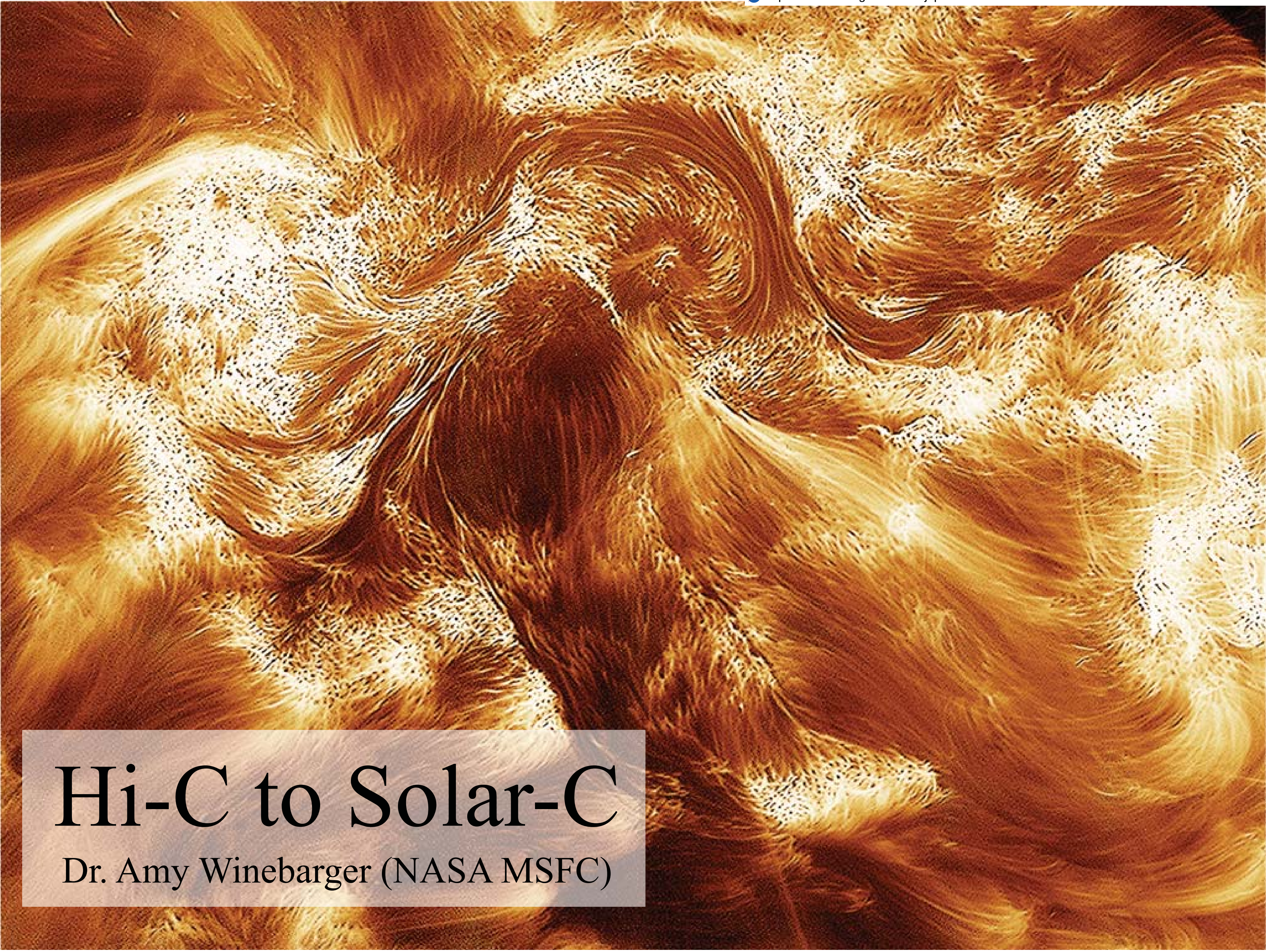
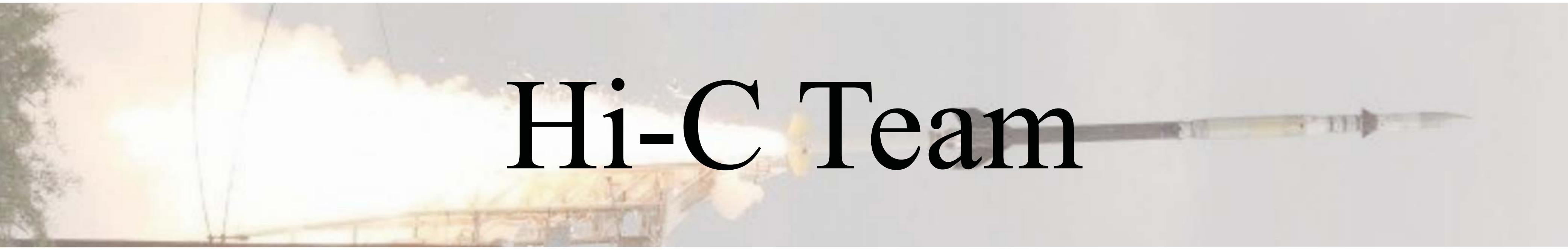


# Hi-C to Solar-C

Dr. Amy Winebarger (NASA MSFC)



# Hi-C Team

**Jonathan Cirtain, PI (MSFC)**

**Science Team:**
Leon Golub (SAO)
Ken Kobayashi (UAH)
Kelly Korreck (SAO)
Robert Walsh (UCLAN)
Amy Winebarger (MSFC)
Bart DePontieu (LMSAL)
Craig Deforest (SWRI)
Sergey Kuzin (LI)
Alan Title (LMSAL)
Mark Weber (SAO)

**Engineering Team:**
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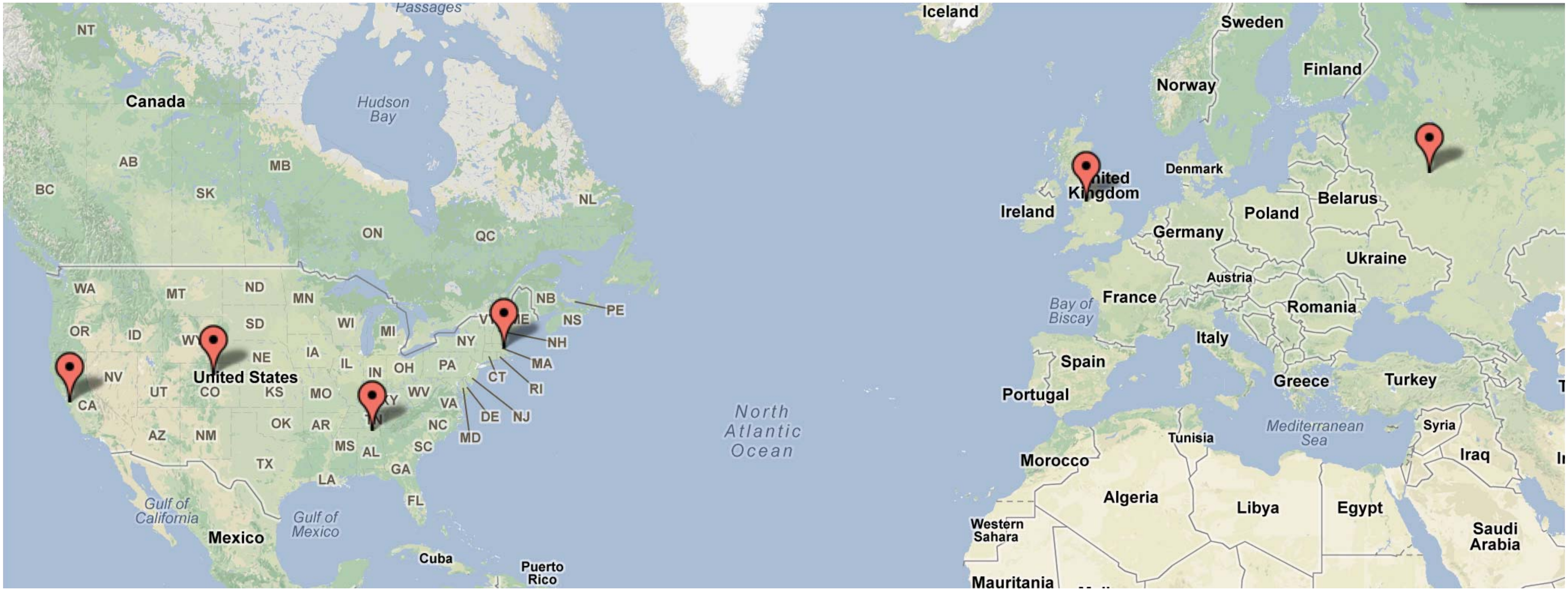
Dyana Beabout (MSFC)
Brent Beabout (MSFC)
William Podgorski (SAO)
Ken McKracken (SAO)
Mark Ordway (SAO)
David Caldwell (SAO)
Henry Berger (SAO)
Richard Gates (SAO)
Simon Platt (UCLAN)
Nick Mitchell (UCLAN)

*Image above shows Hi-C launch team standing in front of the Hi-C rocket on the at White Sands Missile Range.*

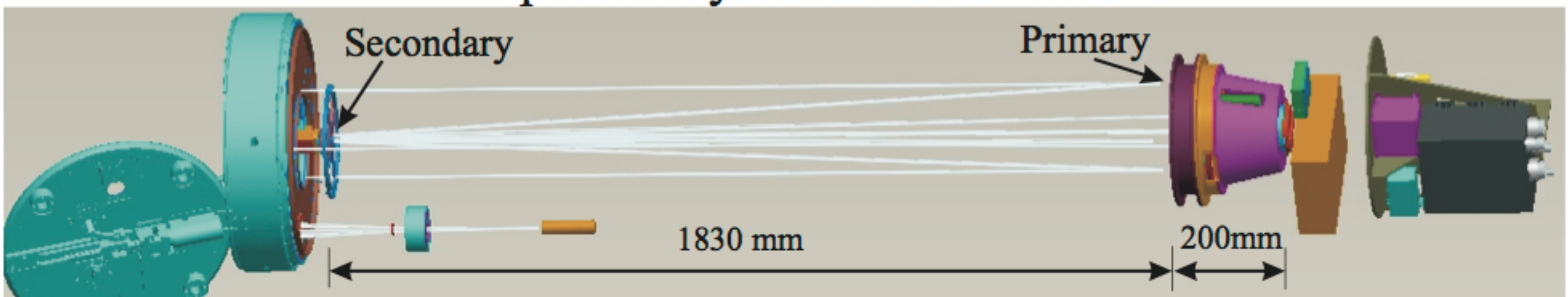
# Partner Institutions




NASA Marshall Space Flight Center (MSFC)
University of Alabama – Huntsville (UAH)
Smithsonian Astrophysical Observatory (SAO)
University of Central Lancashire, UK (UCLAN)
Lockheed Martin Solar and Astrophysical Laboratory (LMSAL)
Southwest Research Institute (SWRI)
Lebedev Institute (LI)

# High-Resolution Coronal Imager

## Optical Layout with Tolerances




Primary to secondary requirements: Distance: +/- 0.05mm
Tilt: 36″
De-center: 0.05mm

Focal Plane: Axial Position: +/- 1mm

Hi-C is a narrowband EUV imager. The wavelength band is center at 193 Å.

**Hi-C Telescope Optical Design**

| | | | |
|---|---|---|---|
| **Telescope Properties:** | | **Primary Mirror:** | |
| Focal Length | 23.9 m | Radius of Curvature | 4000±4.0 mm |
| Plate Scale | 114 µm/arcsec | Diameter | 240 mm |
| Focal Ratio | f/109 | RMS slope error | 0.4 µrad |
| Field of View | 6.8x6.8 arcmin | | |
| RMS Spot Diameter (averaged over f.o.v.) | 0.08 arcsec | **Secondary Mirror:** | |
| **CCD Camera:** | | Radius of Curvature | 370±0.5 mm |
| | | Conic | -1.14±0.10 |
| Size | 49.1 $mm^2$ | Diameter | 30 mm |
| Scale | 0.1 arcsec/pixel | RMS slope error | 0.1 µrad |

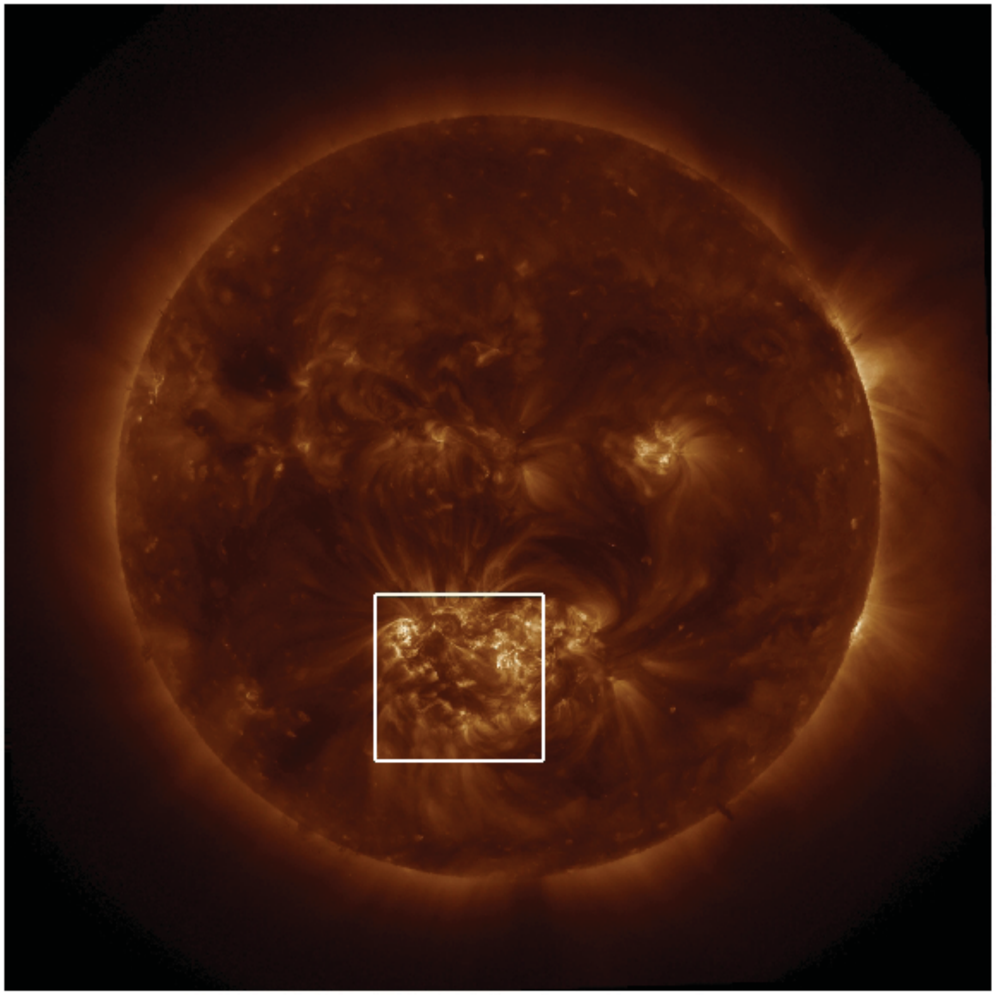
# Launch and Recovery

- Hi-C was launched out of White Sands Missile Range on July 11, 2012.
- The instrument obtained ~5 minutes of solar observations.
- The payload was recovered.

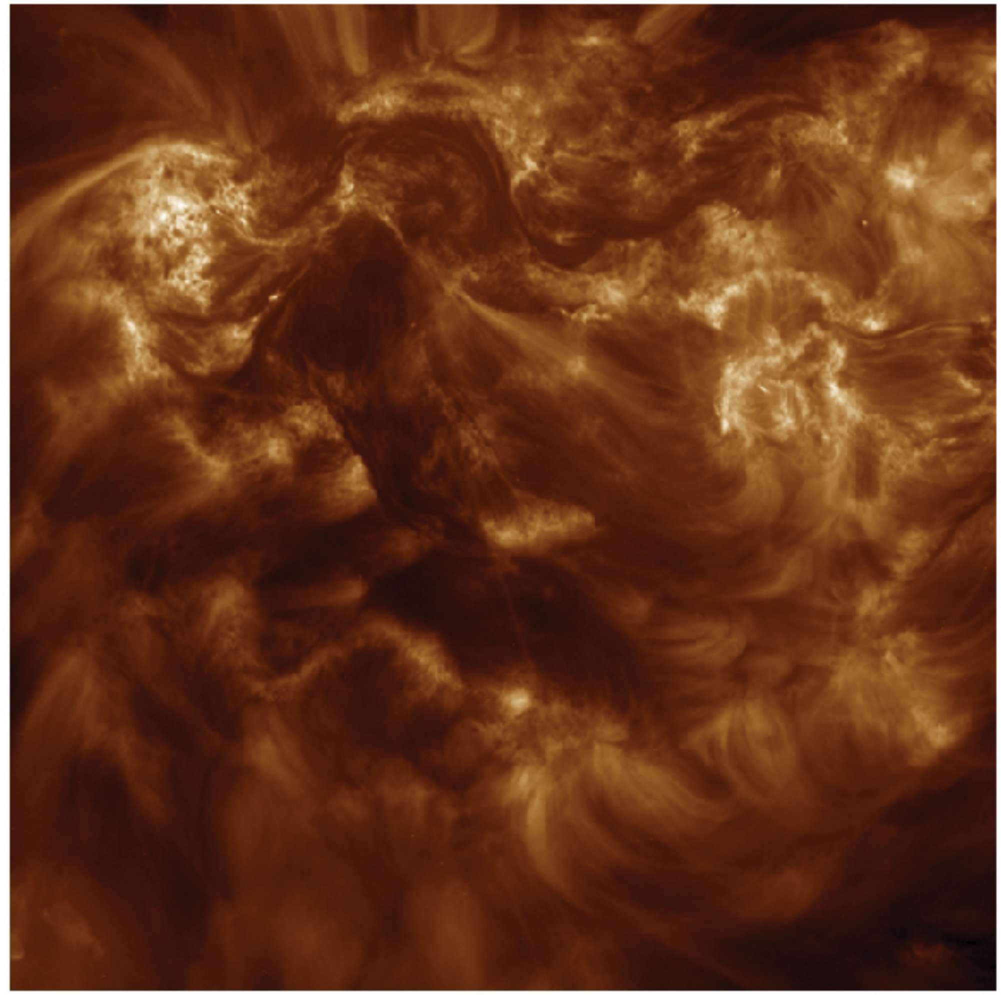
*Recovery team*

# Hi-C Target

AIA 193–Å 11–Jul–2012 18:55:07



Hi–C Field of View



The Hi-C target was Active Region 11520.

# Hi-C Data

Hi-C collected data for 345 s.
Several images was blurred due to rocket jitter and pointing.

**Full frame (4k x 4k) data:**
- 29 full resolution images
- 2 s exposure, 5.5 s cadence

**Partial frame (1k x 1k) data**
- 86 full resolution images
- 0.5 s exposure, 1.4 s cadence

Data was released to the solar physics community via Virtual Solar Observatory in January, 2013. It was downloaded ~900 times in the first 6 months.

# Hi-C First Results

**Spatial Resolution**

Braided Loops (Cirtain et al.)
Low-amplitude Transverse Waves (Morton et al.)
Loop Substructure (Peter et al., Brooks et al.)
Bi-directional Flows along a Filament (Alexander et al.)

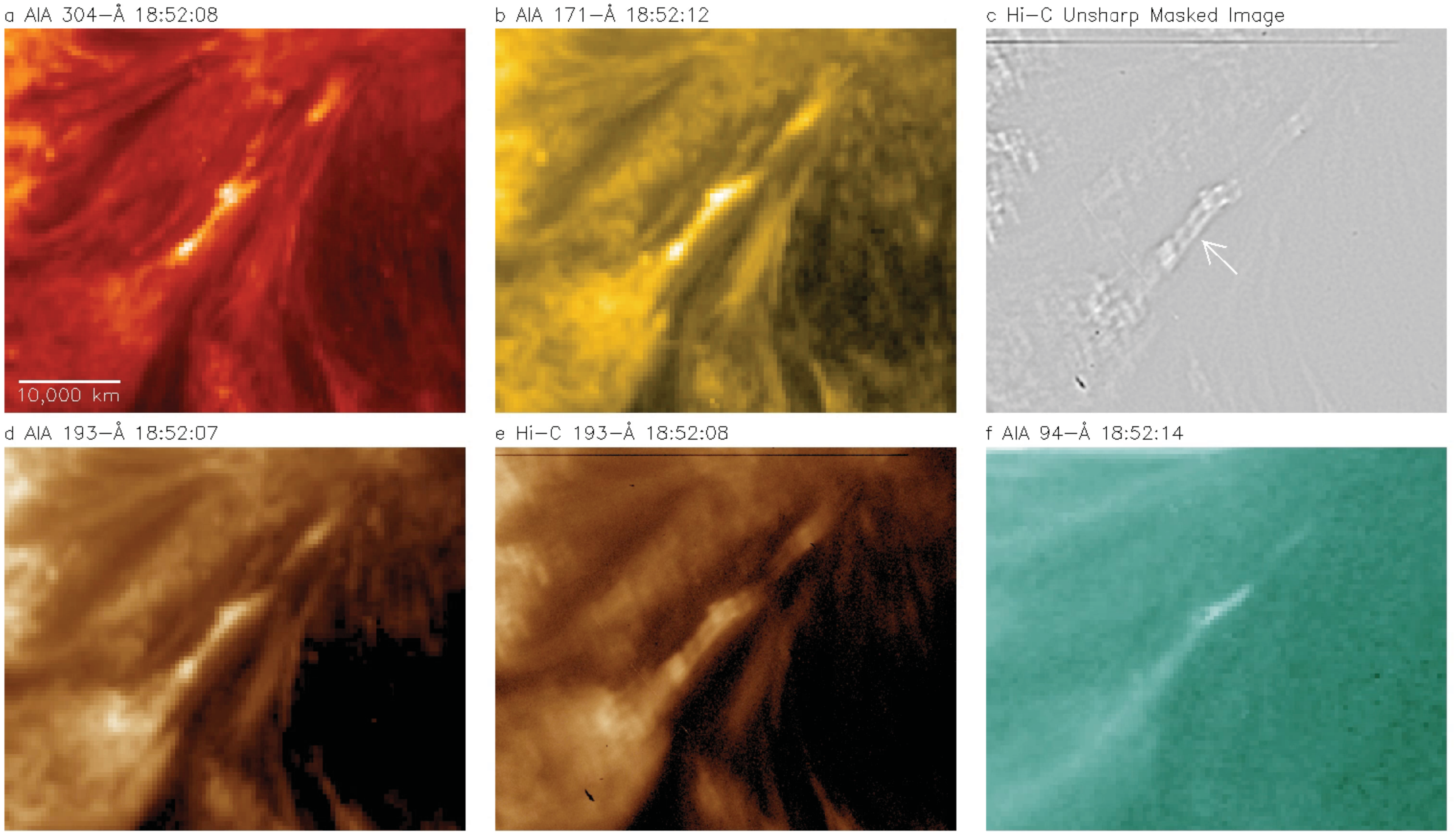
**Temporal Resolution**

Dynamic events in moss (Testa et al.)
Small-scale Bright “Dots” (Regnier et al.)
Evolving Transition Region Loops (Winebarger et al.)

**Required Effective Area**

Linear substructure in transient events (Winebarger et al.)

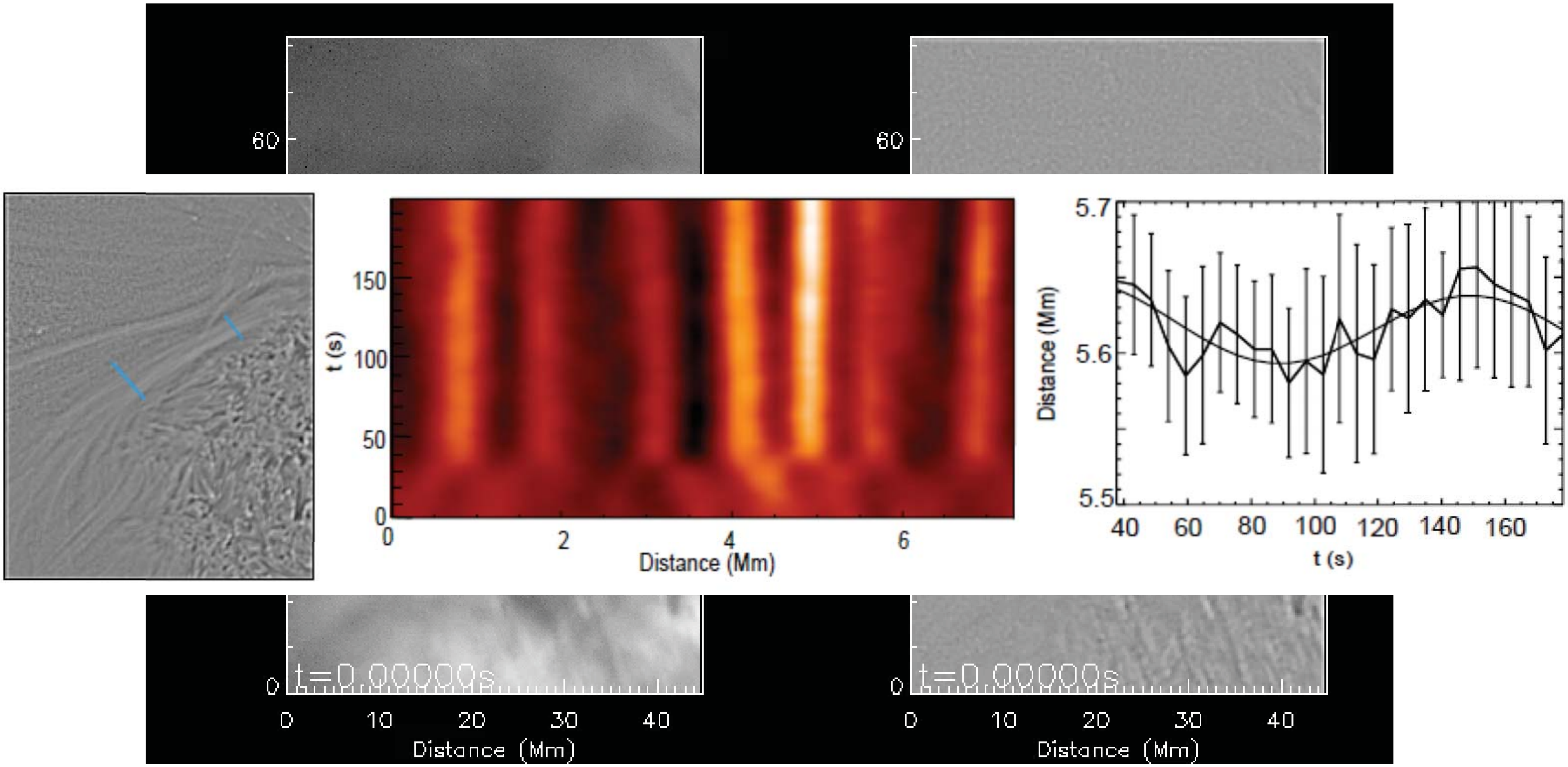
# Braided Loops




Hi-C made the first observations of coronal braiding and reconnection.

Cirtain et al., 2013, Nature, 493, 501

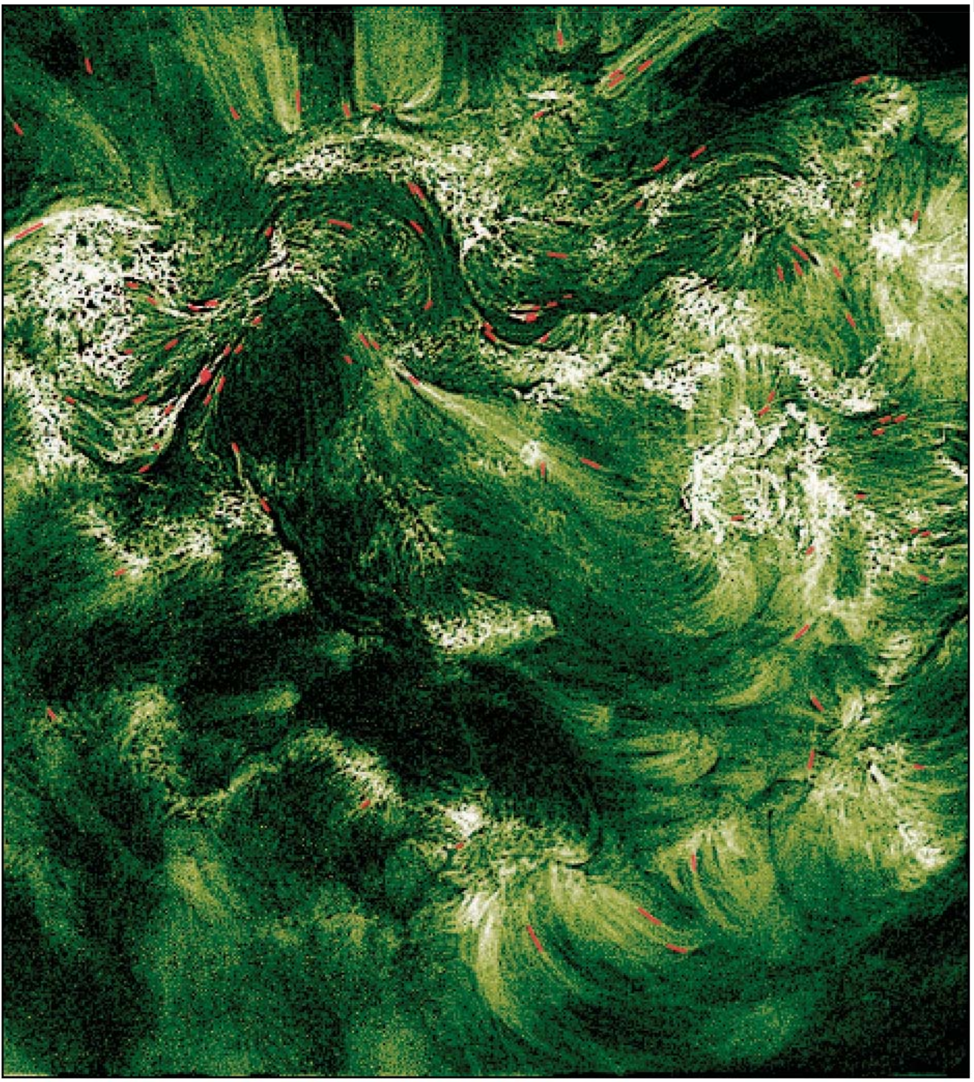
# Transverse Waves

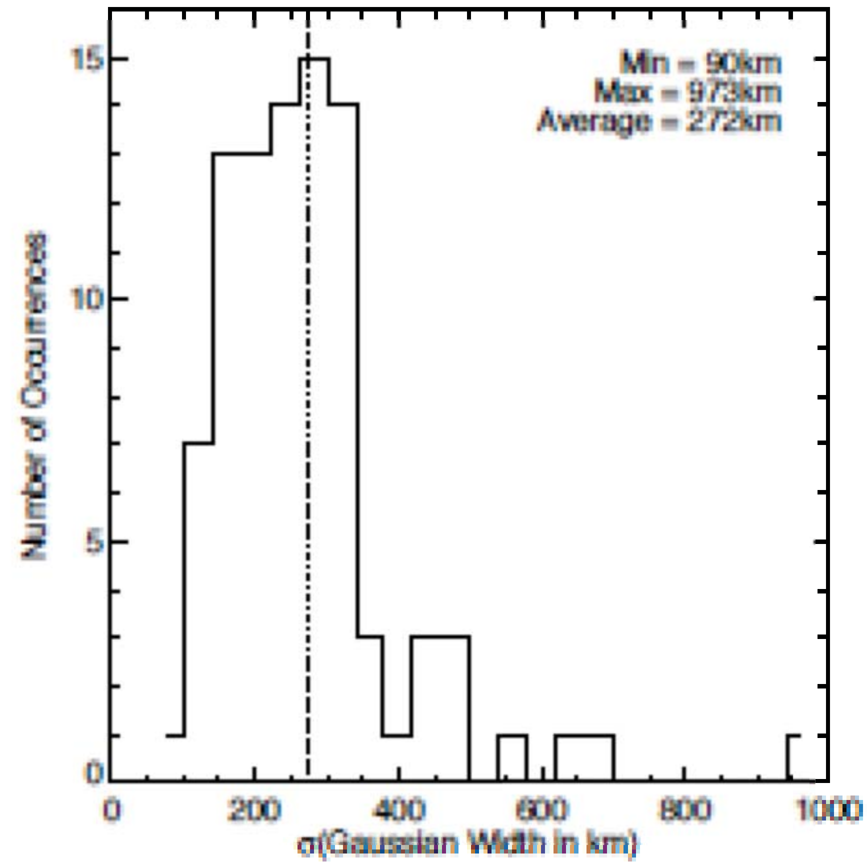



Hi-C observed low-amplitude transverse waves, not observable in AIA.

Morton & McLaughlin, 2013, A&A, 553, L10

# Loop Substructure

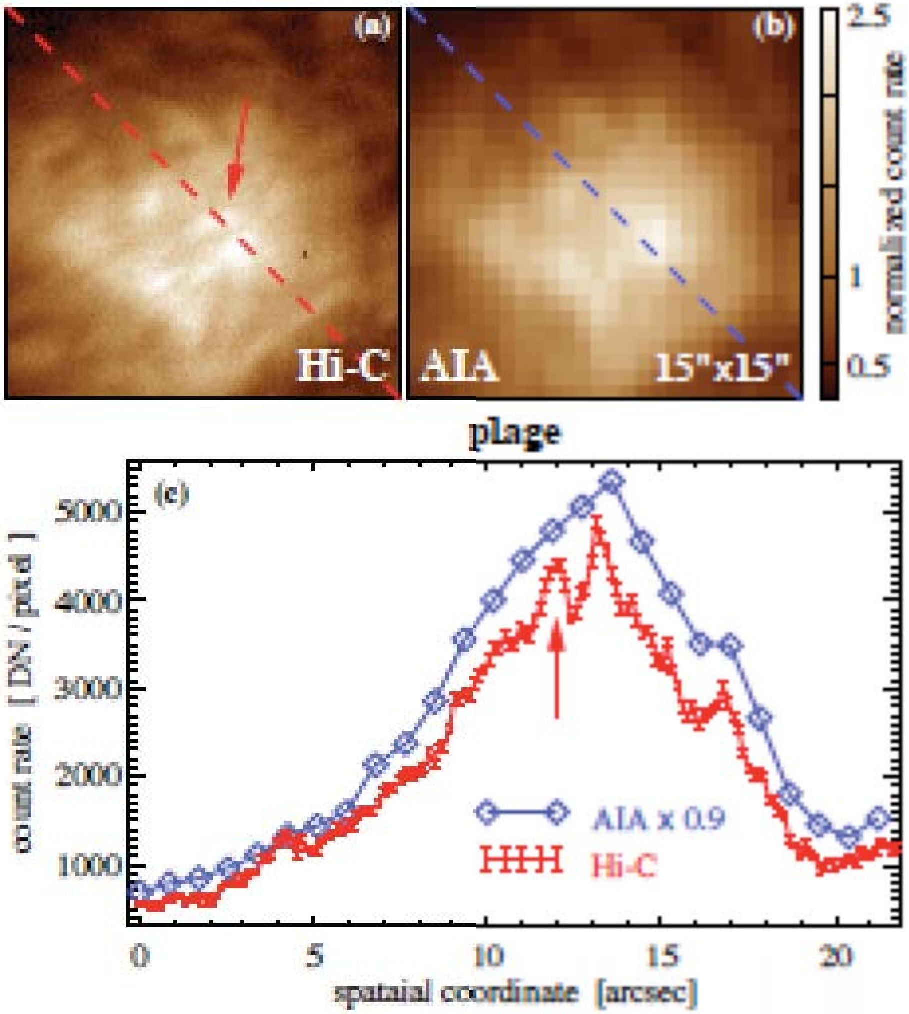


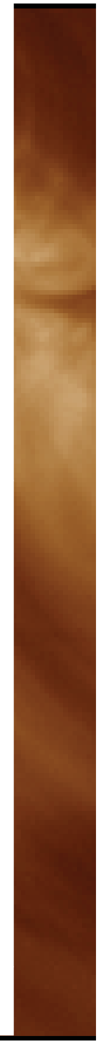


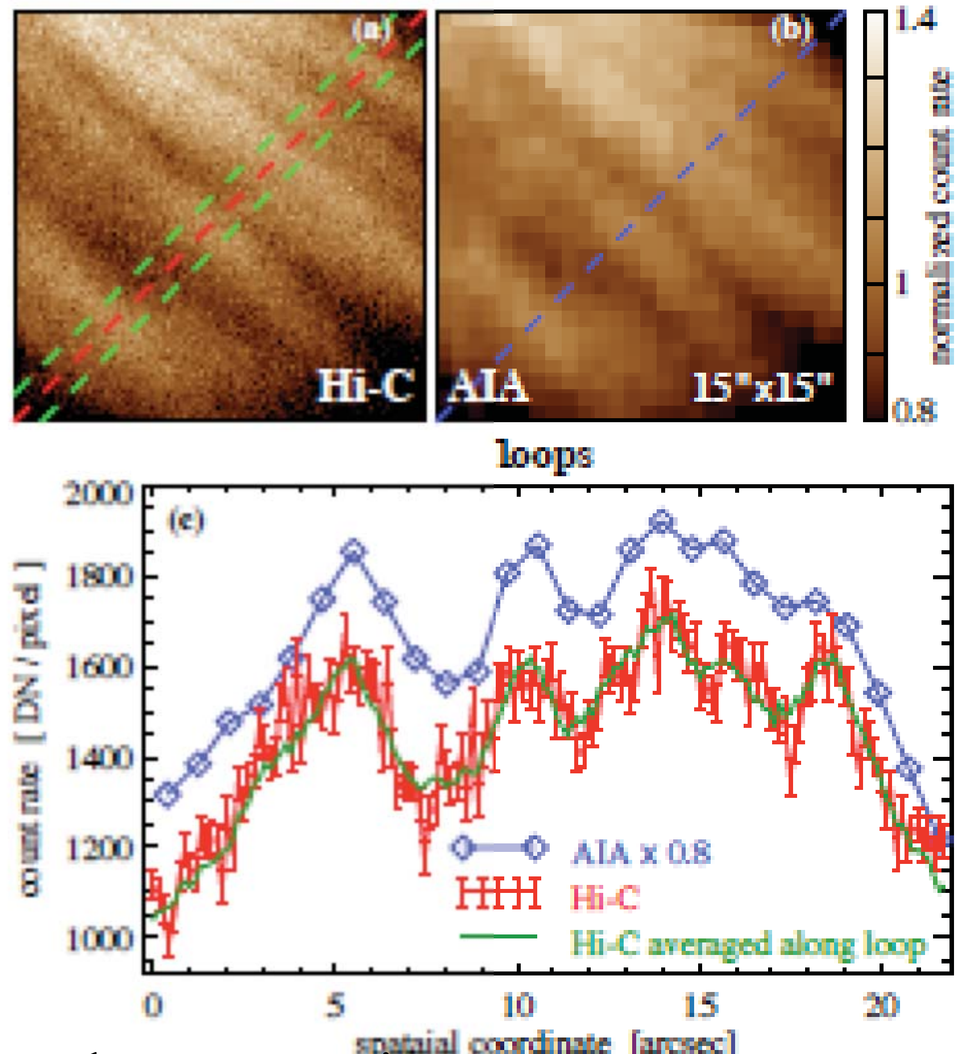

The widths of 91 loop segments were measured.
The most typical width with 270 km.

Brooks et al., 2013, ApJ, 772, 18

# Loop Substructure



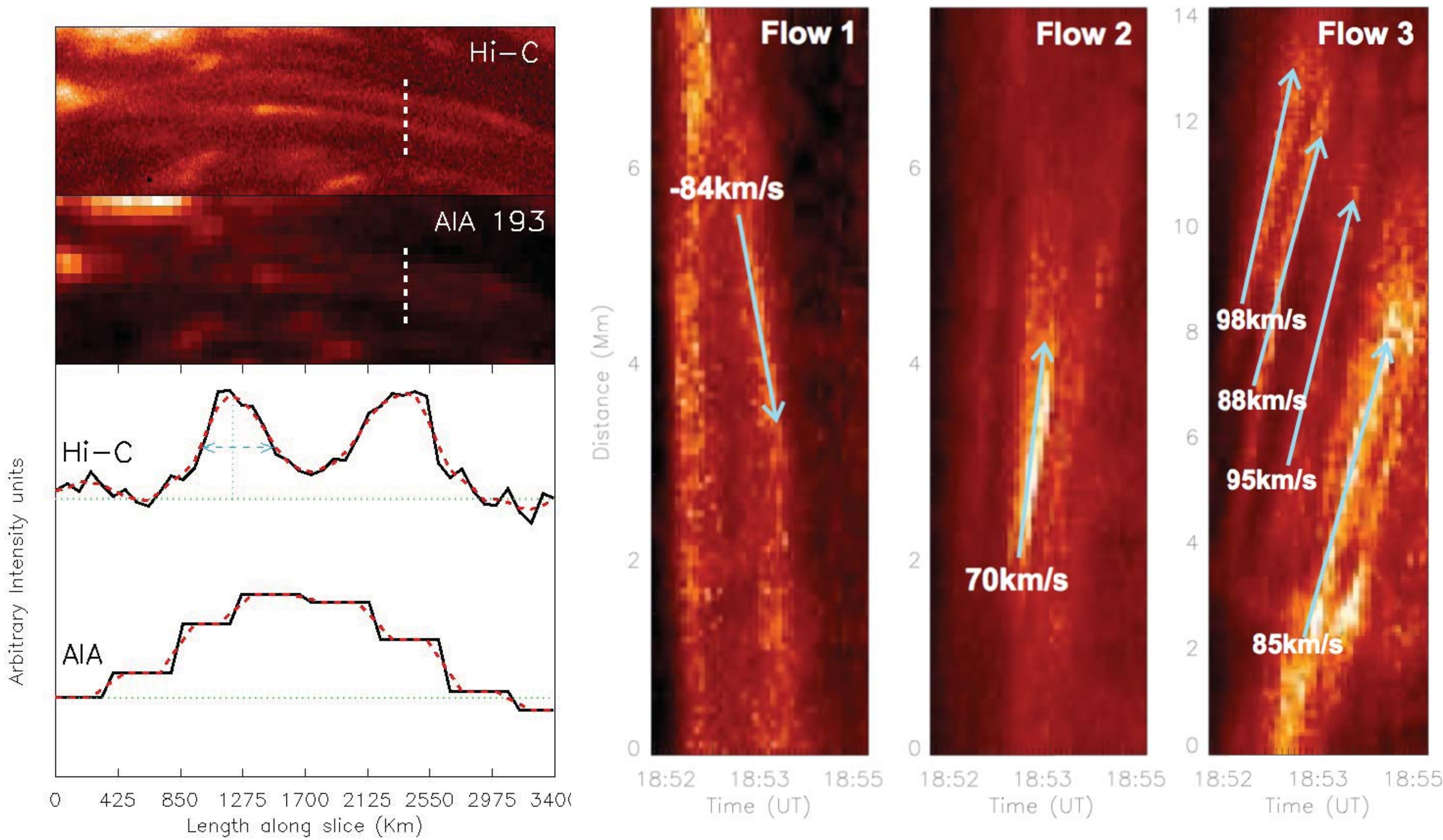






Demonstrated that Hi-C can resolve small-scale structure in the plague, but does not observe it in loops. If loops have substructure, then d < 15 km.

Peter et al., 2013, A&A, 556, 104

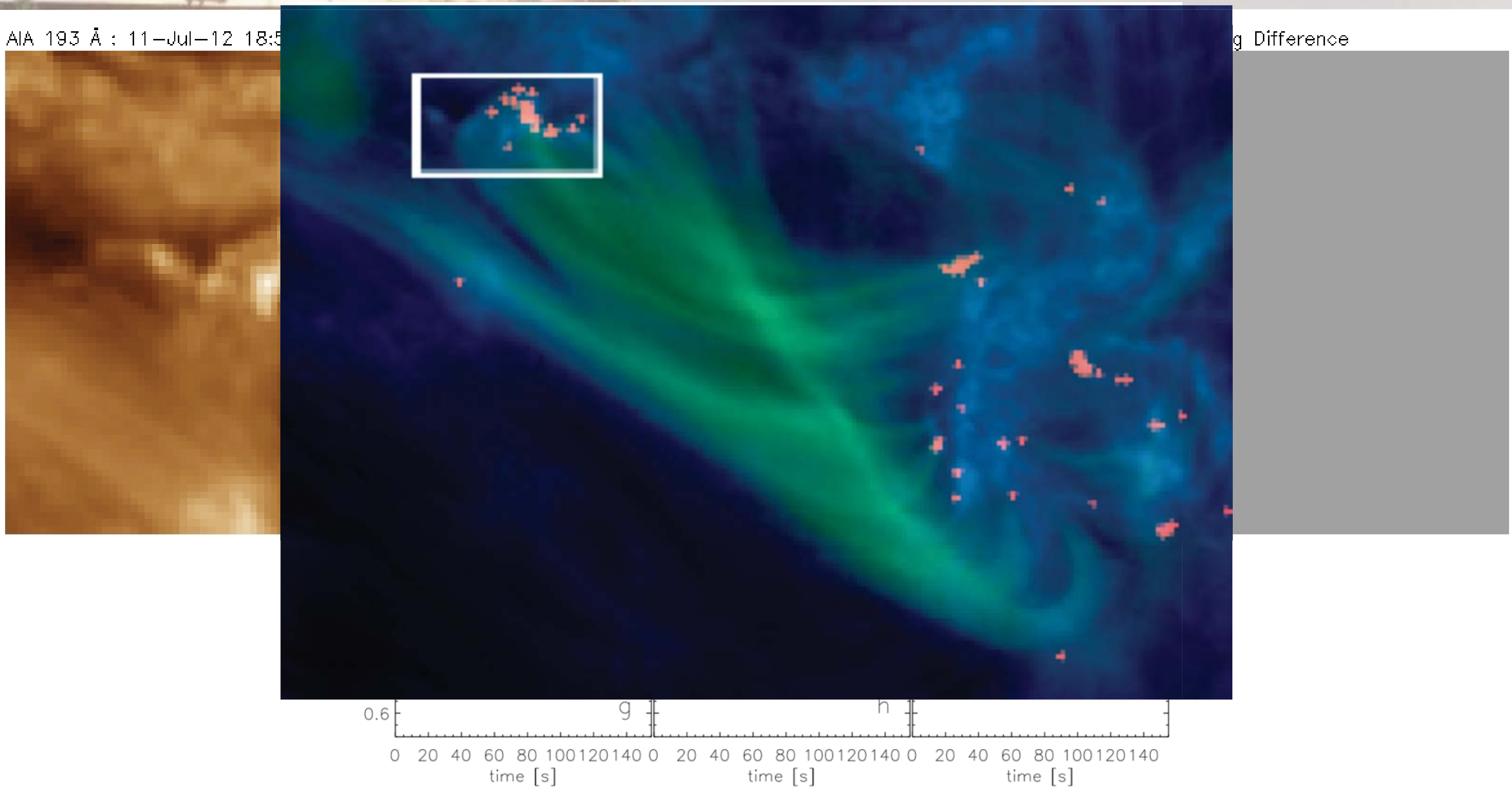
# Bi-directional Flows




Discovered bi-directional flows along a filament that was unresolved by AIA. Velocities were > 70 km/s.

Alexander et al., 2013, ApJ, 775, 32

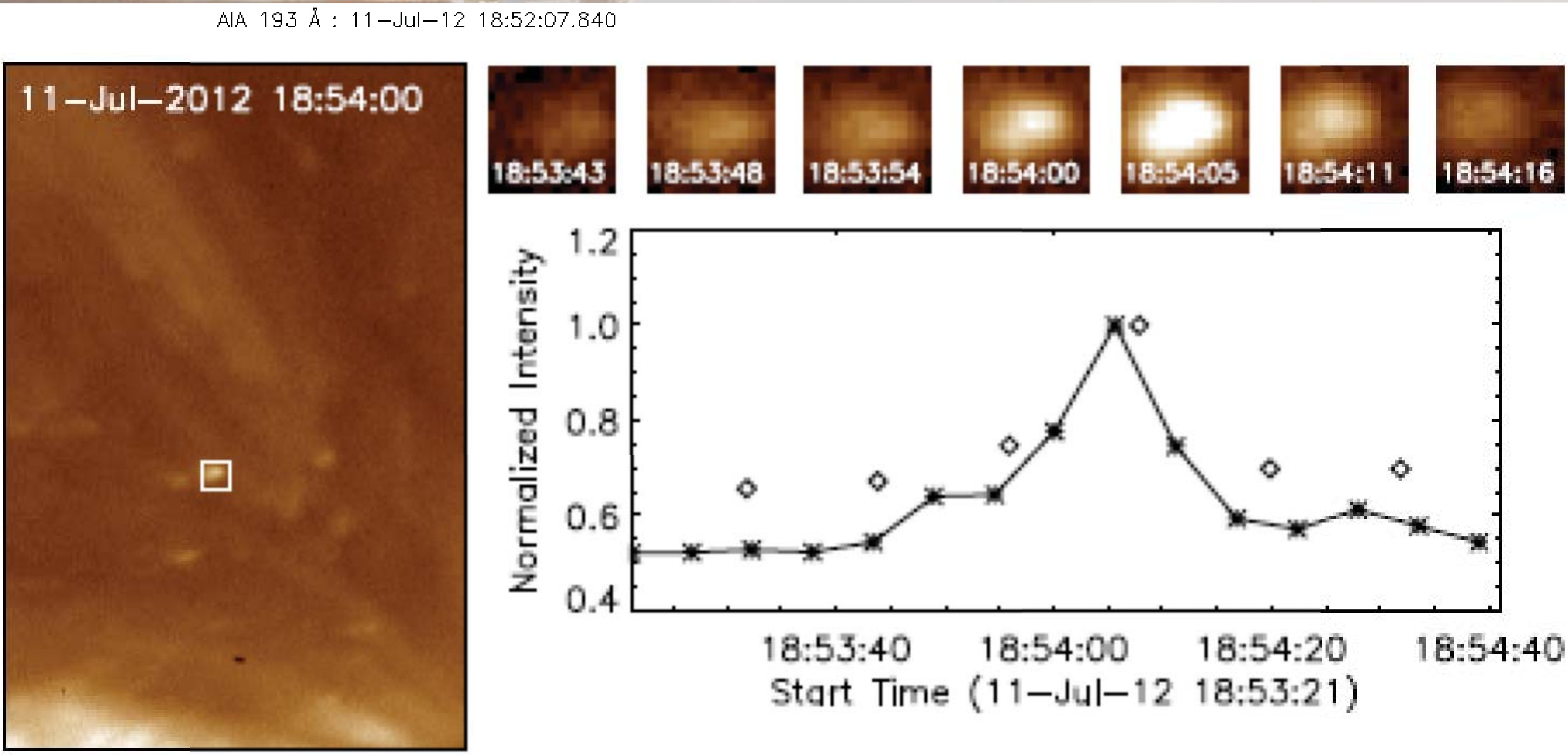
# Dynamics in the Moss

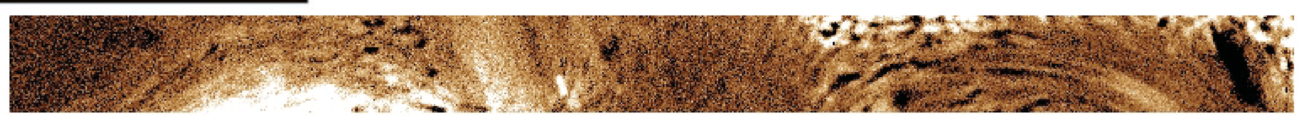



Discovered dynamics in moss at footpoints of crossed high temperature loops. Suggest this was due to coronal reconnection.

Testa et al., 2013, ApJ, 770, 1

# Bright "Dots"

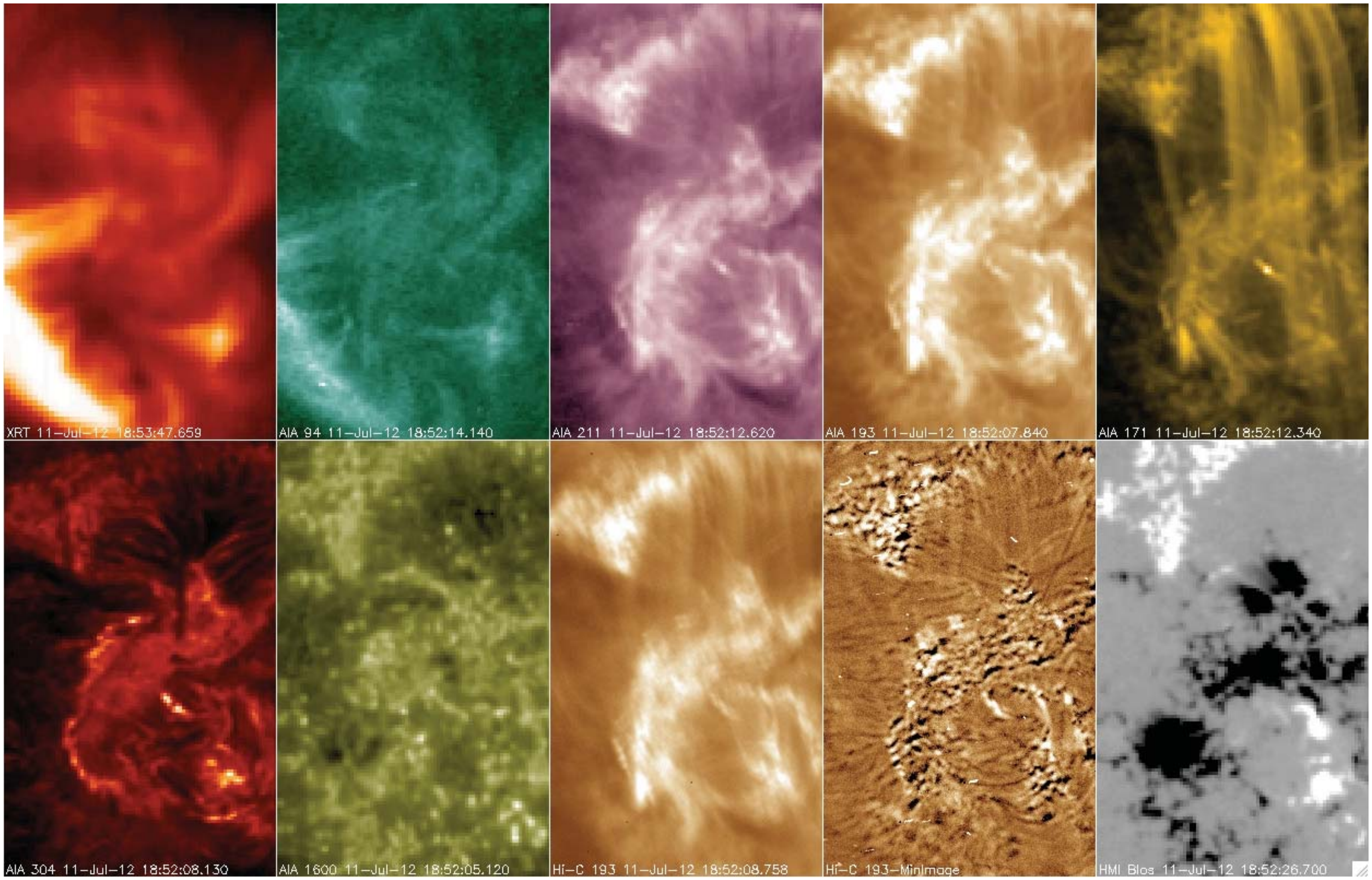


Bright, quickly evolving "dots" were discovered at the northern edge of the Hi-C field of view.

Regnier et al., 2013, ApJ, submitted

# Transition Region Loops

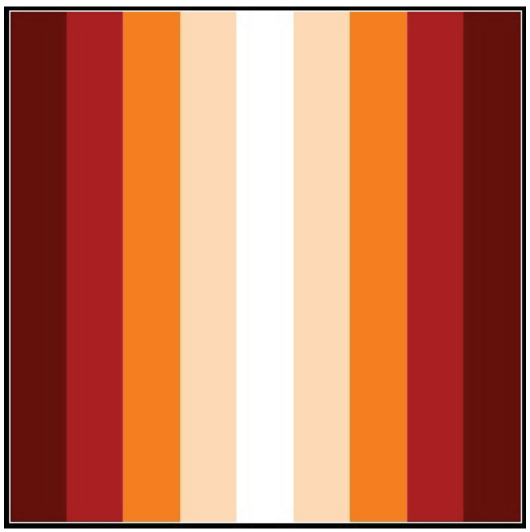


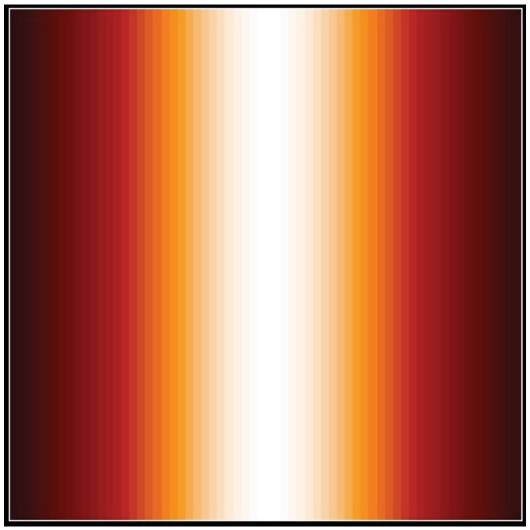

Small-scale, quickly evolving, inter-moss loops were discovered.

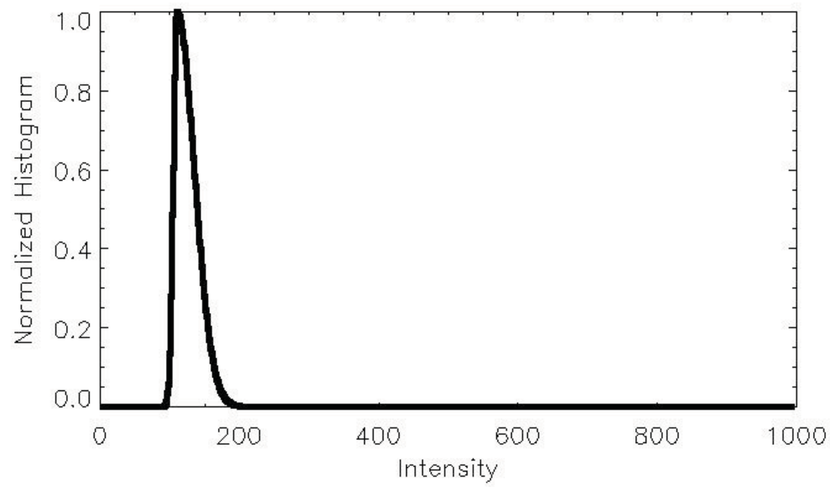
The maximum temperature of the loops were found to be ~$10^5$ K.

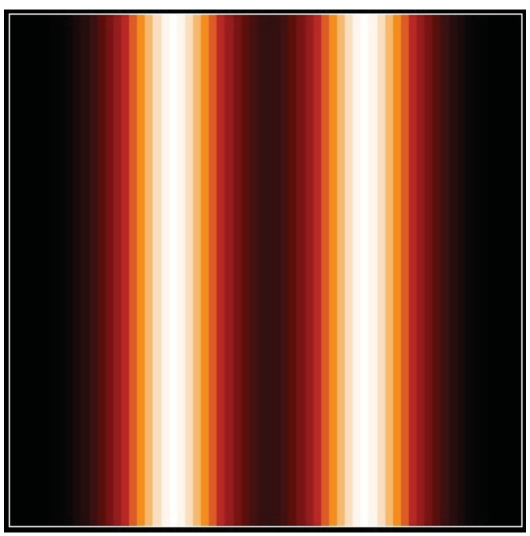
Winebarger et al., 2013, ApJ, 771, 21

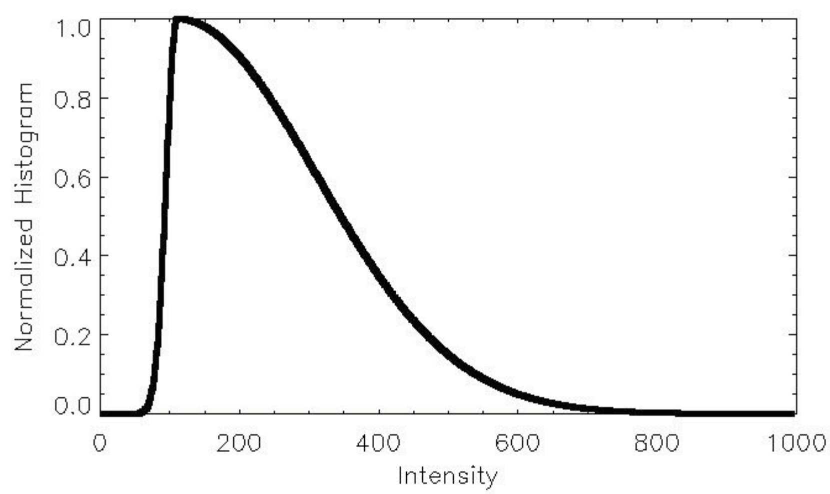
# Effective Area Requirements



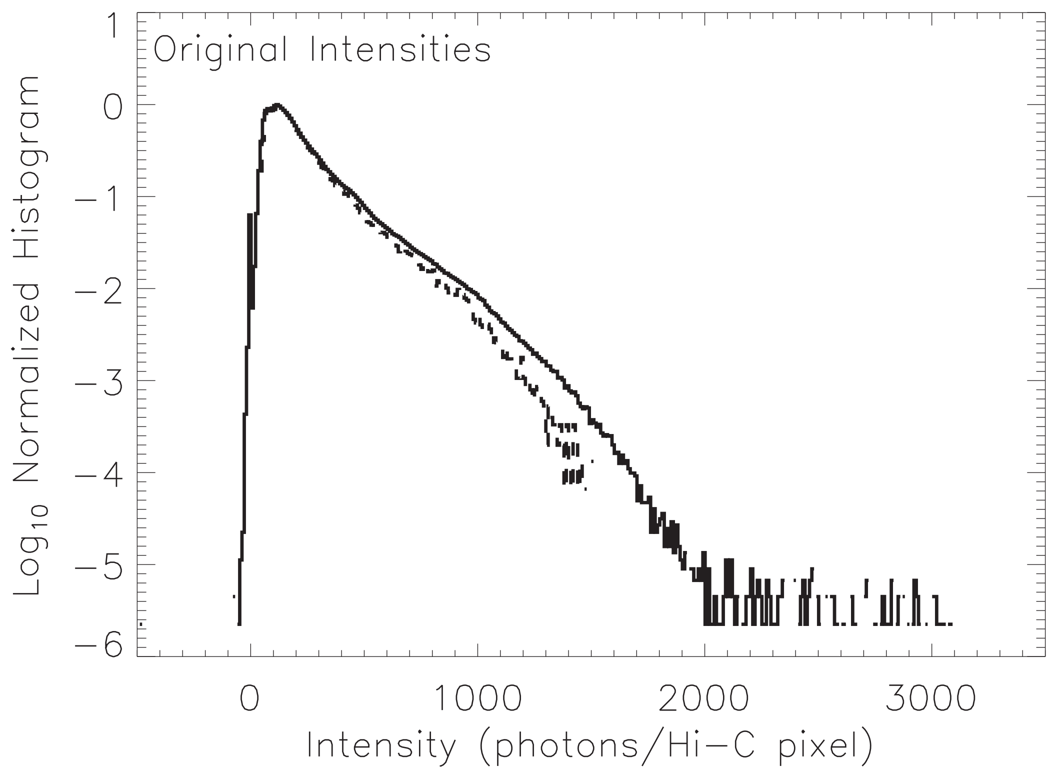






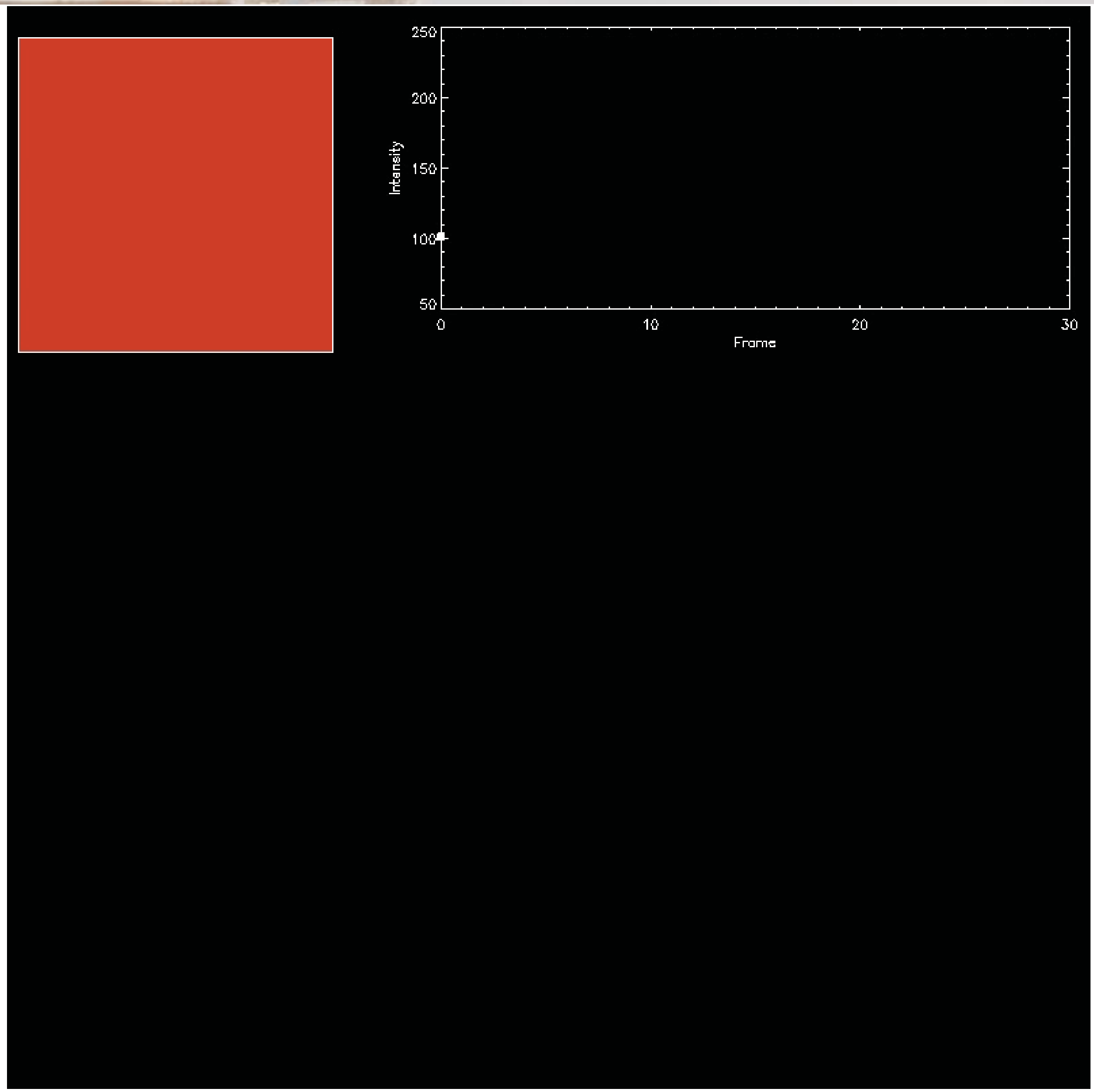
# Observed by Hi-C



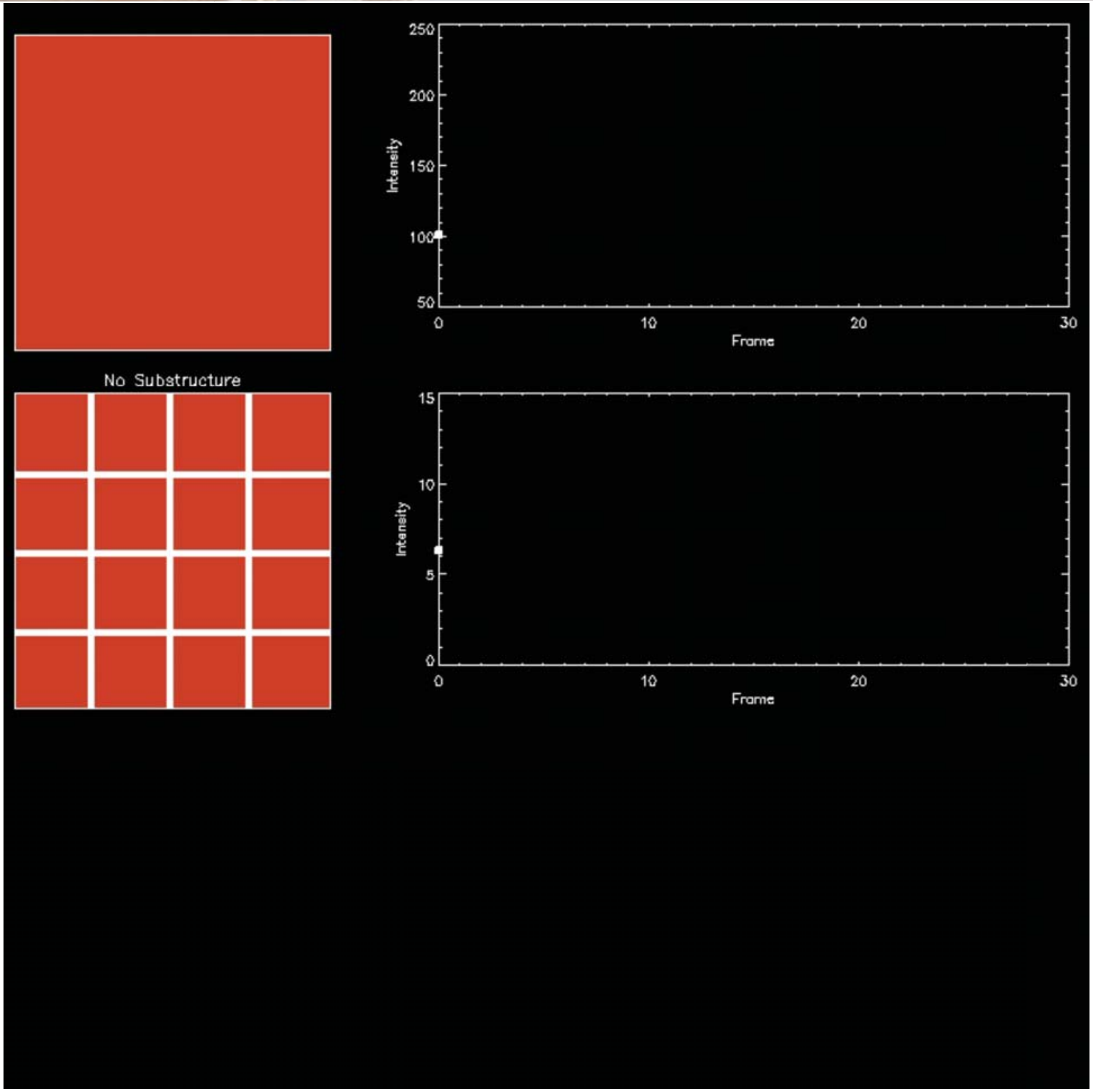

Hi-C initially did not appear to demonstrate the ~3-4 increase in intensity expected for linear substructure.

Winebarger et al., 2013, in prep

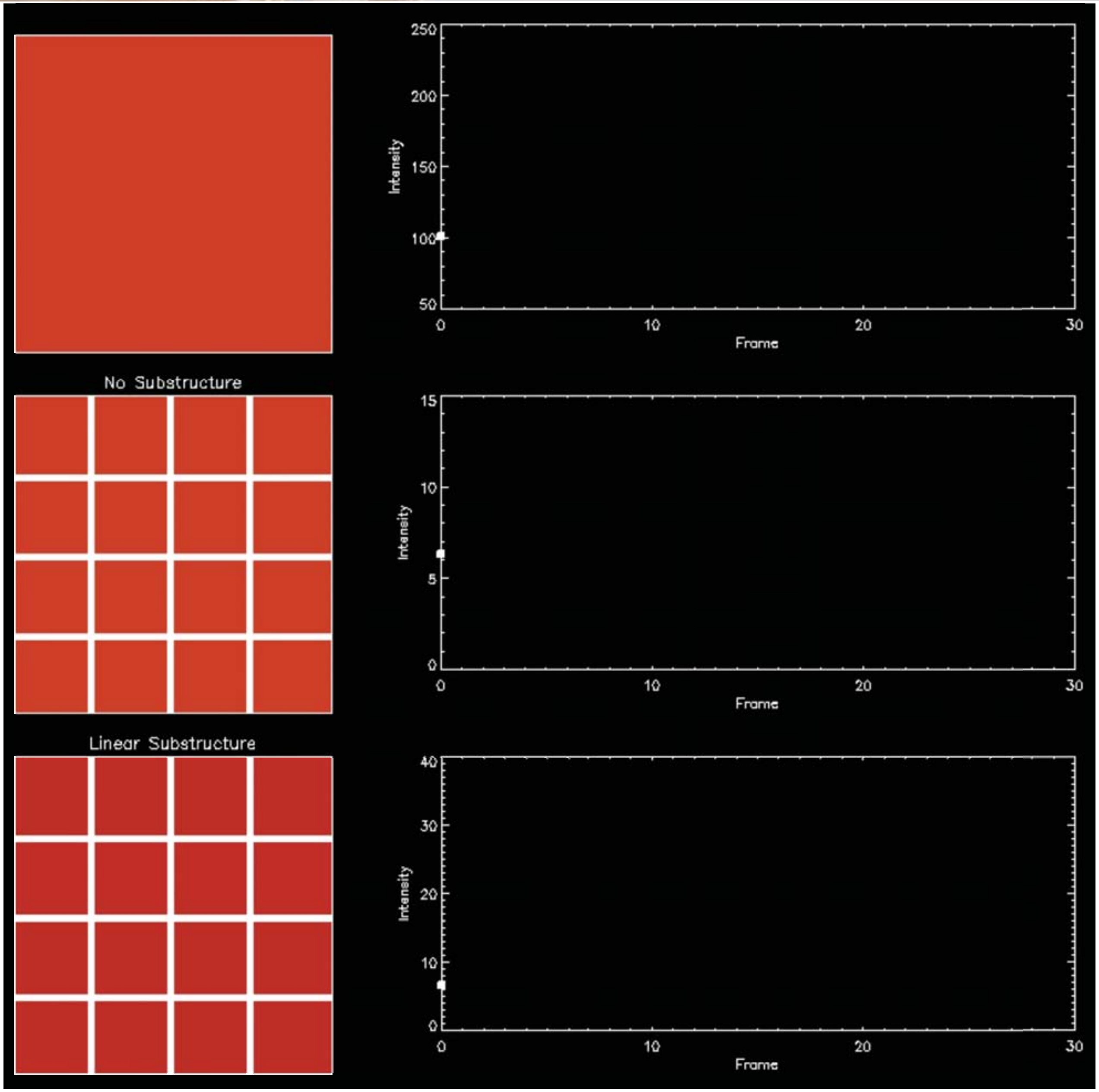
# Transient Events



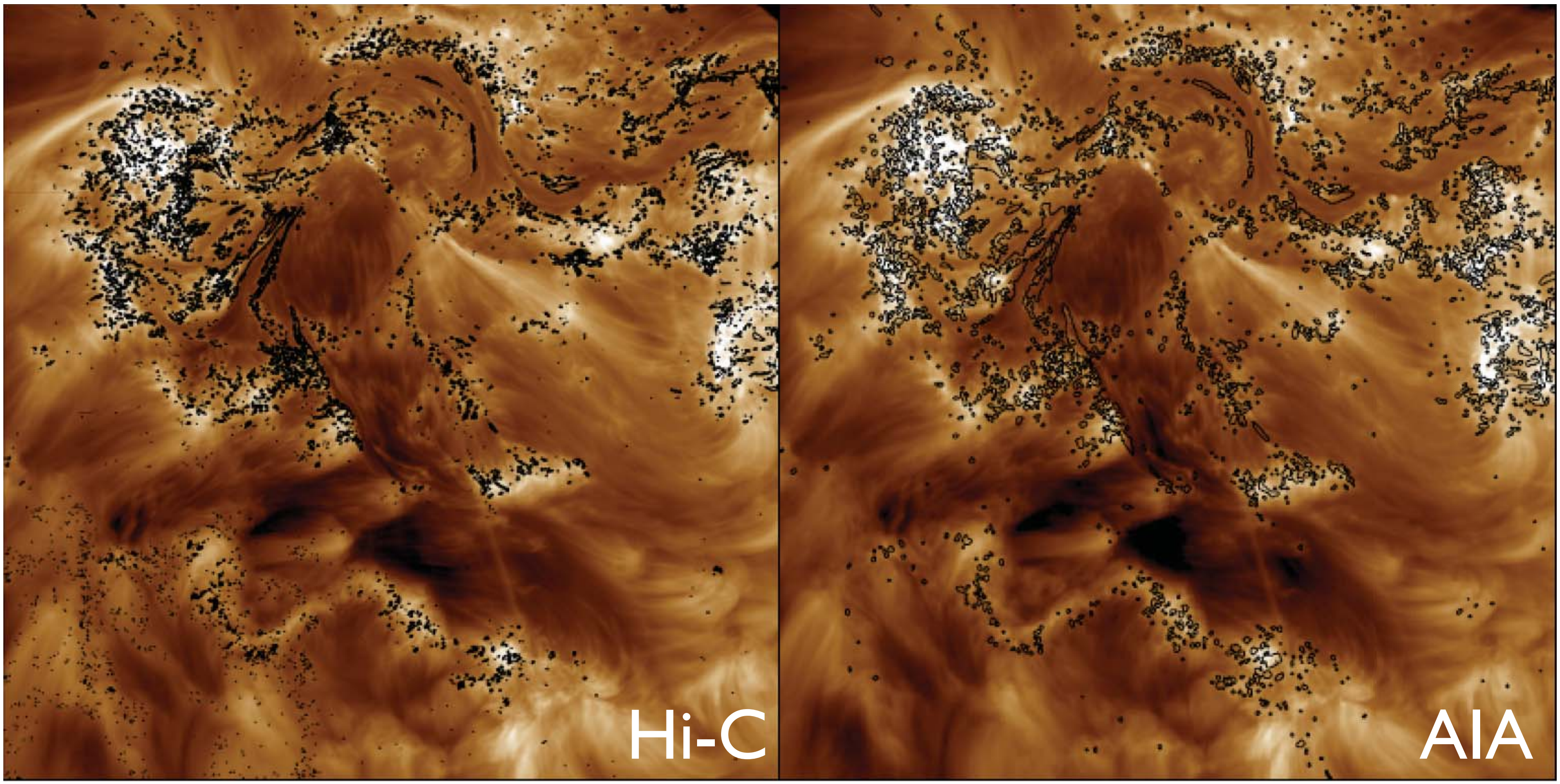
# Transient Events



# Transient Events

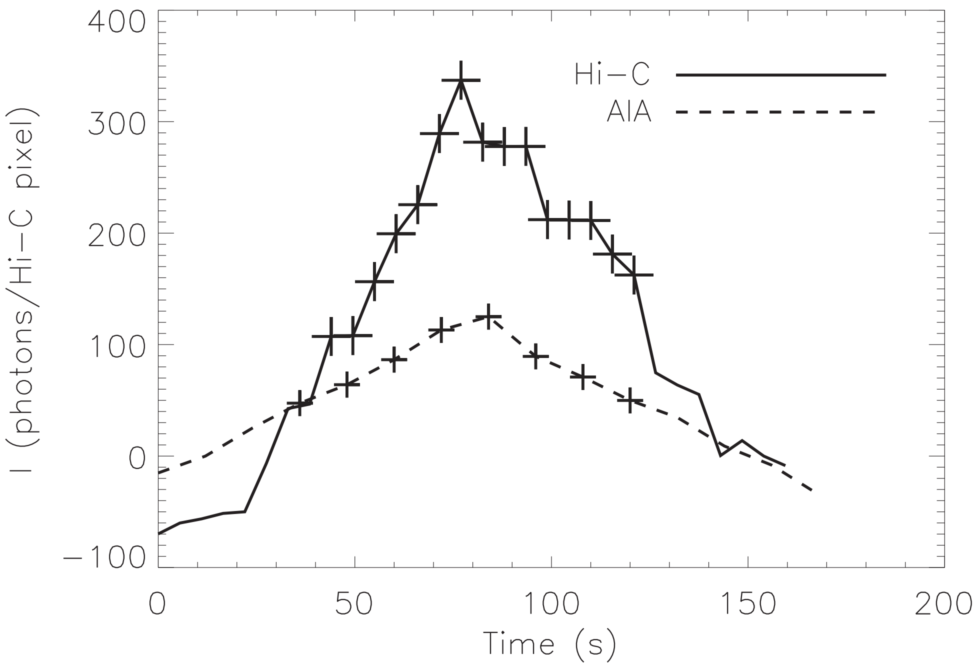


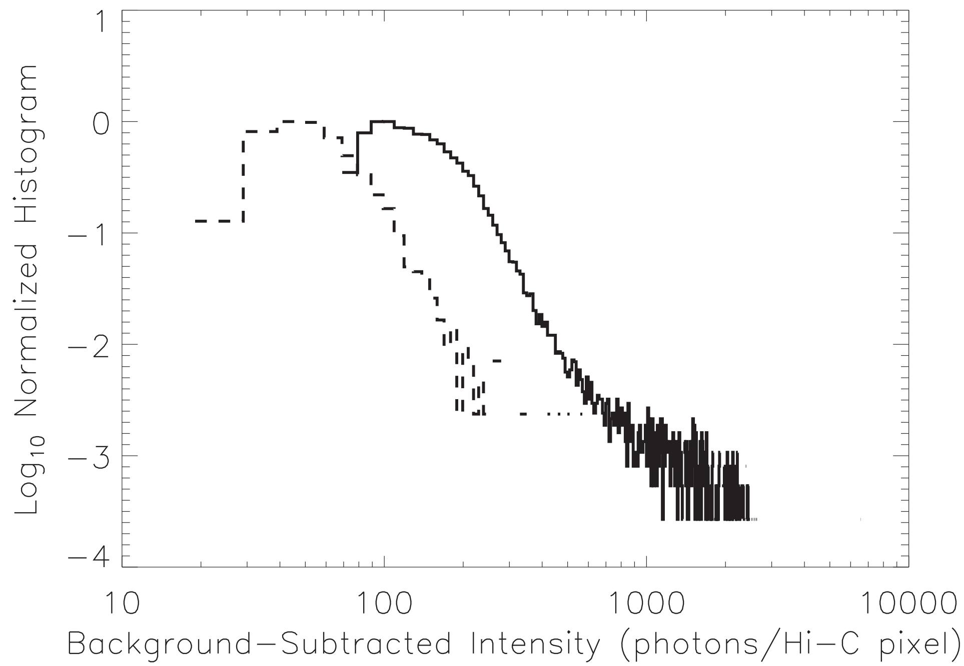
# Transient Events




Found locations of transient events in the Hi-C and AIA data.

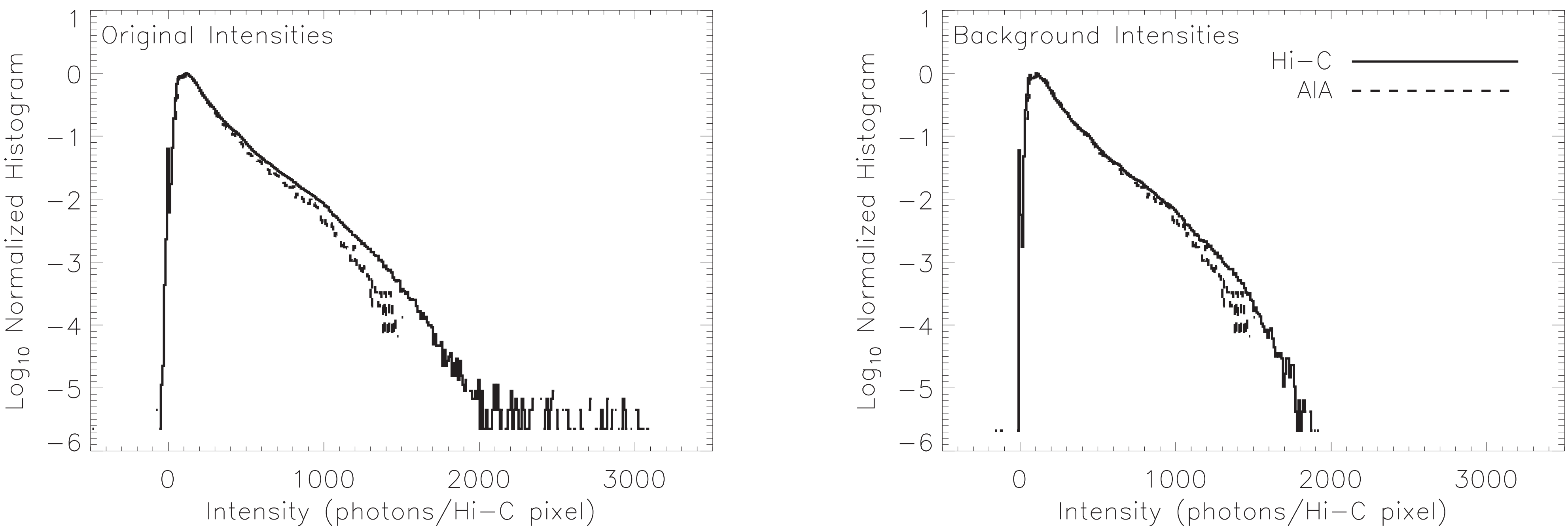
# Transient Events




We found that transient events in Hi-C were 2.5 times brighter than transient events in AIA. We conclude this is due to linear substructure, unresolved by AIA.

# Background




Hi-C reveals that the background varies smoothly, i.e., has little substructure.

Winebarger et al., 2013, in prep

# Conclusions

Hi-C reveals substructure in the solar corona that is not resolved by AIA.

Hi-C reveals quickly evolving structures that cannot be observed with AIA.

Hi-C reveals that there is an intensity enhancement expected for linear substructure, but find the images are dominated by a smoothly varying background.