Hi-C observations of an active region corona, and investigation of the underlying magnetic structure

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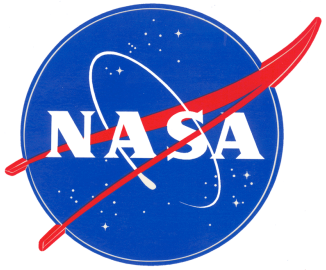
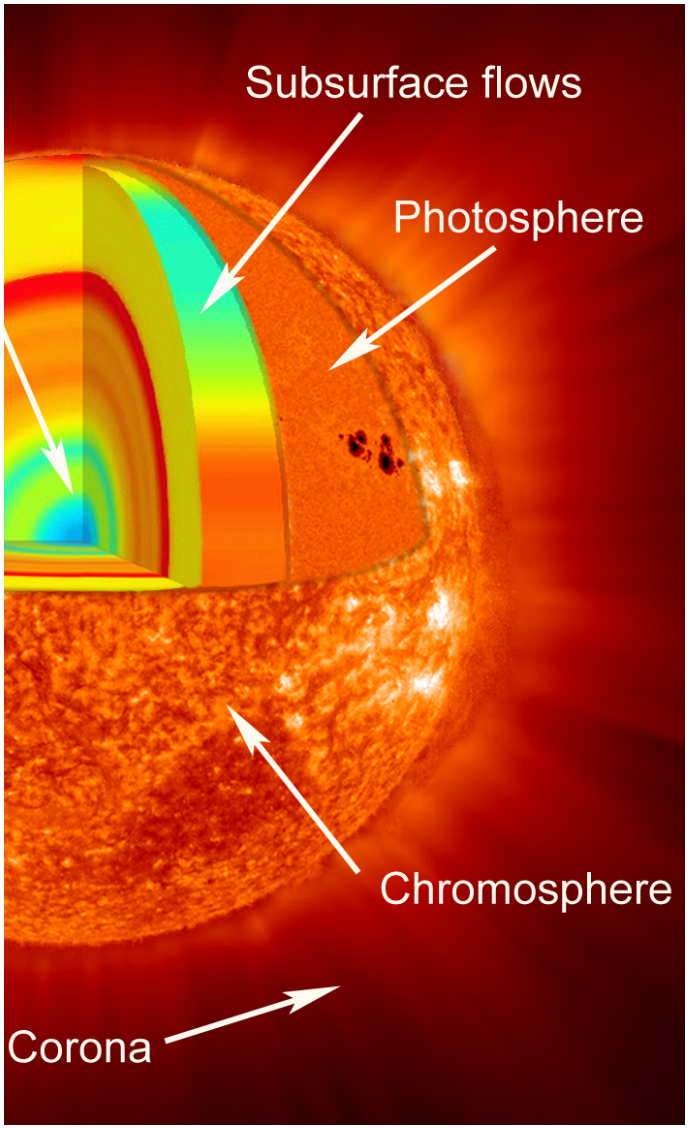
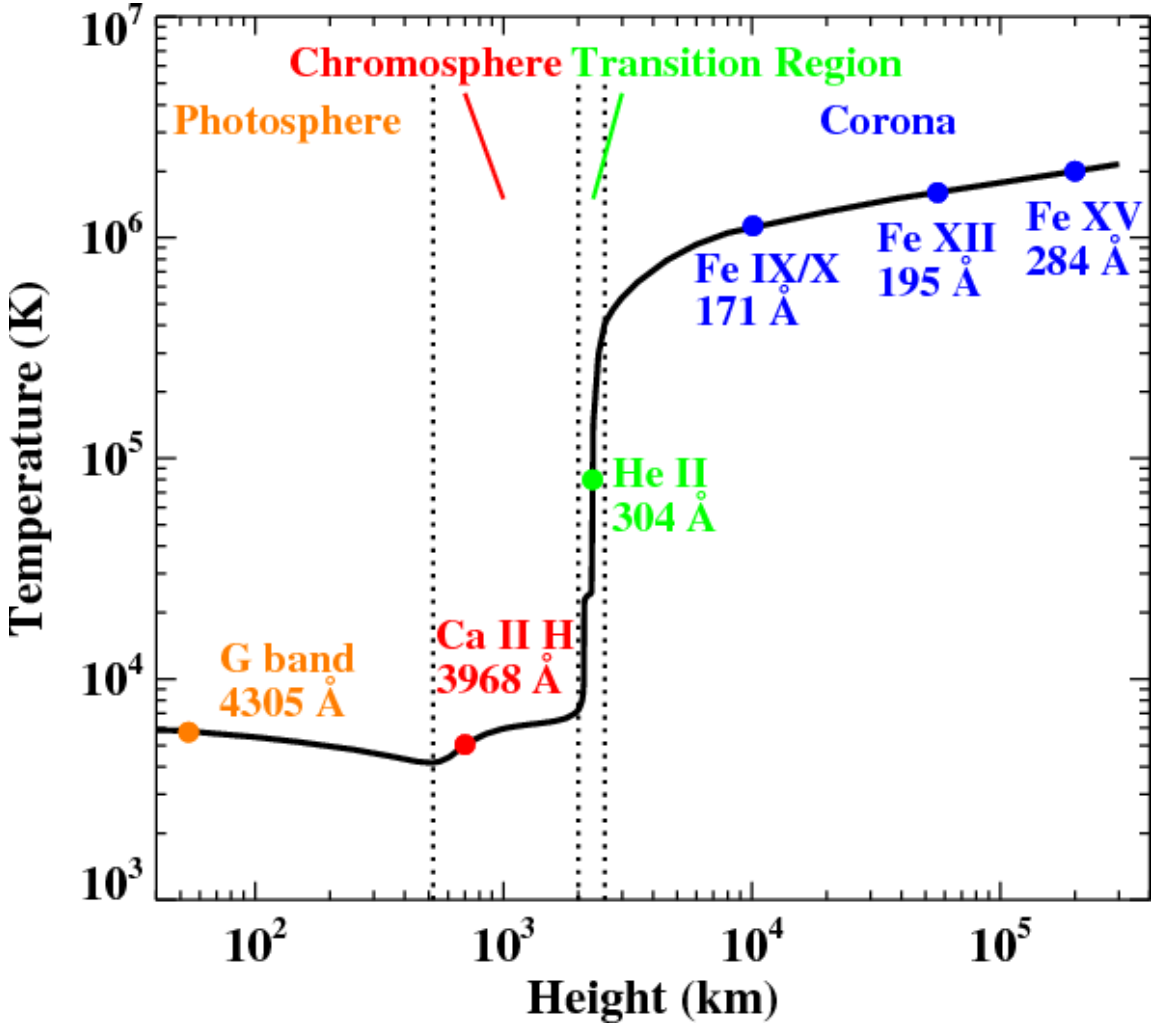


Marshall Space Flight Center

Introduction: coronal heating problem





Transport of required energy to heat the corona?
Proposals:

Wave Heating

MHD waves produced by turbulence in the convection zone travel upward and dissipate in the corona, transferring their energy in the surrounding gas in the form of heat.

All waves except Alfven waves dissipate before reaching the corona?

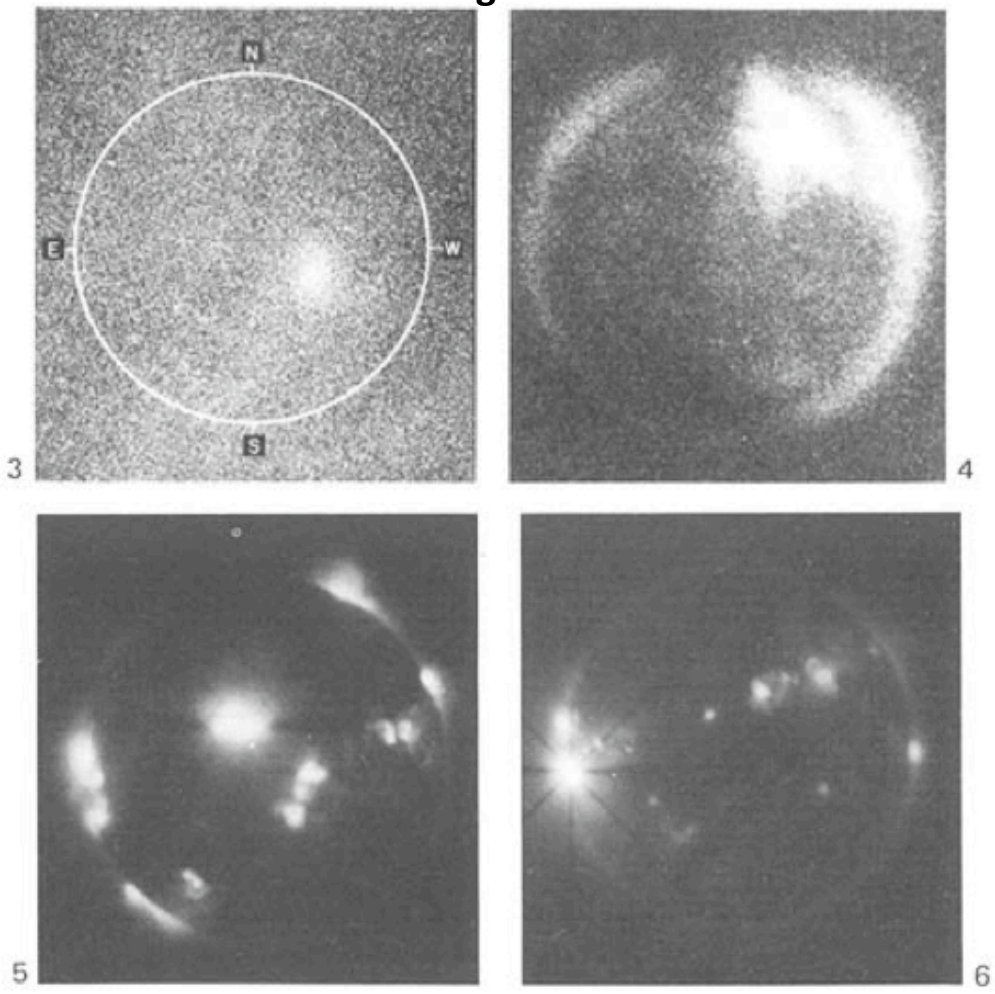
Magnetic/nano-flare Heating

Magnetic energy is built up continuously by the photospheric motion and released in the form of heat by current dissipation via reconnection of braided magnetic field structure, first proposed by Parker three decades ago.

QS -> granulation/convection
ARs-> flux emergence/cancellation? shearing motion?
No significant observational evidence (to my knowledge)!

Early observations

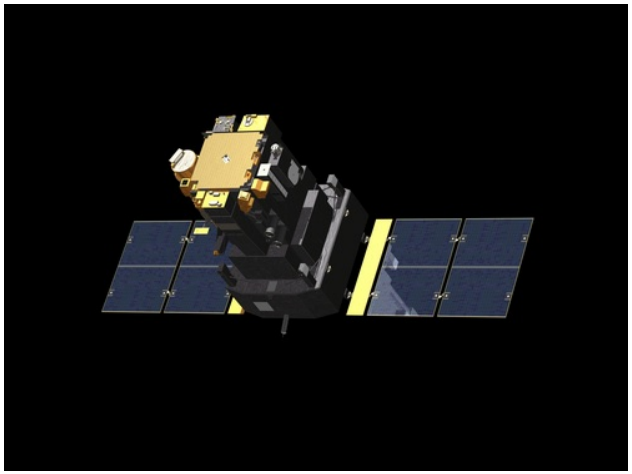
Rocket flights 1963-1969



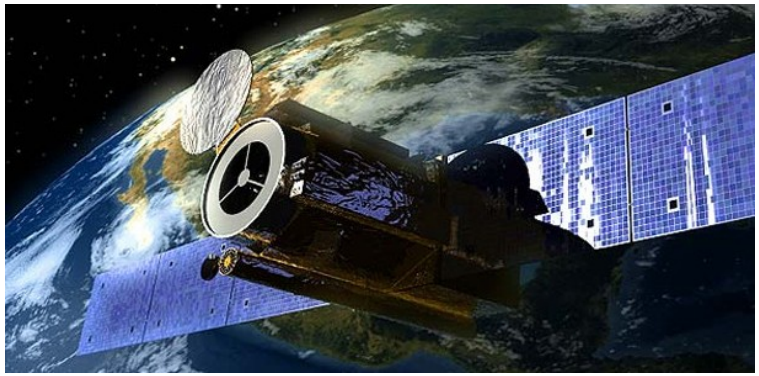
Skylab 1 June 1973

Image credits NASA

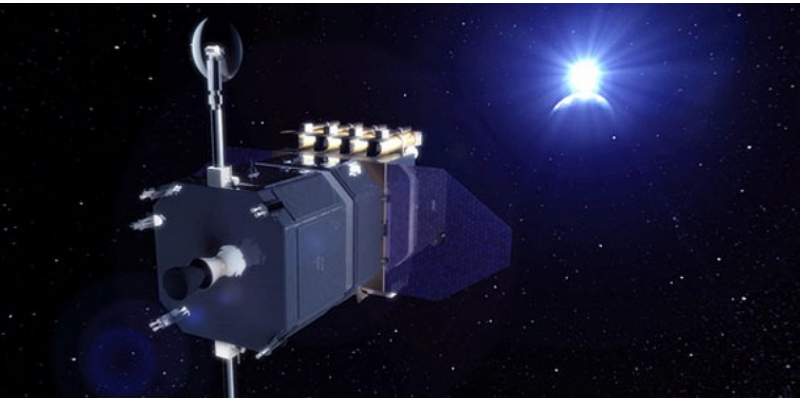
Current Instrumentation



SoHO

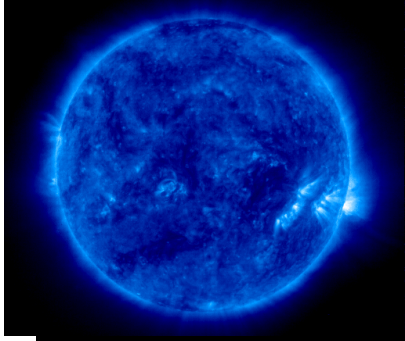


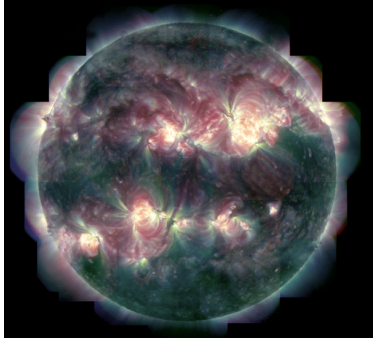
Hinode

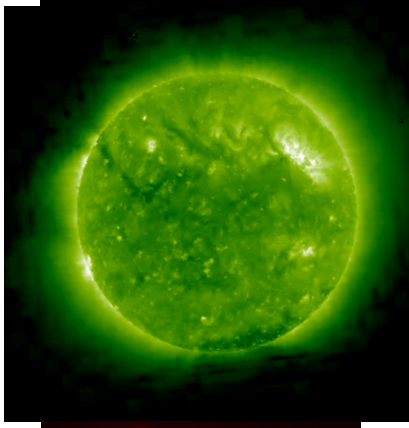


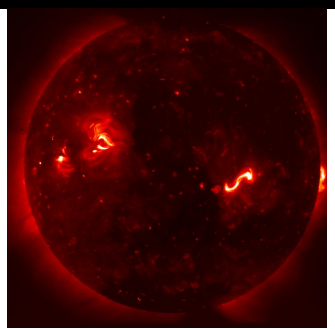
SDO

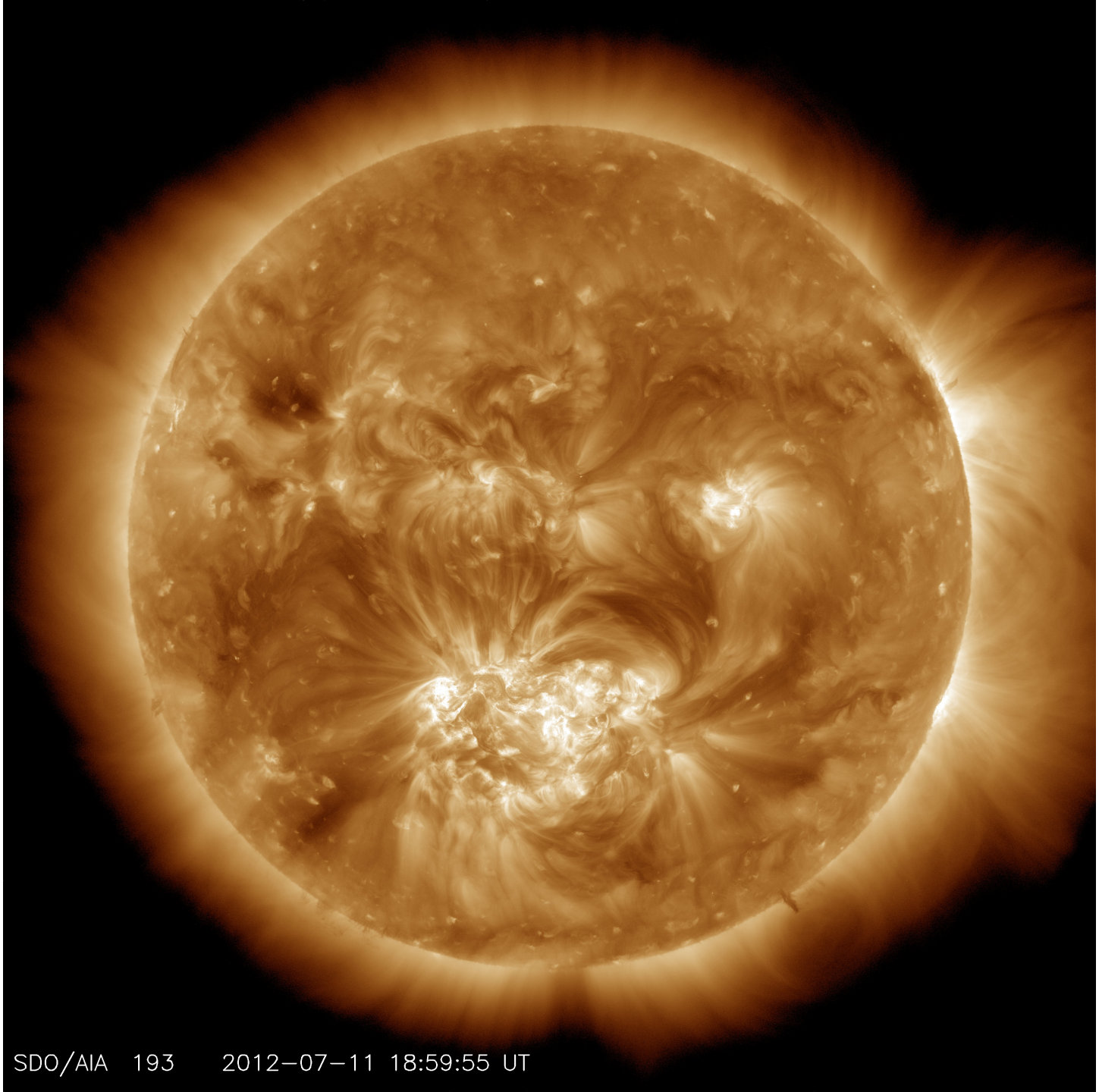
STEREO










SDO/AIA 193 2012-07-11 18:59:55 UT

Instrument	FOV	Resolution
SOHO/EIT	FD	5”
TRACE	510”x510”	~ 1”
STEREO/EUVI	FD	1.6”
Hinode/XRT	FD/PD	2”
SDO/AIA	FD	~ 1.2”
Hi-C	410”x410”	~ 0.2”

1” ~ 725 km

Hi-C Team Members

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)

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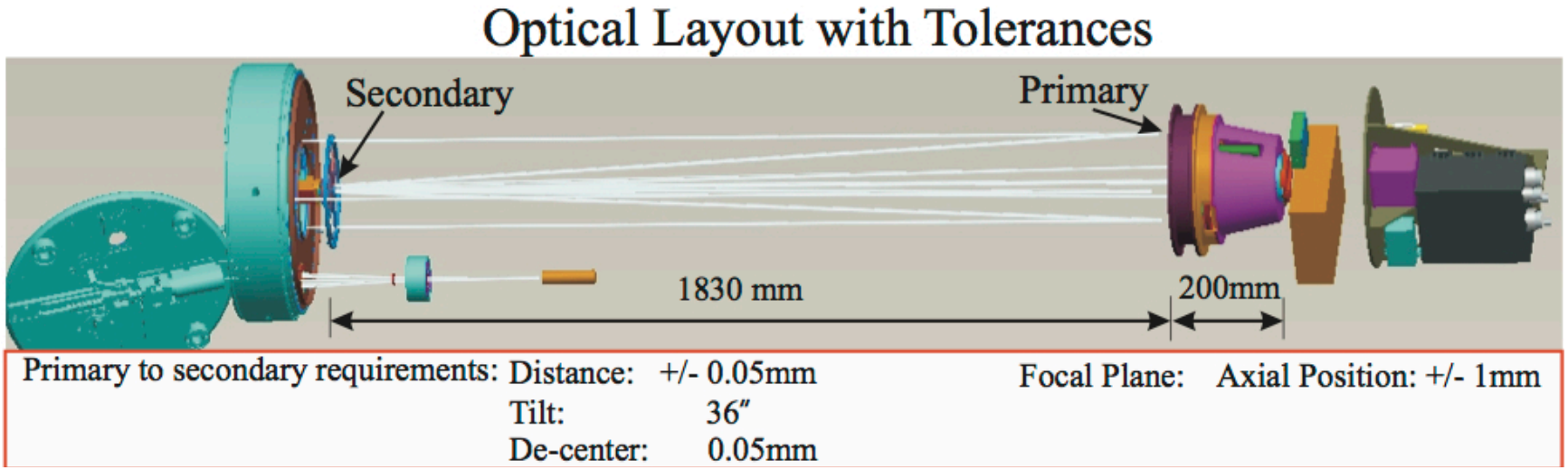
Dyana Beabout (MSFC)
Brent Beabout (MSFC)
William Podgorski (SAO)
Ken McKracken (SAO)
Mark Ordway (SAO)
David Caldwell (SAO)
Henry Berger (SAO)
Richard Gates (SAO)
Simon Platt (UCLAN)
Nick Mitchell (UCLAN)

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

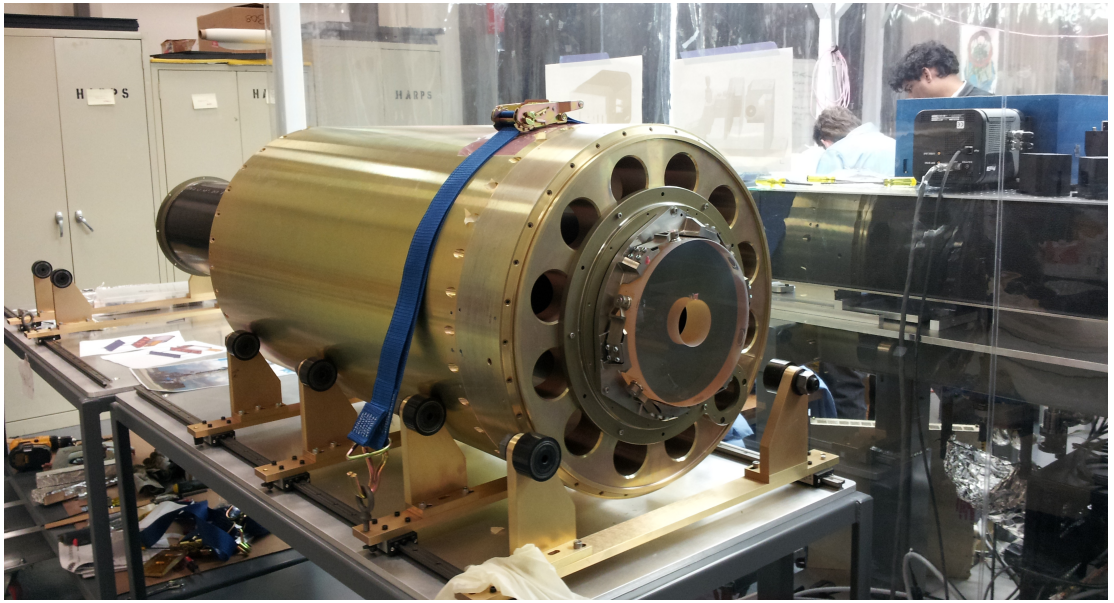
Instrument details

See, Kobayashi, Cirtain, Winebarger et al. 2014, Sol Phys



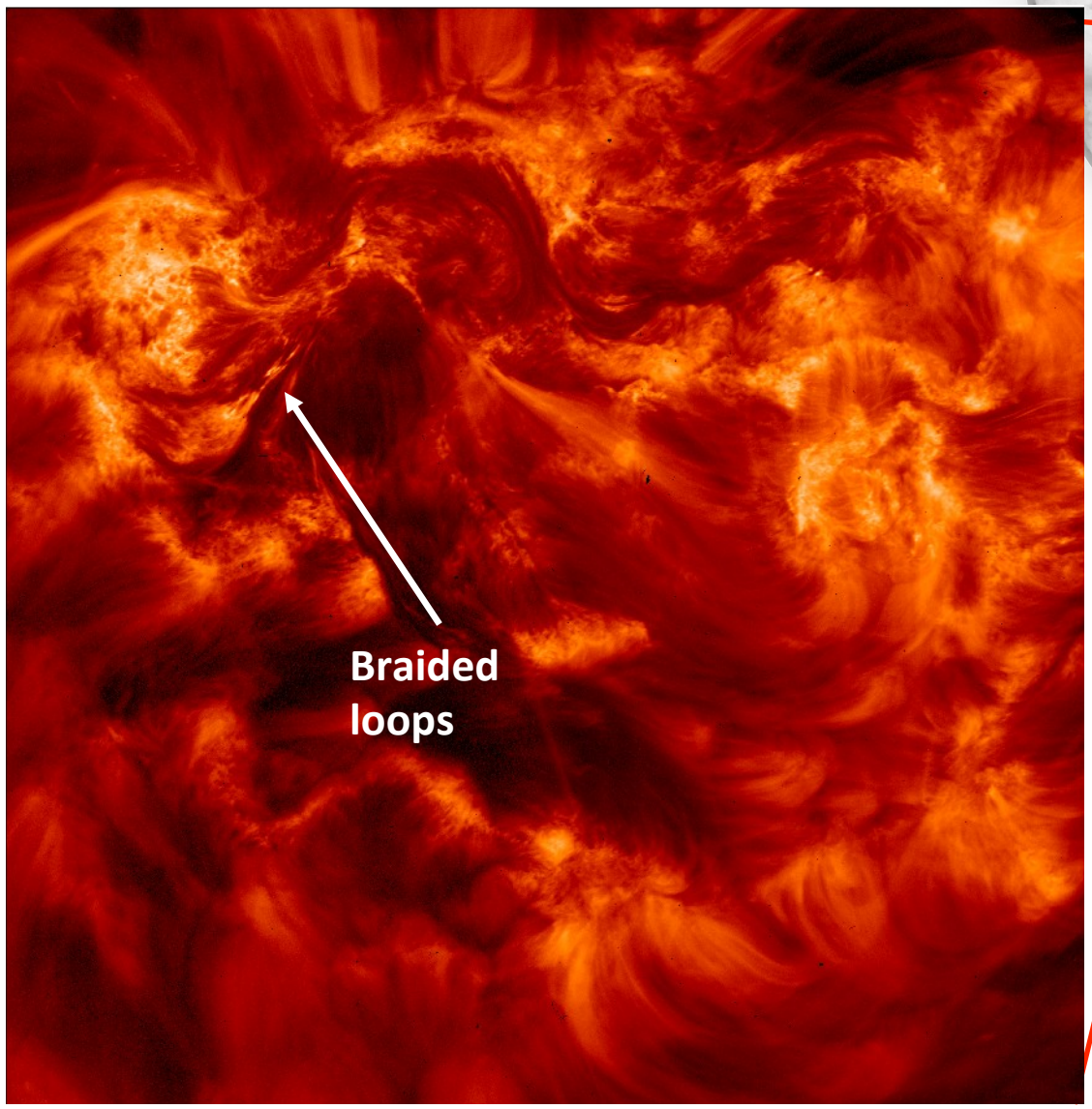
Hi-C is a narrowband EUV imager. The wavelength band is centered on 193 Å.

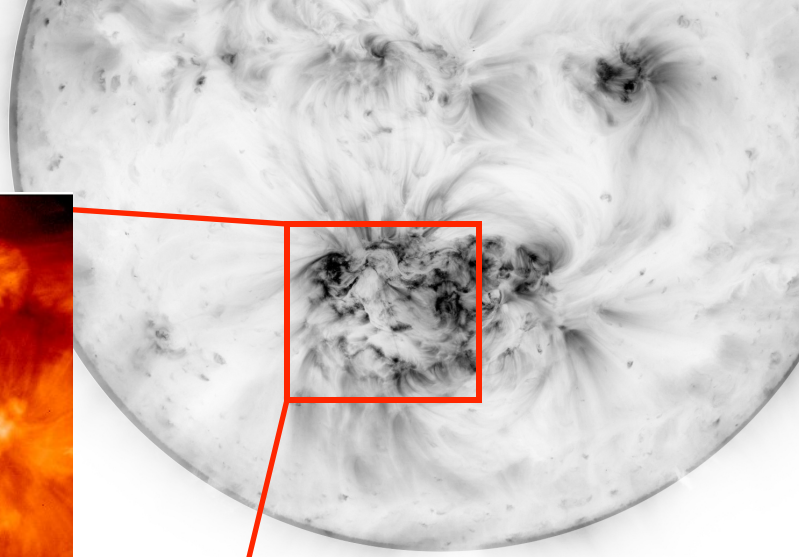
Multilayer coatings by David Windt, RXO LLC.



- 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
- The 193 Å was selected because of the strong emission line of Fe XII (peak formation temperature of 1.5 MK)
- Hi-C collected data for 345 s @ 5.4 s cadence
- The Hi-C target region was NOAA AR 11520; 11 July 2012, 18:51-18:57 UT

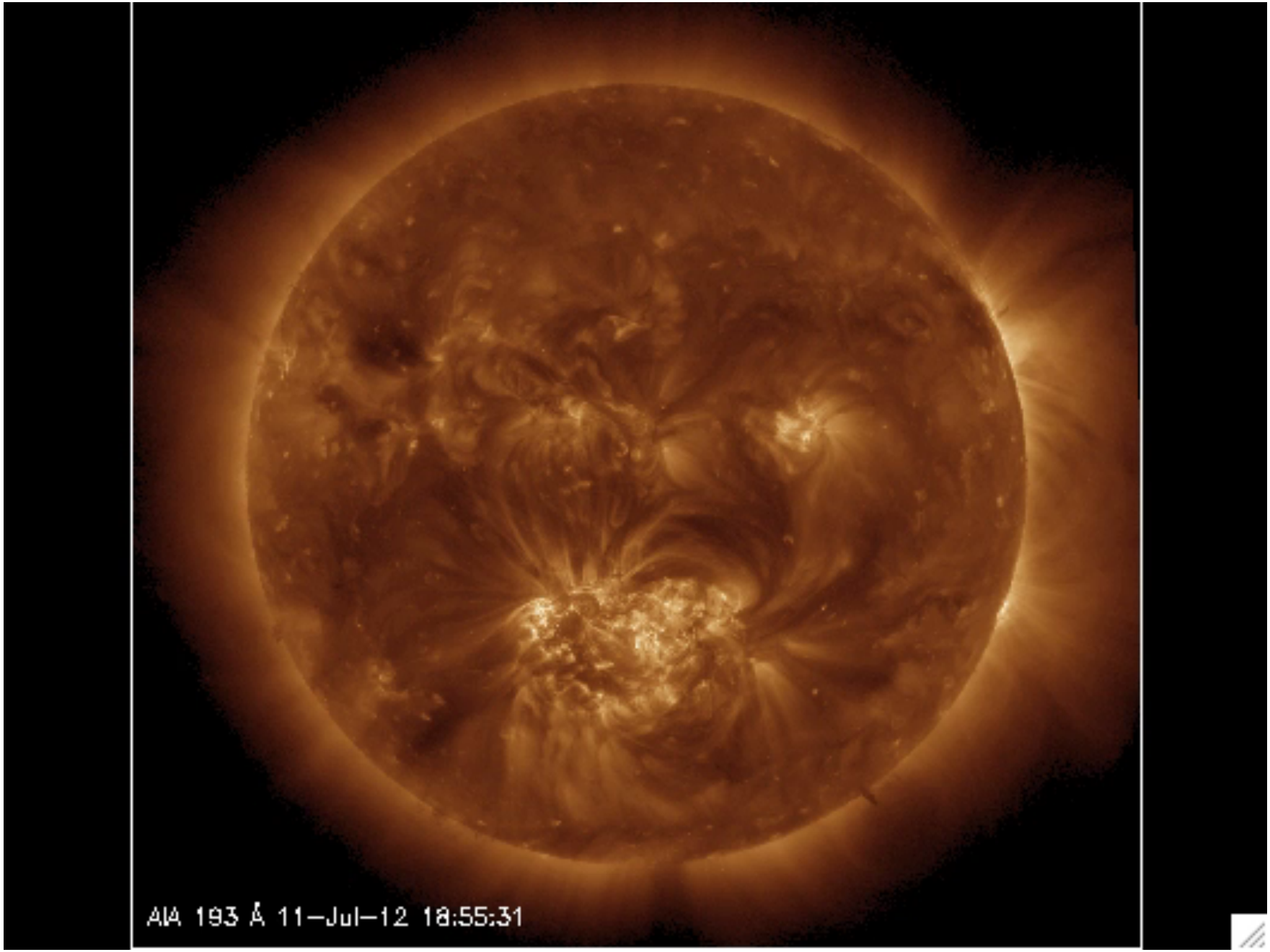
Hi-C First Results

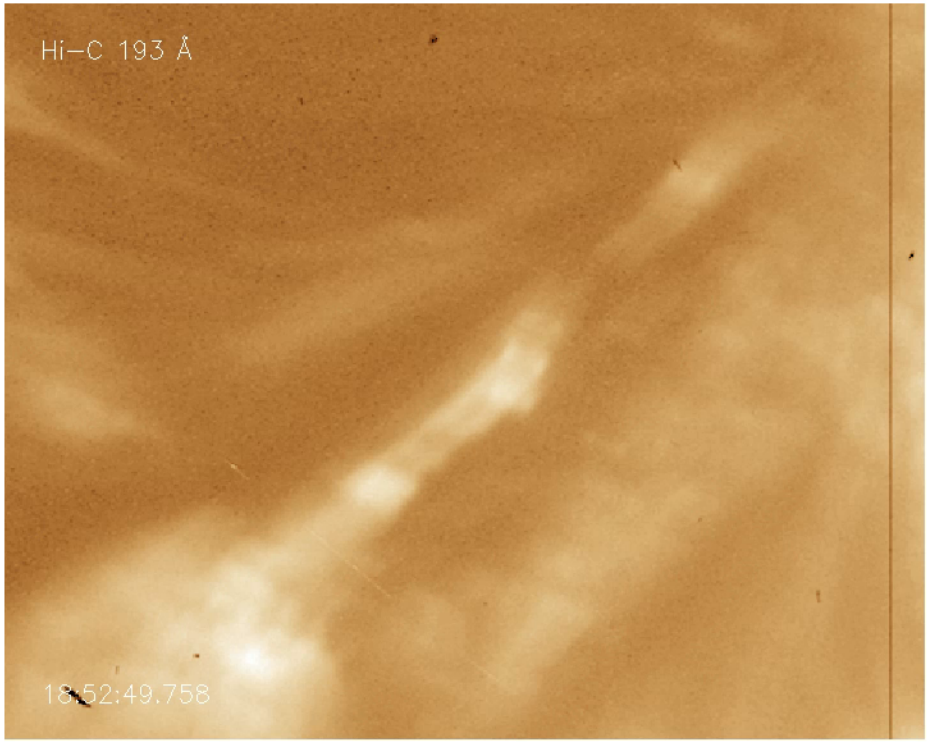




Braided loops

Cirtain, Golub, Winebarger et al. 2013, Nature

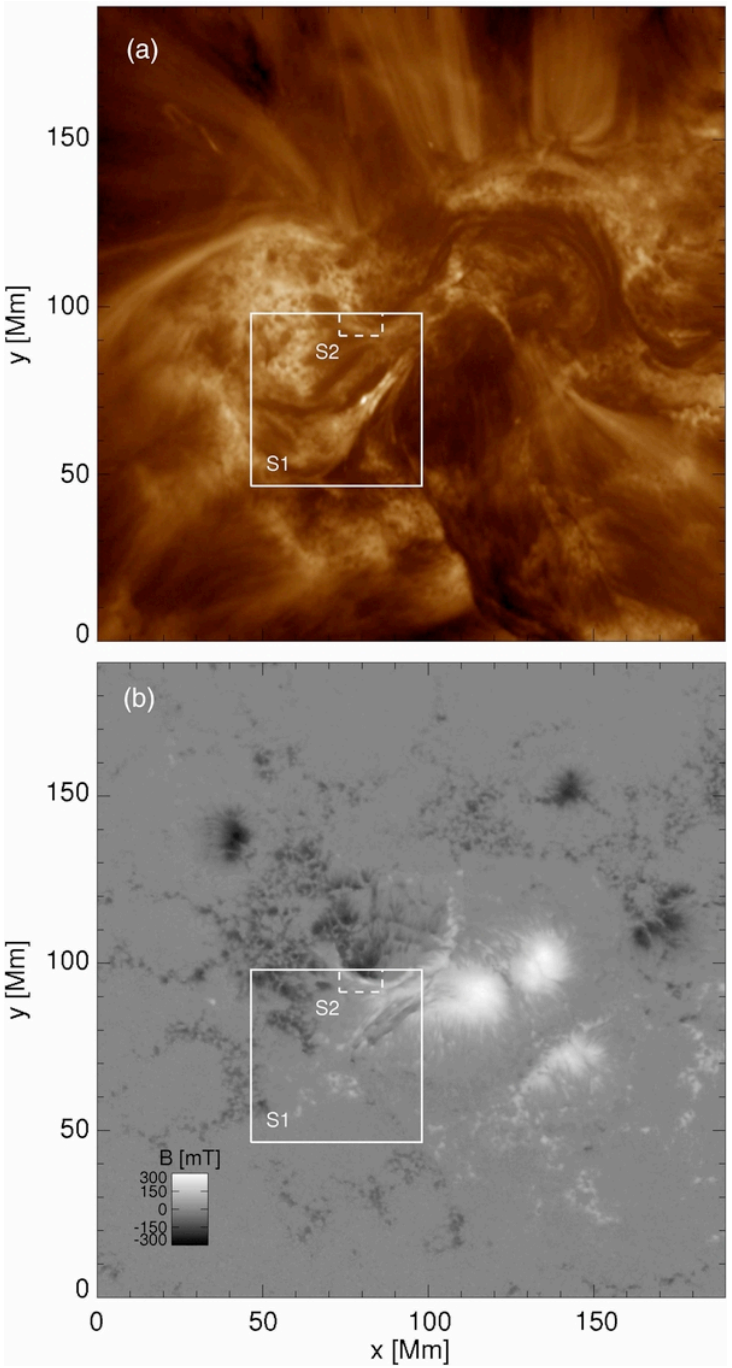

AIA 193 Å 11-Jul-12 18:55:31

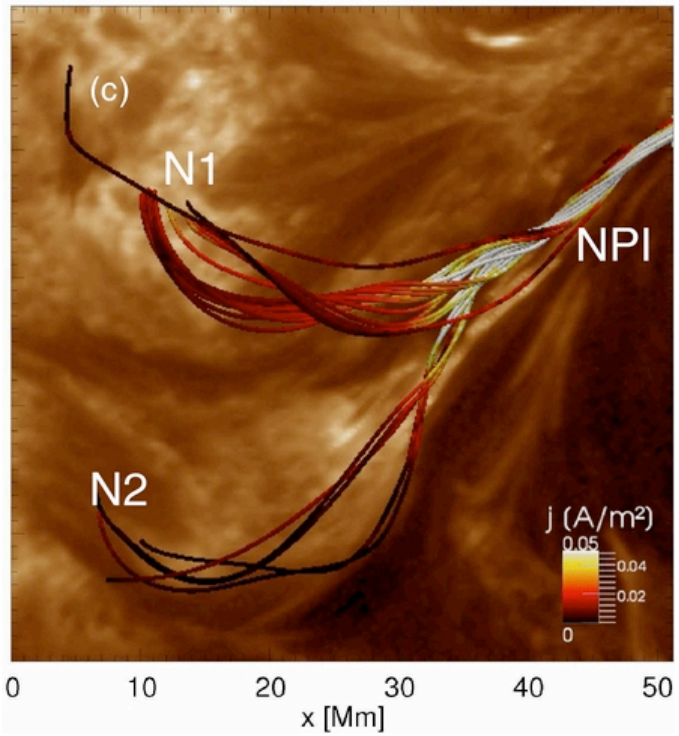

Hi–C 193 Å
18:52:49.758

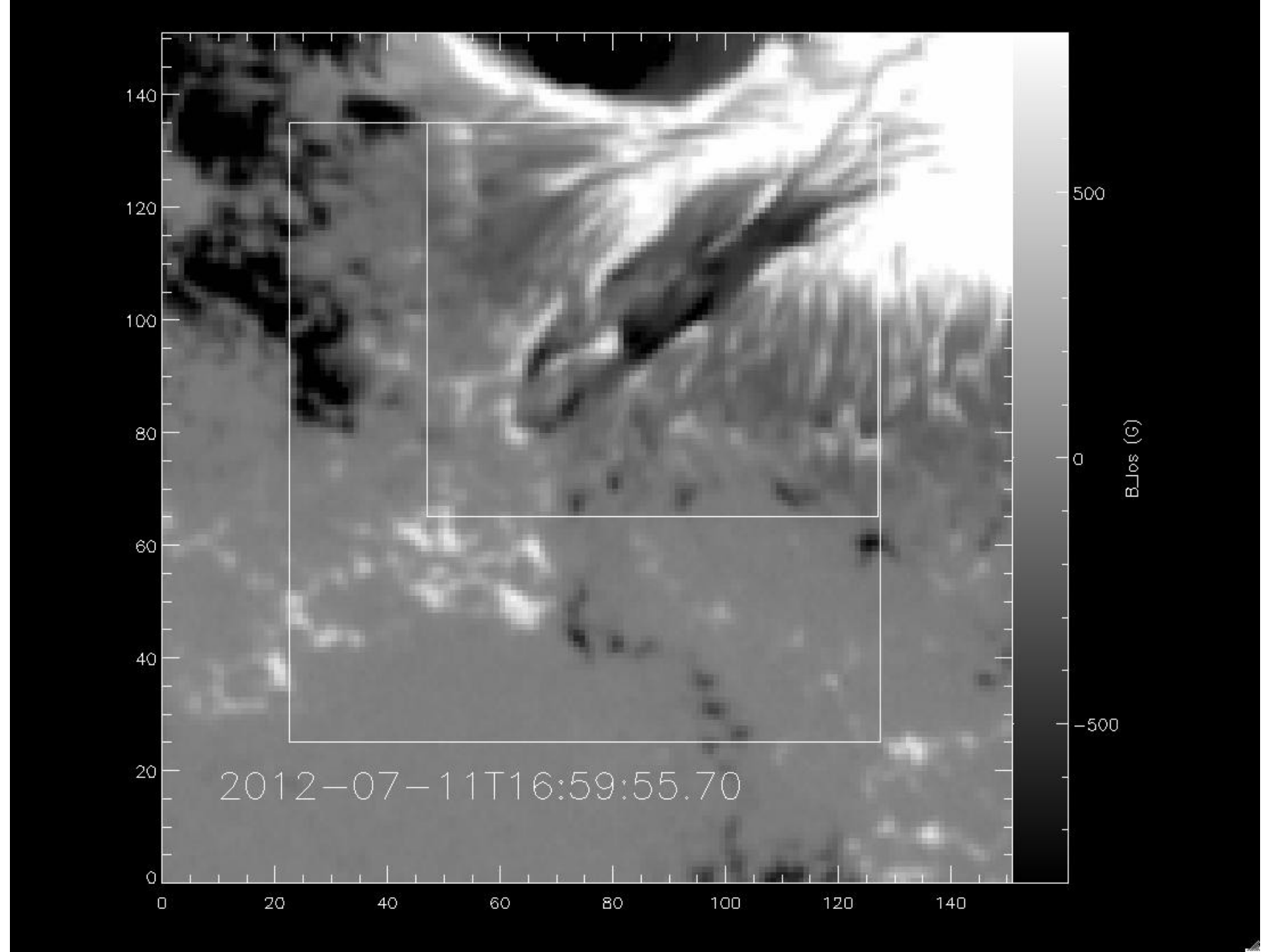

Hi–C 193 Å
18:52:49.758

NLFFF extrapolation confirms the braided structure, and free magnetic energy estimates in the given volume

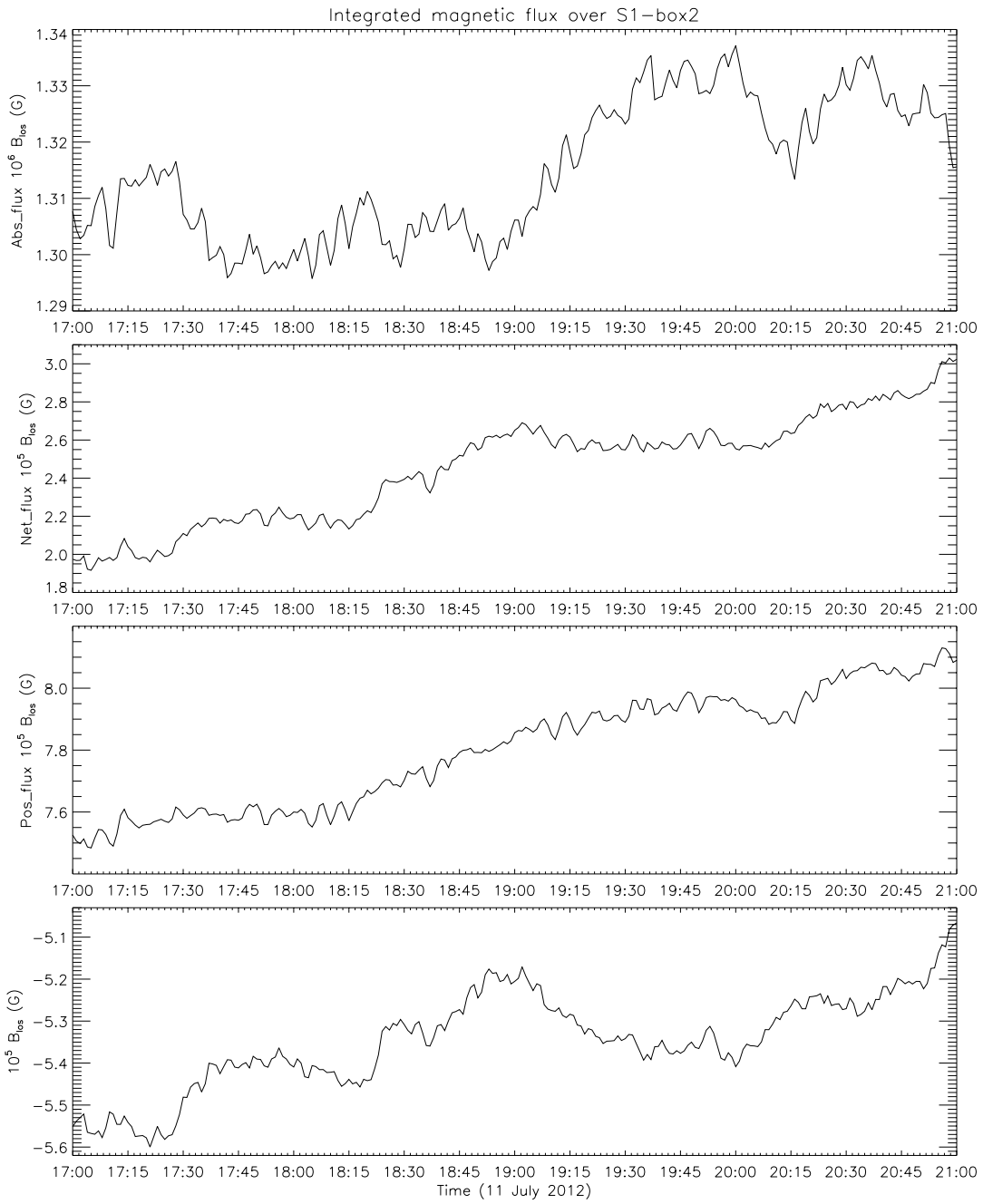
Thalmann, Tiwari & Wiegelmann, 2014



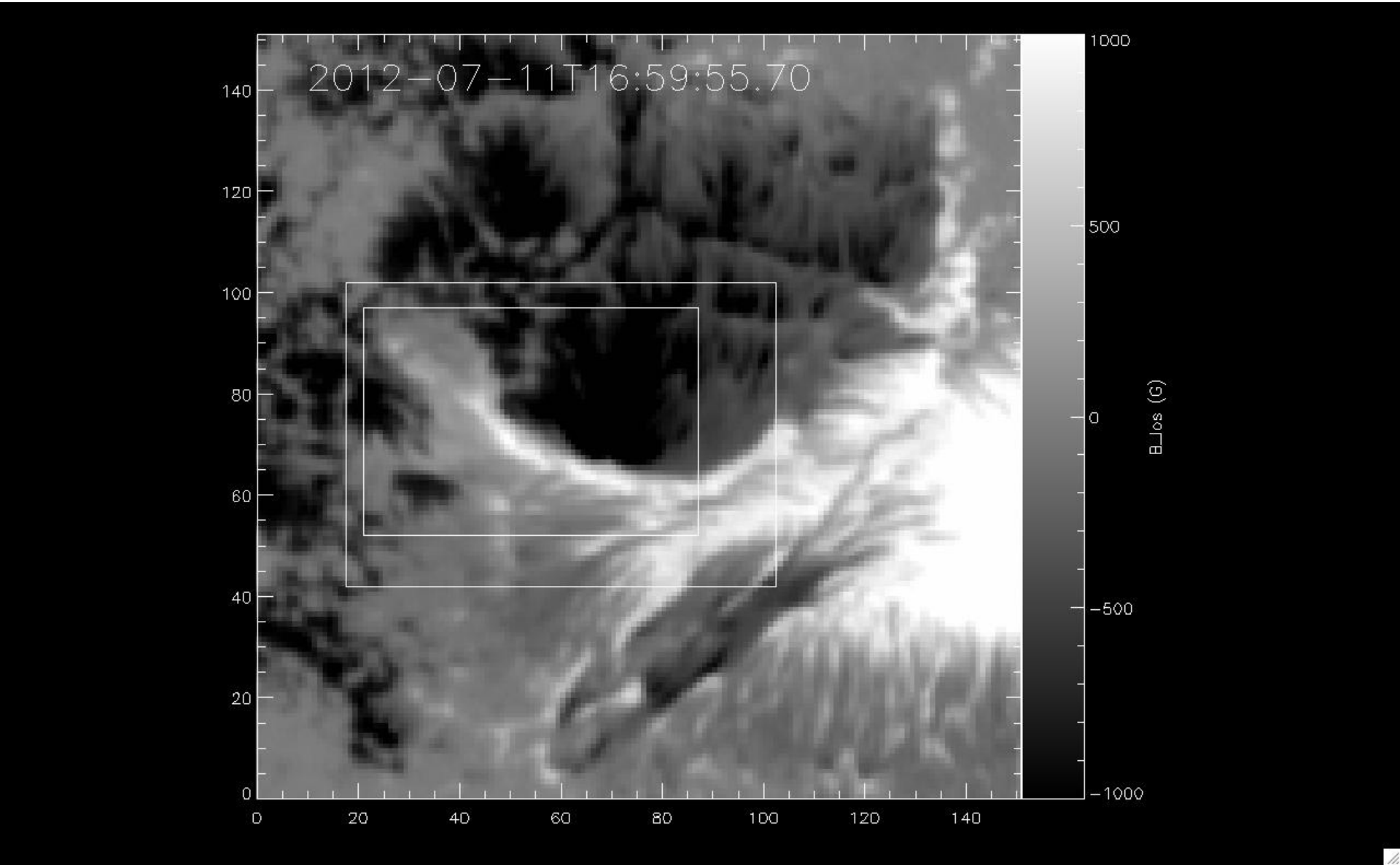



2012-07-11T16:59:55.70
B_los (G)
500
0
-500
0
20
40
60
80
100
120
140

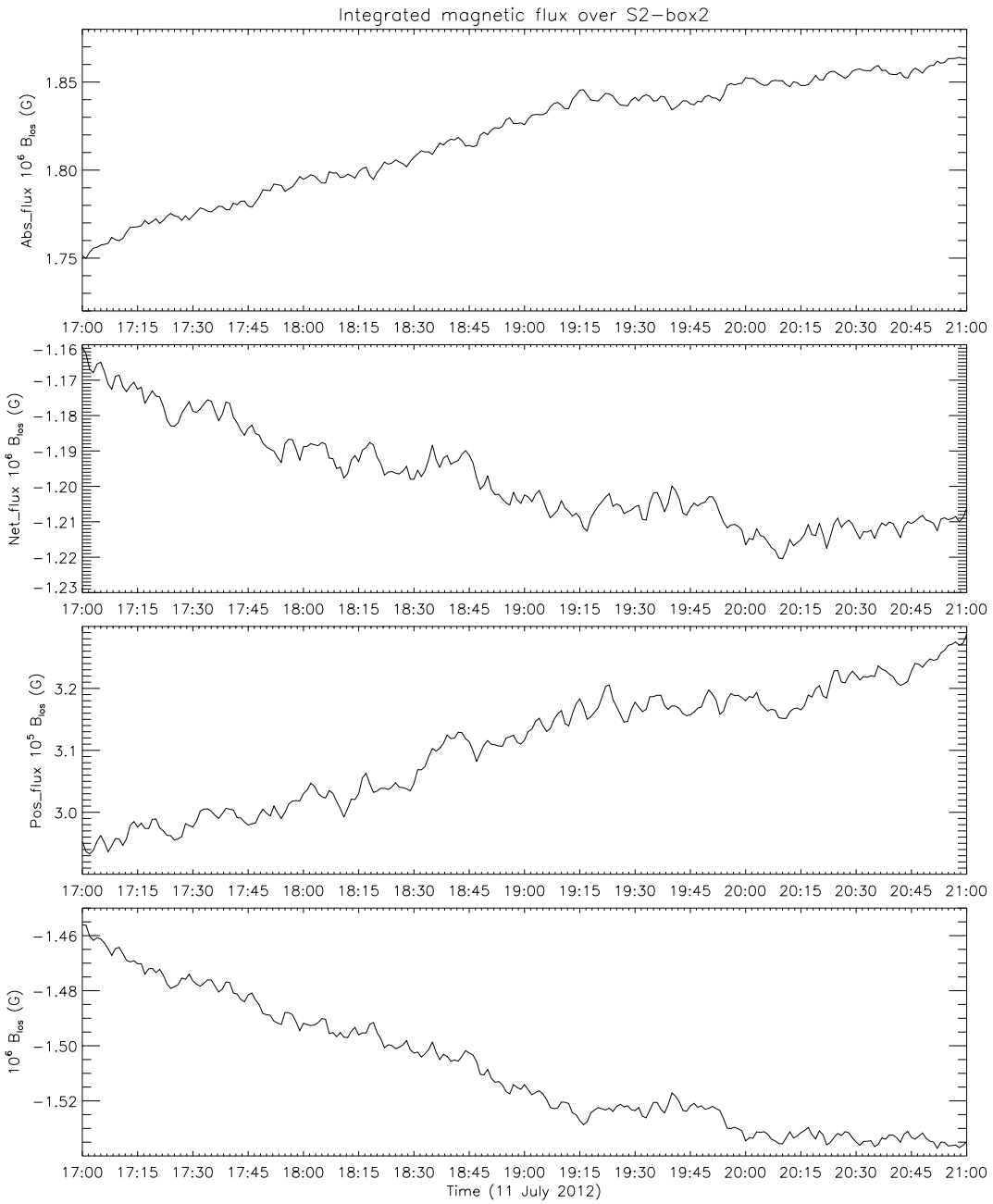
Temporal changes in magnetic flux in S1 region



What mechanism feeds energy to corona released by magnetic reconnection at braided sites?

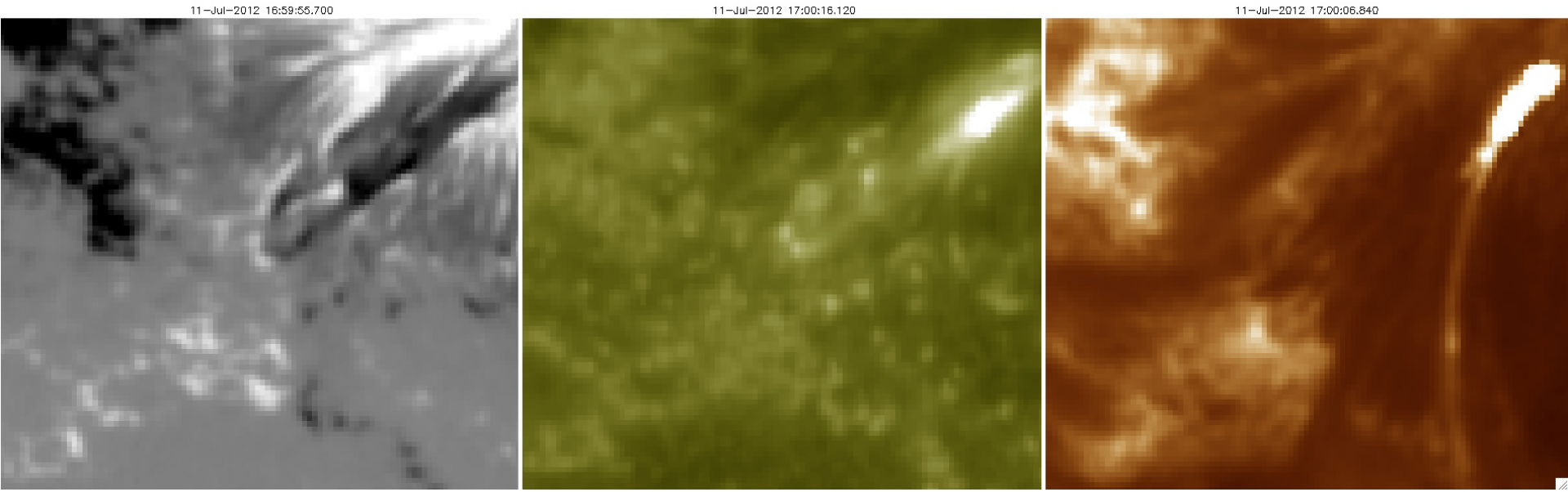


Temporal changes in magnetic flux in region S2



Tracking sites of coronal bright features on photosphere

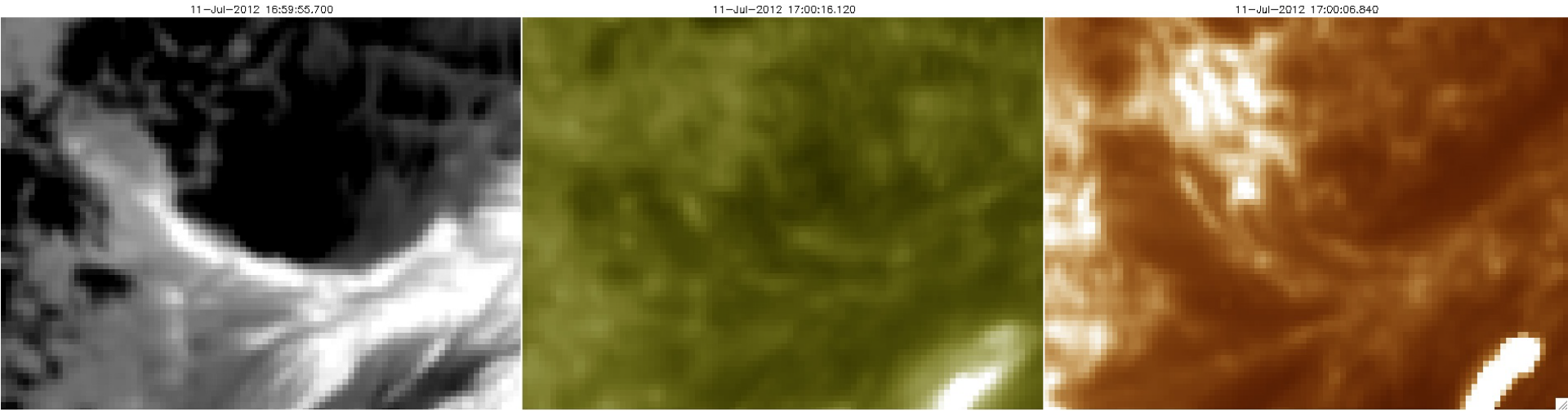
Region S1



…work in progress!

Tracking sites of coronal bright features on photosphere

Region S2

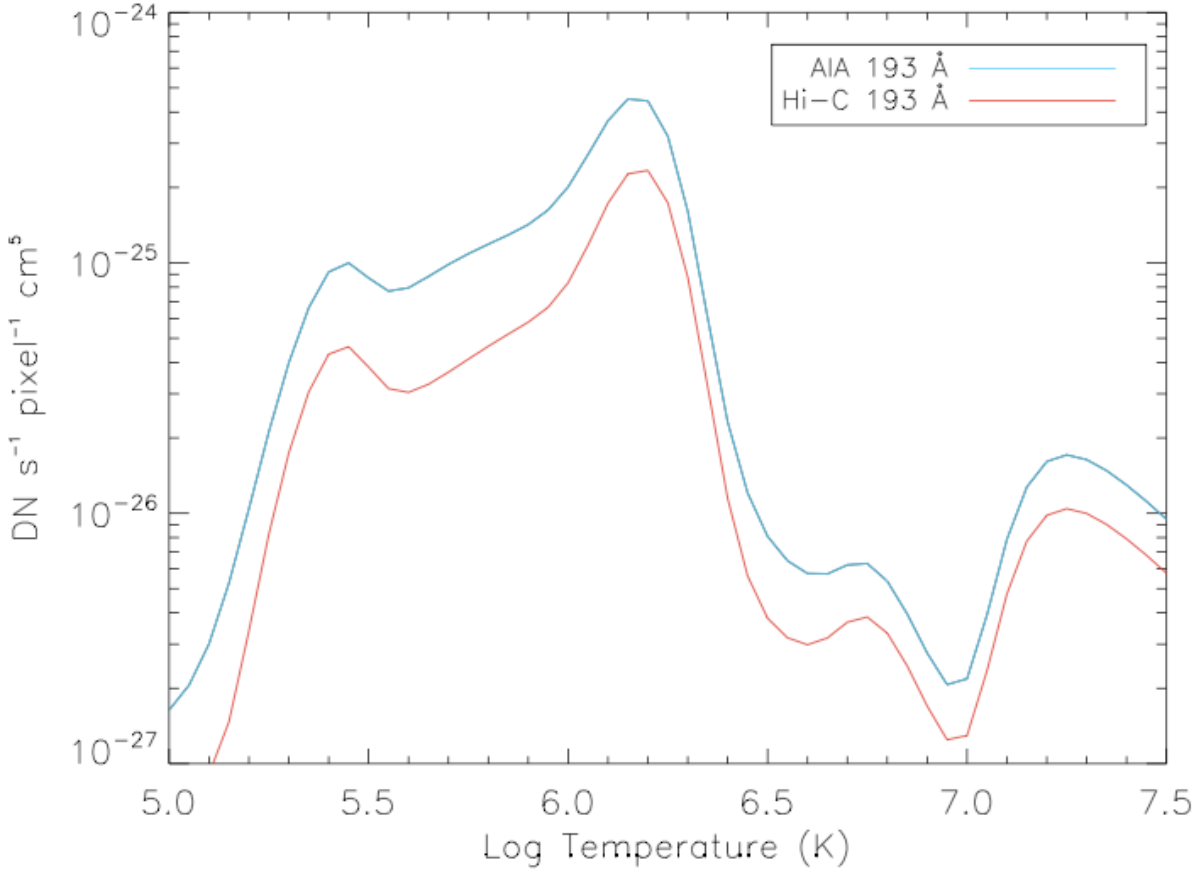


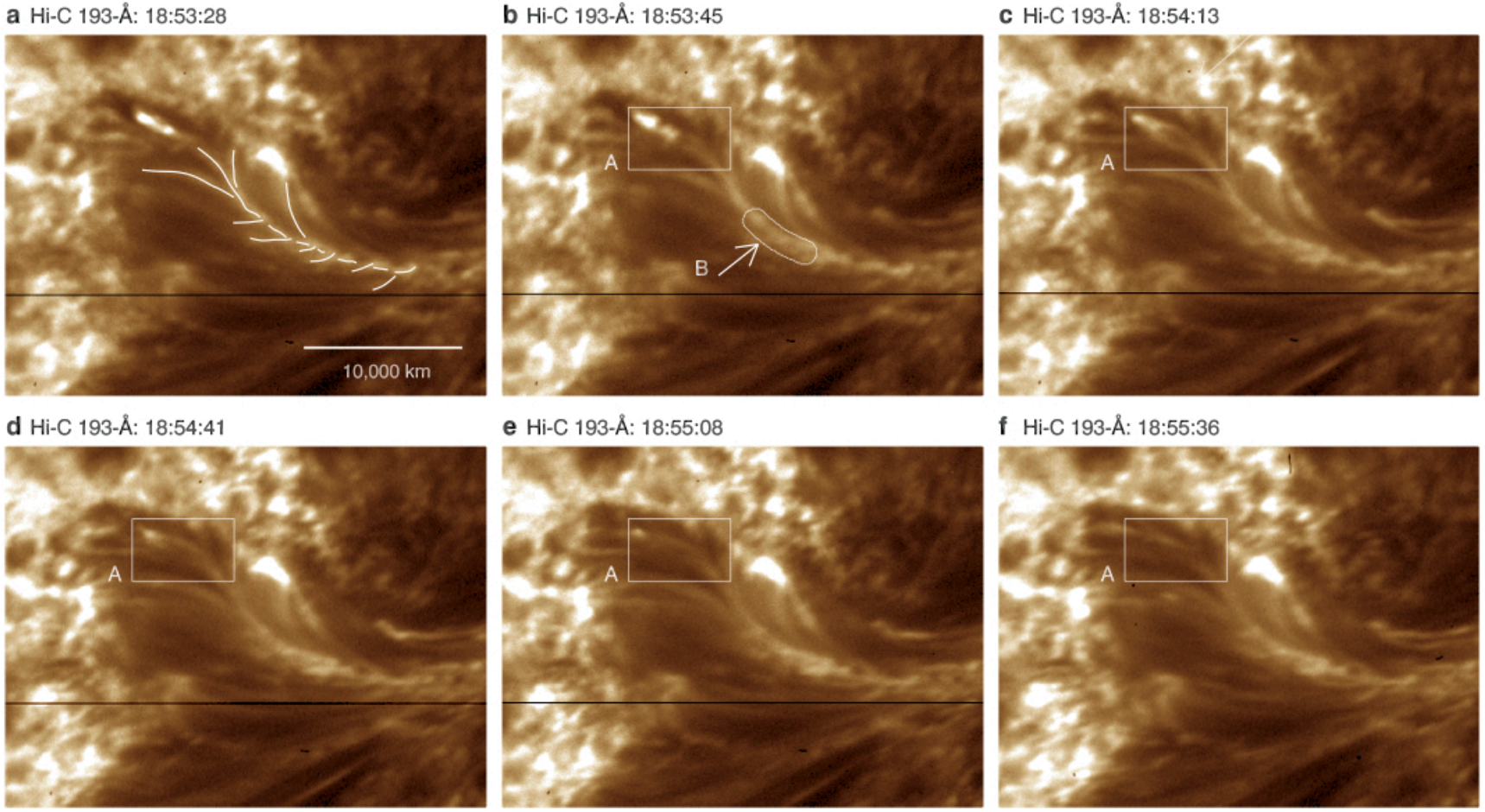
…work in progress!

Summary

- Hi-C: first observational evidence of field line braiding in the AR corona; NLFFF extrapolations support.
- Flux emergence and/or cancellation in the coronal braided region generate large stresses and tension in the coronal field loops which is released as heat in the corona. WORK IN PROGRESS TO CONFIRM!
- The field in these sub-regions are highly sheared and have apparent high speed plasma flows, therefore, the contribution from shearing flows to power the coronal and transition region heating can not be ruled out!

Thanks!


AIA 193 Å
Hi−C 193 Å
10^{-24}
10^{-25}
10^{-26}
10^{-27}
DN s^{-1} pixel^{-1} cm^{5}
5.0
5.5
6.0
6.5
7.0
7.5
Log Temperature (K)


a Hi-C 193-Å: 18:53:28
10,000 km
b Hi-C 193-Å: 18:53:45
A
B
c Hi-C 193-Å: 18:54:13
A
d Hi-C 193-Å: 18:54:41
A
e Hi-C 193-Å: 18:55:08
A
f Hi-C 193-Å: 18:55:36
A