Coronal Science with IRIS

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Coronal science with IRIS

Coronal science from IRIS high-resolution UV imaging/ spectral observations

insights into coronal heating mechanisms and fundamental physical processes

- (I) transition region *IRIS* observations at loop footpoints:
  - diagnostics of coronal heating events
  - evidence of non-thermal, accelerated particles in solar "nanoflares"
- (II) FeXII coronal observations with *IRIS*
- conclusions

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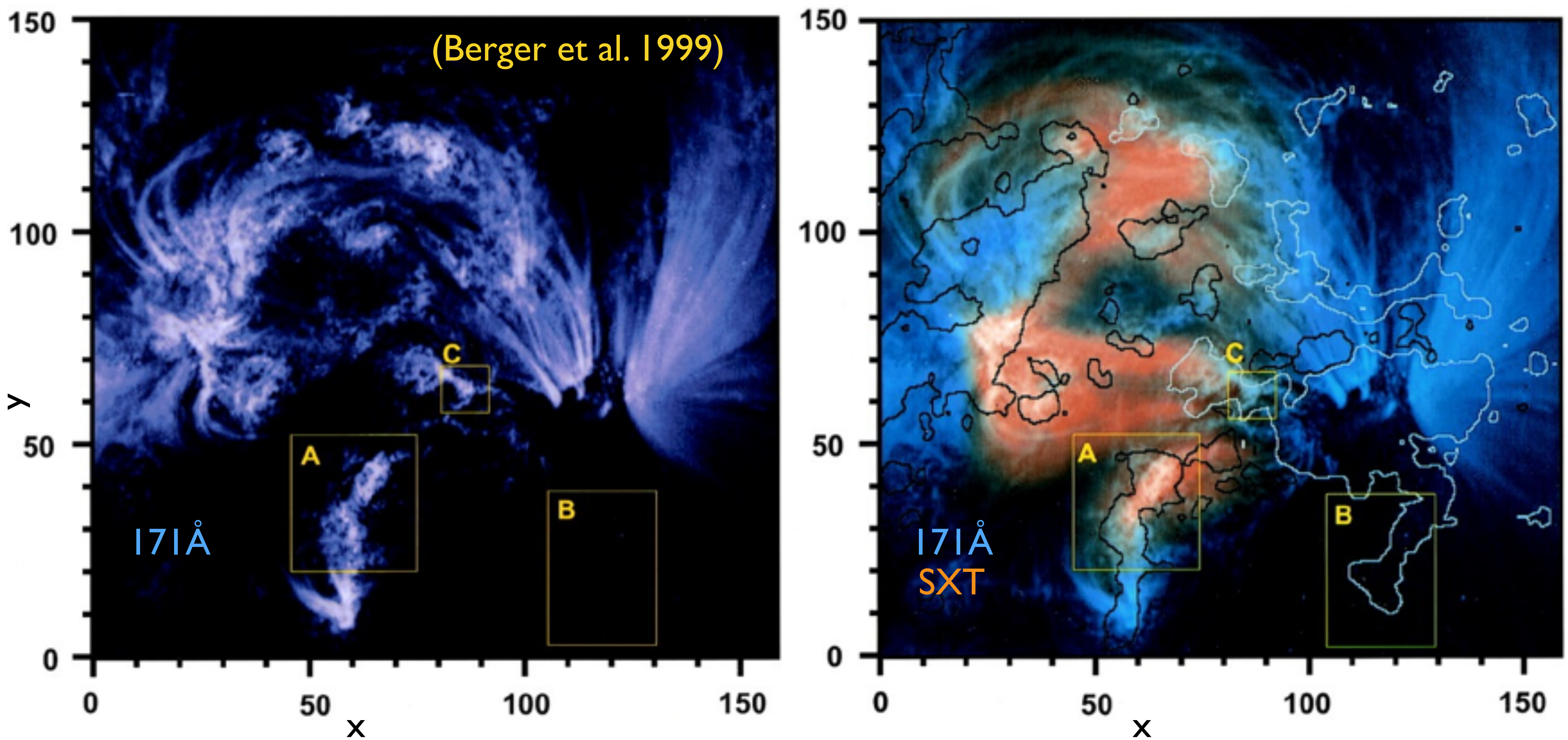
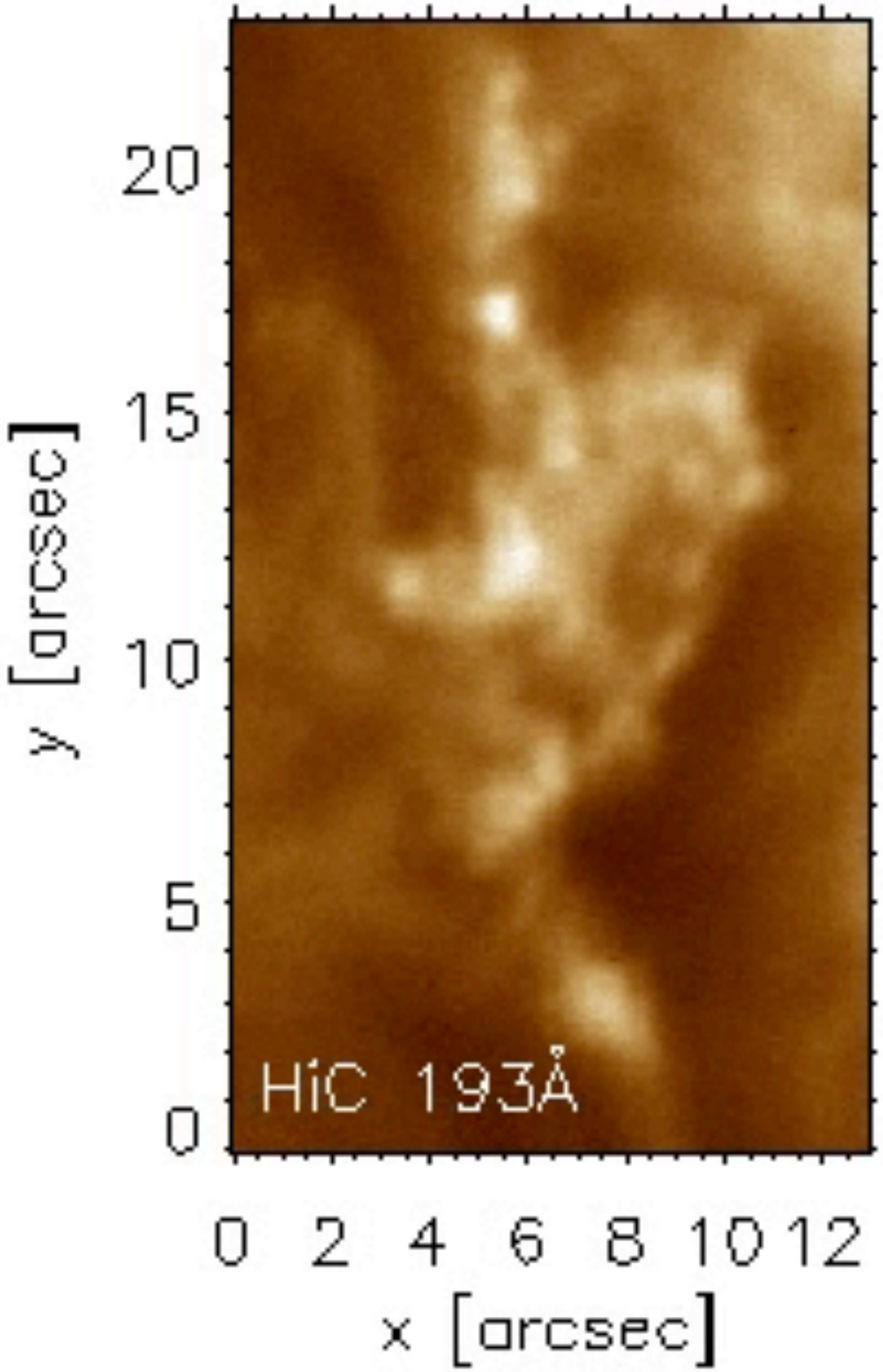
Implication on coronal heating from transition region variability studies

- Coronal heating is difficult to directly detect (e.g., efficient conduction, low high T emission measure, NEI,…) — likely on SMALL spatial/temporal scales
- Transition region (TR) is very sensitive to heating, because of rapid changes of density, temperature gradients, and spatial dimensions in this narrow layer during heating events

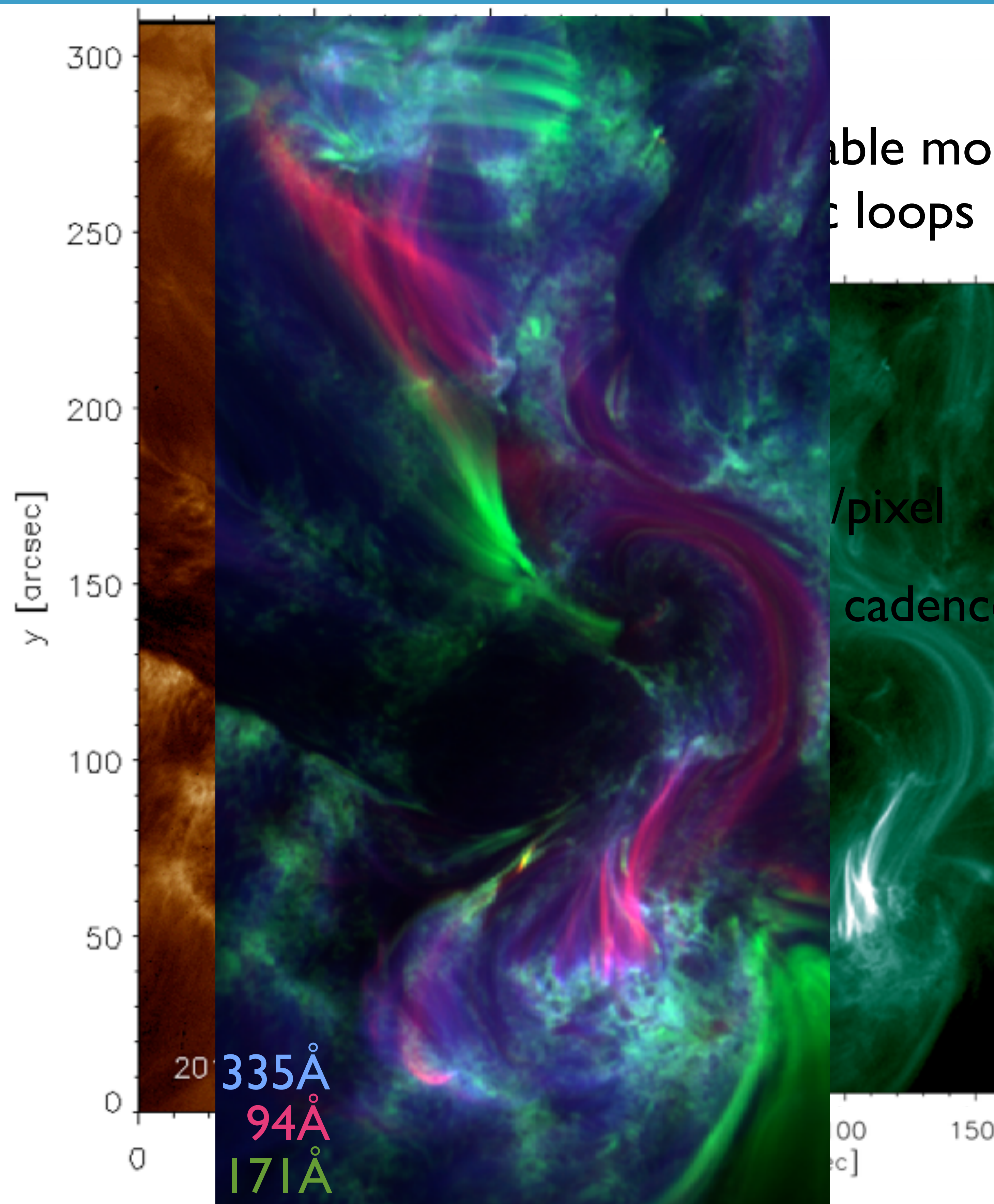


Temporal variability of moss in Hi-C data

(Testa et al. 2013)



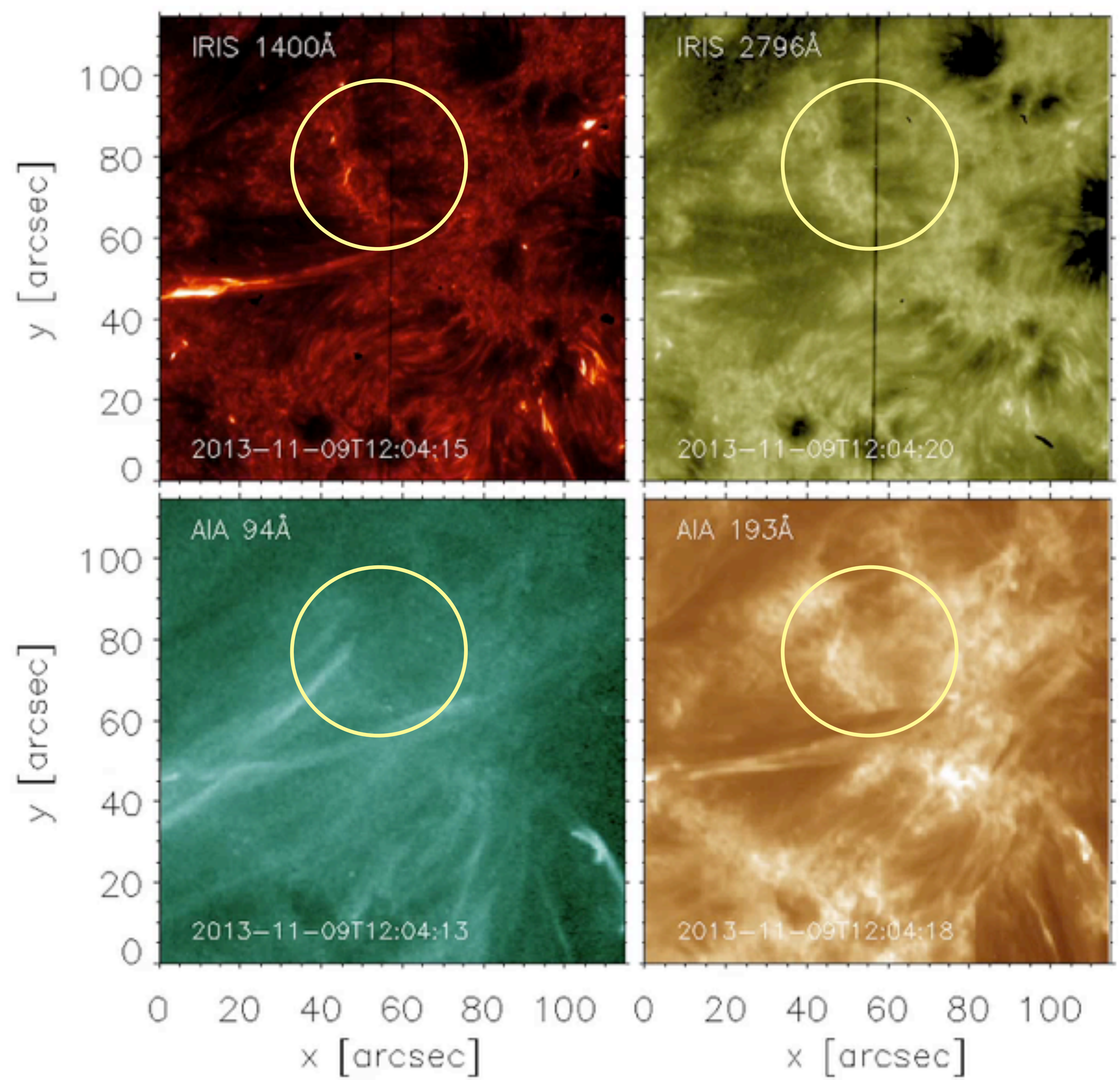
able moss
c loops
/pixel
cadence



IRIS diagnostics of coronal heating and mechanisms of energy transport

(Testa et al. 2014, *Science*)

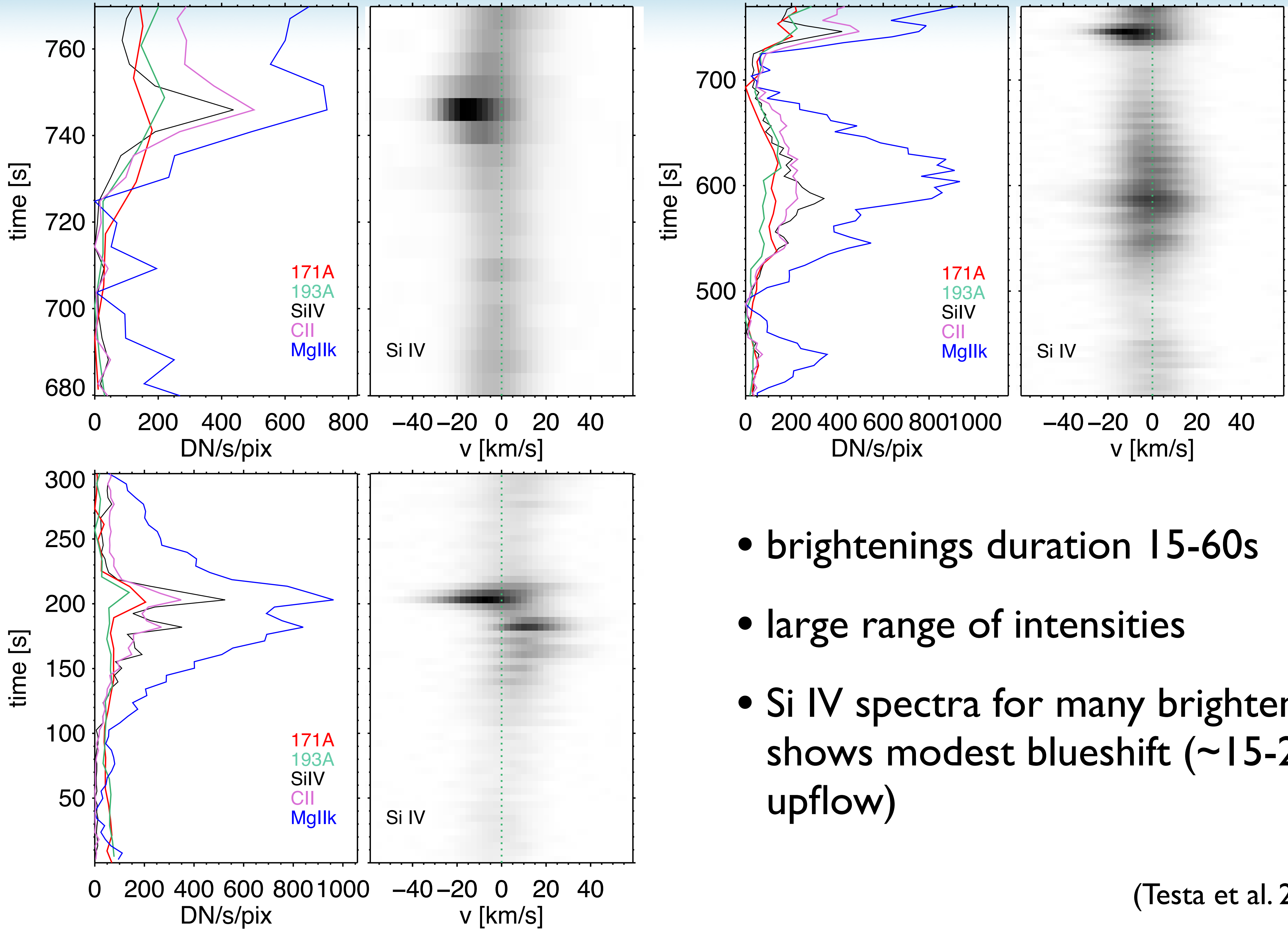
IRIS often observes short-lived brightenings (≲30s) at footpoints of hot loops: signature of coronal heating process?



IRIS provides powerful diagnostics:

- imaging and spectral information in lines formed in different layers of atmosphere
- velocity diagnostics

IRIS high spatial and temporal cadence TR obs



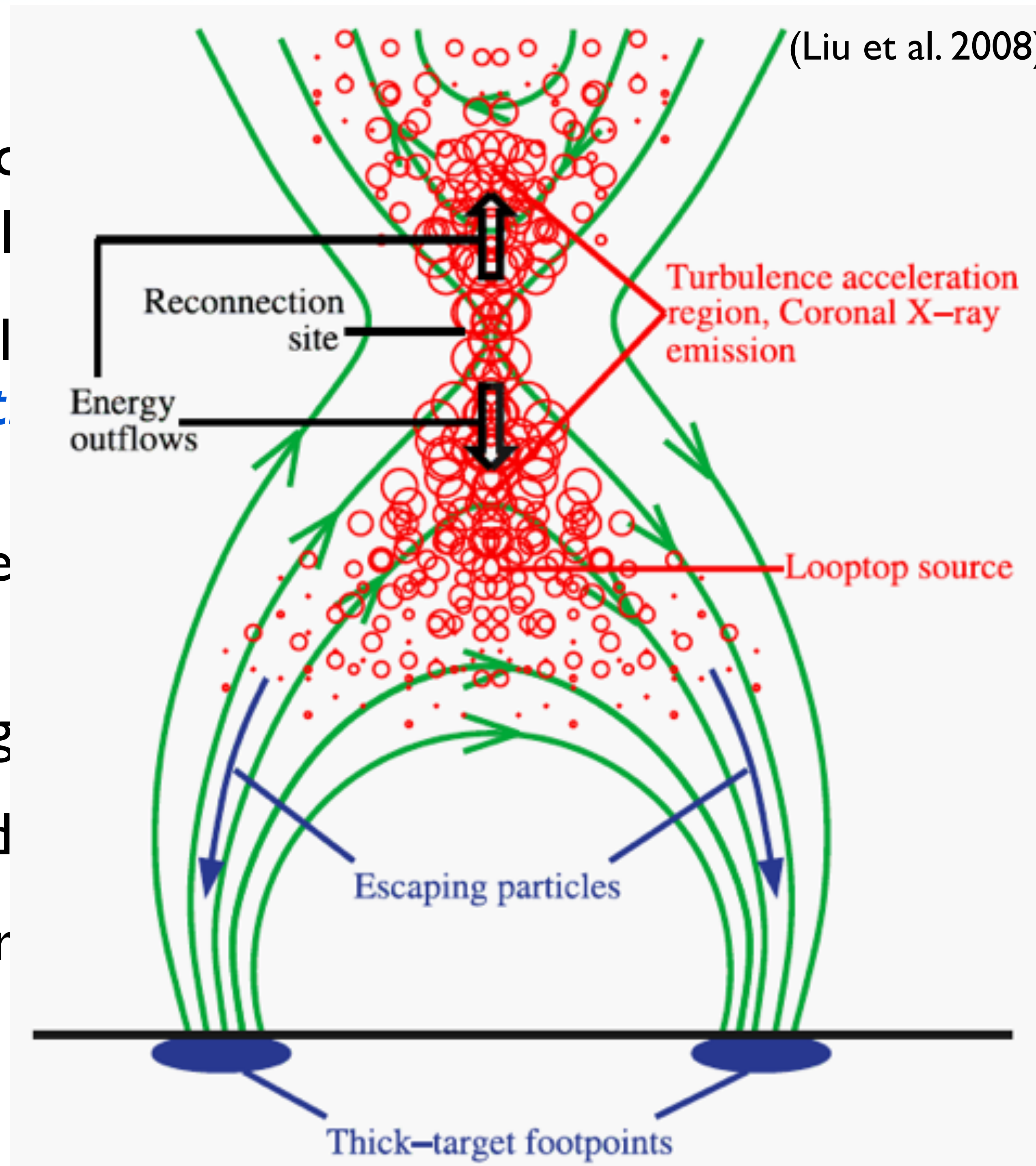
- brightenings duration 15-60s
- large range of intensities
- Si IV spectra for many brightenings shows modest blueshift (~15-20 km/s upflow)

(Testa et al. 2014, *Science*)

What can we learn about heating? Simulations of loops heated by "*nanoflares*"

RADYN loop model

- includes non-Loc ... radiative transfer ⟹ we can model al
- allows to model ... direct heating and *thermal conduct*



(Liu et al. 2008)

We model nanoflare ... ral parameters, but in particular:

- total energ ... ~10-30s)
- initial cond
- cutoff ener

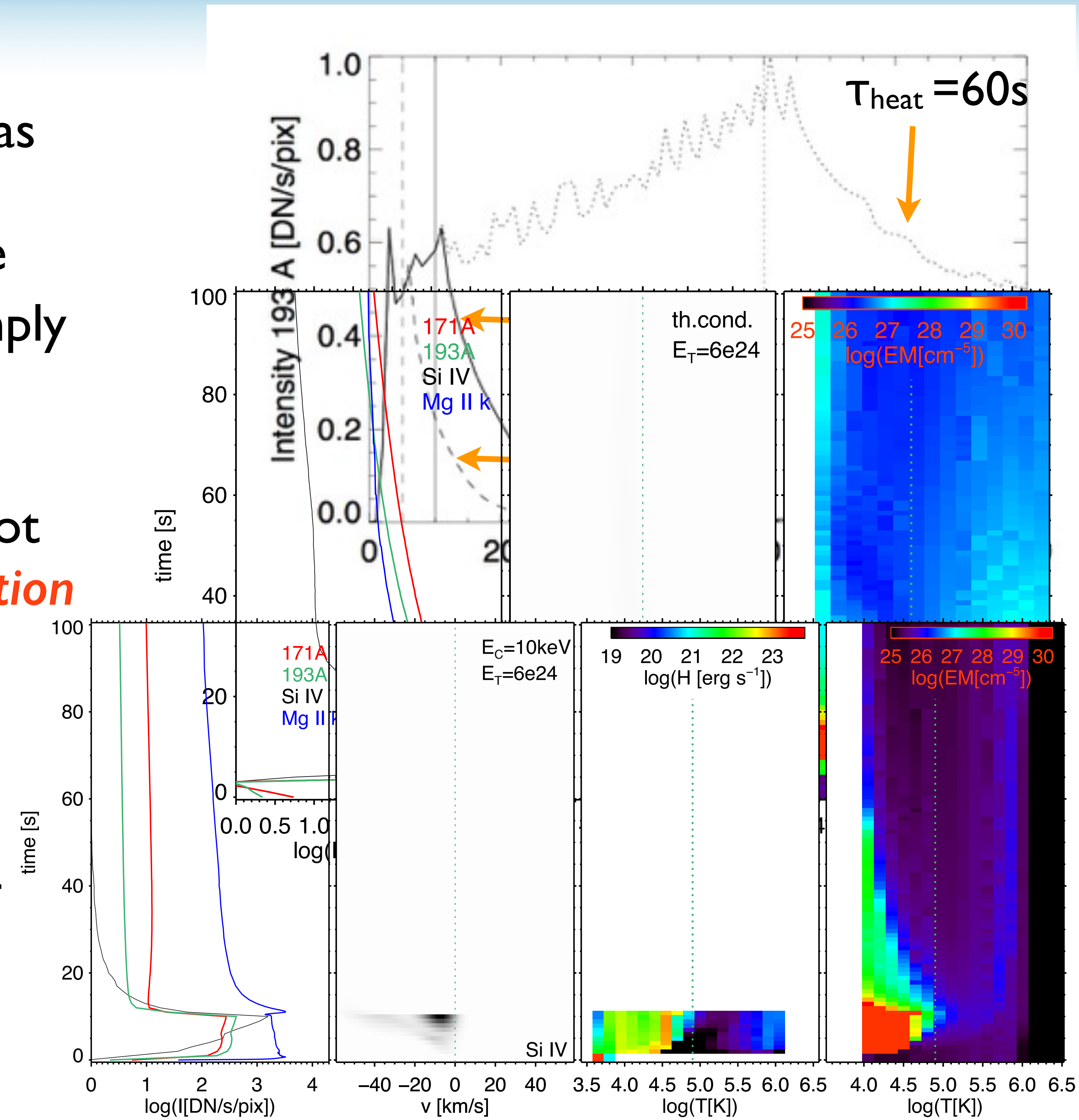
(Testa et al. 2014, *Science*)

What can we learn about heating?
Simulations of loops heated by "*nanoflares*"

- The transition region is a very sensitive diagnostic of the heating as its timescales depend on the timescales of evolution of pressure $\Longrightarrow$ short-lived TR brightenings imply impulsive heating

- blue-shifted SiIV brightenings cannot be reproduced by ***thermal conduction*** from the corona which leads to redshifted only TR emission

- heating by ***non-thermal particles*** reproduces the observed range of lightcurves, and the blueshifts observed for the SiIV emission



(Testa et al. 2014, *Science*)

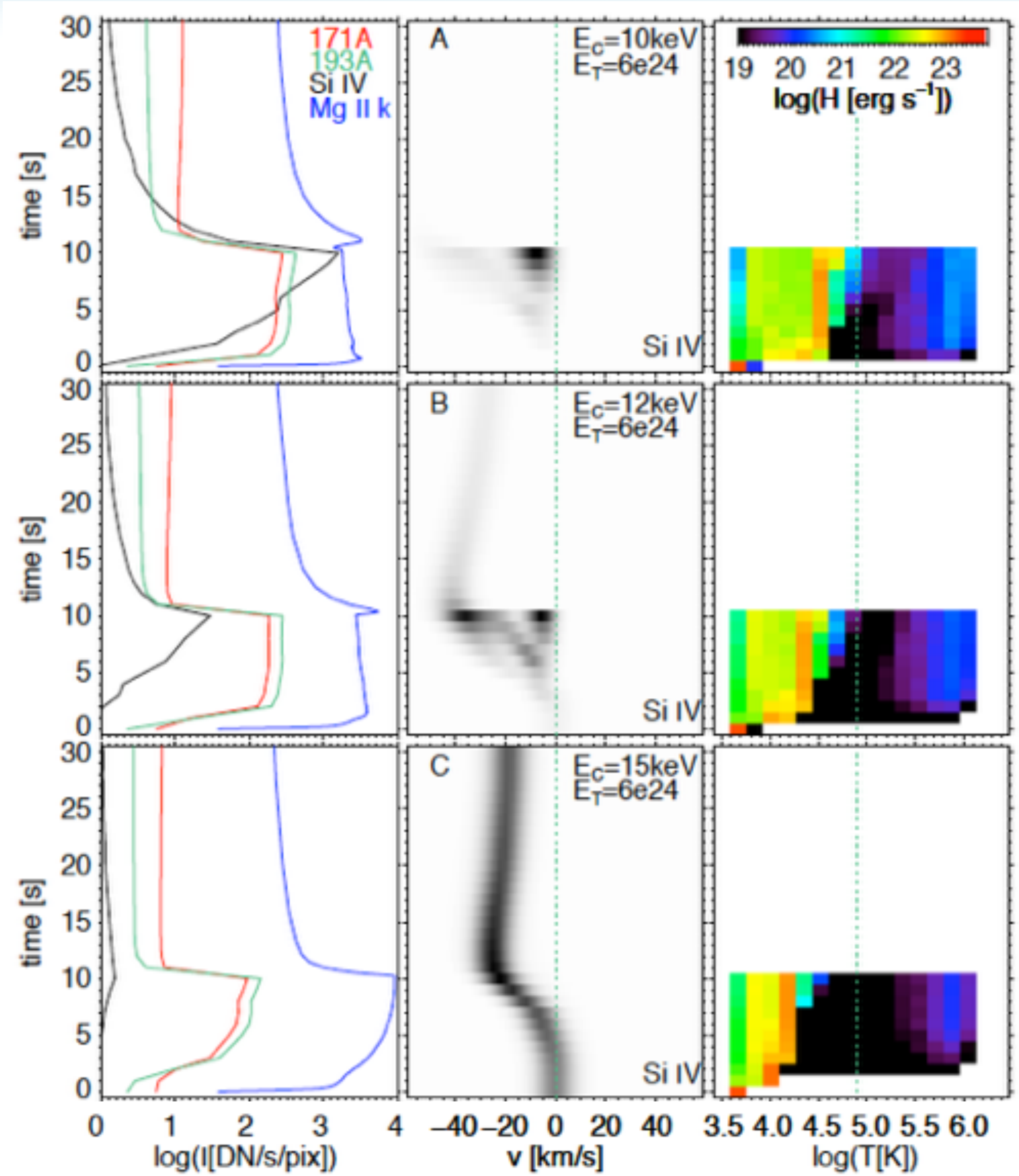
What can we learn about heating? Results of simulations:

- predicted emission is critically dependent on energy cutoff parameter, E_C: comparison with the observations allows to put tight constrain E_C

$\Longrightarrow E_C \sim$10-12 keV

- electron distributions with low E_C (<10 keV) yield results similar to conduction cases (including e.g., initial redshifts in SiIV emission)

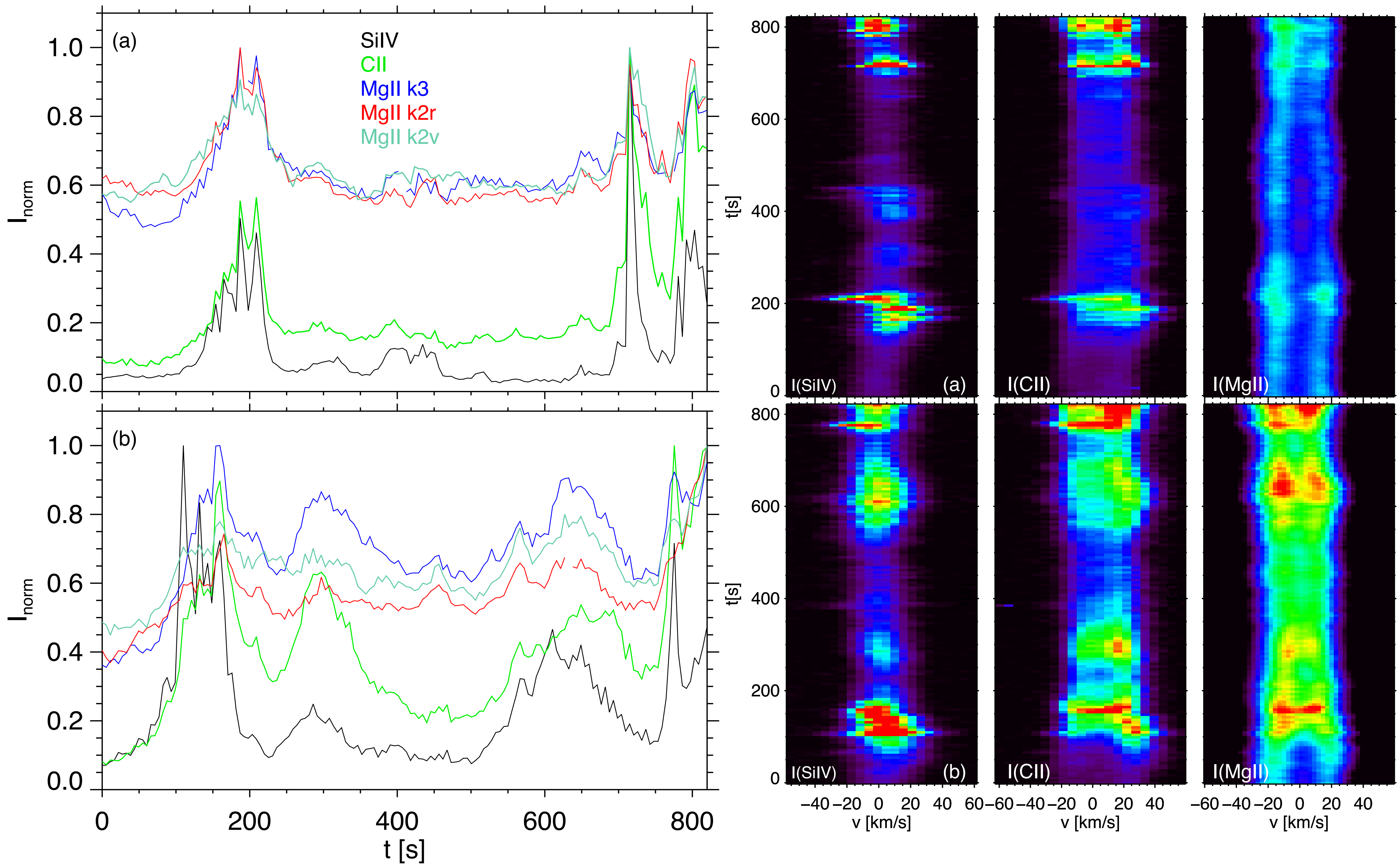
- for $E_C \gtrsim$15 keV, the energy is deposited too deep in the chromosphere $\Longrightarrow$ generally no observable TR brightenings



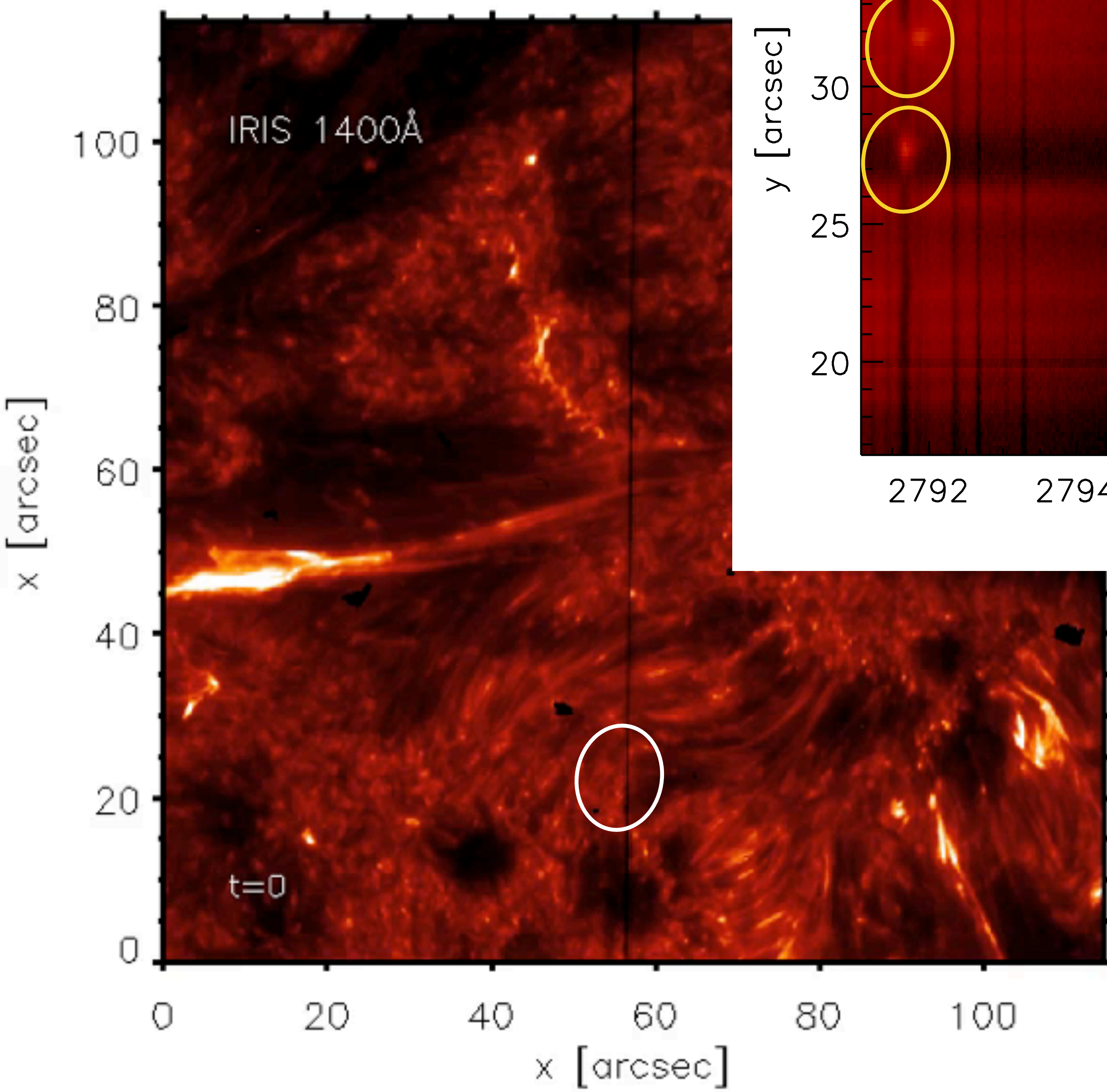
(Testa et al. 2014, *Science*)

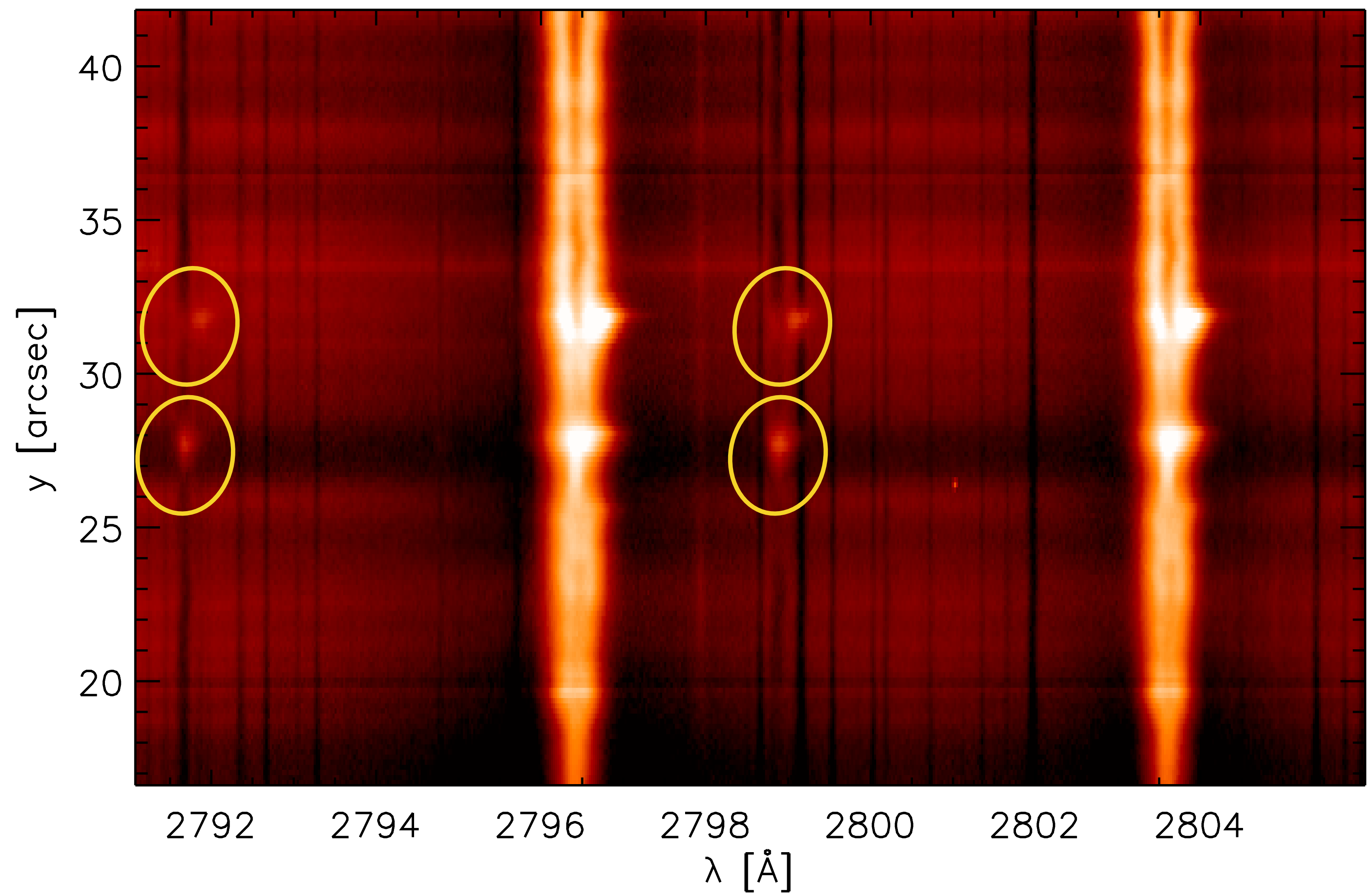
Work in progress

- interpretation of chromospheric diagnostics (C II, Mg II, Mg triplet lines)
- more accurate modeling of initial atmosphere



Heating in the low atmosphere





Mg II triplet emission indicates heating in the low chromosphere (Pereira et al., 2015)

see Tiago's talk

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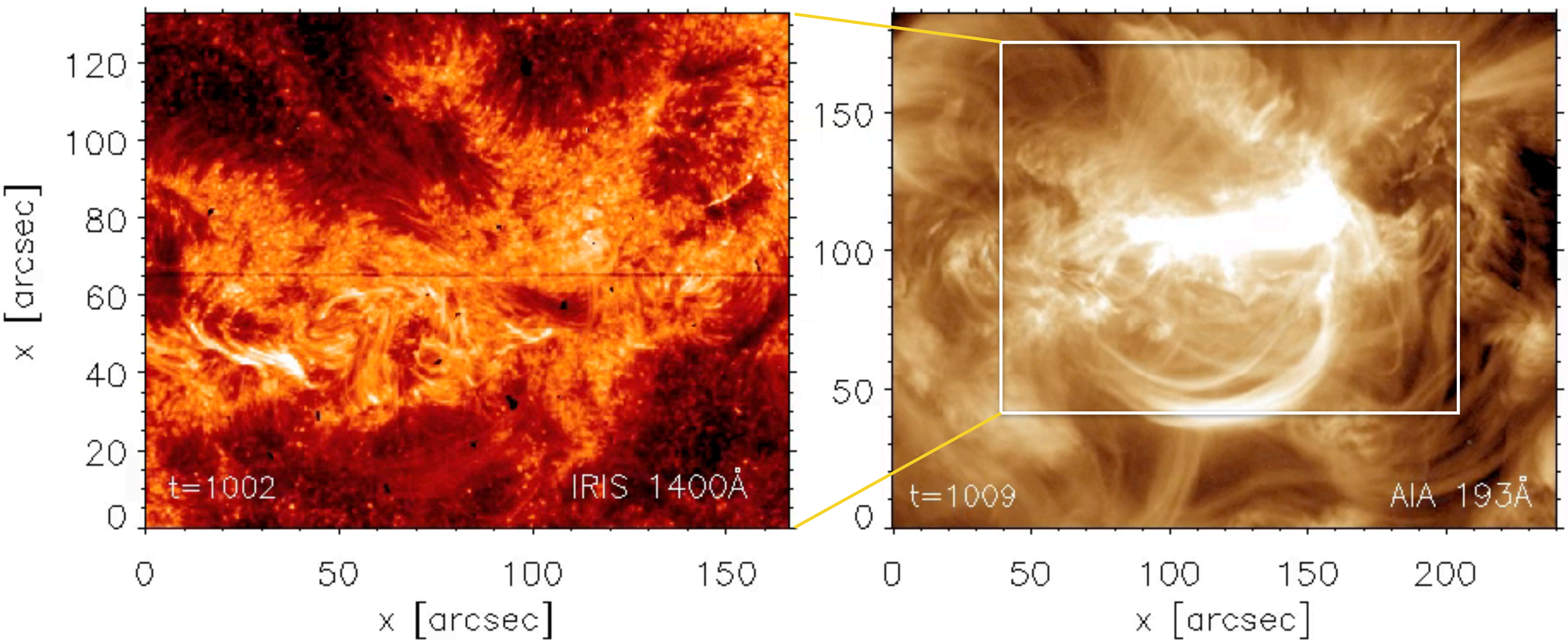
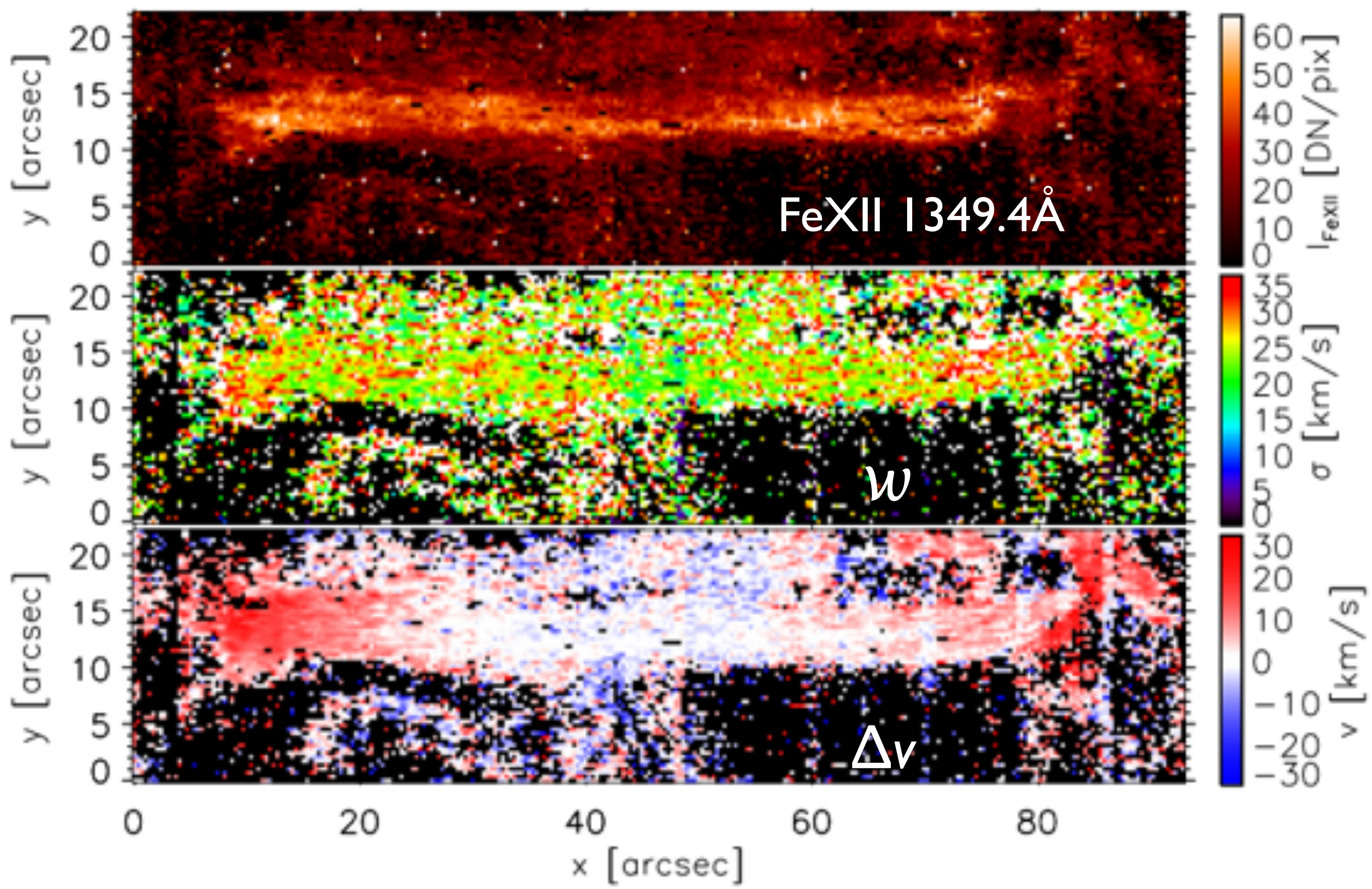
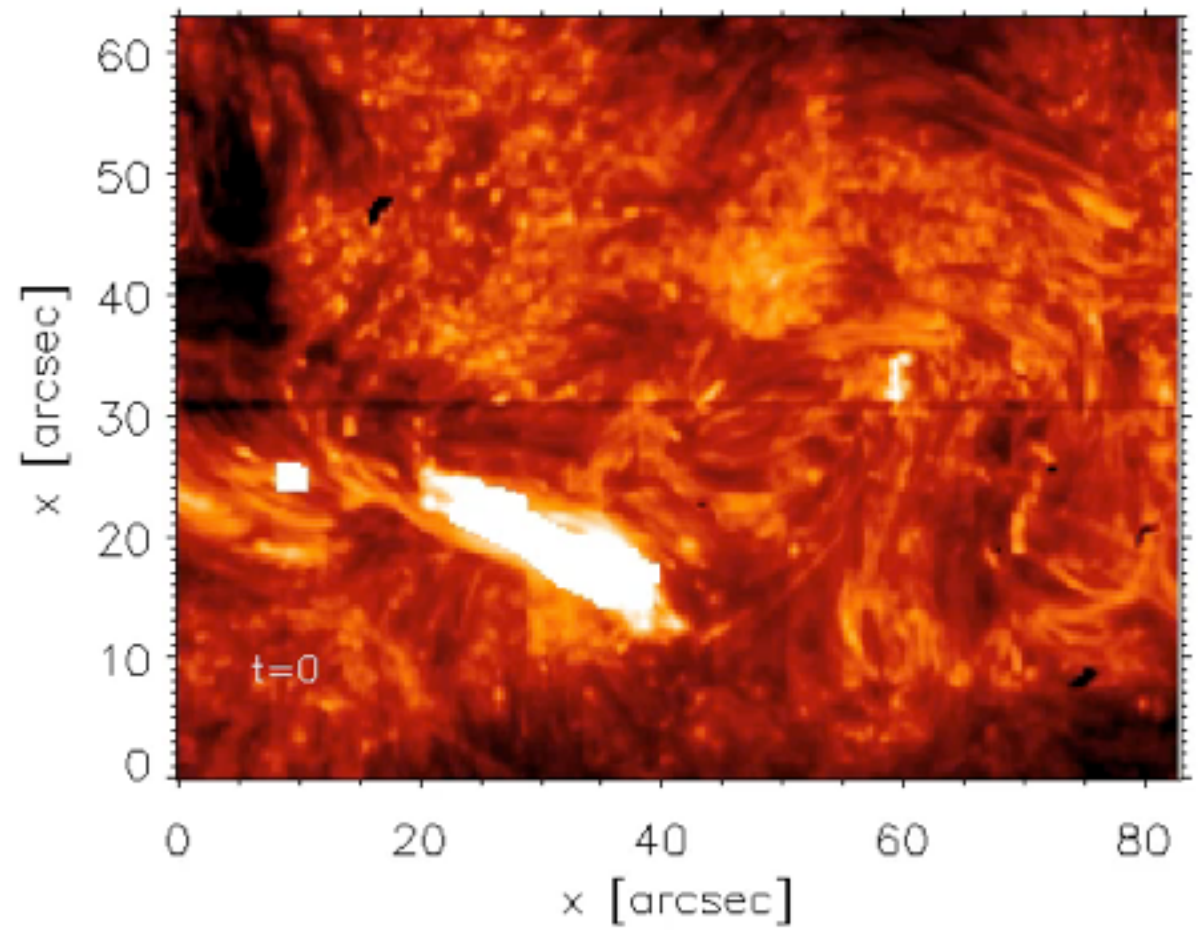
Fe XII IRIS emission



- post-flare loops (C6 flare)
- FeXII line intensity, width, Doppler shift

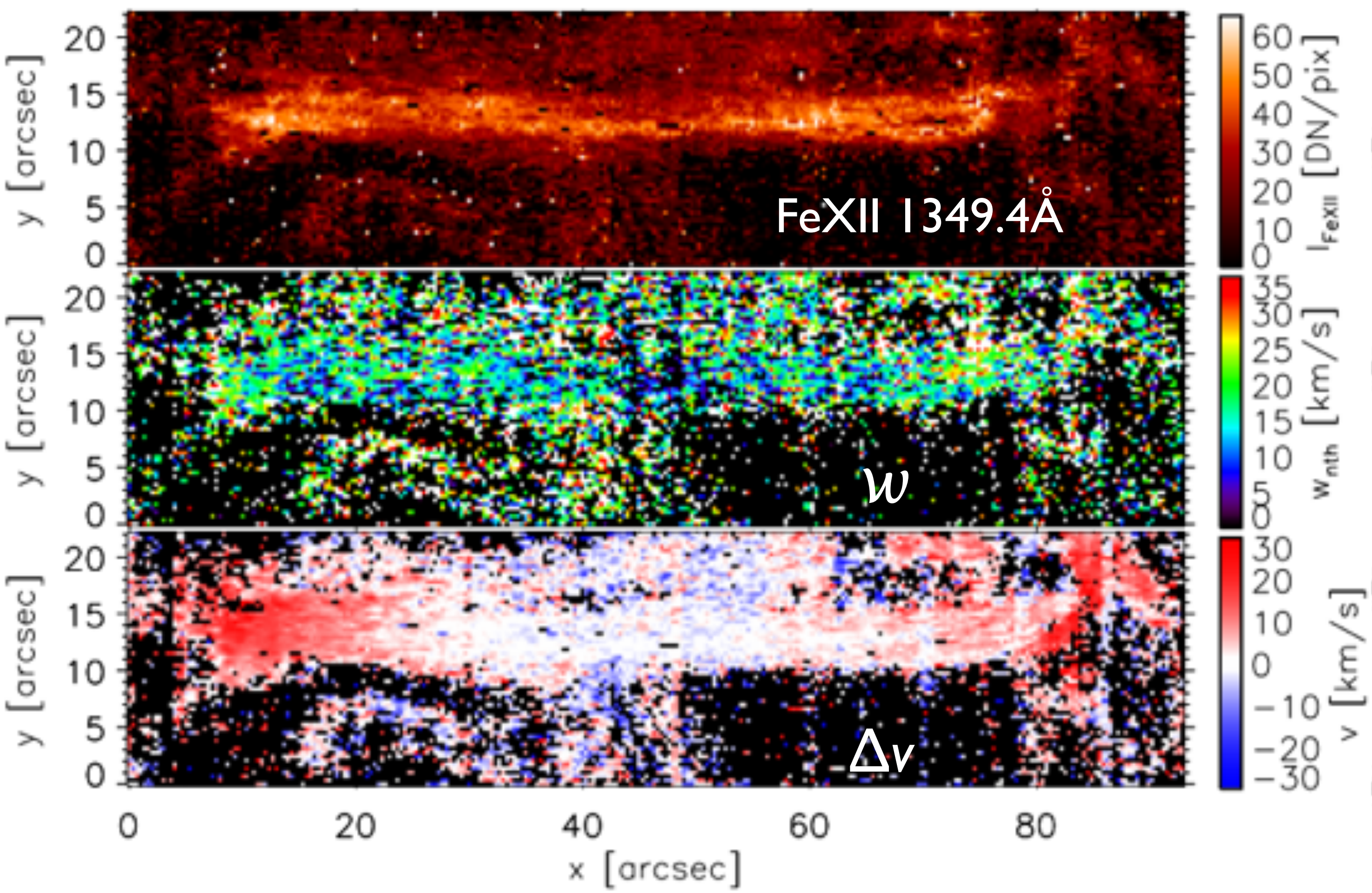
Fe XII IRIS emission

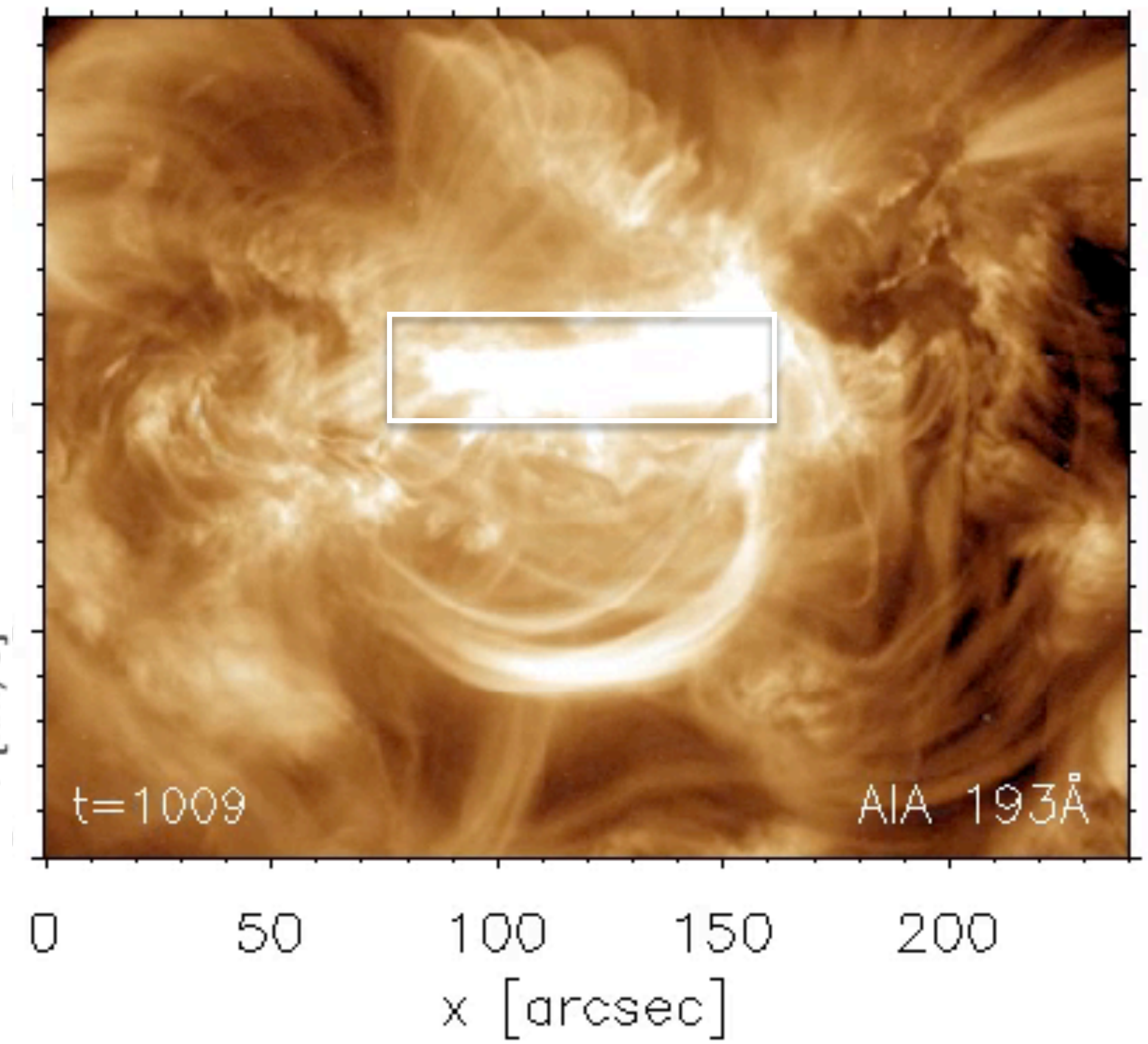




- FeXII line intensity, width, Doppler shift, at high spatial resolution

Fe XII IRIS emission





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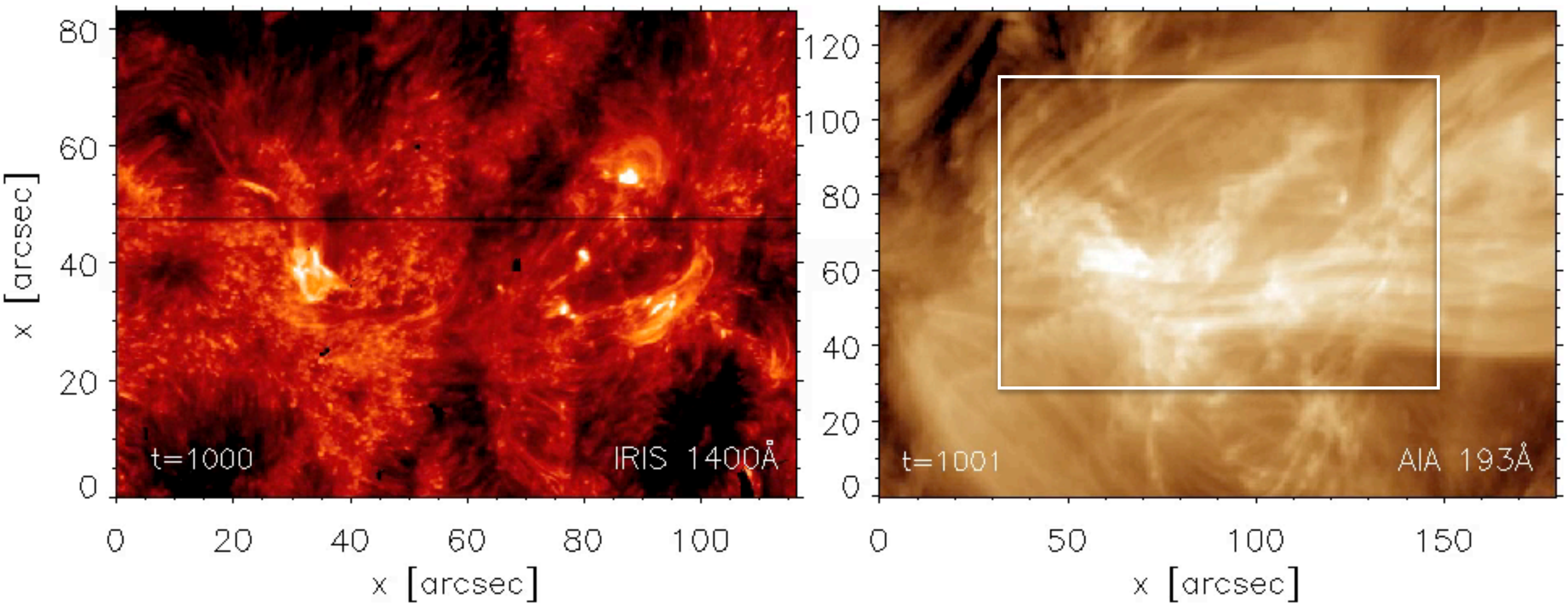
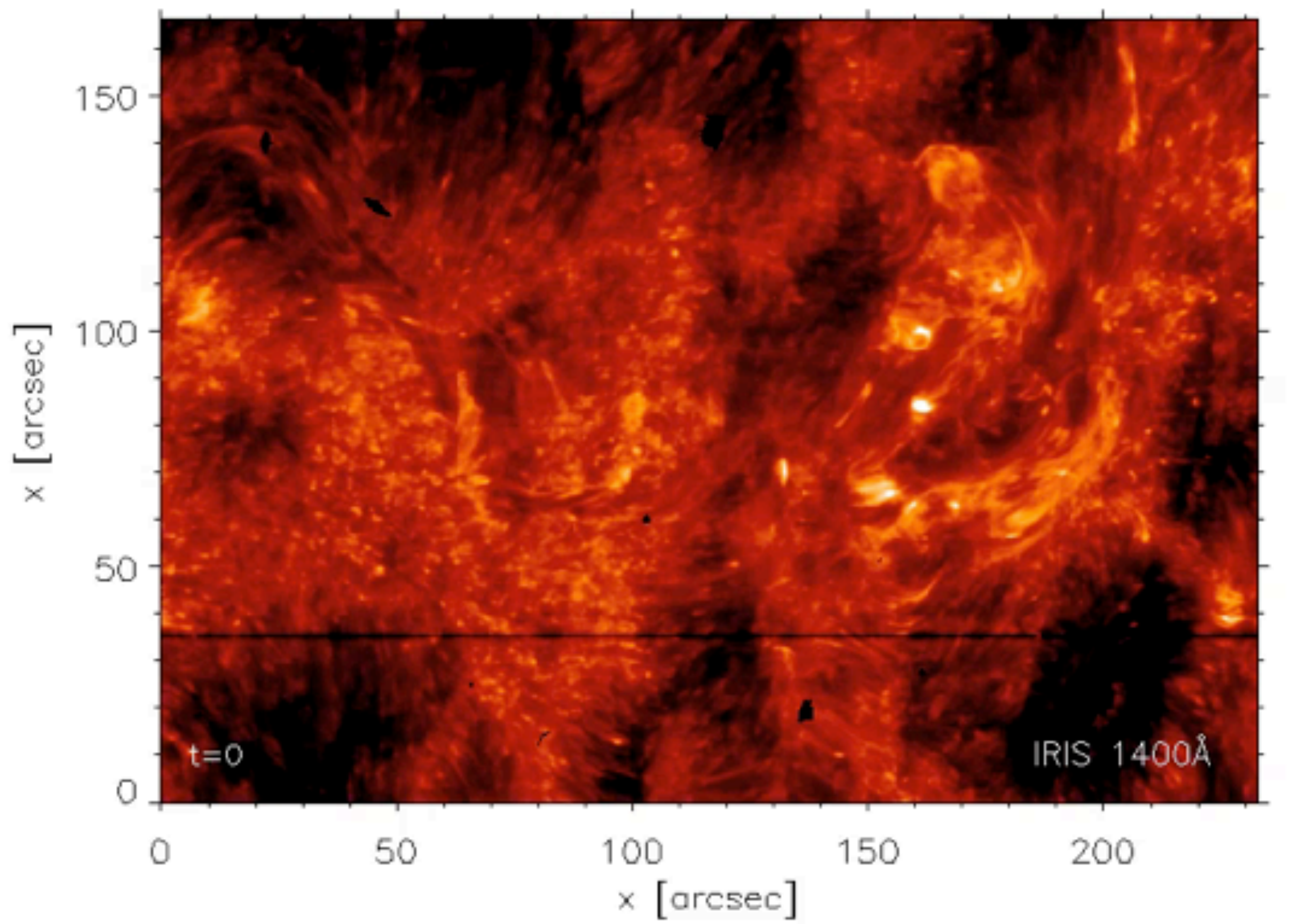
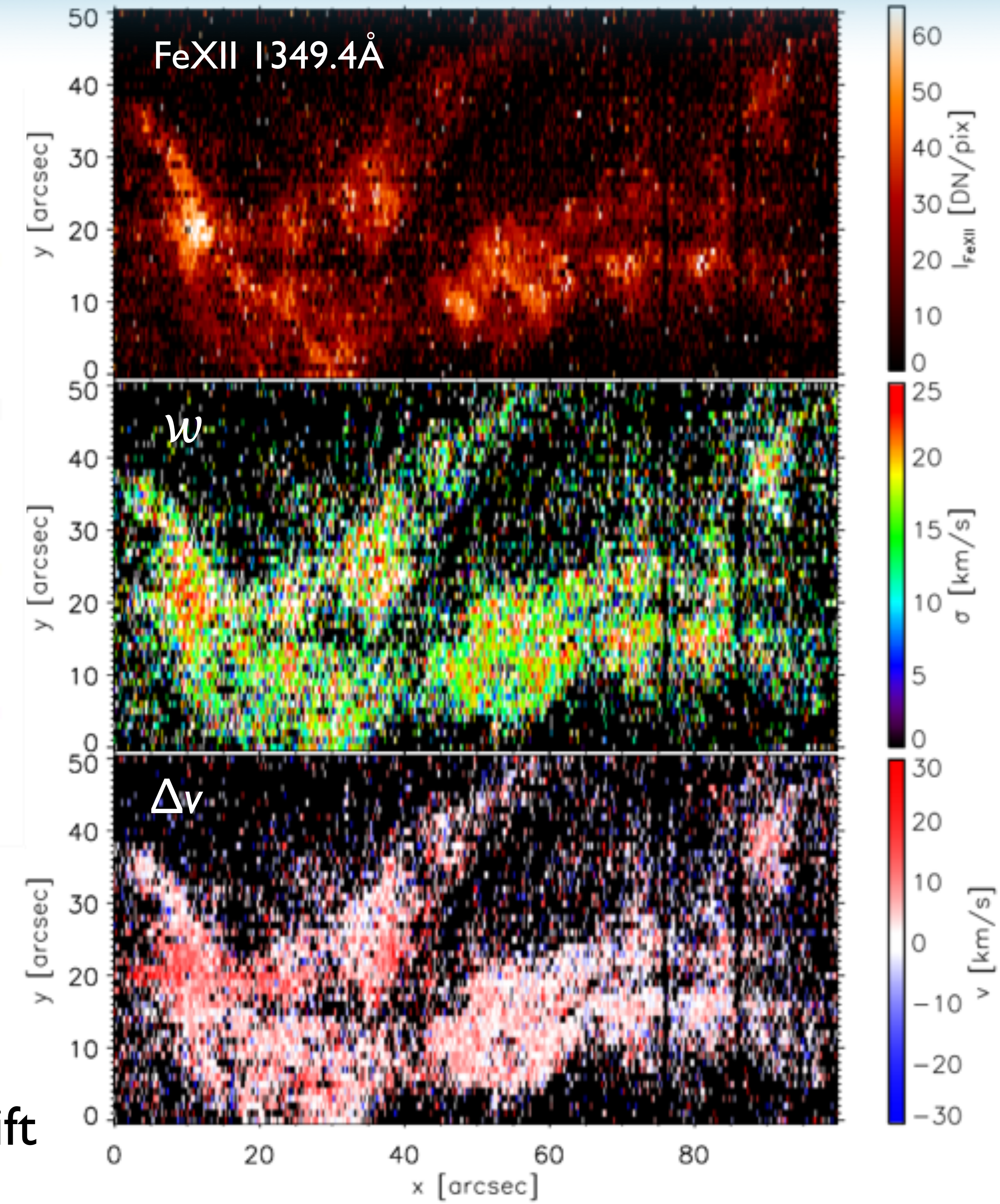


- moss FeXII emission
- FeXII line intensity, width, Doppler shift

Fe XII IRIS emission





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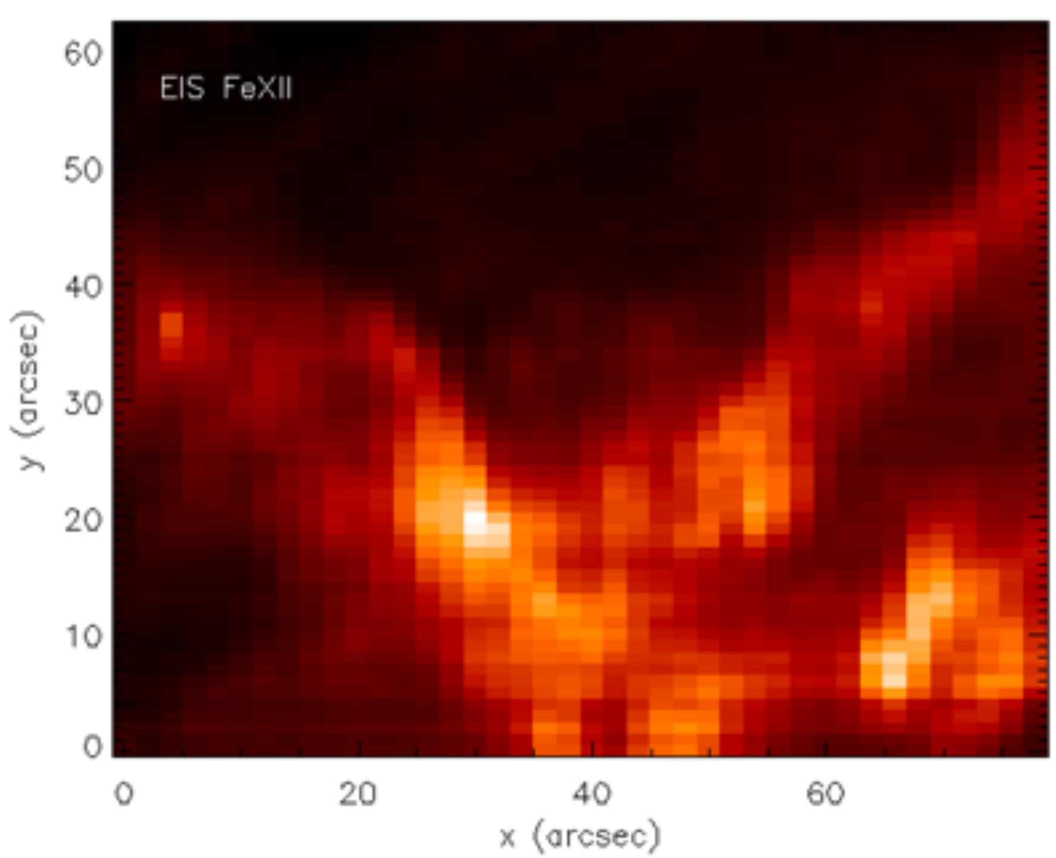

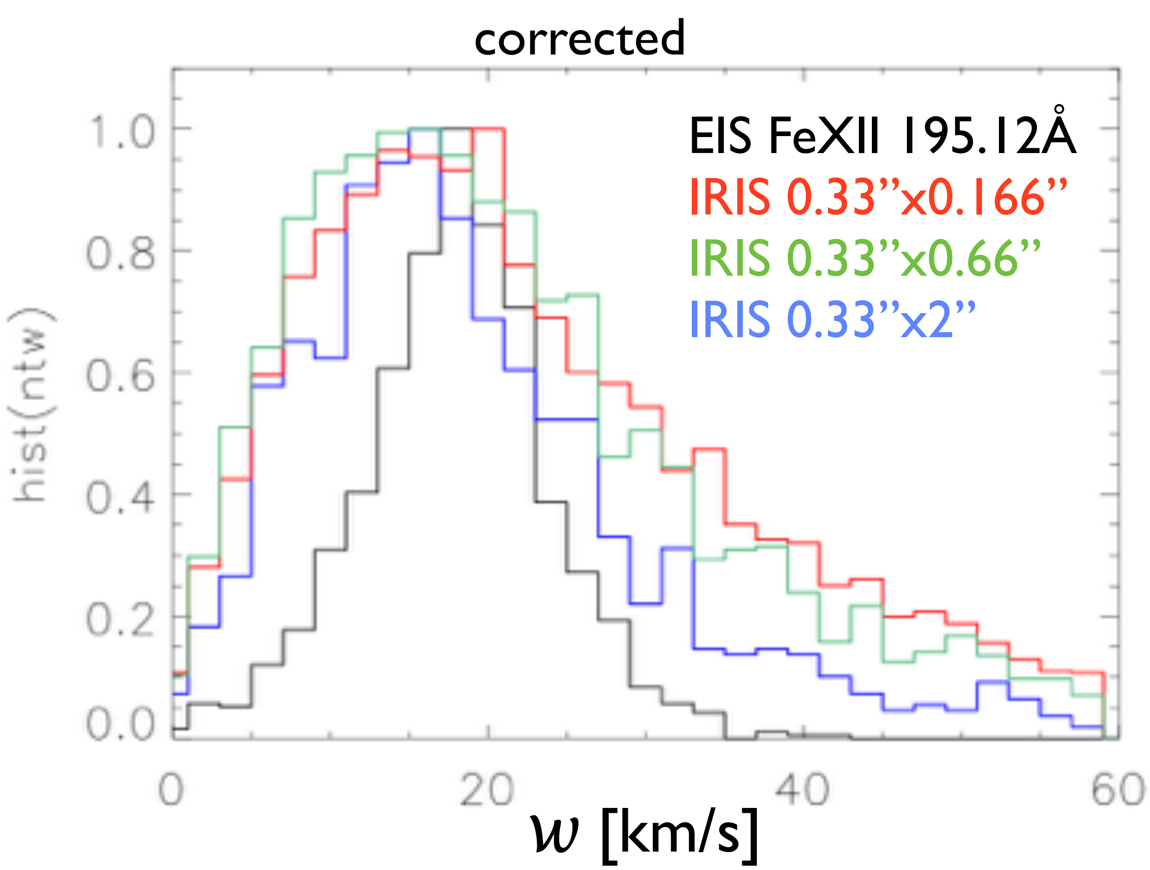

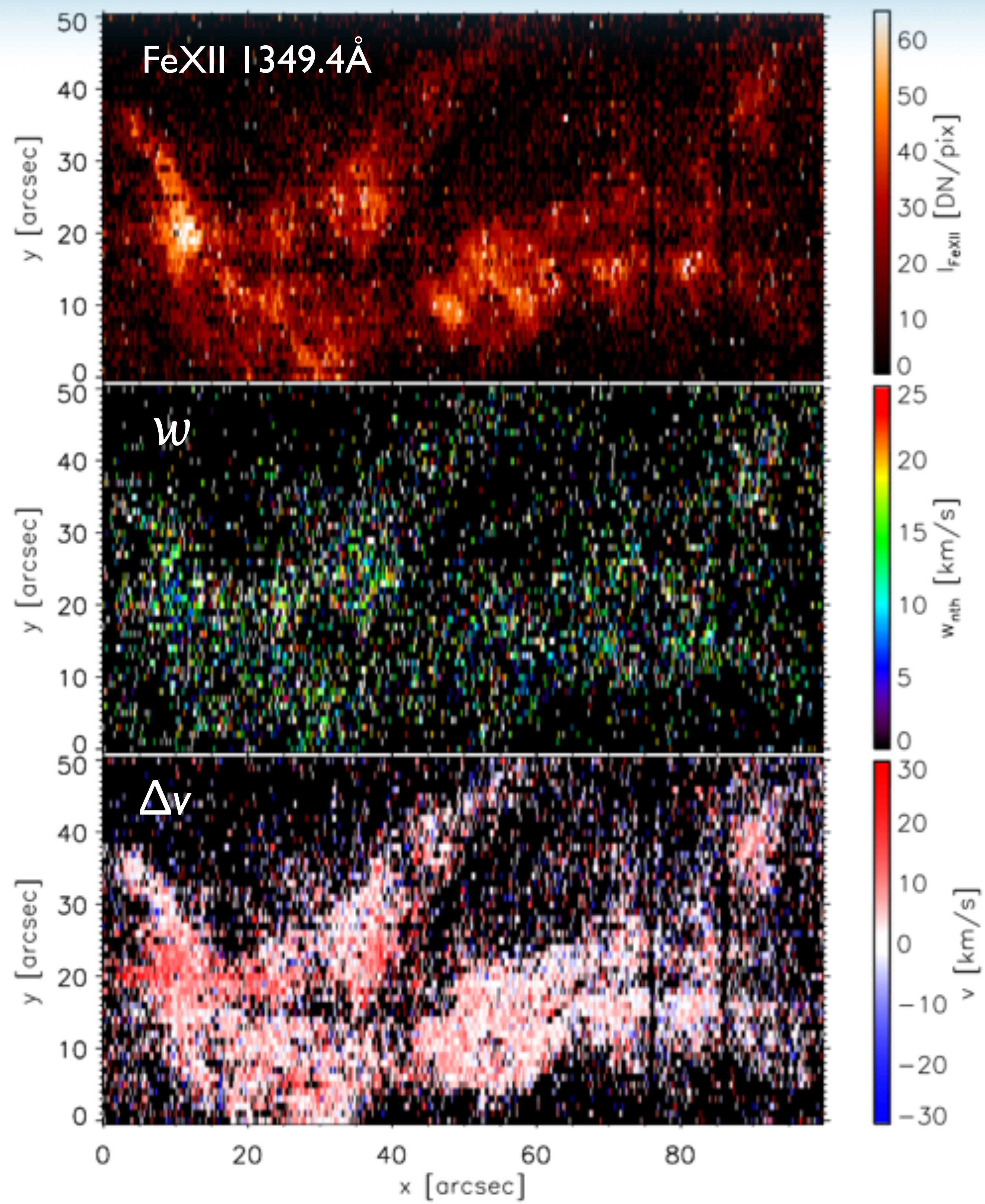

Conclusions

- IRIS provides very high *spatial, spectral and temporal resolution* observations of the loops transition region, chromosphere, and corona that provide constraints on coronal heating

  - dynamics and structuring down to the limit of the resolution $\Longrightarrow$ progress in understanding the role of different processes in atmospheric heating

  - rapid moss variability $\Longrightarrow$ evidence and diagnostics of impulsive, "nanoflare", coronal heating

  - IRIS+modeling $\Longrightarrow$ new diagnostics for energy transport mechanisms (conduction vs. beams)

  - non-thermal electron are produced even outside flares, their parameters are tightly constrained by observations (energy, duration, E_C)

  - Fe XII emission shows systematic redshifts and very small non-thermal line broadening (ξ) in moss, while ξ appears significant in post-flare loops