Using Flare Ribbons to Understand Magnetic Reconnection in Solar Flares

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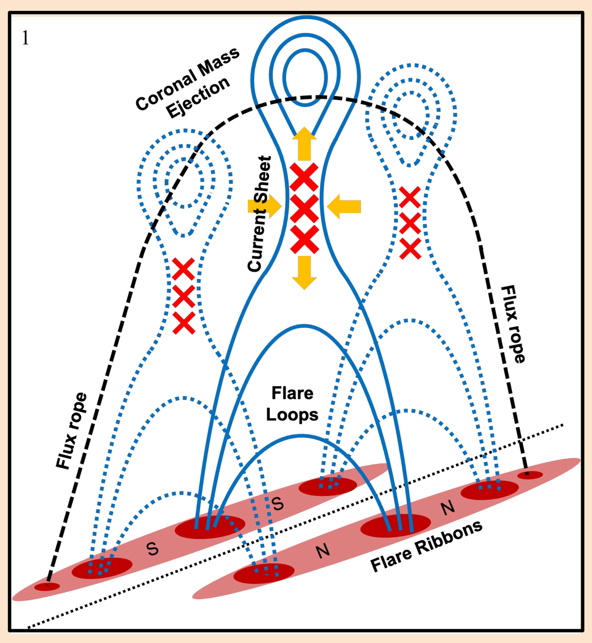
1. Introduction

- Solar flares are the release of magnetic free energy via magnetic reconnection
- Magnetic reconnection is the reconfiguration of the local magnetic field into a lower energy state
- Flare ribbons mark magnetic foot points which can indicate the nature of and speed of magnetic reconnection
- Exact mechanism of reconnection in flares not fully understood; the tearing-mode/plasmoid instability is a key candidate, which predicts bursty/periodic reconnection - however, observational evidence is inconclusive
- Research goal: Examine properties of flare ribbon perpendicular motion of 2 solar flares, using IRIS* data, to search for evidence of bursty/periodic reconnection



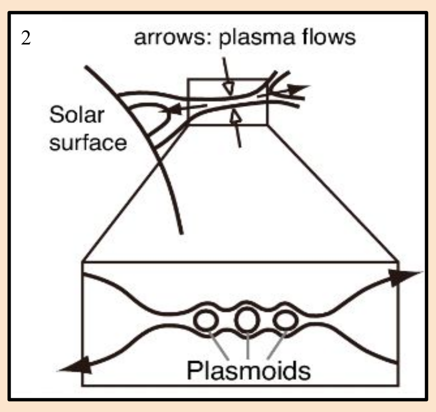


Figure 1: Cartoon showing the standard eruptive model of solar flares
Figure 2: Hillier, A., and Takasao, S., 2022

2. IRIS

- Operated by NASA and Lockheed Martin
- NASA & Lockheed Martin SMEX, launched June 28th, 2013
- Mission ongoing in a geocentric orbit
- UV spectra and imaging of chromosphere

3. Methodology (Flare 1: April 18th 2014)

- Identify a solar flare with clear ribbon separation (moving perpendicular to ribbon length)
- Define cross-section locations parallel to ribbon motion

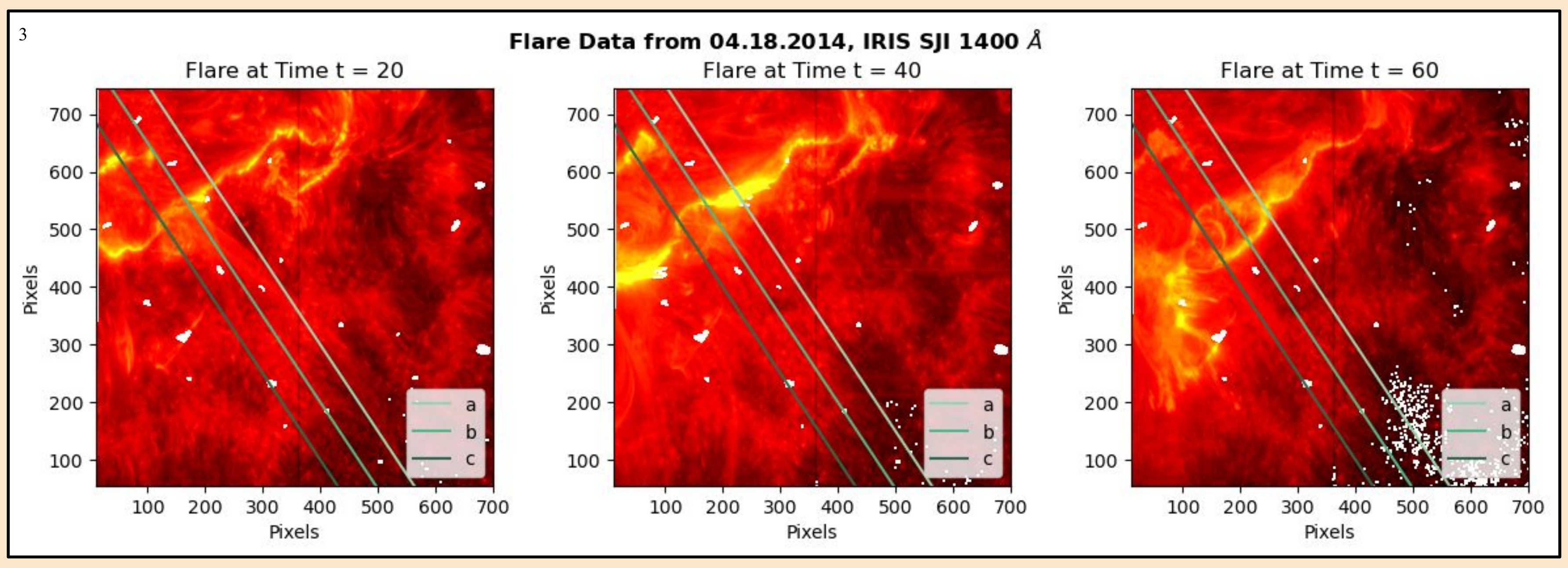
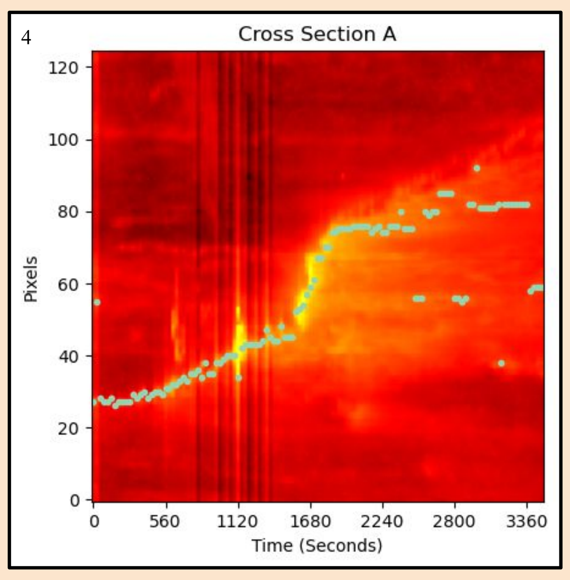


Figure 3: IRIS slit-jaw imager 1400 Å snapshots of flare, cadence = 28 seconds. Colored lines mark locations of cross-sections a-c

- Create stack plots of ribbon evolution along cross-sections
- Identify brightest pixel along cross-section at each time step
- Identify cut-off where pixel tracking breaks down

Figure 4: Example stack plot of cross-section a. Green points mark location of brightest pixel at each time step



- From the stack plot, we can create a time series (for each cross-section) of:
  1. Intensity of brightest ribbon pixel
  2. Position of brightest ribbon source pixel
  3. Velocity of the brightest ribbon source
- These time series are presented below in Figure 5

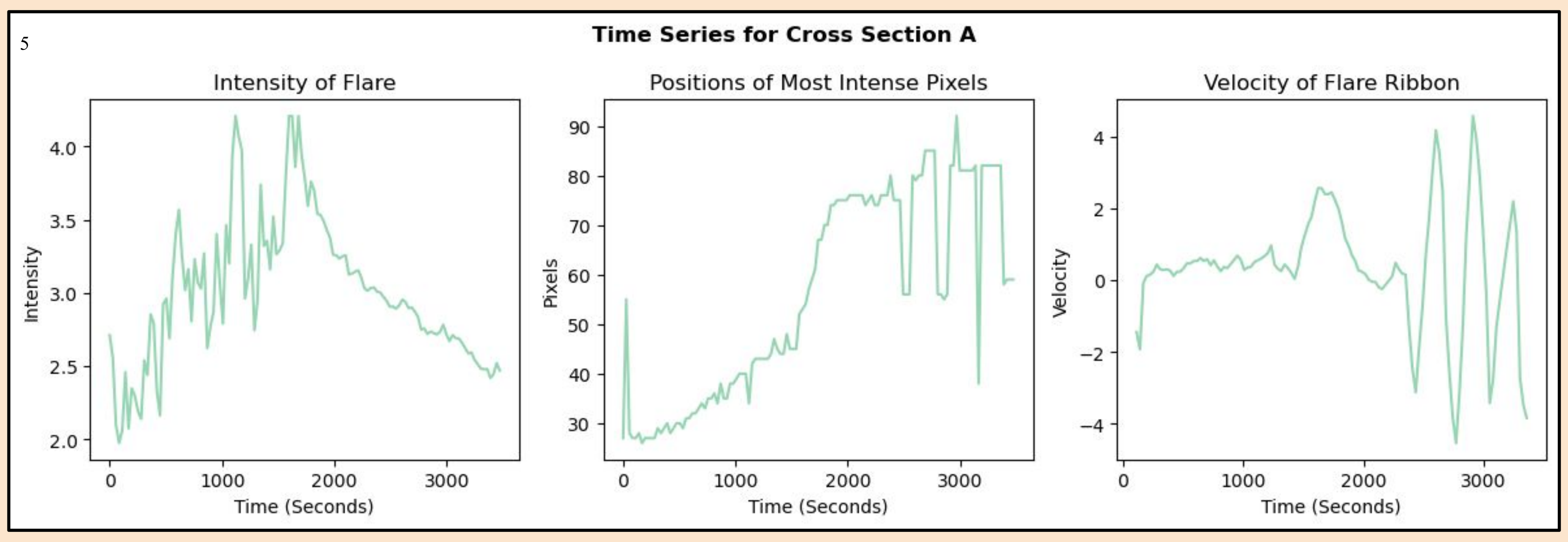


Figure 5: Time series (for cross-section a) of maximum intensity, ribbon position and velocity

3. Methodology (continued)

- To analyze periodicity in the time series we:
  - Detrend that data by subtracted a 500-second moving average (presented in Figure 6)
  - Multiply by a Hanning Window
- Future work is needed to minimize the impacts of occasional discontinuities in the maximum intensity tracking, which influence position and velocity plots.

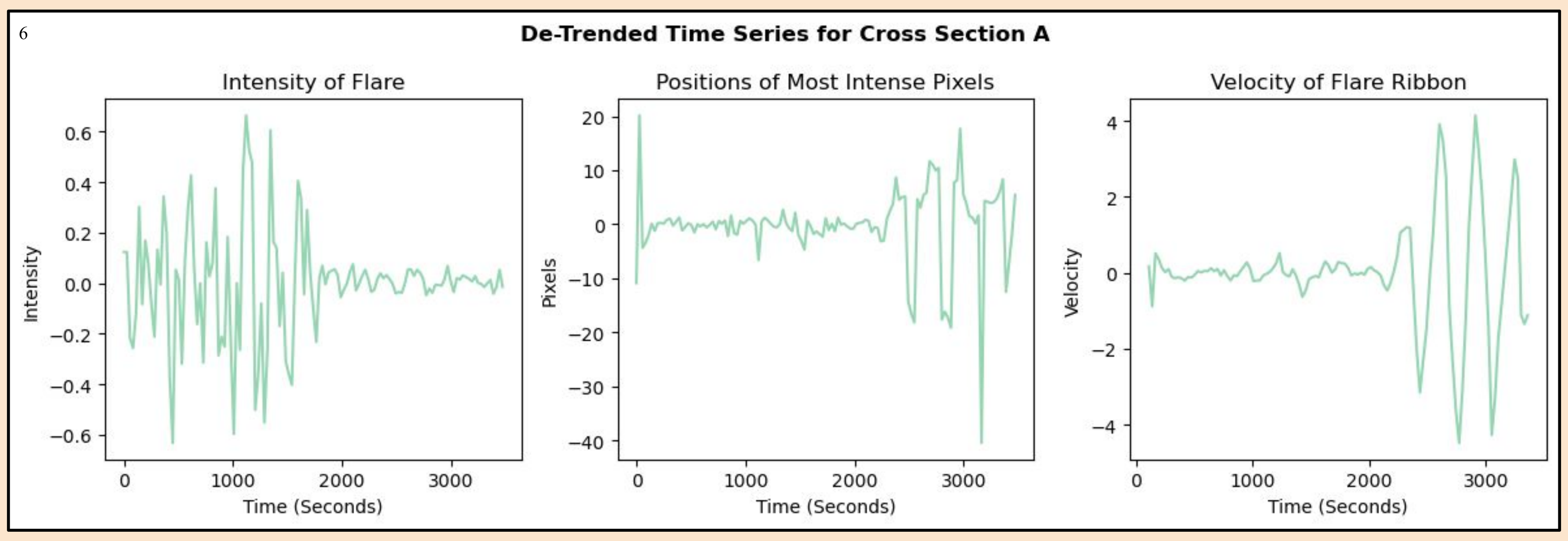


Figure 6: Detrended Time series (for cross-section a) of maximum intensity, ribbon position and velocity

4. Results & Discussion for Flare 1

- By calculating the Fast Fourier Transform of the 3 variables for each cross-section, we discover consistent periods of 250 - 320 seconds, shown below

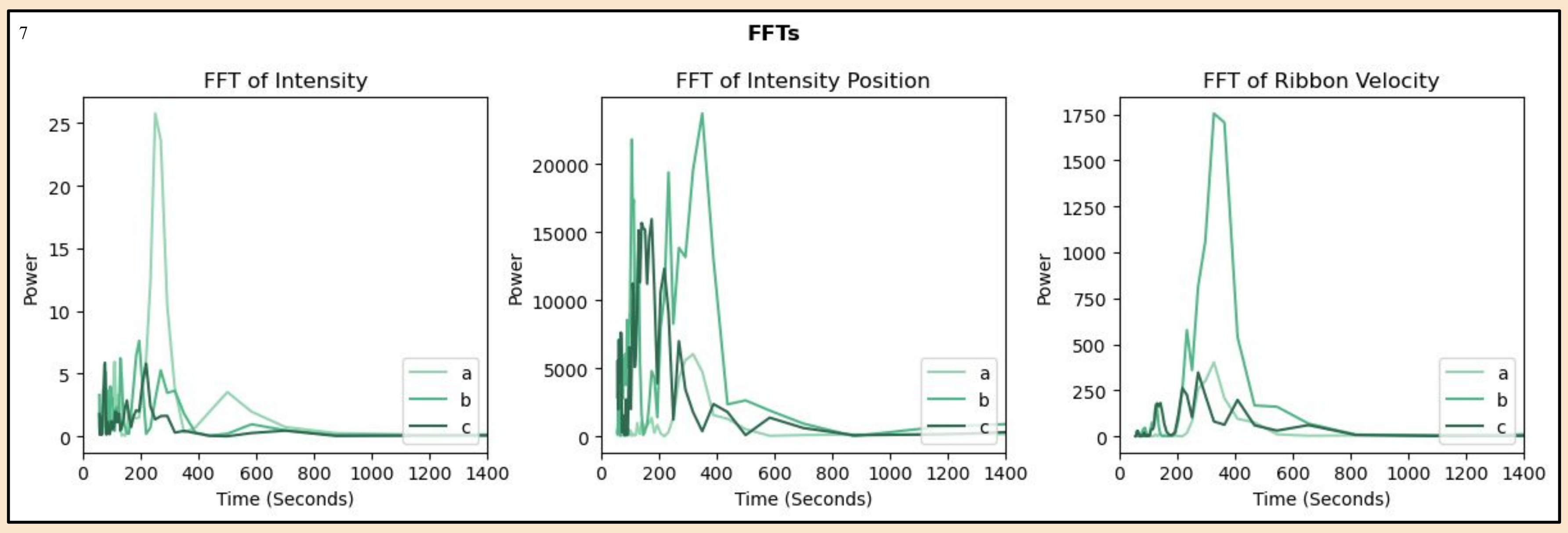
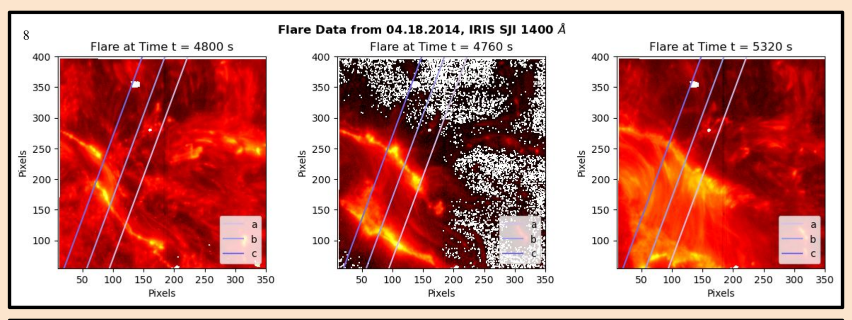
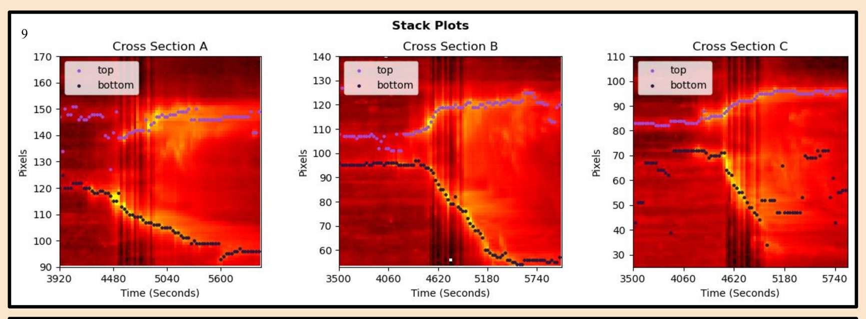


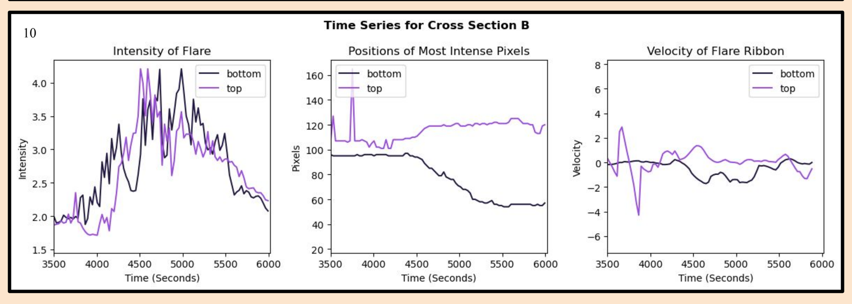
Figure 7: FFTs of detrended intensity, intensity position, and ribbon velocity

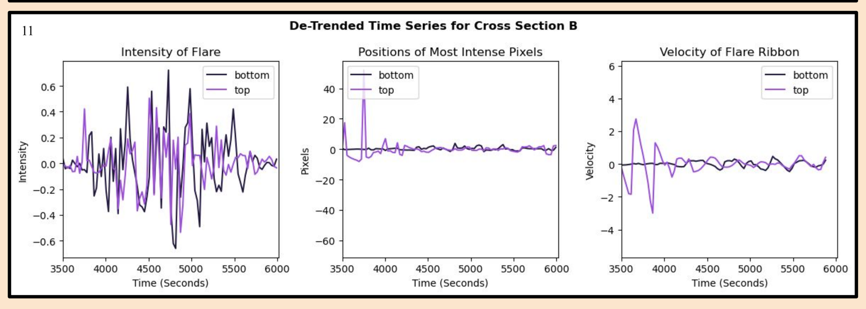
- These results are consistent with published periods found in the same flare within hard X-rays and ribbon widths (Naus et al, 2022)
- This is consistent with evidence of bursty/periodic reconnection in solar flares, but the work must be expanded to a greater flare list

5. Preliminary Analysis, Flare 2 (March 30th 2022)

- Two ribbons in the field-of-view allow us to independently verify periods for each ribbon
- Further work is needed in smoothing discontinuities within the bright pixel tracking for each cross-section
- FFT results pending, following this smoothing
- Figures 8-12 show the stack plot, time-series and detrended time-series of both ribbons for flare 2.





Figures 8-11: Repeats of Figures 3-6, instead for Flare 2, applying the same methodology.

6. Future work

- Strengthen methodology by smoothing brightest pixel tracking
- Explore phase relationship between intensity and velocity oscillations
- Complete analysis of Flare 2 (30th March 2022)
- Apply methodology to further flares, including higher cadence IRIS observations

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