An atlas of archived Flat Crystal Spectrometer (SMM) spectra
(the work in progress)

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Introduction:

We undertook a search for all spectral scans in the Solar Maximum Mission (SMM) Flat Crystal Spectrometer (FCS) data archive in order to prepare for planned missions aimed at measuring high-resolution X-ray spectra of solar active regions (ARs) and flares.

The FCS was a part of X-Ray Polychromator experiment (XRP). XRP employed 2 complementary instruments (FCS and BCS) operating aboard the large NASA SMM solar observatory in the period 1980 – 1989.

XRP was prepared by a consortium of 3 groups: The Astrophysics Research Division of Rutherford and Appleton Lab., MSSL (both UK) and Lockheed (USA).

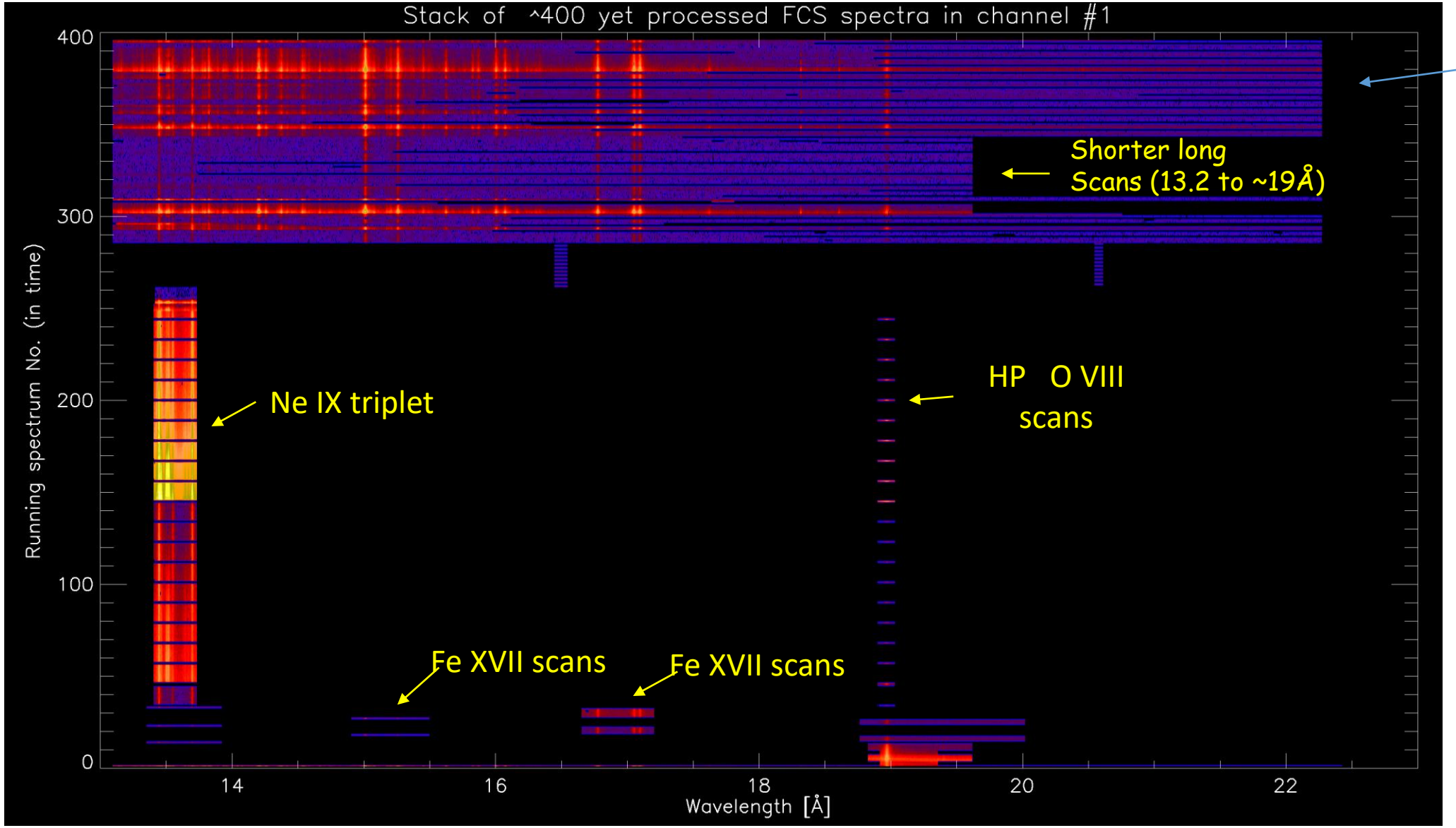
FCS in its spectral spectroscopy mode recorded spectra by scanning (i.e. changing the angle of incidence on flat crystals) in 7 spectral bands covering range between **1.4 Å** and **22.5 Å**. Over the course of the Mission, some of the spectral channels unfortunately failed, but even so hundreds of spectra were recorded and are preserved in a NASA data archive. (https://umbra.nascom.nasa.gov/pub/smm/xrp/data/fis/). Only few of them were thoroughly analysed.

Particularly of note is a vast trove of relatively unanalyzed spectra collected after the Shuttle repair mission of SMM in April 1984.

Channel #1 (diffracting crystal KAP): up to now processed were

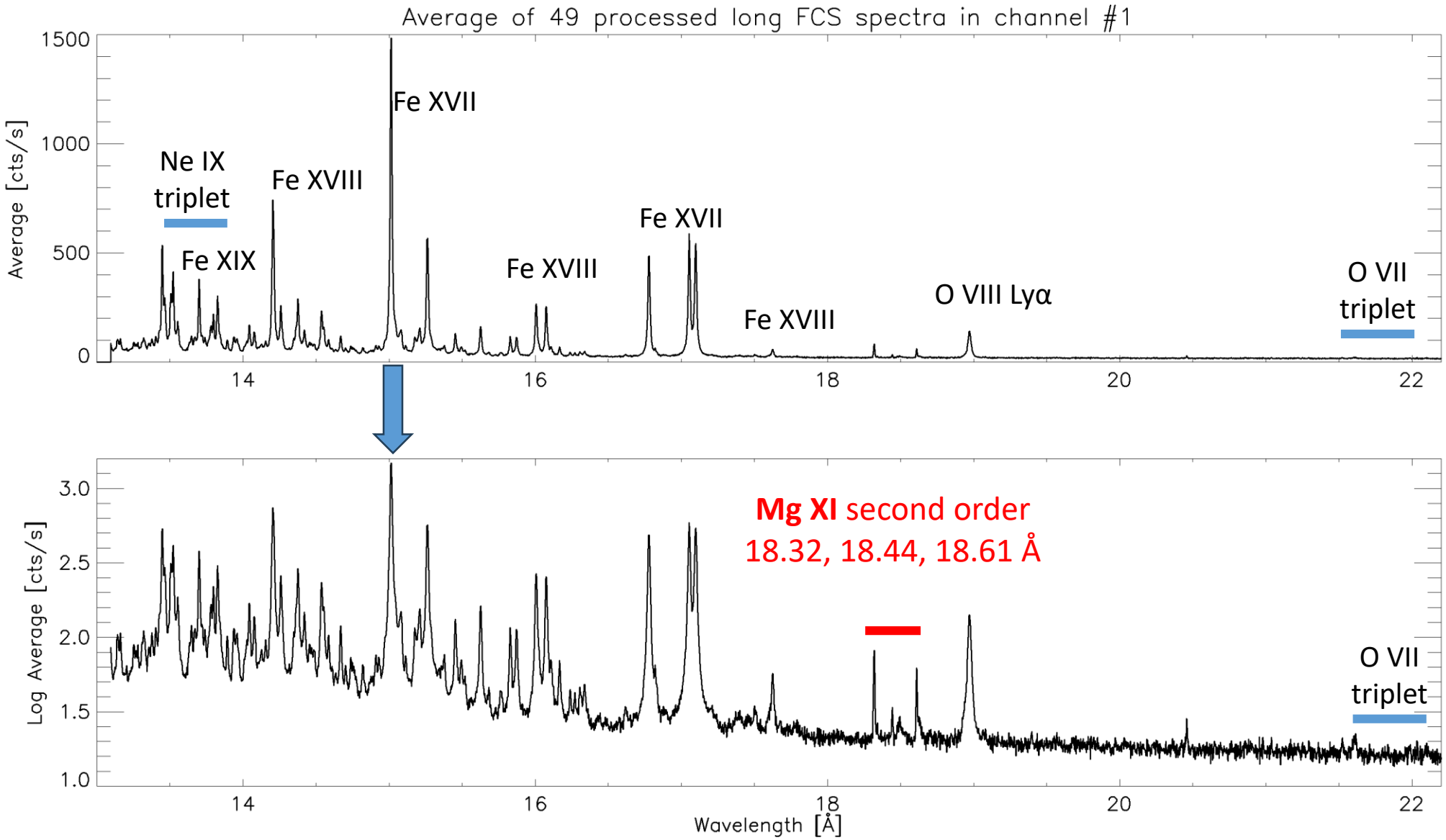
- Total of 395 scans
- Long scans (~14 min.; 13.5-22 Å; 106→49 full scans)
  Shorter long scans (slong ~9.5 min.; 13.5-19 Å)
- Short scans (#1 Ne triplet ~25 s; 13.4-13.8 Å; 321 (305 of them unsaturated)
- Home position scans (HP) of resonance lines for OVIII, Ne IX, Mg XI, Si XII, S XV, Ca XIX and Fe XXV ions → many hundreds identified (not in the present analysis project)
- Obsevations cover 26 observing days of SMM operation (X-ray activity levels from A5.0 ÷ X3.0

The stack of **channel #1** FCS spectra processed: 395

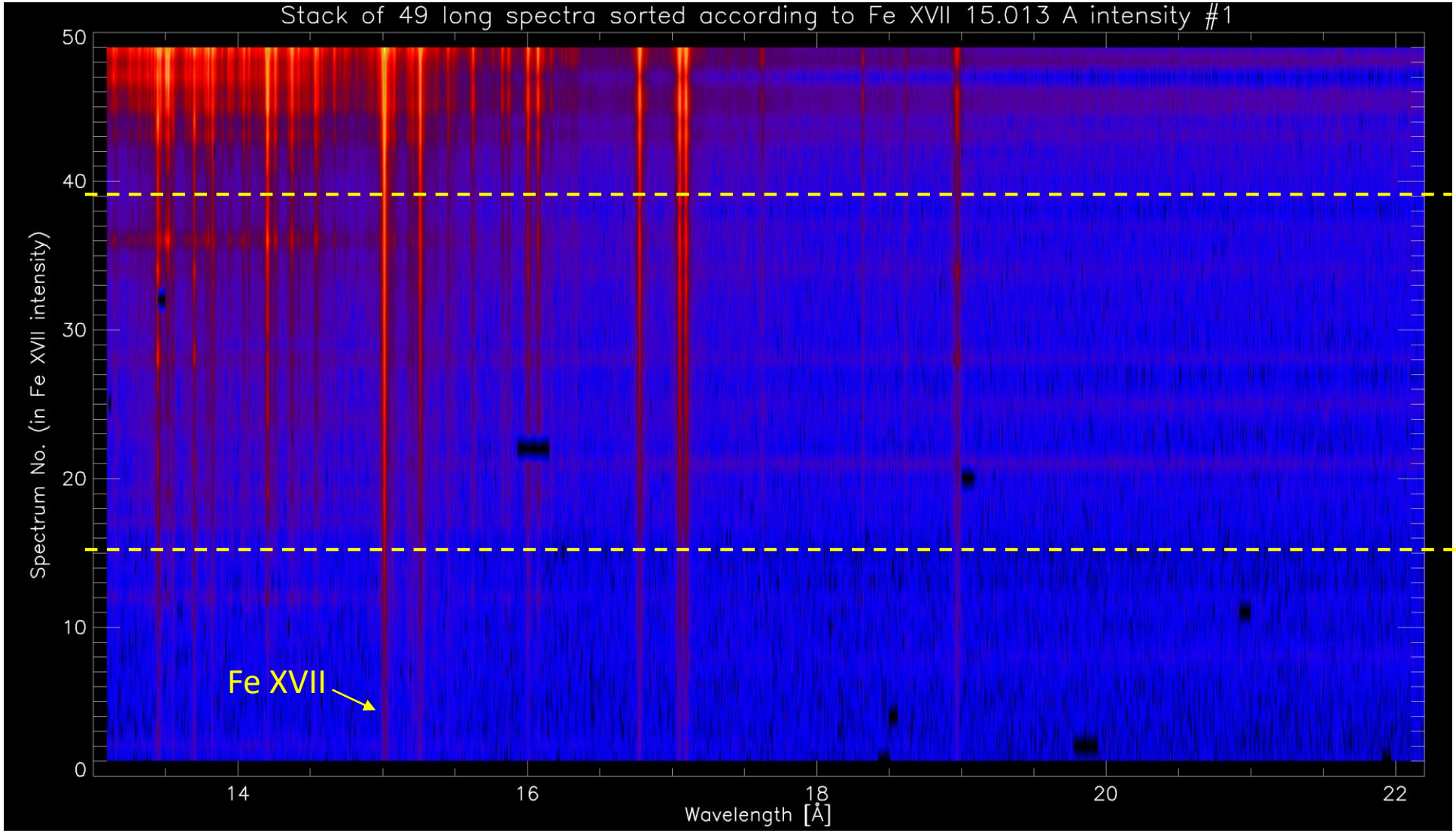


Long scans:49
(13.2 - 22 Å)

Average of 49 full long FCS #1 scans – for identification purposes



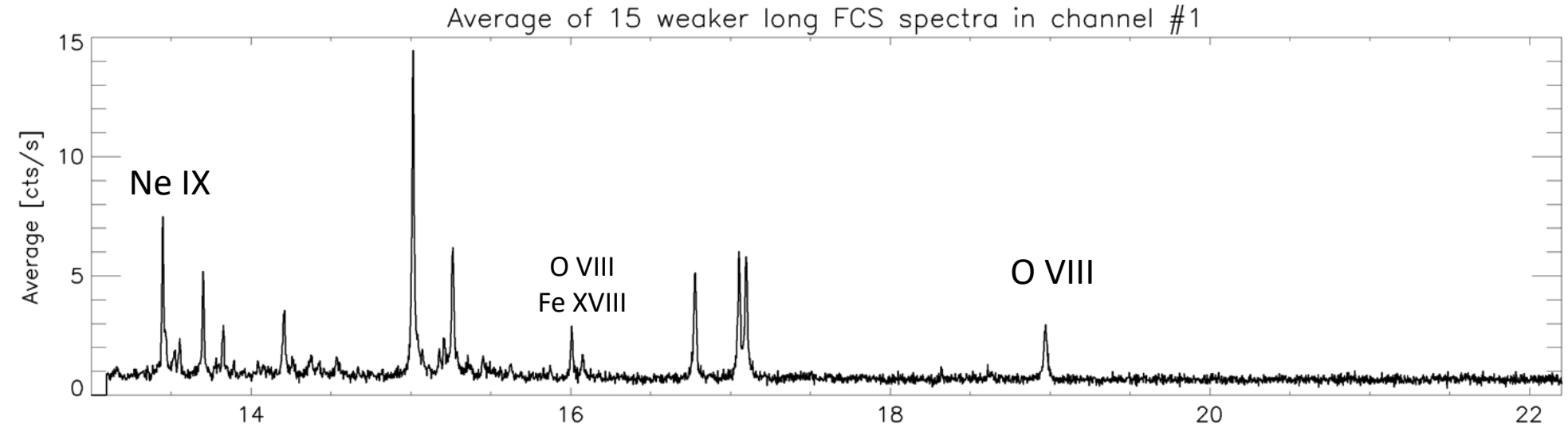
The stack of 49 long spectra sorted according to the strongest line intensity (Fe XVII at 15.01 Å)

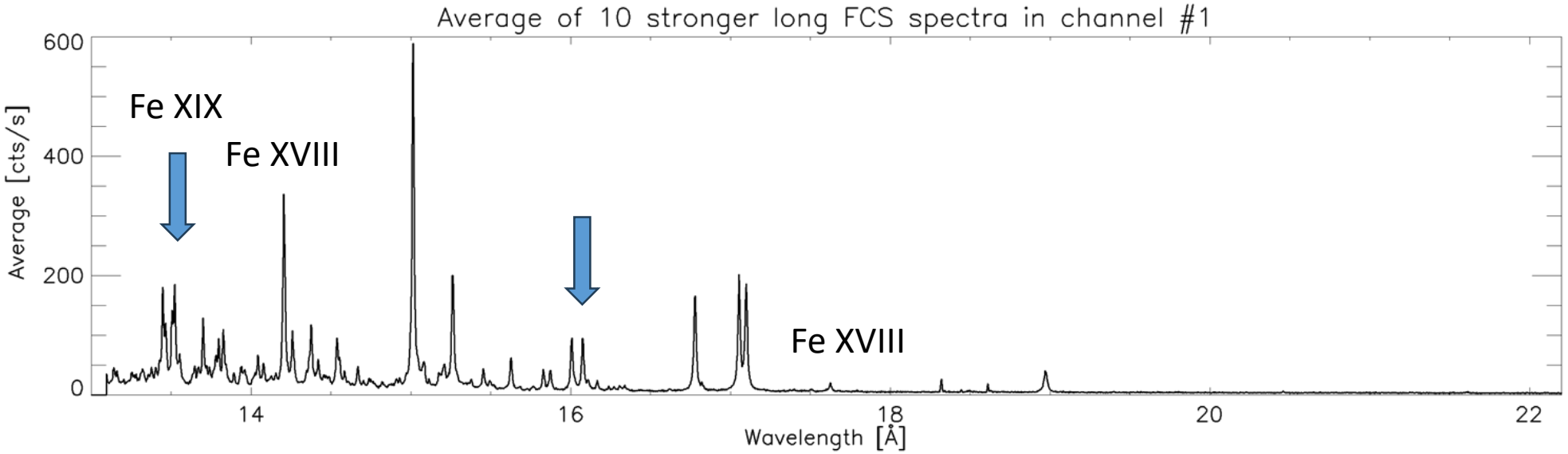


10 stronger spectra

15 weaker spectra

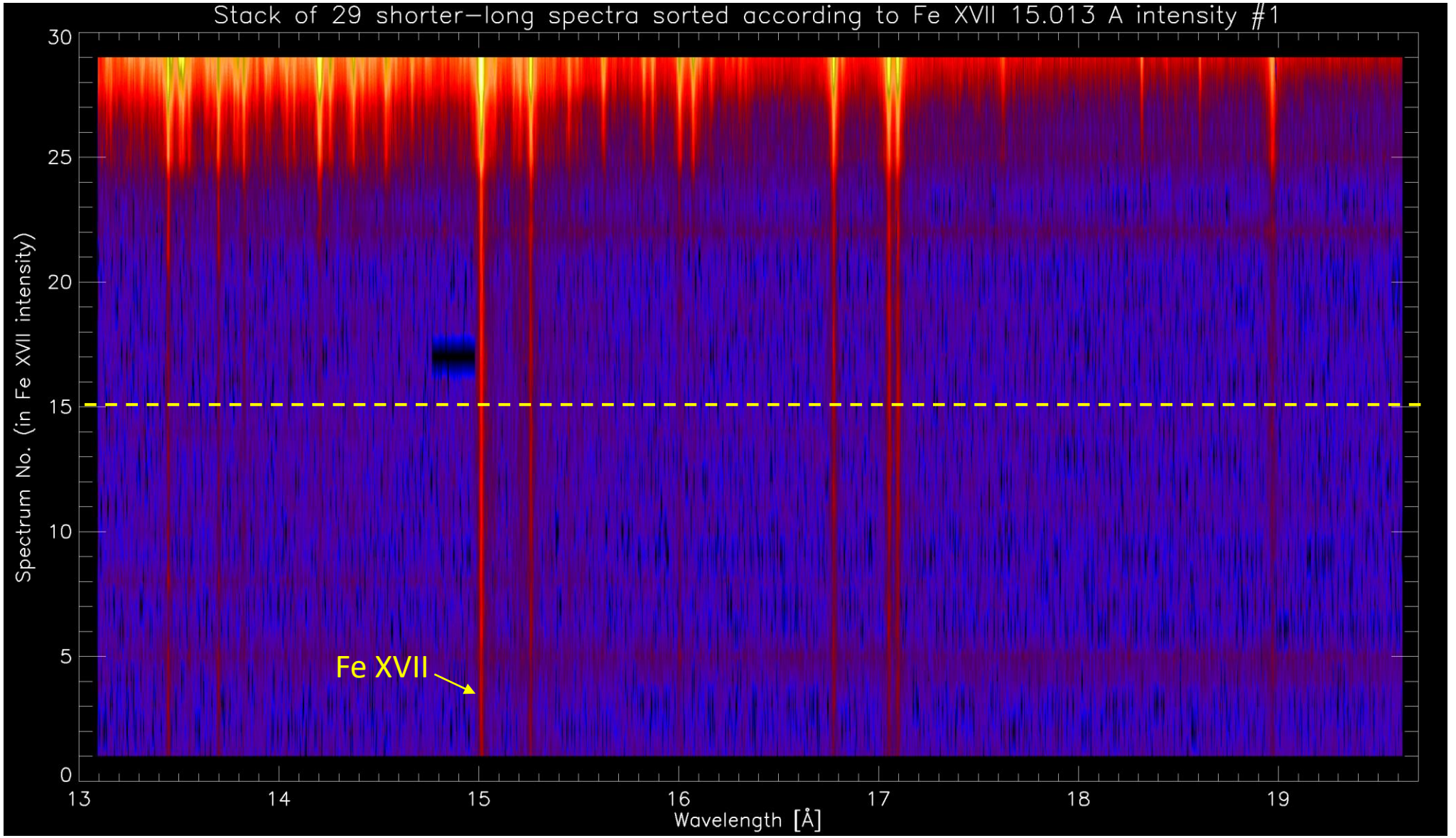
Average of **15 weaker** and **10 stronger**-long FCS #1 spectra



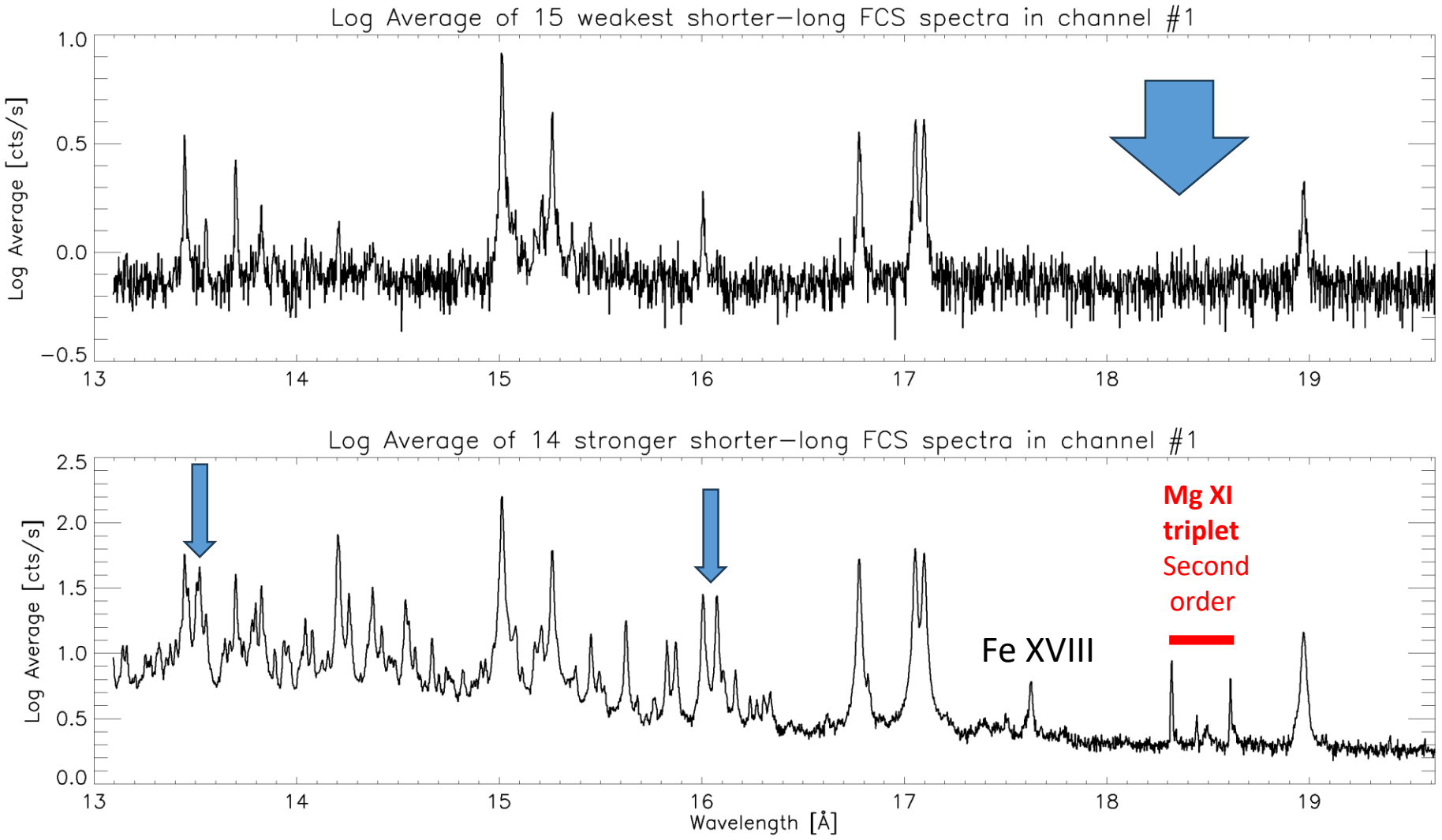


Different proportions of some lines

The stack of 29 shorter-long spectra sorted according to Fe XVII line intensity



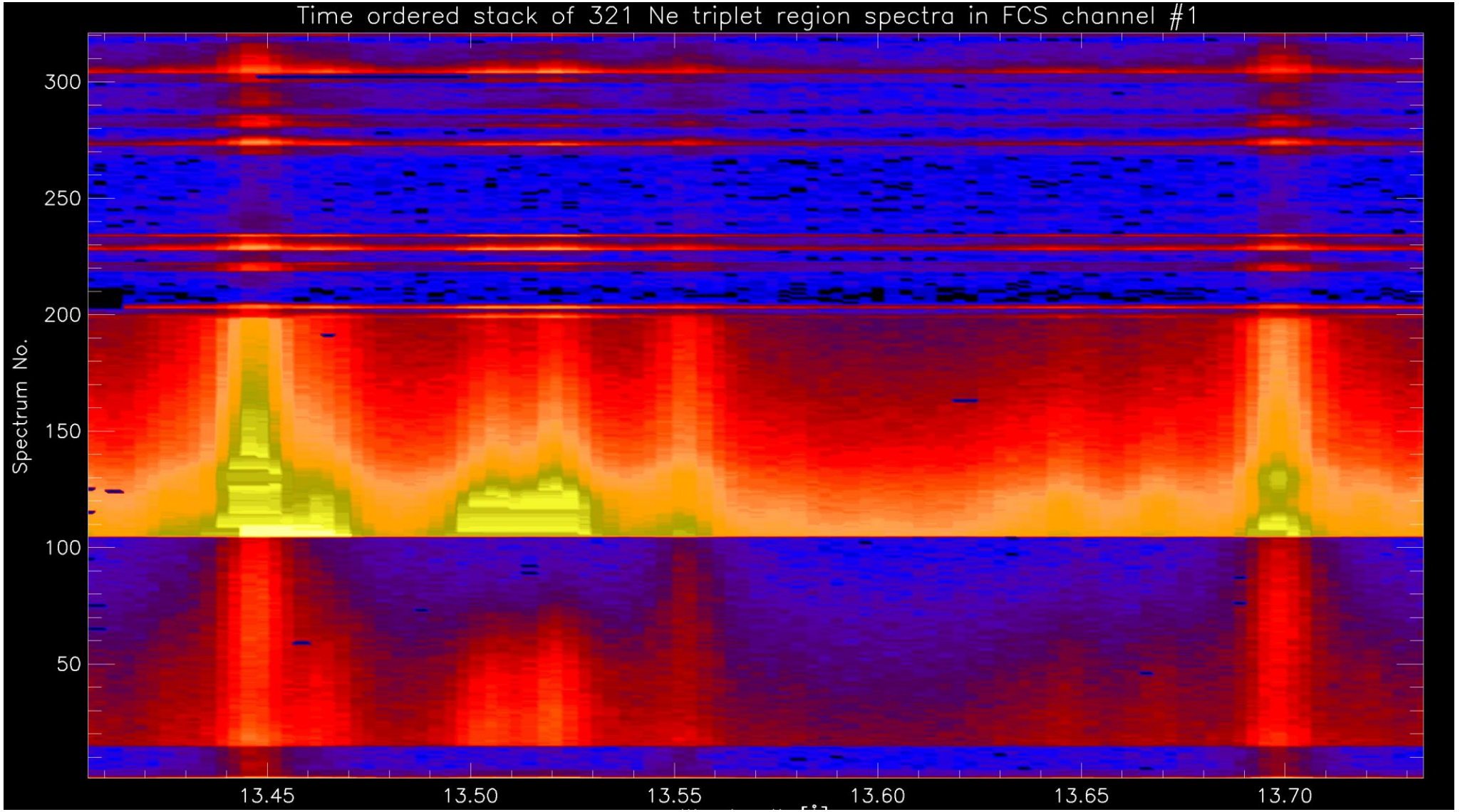
Averages of **15 weaker** & **14 stronger** „shorter-long" spectra



B-class X-ray activity level

M & X-class activity levels

The stack of time ordered 321 Ne IX spectra

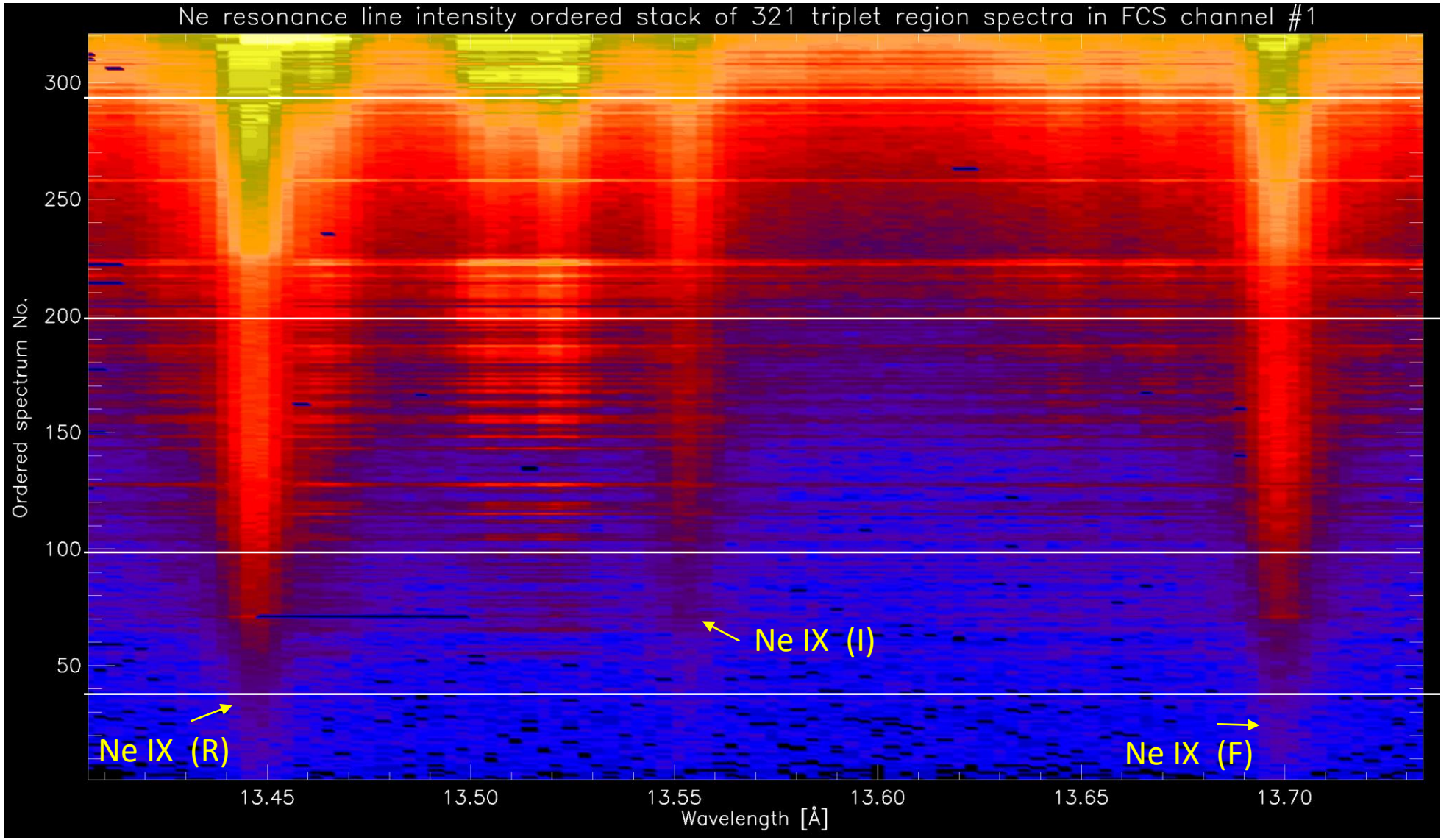


X class

16 saturated

M class

The stack of 321 Ne IX triplet region spectra (long&short scans) sorted according to R line intensity



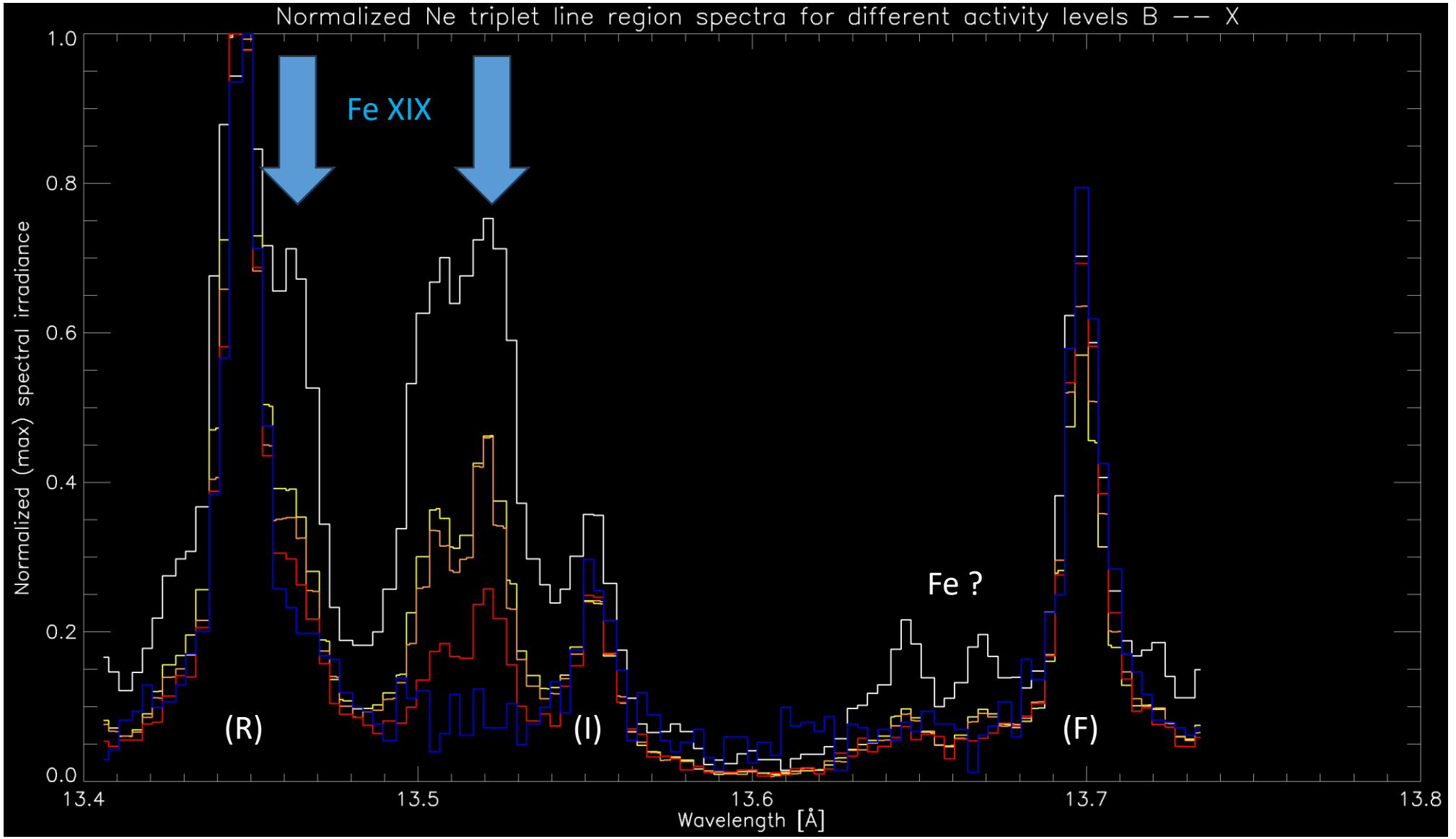
16 saturated spectra

X class

5 levels of activity

B class

Normalised Ne IX triplet line spectral region at different X-ray activity levels



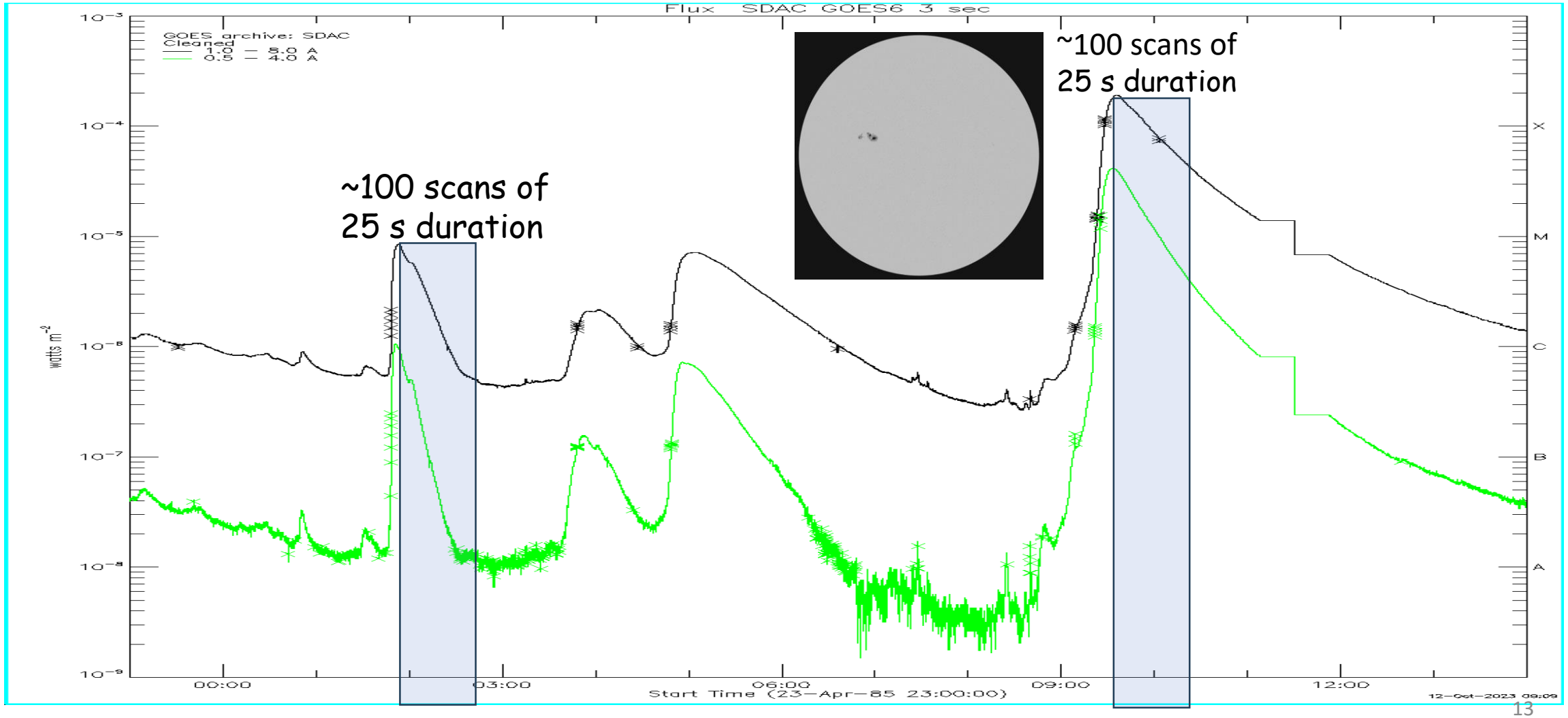
The level of background has been subtracted and the normalisation to the maximum of resonance line has been made.

From the most intense:

White ~X class
Yellow
Orange
Red
Blue ~ B class

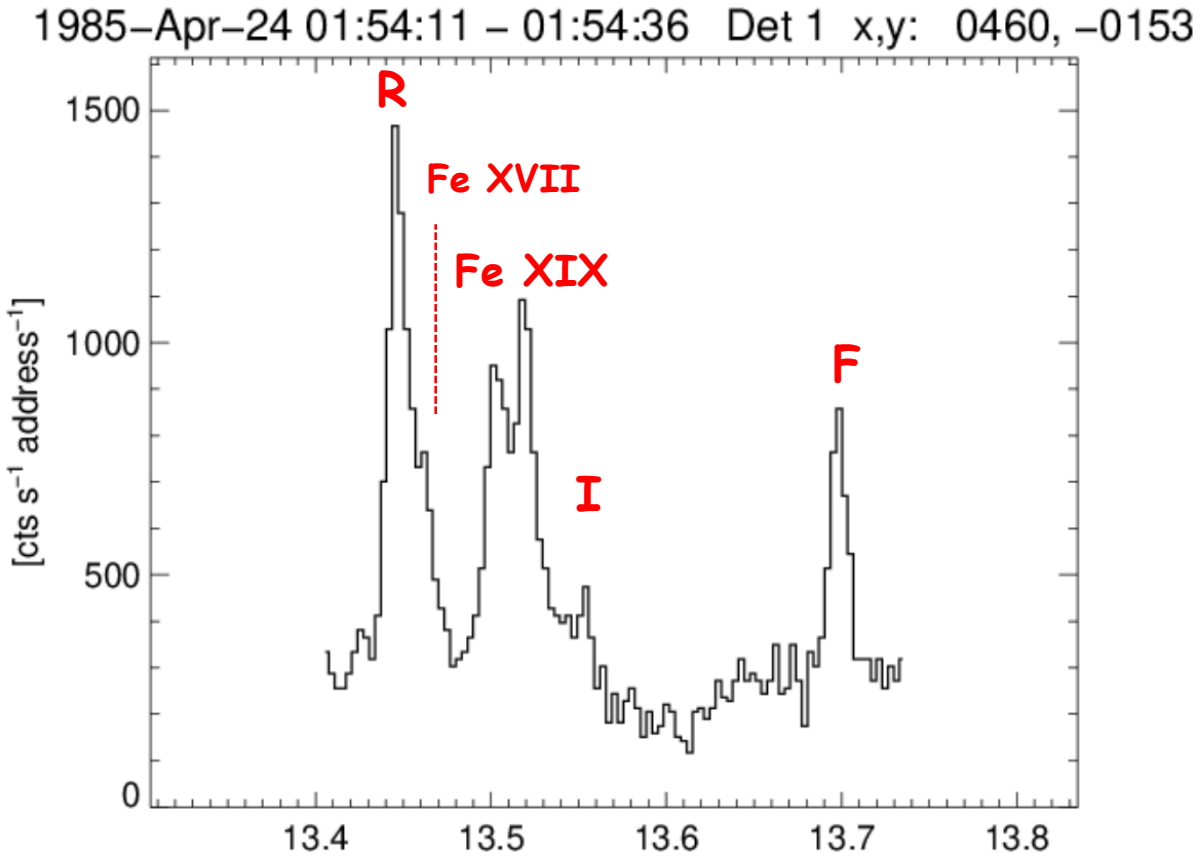
24 Apr. 1985 flares (M & X class) as recorded by GOES

Full-disk white-light from Debrecen Observatory

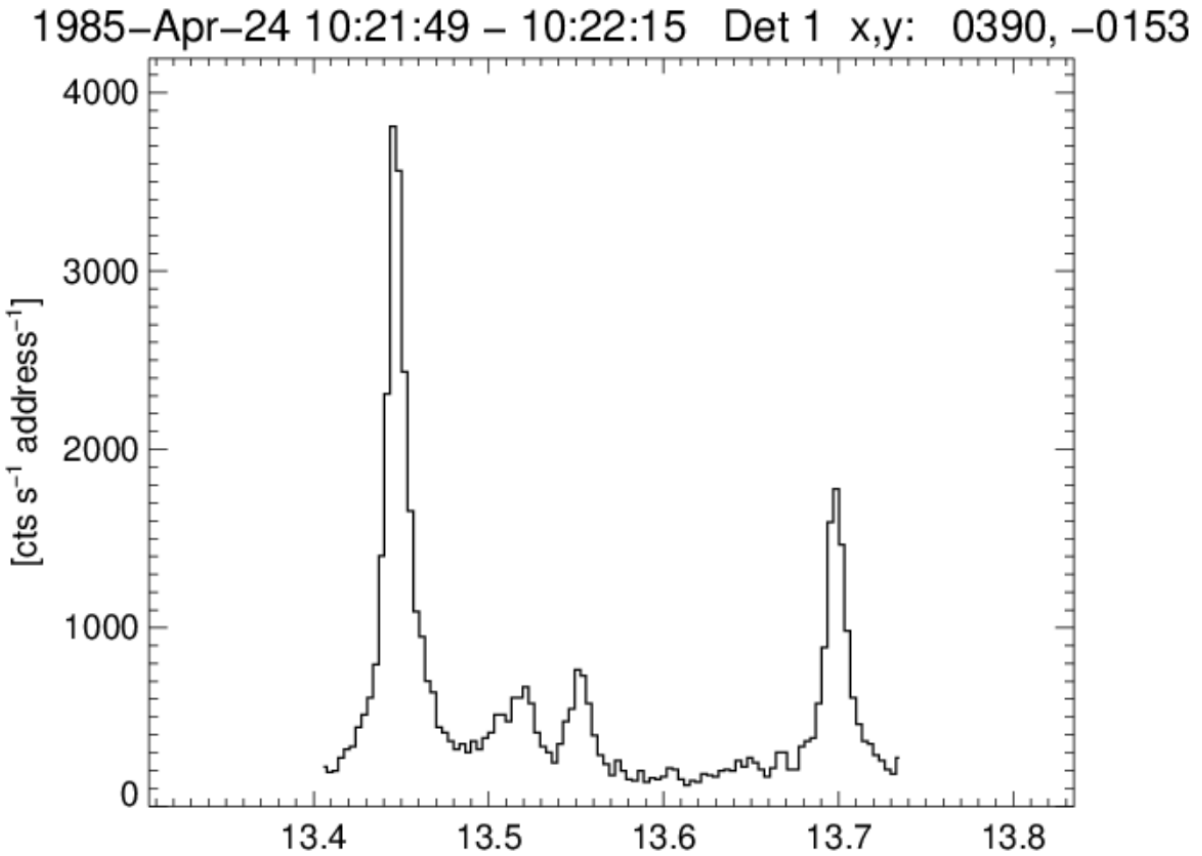


Individual Ne IX triplet spectra observed on 24 Apr. 1985 for **M class** and **X class** flare during decays

M class

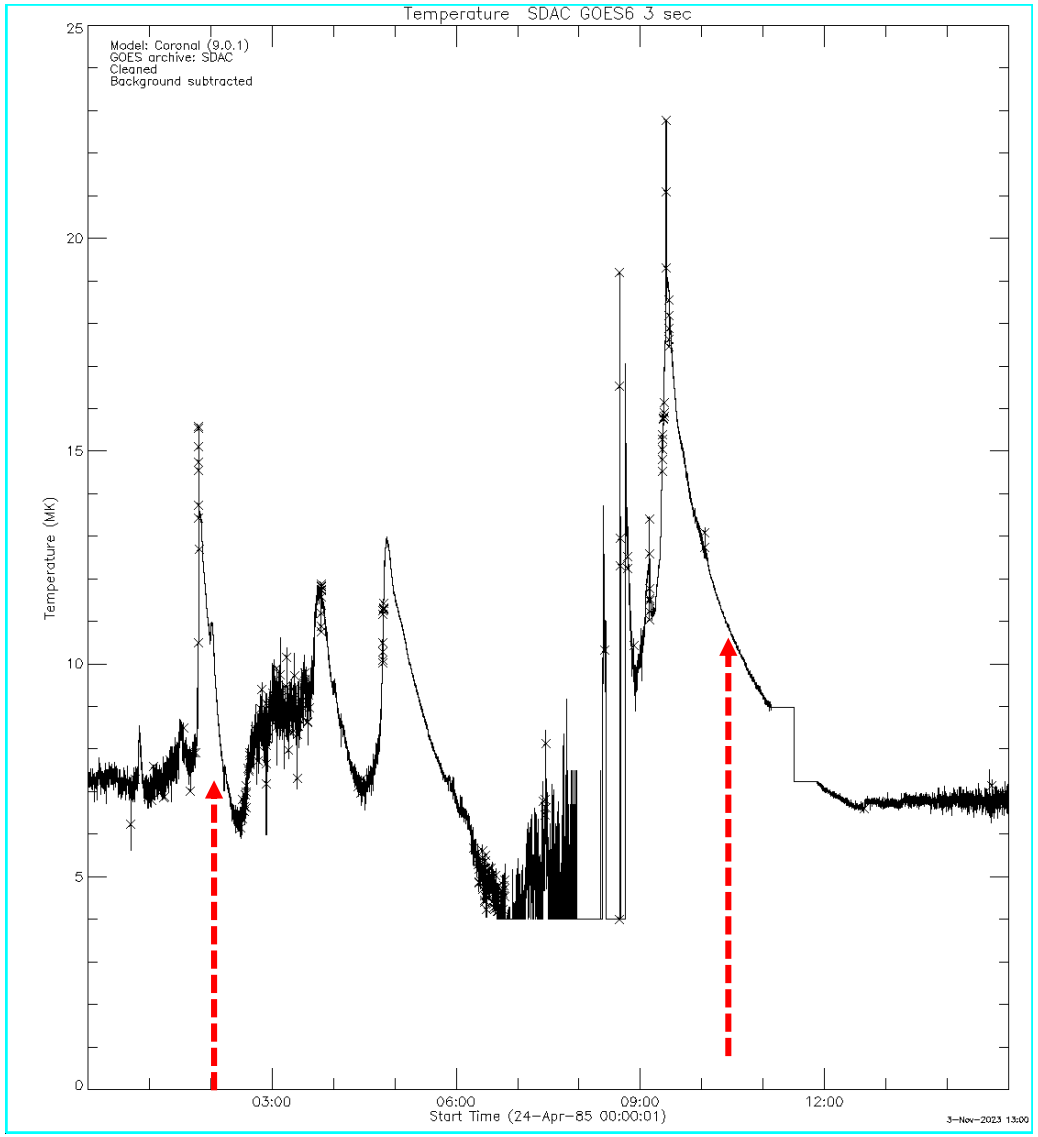


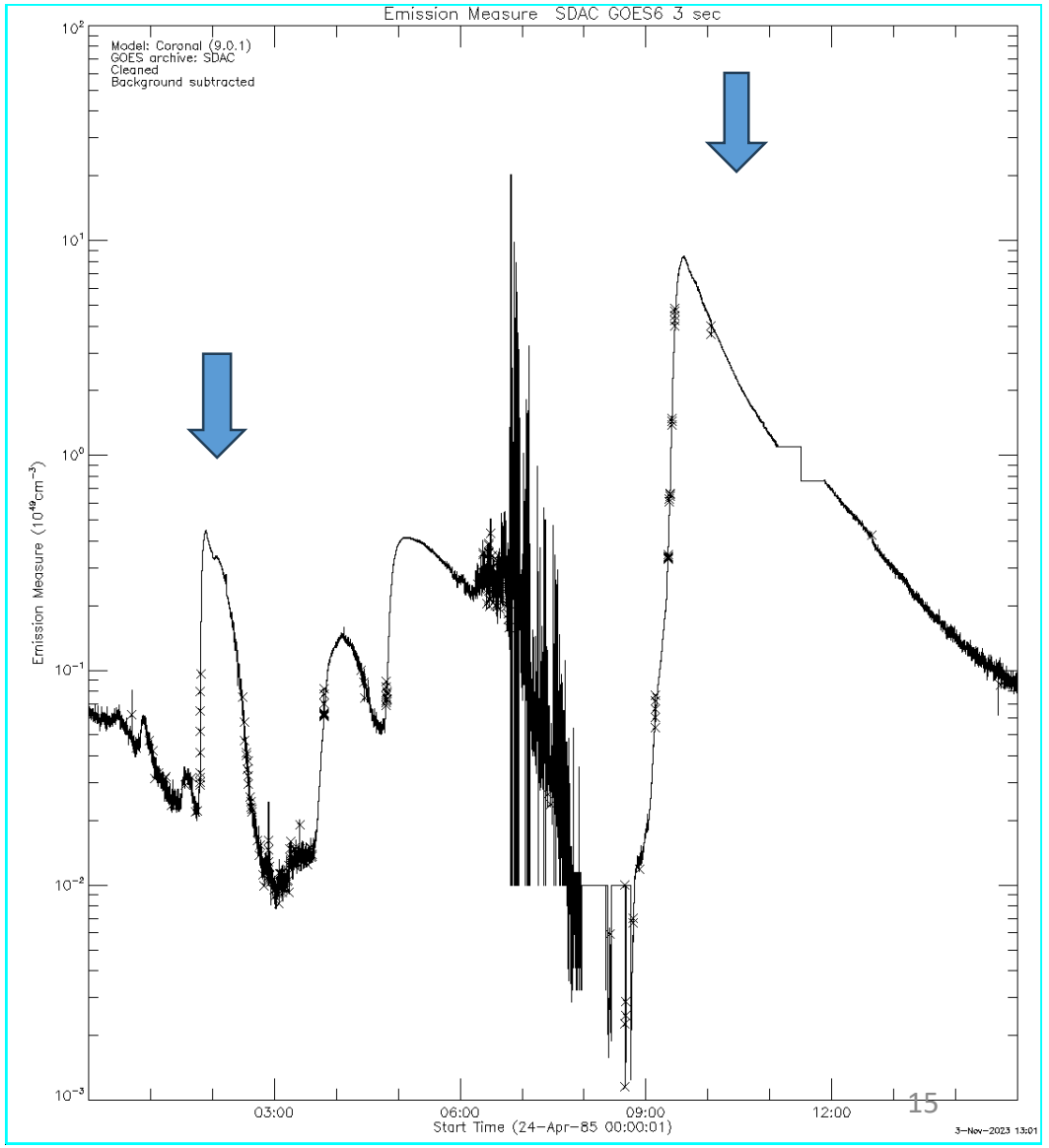
X class



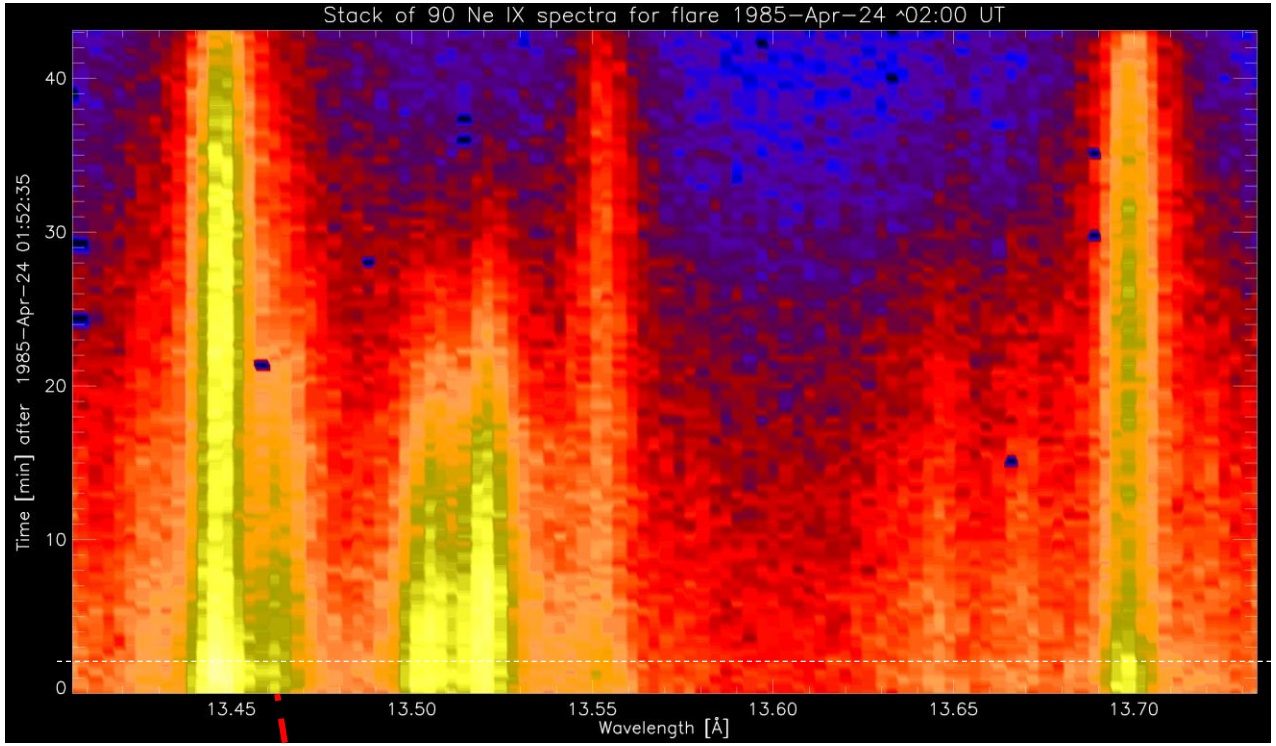
Corresponding physical parameters from GOES

Temperature & EM from GOES (SSW GOES)





M class: 1985-Apr-24 ~02:00 UT

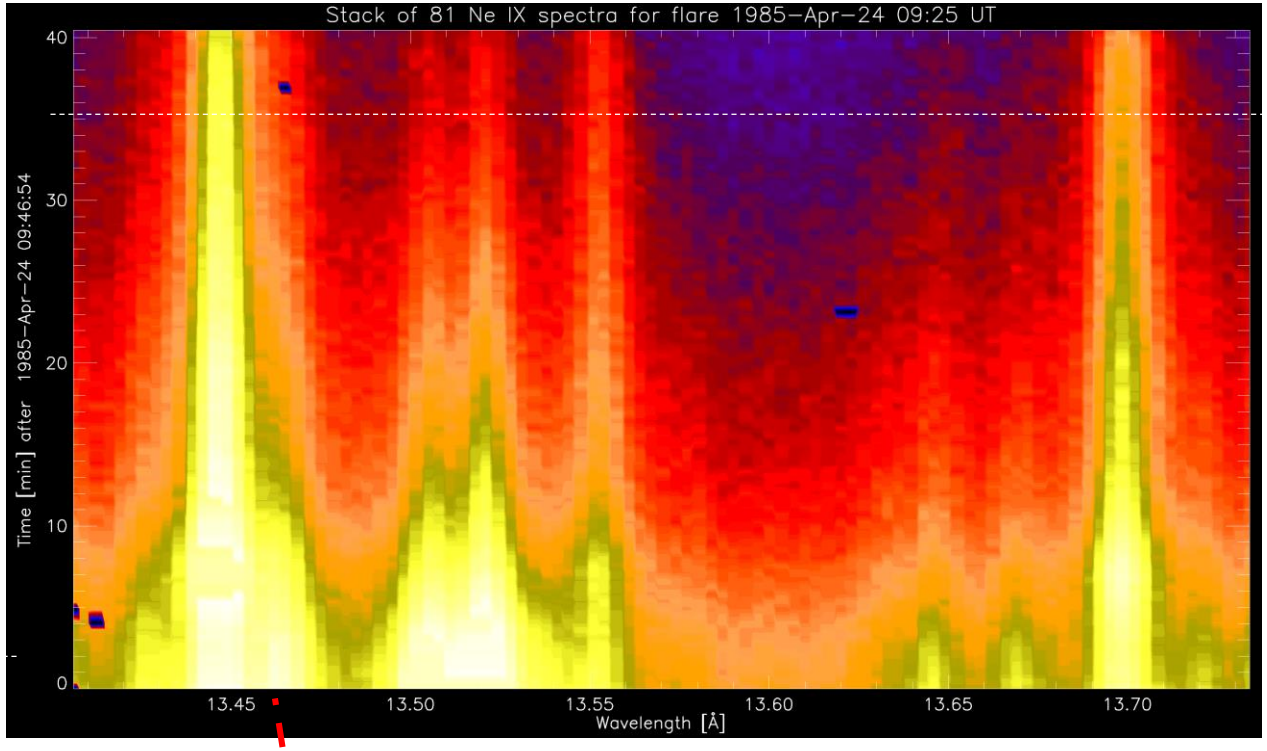


Fe XIX

R I F

Fe XVII

X class: 1985-Apr-24 ~09:25 UT



Fe XIX

R I F

Fe XVII

Wolfson et al., 1983; ApJ 269

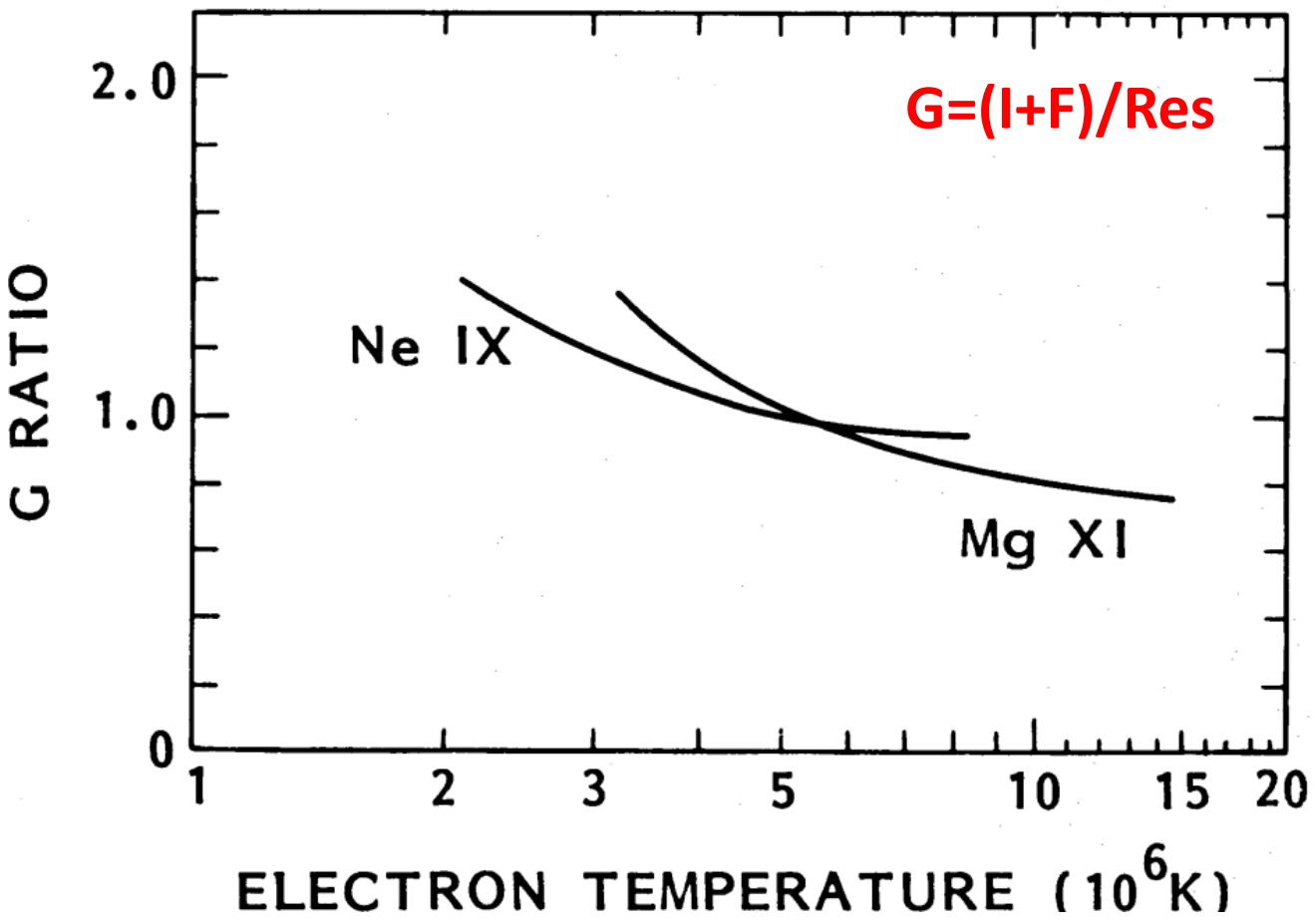


FIG. 4.—Calculated temperature dependence of the *G* ratio (the sum of the intercombination and forbidden line intensities to the resonance line intensity) for Ne IX and Mg XI.

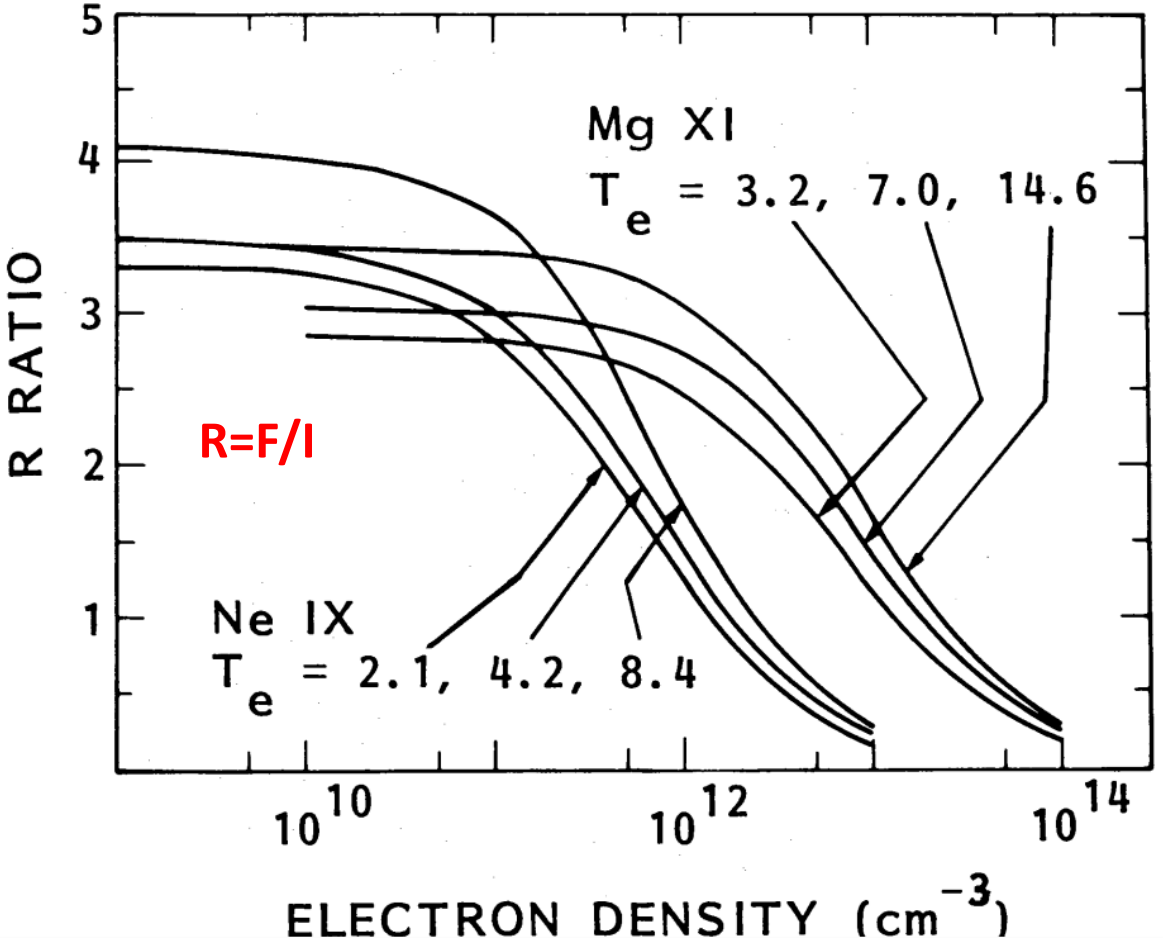
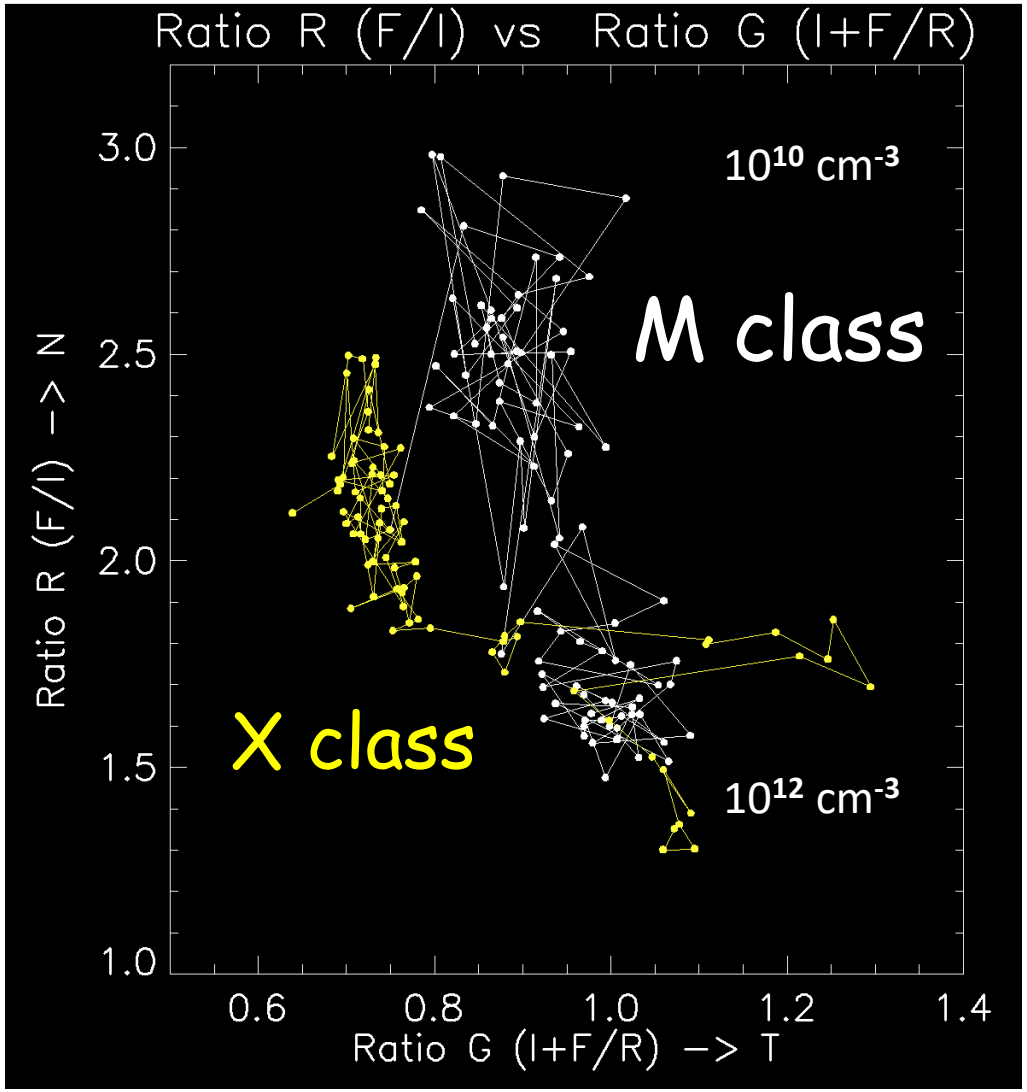


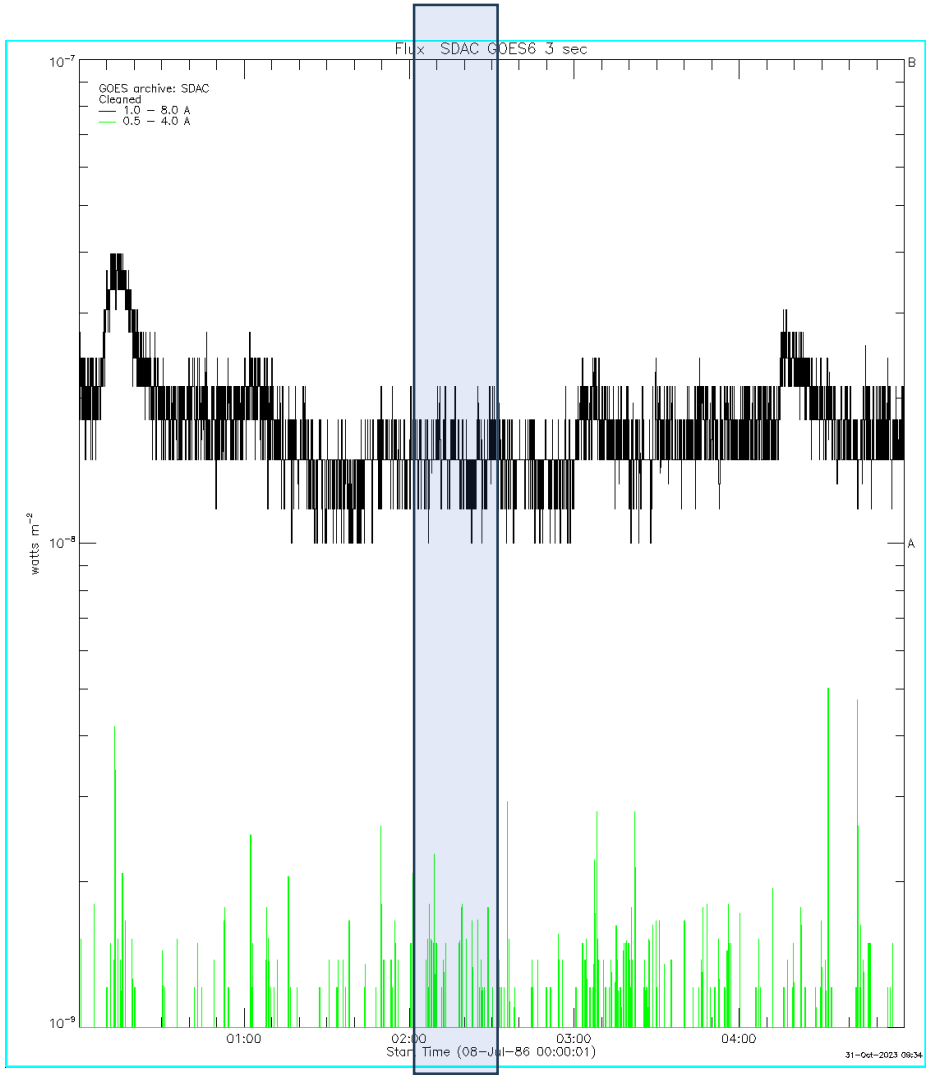
FIG. 3.—Calculated density dependence of the ratio of the forbidden to intercombination line intensities for Ne IX and Mg XI ions for the temperature (10^6 K) of maximum emissivity and for temperatures at which the emissivity is 20% of maximum.

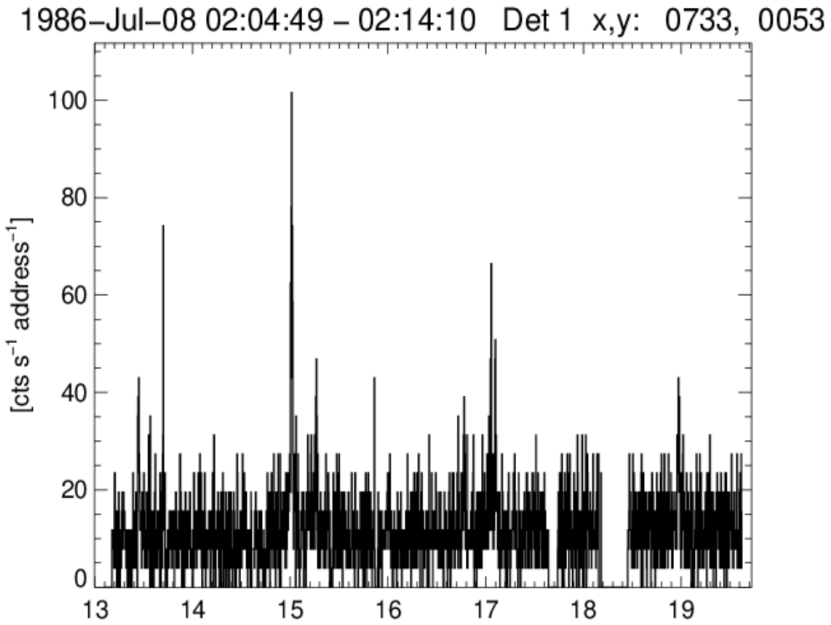
G= (I+F)/Res vs R = F/I ratio

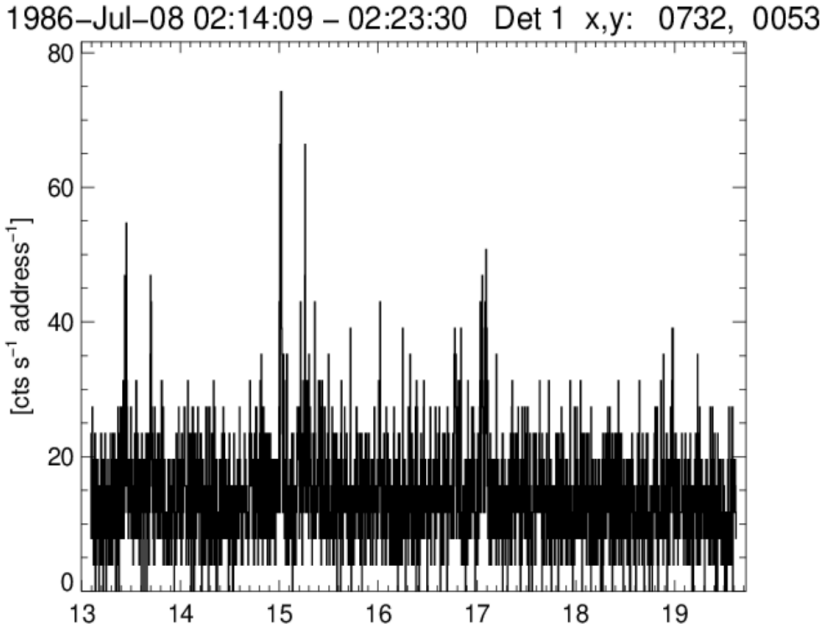


1. Calculate the temprature dependence of G and R ratios for Ne IX based on new atomic data
2. Follow the metodology from Wolfson's paper → determine density spectroscopically
3. Based on emission measure from GOES data and density one can determine actual volume of hot flaring plasma
4. Estimations made based on Woflson et al. calculations lead to the very small volumes……~10^{26} cm^3
   If the emitting source was the sphere its equivalent radius would be ~3000 km only !!!!
   ~4 arcsec size from 1 a.u.

The lowest inspected activity level (**A1.5**)







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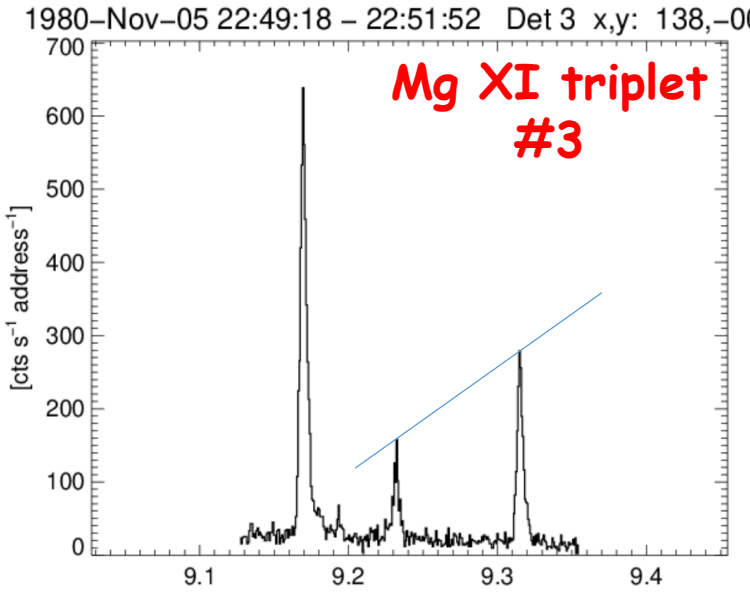
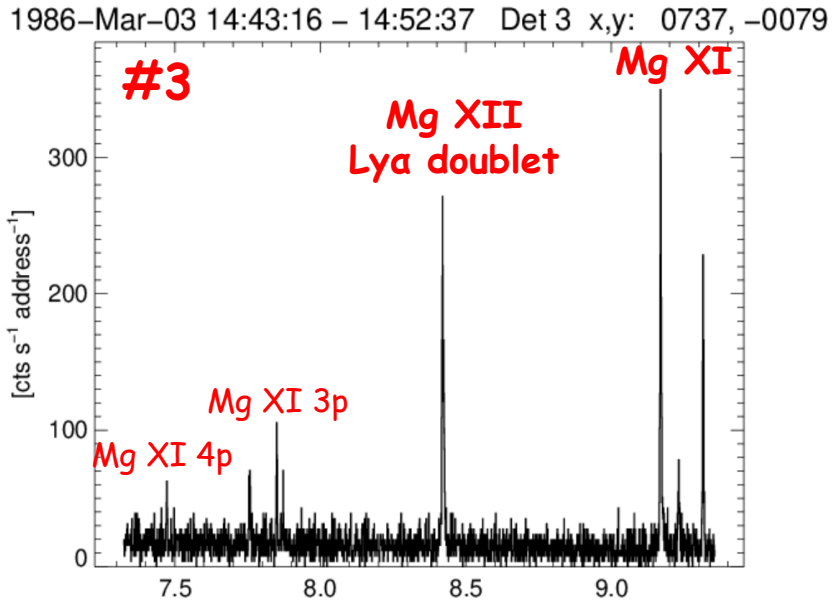
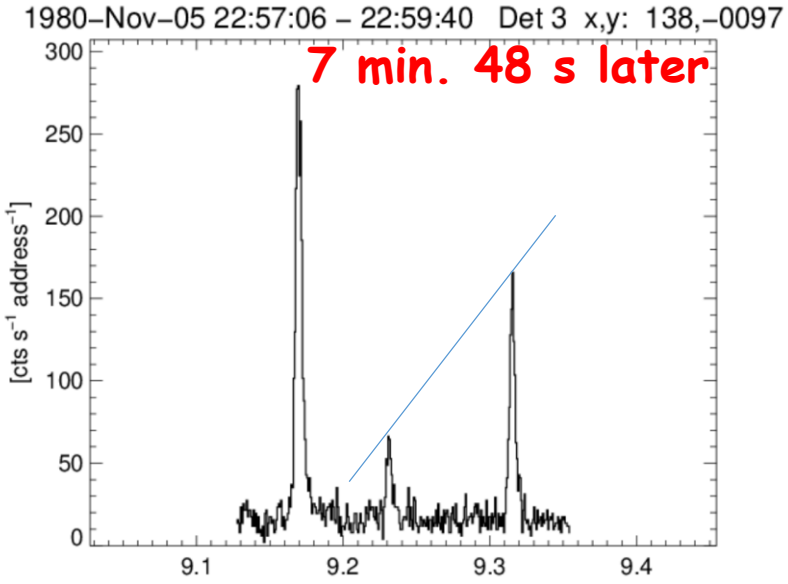
Individual example spectra from **#3 FCS** (ADP crystal)





Mg XII Lya doublet:
8.419 Å & 8.424 Å

#3 Mg XII ~9.3 min.



Mg XI triplet:
R → 9.169 Å
I → 9.232 Å
F → 9.314 Å

#3 Mg XI ~2.5 min.

Concluding remarks

- We inspected 1011 archived data files and identified several hundred spectral scans (so-called SS mode) covering selected portions of spectra in the range 1.4 – 22.5 Å. As the spectral scans were accumulated over time, for the long scans the plasma conditions in the source (AR or flares) often changed substantially.

- For some quiescent periods the conditions of activity are low and stable allowing the parameters of plasma to be determined based on these spectra.

- Most (99.5%) of the spectra we inspected from the FCS archive have not previously been analyzed in detail. The spectra are of unrivalled quality and will allow for possible new spectral line identifications as well as studies of flare and AR plasma thermodynamic properties (density!!).

- We presented examples of some notable spectra that we found and showed their usefulness for the analysis of present and future solar and stellar X-ray spectra.

- Work is still in progress and we are in the process of listing all these many scans.

THANK YOU