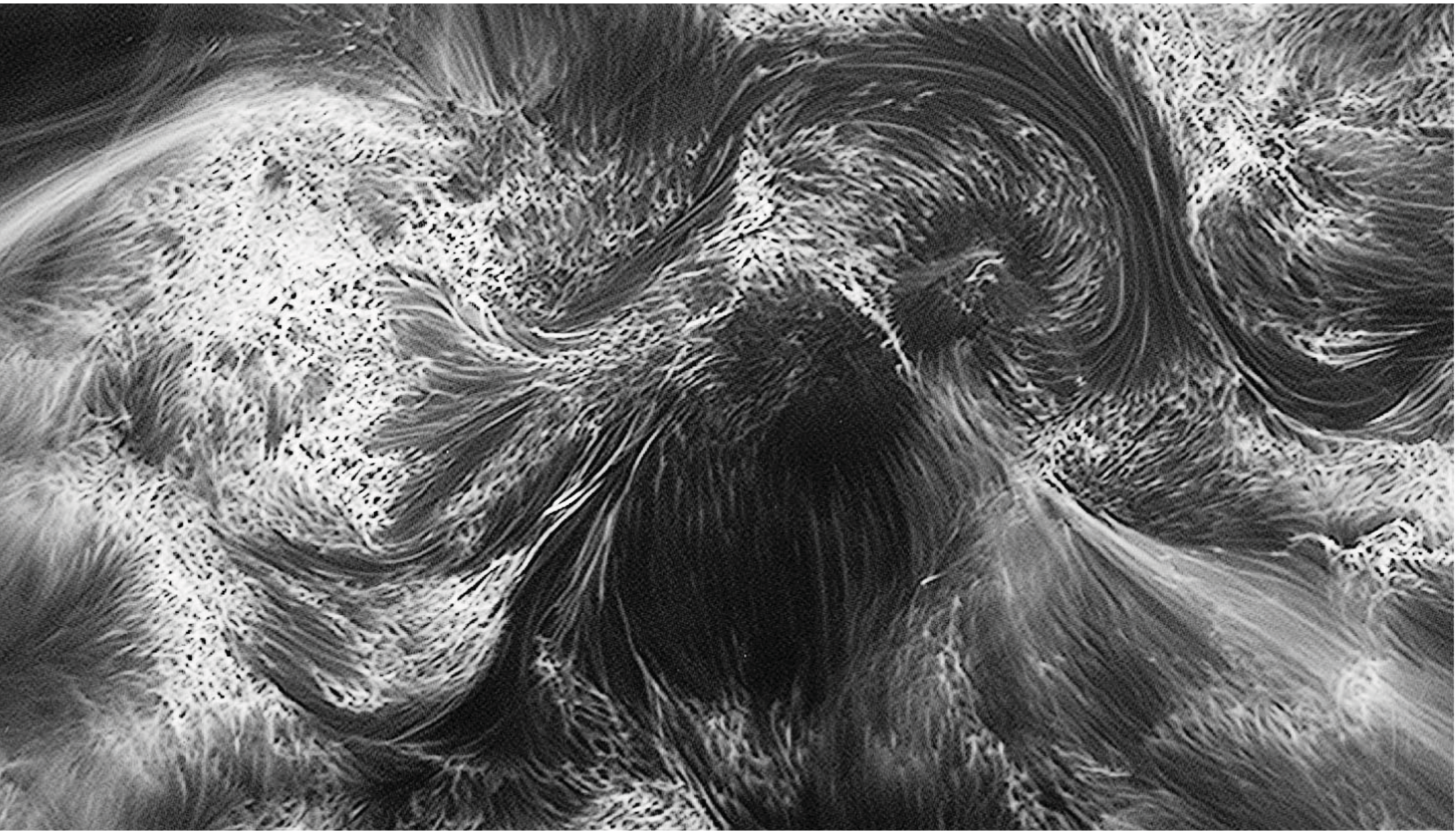
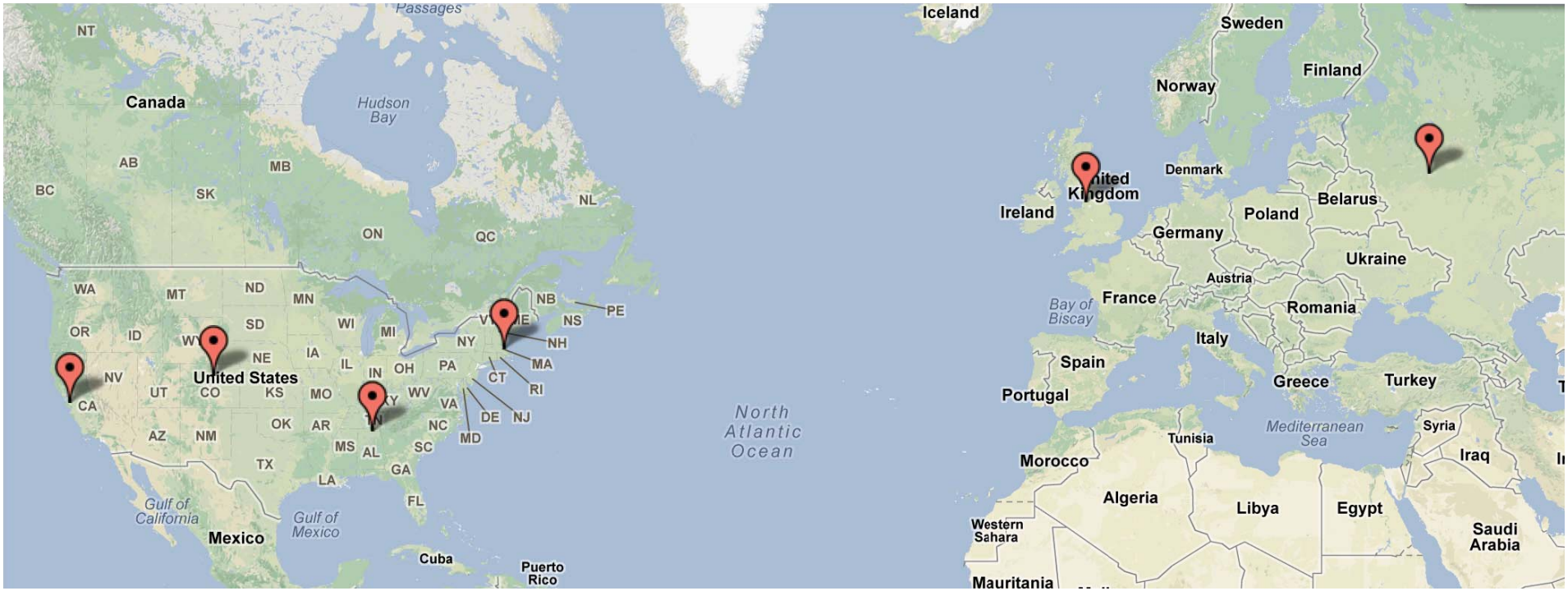


Hi-C First Results

Hi-C 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)

Hi-C Team Members

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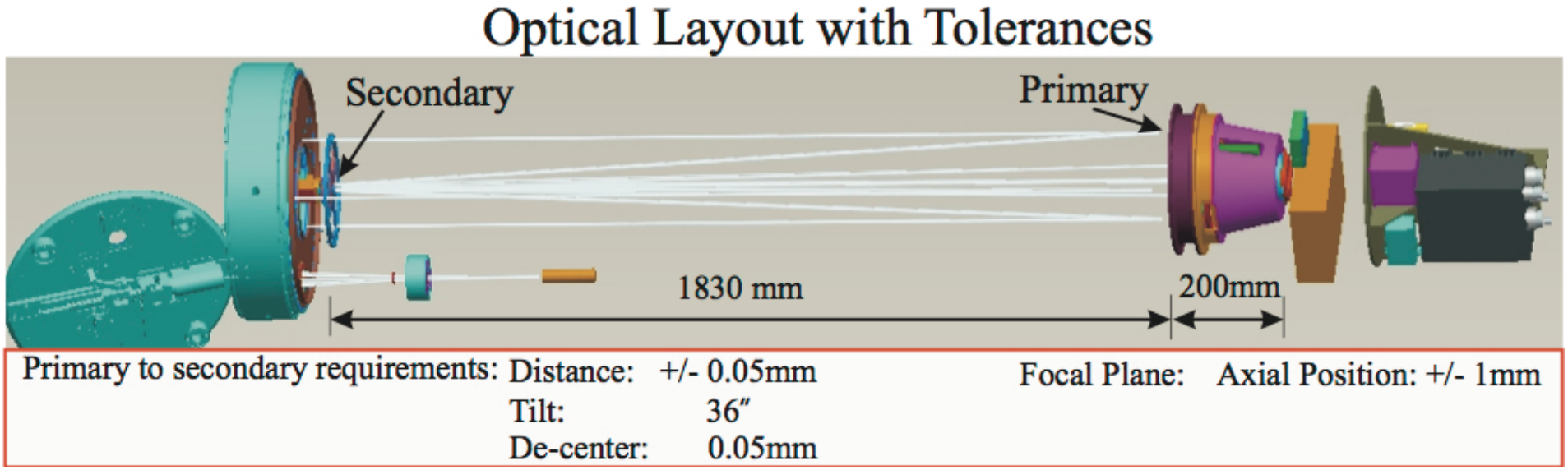
Ken McKracken (SAO)
Mark Ordway (SAO)
David Caldwell (SAO)
Henry Berger (SAO)
Richard Gates (SAO)
Simon Platt (UCLAN)
Nick Mitchell (UCLAN)

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

High-resolution Coronal Imager (Hi-C)



Hi-C is a narrowband EUV imager. The wavelength band is centered on 193 Å.

Multilayer coatings by David Windt, RXO LLC.

Hi-C Telescope Optical Design

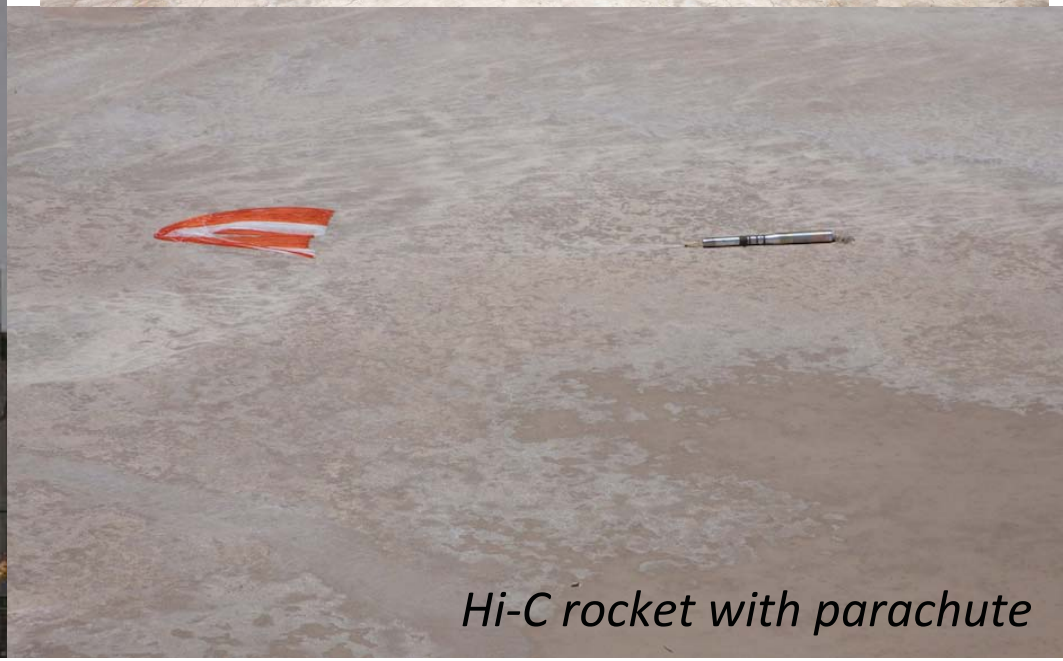
Telescope Properties:		**Primary Mirror:**	
Focal Length	23.9 m	Radius of Curvature	4000±4.0 mm
Plate Scale	114 µm/arcsec	Diameter	240 mm
Focal Ratio	f/109	RMS slope error	0.4 µrad
Field of View	6.8x6.8 arcmin		
RMS Spot Diameter (averaged over f.o.v.)	0.08 arcsec	**Secondary Mirror:**	
CCD Camera:		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

Hi-C Launch

Hi-C was launched from White Sands Missile Range on 11 July 2012

Hi-C Launch and Recovery

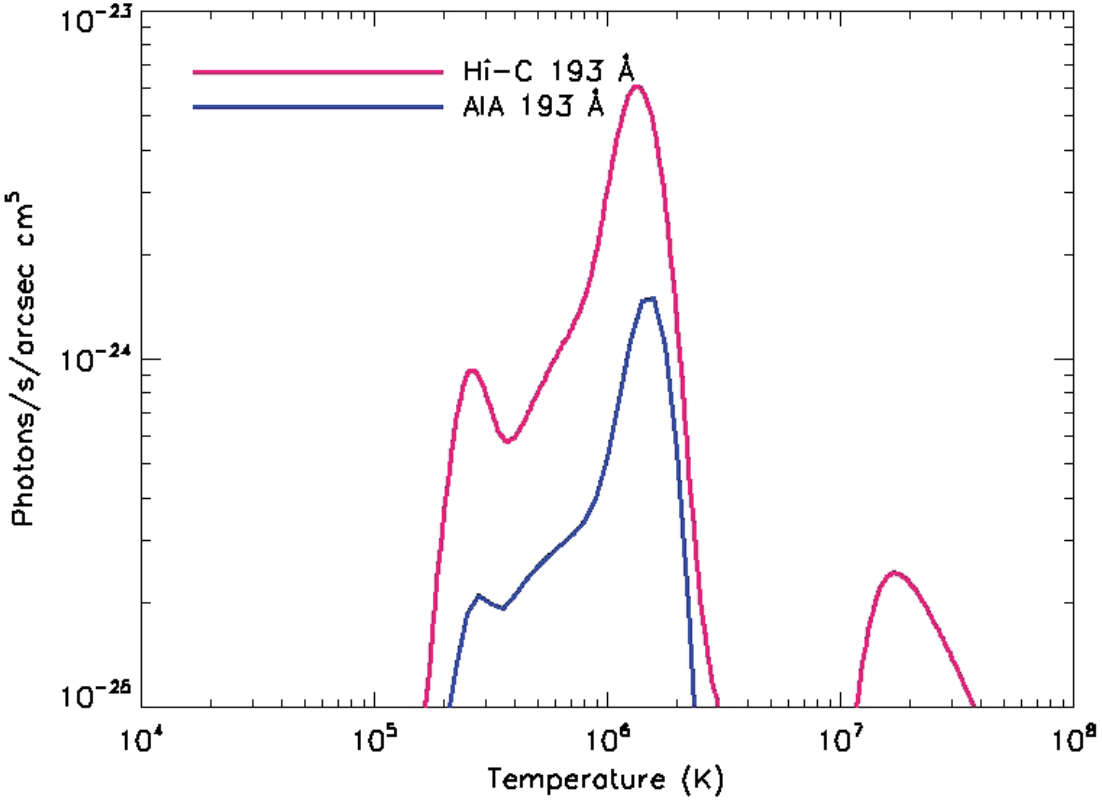
Hi-C recovery team



Hi-C rocket with parachute

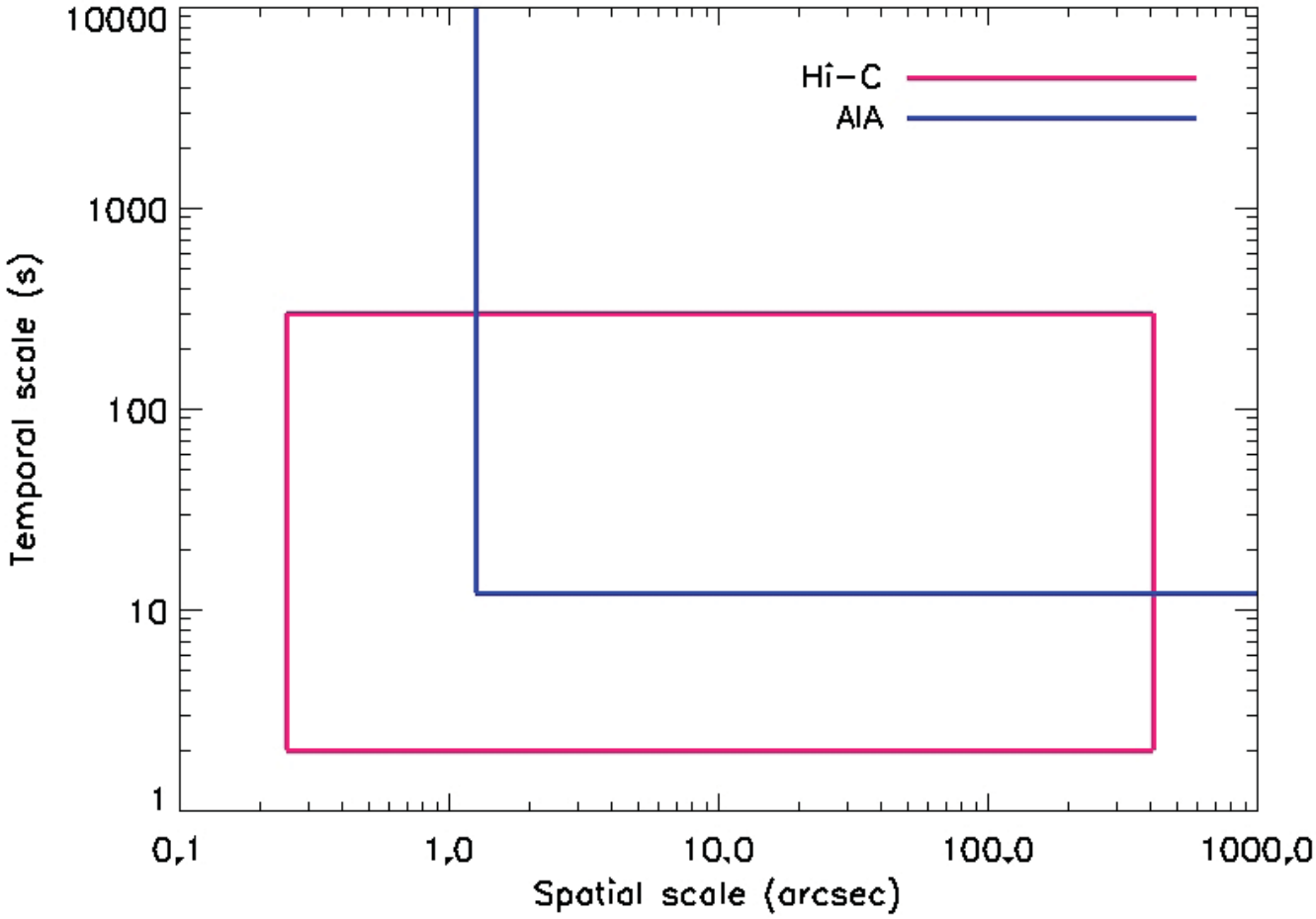
Hi-C Passband

- The Hi-C 193 Å passband is similar to the 193 Å passband on the Solar Dynamics Observatory (SDO) Atmospheric Imaging Assembly (AIA).
- Hi-C has roughly 5 times the effective area of AIA.

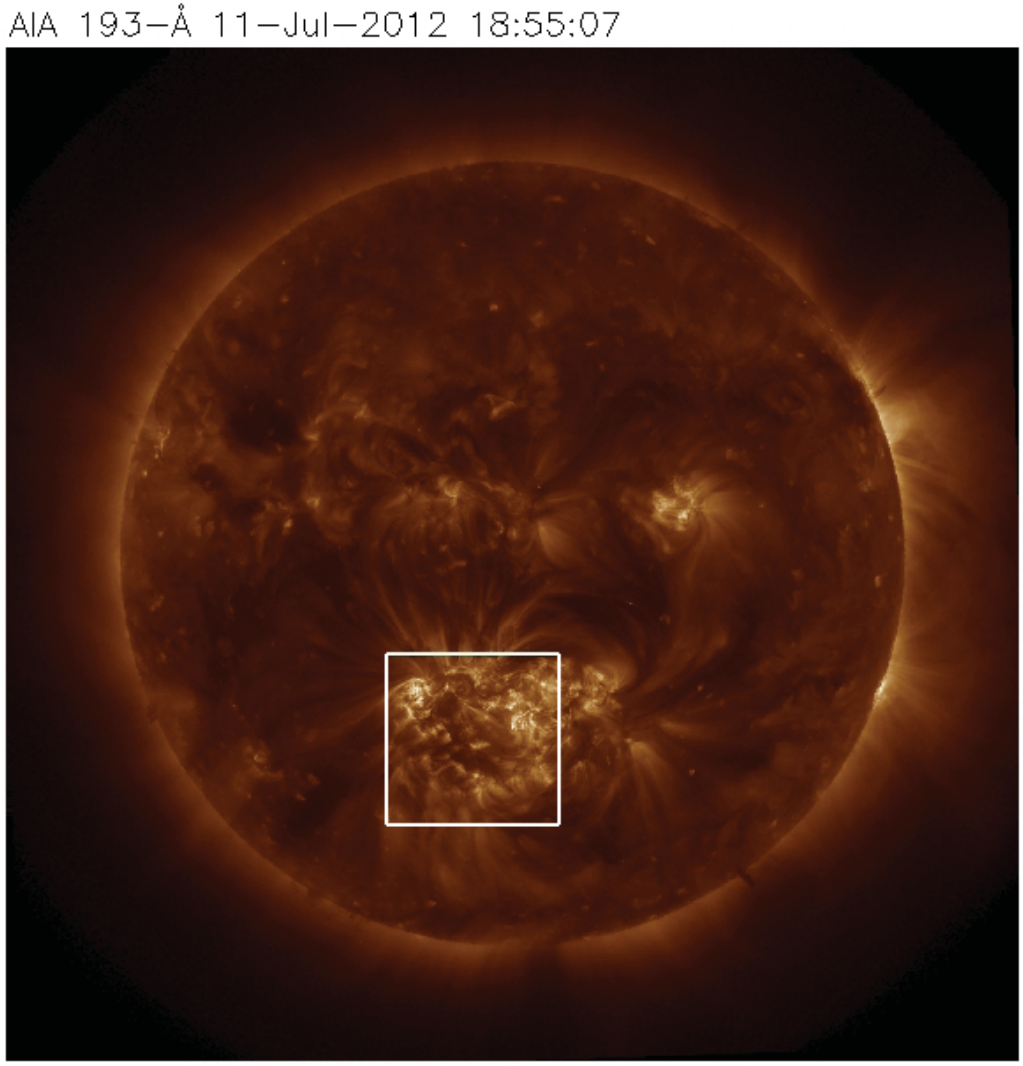


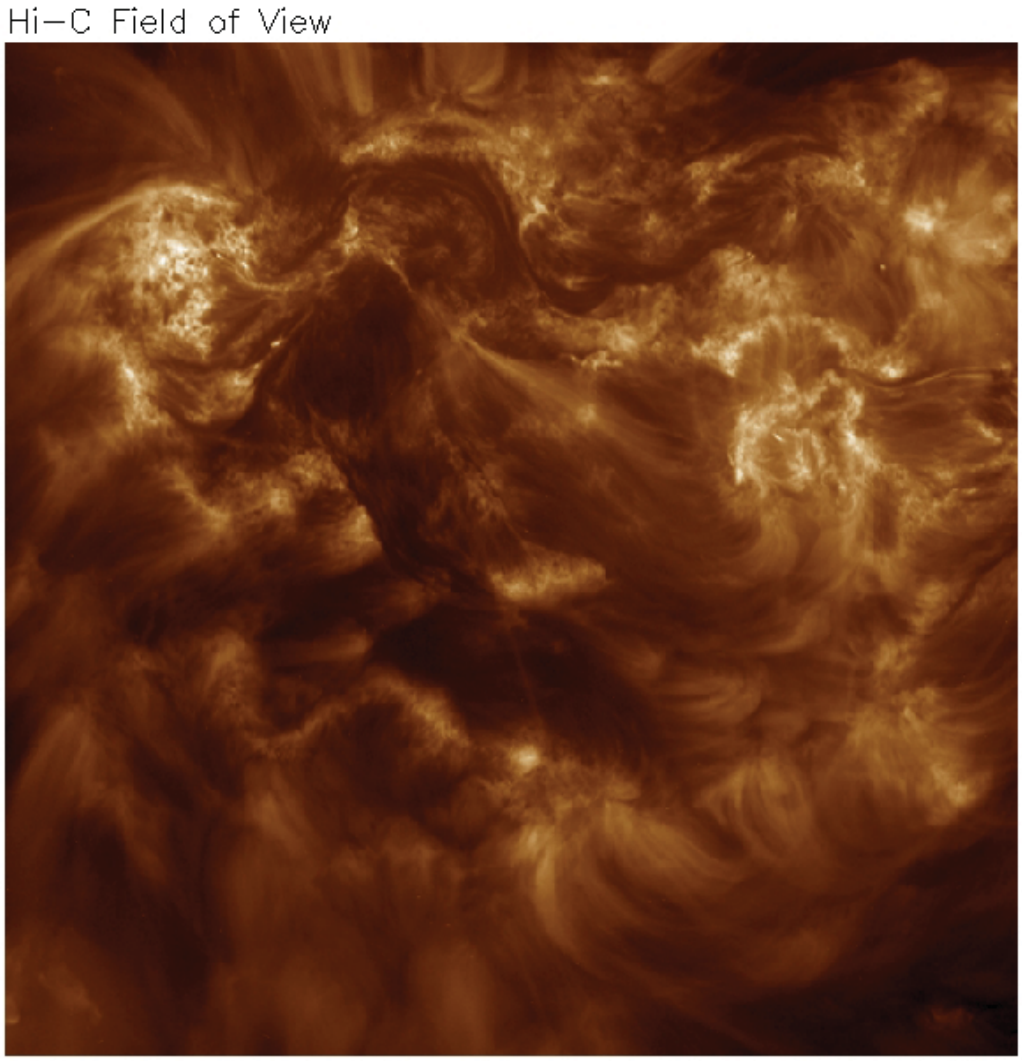
Hi-C Discovery Space

- The spatial resolution of Hi-C is five times better than AIA .
- The cadence of Hi-C is 2.5 – 6 times better than AIA.



Hi-C Target





The Hi-C target was Active Region 11520

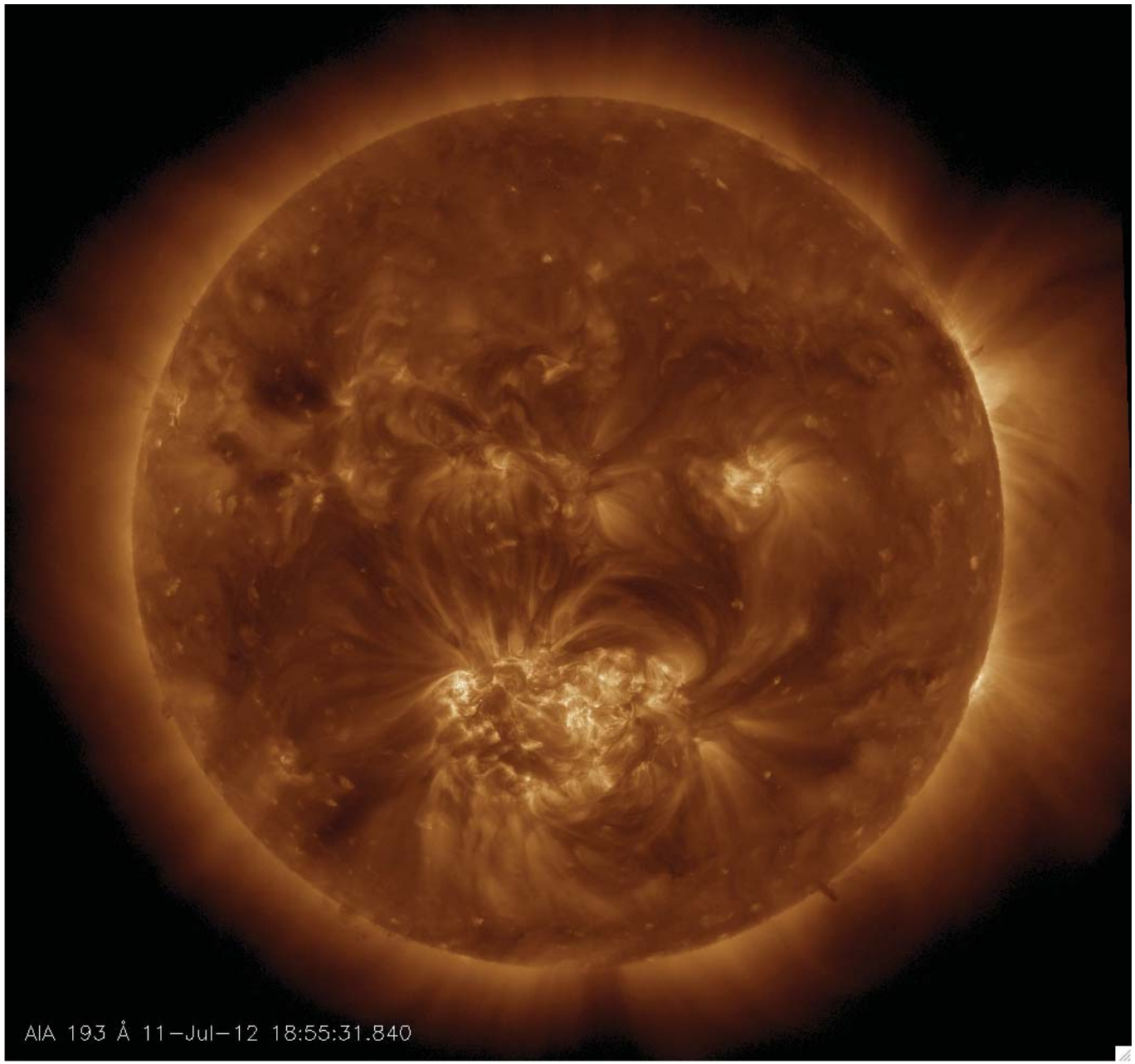
Hi-C Data

- Hi-C collected data for 345 s.
- Small shift in pointing during flight

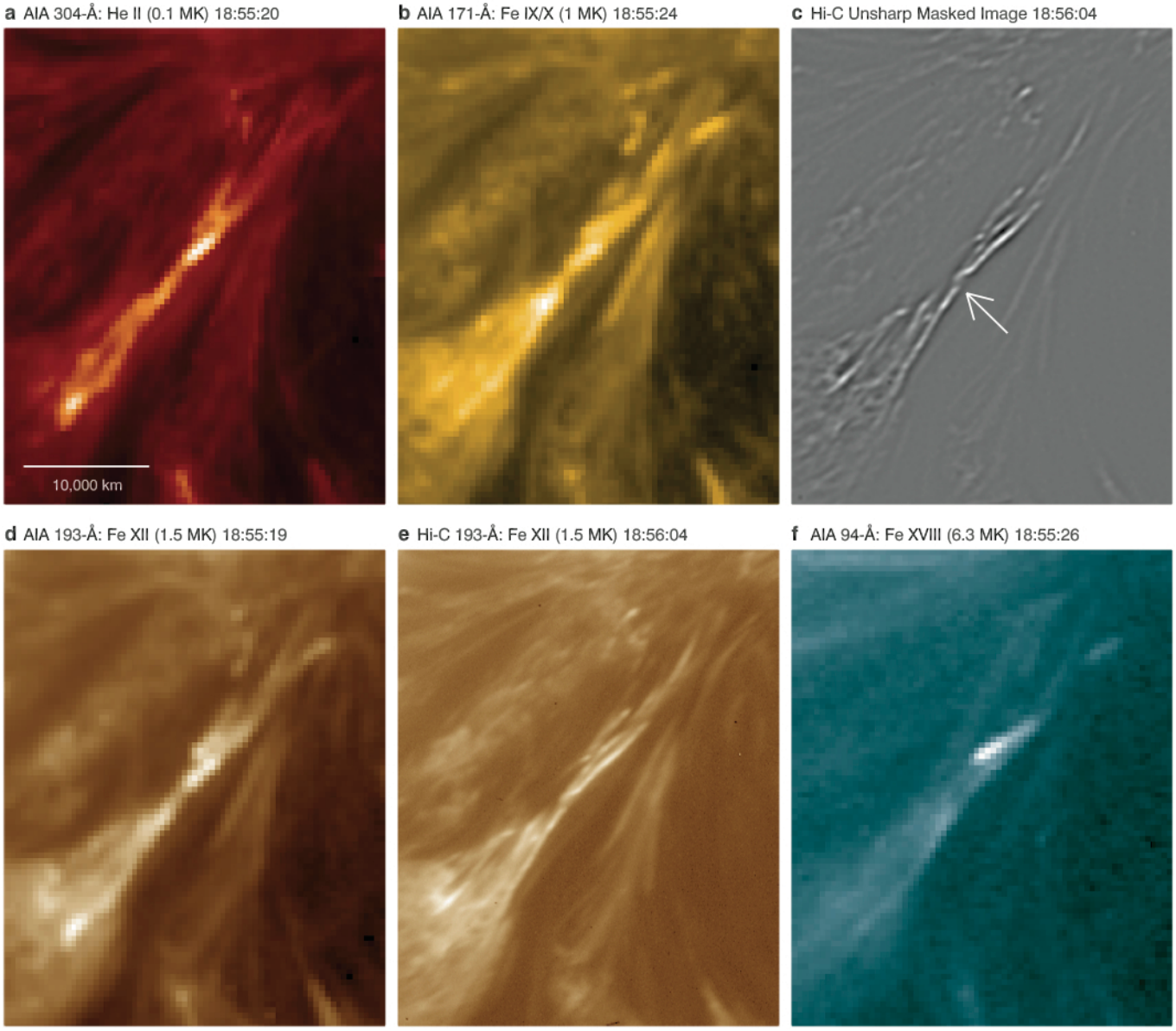
- Full frame (4kx4k) data
  - 30 full resolution images
  - 2 s exposures / 5 s cadence

- Partial frame (1kx1k) data
  - 86 full resolution image
  - 0.5 s exposures / 1.4 s cadence

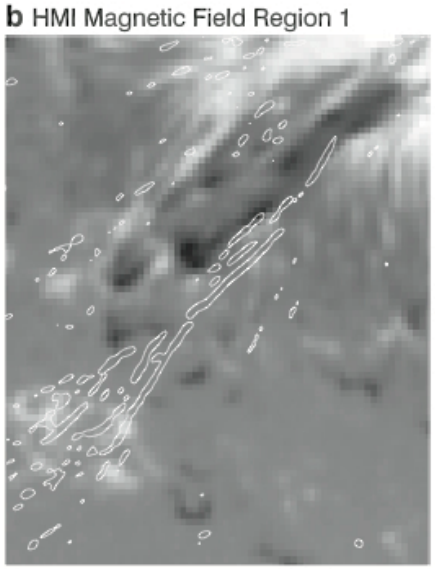
Hi-C First Results



Component Reconnection

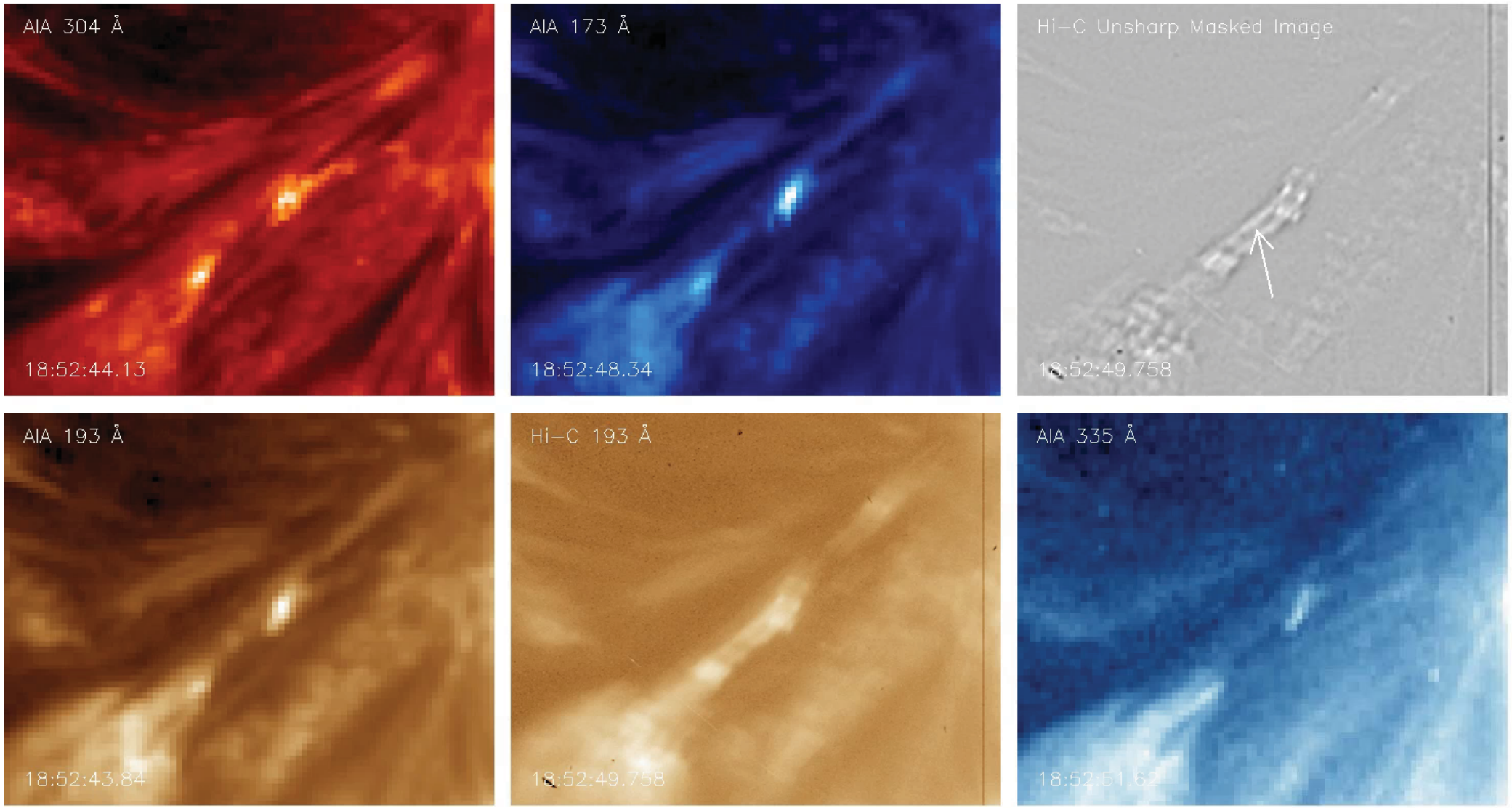


- Magnetic field braiding has been suggested as a energy storage mechanism in the solar corona.
- Hi-C observed braided magnetic field.



Cirtain et al, 2013, Nature

Component Reconnection

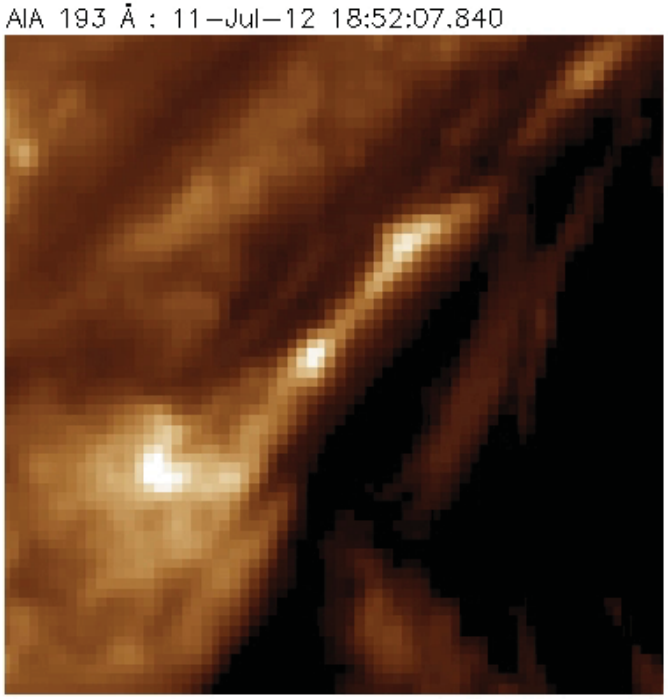


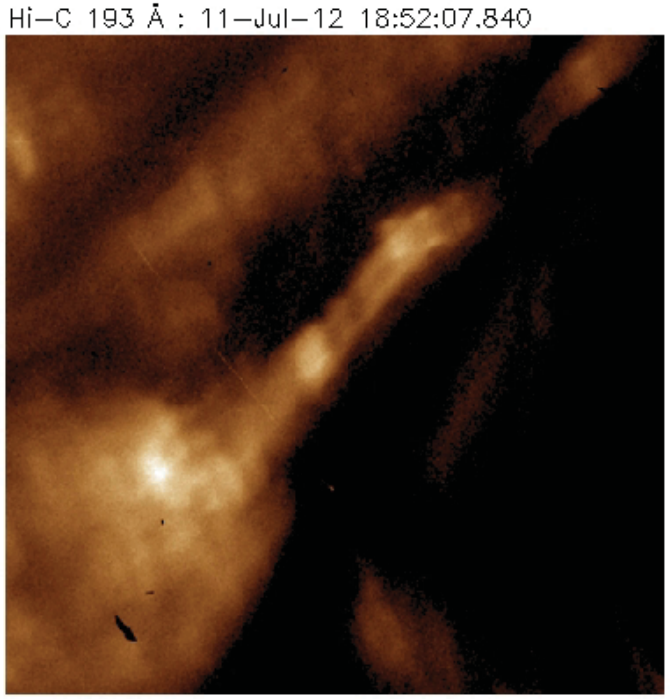
Shortly after the Hi-C flight, a small flare was observed at the field line crossing.

Velocities along strands measured to be ~ 150 km/s.

Cirtain et al, 2013, Nature

Component Reconnection

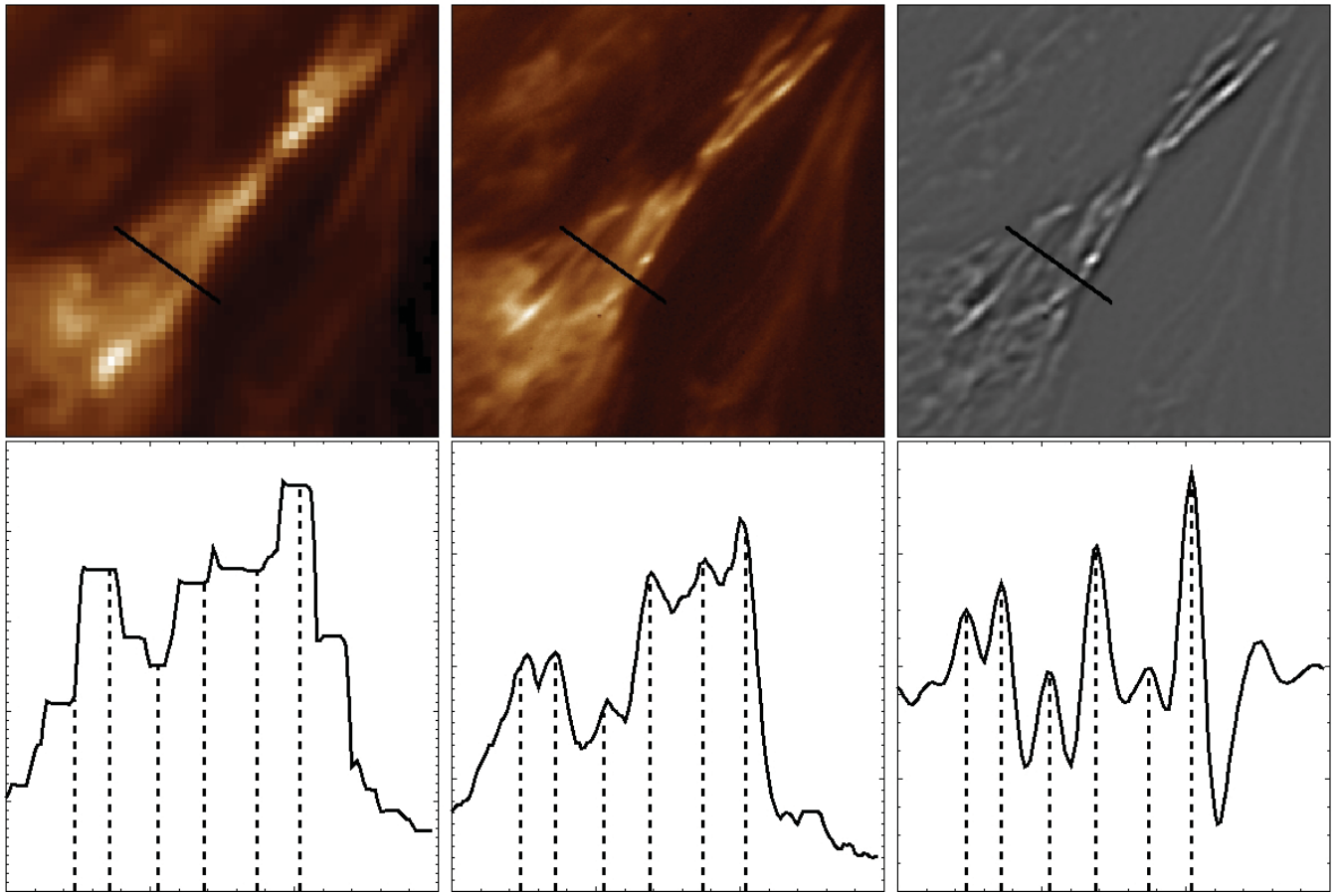




Velocities along structure estimated to be 150 km/s.

Cirtain et al, 2013, Nature

Component Reconnection

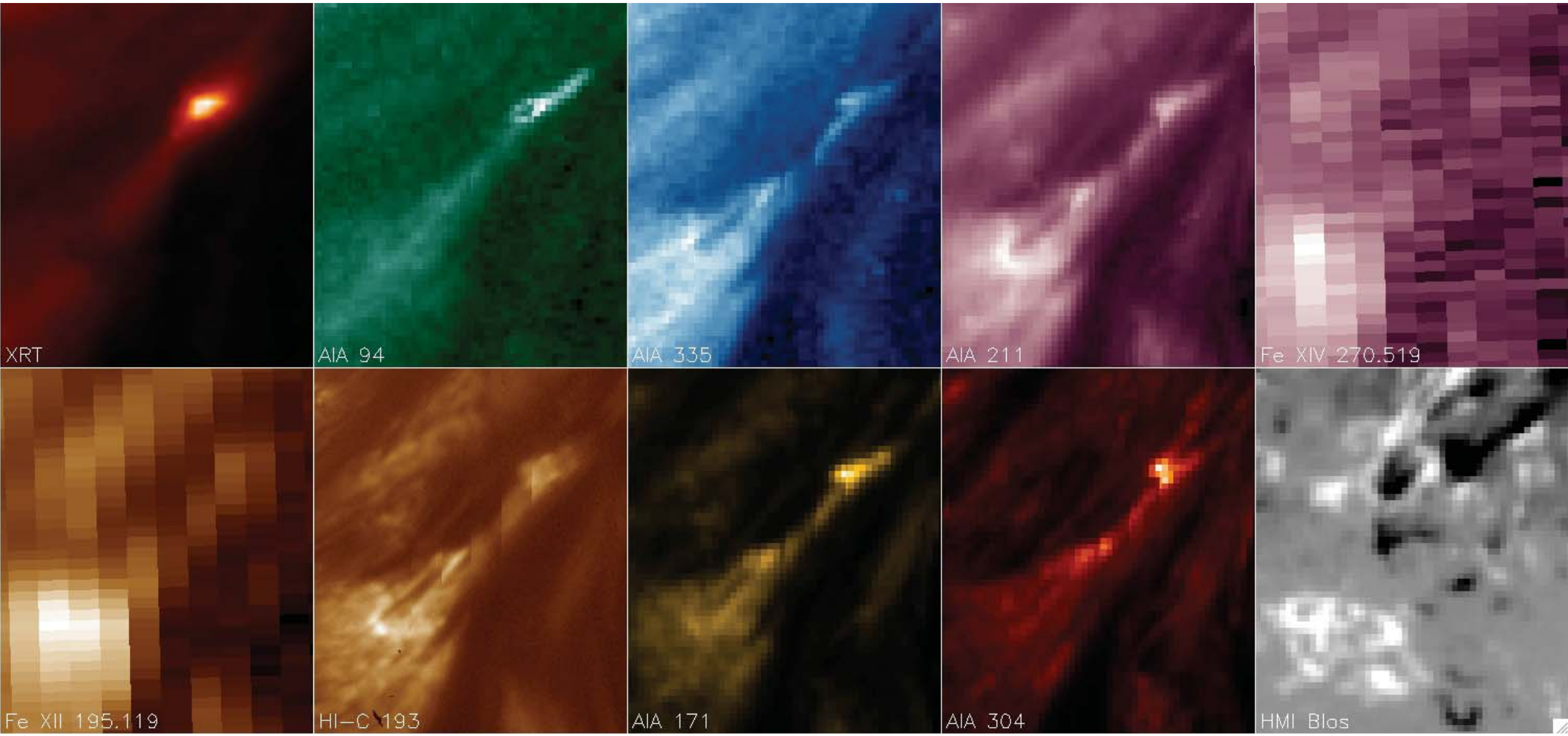


- Cuts across the braided loop show that the loop is composed of at least 6 strands.

Winebarger et al, in prep.

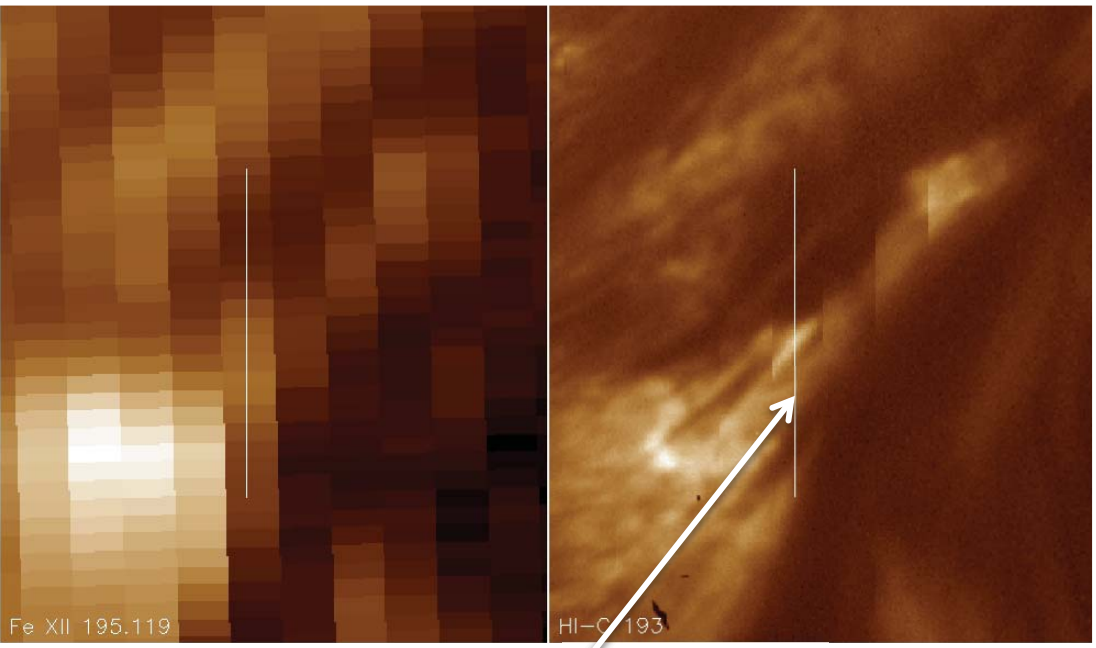
Component Reconnection

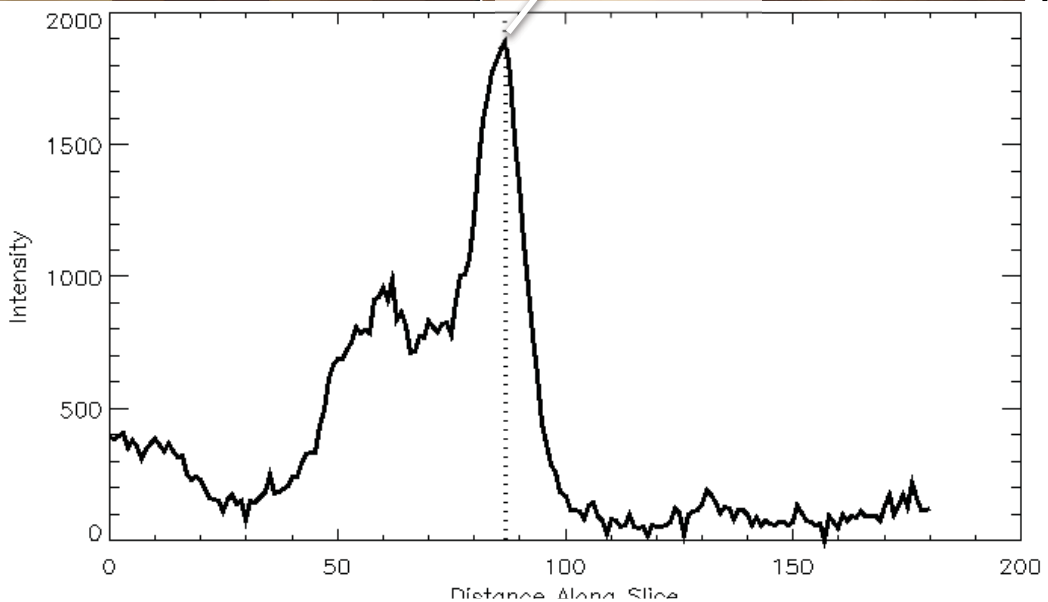
← time



*Winebarger et al, ApJ, **771**, pp. 10, 2013*

Component Reconnection





From EIS, we determine:

- Temperature = 1.8 MK
- Densities = 0.5-7 x 10^{10} cm^{-3}

From Hi-C, we determine:

- radius of structure = 435 km.

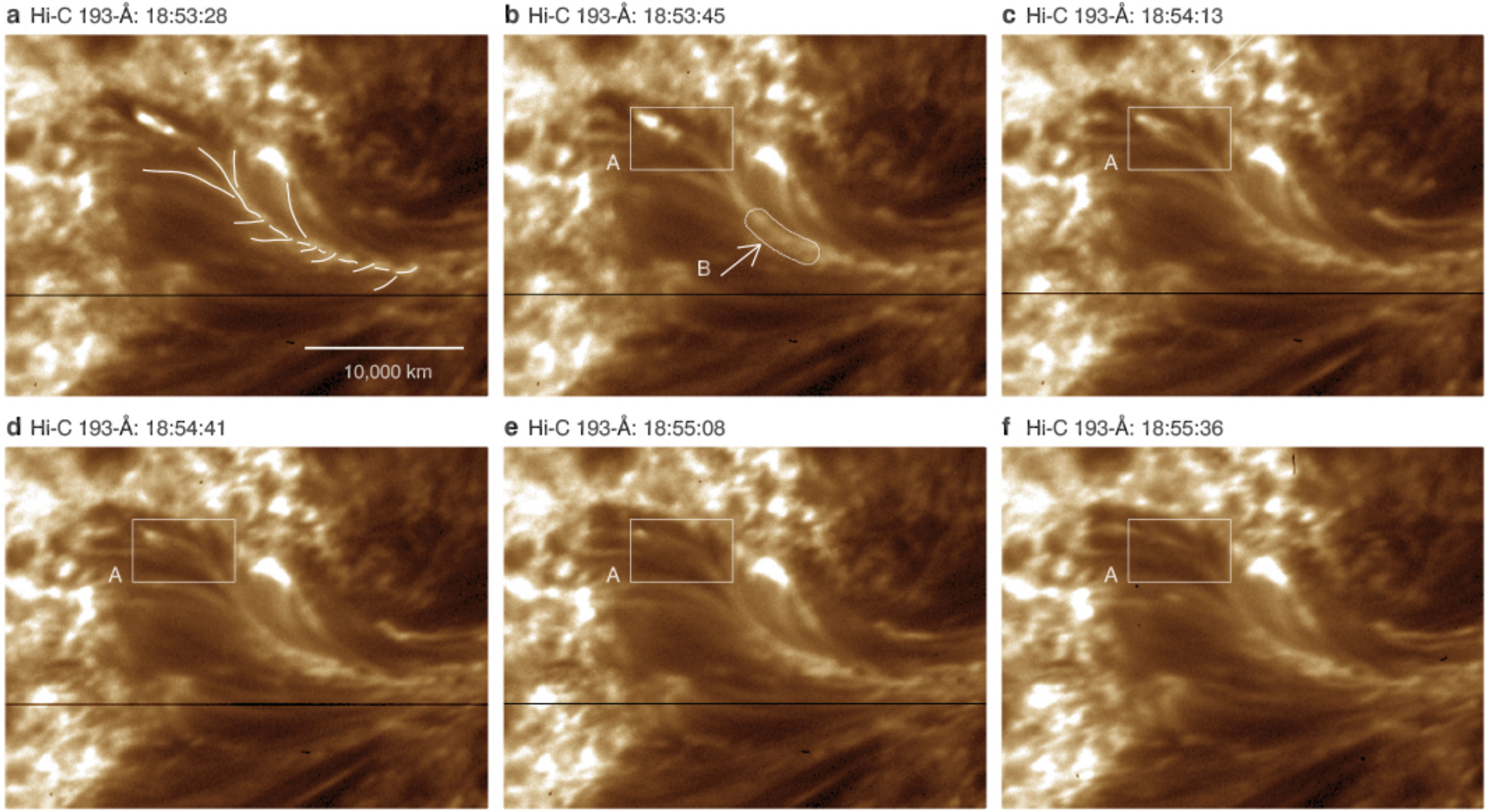
To obtain observed Hi-C intensity, we need:

Density = 1.15 x 10^{10} cm^{-3}

Because this is in the range of densities determined from EIS, we conclude the substructure is likely resolved.

*Winebarger et al, ApJ, **771**, pp. 10, 2013*

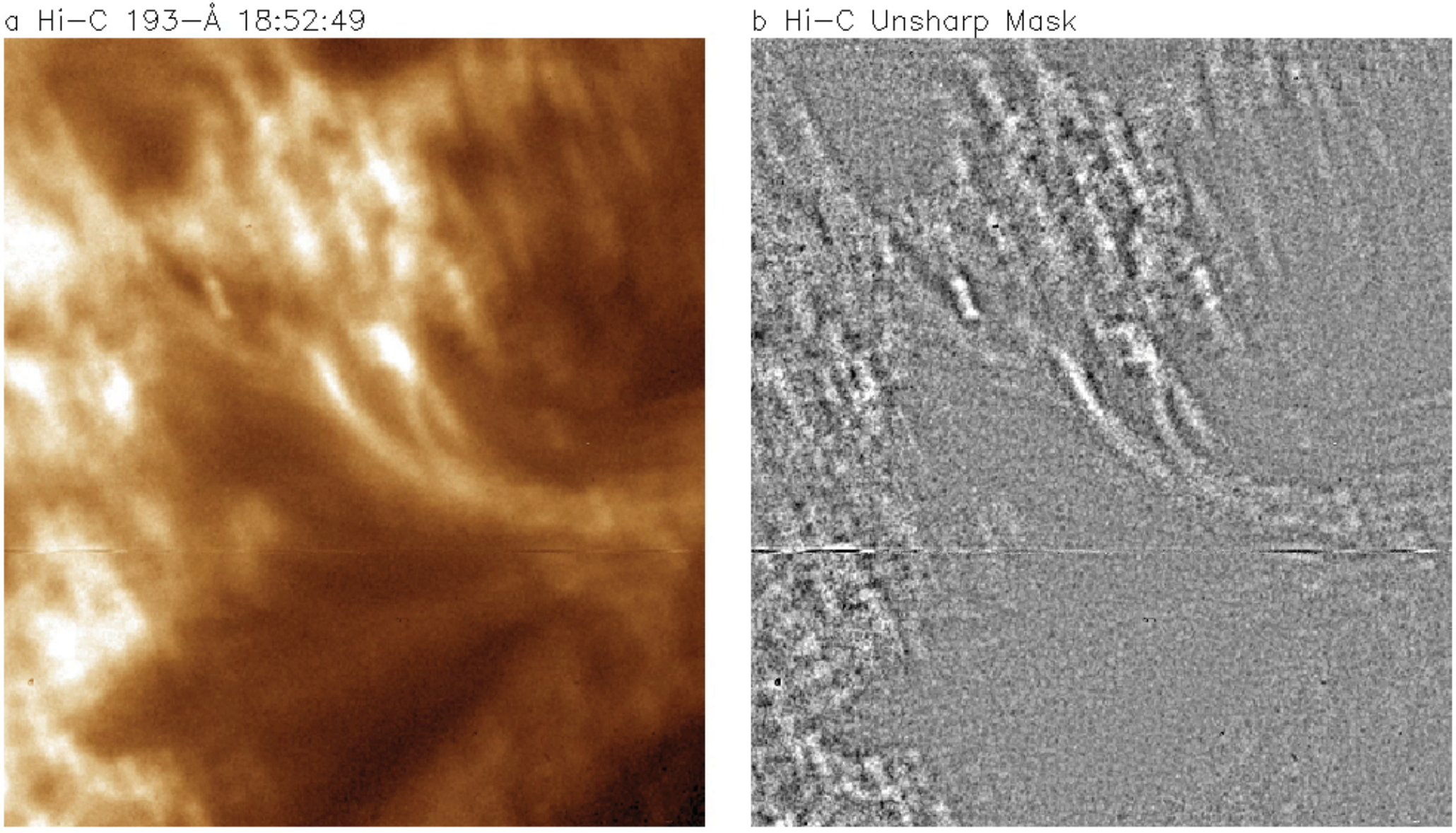
Braided Loop



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

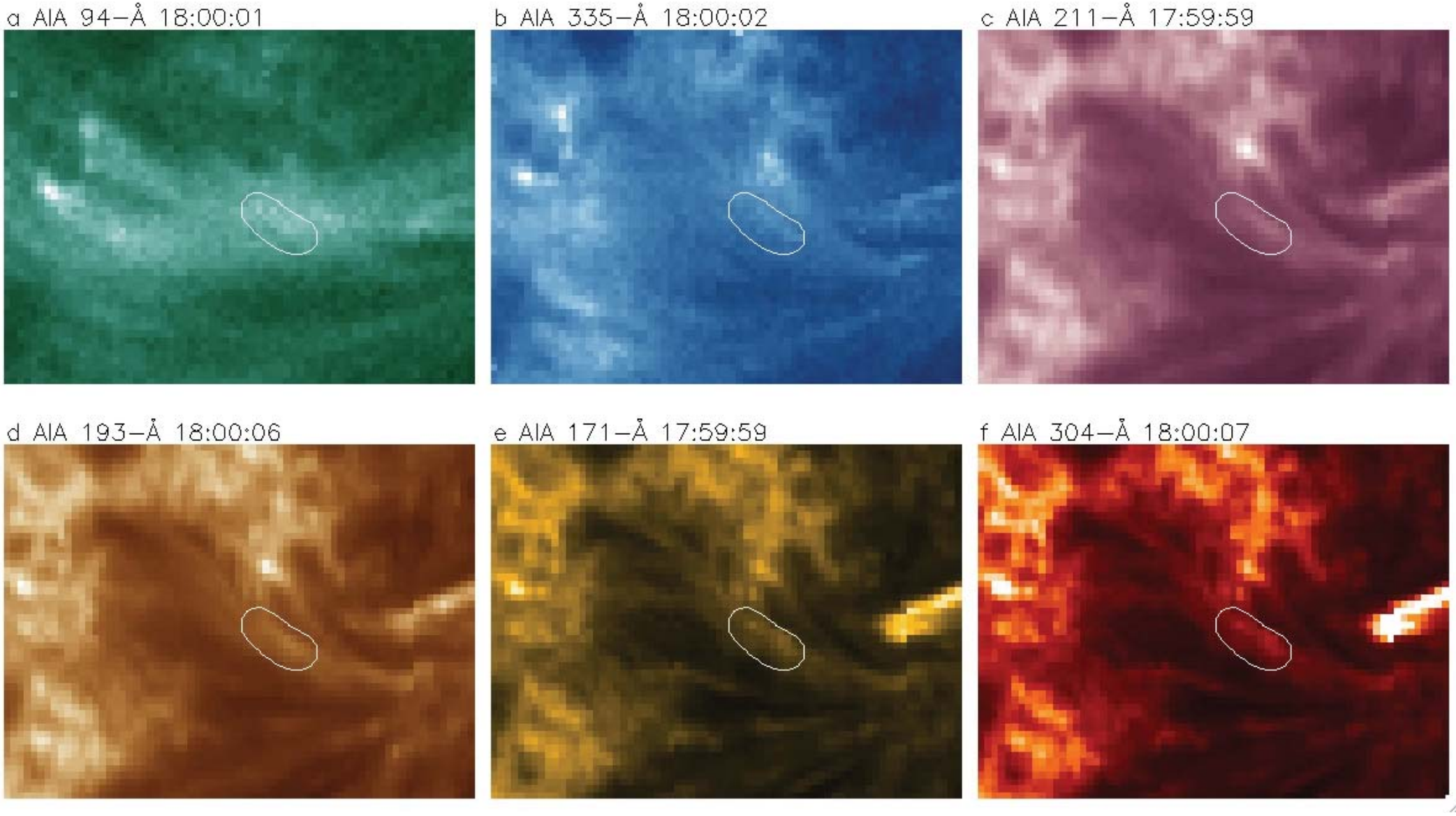
Cirtain et al, 2013, Nature

Braided Loop



Cirtain et al, 2013, Nature

Braided Loop



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

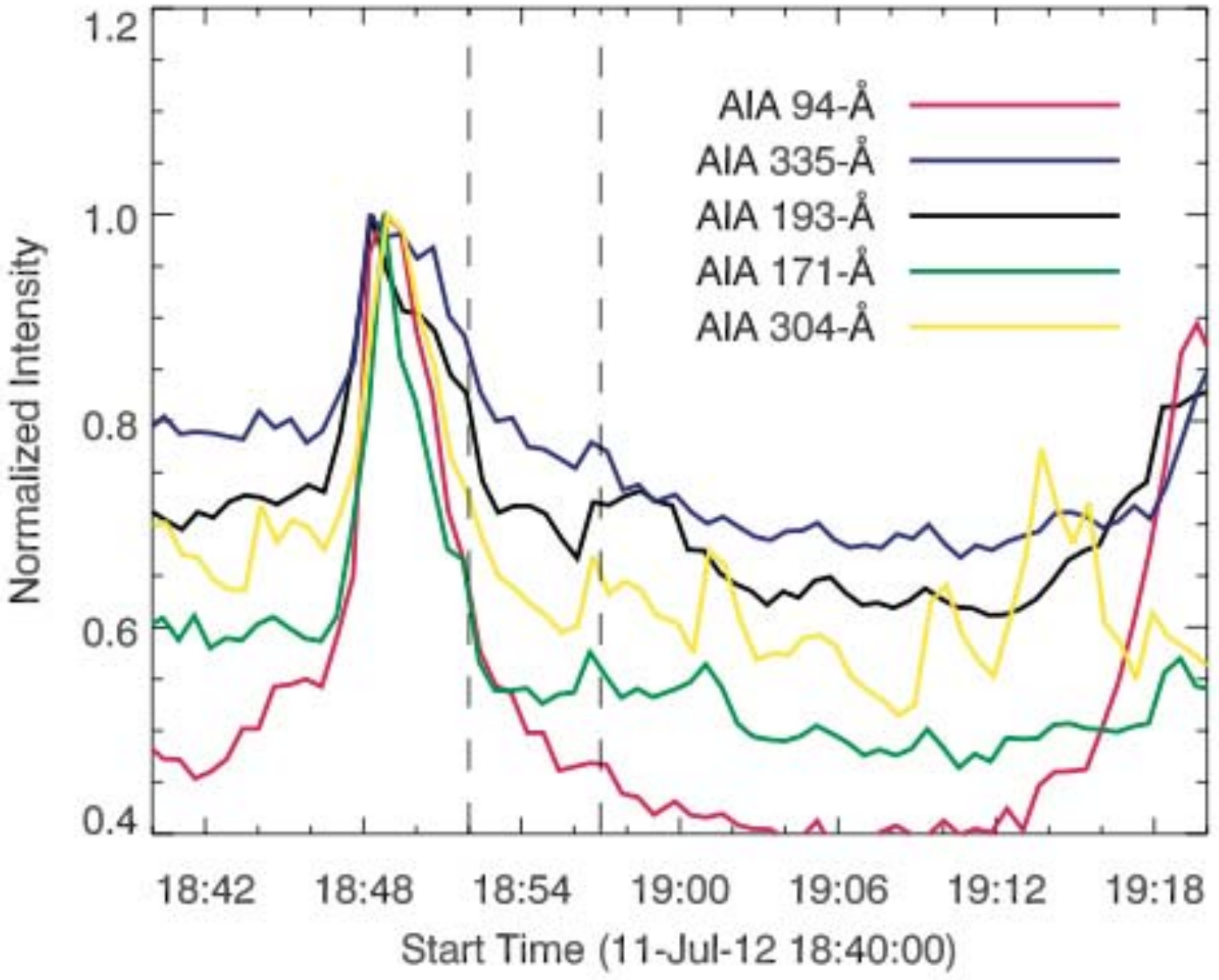
Cirtain et al, 2013, Nature

Braided Loop

Hi-C observed the loop in decline after heating event.

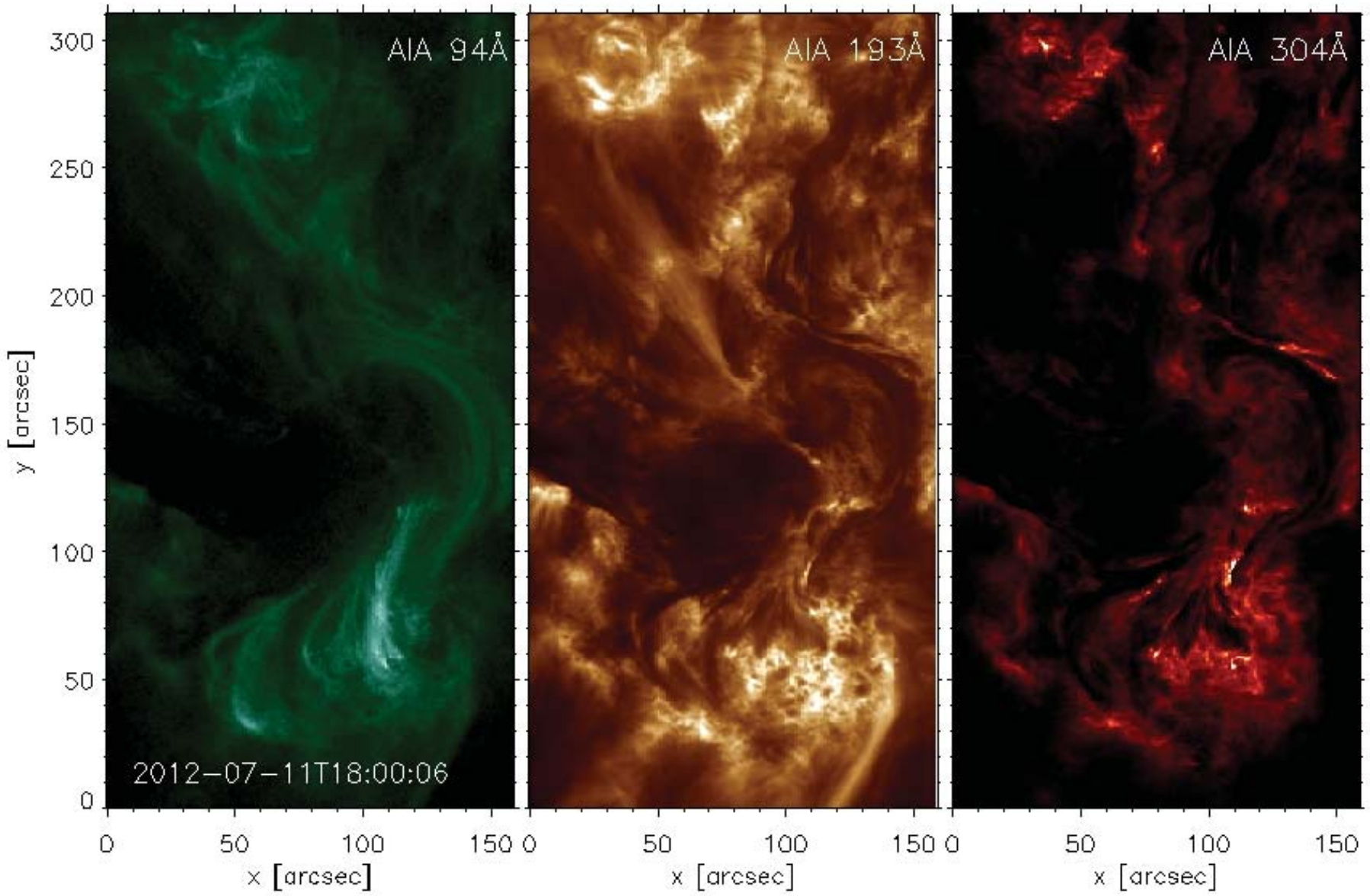
B_ϕ ~ *100G*
V ~ 10^{11} km^3
$(B_\phi)^2 V/8\pi = 10^{29}$ ergs

Note: From EIS and AIA data an estimate of the radiated power loss is ~ 10^{26} ergs sec^{-1}



Cirtain et al, 2013, Nature

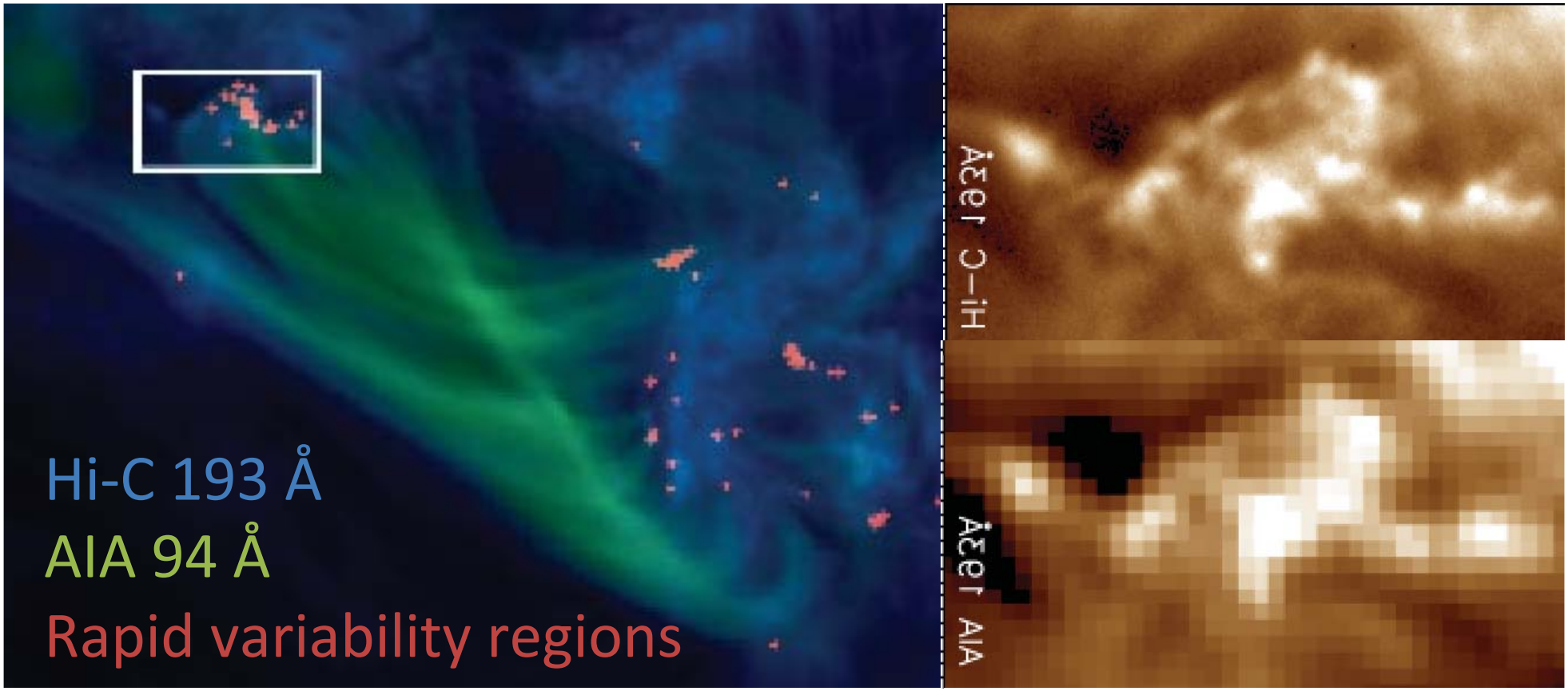
Dynamic Moss



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

*Testa, DePontieu, et al., ApJ, **770**, L7 (2013)*

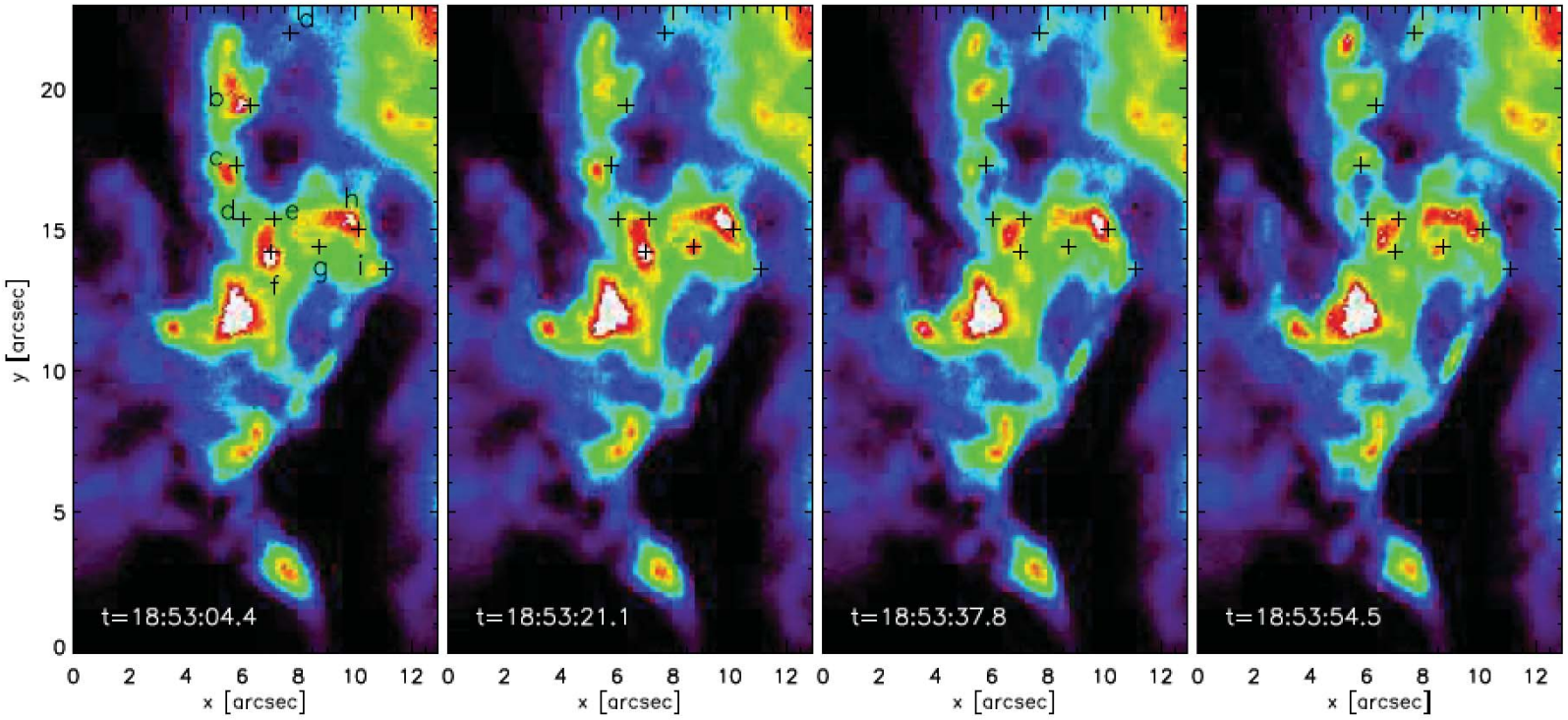
Dynamic Moss

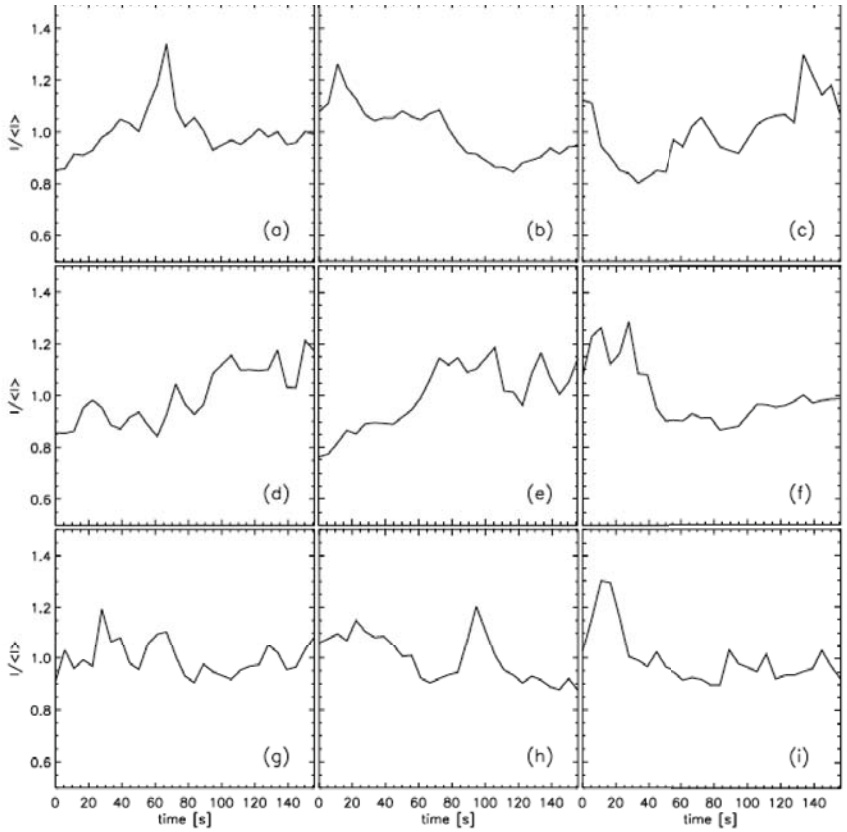


- Dynamic moss occurs at footpoint of high temperature loops.

*Testa, DePontieu, et al., ApJ, **770**, L7 (2013)*

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, DePontieu, et al., ApJ, **770**, L7 (2013)*

Summary

- For the first time in the corona, Hi-C revealed magnetic braiding and component reconnection consistent with coronal heating.

- Hi-C shows evidence of reconnection and heating in several different regions and magnetic configurations with plasma being heated to $0.3 – 8 \times 10^6$ K temperatures.

- Surprisingly, many of the first results highlight plasma at temperatures that are not at the peak of the response functions.

Hi-C and you

- **All** Hi-C data is available via the VSO:

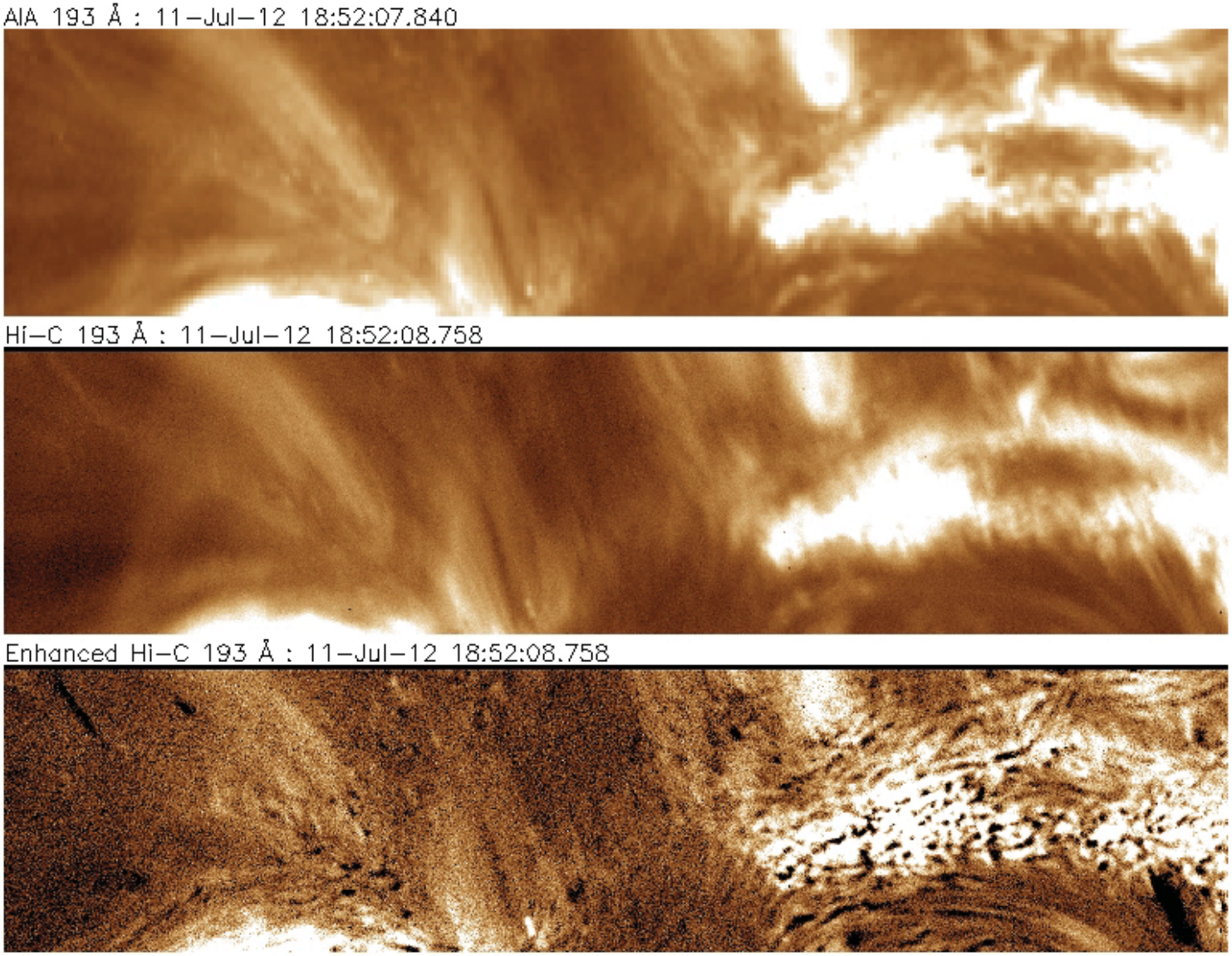
  http://sao.virtualsolar.org/VSO/DataProvider/MSFC/Hi-C/

- Data analysis resources and IDL calibration software:

  http://hic.msfc.nasa.gov/data_analysis.html

SAO and MSFC, along with our science and instrument partners, will submit a suborbital mission proposal for Hi-C. Passband***s*** will be 17.4 and 30.4nm. Cadence will be increased from 5.4 sec to < 2sec. Camera electron noise (our largest source of noise in Hi-C I) will drop from 100+ e^{-1}/pixel to < 10 e^{-1}/pixel (AIA is about 25)

“Dots”

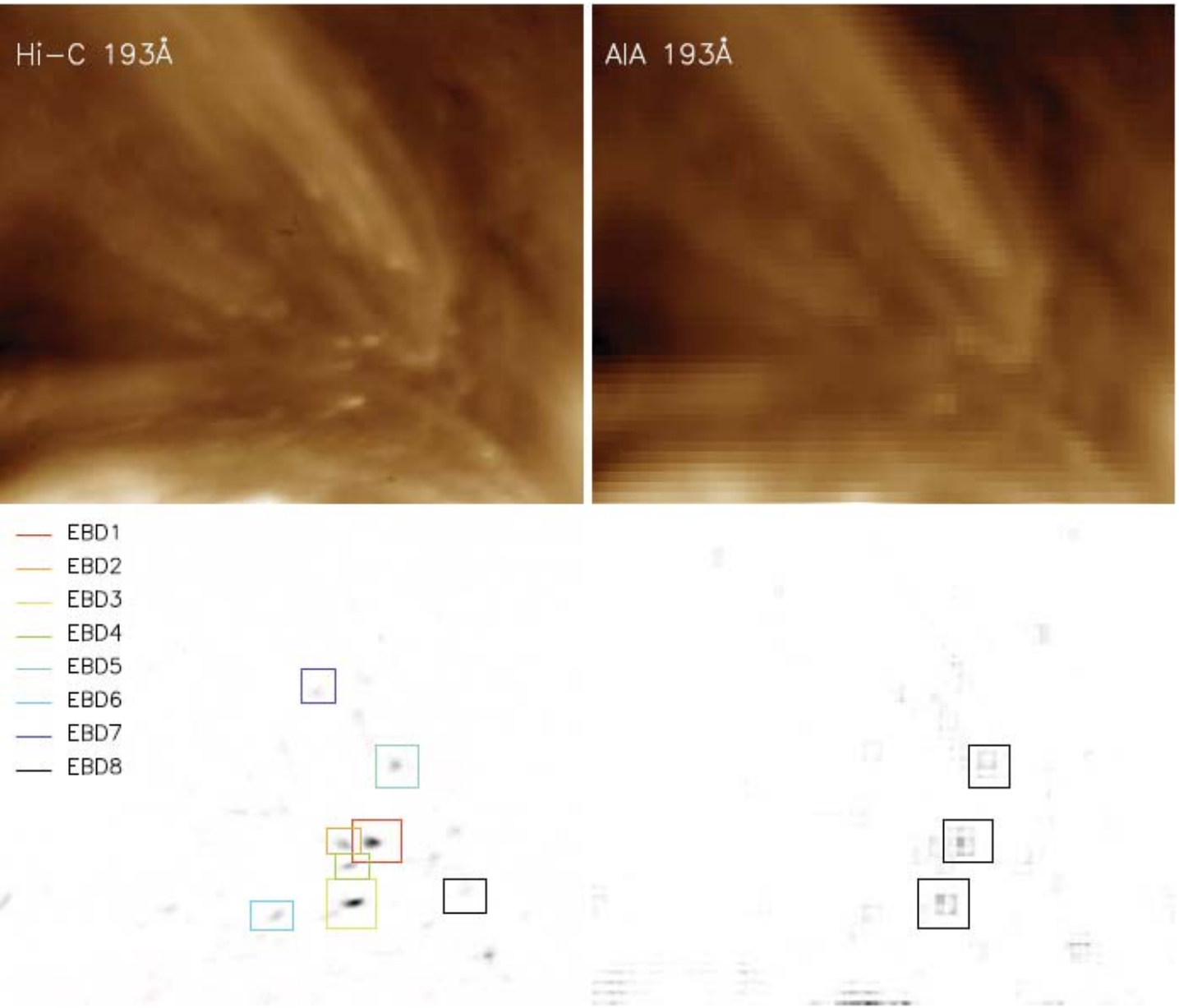


``Dots'' are small-scale, short-lived brightenings that occur at the periphery of the active region.

They may be associated with open fields.

Regnier, Walsh, in prep.

“Dots”



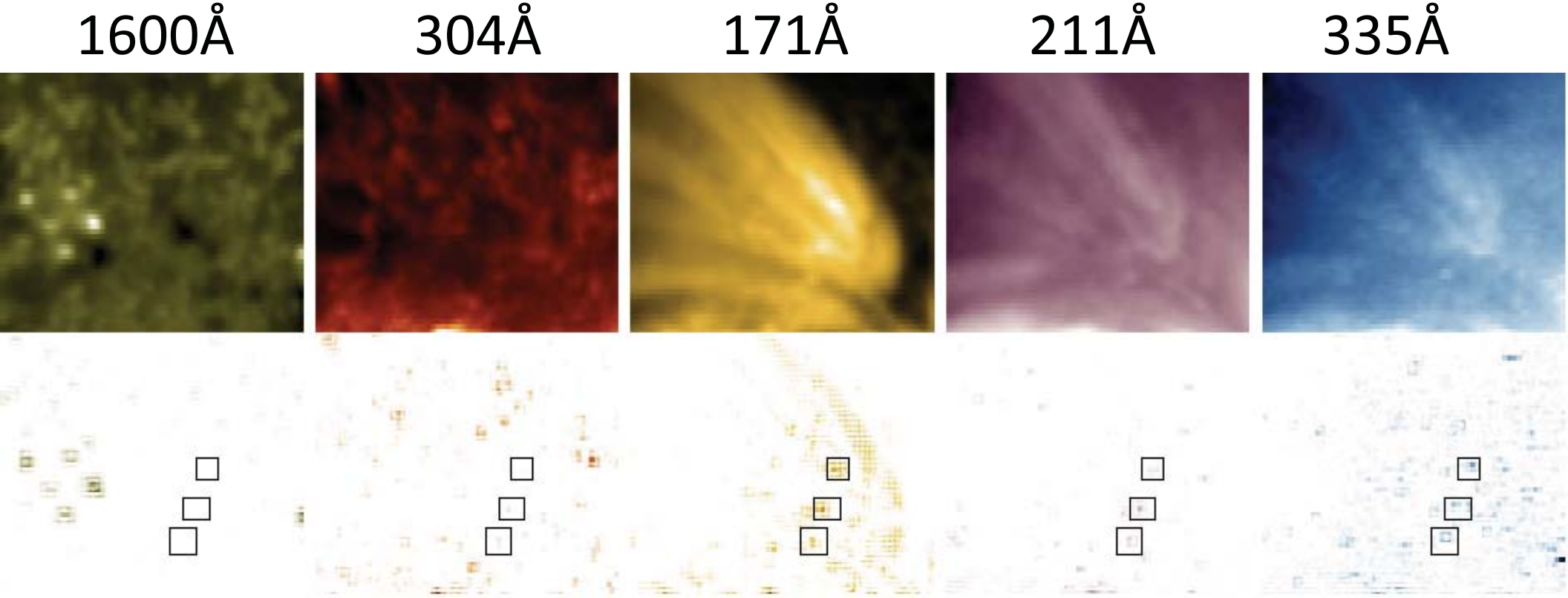
A filtering technique is used to determine locations of dots.

8 dots are identified in Hi-C data with this method.

3 dots are found in AIA 193 data.

Regnier, Walsh, in prep.

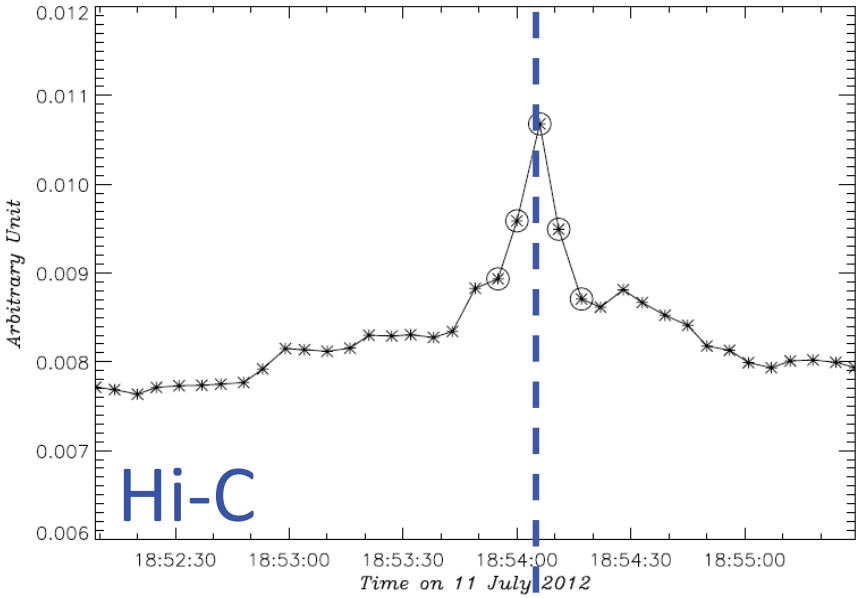
“Dots”

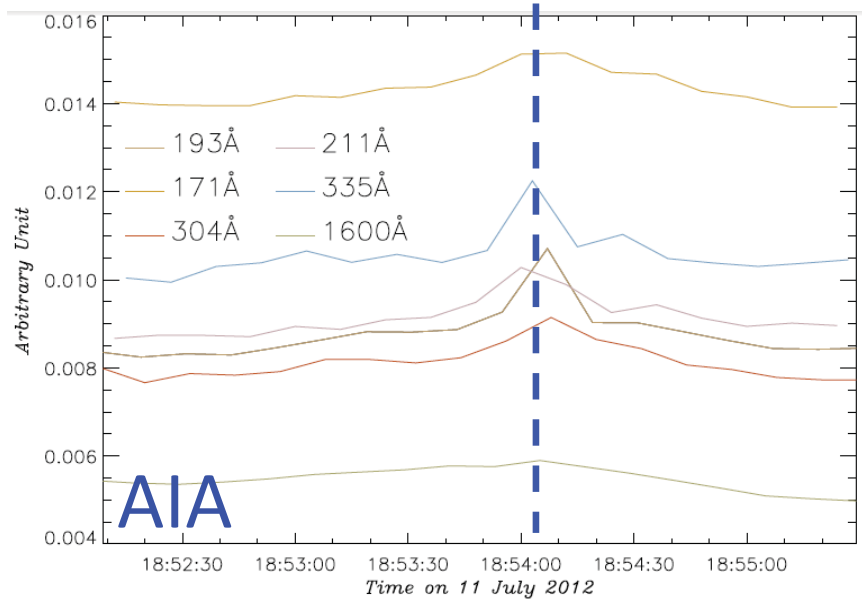


Some of these dots are observed in other AIA passbands.

Regnier, Walsh, in prep.

“Dots”

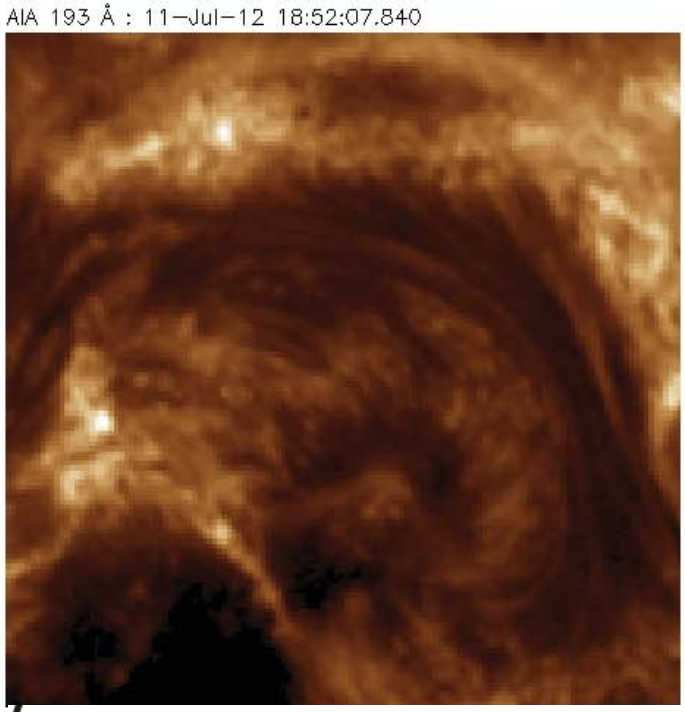


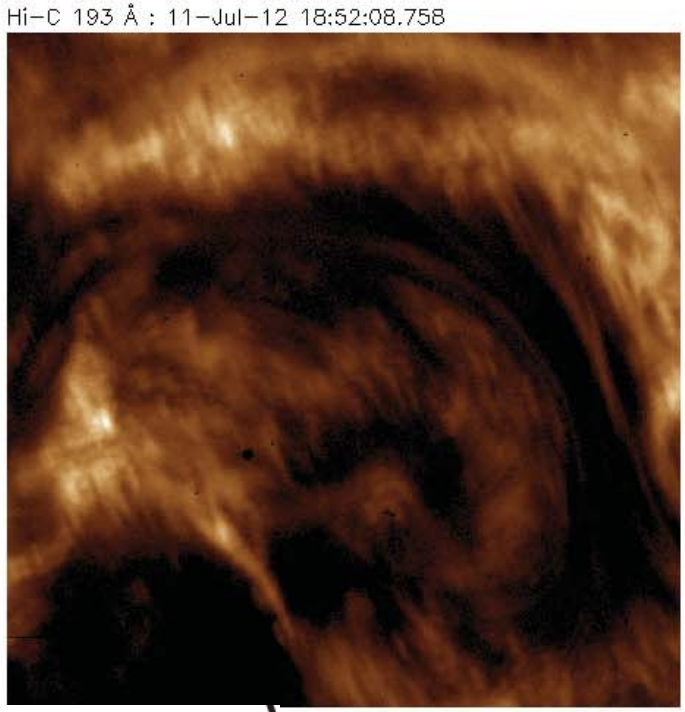


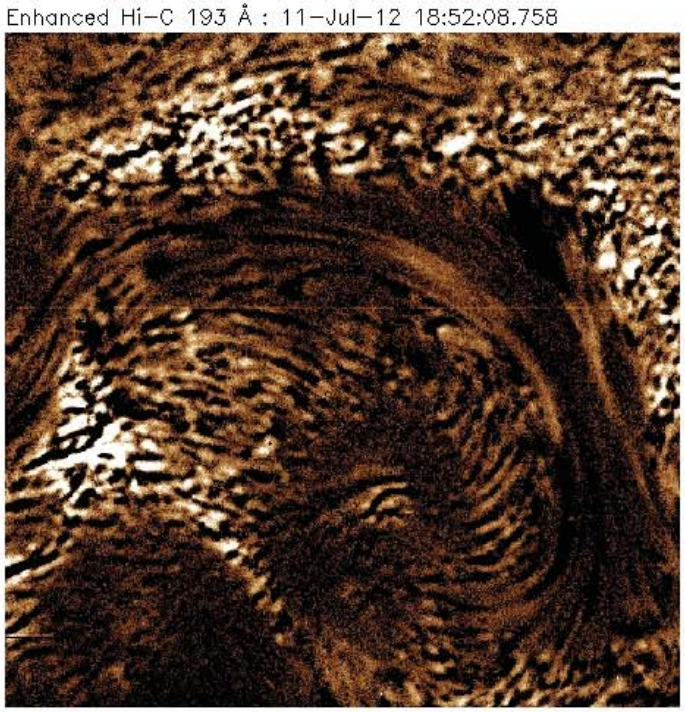
- Dots generally appear in only one AIA image, but several Hi-C images.
- Characteristic duration of 25s
- Characteristic length of 680 km (<1’’)
- Not fully spatially or temporally resolved in SDO/AIA

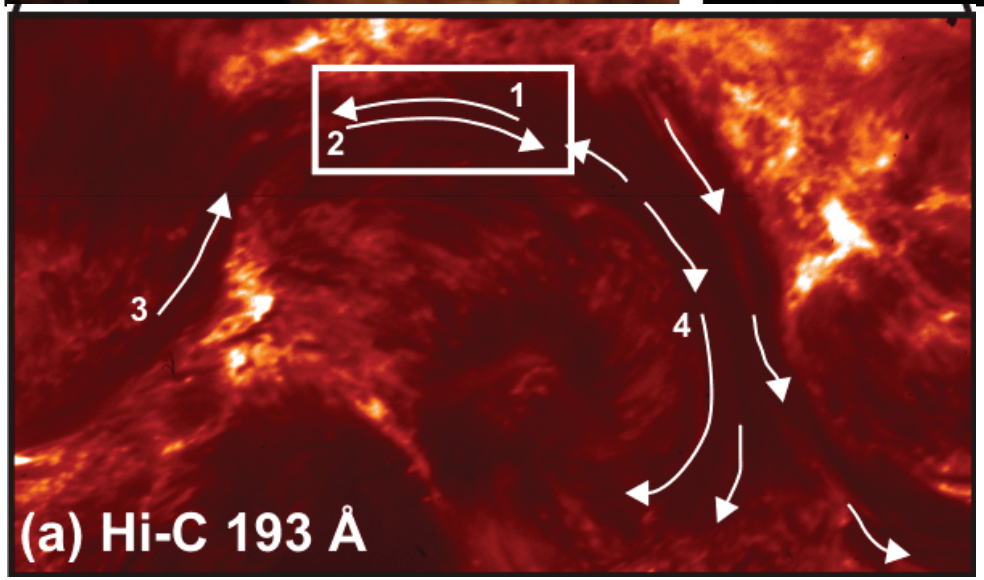
Regnier, Walsh, in prep.

Bi-directional Flows in Filaments





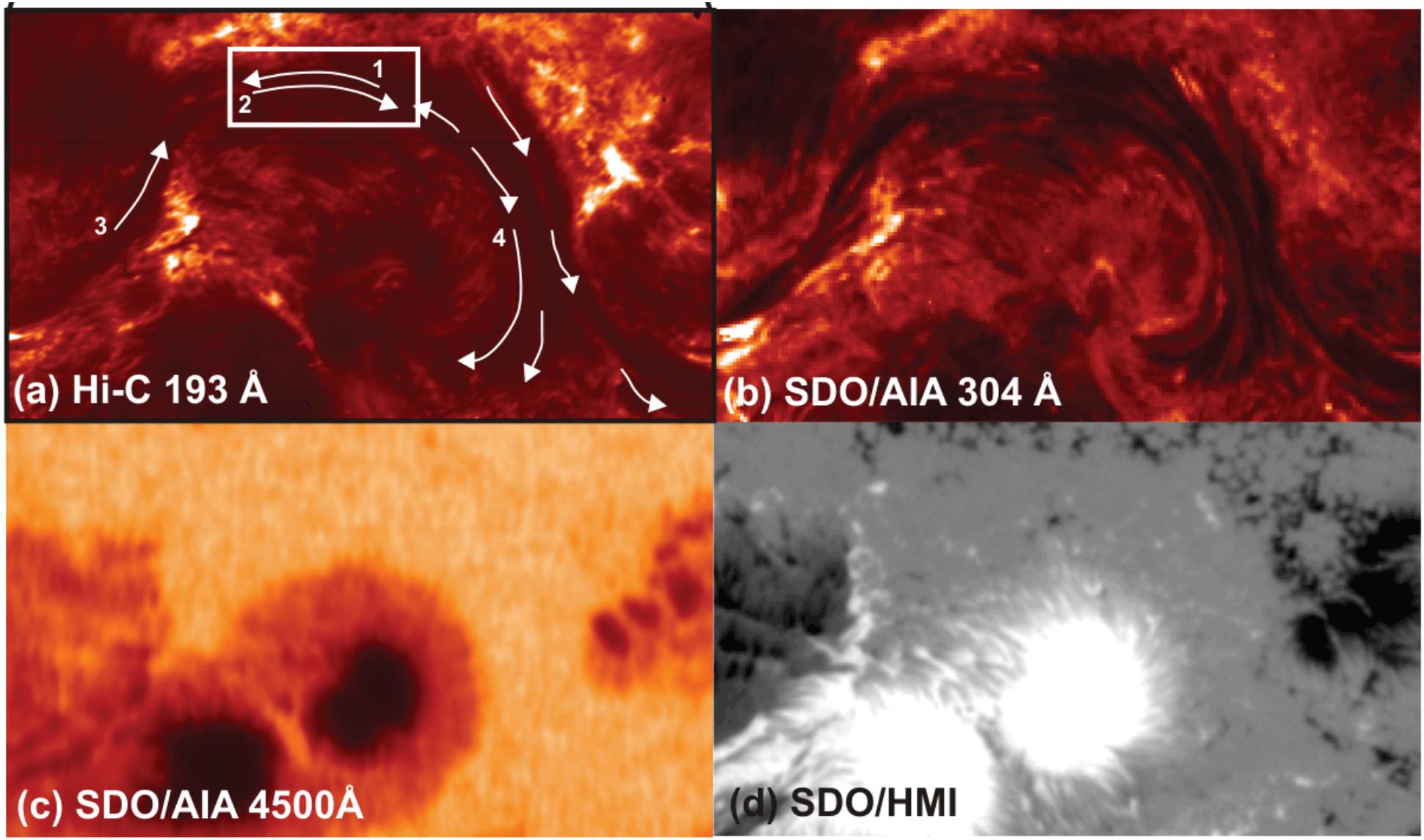




Hi-C observed bi-directional flows in a filament. This is the first observations of such flows in the EUV channel.

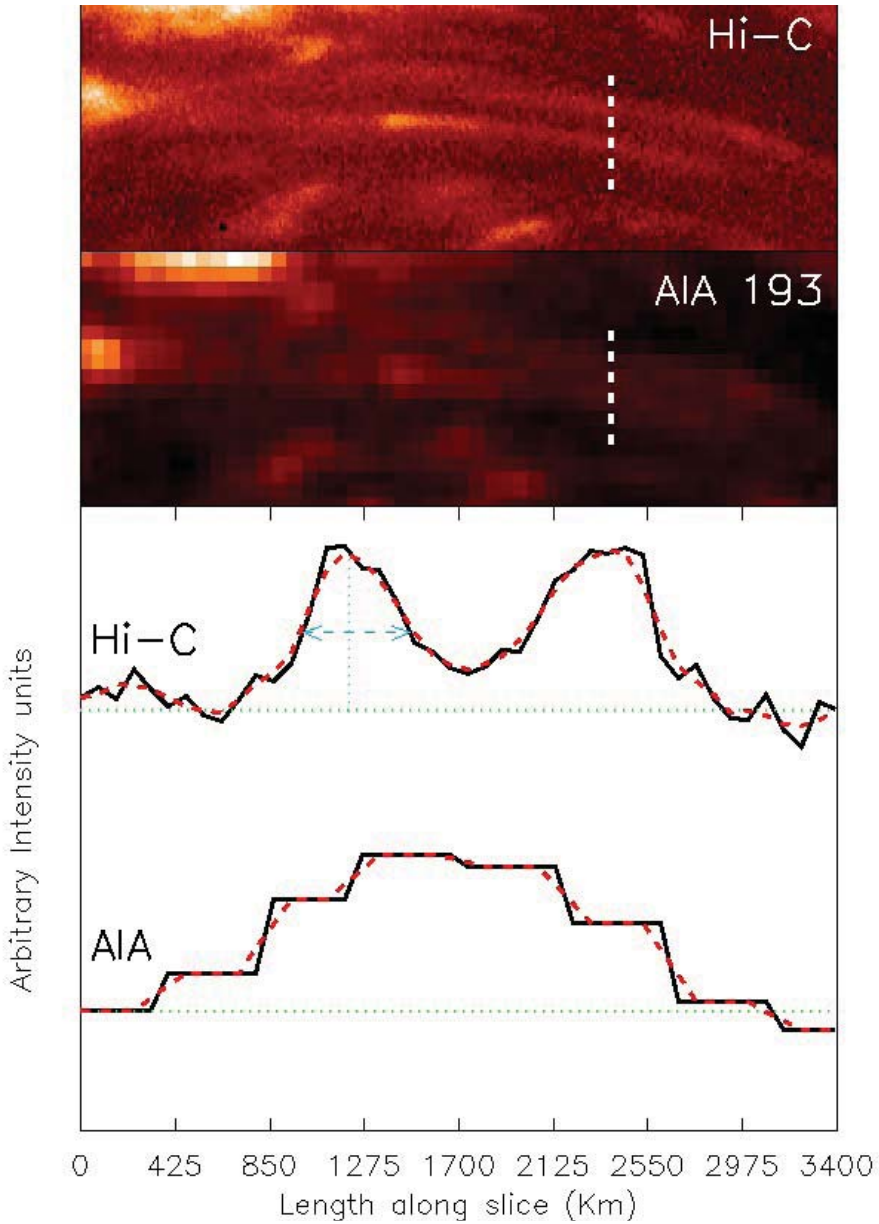
Alexander, Walsh, in prep.

Bi-directional Flows in Filaments



Alexander, Walsh, in prep.

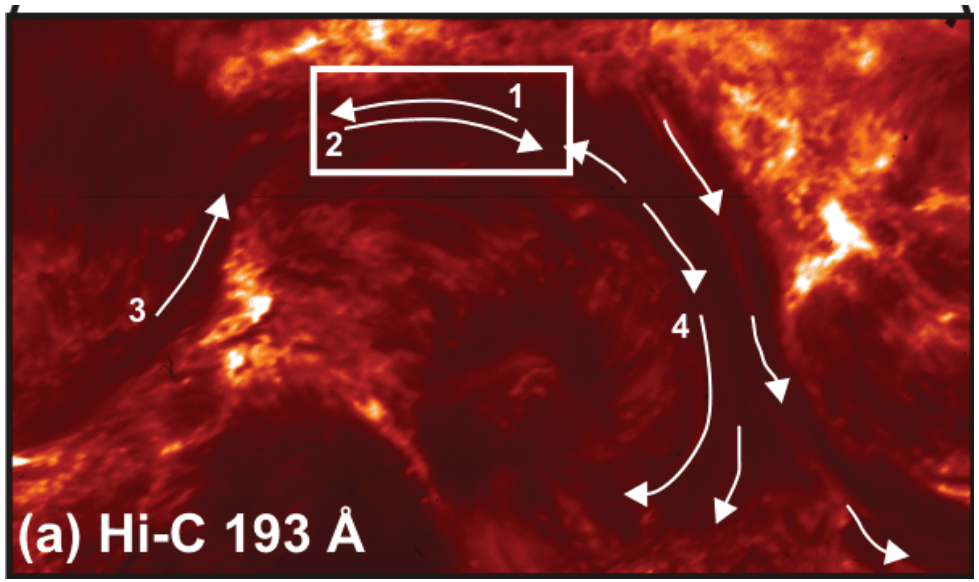
Bi-directional Flows in Filaments

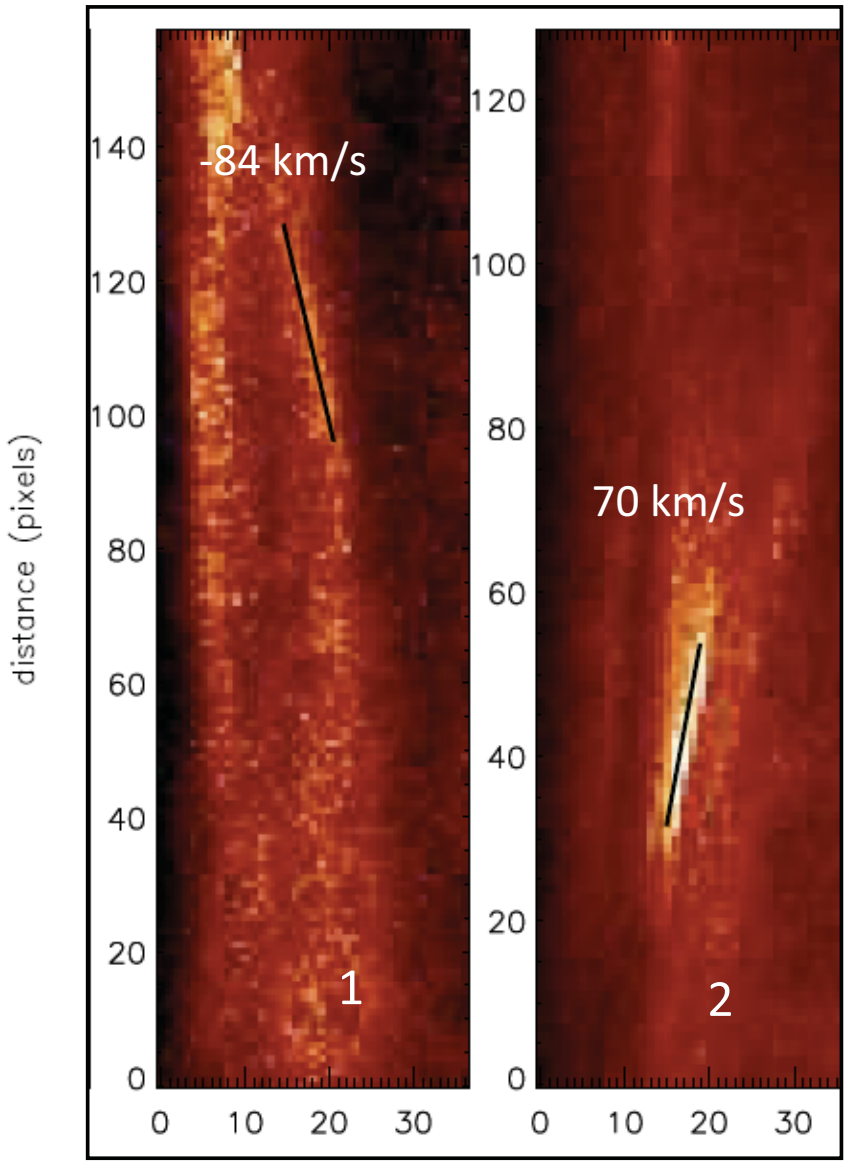


- Hi-C resolves two structures roughly 0.8” wide
- AIA sees only a single structure.

Bi-directional Flows in Filaments

Velocities of Flows 1 and 2 are roughly equal and in opposite directions.

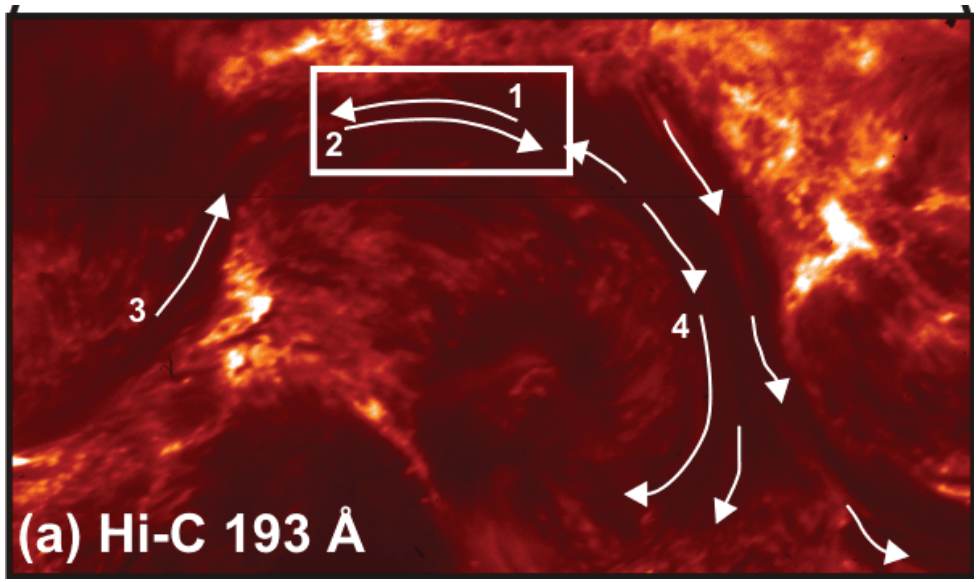


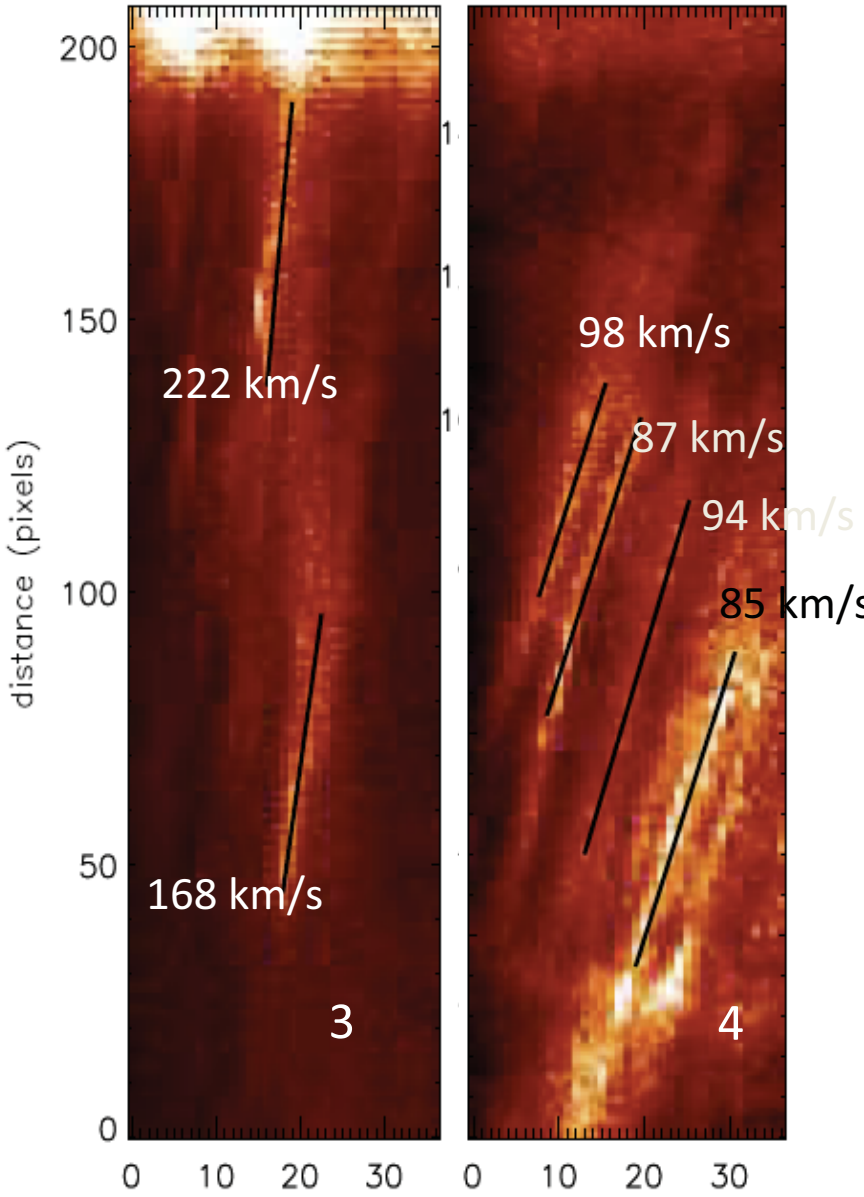


Alexander, Walsh, in prep.

Bi-directional Flows in Filaments

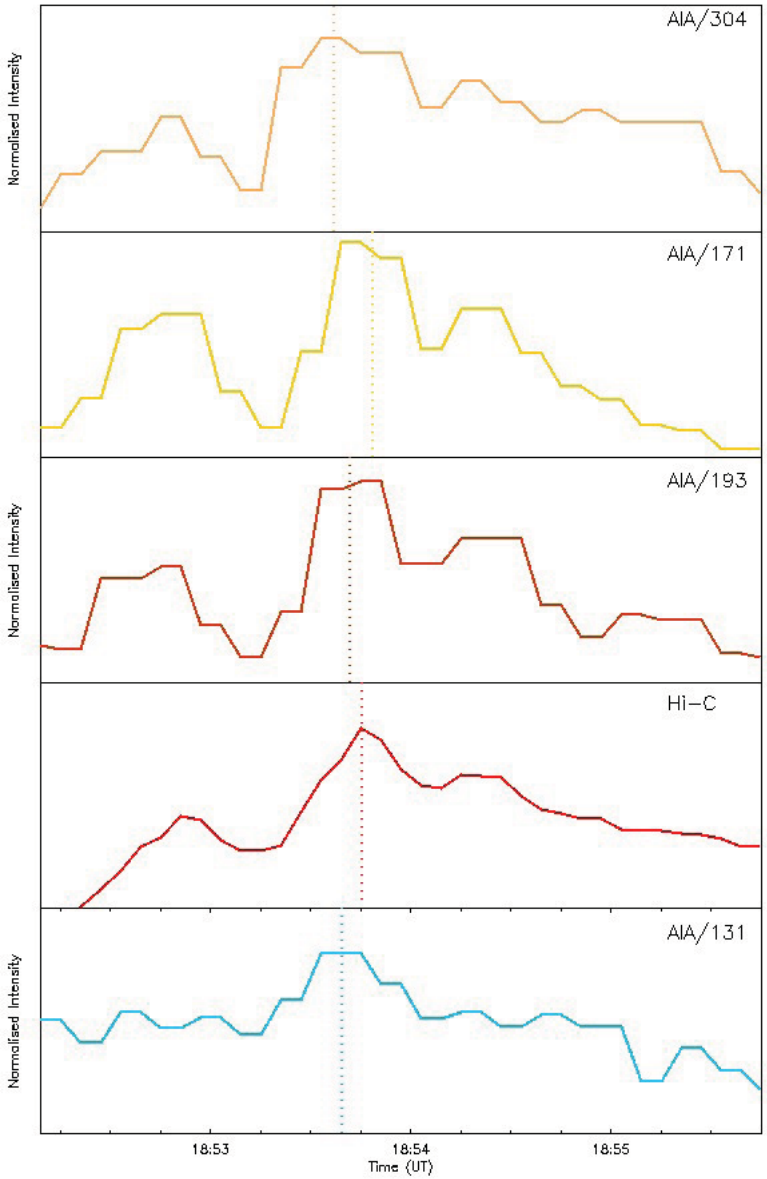
Velocities of Flows 3 is > 150 km/s and Region 4 shows period flows of ~100 km/s.



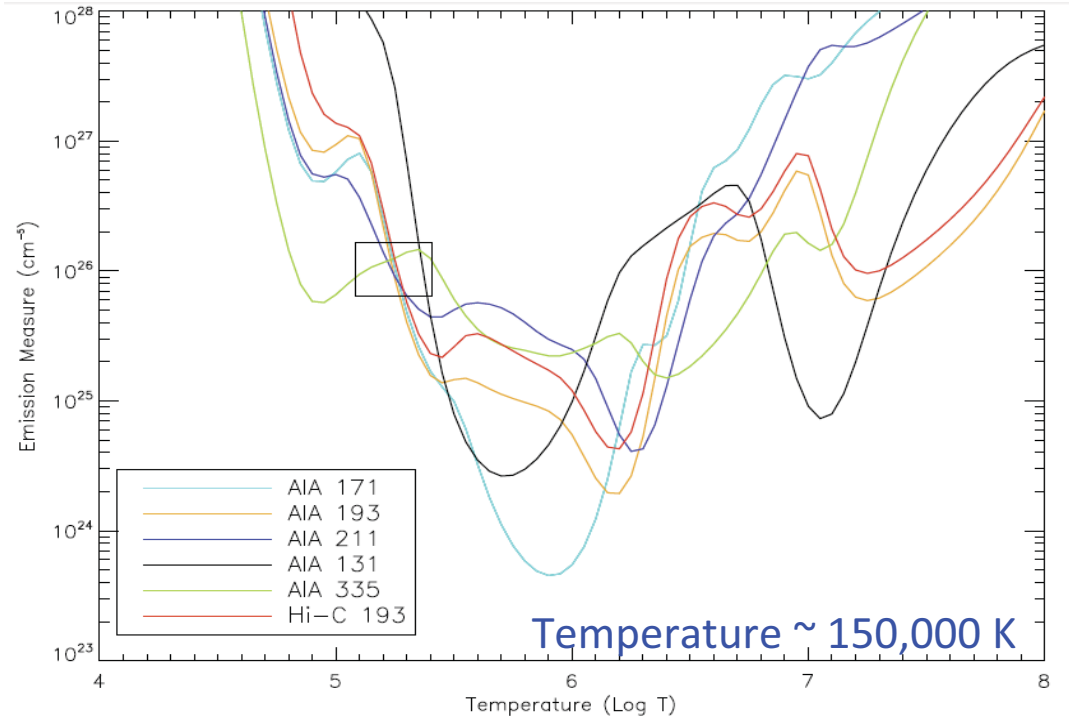


Alexander, Walsh, in prep.

Bi-directional Flows in Filaments

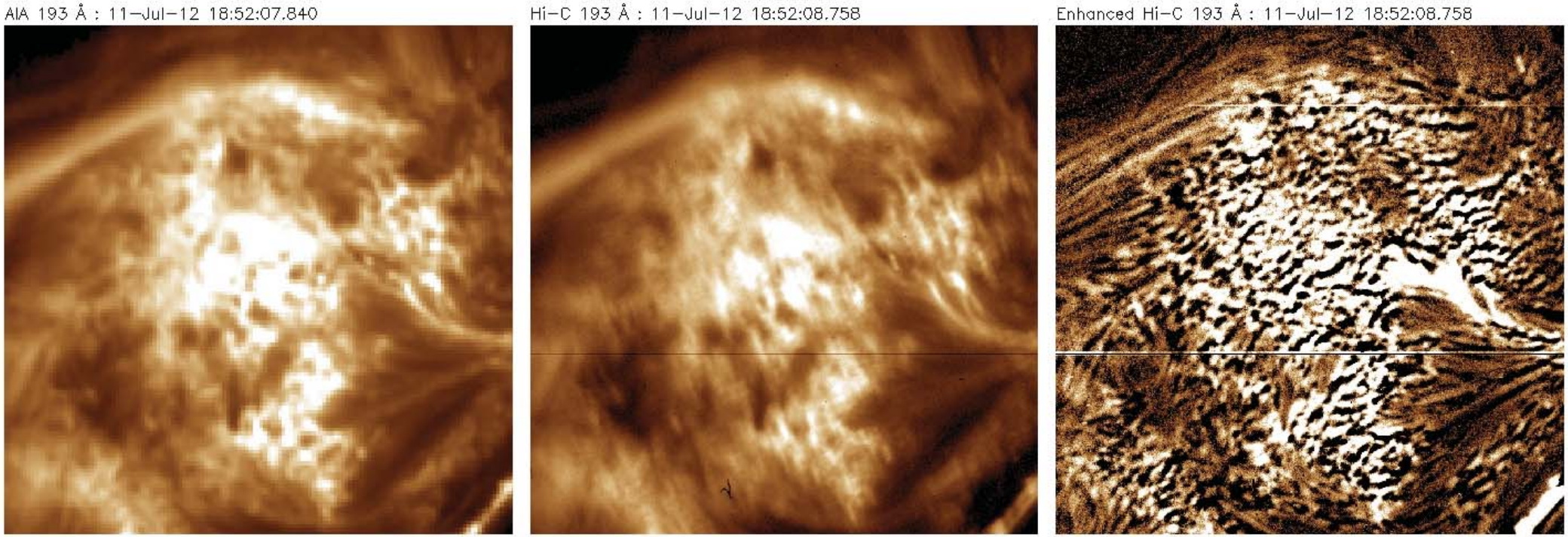


Light curves and EM Loci plots indicate the plasma is at an isothermal, cool temperature.



Alexander, Walsh, in prep.

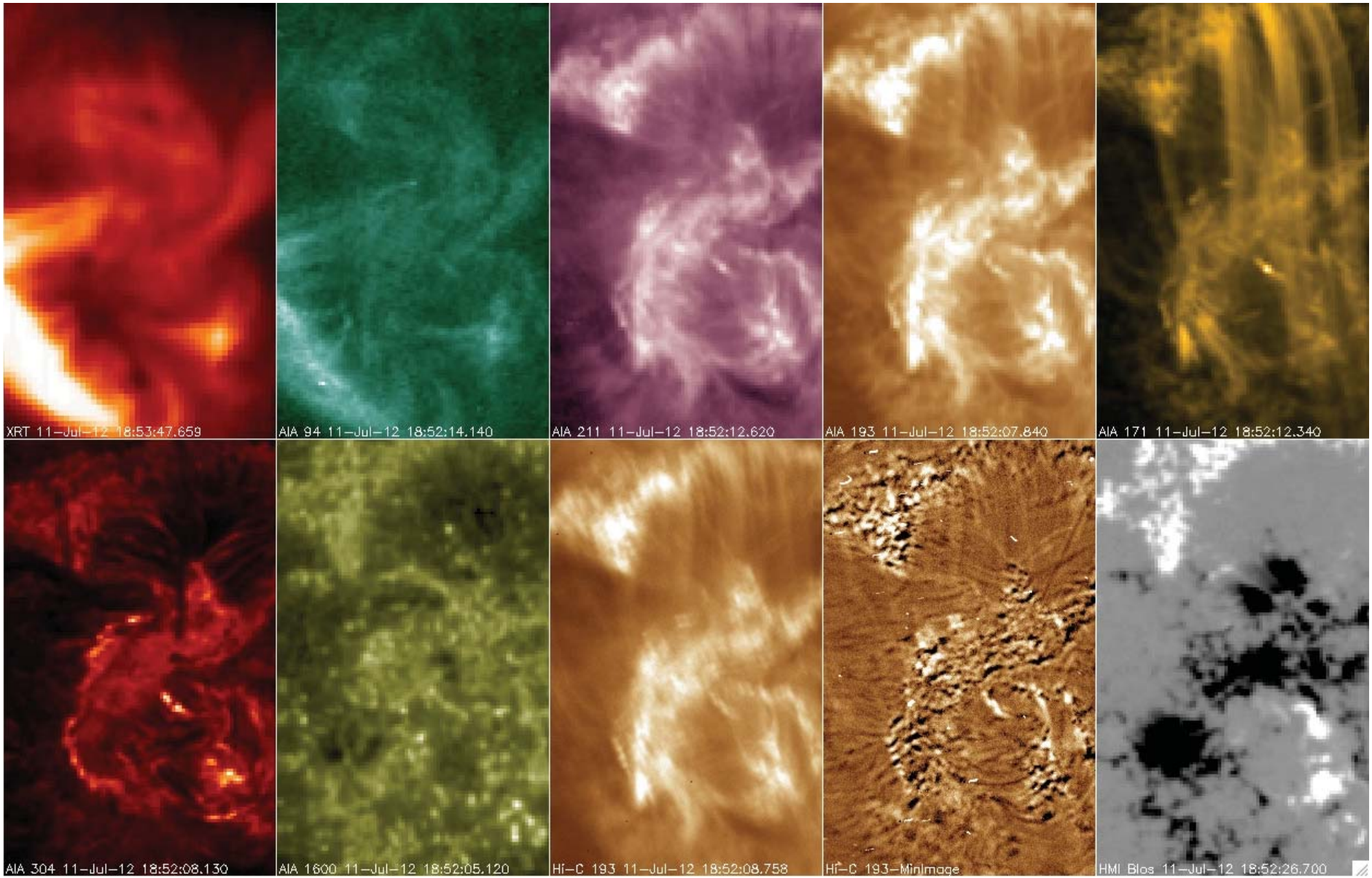
Spicules in Moss



Hi-C reveals many short-lived absorption features in the moss.
These features are likely spicules – dense plasma at chromospheric temperatures.
Currently studying the lifetime and evolutions of these features.

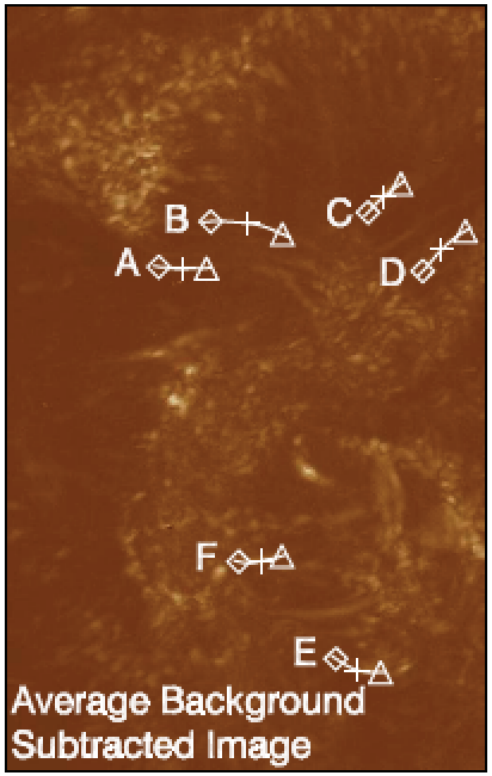
Winebarger, in prep.

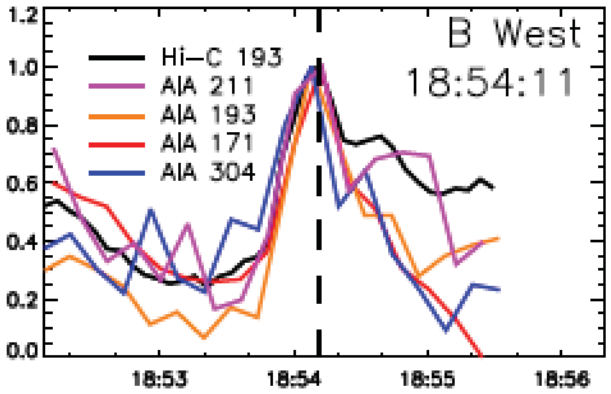
Flashing Loops

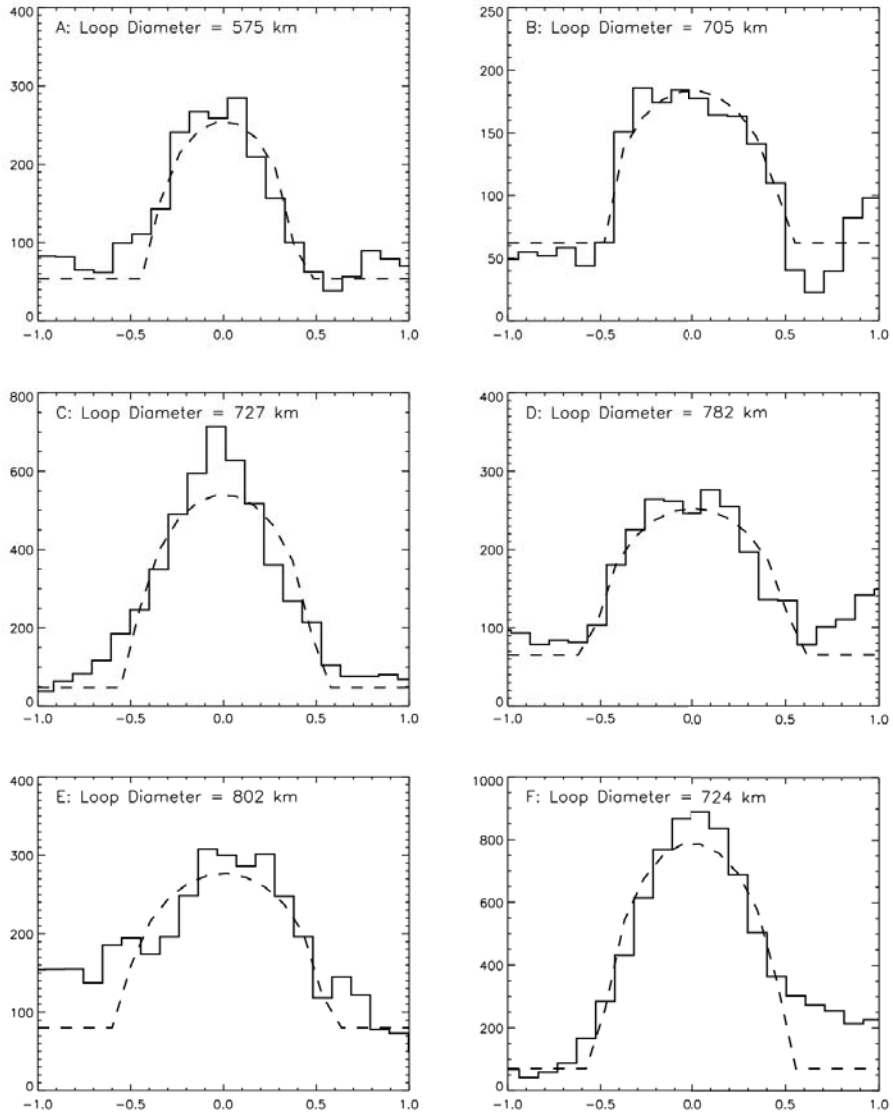


Winebarger, Walsh, in prep.

Flashing Loops







- Six loops were identified.
- Diameter of loops 575-800 km
- Lifetime of loops < 60 s.

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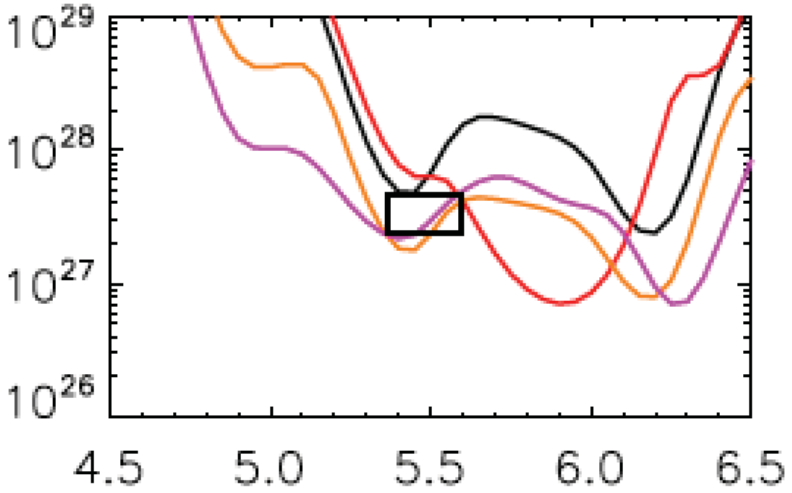
Flashing Loops



Loop	Photospheric Log T	Photospheric Log EM	n_e
A	5.48± 0.12	27.52± 0.15	7.58E+09
B	5.47± 0.13	27.61± 0.13	7.62E+09
C	5.47± 0.12	28.03± 0.12	1.21E+10
D	5.47± 0.12	27.74± 0.12	8.34E+09
E	5.44± 0.14	28.01± 0.06	1.13E+10
F	5.44± 0.14	28.27± 0.06	1.60E+10

- Because loops evolve identically in multiple AIA filters, we conclude the loops are isothermal.
- EM Loci analysis indicate a cool (300,000 K) temperature.
- Density estimates are 7-10 x 10^9 cm^{-3}.

Winebarger, Walsh, in prep.

Summary

- Hi-C obtained the highest spatial and temporal resolution observations ever taken in the solar corona.
- Hi-C reveals dynamics and structure at the limit of its temporal and spatial resolution.
- Hi-C observed ubiquitous fine-scale flows consistent with the local sound speed.