RESIK soft X-ray spectra - status of database

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RESIK

The instrument called RESIK (**Re**ntgenovskij **S**pectrometer s **I**zognutymi **K**ristalami) consists of two double detector (*Yohkoh* spare BCS) four crystal X-ray spectrometer obtaining spectra in bands:

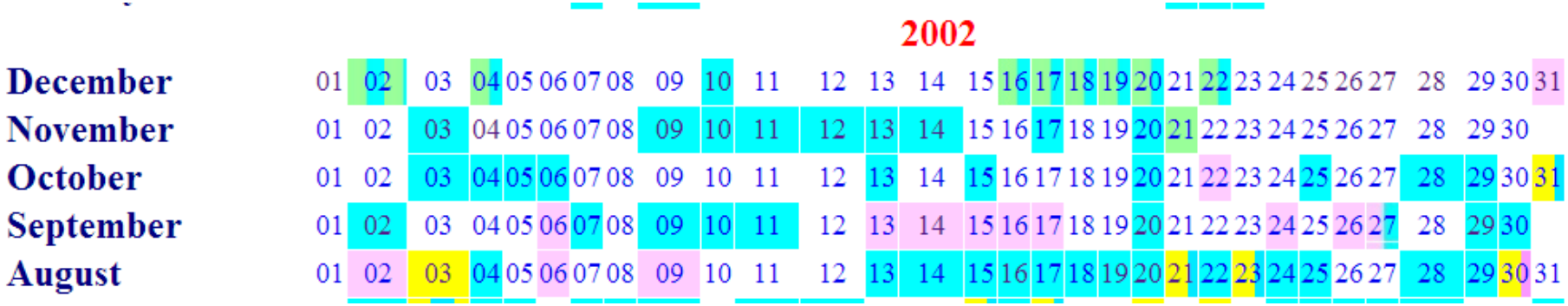
#1: 3.37 - 3.88 Å
#2: 3.82 - 4.33 Å
#3: 4.31 - 4.89 Å
#4: 4.96 - 6.09 Å

RESIK was the last solar soft-X-ray Bragg spectrometer flown (in 2001). RESIK observed numerous flares as well as active region emissions. During flares, the spectra collection times could be as short as 2 s. In non-flaring periods DGI was 5 min. By now the observations for **45 flares** have been reduced to so-called level 2 (science grade absolute fluxes). The publicly available database includes ~5500 spectra.
http://www.cbk.pan.wroc.pl/experiments/resik/RESIK_Level2/index.html
Many measurements were taken during the flares' rise phase. As will be shown later, for some events peculiar line intensity ratios are seen, reflecting presence of non-"standard" conditions in flaring plasma. For some lines, observed intensity ratios cannot be explained even in the multi-temperature approach.

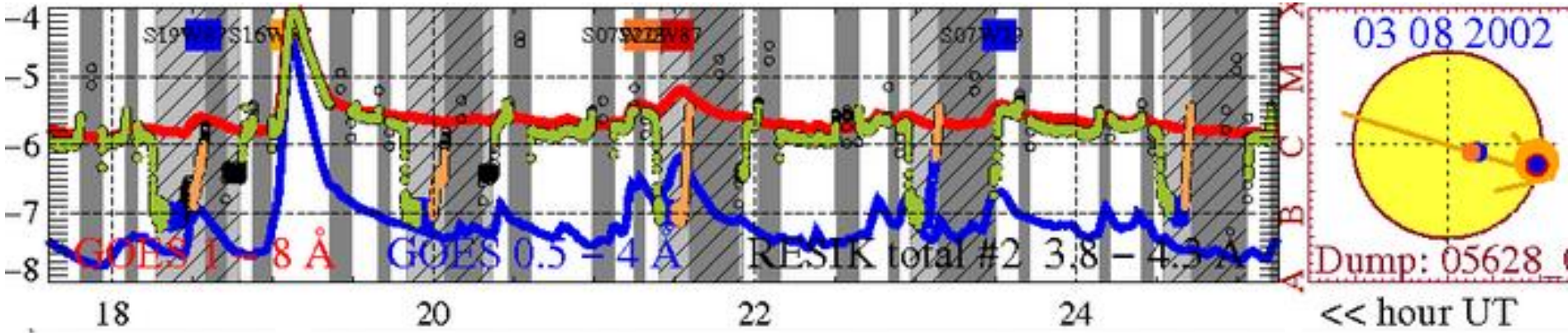
RESIK catalogue

http://www.cbk.pan.wroc.pl/resik_catalogue.htm

How to start working with data



The first panel of one orbit



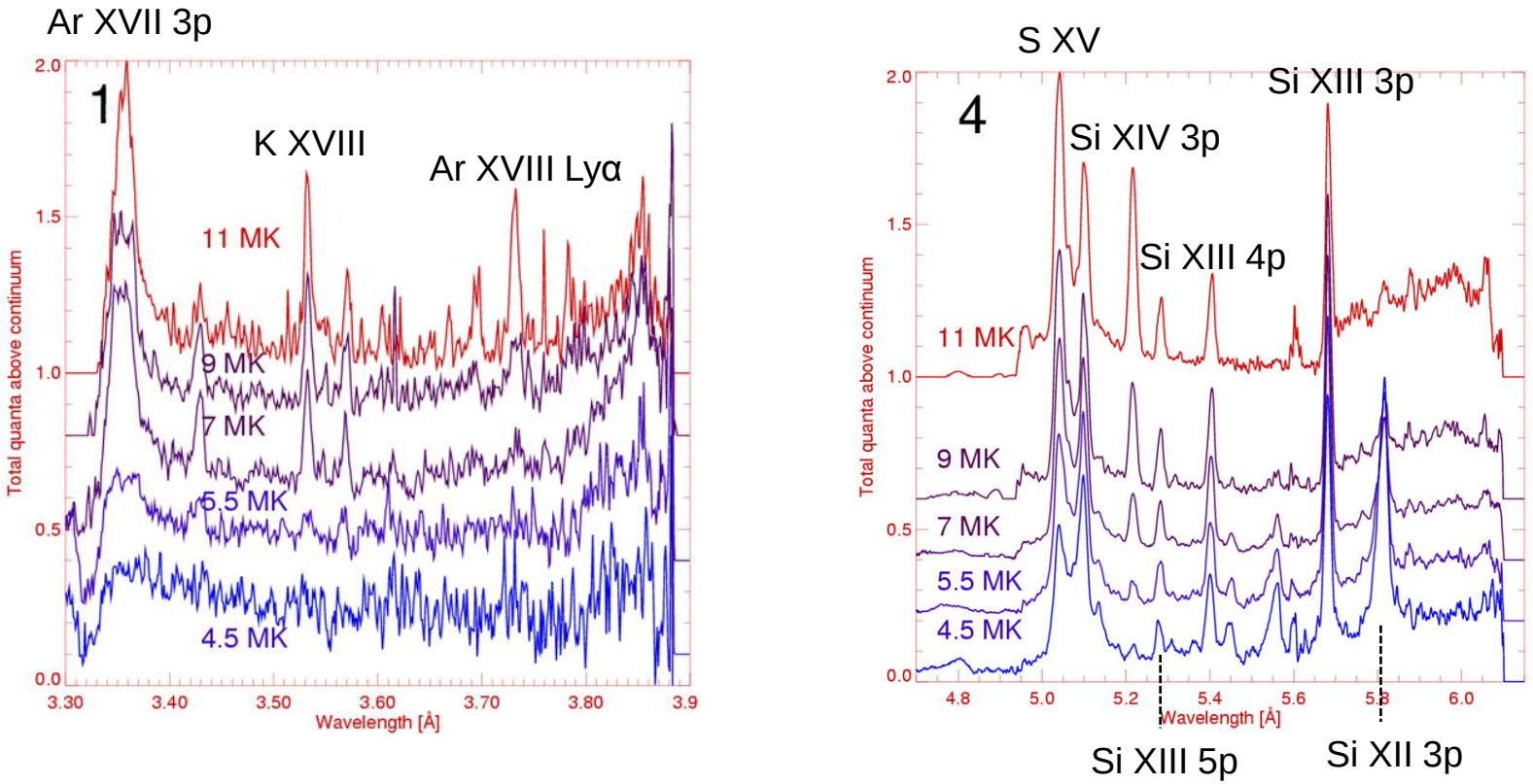
RESIK Level_2 spectra- science grade

http://www.cbk.pan.wroc.pl/experiments/resik/RESIK_Level2/index.html

Date	GOES class	Location
Quiet (312 individual spectra)		
26 December 2002 (max ~ 03:52 UT)	B6.0	S30W91
27 December 2002 (max ~ 21:58 UT)	B6.3	N13E01
11 March 2003 (max ~ 05:50 UT) *	B7.3	N16W28
25 December 2002 (max ~ 23:10 UT)	B8.0	S15W91
22 February 2003 (max ~ 04:50 UT) *	B9.6	N16W02
29 December 2002 (max ~ 02:05 UT)	B9.9	S30W91

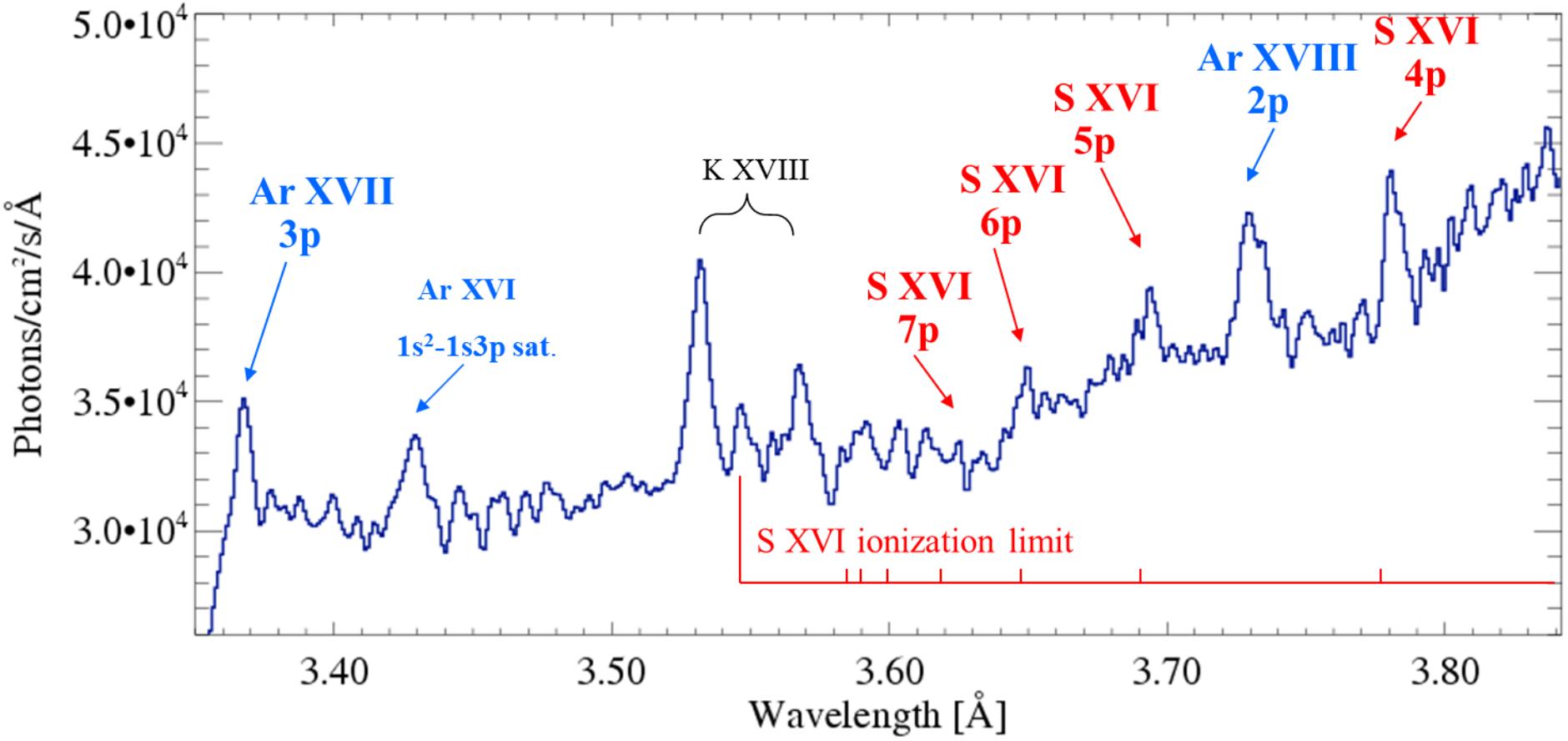
Date	GOES class	Location
17 March 2003 (max ~ 19:05 UT)	X1.5	S14W38
3 August 2002 (max ~ 19:07 UT)	X1.0	S16W87
7 January 2003 (max ~ 23:30 UT)	M4.9	S11E89
04 October 2002 (max ~ 05:38 UT)	M4.0	S19W09
10 September 2002 (max ~ 14:56 UT)	M2.9	S10E43

Temperature grouped #1 and #4 spectra



RESIK spectra collected between 1 January and 14 March 2003. During this period 1163 spectra have been measured. The collected set of spectra covers as well very low activity level (~B4) as few M class flares. No single X class flare occurred during selected period. (Sylwester, B. et al., Adv. Space Res., 38, 1534, 2006)

Average channel 1 spectrum for 14 flares (2003, Δt≈9h)

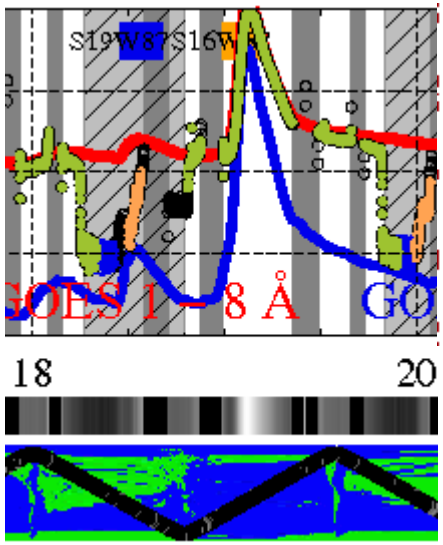


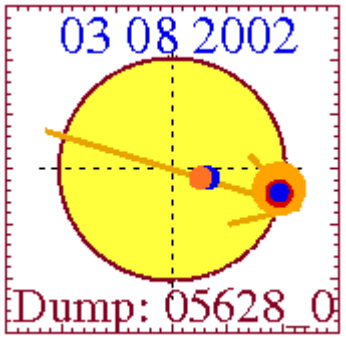
RESIK range (3.37 Å to 6.09 Å) includes many strong emission lines due to transitions $1s^2$- 1s(np) and 1s - np, in He-like and H-like ions respectively; the n = 2 and 3 lines are routinely observed for Si, S and Ar ions. For some flares we have observed enhanced emission in spectral features coinciding with these transitions for **n up to 9 or 10**. Respective observed line series decrements have been determined and discussed in the paper by Kepa et al., 2006 (Adv. Space Res., 38, 1538).

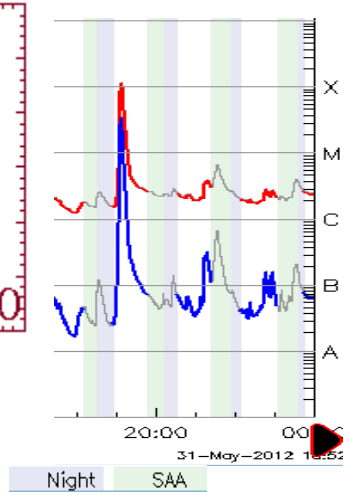
Conclusions based on early analysis of 14 flares

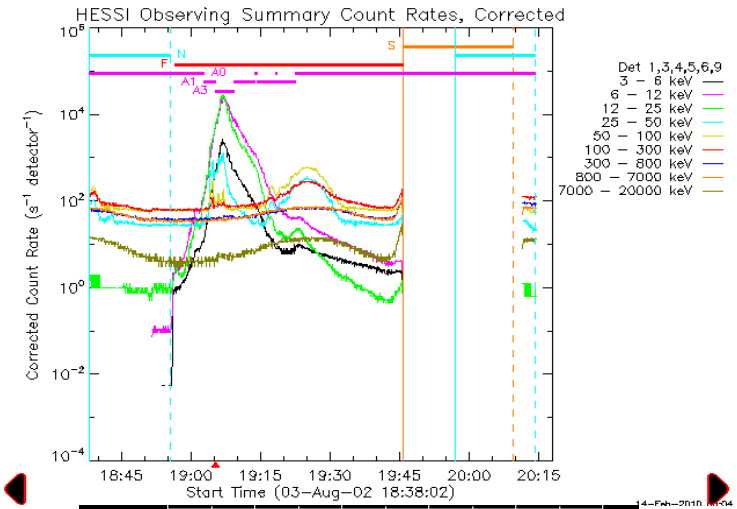
- The high **n** Rydberg series of H- and He-like ions of Si, S and Ar have been observed. Comparison of observed and theoretical intensity ratios showed that the observed higher-n line intensities are generally larger than theoretically expected under an isothermal, equilibrium plasma assumptions *for impulsive phase spectra*.
- Ratios of measured and expected values are systematically larger for H–like ions than for He–like ions.
- In order to explain the observed values of ratios unrealistically high values of plasma temperature need to be assumed.
- One of the possible explanation is that there are unresolved blends from yet unknown transitions which contribute to the derived intensities. Better spectral resolution may help verify this (ChemiX).

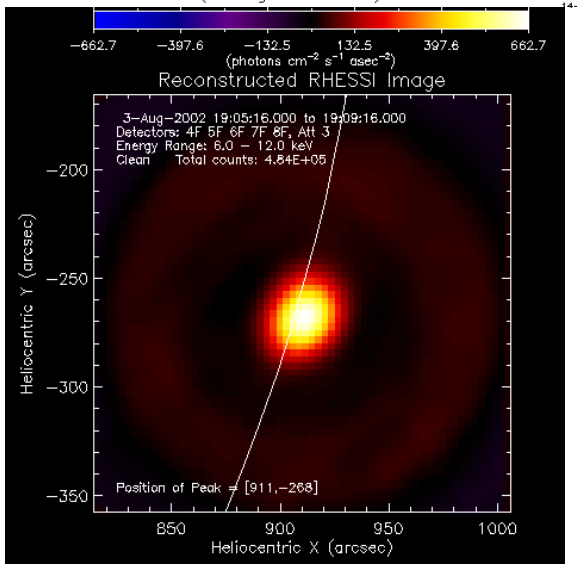
Level_2 data analyses
2002/08/03 **19:07:00 X1.0** S16W87











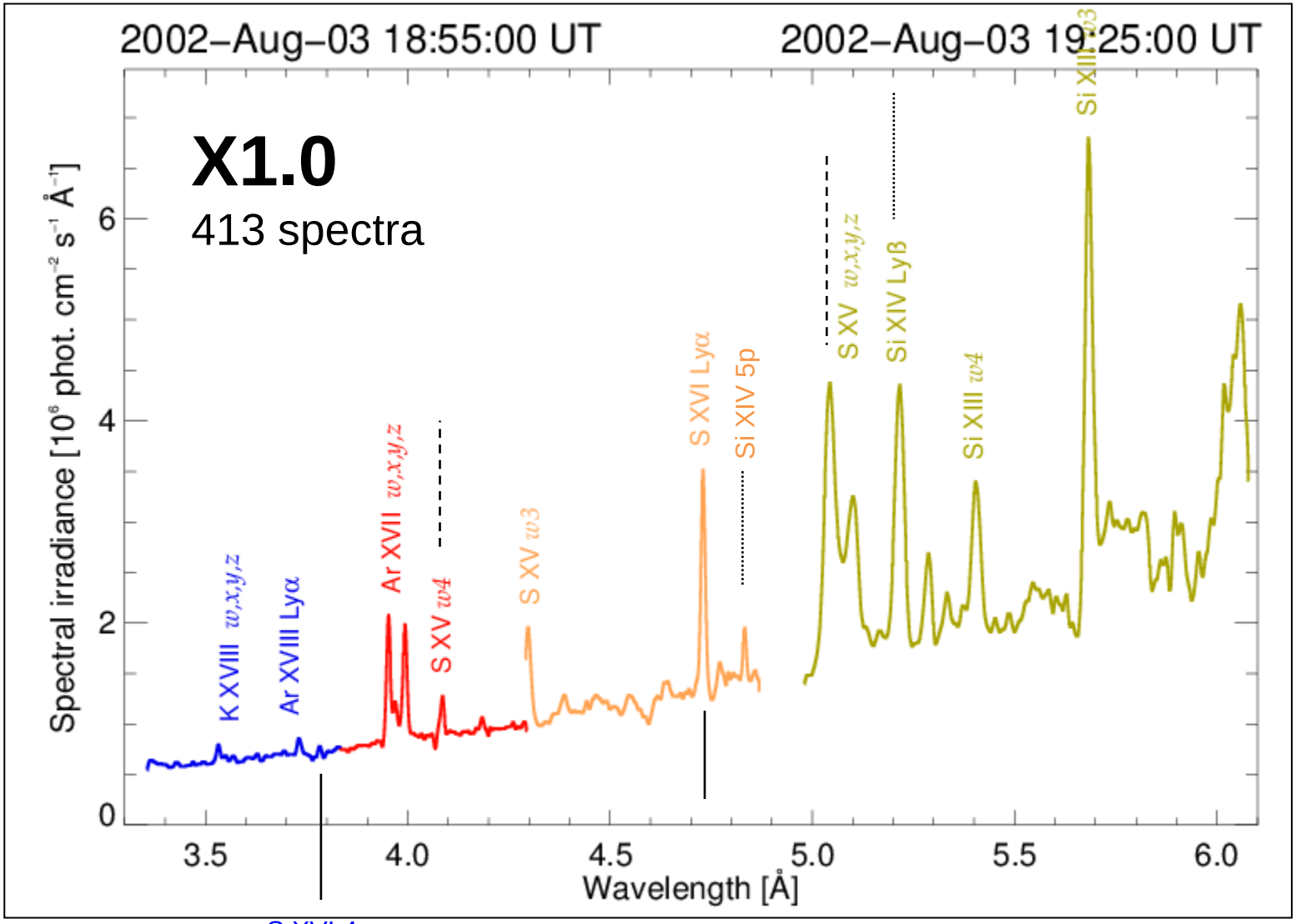
413 RESIK spectra available for this rapidly evolving event. Good coverage of all phases. Good *RHESSI* data showing the source at the limb. *RHESSI* spectra extend above 100 keV.

A good candidate for further collaborative study.

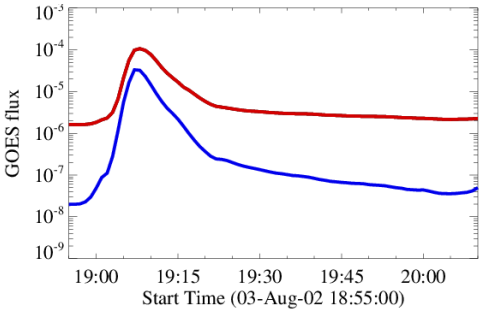
SOL2002-08-03T19:07

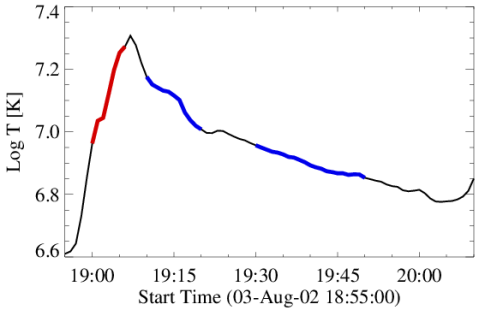
Channels 1, 2 and 4 with good PHA settings.

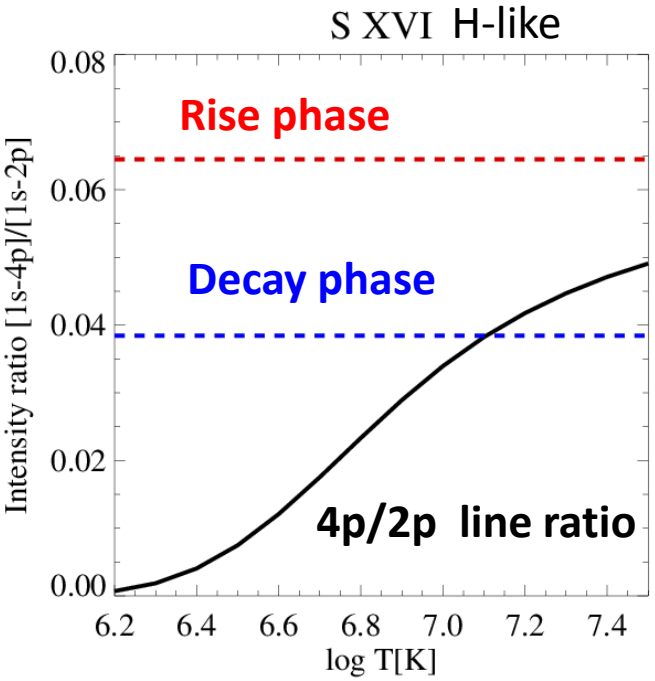
Channel 3: acceptable for higher count rates

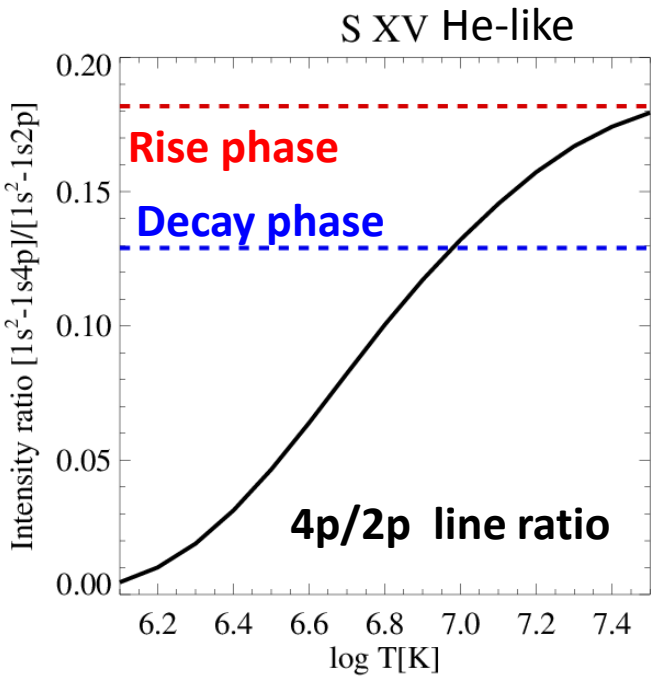


SOL2002-08-03T19:07 (sulfur lines)





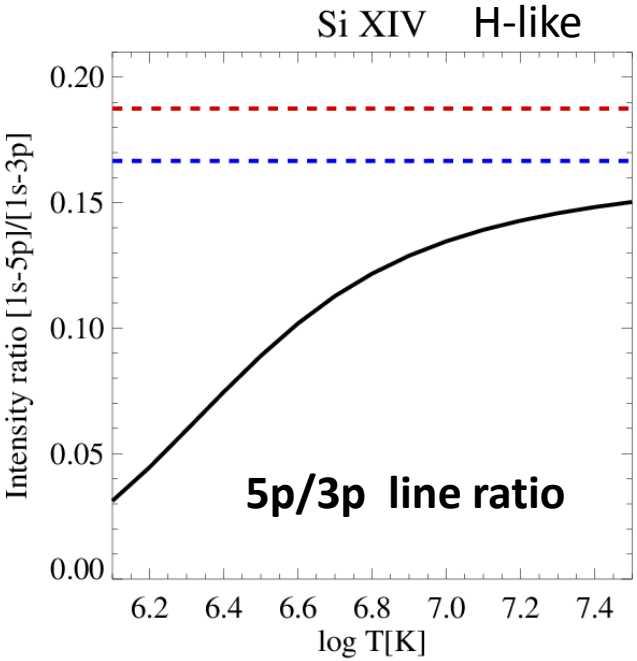




GOES fluxes and corresponding isothermal temperature (preflare levels subtracted).
Periods marked in **red** and **blue** on the temperature curve correspond to times observed with RESIK.

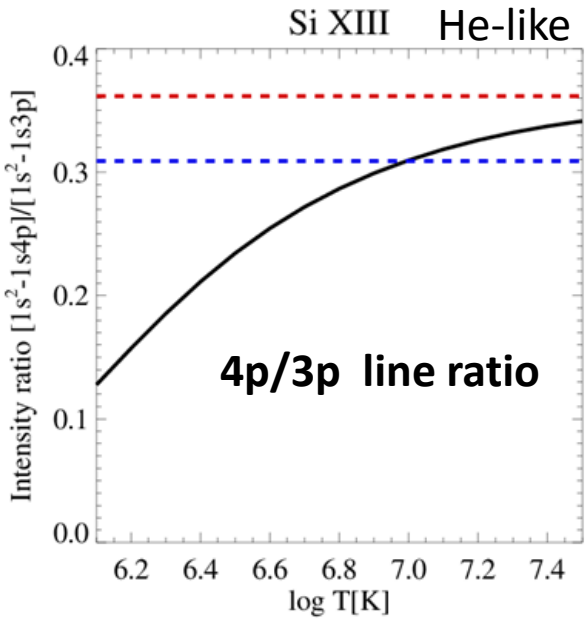
Theoretical intensity ratios have been calculated using CHIANTI 7.0 (**solid black**).
Dashed lines correspond to values of the ratios as obtained from averaged RESIK spectra: integrated (when available) during the rise phase (**red**) and during the decay (**blue**). Rise phase ratio above thermal interpretation - possible non-thermal contribution.
We will try to correlate behaviour of this ratio with hard X-rays.

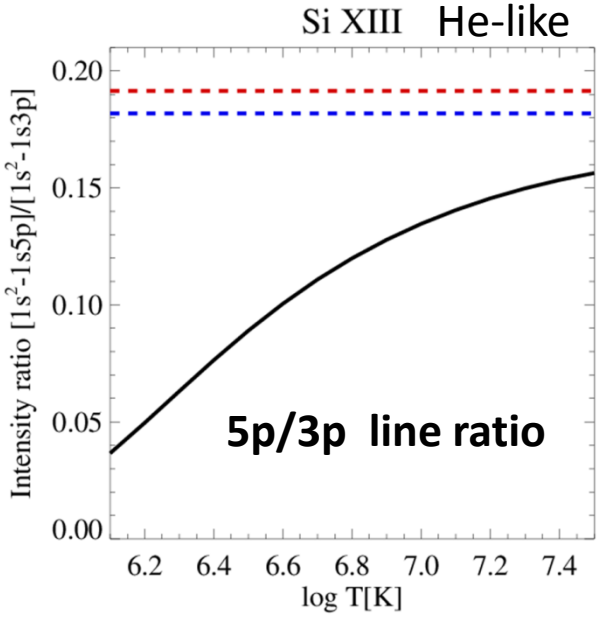
SOL2002-08-03T19:07 (Si higher member lines)



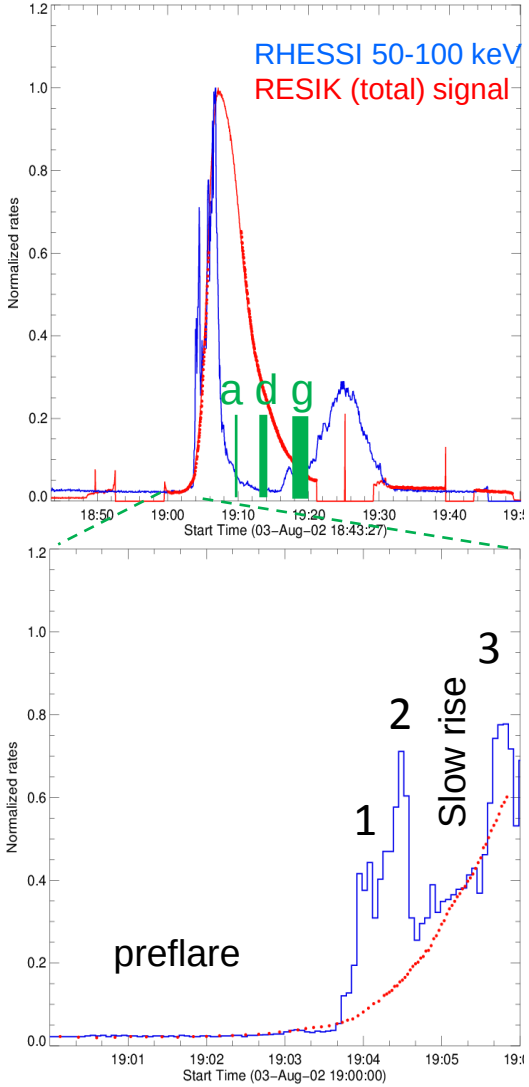
Also in this case, H-like ratio is above the thermal range, not only for the rise, but also for decay phase!
Should it give us a hint that tails of el. distribution function is enhanced all the time?

For He-like transitions 5p levels appear much stronger populated than in thermal case. The higher is excitation energy, the larger is overpopulation.

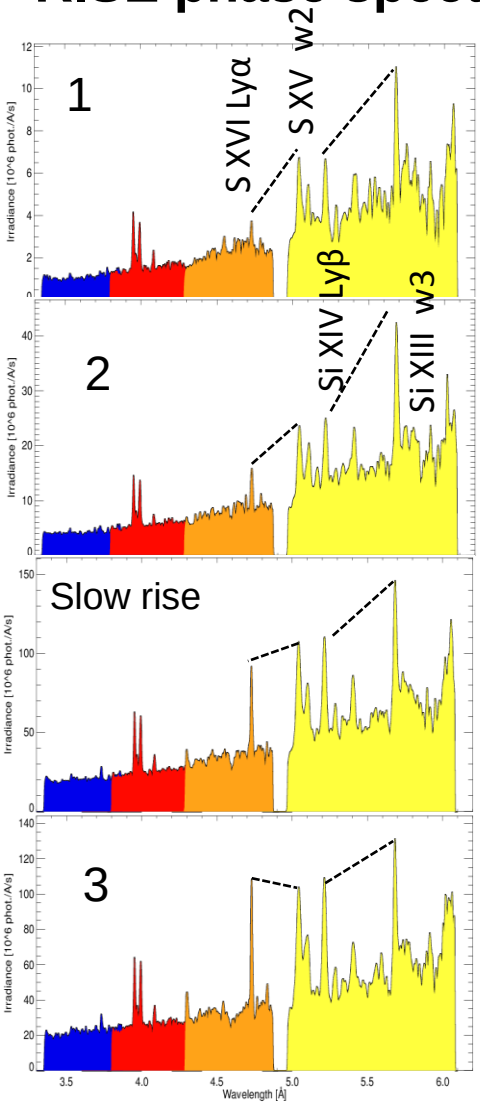




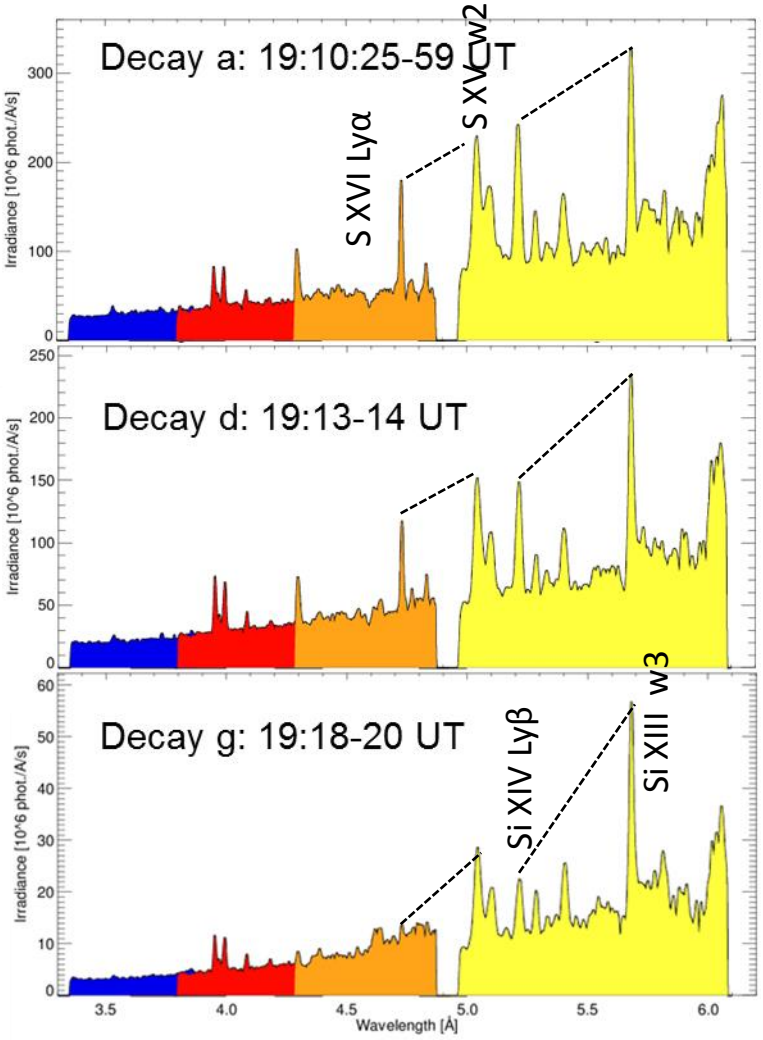
SOL2002-08-03T19:07 (This was a flare with particularly strong & fast hard X-ray emission)



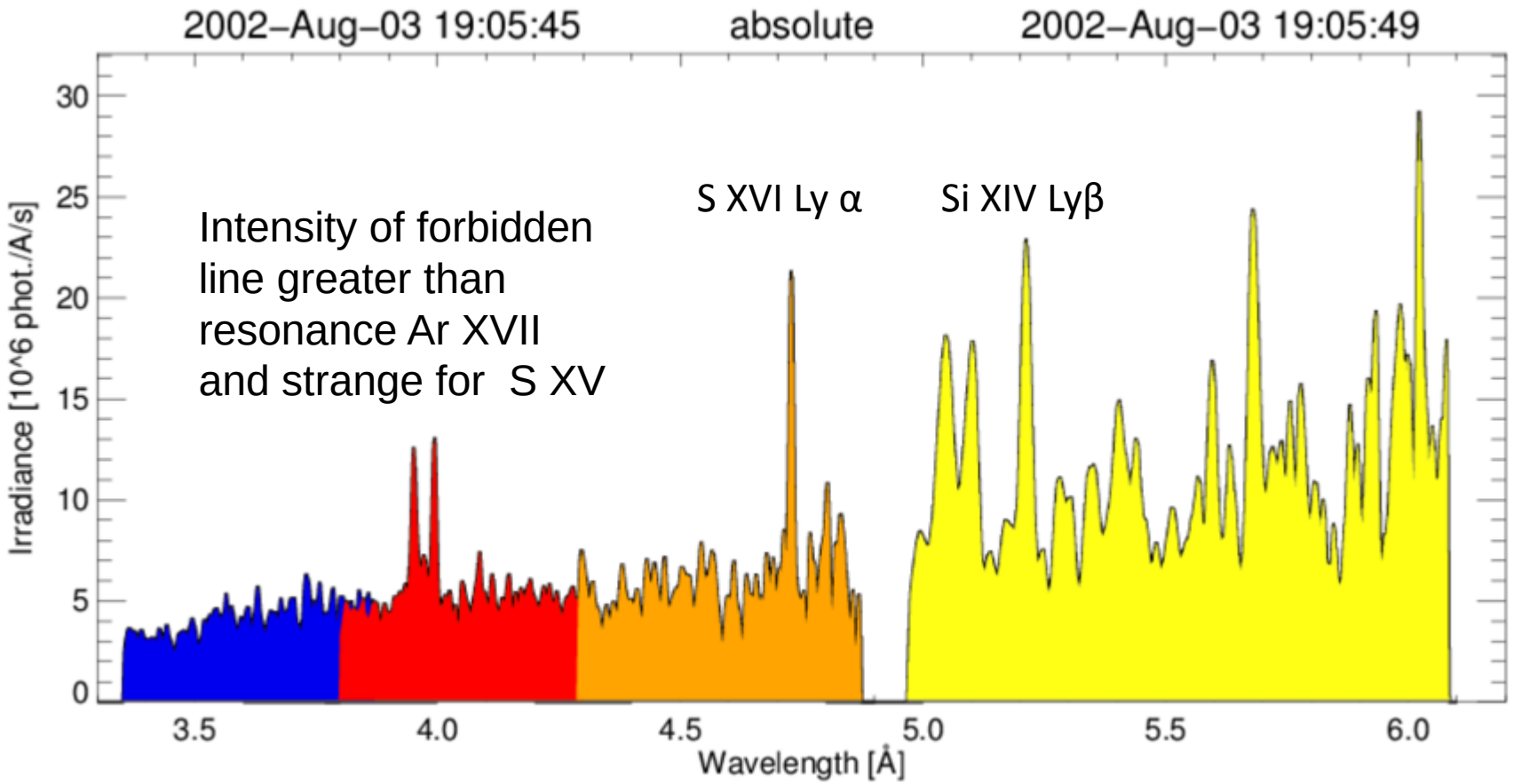
RISE phase spectra



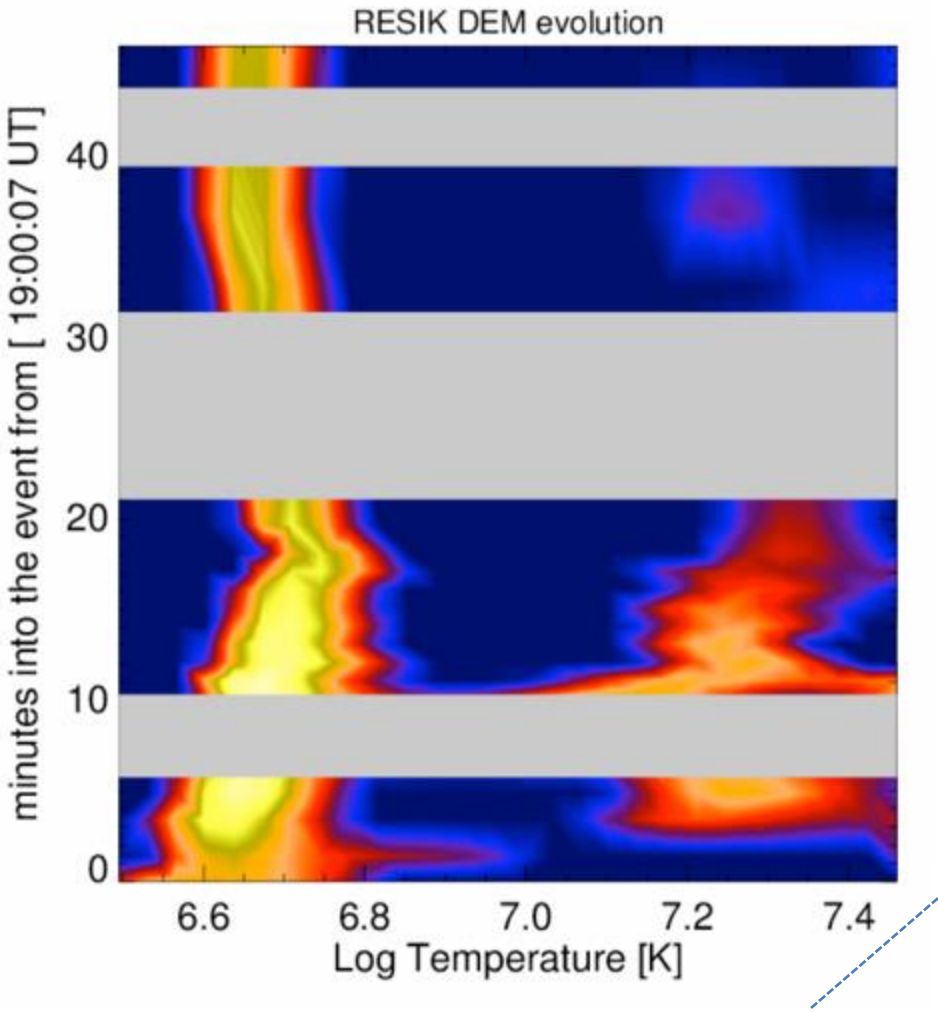
DECAY

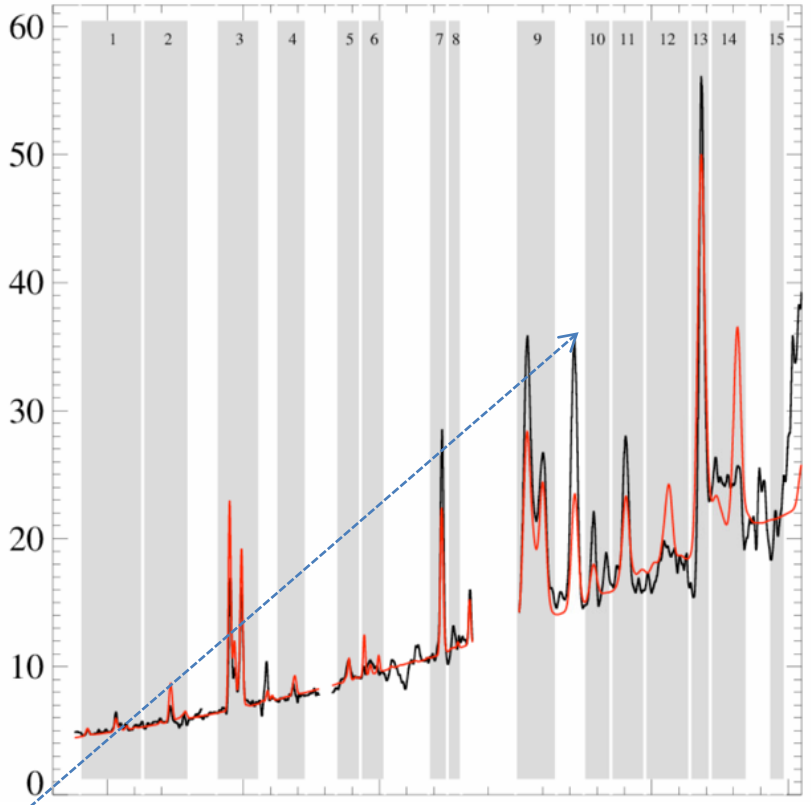


The unusual spectrum seen



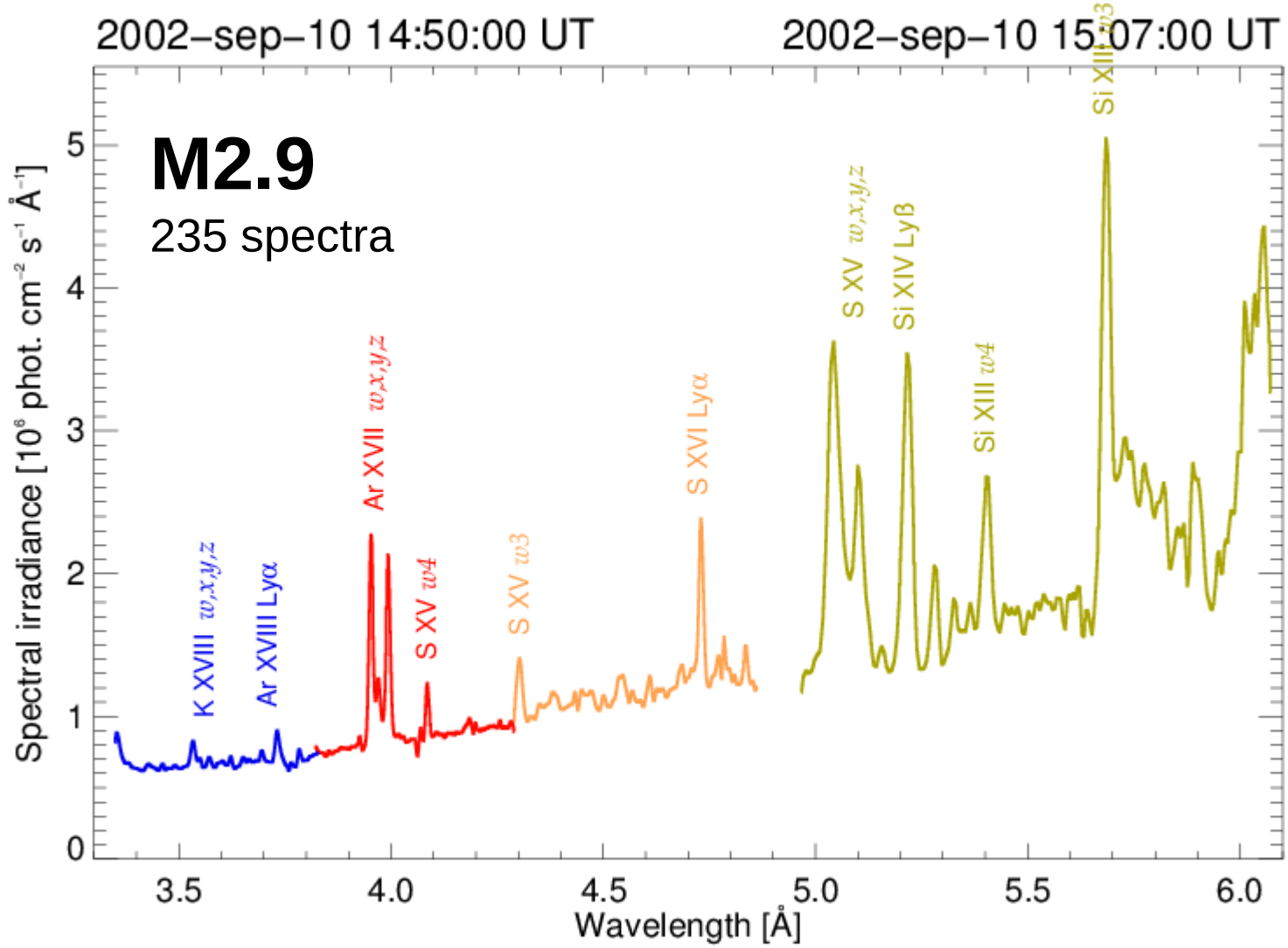
Multi-Temperature approach

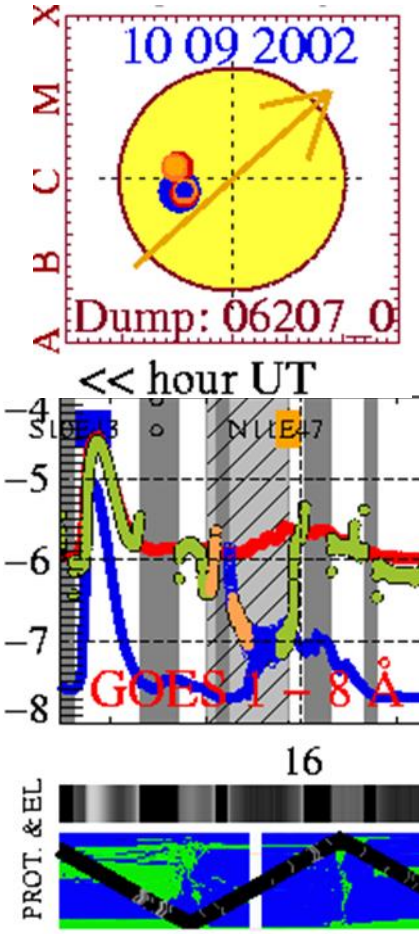




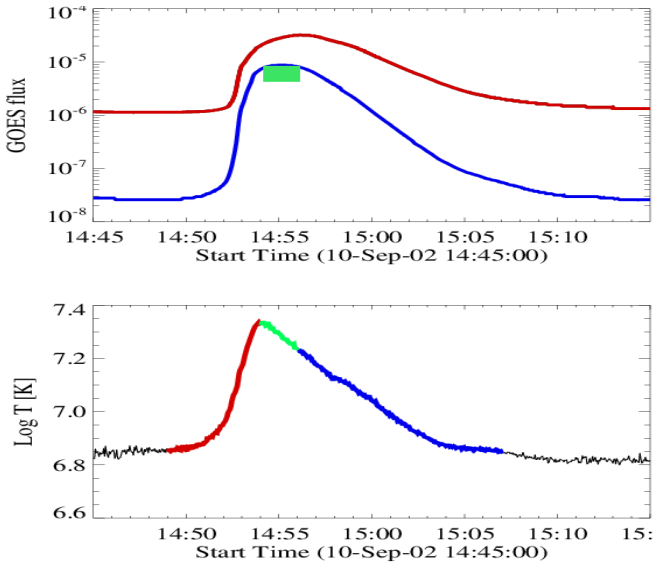
- It is always the case that Si XIV Lyβ is observed stronger than from the DEM model.
- Also higher n's are too strong. Continuum looks OK.

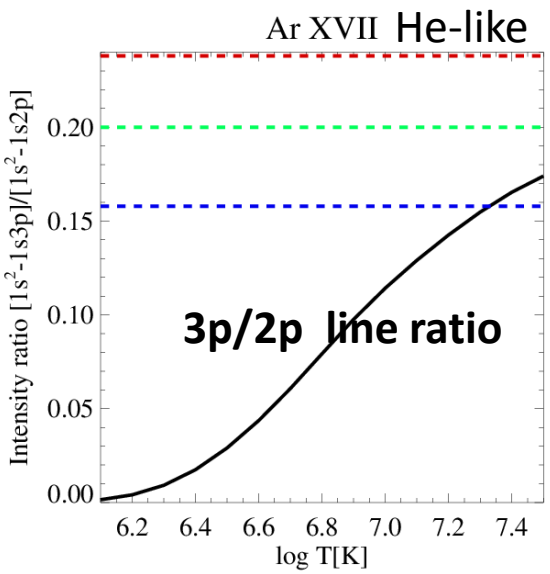
Another flare, a possible good candidate for non-typical spectral evolution SOL2002-09-10T14:56

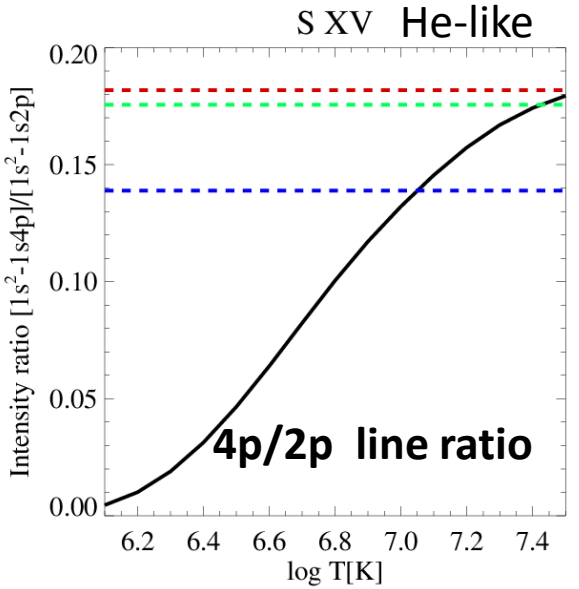




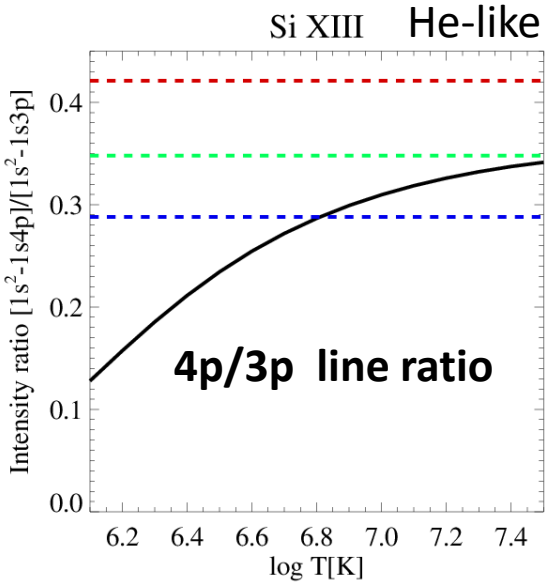
SOL2002-09-10T14:56

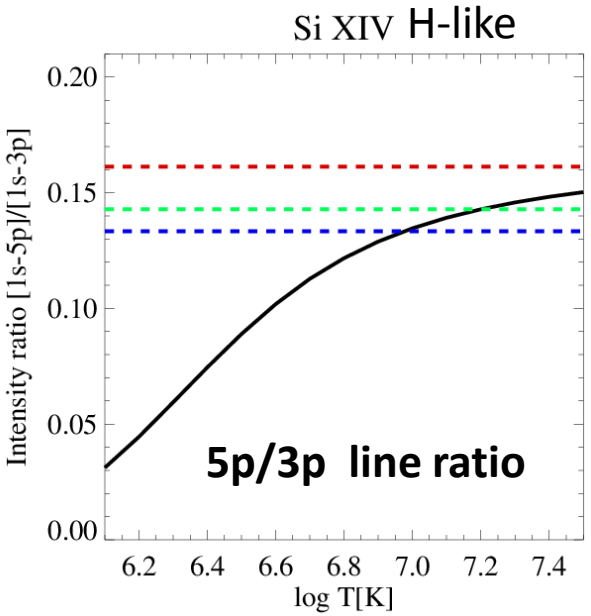




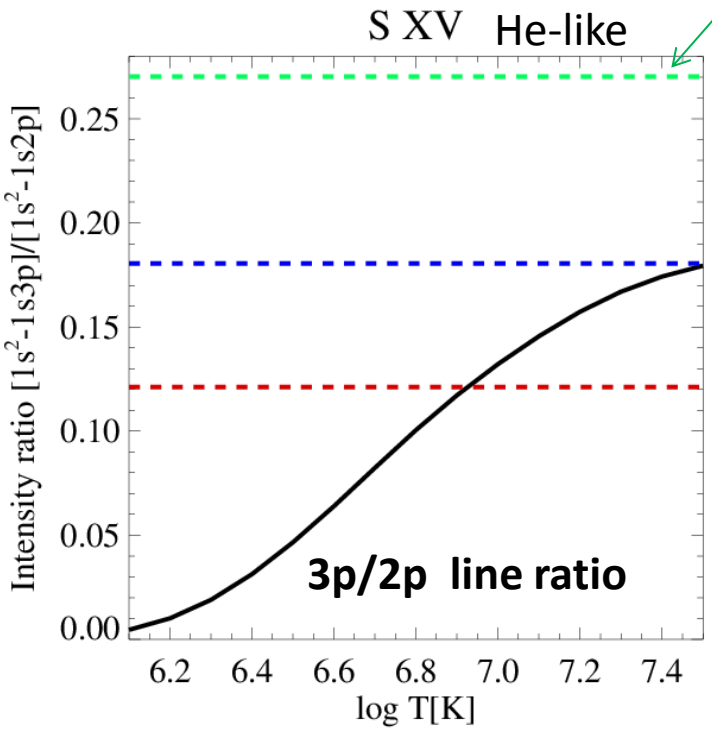


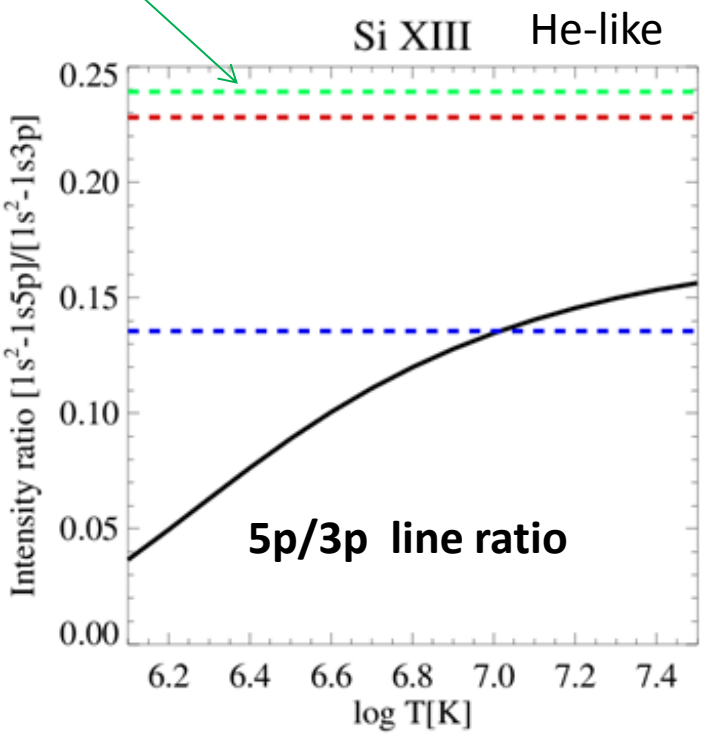
This time also Ar transitions are taken into account. For the rise and maximum phase the ratio 3p/2p is problematic is H-like ions. 4p/2p and 5p/3p look reasonable, 4p/3p for Si He - like are also „OK”.





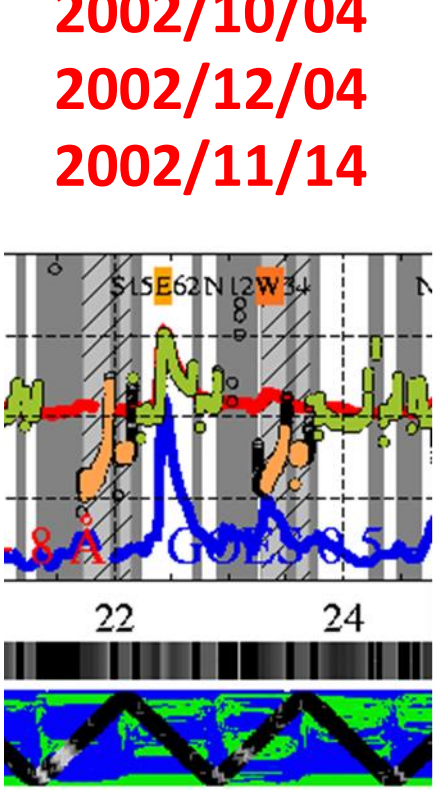
Other peculiar ratios seen at flare maximum

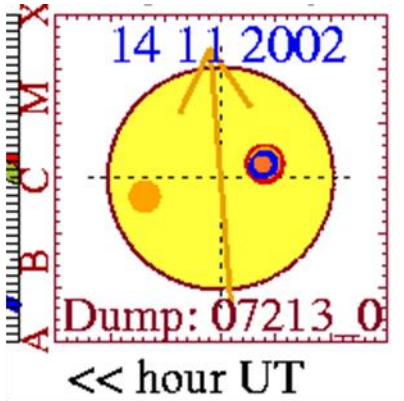


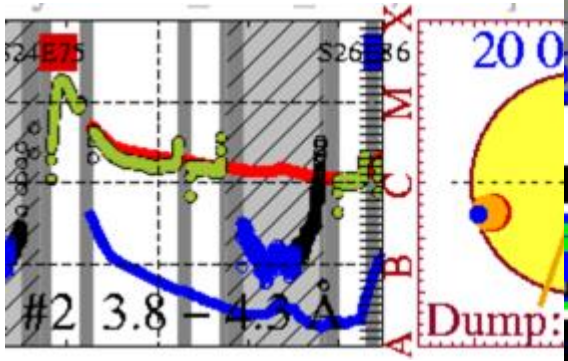


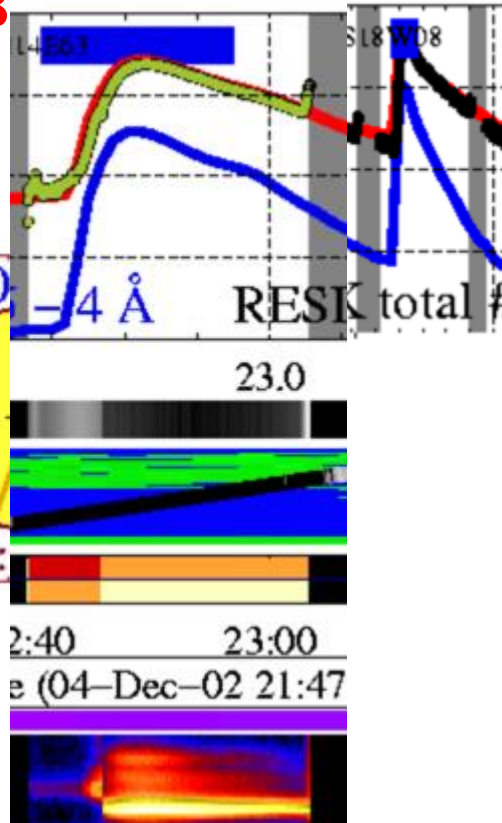
Other reduced Level_2, ready to be analysed

2002/08/03	**19:07:00**	**X1.0**	**S16W87 under analysis**
2002/09/10	**14:56:00**	**M2.9**	**S10E43 under analysis**
2002/09/20	**09:28:00**	**M1.8**	**S24E75 candidate**
2002/10/04	**05:38:00**	**M4.0**	**S18W08**
2002/12/04	**22:49:00**	**M2.5**	**N14E63**
2002/11/14	**22:26:00**	**M1.0**	**S15E62**









Multi-thermal analysis- submitted to ApJ

Conclusions from prompt analysis of the two selected events

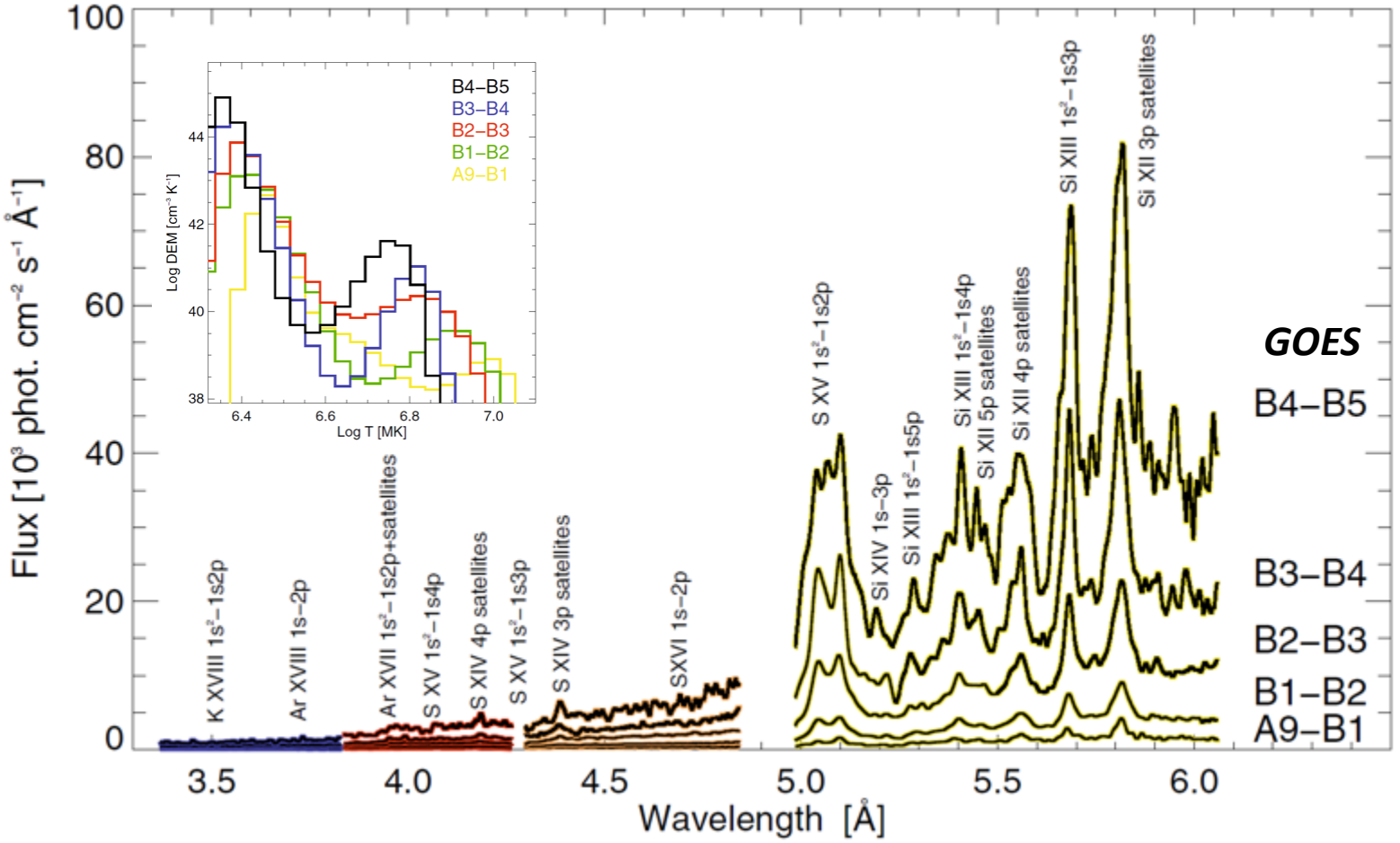
- Intensities of Lyα lines are very strong during rise phases, especially if accompanied by harder X-rays.
- Intensities of higher-n transitions much stronger than predicted for thermal plasma, especially during rise phases.
- Si XIV Lyβ too strong nearly always - very unusual, as no instrumental effects can be blamed…
- Probably 5-6 flares will be suitable for in-depth analysis combining RESIK, *GOES* 3s and *RHESSI* imaging.
- If time-dependent ionisation & non-thermal excitation modules can be incorporated into CHIANTI – this will help for modelling the non-equilibrium signatures.

Another approach that we used is to look to all Level_2 RESIK spectra accompanied by *RHESSI* at various intensity levels

The database contains ~ 5500 RESIK spectra & corresponding *GOES* and *RHESSI* data when available. The two exercises done:

1. Select RESIK spectra for times when *RHESSI* flux in the lowest energy band 3-6 keV is quite weak (< 5 cts/s) → the spectra would correspond to thermal case.
2. Analysis the other end of these spectra collected when *RHESSI* rates in channel 12-25 keV were substanial. We grouped them into classes according to the level of flux in *RHESSI.*

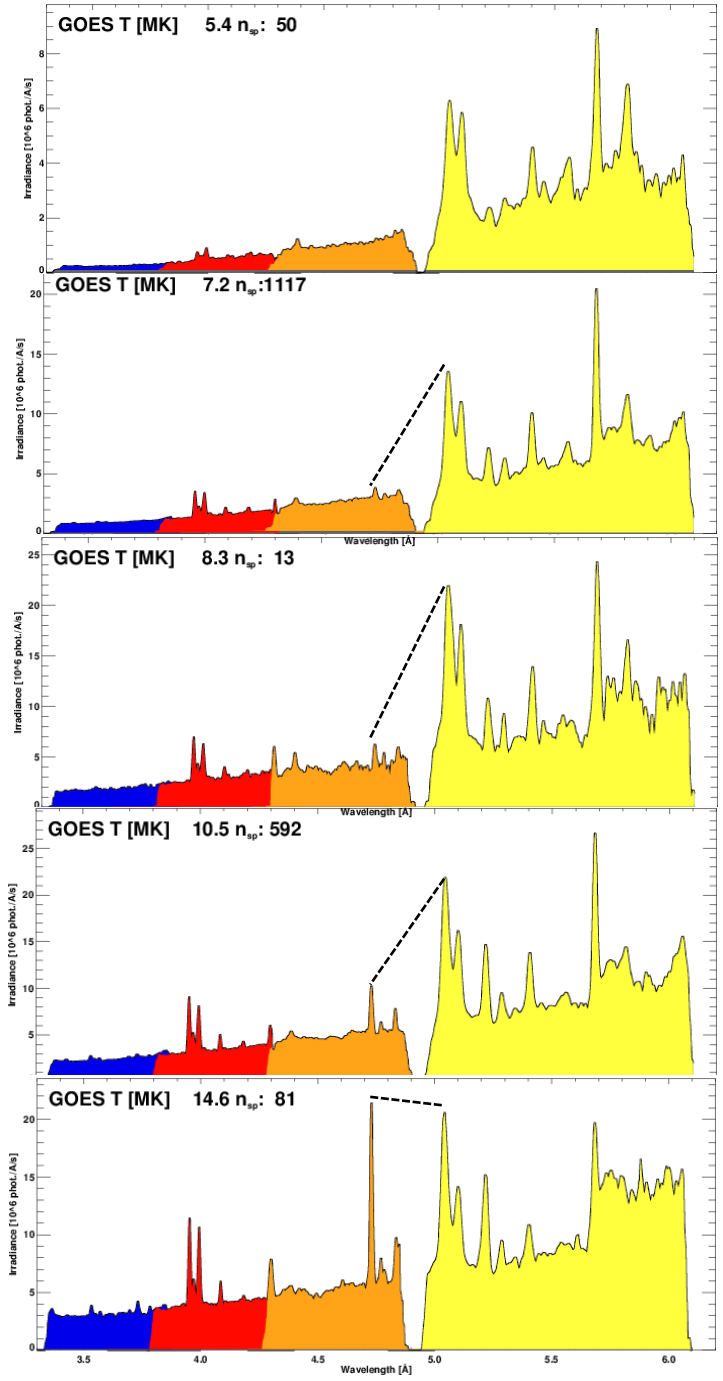
Non-flaring spectra
can be described thermally in the multi -T approach



A&A 51
DOI: 10.

Soft X-ray coronal spectra at low activity levels observed by RESIK

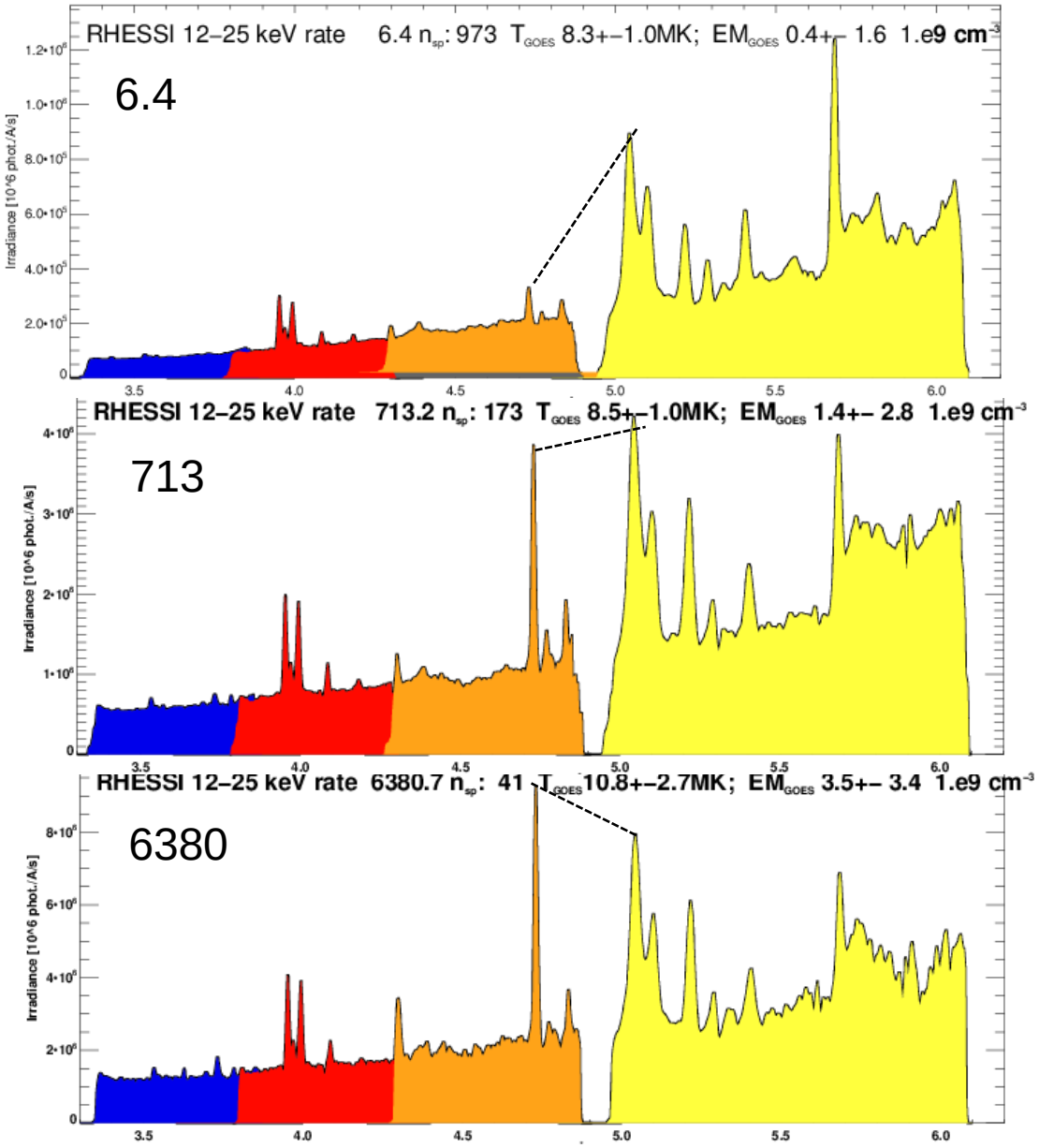
B. Sylwester[1], J. Sylwester[1], and K. J. H. Phillips[2]



THERMAL RESIK spectra corresponding to the low *RHESSI* 3-6 keV flux (<5 cts/s). Spectra are grouped according to T_{GOES}.

First, we normalized spectra per unit EM. Next, we selected these for which T_{GOES} falls within given temperature intervals and then constructed the averaged spectrum. So, the result is the stack of average spectra at given temperature T. The number of spectra in the average is indicated.
These represent typical patterns for thermal cases.

RESIK spectra for intense *RHESSI 12-25 keV*



The flux level in *RHESSI* channel 12-25 keV is indicated.

The *GOES* temperatures can be obtained for these times of intense *RHESSI* 12-25 keV flux.

Unexpectedly T_{GOES} is quite similar for so different levels of non-thermal admixture.

On RESIK spectra we progressively see stronger Lyα line series, much stronger than respective thermal cases.

Take home message

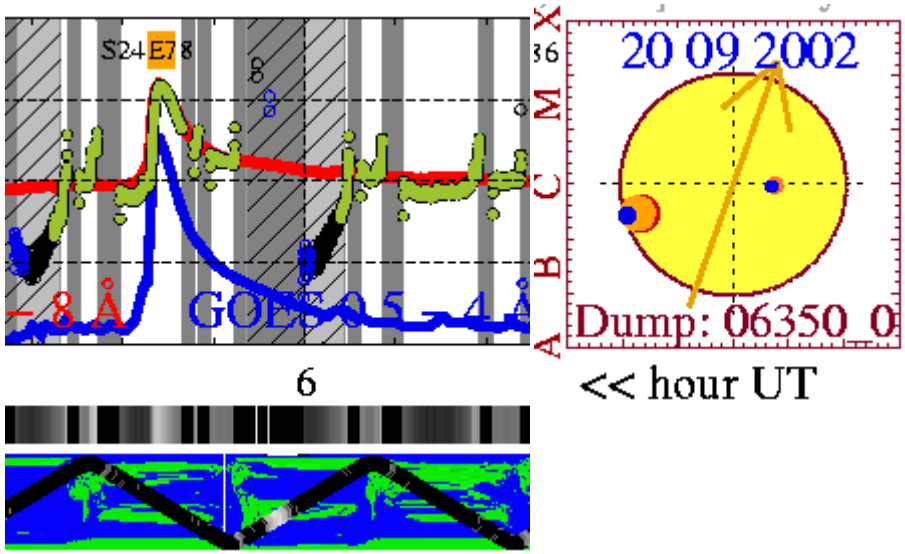
- Intensities of high-n members of H and He-like line series for Si, S and Ar have been observed stronger than expected during rise.
- Decay phase ratios less peculiar.
- At times of impulsive hard X-rays, Lyα lines progresively much stronger as intensity of 12-25 keV flux increases.
- Selection of other strange cases/flares in progress.
- Time variability of many lines will be studied in comparison with *RHESSI*.
- No good explanation for G of T for H-like lines
- CHIANTI in need to model time-dependent IE with non-thermal excitation as an option.

Selected to be reduced (with impulsive phase)

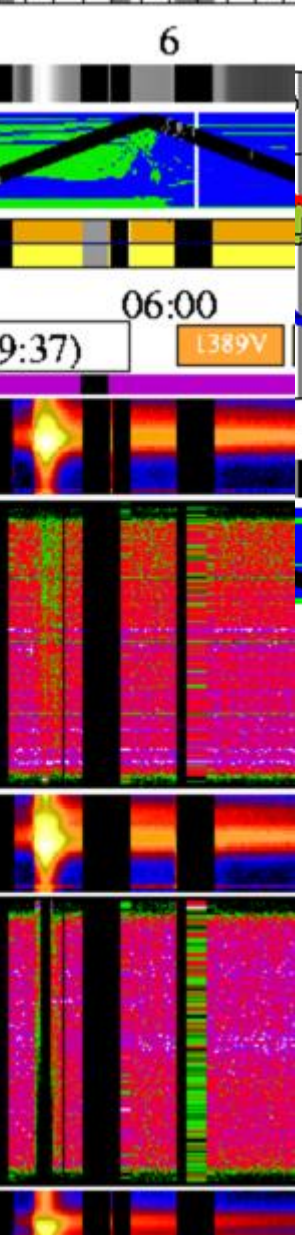
2002/05/07	03:46:00	M1.4	S09E28
2002/08/16	22:12:00	M1.2	S05E06
2002/08/16	23:33:00	M1.7	S05E05
2002/08/20	02:57:00	M1.4	S08W35
2002/08/21	05:34:00	X1.0	S10W50
2002/09/20	05:12:00	M1.5	S24E78

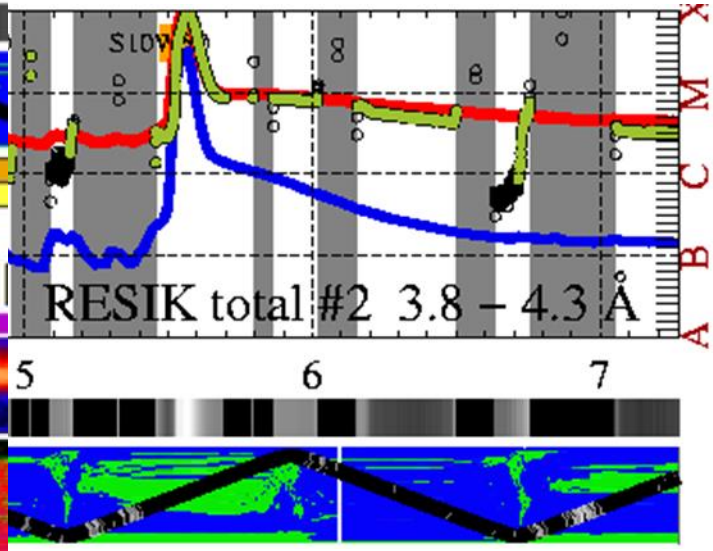
Selected to be reduced (with impulsive phase) no *RHESSI*

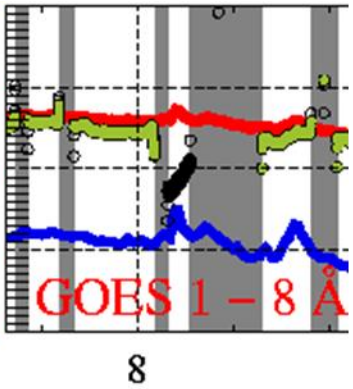
2002/09/20 05:12:00 M1.5 S24E78

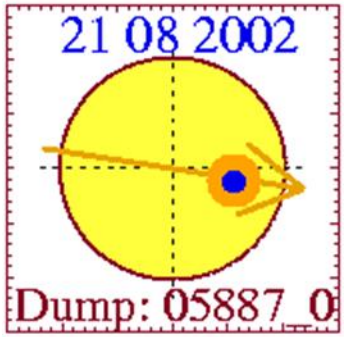


2002/08/21 05:34:00 **X1.0** S10W50

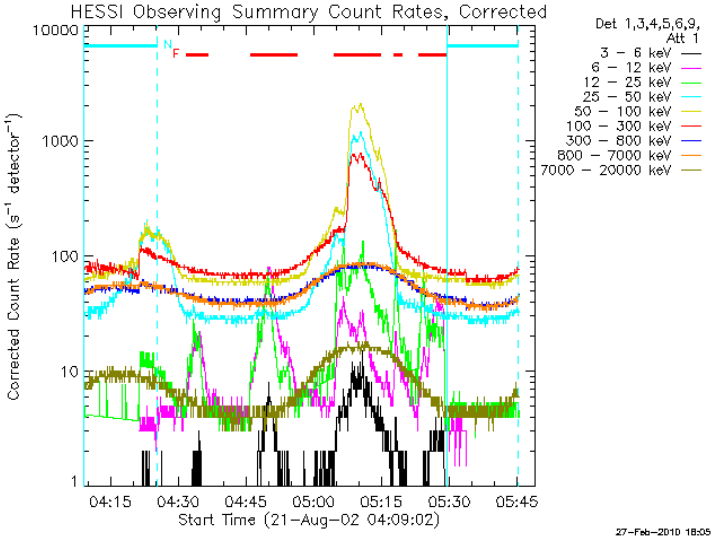




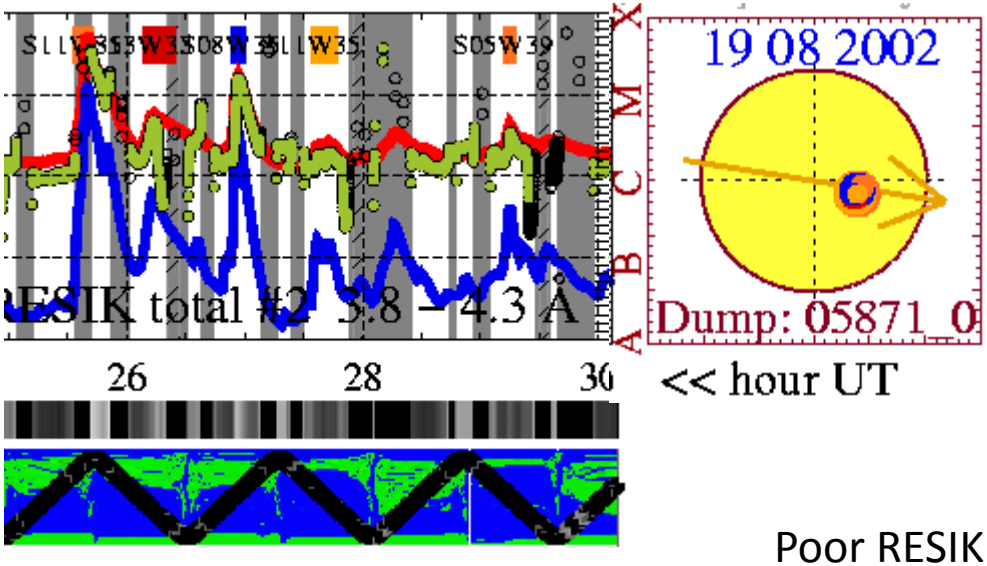


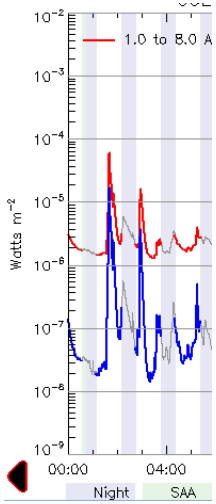


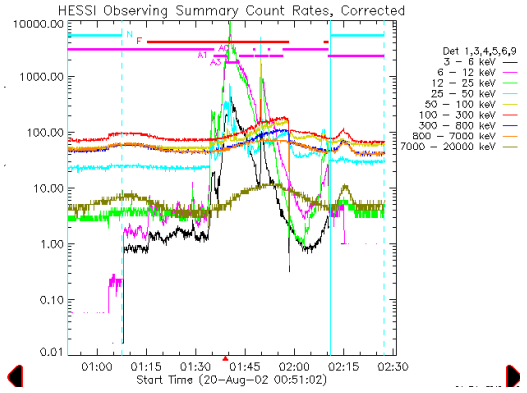
RESIK Saturated



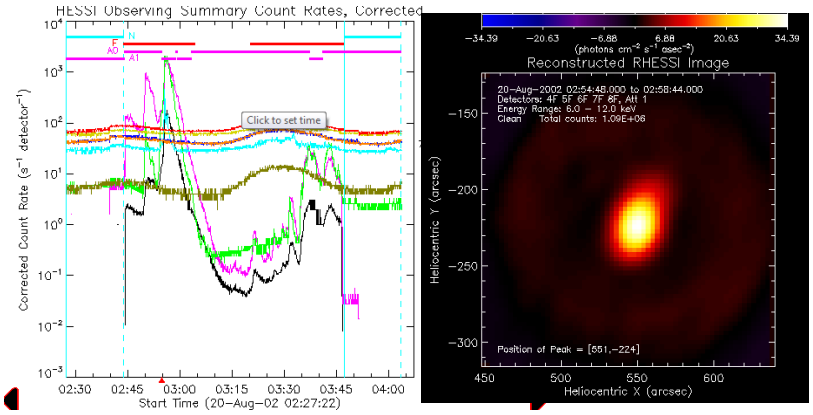
2002/08/20 01:40:00 **M5.0** S11W35
2002/08/20 02:57:00 **M1.4** S08W35

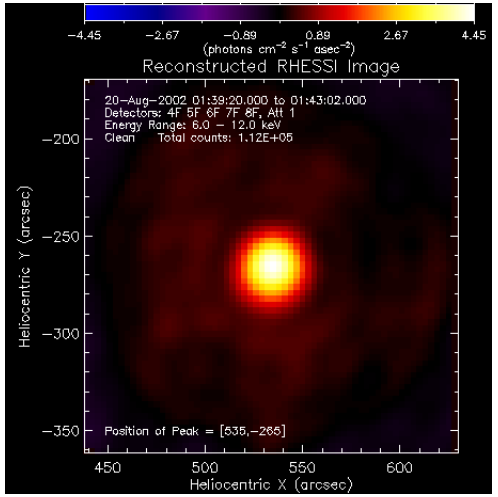






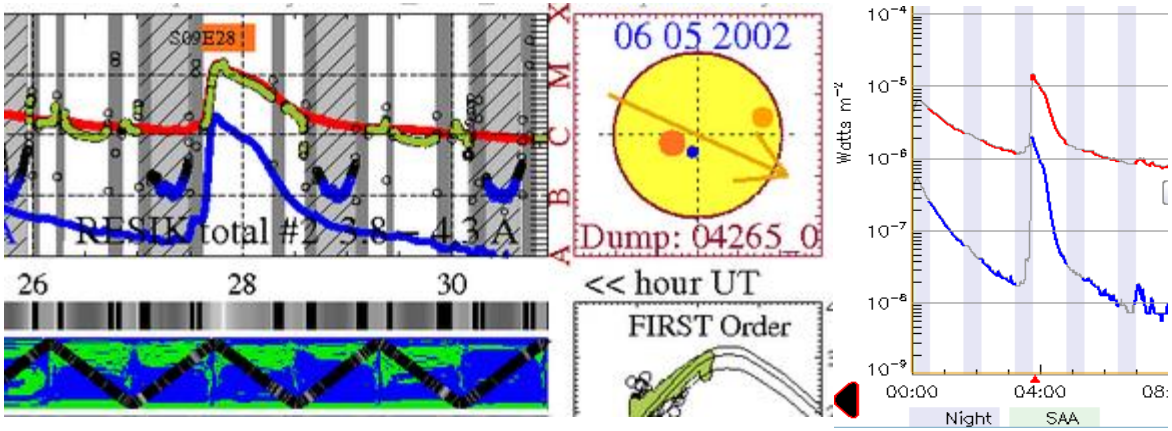
Poor RESIK spectra

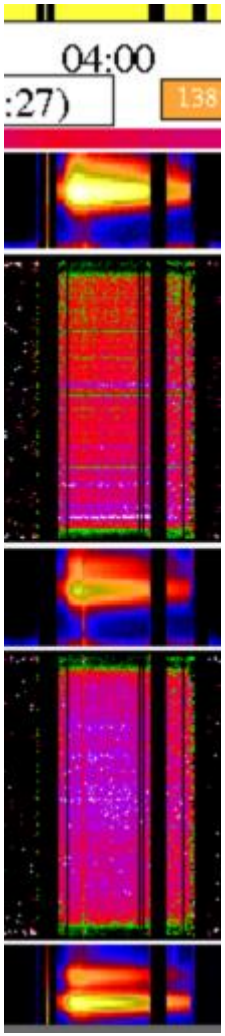


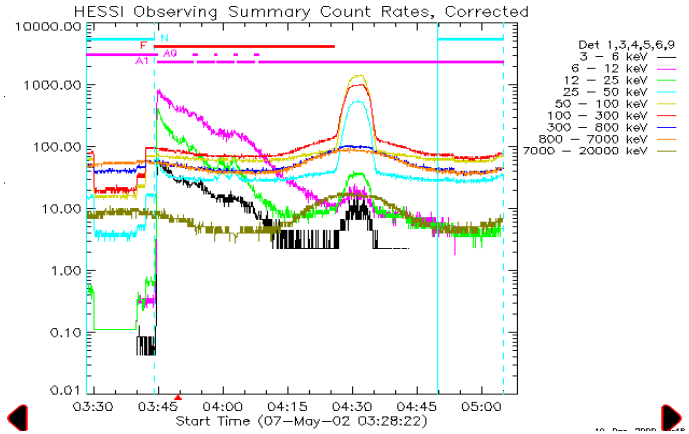


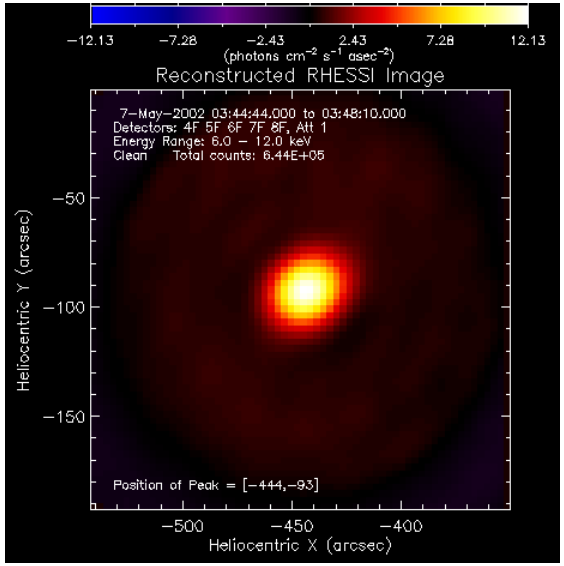
2002/05/07 **03:46:00 M1.4** S09E28

RESIK OK



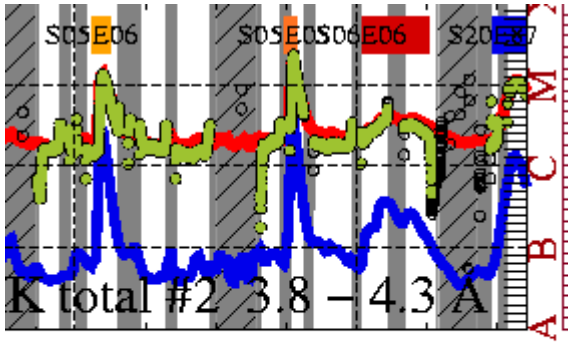


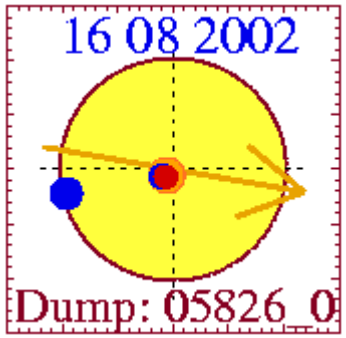


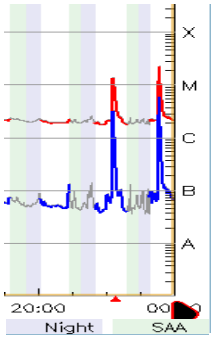


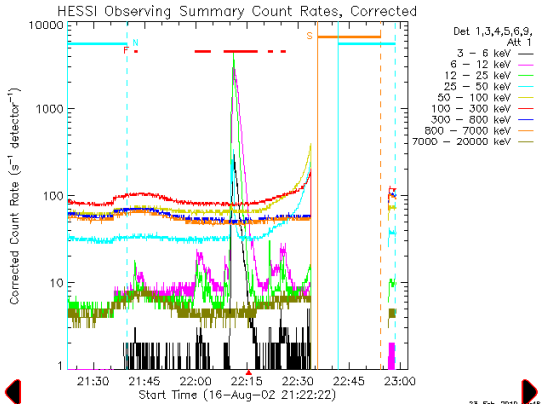
2002/08/16 **22:12:00 M1.2** S05E06

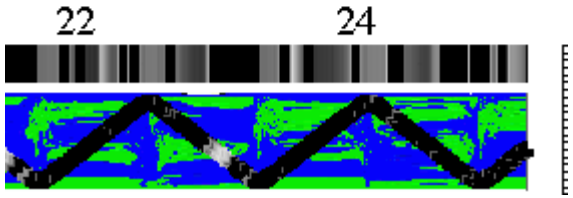
2002/08/16 **23:33:00 M1.7** S05E05

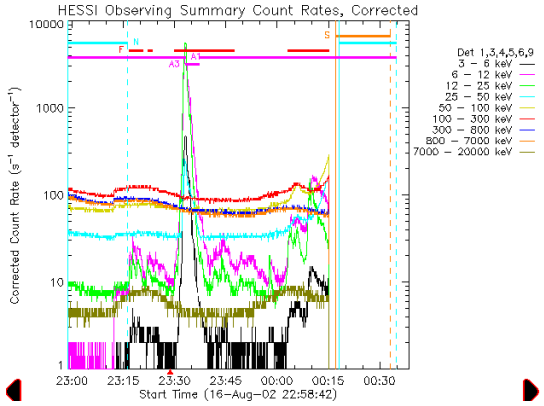


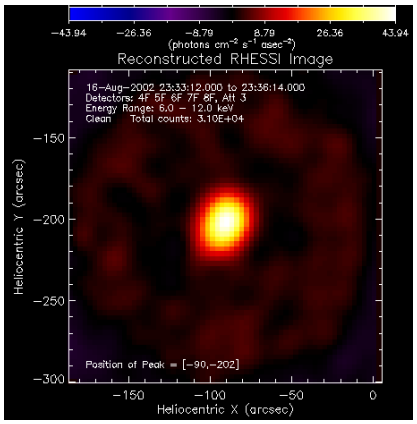


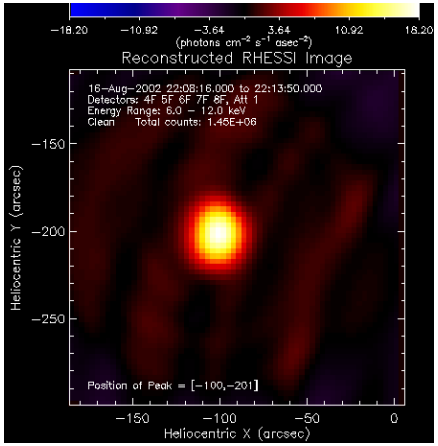










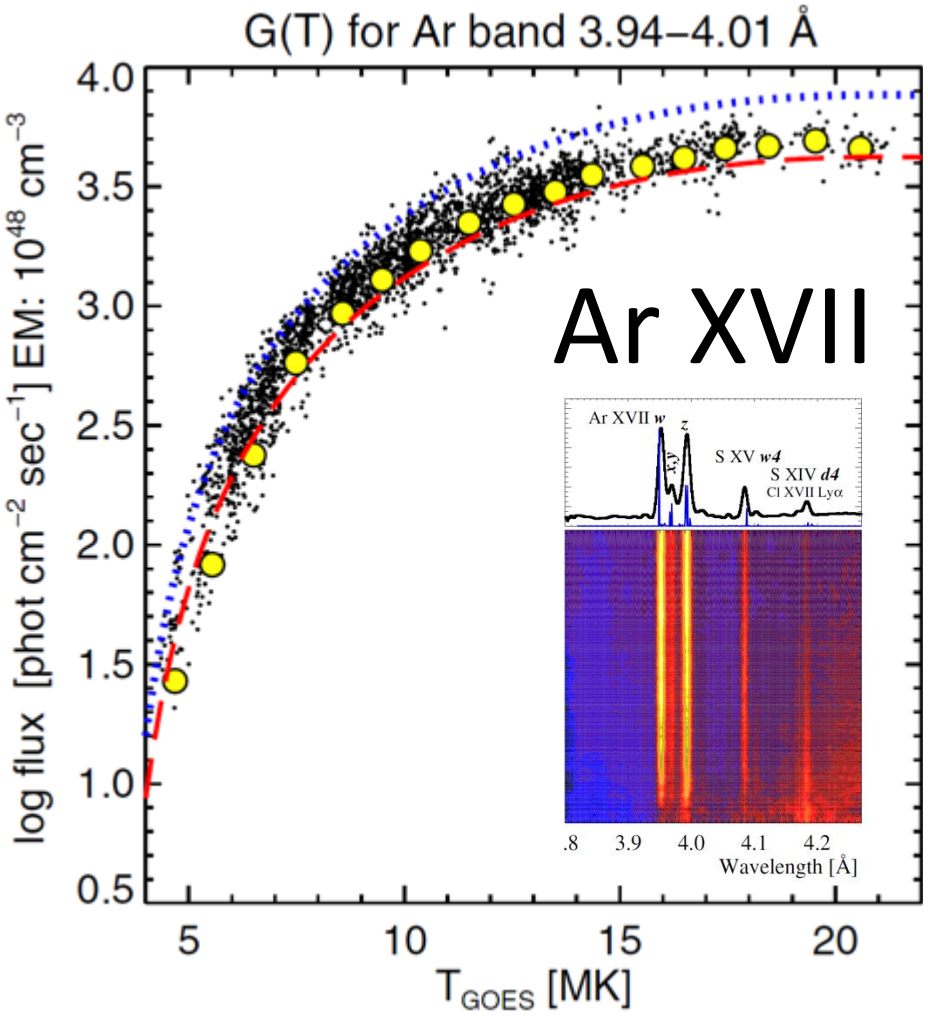


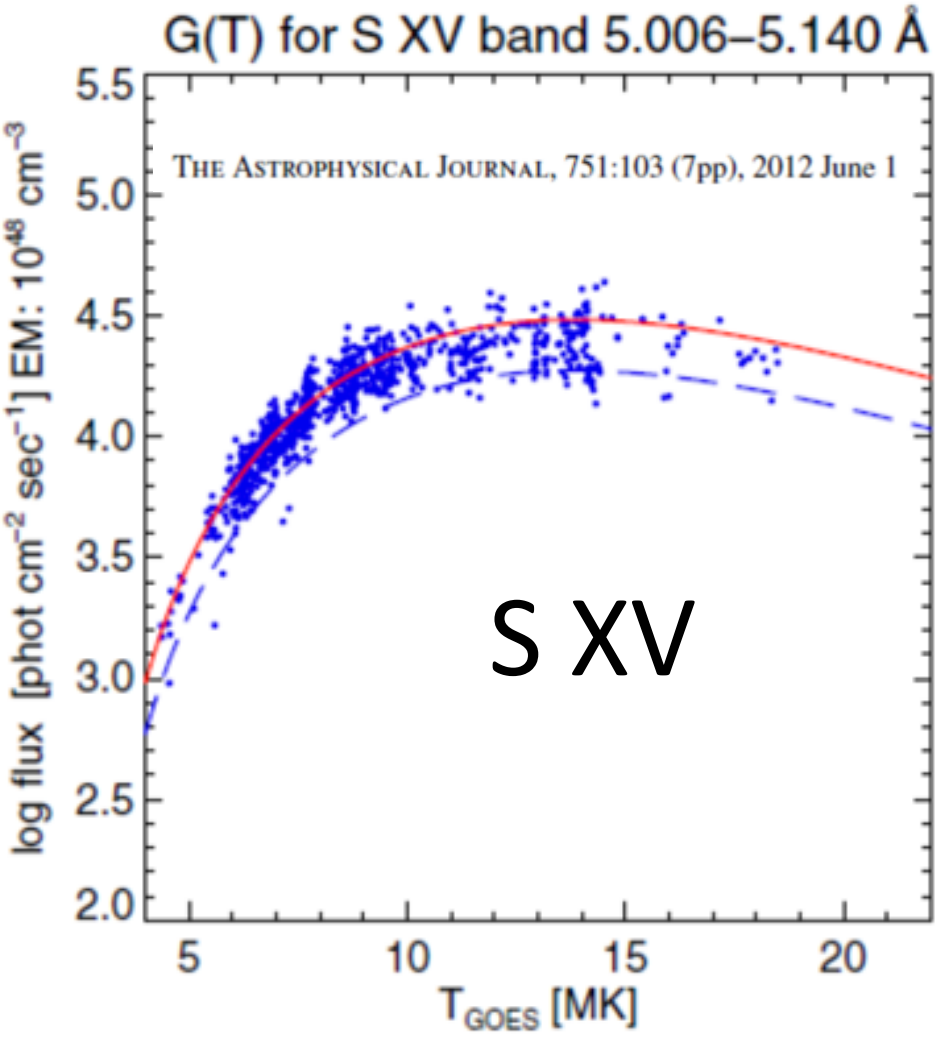
Papers (non-T) based on RESIK data

3 flares analysed

1. Dzifcakova et al., A&A 488, p. 311, 2008
2. Kulinova et al., A&A 533, p. A81, 2011
3. Kulinova et al., ASP Conference Series, Vol. 454, p. 329, 2012

G of T for He- like ions is OK





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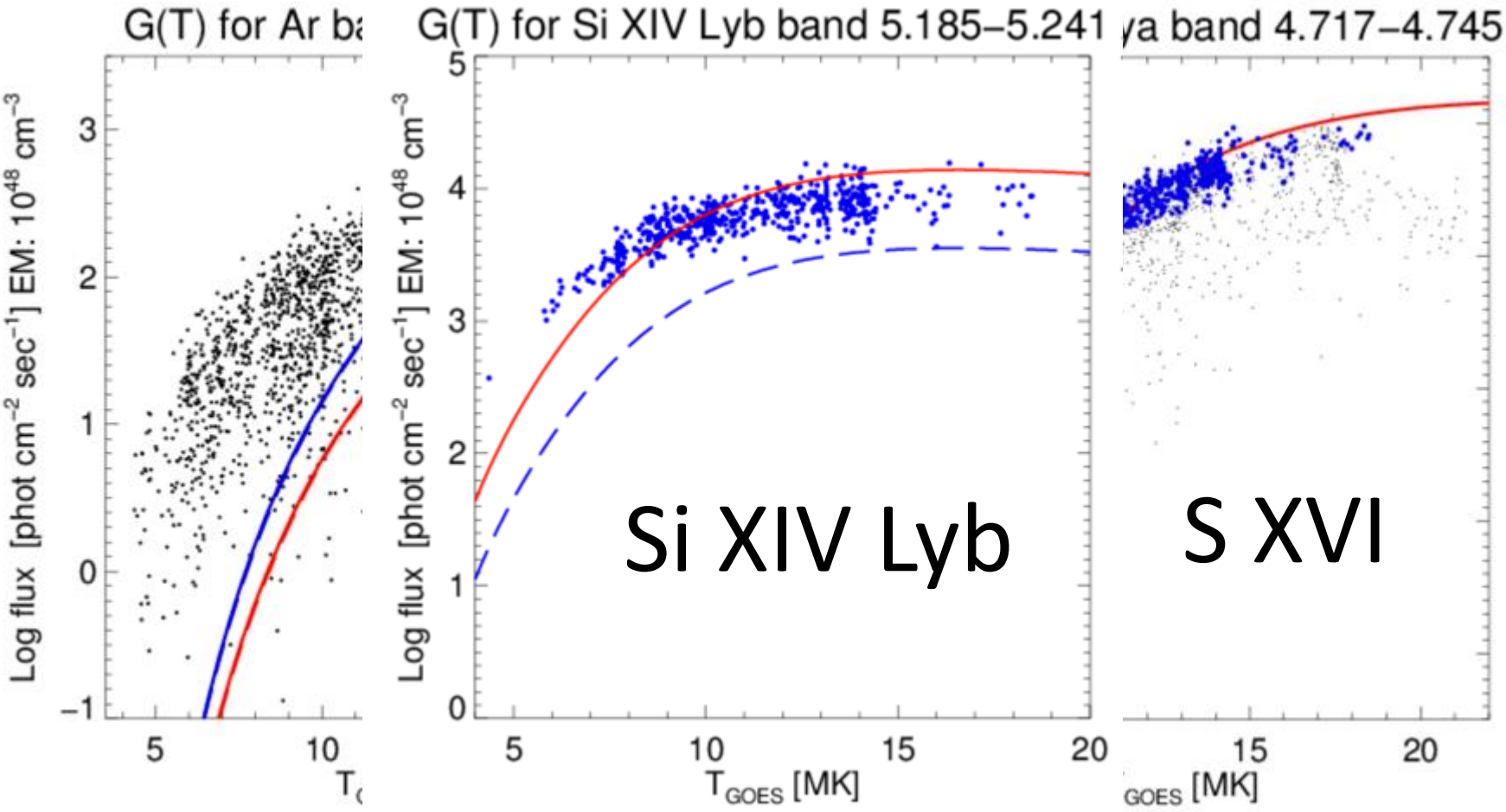
G of T for H- like ions is NOT good



Unpublished- no good explanation