EVE Spectroscopy of Solar Flares

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Why is EVE important?

Because MEGS opens new domains in parameter space, from which we can discover things

- Spatial resolution X
- Spectral resolution Δ
- Time resolution O
- Spectral range Δ
- SNR O
- Calibration O*

*O = good, Δ = indifferent, X = bad

What is EVE doing?

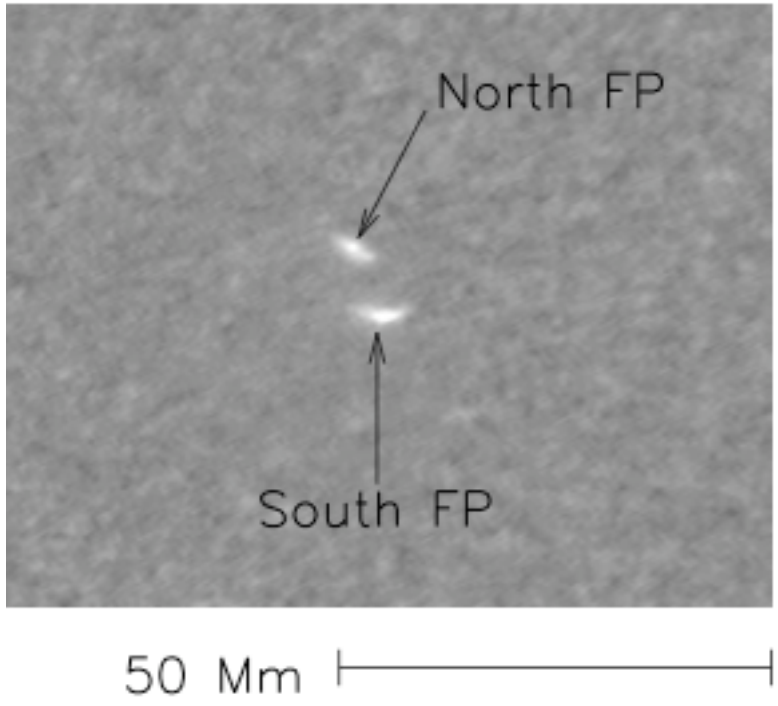
Published or dreamed-of research projects

• Doppler shifts	Δ
• Non-thermals	~
• SEPs	X
• Continuum characterization	O
• Flare impulsive phase	~
• Flare Energetics	O
• Dimming	O
• Late phase	O
• Coronal Heating	?
• Prominences	?
• DEM analysis	?
• Abundance variations	?

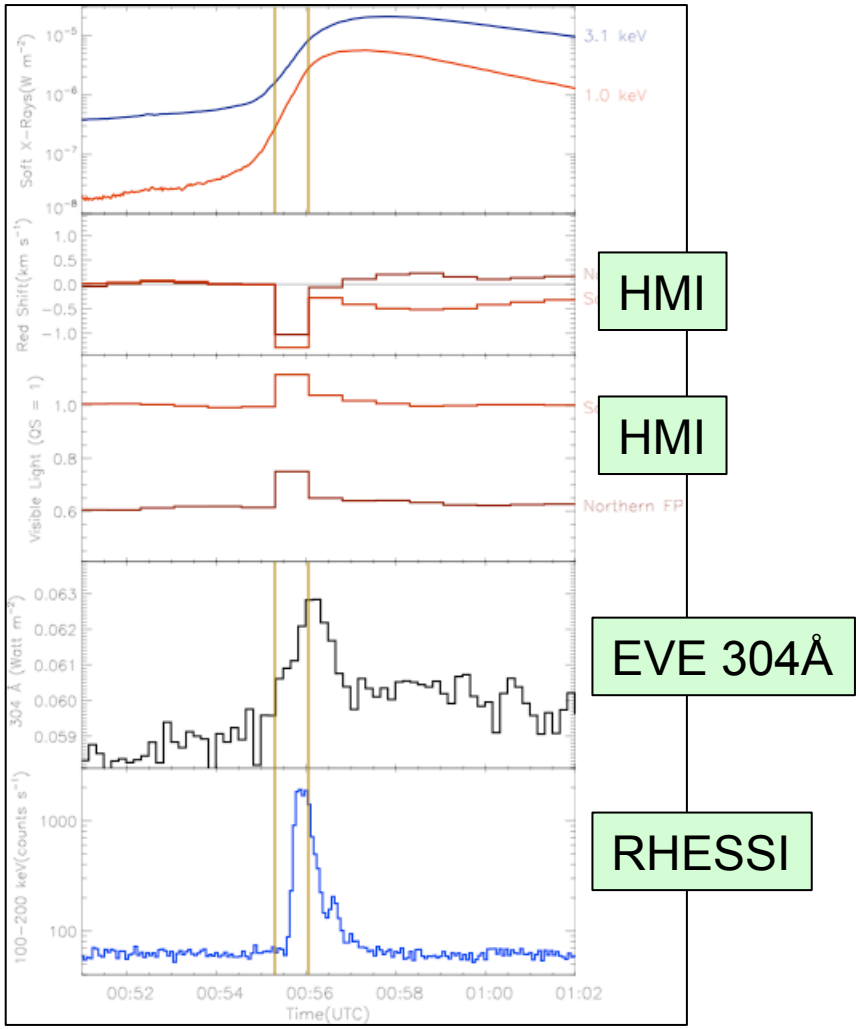
…

*O = good, ~ = indifferent, X = bad

EVE: the impulsive phase

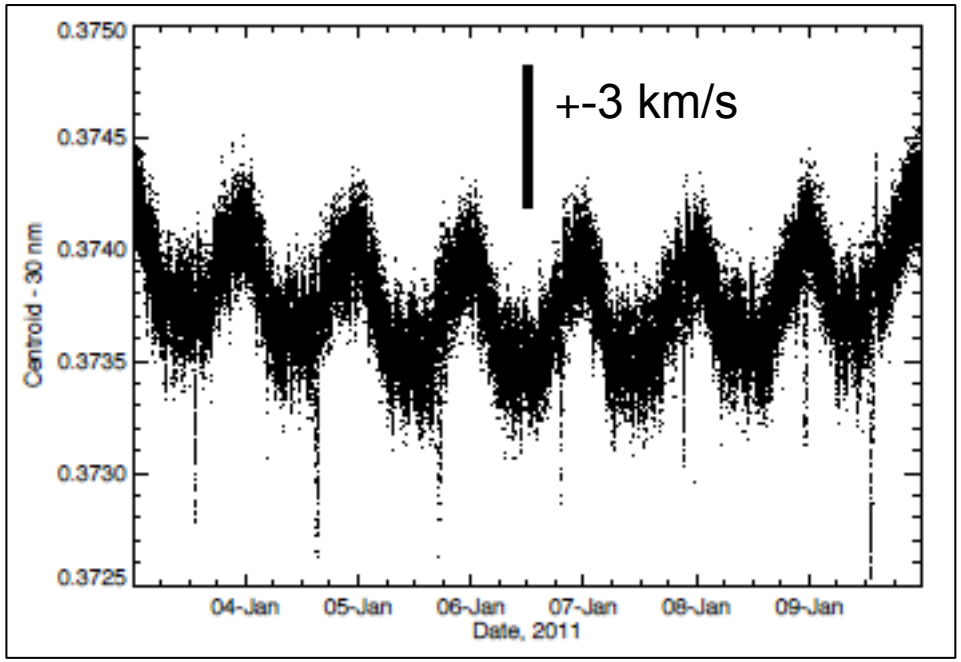


From Martinez-Oliveros et al. 2011. Recall early observations of impulsive-phase EUV from Donnelly, Neupert, Cheng…



SOL2010-06-12 white-light flare

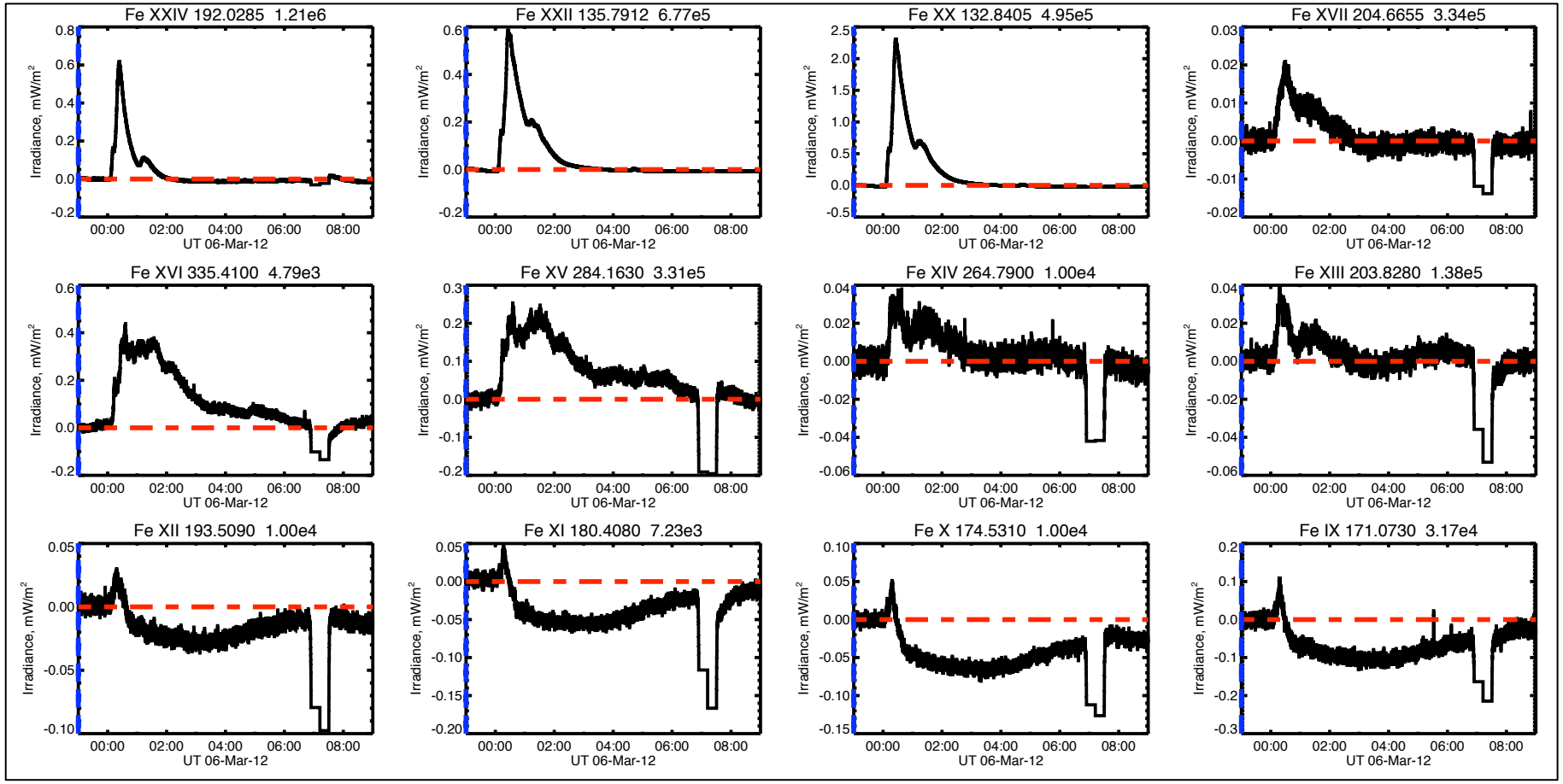
EVE: Doppler shifts



From Hudson et al. 2011. With only 1 Å resolution, but <0.01 Å random error (@10 s), EVE clearly resolves SDO's orbital Doppler shifts

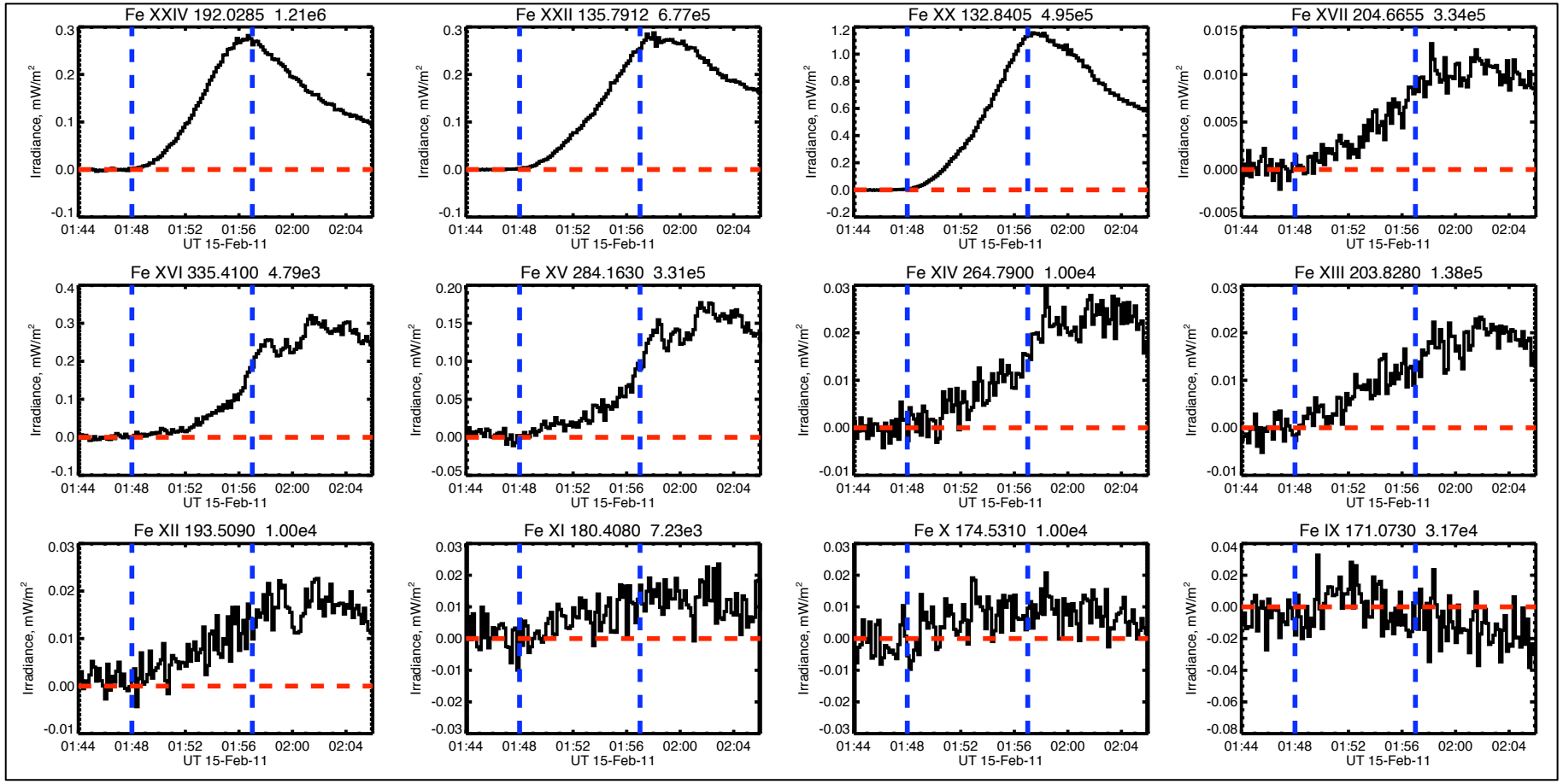
- The EVE MEGS-A has great stability and excellent sensitivity
- Flare Doppler signals are also detectable
- There is also *some* position sensitivity

EVE: The Fe Cascade



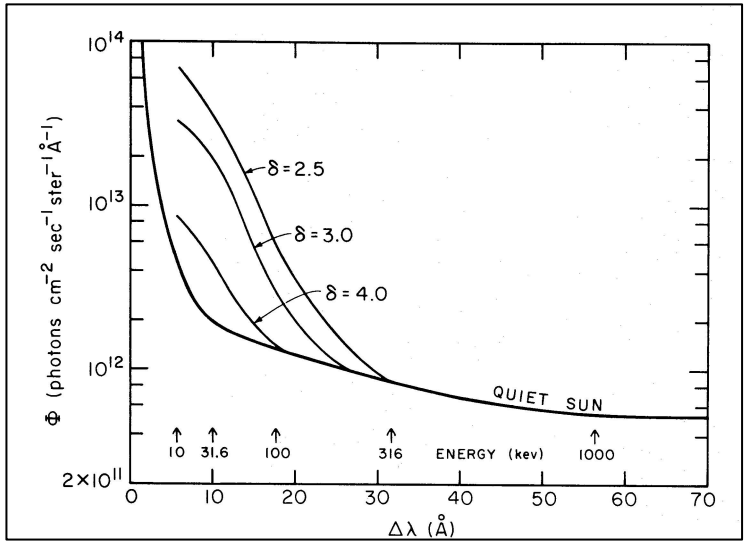
- EVE shows many ionization states of Fe
- The loop cooling and the dimming are easy to spot

EVE: The Fe Cascade

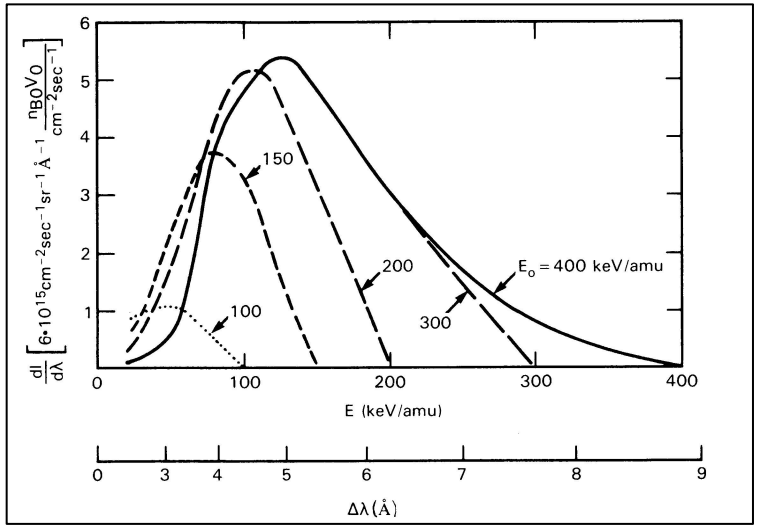


- Higher time resolution shows the loops cooling
- Is there a hint of low-excitation emission in the impulsive phase?

Charge-exchange signatures: theory



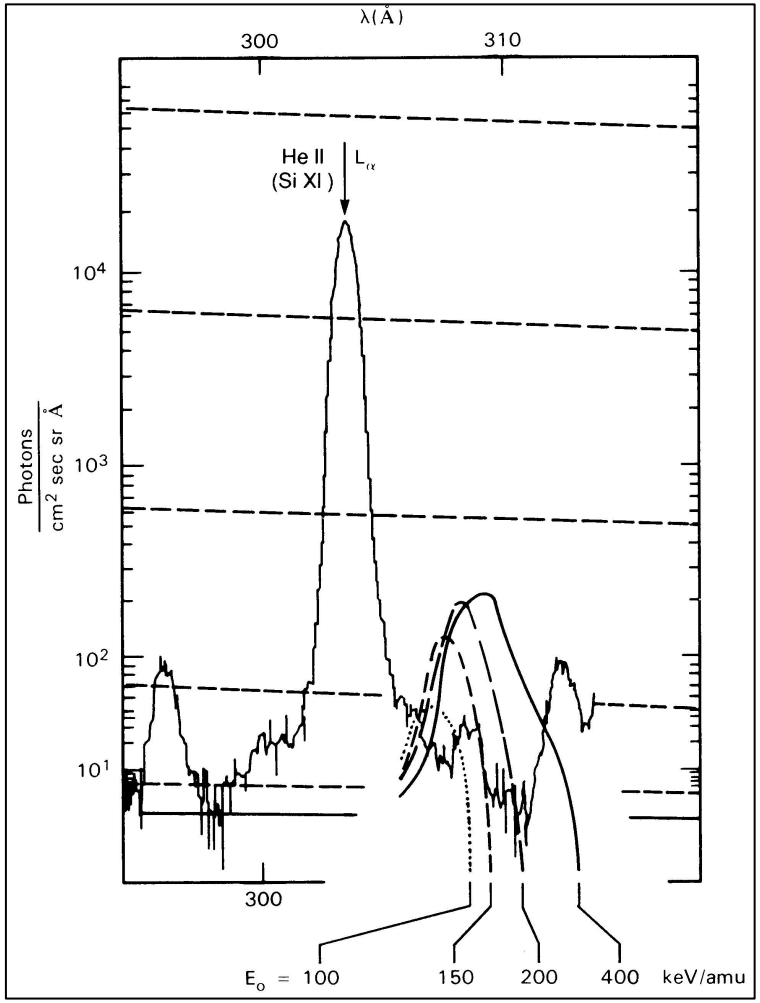
Orrall & Zirker (1976), for hydrogen



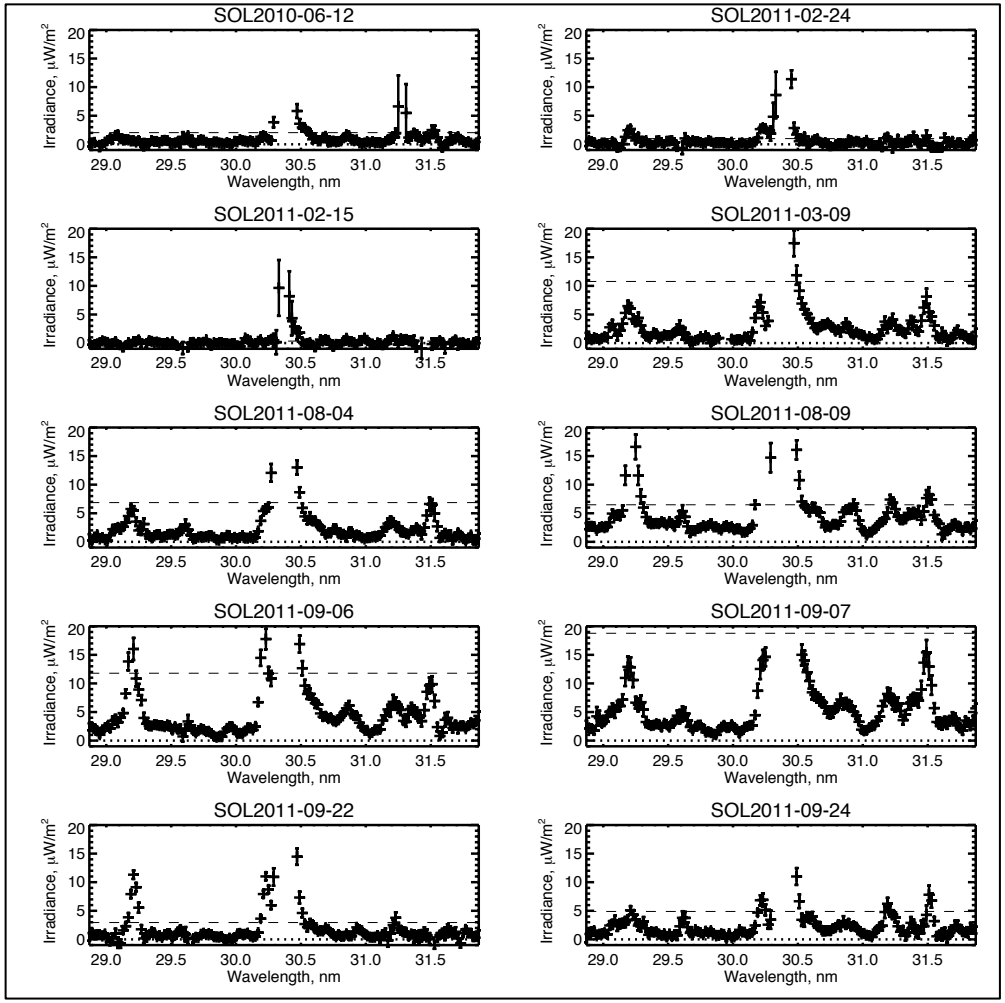
Peter et al. (1990), for helium

- Accelerated particles penetrating a neutral atmosphere can pick up electrons and radiate in the line wings
- Detection would be a boon, because we would have a remote-sensing technique for ions, which only weakly emit bremsstrahlung and for which the γ-ray threshold energies are high
- Searches thus far have been ambiguous but limited

Charge-exchange signatures: EVE



Peter et al. (1990) expectation



EVE realization: 8 major flares, no bright 304 Å wings whatsoever (difference spectra, gradual phase, linear scale here)

Charge-exchange: Postmortem

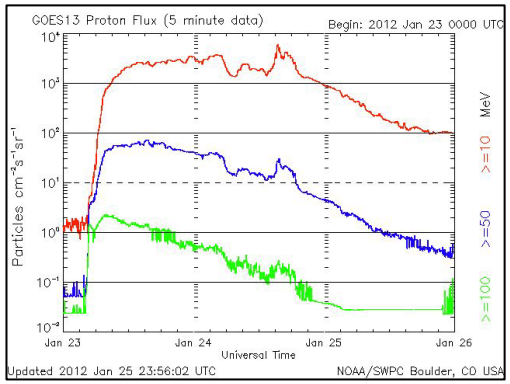
• There is no hint of charge-exchange wings near the He II Ly-α analog at 304 Å – no α-particles?

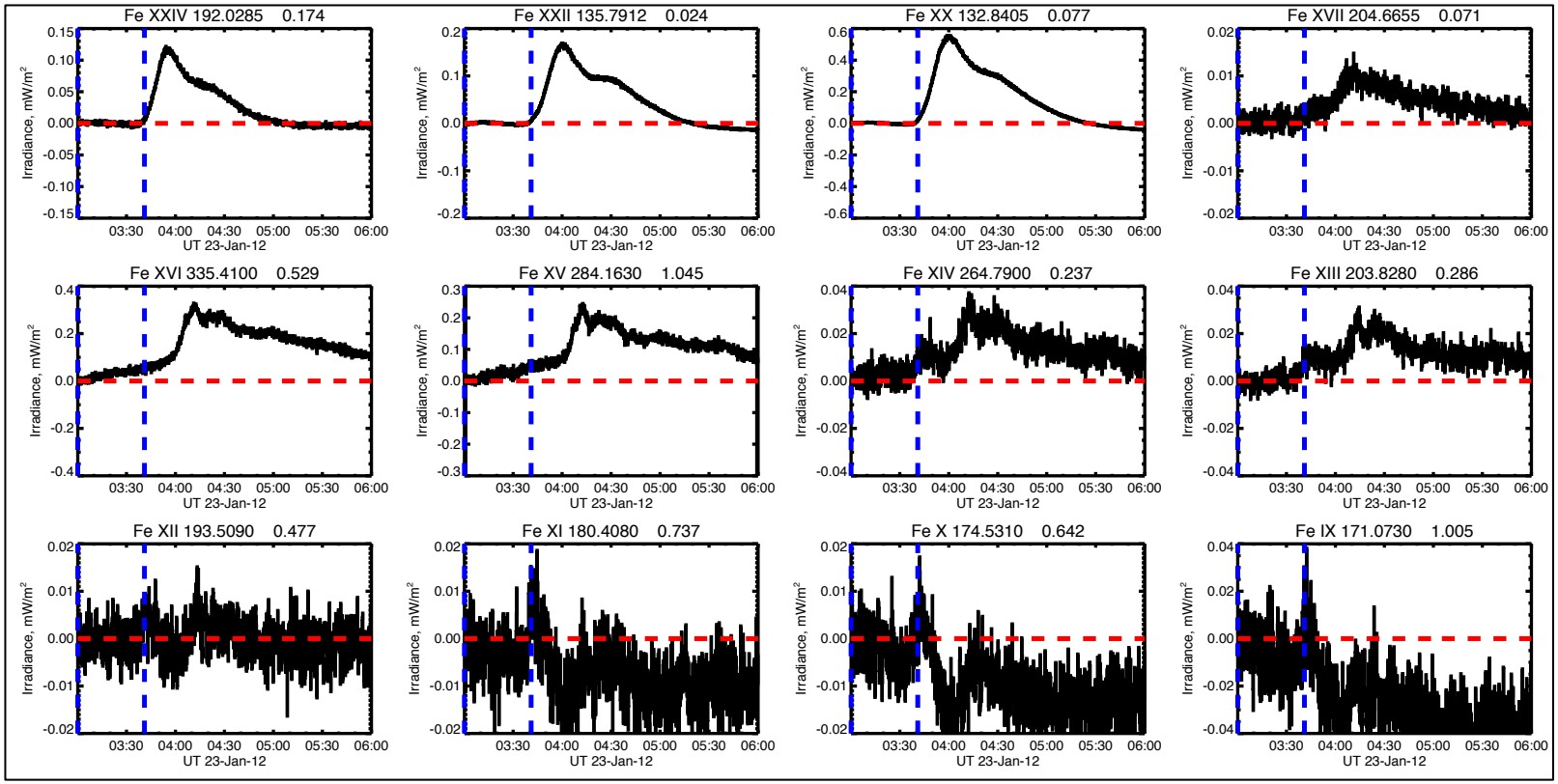
• The theory has too many “reasonable assumptions” (recall Uri’s comments)

• The observational result is robust and somewhat disappointing (but only one pixel)

• We should not give up on this, though; charge-exchange products are observed in comets and the aurora. And, we know that α-particles are abundant in SEPs

Charge-exchange: Search for SEPs
(eg, charge exchange on solar-wind oxygen)





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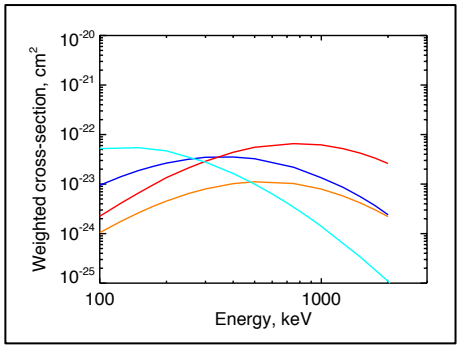
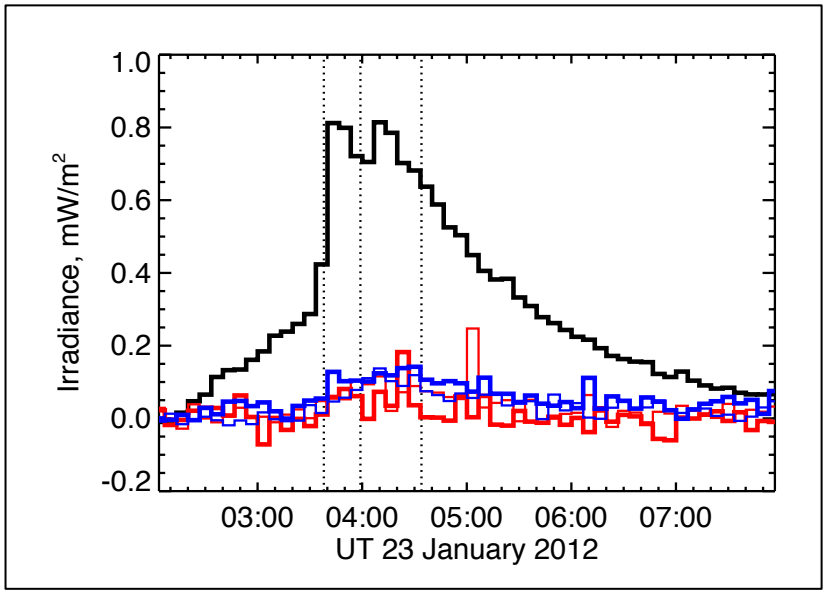
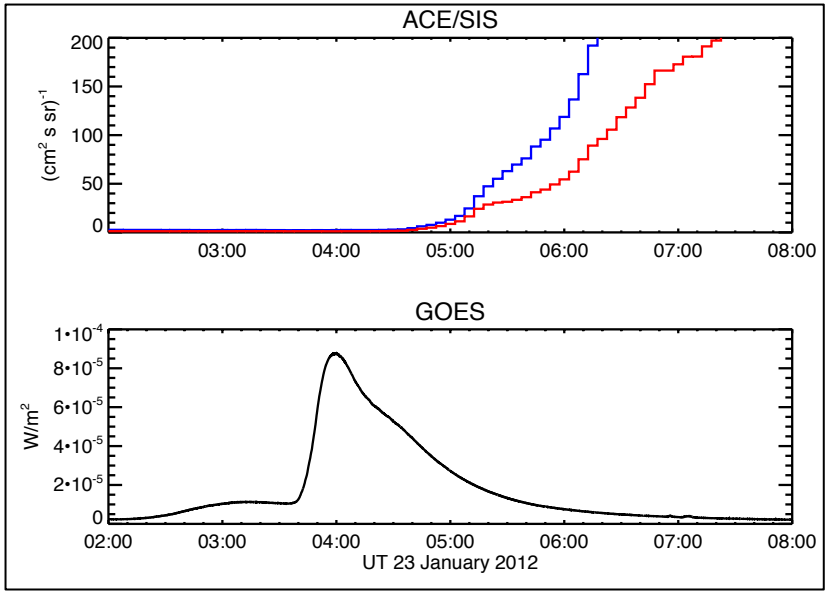




Light curves for 304 A and ~1 MeV wings



SEPs arrival at ACE (10 and 30 MeV)

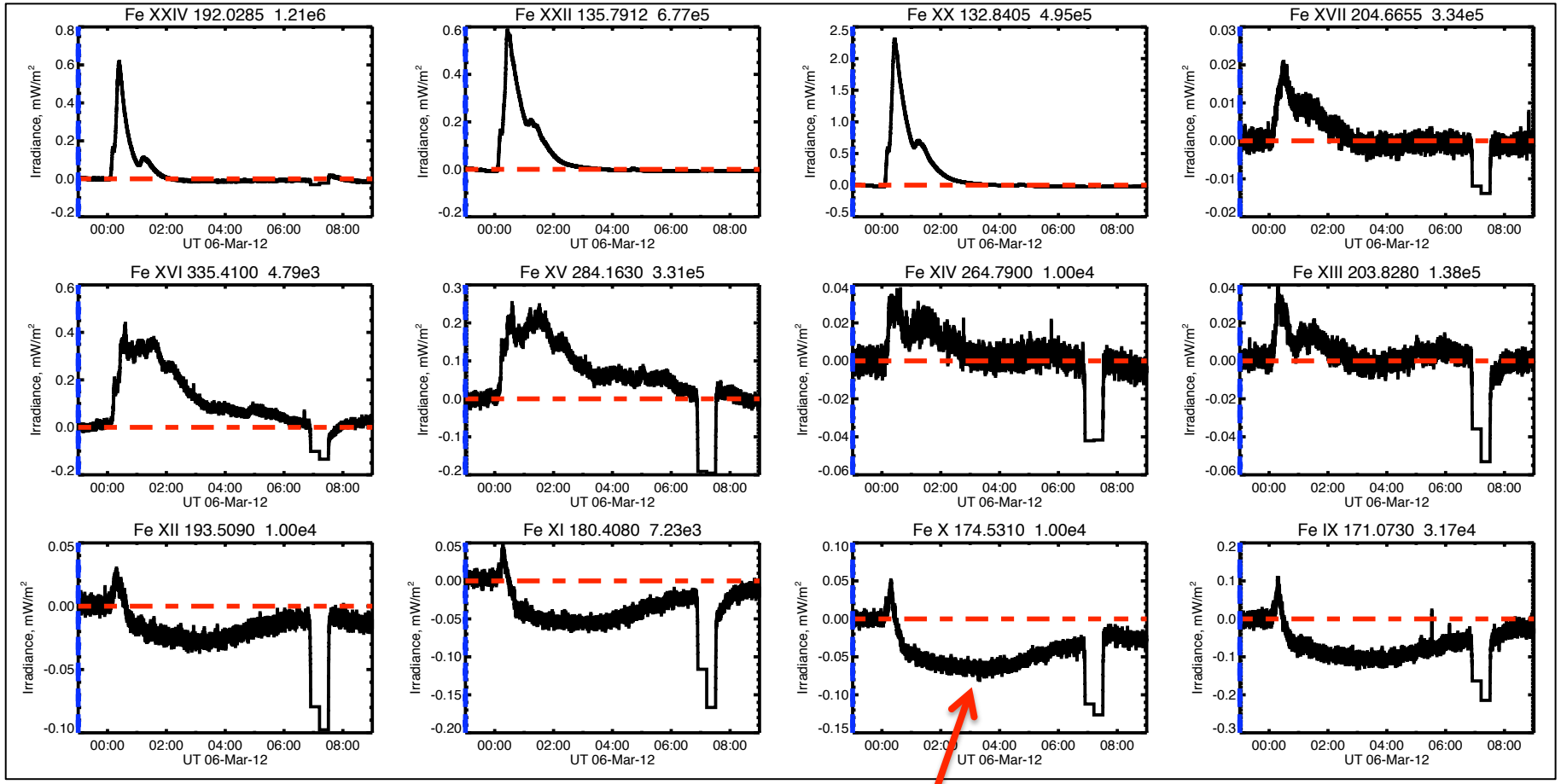
Search for SEPs, bottom line

- EVE is not sensitive enough because of the high background levels

- Remote sensing of SEPs via imaging spectroscopy should be possible

- As noted by others (e.g., Kahler & Raymond), this capability would be a wonderful new development

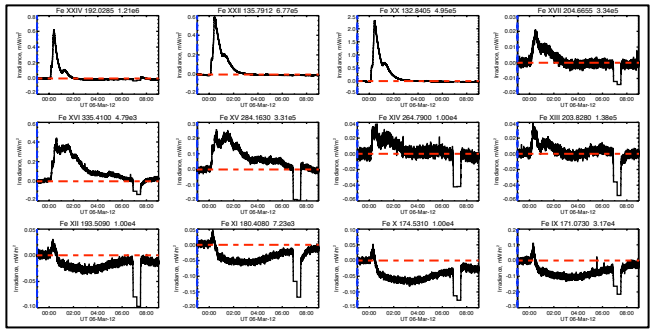
Where does CME mass originate?

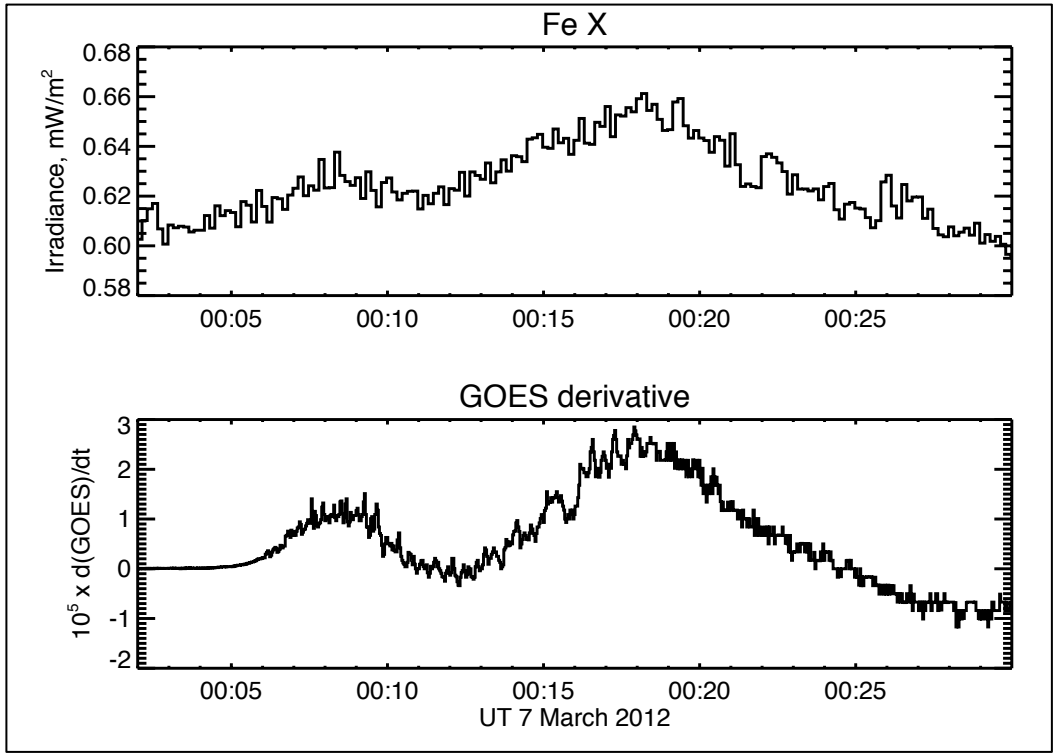


Dimming (CME)

Where does CME mass originate?

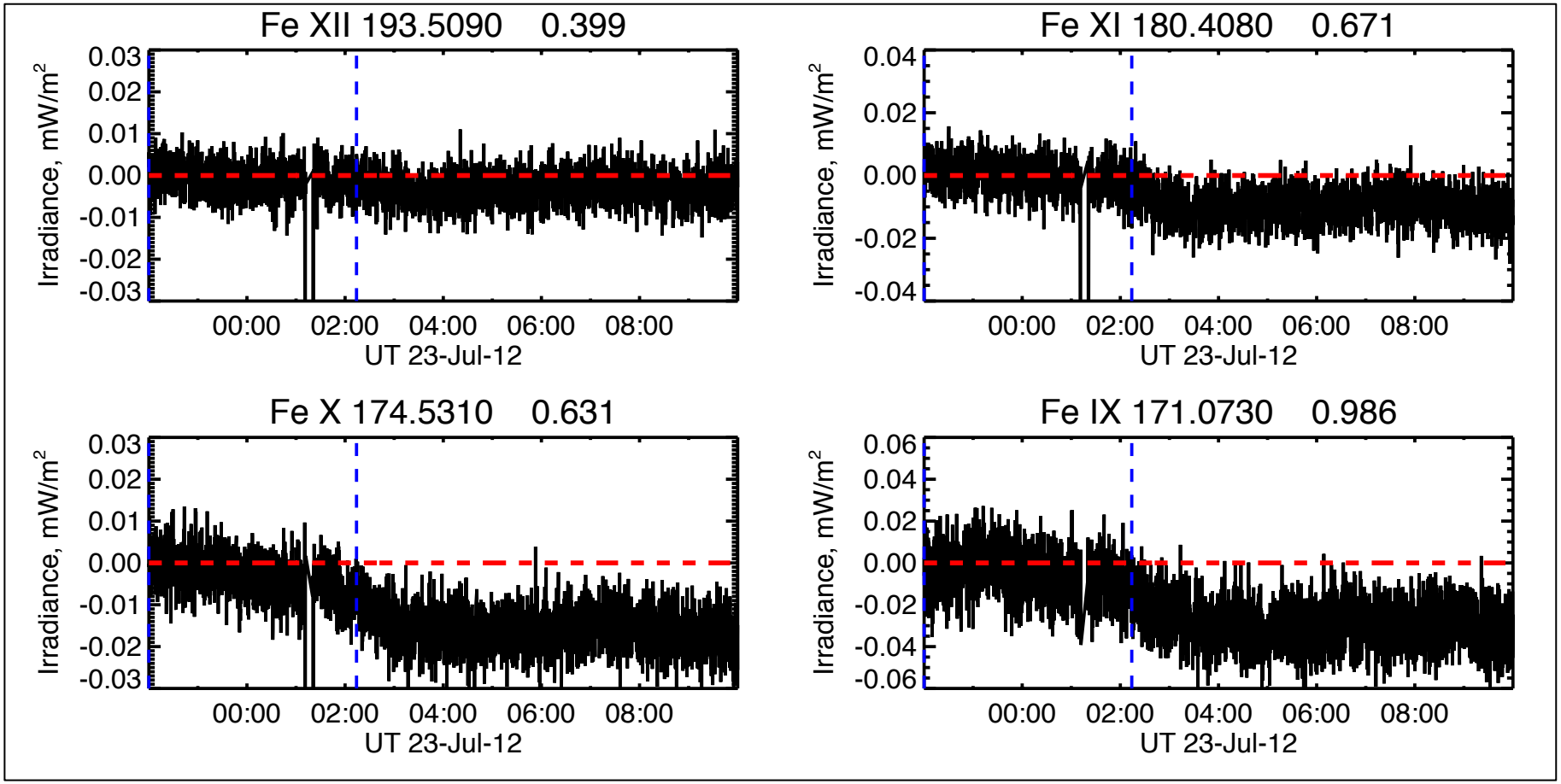
To understand this, check the impulsive phase

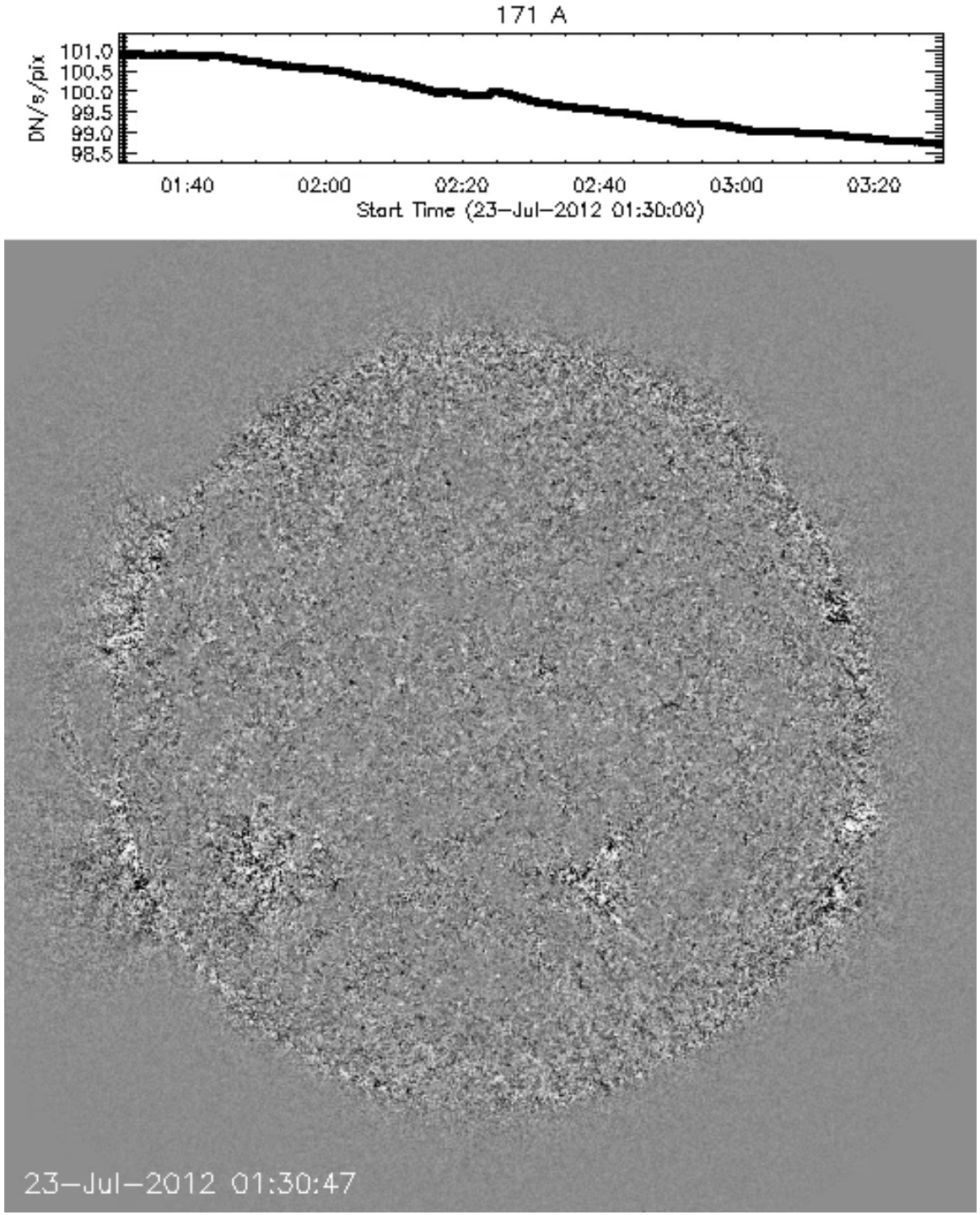




- The Fe X flows originate in the impulsive phase
- The EVE time-series data thus strongly indicate the transition region for the source of dimmed mass
- Analysis with AIA needed

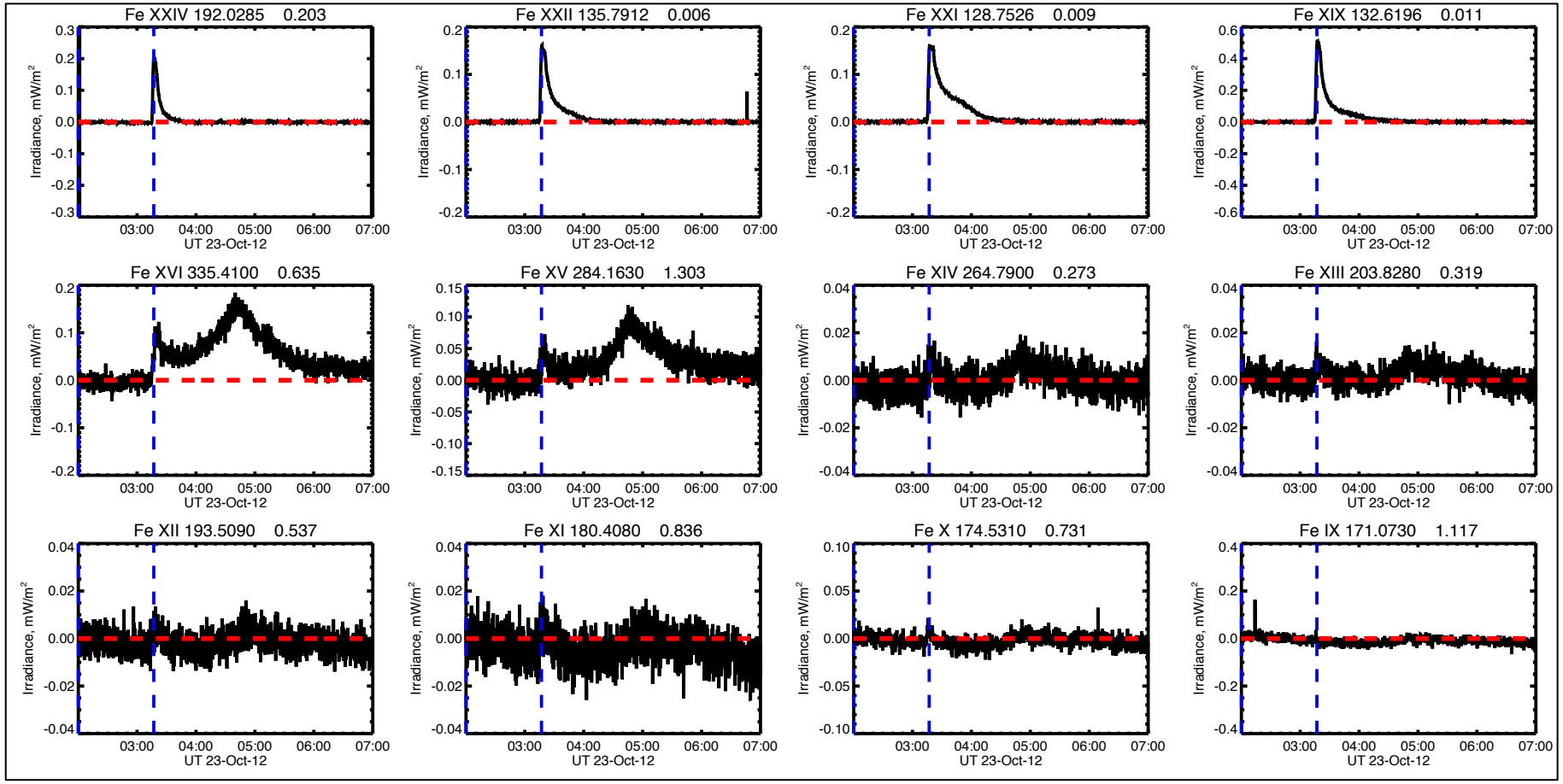
“Halo dimming” from a backside event?





- AIA 171 A base differences, courtesy N. V. Nitta
- The image means are very stable and hint at the event at 02:25
- There's not much hint of a response from a spherically-symmetric diffuse corona, but the dimming is widespread

Last item



This is SOL2012-10-23 (X1.8), a γ-ray flare with a type II burst but no CME and correspondingly no EVE dimming. Note the nice EVE late phase in Fe XV-XVI.

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Conclusions

- EVE is a great resource for research on solar flares, and we expect many more results
- Ly-α is still a problem
- It would be nice to have imaging spectroscopy of Ly-α and He II 30.4 nm; with this we could likely detect SEPs at their point of acceleration