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Multi-Stranded Coronal Loops: Quantifying Strand Number and Heating Frequency from Simulated SDO/AIA Observations

Thomas Williams [1,2] (thw38@aber.ac.uk), Robert Walsh [2], Stephane Regnier [3], and Craig Johnston [4]

[1] Aberystwyth University
[2] University of Central Lancashire
[3] Northumbria University
[4] University of St Andrews

Scientific Motivation

Coronal loops form the basic building blocks of the solar corona yet we still do not know their fundamental topology or how they are heated to temperatures exceeding 1 MK. Using an updated numerical scheme, this work investigates whether it is possible to infer the heating rate and number of sub-element strands hidden in current observational data.

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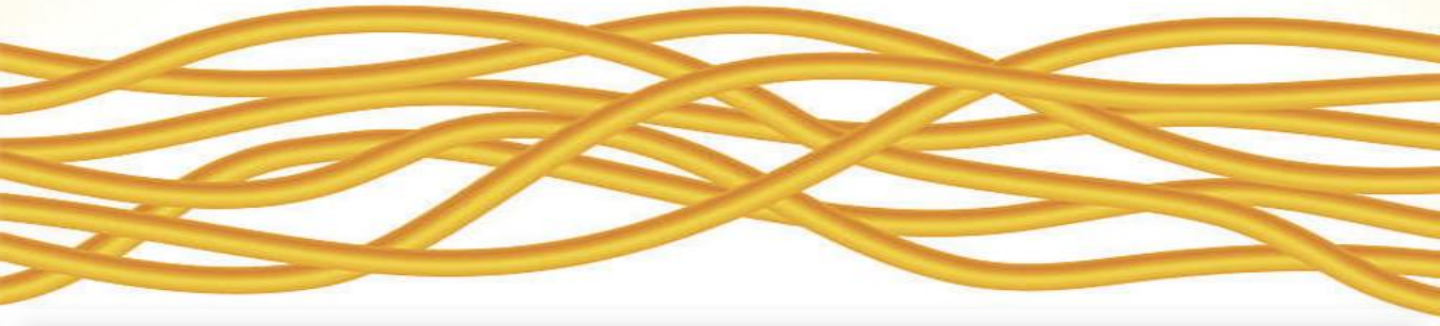
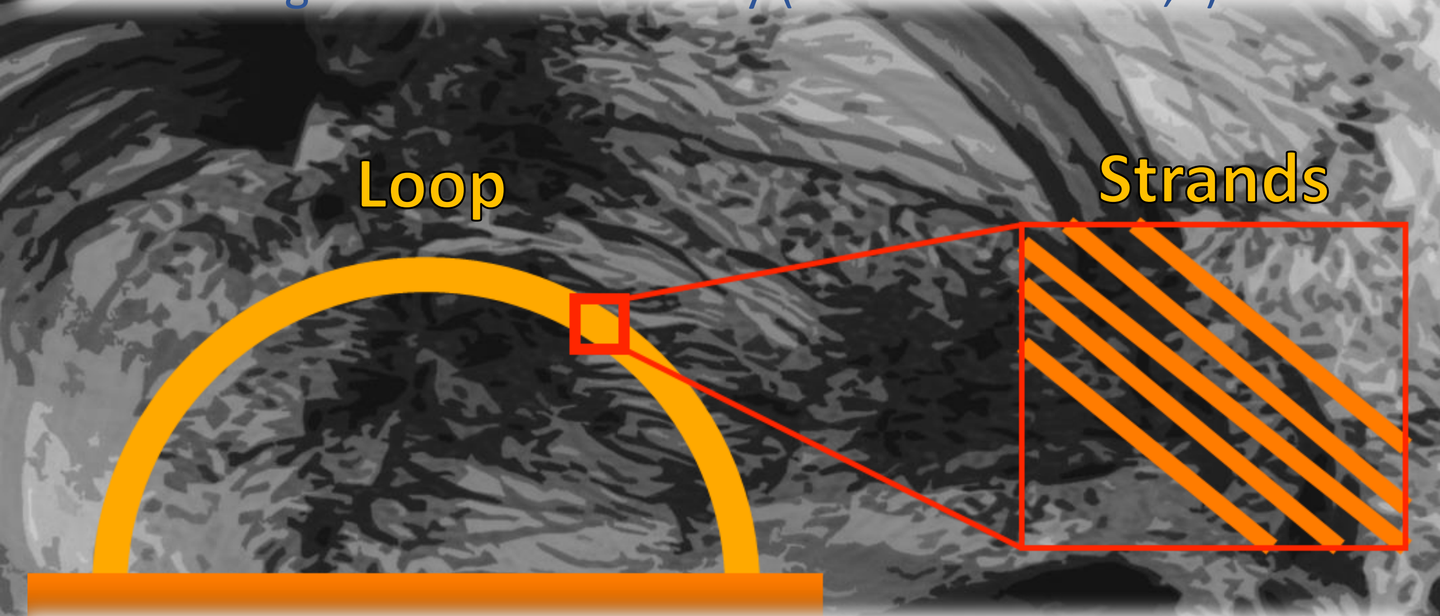


Multi-Stranded Loops Code

The Multi-Stranded Loops code is a 1D hydrodynamic code based on LareXd (Arber+ 2001), which has been adapted for multi-stranded loops (Sarkar & Walsh, 2008,2009). For this study the code has been updated to solve the numerically challenging transition region as a discontinuity (Johnston+ 2017a,b).



Case Study

The simulated loop is 100 Mm long with a 1 Mm radius, giving it a 50:1 aspect ratio. The strand topology is varied such that the loop consists of $n =$ 8, 16, or 64 sub-element strands. Each configuration is subjected to nanoflares with repetition times, $t =$ 250, 500, 750, 1000, 1250, and 1500 seconds. The energy deposition of each nanoflare event is varied between $2.5 \times 10^{23} - 1.2 \times 10^{25}$ erg such that the total energy injected to the loop is roughly constant for all 18 loop configurations employed in the case study.

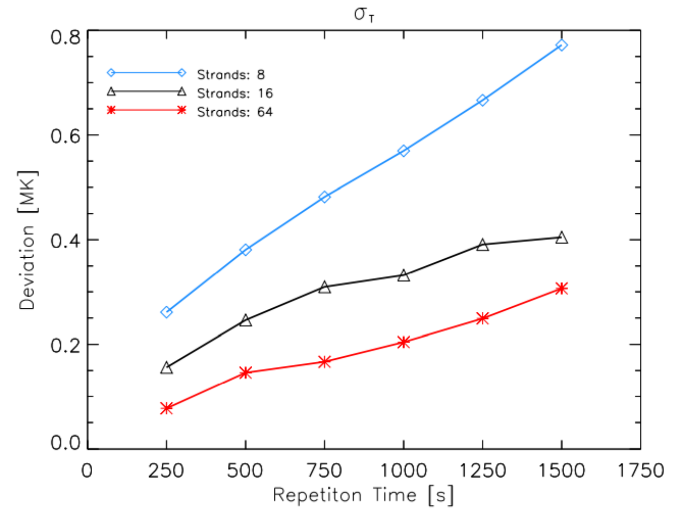


Figure 1: Standard deviation of apex temperature for loops consisting of 8 (*blue*), 16 (*black*) and 64 (*red*) sub-element strands as a function of nanoflare repetition time.

Results & Analysis

Figure 1 shows the standard deviation in apex temperature for the 18 loops during a 6-hour window. The more (less) frequently heated strands result in loops with smaller (larger) variations in apex temperature. When the nanoflare repetition time is fixed, a similar trend is also seen for the number of sub-element strands contained within a loop.

Synthetic AIA light-curves are determined for the 18 loops in the case study. It is found the relatively cooler channels (171, 193, 211) have sensitivity orders of magnitude greater than the other AIA channels and so the following analysis focuses on these channels. Figure 2 shows the relative intensity of the AIA 171/193, and 193/211 channels for all 18 loop configurations. Combining these with the standard deviations of Figure 1, it may be possible to infer heating rates of loops.

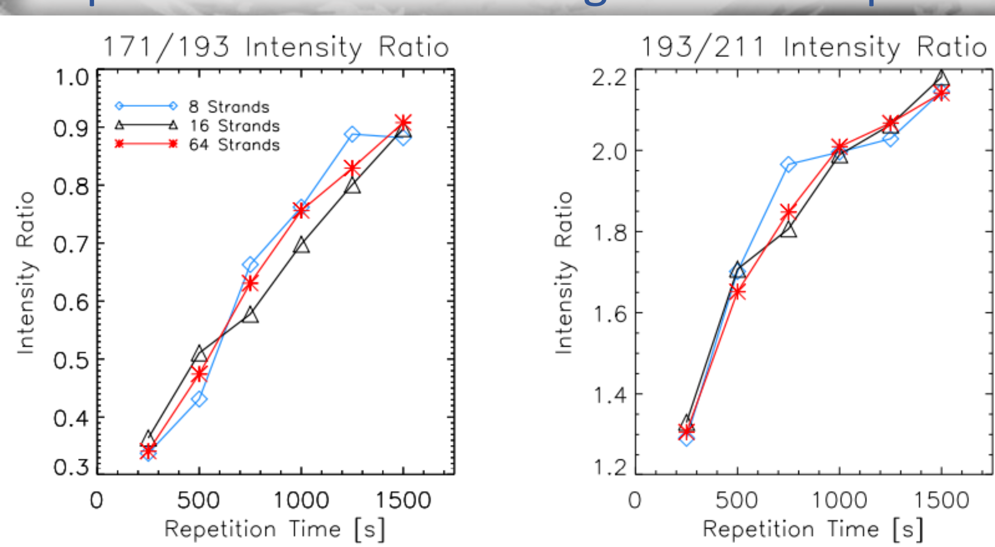


Figure 2: Synthetic AIA 171/193 (*left*) and 193/211 (*right*) intensity ratios as a function of nanoflare repetition time.

For example, consider a real loop with a standard deviation in temperature of 0.4 MK; from Figure 1 there are 3 candidate loops which all have different nanoflare repetition times and/or sub-element strands (Table 1). However, when analysing the intensity ratios of 171/193 and 193/211 it may be possible to infer the sub-element strand topology and the nanoflare repetition time of the real loop by then matching the intensity ratios of the real loop to the synthetic ones.

Table 1: Intensity Ratios for Forward Modelling

No. of Strands	Repetition Time [s]	171/193 Ratio	193/211 Ratio	σ_T [MK]
8	500	0.43	1.71	0.38
16	1250	0.80	2.07	0.39
16	1500	0.90	2.18	0.41

Summary

The results presented in this poster outline that it may be possible to determine the heating frequency and sub-element strand topology of real loops. This may be achieved by taking AIA intensity ratios and standard deviation in apex temperature measurements from spectrometer data over an observational window of several hours and comparing them to loop forward models. The model that most closely matches the intensity ratios and the apex temperature standard deviation is likely to provide a good approximation for the nanoflare heating frequency and the total number of strands within the loop(s).

References

Full-text paper: https://doi.org/10.1007/s11207-021-01848-8
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Johnston+ 2017a: https://doi.org/10.1051/0004-6361/201629153
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