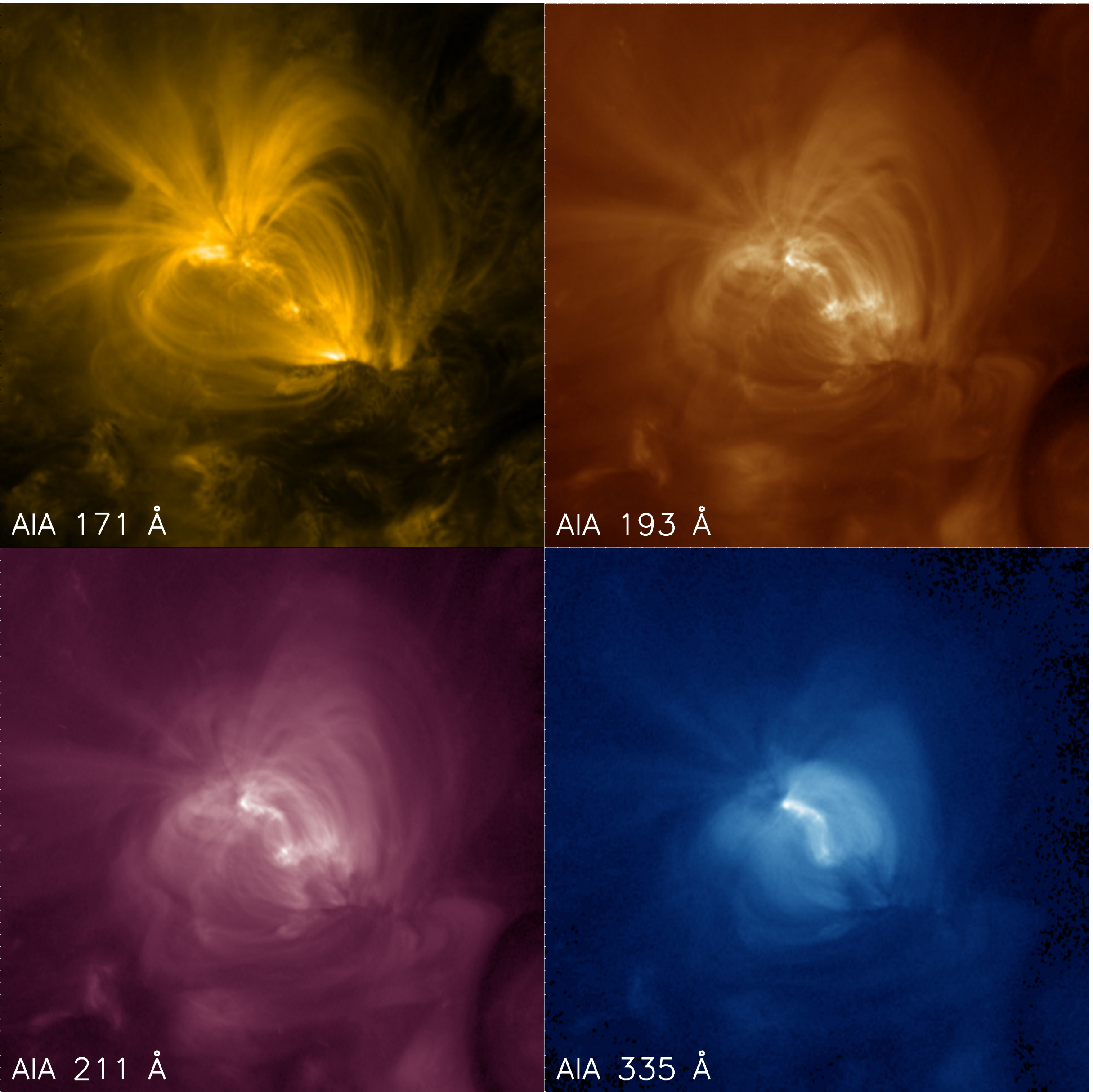
Identifying Observables that Discriminate Between Impulsive and Footpoint Heating: Long Time Delays

Amy Winebarger[1], Roberto Lionello[2], Cooper Downs[2],

Zoran Mikic[2], Jon Linker[2]

[1]NASA MSFC, ST 13, Huntsville, AL 35802
[2]Predictive Science Inc., 9990 Mesa Rim Rd., Ste. 170, San Diego, CA 92121-2910

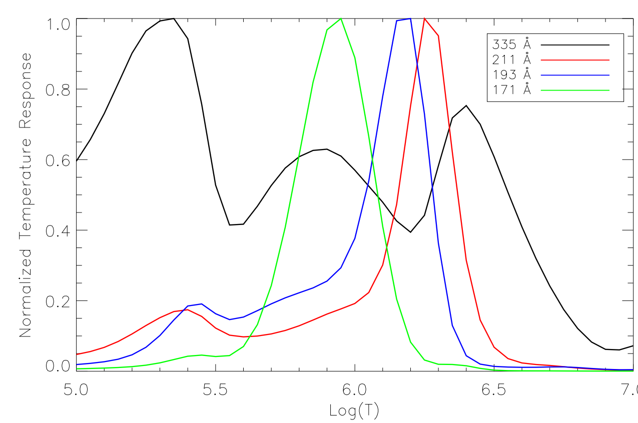
Time Lag Analysis of AR 11082

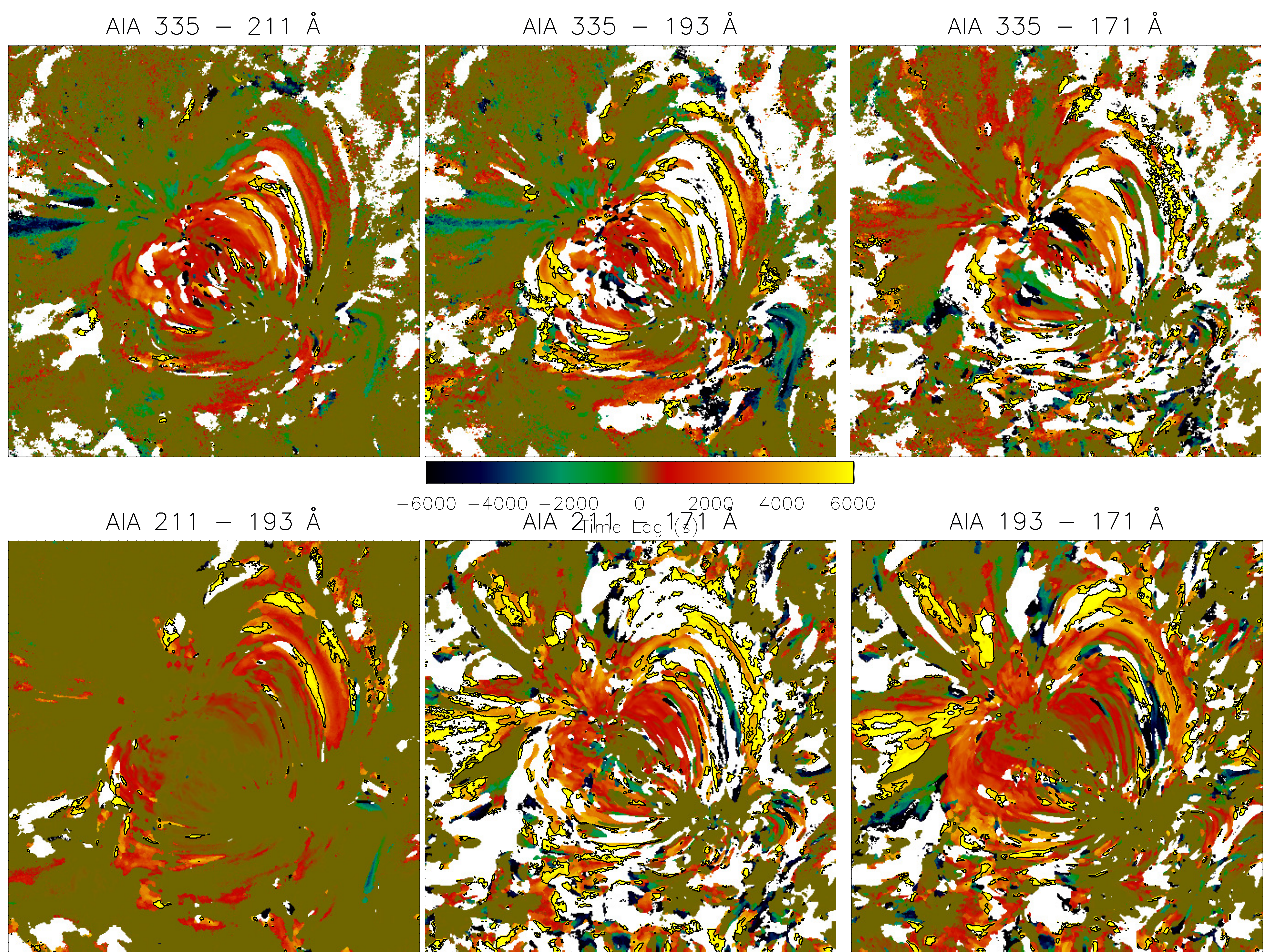


Active Region 11082 was observed on 2010 June 19 and originally studied by Viall and Klimchuk (2012).

We only consider 4 EUV AIA channels.

171, 193, and 211 are narrow and sharply peaked. 335 is broad with multiple peaks.





AIA 335 – 211 Å
AIA 335 – 193 Å
AIA 335 – 171 Å
−6000 −4000 −2000 0 2000 4000 6000
Time Lag (s)
AIA 211 – 193 Å
AIA 211 – 171 Å
AIA 193 – 171 Å

CAN LARGE TIME DELAYS OBSERVED IN LIGHT CURVES OF CORONAL LOOPS BE EXPLAINED IN IMPULSIVE HEATING?

Roberto Lionello[1], Caroline E. Alexander[2], Amy R. Winebarger[2], Jon A. Linker[1], and Zoran Mikić[1]
[1] Predictive Science, Inc., 9990 Mesa Rim Rd., Ste. 170, San Diego, CA 92121-3933, USA; lionel@predsci.com, linkerj@predsci.com, mikicz@predsci.com
[2] NASA Marshall Space Flight Center, ZP 13, Huntsville, AL 35805, USA; caroline.e.alexander@nasa.gov, amy.r.winebarger@nasa.gov
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ABSTRACT

The light curves of solar coronal loops often peak first in channels associated with higher temperatures and then in those associated with lower temperatures. The delay times between the different narrowband EUV channels have been measured for many individual loops and recently for every pixel of an active region observation. The time delays between channels for an active region exhibit a wide range of values. The maximum time delay in each channel pair can be quite large, i.e., >5000 s. These large time delays make-up 3%–26% (depending on the channel pair) of the pixels where a trustworthy, positive time delay is measured. It has been suggested that these time delays can be explained by simple impulsive heating, i.e., a short burst of energy that heats the plasma to a high temperature, after which the plasma is allowed to cool through radiation and conduction back to its original state. In this paper, we investigate whether the largest observed time delays can be explained by this hypothesis by simulating a series of coronal loops with different heating rates, loop lengths, abundances, and geometries to determine the range of expected time delays between a set of four EUV channels. We find that impulsive heating cannot address the largest time delays observed in two of the channel pairs and that the majority of the large time delays can only be explained by long, expanding loops with photospheric abundances. Additional observations may rule out these simulations as an explanation for the long time delays. We suggest that either the time delays found in this manner may not be representative of real loop evolution, or that the impulsive heating and cooling scenario may be too simple to explain the observations, and other potential heating scenarios must be explored.

NO

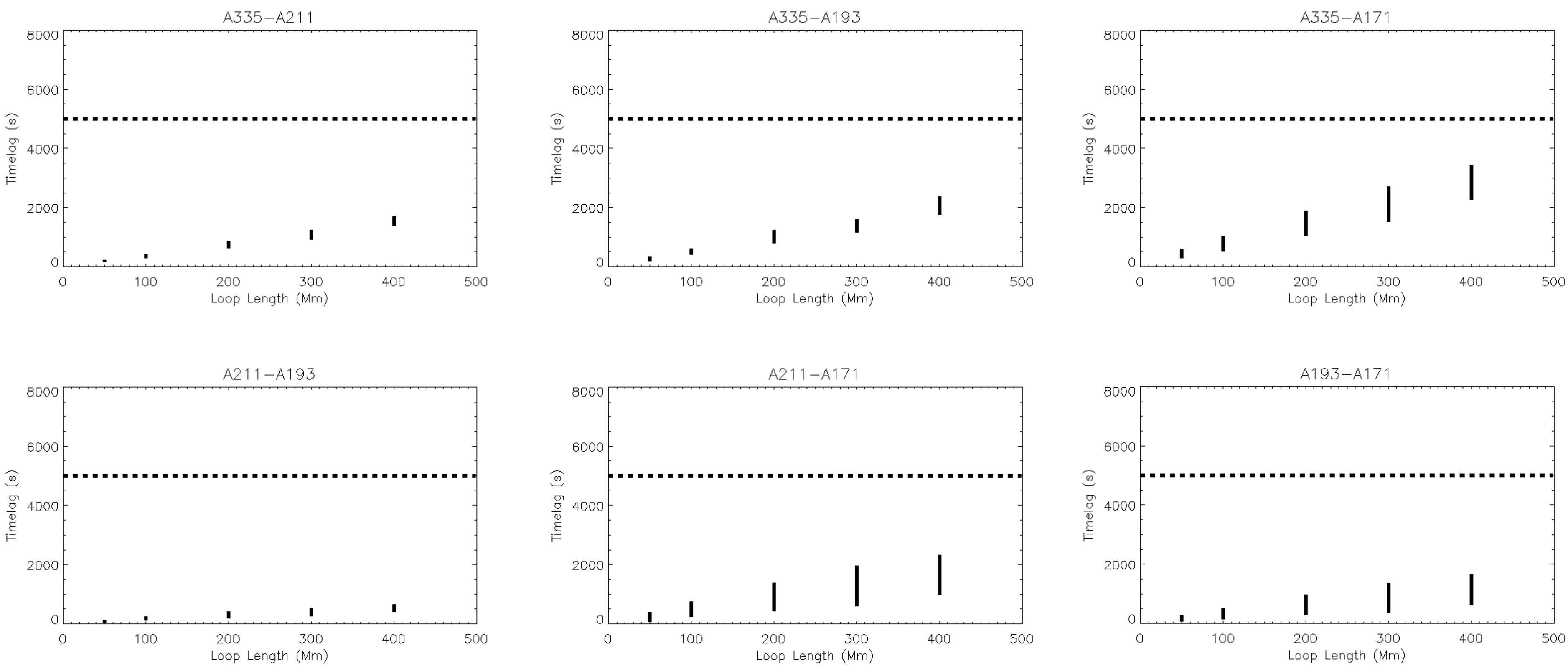
Key words: Sun: corona – Sun: UV radiation

Parameter Space Considered

- Loop length – 50 Mm – 400 Mm
- Abundances – photospheric and coronal abundances.
- Heating magnitude – A wide range of heating magnitudes that results in loops with equilibrium temperatures from 2- 10 MK.
- Area expansion – constant and expanding cross section.

Resulted in over 100 simulations. For each one, we calculated time lags in all channel pairs.

Impulsive Heating Timelags

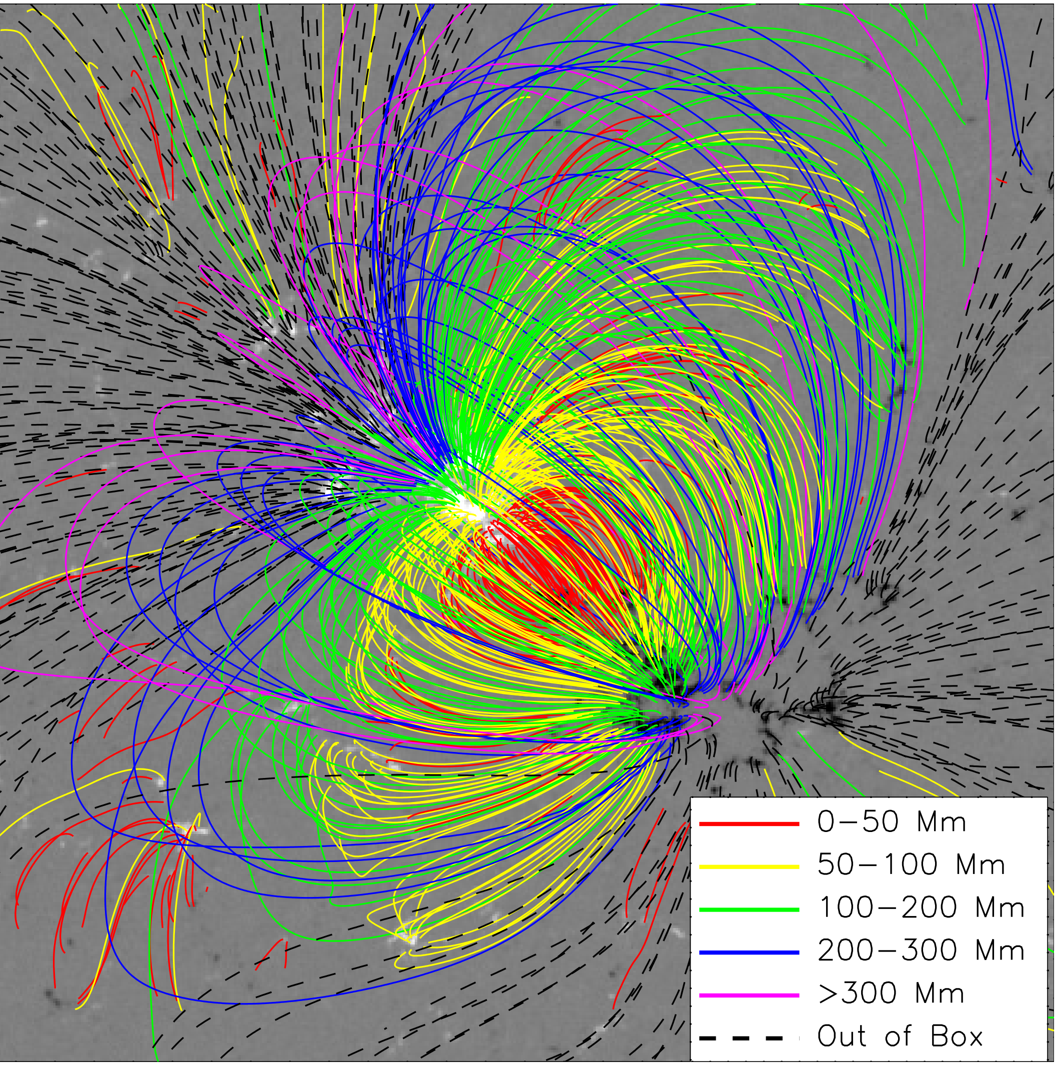


Impulsive heating with coronal abundances can not reproduce the long time delays.

Reasons for failure

- Time lags do not represent loop evolution
  - *The method could be detecting another evolutionary time scale in the active region*
  - *Multiple structures along the line of sight could be confusing the analysis*
- Low-frequency impulsive heating is not the correct heating model
  - *Several recent studies have considered the impact of mid-frequency heating*
  - *Steady, footpoint heating driving Thermal Non-Equilibrium (TNE) is another possibility*

Can Long Time Delays be Explained by TNE?



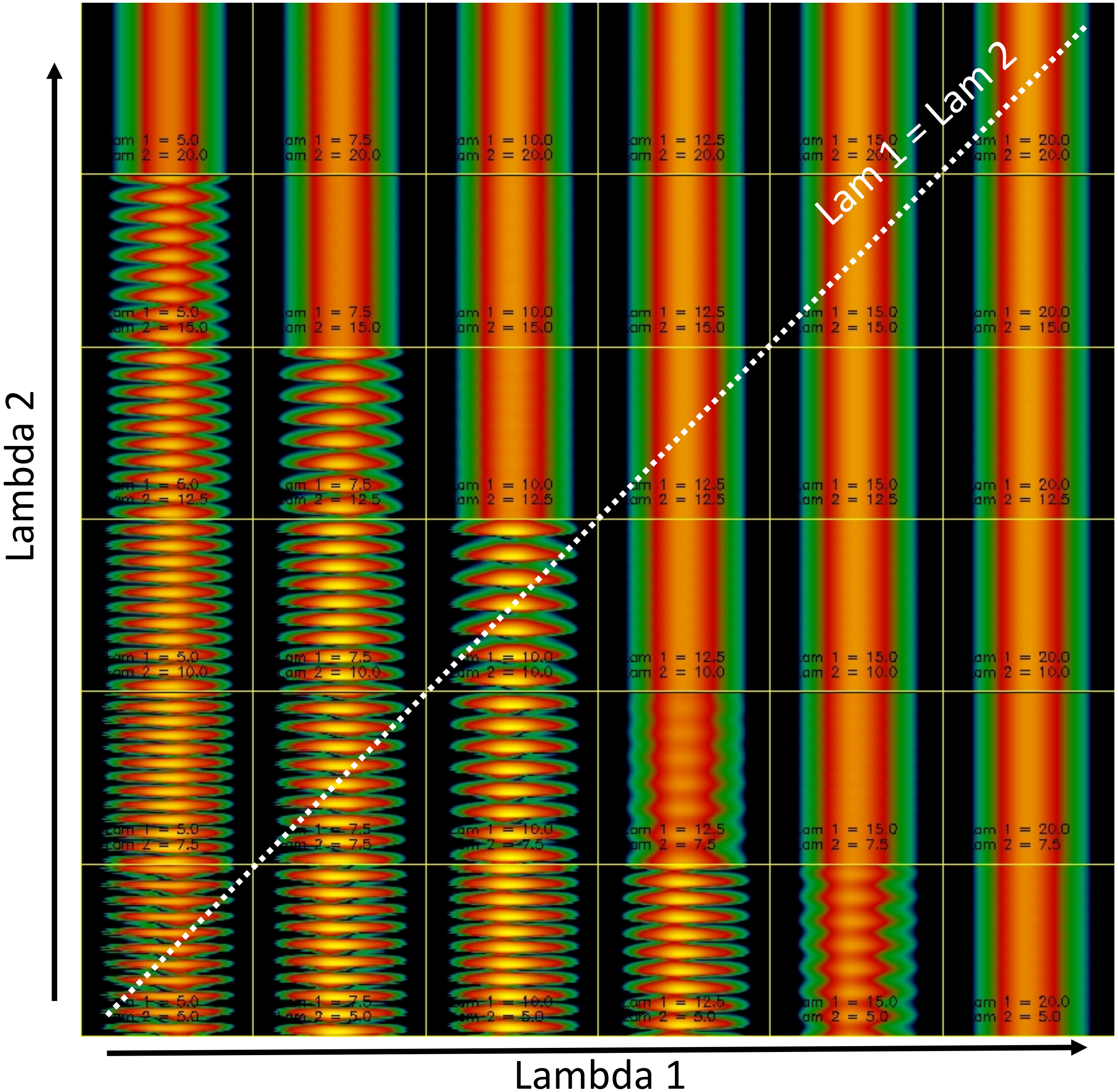
Chose 5 representative loops from the potential field.

Varied heating parameters to find TNE solutions.

H = H1 exp(– s/lambda1) +
H2 exp(- (L-s)/lambda2))

Calculated timelags from simulated lightcurves.

Example Simulation



50 Mm loop

For this set of simulations:
H1 = H2

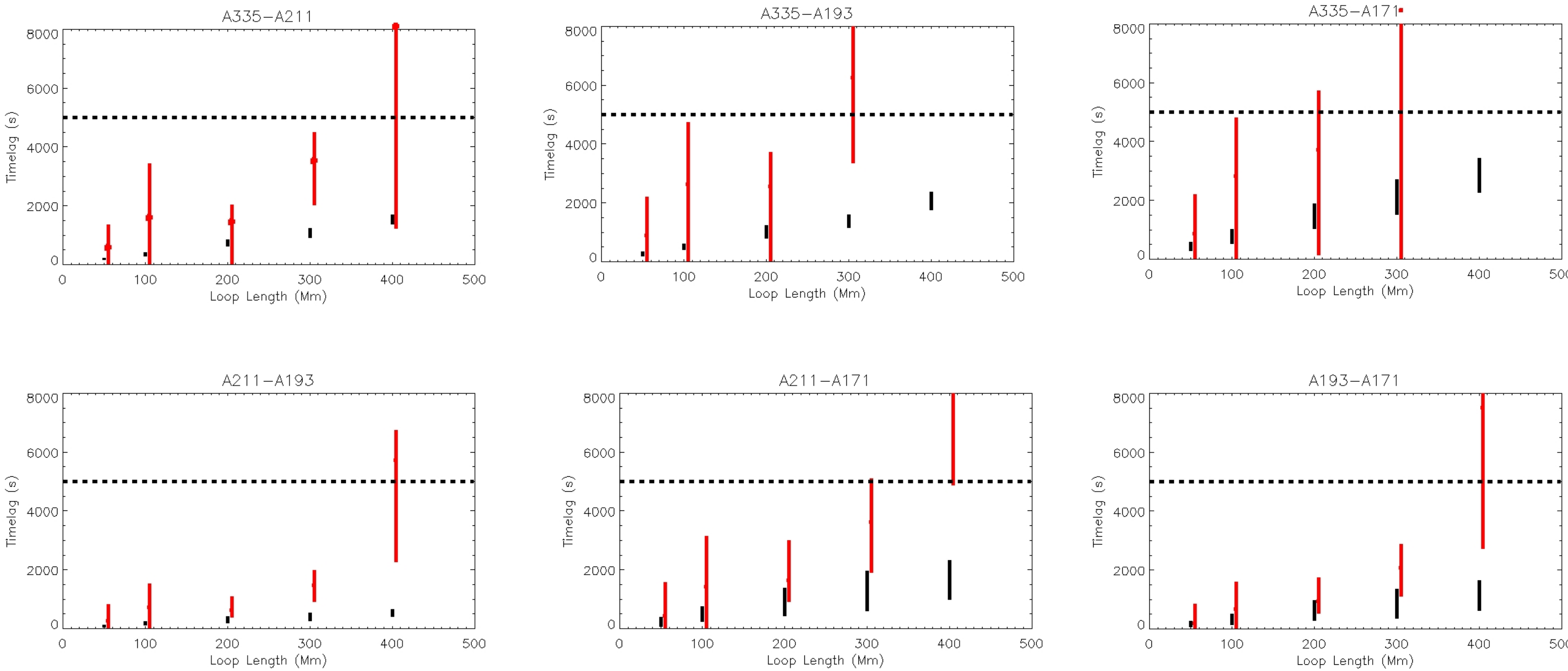
Total energy is constant.

For all the solutions in TNE, calculated lightcurves and timelags.

Footpoint

Impulsive

Results from study



Footpoint heating can generate much longer time delays than impulsive heating.

Conclusions

- Time lag analysis shows very long time lags between all channel pairs.
- Impulsive heating cannot address these long time lags.
- Footpoint heating can produce longer timelags than impulsive heating.
- *What's next: Analyze and model a single active region.*

Reasons for failure

- Time lags do not represent loop evolution
  - *The method could be detecting another evolutionary time scale in the active region*
  - *Multiple structures along the line of sight could be confusing the analysis*
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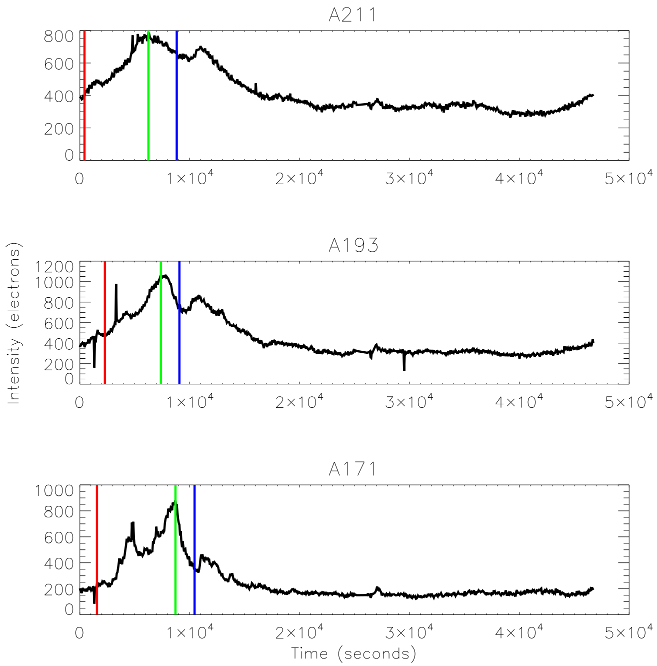
Step 1

- Examine each lightcurve in each pixel
- Define “events” (based on lots of parameters)
- Repeat for every pixel

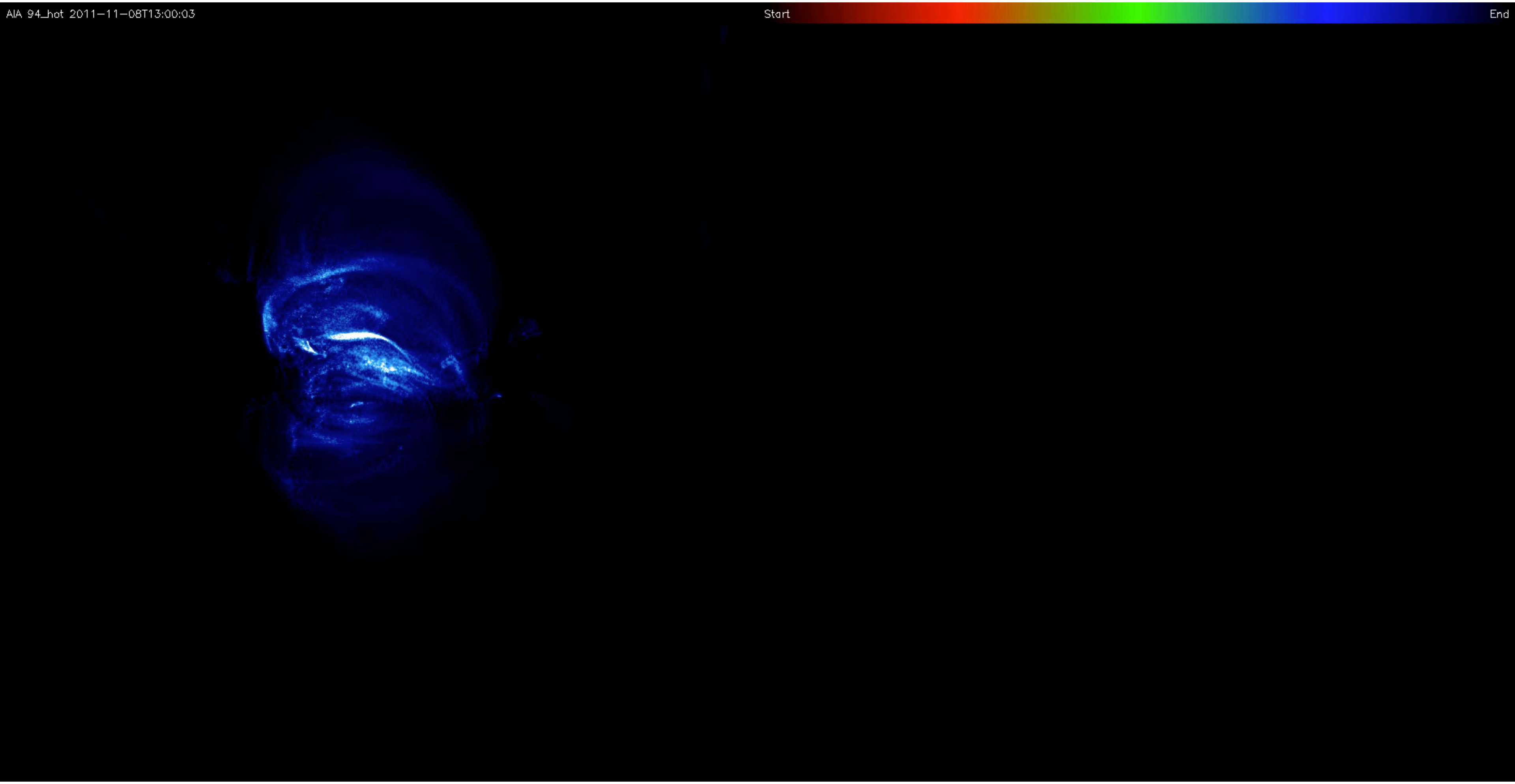
  every channel



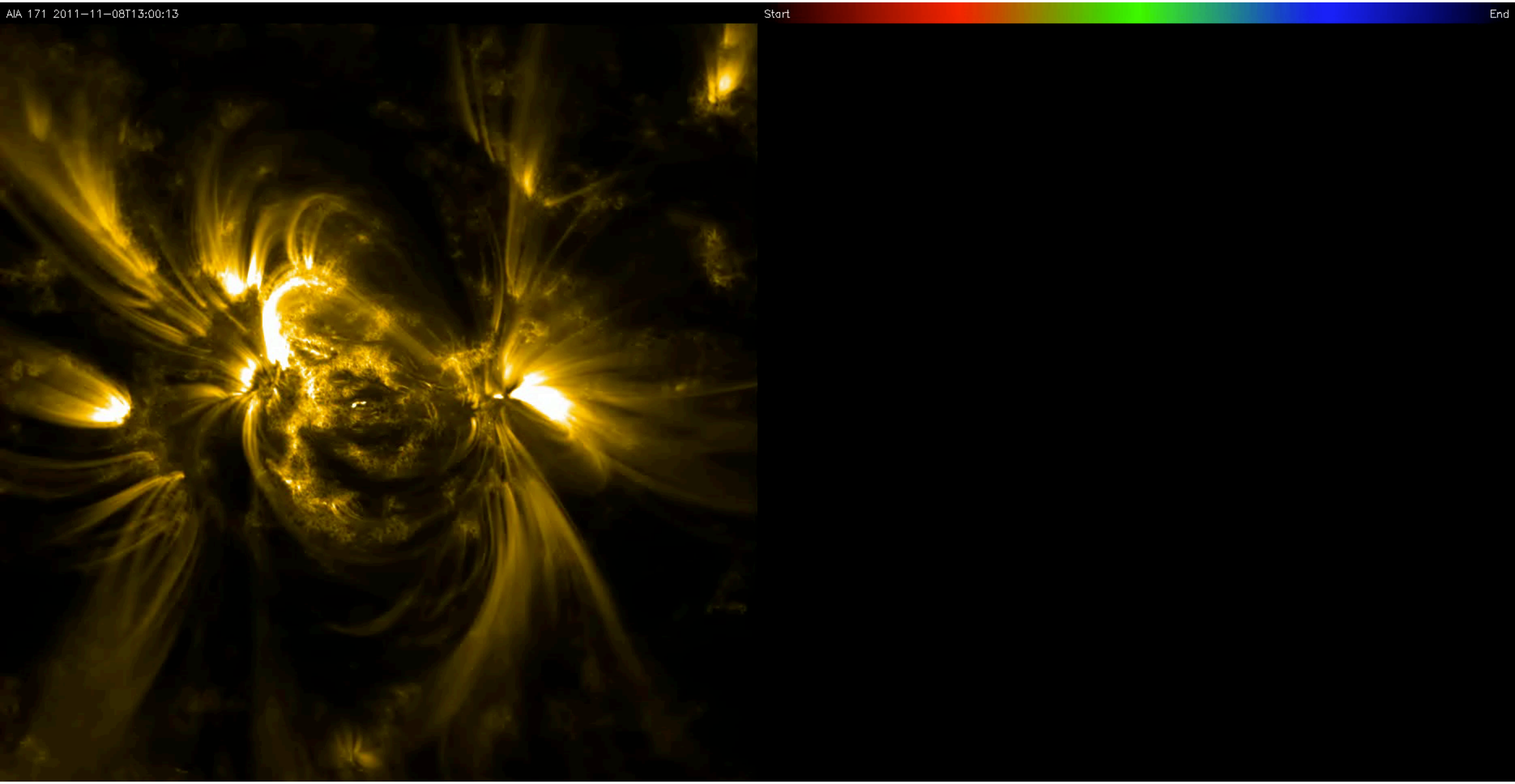
Based on Ugarte-Urra & Warren (2014)

Developed with : Brian Fayok, Chris Bethge, Sanjiv Tiwari

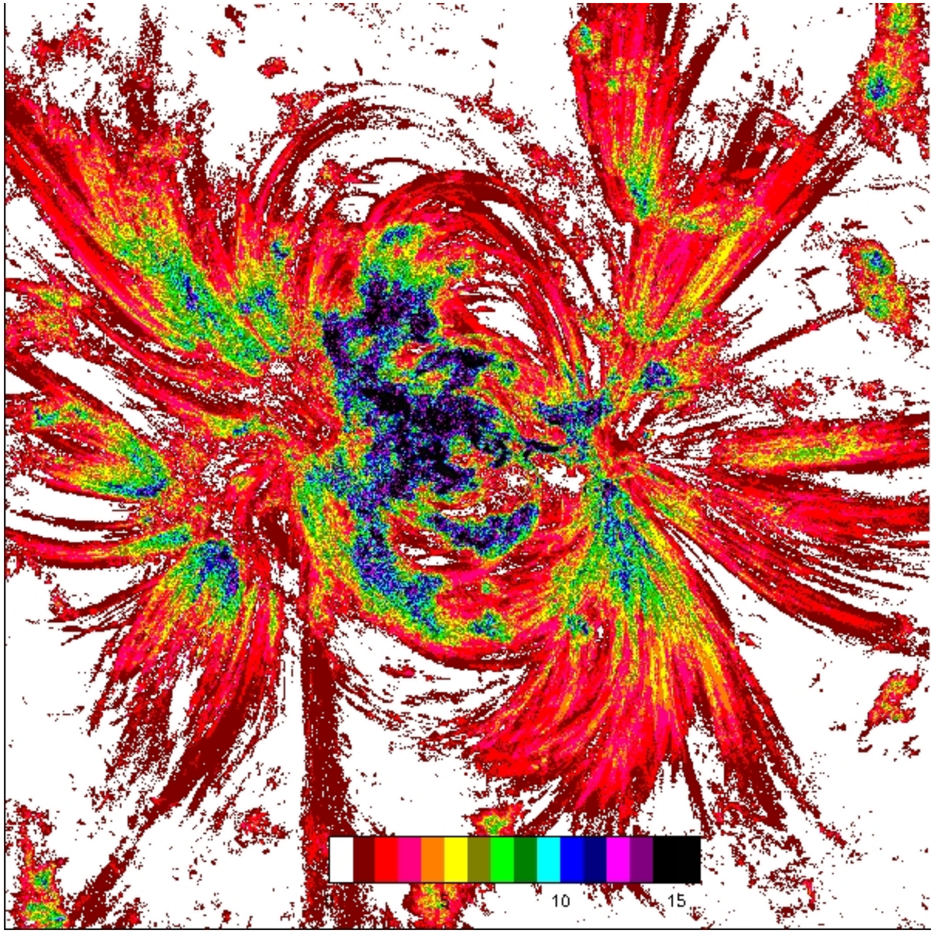
Step 1 – Event movie in Hot 94

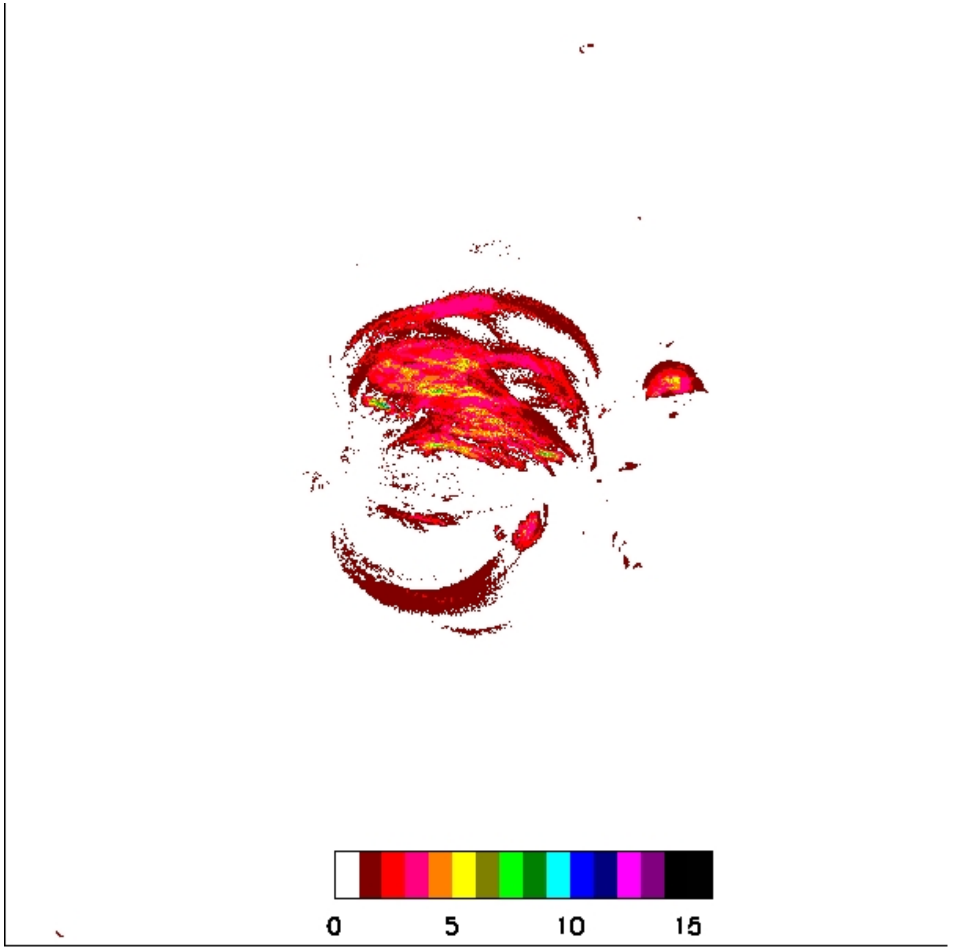


Step 1 – Event movie in 171



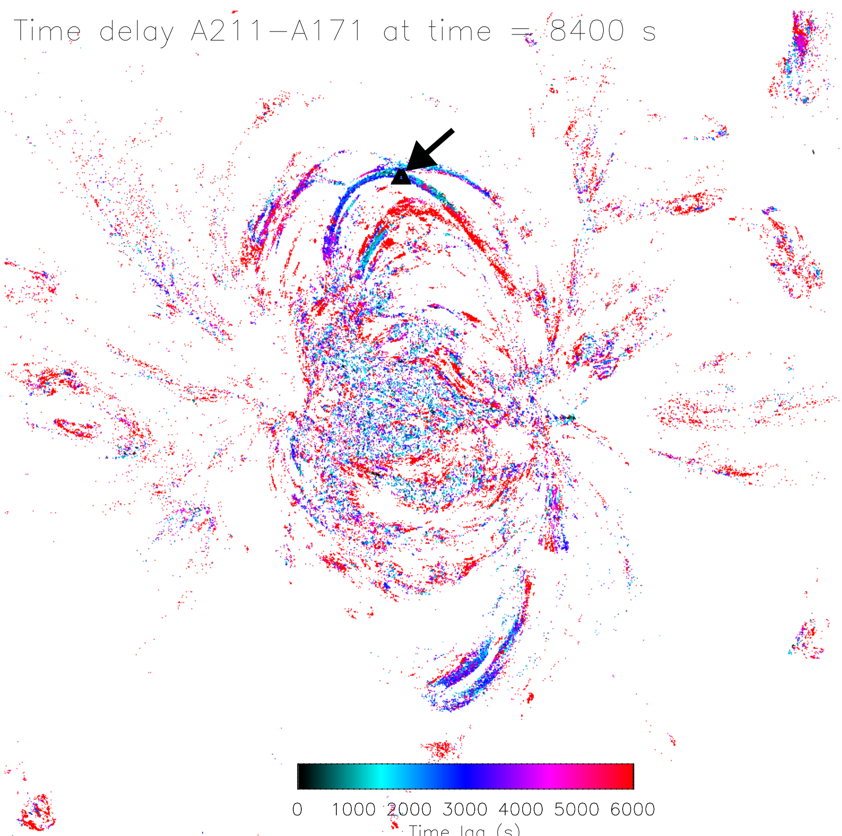
Step 1 – Event statistics

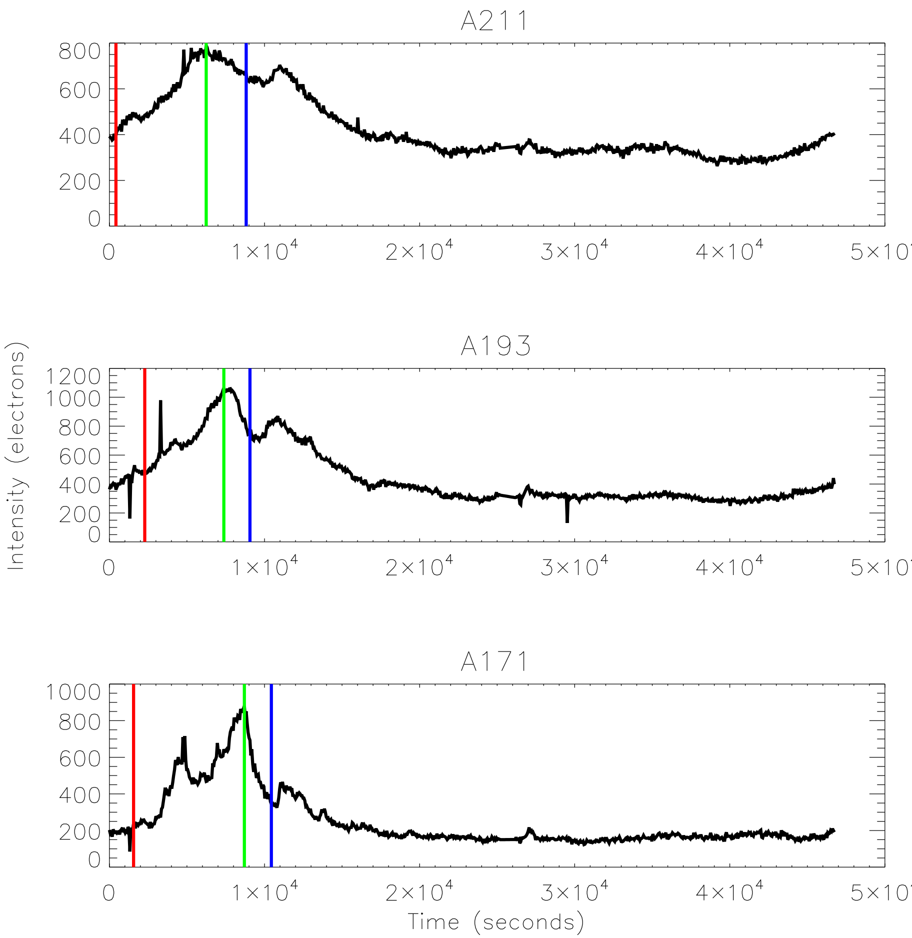




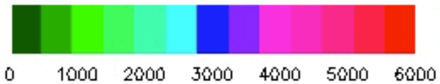
Step 2 – Calculate time delay

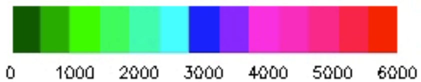
Calculate the delay between the peaks of each event in subsequent channels.





Step 3 – Make time delay movie





What’s next?

- Determine best parameters for event detection in all channels
- Two papers to be submitted this year
  - Code description
  - First results
- Apply to a large scale study of active regions loops
- Determine loop delay times
- Answer the question: Are time delays consistent with impulsive heating or footpoint heating?