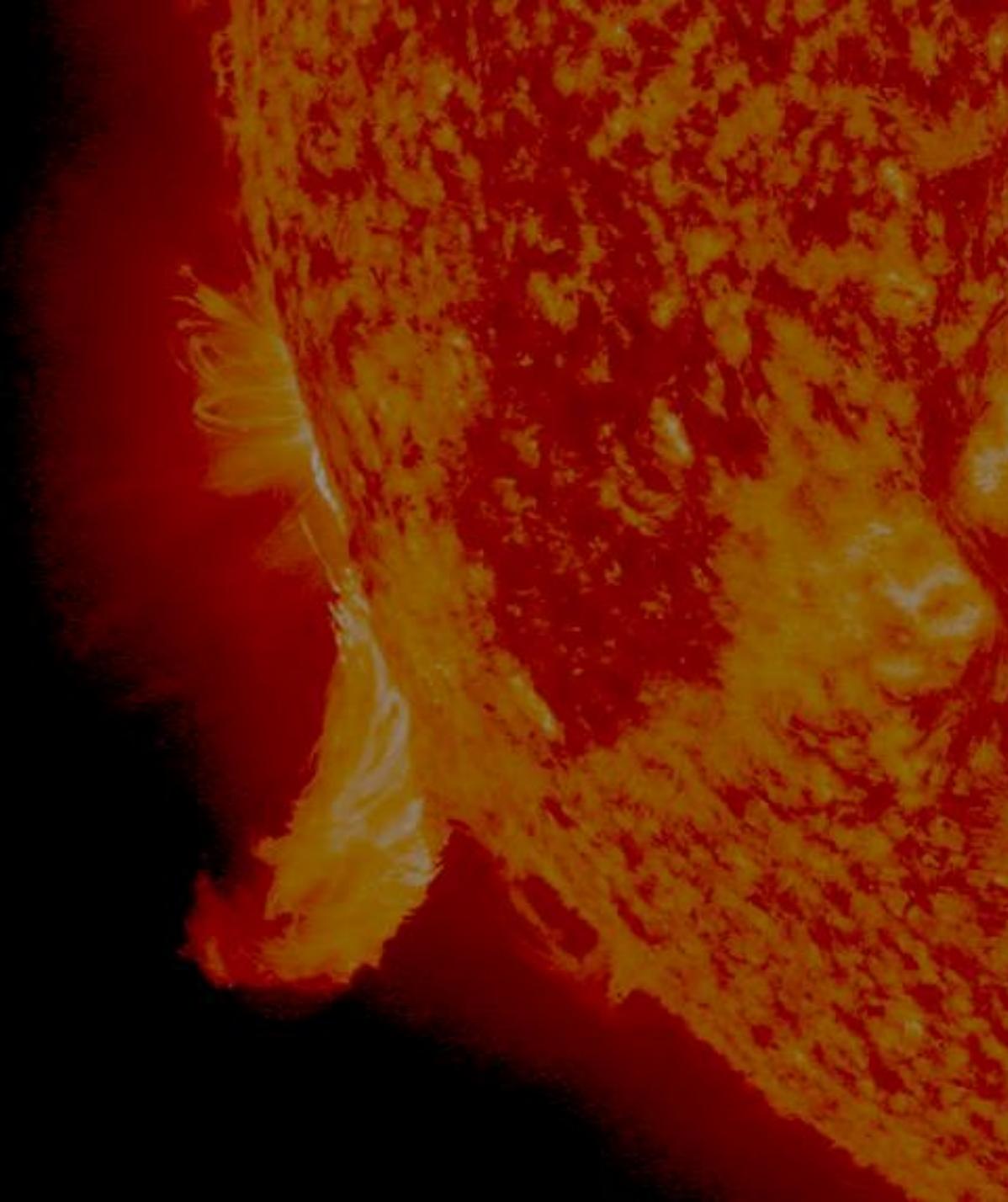
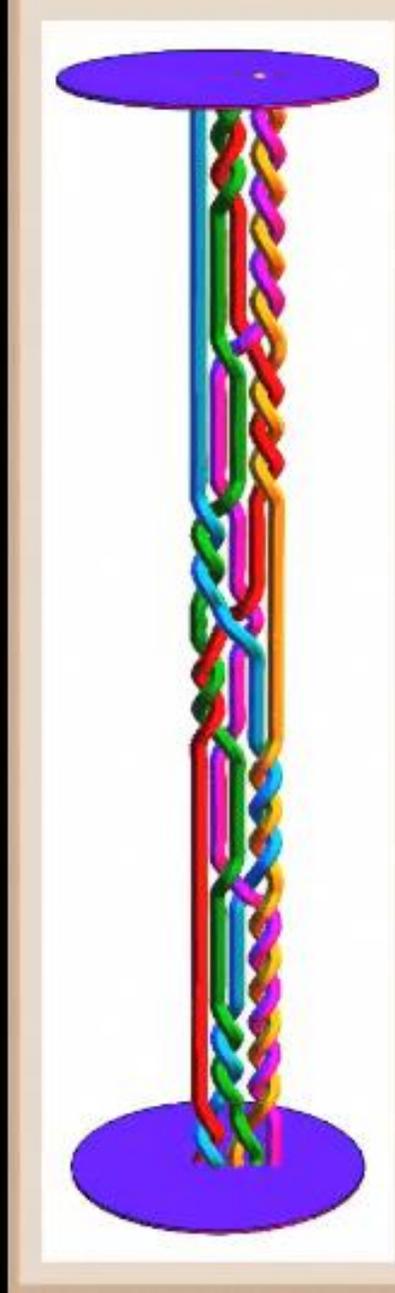
# Avalanche Model

- Analogy is a sand pile, once criticality is reached a small addition triggers avalanche
- Can be applied to reconnection
- In reconnection twisting motions of foot points are “grains of sand” being added



# Reconnection In Action

- Initial braidword  $\{-1, -3, -1, 4, -2, 4, -2, 4, -2, 4, 4, 4, 4, -3, 2, 4, 4, 4, 4, -2, 1, 1, 1, -3, -2, 3, -1, -1, -1, 2, -4, -4, -4, -4, -2, 3, -4, -4, -4, -4, 2, -4, 2, -4, 2, -4\}$
- First reconnection occurs removing -2 crossing
- Final braidword  $\{-1, -3, -1\}$



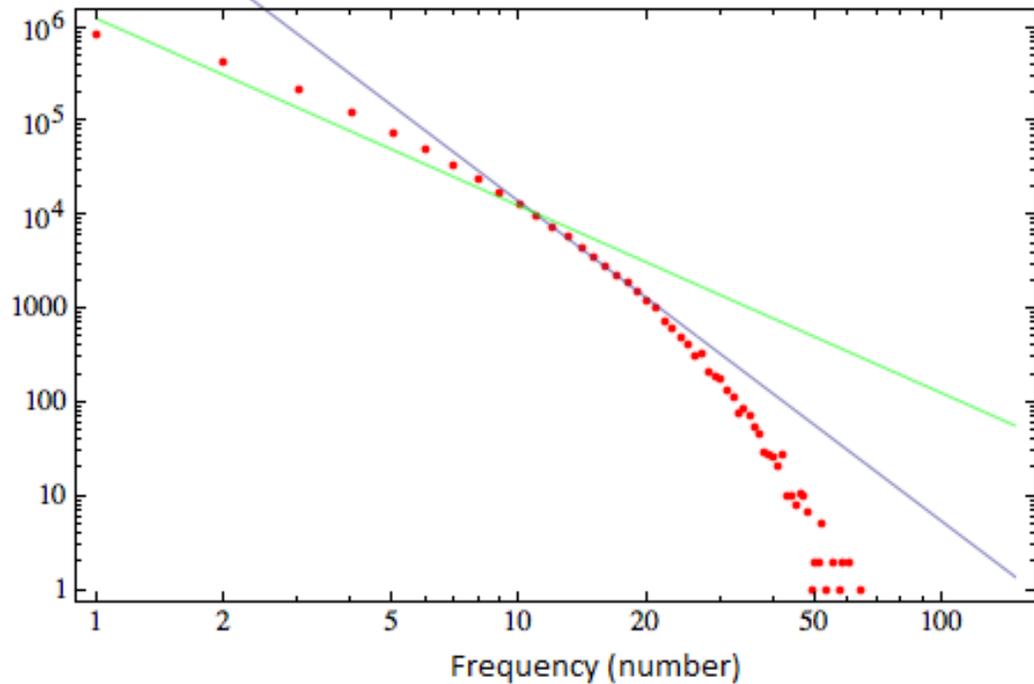
# Methods and Predictions

- Expect a power law distribution
- Initial parameters (B min, length, diameter) from the previously shown non-linear force free field modelling gives minimum crossing number
- Found parameters for energy simulation by running reconnection simulation with parameters optimised through repeated trials

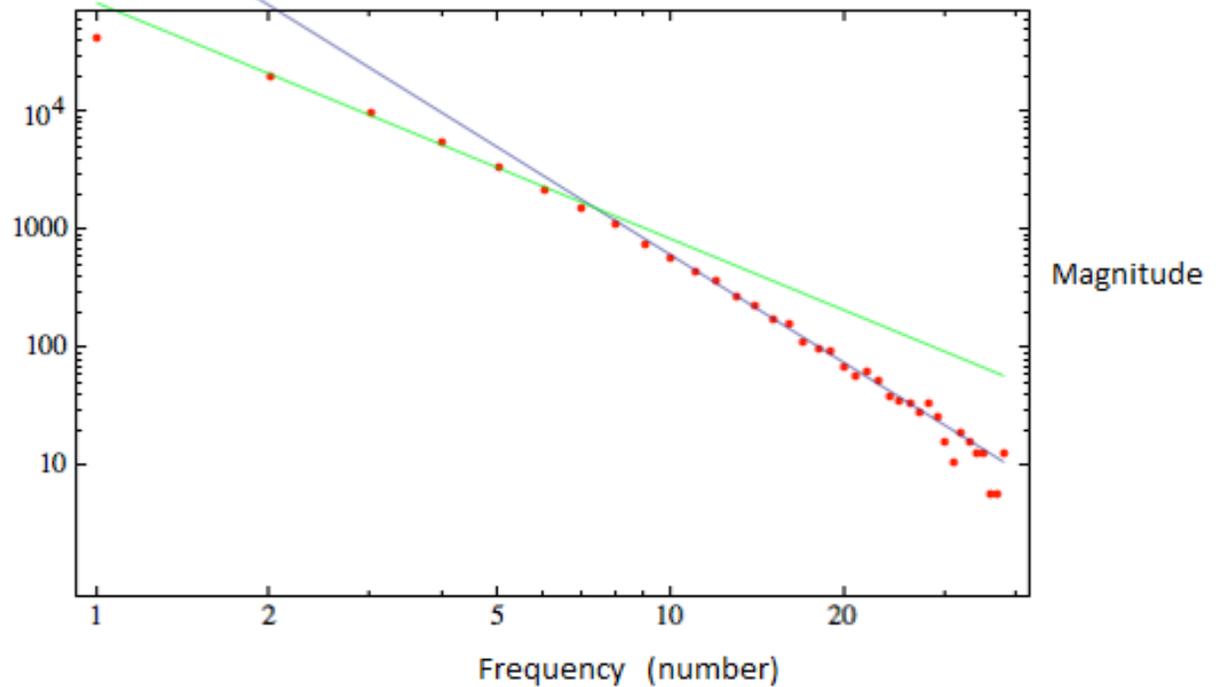
# Finding Parameters

- Analysed the results to see what the best fit was
- Braidsize 10000, Reconnections 10000, Runs 500, Power Law -3.41401
- Braidsize 500, Reconnections 1000, runs 500, Power Law = -3.02347

Frequency vs Magnitude

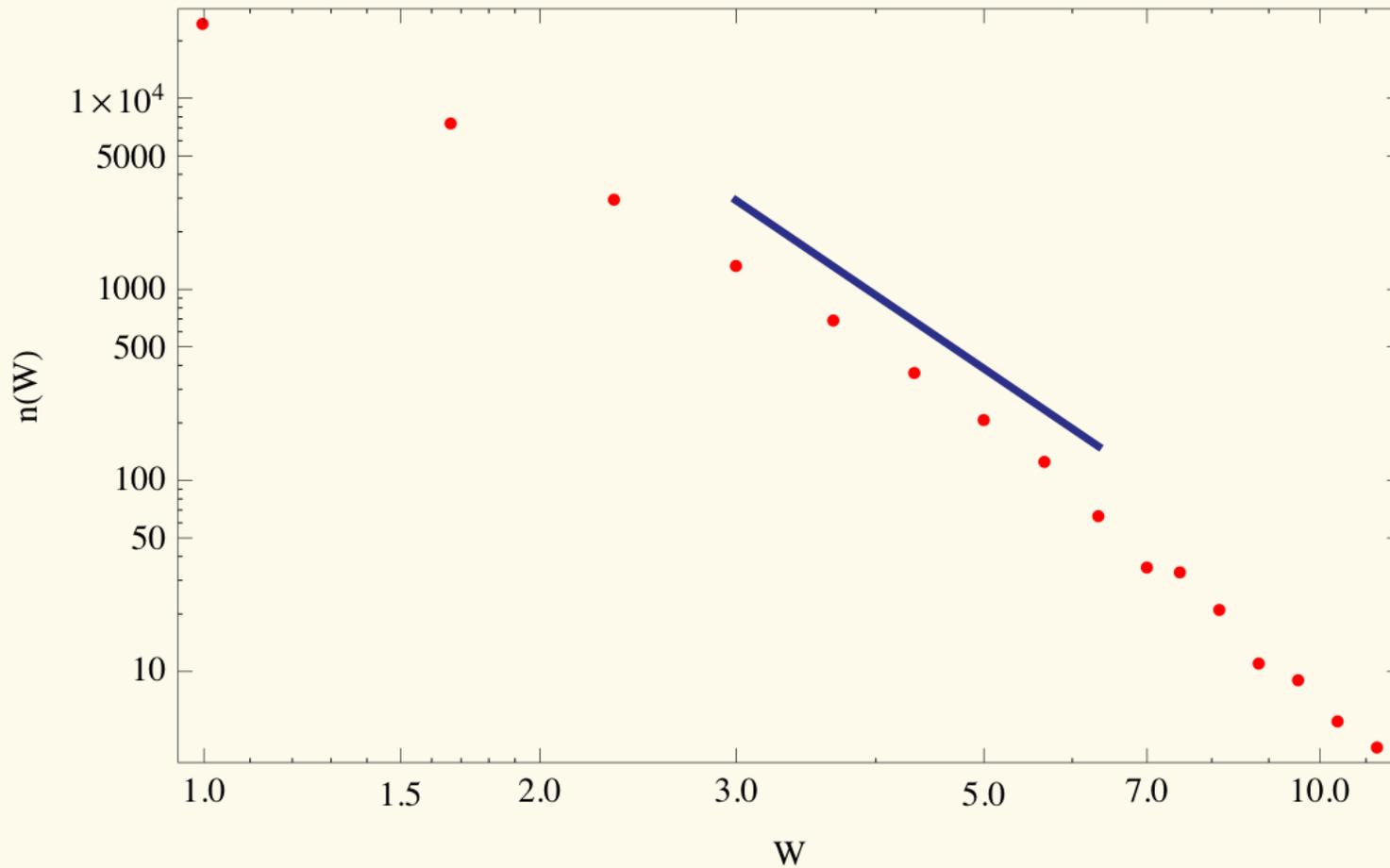


Plot of Frequency vs Magnitude



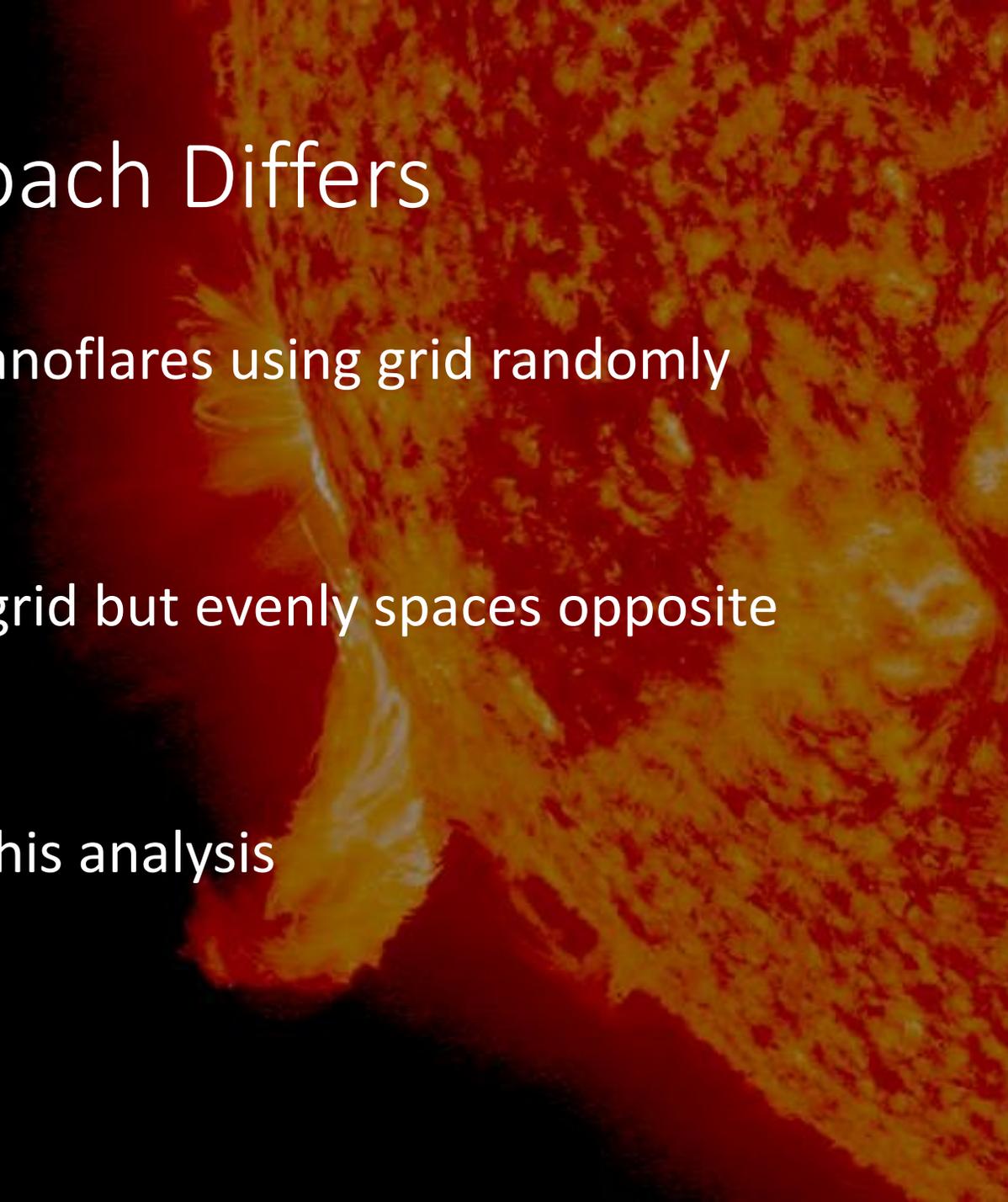
# Results

Found power law fit as expected, approx. -2.8



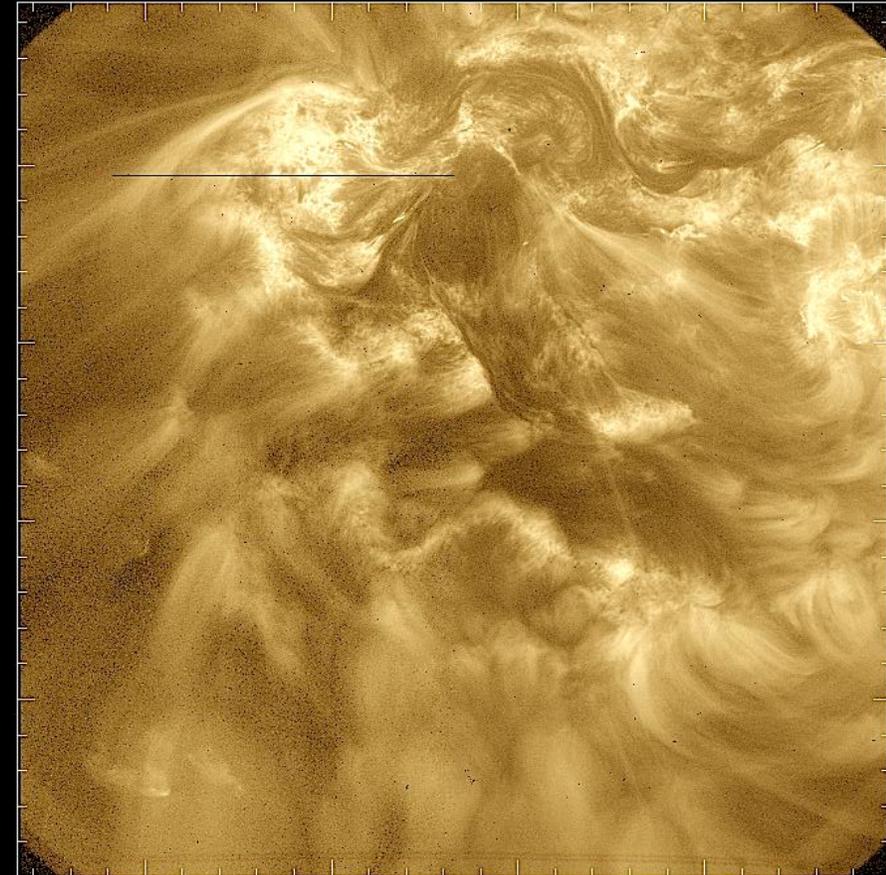
# How This Dynamic Approach Differs

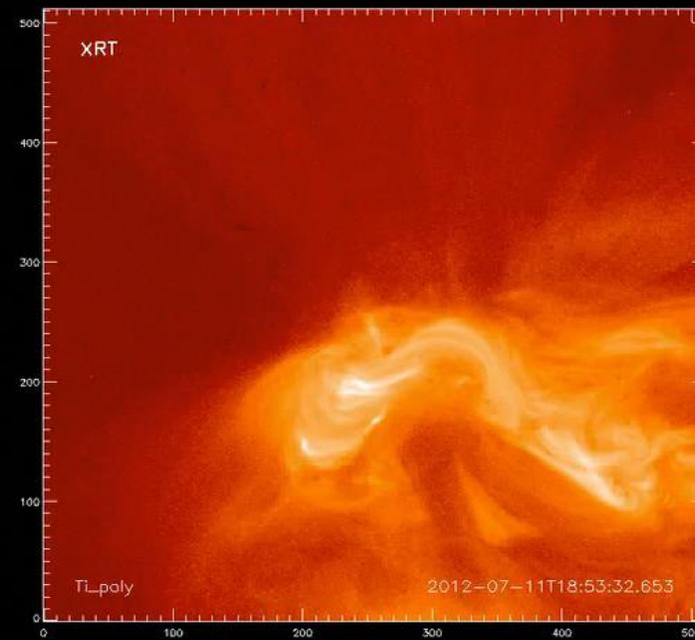
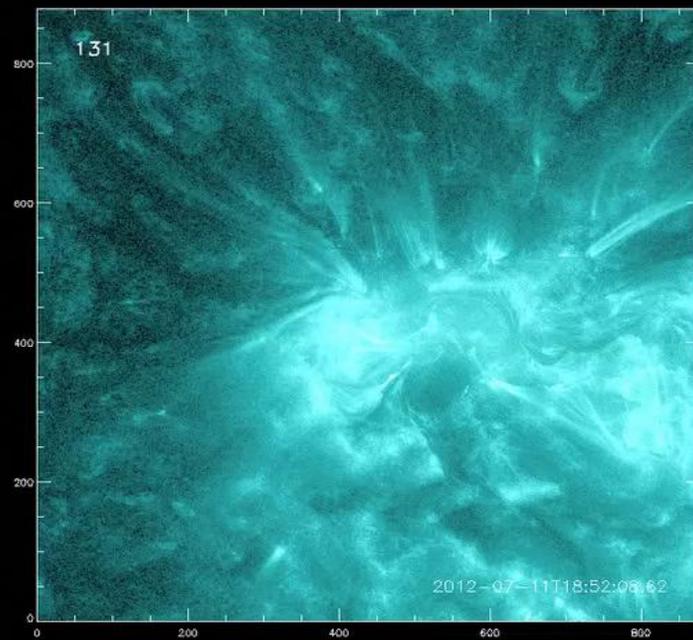
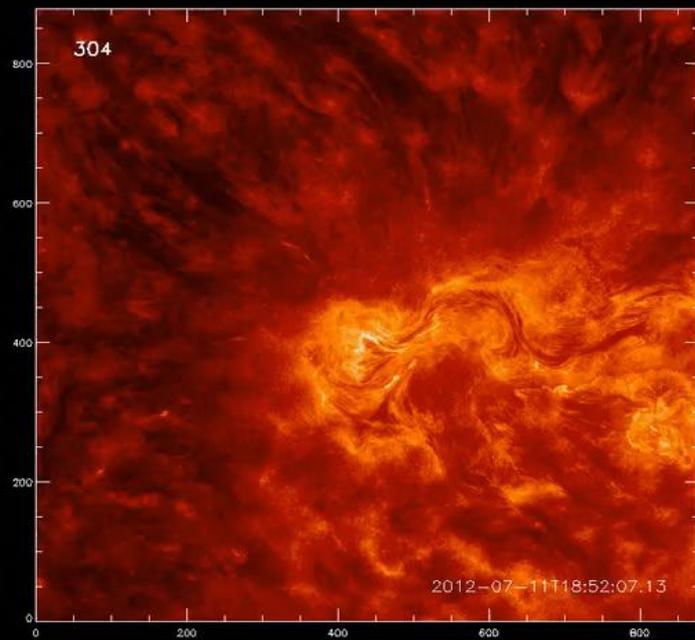
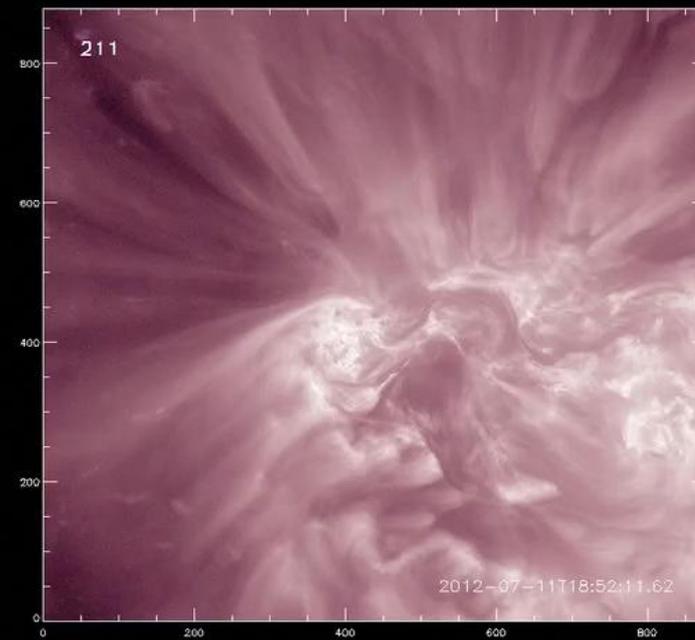
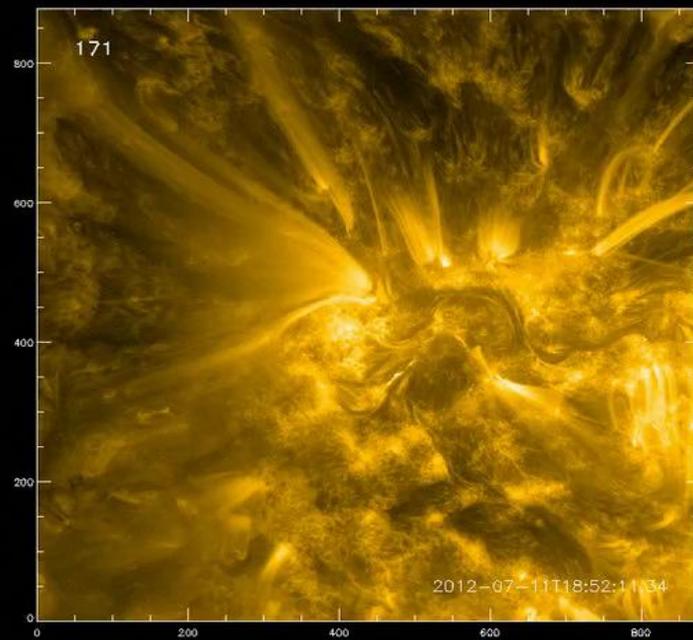
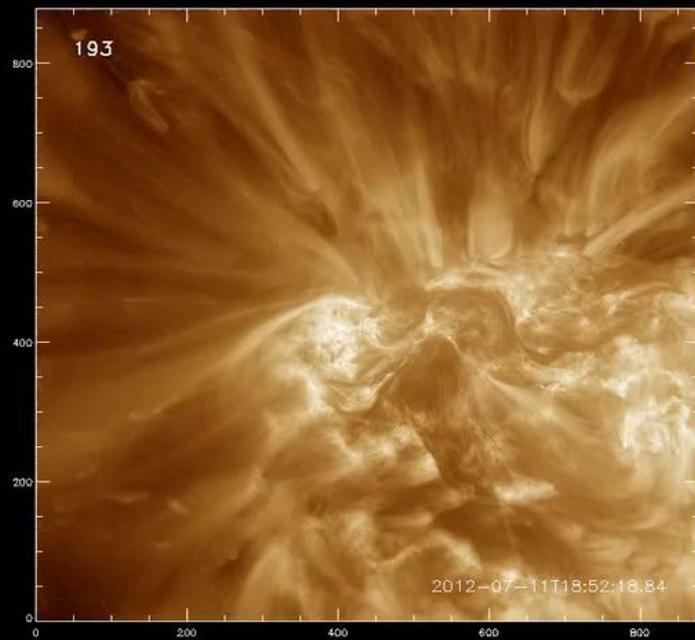
- Zirken&Cleveland(1992) modelled nanoflares using grid randomly depositing energy
- Longcope&Noonen(2000) also uses grid but evenly spaces opposite poles
- Both have shortcomings avoided in this analysis



# Comparison to Observation

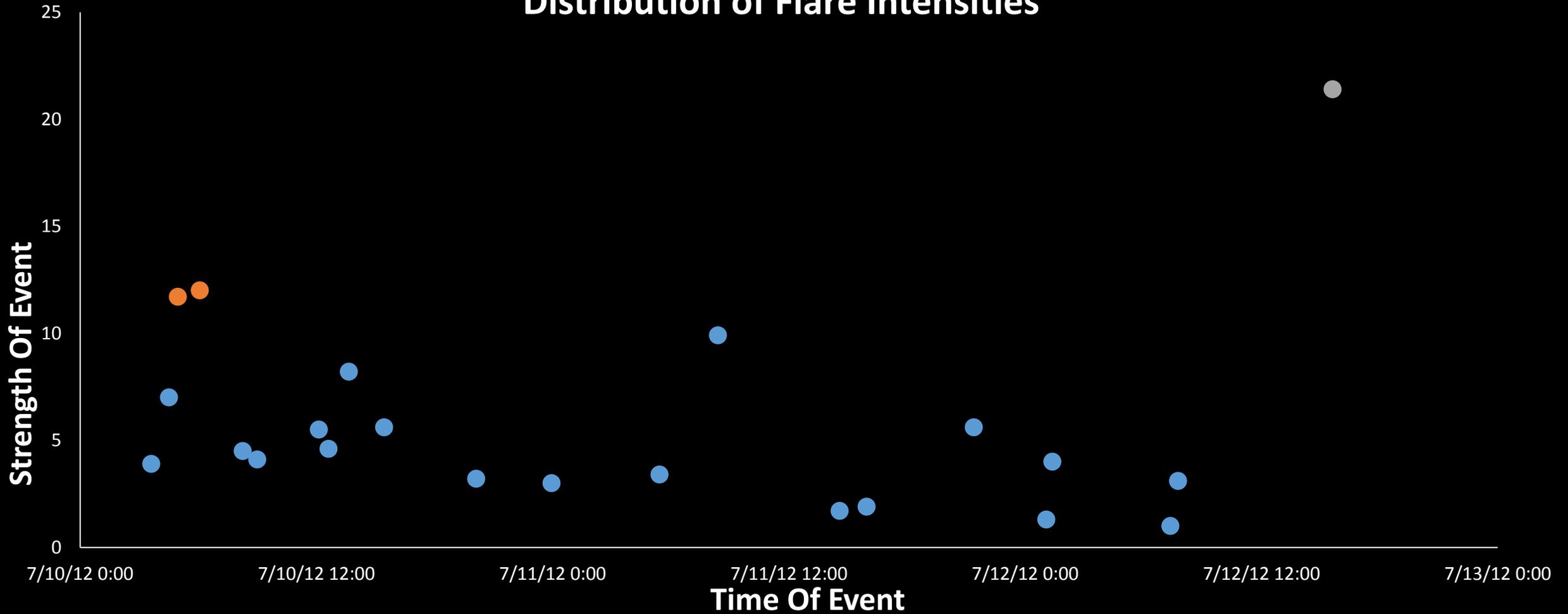
- Analysed the Hi-C (High-Resolution Coronal Imager) region to determine the number of flares in the two day period surrounding Hi-C
- Expect distribution in types of flares with smaller more likely consistent with power law





# Results Of Observations

## Distribution of Flare Intensities



# Past and Future

- Updated modelling of reconnection to include avalanche model
- Ran simulations using this updated model and found a power law as expected
- To the future: Increase sophistication of model further by including internal twist

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