Spectral signatures of the impulsive energy release in SMM BCS spectra

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General information

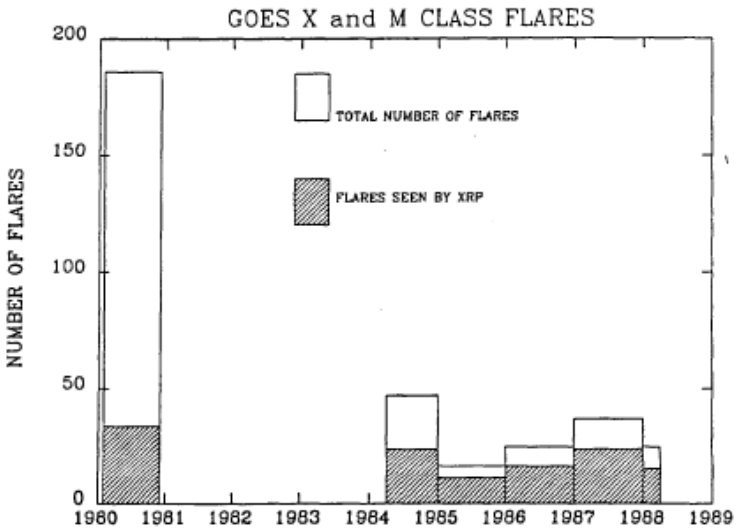
Total of **82 impulsive flares** have been selected based on HXRBS data.

C class→ 27
M class→50
X class→ 5

25 flares occured during 1980; the rest after the SMM rescue (1984 -1989).
Spectra for **16** flares have been deconvolved using Withbroe-Sylwester procedure.

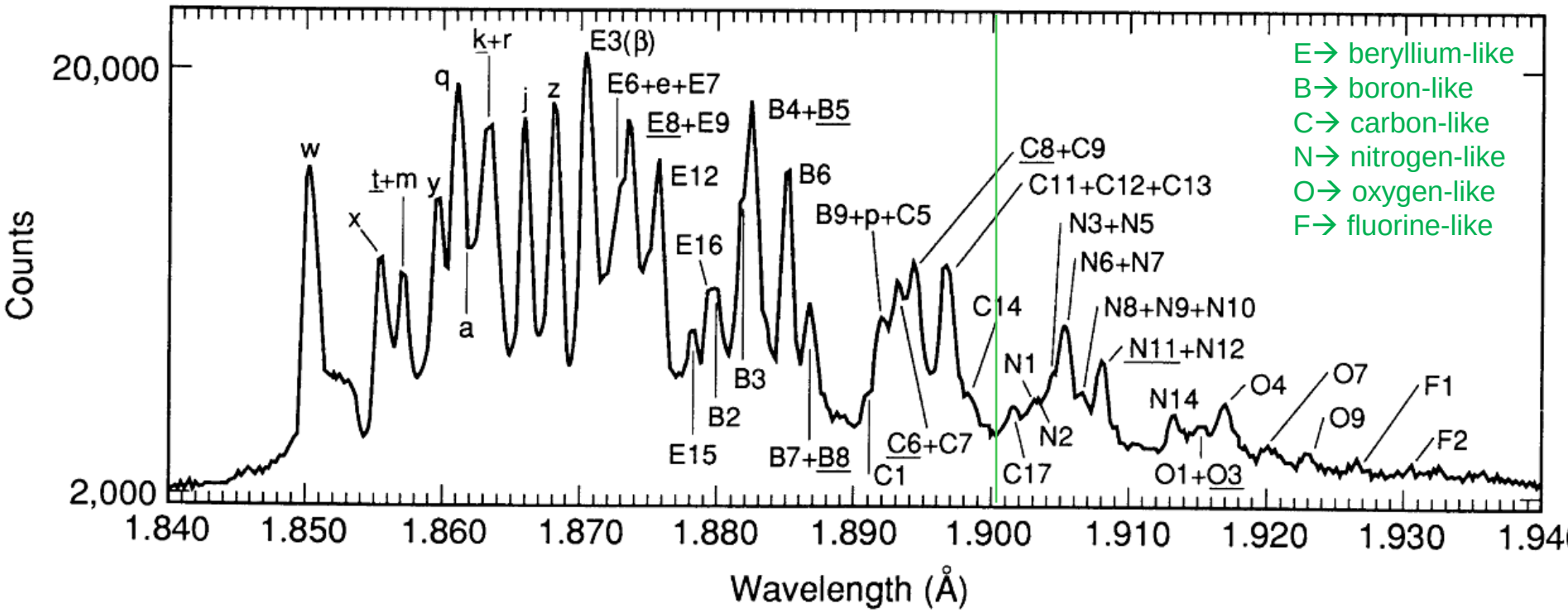
SOL1980-04-10T09:23	M4.0	1N	N12W42
SOL1980-04-30T20:24	M2.2	SN	S13W90
SOL1980-07-01T16:29	X2.5	1B	S12W38
SOL1980-04-07T18:44	M1.2	SB	N12W06
SOL1980-11-12T17:04	M1.4	1B	S14W11

BCS Ca: 3.16-3.23 Å
BCS Fe: 1.845-1.9 Å



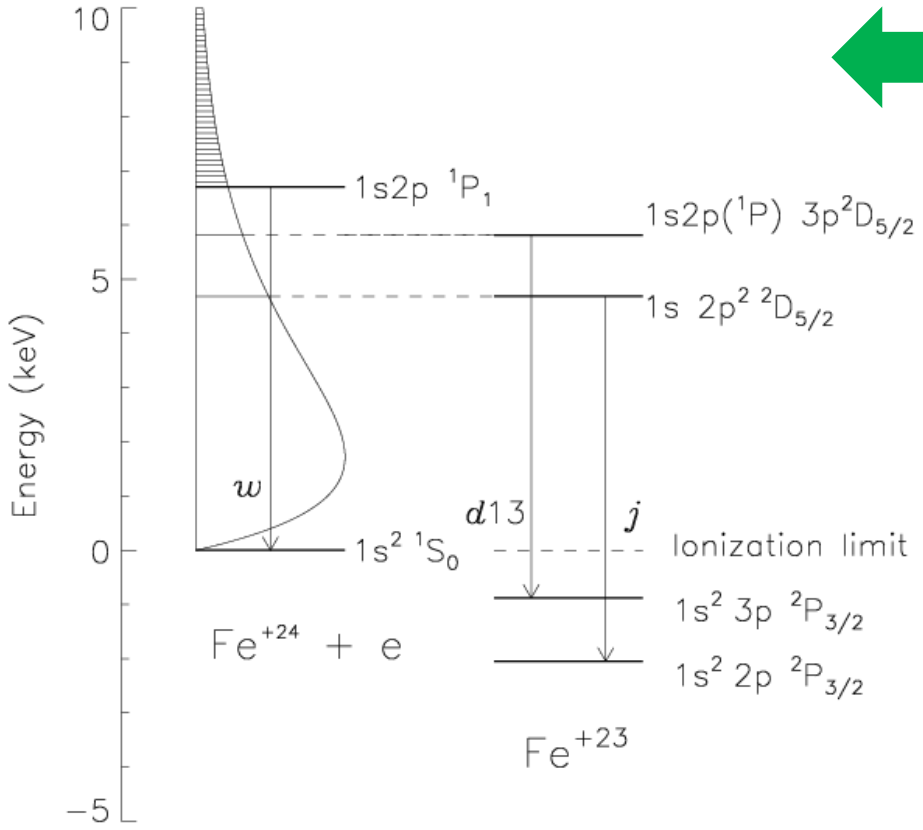
X&M flares observed by SMM

Tokamak spectrum (Beiersdorfer et. al., 1993)



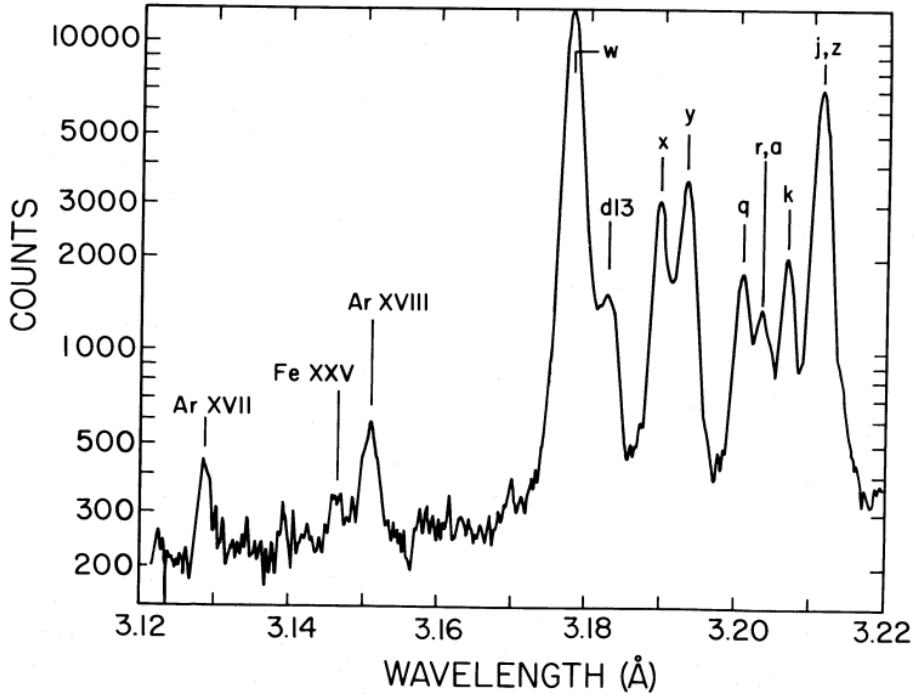
Data have been accumulated by integrating over 24 discharges and are plotted on logarithmic scale to emphasise weak transitions. Labeled are lines contributing at least 20% of total, underlined contribute > 50%.
Lowercase letters → notation of Gabriel, 1972.

Energy level diagram for Fe^{+24} and Fe^{+23}



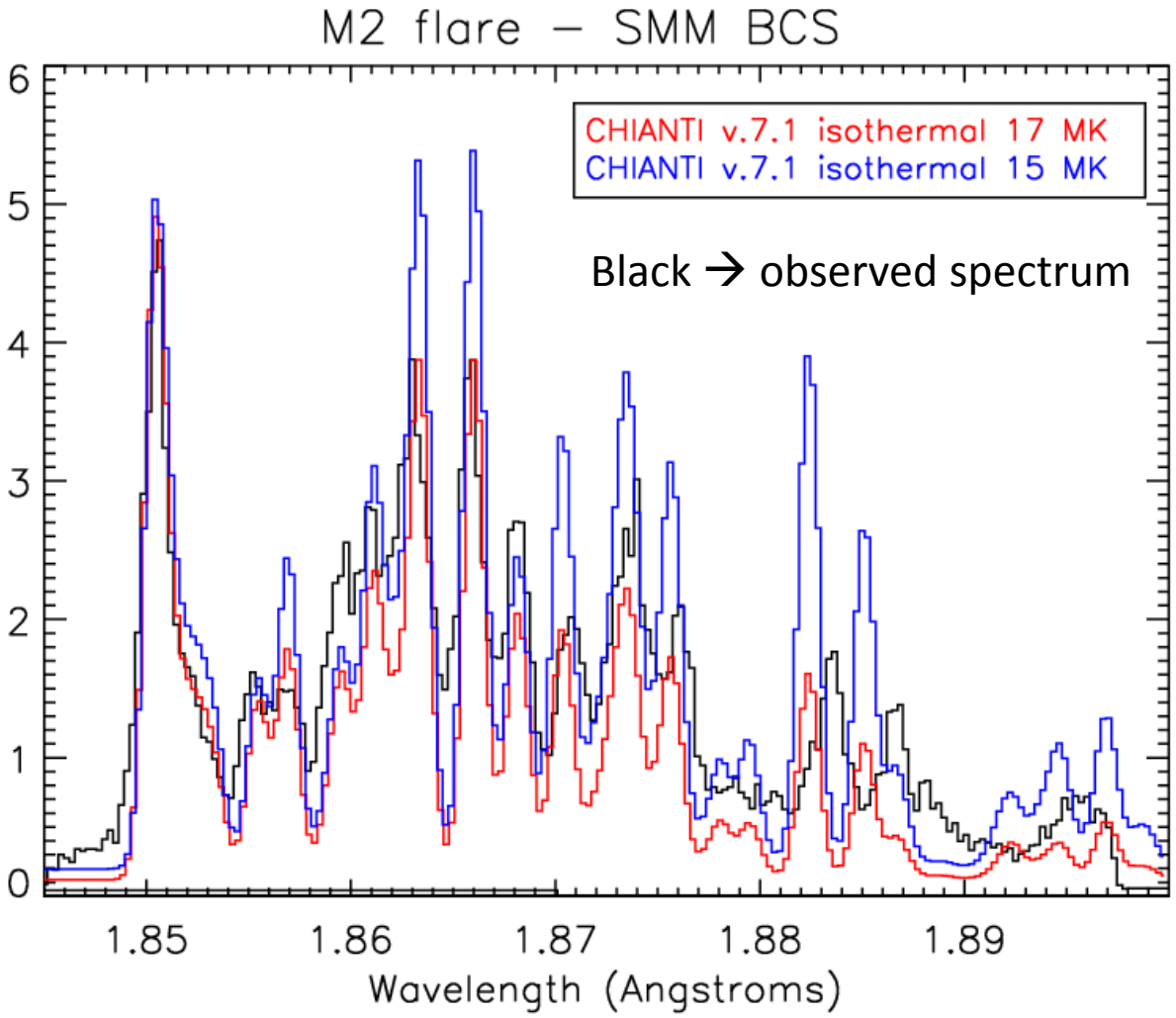
From the book by K.J.H. Phillips, U. Feldman and E. Landi; Ultraviolet and X-ray spectroscopy of the solar atmosphere, 2008

Line *w* of Fe XXV is excited by electrons with E>6.7 keV,
the Fe XXIV satellite *j* is excited by mono-energetic electrons with
E=4.69 keV, and the Fe XXIV satellite *d*13 by mono-energetic electrons with
E=5.82 keV.



From Seely & Doschek, 1989: SOLFLEX experiment on P78-1; spectra from 1981 Aug. 03 flare: during a peak emission phase (09:51:33-09:57:19 UT)

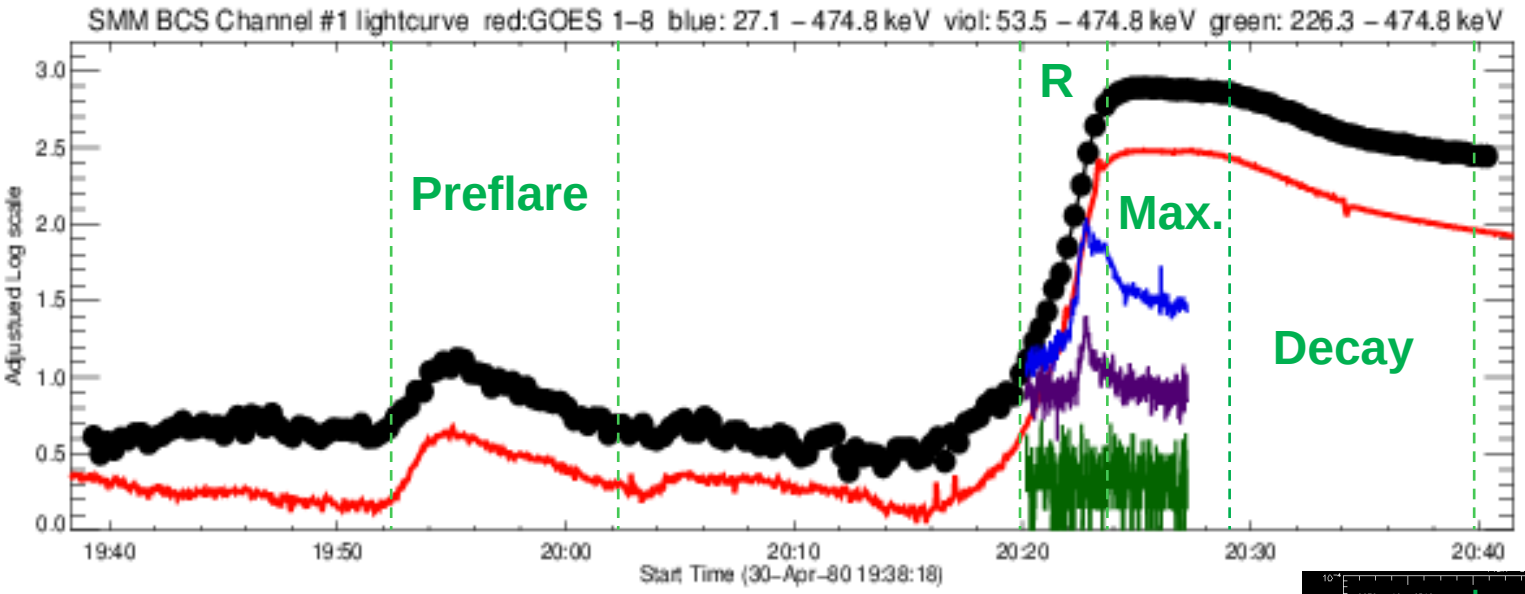
The isothermal fitting of Fe spectra

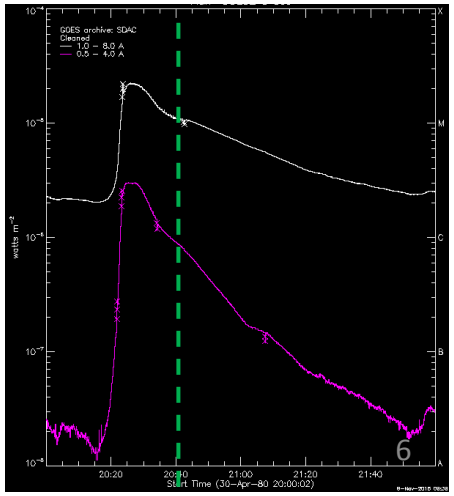


Sensitivity of Fe spectrum on physical conditions of emitting plasma: 2 MK difference in T causes big difference in spectra appearance.

G. del Zanna, 2015; private communication

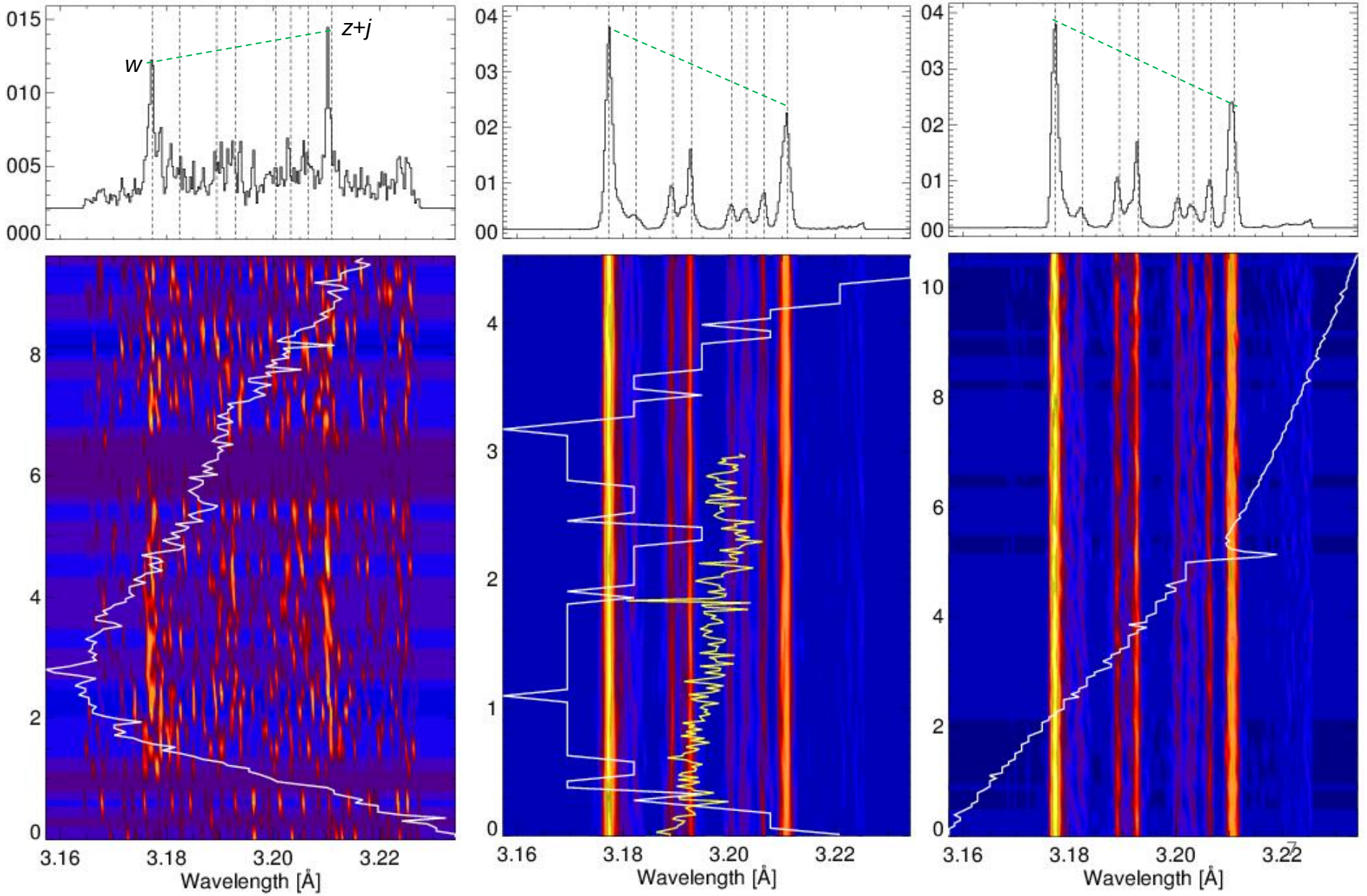
SOL1980-04-30T20:24 (**M2.2**, SN at S13W90)





Total of 203 spectra:
Preflare → 33 spectra
Rise→ 13 spectra during 4 minutes
Max. → 16 spectra
Decay → 36 spectra

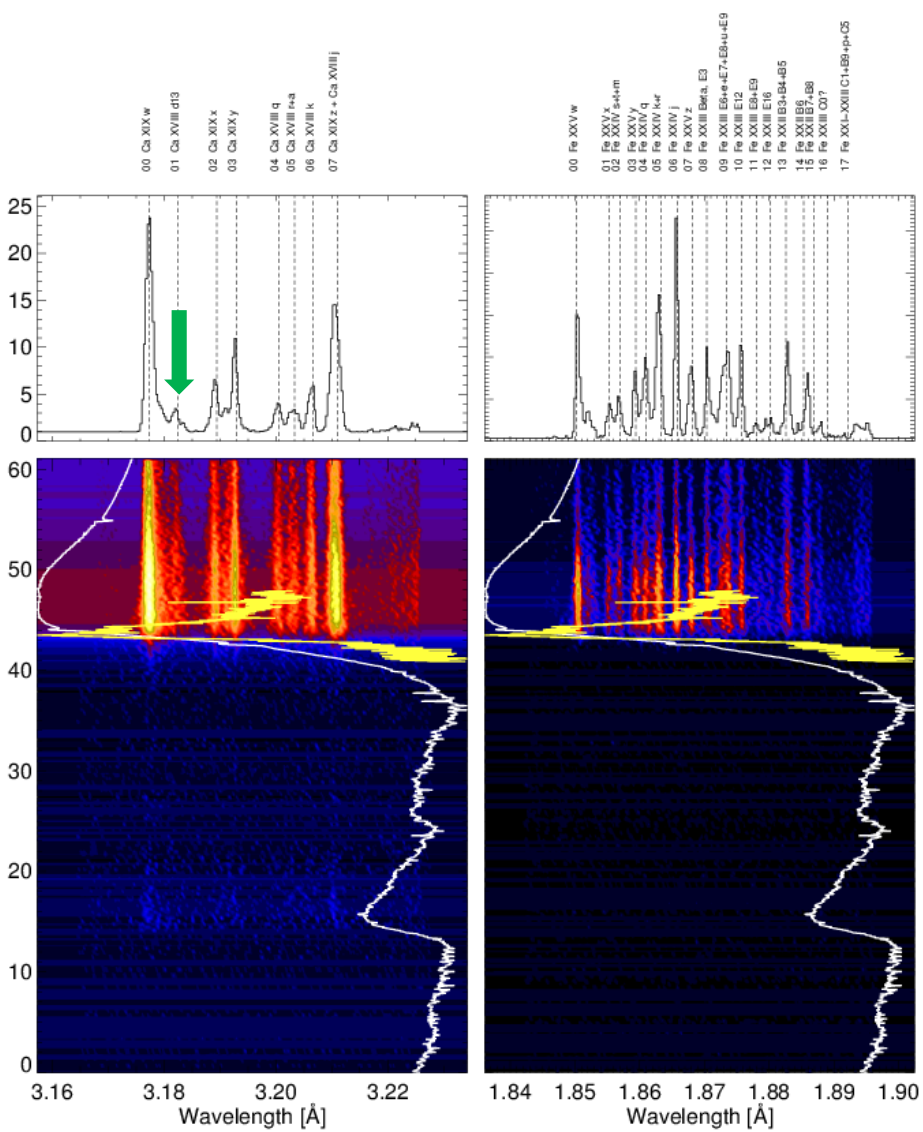
Ca spectra for precursor, maximum and decay

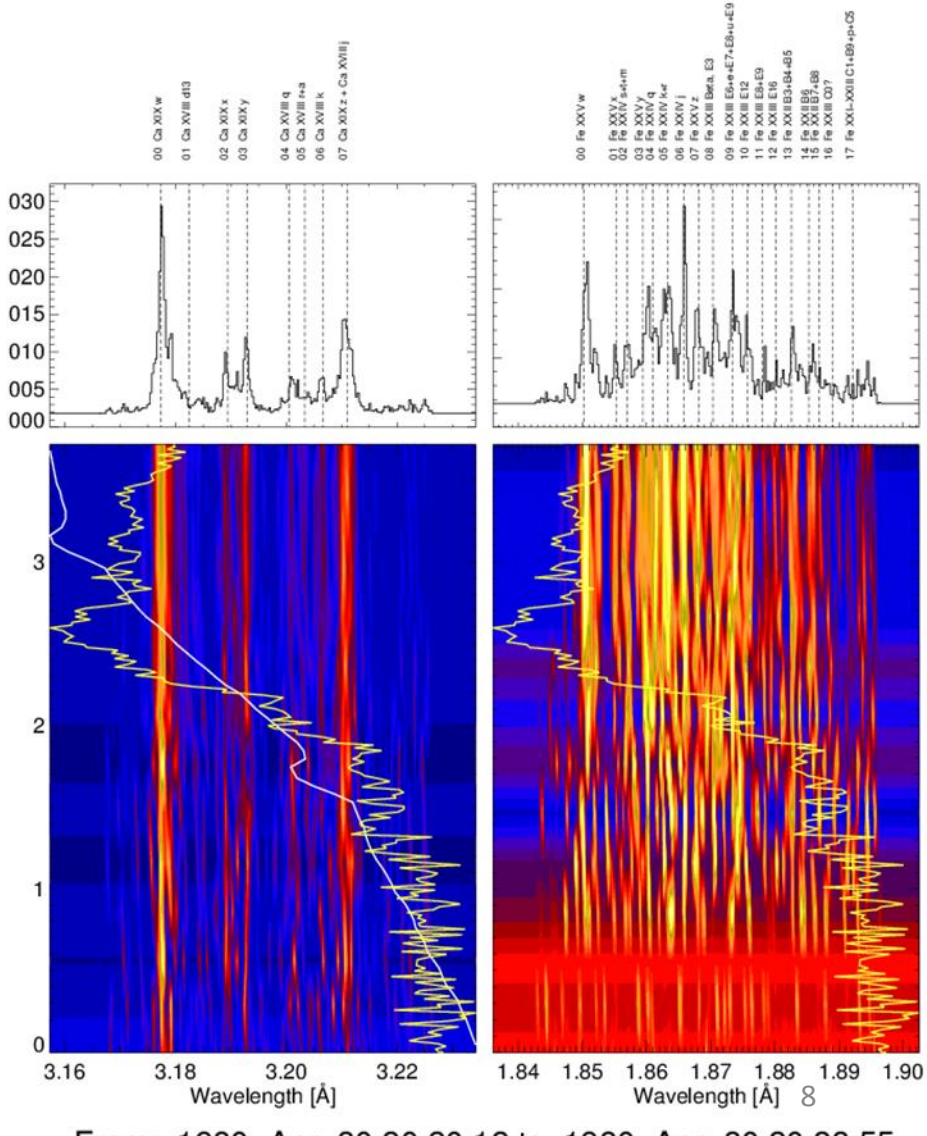


SOL1980-04-30T20:24

Entire flare (60 minutes)

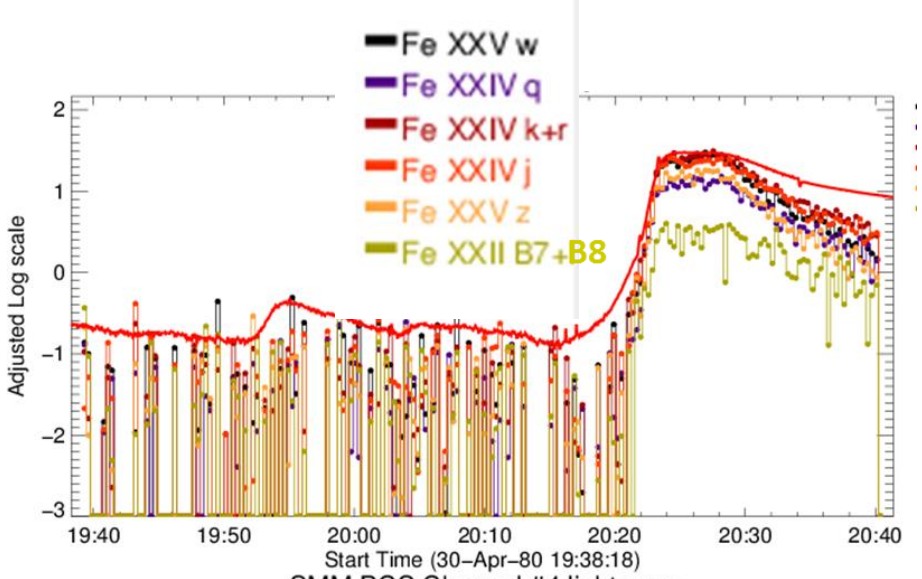
Rise (4 minutes)

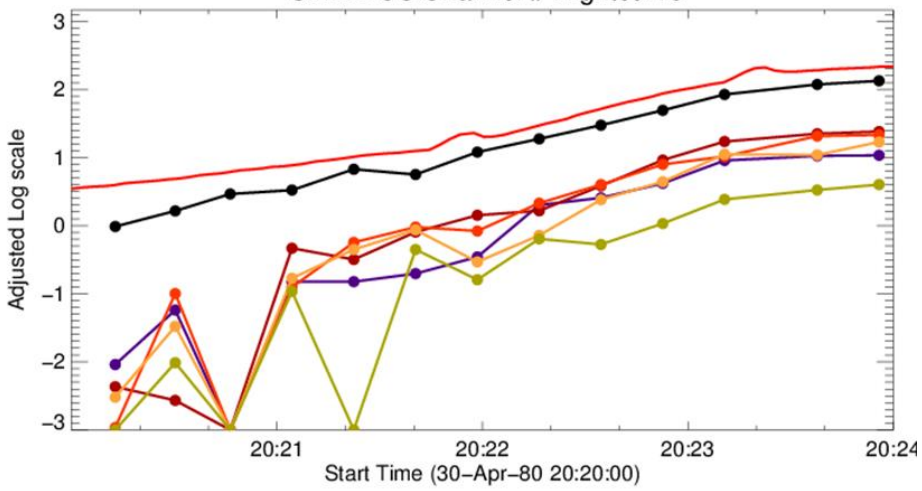


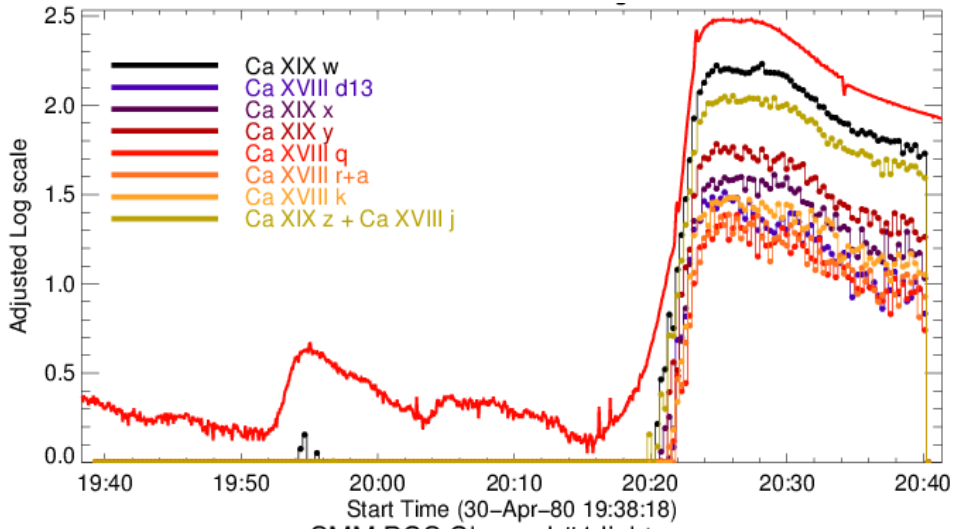


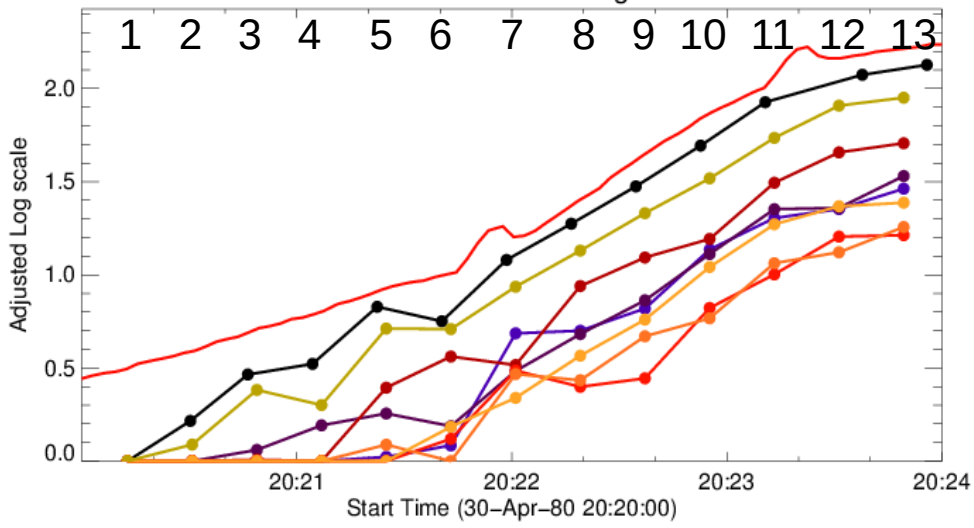
From: 1980–Apr–30 20:20:12 to 1980–Apr–30 20:23:55

Time intensity plots: total flare & rise phase

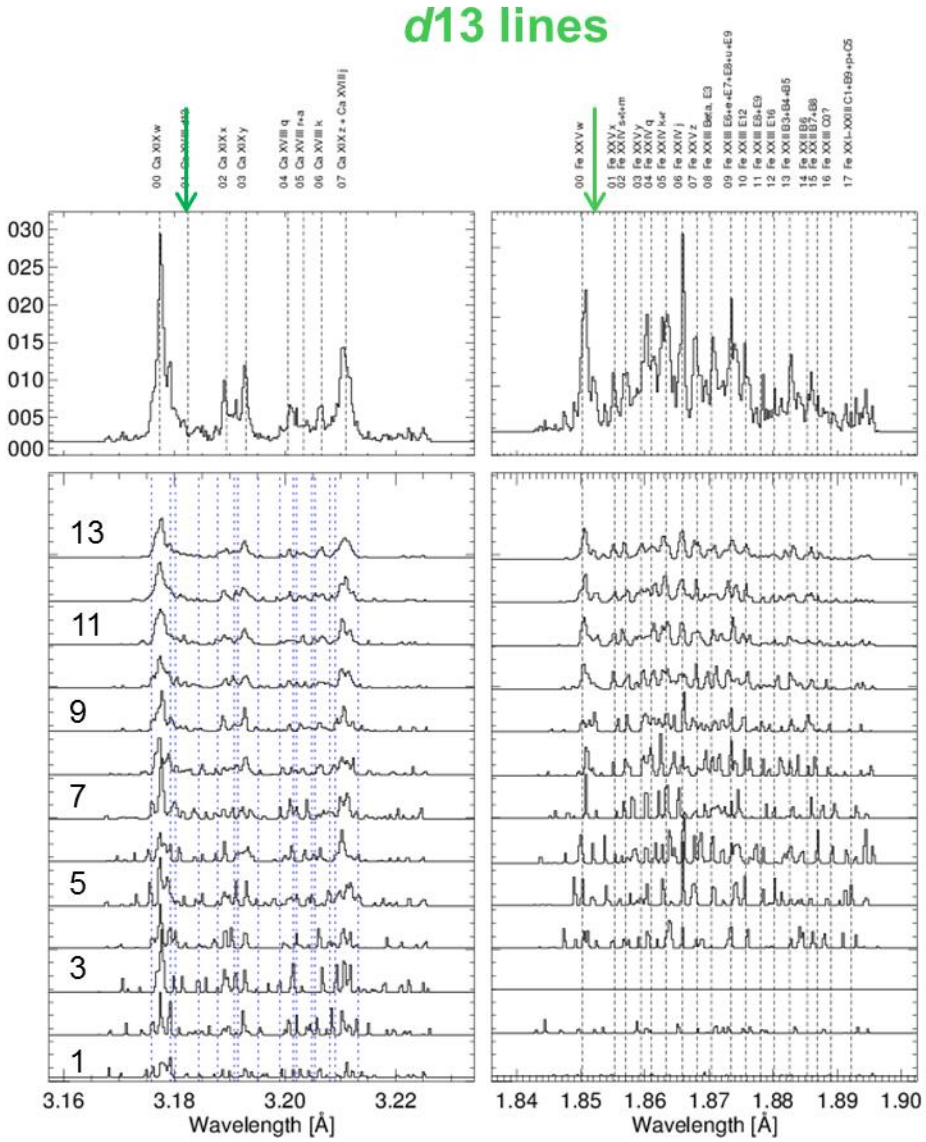








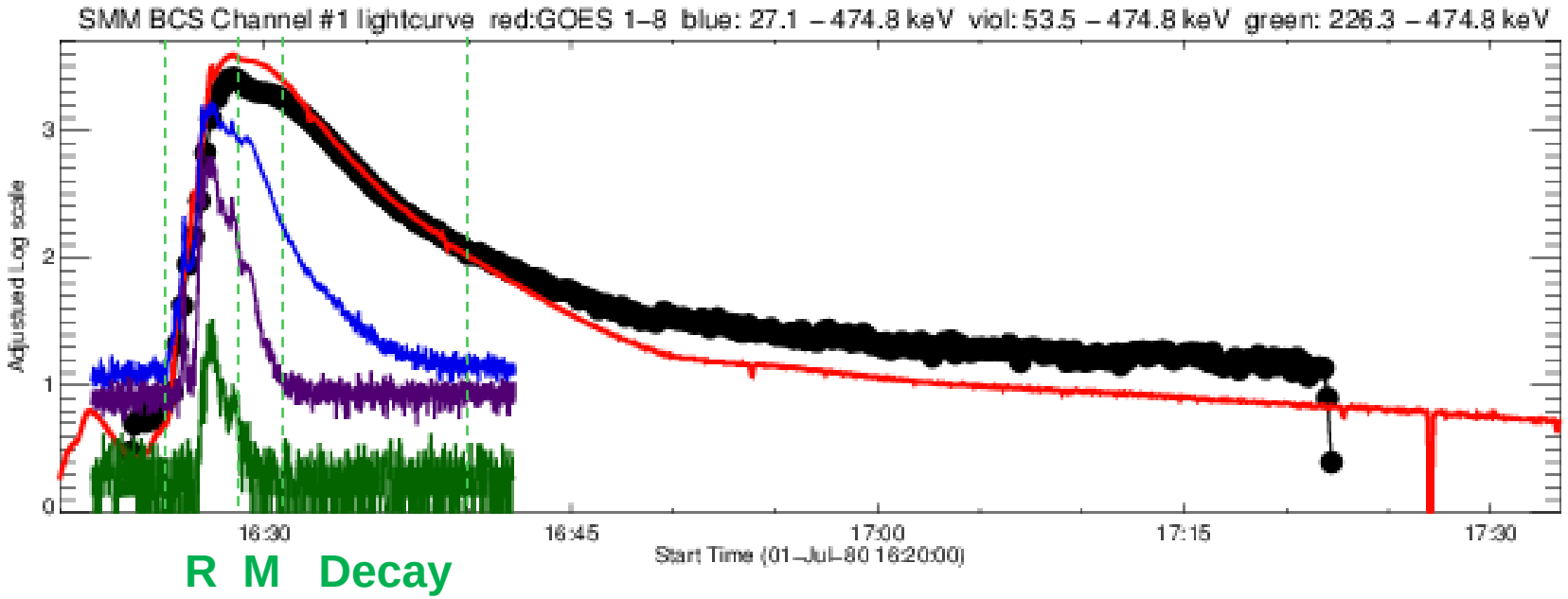
Teh stack of spectra for Ca &Fe (rise phase)



For BCS Fe spectra the *d*13 lines (1.8527 Å) are masked by the fact that *w* (1.850 Å) line is broad during the impulsive phase, so it is difficult to measure the *j*/*d*13 ratio (*j* satellite is well resolved). However using deconvolved spectra this may be a possible diagnostic tool.

We are awaiting for future higher-resolution spectra.

SOL1980-07-01T16:29 (**X2.5**, 1B at S12W38)



Total of 301 spectra

R→ 12 spectra (< 3min.)

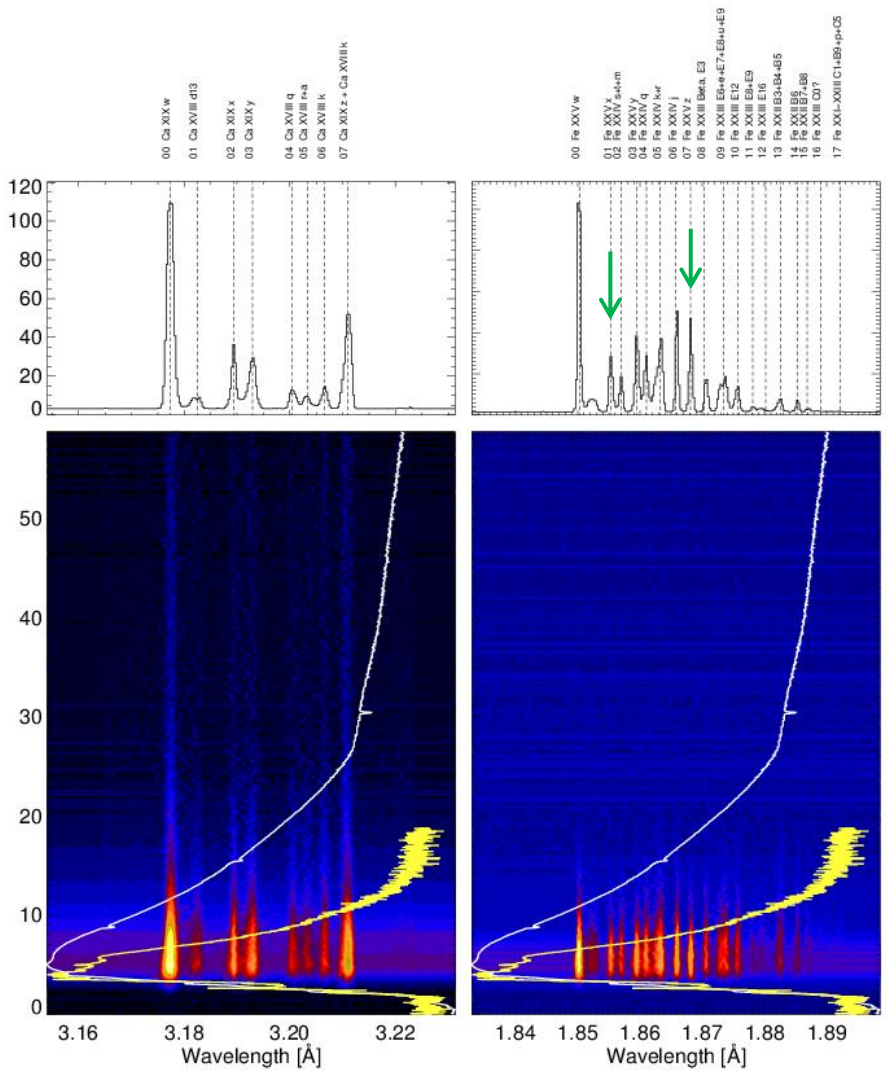
M→ 10 spectra

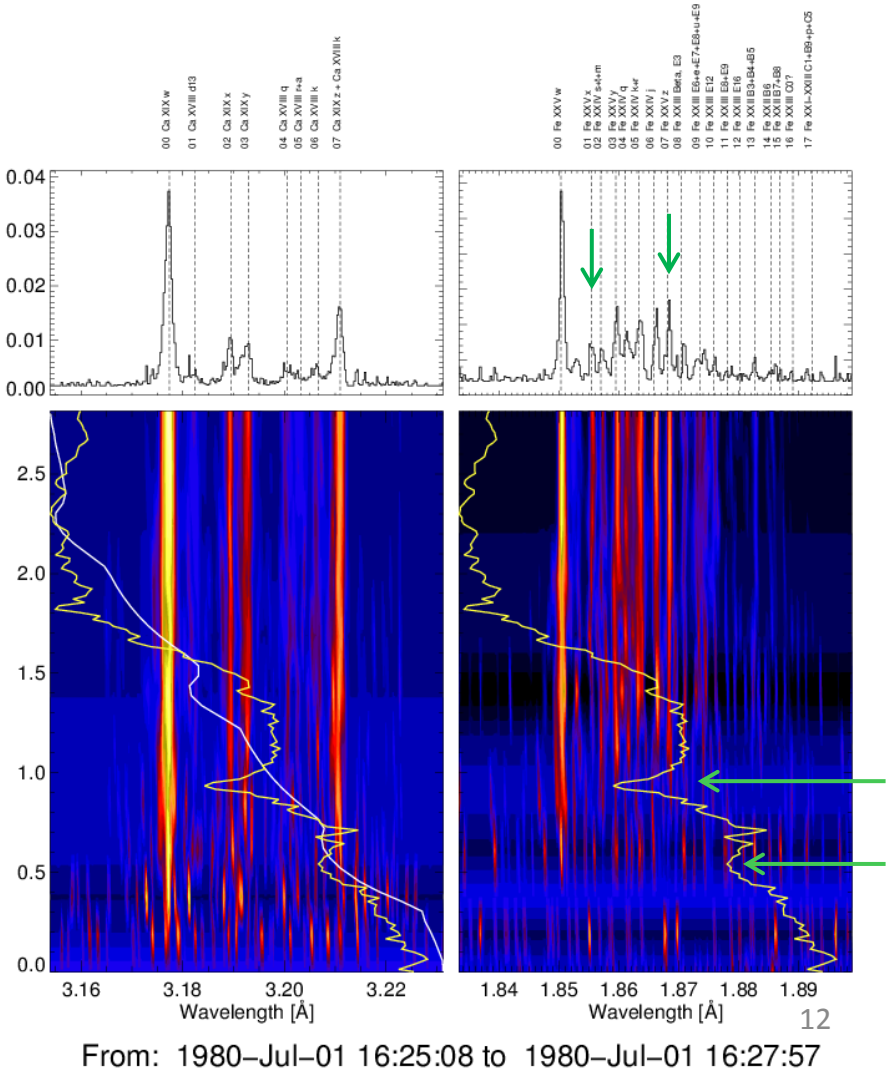
D→ 45 spectra

SOL1980-07-01T16:28

Entire flare (1 h)

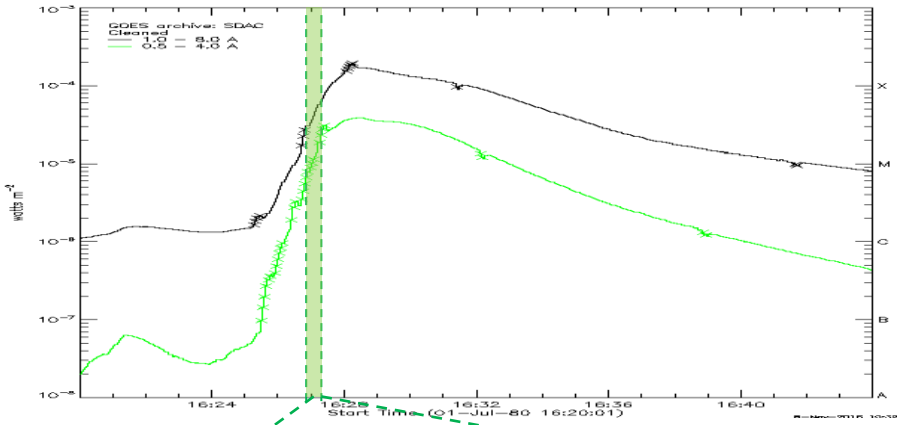
Rise (< 3 min.): **time delays** of Ca & Fe

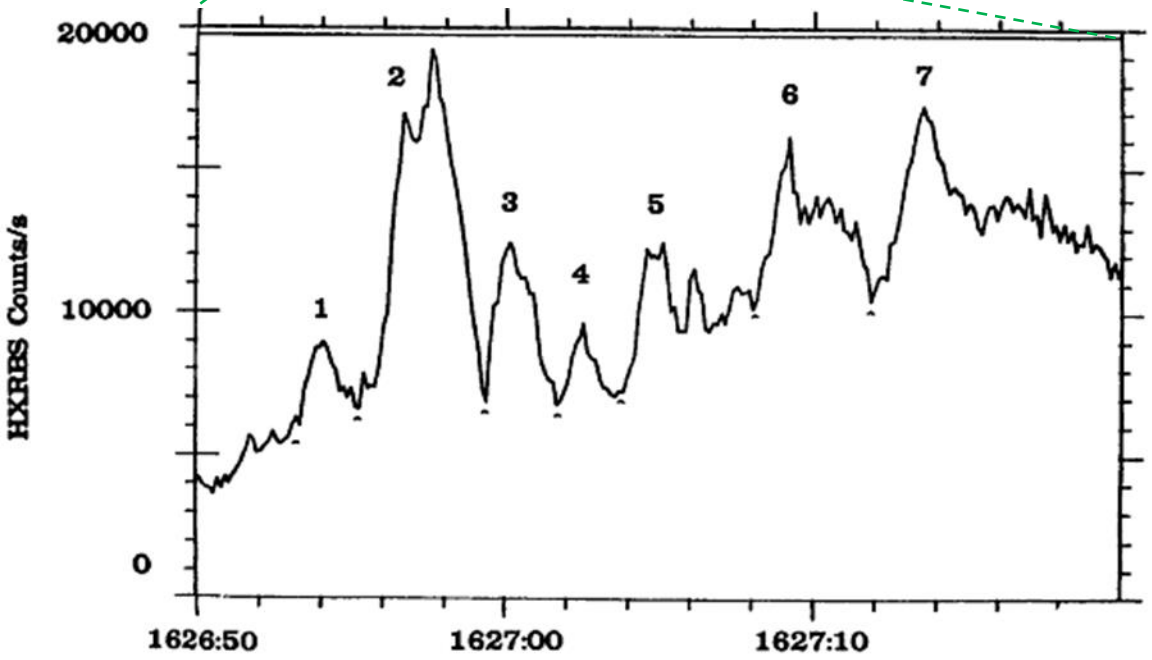




From: 1980–Jul–01 16:25:08 to 1980–Jul–01 16:27:57

SOL1980-07-01T16:28

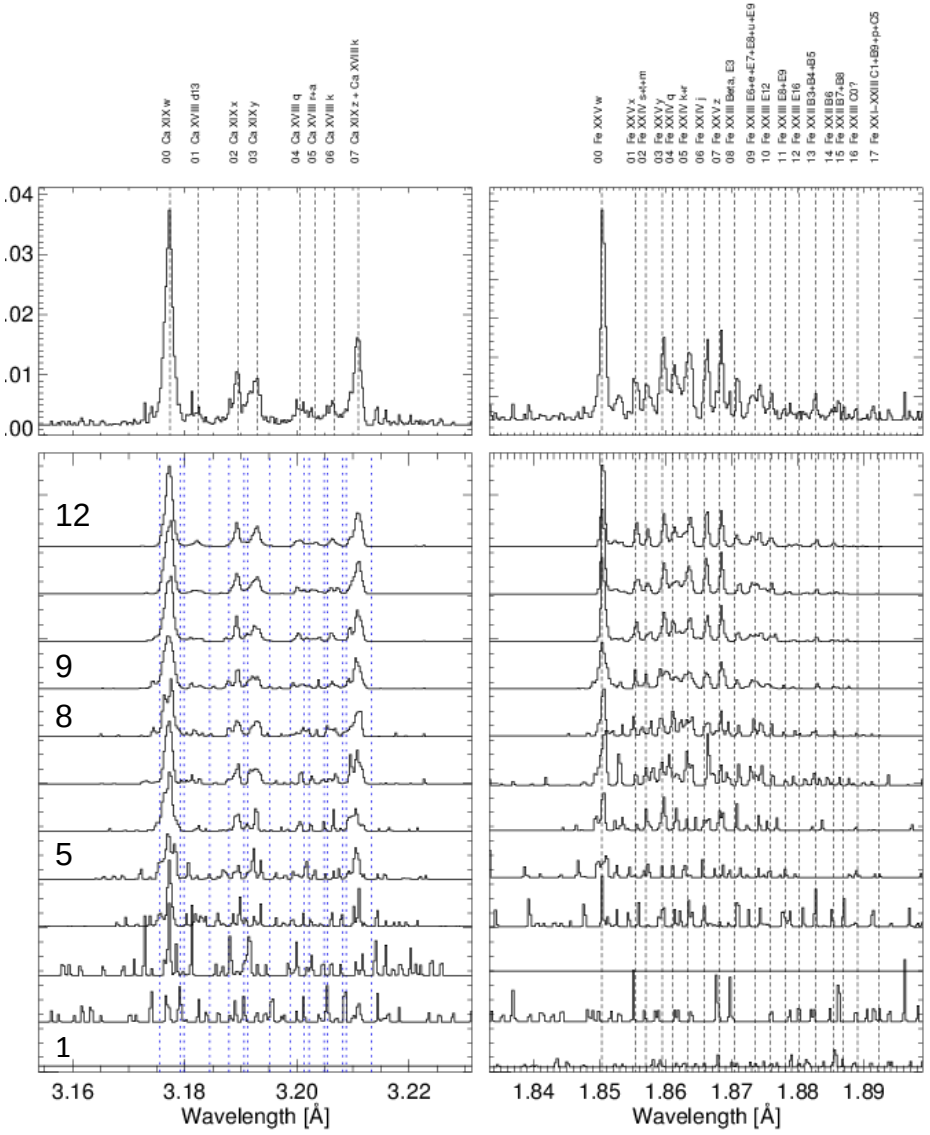


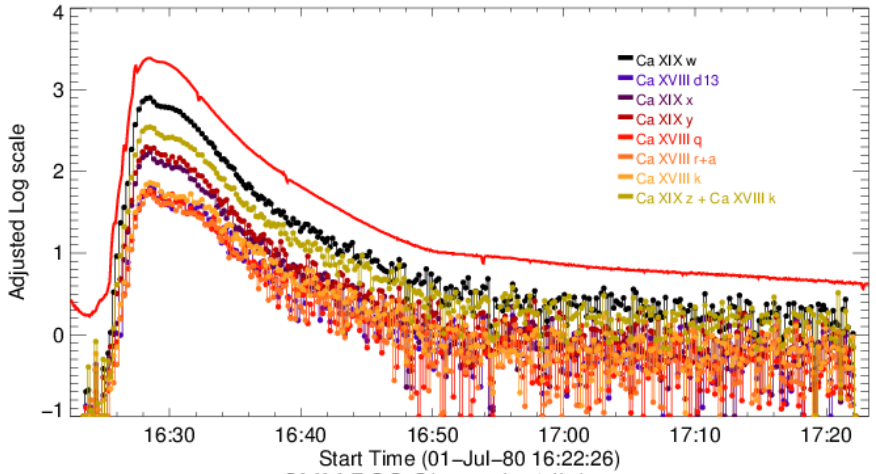


Time-intensity plot of 7 rapid impulsive rises in hard X-rays: **33- 490 keV, HXRBS**.
(NASA Conference Publ.,1985)

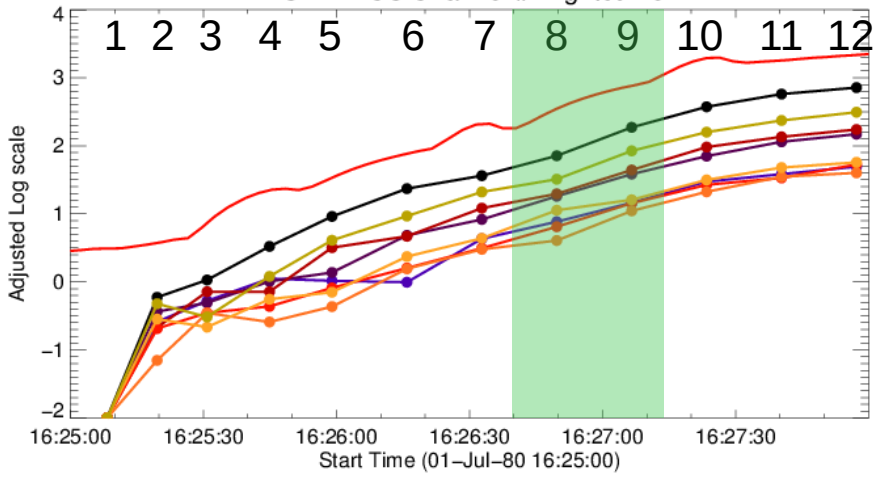
Only two BCS spectra (8&9 during the rise phase) have been recorded during the **30 s** phase of impulsive spikes in HXRBS

Rise phase

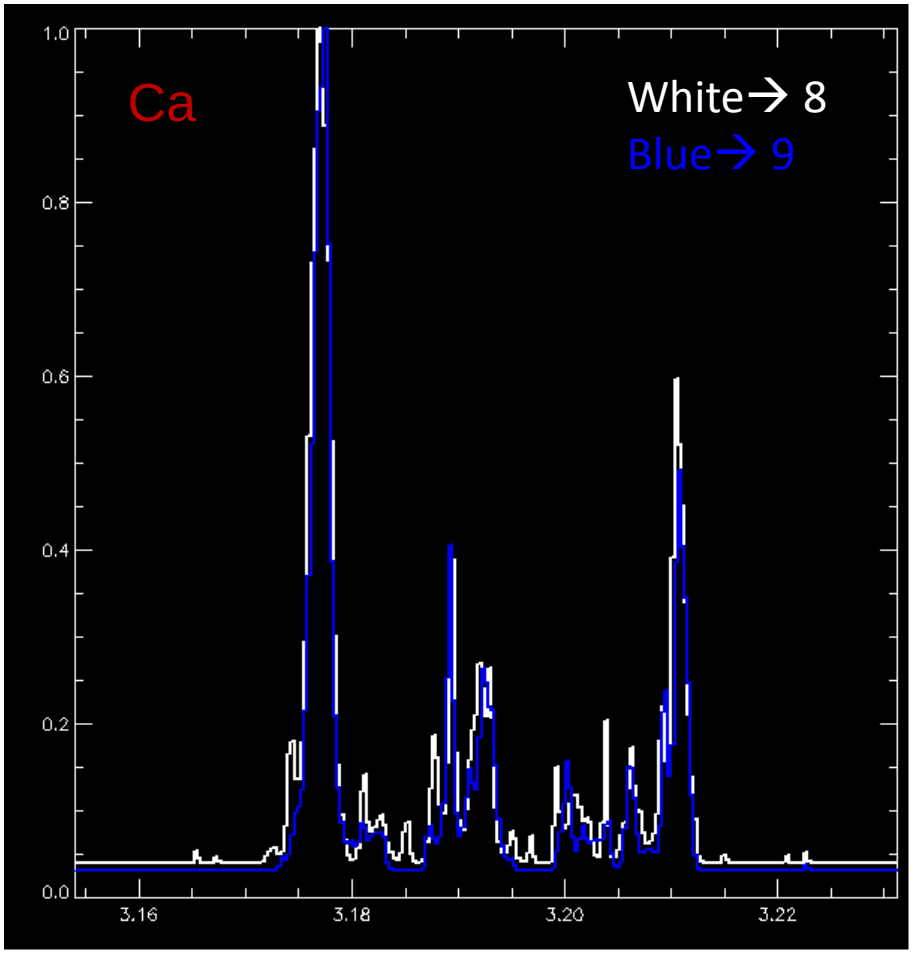


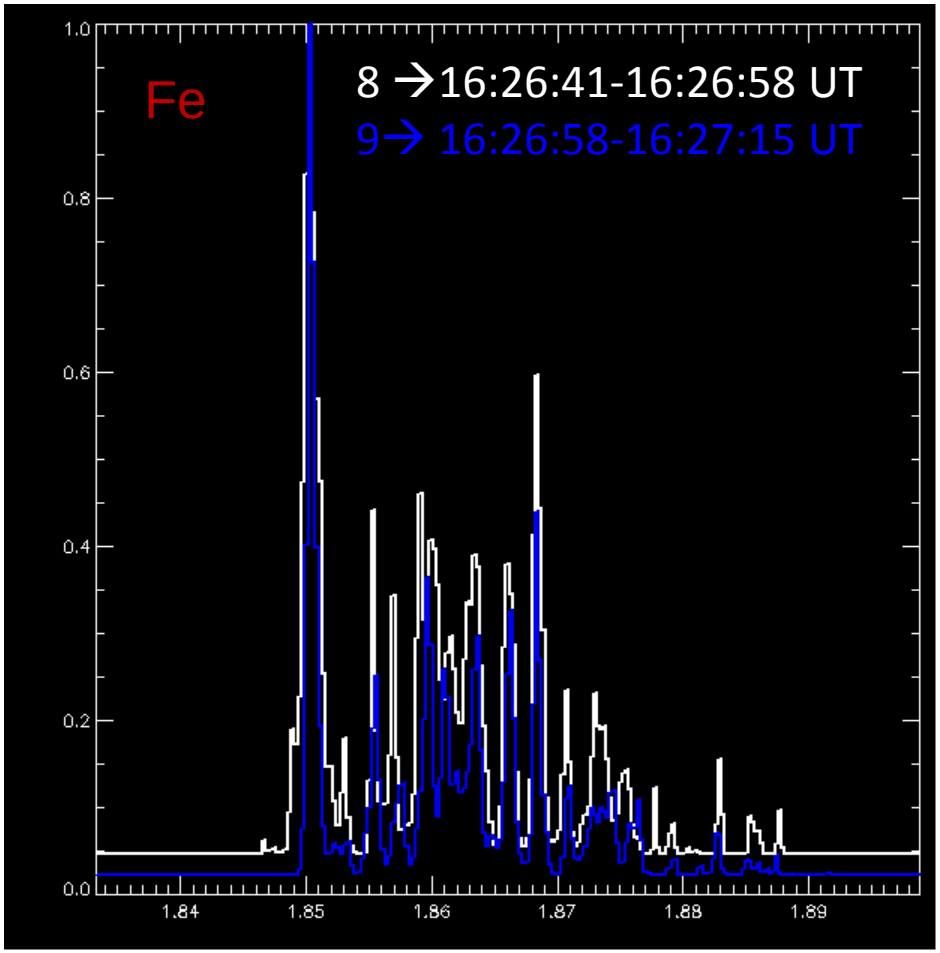


SMM BCS Channel #1 lightcurve



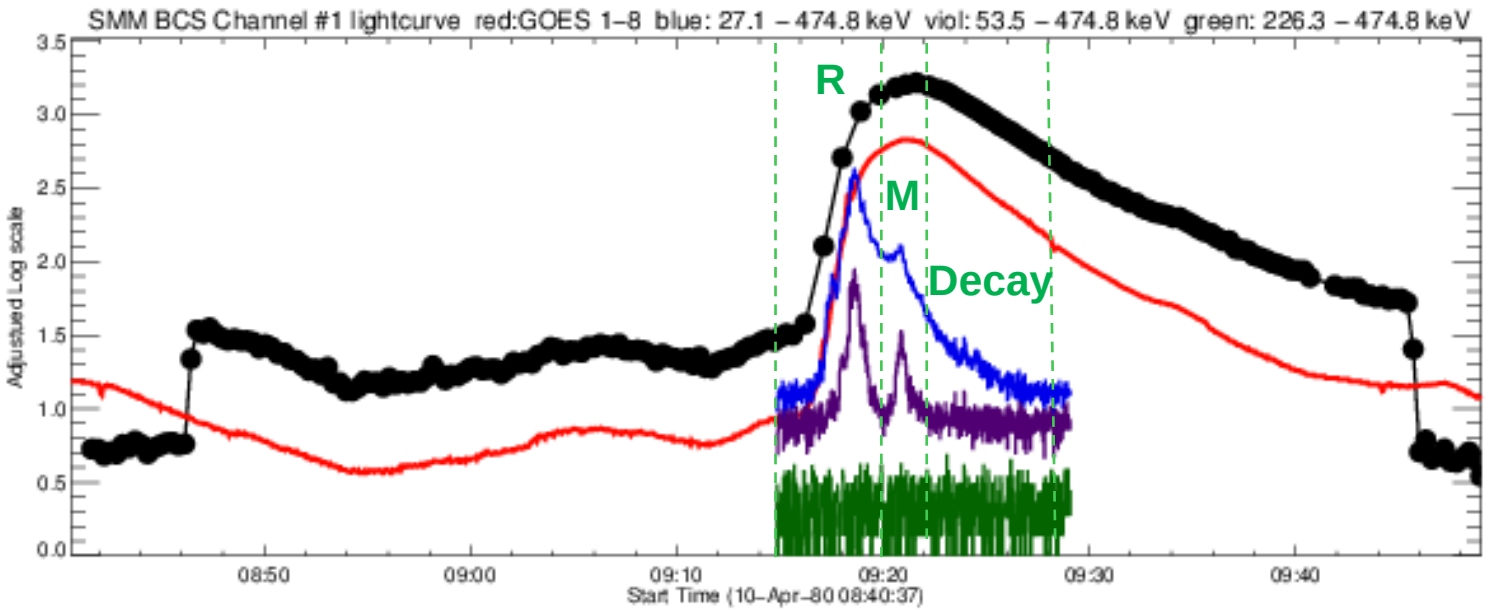
BCS Ca & Fe for spike's period (2 spectra)





The difference in time (16:26:49 UT and 16:27:06 UT) between these two spectra is 17 seconds. The change of the physical conditions is evident.

SOL1980-04-10T09:23 (**M4.0**, 1N at N12W42)



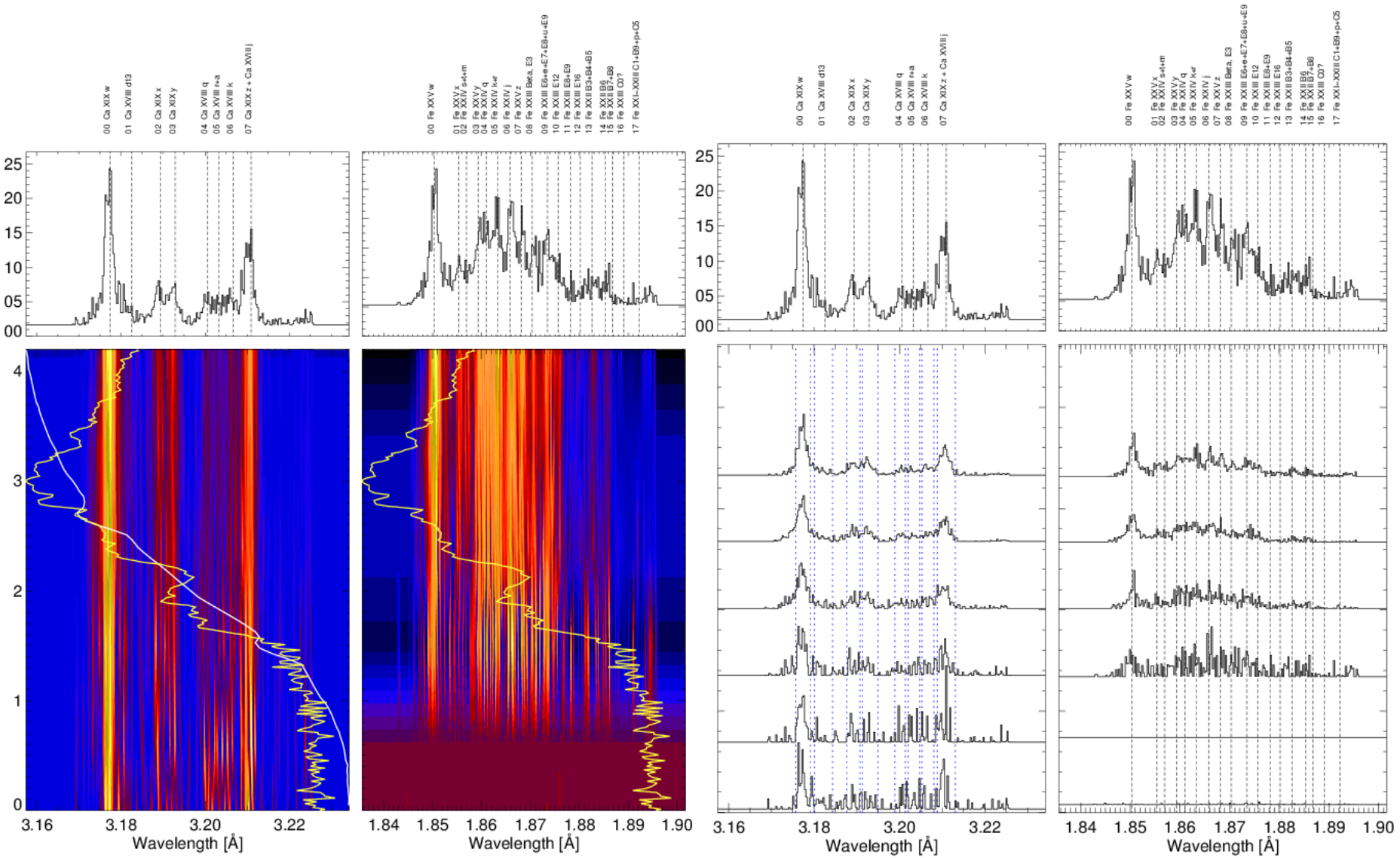
Total of 208 spectra

R→ 6 spectra

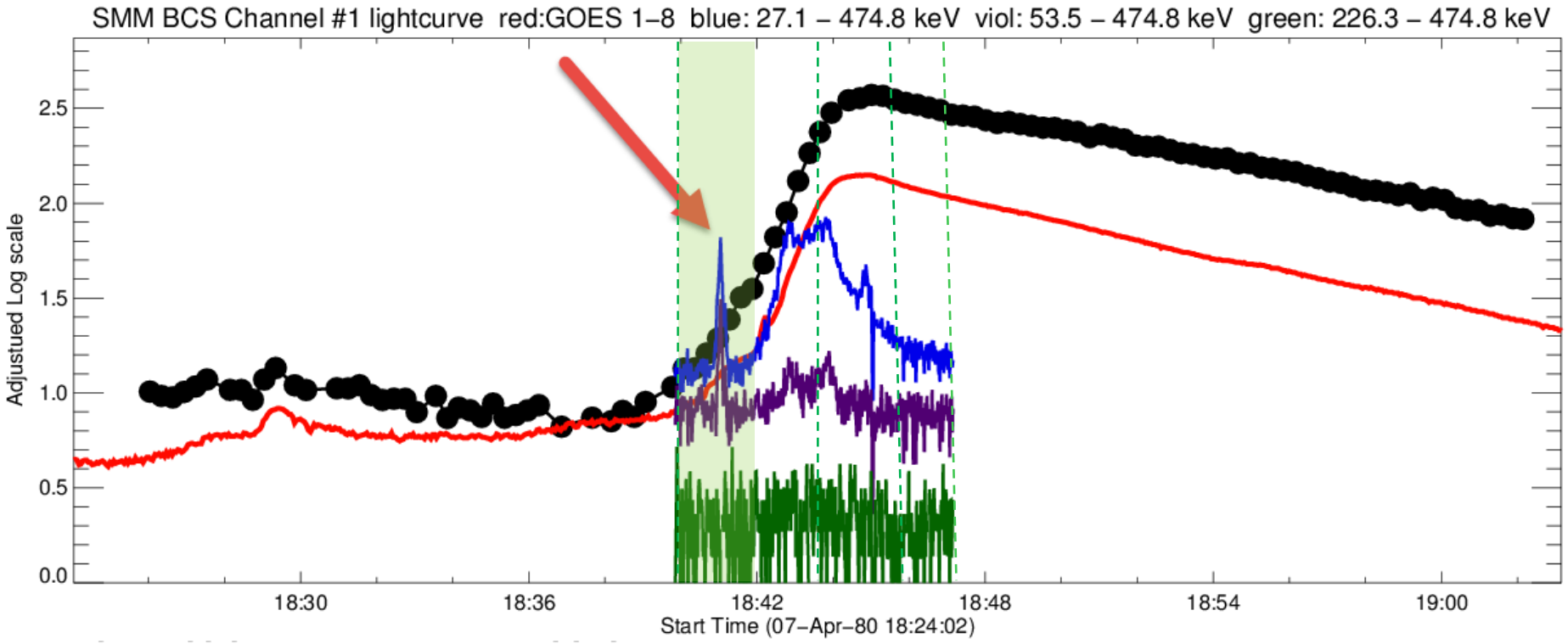
M→ 3 spectra

Decay→ 19 spectra

Rise phase (double source?)



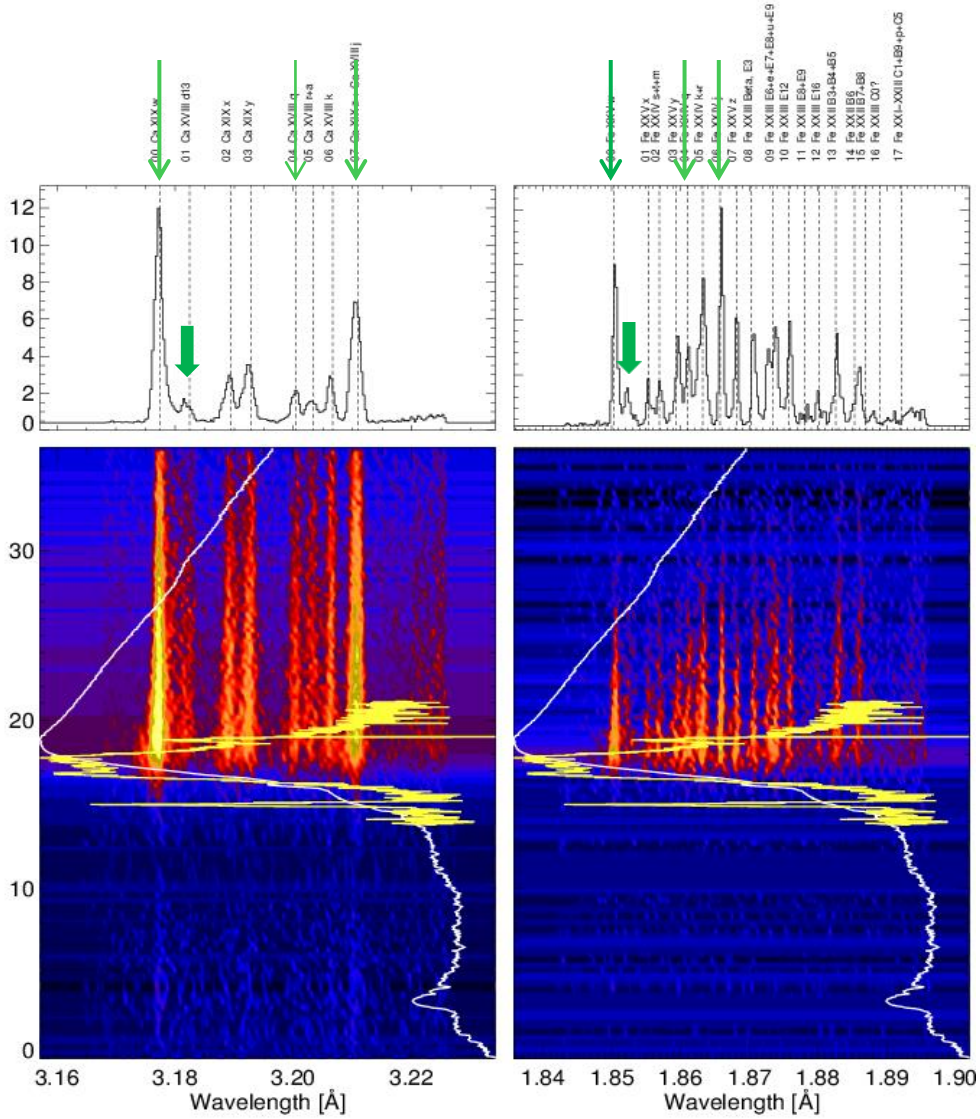
SOL1980-04-07T18:44 (**M1.2**, SB at N12W06)



Rise→ 12 spectra
Max.→ 3 spectra
Decay→ 8 spectra
Spike→ 3 spectra

7 spectra have been registered during 2 minutes including the spike at 18:41 UT

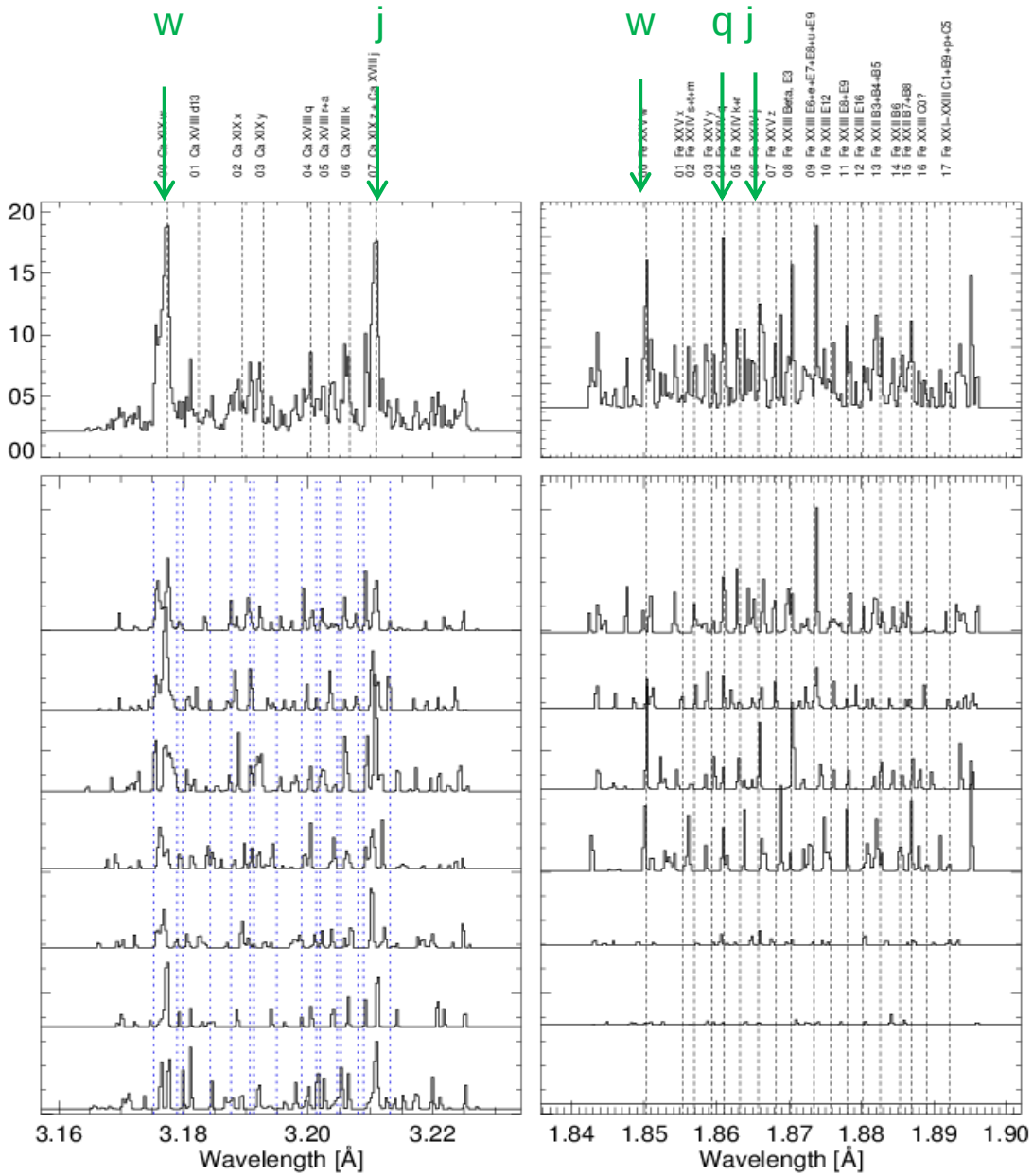
Spectra for entire flare



j intensity < w for Ca
j intensity > w for Fe
j intensity > q for Fe

d13 resolved
Remember Z^4 scaling of satellite line intensity

The spectra during 2 min. interval (**spike included**)

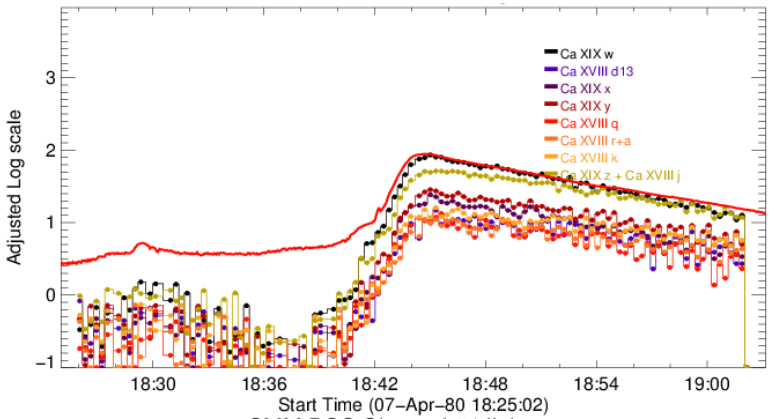


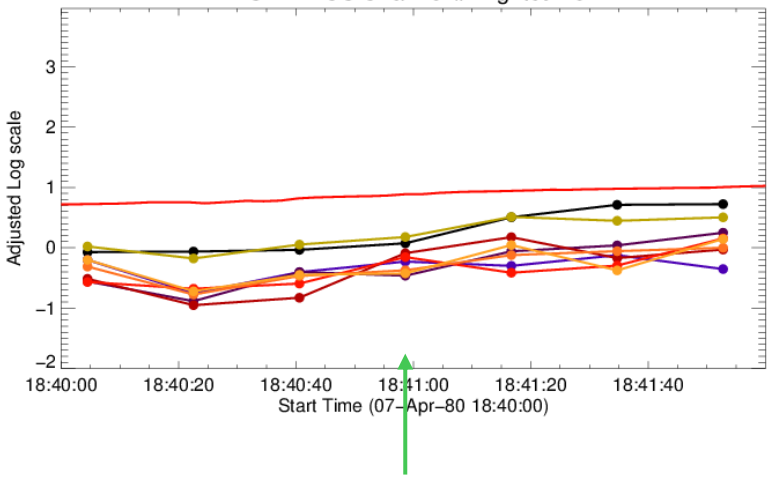
spike

j ≤ w for Ca
j<w for Fe
j<q for Fe ?

entire

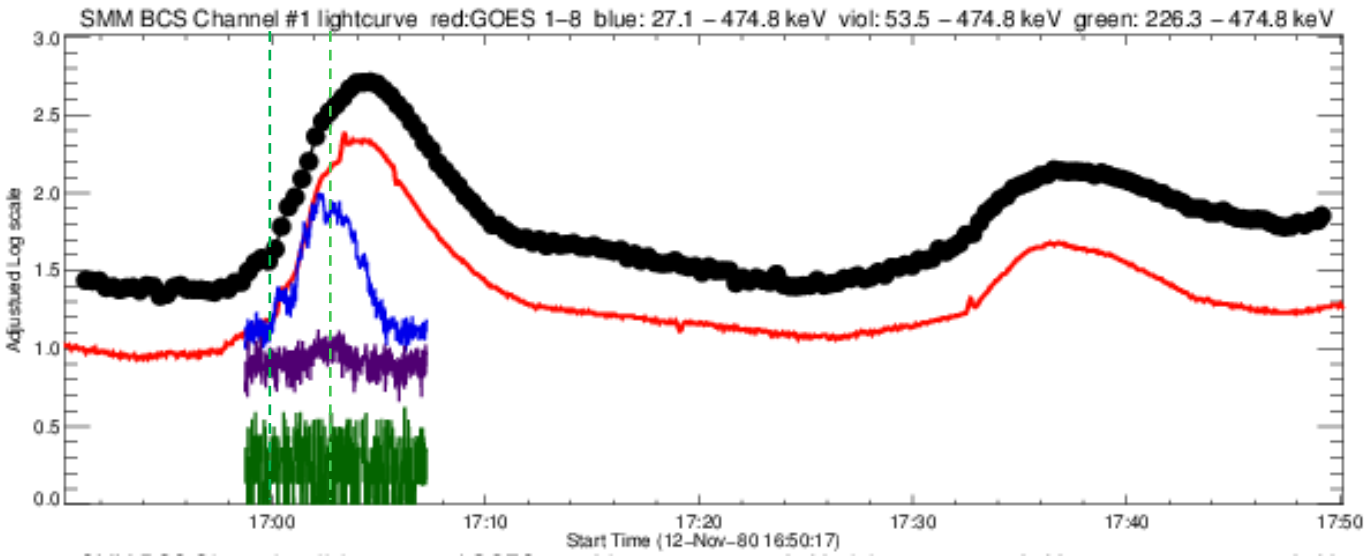
j < w for Ca
j > w for Fe
j > q for Fe





Spike time

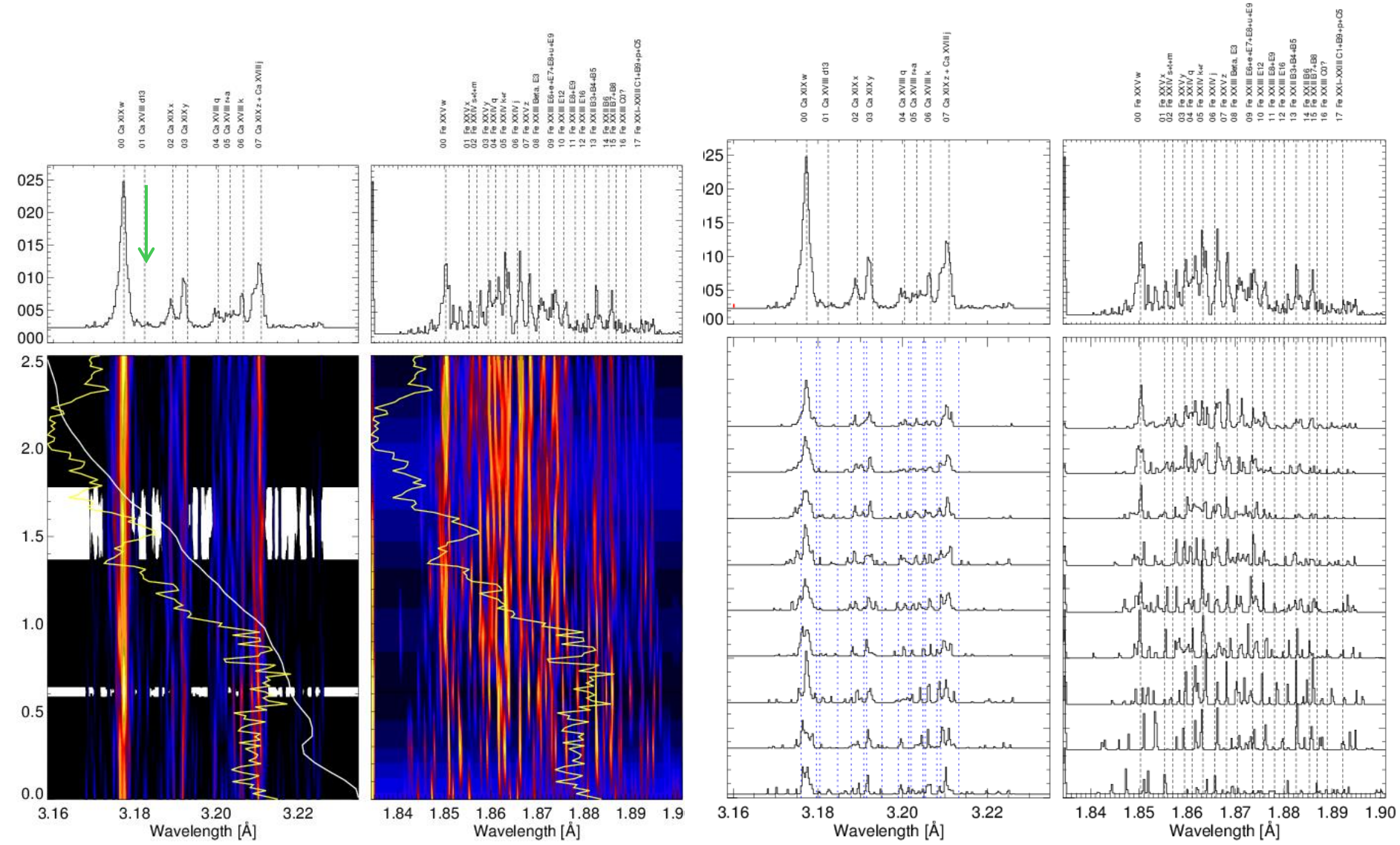
SOL1980-11-12T17:02 (**M1.4** 1B S14W11)



184 spectra

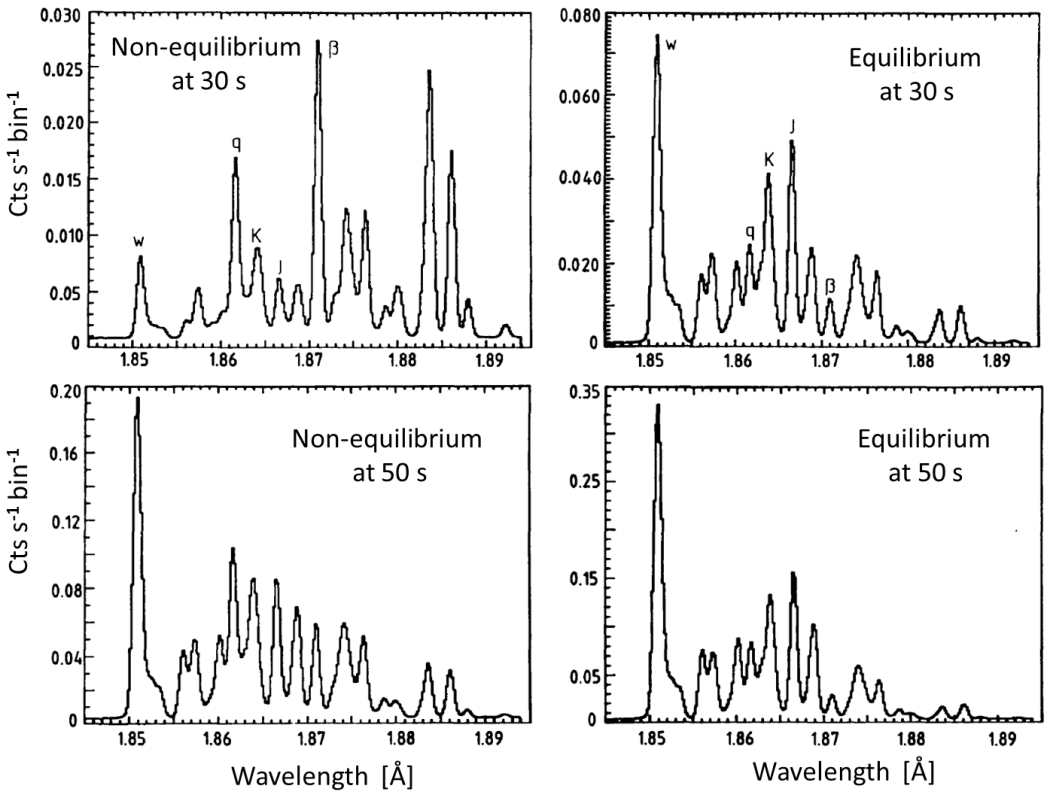
9 spectra during 3 minutes rise phase: 17:00÷17:03 UT

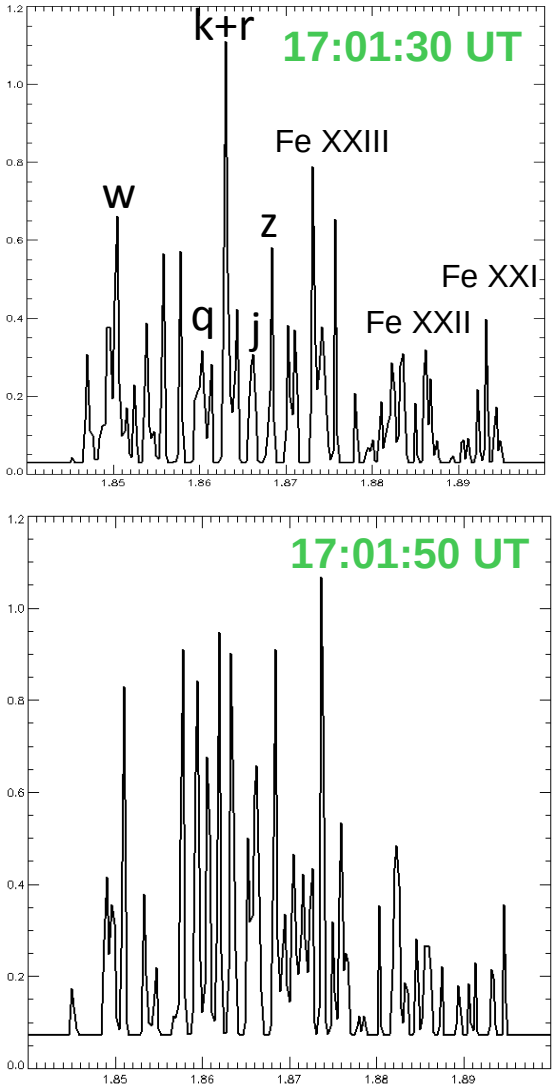
SOL1980-11-12T17:02 (M1.4); rise



BCS Fe spectra for SOL1980-11-12T17:02

Synthetic spectra from Mewe et al., 1985





To get enough S/N during the impulsive phase one needs to sum over ~ minute!

Instruments with higher sensitivity needed.

deconvolved

Concluding remarks

- The deconvolution of BCS spectra allows to make their „revitalization”. Lines after deconvolution are much better resolved. This leads sometimes to splitting into two components (manifestation of contribution from more than one source). Time delay between individual lines’ appearance can be followed.
- The preliminary inspection of deconvolved spectra indicates for many peculiarities during the rise phase.
- We plan to make the deconvolution for selected 82 flares → a catalogue of impulsive events’ spectra.
- Selecting individual/interesting events for advanced/detailed analysis.
- In spite of this we are awaiting for future spectra with higher-resolution (SolpeX, ChemiX).

Abstract

- In this study we searched the spectra collected by BCS SMM in 1980 and 1984-1989 focusing on the behavior of spectral features during **the impulsive flare phase** recorded by the HXRBS spectrometer, also a part of SMM instrument package. **82** flares have been identified accompanied by strong impulsive HXR emission. The SMM BCS spectra are the best ever obtained as concerns the spectral resolution. Before inspecting, the instrumental profiles calculated using modern XOP package have been deconvolved.
- Deconvolution further increases the spectral resolution allowing to see on the spectra tens of lines in the ranges 3.16 - 3.23 Å (Ca XIX He-like region) and 1.83-1.94 Å (Fe XXV - Fe Kα region). Time evolution of the spectra will be presented as well as the lightcurves in selected lines formed in various processes (direct excitation, dielectronic recombination, inner-shell excitation).
- Observed patterns, representative for the impulsive phase will be shown and discussed.