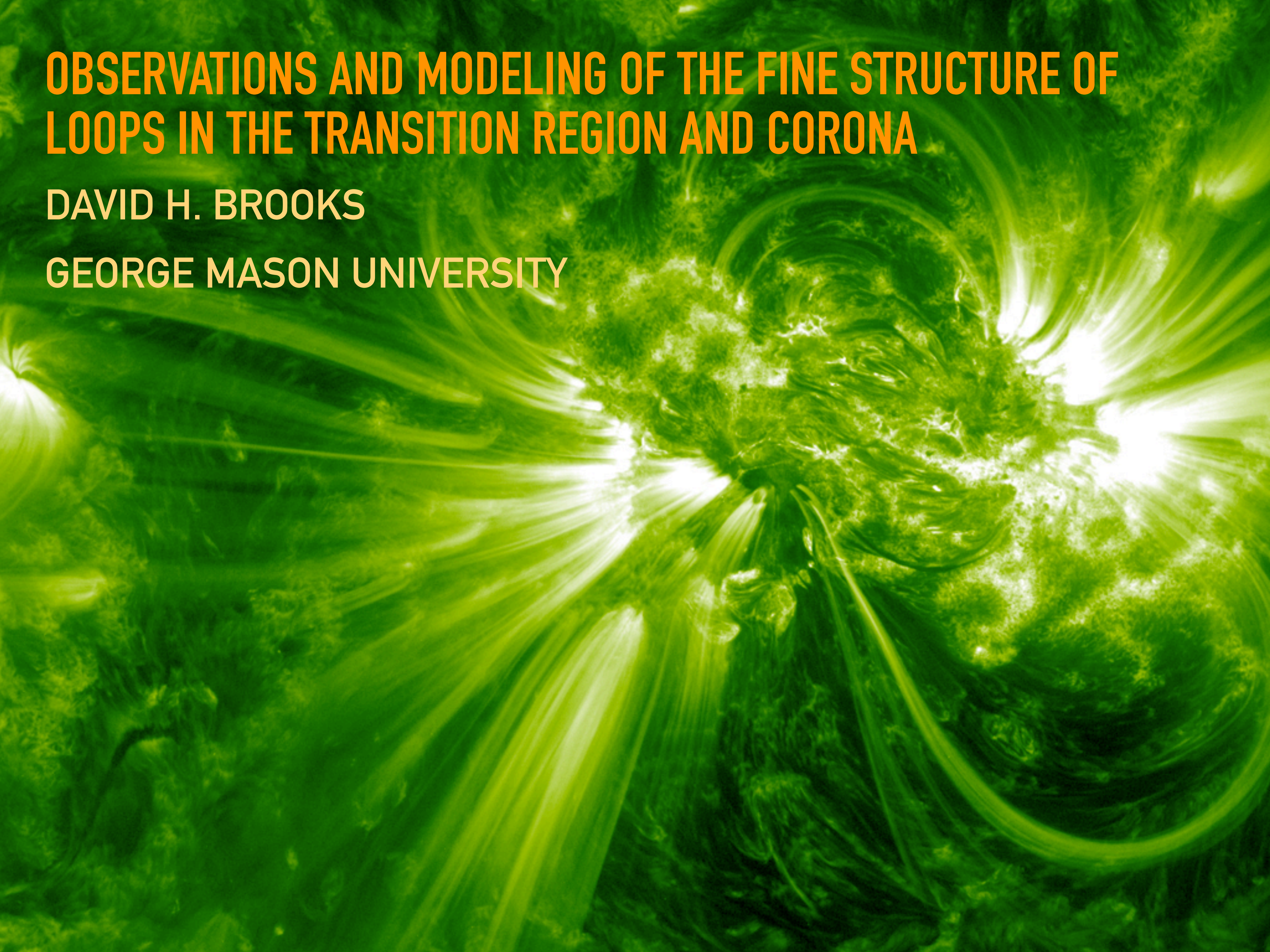
OBSERVATIONS AND MODELING OF THE FINE STRUCTURE OF LOOPS IN THE TRANSITION REGION AND CORONA

DAVID H. BROOKS

GEORGE MASON UNIVERSITY



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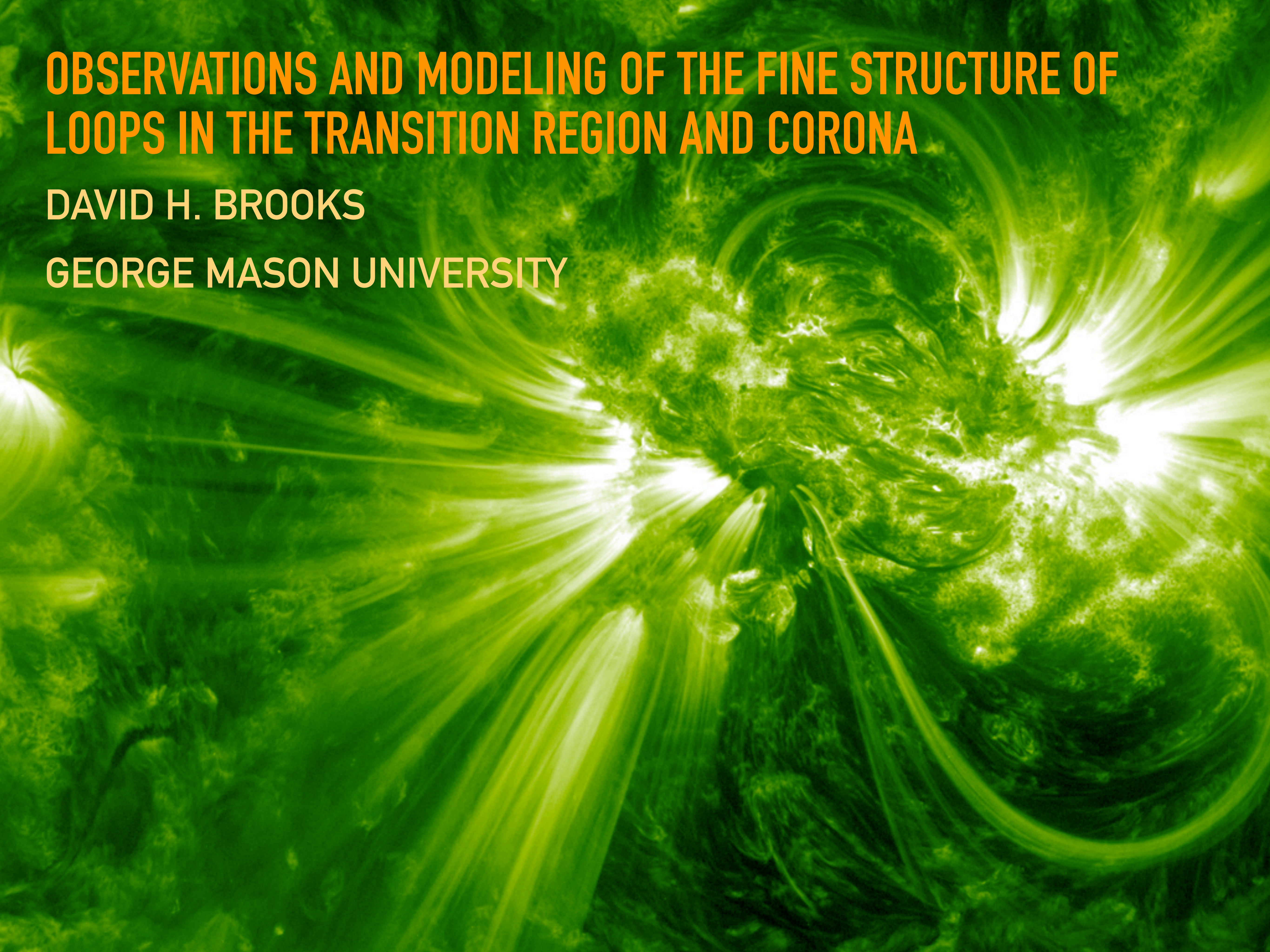


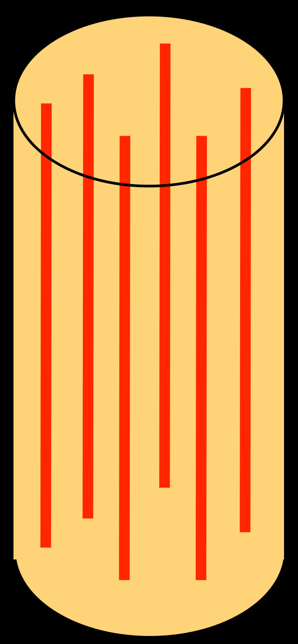
MOTIVATION

- Spatial resolution plays a critical role in interpreting observations of the corona.
- Some coronal heating mechanisms are expected to operate on very small spatial scales e.g. current sheets form on spatial scales of *hundreds of m*.
- Most coronal loops are filamented, so measurements are averaged properties of loop structures (T, n, r)…?
- Several observational results suggest 1MK loops are nearly isothermal (Del Zanna & Mason 2003, Aschwanden & Nightingale 2005, Warren et al. 2008, Tripathi et al. 2009) and organized on spatial scales of *hundreds of km.*

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



l: pixel length

n: density!

N strands

Radius r

Density n

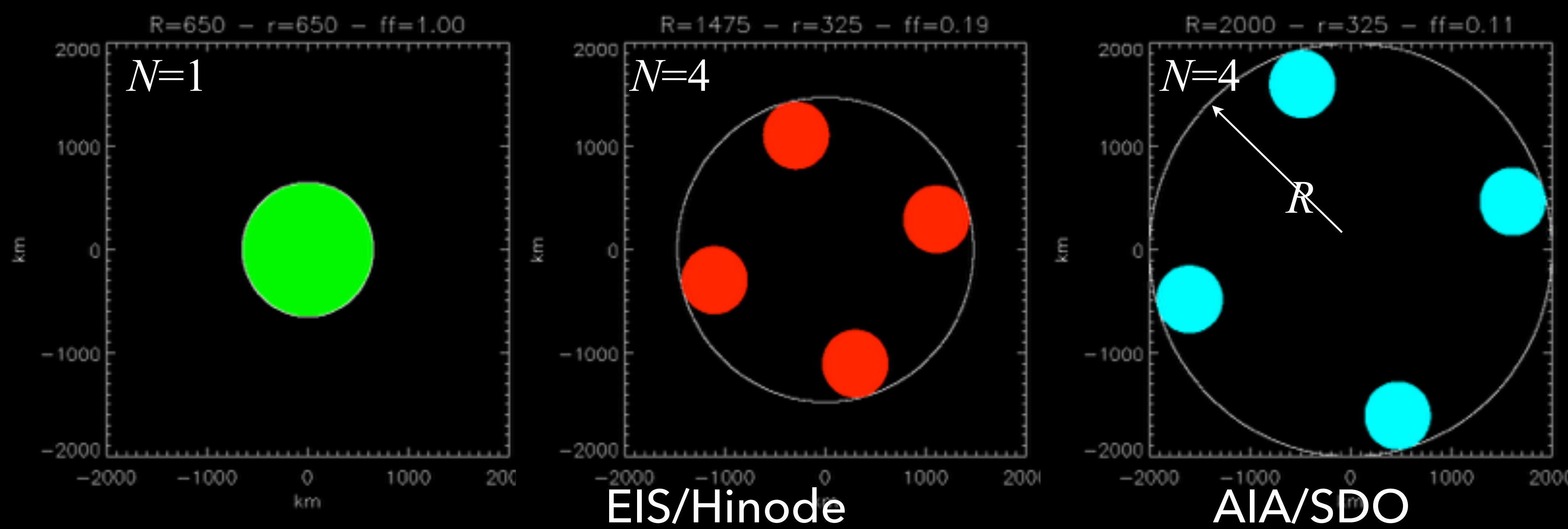
Temperature T

Envelope R

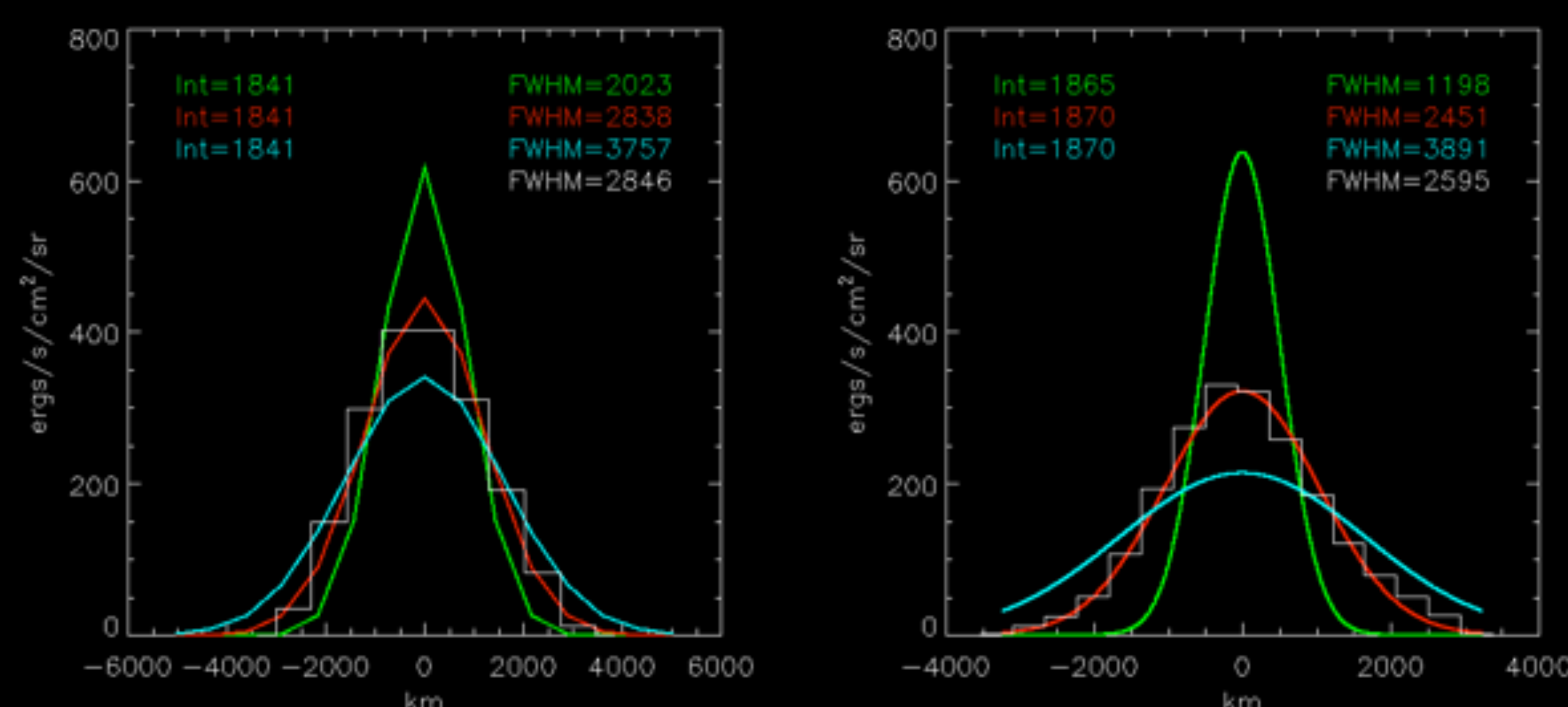
$$I_{tot} = ANr^2$$

(Brooks et al. 2012)

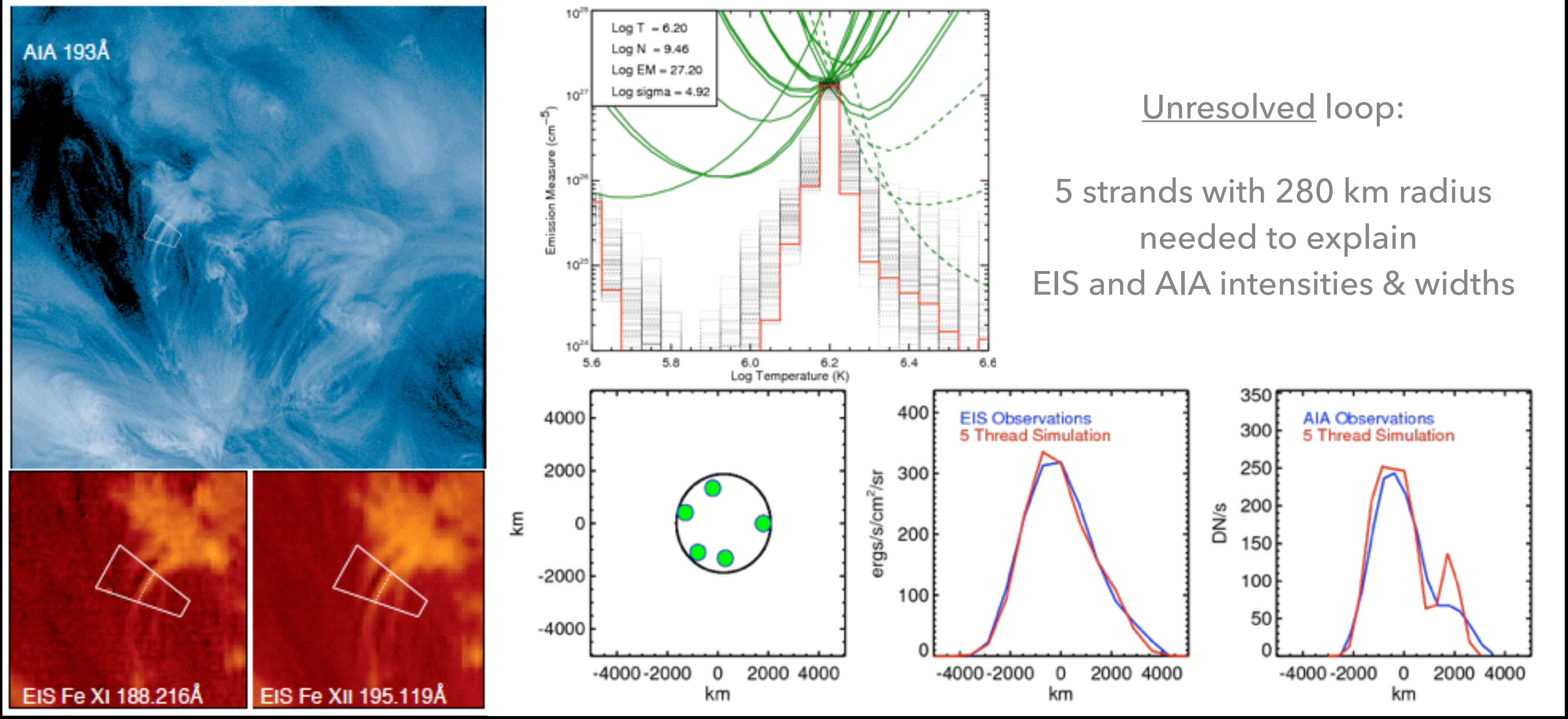
$$I_{tot} = ANr^2$$



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



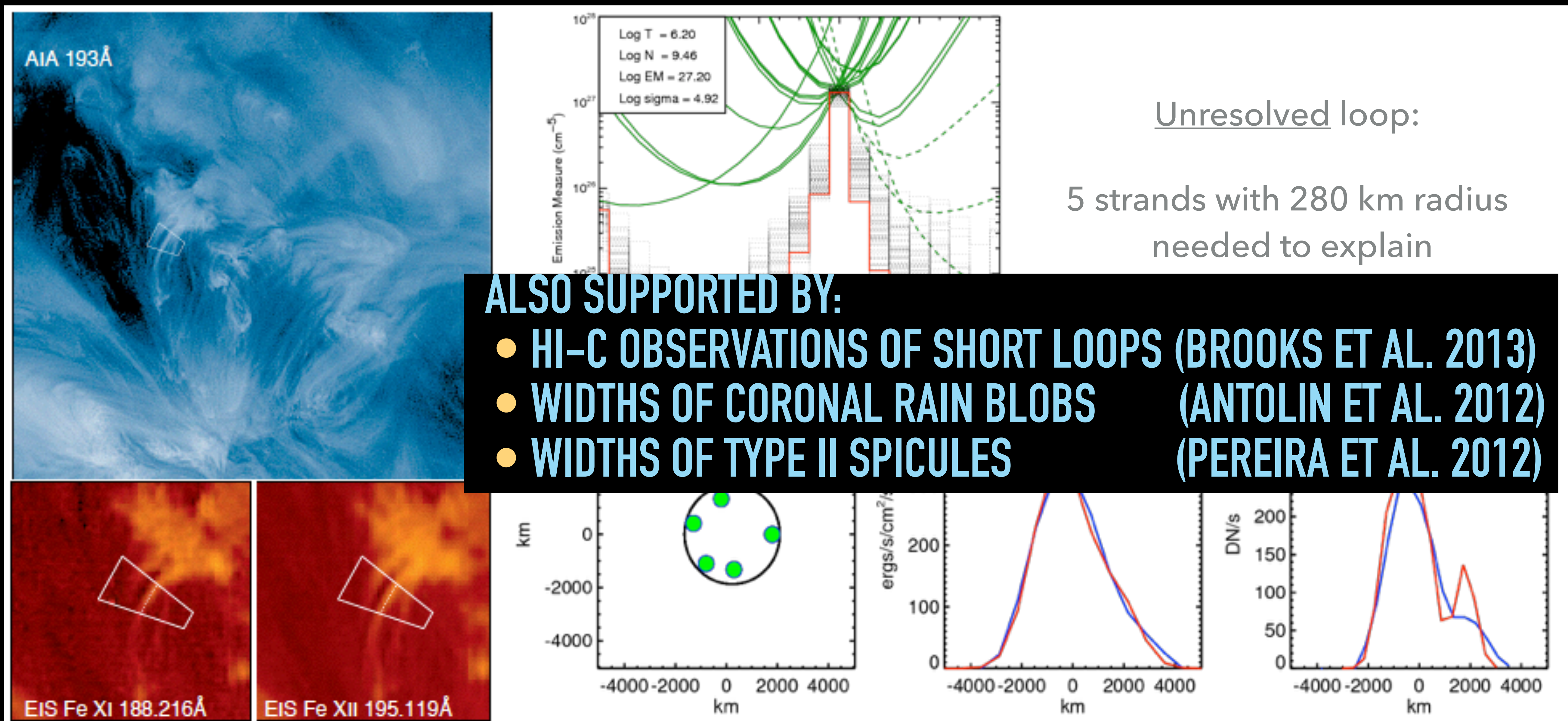
DETERMINE THE MINIMUM NUMBER OF STRANDS – TYPICAL CASE



Unresolved loop:

5 strands with 280 km radius needed to explain EIS and AIA intensities & widths

DETERMINE THE MINIMUM NUMBER OF STRANDS – TYPICAL CASE



ALSO SUPPORTED BY:

- HI-C OBSERVATIONS OF SHORT LOOPS (BROOKS ET AL. 2013)
- WIDTHS OF CORONAL RAIN BLOBS (ANTOLIN ET AL. 2012)
- WIDTHS OF TYPE II SPICULES (PEREIRA ET AL. 2012)

THE UNRESOLVED FINE STRUCTURE RESOLVED (HANSTEEN ET AL. 2014)

ON THE UNRESOLVED FINE STRUCTURES OF THE SOLAR ATMOSPHERE IN THE 3×10^4–2×10^5 K TEMPERATURE REGION

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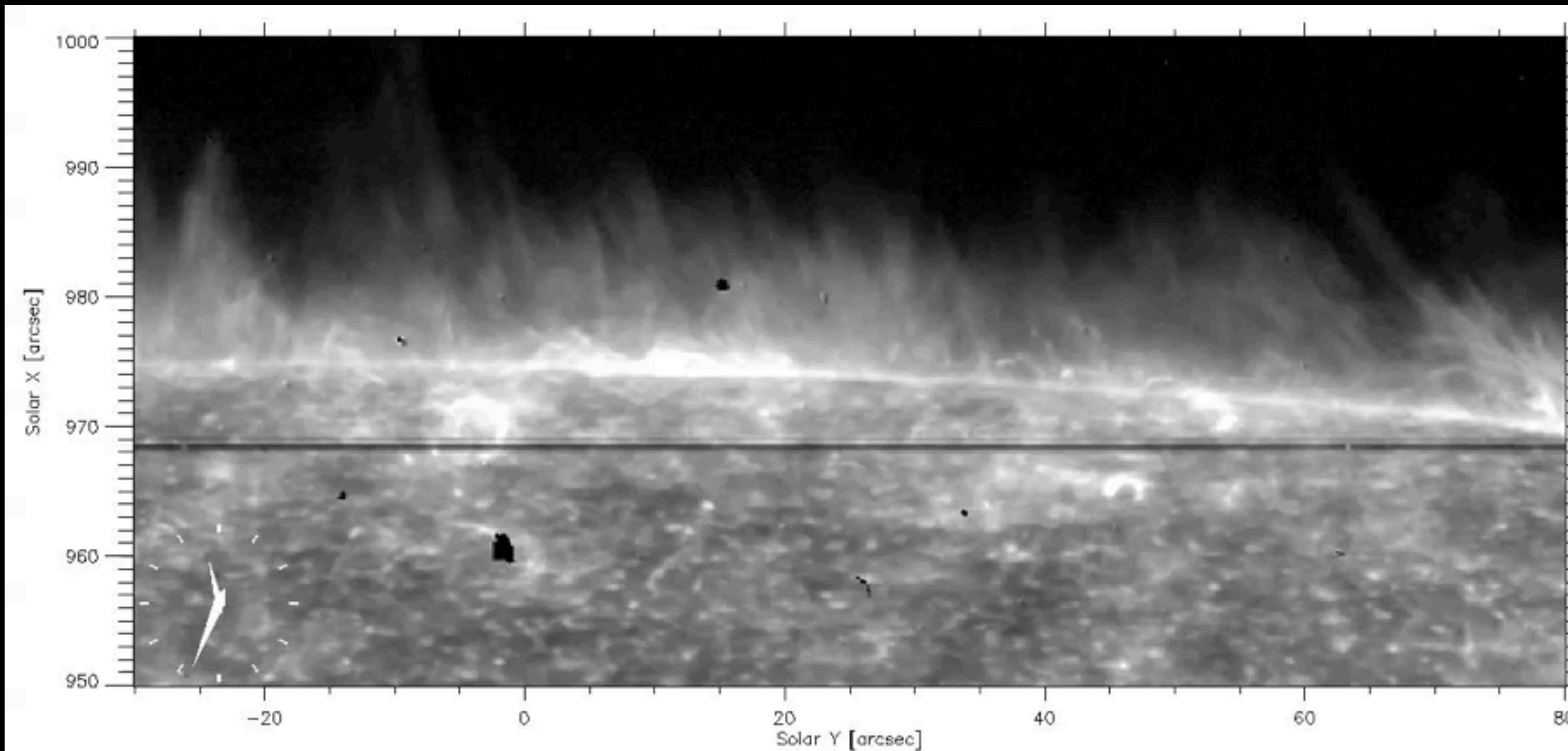
ABSTRACT

The solar atmospheres from the chromosphere through the transition zone and all the way up into the corona usually are considered to be parts of one continuous structure. Now that stellar measurements in the far-ultraviolet have become available, an attempt is being made to apply solar physics ideas to solar type stars. The intention of this paper is to reexamine the experimental facts concerning the relations between the solar chromosphere, transition zone, and corona.

Experimental evidence is presented to argue that the solar plasma in the temperature region 4×10^4–2.2×10^5 K occurs in structures magnetically isolated from the chromosphere and corona. It is suggested that while a small part of the emission detected in the 4×10^4–2.2×10^5 K region consists of the "true" transition zone plasma, i.e., the interface between chromospheric and coronal temperatures, that most of it belongs to an altogether different entity. It is also suggested that this particular entity be called unresolved fine structures.

THE UNRESOLVED FINE STRUCTURE RESOLVED (HANSTEEN ET AL. 2014)



IRIS Si IV slit-jaw images

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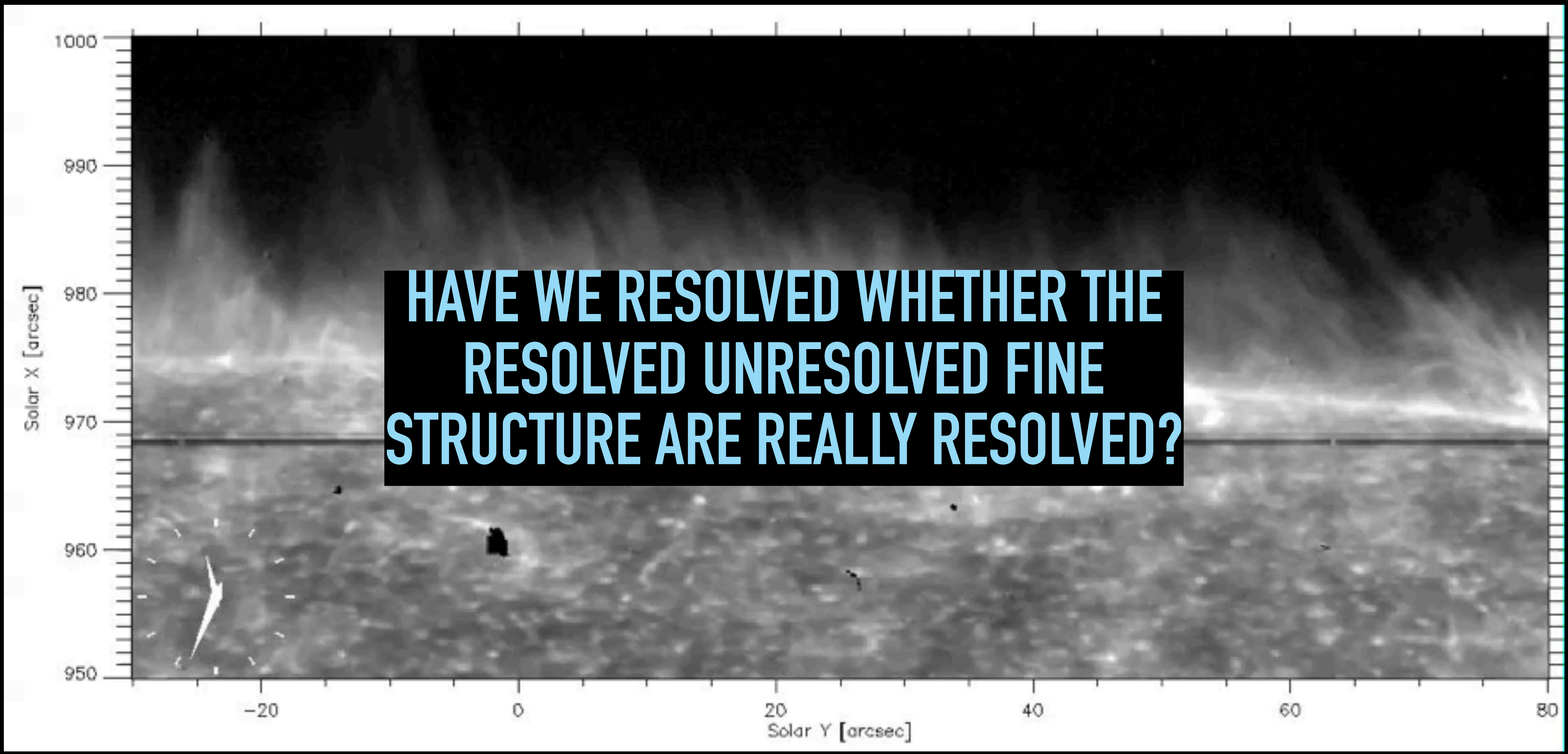
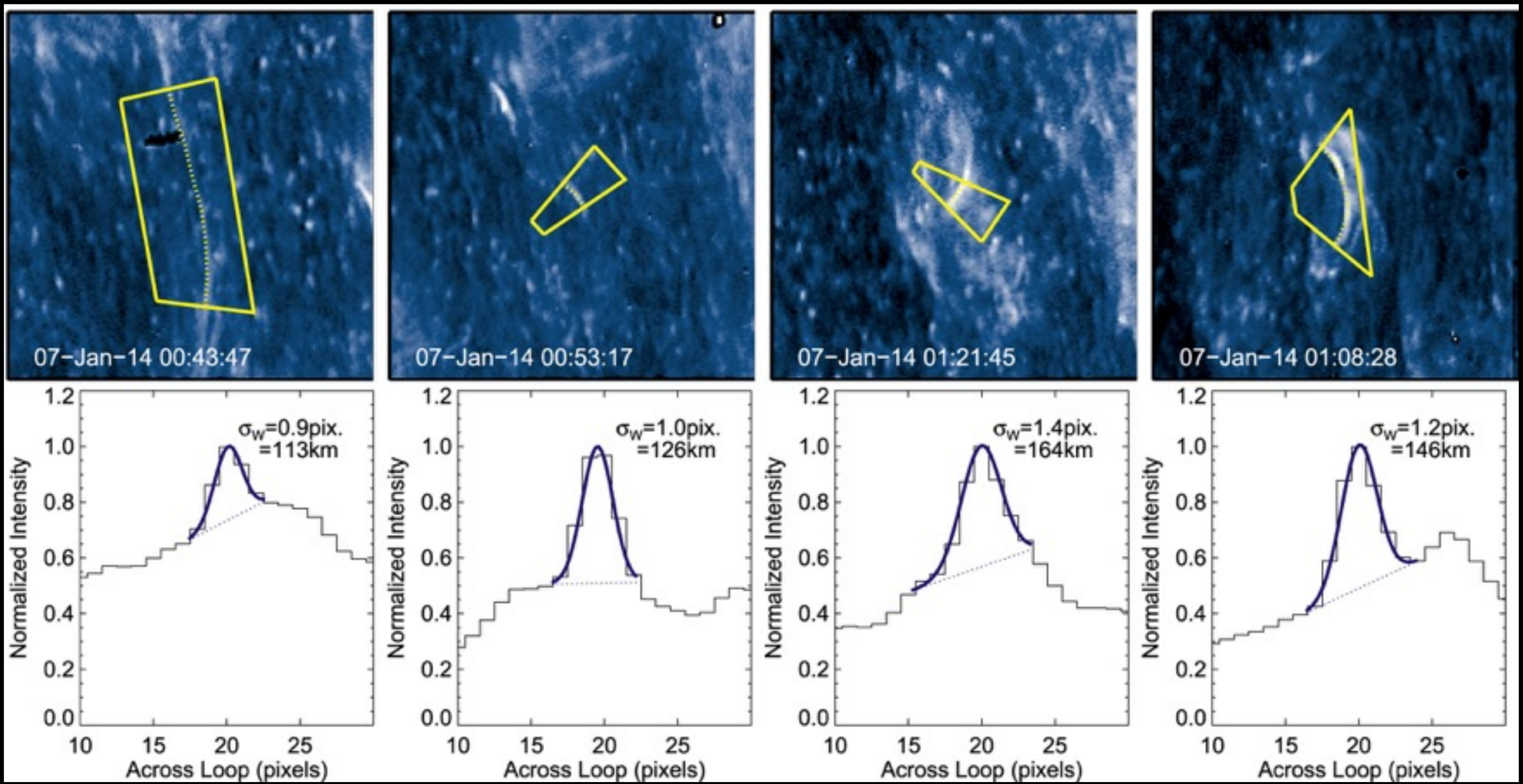


HAVE WE RESOLVED WHETHER THE RESOLVED UNRESOLVED FINE STRUCTURE ARE REALLY RESOLVED?

IRIS Si IV slit-jaw images

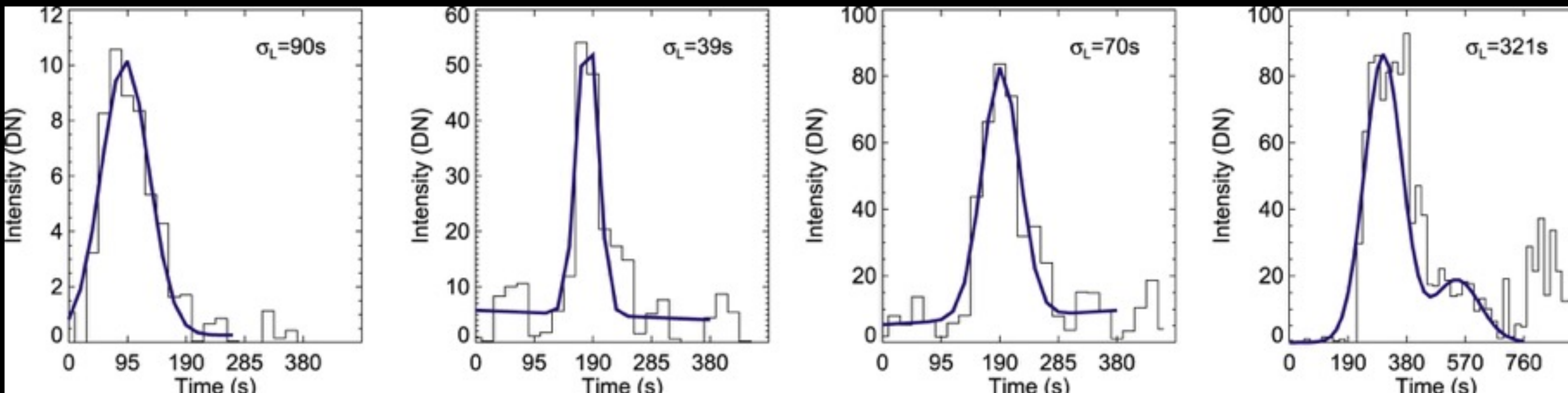
UFS OBSERVATIONAL PROPERTIES FROM 108 LOOPS



Widths & Lengths from cross-field intensity profiles

Brooks et al. (2016)

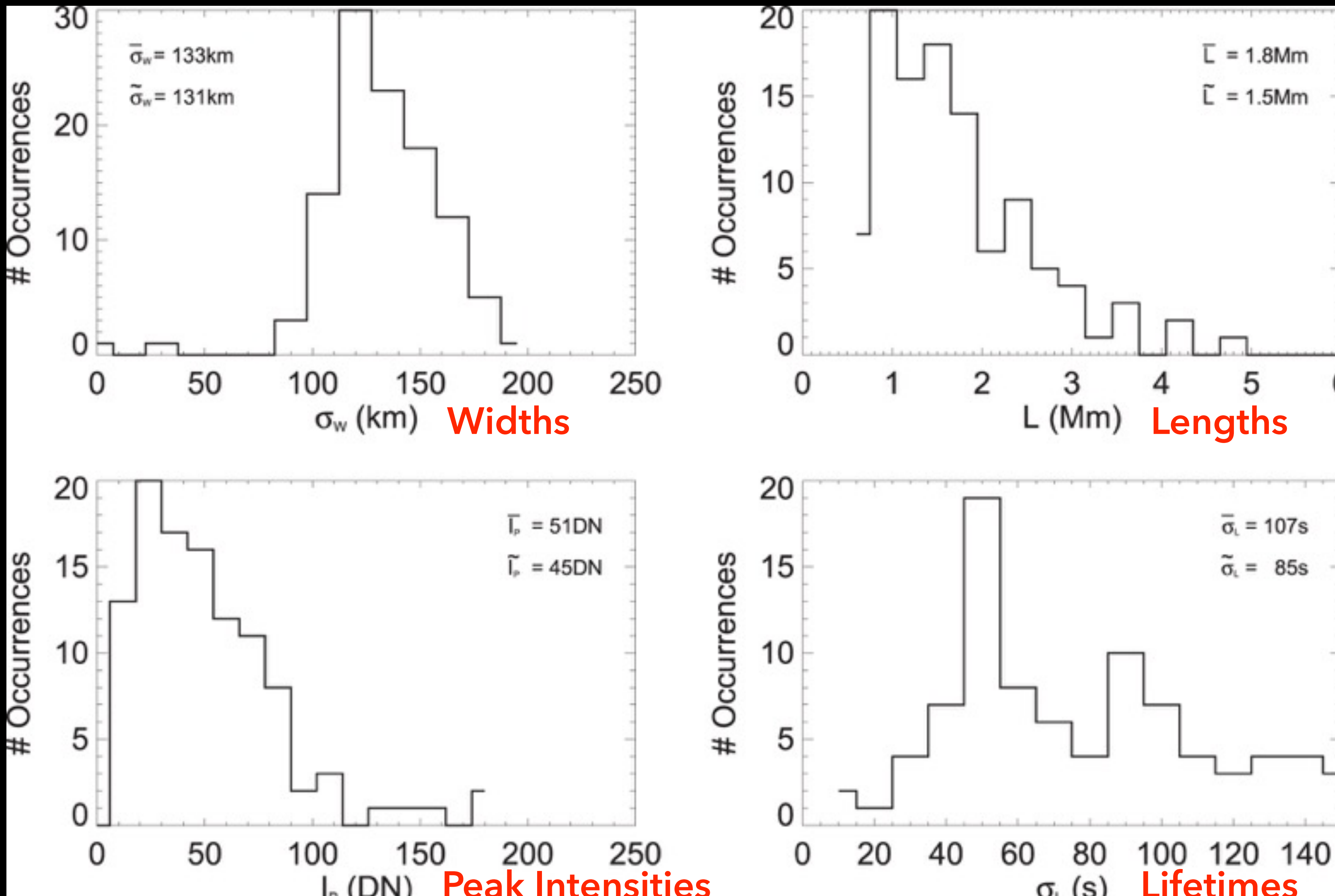
UFS OBSERVATIONAL PROPERTIES FROM 108 LOOPS



Peak brightness & Lifetimes from intensity profiles.

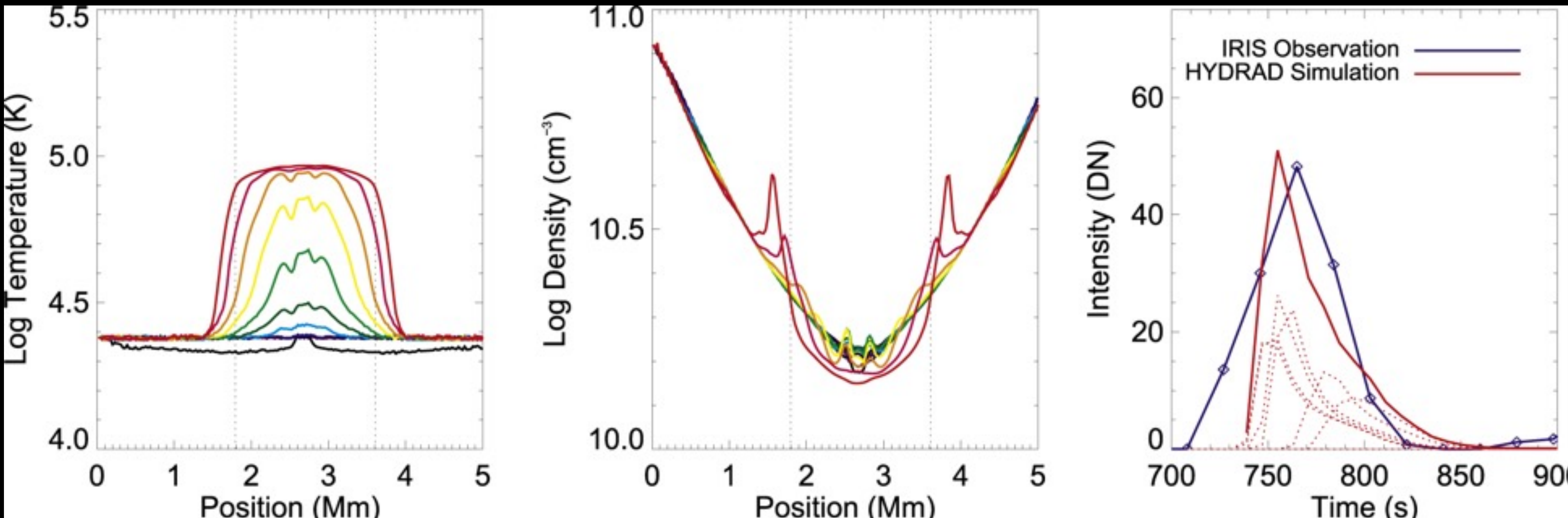
Brooks et al. (2016)

UFS OBSERVATIONAL PROPERTIES FROM 108 LOOPS



Brooks et al. (2016)

IMPULSIVE HEATING EVENT IN A SINGLE STRAND



Time increases from blue to red

1-D hydrodynamic model with non-equilibrium ionization

(Bradshaw & Mason 2003, Bradshaw & Cargill 2013)

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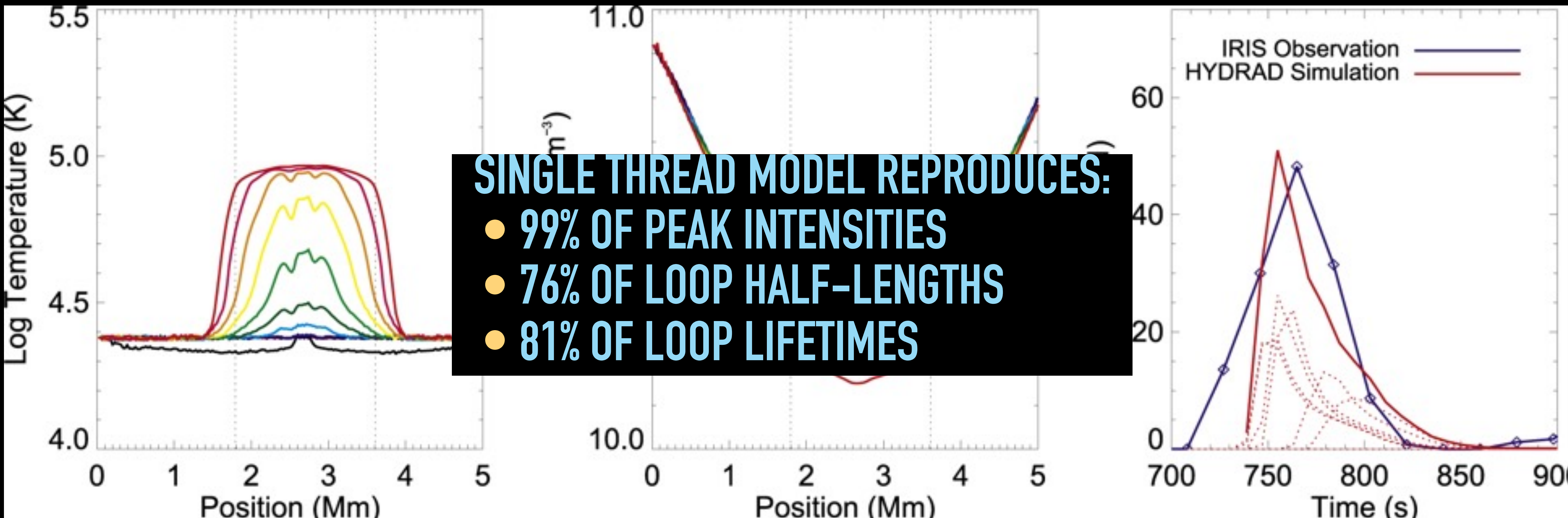


SINGLE THREAD MODEL REPRODUCES:

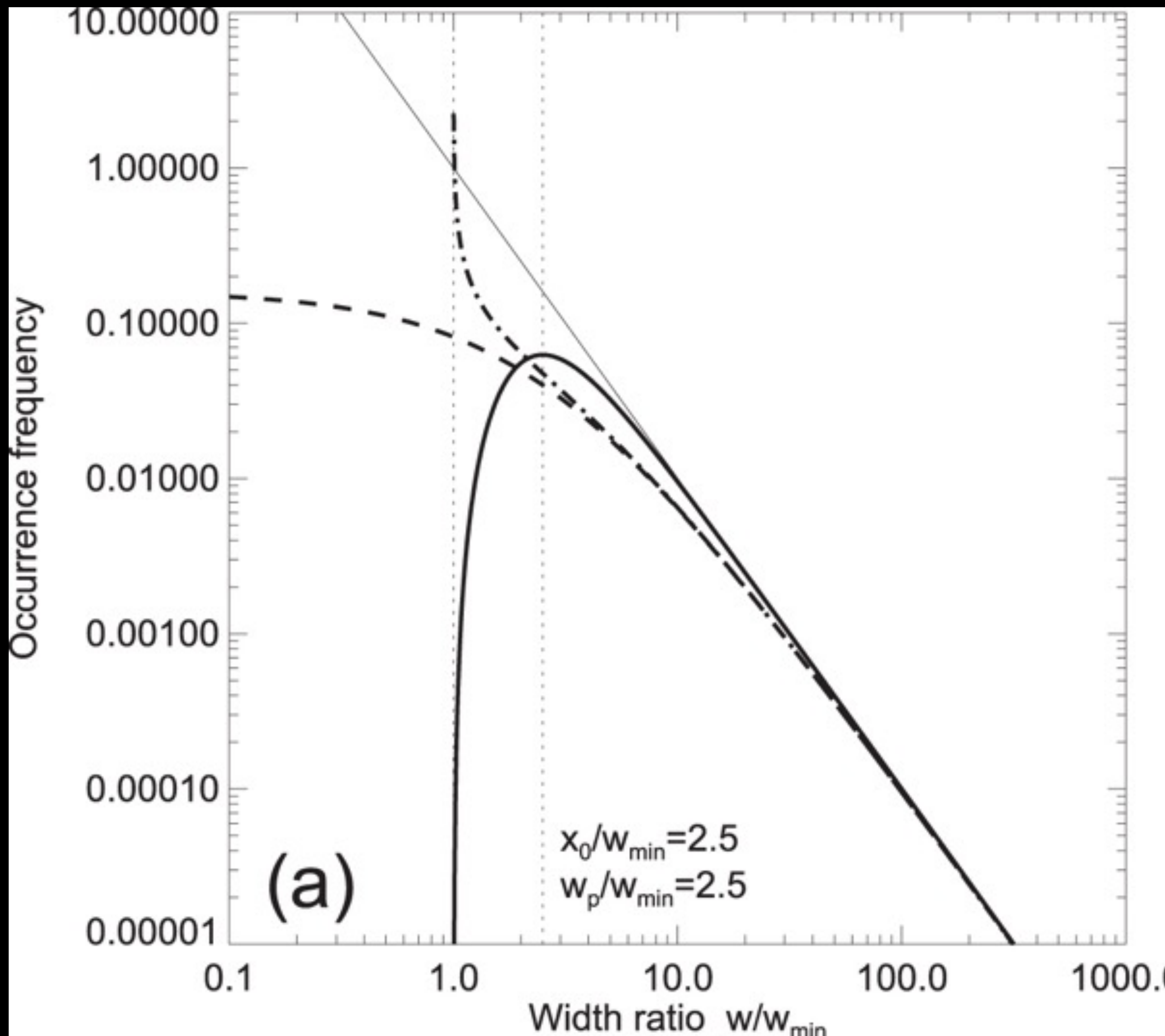
- 99% OF PEAK INTENSITIES
- 76% OF LOOP HALF-LENGTHS
- 81% OF LOOP LIFETIMES

Time increases from blue to red

1-D hydrodynamic model with non-equilibrium ionization

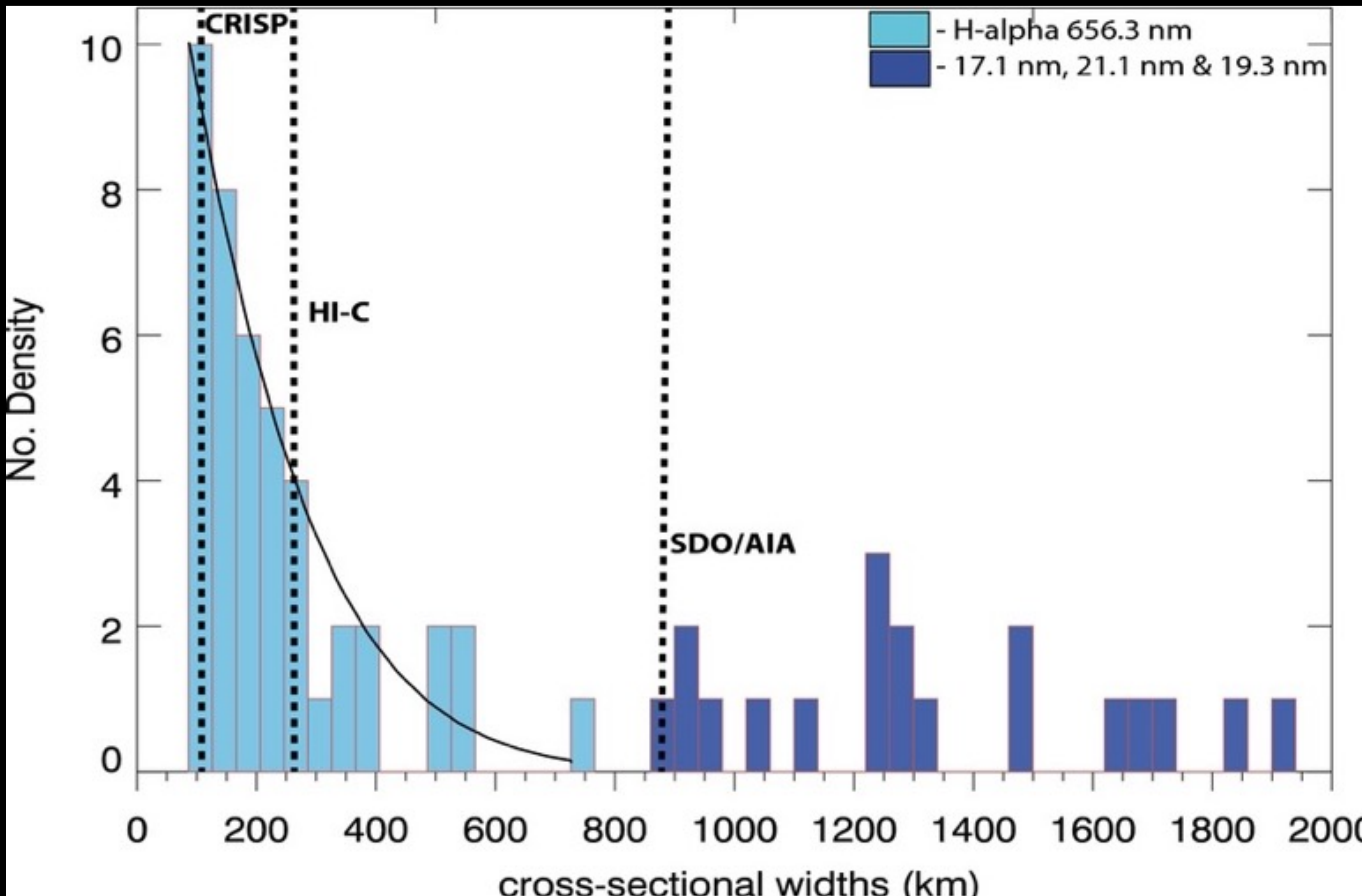
(Bradshaw & Mason 2003, Bradshaw & Cargill 2013)

WHAT IS THE DISTRIBUTION OF LOOP WIDTHS? POWER-LAW?



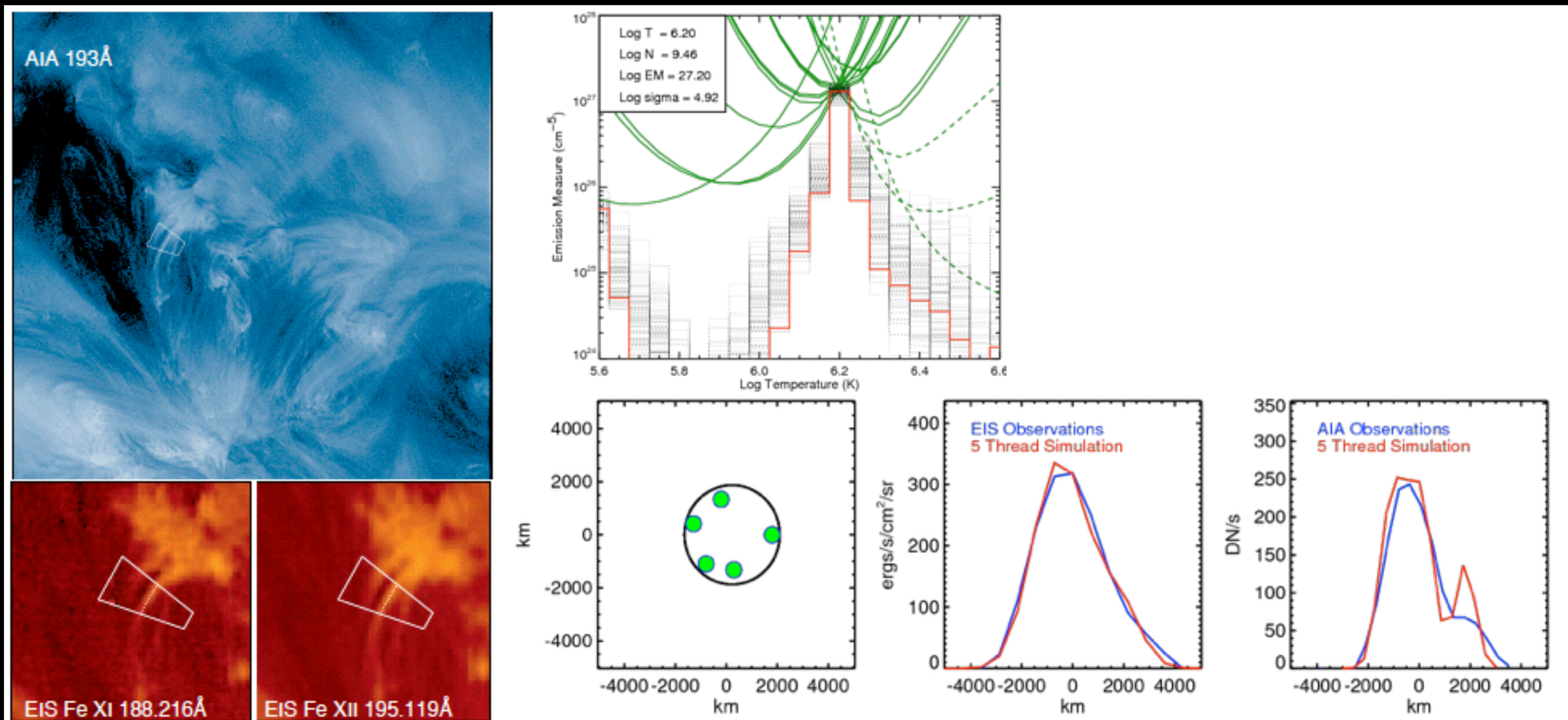
Aschwanden & Peter (2017)

DOES IT EXTEND TO VERY SMALL SPATIAL-SCALES? OR IS THERE A CUT-OFF?



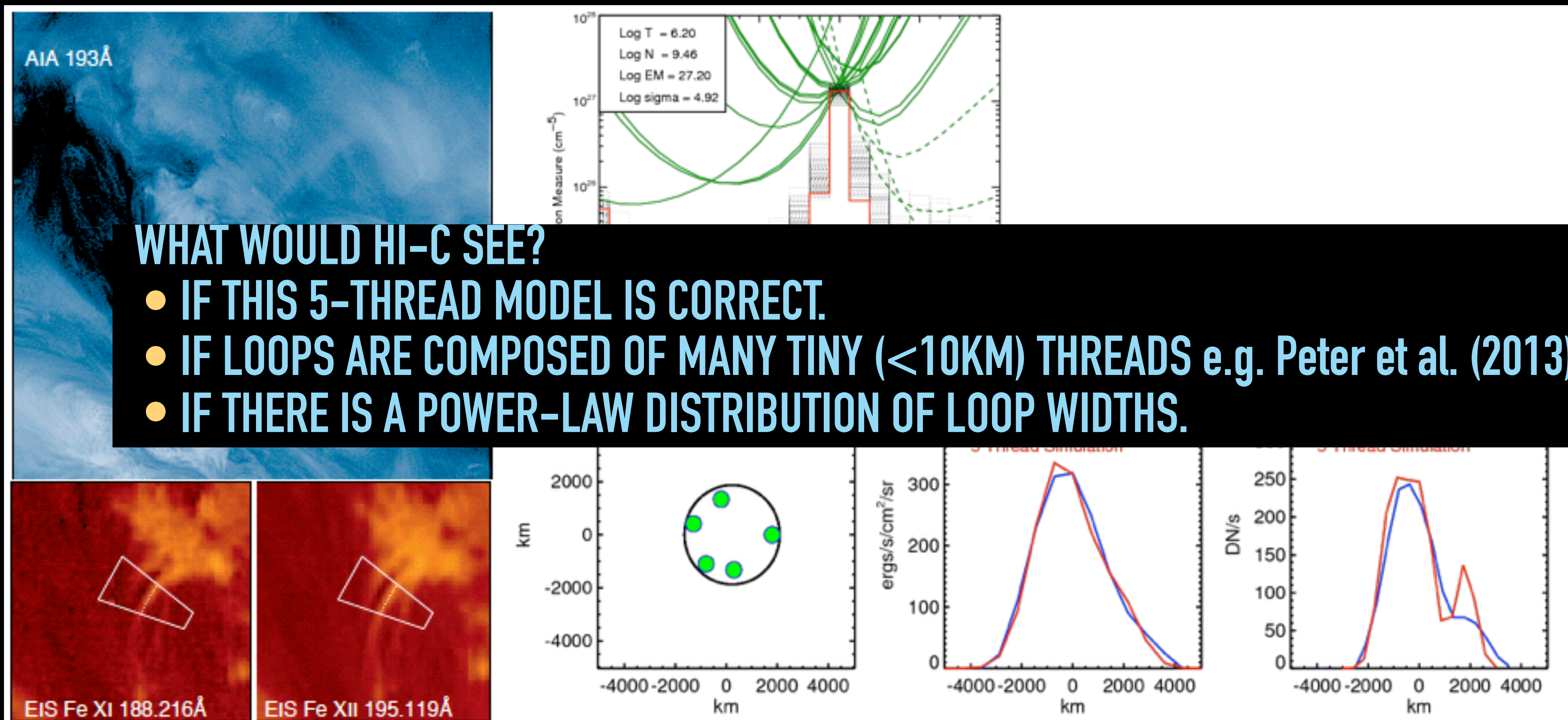
Scullion et al. (2014)

NEW SIMULATIONS



Brooks et al. (2012) EIS/AIA loop sample

NEW SIMULATIONS

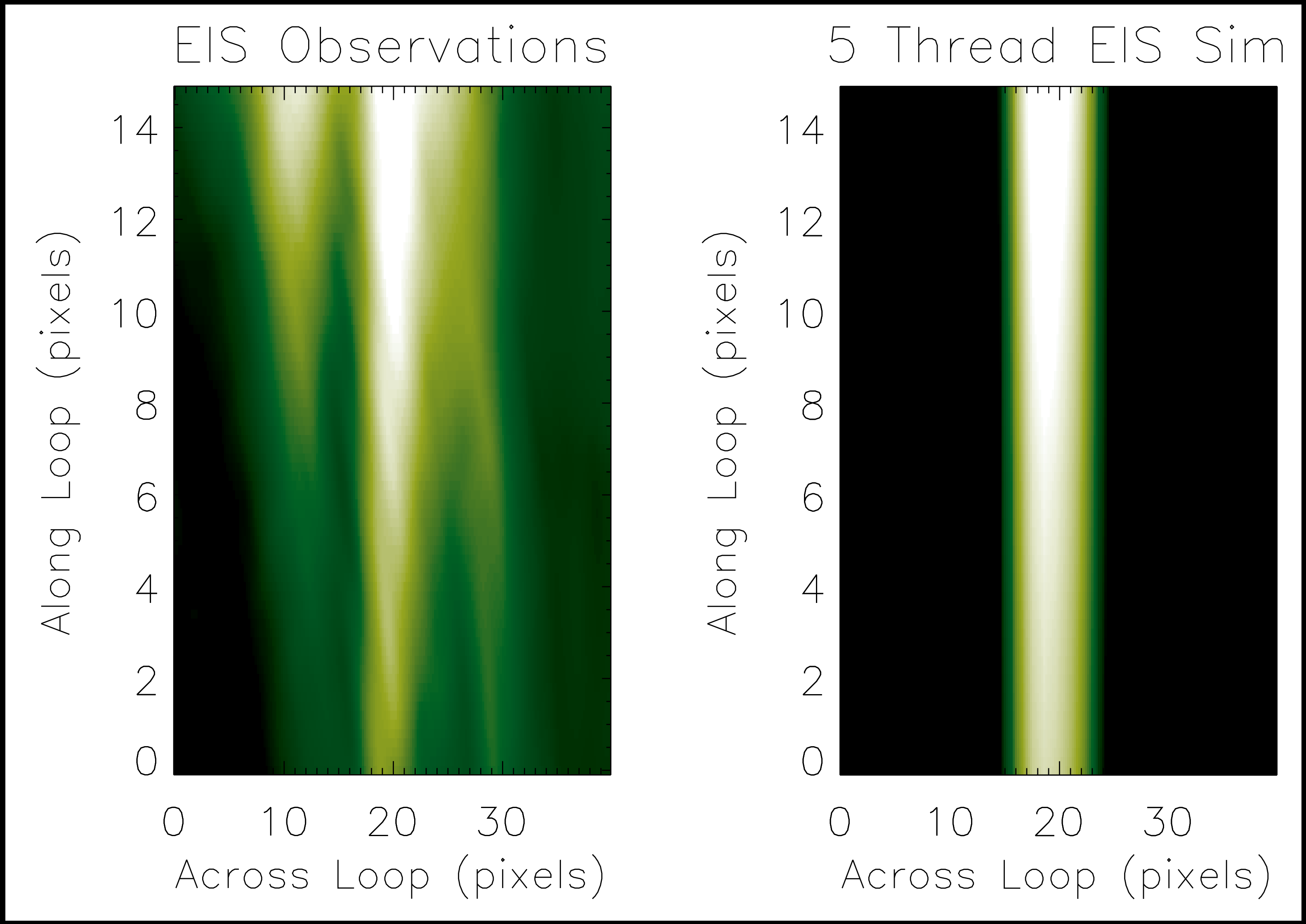


WHAT WOULD HI-C SEE?

- IF THIS 5-THREAD MODEL IS CORRECT.
- IF LOOPS ARE COMPOSED OF MANY TINY (<10KM) THREADS e.g. Peter et al. (2013).
- IF THERE IS A POWER-LAW DISTRIBUTION OF LOOP WIDTHS.

Brooks et al. (2012) EIS/AIA loop sample

5-THREAD SIMULATIONS (STRANDS 280KM)



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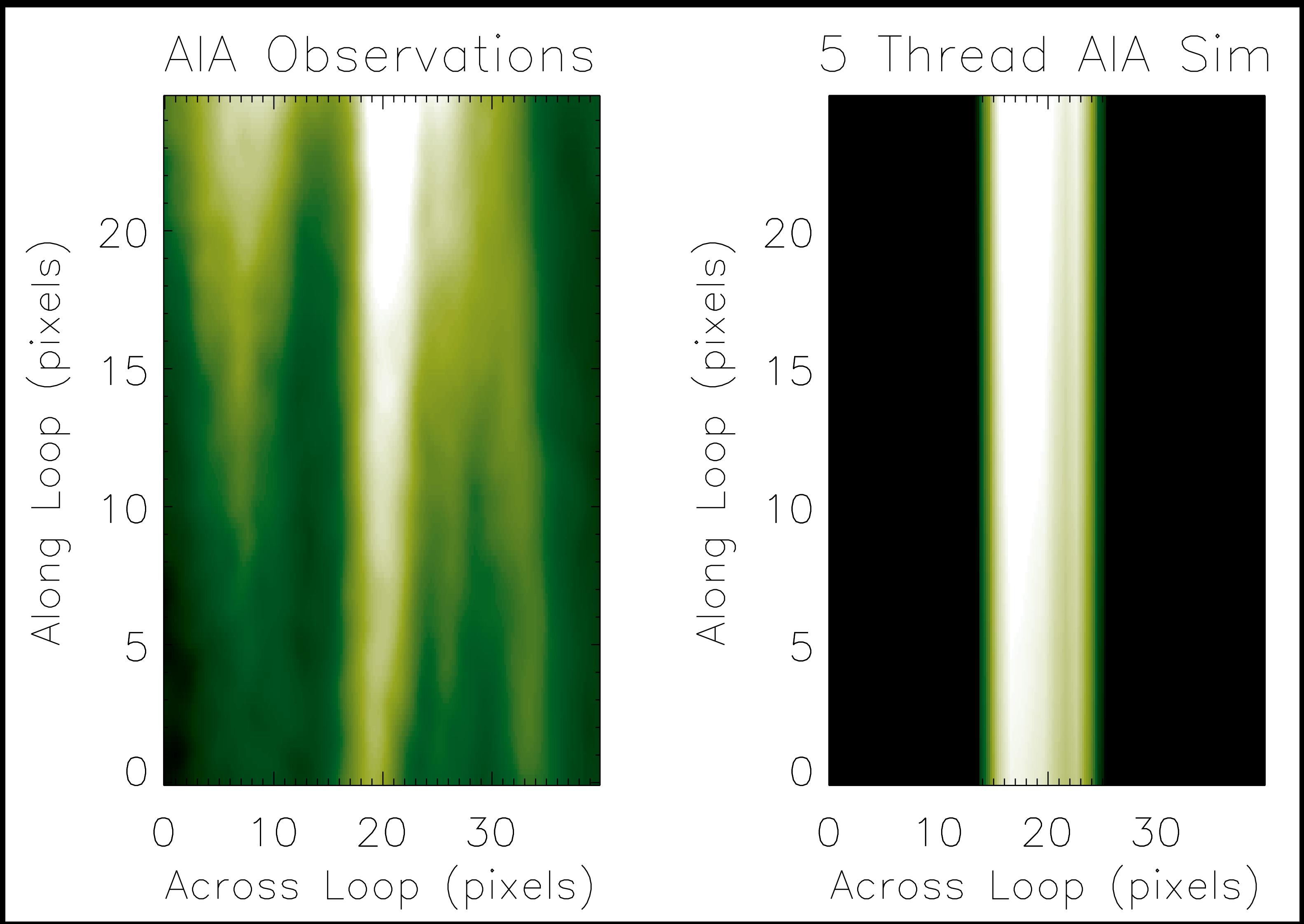

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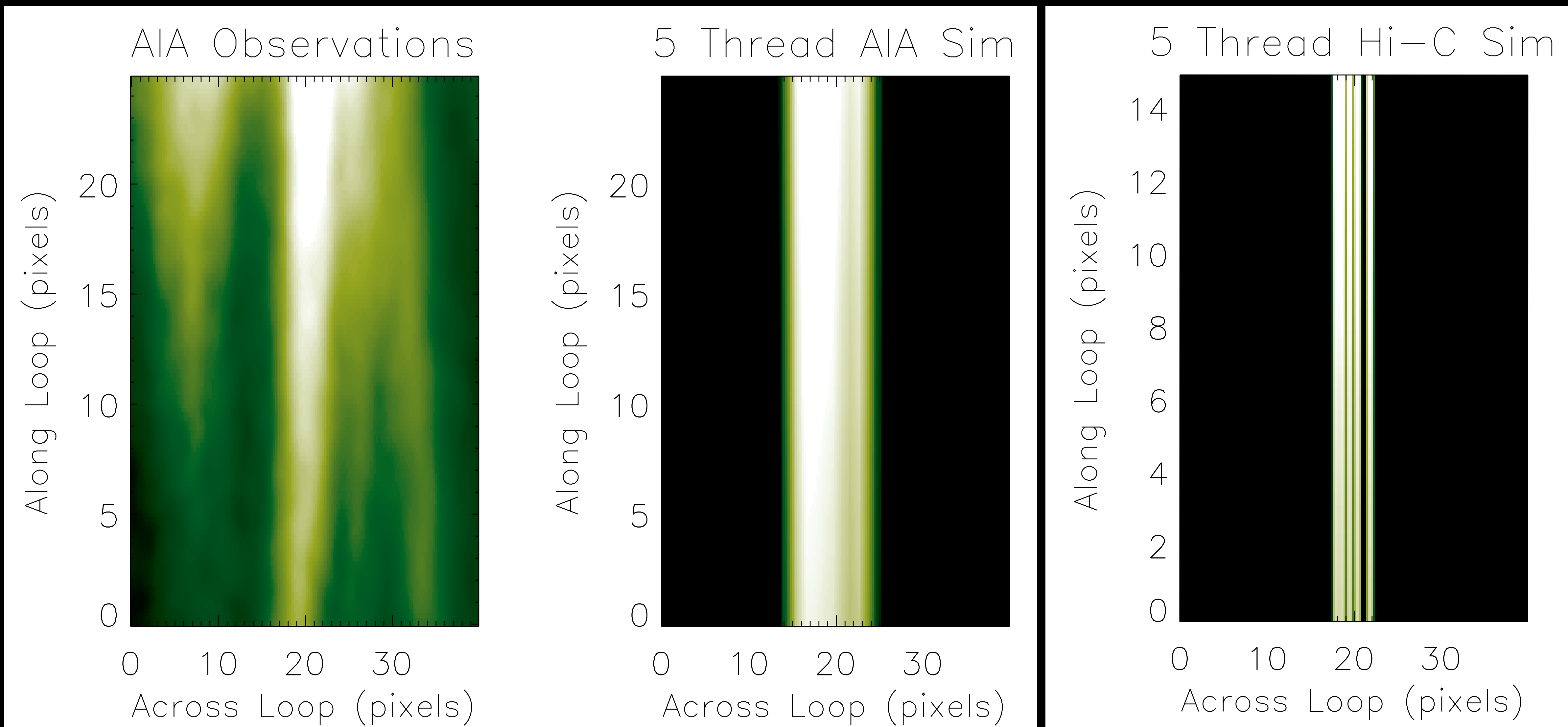
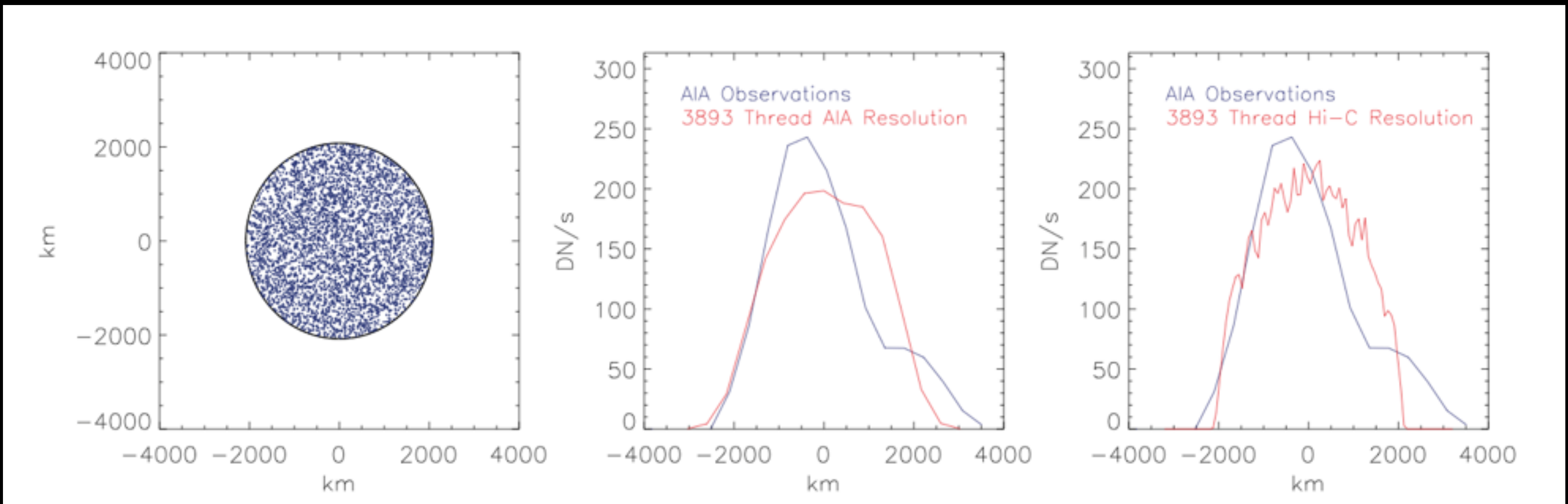
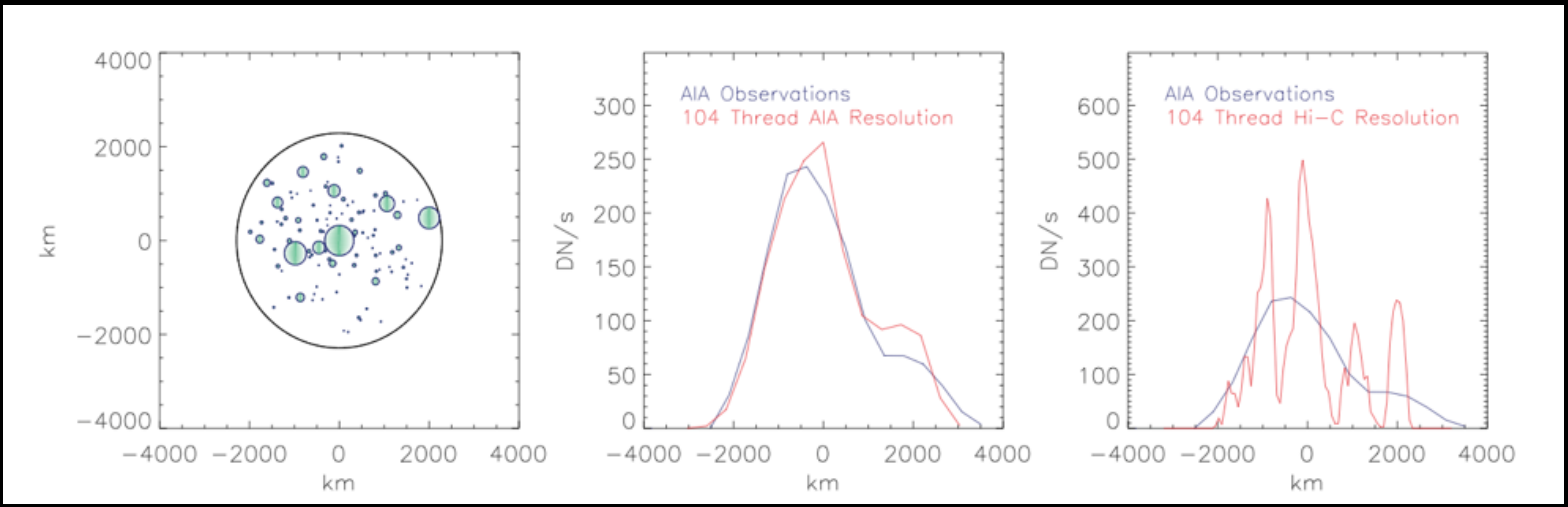


3893 THREAD SIMULATION (STRANDS < 10KM)



104 THREAD SIMULATION (POWER-LAW DISTRIBUTION, STRANDS: 10–322KM)



CONCLUSIONS

- Modeling suggests that coronal loops are nearly resolved and composed of only a few strands (1-10), with typical sizes in the hundreds of km. "Multi-stranded" means "A few strands".
- Properties of transition region loops (UFS) are consistent with single thread models, typical sizes in the hundreds of km.
- Models of a few hundred km threads are most consistent with the data:
  - Intensity profiles of power-law simulations dominated by largest strands
  - Very small threads do not produce smooth profiles when models are "data driven"