Evidence of coronal nanoflares in active region moss high cadence observations

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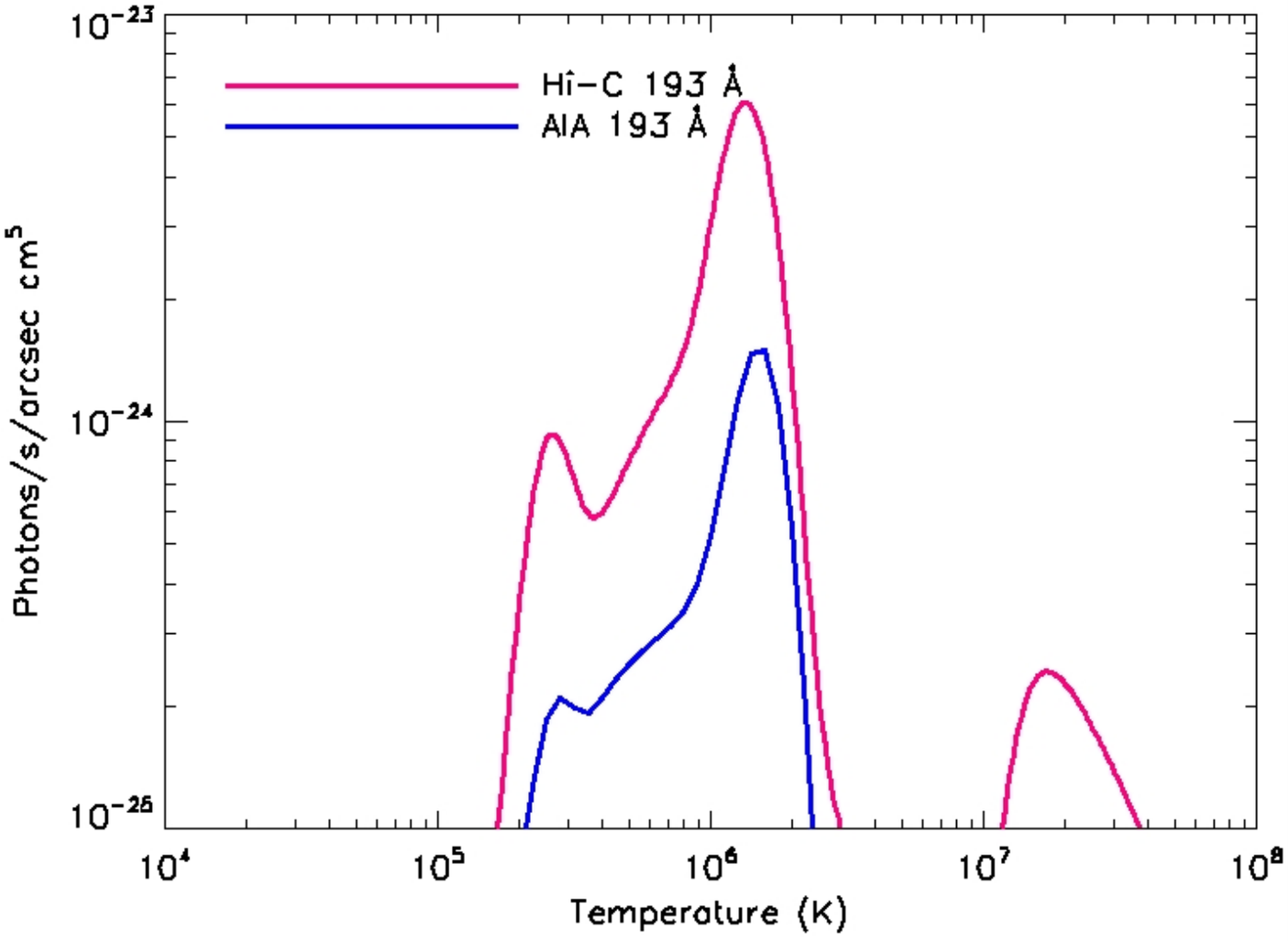
Hinode 7 meeting, Nov 13 2013

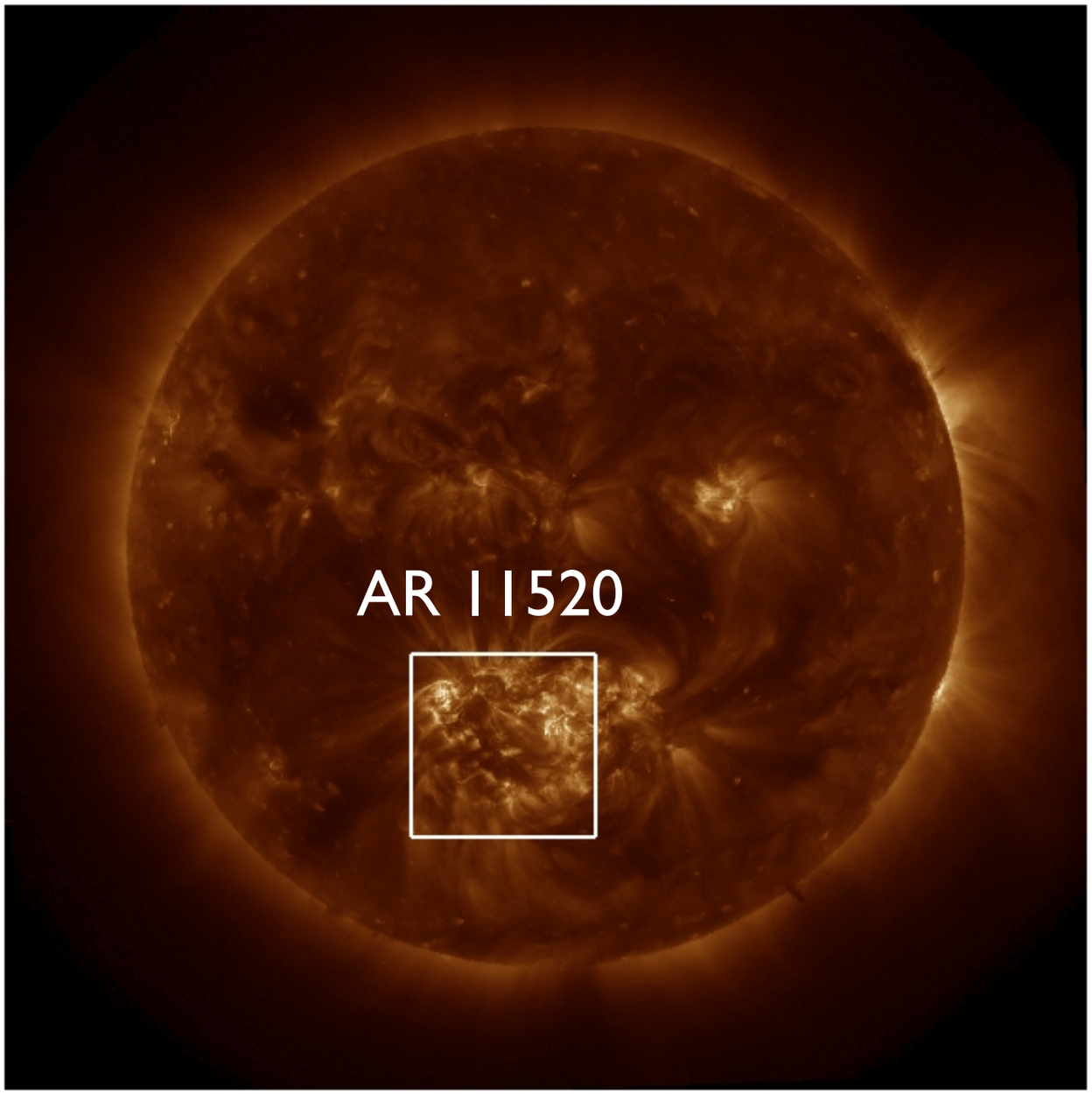
The Hi-C instrument

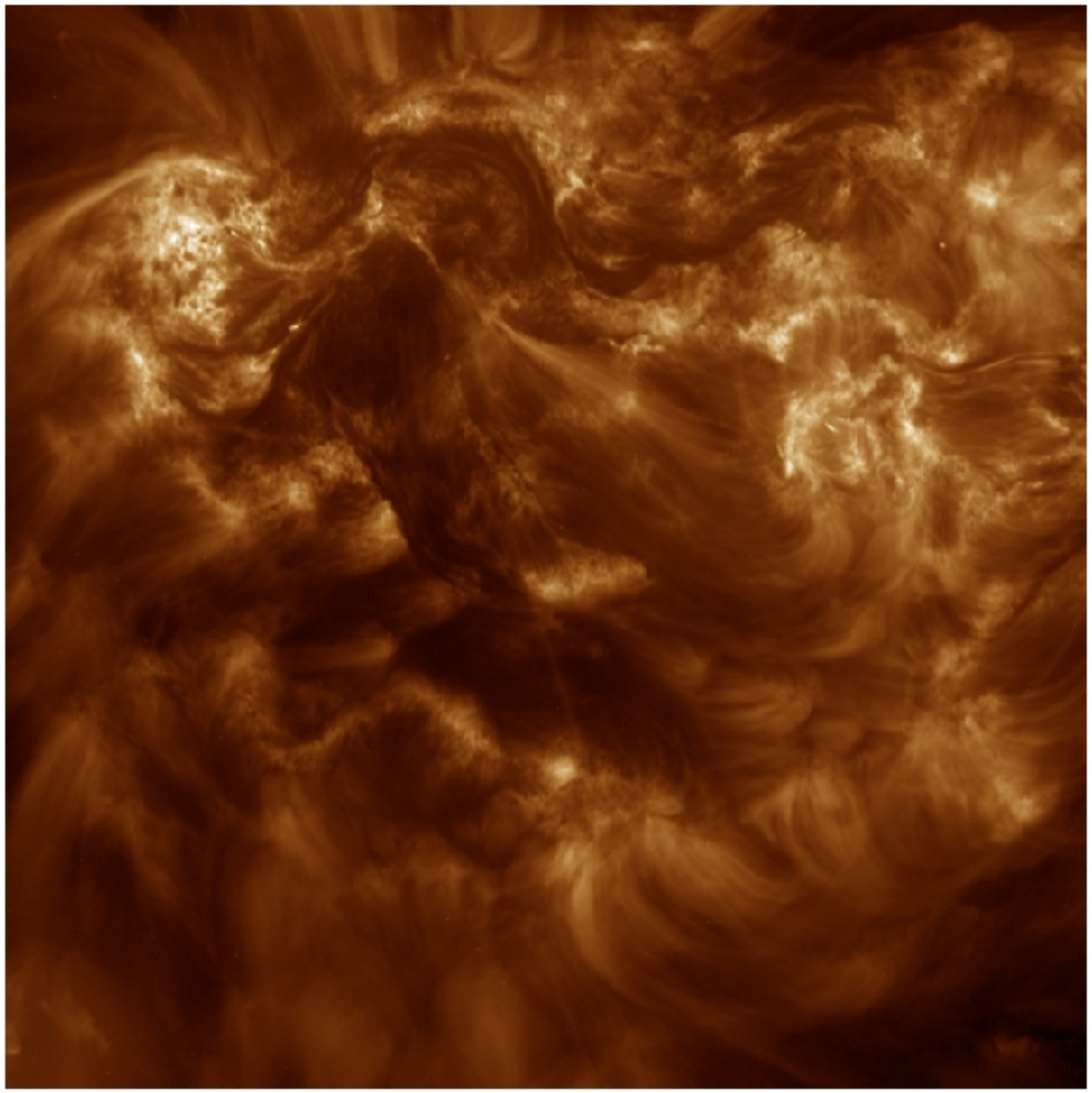
High-resolution Coronal Imager -- Hi-C (Cirtain et al. 2013)

- 6.8‘x6.8’ fov
- 5.5s cadence
- 0.1”/pixel (~0.3” resolution)
- 193Å narrow passband
- Hi-C collected data for 345s (small pointing shift during flight)
- full frame 4k x 4k data: 30 full resolution images, 2s exposure
- partial frame 1k x 1k data: 86 full resolution images, 1.4s cadence



The Hi-C target and field of view





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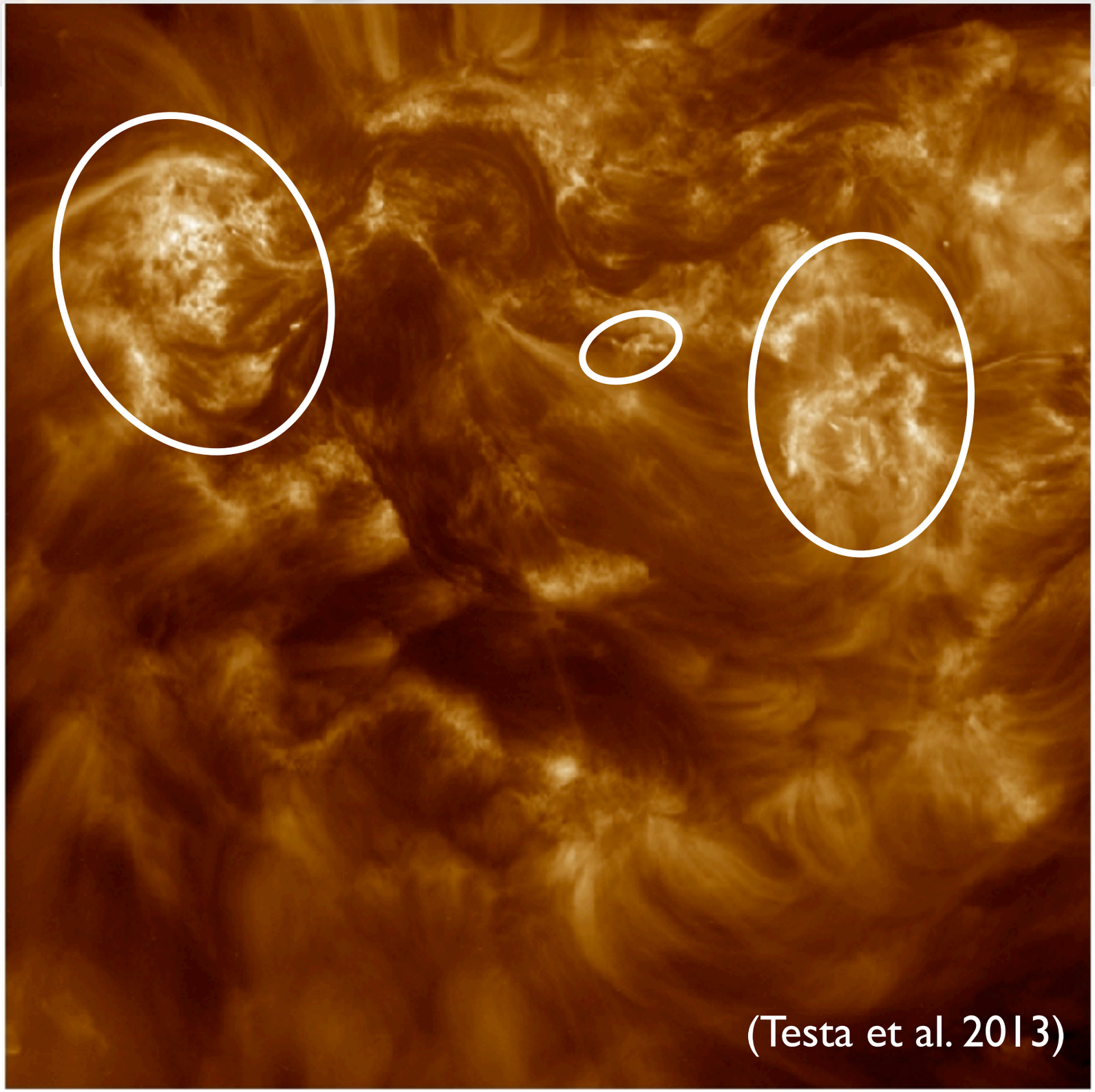
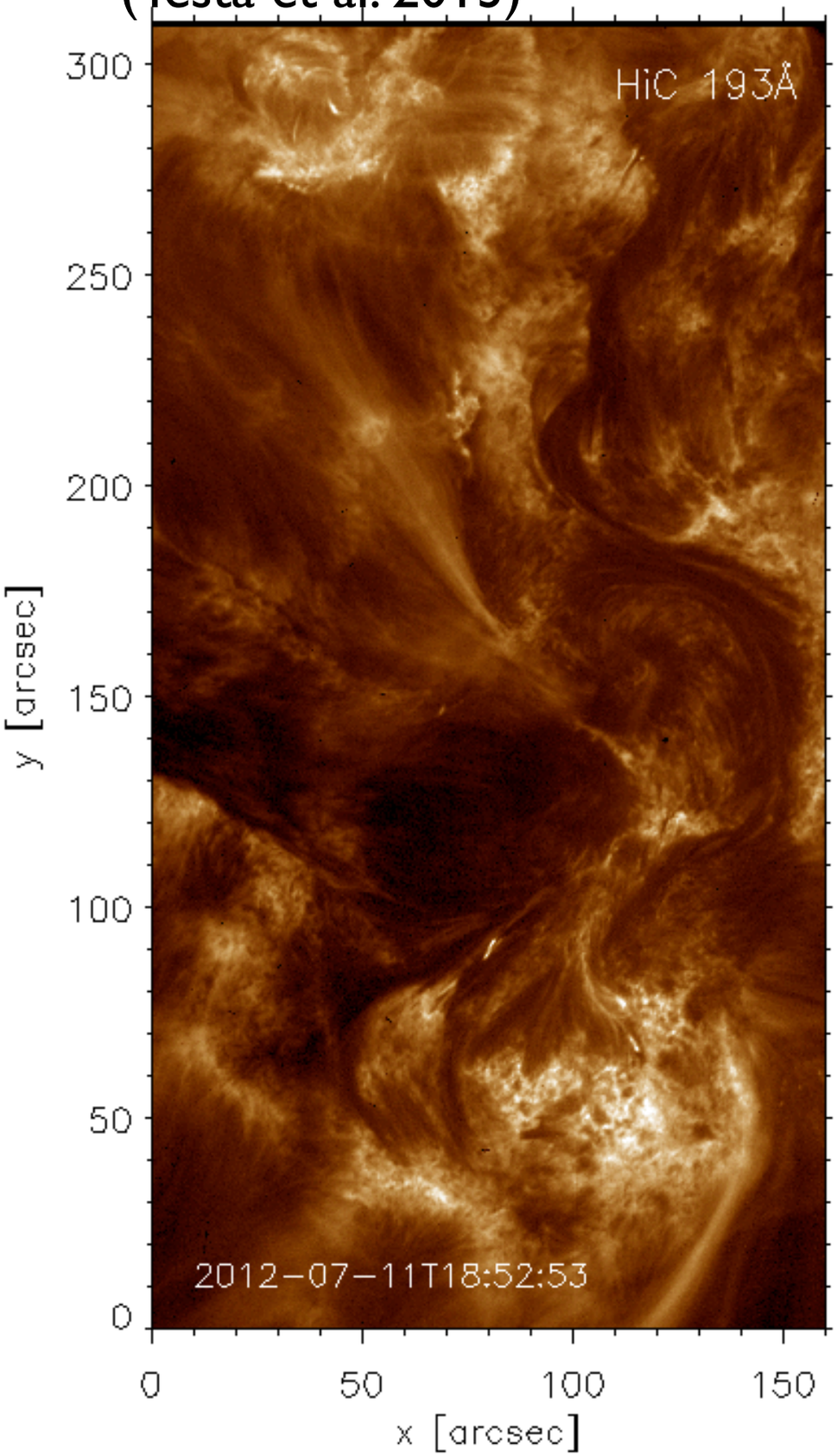
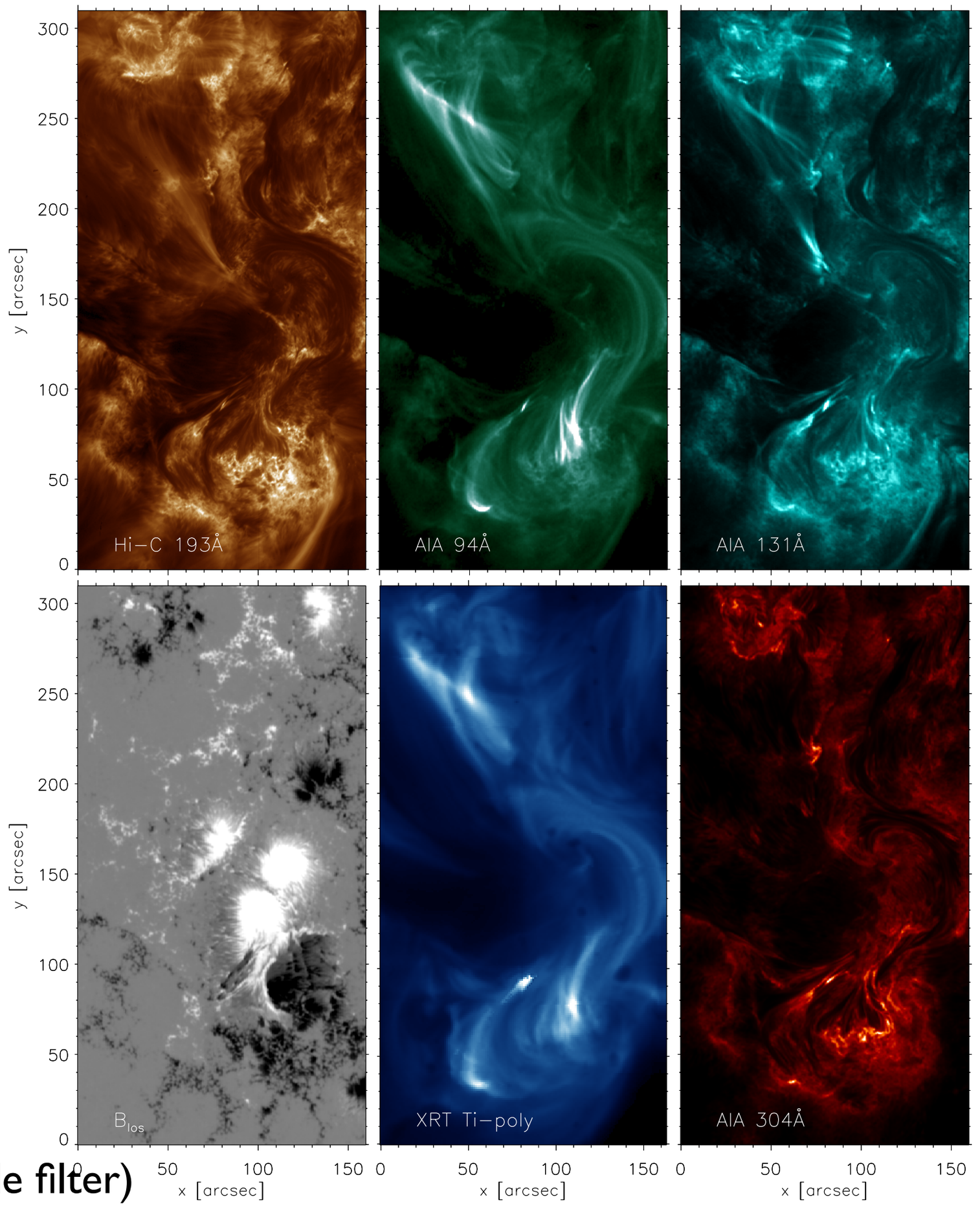
Moss variability as observed by Hi-C



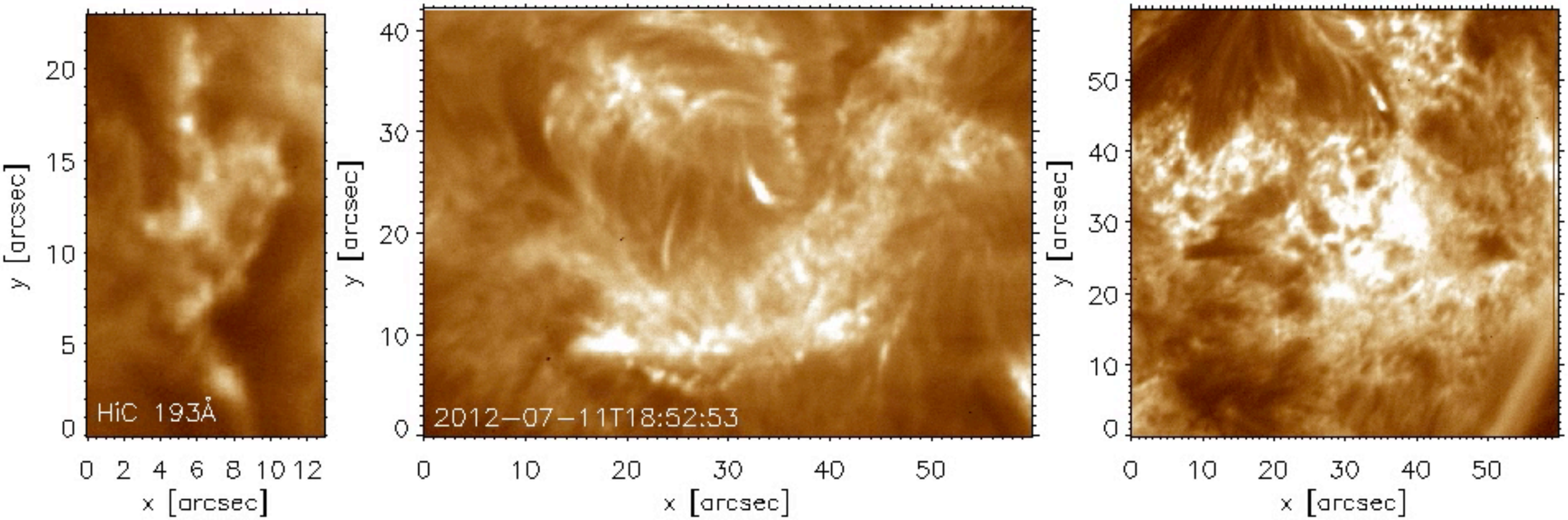
(Testa et al. 2013)





- AIA data (0.6"/pix, 12s cadence)
- XRT data (1"/pix, 15s cadence, single filter)

Temporal variability of moss



- Moss, i.e., TR emission at the footpoints of hot loops (≳3MK) is generally slowly variable, on scales of ~ minutes (e.g., Antiochos et al. 2003, De Pontieu et al. 2003, Brooks et al. 2009)

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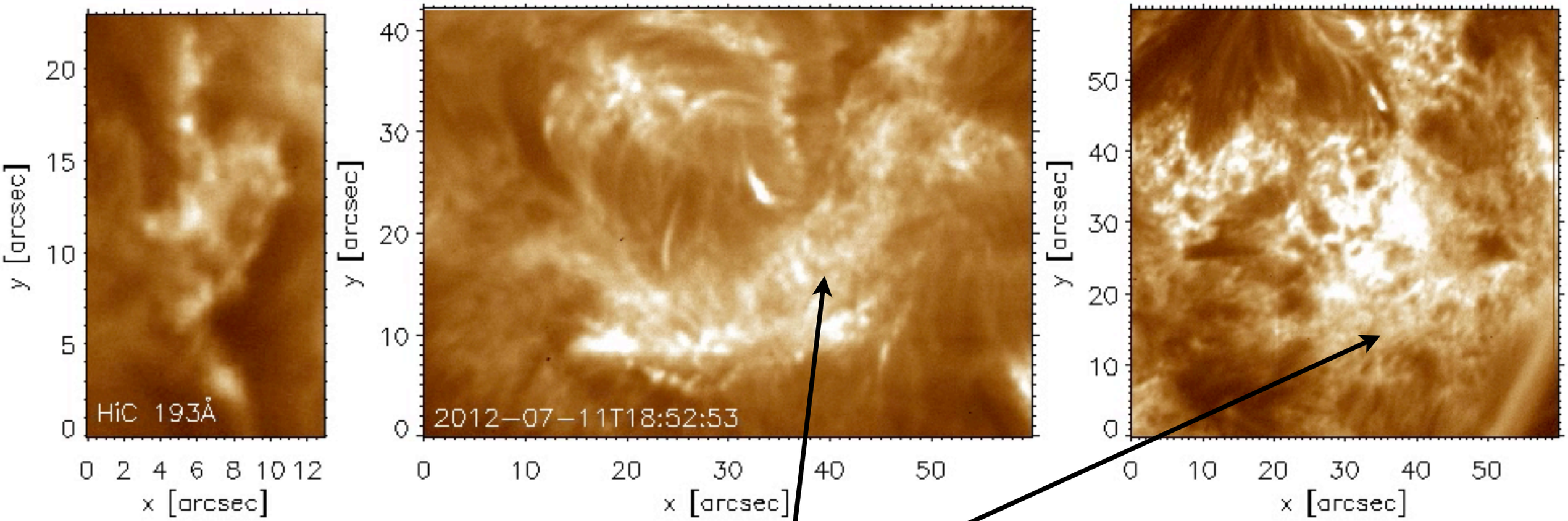

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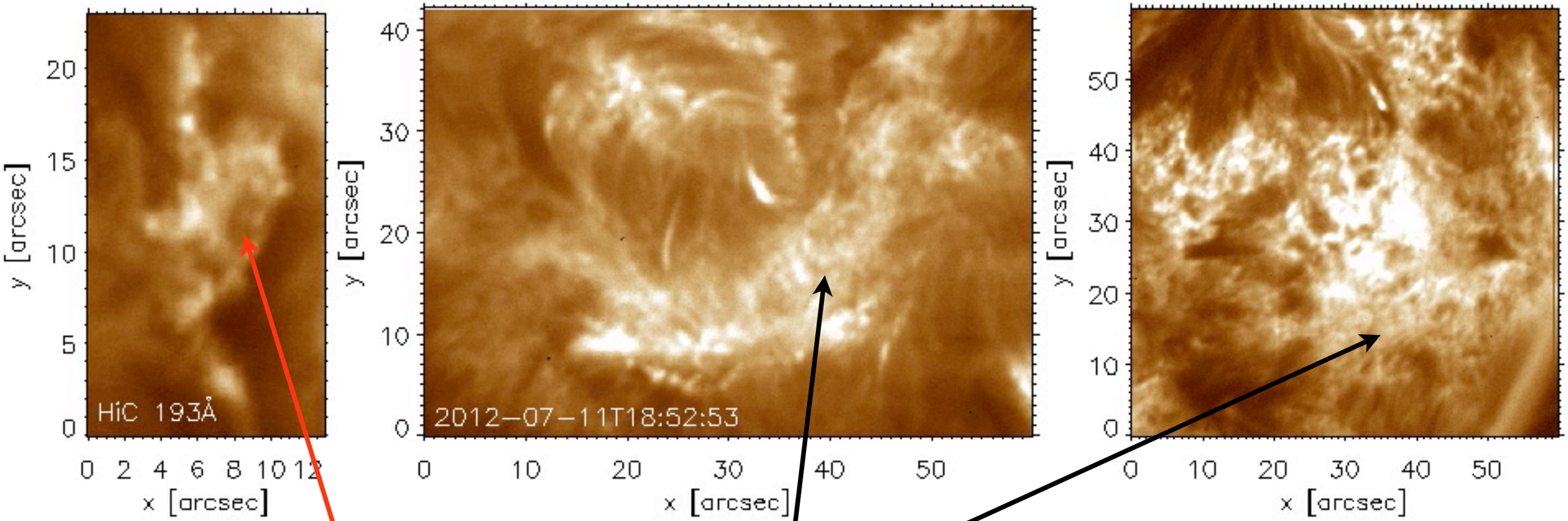

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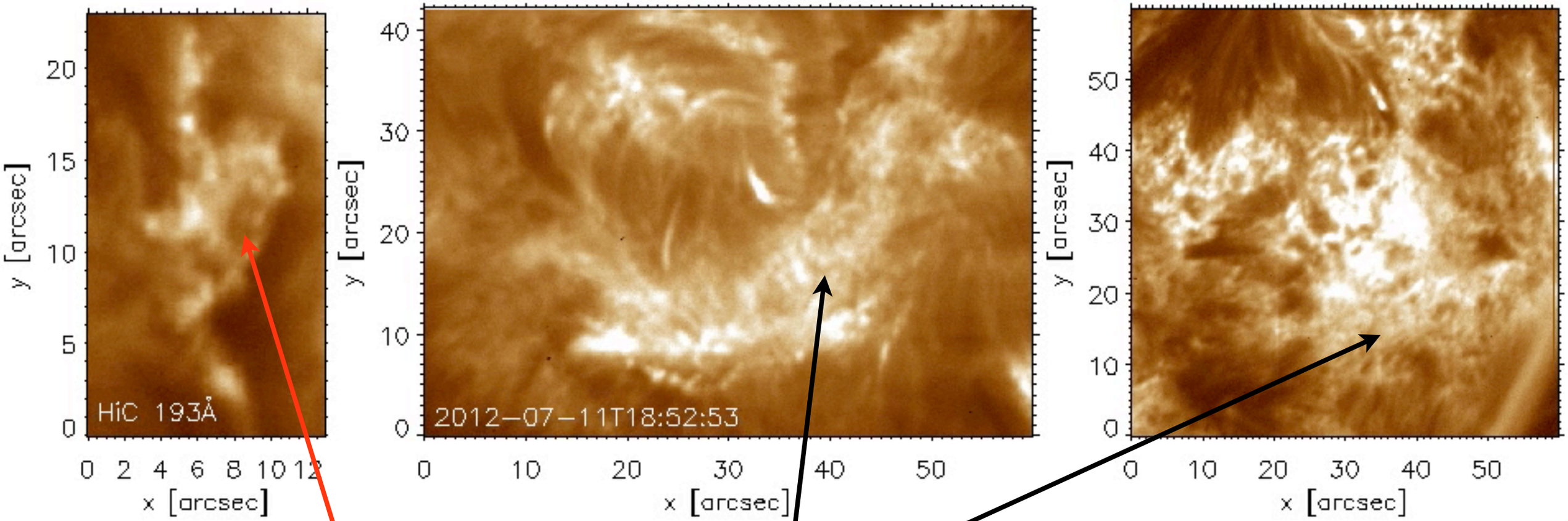

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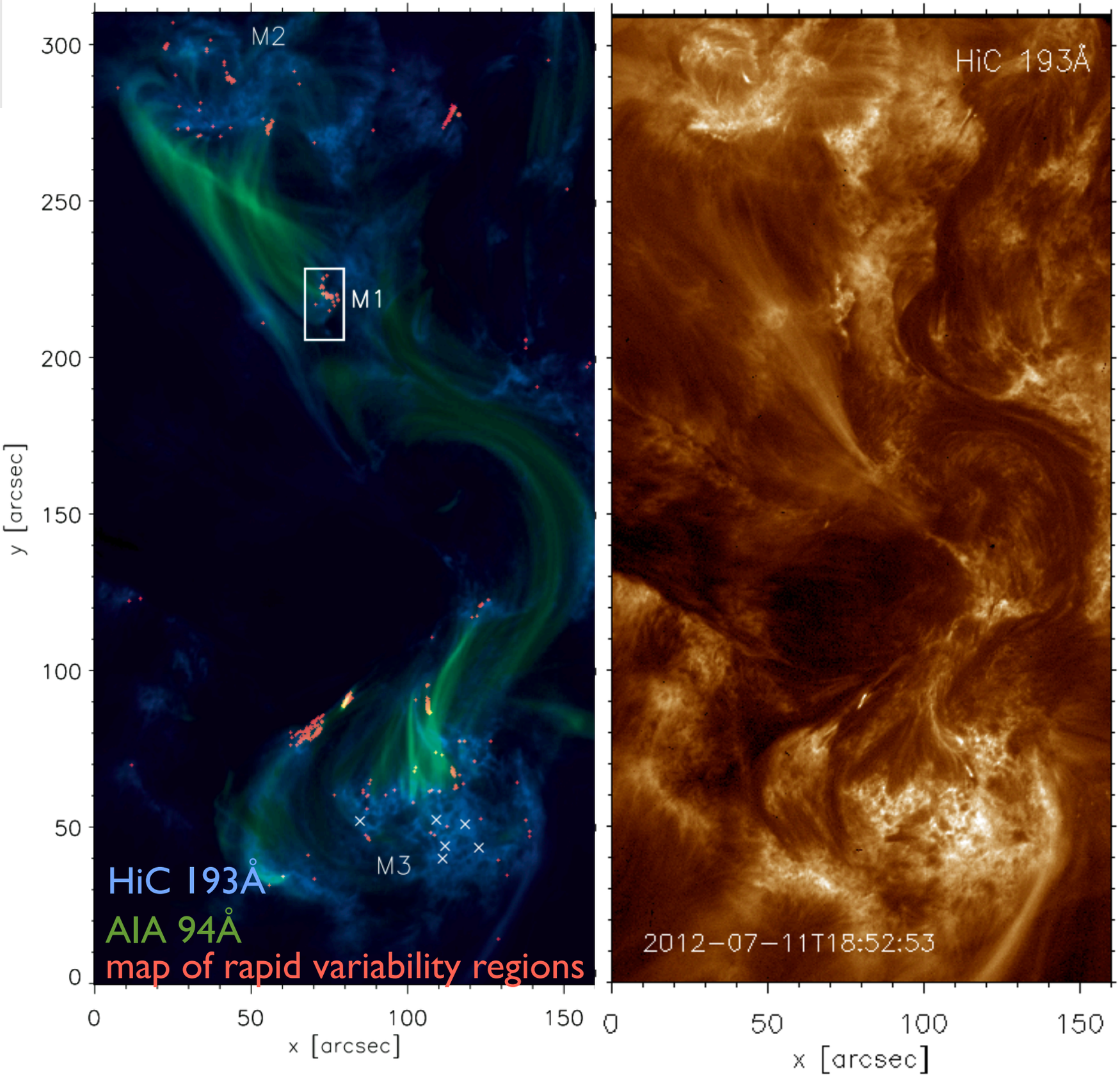
What makes this moss region special?

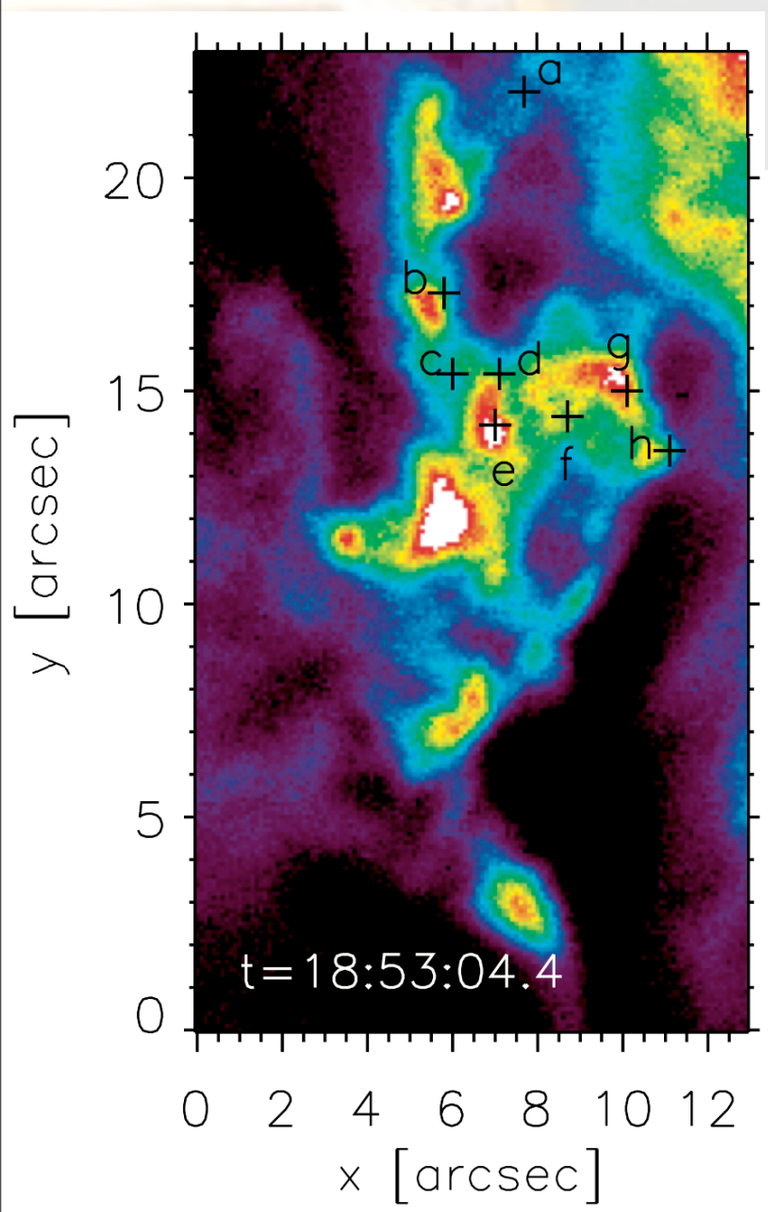
Rapidly variable moss

to highlight regions with rapid variability:

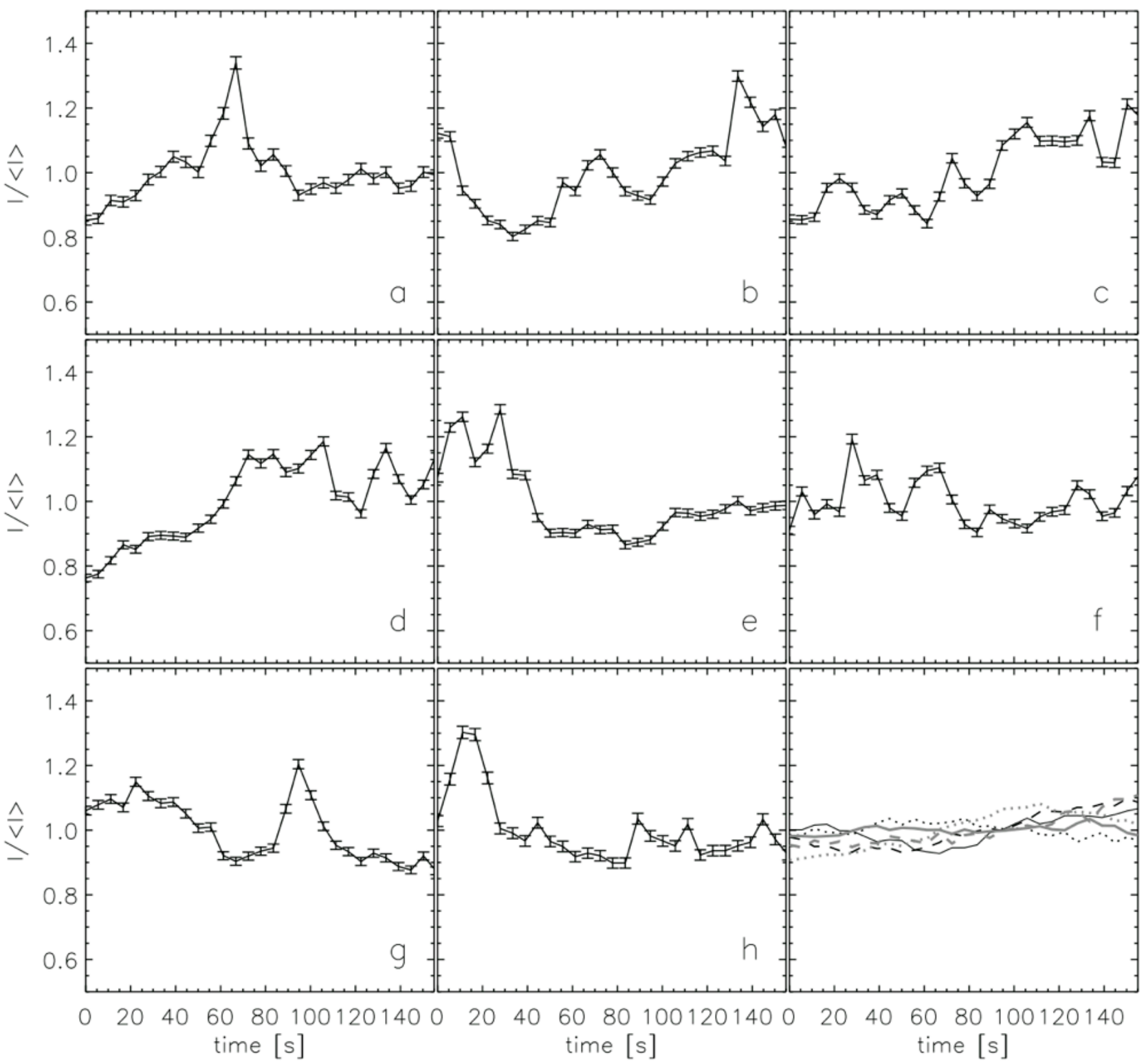
- lightcurves of running difference HiC images
- calculate the number of zero crossings -- we focus on short-lived brightenings, not on longer term trends



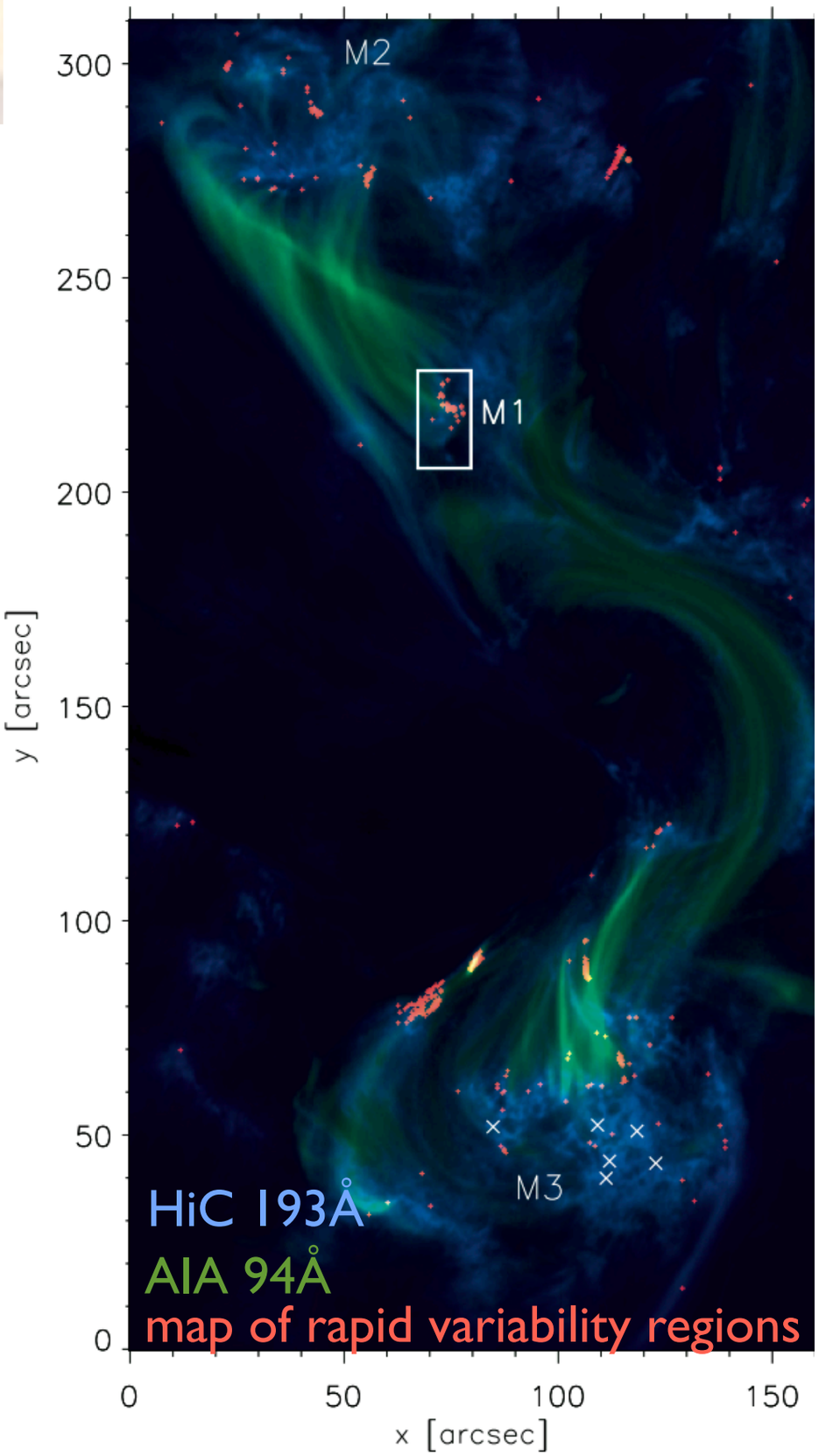
Rapidly variable moss: sample lightcurves

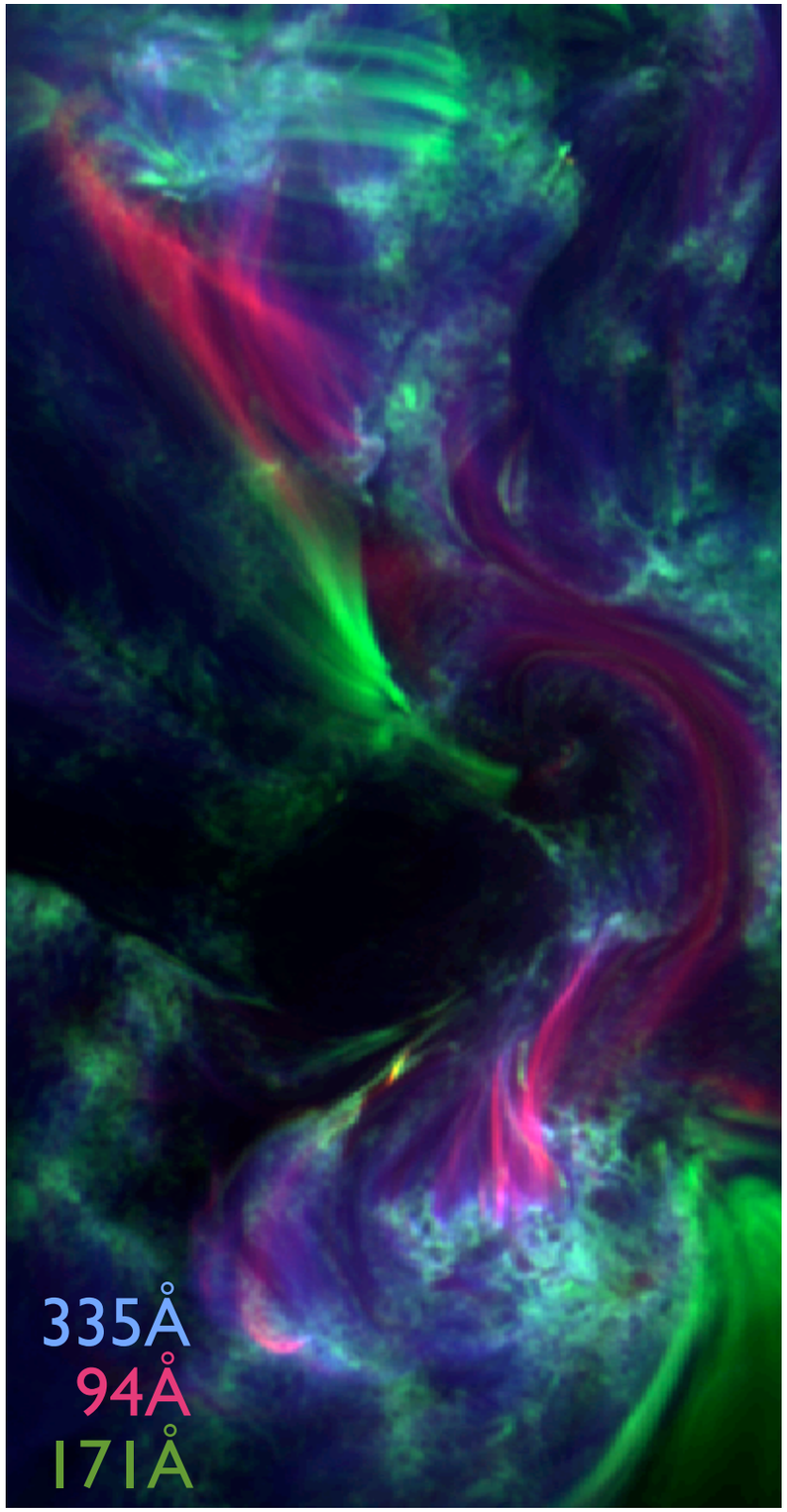


Hi-C lightcurves show rapid variability (events as short as ~15s) with increases of the order of 20-30%



Causes for moss rapid variability?





Rapid variability moss regions map the footpoints of bright hot loops

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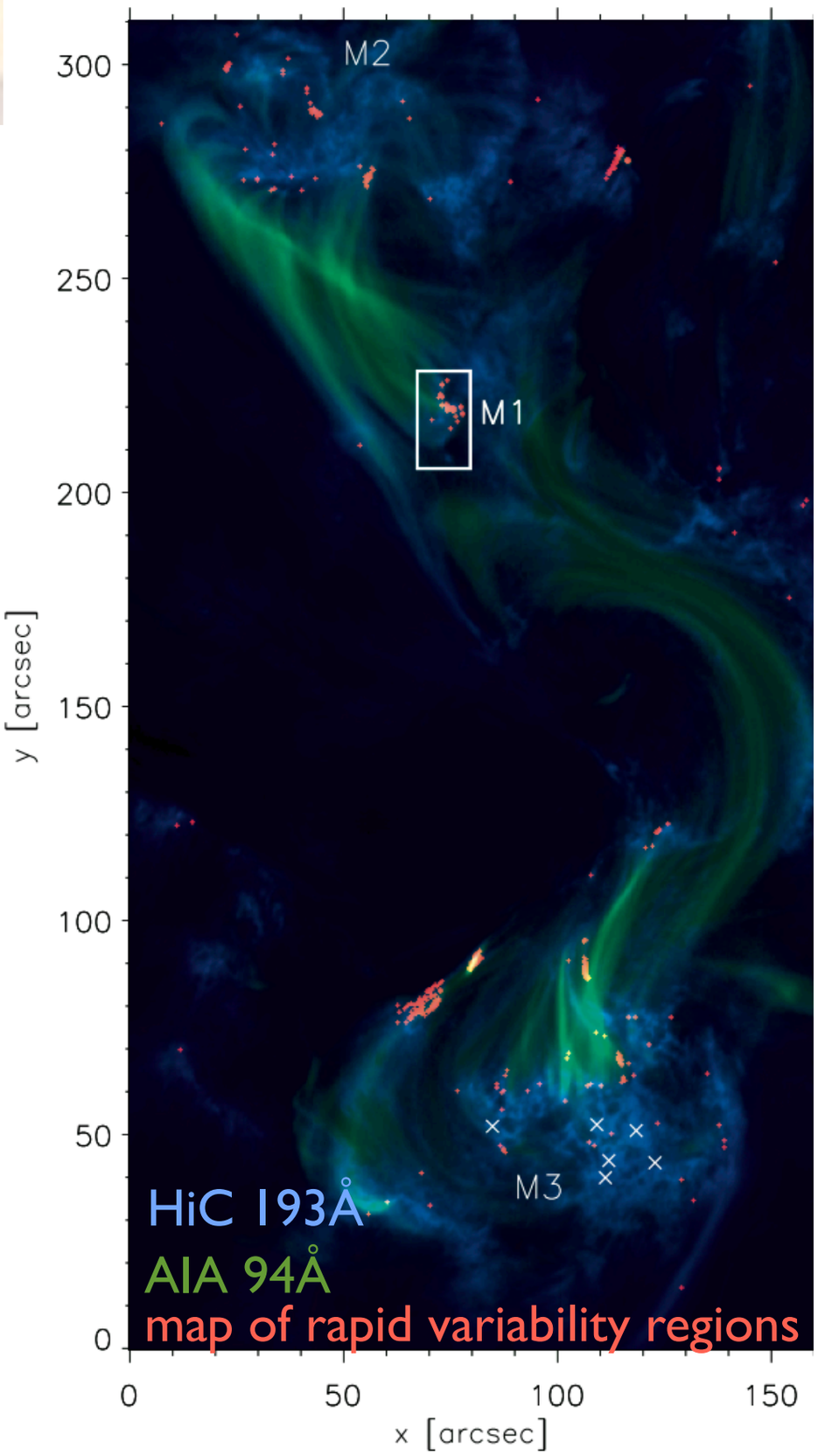

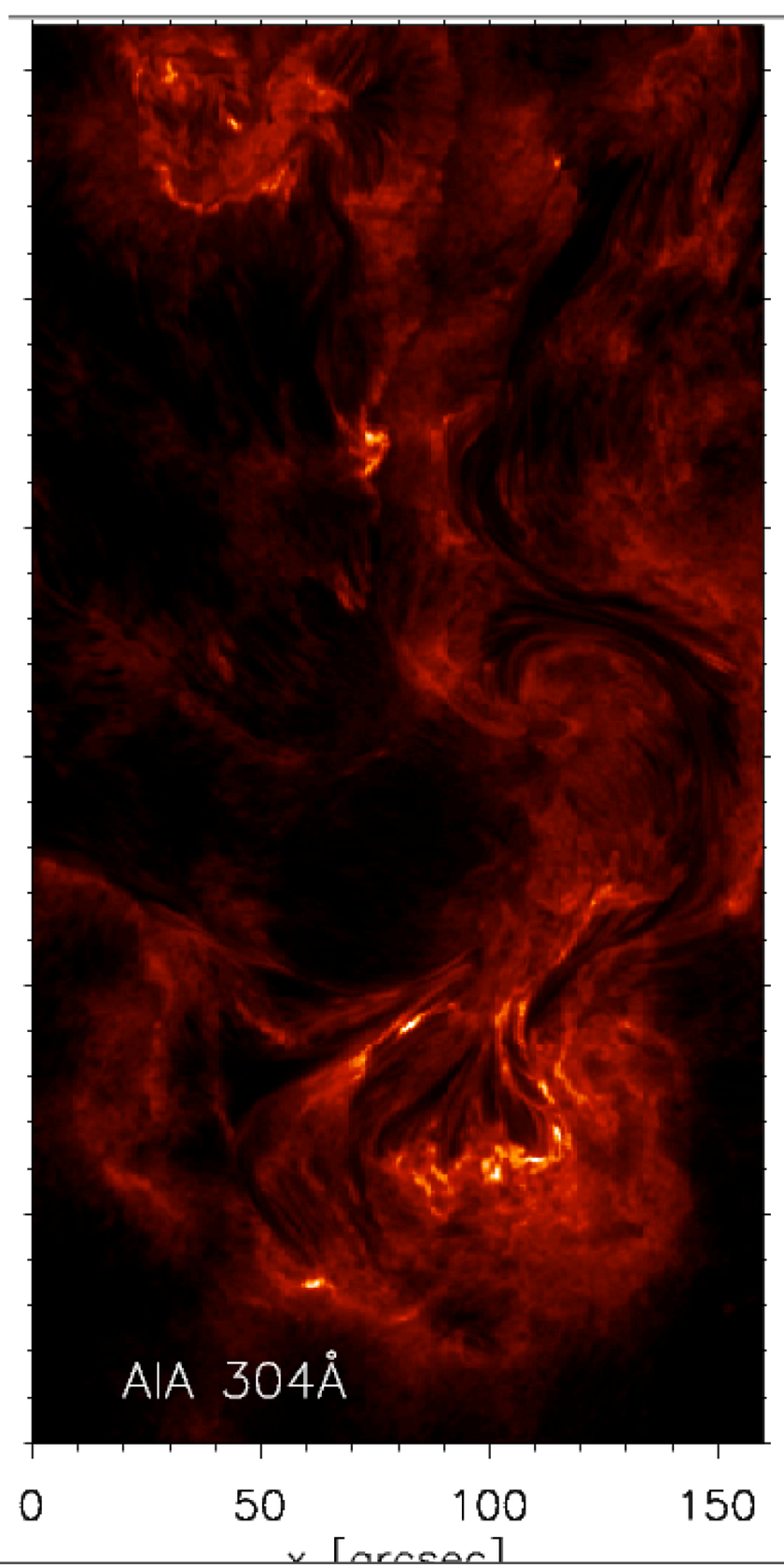

Rapid variability moss regions map the footpoints of bright hot loops, and also match well the brightest 304Å regions

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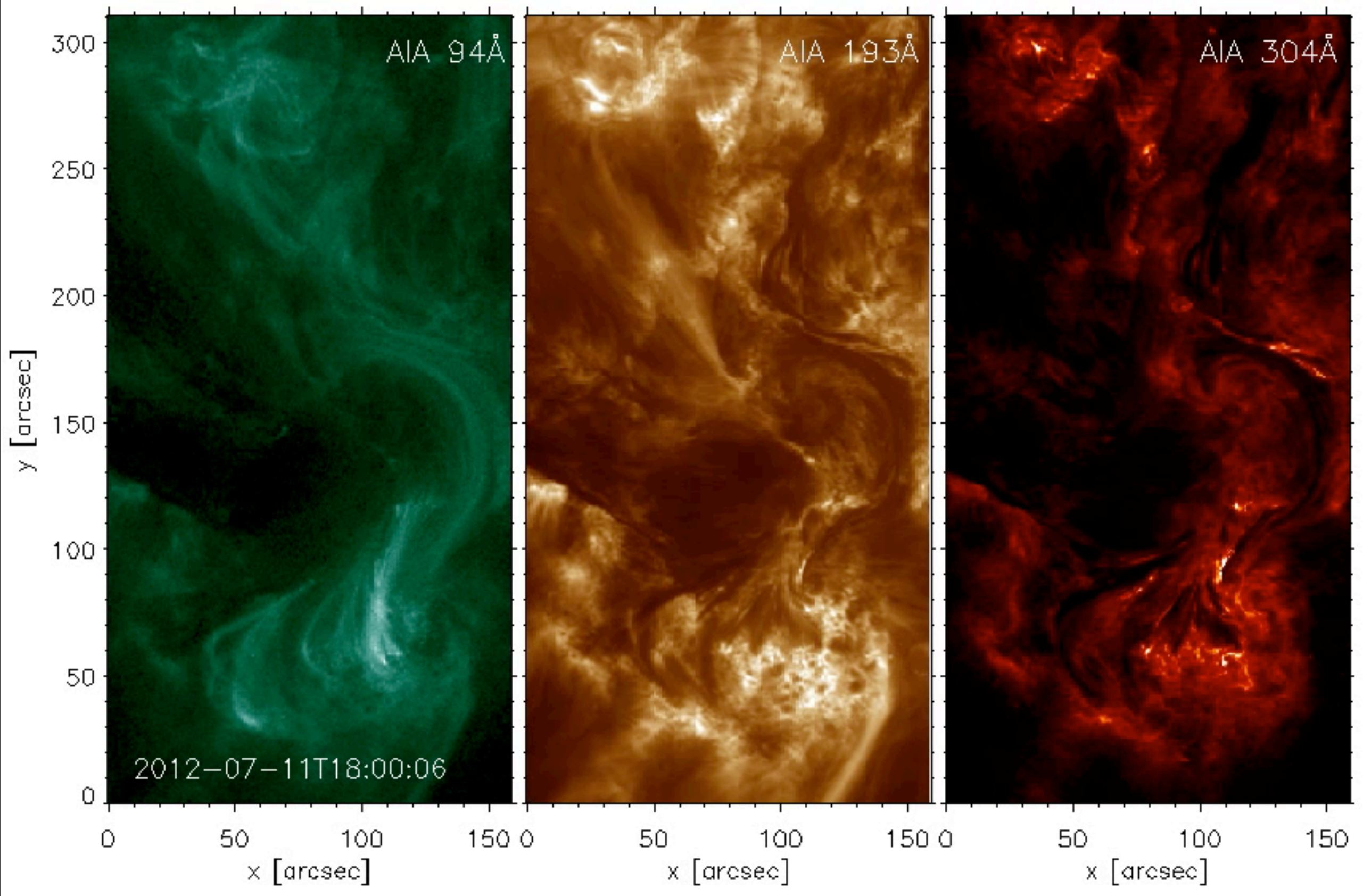

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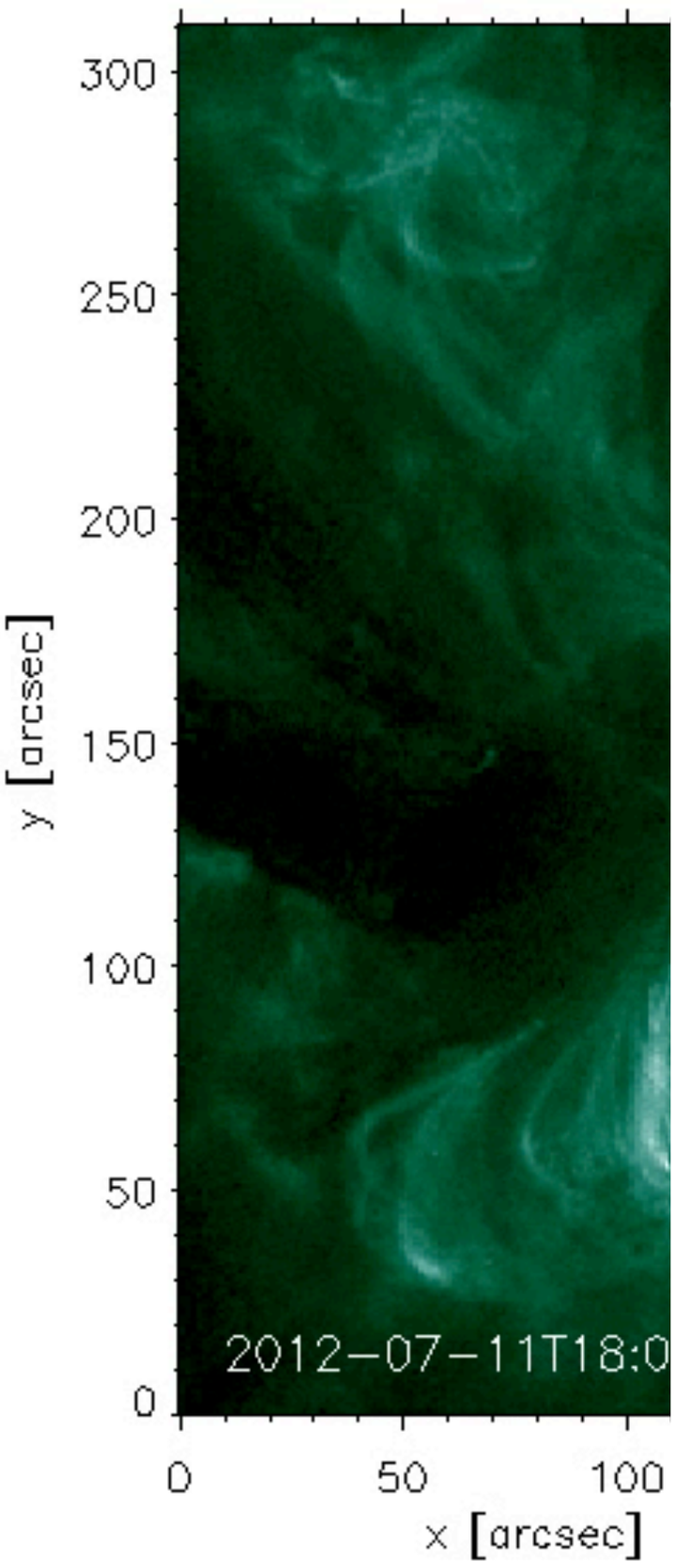

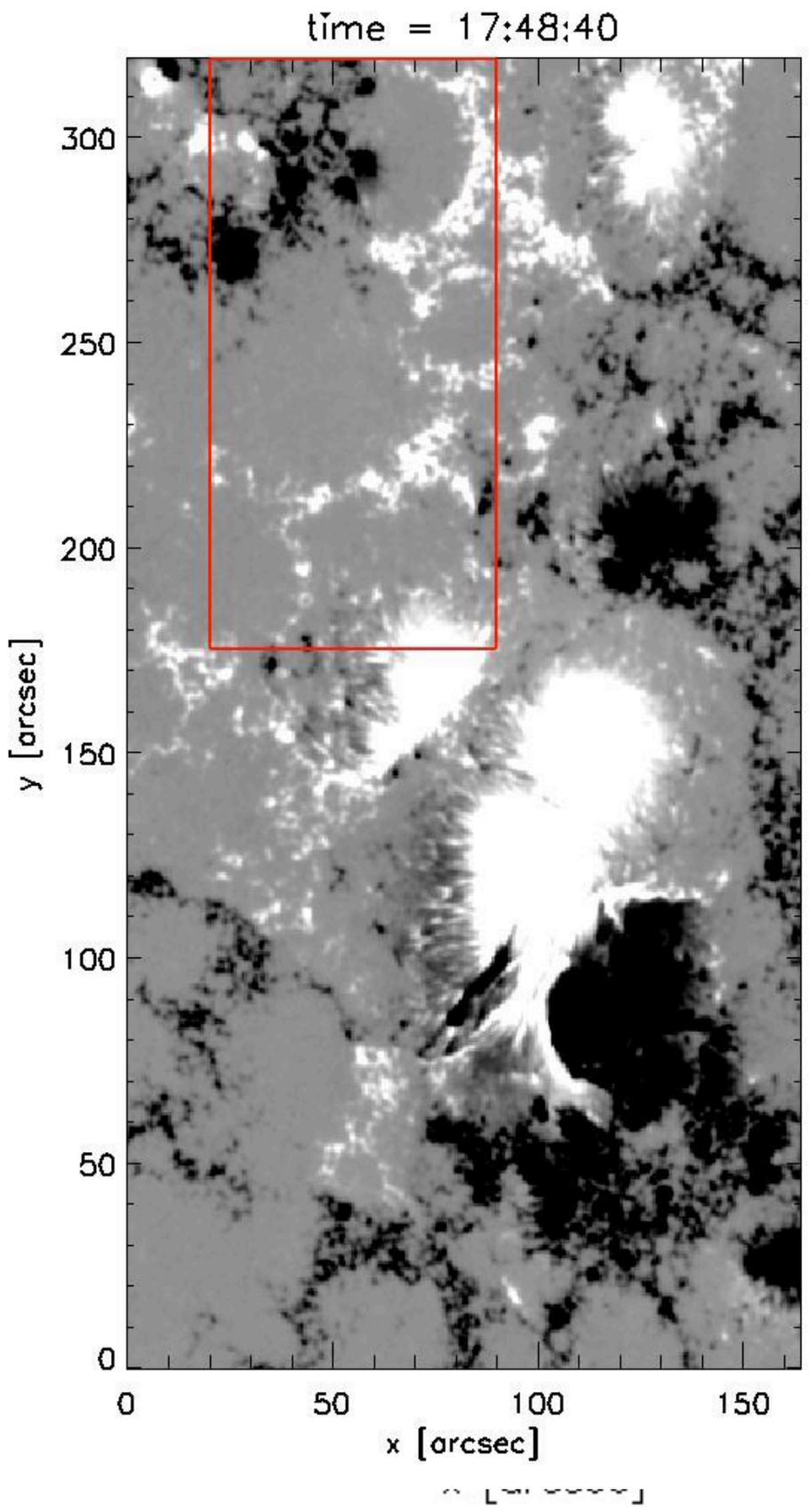

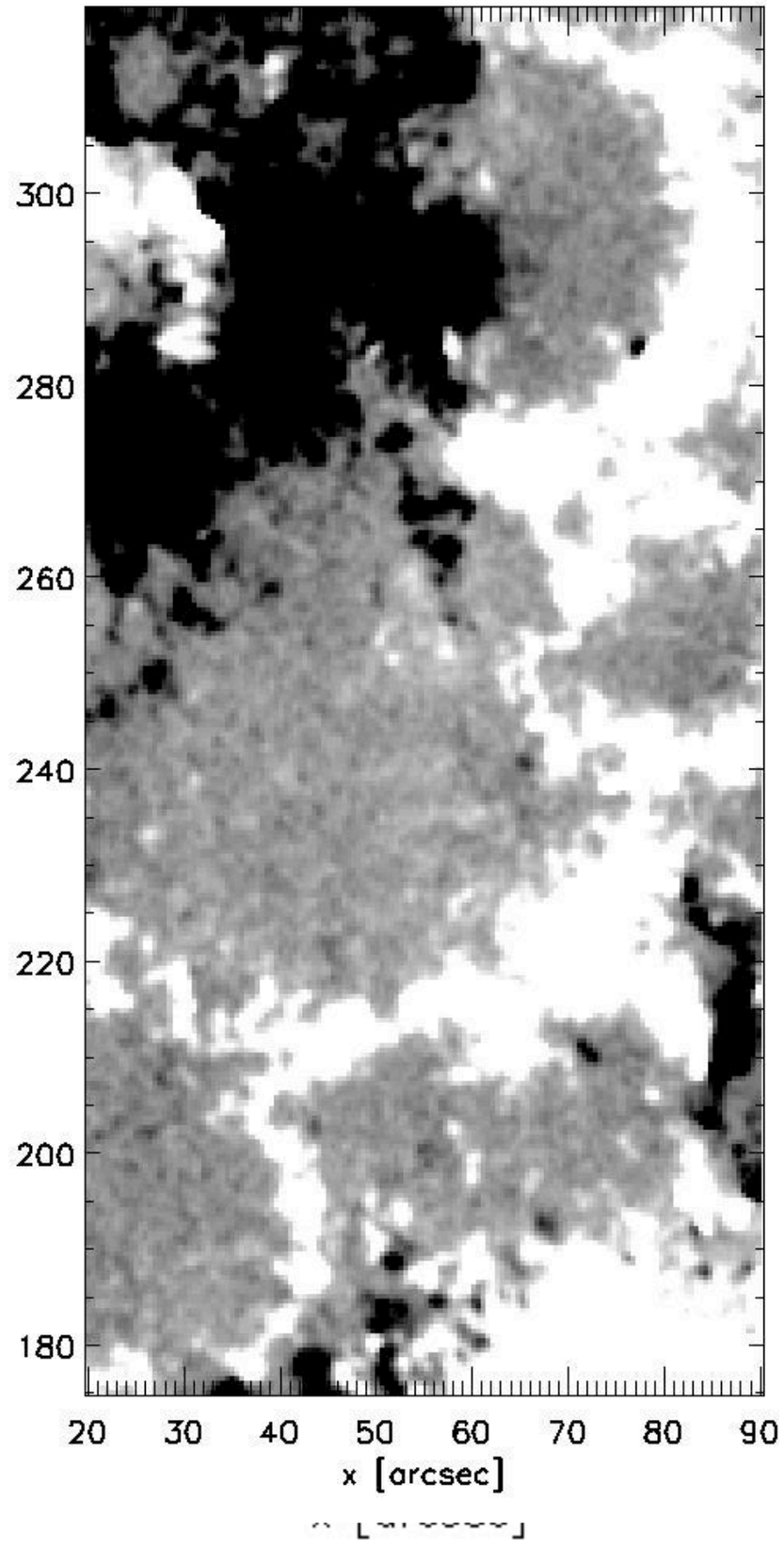

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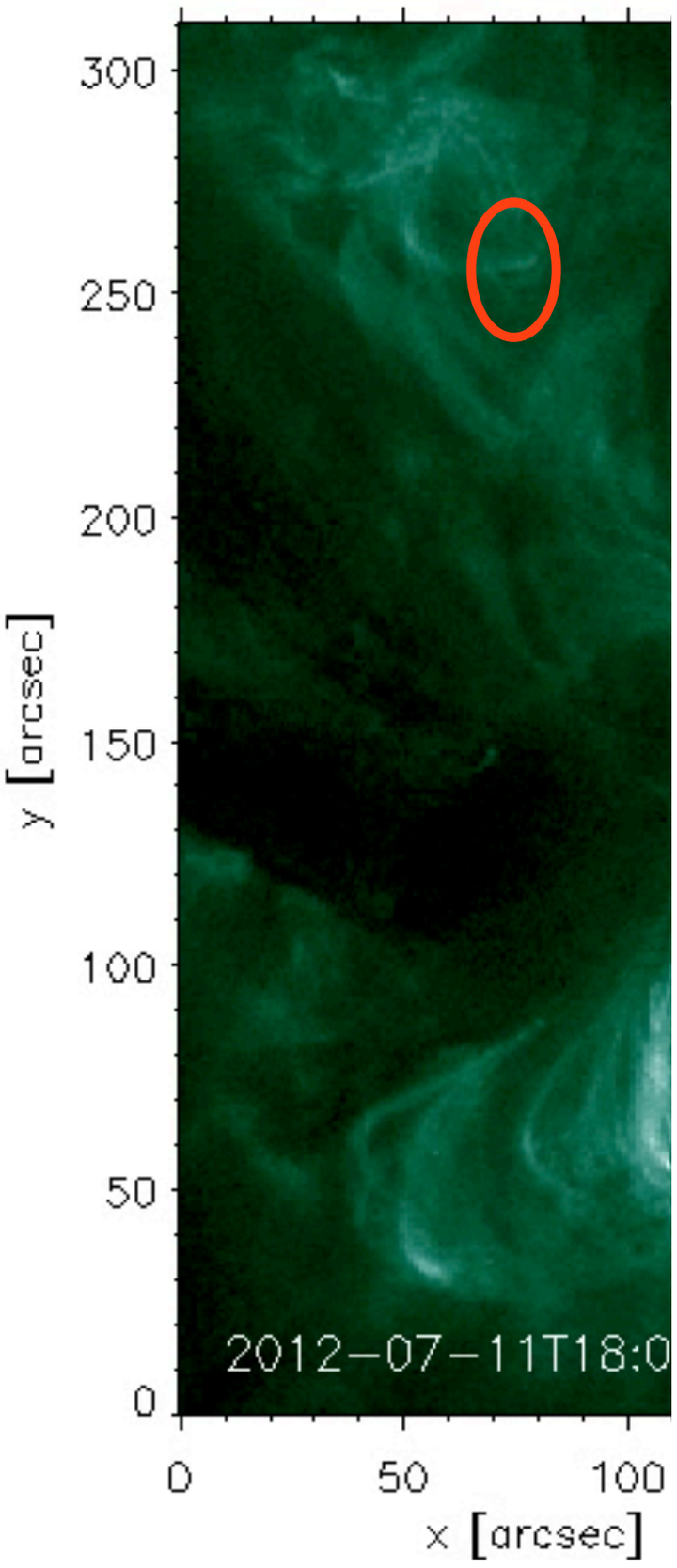

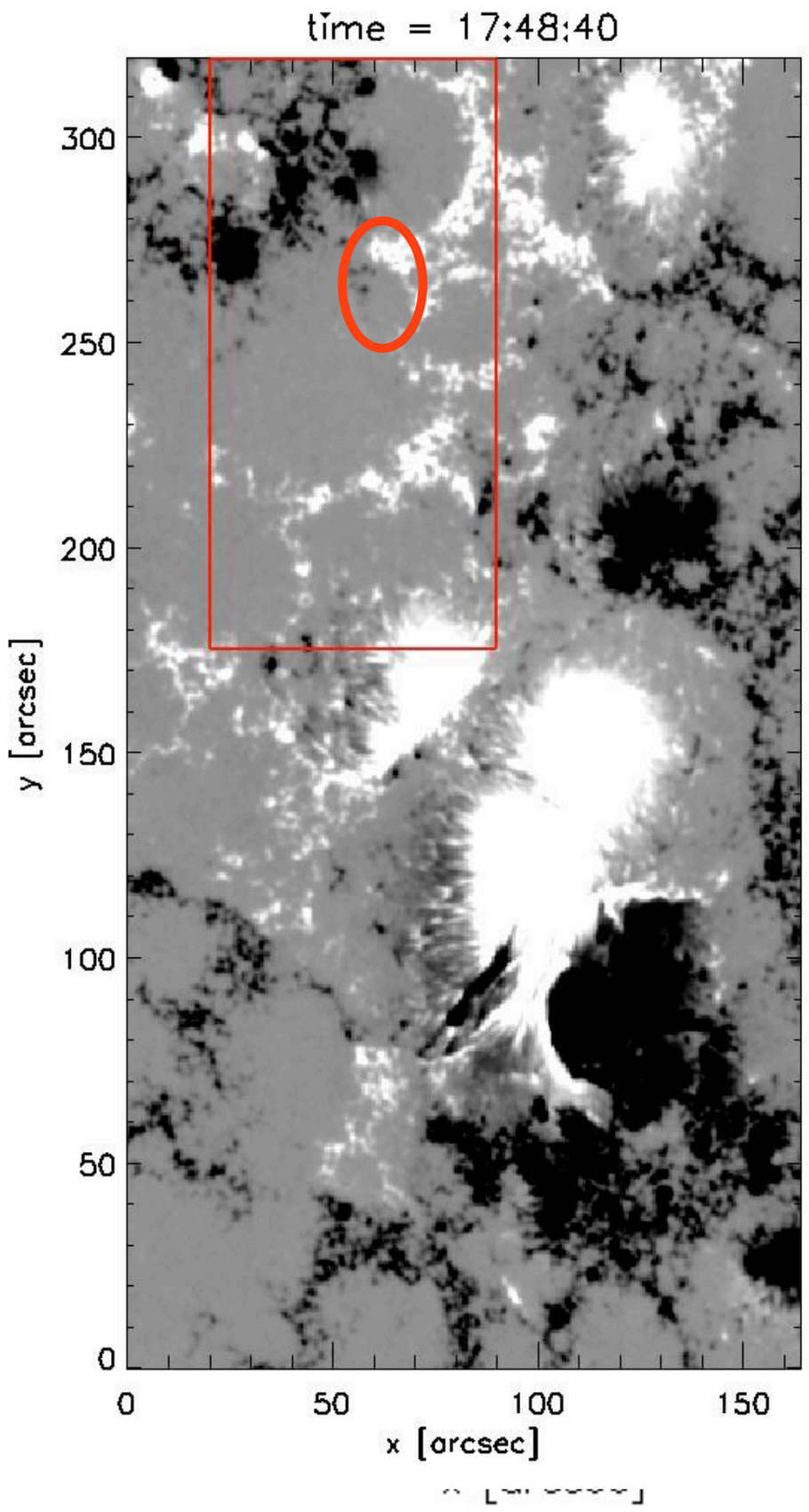

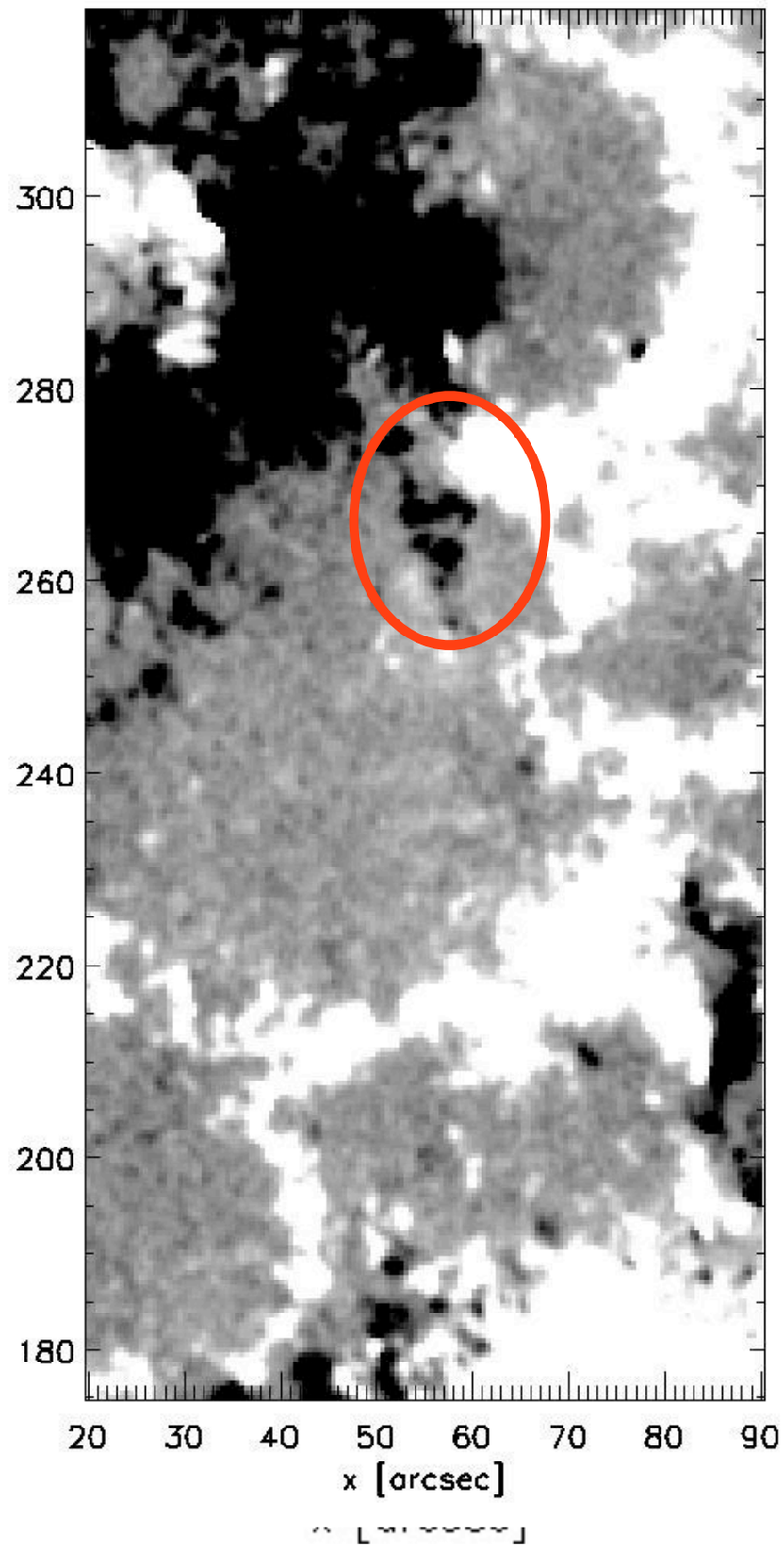

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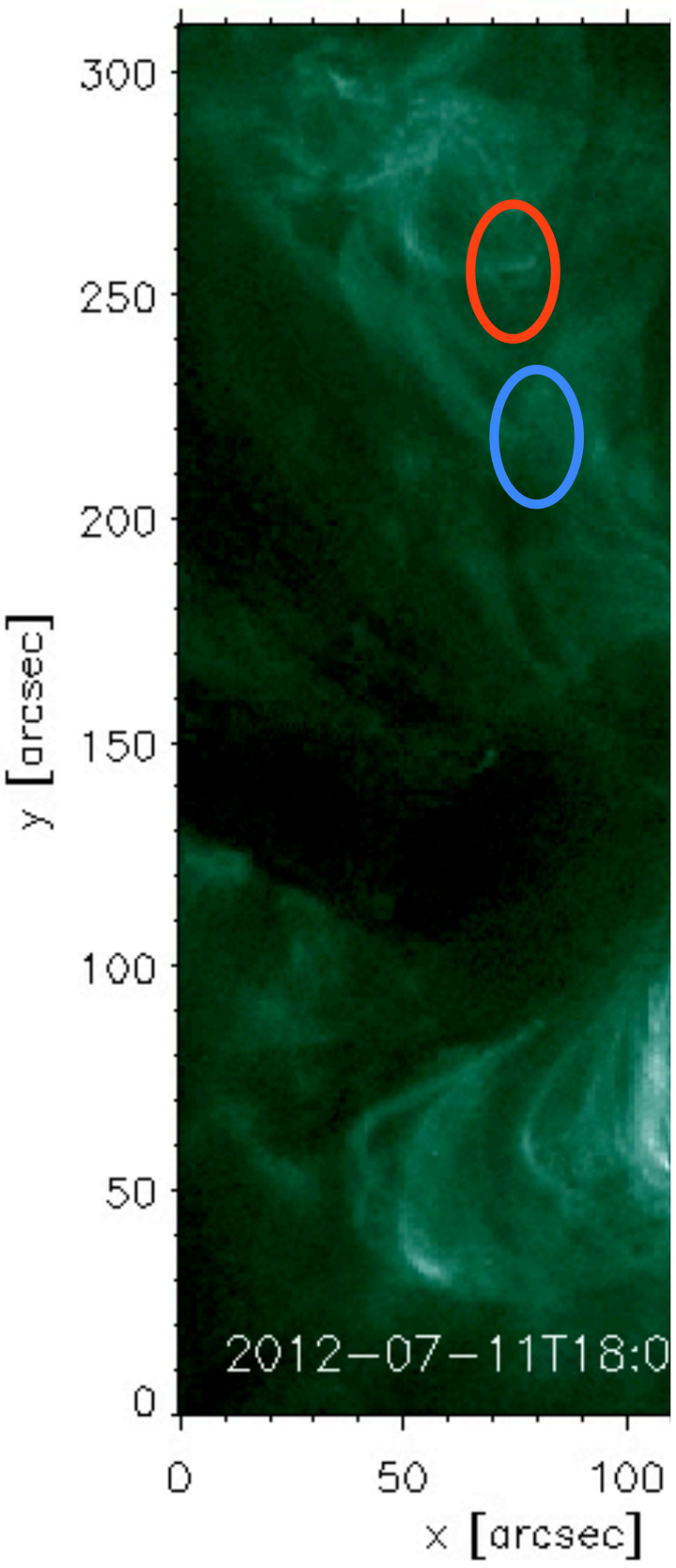

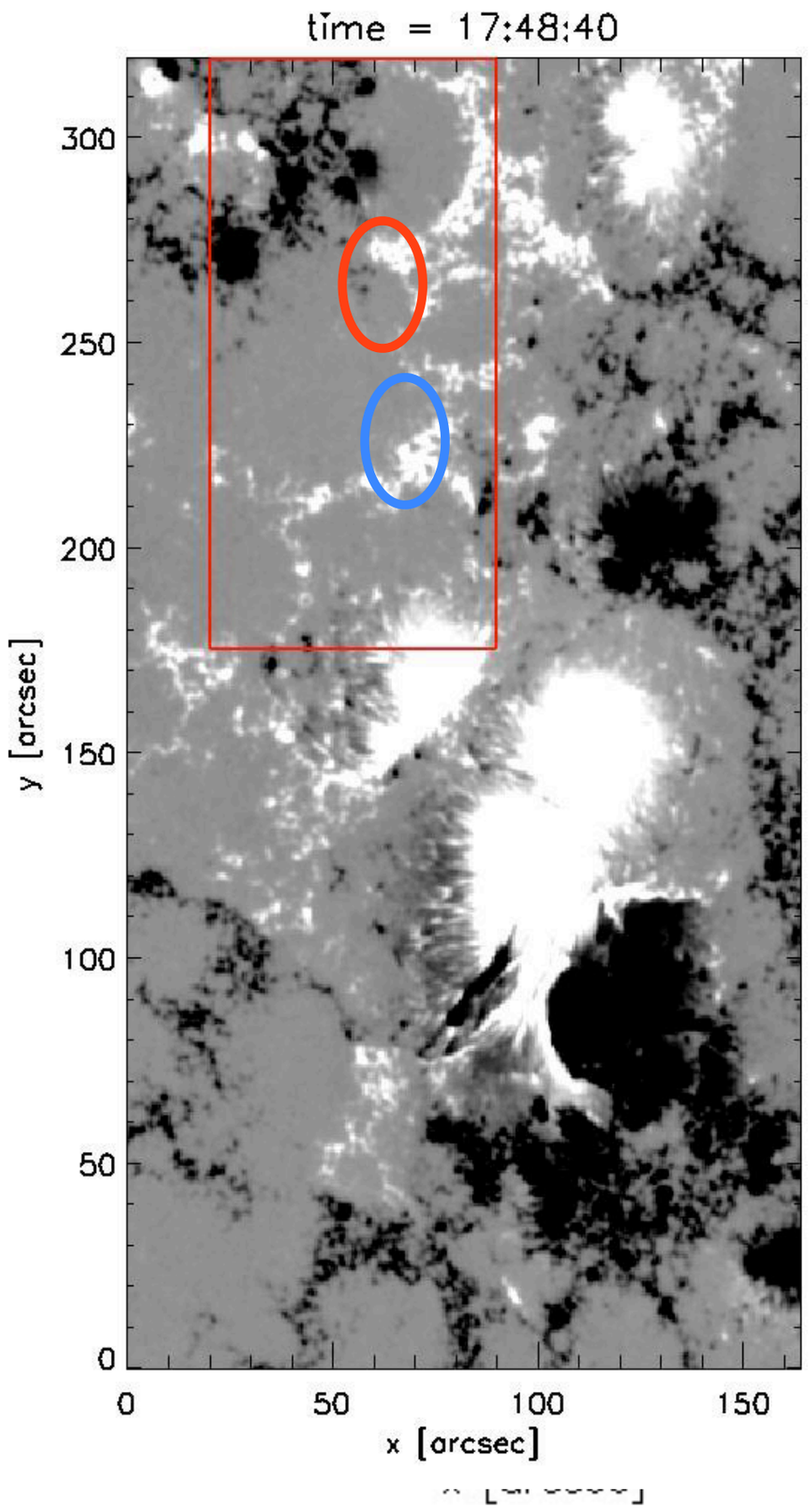

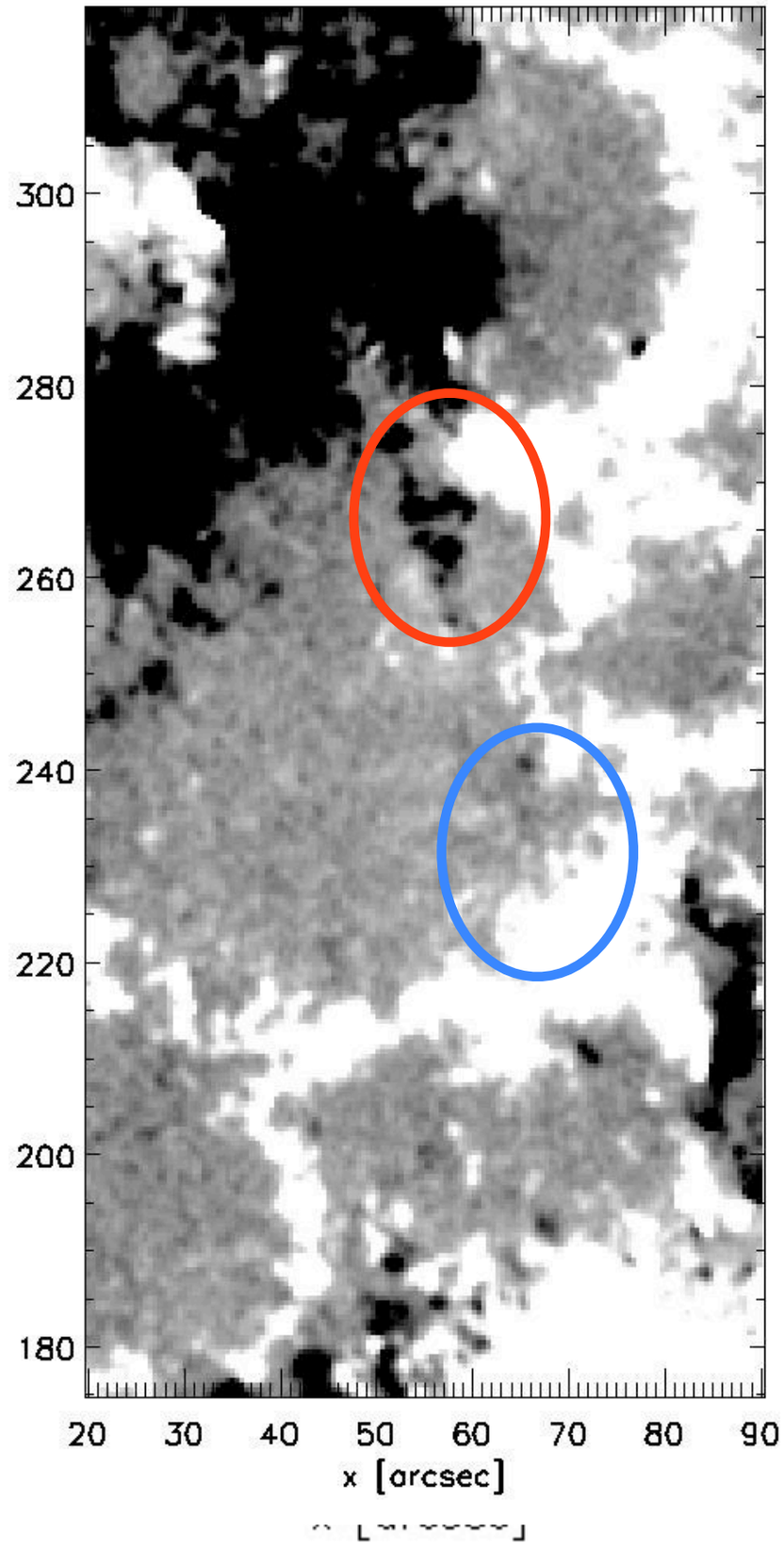

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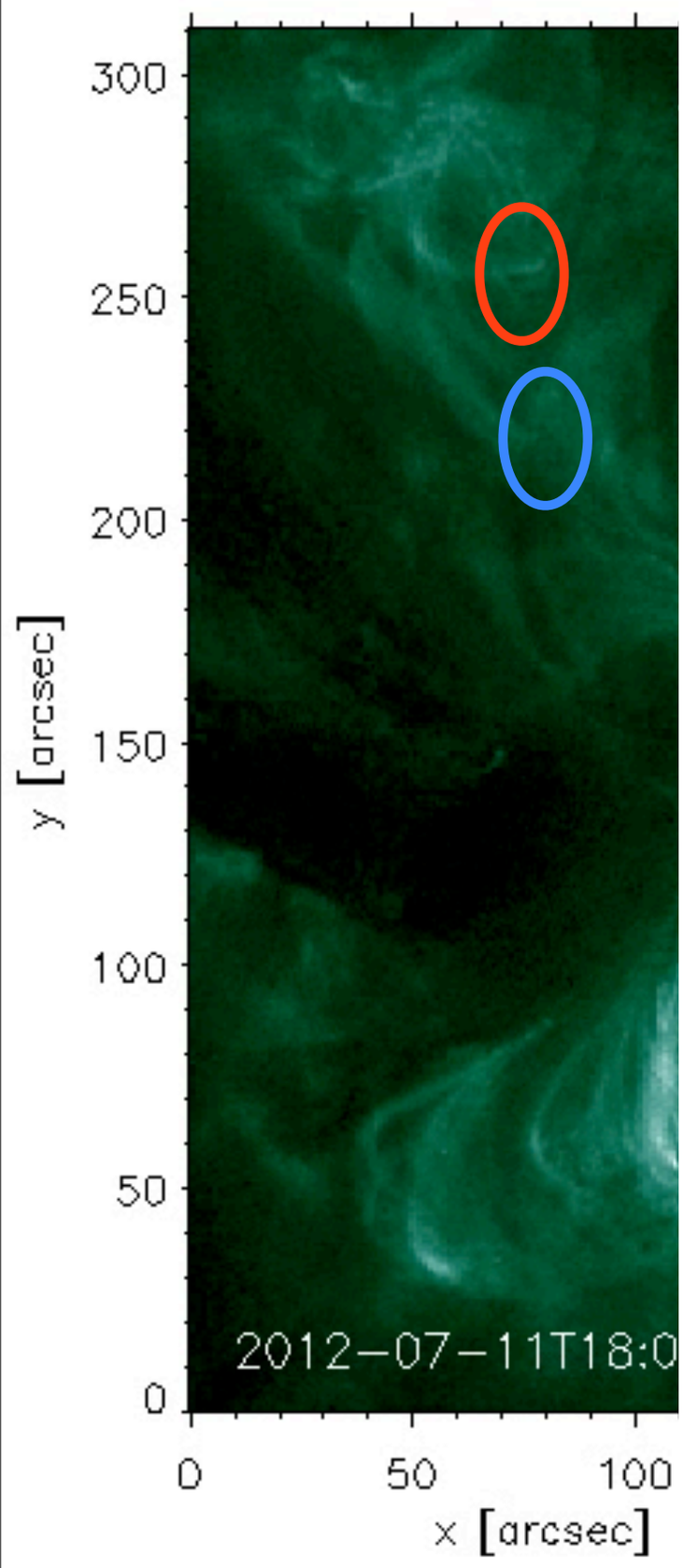
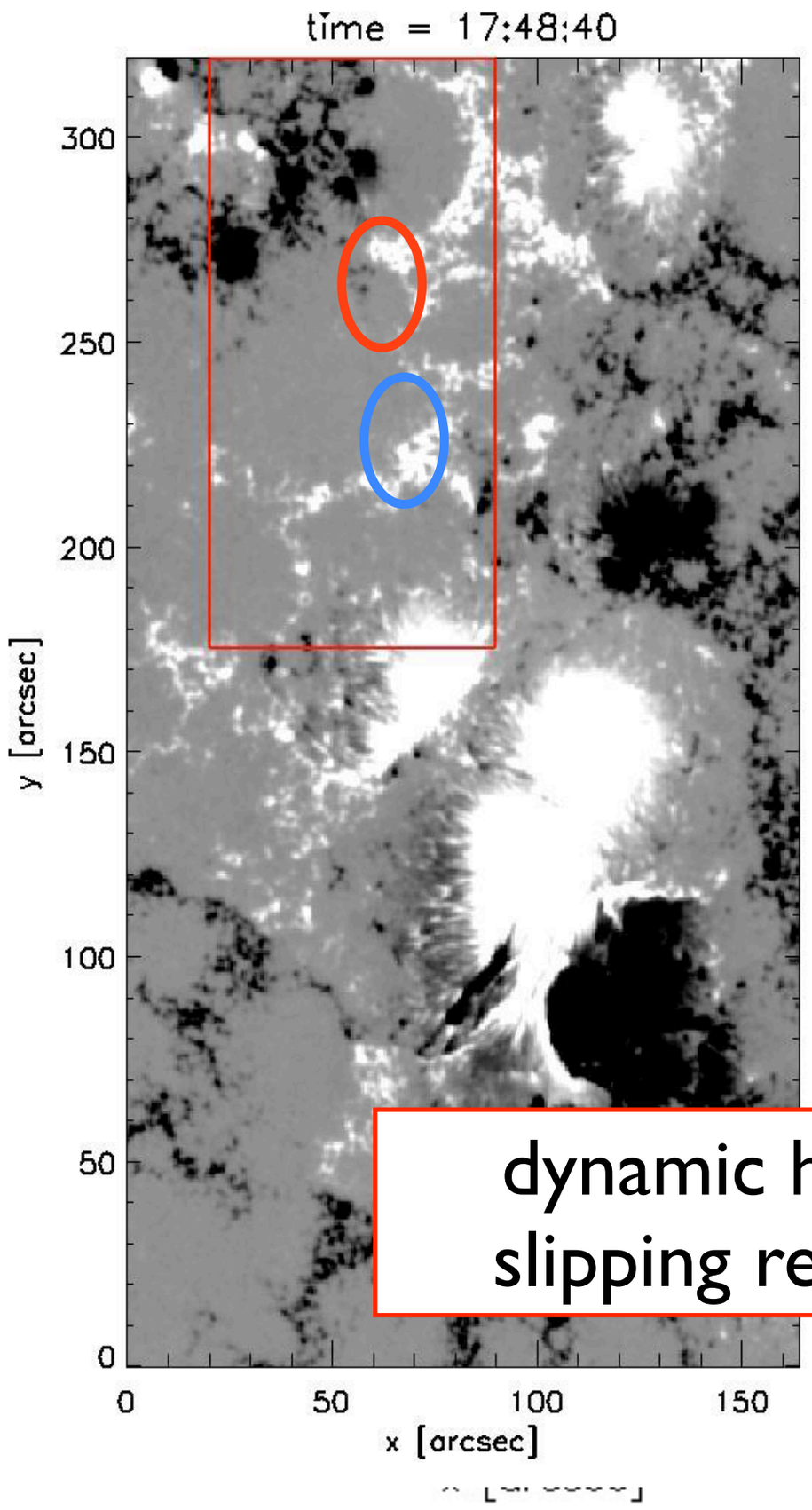
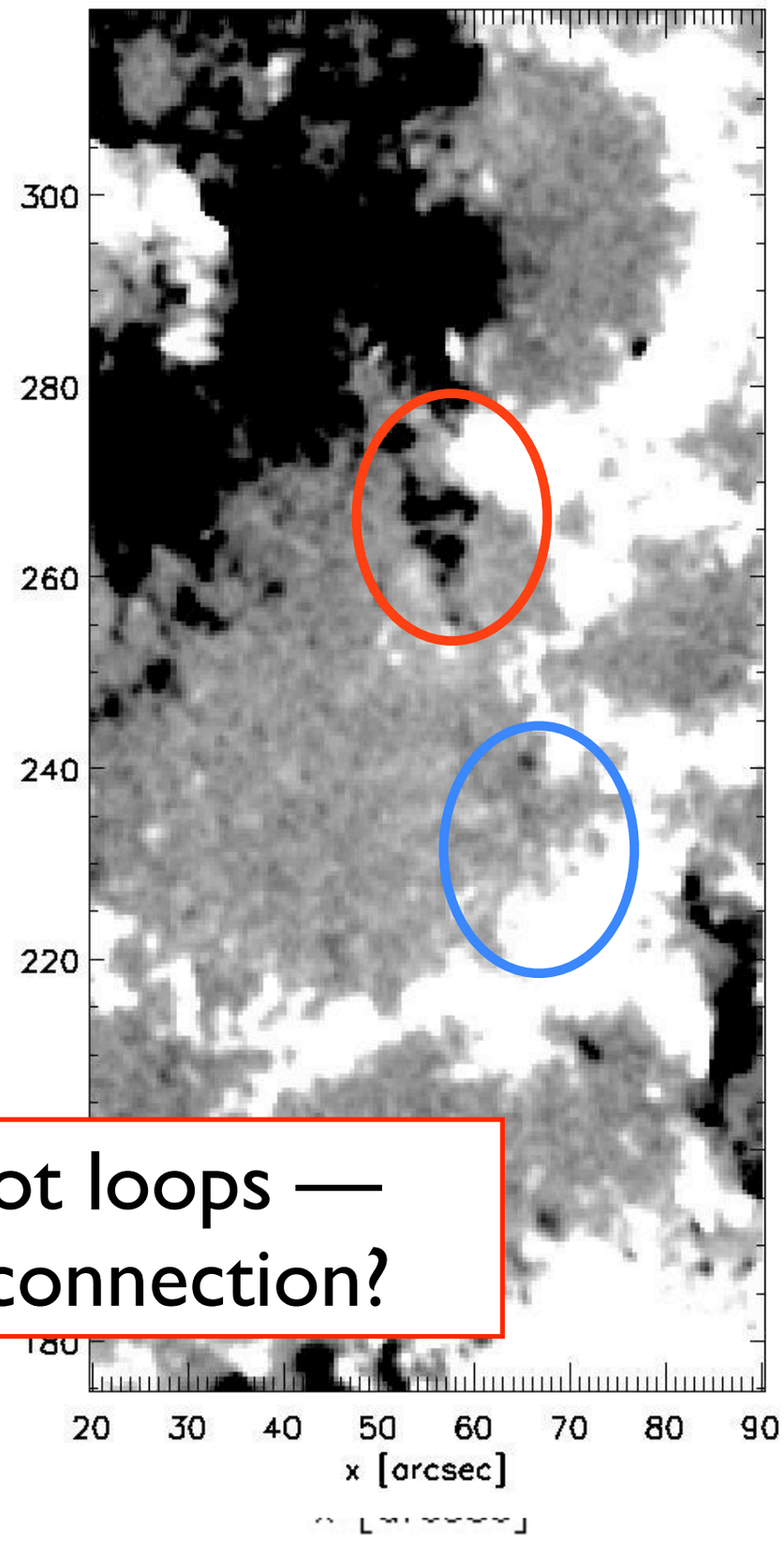
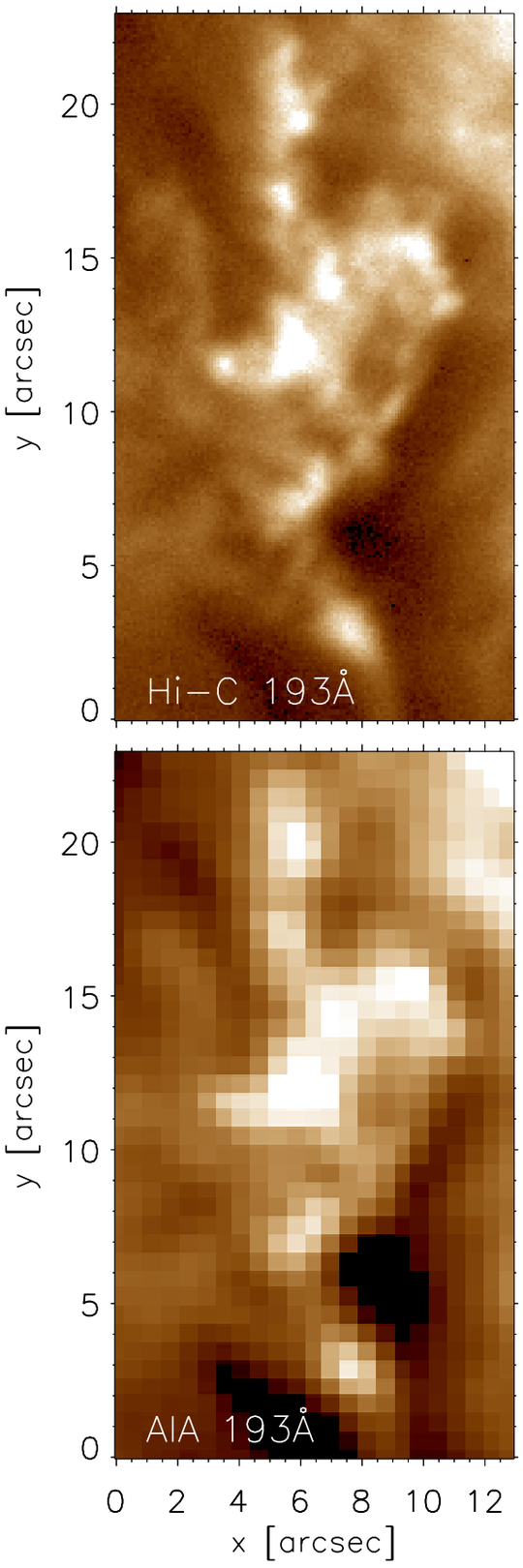


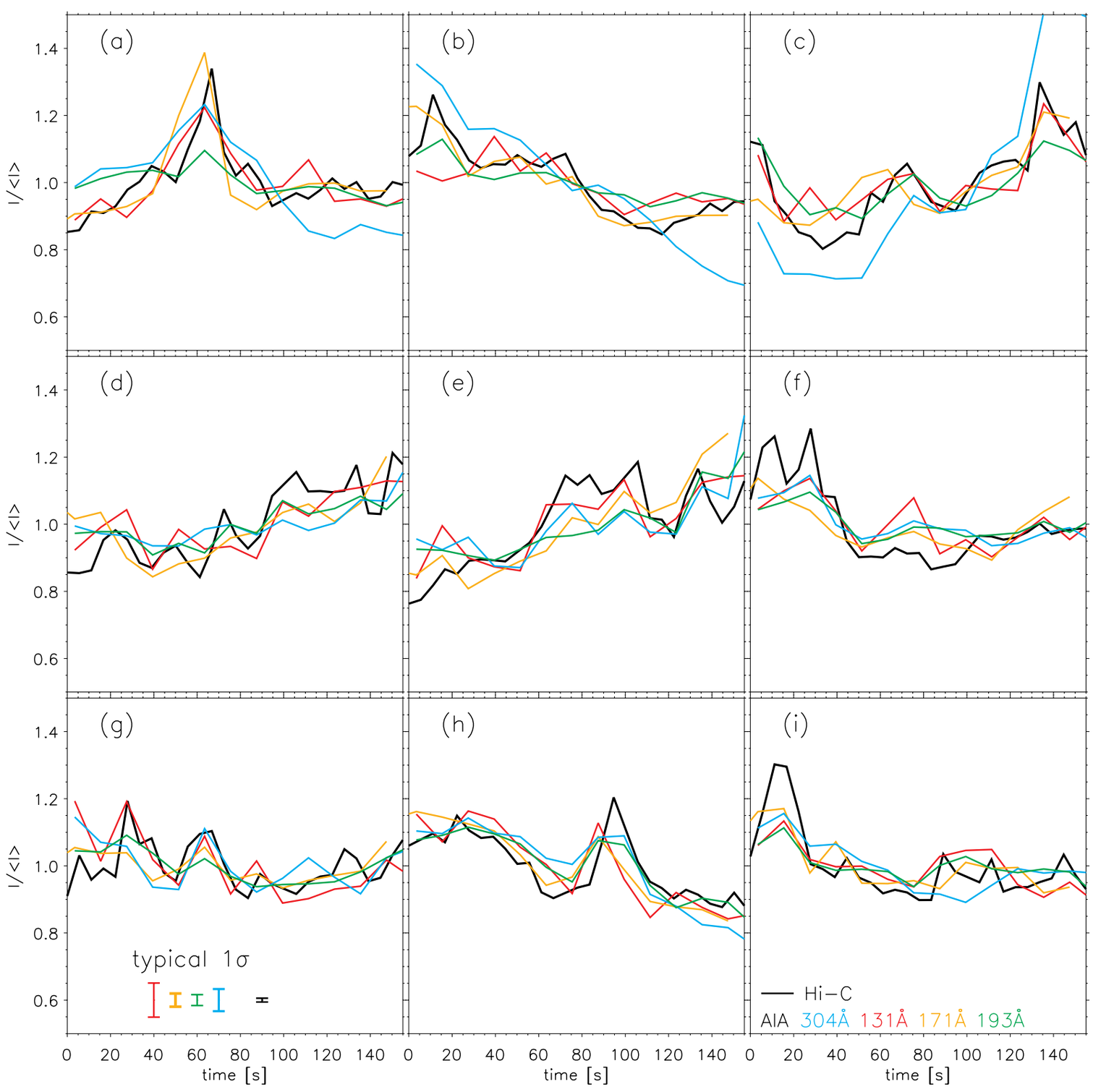




dynamic hot loops — slipping reconnection?

Can we see the moss brightenings in AIA?





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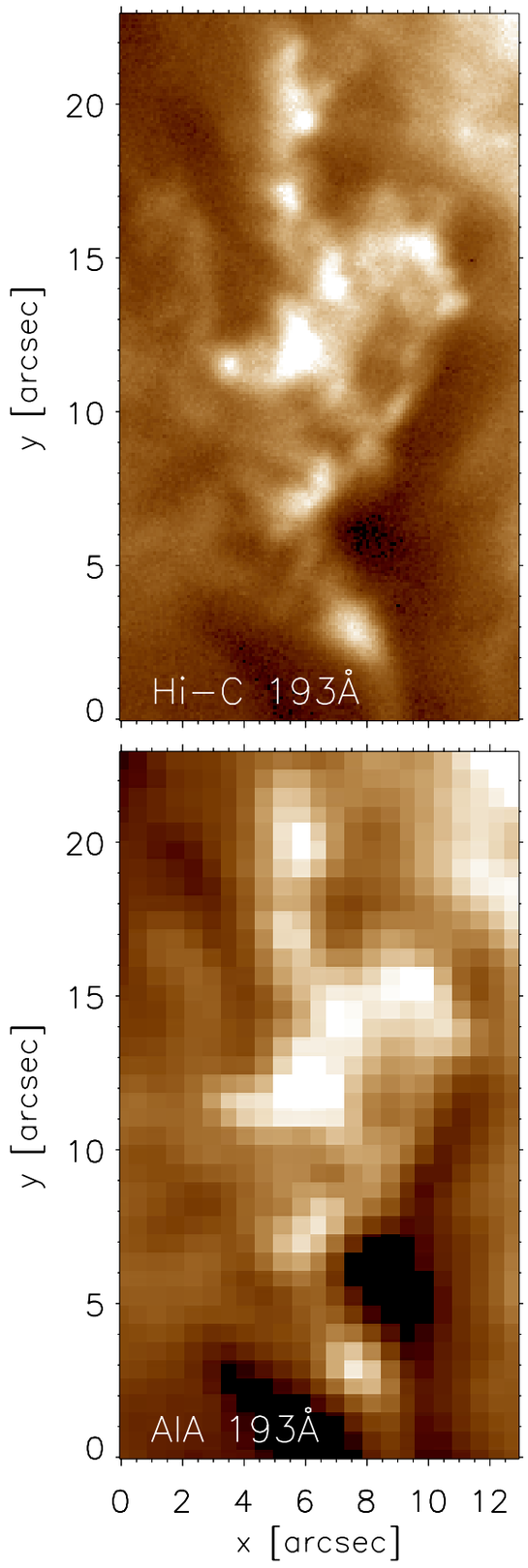

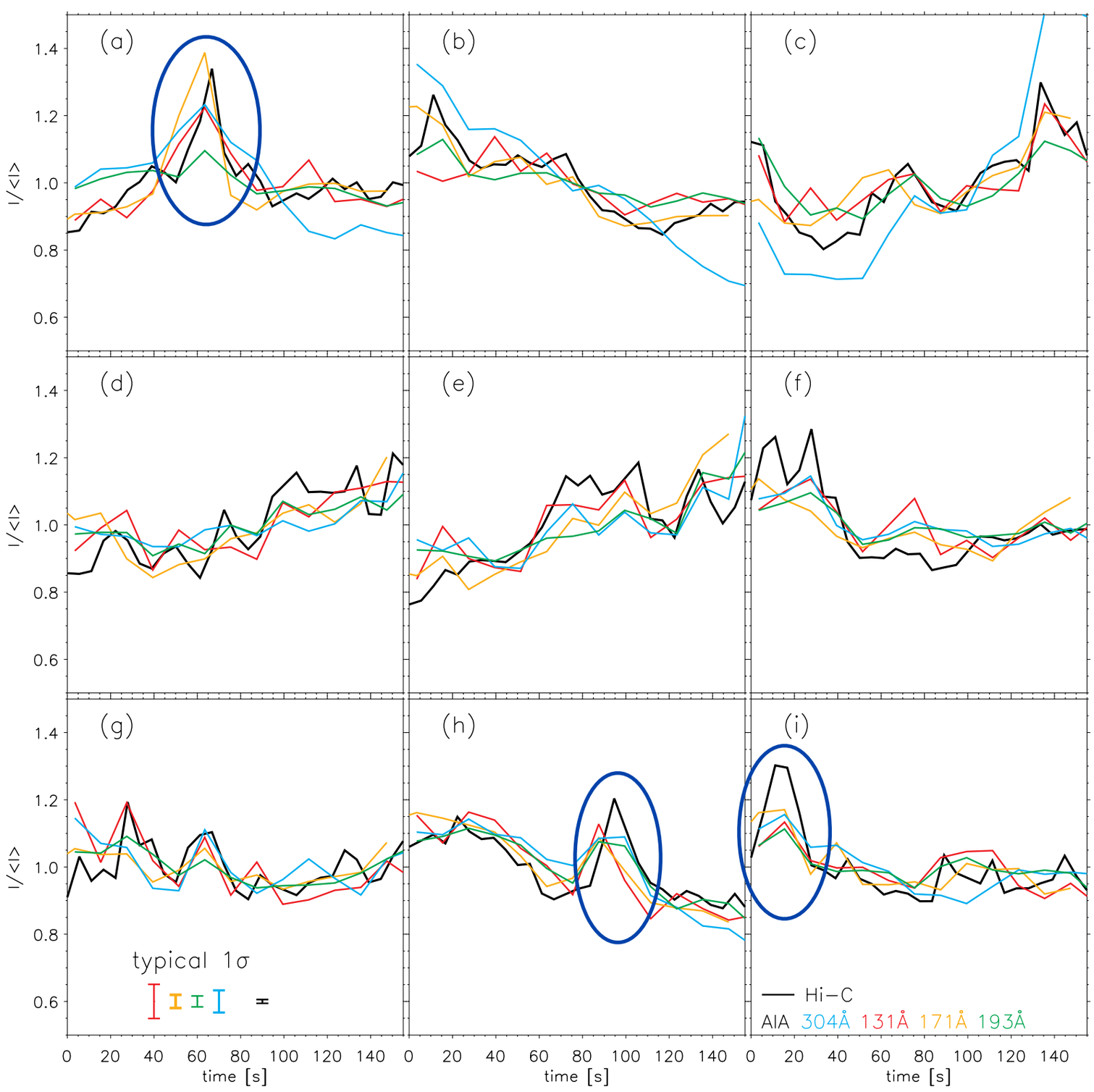

...only a few....

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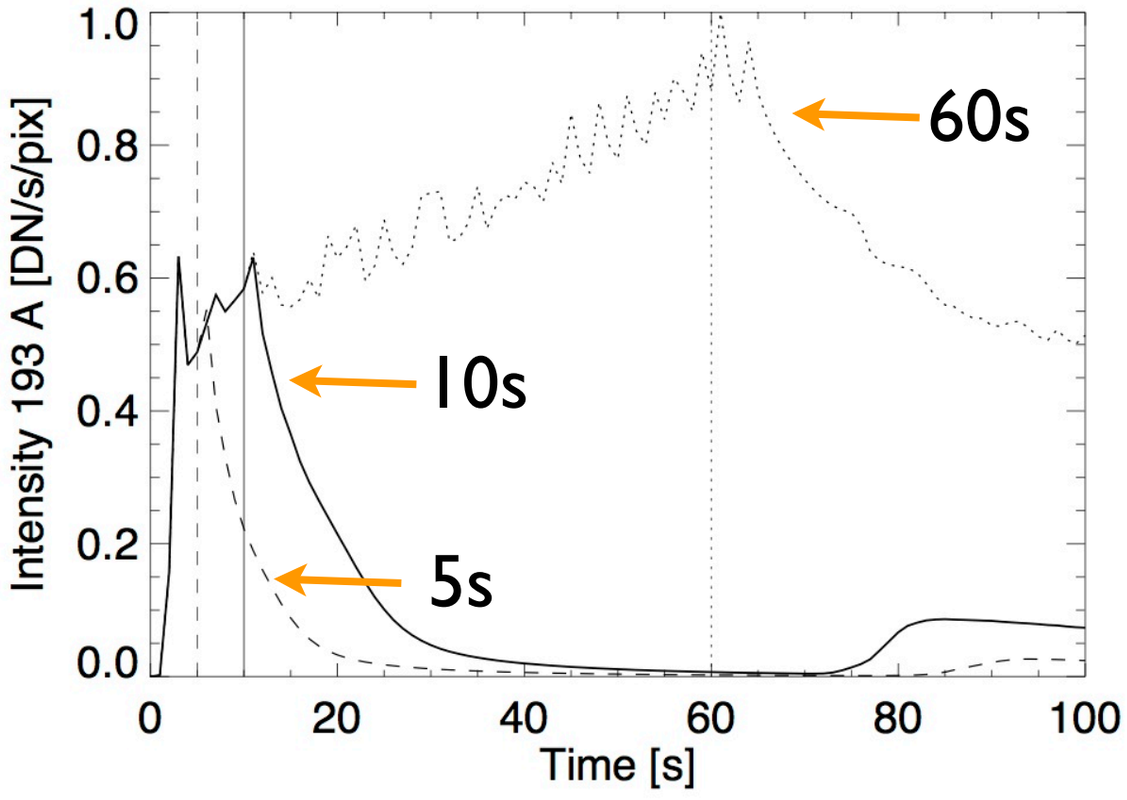

1D HD loop models for impulsive heating with different durations τ_{heat} = 60s, 10s, 5s

193Å intensity integrated at loop footpoints (<3x10^{8}cm) shows short duration brightenings at the 'footpoint' for short lived heating events

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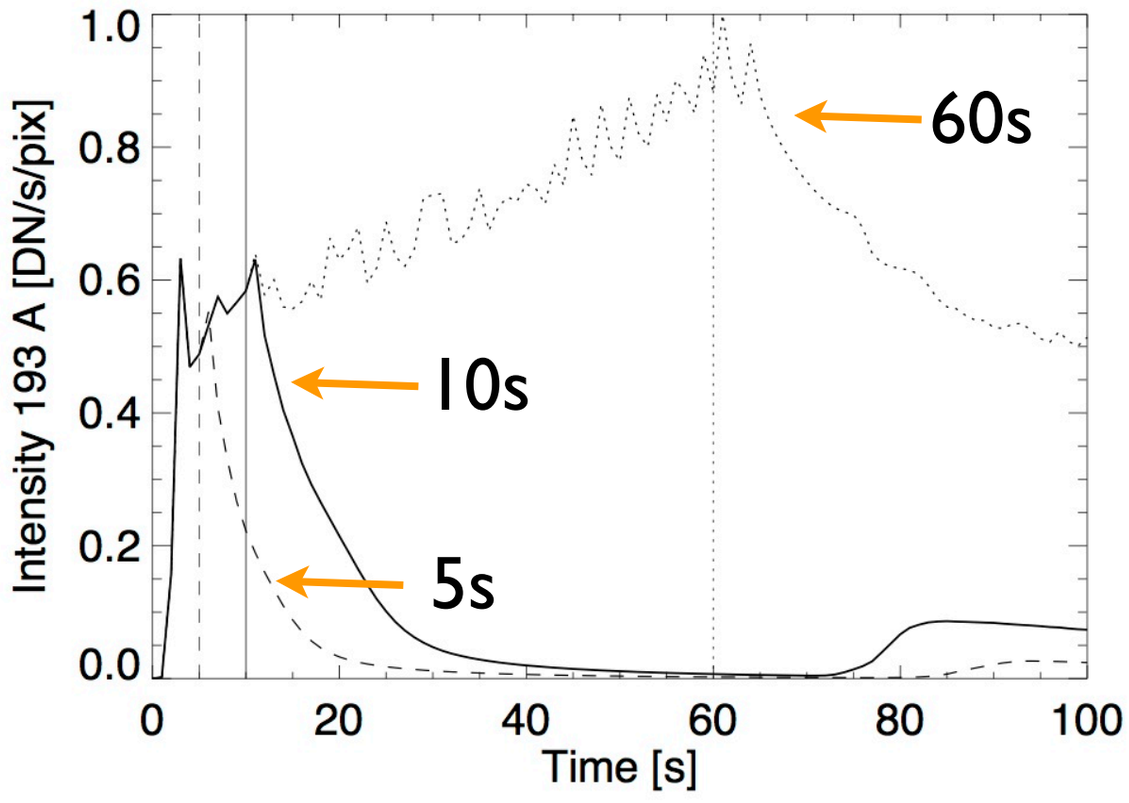

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Energetics of moss brightenings

Estimate of energy, time scales in the events

$E = 3\ n\ k_B\ T\ V$

(Testa et al. 2013)

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$E \sim 3 \times 10^{23}$ erg

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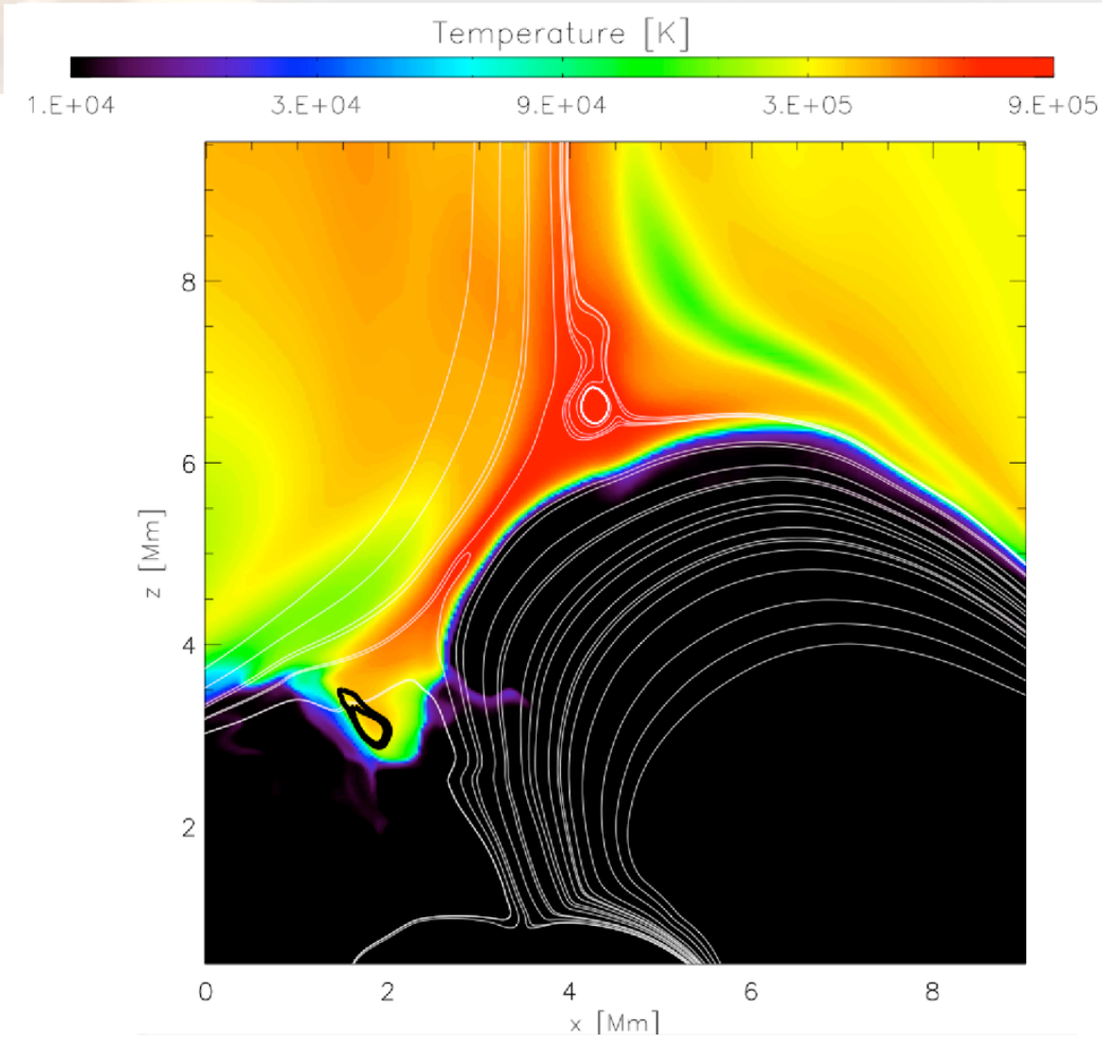
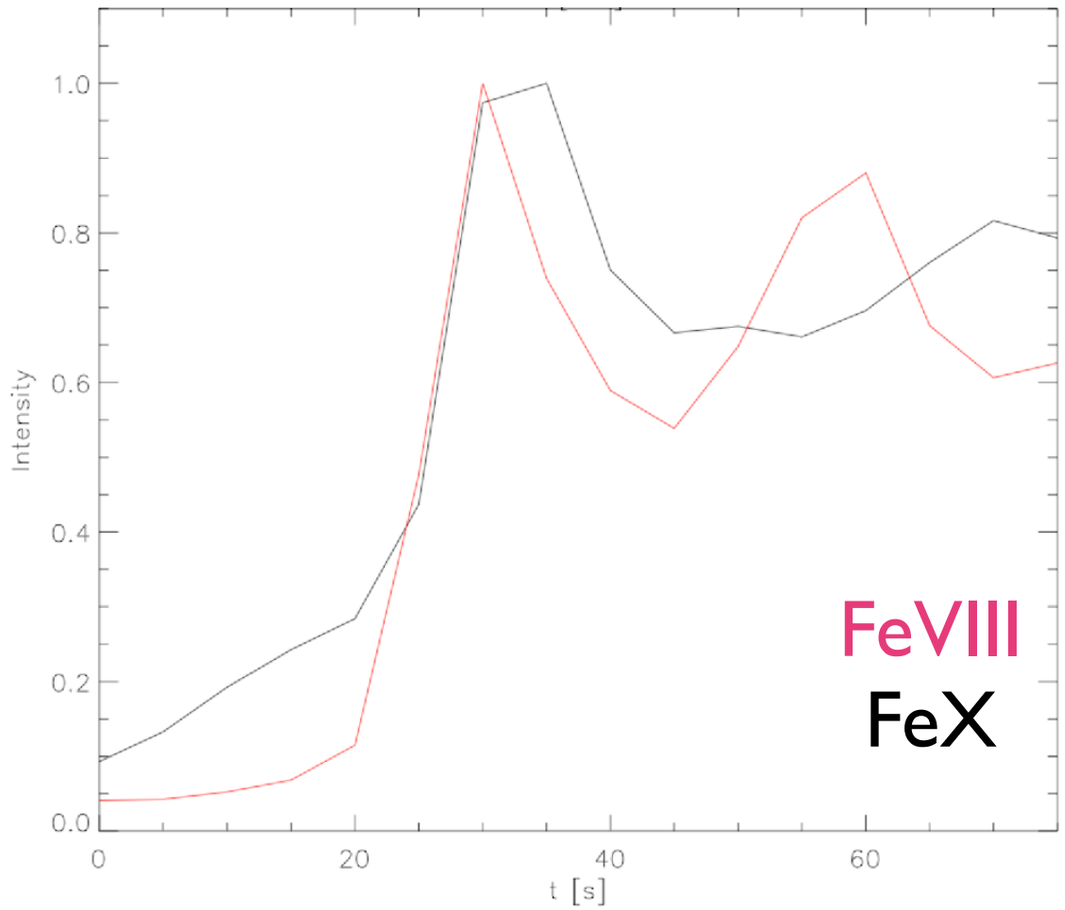
2D MHD Bifrost Simulations





2D MHD simulations (Martinez-Sykora et al. 2012); magnetic field configuration with a reconnection X point in the corona

- brightenings at the 'footpoint' (synthetic Fe VIII intensity contours)
- lightcurves show variability on timescales of the order of ~15-20s

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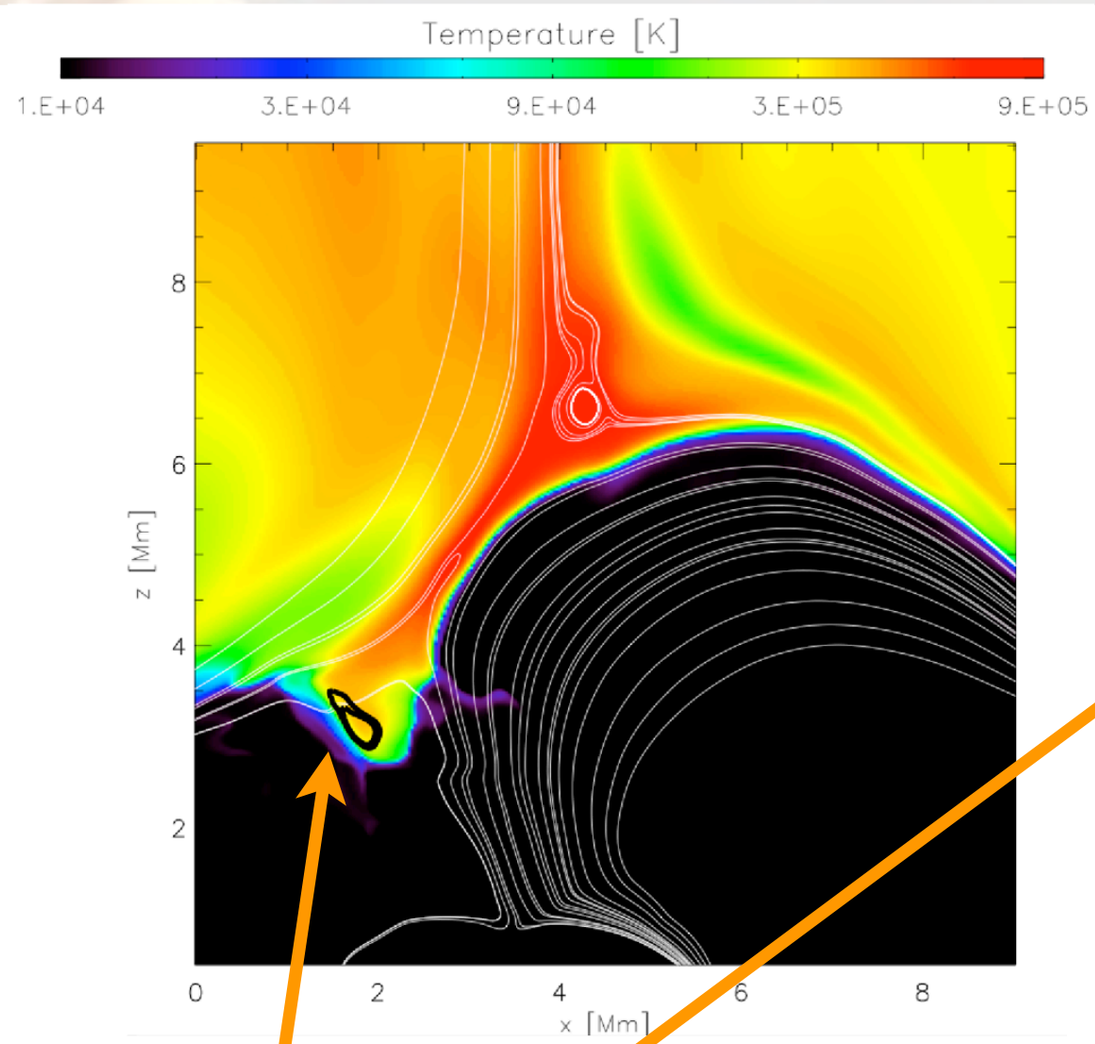

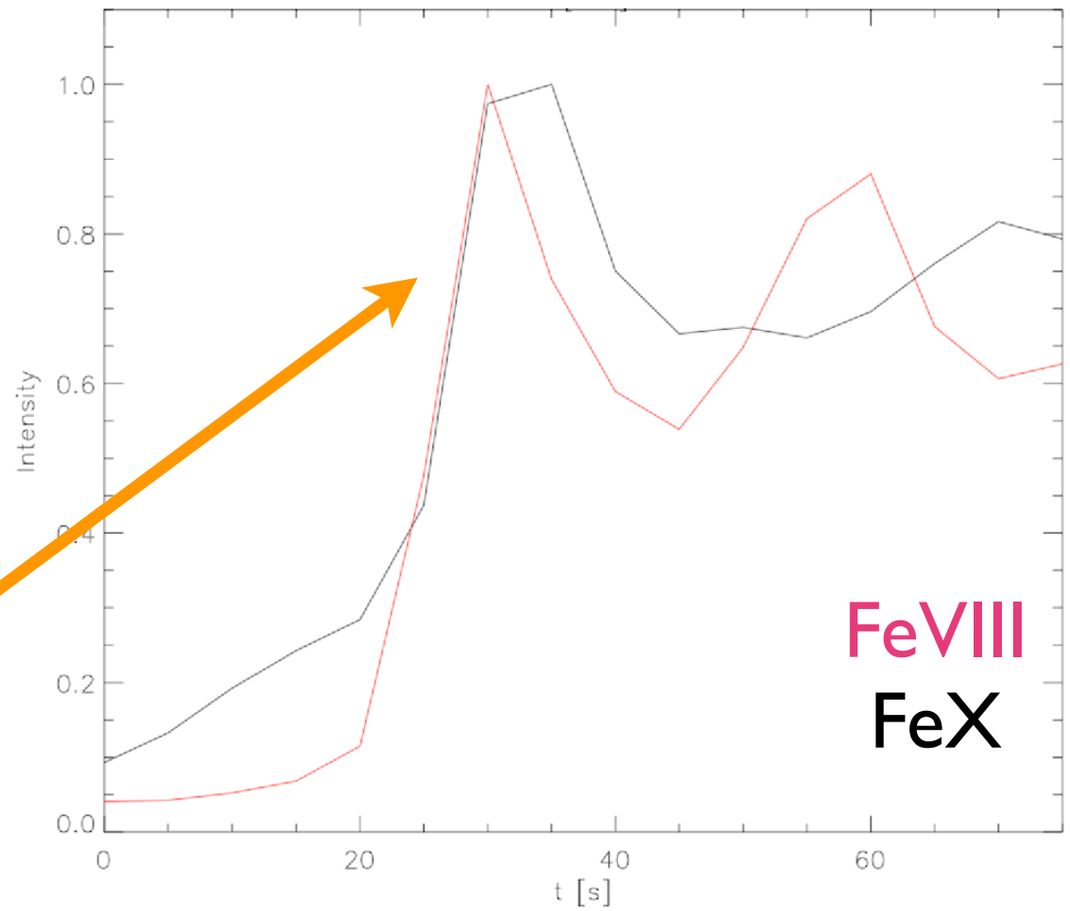

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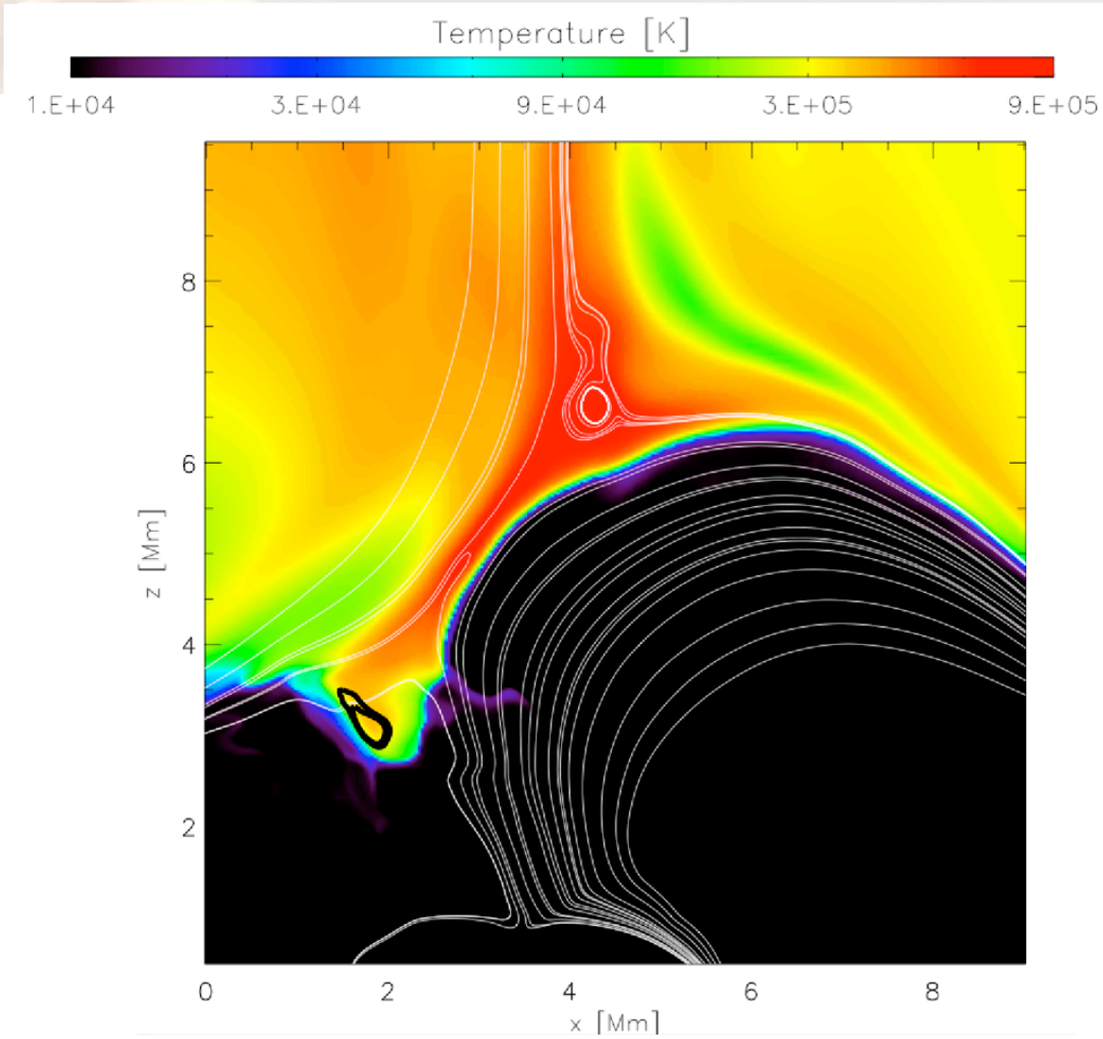
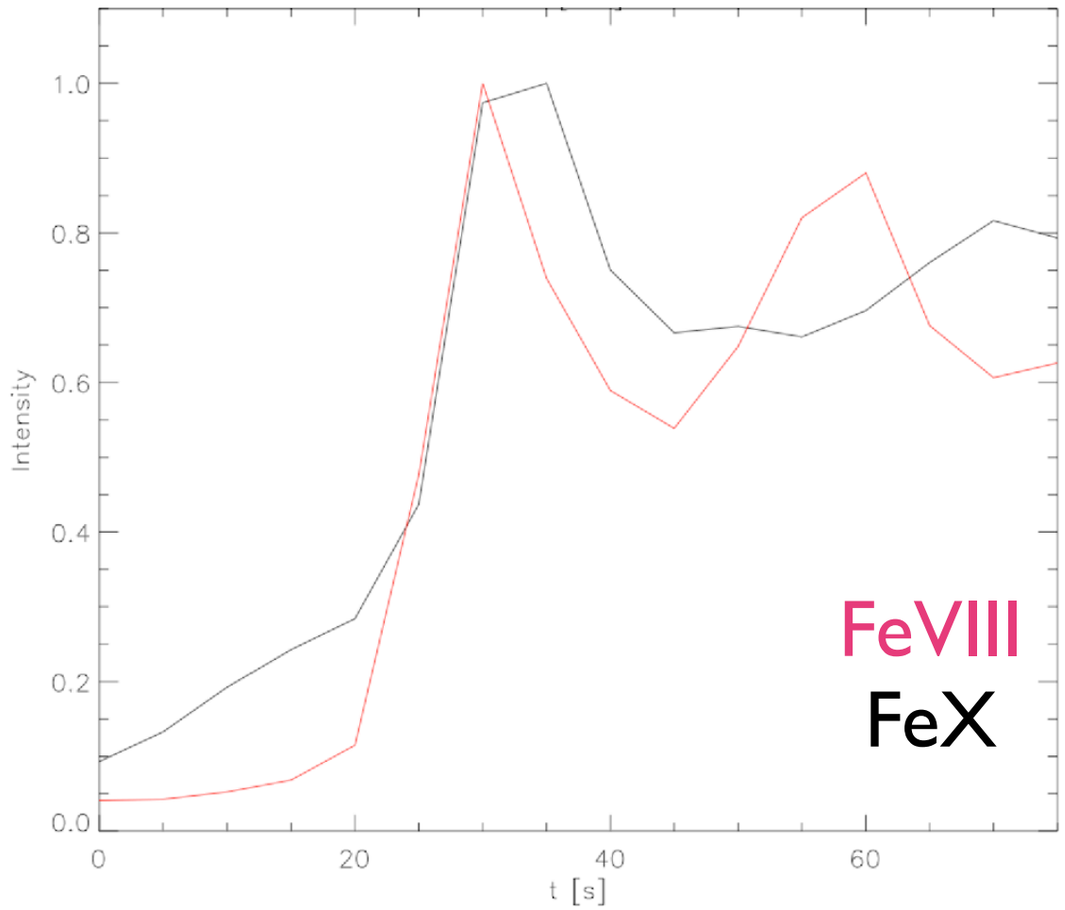
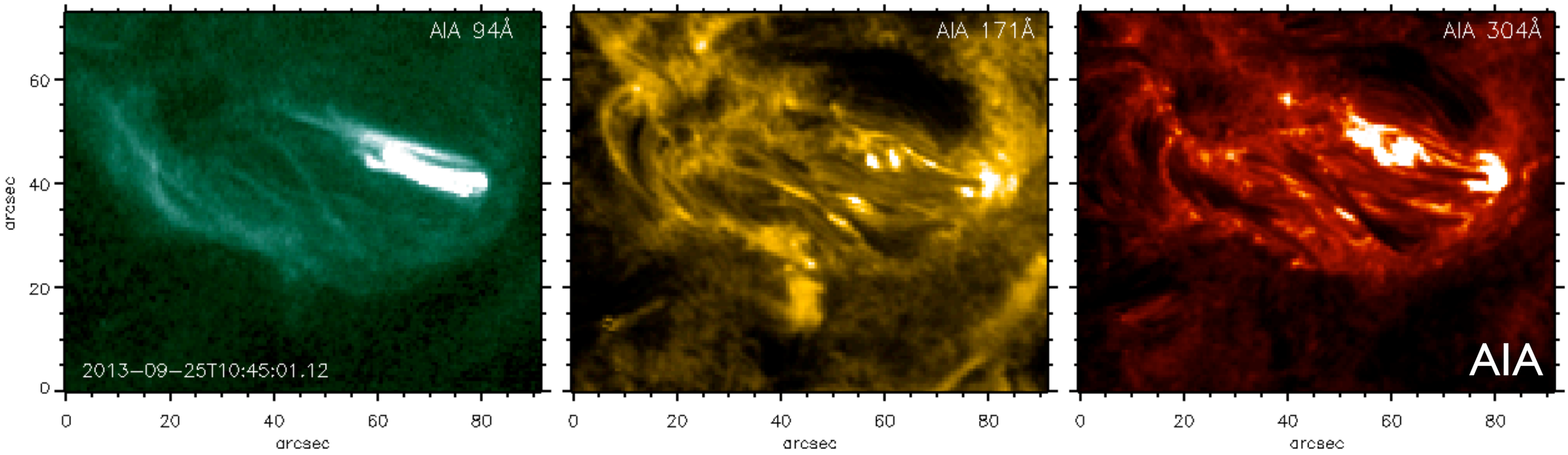




However: this 2D model is not hot enough (T only up to ~1MK) therefore not necessarily a good comparison for our case were we have much hotter loops (≳4MK) and thermal conduction is going to be much more efficient

IRIS high spatial and temporal cadence TR obs



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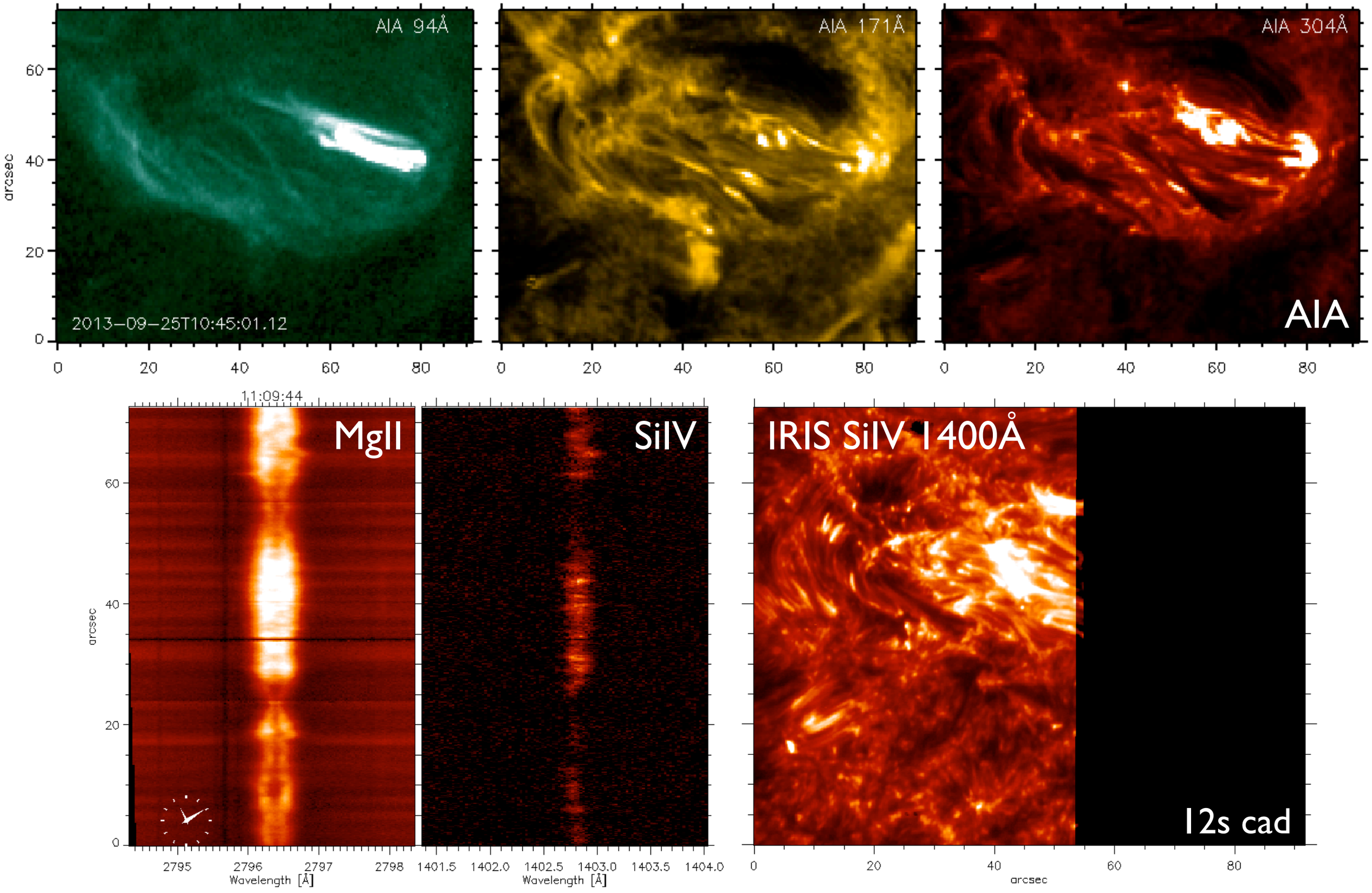

Conclusions

Hi-C provided the highest *spatial and temporal resolution* solar coronal images ever taken revealing dynamics and structuring down to the limit of the resolution:

- Evidence of impulsive, "nanoflare", coronal heating
- Rapidly variable moss is **not** observed everywhere in the AR but only where the hottest and most dynamic loops are.
- Even if the moss observations do not allow to exclude heating in the TR, the observed correlation with the coronal and magnetic features suggest that the rapid variability is due to reconnection events and consequent energy release in the corona (nanoflares)
- high spatial and temporal resolution IRIS observations (with AIA, and XRT) will allow us to investigate the TR response to coronal nanoflares, and the mechanism of energy transport (conduction vs. beams ; see e.g., Brosius & Holman 2012)