Resolving Loops in the Solar Corona

Lessons from EIS, AIA, Hi-C

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Motivation

- To solve the coronal heating problem we need to measure the properties of fundamental resolved coronal structures.

- Most coronal loops are filamented(?), so current measurements are averaged properties of loop structures (T, n, r)...

- We need to build an instrument that observes fundamental resolved coronal loops.

- We need to know at what spatial scale we resolve fundamental coronal loops? Tens, hundreds, thousands of km?

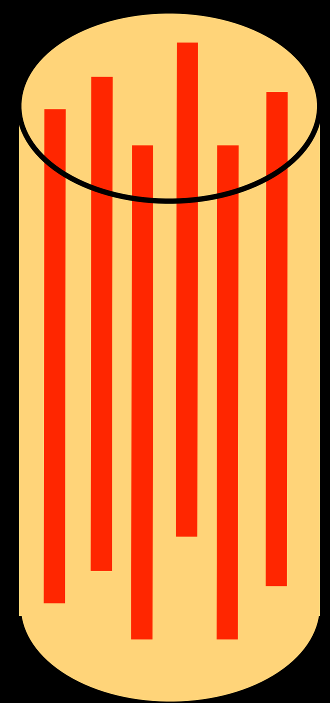
- Study of spatial scales using EIS and AIA applied to Hi-C. Supporting evidence from other sources.


AIA/SDO
Density
Position
Temperature
Position
–2000 –1000 0 1000 2000
Distance (km)
–2000 –1000 0 1000 2000
Distance (km)
What size are fundamental loops?
Unknown. Ambiguous.

Estimating the volume of emission: Multi-strand model - known geometry

$$I_{tot} = G(T,n)n^2\frac{V}{l^2} = G(T,n)n^2\frac{N\pi r^2 l}{l^2}$$

Atomic Data



N strands
Radius r
Density n
Temperature T
Envelope R

l: pixel length

n: density!

$$I_{tot} = ANr^2$$

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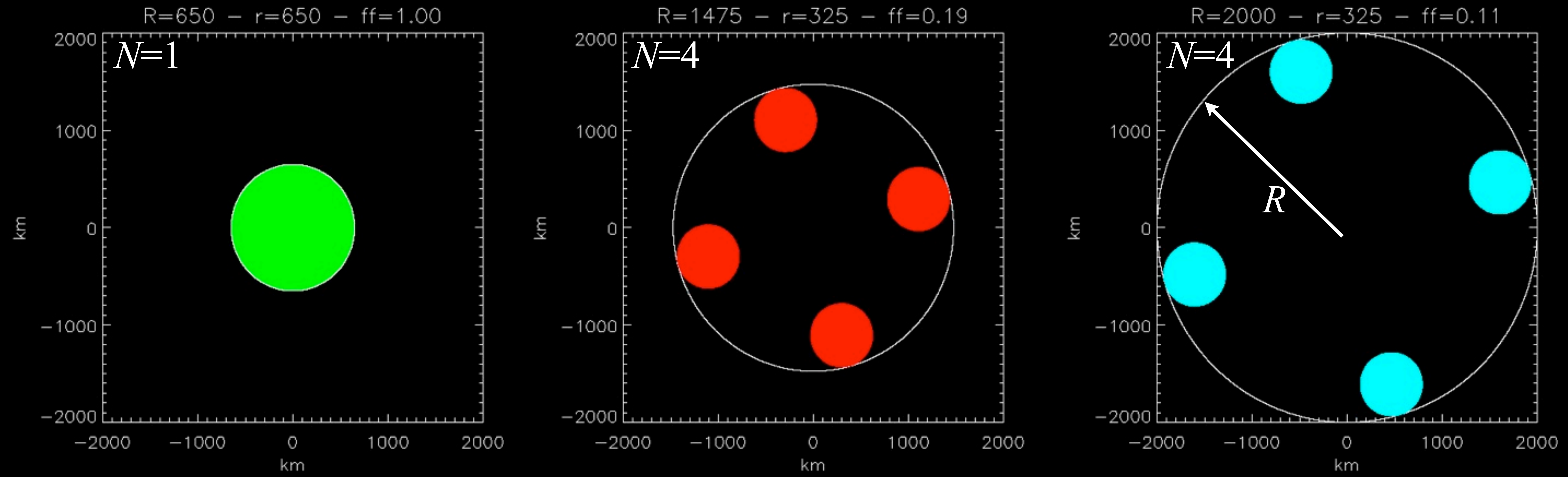
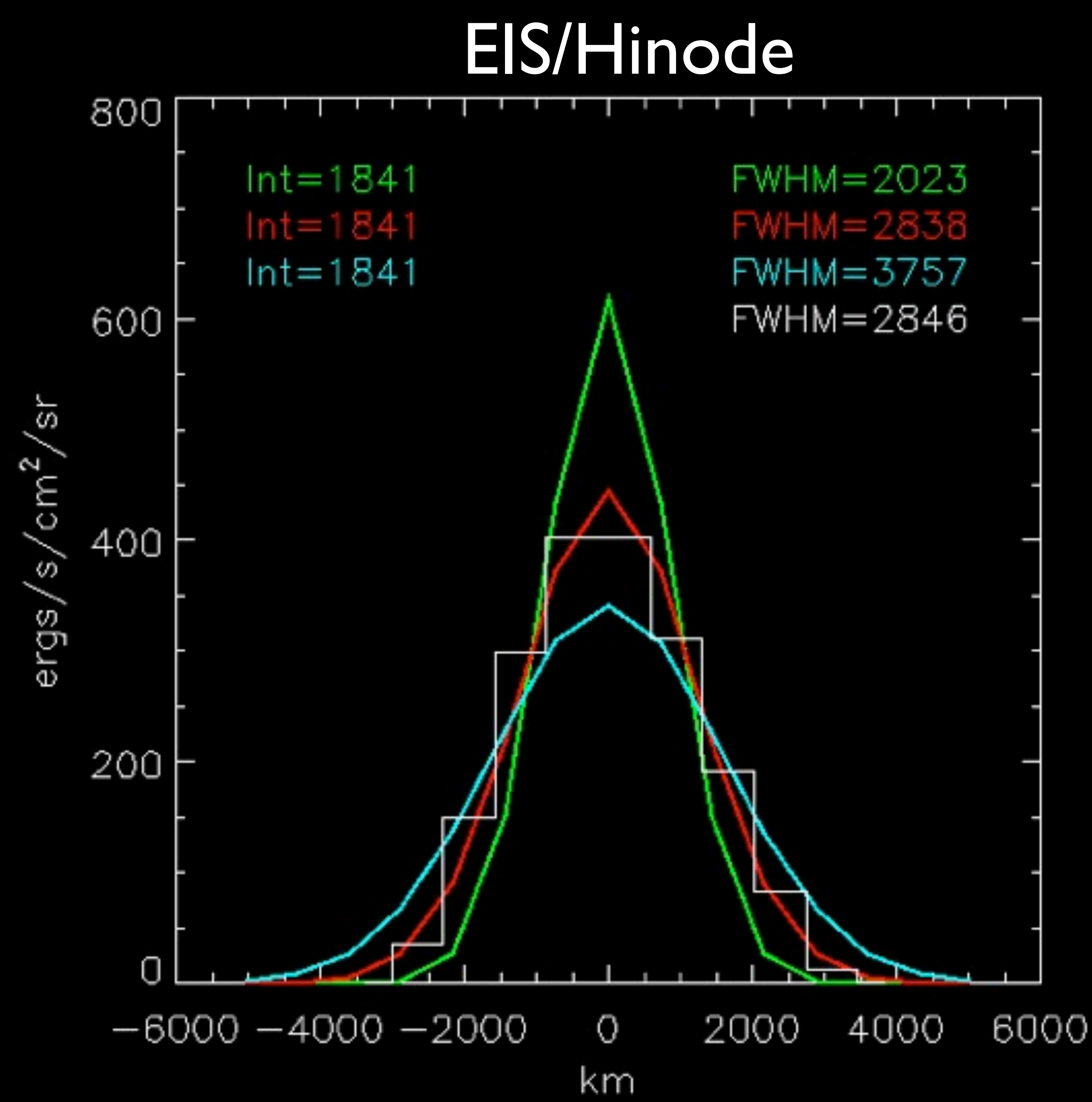
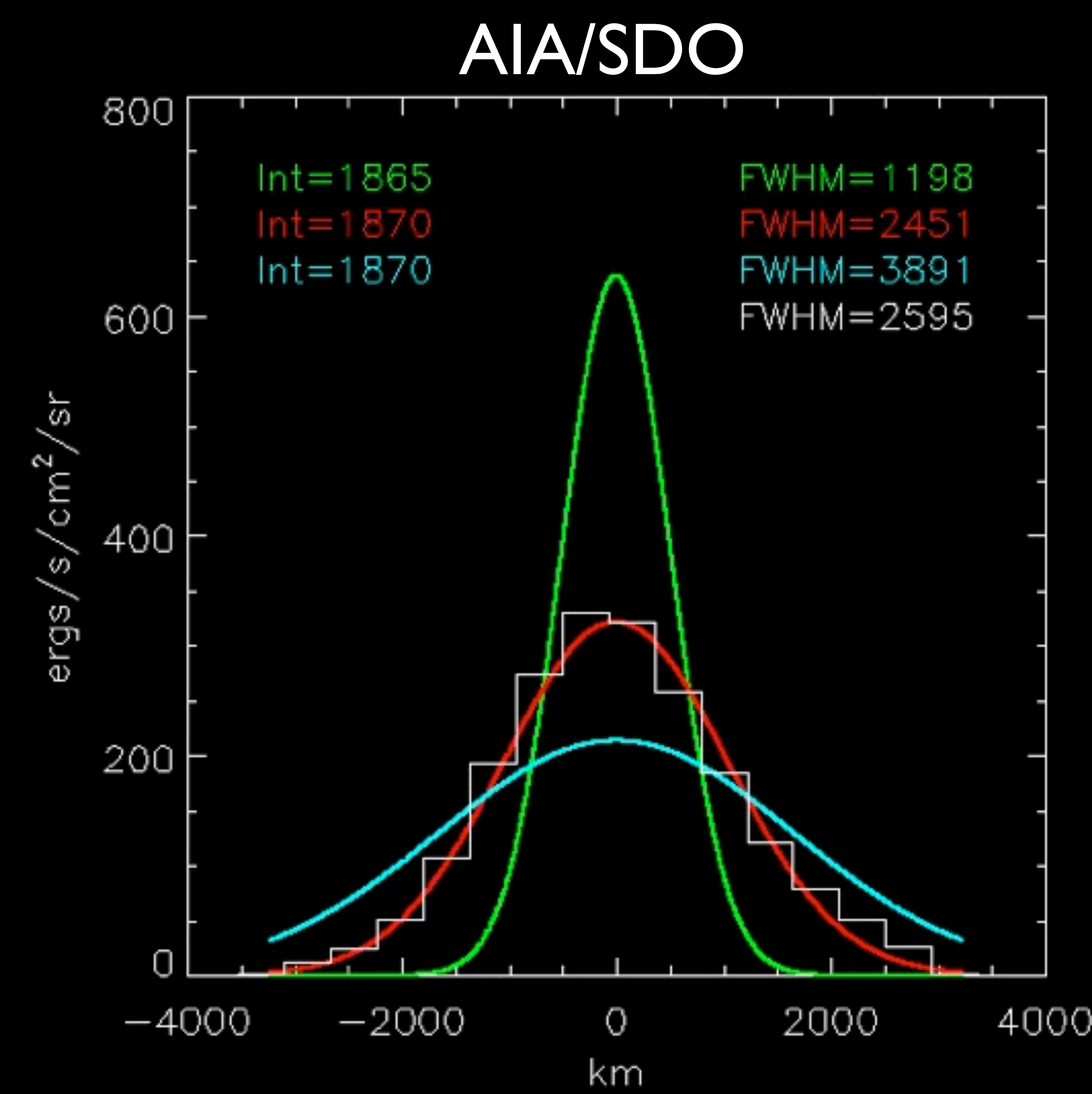
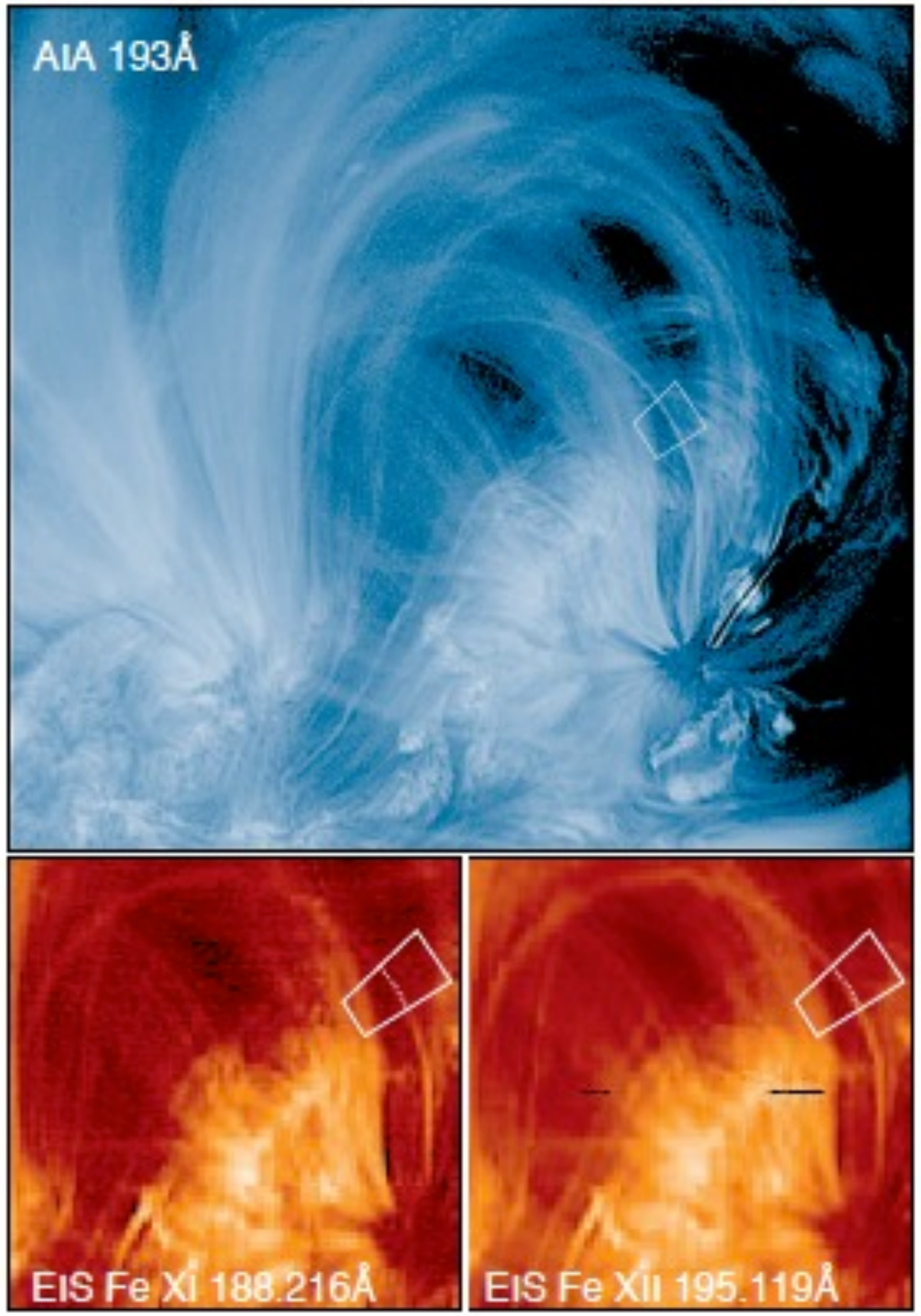


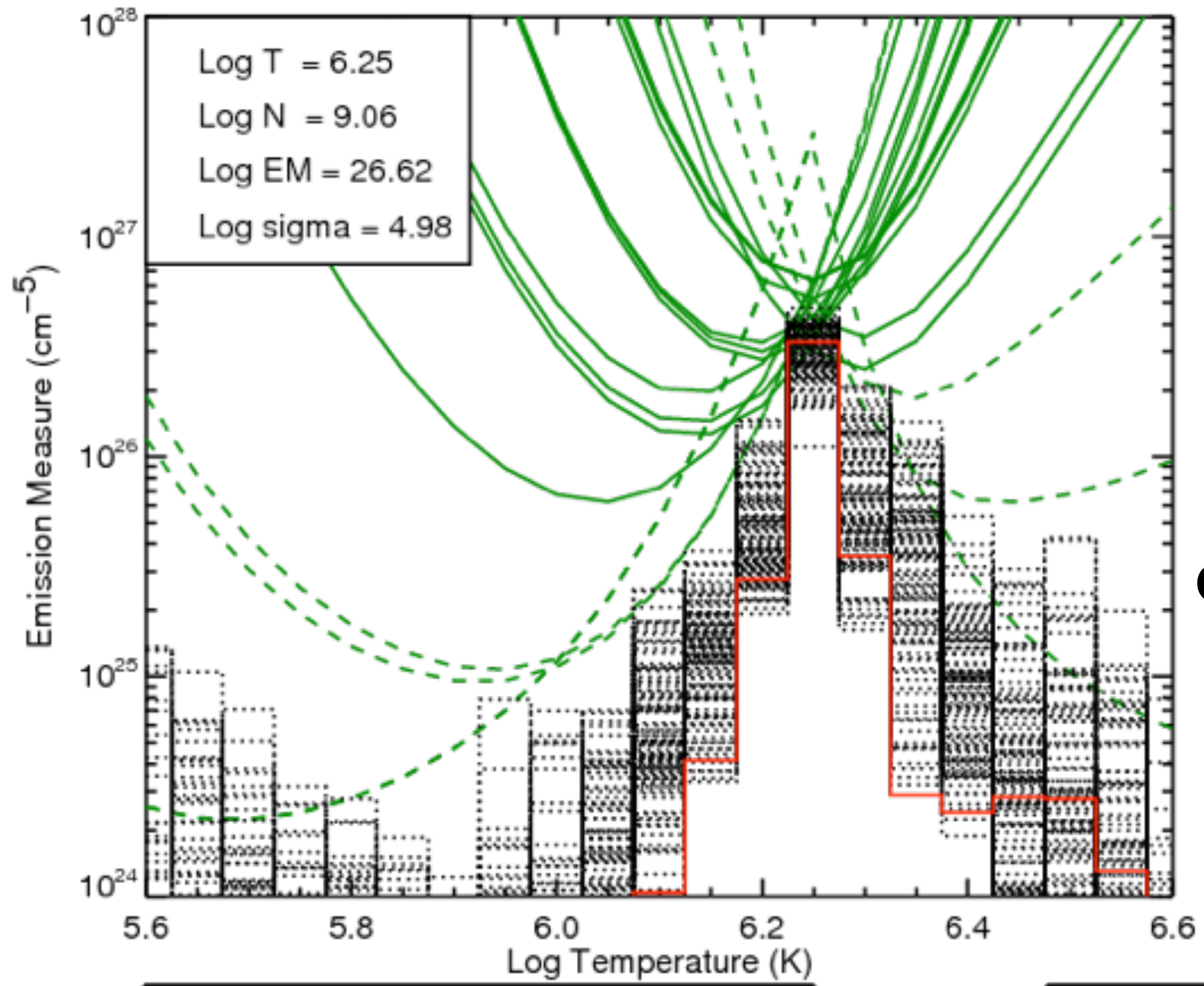
$$I_{obs}(x) = PSF_{inst} * f(r, N, R)$$



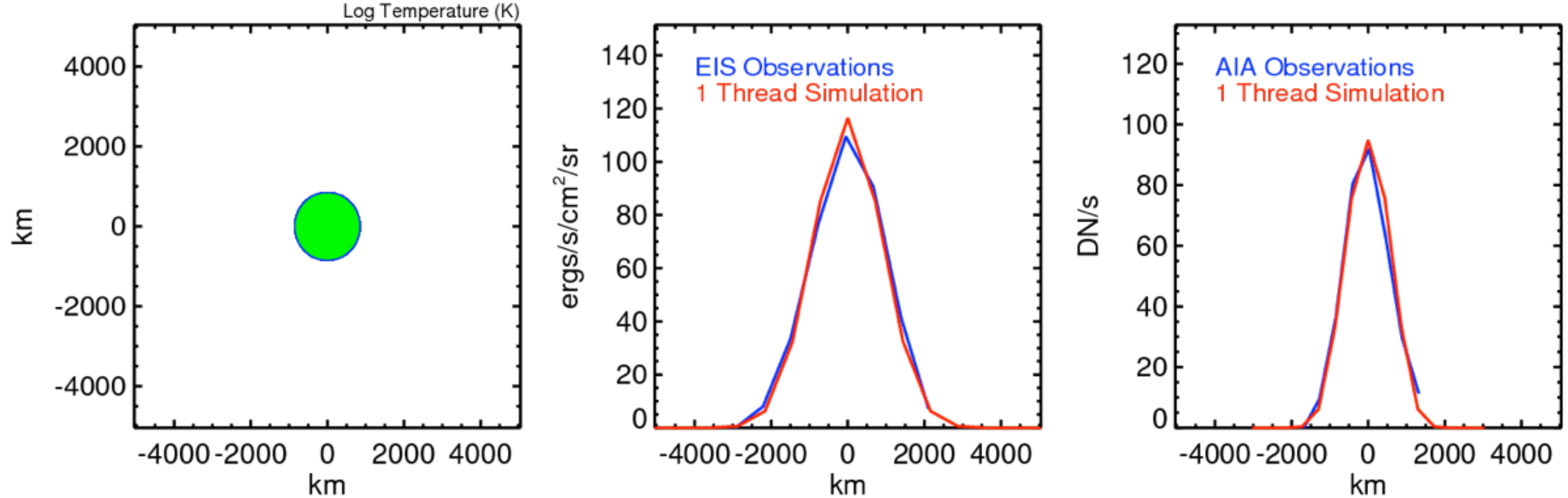


Data analysis - rare case



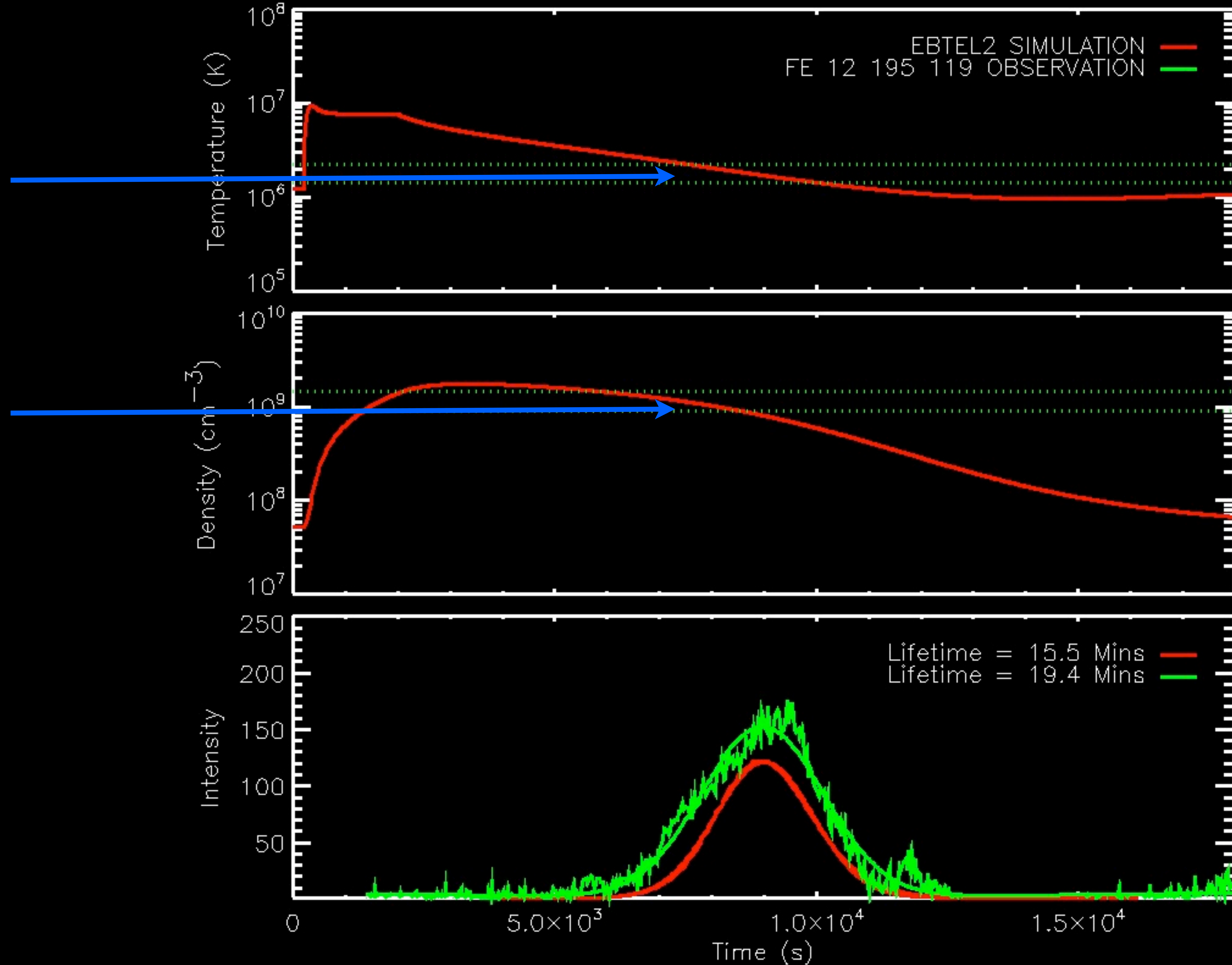


<u>Resolved</u> loop:
1 strand with 830 km radius
explains EIS and AIA intensities and widths

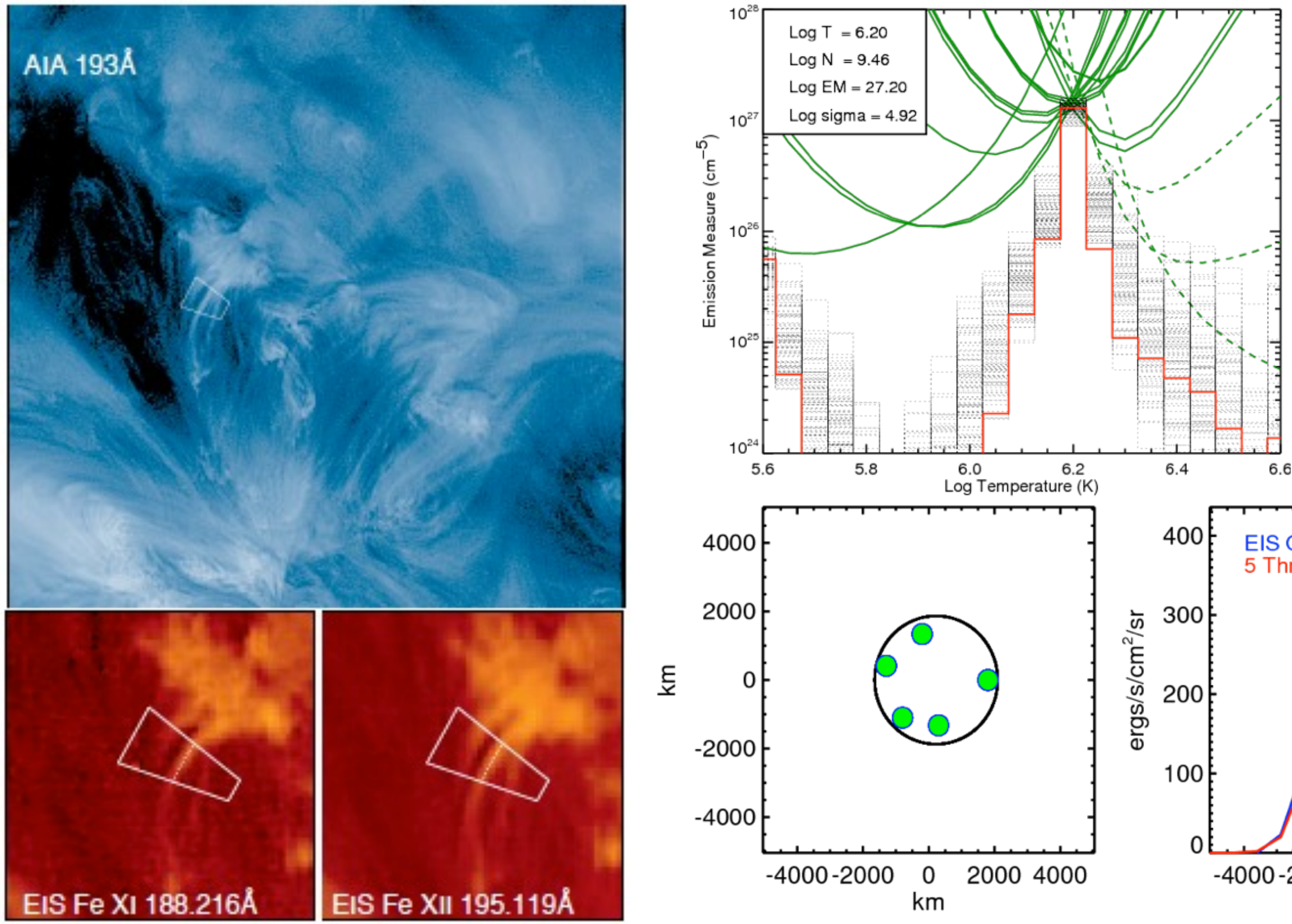


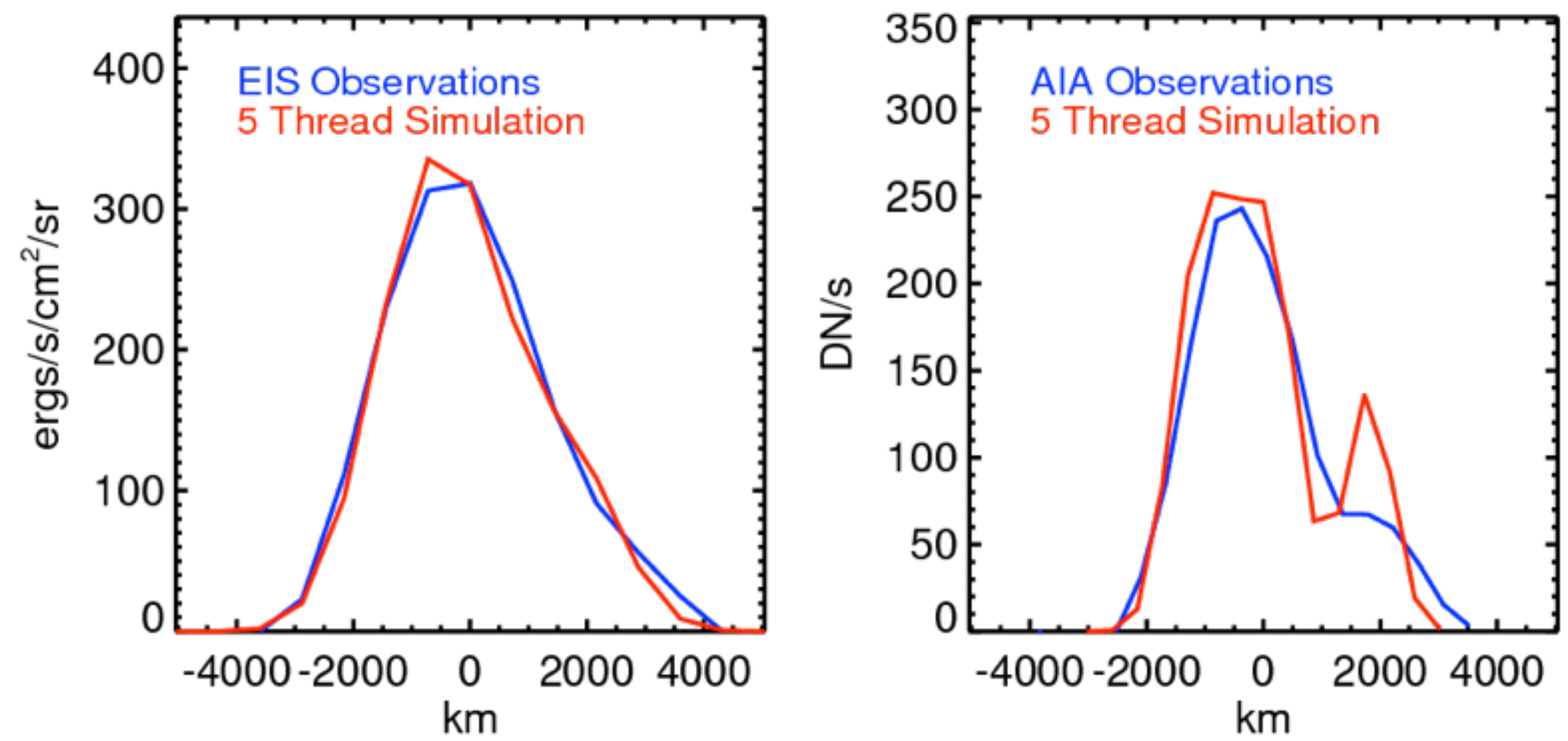
Consistent with single strand cooling time

Observed Temperature, Density, and Lifetime are matched!



Data analysis - typical case



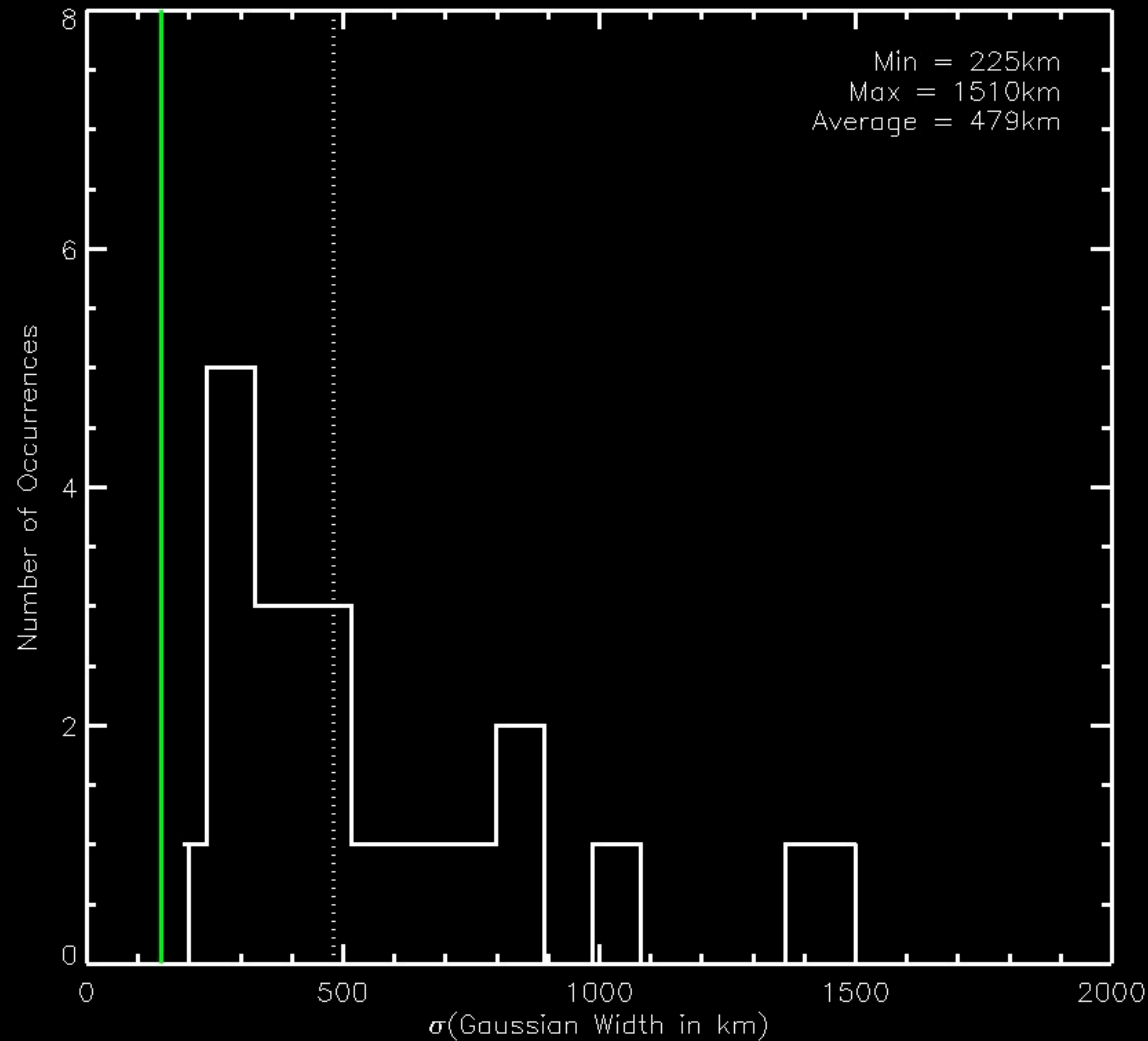


Unresolved loop:
5 strands with 280 km radius
needed to explain
EIS and AIA intensities and widths

Results

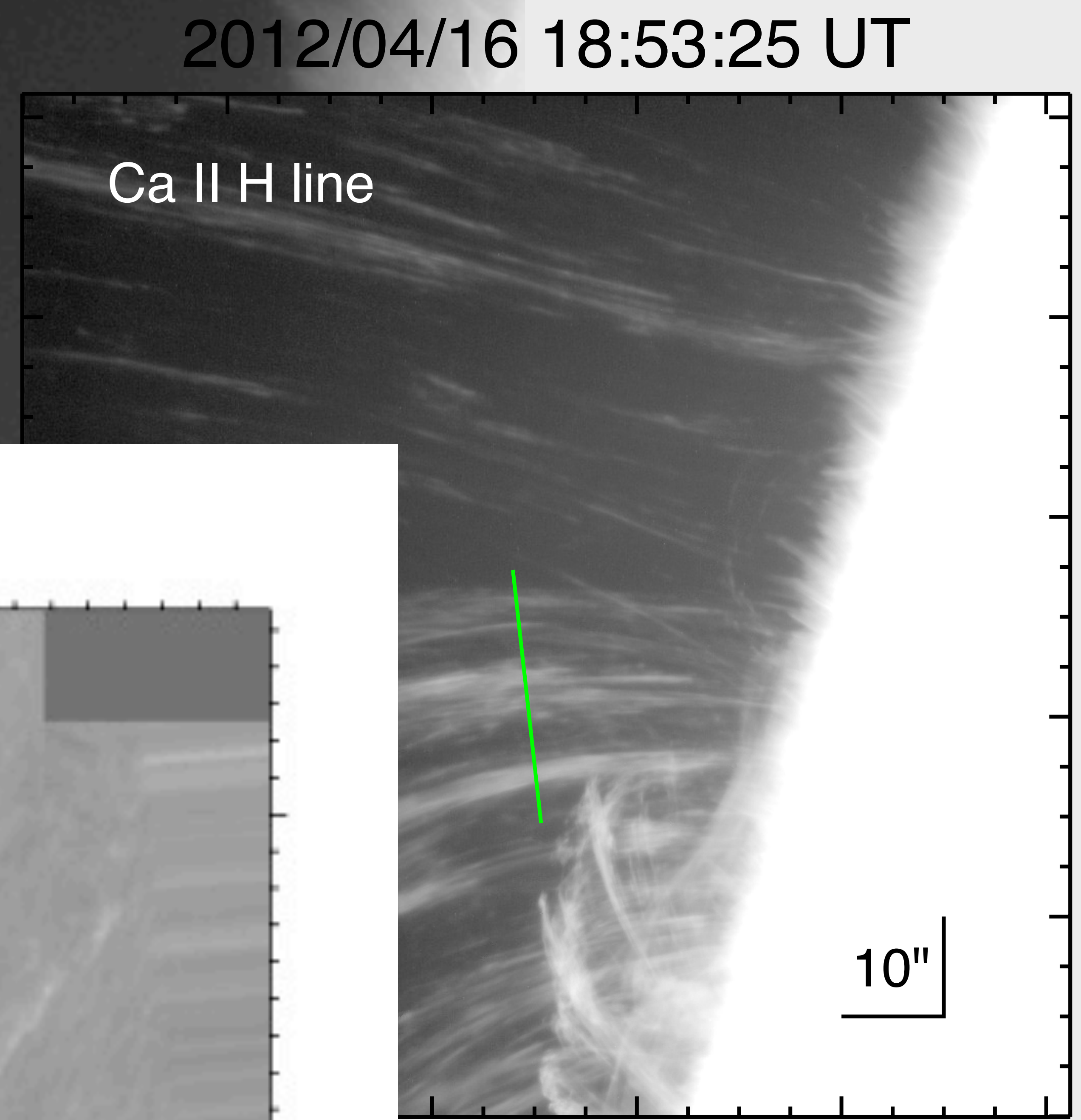
$1 \leq N \leq 8$; Four $N = 1$ loops ; $\mu_{1/2}(r) = 470$ km

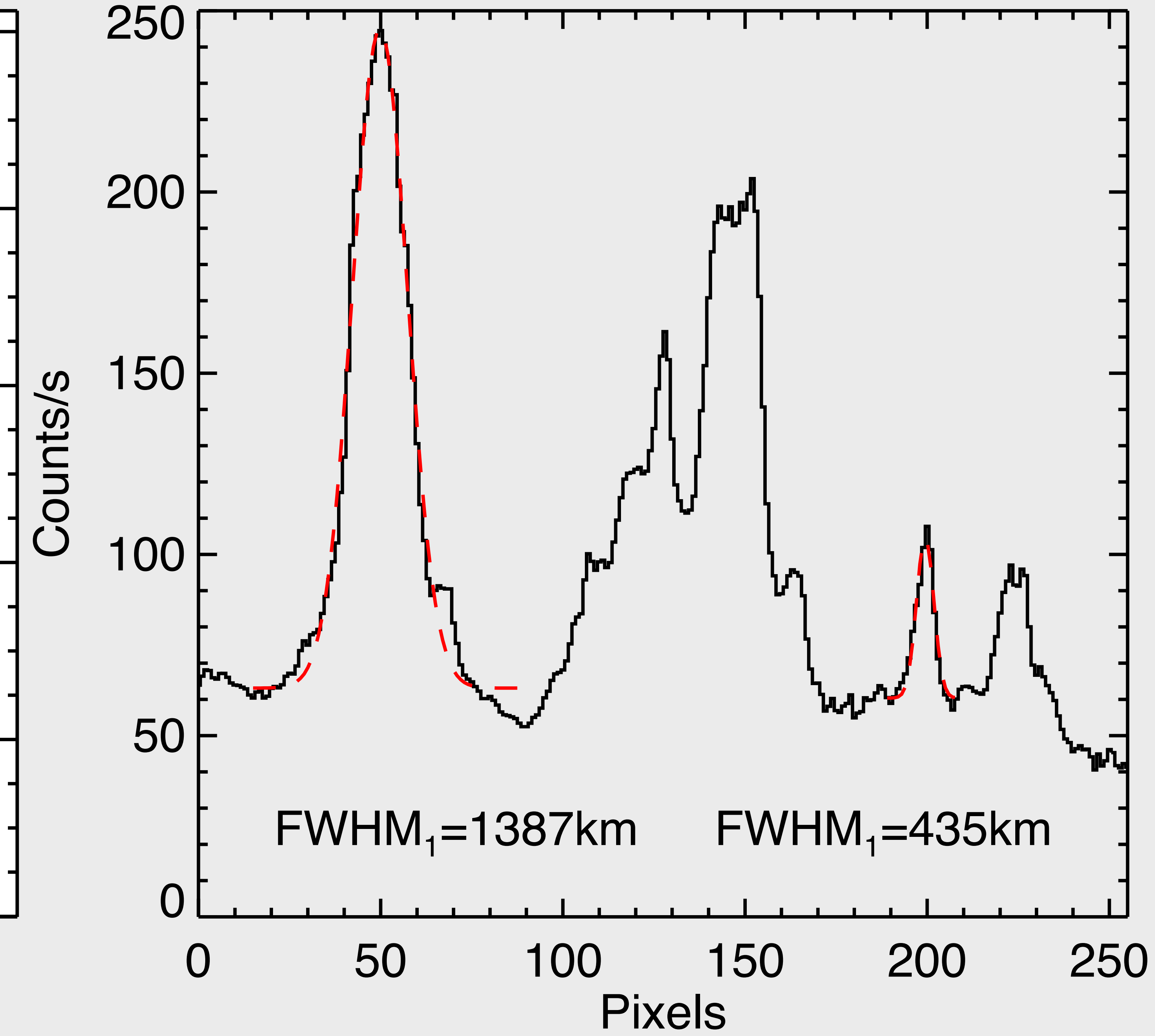
Brooks et al (2012)

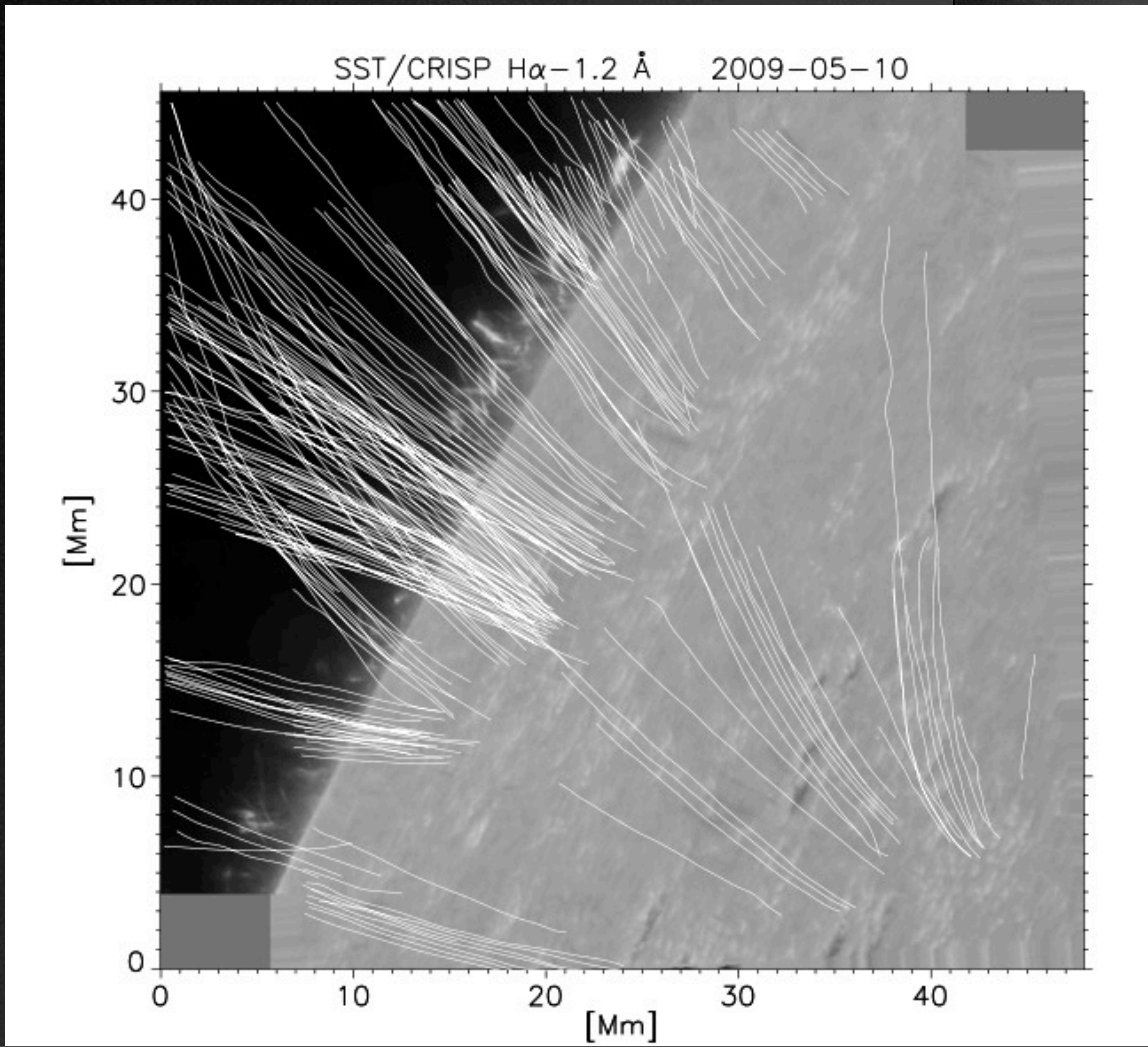


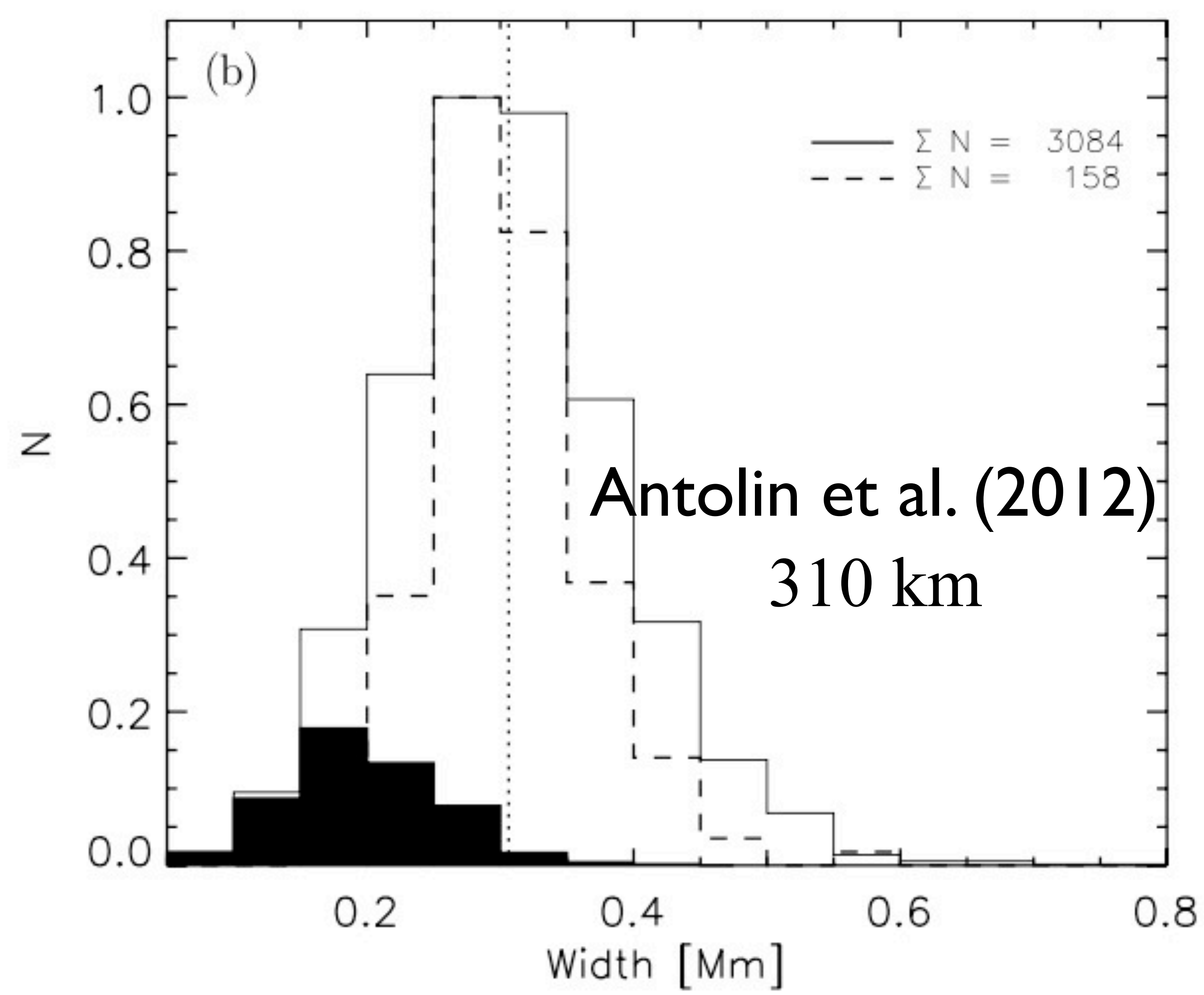
Hundreds! 0.2-0.3” (0.1”/pixel) should resolve all these loops!

Coronal rain





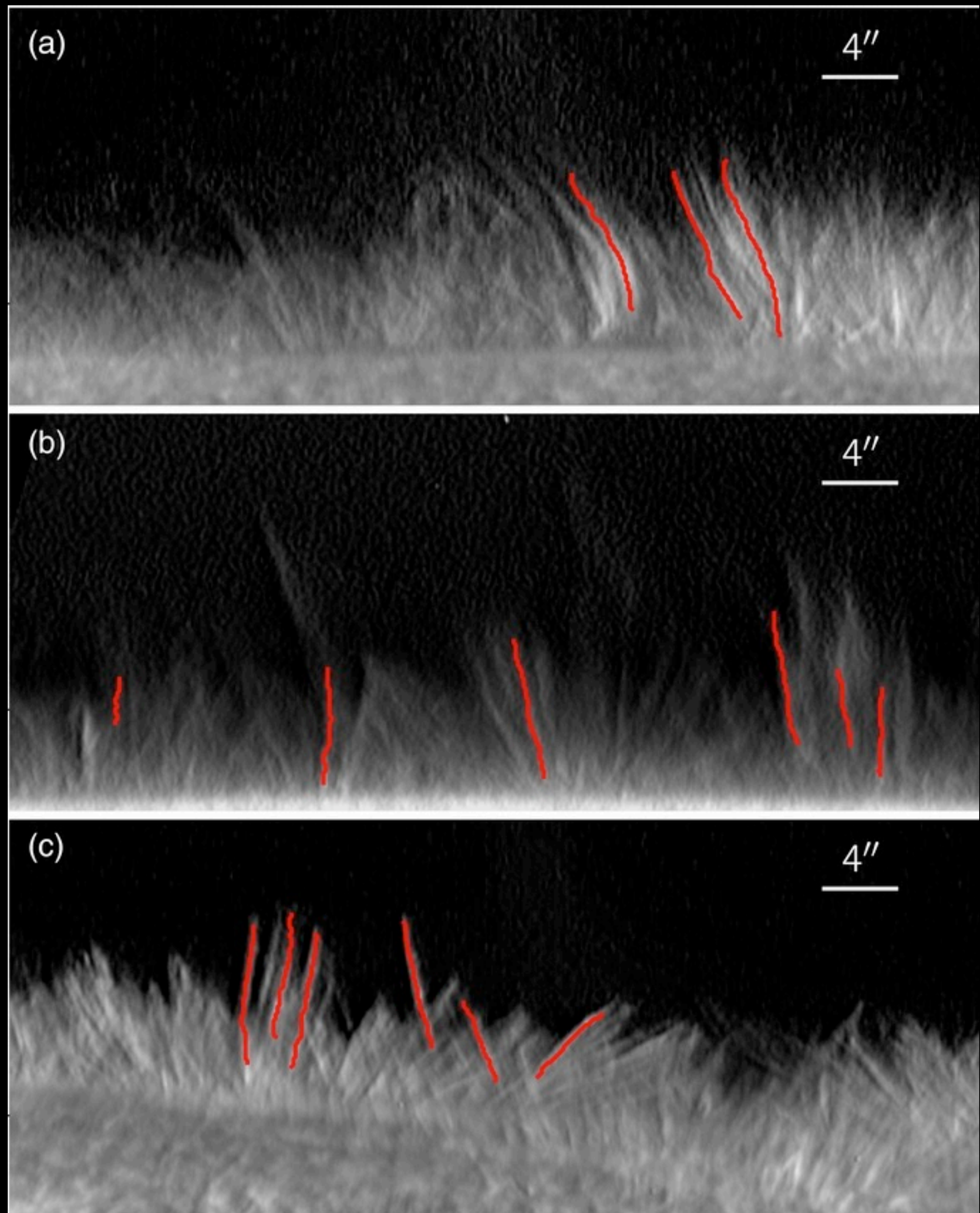


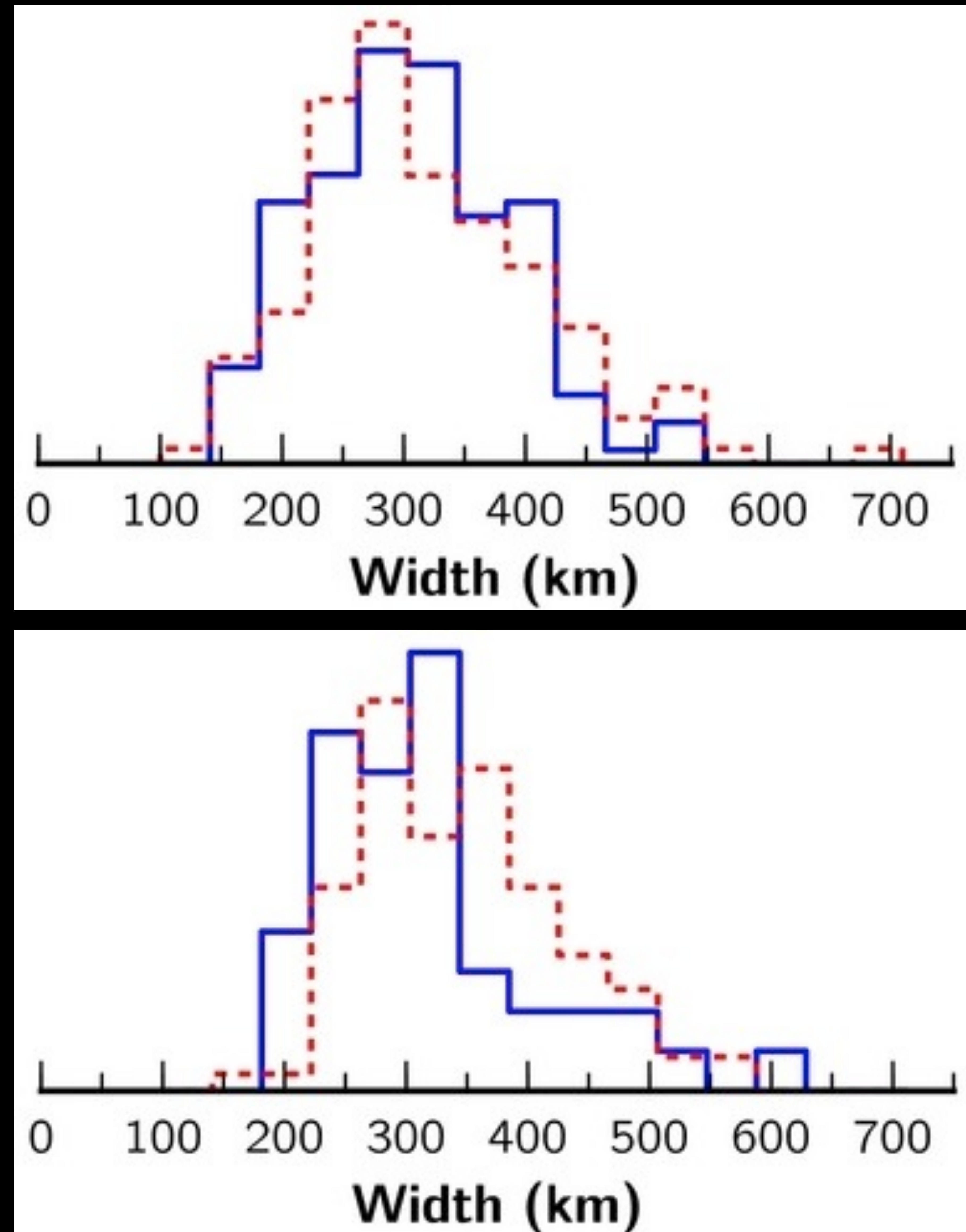


Antolin et al. (2012)
310 km

Type II Spicules (QS, CH, AR)

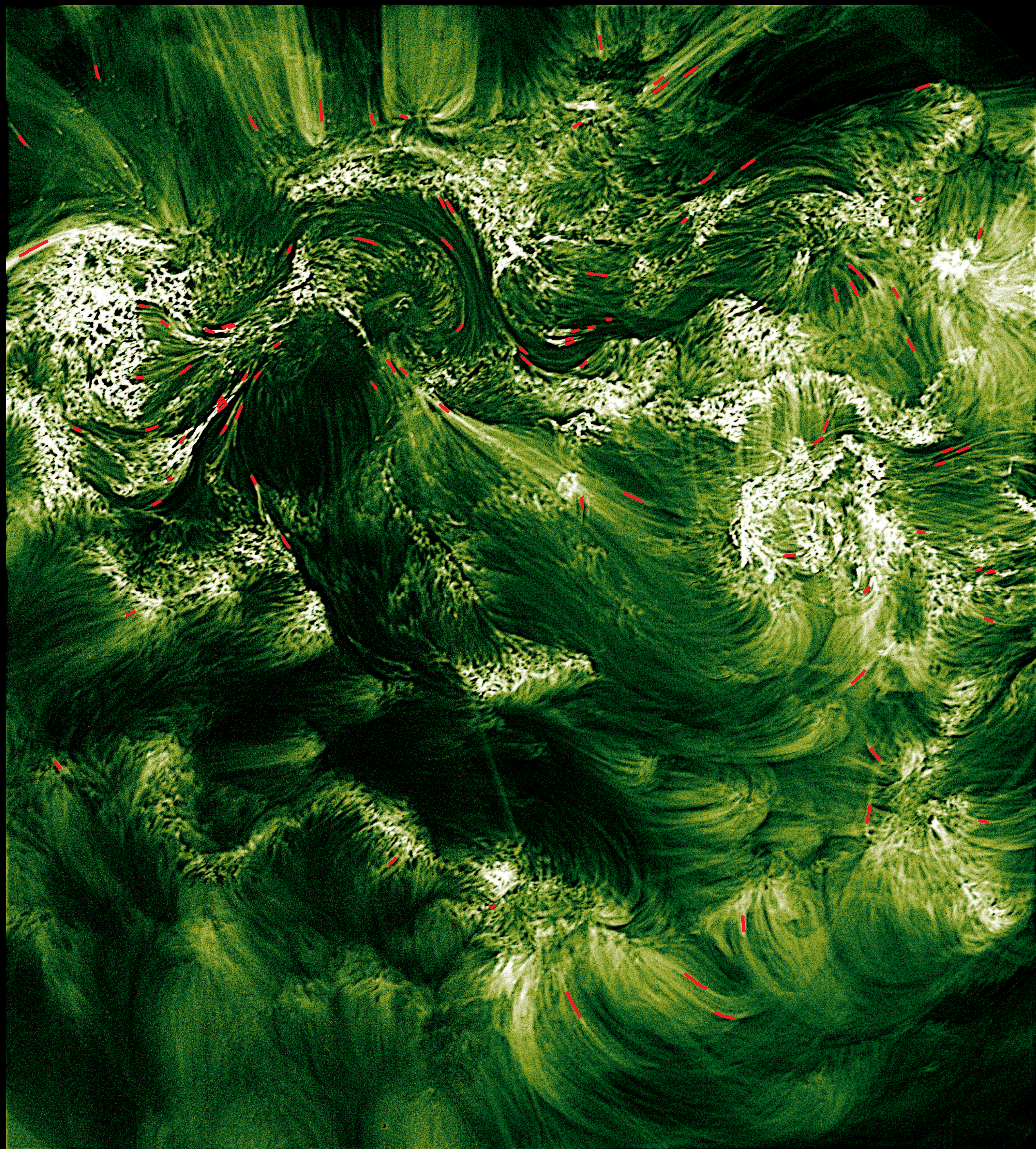
Mean Width = 304-348km



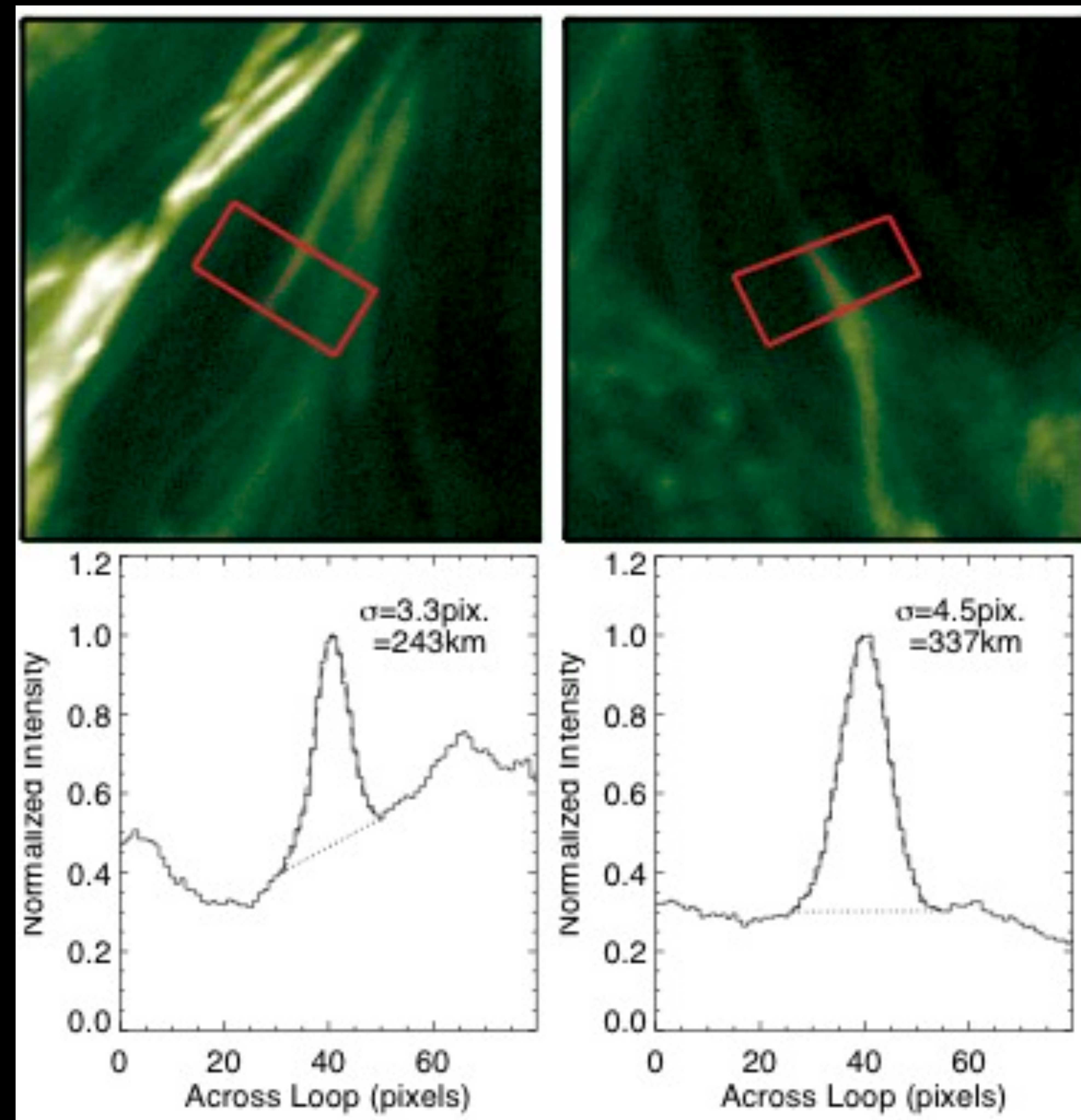


Pereira et al (2012)

Hi-C has 0.1”/pixel

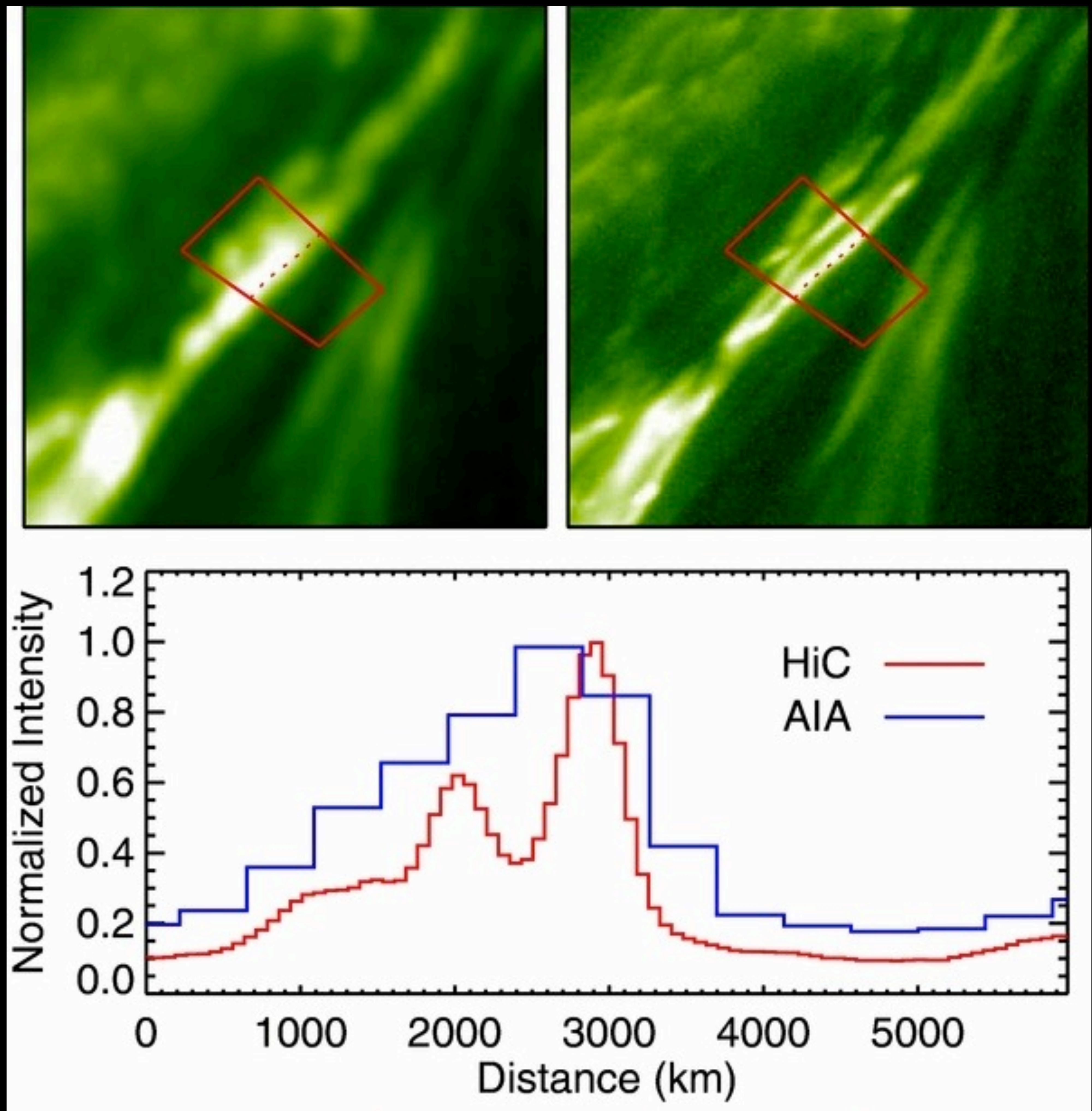


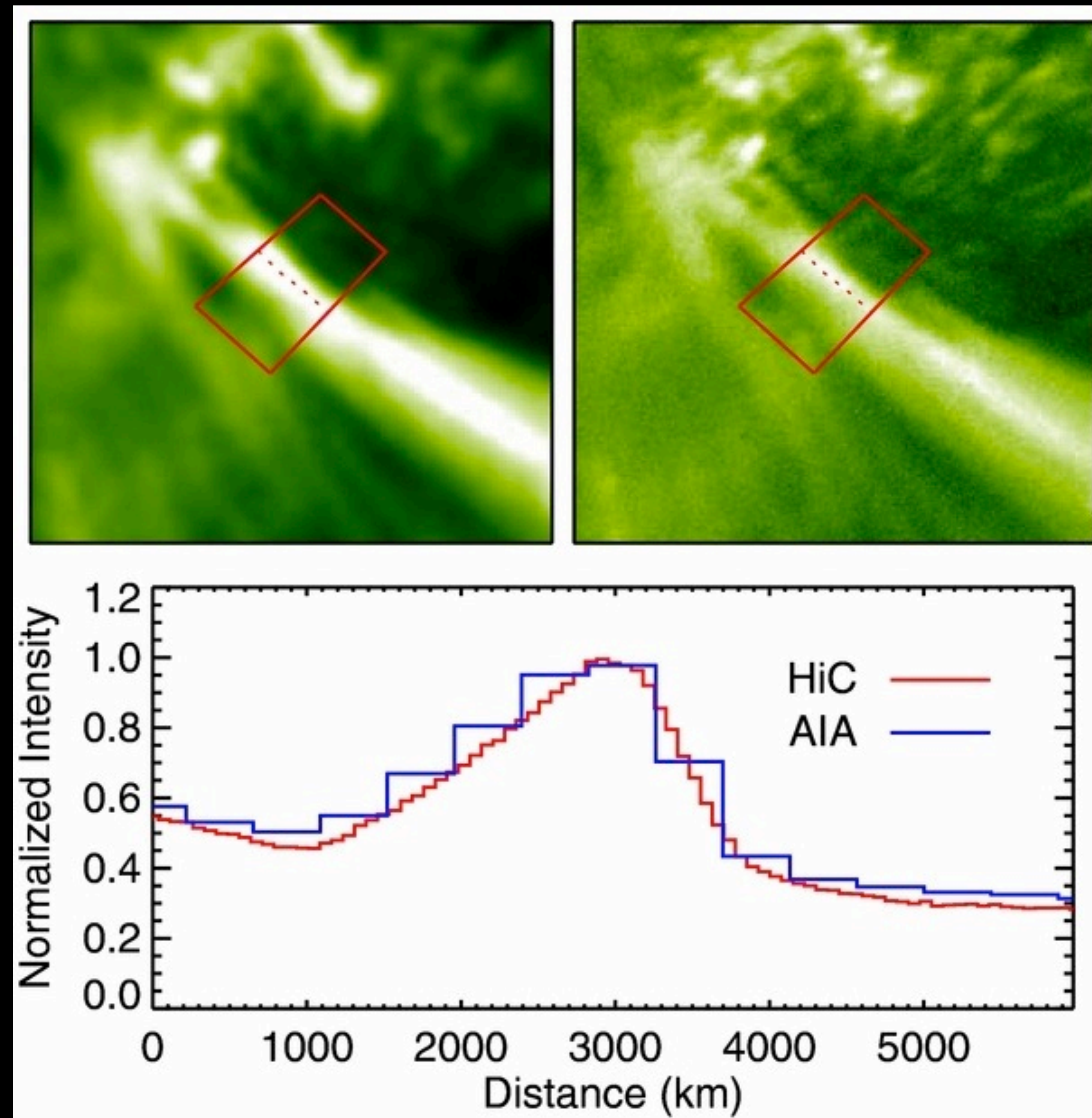
91 Loop Segments



(Brooks et al. 2013)

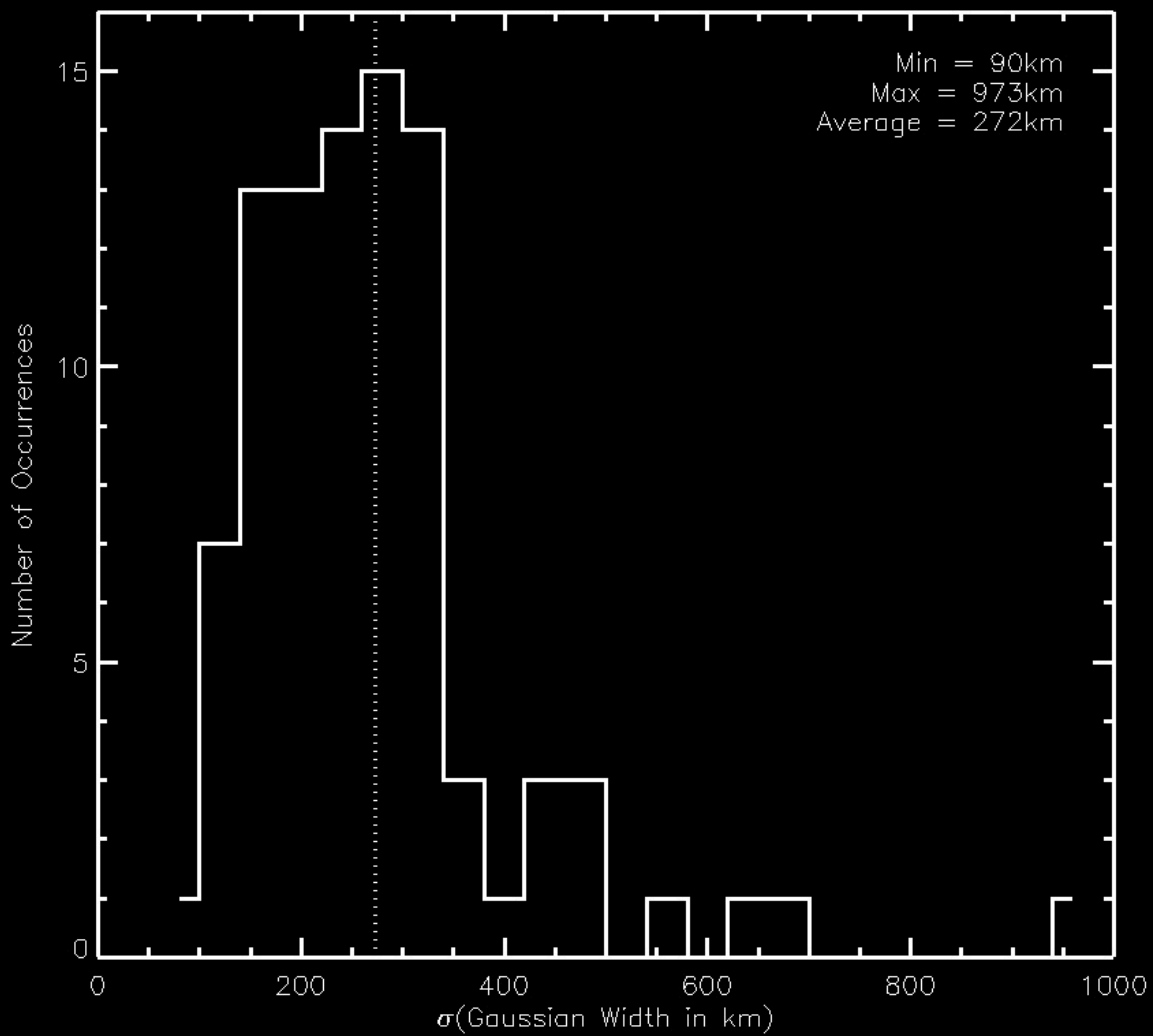
Hi-C reveals substructure in some AIA examples but not others

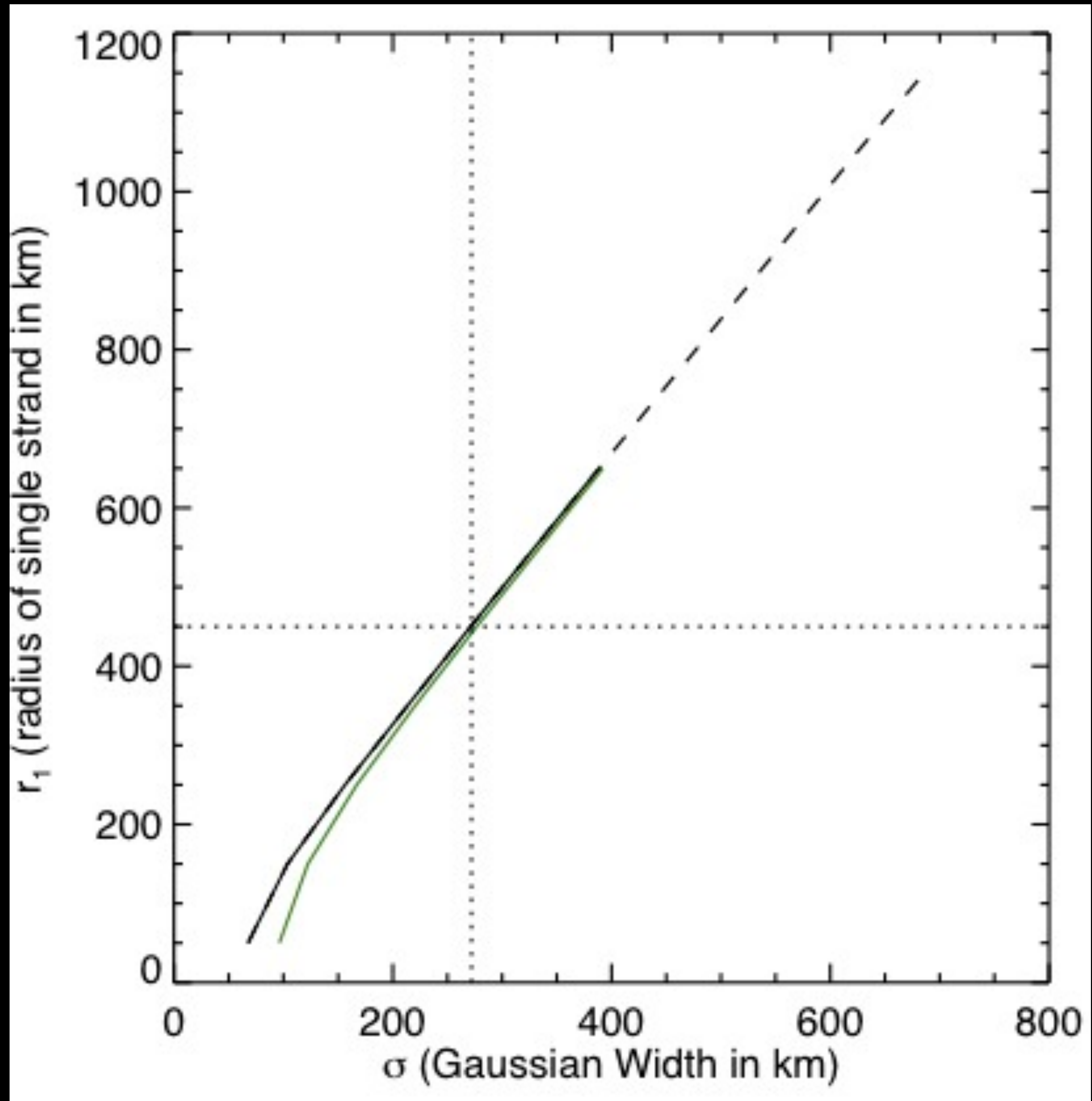




Only a few "traditional" loops in Hi-C FOV. Many of our sample are relatively short.

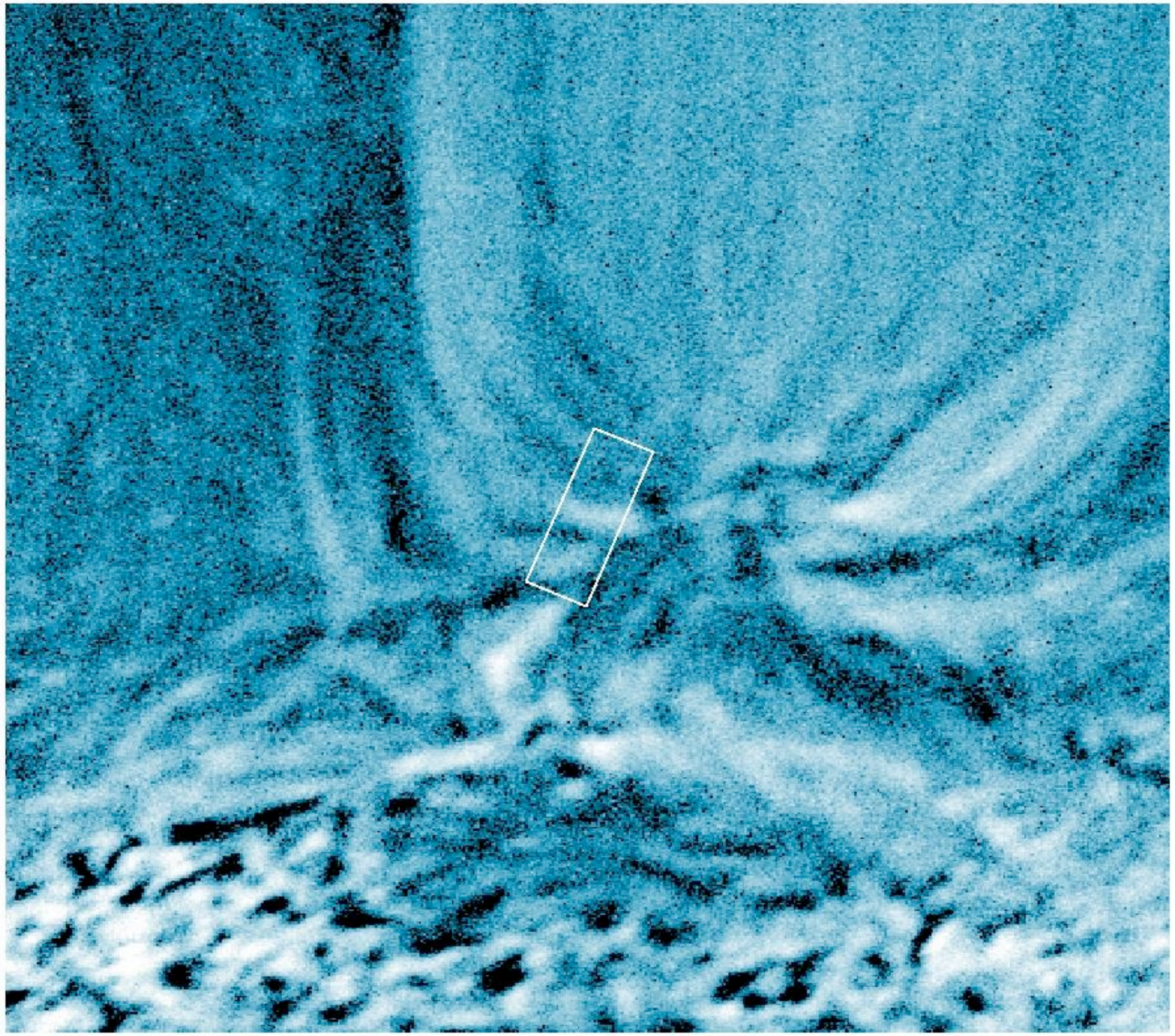
Results: Average Width = 270km Loop Radius = 450km

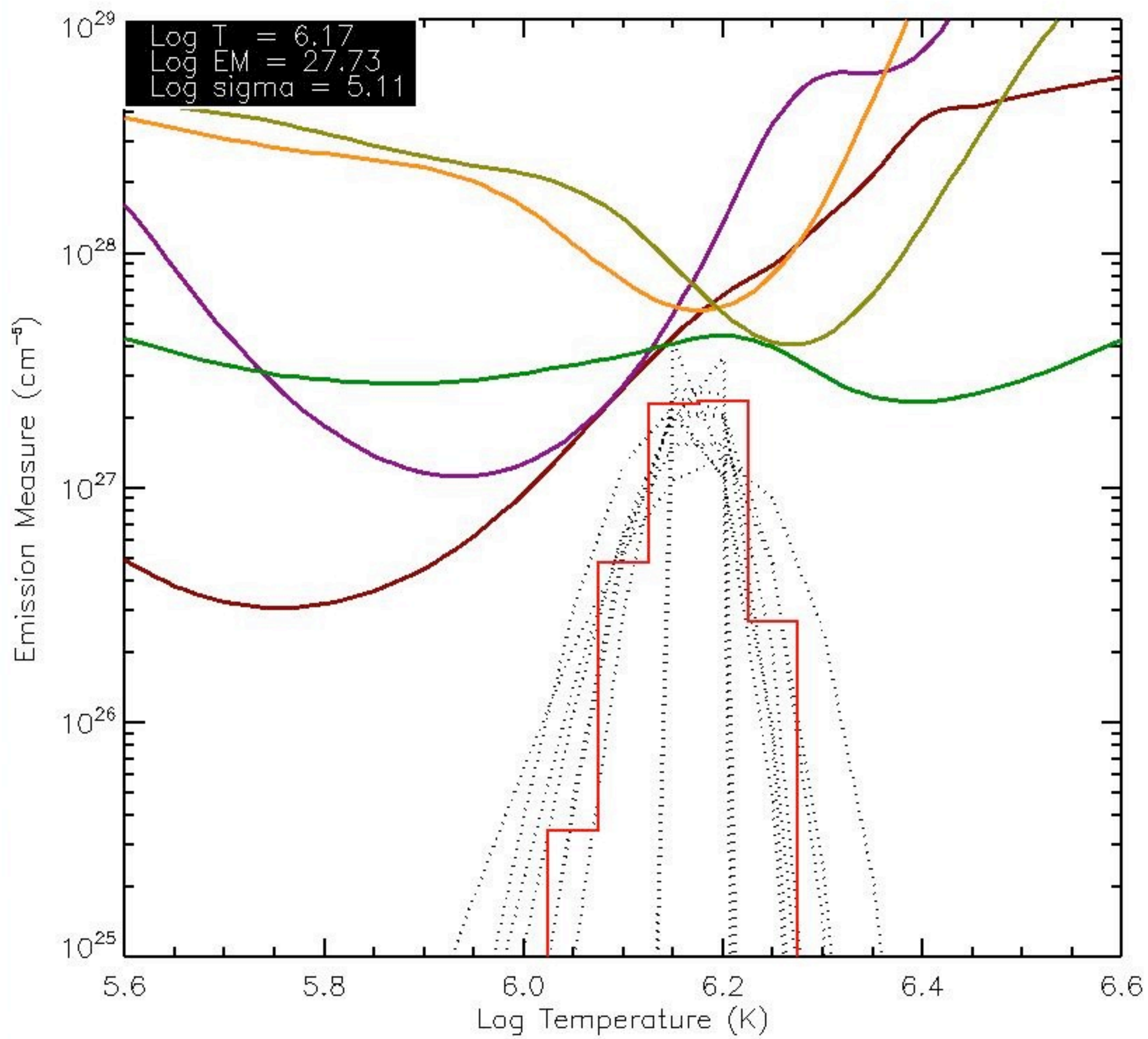




Consistent with EIS (470km average)

Typical AIA DEM for short Hi-C loop: Log Gaussian T width < 5.5 (0.32MK)





Consistent with EIS results (Warren et al. 2008, Tripathi et al. 2009)

Conclusions

- Observed at 1000km spatial scales, a few of the longest 2MK loops are resolved monolithic structures, but most are still unresolved and multi-stranded. Temperature distributions are nearly isothermal.

- Modeling suggests they are nearly resolved and composed of only a few strands (1-10), with typical sizes in the <u>hundreds of km</u>. "Multi-stranded" means "A few strands".

- Observed at 100km spatial scales (Hi-C, Solar-C!) all EIS loops should be resolved. Hi-C does not reveal significant numbers of smaller loops (85% seen by AIA).

- Heating mechanism operates on a spatial scale of hundreds of km. Much larger than theory predicts! Corona is nearly isothermal over hundreds to thousands of km!

The End

Results published in:

Brooks et al. (2012), ApJ, 755, L33
Brooks et al. (2013), ApJ, 772, L19