Fachhochschule Nordwestschweiz

IRIS and RHESSI observations of the chromospheric response to energy input during the 29th March 2014 flare

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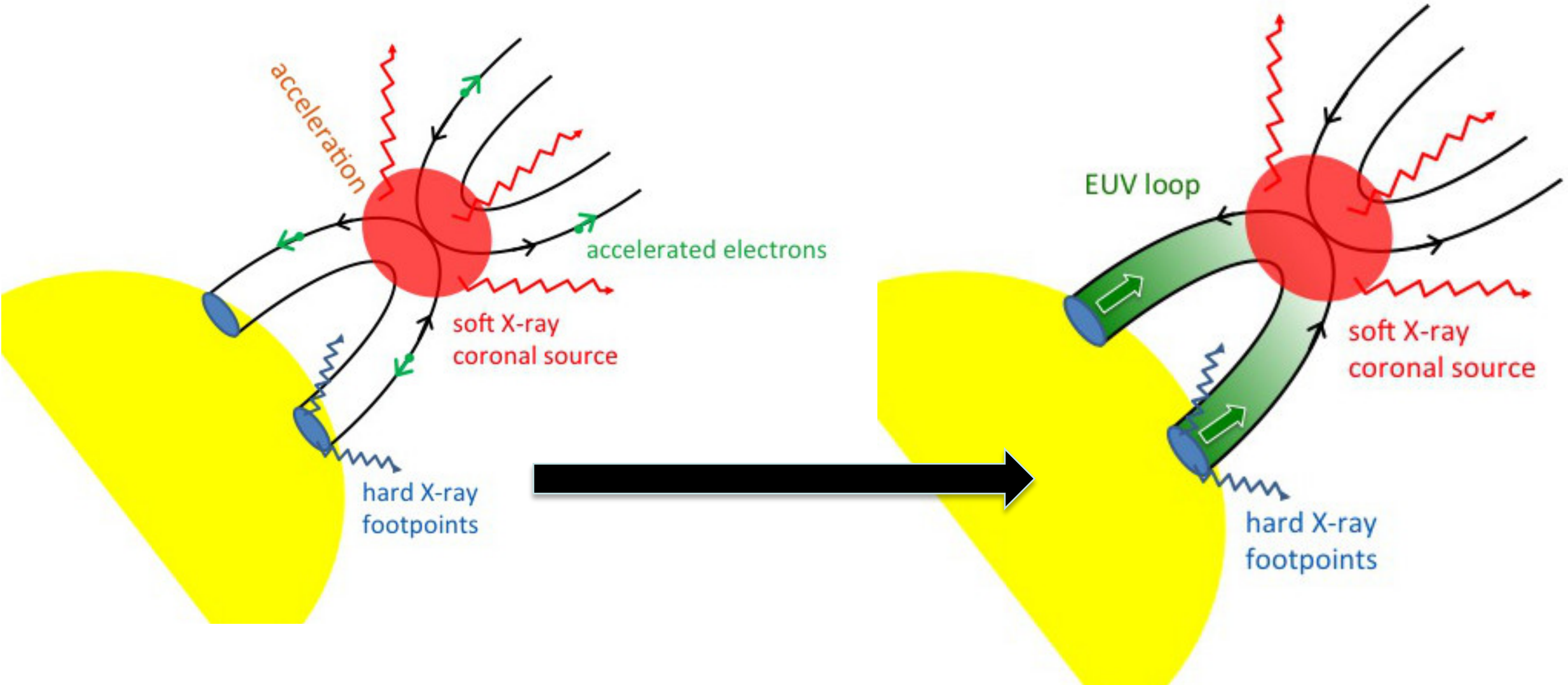
Chromospheric evaporation in the standard solar flare model



Energy deposition in the chromosphere leads to heating and overpressure causing plasma to expand upward → EUV / soft X-ray loops

Drivers of chromospheric evaporation

Evaporation can be driven via

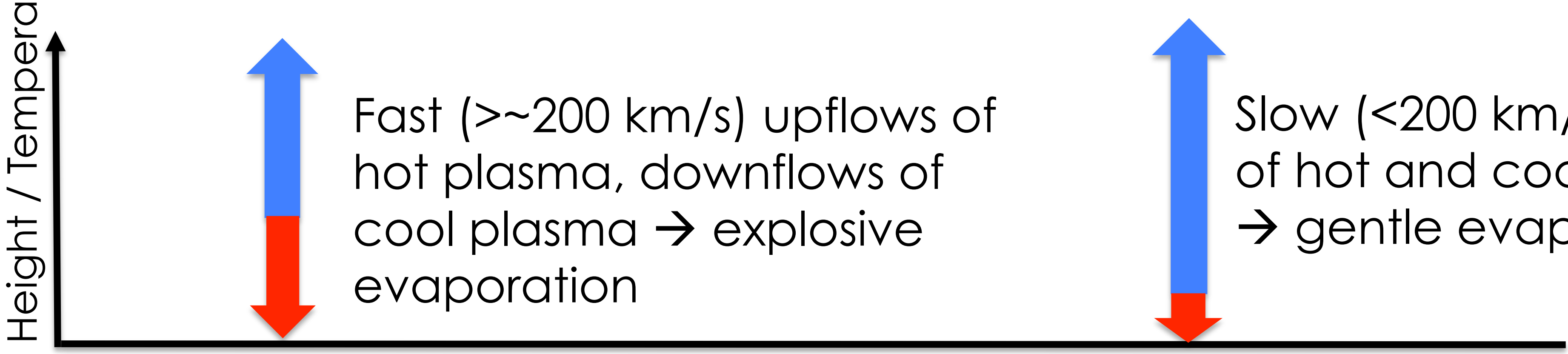
a) energy-input by non-thermal electron beam (eg. Fisher 1989)

b) energy input by thermal conduction (Longcope 2014)

It can be (depending on beam energy)

a) “explosive”

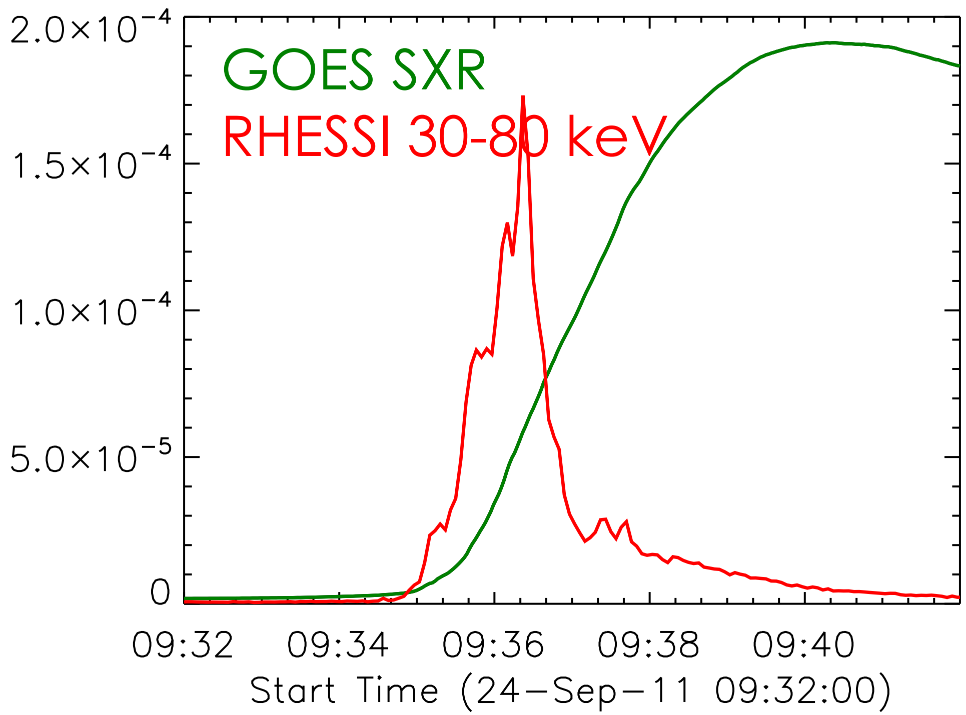
b) gentle



→ Relative and absolute velocities can be used to distinguish the two types

Observations of chromospheric evaporation

Indirect observations



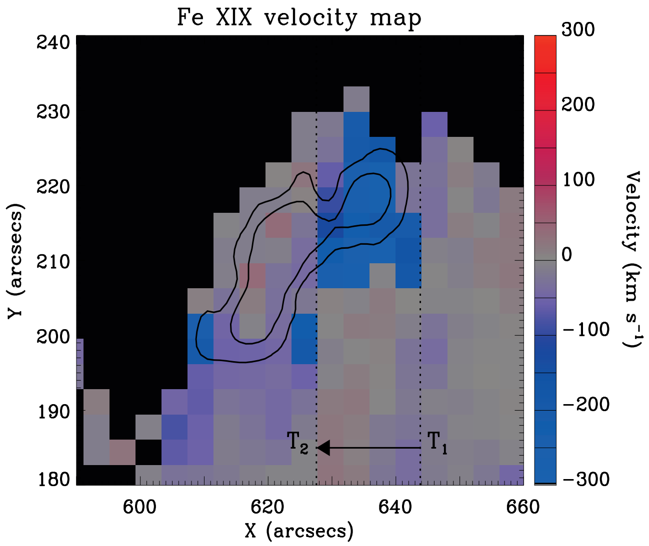
Hard X-rays indicate start of energy input

Soft X-rays as signature of evaporated plasma

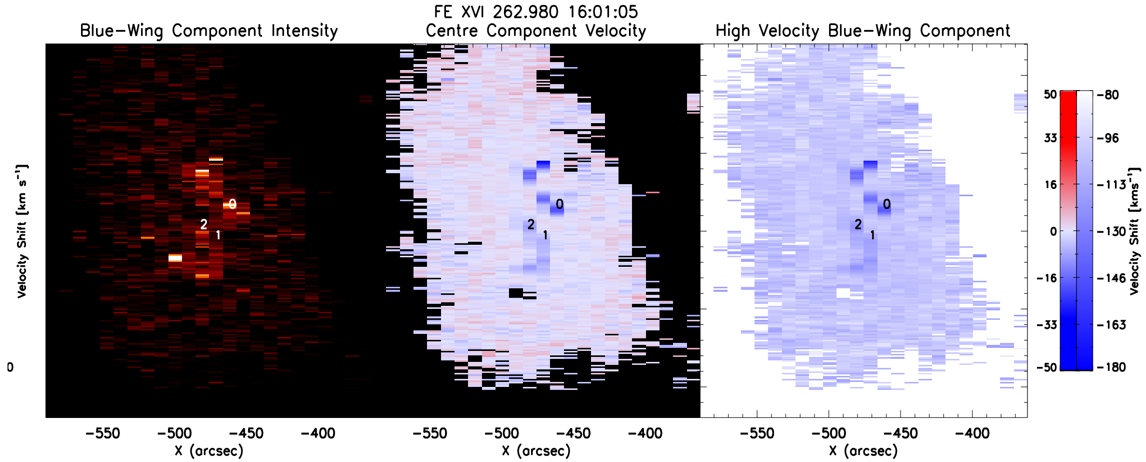
Consequence of electron beam heating of the chromosphere: Neupert effect (time-integrated HXR flux ~ SXR flux) (e.g. Neupert 1968, Dennis & Zarro 1993, Veronig et al. 2005)

Direct observations

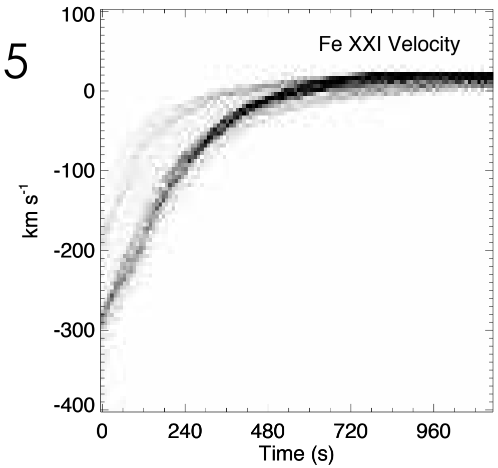
Observations of blue-shifted MK plasma from locations associated with HXR footpoints and flare ribbons



Milligan et al. 2006

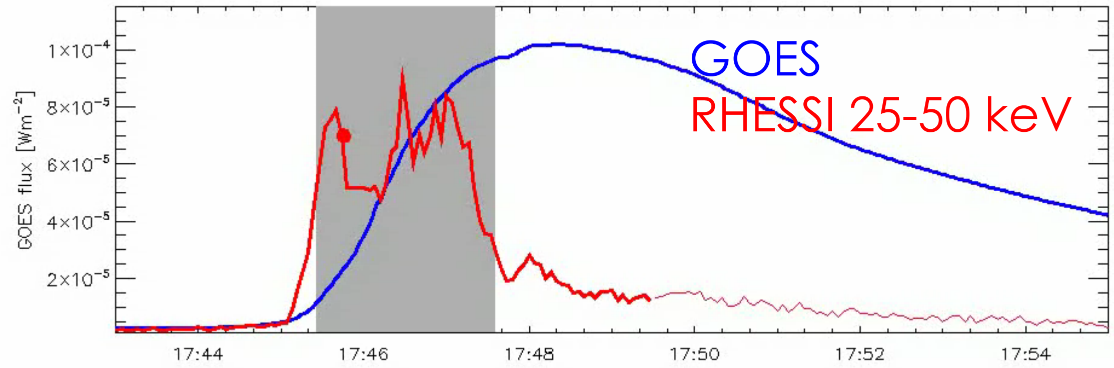


Graham & Cauzzi 2015



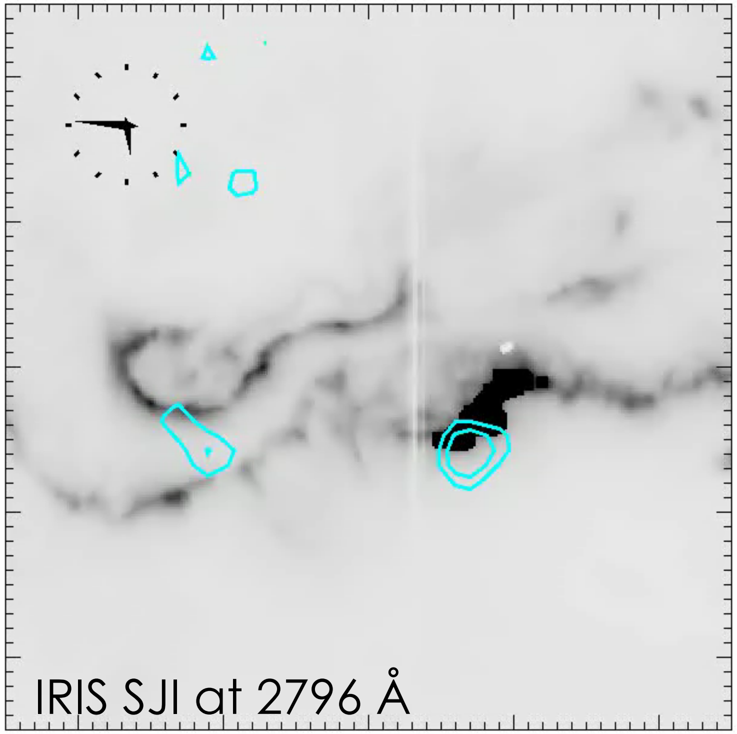
And other observations with IRIS (Tian et al. 2015, Young et al. 2015, Brosius et al. 2015, Li 2015, Polito et al. 2016)

Observations of chromospheric evaporation in the March 29th 2014 flare

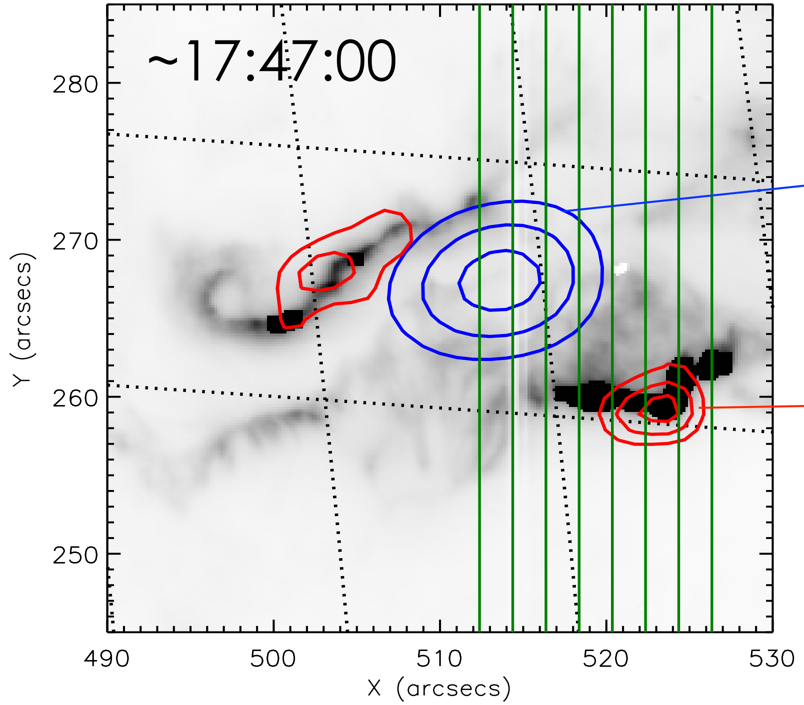


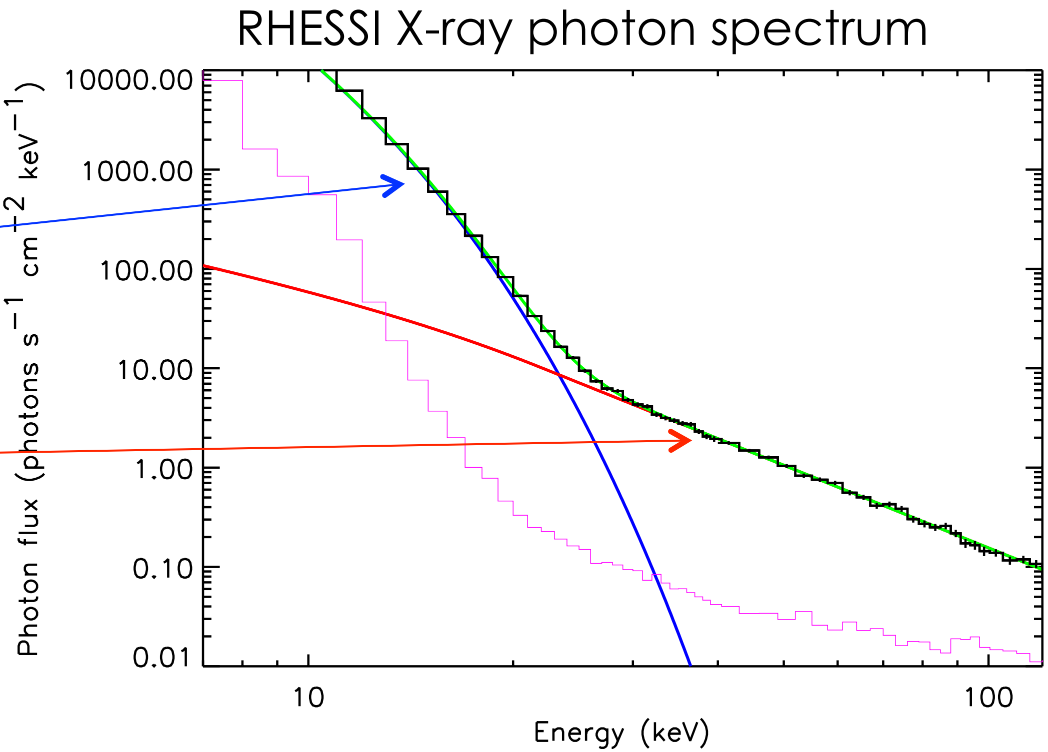
GOES X1 flare from
29 March 2014
(Kleint et al. 2015, Young et al. 2015, Li et al. 2015 …)

Two moving flare ribbons
HXR emission for 2 min
coinciding with location
of ribbons



RHESSI: Location, timing and, amount of energy input





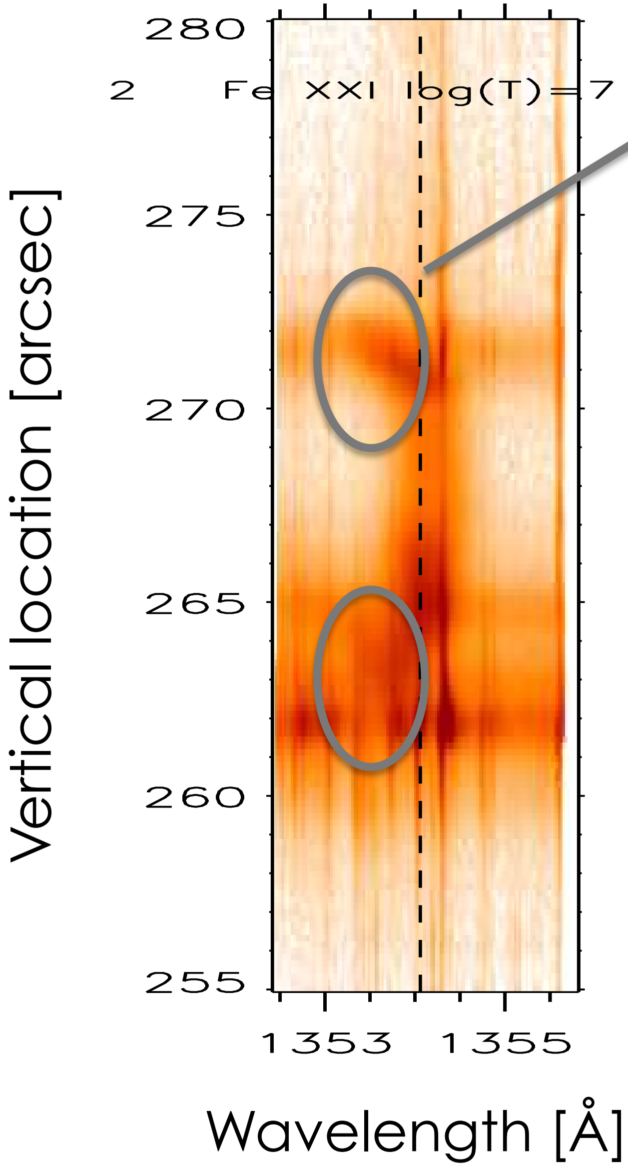
IRIS SJI at 2796 Å

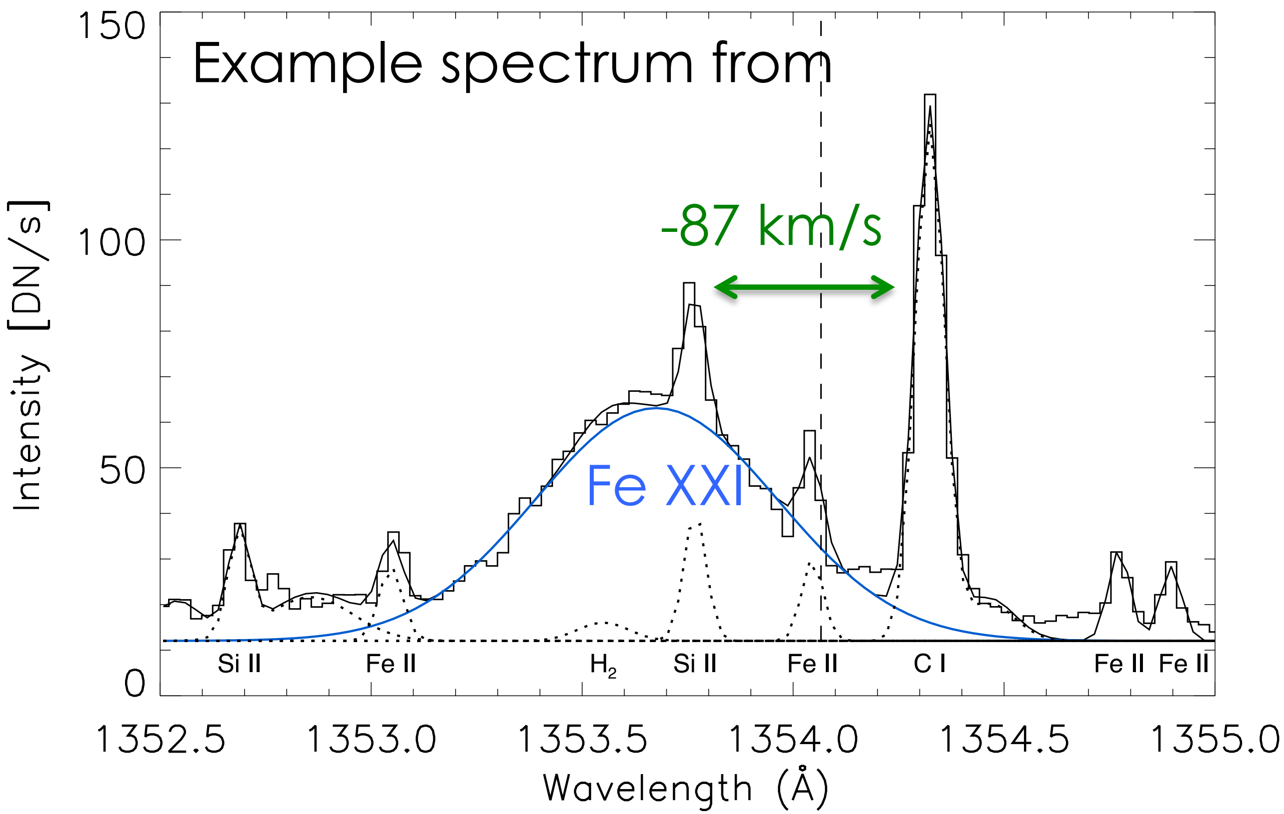
6-12 keV: Coronal source, thermal

30-70 keV: Non-thermal electrons, location of energy deposition

IRIS: Location, timing, and velocity of evaporating plasma

- Use Fe XXI as diagnostic of hot (~10 MK) plasma
- Blue-shifts at location of flare ribbons

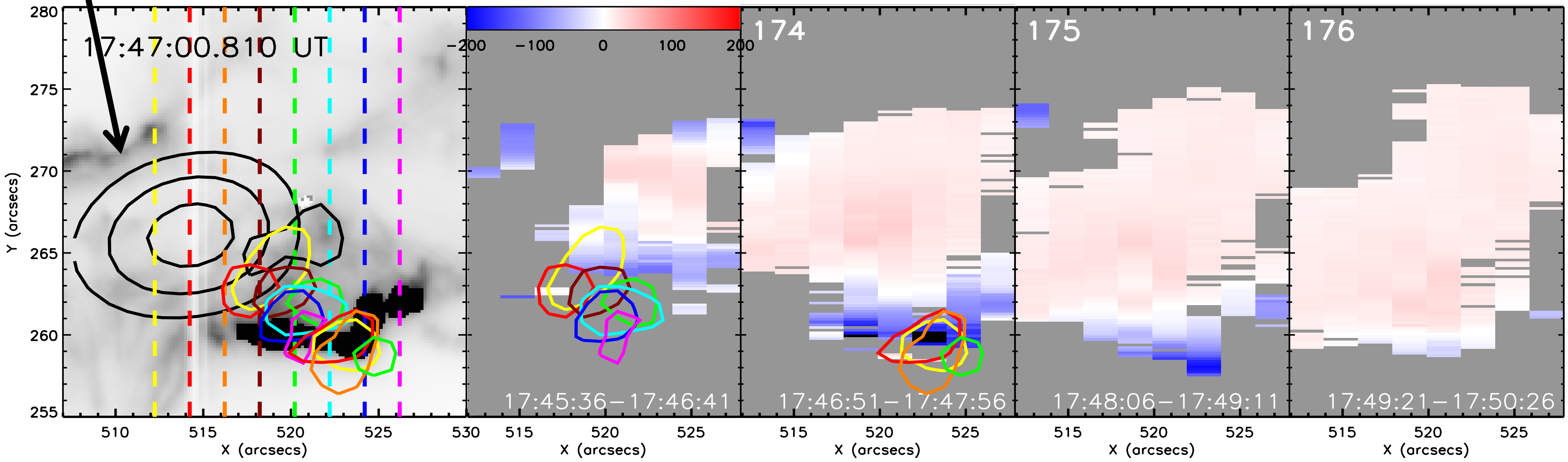


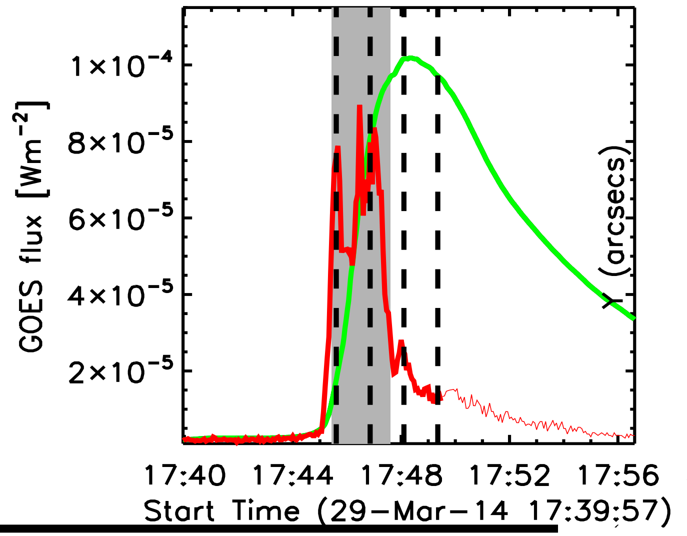


Location of upflows relative to HXR source locations

RHESSI SXR source at 6-12 keV

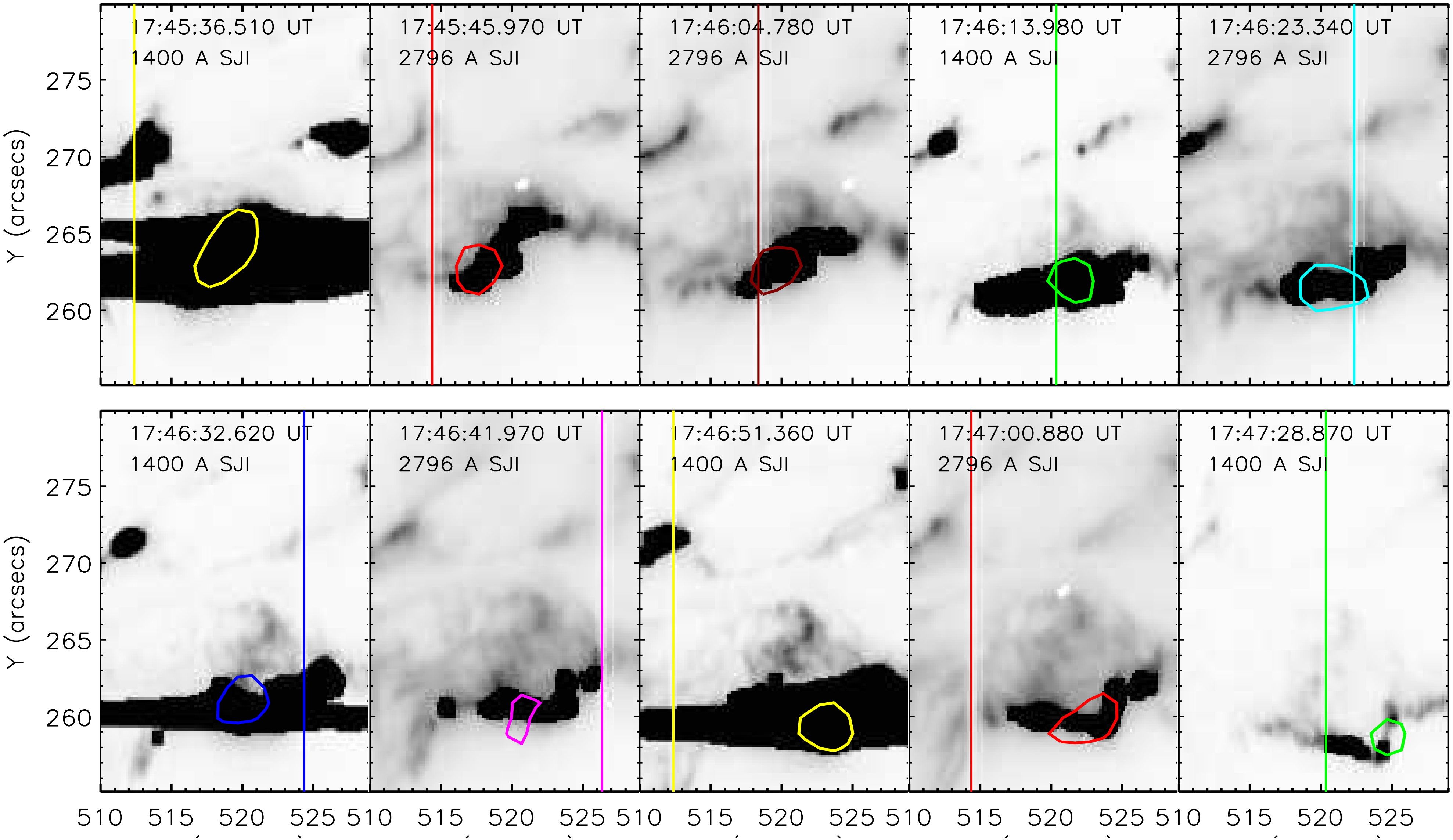
Battaglia et al. 2015





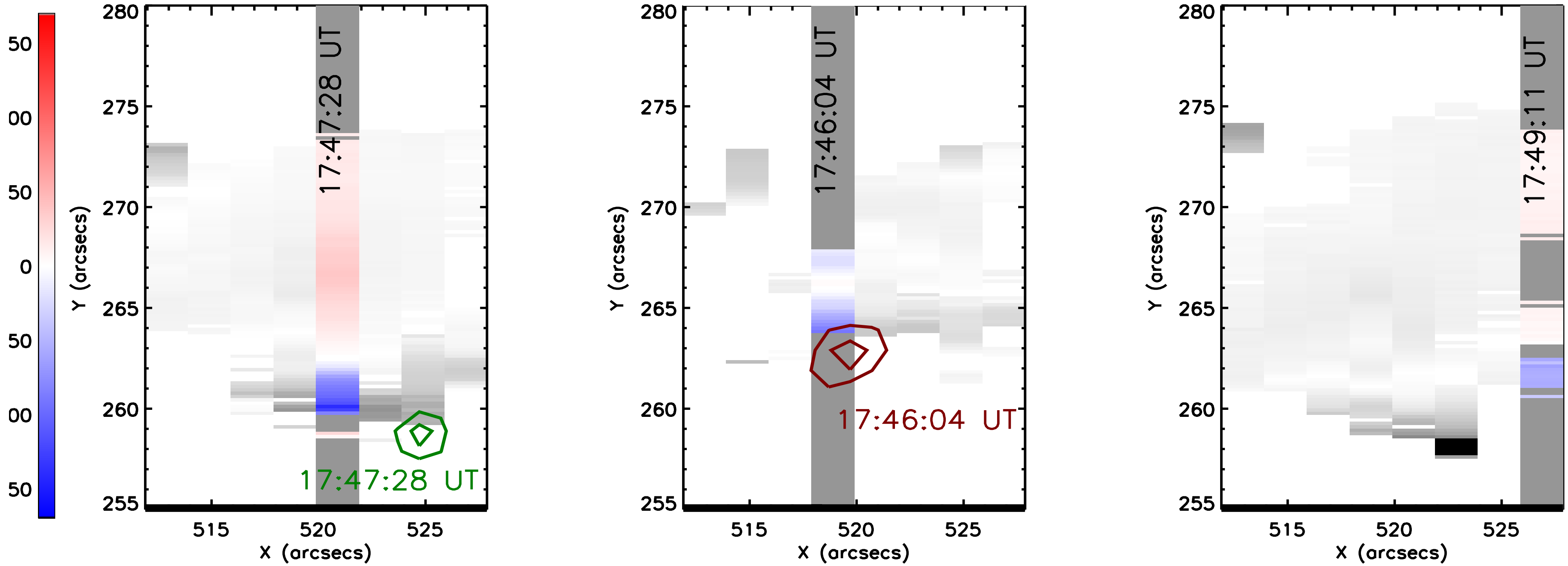
- → Upflows along the flare ribbons
- → Maximum speed ~ 200 km/s
- → Sustained several minutes after HXR

IRIS slit position relative to HXR source

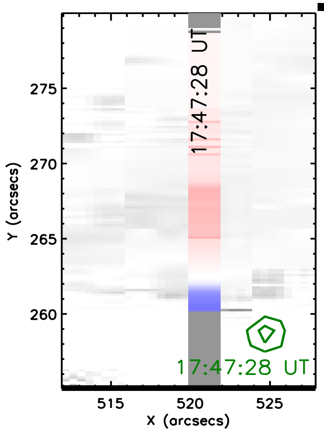


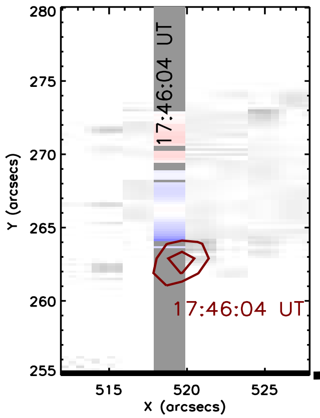
We can distinguish 3 cases

1) Upflows observed ~ 30 – 75 s after hard X-rays at a given location
2) Upflows observed co-temporally with hard X-rays but not from same location
3) Upflows not associated with hard X-rays



Interpretation

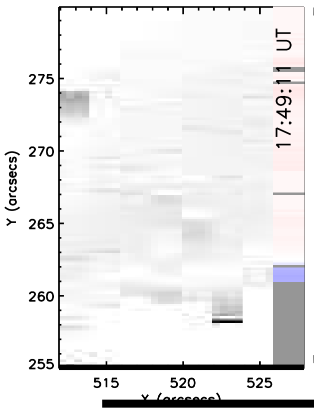




Electron beam driven chromospheric evaporation, transitioned from explosive to gentle and sustained for several minutes (Fischer 1987)

Rationale: Electron energy flux (as found from RHESSI spectrum) ~ (2.8-6.6)x10^{10} erg $cm^{-2}s^{-1}$ → would trigger explosive evaporation (but not observed).
But: why are there no upflows at the location of HXR where the IRIS slit was co-spatial?

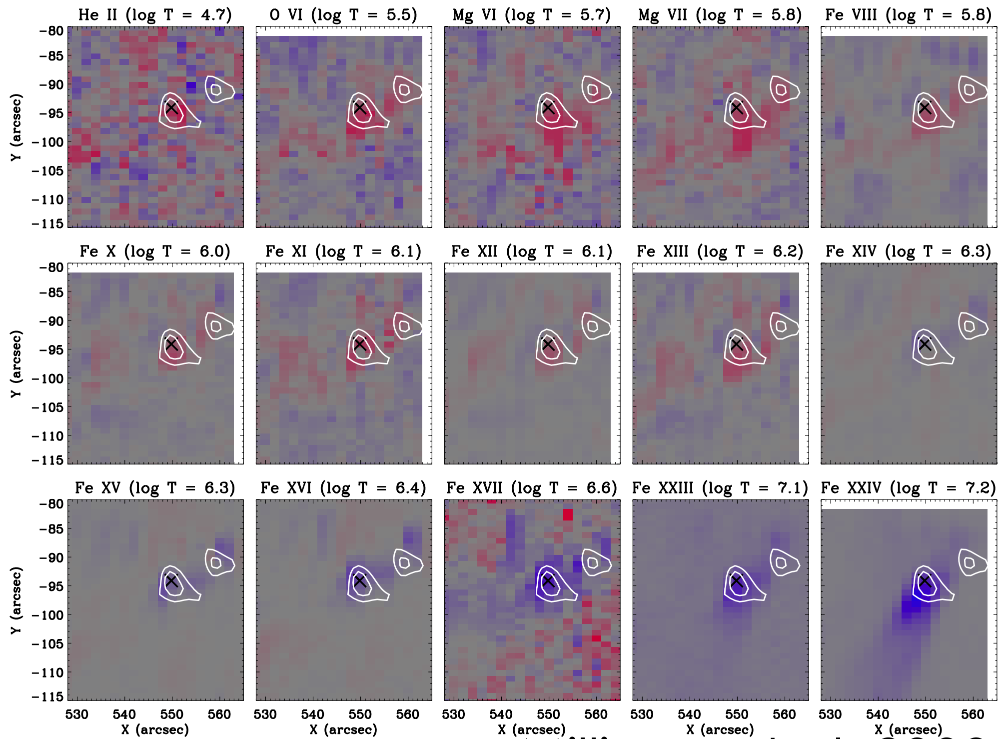
Possible reasons:
- Co-alignment of instruments
- Delayed onset of EUV emission due to ion equilibration time



Conductively driven evaporation due to temperature gradient between hot (~ 20 MK) coronal source and chromosphere

$$L_{cond} = 10^{-6}\frac{T^{7/2}}{L_T} \approx 2.2\text{x}10^{9} \text{ erg cm}^{-2}\text{s}^{-1}$$

Observations at other temperatures?



Milligan et al. 2009

Use EIS and other lines observed with IRIS (Polito et al. 2016, Li et al. 2015, Graham & Cauzzi 2015, Tian et al. 2015, ..)

This flare: Li et al. 2015 for selected pixels

We find:
OIV: inconclusive, mixed red and blue shifts from location of FeXXI blue-shifts
SIIV: red-shifts near leading edge of flare ribbons

EIS: line selection sparse. Suggestive of down-flows in FeXVI (2.8 MK) and FeXVII (5.6 MK) near

Conclusion: it is complicated (see also summary by L. Kleint)!

Conclusions

- FeXXI is blue-shifted along the flare ribbon in the 29th March 2014 flare
- Location, timing, and energy input calculated from hard X-rays suggests **electron beams as dominant means of energy input during the flare peak**
- Sustained upflows after the X-ray peak and at locations not associated with HXR emission suggest **energy input by thermal conduction as equally important** and (in parts) main driver of chromospheric evaporation