Probing Current Sheet Instabilities from Flare Ribbon Dynamics

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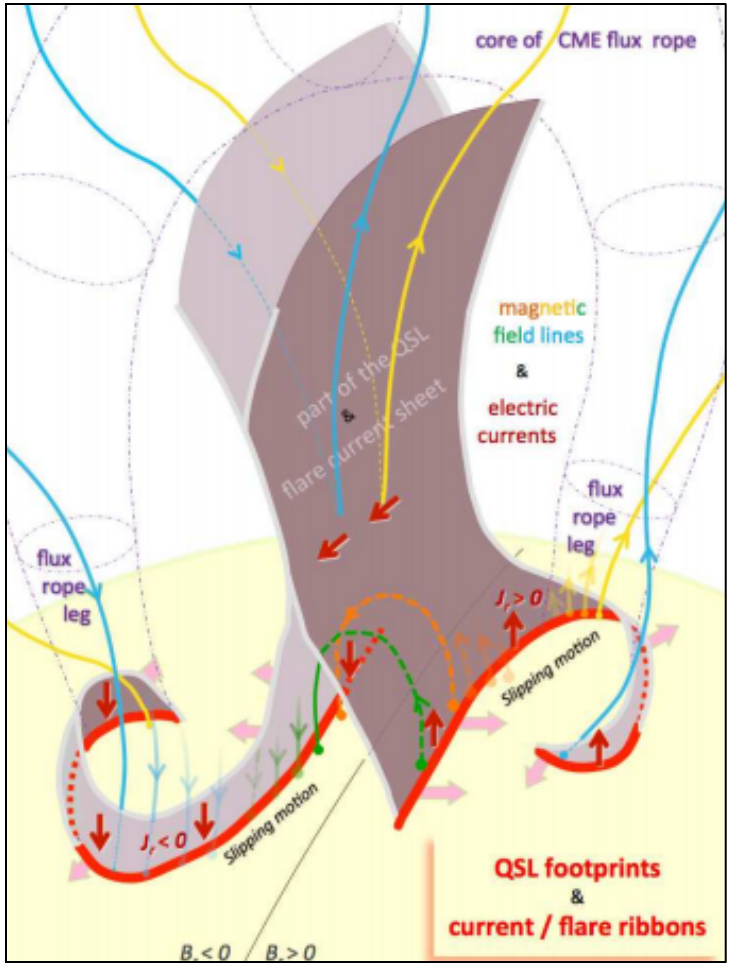
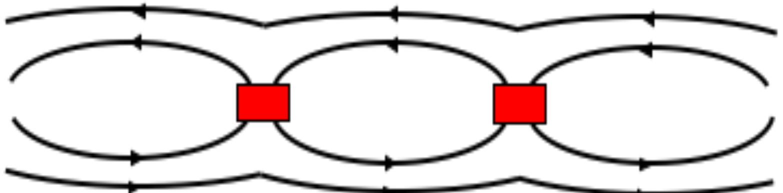
Ribbon Insights into Flare/Eruption Dynamics

- Due to their magnetic connectivity, behaviour of flare ribbons must reflect processes in the flaring current sheet region (*Forbes & Lin 2000*).
- Understanding current sheet processes, such as plasma instabilities and their relationship to turbulence, are needed to explain the breakdown of MHD required to cause observed fast reconnection.
- The tearing mode instability, believed to produce a turbulent cascade of reconnection through fragmenting and coalescing magnetic islands, is one key process of interest.

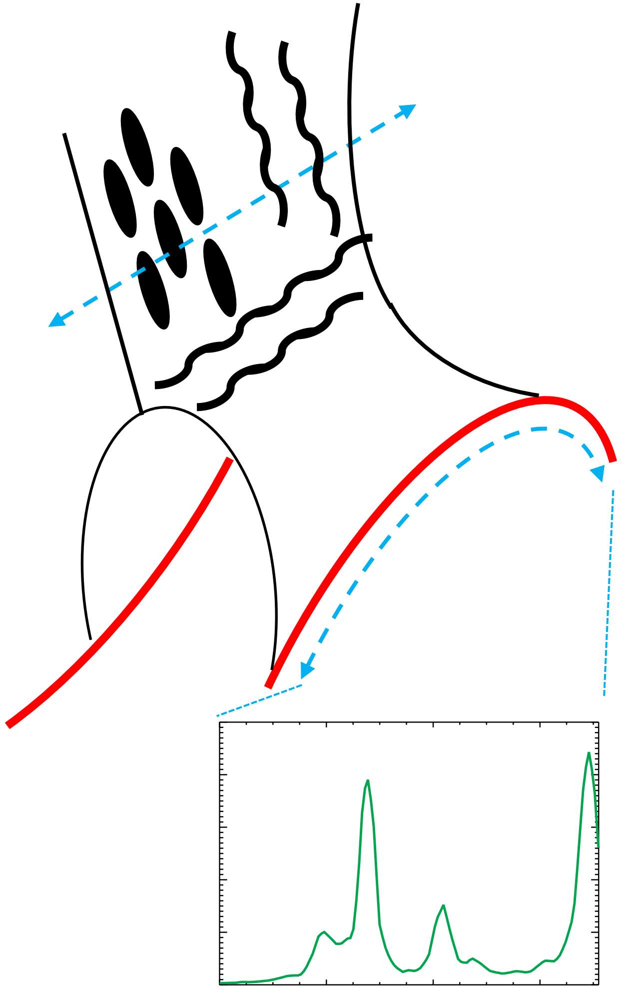


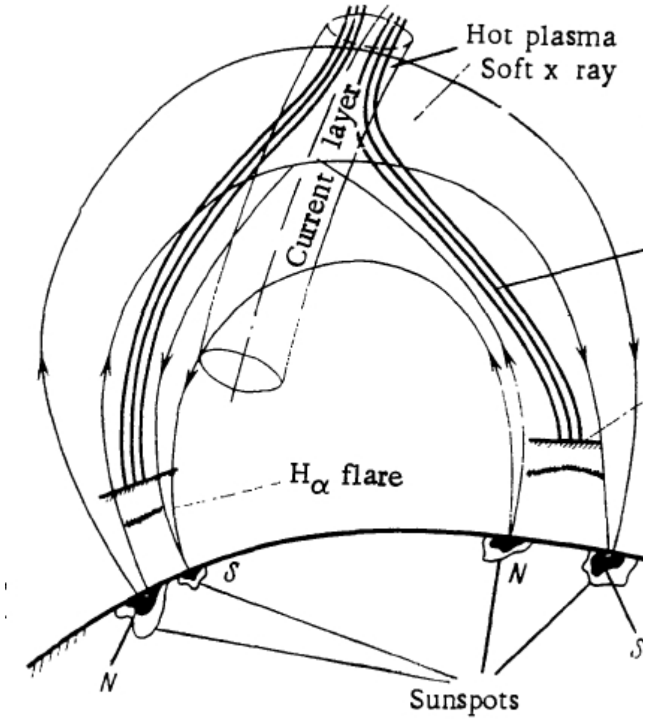
Janvier et al 2014



Our Project Aim

- Search for growth and timing of key spatial scales along the flare ribbons of a small, *simple* event.
- Compare observed parameters with those predicted by instability theory, and to the timing of plasma turbulence and flare onset.

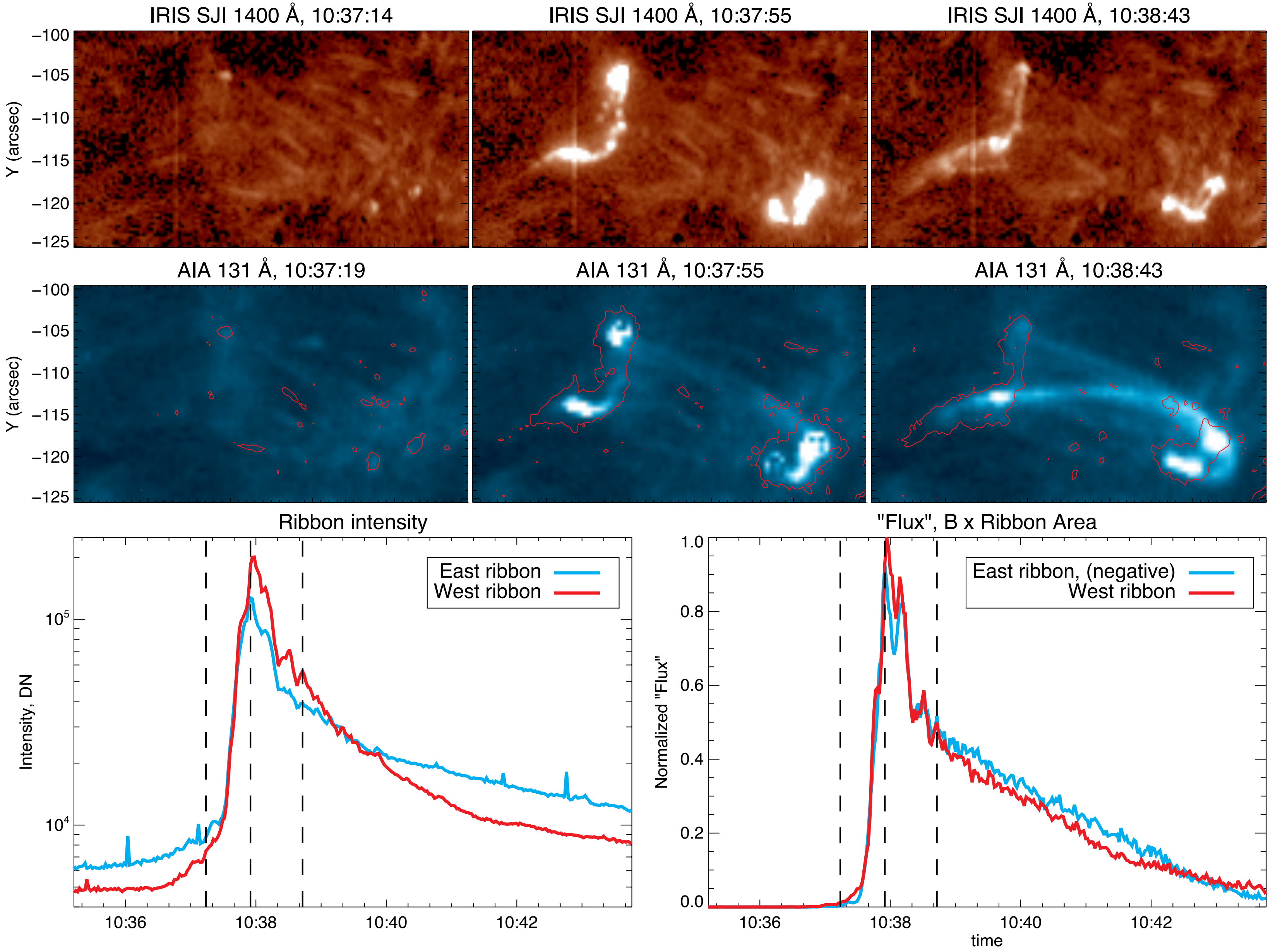




Pikelner et al 1977

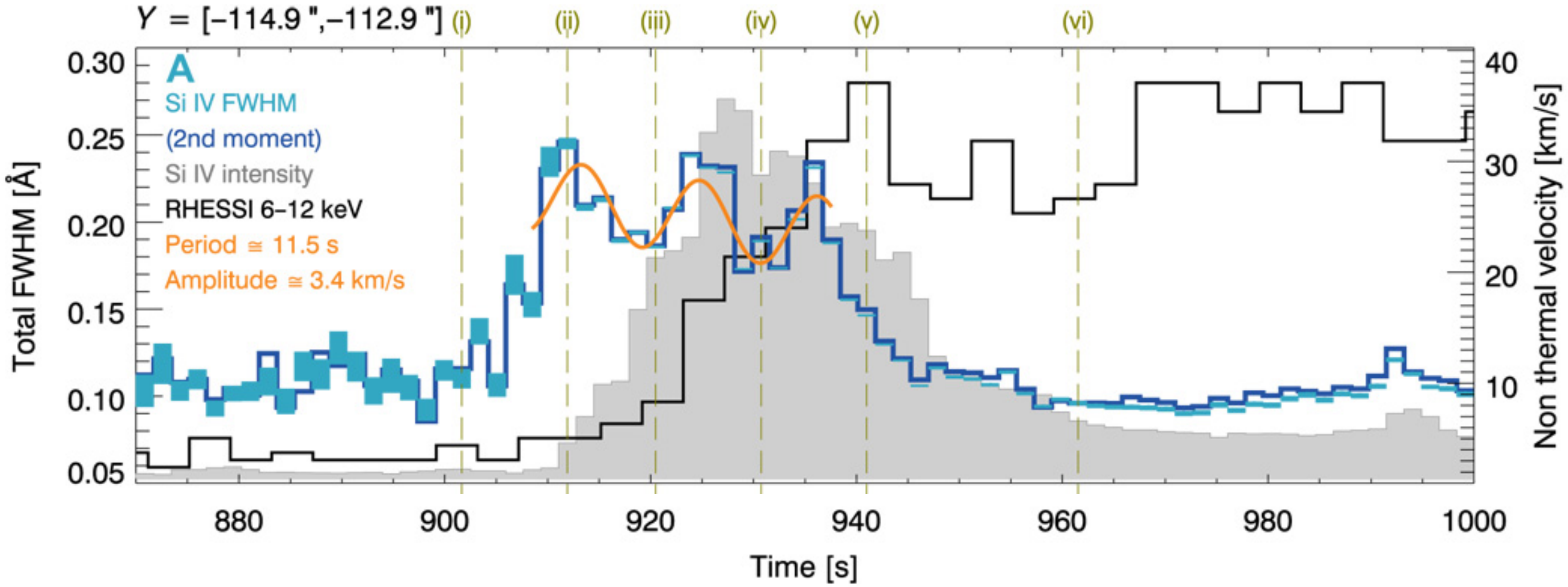
6th Dec 2016 – B-class flare

- IRIS SJI 1400 Å, 1.7 s cadence.
- Ribbons brightening cotemporally, followed by the appearance of loops in AIA 131.
- BxA equal in both ribbon over impulsive phase.



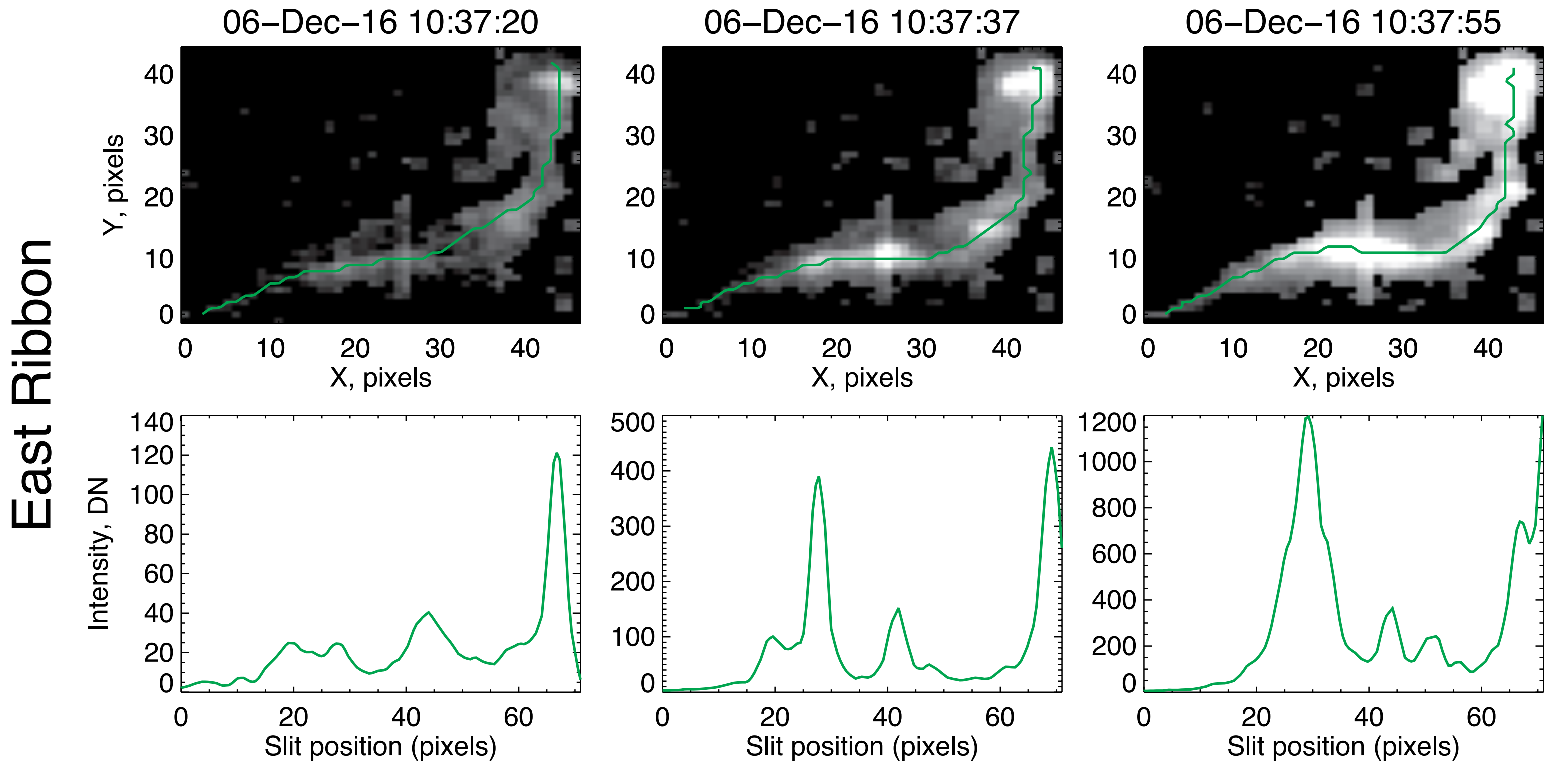
6th Dec 2016 – *Jeffrey et al 2018*

- Non-thermal velocities rise precedes ribbon intensity enhancement.
- Suggests plasma turbulence occurs before plasma heating and flare onset.
- The ongoing presence of turbulent signatures mean the driver of turbulence persists for longer.

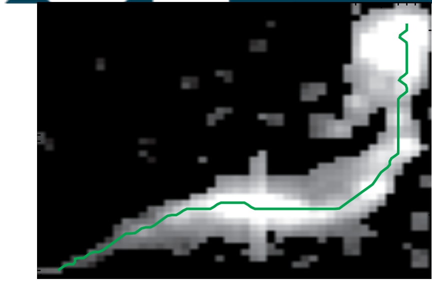


Ribbon Tracking

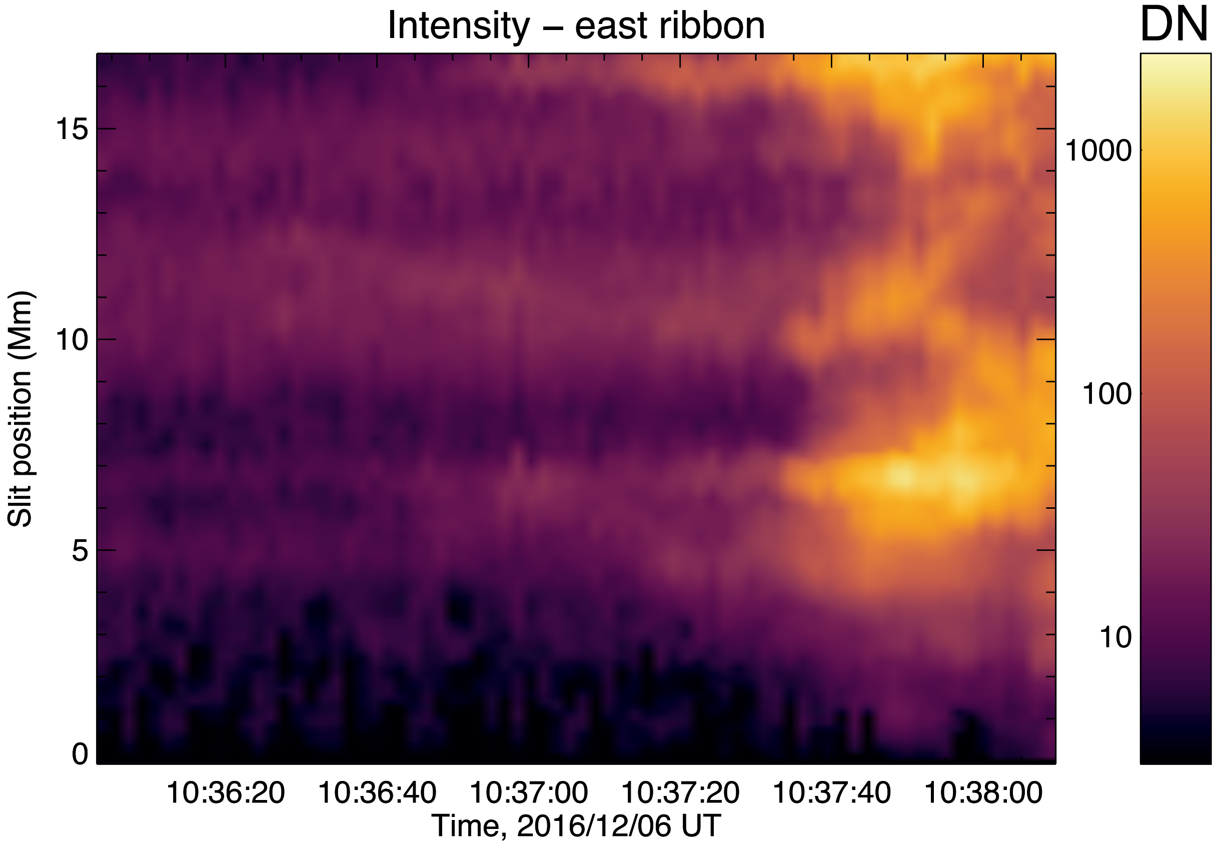
- Track a central slit along the evolving ribbons, plotting the mean intensity around each pixel along the centroid slit.
- Process the signal, and calculate the spatial Fast-Fourier Transform for each time step.



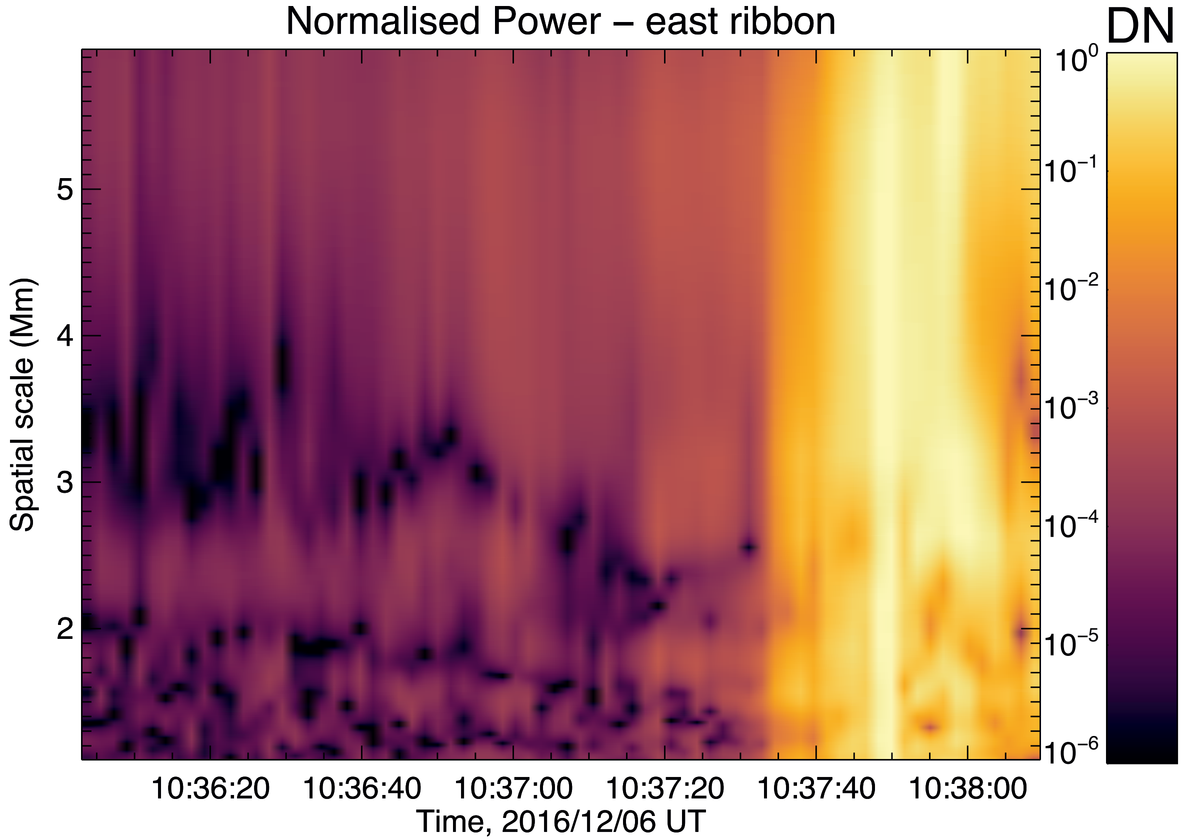
Intensity & Power Evolution



- We produce a stack plot of spatial FFTs at each time step.
- We detect power growth across the wavelength range, of up to 6 orders of magnitude.
- Growth start-time appears to vary with wavelength.



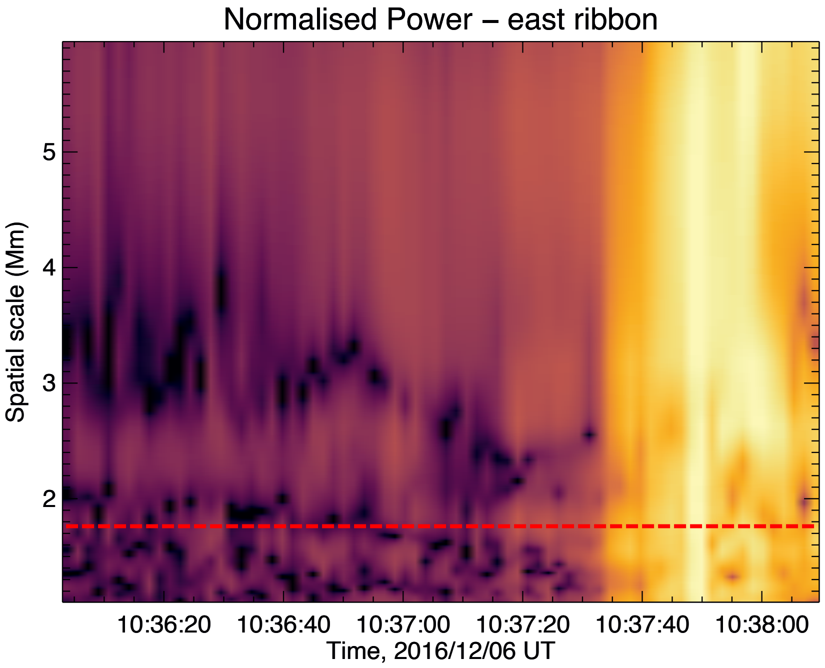
Intensity – east ribbon



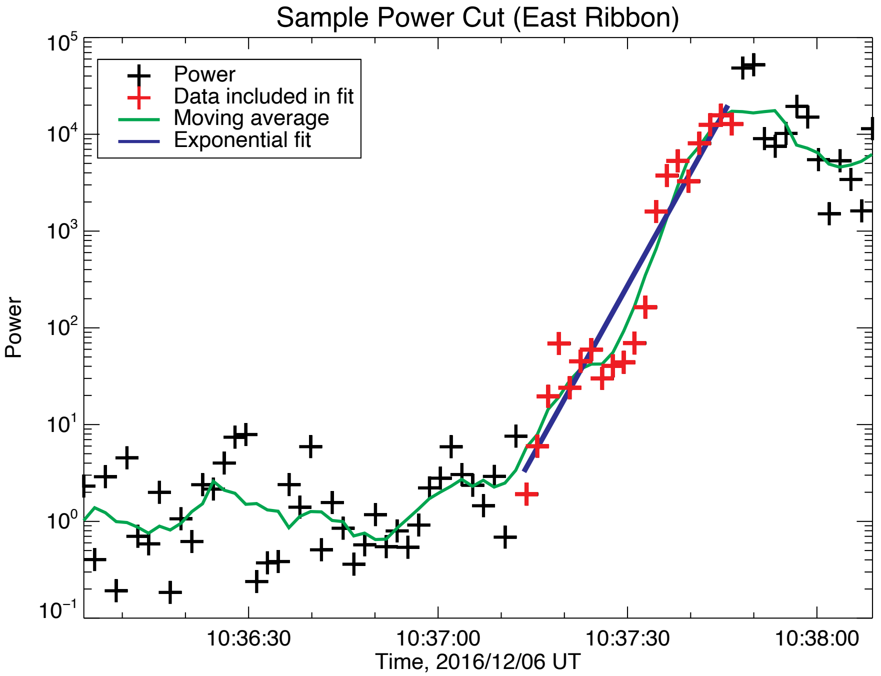
Normalised Power – east ribbon

Instability Growth Rate

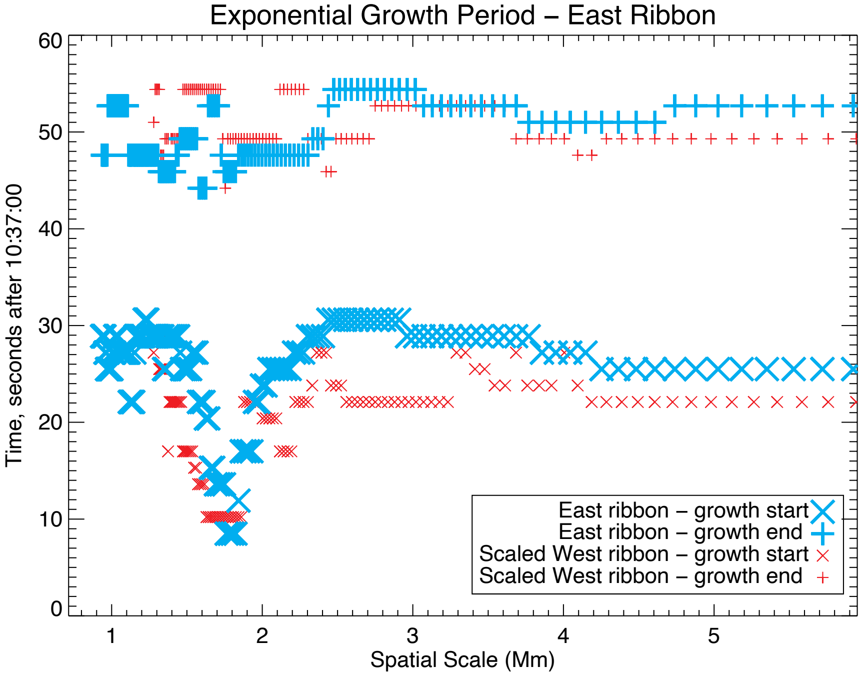
- We take a horizontal cross-section, to sample the time evolving power and determine the rate/duration exponential growth at each specific spatial scale.
- We detect evidence of cascade & inverse cascade from key wavelength.



Normalised Power – east ribbon



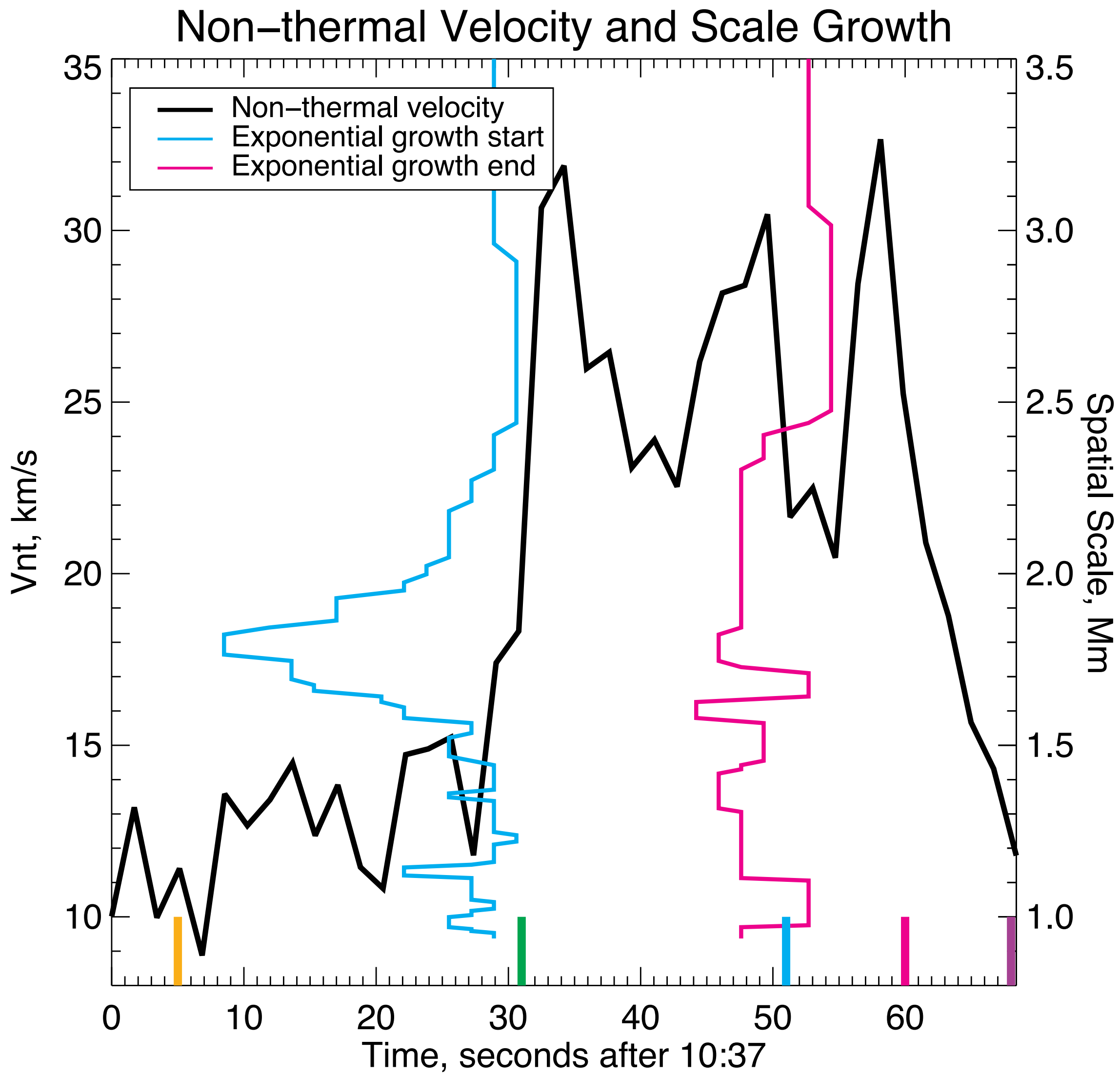
Sample Power Cut (East Ribbon)



Exponential Growth Period – East Ribbon

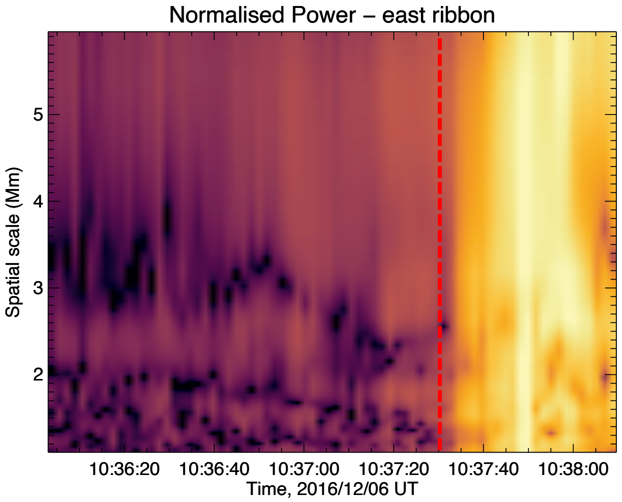
Instability Relationship with Turbulence

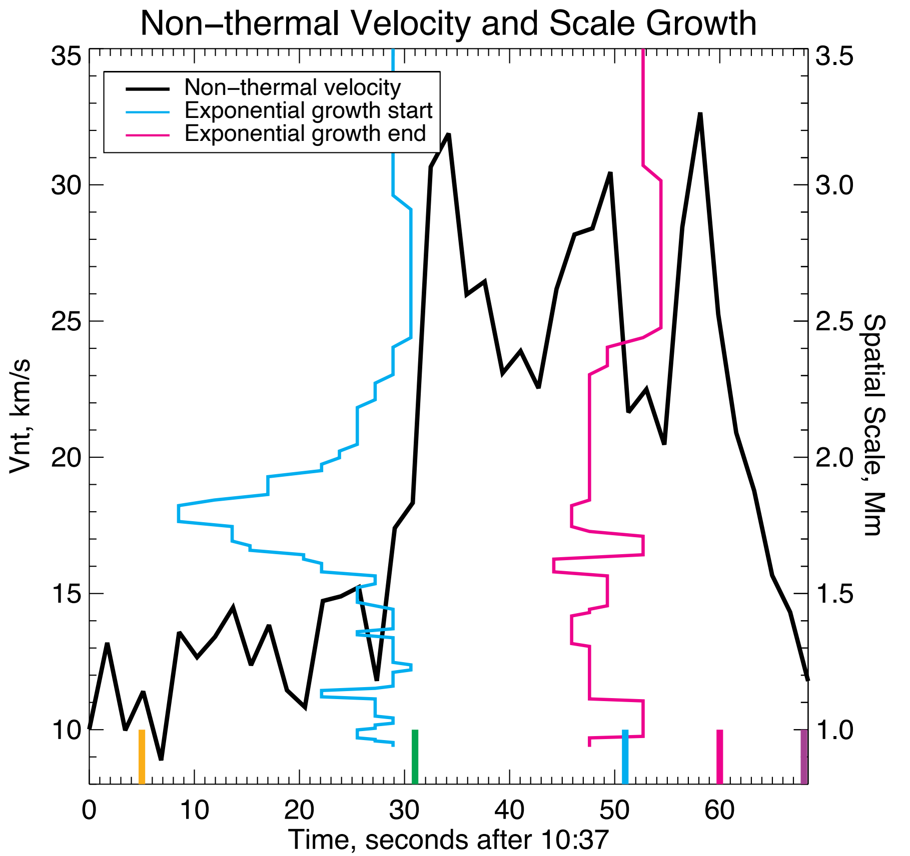
- Exponential growth rates, and (inverse) cascade are suggestive of tearing mode instability.
- Growth precedes non-thermal velocity turbulence signatures (Jeffrey et al 2018) by around 15 s.
- Indicates that plasma turbulence is driven by tearing mode instability for this confined event.

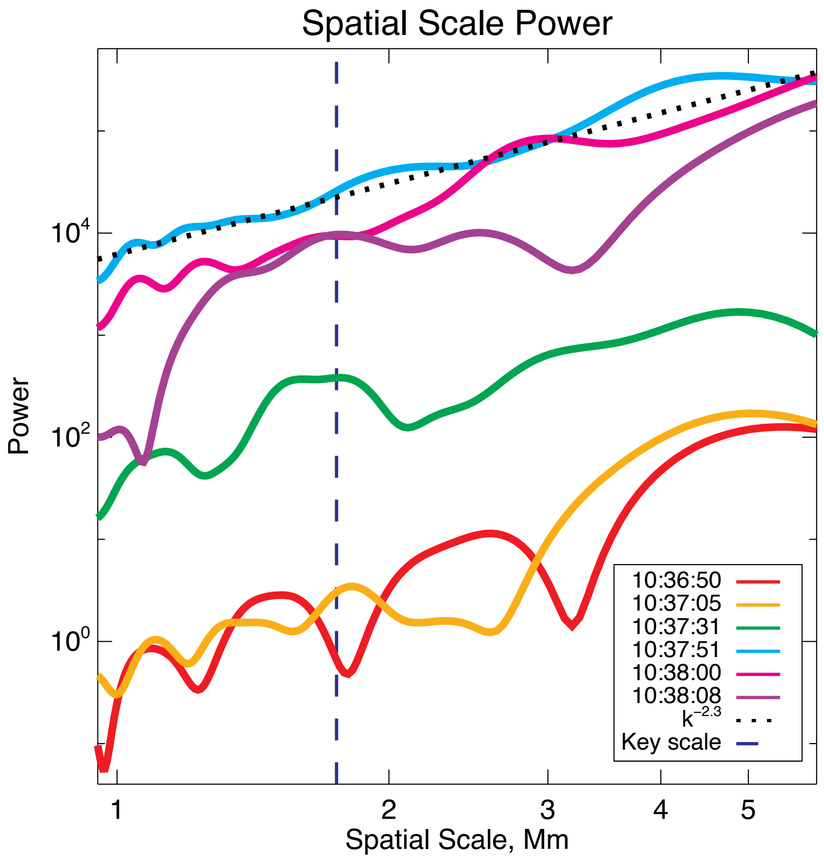


Spatial Scale Power Law

- Spatial scales reach an end state with a power law of 2.3, consistent with simulations of tearing-induced turbulence (e.g. Dong et al 2018).







Conclusion

- Behaviour of spatial scales in flare ribbons consistent with the presence of the tearing-mode instability in flaring current sheet.
- Timing suggests that tearing-mode instability triggers plasma turbulence through a cascade and inverse cascade, producing a spatial power law of 2.3.
- This sheds light on the complex interplay and feedback between reconnection, turbulence and current sheet disruption at flare onset.

- Work has been accepted this morning in ApJ – will upload to arXiv (and add to ADS library) this week!

https://ui.adsabs.harvard.edu/public-libraries/4bO5hFMySK2fC_l3a8OmCQ