Observational evidence for nanoflares

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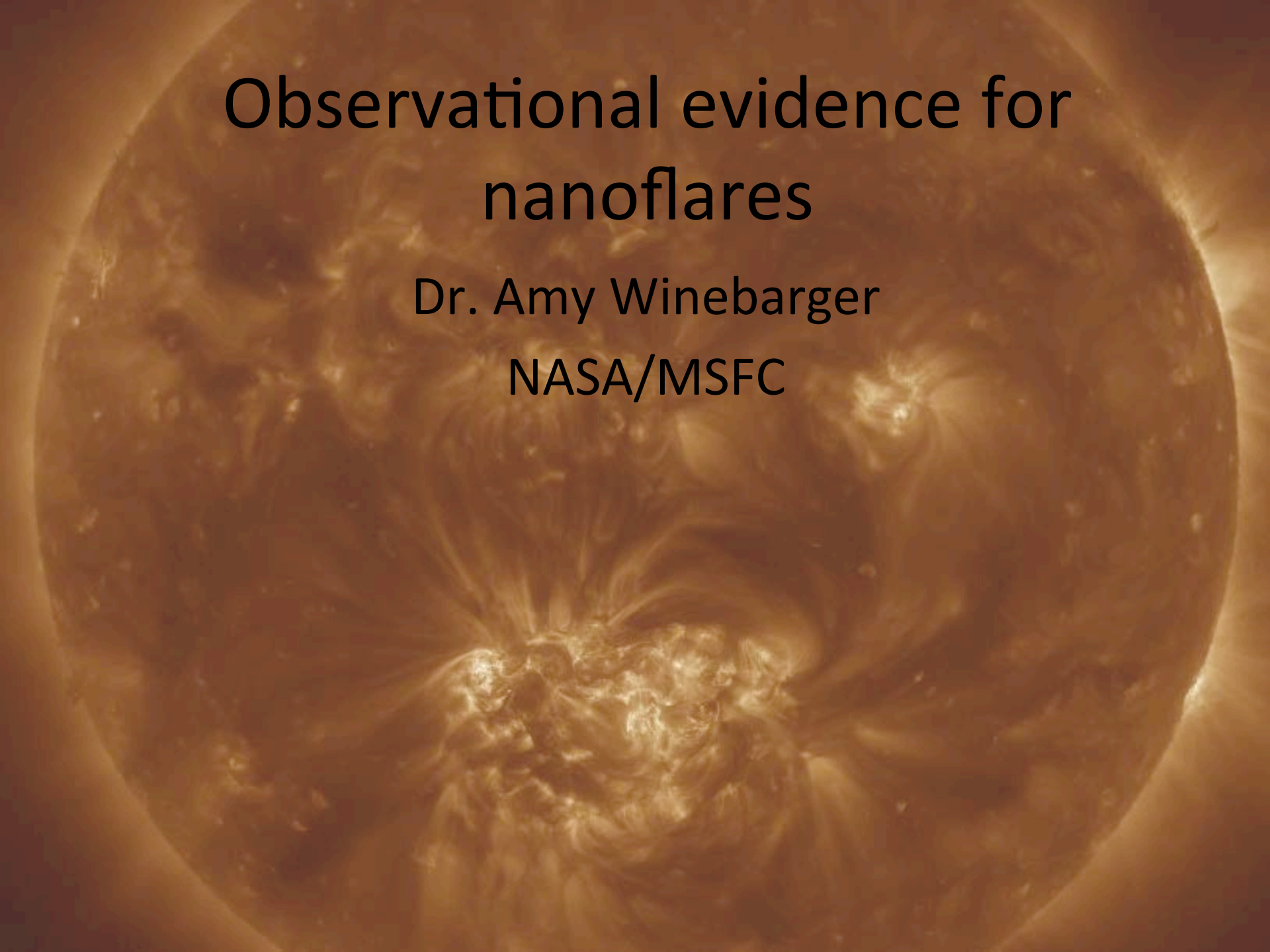

What is a nanoflare?

(I really don't like this word…)

- Small energy release (Parker's definition)
- Over what spatial scale?
- Over what temporal scale?
- At what frequency?
- At what location?

Observational signatures would be different depending on how these secondary questions are answered.

“Classic nanoflare” due magnetic reconnection

- Small energy release (Parker’s definition)
- Over what spatial scale? << Loop length
- Over what temporal scale? Durations << cooling time
- At what frequency? Low frequency – Repeat on time scales > cooling time to allow for stress to build back up after reconnection event
- At what location? Equally distributed throughout the corona/chromosphere ?

“Nanoflare” due to wave heating

- Small energy release (Parker’s definition)
- Over what spatial scale? ~ Loop length
- Over what temporal scale? Durations << cooling time
- At what frequency? High frequency – Repeat on time scales << cooling time
- At what location? More energy released in chromosphere

“Nanoflare” due to wave heating

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THE SPATIAL AND TEMPORAL DEPENDENCE OF CORONAL HEATING BY ALFVÉN WAVE TURBULENCE

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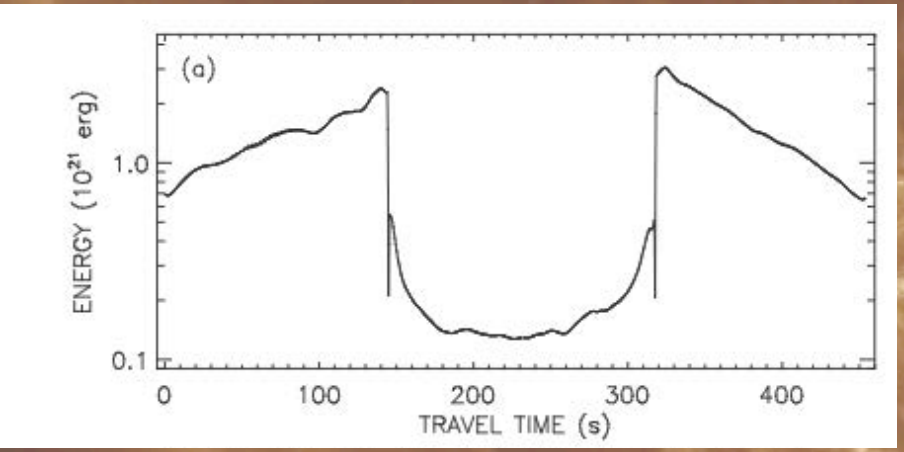
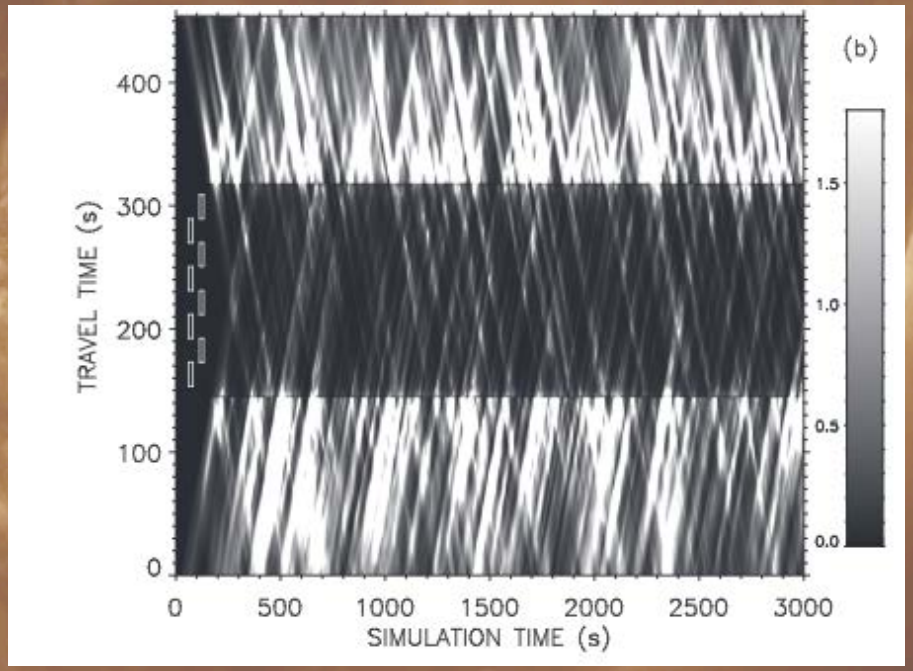
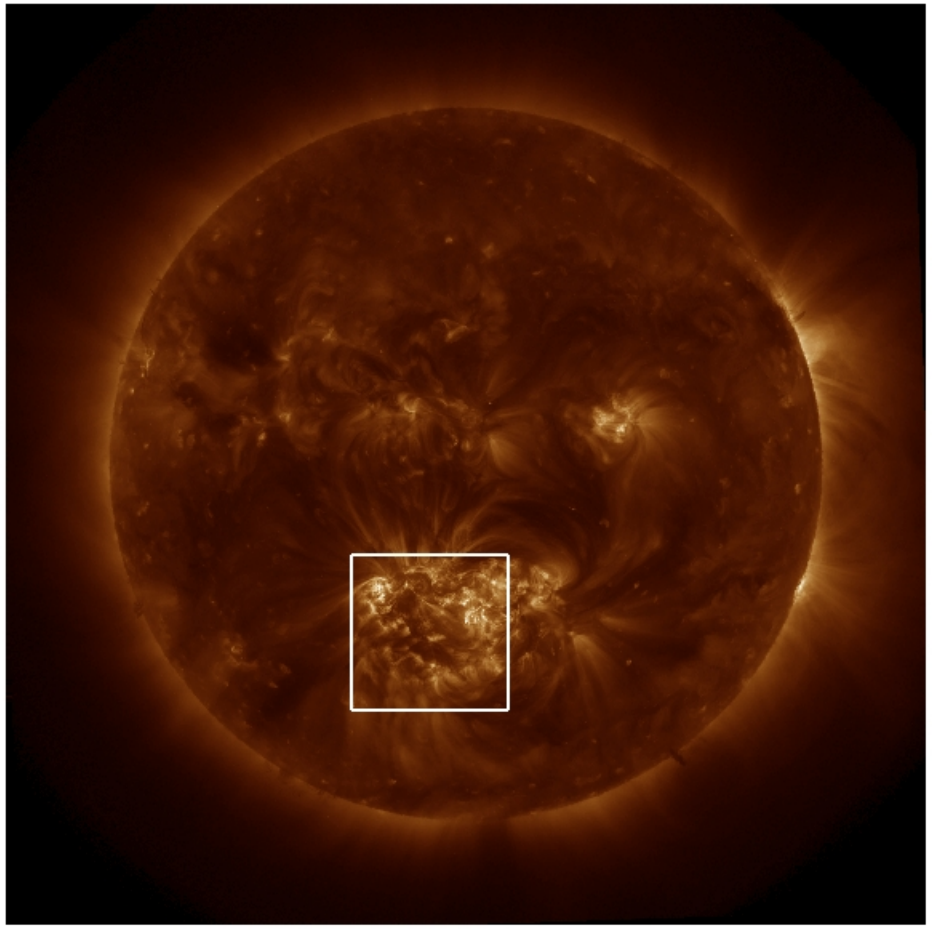
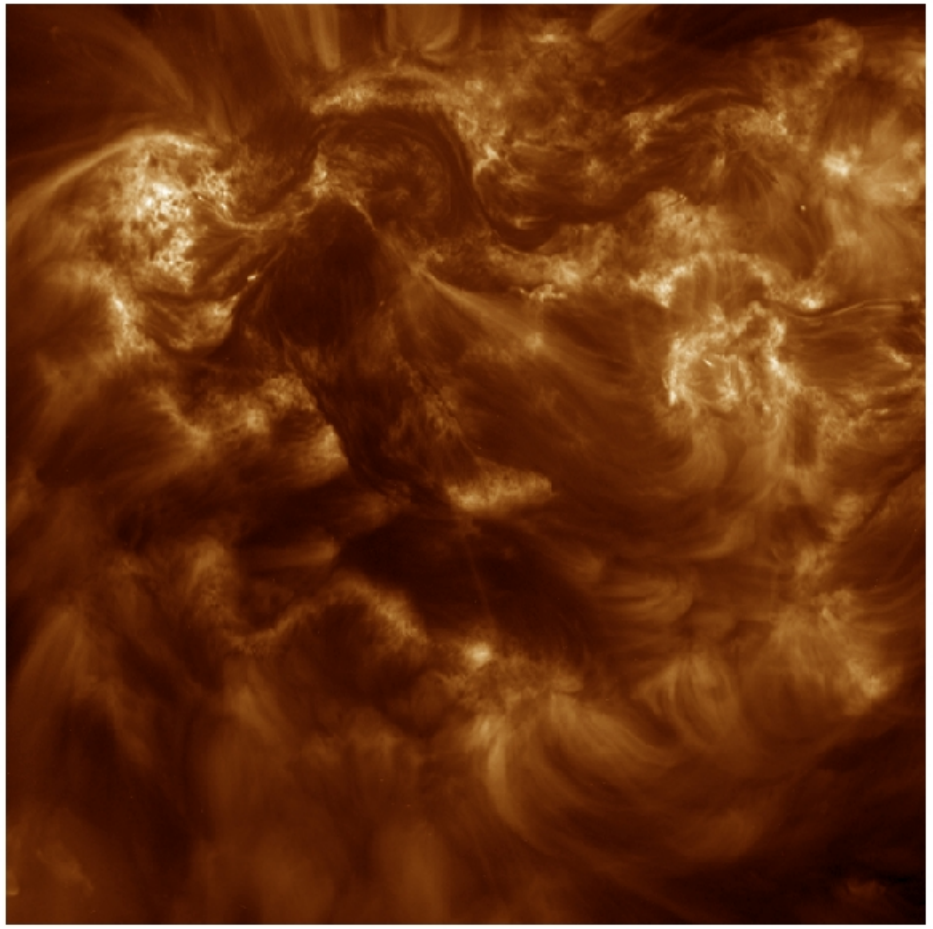


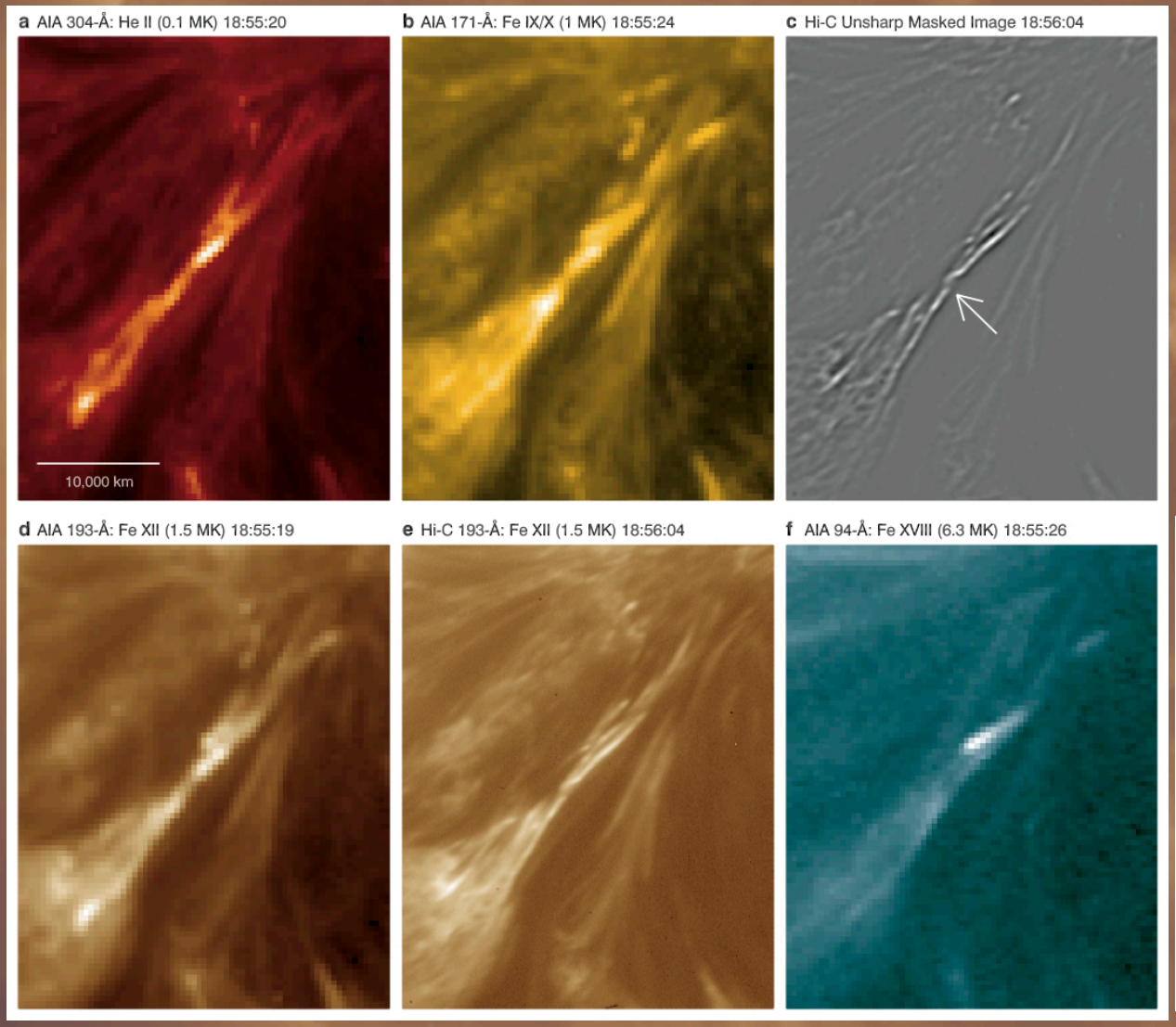


“Classic nanoflare” signatures in Hi-C 1

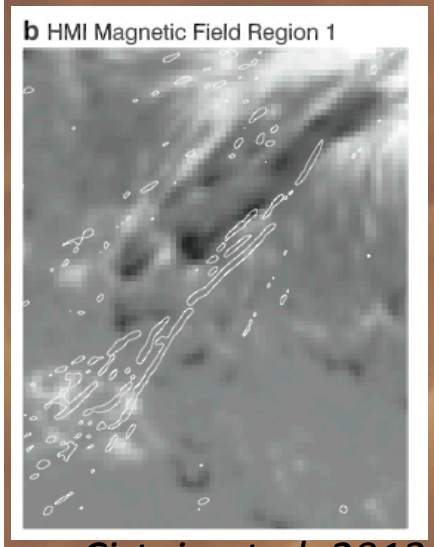




Component Reconnection

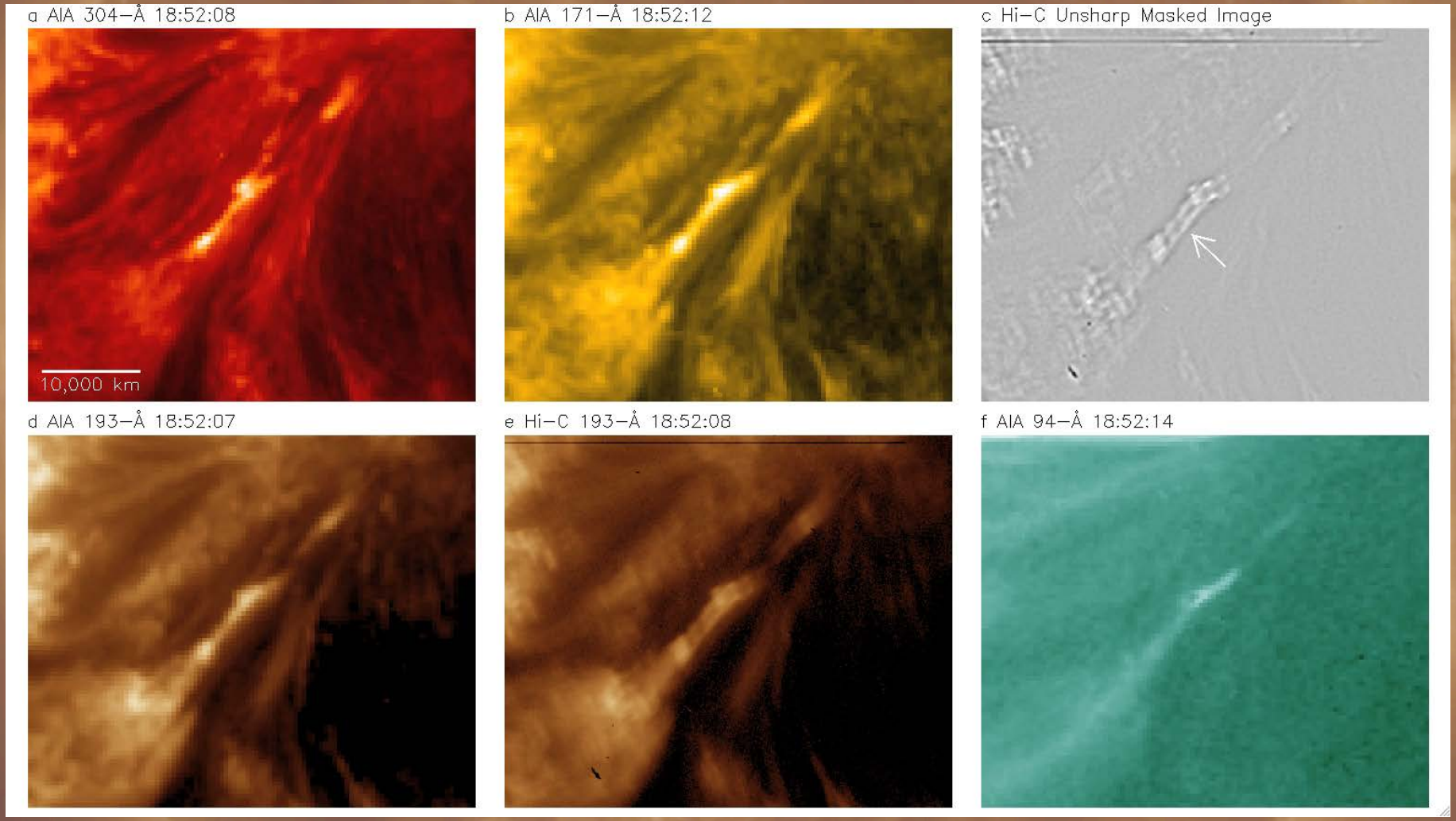


- Magnetic field braiding has been suggested as a energy storage mechanism in the solar corona.
- Hi-C observed braided magnetic field.



Cirtain et al, 2013, Nature

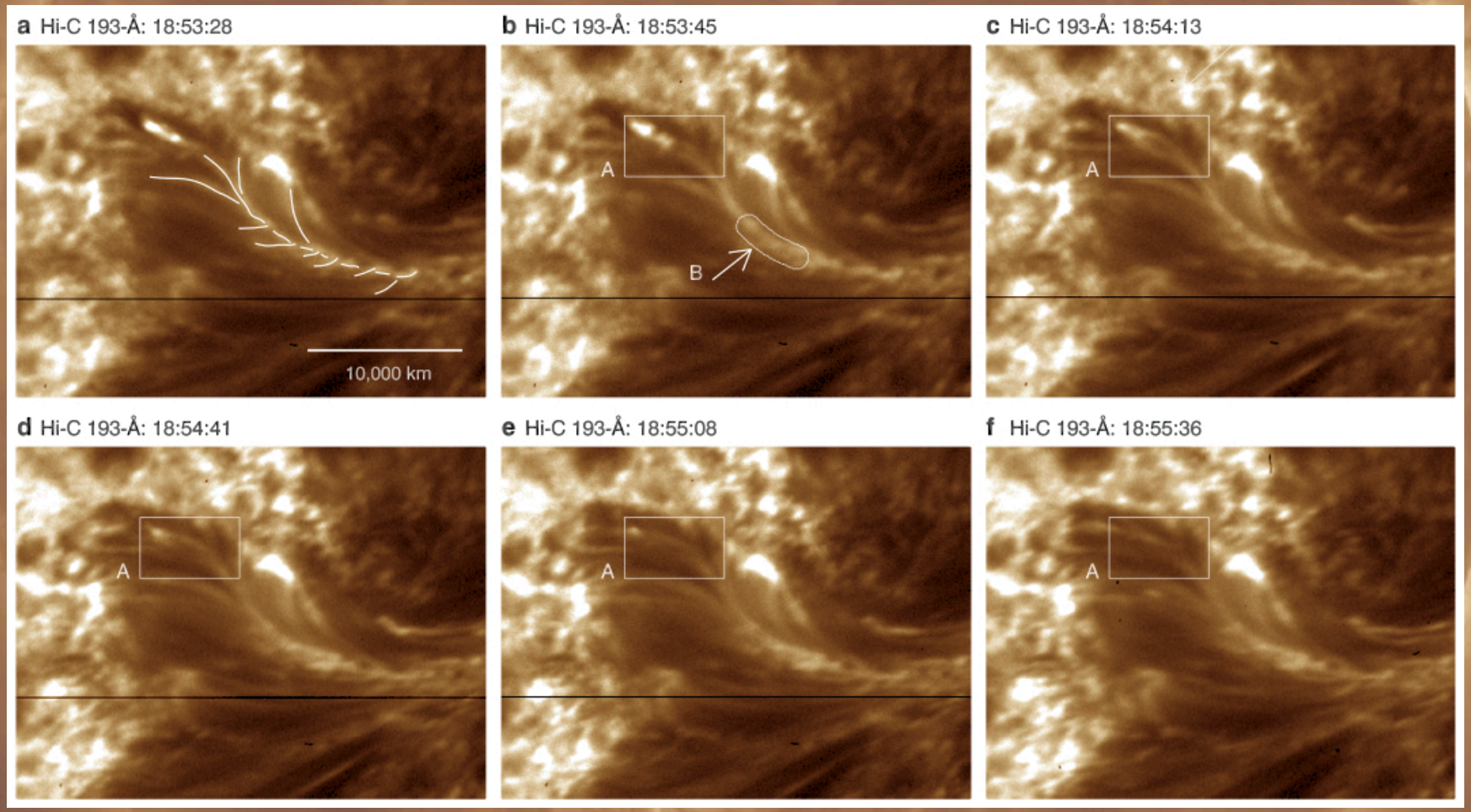
Component Reconnection



Shortly after the Hi-C flight, a small flare was observed at the field line crossing.

Cirtain et al, 2013, Nature

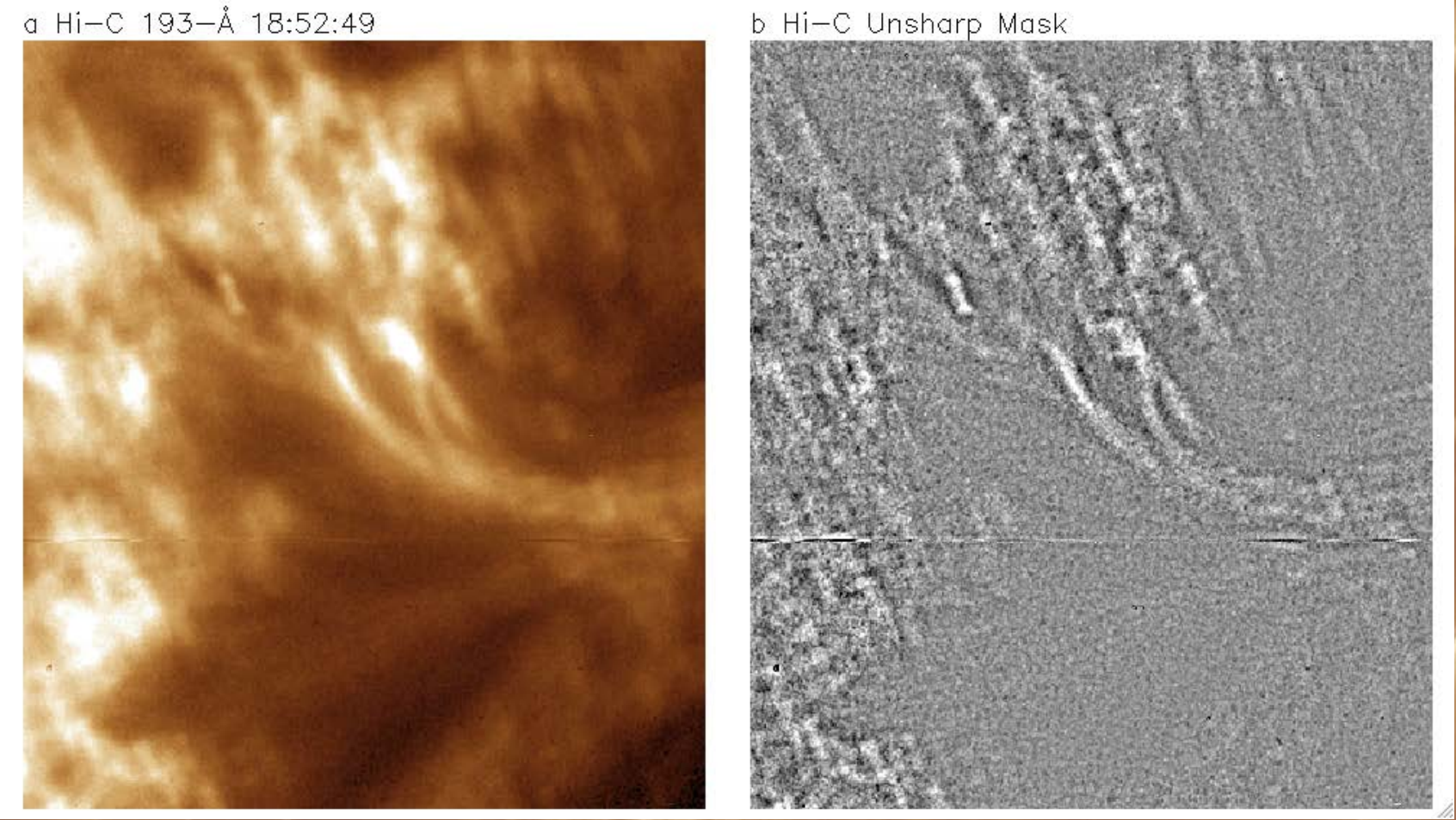
Braided Loop



Multiple strands join into this structure. It appears to unwind during Hi-C observations.

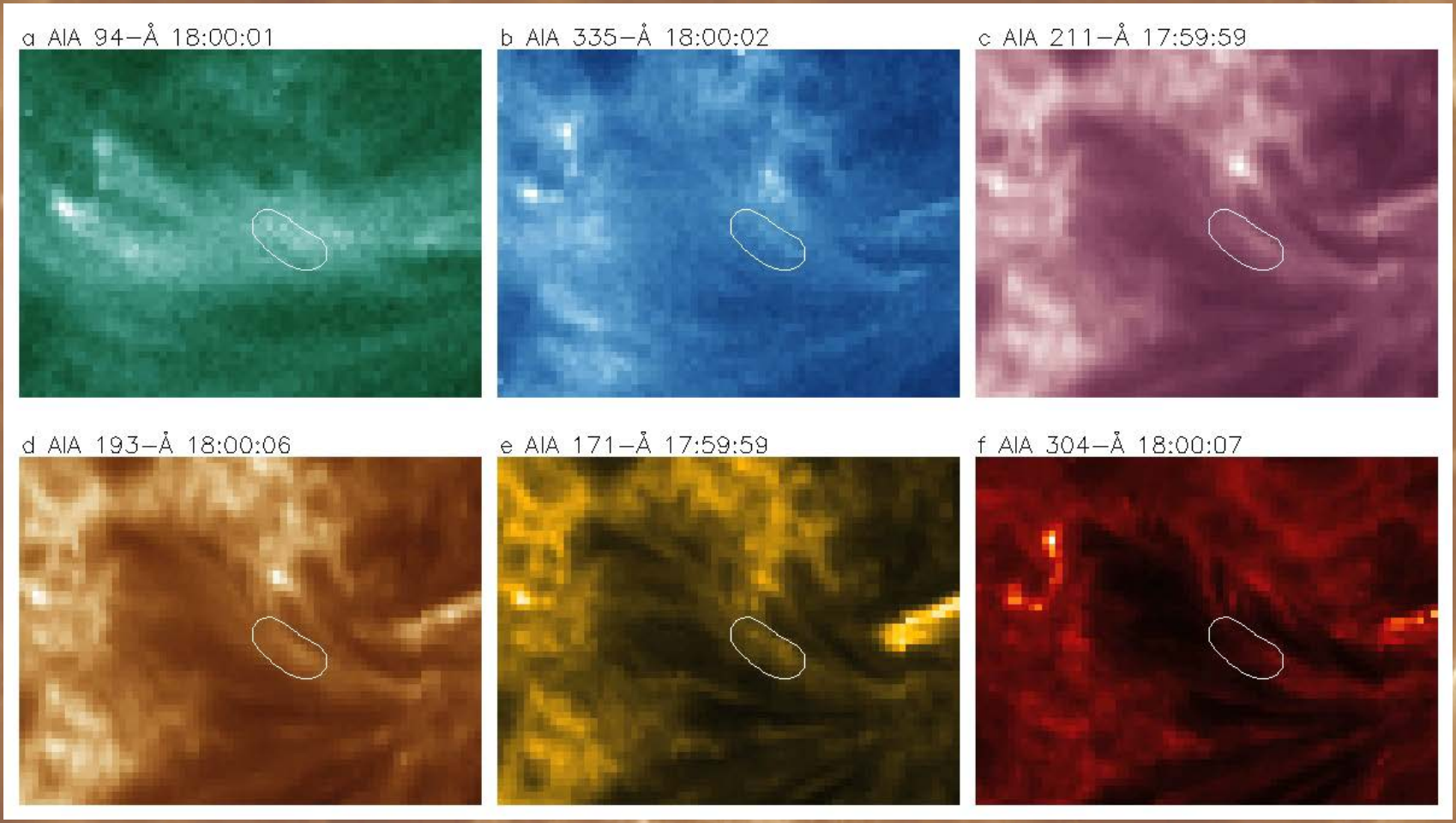
Cirtain et al, 2013, Nature

Braided Loop



Cirtain et al, 2013, Nature

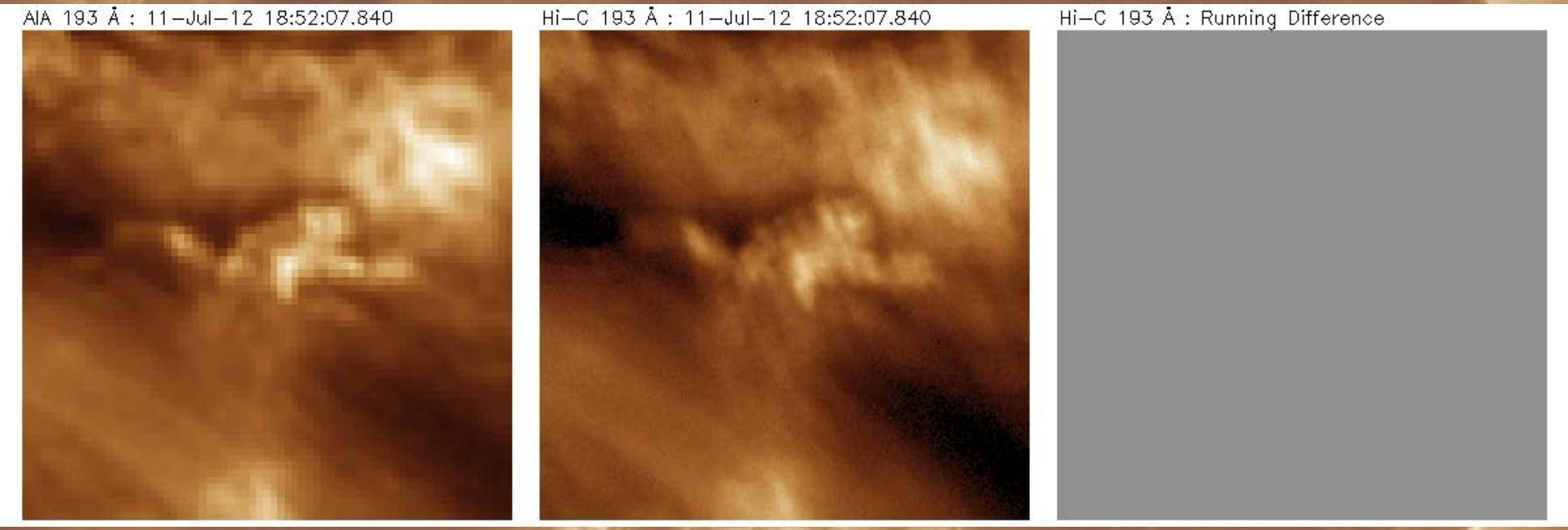
Braided Loop



Loop involved in heating event prior to Hi-C flight.

Cirtain et al, 2013, Nature

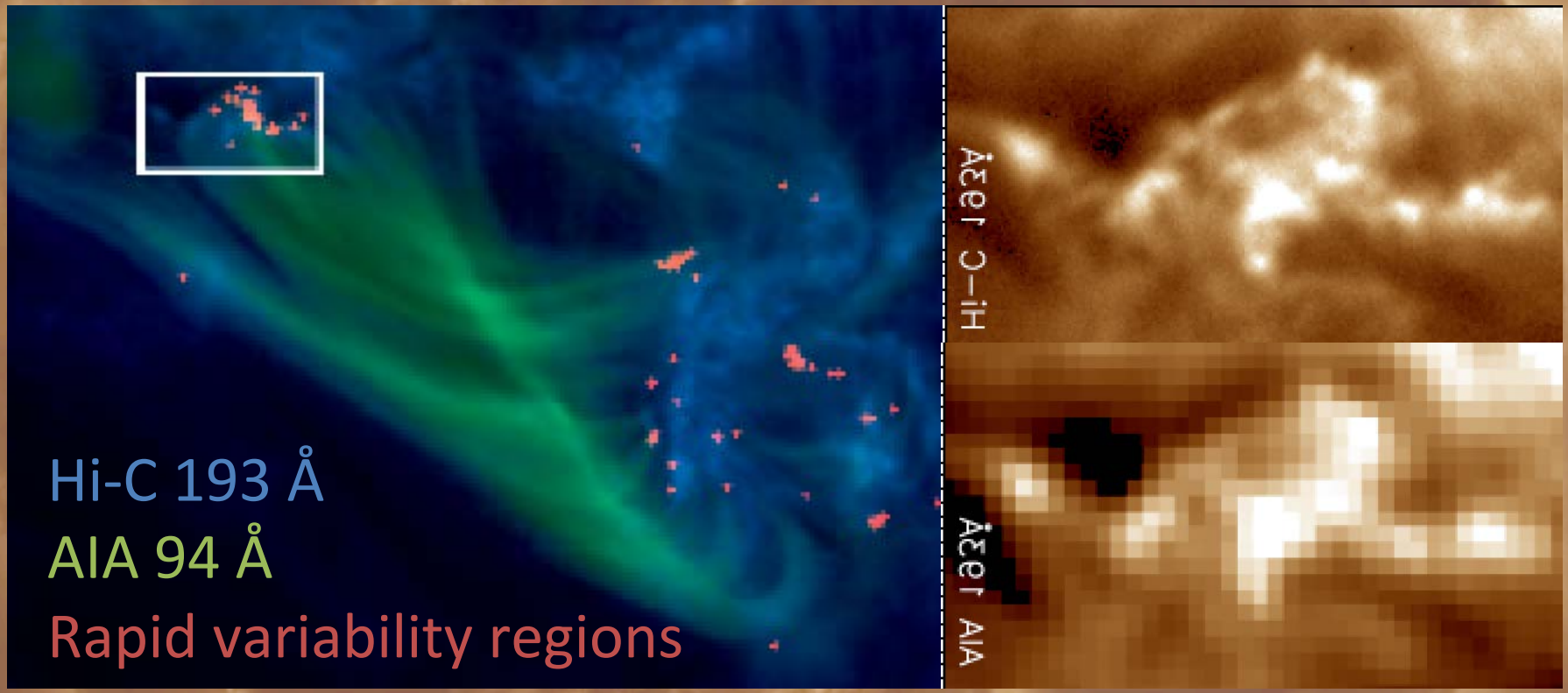
Dynamic Moss



- Hi-C observed a location of highly dynamic moss.

Testa, et al. 2013, ApJ

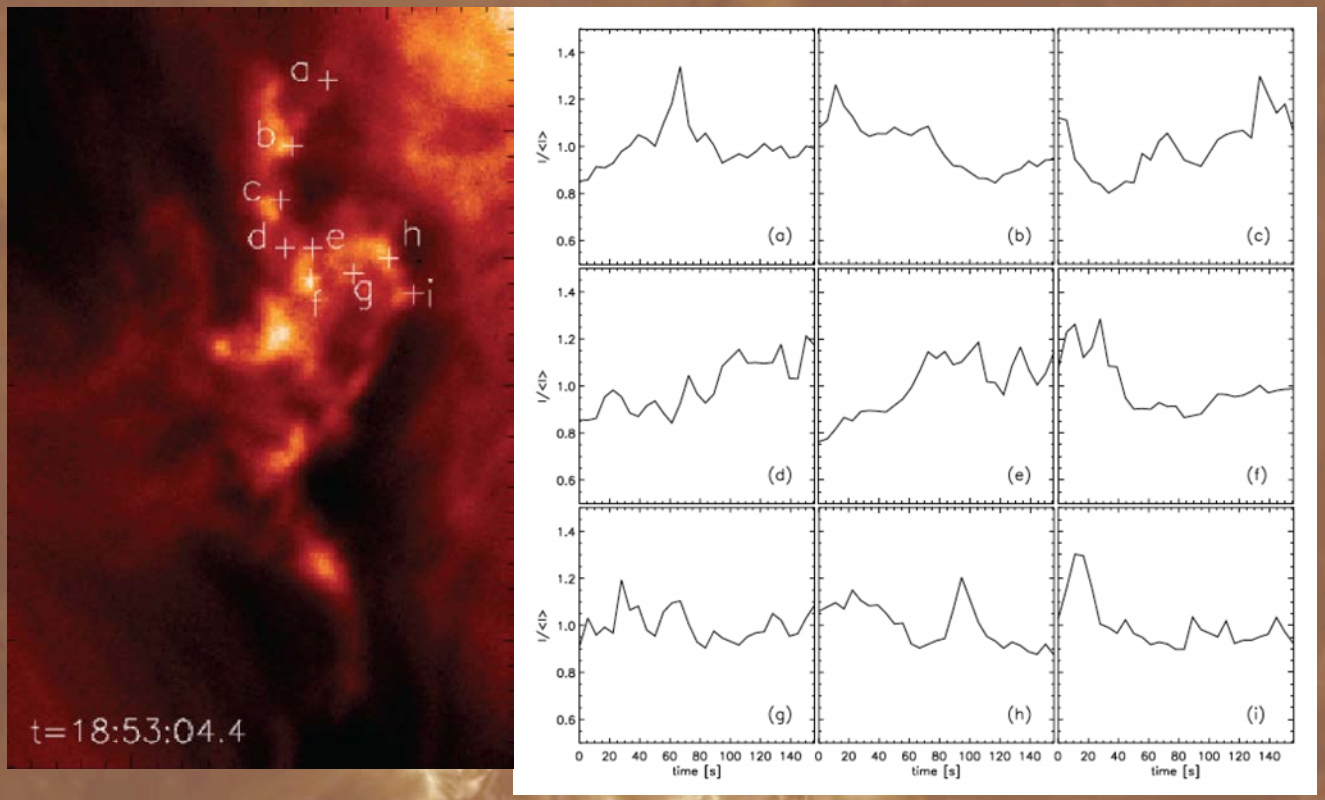
Dynamic Moss



- Dynamic moss occurs at footpoint of high temperature loops.

Testa, et al. 2013, ApJ

Dynamic Moss



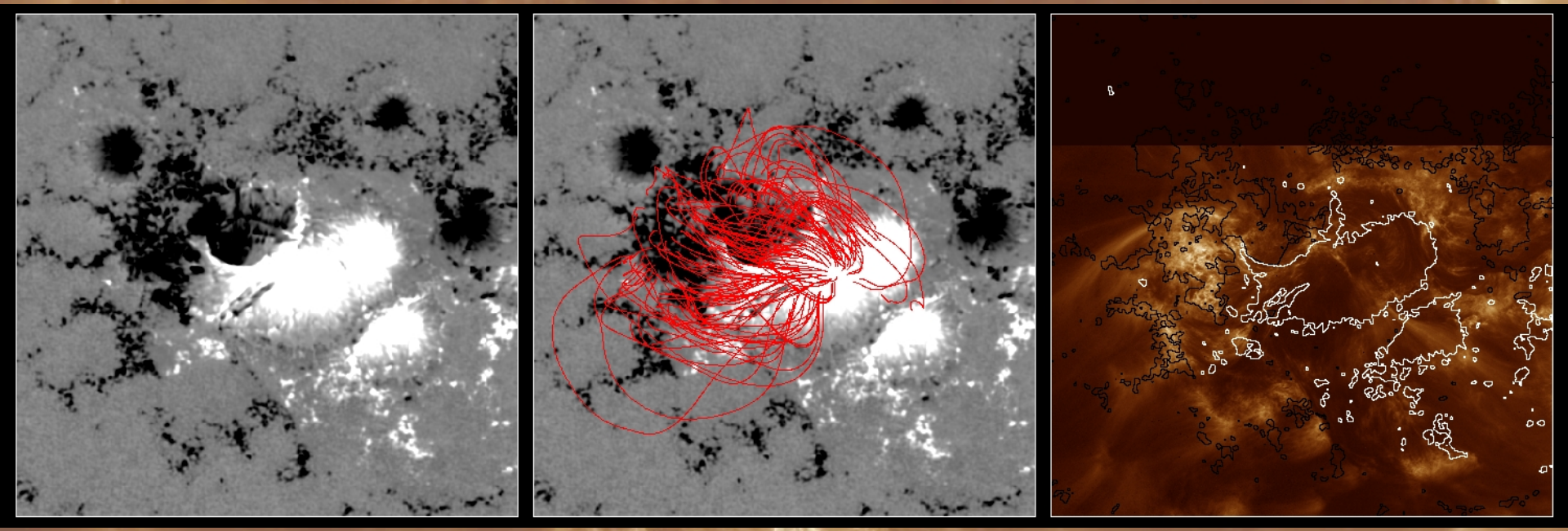
- Events as short as 15 s with increase in intensity on the order of 20-30%.
- Suggestive of footpoint response to coronal reconnection.

Testa, et al. 2013, ApJ

Observational evidence for ...

- "Classic nanoflare"
  - Crossed/tangled loops
  - Time dependent brightenings
  - Dynamic moss
- Wave heating / non-classic nanoflare
  - Everything else?

A quick model of Hi-C 1 Active Region



Heating models:

High frequency period ~ cooling time/3

Low frequency period ~ cooling time * 1.5

Heating magnitude chosen so that emission measure weighted average temperature ~ 4 MK.