

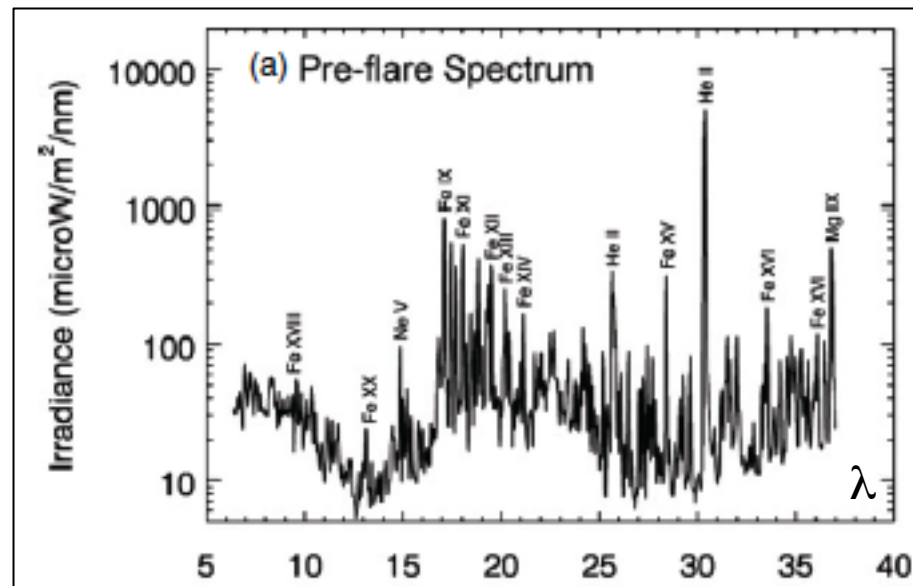
CME Mass Estimates from EVE Dimmings

Hugh Hudson

UC Berkeley and University of Glasgow

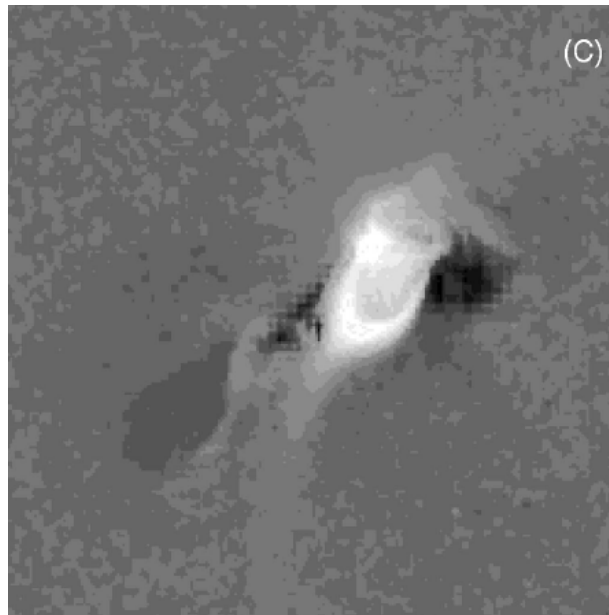
EVE

- Matthieu Kretzschmar will have explained the instrument and data yesterday!
- EVE conducts Sun-as-a-star spectroscopy at 1Å resolution at 10 s cadence over 70-1050 Å, plus some photometry and pinhole imaging.

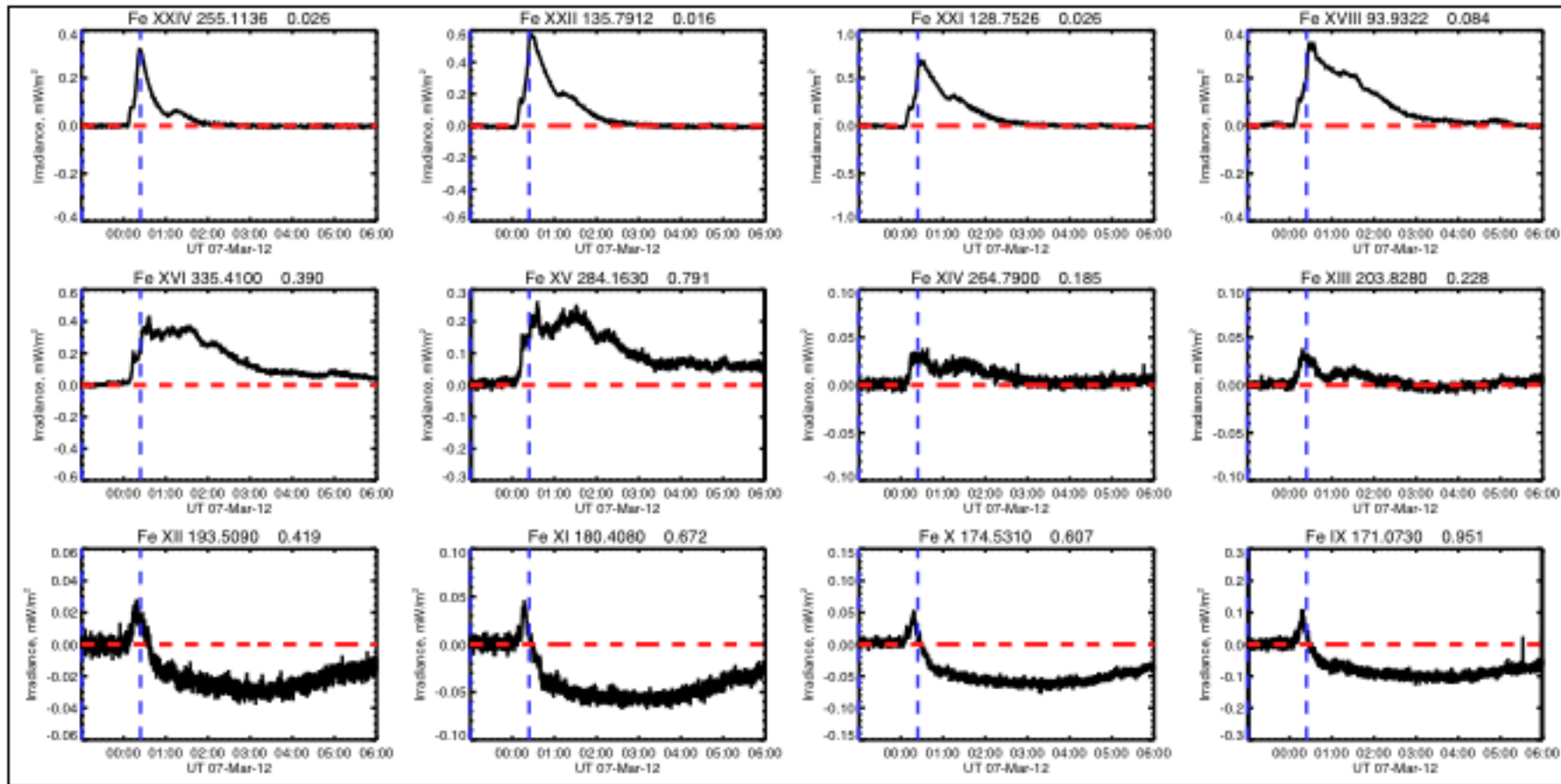


Dimming

- “Coronal Depletions” in white-light coronagraphs
- “Transient coronal holes” in Skylab X-ray imaging
- The green line?
- Yohkoh/SXT (Hudson & Webb, 1997; Sterling & Hudson 1997)

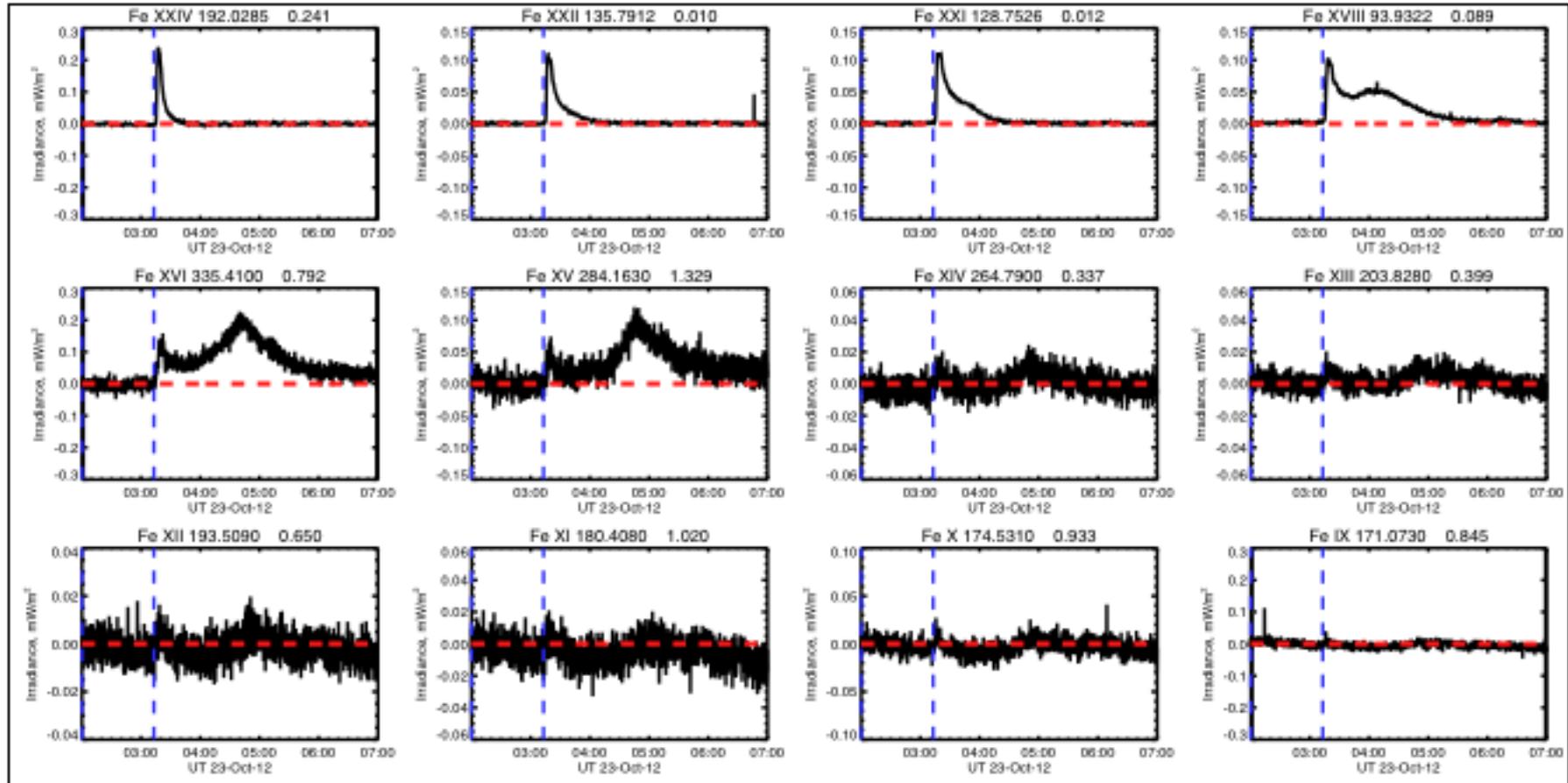


“Fe Cascade” plot



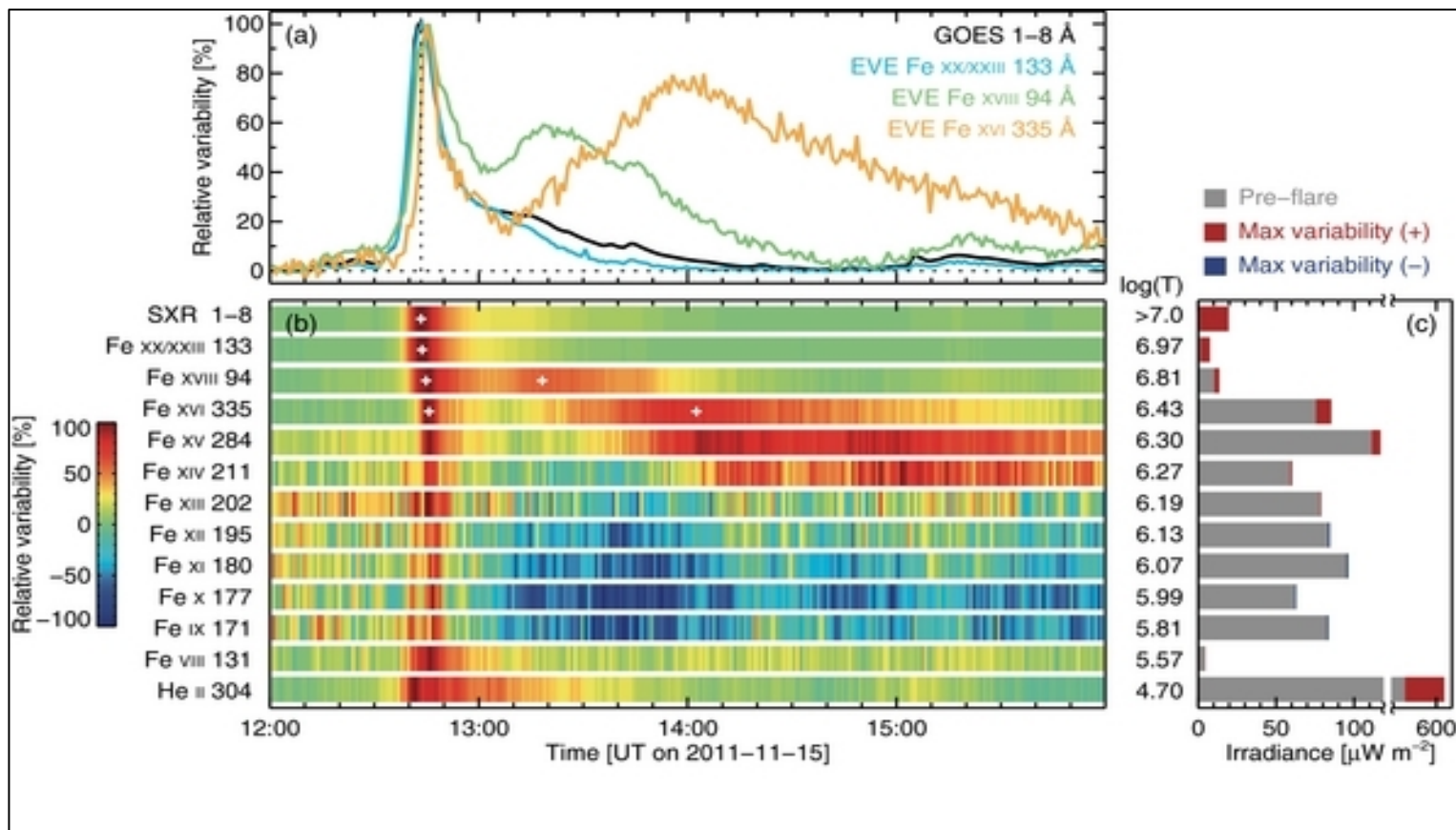
- Twelve ionization states of Fe (IX – XXIV)
- Preflare background subtracted

“Fe Cascade” plot



- No dimming in this one (SOL2012-10-23 X1.8)
- Possible “EVE late phase”

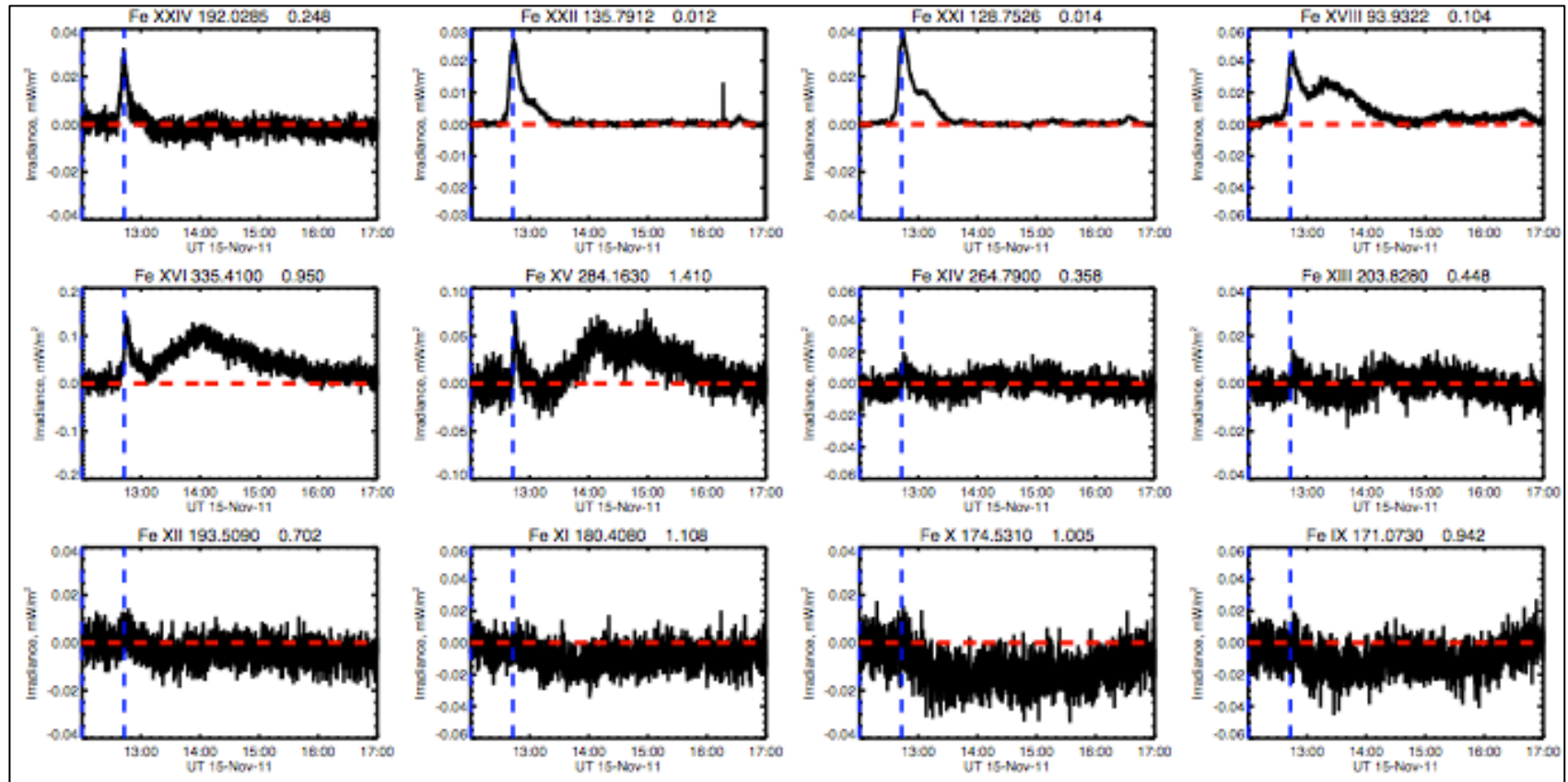
Alternative view



SOL2011-11-15 M1.9

Sun et al. 2013

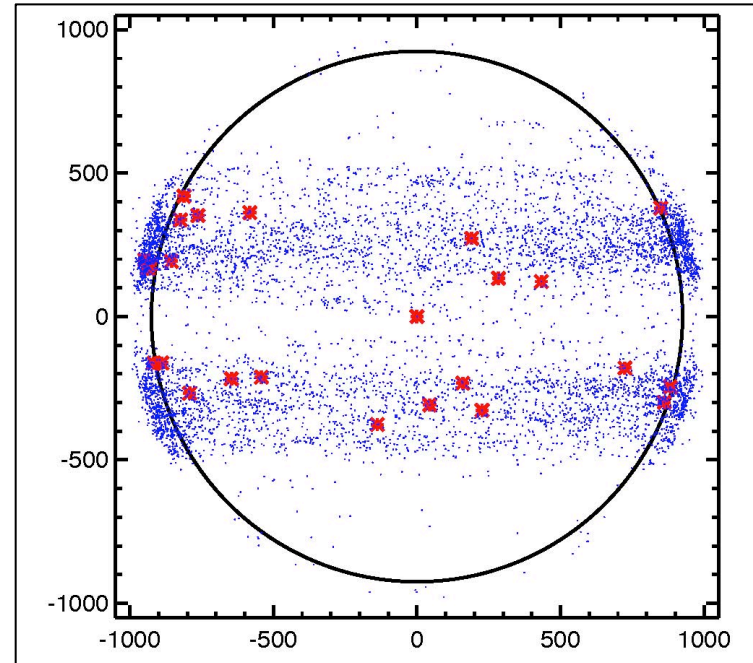
Fe Cascade comparison



SOL2011-11-15 M1.9

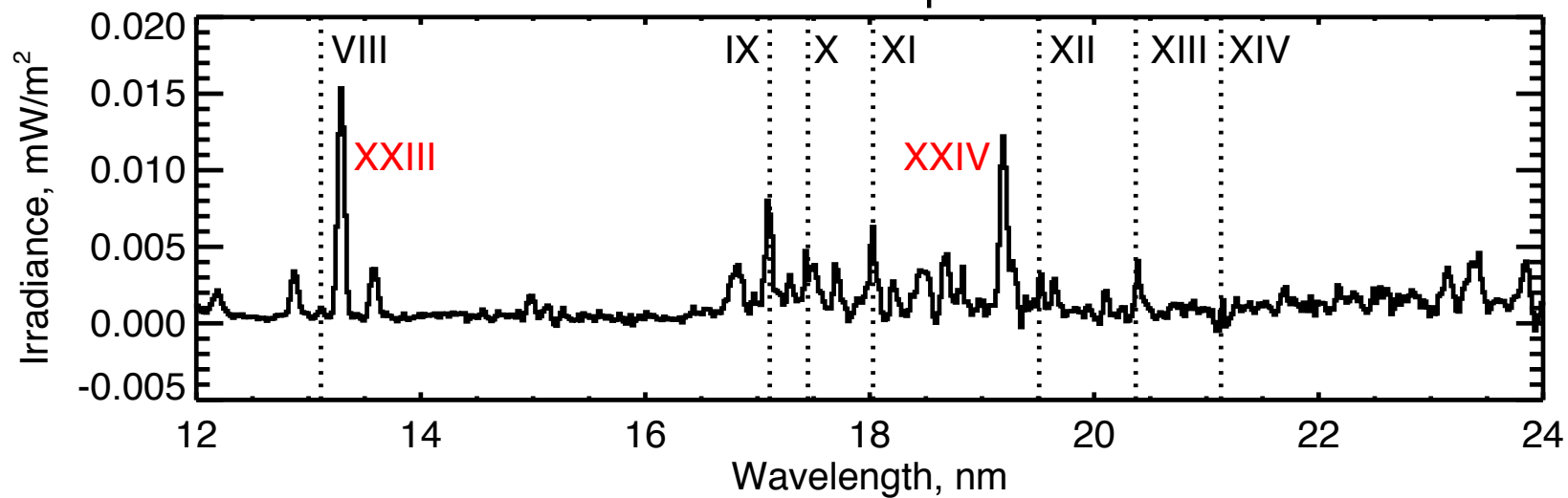
Event	IAU Number	GOES	Fe X	Dim?	CME?
1	SOL2011-02-15T01:44	X2.2	-9.0	Dim	CME
2	SOL2011-03-09T23:13	X1.5	-1.1	No	No
3	SOL2011-08-09T07:48	X6.9	-7.4	Dim	CME
4	SOL2011-09-06T22:12	X2.1	-29.2	Dim	CME
5	SOL2011-09-07T22:32	X1.8	-4.0	No	CME
6	SOL2011-09-22T10:29	X1.4	-21.1	Dim	CME
7	SOL2011-09-24T09:21	X1.9	-14.3	??	CME
8	SOL2011-11-03T20:16	X1.9	-4.5	No	No
9	SOL2012-01-27T17:37	X1.7	-29.4	Dim	CME
10	SOL2012-03-05T02:30	X1.1	-3.1	Dim	CME
11	SOL2012-03-07T00:02	X5.4	-59.9	Dim	CME
12	SOL2012-03-07T01:05	X1.3	-16.3	Dim	CME
13	SOL2012-07-06T23:01	X1.1	-5.5	Dim	CME
14	SOL2012-07-12T15:37	X1.4	-15.4	Dim	CME
15	SOL2012-10-23T03:13	X1.8	-1.7	No	No
16	SOL2013-05-13T01:53	X1.7	-6.3	Dim	CME
17	SOL2013-05-13T15:48	X2.8	-8.8	Dim	CME
18	SOL2013-05-14T00:00	X3.2	-17.6	Dim	CME
19	SOL2013-05-15T01:25	X1.2	-11.9	Dim	CME
20	SOL2013-10-25T07:53	X1.7	9.2	Dim	CME
21	SOL2013-10-25T14:51	X2.1	-14.6	Dim	CME
22	SOL2013-10-28T01:41	X1.0	-17.5	Dim	CME
23	SOL2013-10-29T21:42	X2.3	-2.9	Dim	CME
24	SOL2013-11-05T22:07	X3.3	-15.4	Dim	CME
25	SOL2013-11-08T04:20	X1.1	-20.6	Dim	CME
26	SOL2013-11-10T05:08	X1.1	-21.0	Dim	CME
27	SOL2013-11-19T10:14	X1.0	-18.4	Dim	CME
28	SOL2014-01-07T18:04	X1.2	-2.2	Dim	CME
29	SOL2014-02-25T00:39	X4.9	-50.6	Dim	CME
30	SOL2014-03-29T17:35	X1.0	-12.8	Dim	CME
31	SOL2014-04-25T00:17	X1.3	-9.6	Dim	CME

X-class Flares, CMEs, and Dimmings

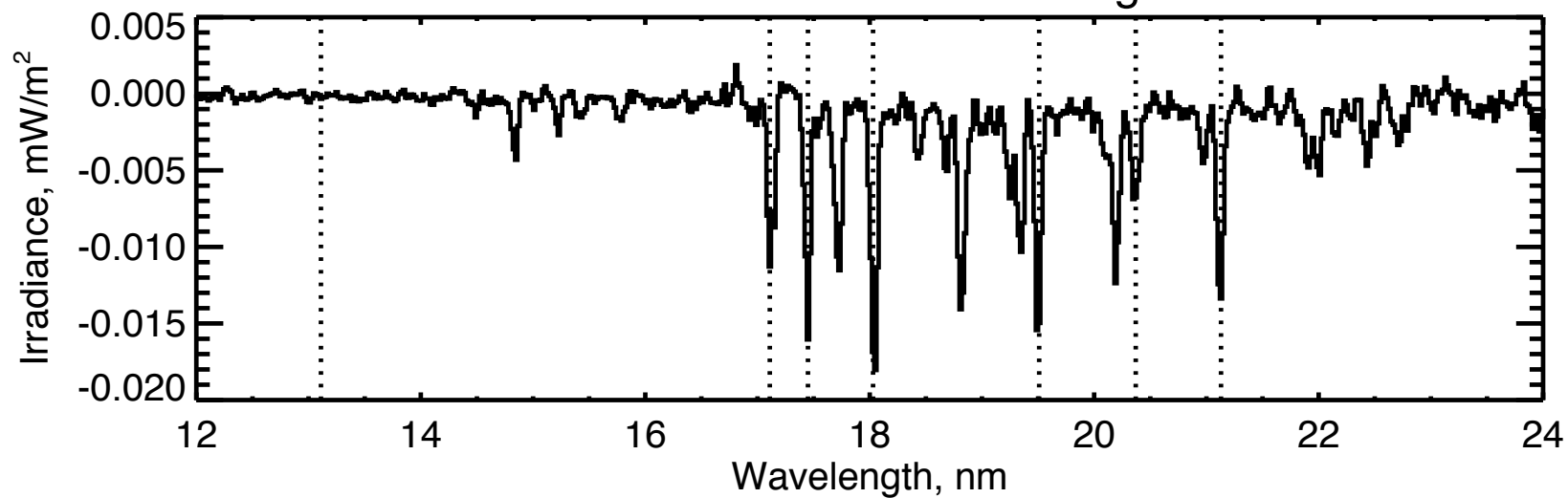


- Generally, there is a one-to-one mapping between dimming and CME occurrence.
- X-class events without CMEs tend also not to have dimmings.

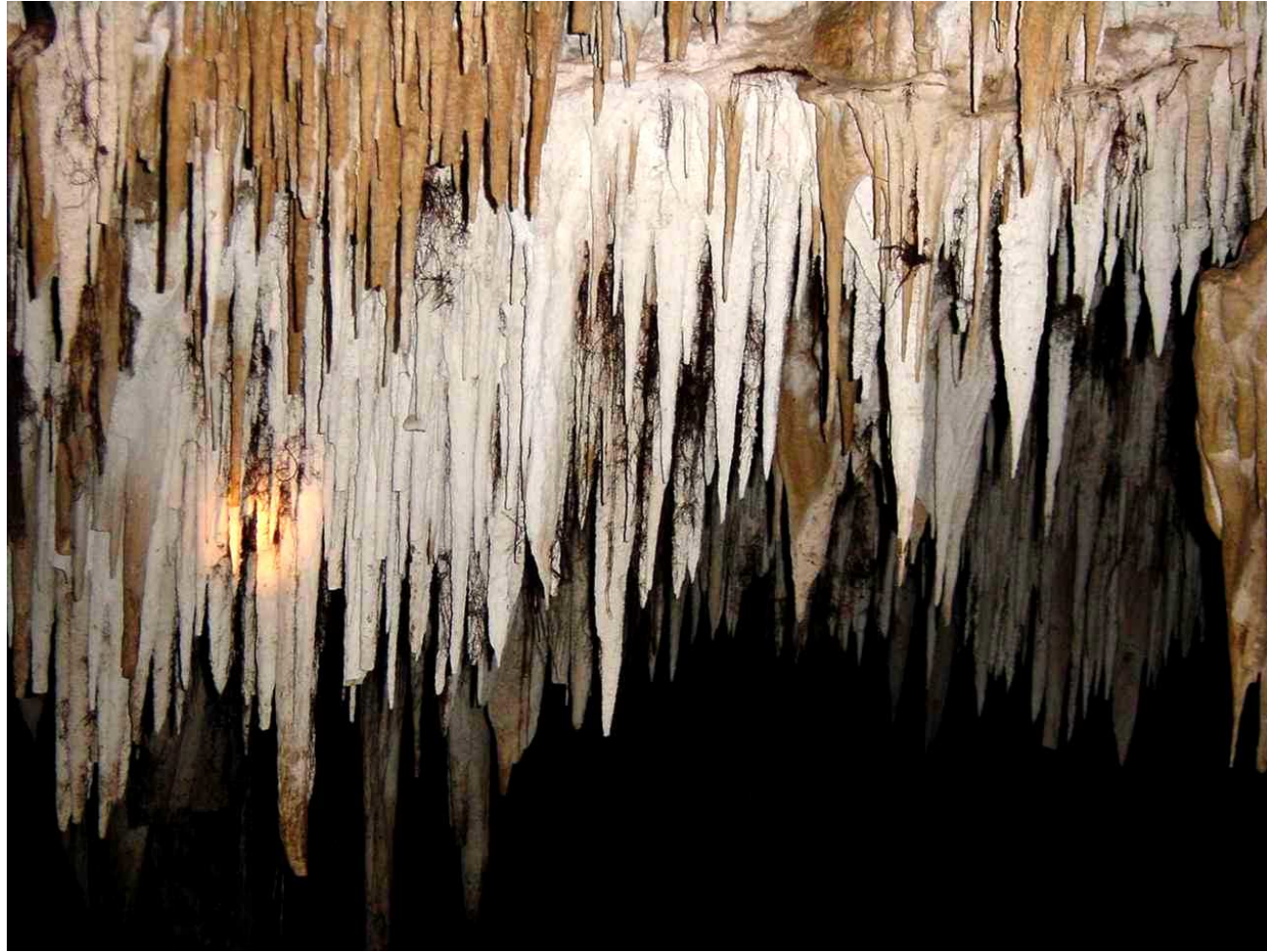
SOL2013-11-05 Impulsive Phase



SOL2013-11-05 Dimming

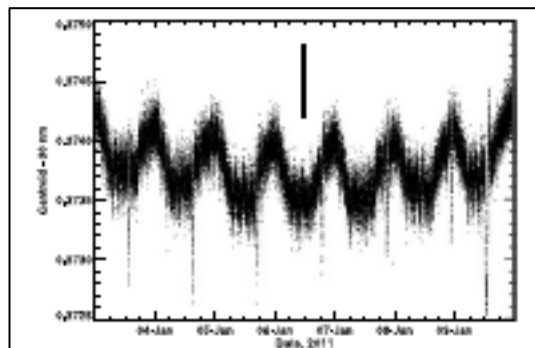


Stalactites vs. stalagmites



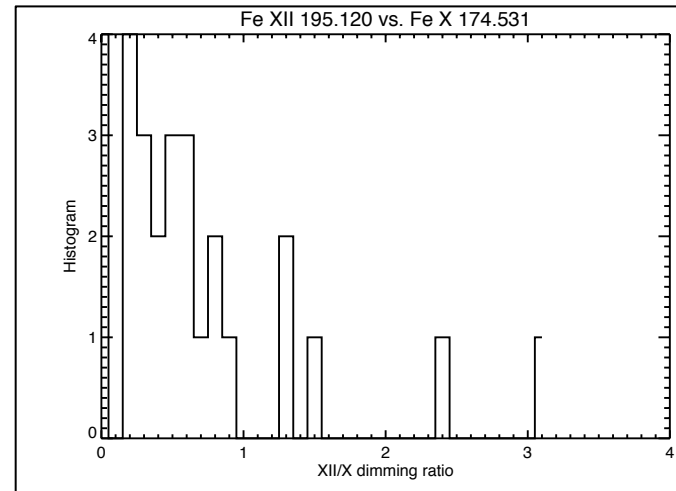
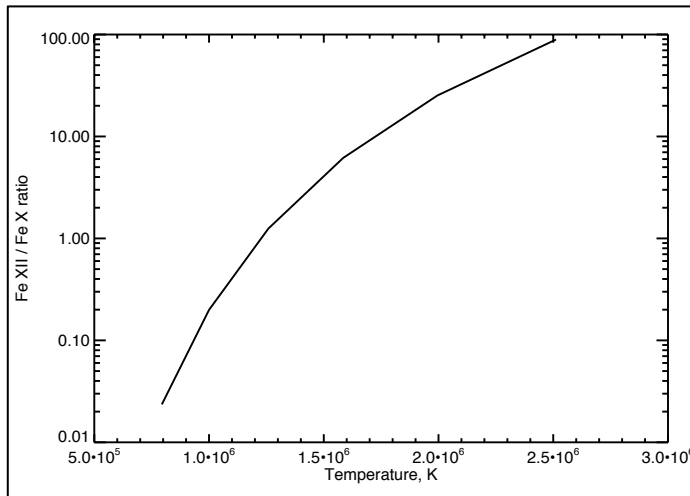
Comment

- The “stalactite” spectrum is a difference, and we do not really have a negative DEM.
- The EVE dimming sources are reasonably well localized (eg, via SDO images) and correspond to stationary plasmas at these locations.
- We may therefore be able to use them to calibrate the EVE wavelength scale (the “overlappograph effect,”) bearing in mind solar rotation.



SDO diurnal Doppler shift
(Hudson et al. 2011)

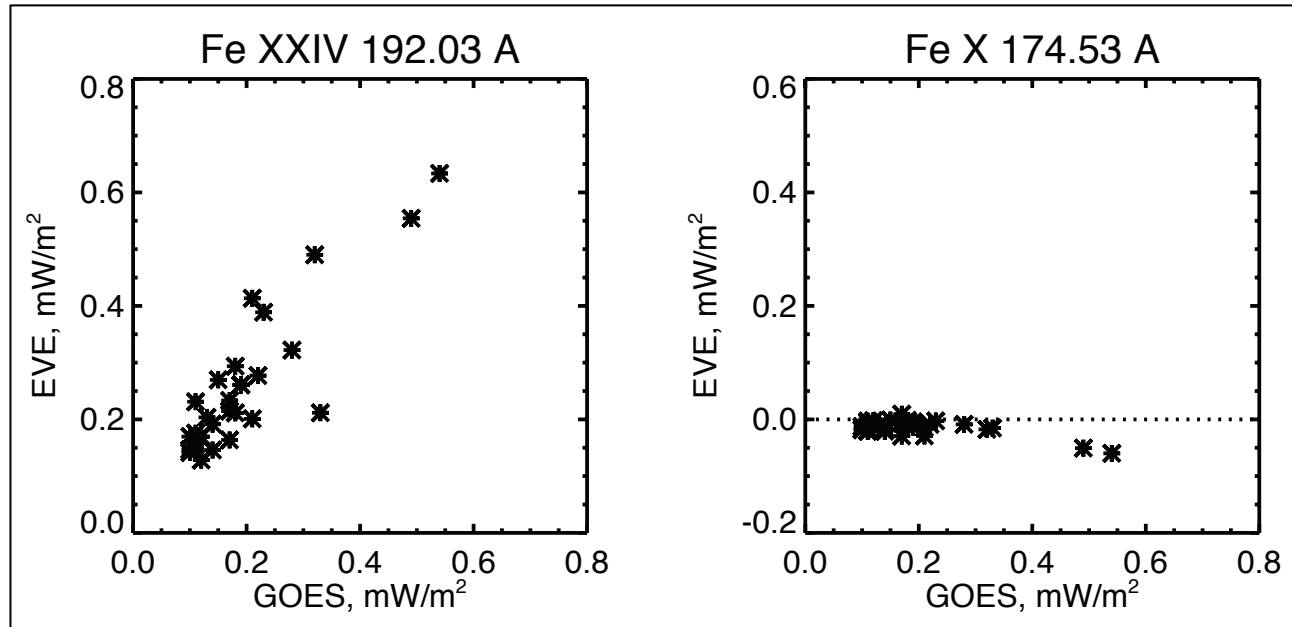
Rough characterization of mean dimming temperature via line-ratio technique:



This may be fairly precise, because the EVE dimmings typically involve only Fe IX – Fe XII, a narrow range implying an origin in the quiet corona rather than the core of an active region.

Note that a further parameter is needed to get a mass. I have just assumed density 10^9 cm^{-3} thus far.

Does dimming magnitude correlate with GOES class?



Yes. Powerful flares blow out more corona.

What fraction of the CME mass is from the observed dimming?

- J.P. Mason et al. (2014, arXiv:1404.1364) have analyzed an EVE dimming event (SOL2010-08-07, M1.0) in detail (cf. Fletcher et al., 2013).
- For this event, A. Vourlidas estimated a CME instantaneous mass, via STEREO fitting, of some 6.4×10^{15} g.
- For this event, we find

$$M_{\text{EVE}}/M_{\text{CME}} \sim 0.1 / n_9$$

and so the bulk of the CME mass probably came from outside EVE's view (not necessarily the outer corona, though).

Future work

- AIA imaging of these X-flare events
- What are the MEGS-B signatures?
- Hinode X-ray imaging comparison
- Detailed comparison with CME masses
- Inverse search: given a frontside halo CME, what is its dimming signature irrespective of GOES class?

Thanks!

