Integrating Models and Observations

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For the past ten years, the coronal loops community has held bi-annual workshops to discuss the analysis of coronal loop observations and the latest efforts to model the loop structures. During this time, several heating scenarios have been proposed to explain loop observations. These heating scenarios rely on different heating frequencies, locations, and durations, as well as different loop sub-structure. Often the scenarios are developed to explain an observation, hence all heating scenarios match some observational criteria. The key to discriminating between the competing heating scenarios is to first identify the distinguishing observables. For instance, both effectively steady and nanoflare-heating scenarios can produce quasi-steady intensities. Observing quasi-steady intensities, then, does not help determine which heating scenario is most likely. These heating scenarios may, however, predict different velocities or different emission measure distributions.
In this talk, I will discuss a few of the expected observations for some simple heating scenarios. I will ask the modeling community to calculate similar observations for the different heating scenarios to generate a standard list of expected observations. After the community develops this list, comparisons with actual loop observations can then distinguish the most likely heating scenario.

Integrating Models and Observations

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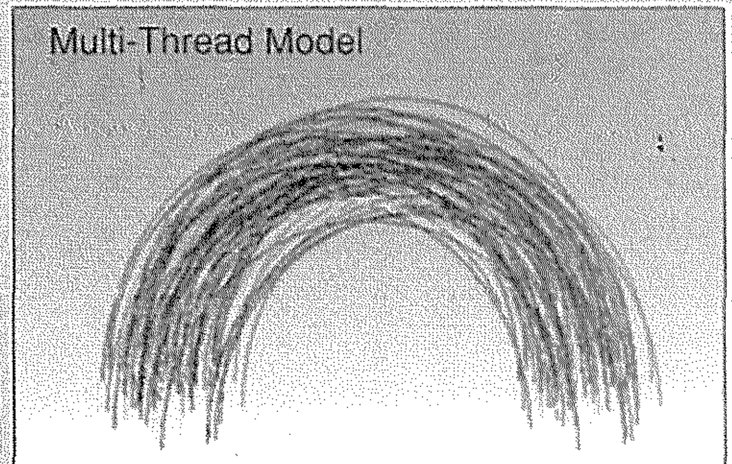
Motivation

- *In previous loops workshops, the data seemed to support all the models.*
- *What were distinguishing characteristics of the models and of the data?*

Major Points

- *Confront the data!*
- *Define a common language*
- *Determine discriminating observations*
- *Drive the observations*

Loop Sub-structure



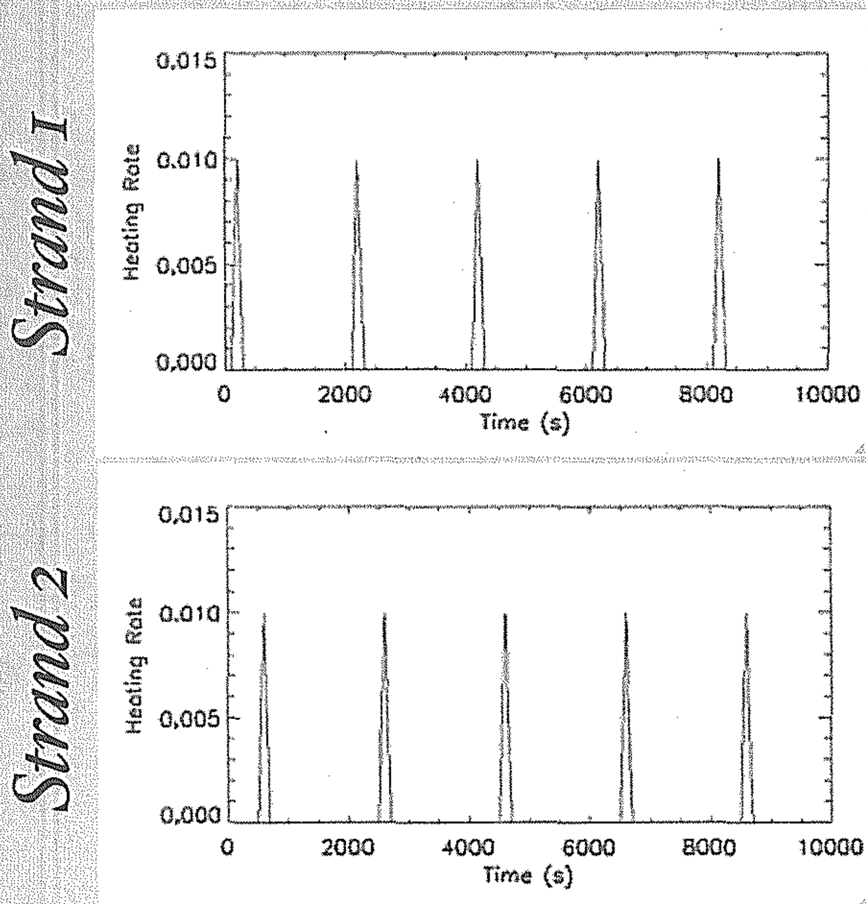
In Santorini, Jim suggested:

- *Strand = fundament flux tube*
- *Loop = Coherent structure in an image*
- *n = number of strands*
- *Loop can be a single strand (corona is being resolved).*
- *Loop can be many sub-resolution strands.*

Temporal Characteristics

- δ = *duration of a single heating event*
- $\tau = (1/f)$ = *time between heating events on a single strand*
- T = *total time of all heating events*

Temporal Characteristics



Long Nanoflare Storm

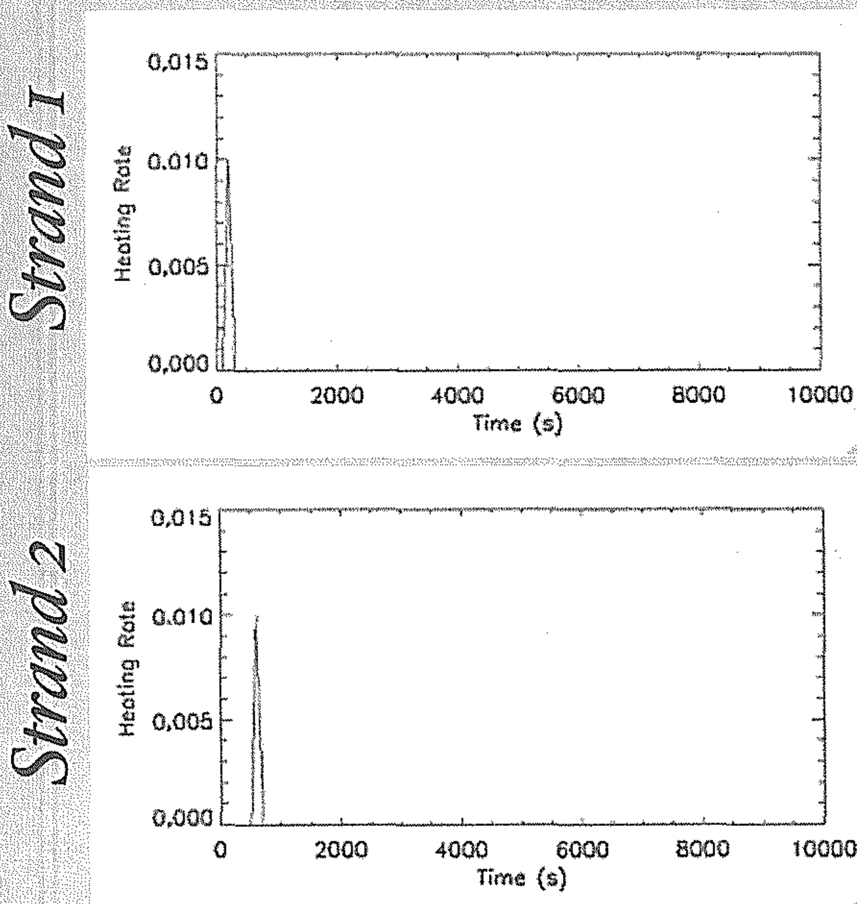
δ = short (impulsive)

$\tau > \tau_{cool}$

$T >> \tau_{cool}$

Heating in different strands are offset

Temporal Characteristics



Short Nanoflare Storm (IHMS)

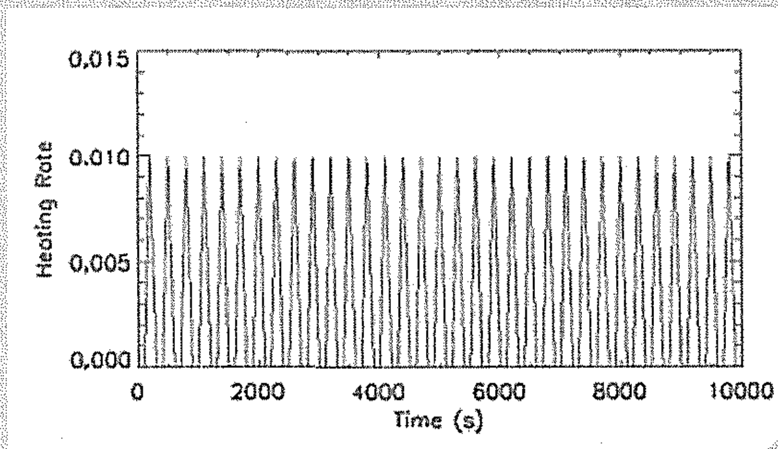
δ = short (impulsive)

$\tau = \infty$

$T = \delta$

Heating in different strands are offset

Temporal Characteristics



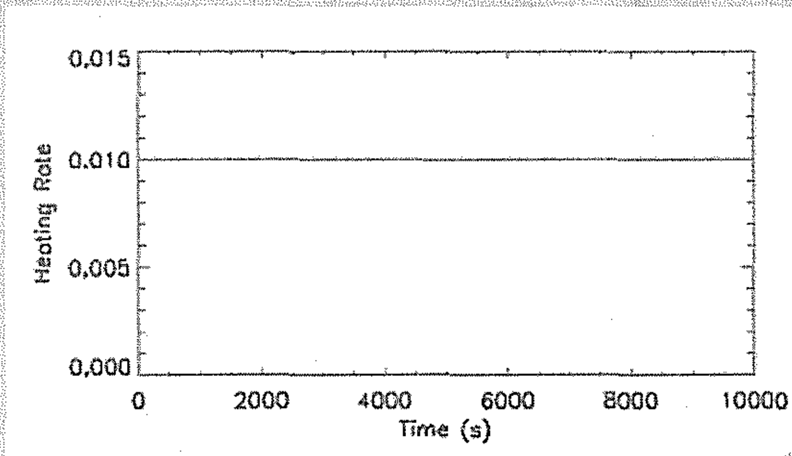
High-frequency Heating

δ = *short (impulsive)*

$\tau < \tau_{cool}$

$T = \infty$

Temporal Characteristics



Steady Heating

$\delta = \infty$

$\tau = 0$

$T = \infty$

Spatial Characteristics

- *σ = width of heating along loop (Uniform or Localized)*
- *s_0 = location of heating along loop (Random or Centralized)*

Magnitude Characteristics

- *E_0 = magnitude of the event (constant, normally distributed, power-law distribution, proportional to B/L?)*

Characteristics

No where near exploring parameter space

- n = *number of strands*
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Characteristics

- *n = number of strands*
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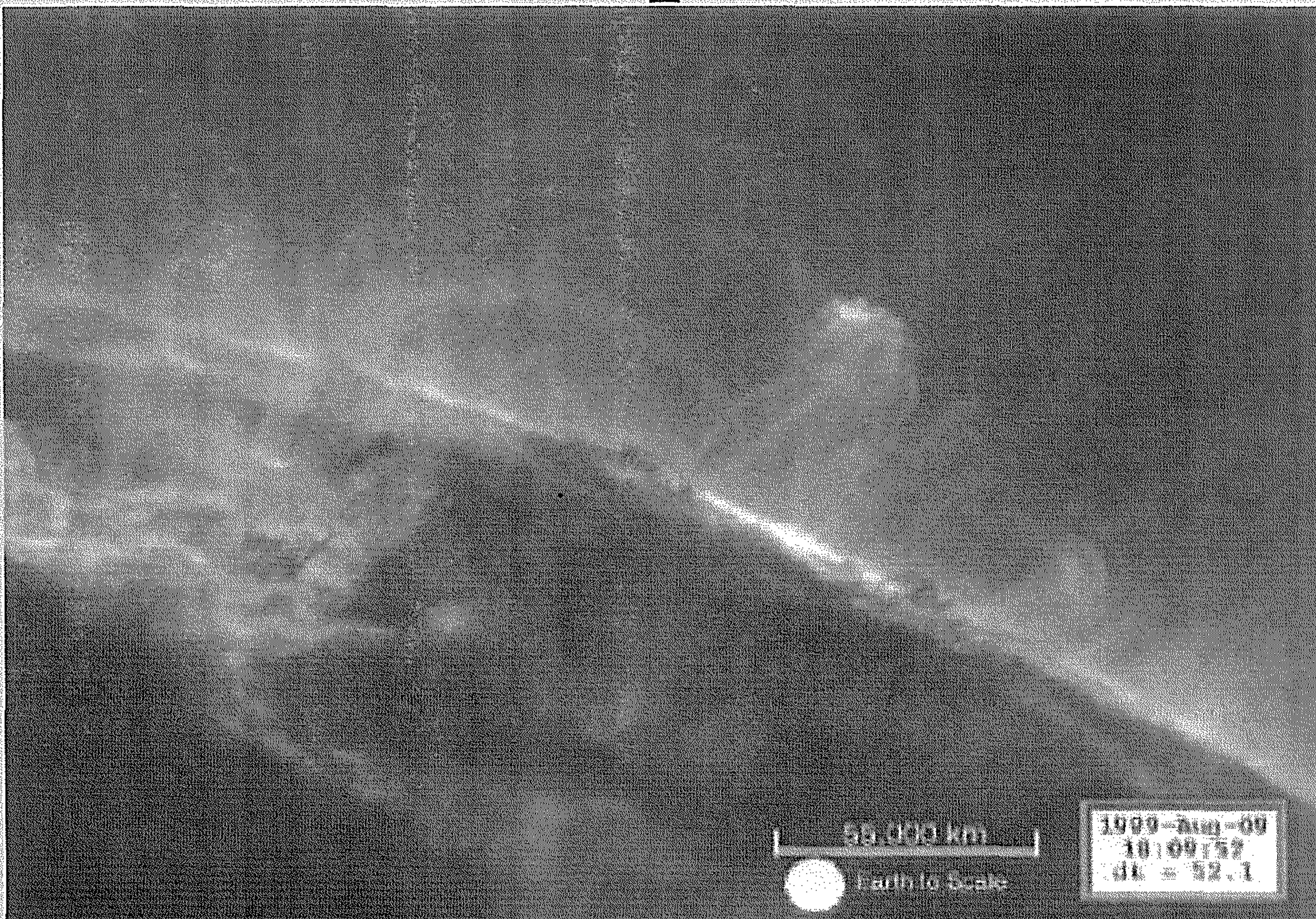
No where near exploring parameter space

Does not include other fundamental parameters like loop length, radiative loss function, area expansion etc.

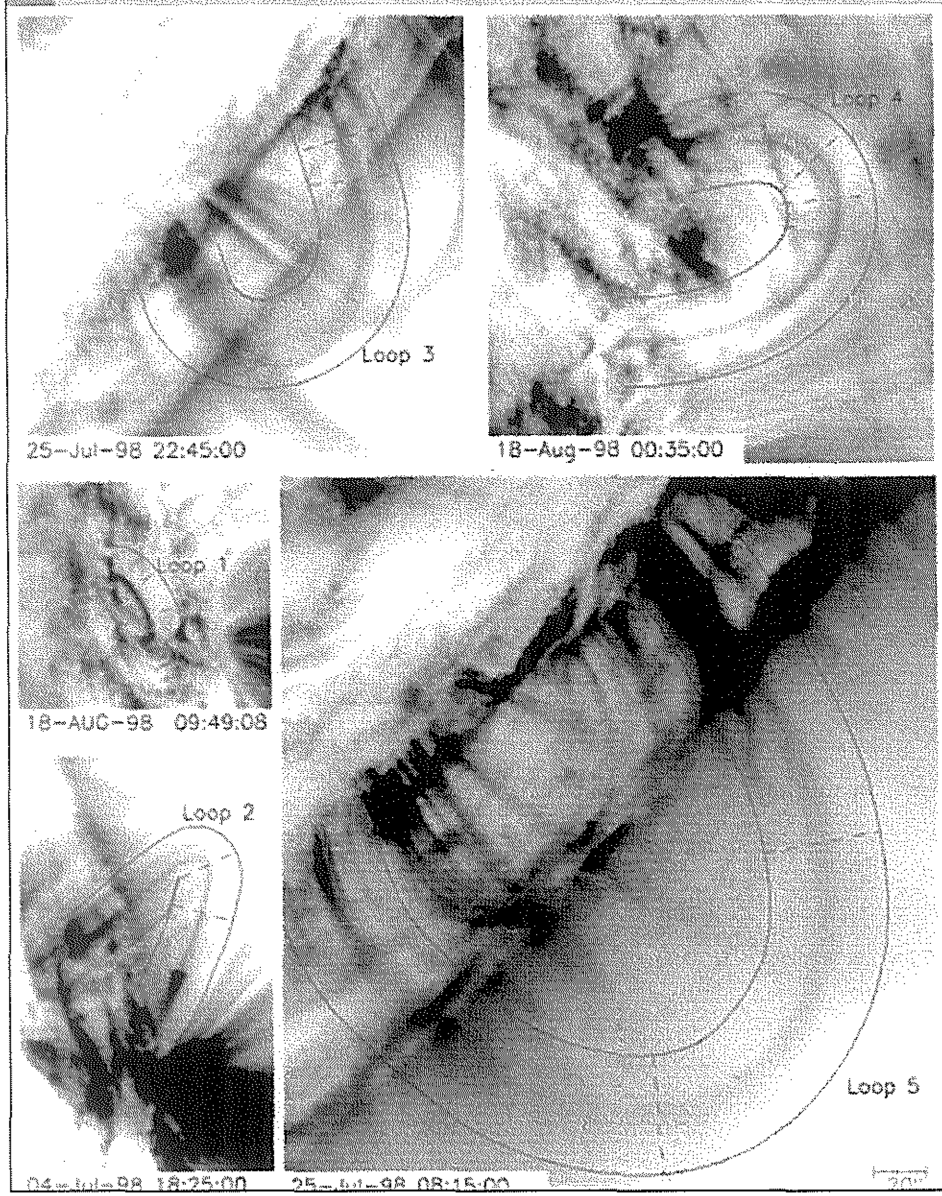
Model vs. Observables

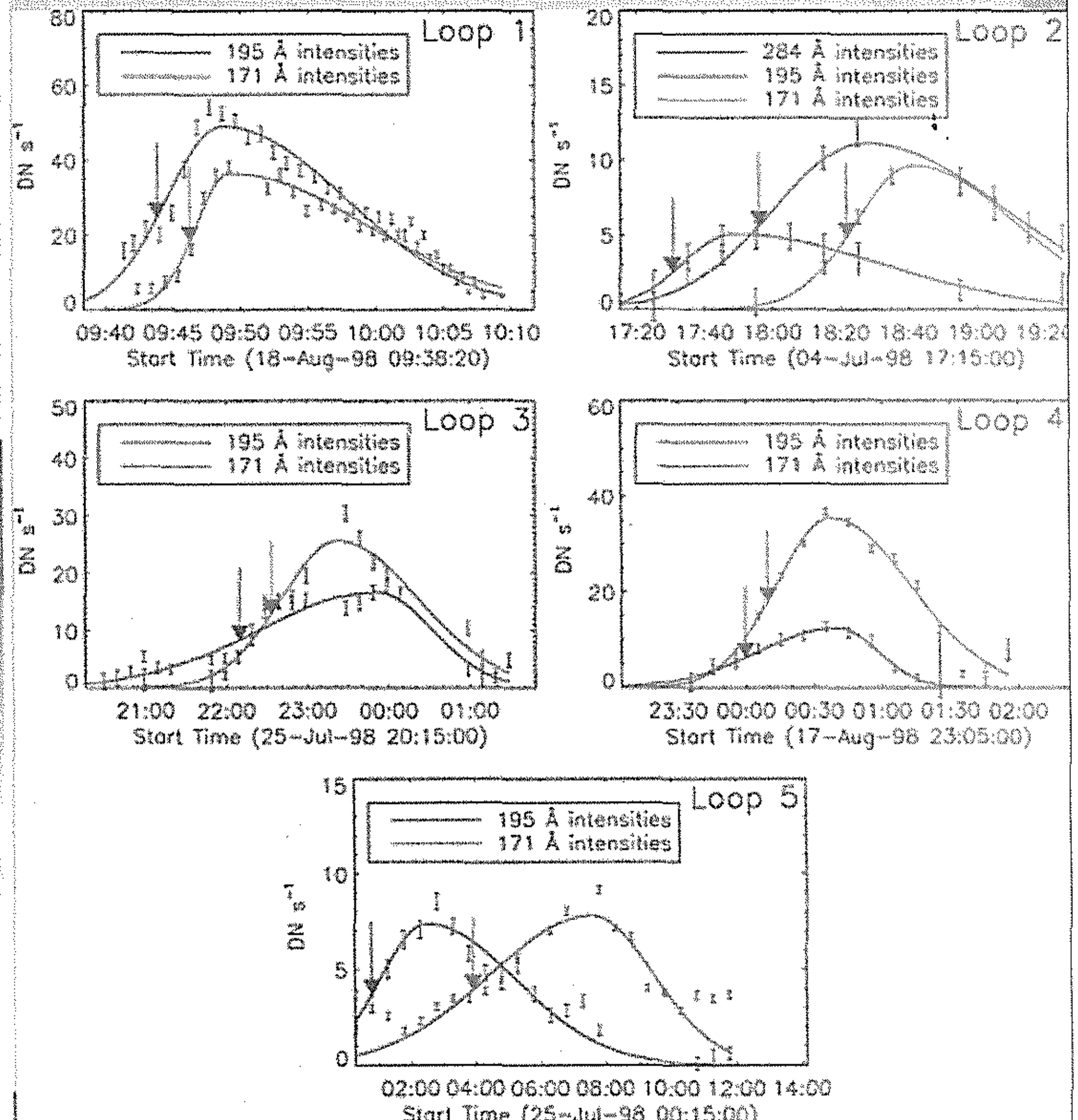
	Steady, Uniform	Short Nanoflare	Long Nanoflare
I(time)	steady	evolving, longer lifetimes than expected	quasi-steady
Density	within a factor of 3 of RTVS	higher at low temperatures, lower at high temperatures	higher at low temperatures, lower at high temperatures
Bulk Flows	~ 0 or siphon flows	blue shifts at high temperatures, red shifts at low temperatures	~0
NT Velocity	none expected	slight non-thermal broadening	significant non-thermal broadening
DEM at apex	Any DEM possible, should agree with footpoint pressures	Narrow and evolving	steady and broad with specific relationship between hot and cold

EUV Loops Evolve

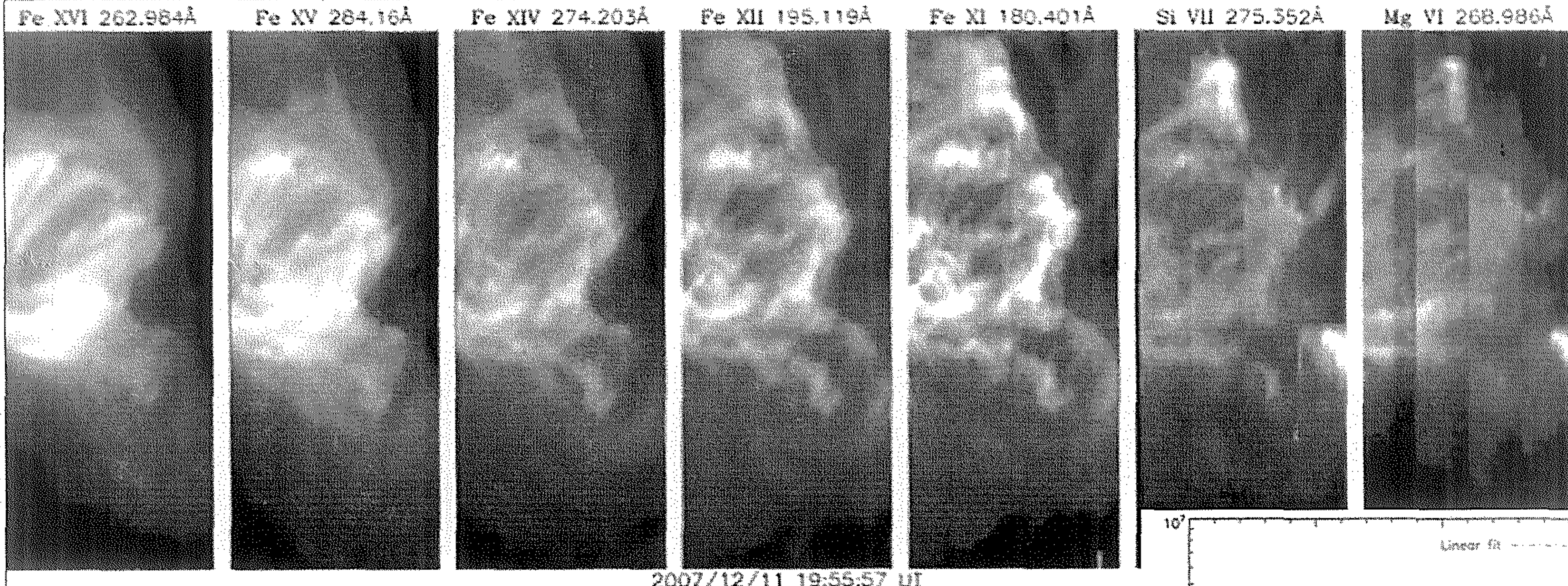


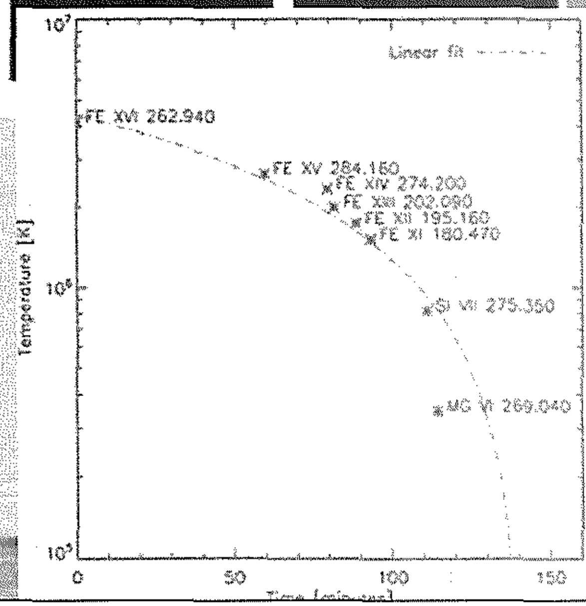
EUV Loops Evolve





EUV Loops Cool

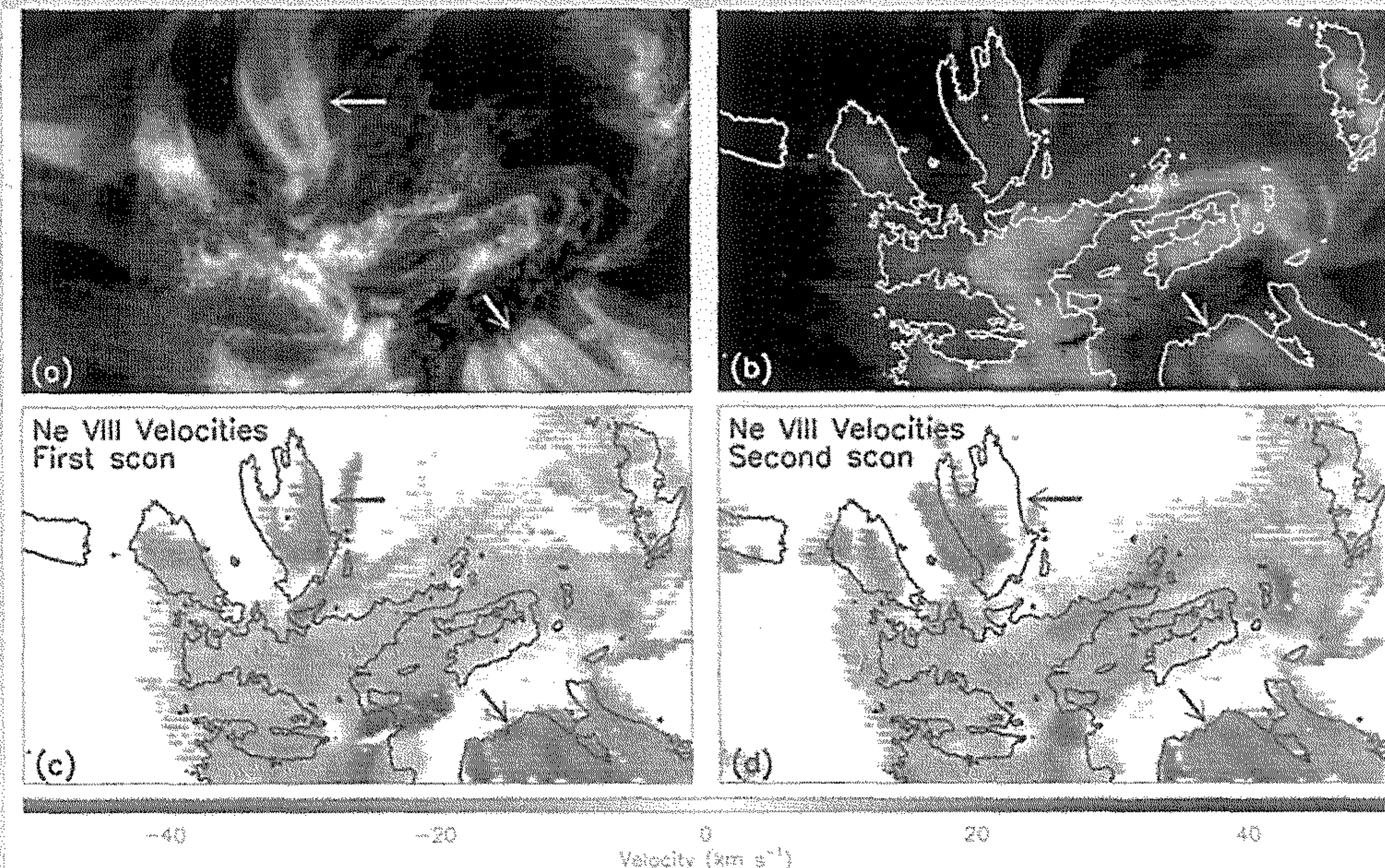




Ugarte-Urra et al., ApJ, 2009

Monday, June 27, 2011

EUV Loops Drain



Winebarger et al., ApJ, 2002.

Model vs. Observables

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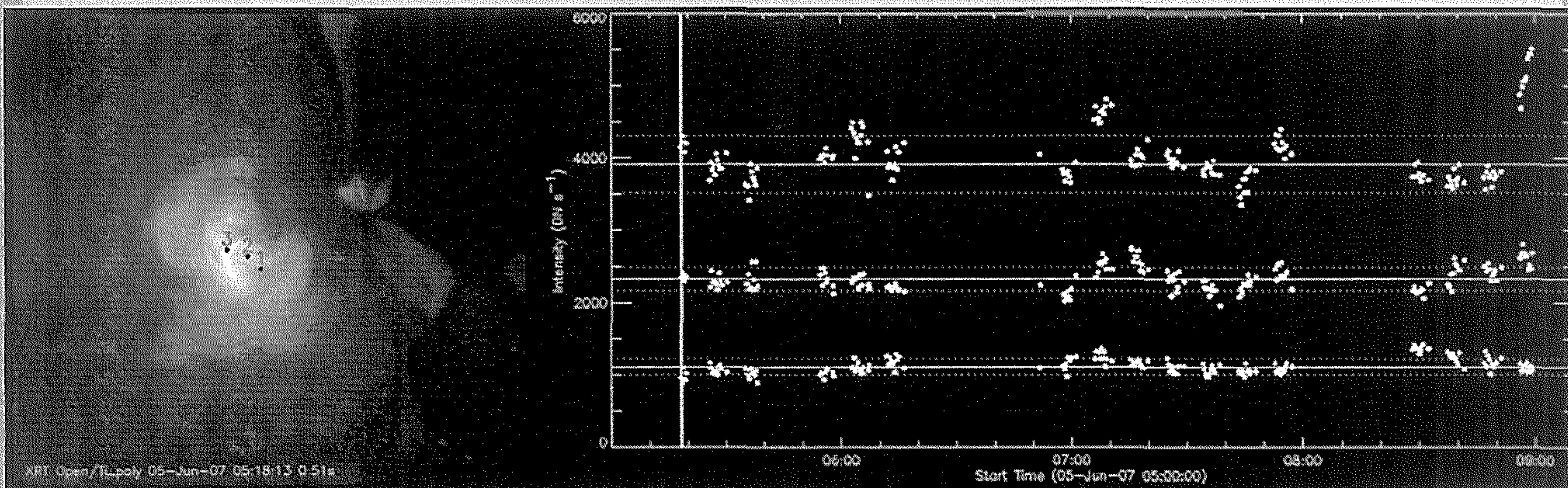
EUV Loops

- *Appear to have good agreement with "short nanoflare storms"*
- *YET! There are still some disagreements! The loops cool too slowly from X-ray to EUV images.*
- *There could be additional heating models that also match observations (see Roberto's talk).*
- *What about other structures? Both analysis and models for other structures are controversial.*

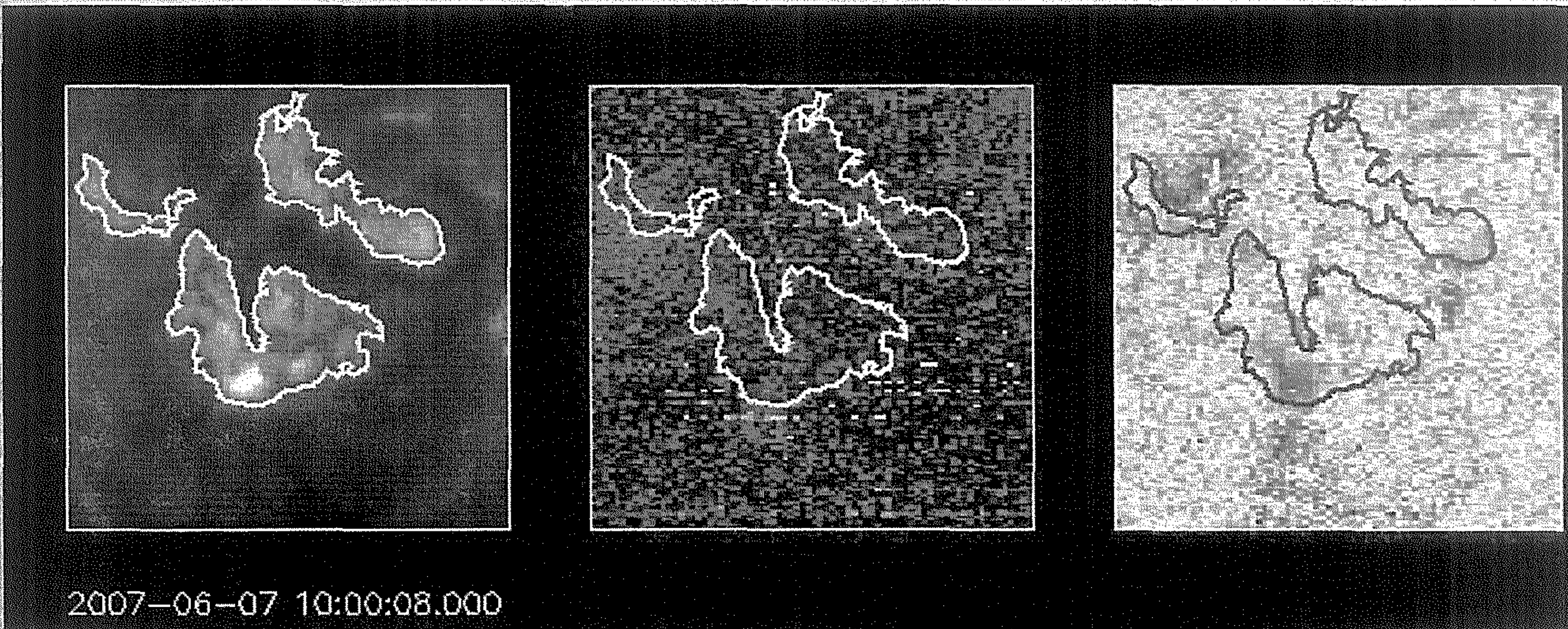
Summary

- *Use consistent descriptors of heating models*
- *Generate a consistent set of observables*
- *Confront the data!*
- *Drive new observations!*

Moss/Core Loops are



Moss/Core Loops



Moss/Core Loops don't have a strong velocity signature.

Brooks, et al. ApJ, 2009

Data Summary

EUV Loops:

- *Evolve*
- *Cool*
- *Drain*

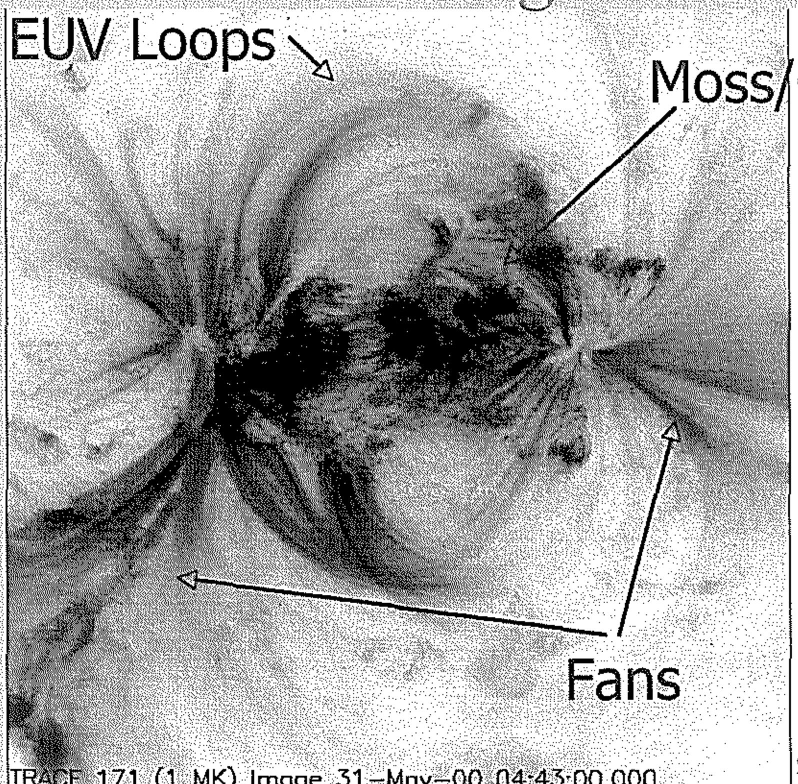
Moss/Core Loops :

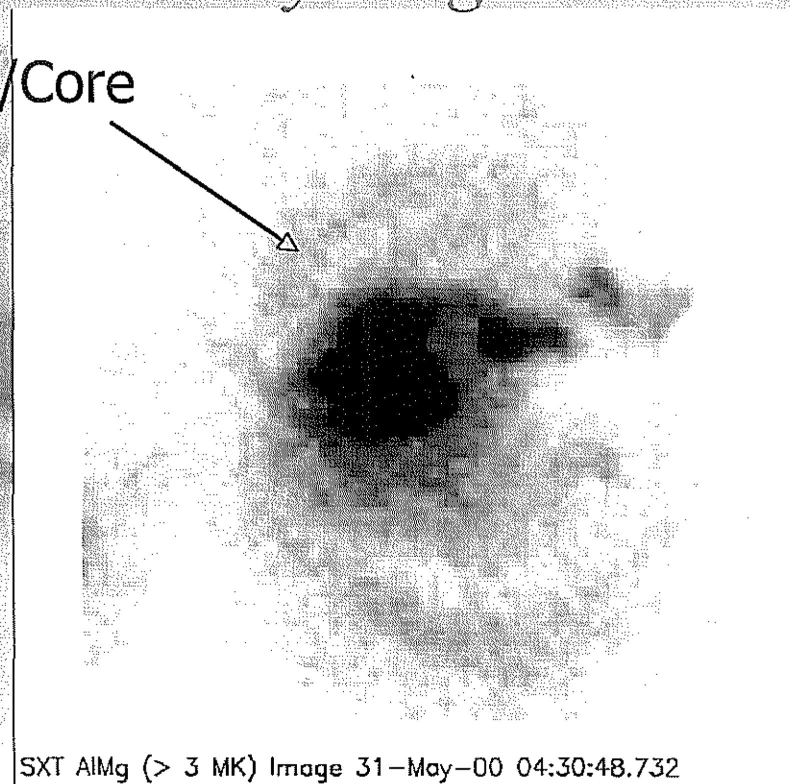
- *Steady*
- *No strong velocity signature*

Three Types of Structures

~1 MK
EUV image

>3 MK
X-ray image





Model Variables

	Steady	IHMS "short storm"	Nanoflare "long storm"
n	1	~10	>> 1000
τ_{reheat}	$<< \tau_{cool}$	∞	$>> \tau_{cool}$
τ_{delay}	N/A	$< \tau_{cool}$	$< \tau_{cool}$
Reference	Rosner, Tucker, and Vaiana, ApJ, 1978.	Warren, Winebarger, & Hamilton, ApJ, 2002.	Cargill & Klimchuk, ApJ, 2004.