CME Mass Estimates from EVE Dimmings

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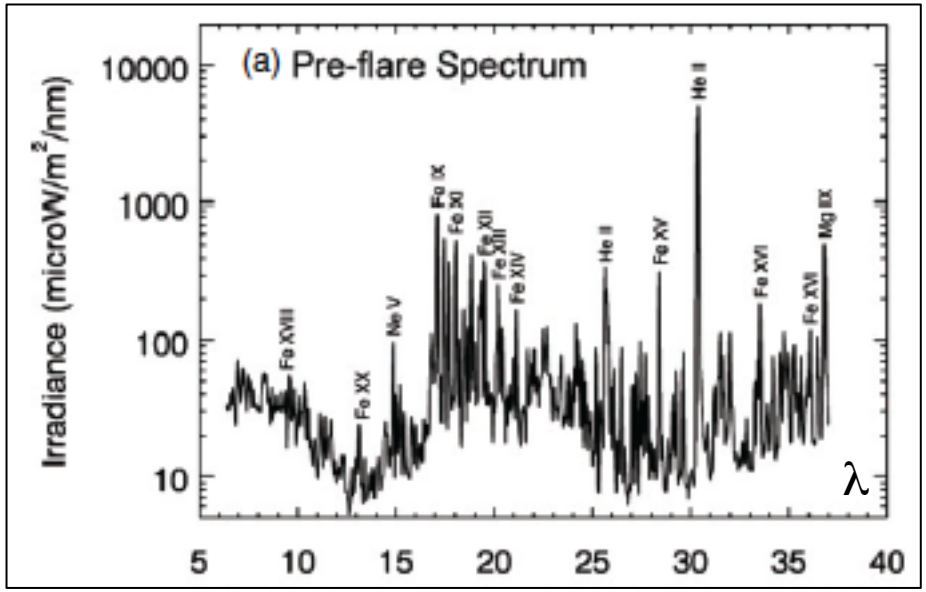
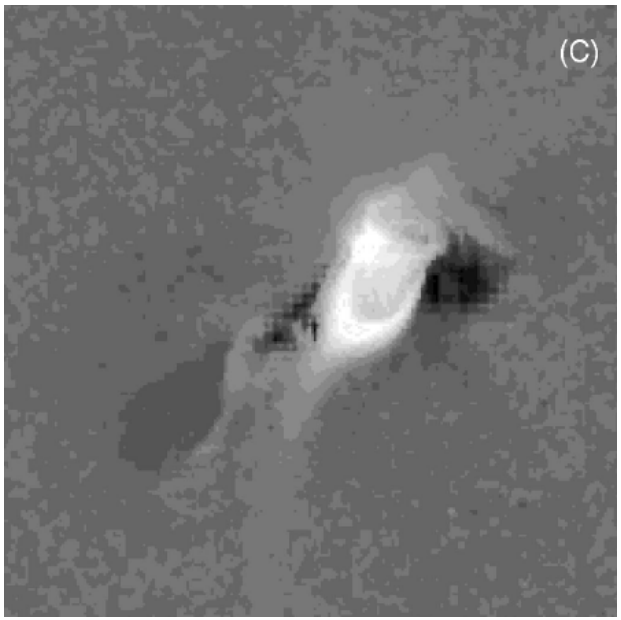
EVE

- 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.

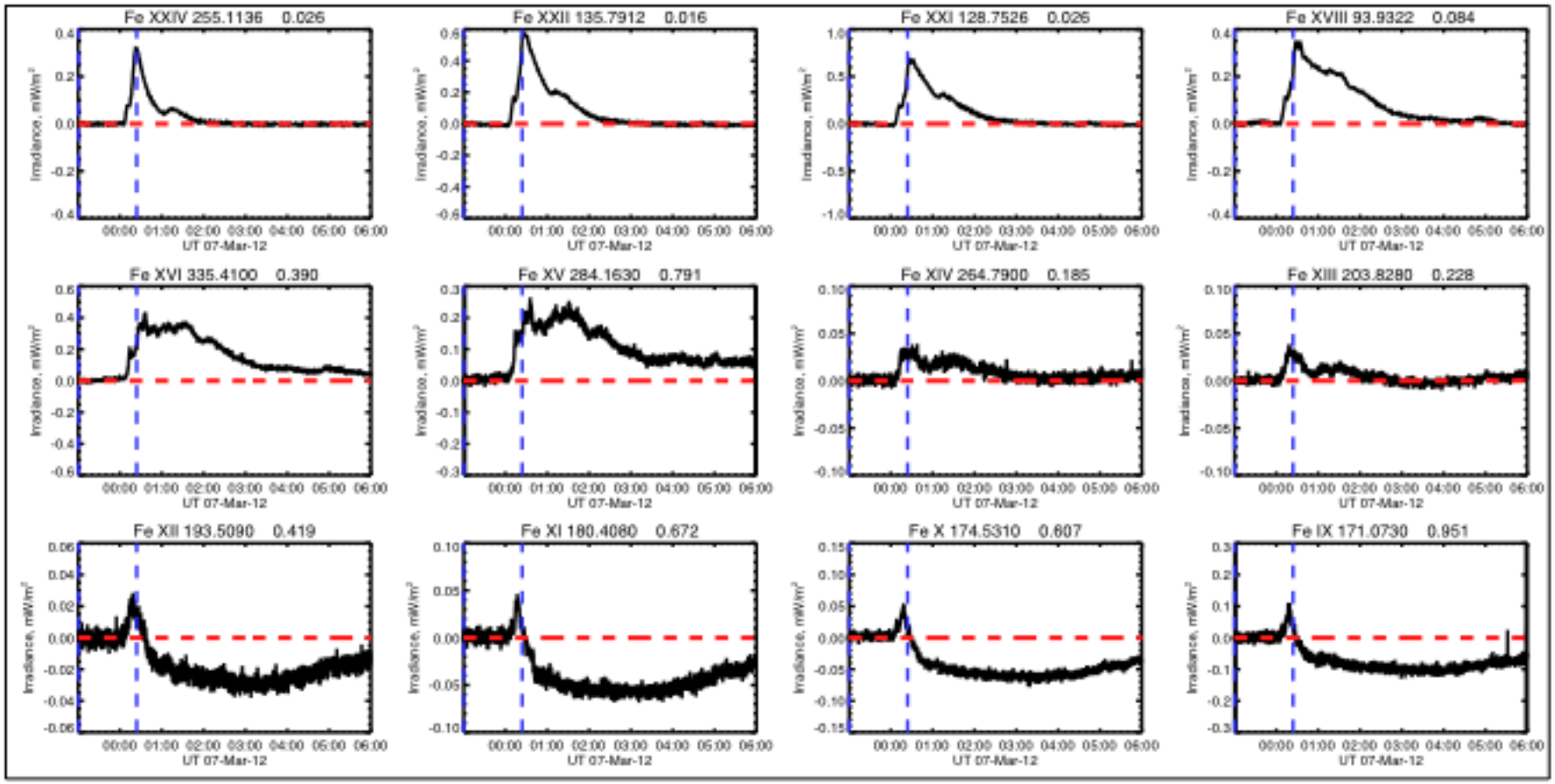


Dimming

- “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)

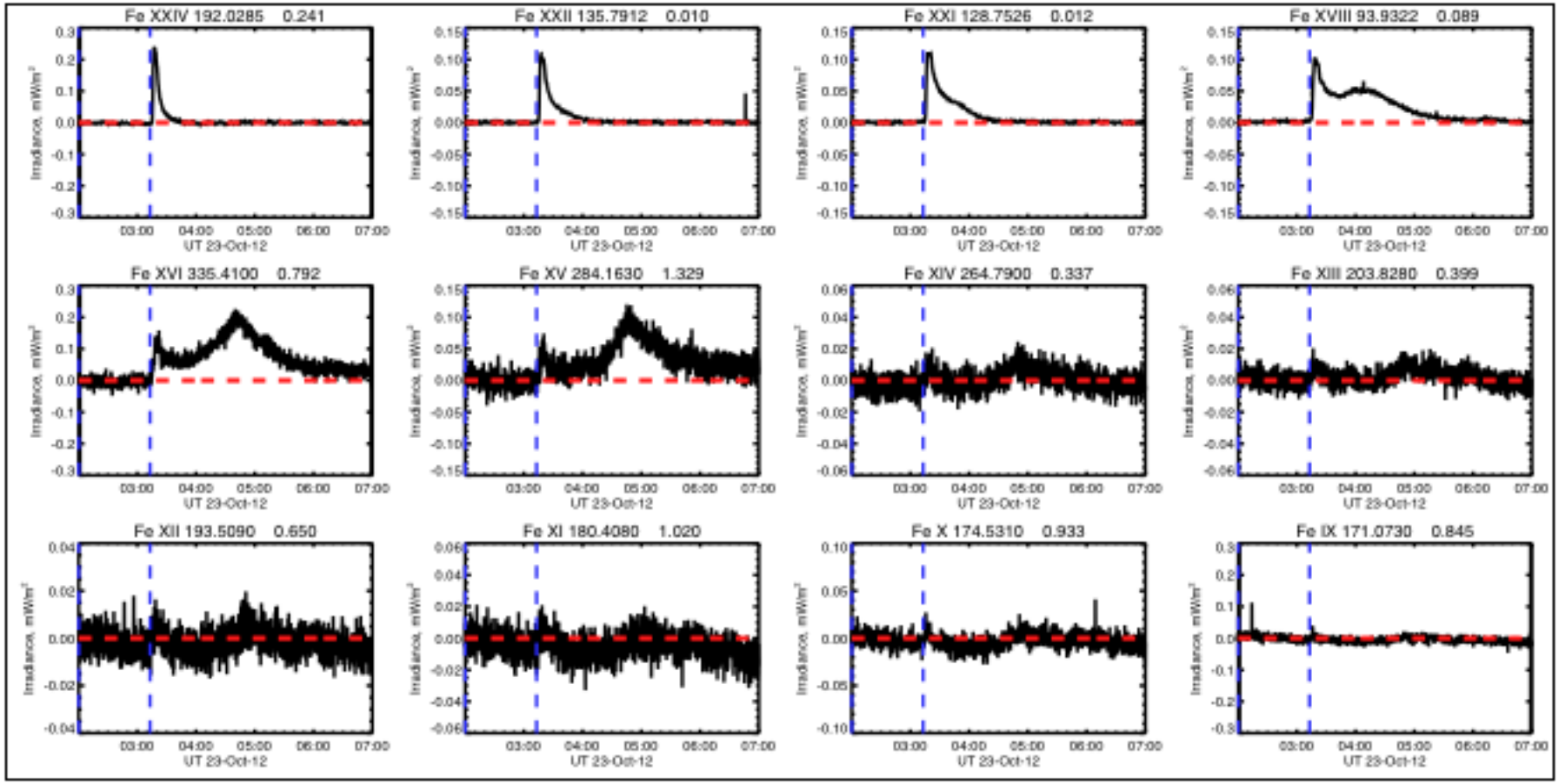


“Fe Cascade” plot



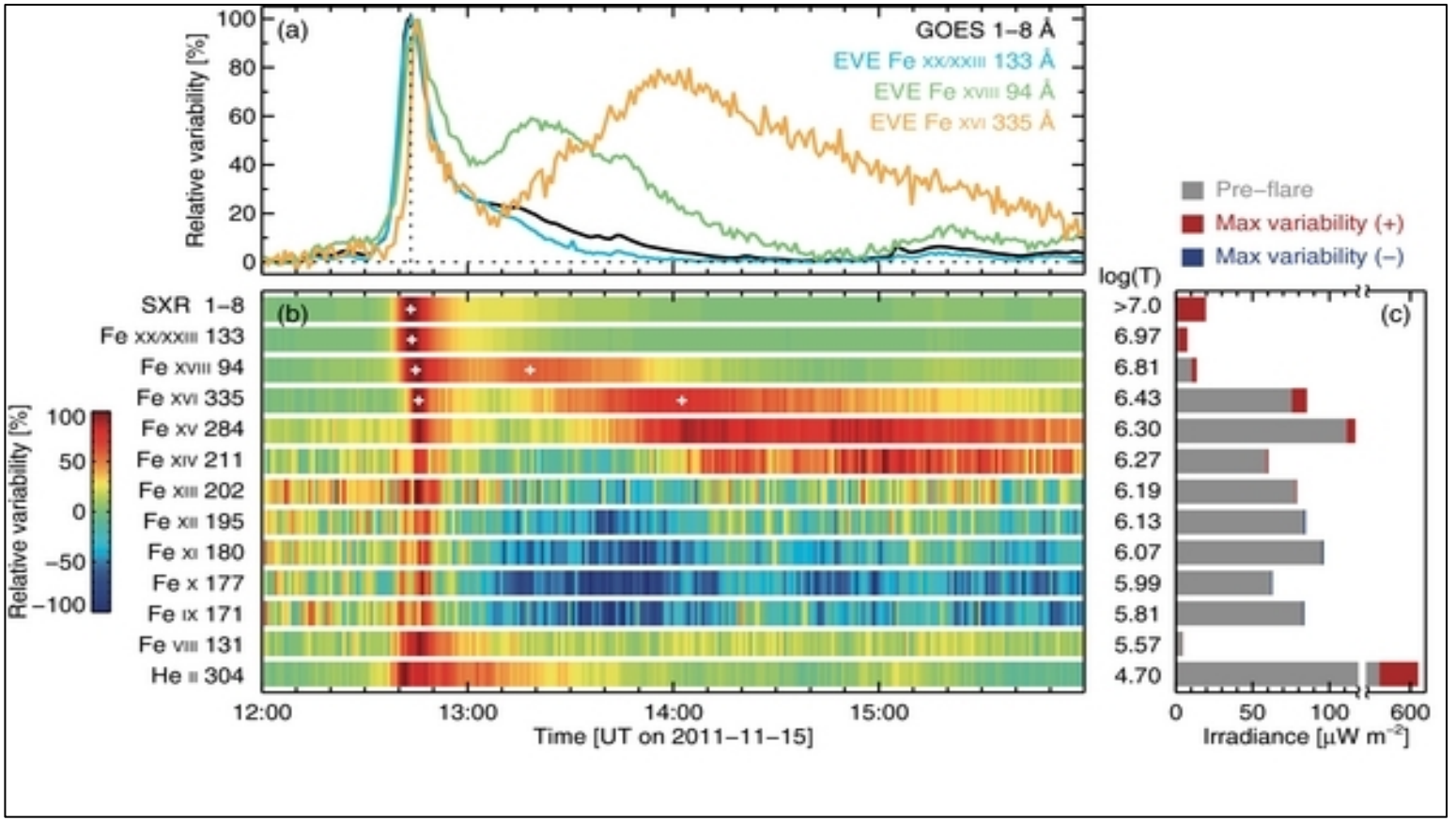
- Twelve ionization states of Fe (IX – XXIV)
- Preflare background subtracted

“Fe Cascade” plot



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

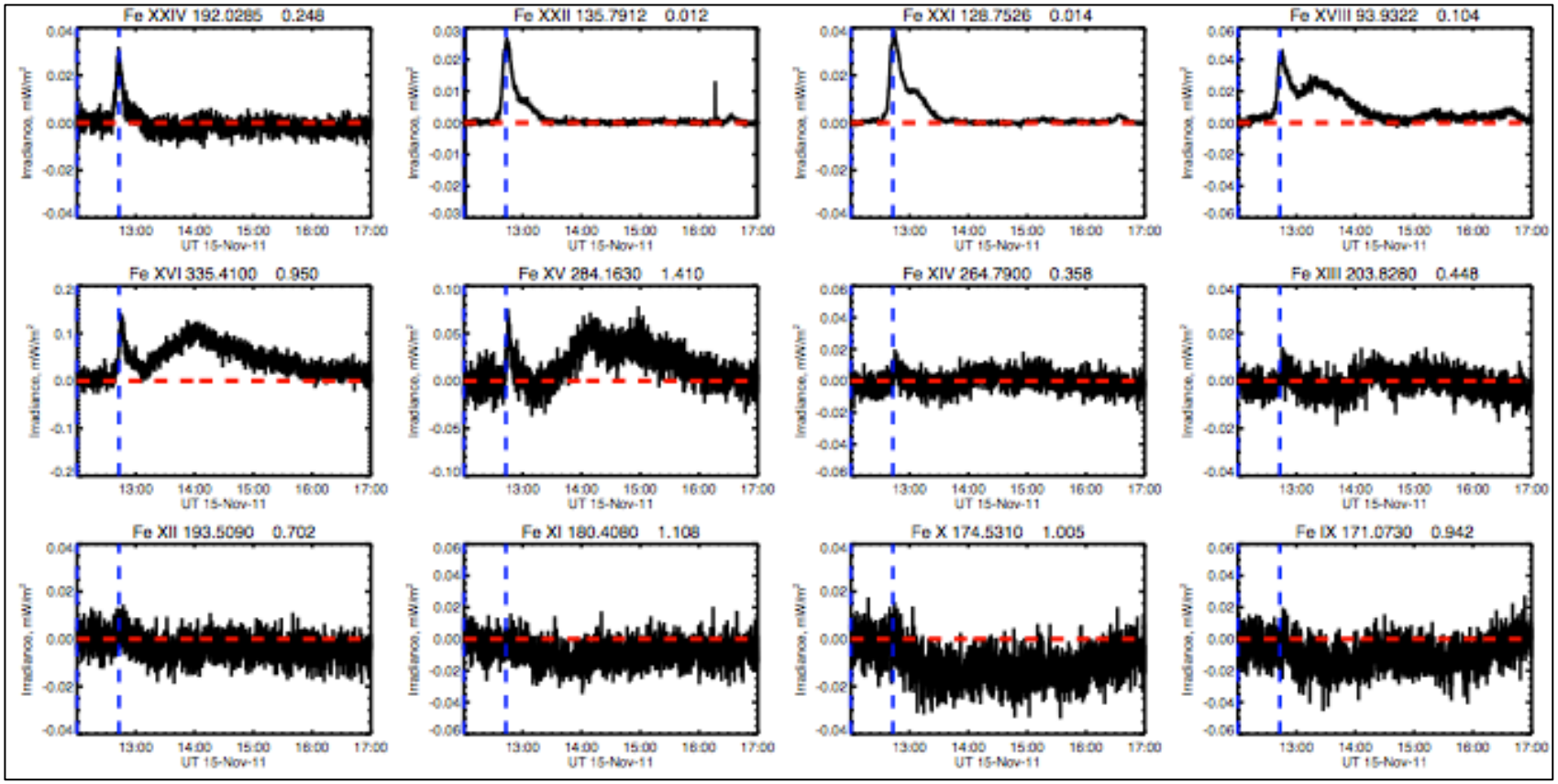
Alternative view



SOL2011-11-15 M1.9

Sun et al. 2013

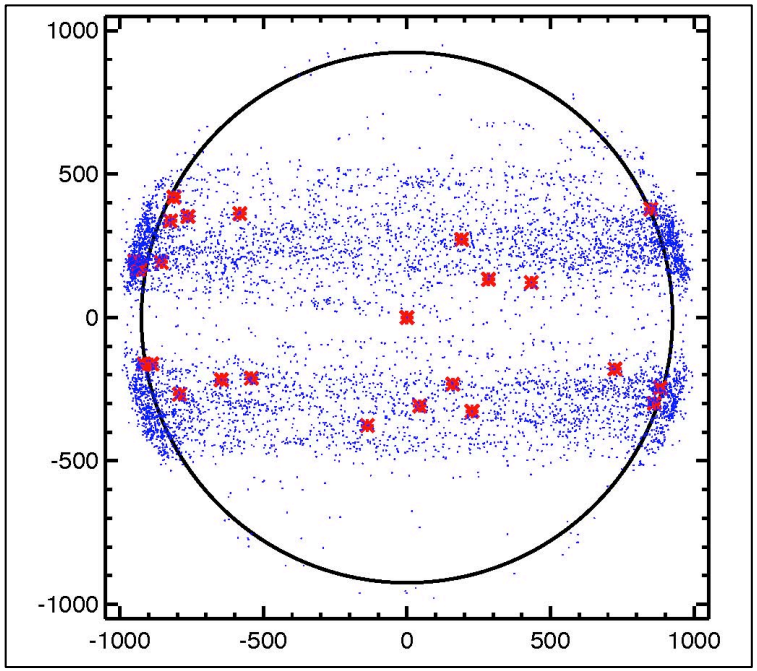
Fe Cascade comparison



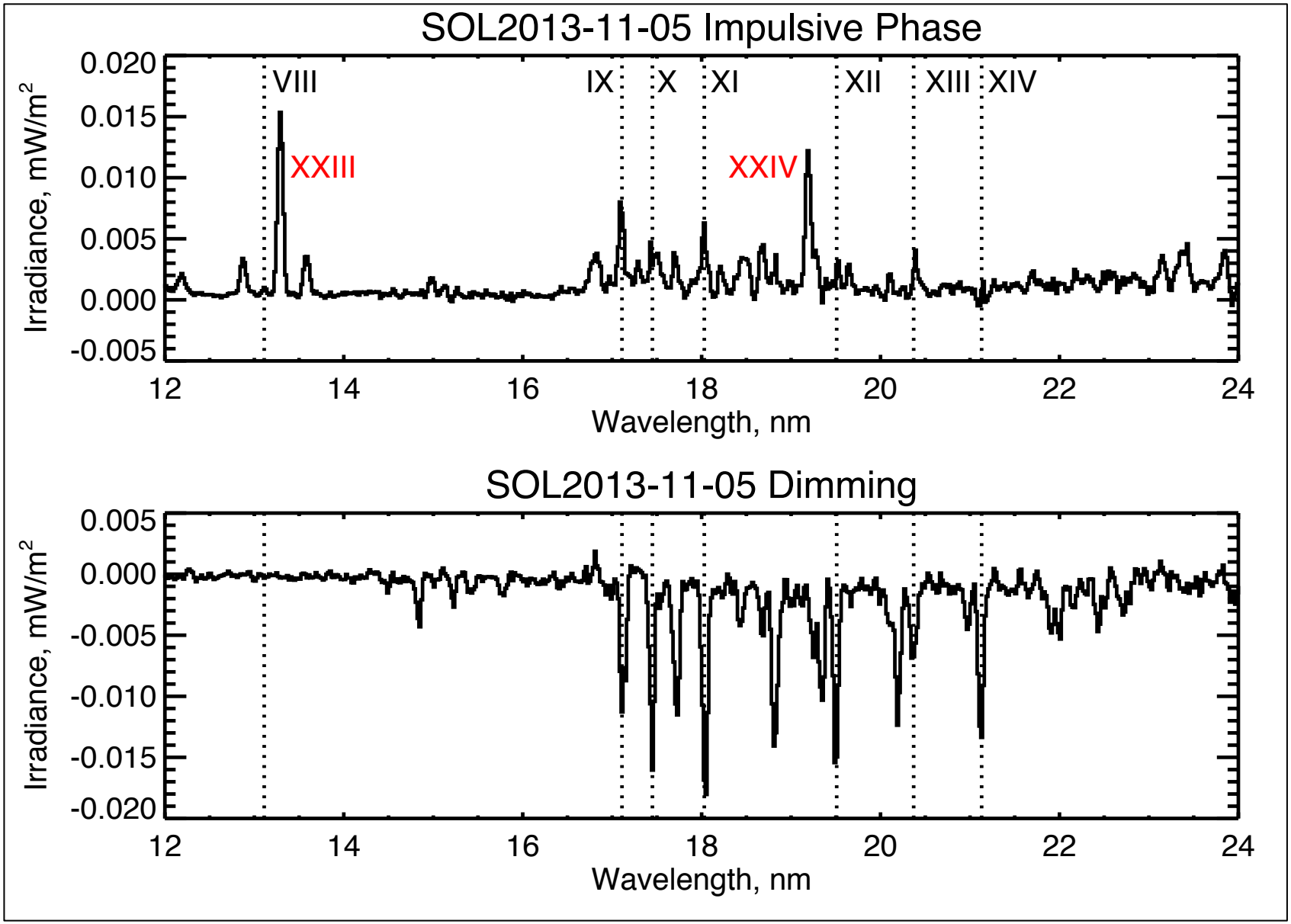
SOL2011-11-15 M1.9

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

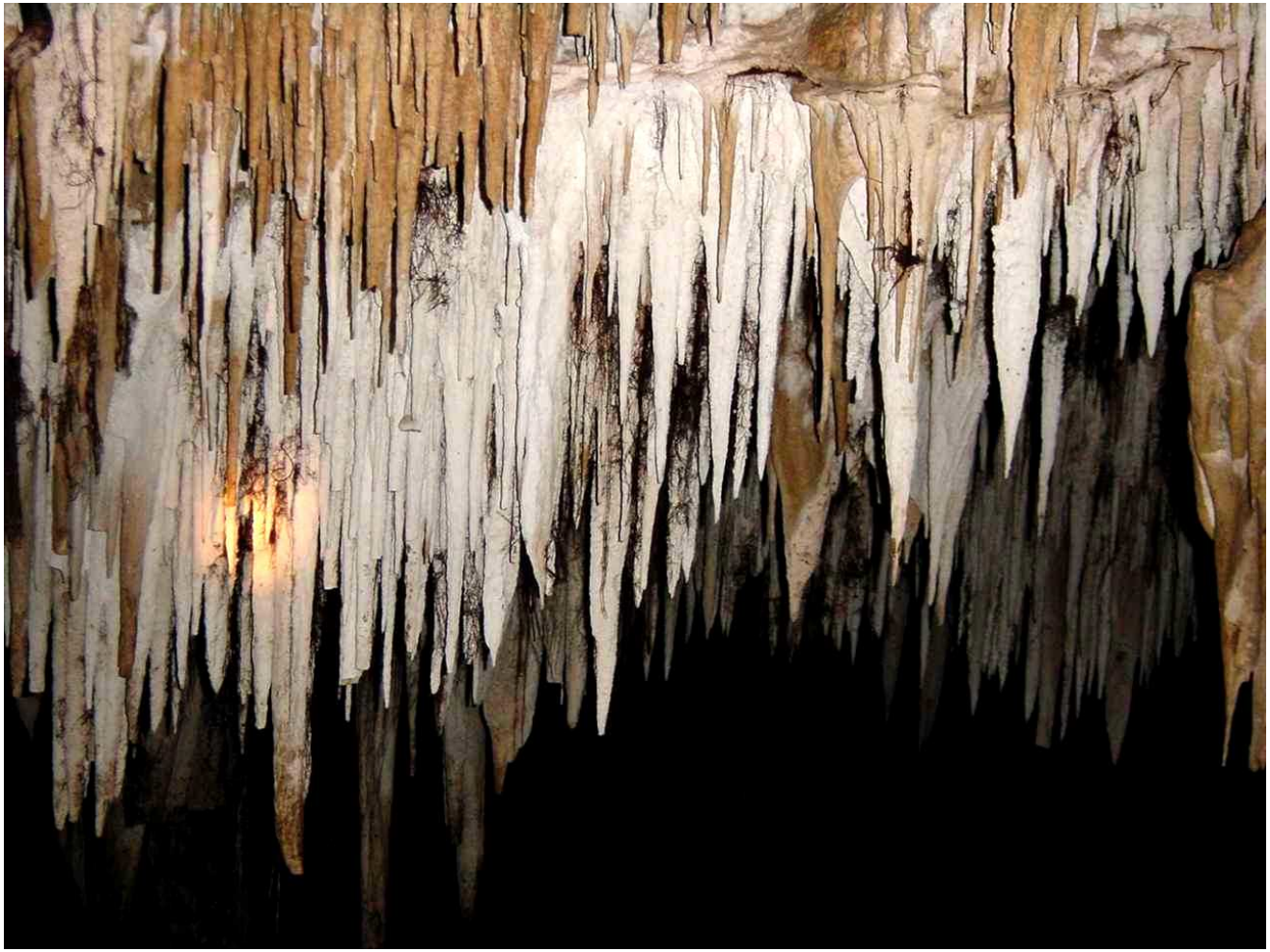
X-class Flares, CMEs, and Dimmings



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

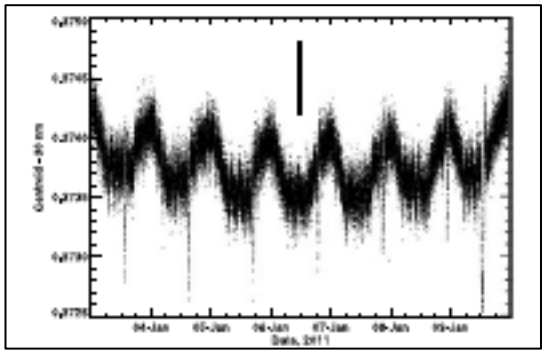

SOL2013-11-05 Impulsive Phase
Irradiance, mW/m2
0.020
0.015
0.010
0.005
0.000
-0.005
VIII
IX
X
XI
XII
XIII
XIV
XXIII
XXIV
12
14
16
18
20
22
24
Wavelength, nm
SOL2013-11-05 Dimming
Irradiance, mW/m2
0.005
0.000
-0.005
-0.010
-0.015
-0.020
12
14
16
18
20
22
24
Wavelength, nm

Stalactites vs. stalagmites



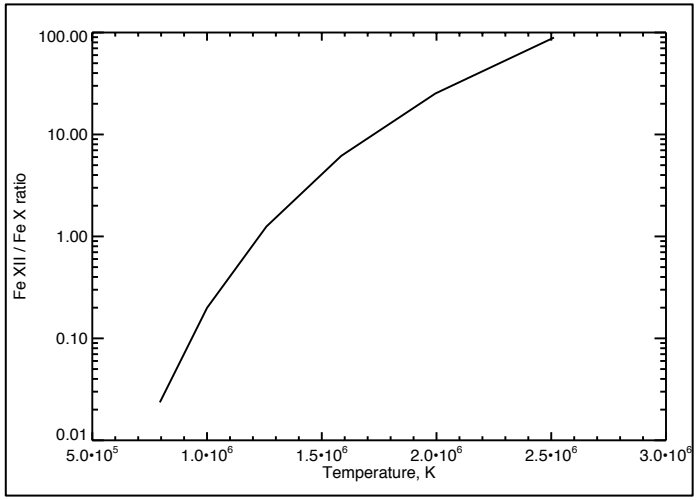
Comment

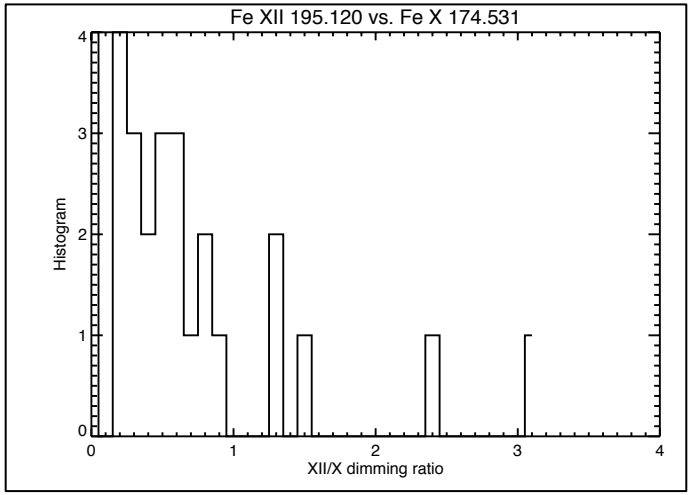
- The “stalactite” spectrum is a difference, and we do not really have a negative DEM.
- The EVE dimming sources are reasonably well localized (eg, via SDO images) and correspond to stationary plasmas at these locations.
- We may therefore be able to use them to calibrate the EVE wavelength scale (the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

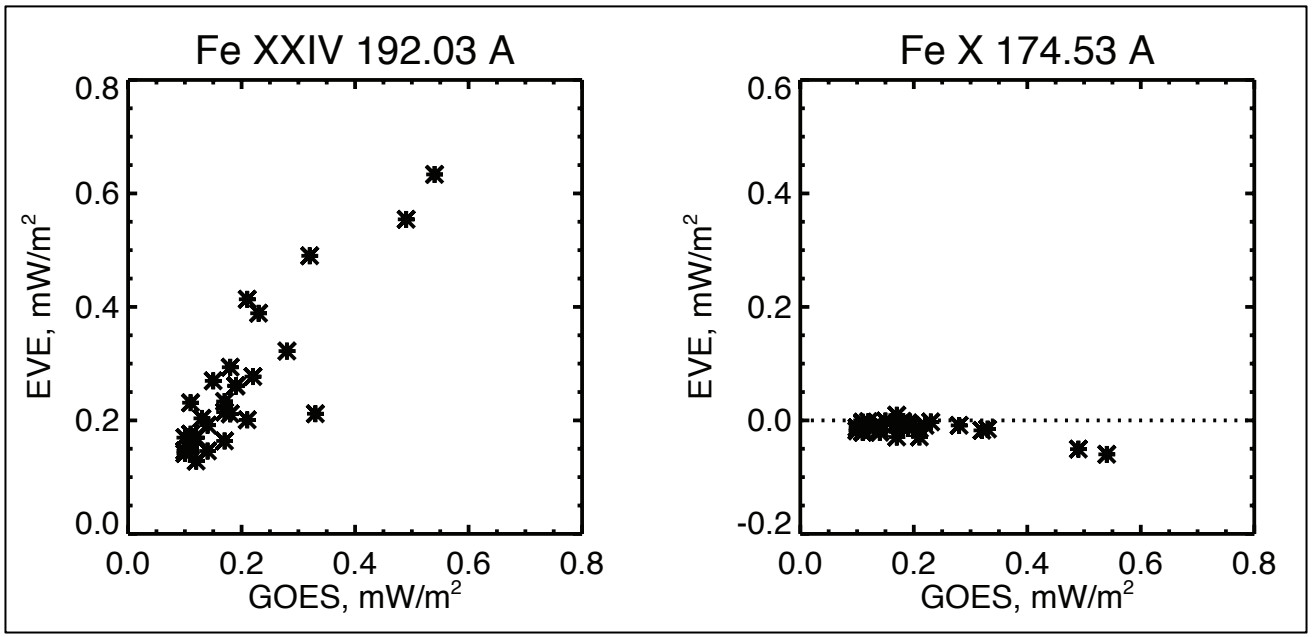




This may be fairly precise, because the EVE dimmings typically involve only Fe IX – Fe XII, a narrow range implying an origin in the quiet corona rather than the core of an active region.

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

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

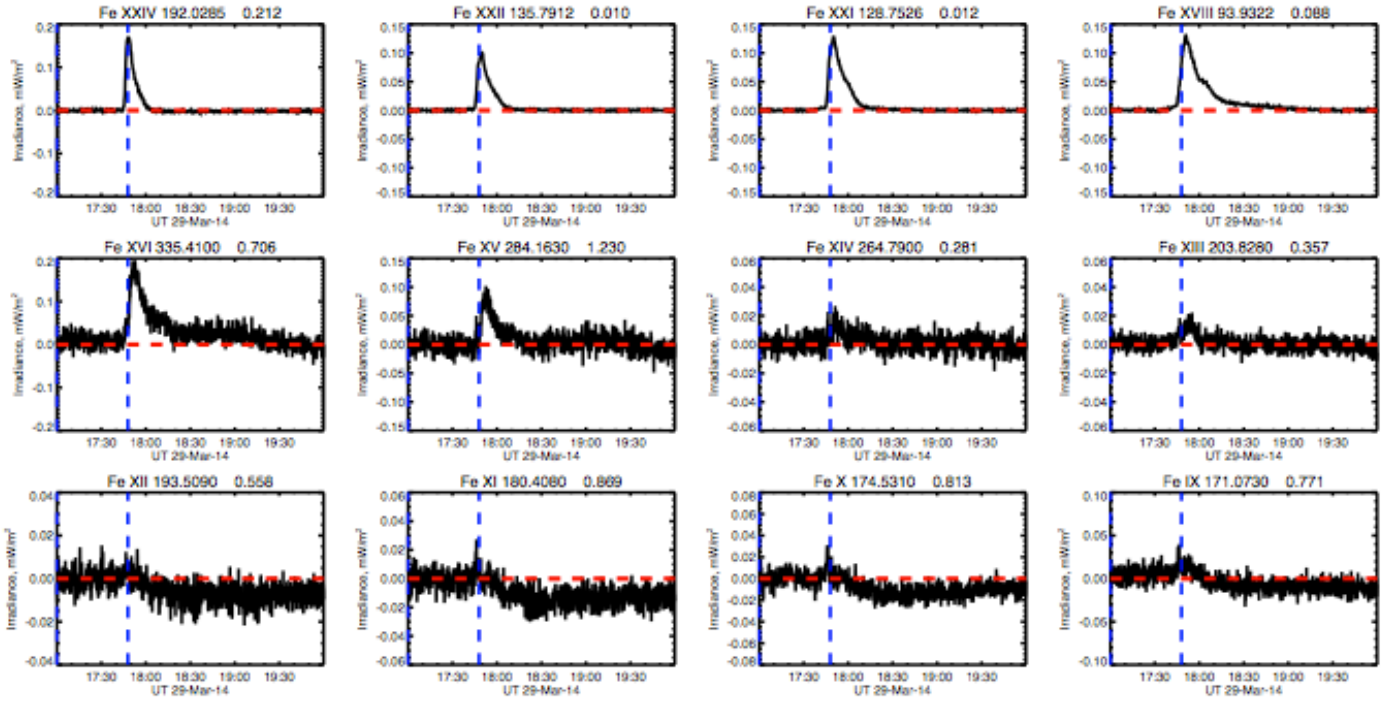
and so the bulk of the CME mass has come from outside EVE's view (not necessarily the outer corona, though).

Conclusions and future tasks

- CMEs and dimmings are one-to-one for X-class flares
- Dimming masses are fairly large
- Dimming mass correlates with flare class

- Look at AIA
- Look at MEGS-B
- Get better CME masses
- Do inverse search: what are the EVE signatures associated with frontside halo CMEs, irrespective of GOES class?

Thanks!


Fe XXIV 192.0285 0.212
Fe XXII 135.7912 0.010
Fe XXI 128.7526 0.012
Fe XVIII 93.9322 0.088
Fe XVI 335.4100 0.706
Fe XV 284.1630 1.230
Fe XIV 264.7900 0.281
Fe XIII 203.8280 0.357
Fe XII 193.5090 0.558
Fe XI 180.4080 0.869
Fe X 174.5310 0.813
Fe IX 171.0730 0.771
Irradiance, mW/m²
17:30 18:00 18:30 19:00 19:30
UT 29-Mar-14