Time evolution of the chromospheric heating and evaporation process

Case study of an M1.1 flare on 2014 September 6

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[Tian et al. 2015, arXiv:1505.02736]

IRIS sit-and-stare flare observations

- IRIS observes Fe XXI λ 1354.1, formed at 11 MK
- Ideal for studying evaporation of hot plasma during flares

- 0.3" spatial resolution → individual flare kernels resolved

- Sit-and-stare gives best time resolution (~ few seconds)

Examples

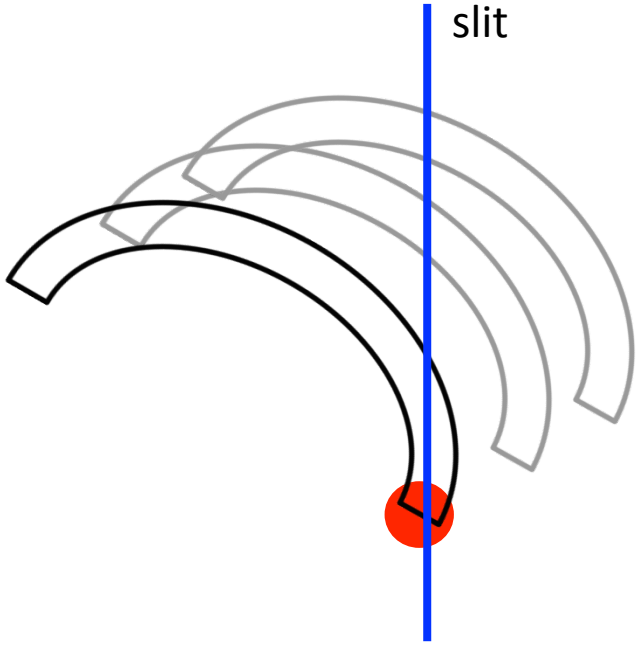
1. 6-Sep-2014, 16:56 UT, M1.1
2. 10-Sep-2014, 17:33 UT, X1.6

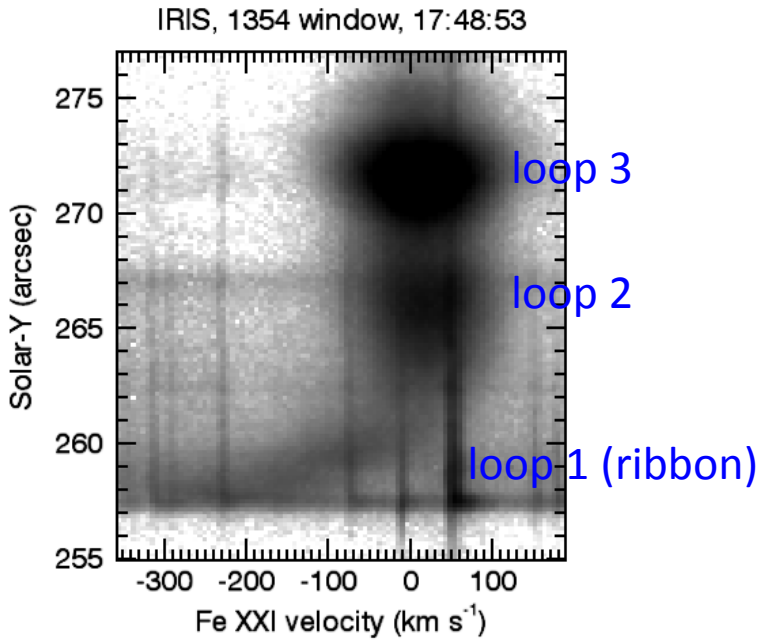
X. Cheng et al. (2015, ApJ, 804, 82)
T. Li & J. Zhang (2015, ApJ, 804, L8)
Graham & Cauzzi (2015, ApJ, 807, L22)
D. Li et al. (2015, ApJ, 807, 72)

Note: IRIS flare list at http://iris.lmsal.com/documents.html

What do we expect to see?

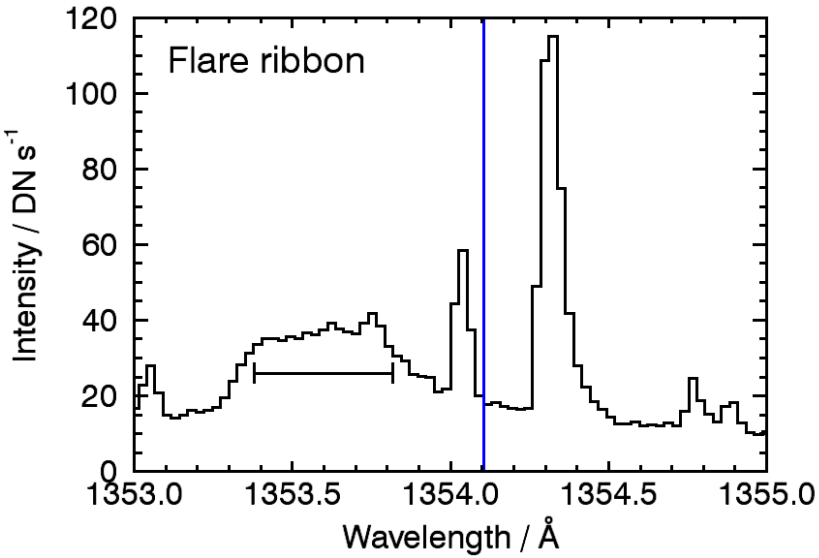
- Chromospheric heating (e.g., particle beams) leads to evaporation of hot (>10 MK) plasma, which fills up coronal loops with hot, dense plasma.



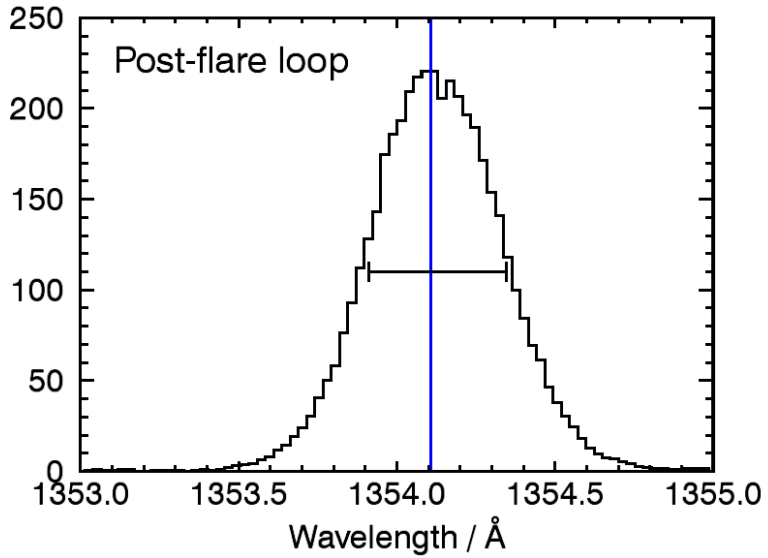


Spectra from ribbons and loops

- Blending from multiple chromospheric lines (narrow)
- Enhanced continuum
- Fe XXI blue-shifted and weak



- Limited blending (only C I)
- Fe XXI at rest and strong



Critical questions

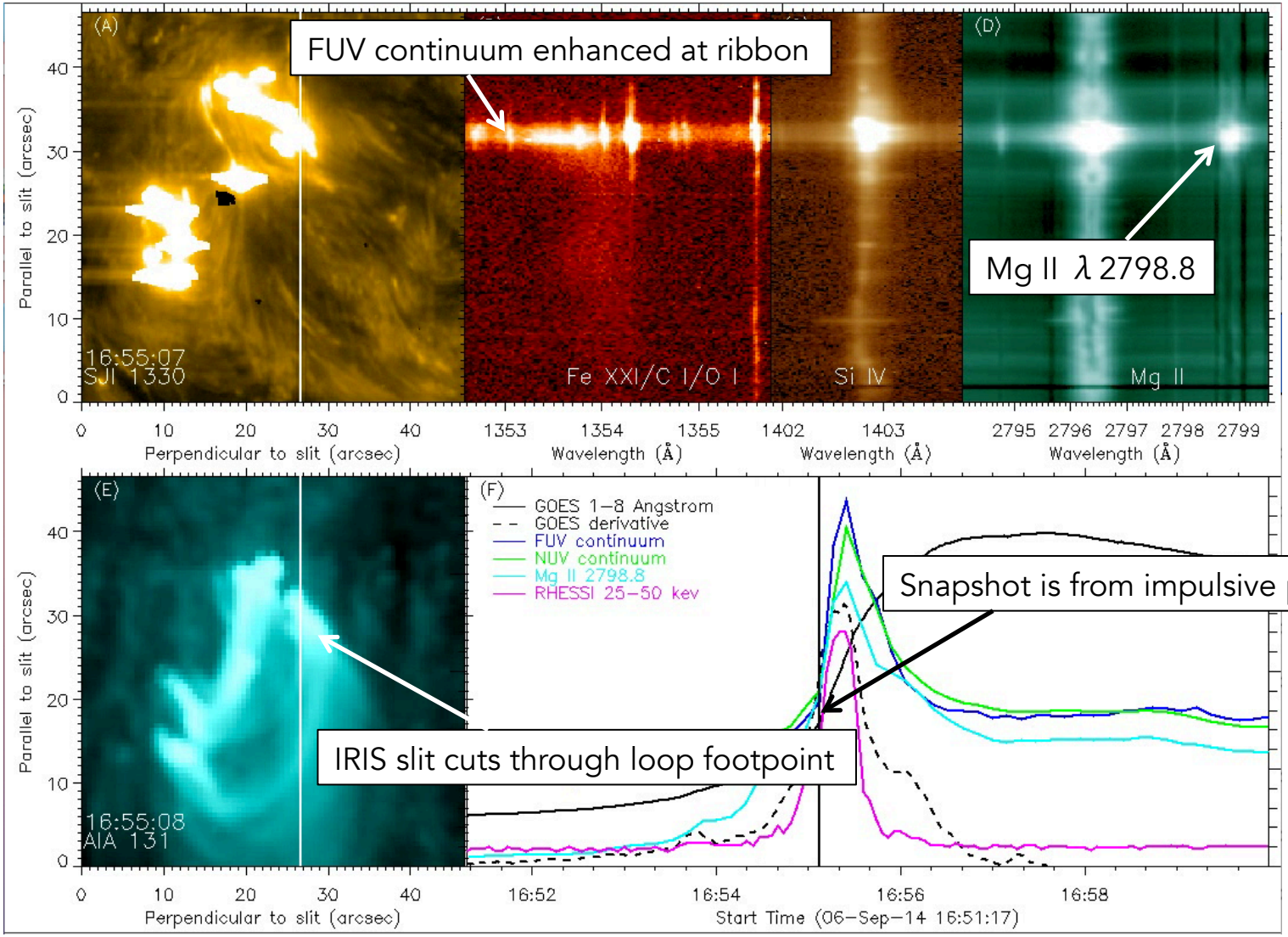
- How does the timing of 11 MK plasma relate to…
  - …timing of HXR bursts
  - …timing of chromospheric heating

- Data sources:

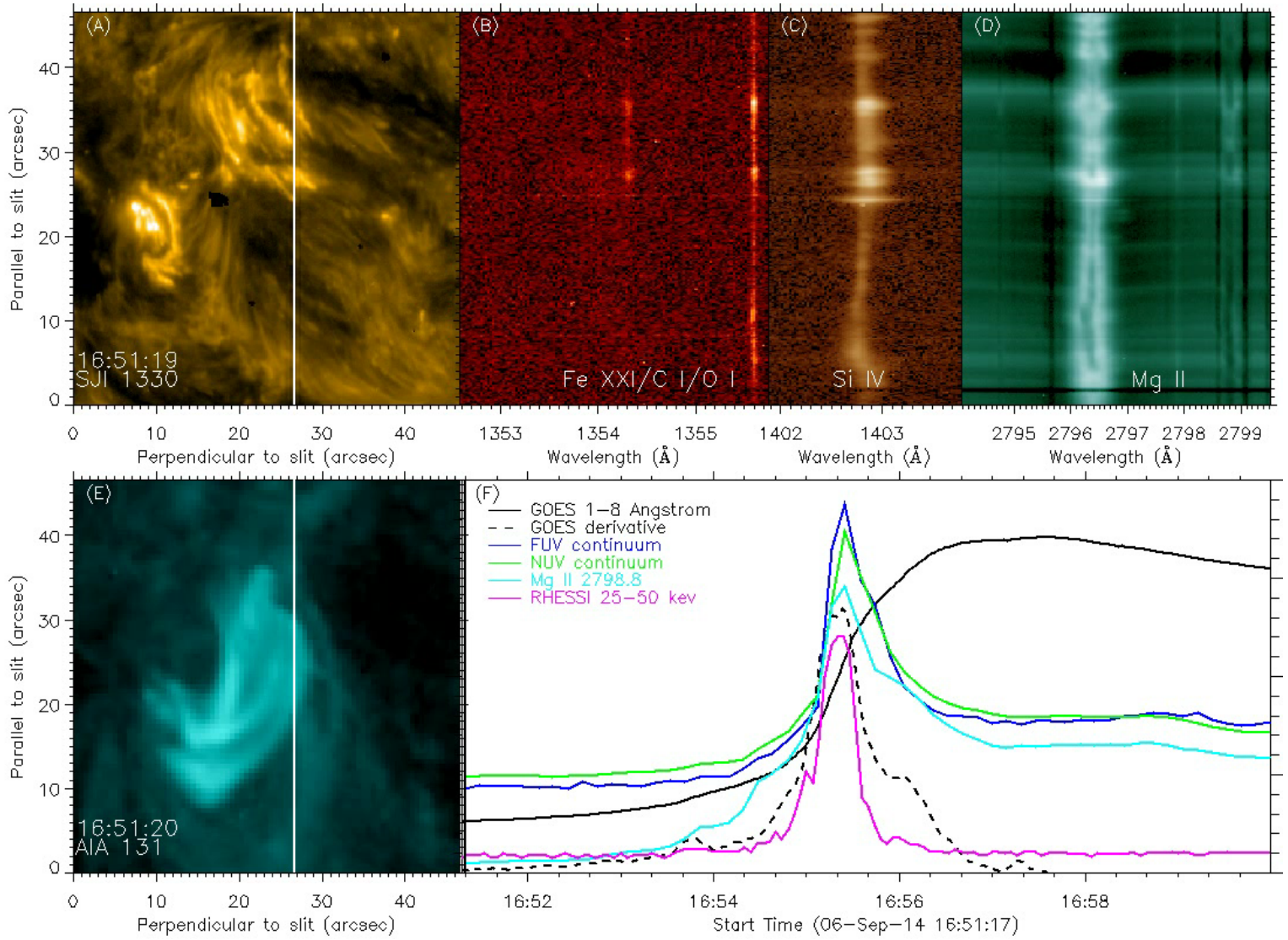
  HXR – RHESSI & GOES derivative

  Chromosphere – IRIS: NUV & FUV continua; Mg II λ 2798.8

Movie snapshot

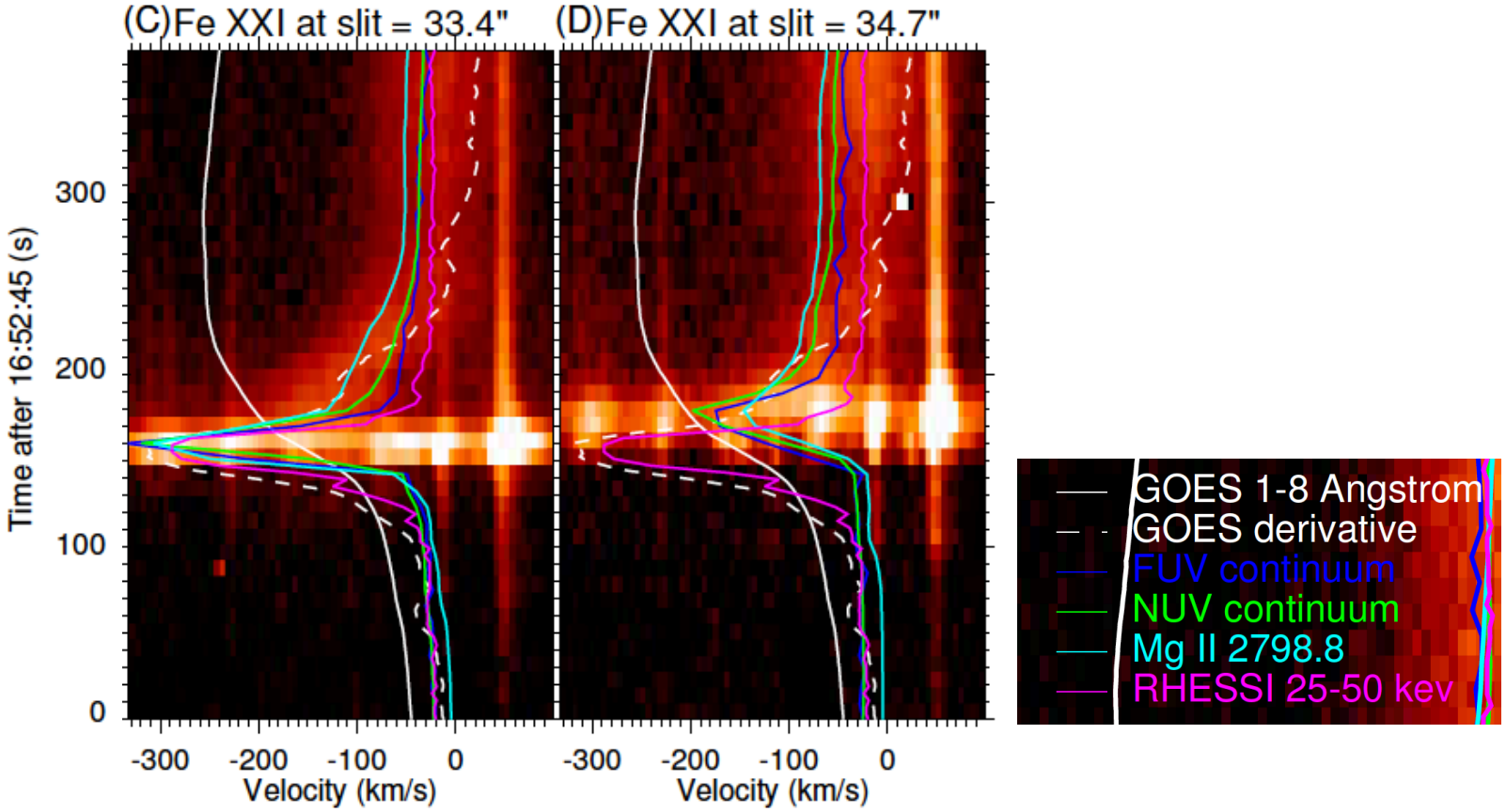


Movie


(A)
(B)
(C)
(D)
16:51:19
SJI 1330
Fe XXI/C I/O I
Si IV
Mg II
Parallel to slit (arcsec)
Perpendicular to slit (arcsec)
Wavelength (Å)
(E)
16:51:20
AIA 131
(F)
GOES 1–8 Angstrom
GOES derivative
FUV continuum
NUV continuum
Mg II 2798.8
RHESSI 25–50 kev
Start Time (06–Sep–14 16:51:17)

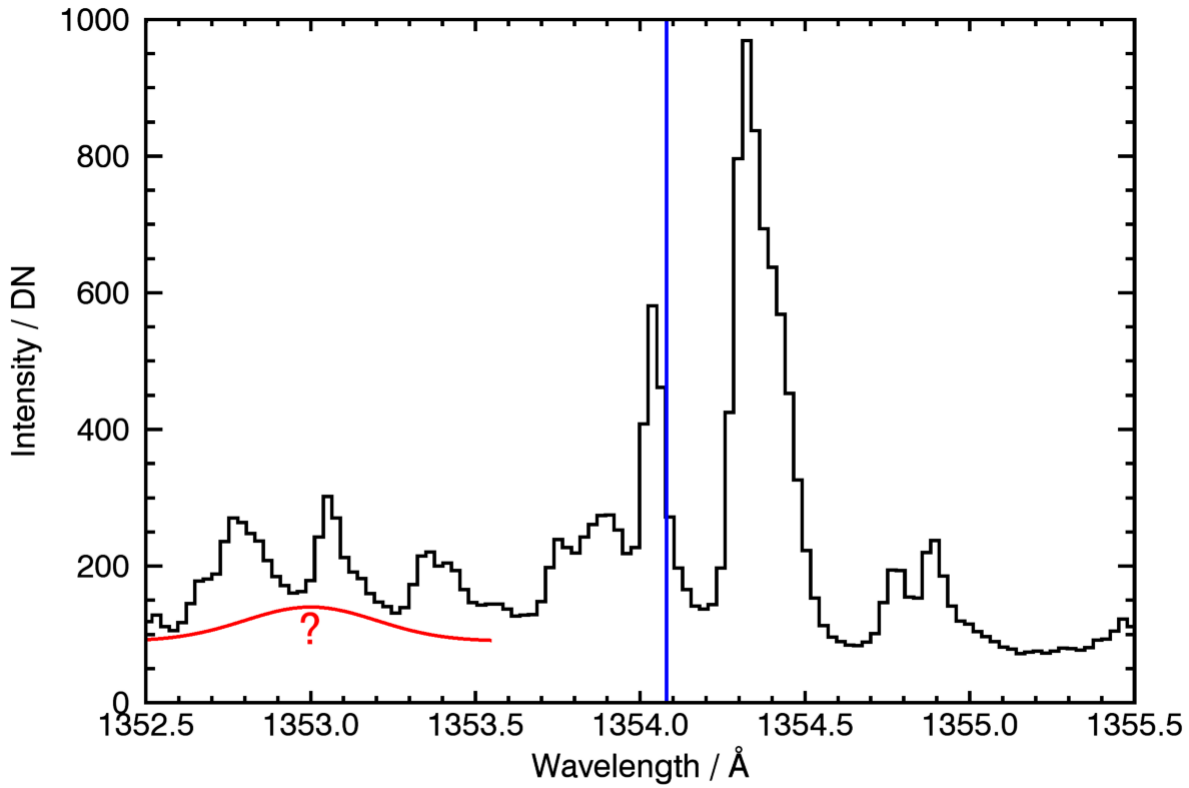
Time evolution of Fe XXI

- Time evolution of two "clean" flare kernel locations
- Fe XXI starts at ≈-200 km/s and moves to rest in ≈ 3 mins



Is Fe XXI present when chromosphere heated?

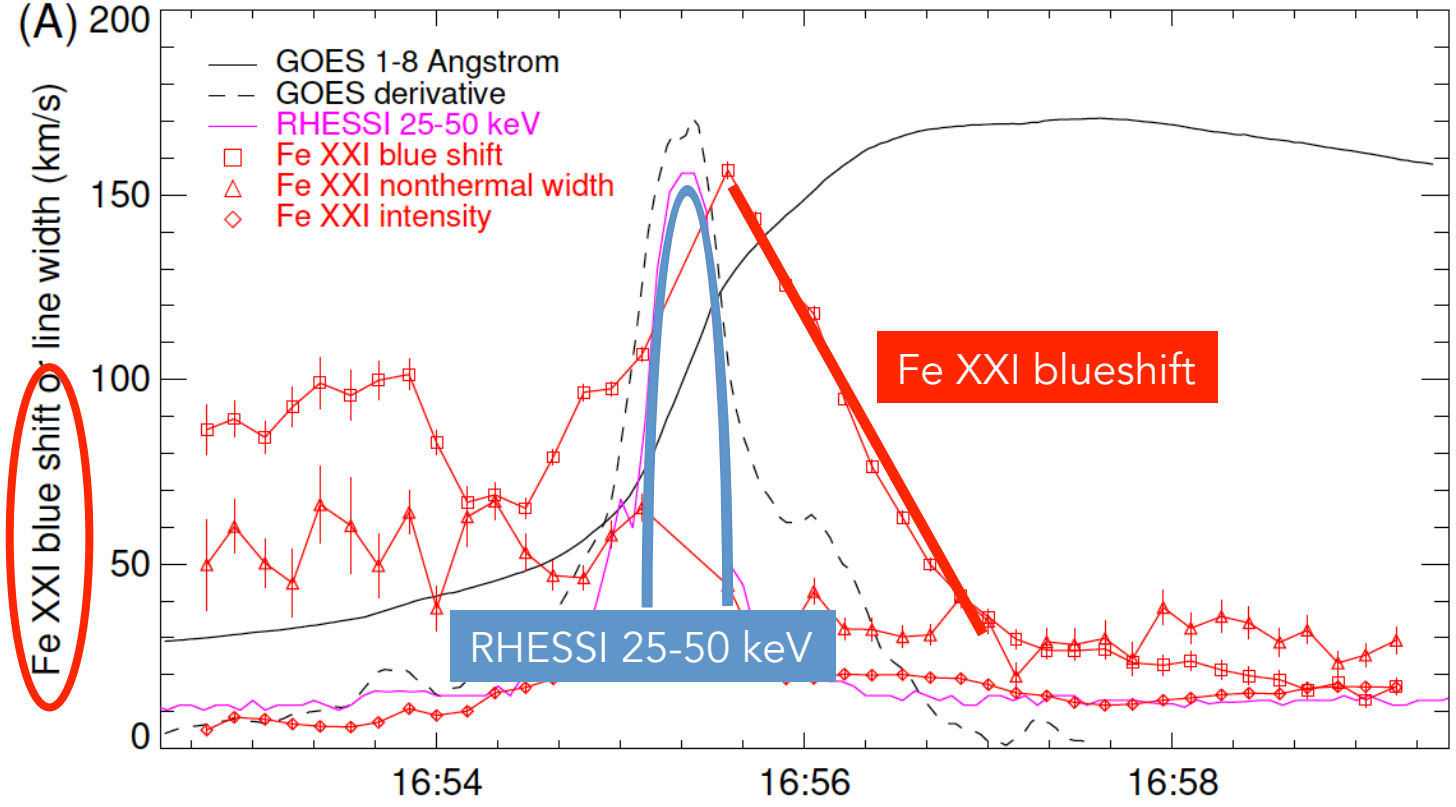
- The Fe XXI line is difficult to identify when the FUV continuum brightens



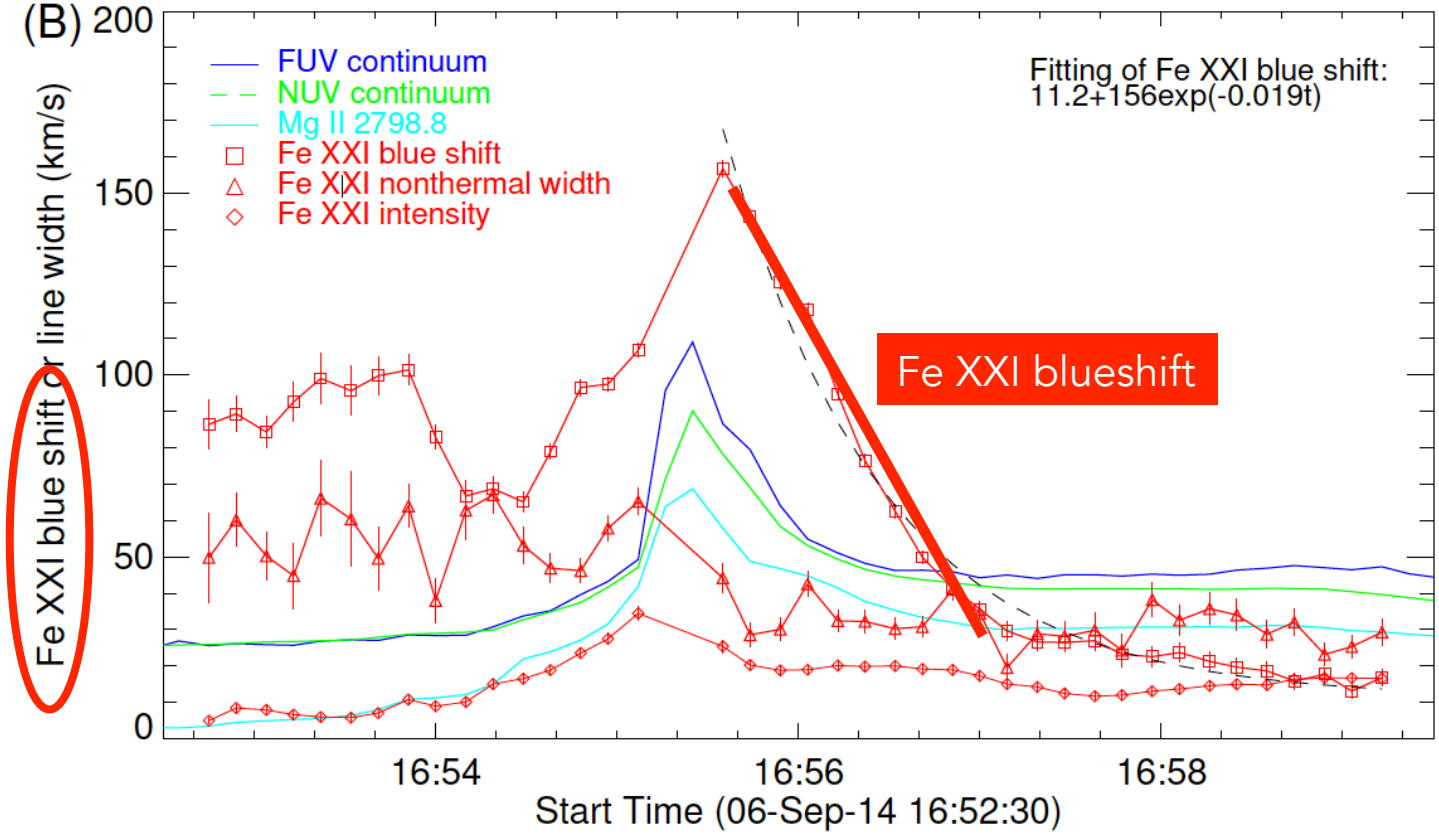
Spectrum from peak of FUV continuum – *is Fe XXI present?*

Young et al. (2015) and Graham & Cauzzi (2015) suggest 60-75 second delay for X-flares

Fe XXI correlation with X-rays

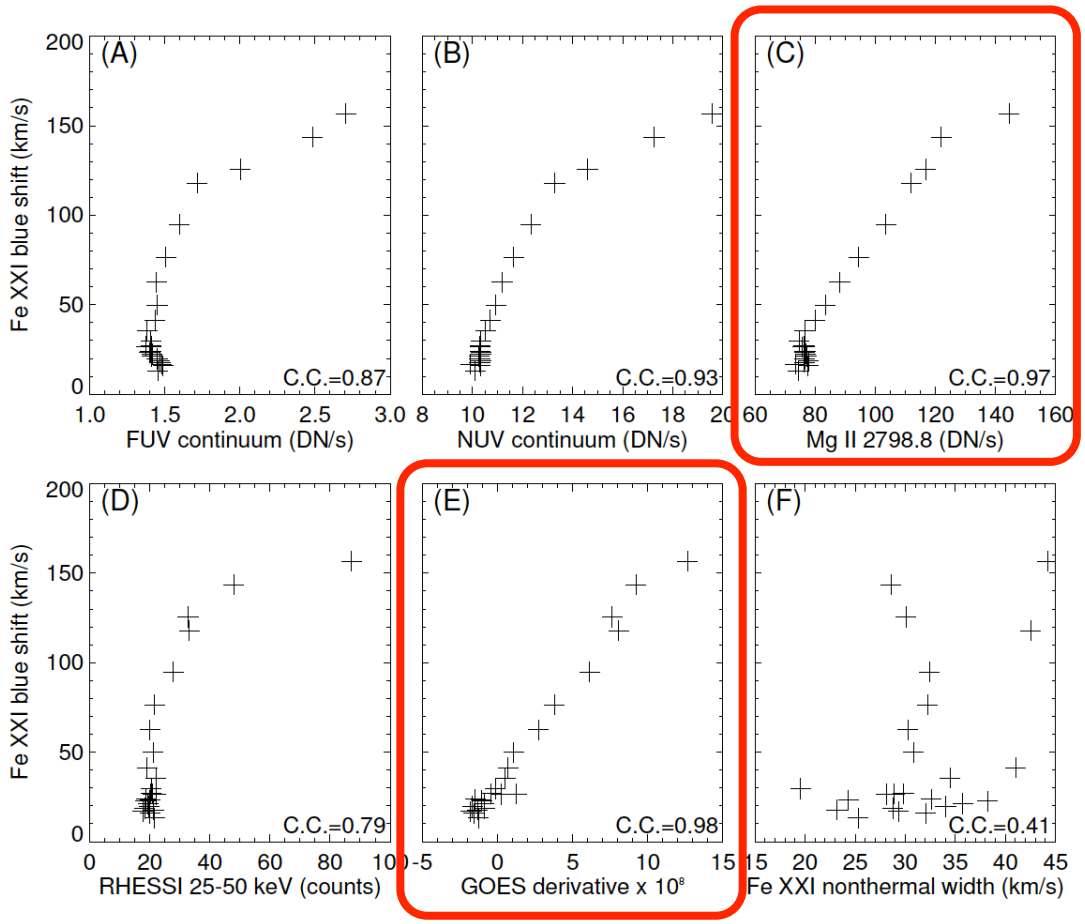


Fe XXI correlation with chromosphere



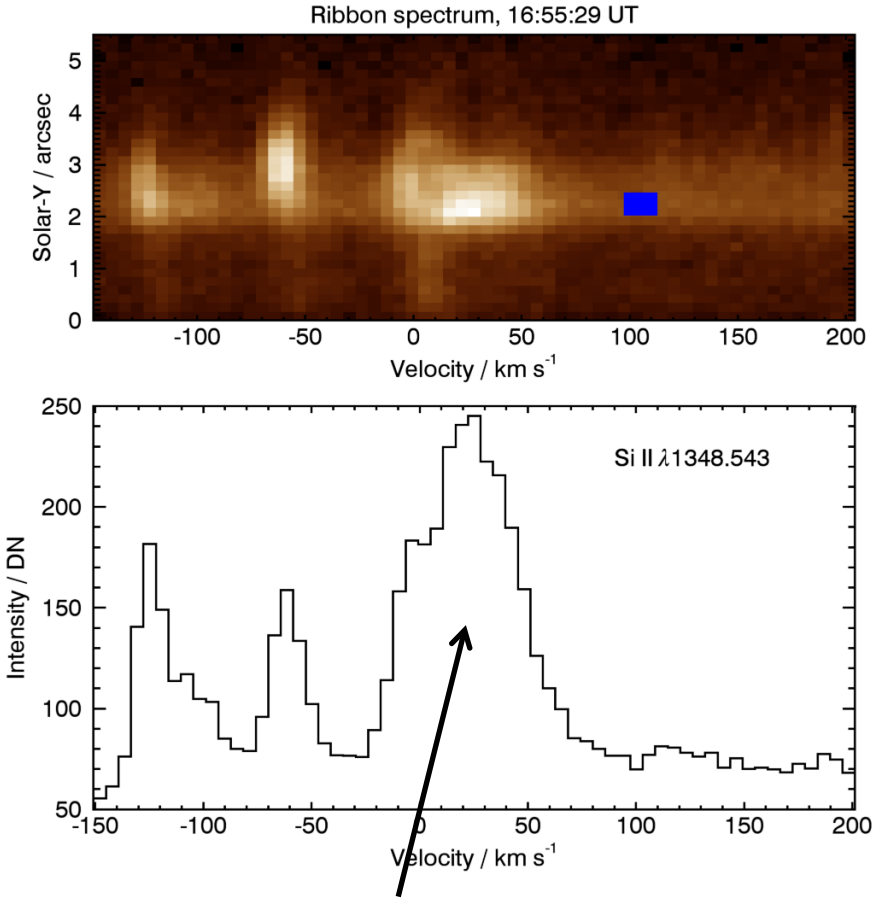
Correlation plots

- Look for correlations between magnitude of Fe XXI blueshift and other parameters

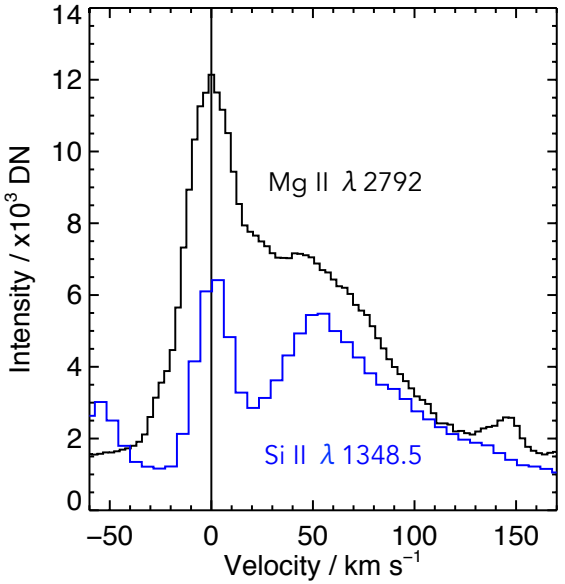


Chromospheric lines

- A common feature of IRIS flares is extended red wing of chromospheric lines



Red-shifted component to cool lines



More extreme example:
29-Mar-2014 X-flare

Also see Brannon et al. (2015, arXiv:1507.01554)

Summary

- Clear chromospheric evaporation signature
  - Large blueshift (200 km/s) at ribbon
  - Decreases to zero after ≈3 mins
- Fe XXI *may* appear at same time as HXR burst and continuum enhancement
  - noisy chromospheric "background" prevents measurement
  - definitely appears within ≈20-30 seconds for this flare
- Challenge for modelers
  - can predict timing of Fe XXI appearance?
  - spatial extent of blue-shifted Fe XXI along loop?
- Chromospheric lines (Si IV and cooler) show extended red wings at ribbon sites
  - two-component structure often seen