

# Preview of First Results from Hi-C 2.1 and Coordinated Observations



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Harry Warren (NRL)



# Solar Instrumentation Programs at MSFC

## SOUNDING ROCKETS

- **SUMI** (J. Cirtain, PI)
  - Launched from WSMR on July 2012
- **Hi-C 1** (J. Cirtain, PI)
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- **MaGIXS** (A. Winebarger, PI)
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## OBSERVATORIES

### HINODE (Solar B)

- SOT: Solar Optical Telescope
- XRT: X-Ray Telescope
- EIS: EUV Imaging Spectrometer

### COSIE

- Coronal Spectrographic Imager in the EUV

\*\*\*\*\*

... Cameras & Optics

OPERATIONAL  
FLOWN  
IN DEVELOPMENT  
PROPOSED

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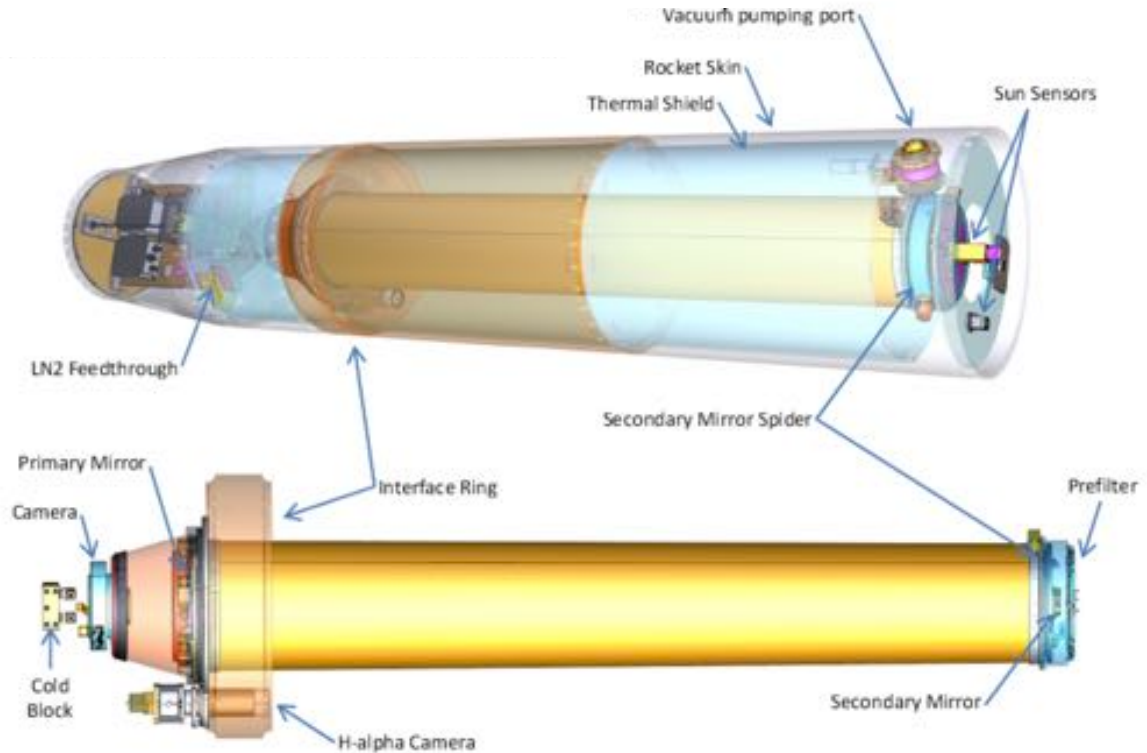
- Coronal Spectrographic Imager in the EUV

\*\*\*\*\*

... Cameras & Optics

# Hi-C: High-resolution Coronal imager

- Telescope design capable of  $\sim 0.2\text{-}0.3''$  ( $\sim 150$  km) spatial resolution imaging of the corona.
- Requires high rocket pointing stability to achieve resolution goal (Sparcs system).
- Capable of high-cadence observations through rapid CCD readout duration ( $\sim 2$  seconds) and data storage system.



# Hi-C 1: High-resolution Coronal imager

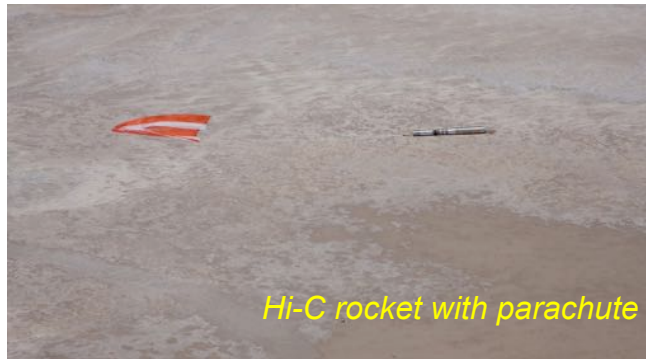
*Hi-C 1 Launch  
White Sands, NM  
July 11, 2012*



*Hi-C recovery team*



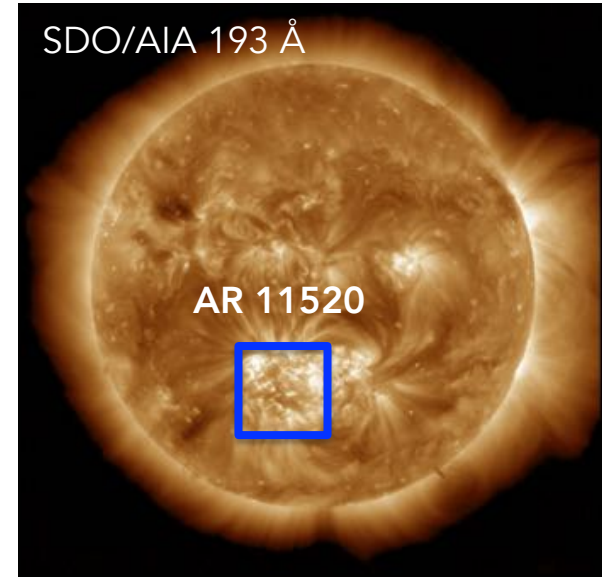
*Hi-C rocket with parachute*



Data available via the Virtual Solar Observatory (VSO).

Guidebooks available at [hic.msfc.nasa.gov](http://hic.msfc.nasa.gov).

SDO/AIA 193 Å



AR 11520

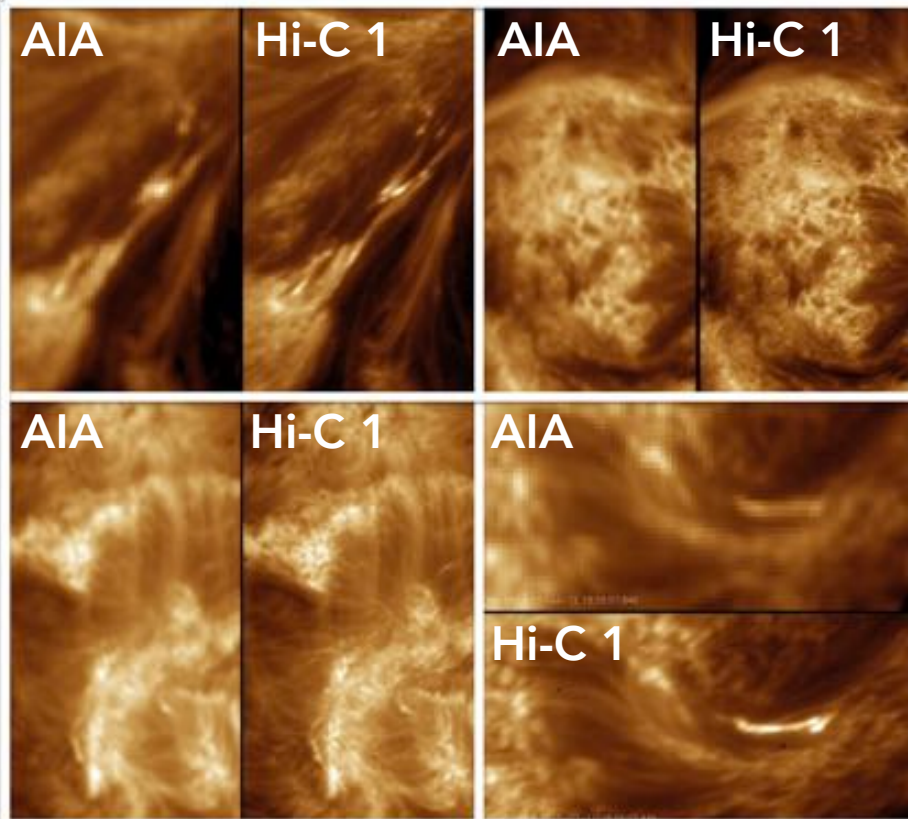
# Hi-C 1: High-resolution Coronal imager

Bandpass – 193 Å [ $\sim 1$  & 10MK]

26 publications for 5 minutes of data! [<https://hic.msfc.nasa.gov/publications.html>]

Science highlights:

- Braided loops triggering energy release through magnetic reconnection
  - (*Cirtain et al. 2013, Nature*)
- Subflare triggers
- Nanoflare heating
- Loop sub-structure
- Moss dynamics
- Penumbral jets
- Flows along filament threads
- MHD waves



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... Cameras & Optics

# Hi-C 2: High-resolution Coronal imager

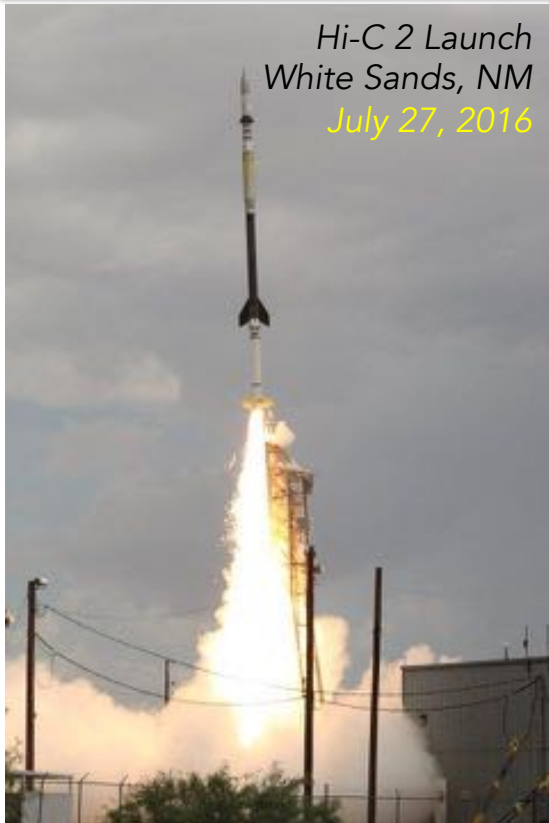
*Hi-C 2 Launch  
White Sands, NM  
July 27, 2016*

Hi-C 2 mirror recoated to explore the important Chromospheric-Coronal Connection by targeting specific candidates likely to contribute to coronal heating:

1. Type II spicules
2. Hot active region core loops

## Updates for re-flight:

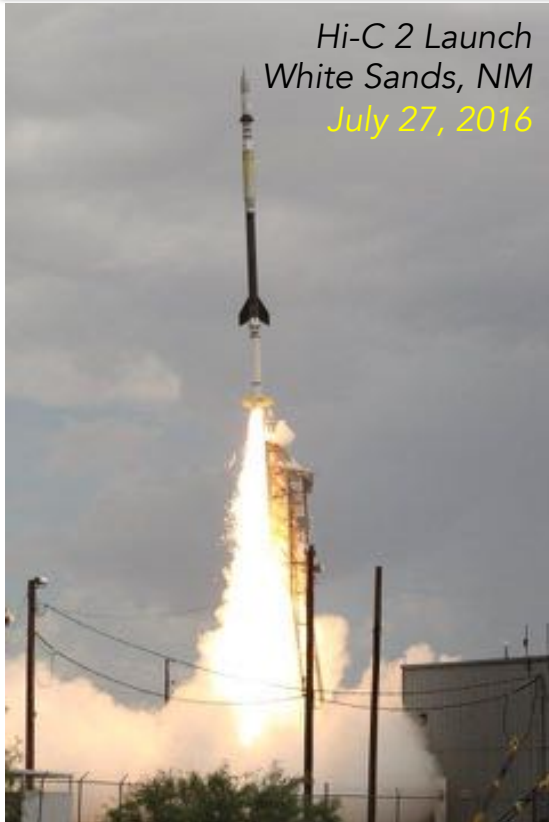
- Cooler bandpass centered on **172 Å** (~.6 MK)
- Significant improvement in camera quality (new MSFC-build designed for super low noise)
- **IRIS!**



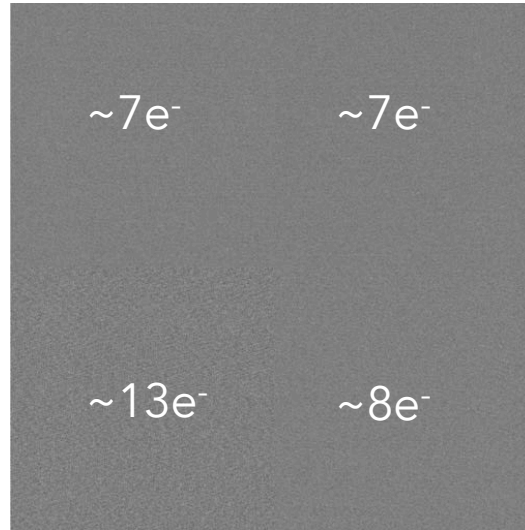


# Hi-C 2: High-resolution Coronal imager

*Hi-C 2 Launch  
White Sands, NM  
July 27, 2016*



Fantastic flight performance  
verification of the low-noise  
MSFC-built camera.



# Hi-C 2...: High-resolution Coronal imager

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Cleaned up

Checked alignment

Upgraded cooling system

Added Hall Effect Sensor

Re-proposed

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... Cameras & Optics

# Hi-C **2.1**: High-resolution Coronal imager

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3.5 months after ATP....

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# Hi-C 2.1: High-resolution Coronal imager

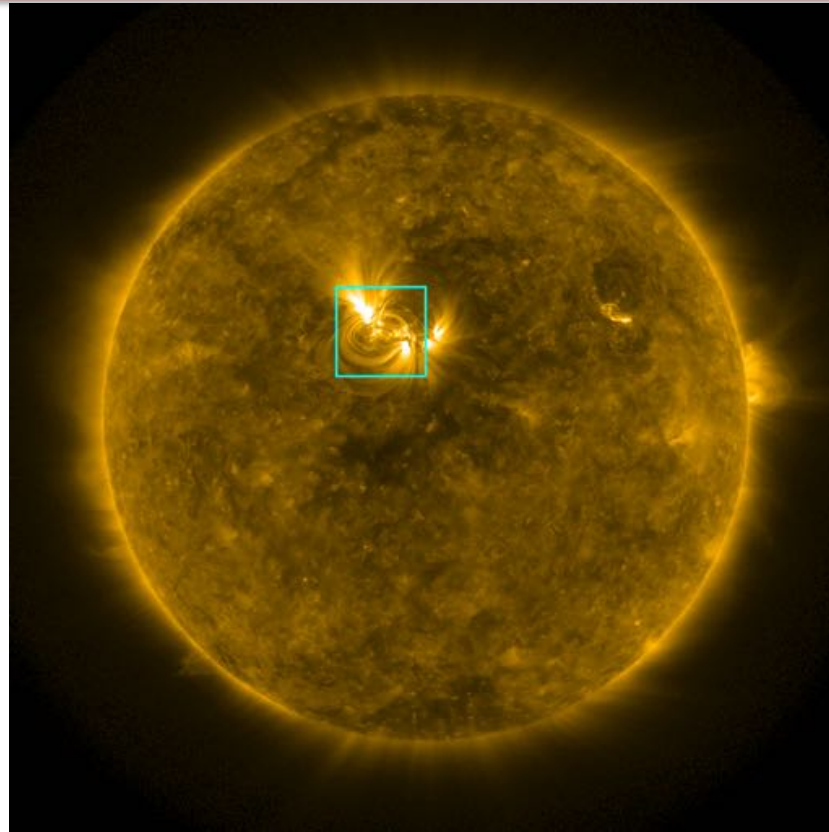
*Hi-C 2.1 Launch  
White Sands, NM  
May 29, 2018*



# Hi-C 2.1: High-resolution Coronal imager

2018 May 29  
18:54 UT

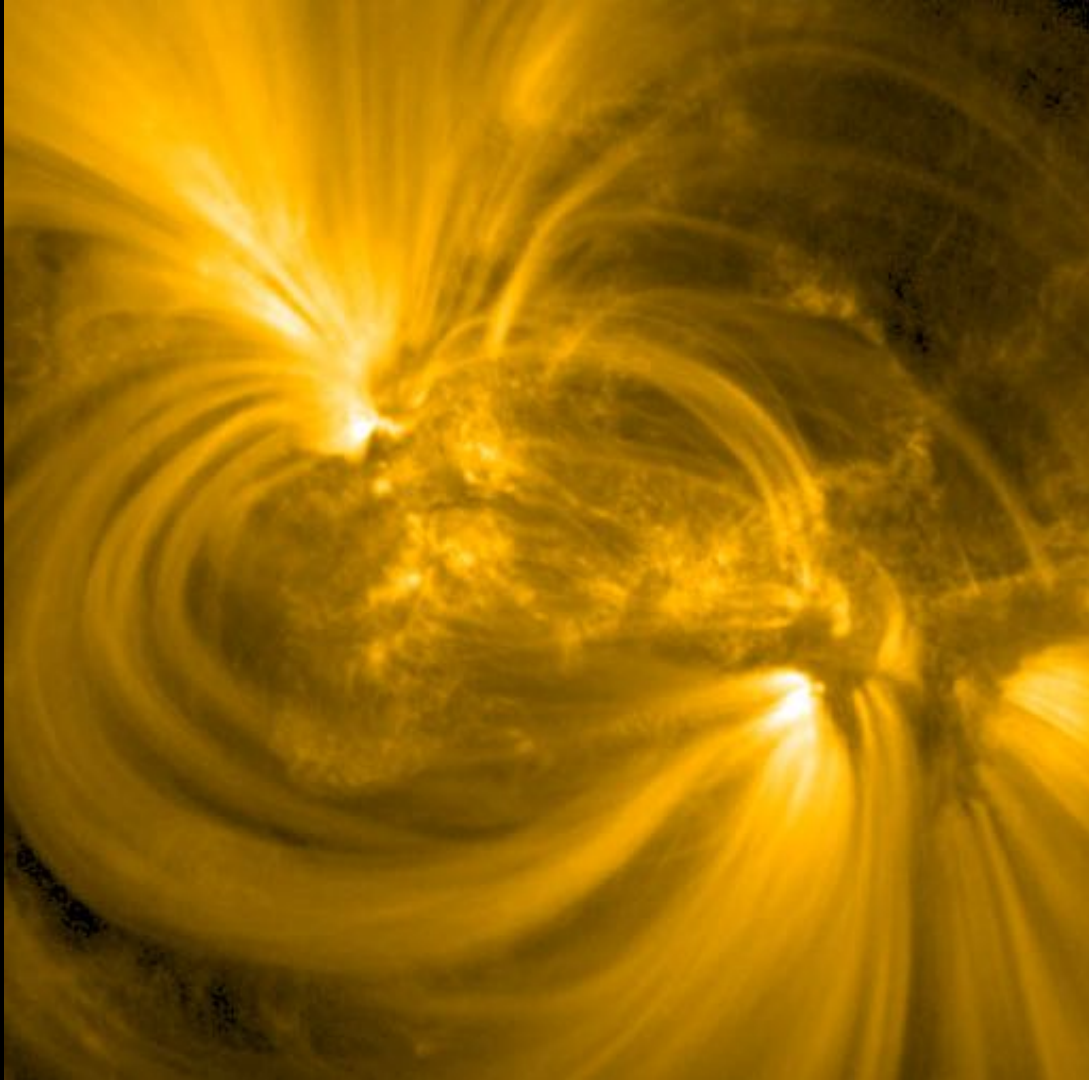
Target: AR 12712



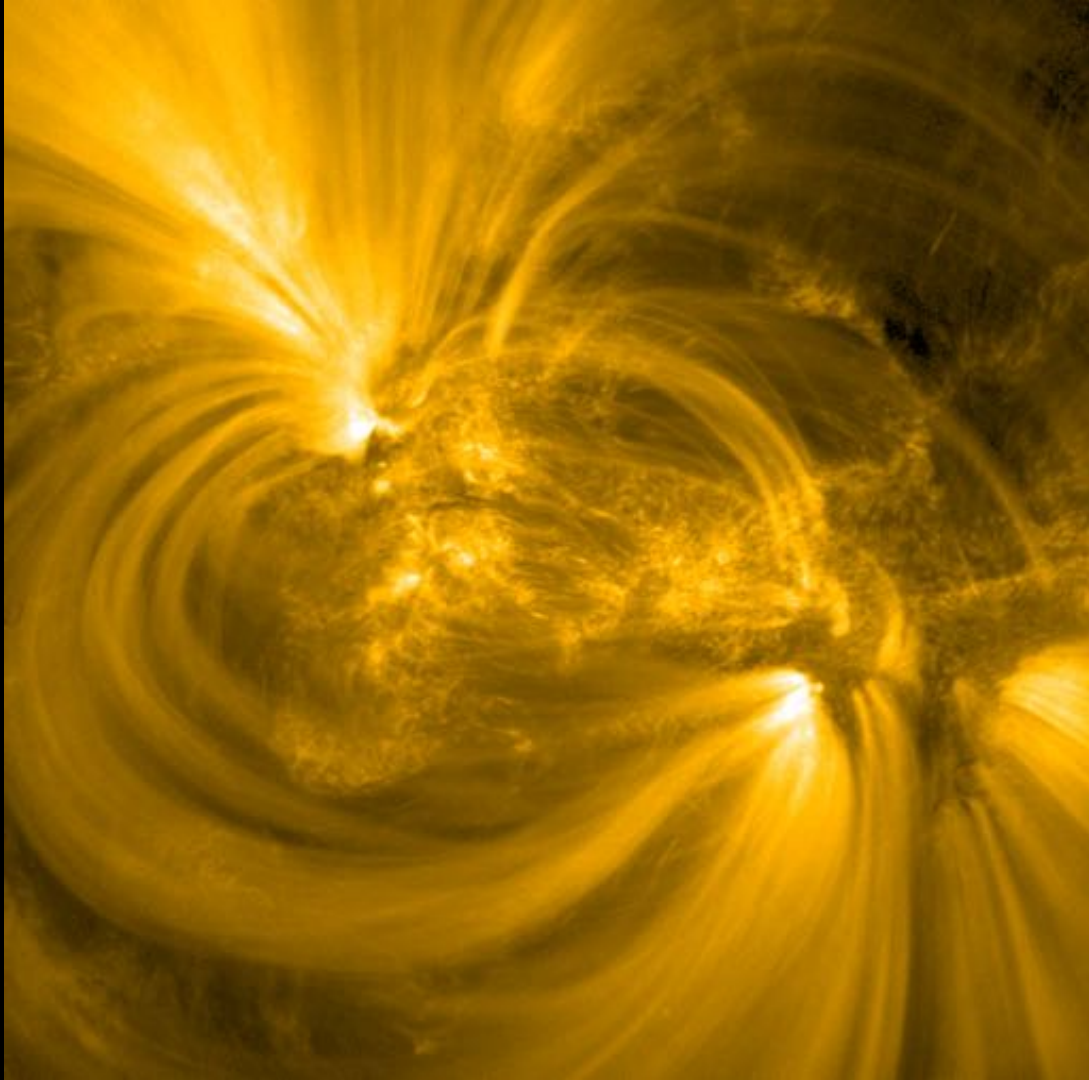
~ 15 minute flight

~ 5 minutes of solar  
viewing data

SDO/AIA  
171 Å

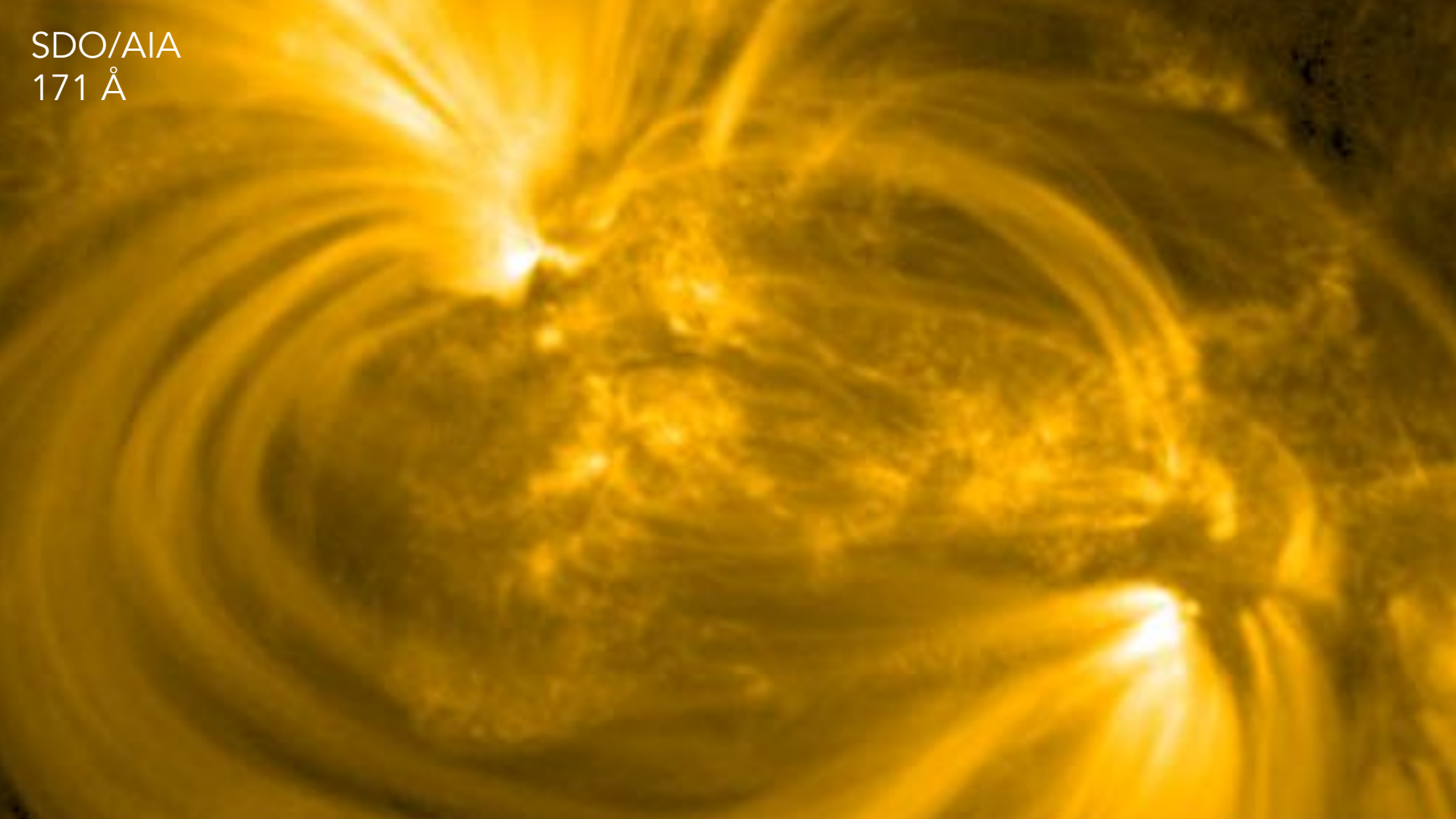


Hi-C 2.1  
172 Å

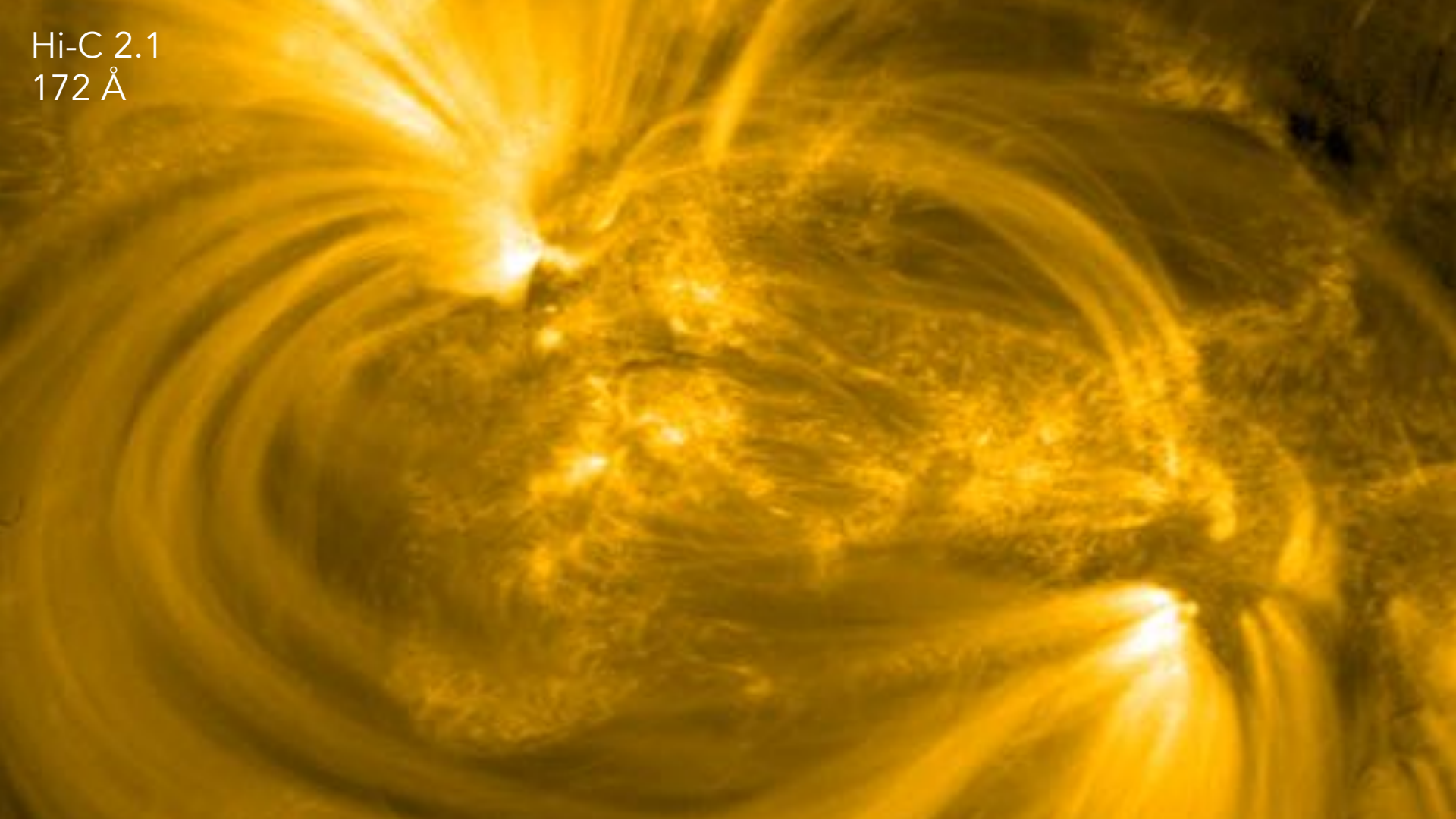




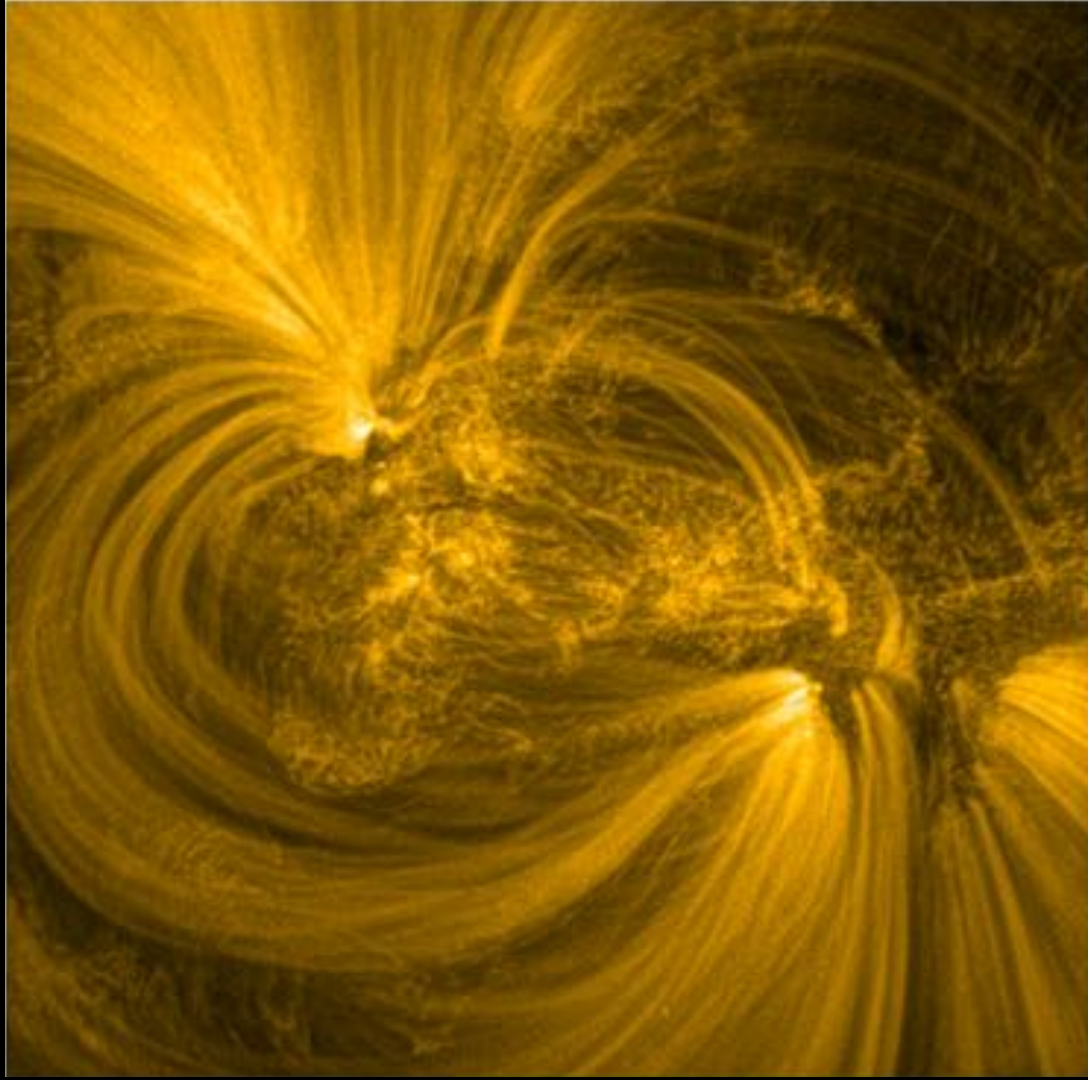
SDO/AIA  
171 Å



Hi-C 2.1  
172 Å

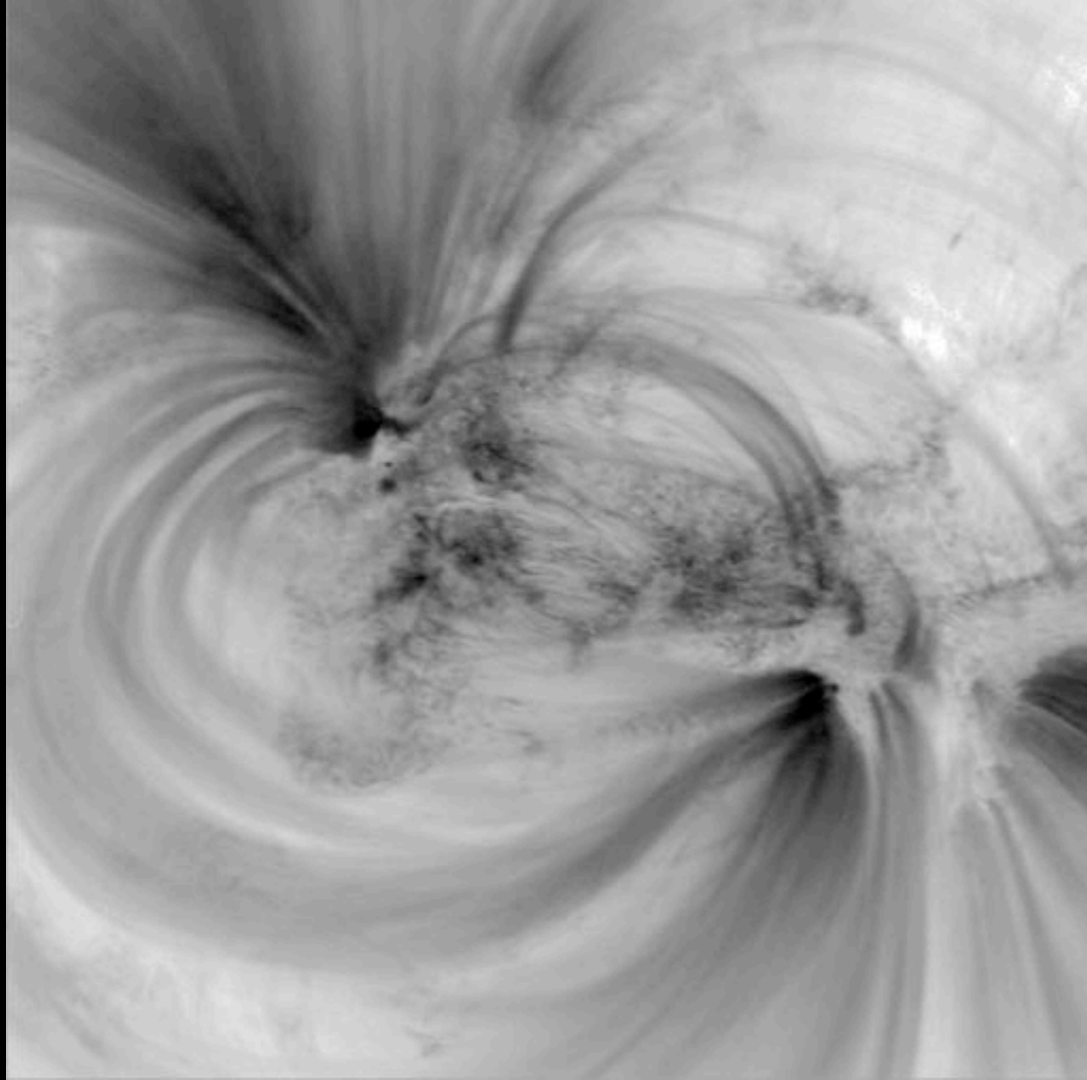


Hi-C 2.1  
172 Å



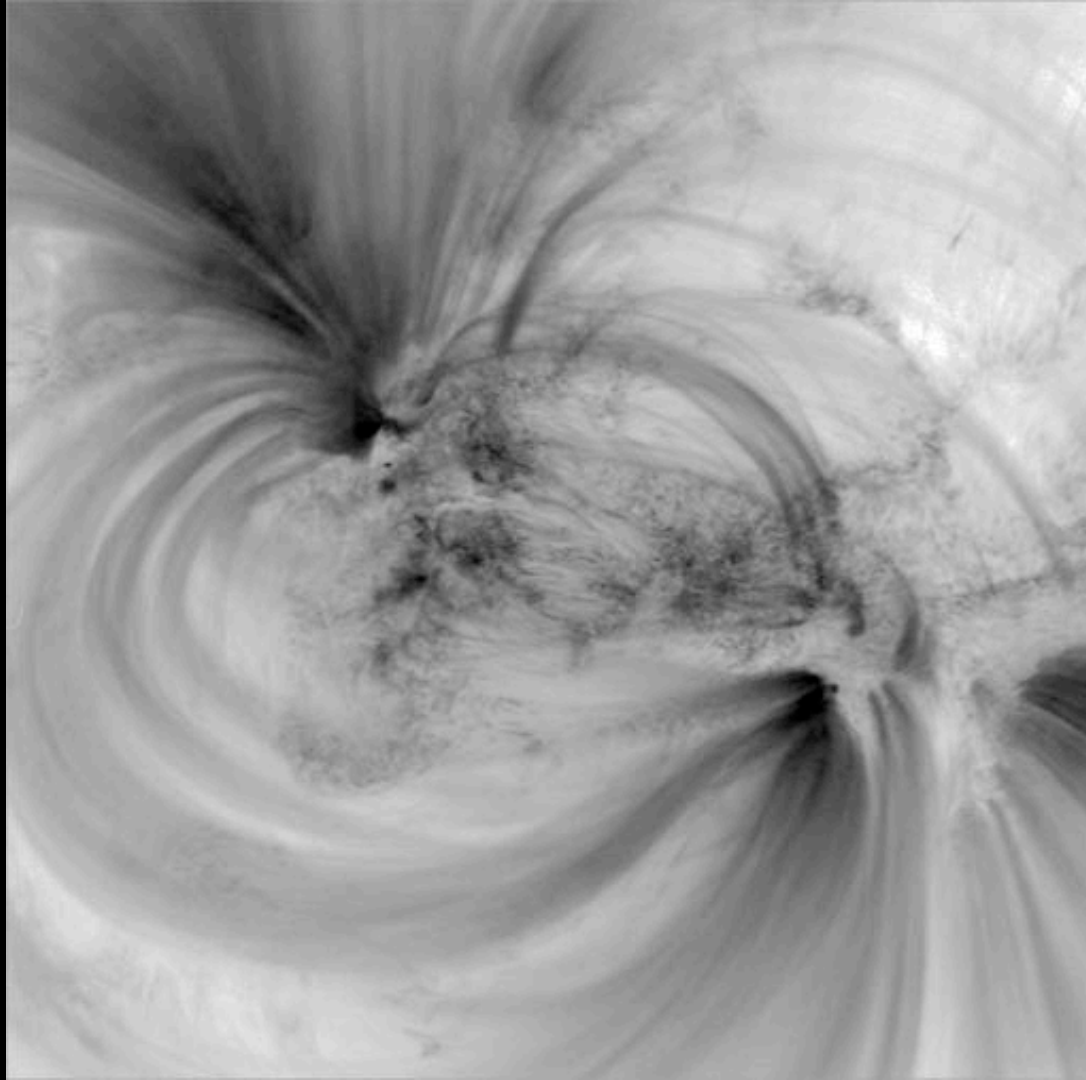
Sharpened

Hi-C 2.1  
172 Å



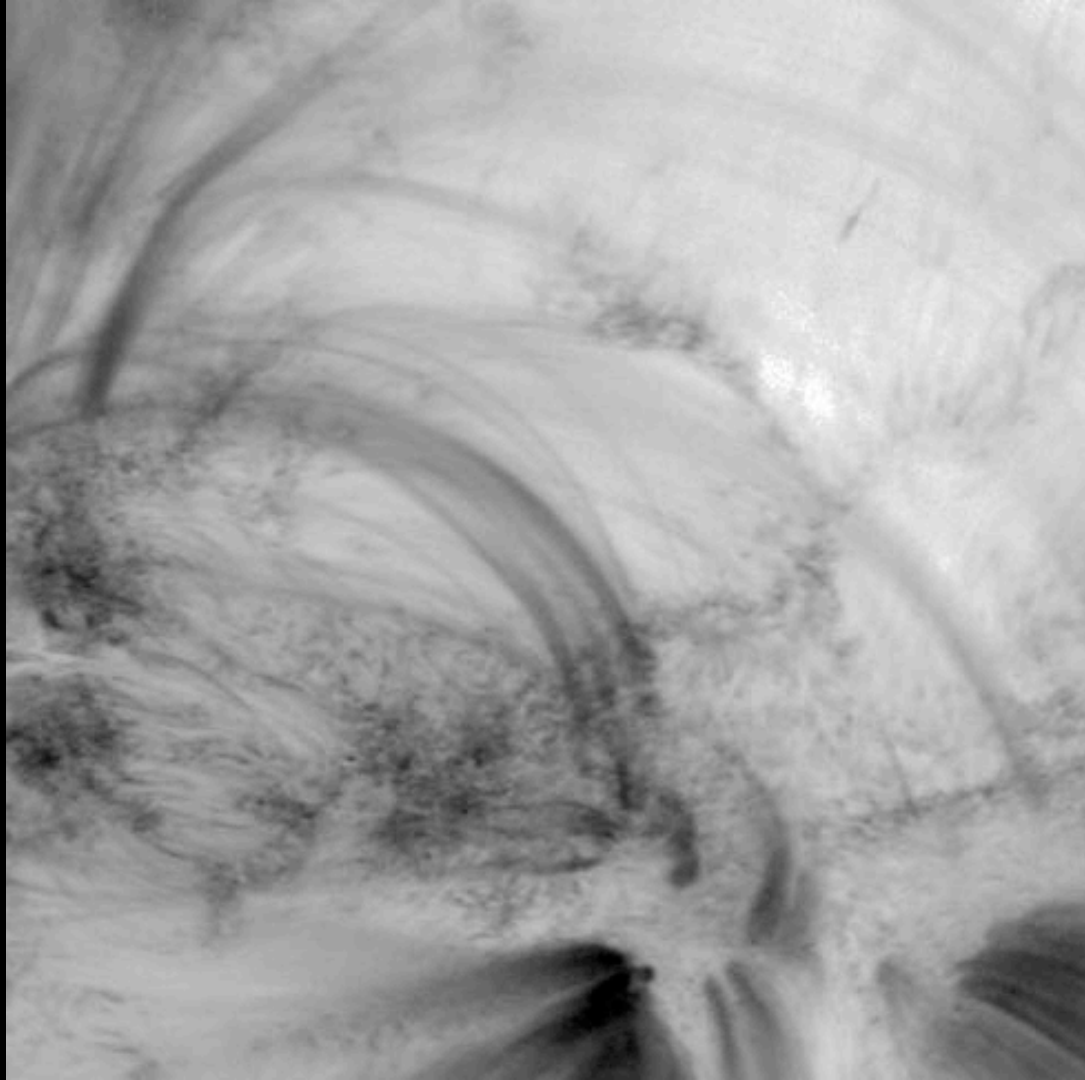
With Jitter

Hi-C 2.1  
172 Å



Without Jitter

Hi-C 2.1  
172 Å



Without Jitter  
Zoomed in

# Hi-C 2.1: What makes this instrument work?

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HIGH SPATIAL RESOLUTION

HIGH TEMPORAL RESOLUTION

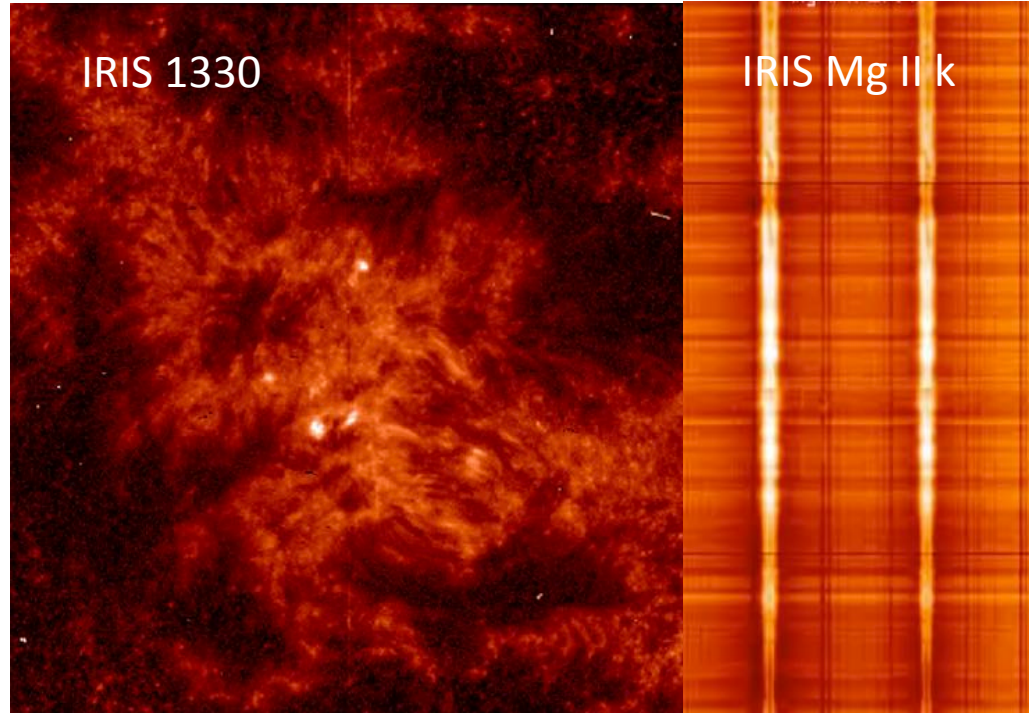
LOW NOISE CAMERA

**COORDINATED DATA SETS**

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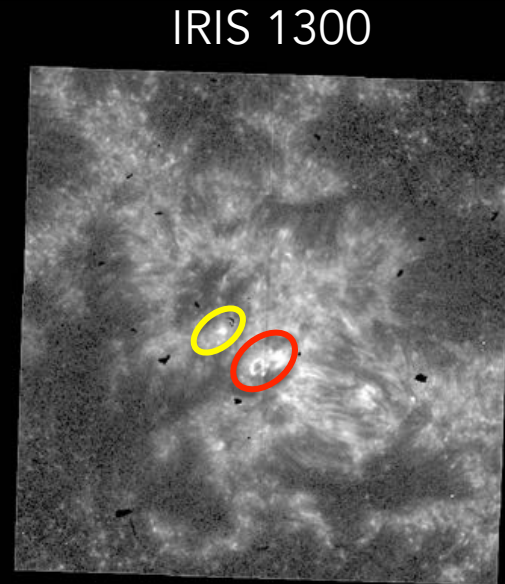
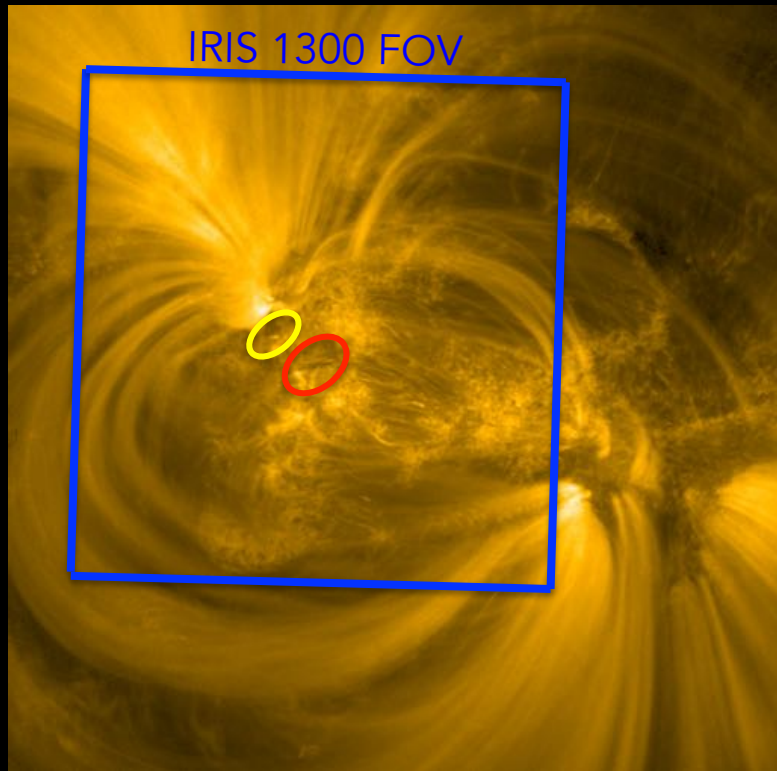
# Hi-C 2.1: IRIS coordinated data

IRIS observations of a subset of the region at high resolution and spectra will be used to tie small features in the chromosphere to those in the corona.

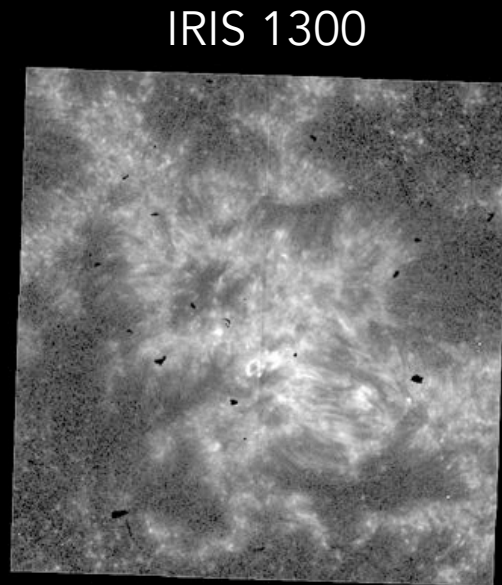
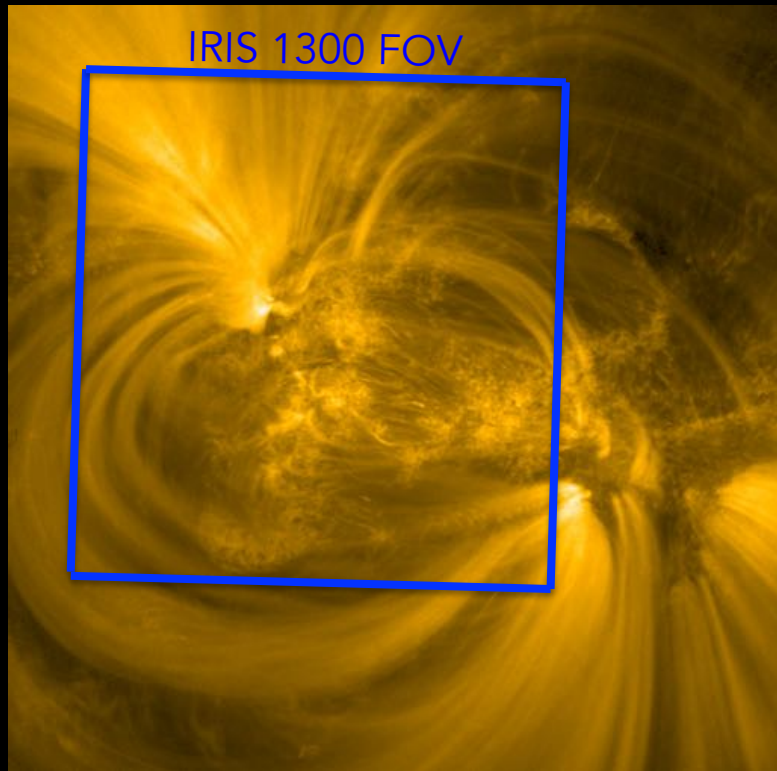




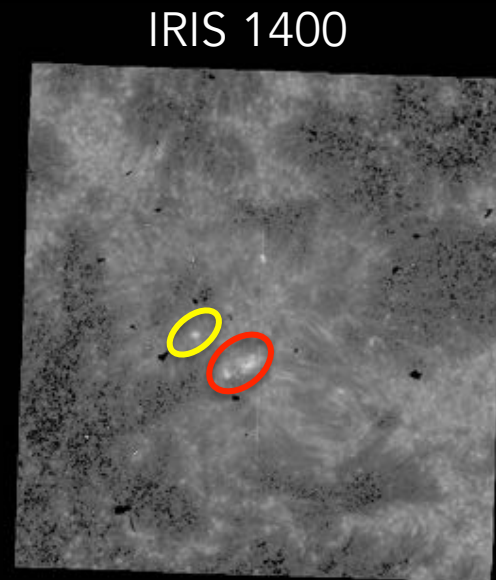
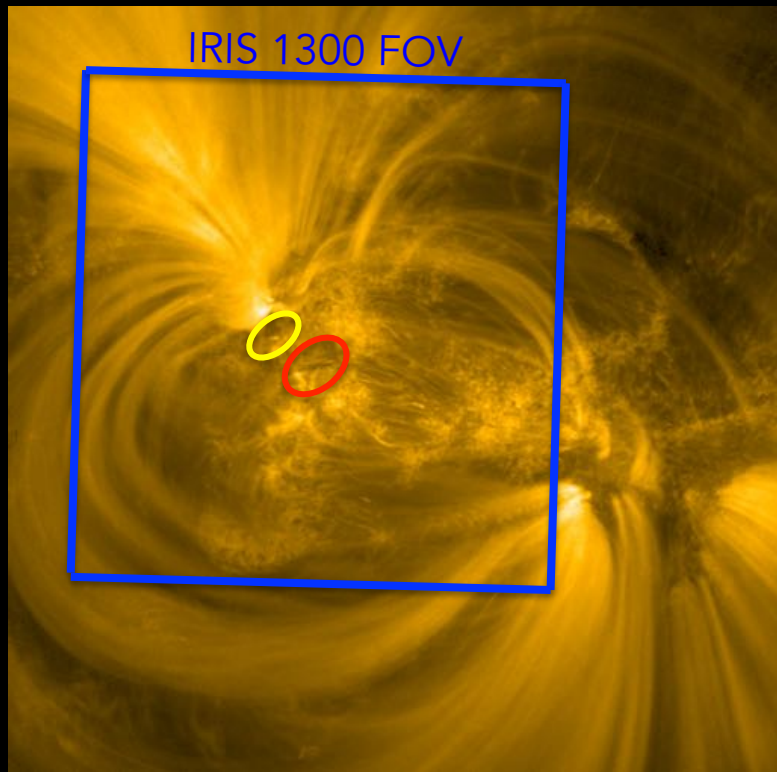
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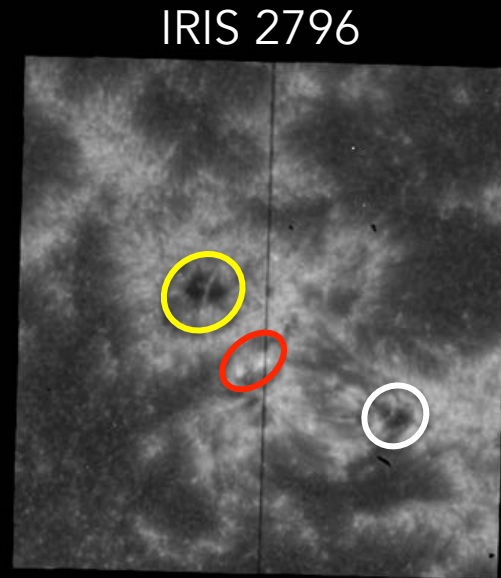
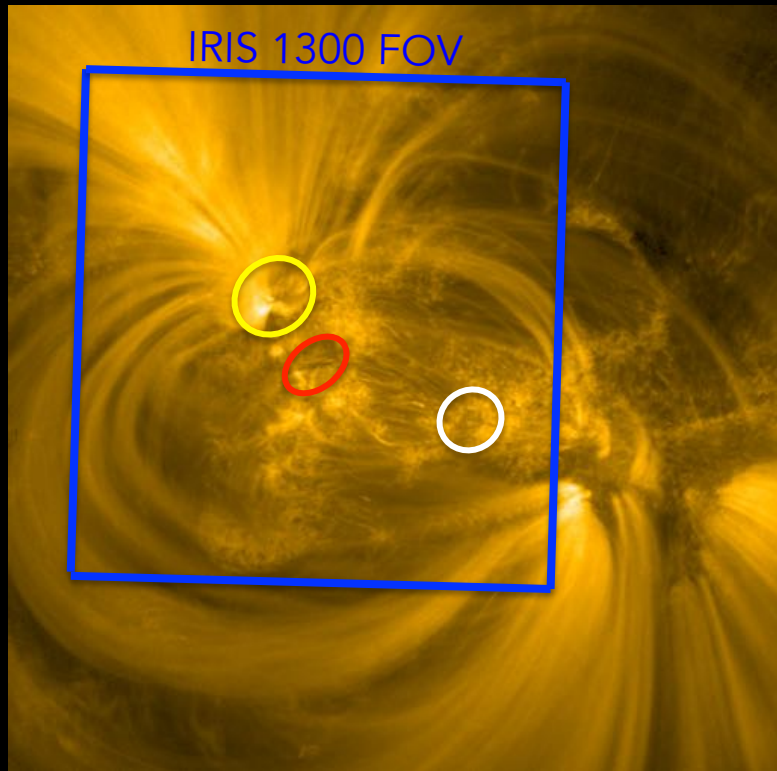
# Hi-C 2.1: IRIS coordinated data



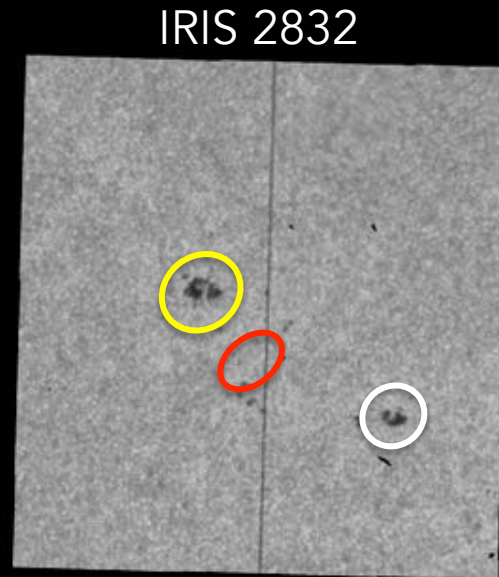
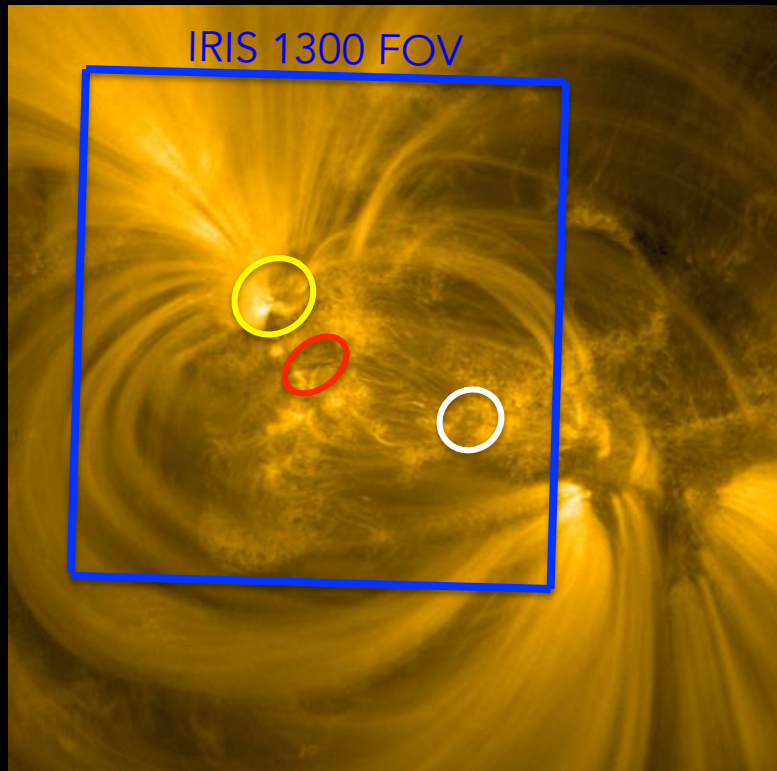
# Hi-C 2.1: IRIS coordinated data



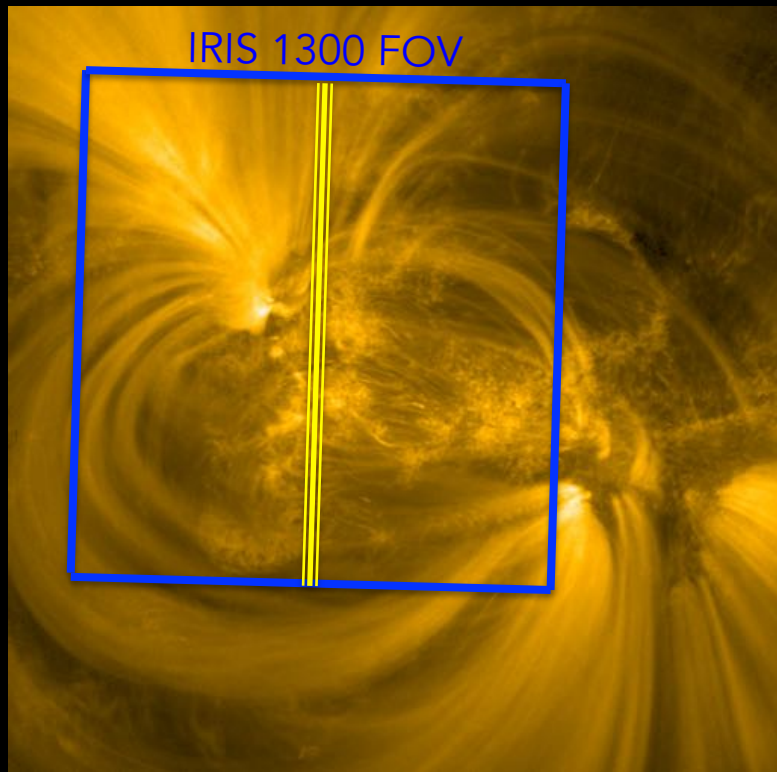
# Hi-C 2.1: IRIS coordinated data



# Hi-C 2.1: IRIS coordinated data



# Hi-C 2.1: IRIS coordinated data



Hi-C 172



IRIS Si IV



IRIS Mg II k



# Hi-C 2.1: Hinode coordinated data

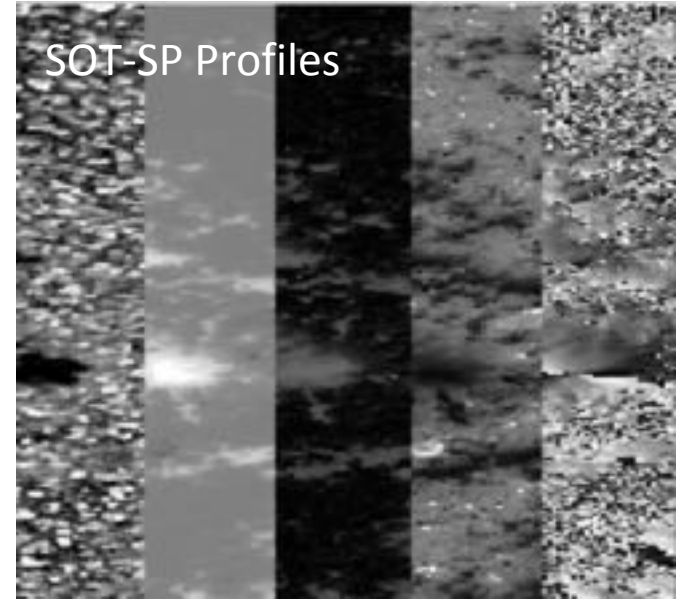
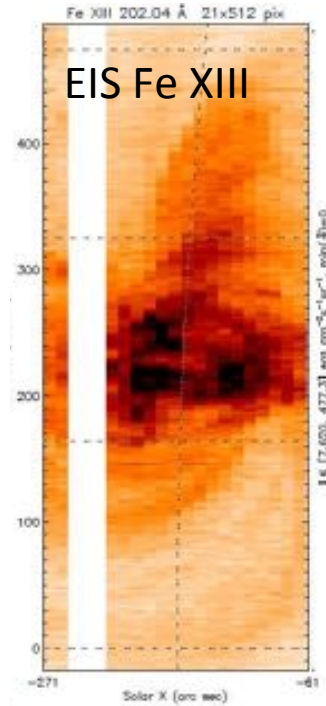
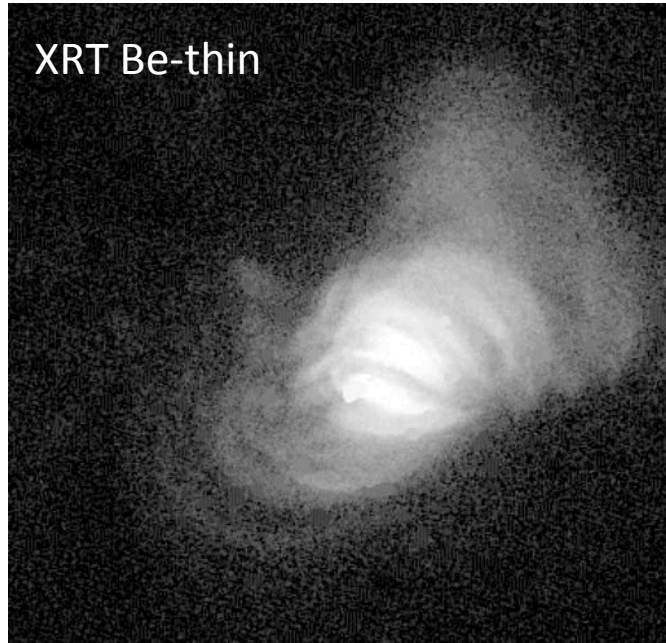
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All three Hinode instruments successfully captured the Hi-C 2.1 region.

- XRT provides coronal context of the movement of hot plasma in the upper atmosphere above the Hi-C features.
  - EIS provides narrowband spectra of the hot coronal loops thereby precisely measuring plasma flow properties.
  - SOT-SP provides underlying magnetic field information to high precision.
-

# Hi-C 2.1: Hinode coordinated data

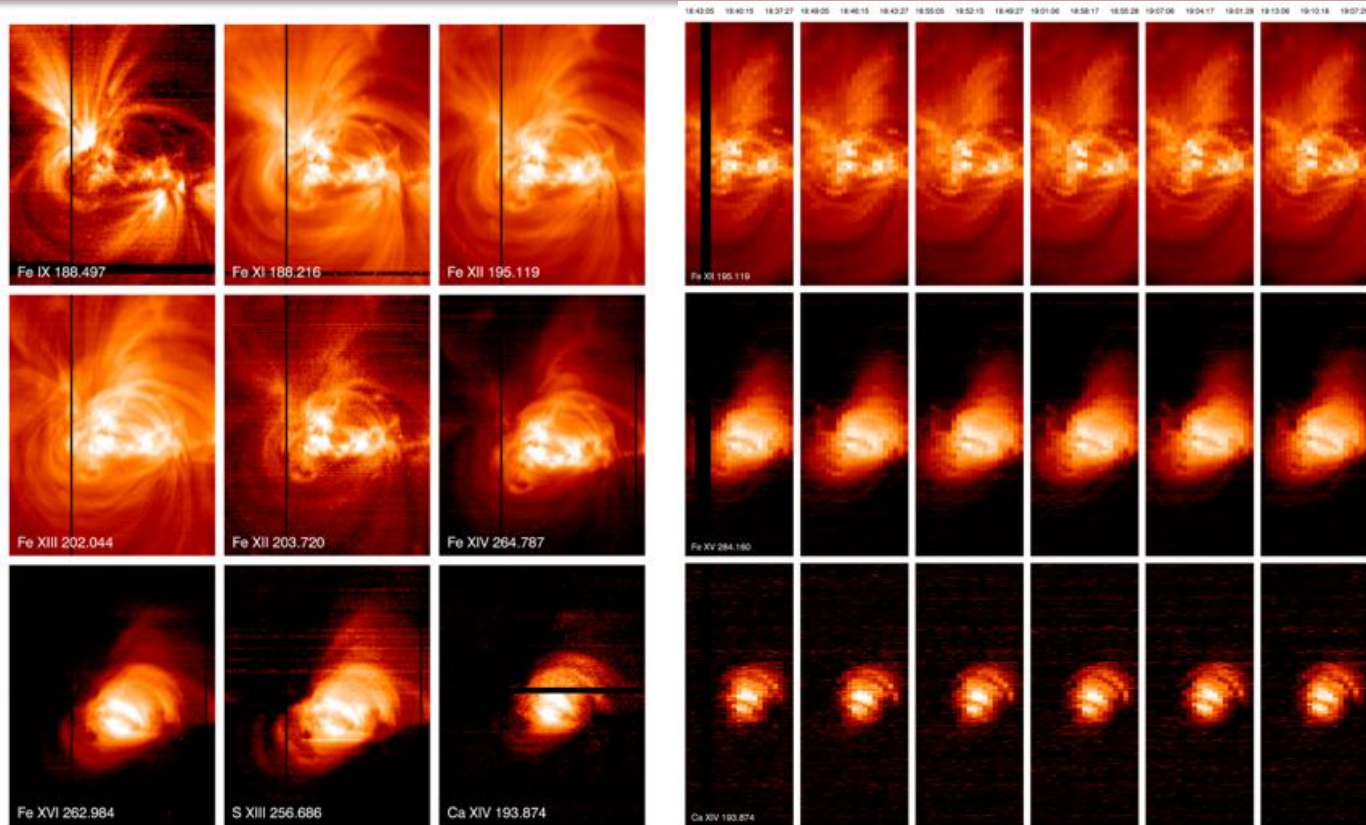
All three Hinode instruments successfully captured the Hi-C 2.1 region.





# Hi-C 2.1: Hinode coordinated data

**EIS BACK  
just in time!**



# Hi-C 2.1: Additional Coordinated Data Sets

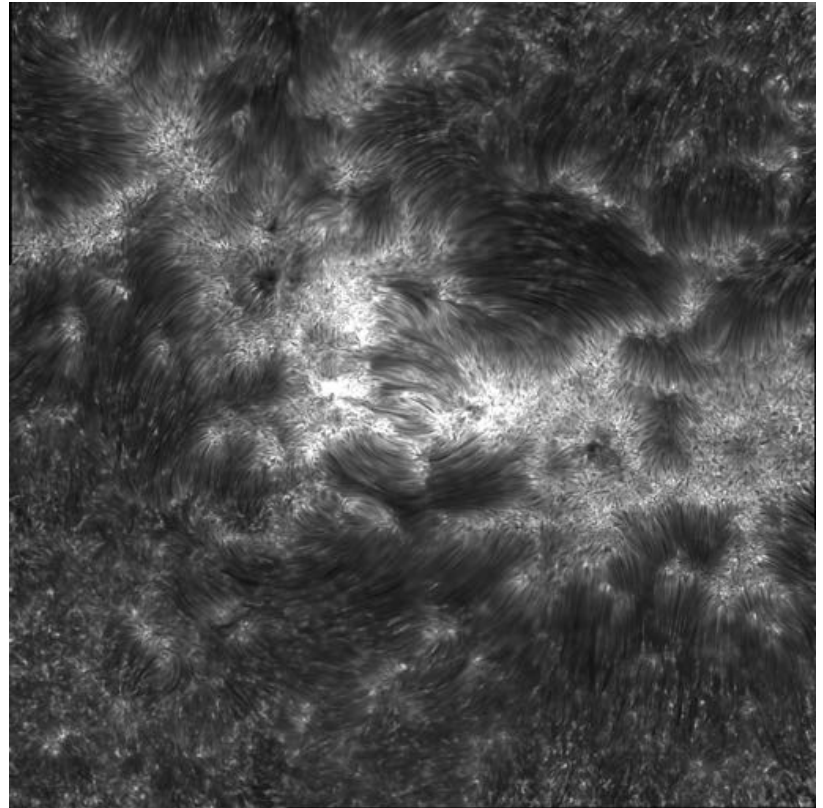
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- ✧ NSO / IBIS
- ✧ NuSTAR
- ✧ BBSO
- ✧ Owens Valley
- ✧ ~SST

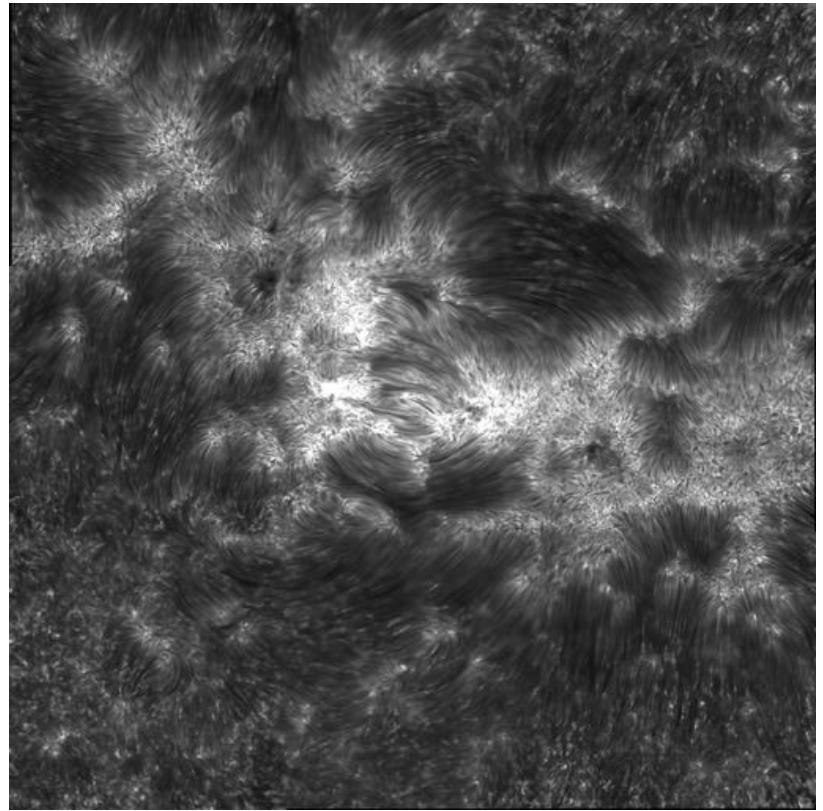
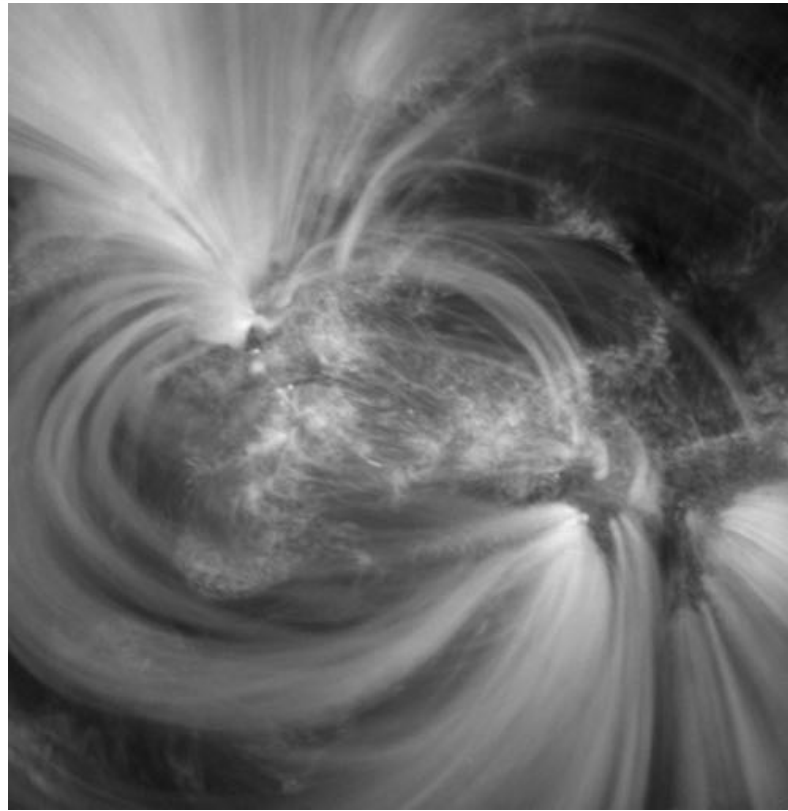
# Hi-C 2.1: IBIS coordinated data

- ✧ NSO / IBIS
- ✧ NuSTAR
- ✧ BBSO
- ✧ Owens Valley
- ✧ ~SST

IBIS Mosaic  
14:19 – 15:13 UT  
Ca II 8542 Å

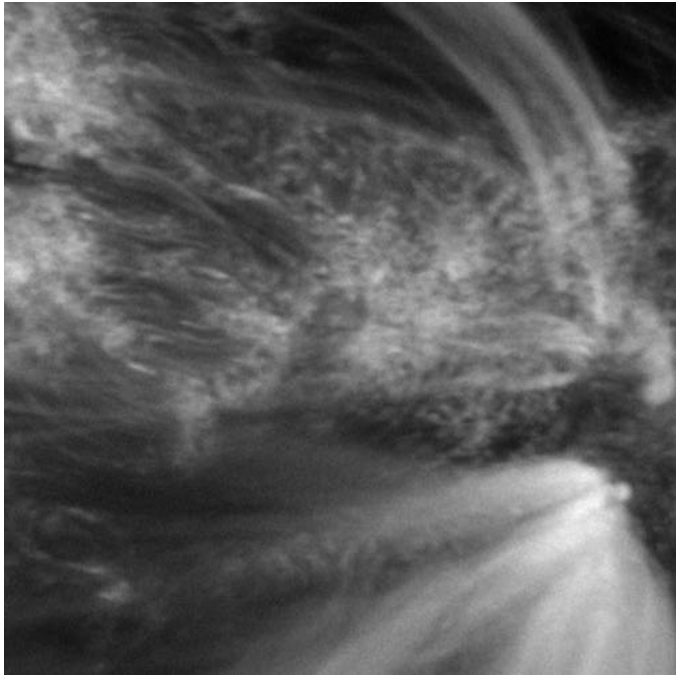


# Hi-C 2.1: IBIS coordinated data

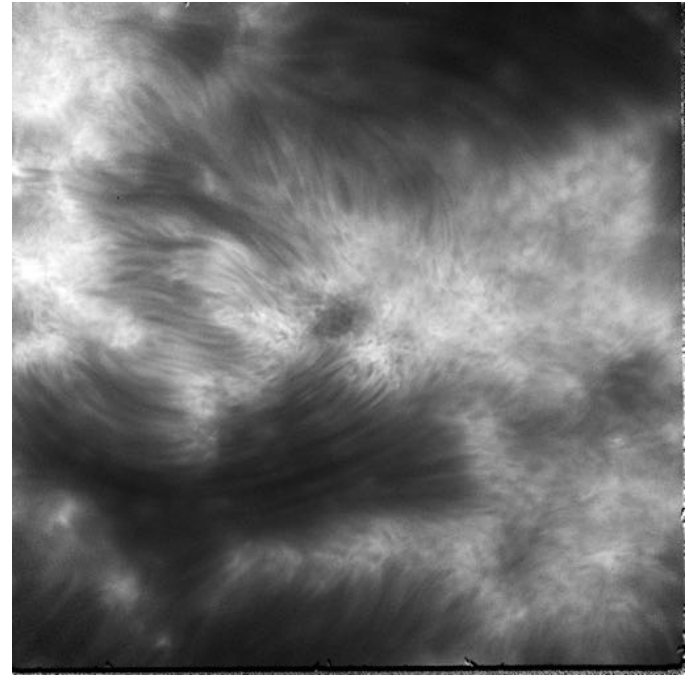


# Hi-C 2.1: IBIS coordinated data

Hi-C 172 Å  
18:56:22 UT

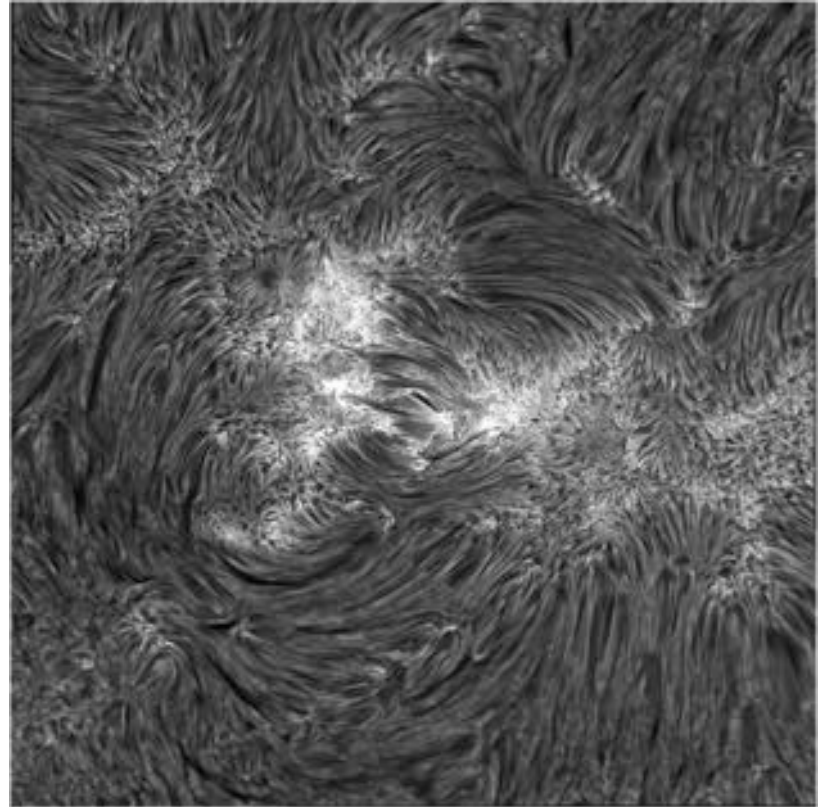


IBIS Ca II 8542 Å  
18:56:53 UT

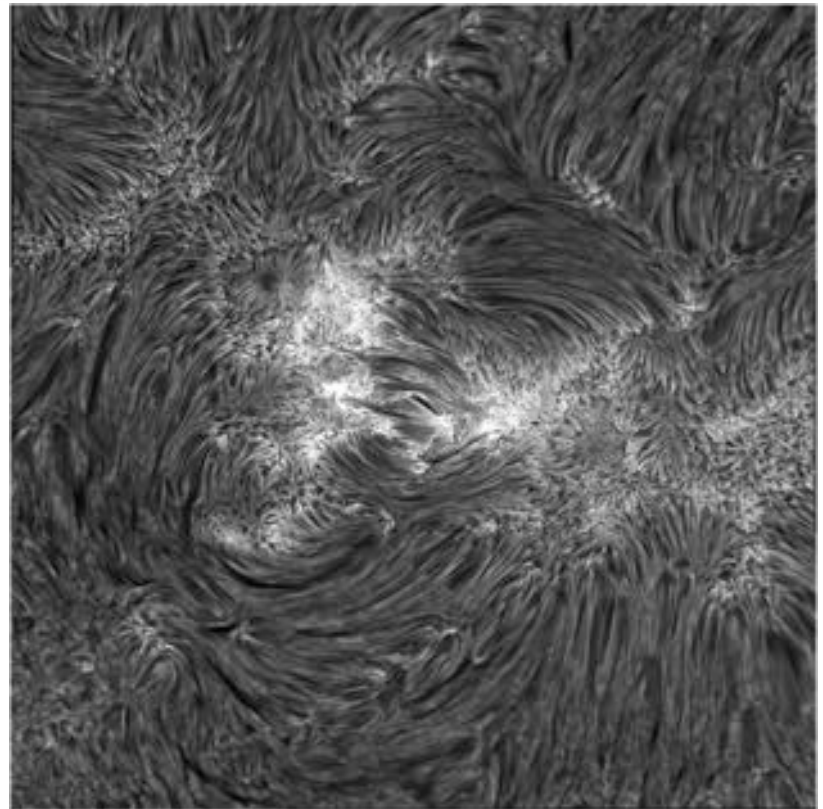
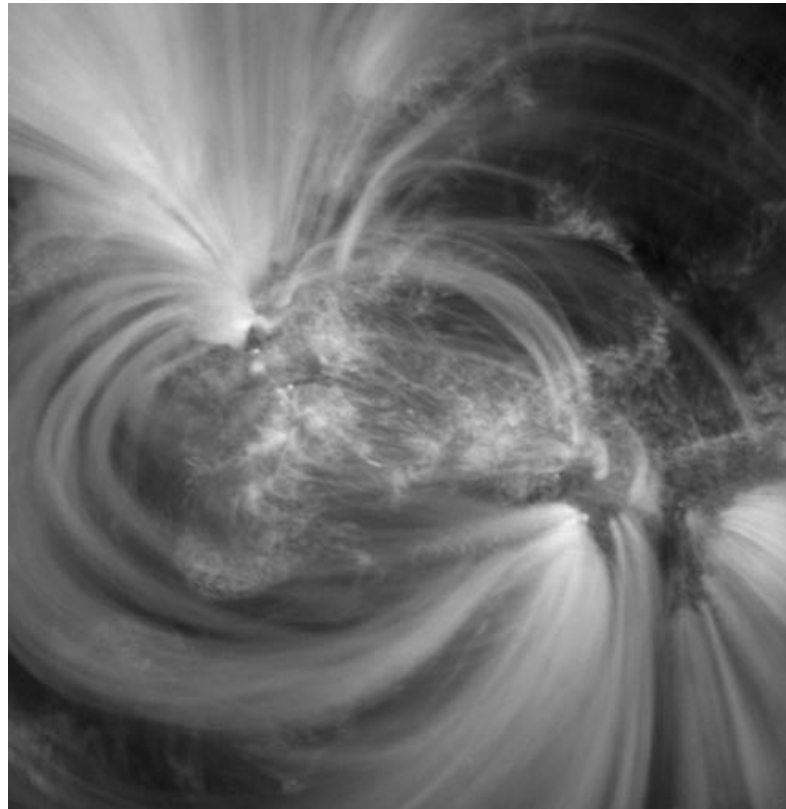


# Hi-C 2.1: IBIS coordinated data

IBIS Mosaic  
14:19 – 15:13 UT  
H $\alpha$  6563 Å  
0.098 "/pixel

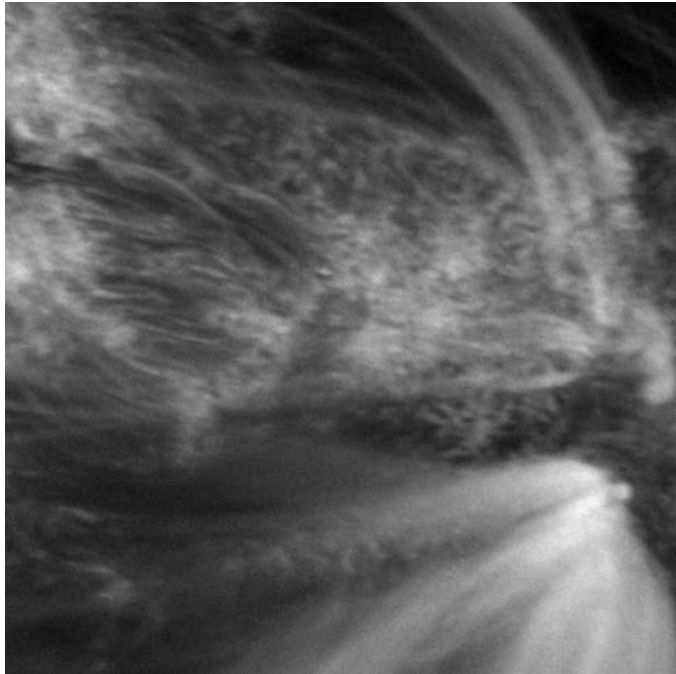


# Hi-C 2.1: IBIS coordinated data

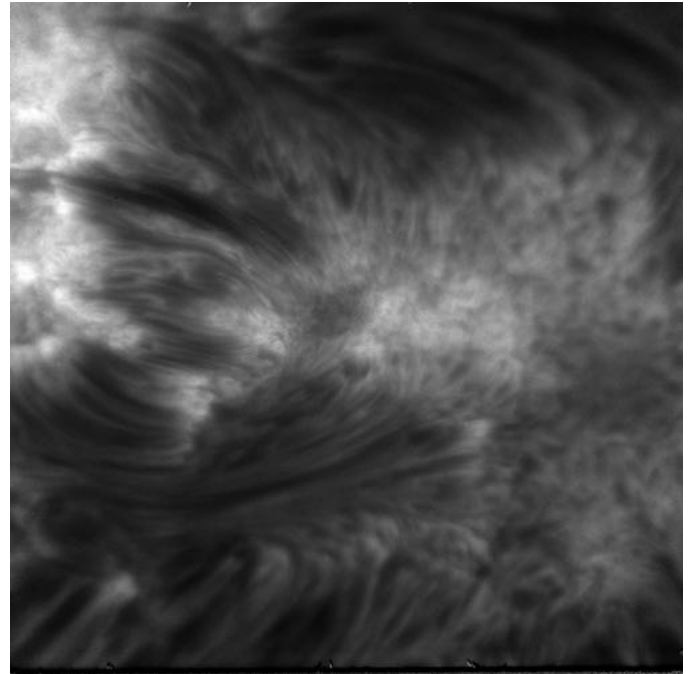


# Hi-C 2.1: IBIS coordinated data

Hi-C 172 Å  
18:56:22 UT



IBIS H $\alpha$  6563 Å  
18:56:22 UT





# Hi-C 2.1: NuSTAR coordinated data

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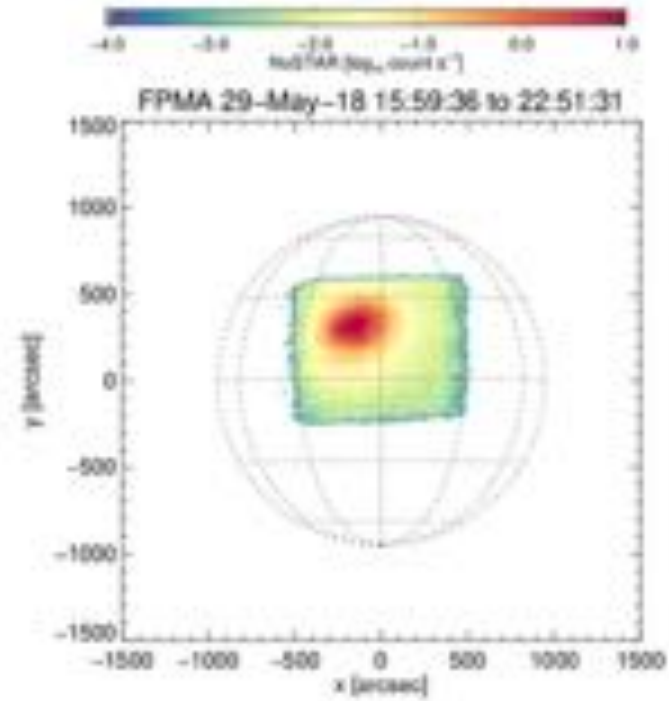
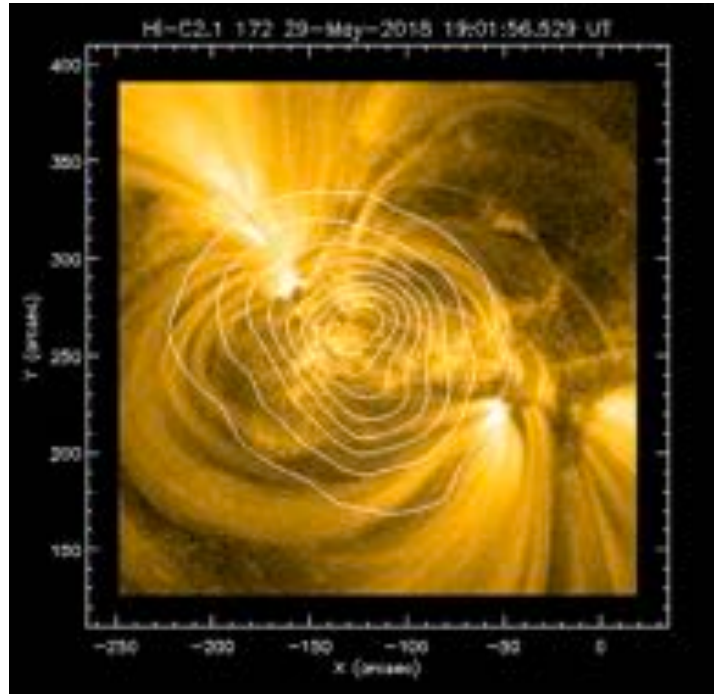
- ✧ NSO / IBIS
- ✧ NuSTAR
- ✧ BBSO
- ✧ Owens Valley
- ✧ ~SST

Hard X-ray Astrophysics Mission  
High Sensitivity

5 orbits on day of launch,  
primarily targeting AR 12712

# Hi-C 2.1: NuSTAR coordinated data

- ✧ NSO / IBIS
- ✧ NuSTAR
- ✧ BBSO
- ✧ Owens Valley
- ✧ ~SST



# Hi-C 2.1: Additional Coordinated Data Sets

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- ✧ NSO / IBIS
- ✧ NuSTAR
- ✧ BBSO
- ✧ Owens Valley
- ✧ ~SST

\*\* Special thanks for assisting with the coordinations goes out to:

L. Glesener,  
K. Reardon,  
B. Chen,  
Y. Chai,  
N. Karuda,  
P. Antolin,  
J. Leenaarts,  
G. Vissers

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# Hi-C 2.1: Science topics being pursued

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- Thin, stranded loops [width variations]
  - Flows between transition region, chromosphere, and corona
  - Spicules
  - Nano/microflares
  - Moss/Plage brightenings
  - Flows along loops
  - Waves
  - Mini-jets
  - Etc.
-

# Hi-C 2.1: AGU plug

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Add AGU session approved for highlighting suborbital results.

Hi-C 2.1 science results expected to be presented in this session!



**FALL MEETING**

Washington, D.C. | 10-14 Dec 2018

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# Hi-C 2.1: POCs

Amy Winebarger

Sabrina Savage

Laurel Rachmeler

Leon Golub



*Thanks, and stay tuned....*

