

Review of Level_2 RESIK spectra

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RESIK

The instrument called RESIK (Rentgenovskij Spectrometer s Izognutymi Kristalami) consists of two X-ray spectrometers giving the spectra in the following ranges:

#1: 3.37 - 3.88 Å

#2: 3.82 - 4.33 Å

#3: 4.31 - 4.89 Å

#4: 4.96 - 6.09 Å

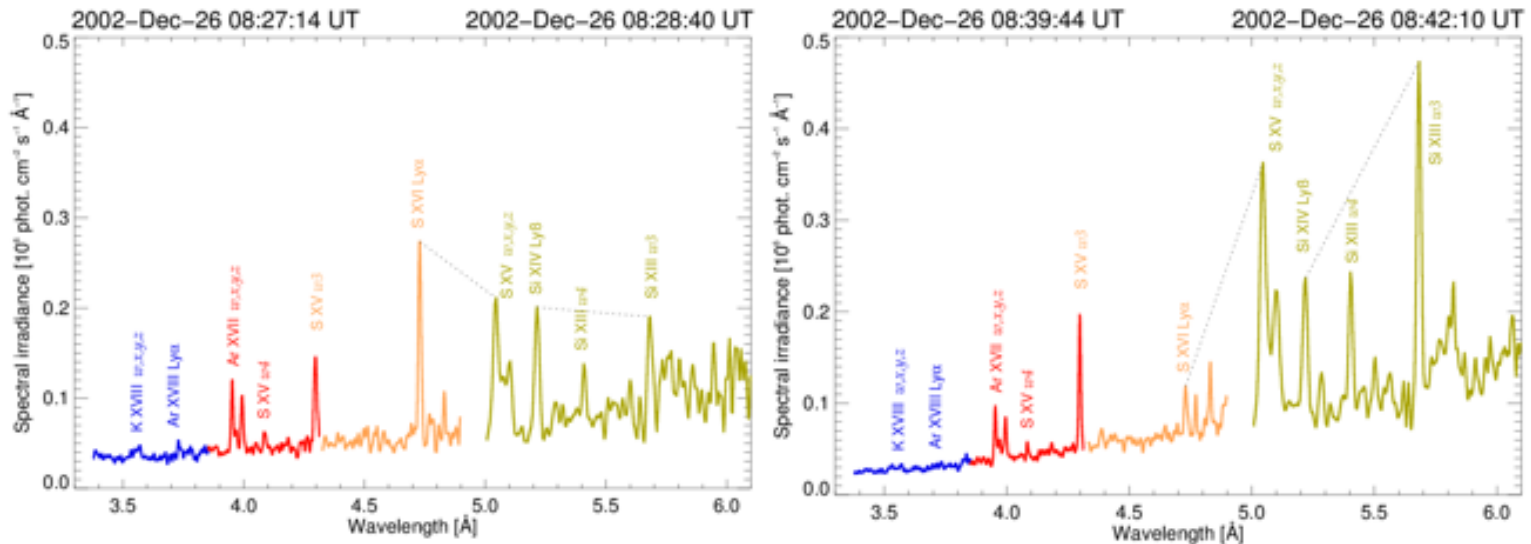
RESIK was the last solar soft-X-ray Bragg spectrometer flown in 2001. Its nominal wavelength coverage is 3.3 Å – 6.1 Å. RESIK observed numerous flares as well as active regions. During flares, the spectra collection times was as short as 2 s. By now the measurements for more than 101 flares (more than 10 000 spectra) have been reduced to so-called level 2 (the intensity [photons cm⁻² s⁻¹ Å⁻¹] vs the wavelength). The reduced spectra are available at:

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

Many measurements were taken during the flares' rise phase. For some events peculiar line intensity ratios are seen, possibly reflecting presence of non-equilibrium conditions in flaring plasma. For some lines, observed intensity ratios cannot be explained even in the multi-temperature approach.

They possibly can be interpreted by assuming that the plasma is out of equilibrium.

The example of RESIK spectra



The left panel presents the spectrum averaged during the rise phase of C1.9 flare observed on 26 Dec. 2002 (SOL2002-12-26T08:35). The right panel corresponds for the decay phase. The colours show the different channels. The dotted lines connect the pairs of lines for ions S XVI and S XV oraz Si XIV and Si XIII.

RESIK catalogue

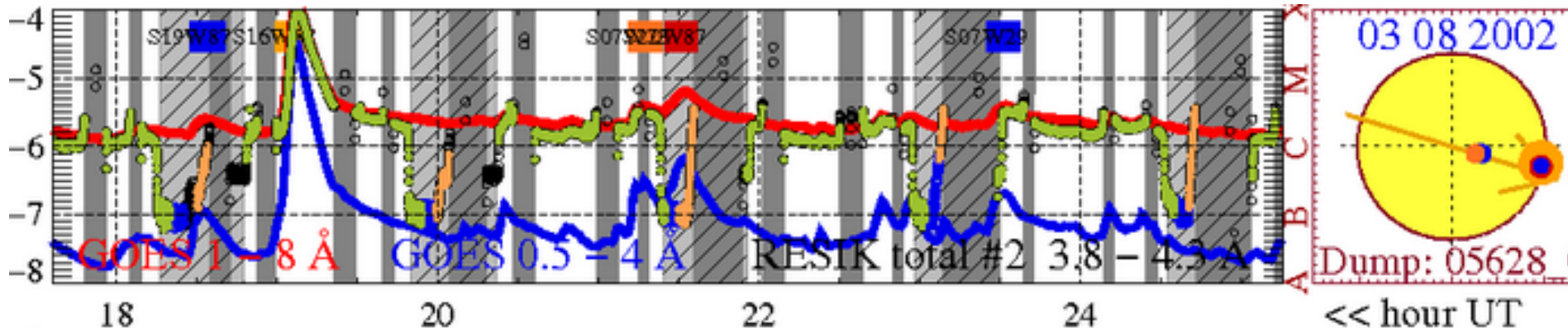
http://www.cbk.pan.wroc.pl/resik_catalogue.htm

2002

December	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
November	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
October	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
September	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
August	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31



The first panel of one orbit



RESIK Level_2 spectra

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

Date



Quiet (312 individual spectra)

26 December 2002 (max ~ 03:52 UT)
27 December 2002 (max ~ 21:58 UT)
11 March 2003 (max ~ 05:50 UT) *
25 December 2002 (max ~ 23:10 UT)
22 February 2003 (max ~ 04:50 UT) *
29 December 2002 (max ~ 02:05 UT)

GOES class



B6.0
B6.3
B7.3
B8.0
B9.6
B9.9

Location



S30W91
N13E01
N16W28
S15W91
N16W02
S30W91

Date



17 March 2003 (max ~ 19:05 UT)
3 August 2002 (max ~ 19:07 UT)
7 January 2003 (max ~ 23:30 UT)
04 October 2002 (max ~ 05:38 UT)
10 September 2002 (max ~ 14:56 UT)



GOES class



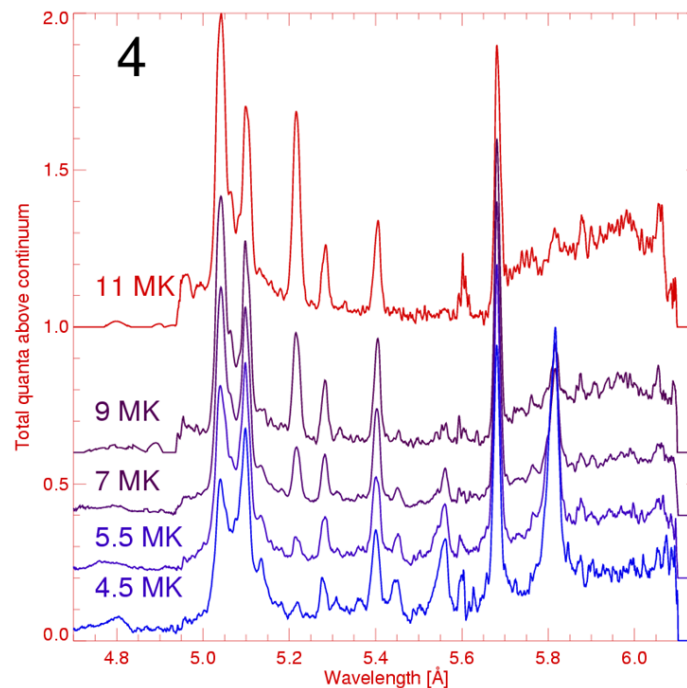
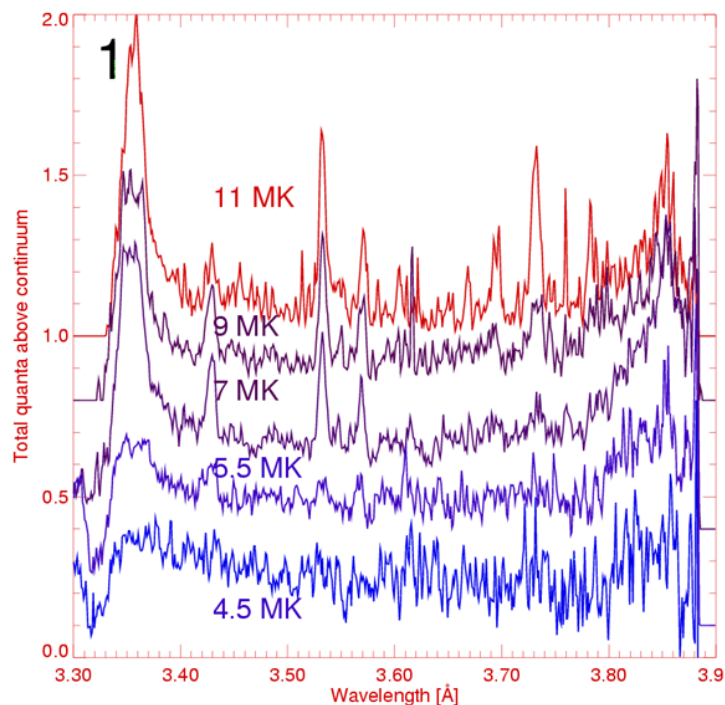
X1.5
X1.0
M4.9
M4.0
M2.9

Location



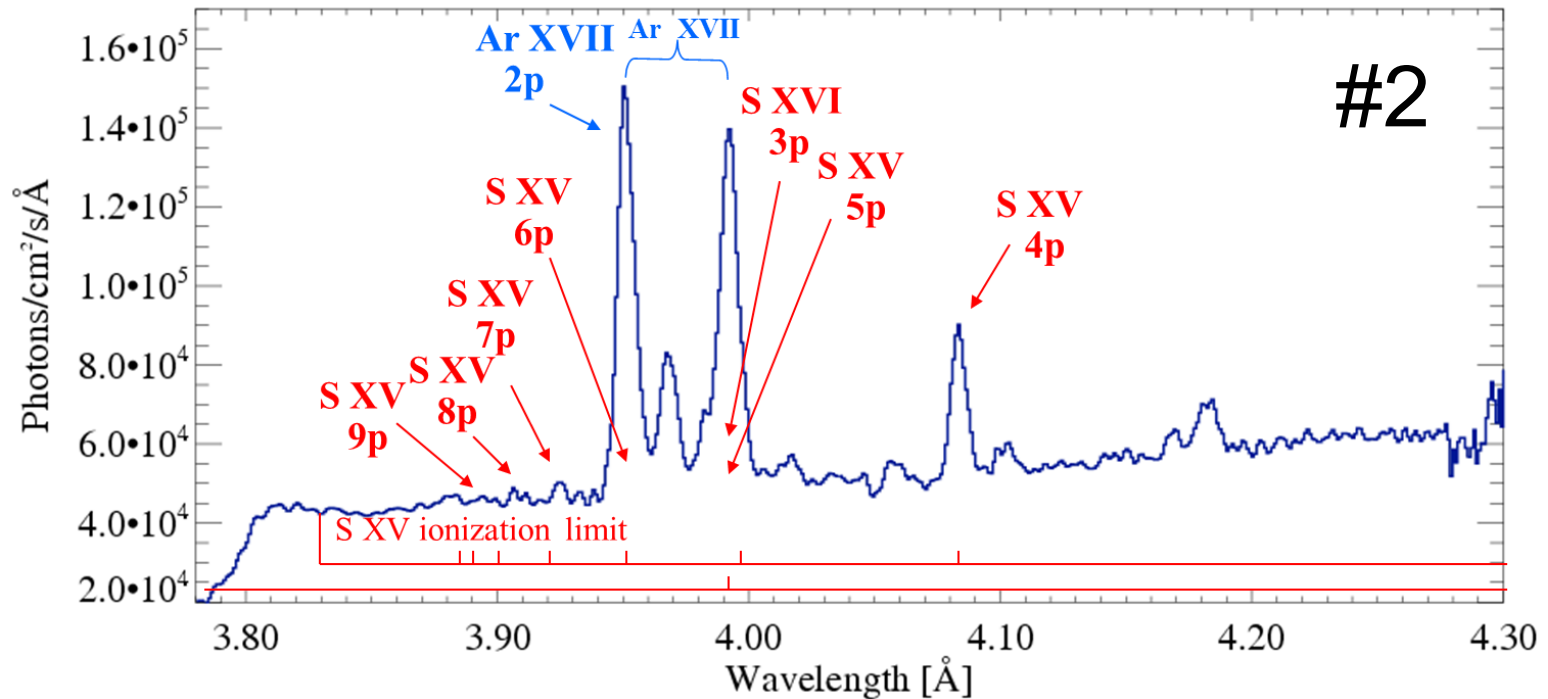
S14W38
S16W87
S11E89
S19W09
S10E43

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 (\sim 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 spectra for 14 flares (2003, $\Delta t \approx 9$ hours)

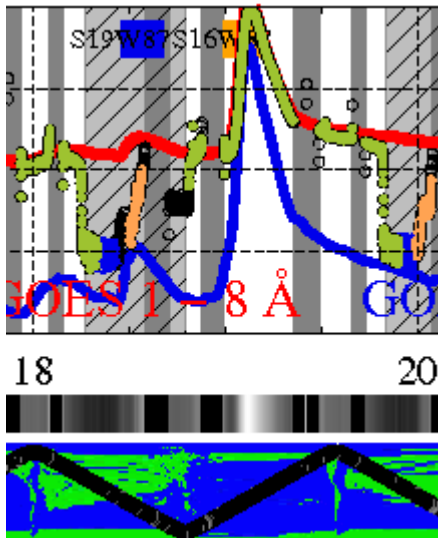


RESIK range (3.37 \AA to 6.09 \AA) includes many strong emission lines due to transitions $1s^2 - 1s(np)$ and $1s - np$, in He-like and H-like ions respectively; the $n = 2$ and 3 lines are routinely observed for Si, S and Ar ions. For some flares we have observed enhanced emission in spectral features 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).

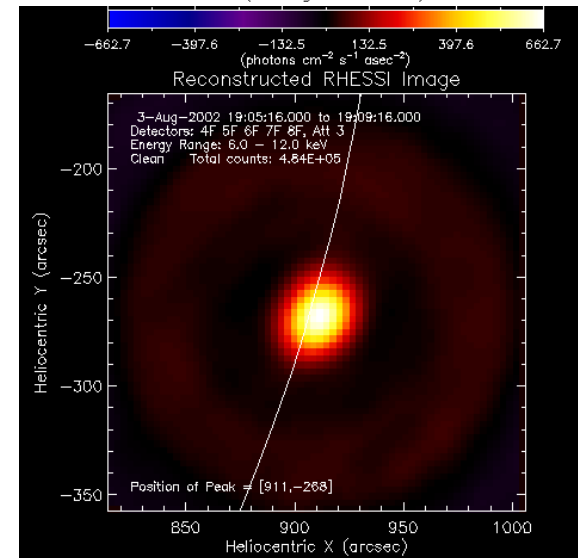
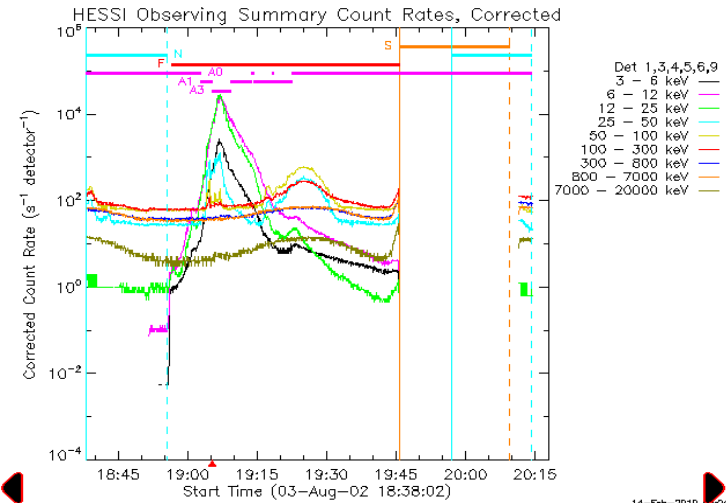
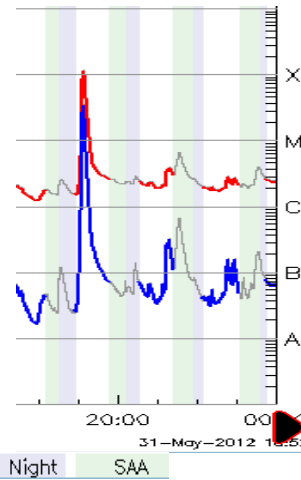
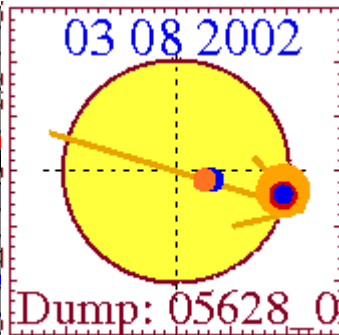
Conclusions based on 14 flares

- The high n Rydberg series of hydrogen and helium-like ions of Al, Si, S and Ar have been observed from RESIK spectra. Comparison of the intensities of observed and theoretical ratios showed that the observed ratios are generally larger than theoretically expected under an isothermal, equilibrium plasma assumptions.
- Ratios of observed and expected values are systematically larger for H-like in respect to He-like ions.
- In order to explain the observed values of ratios for He-like ions unrealistically high values of plasma temperature has to be assumed.
- Thermal explanation of the ratios measured for H-like ions appears to be impossible.
- One of the possible explanations of the pattern observed is that all derived intensities are „an upper limit” as there might be unresolved blends from yet unknown transitions which contribute to the derived intensities.

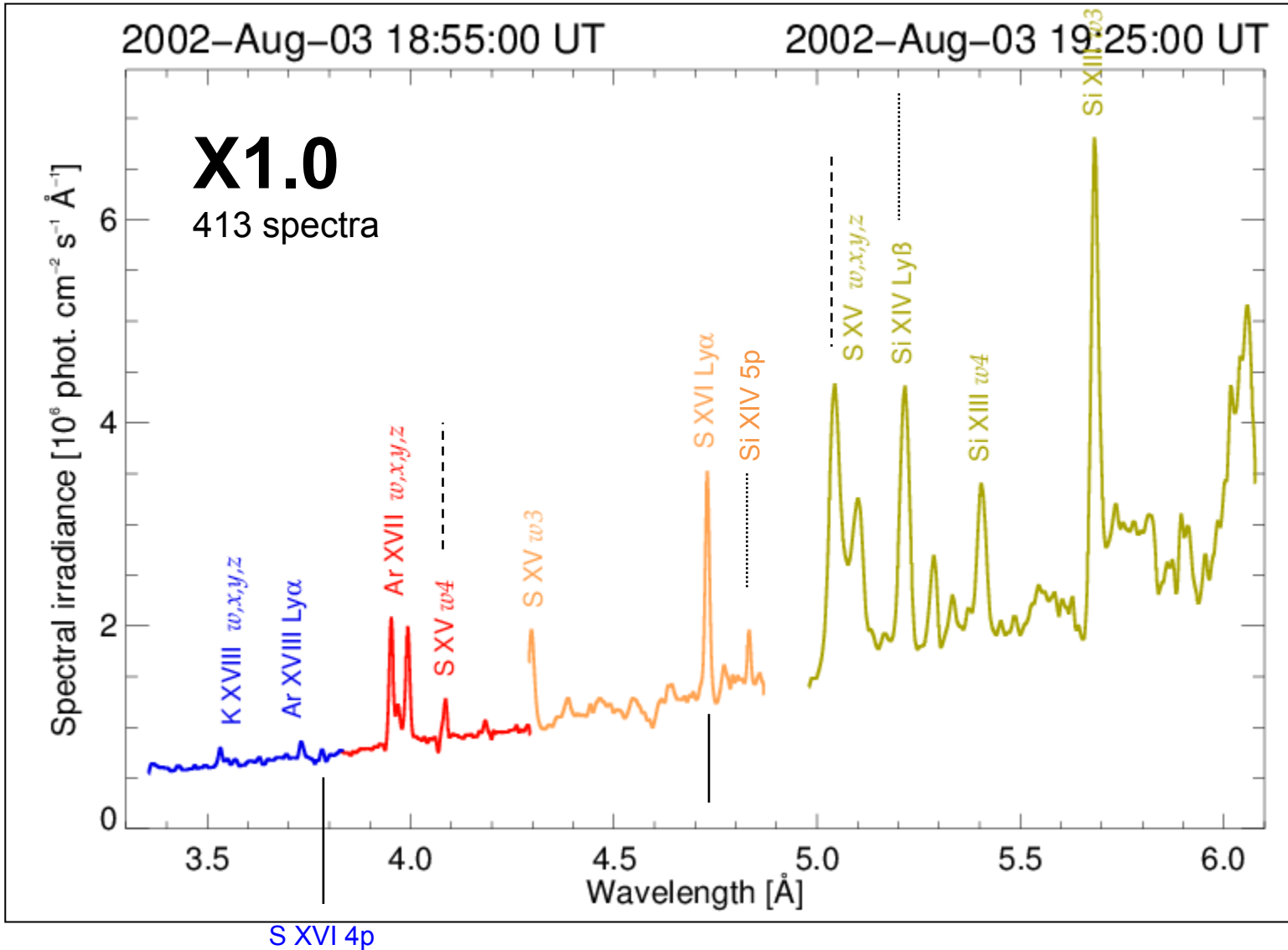
2002/08/03 19:07:00 X1.0 S16W87



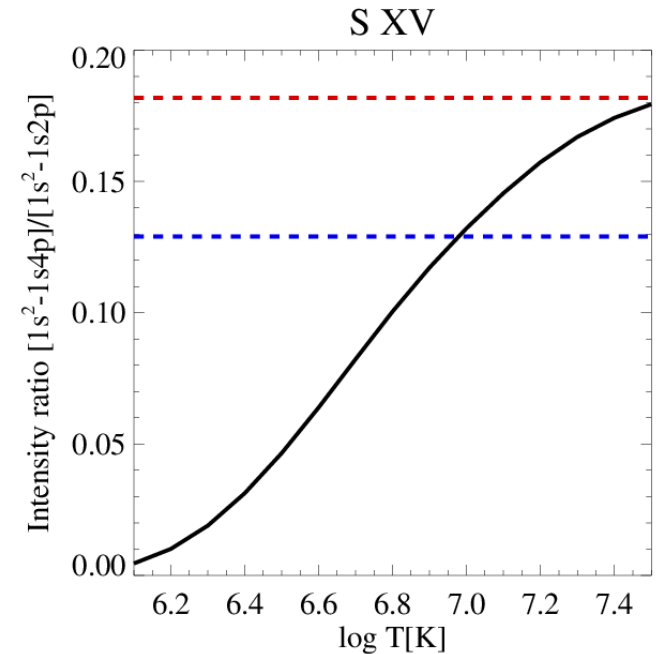
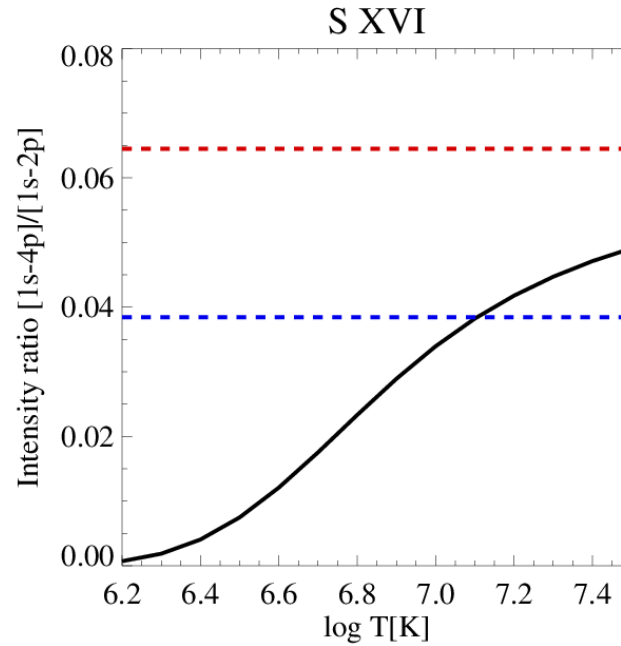
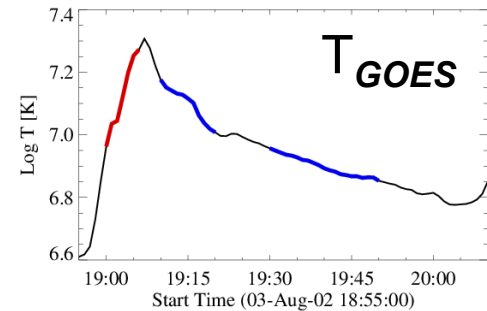
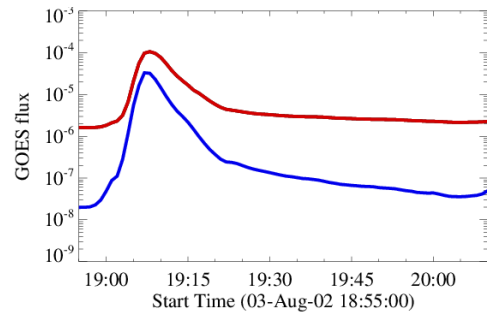
413 RESIK spectra



SOL2002-08-03T19:07



SOL2002-08-03T19:07 for S



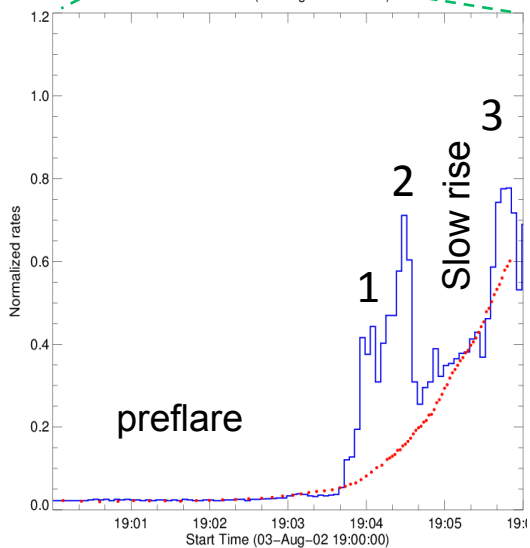
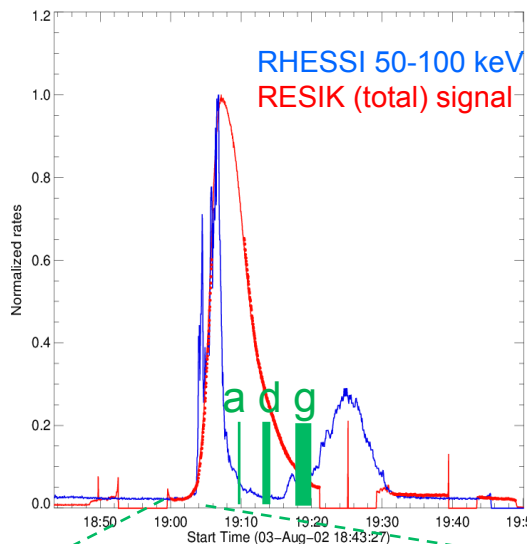
GOES fluxes and corresponding isothermal temperature (preflare fluxes subtracted).

Periods marked in red and blue on the temperature curve correspond to times observed with RESIK.

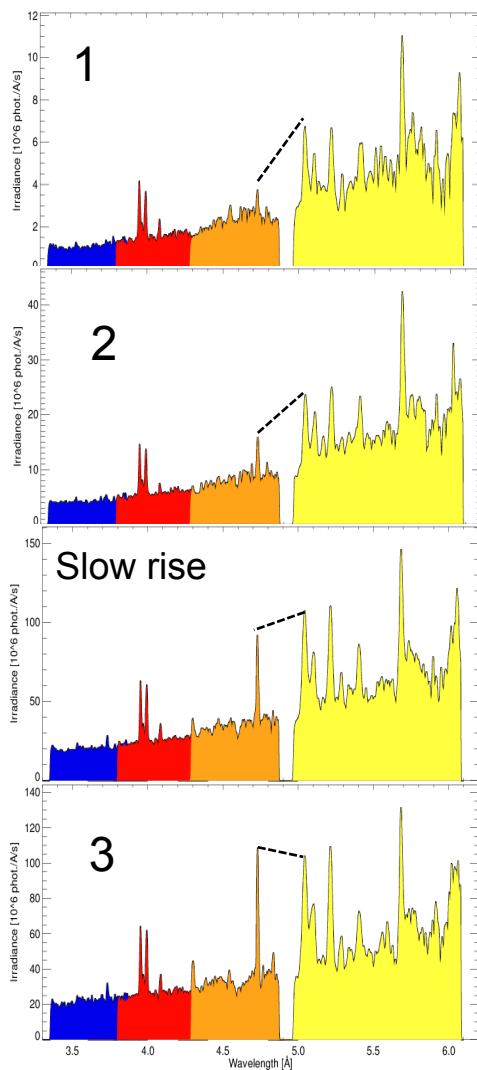
Theoretical intensity ratios have been calculated using CHIANTI 7.0 (**solid black**).

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**).

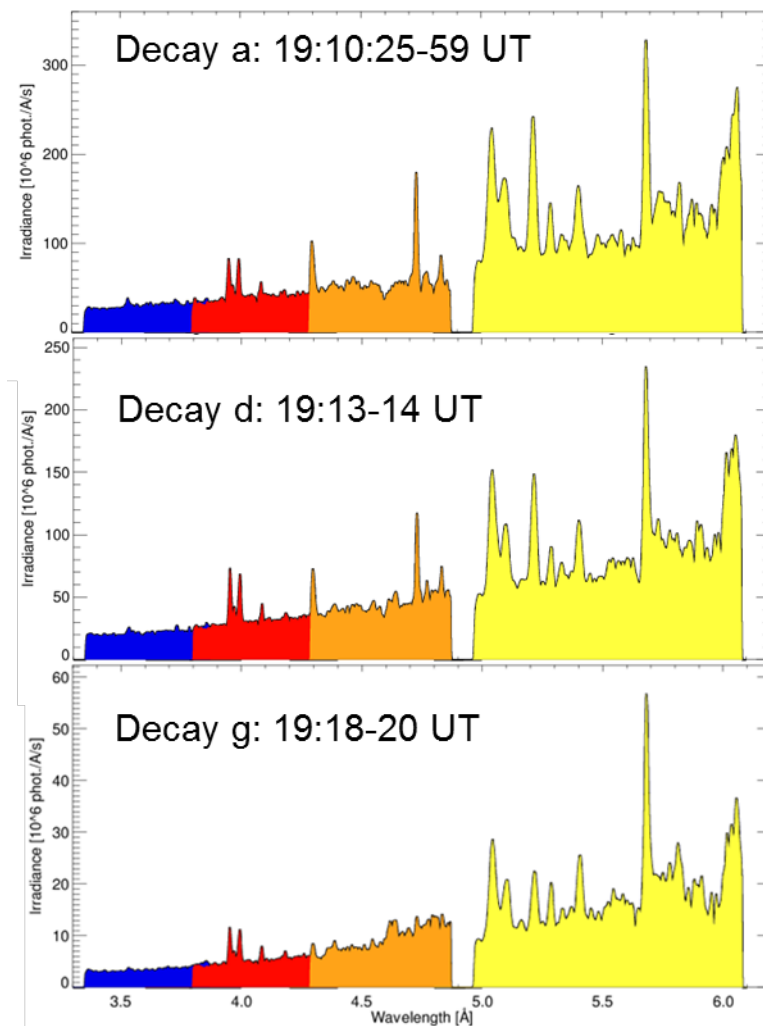
SOL2002-08-03T19:07



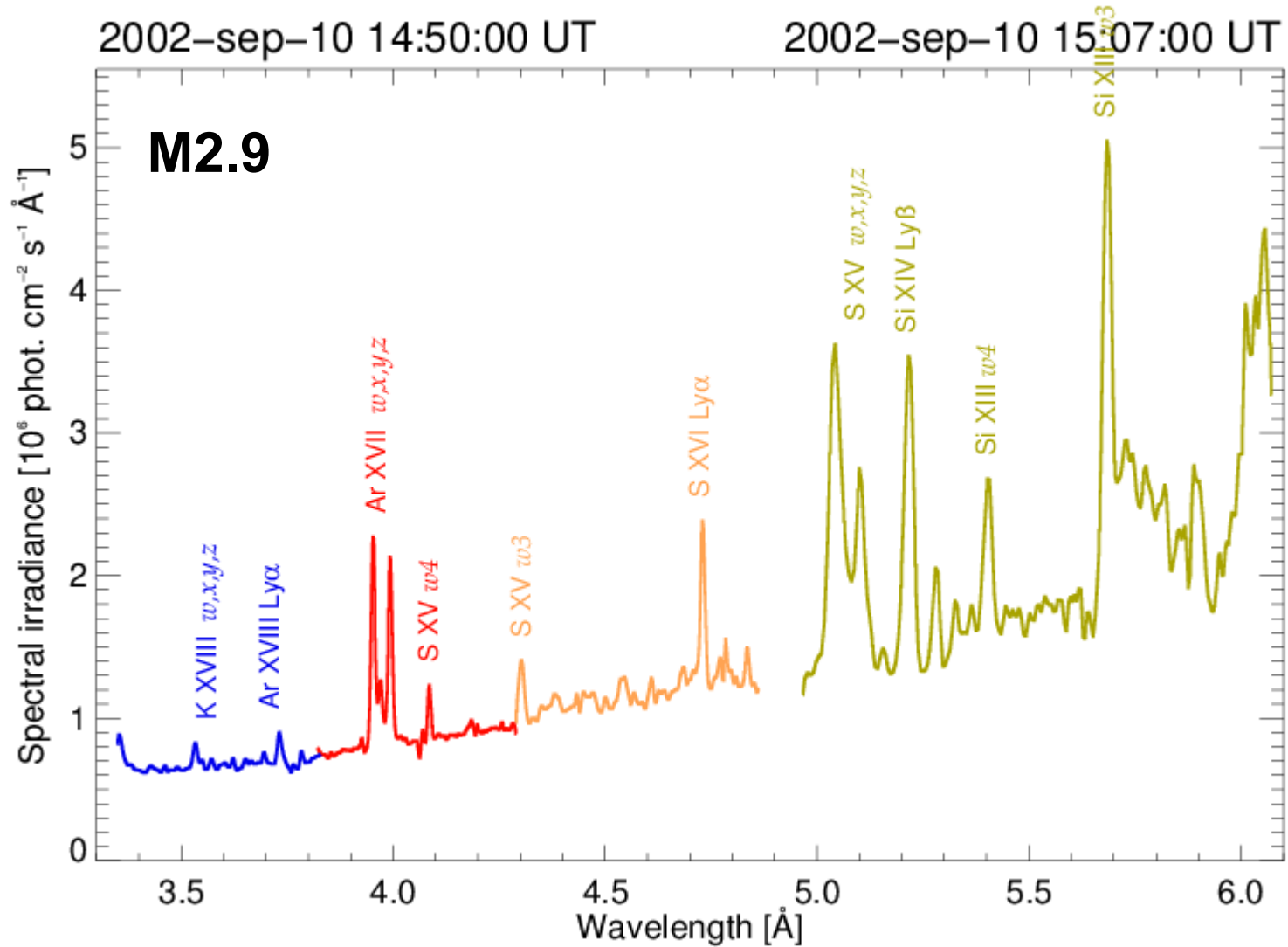
RISE



DECAY

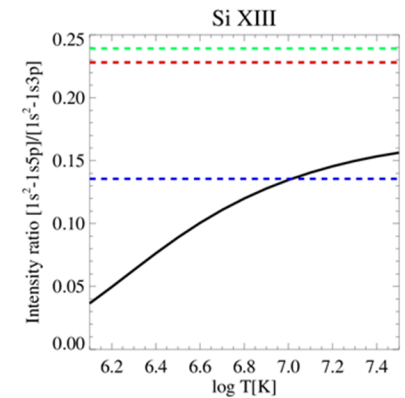
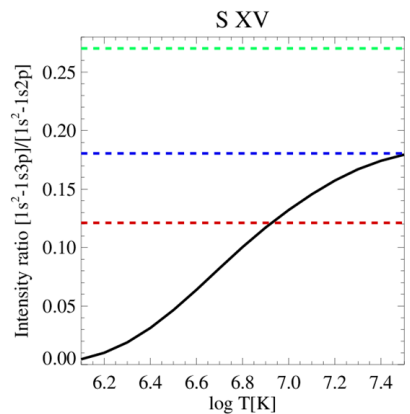
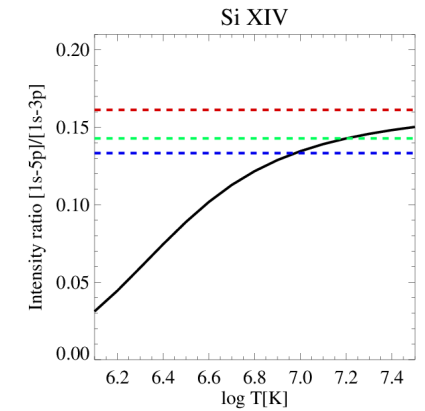
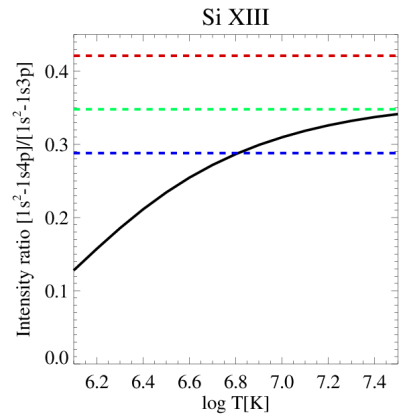
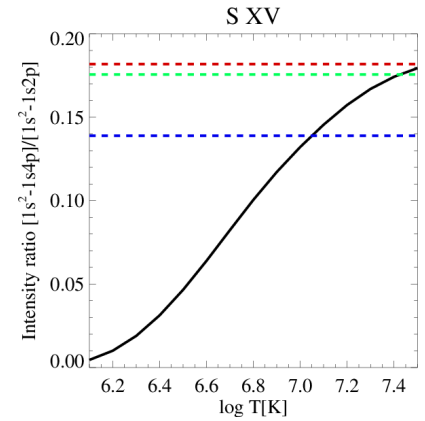
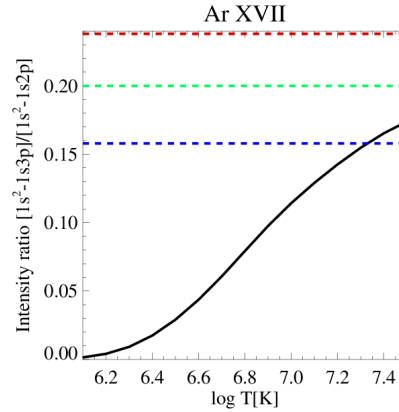
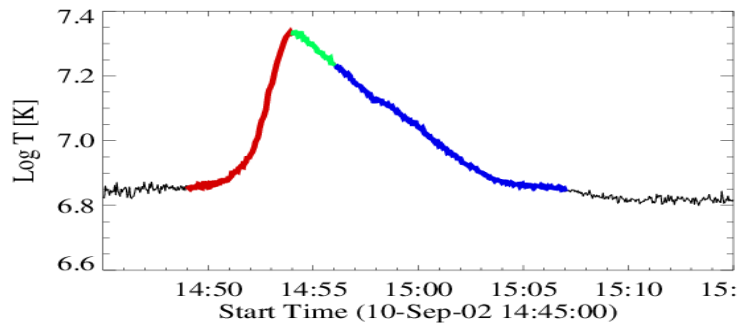
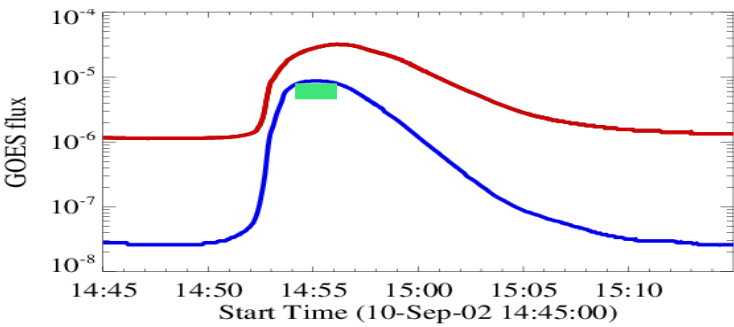


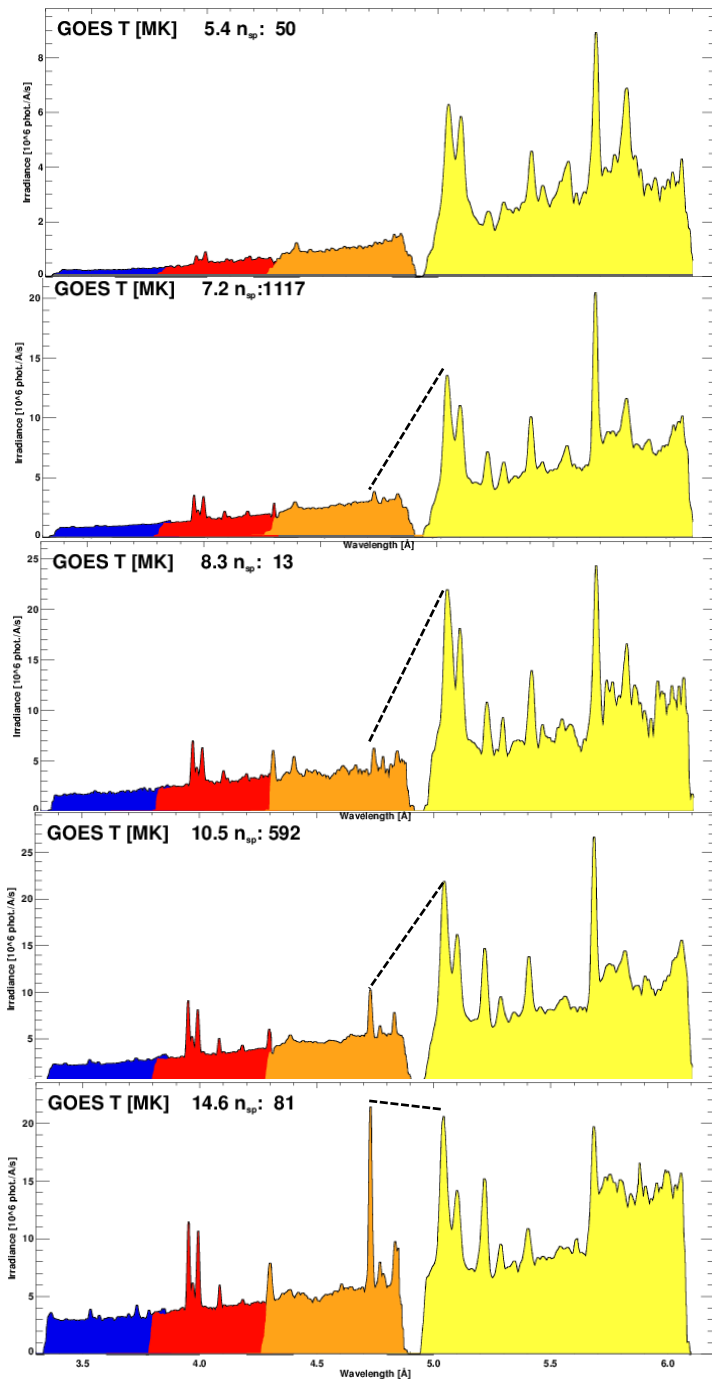
SOL2002-09-10T14:56



SOL2002-09-10T14:56

Strange/unexpected ratios





We selected total of ~ 5500 RESIK spectra & corresponding *GOES* and *RHESSI* data when available.

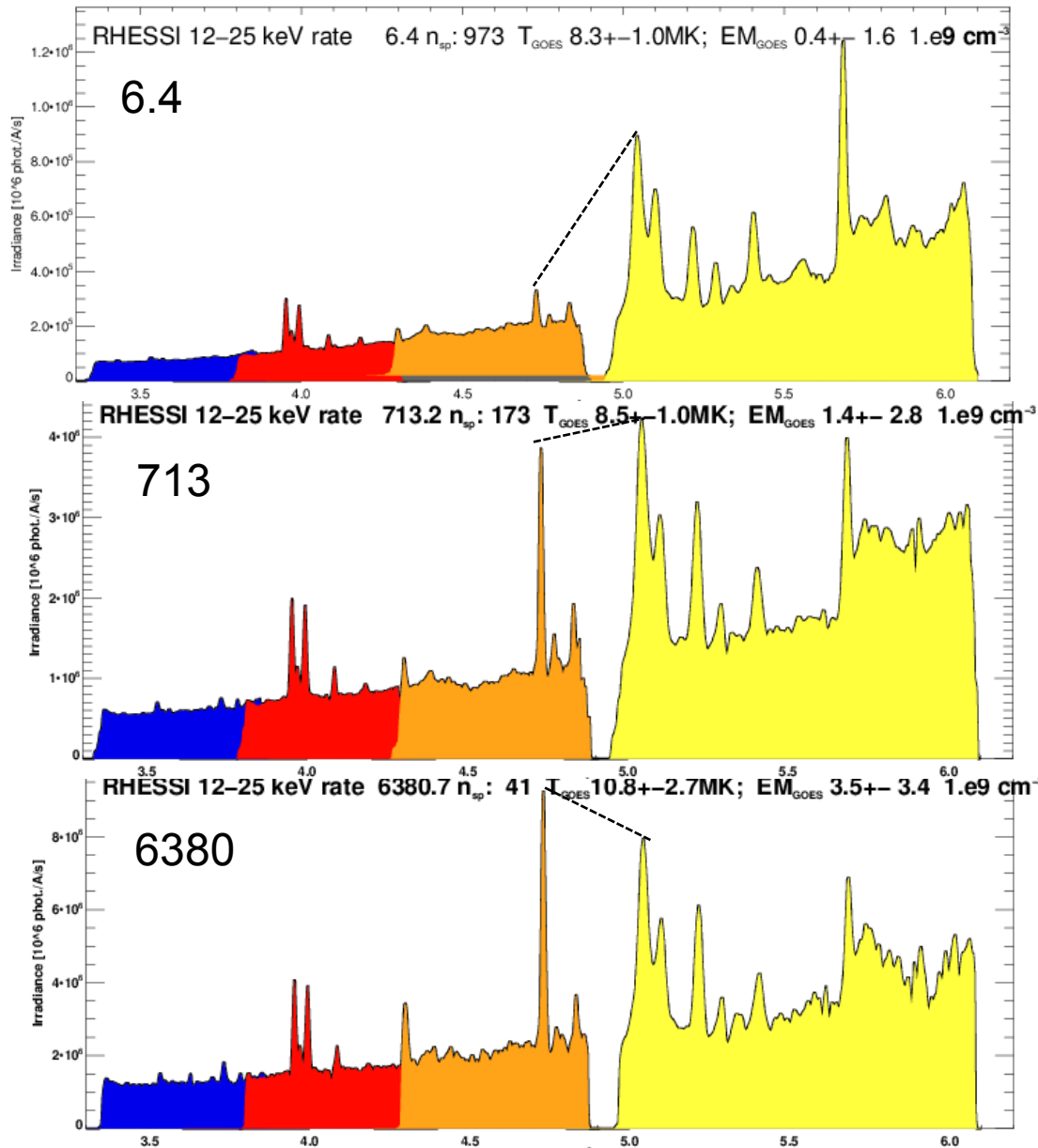
RESIK spectra when *RHESSI* flux in the lowest energy band 3-6 keV is weak (< 5 cts/s) \rightarrow thermal plasma

The rest spectra correspond to >5 cts/s in *RHESSI* 3-6 keV.

RESIK spectra corresponding to the lowest *RHESSI* 3-6 keV flux (<5 cts/s) vs temperature from *GOES*.

We selected spectra corresponding to different temperature intervals and then constructed the averaged spectrum. The resulting averaged *GOES* temperature together with the amount of spectra taken into account are indicated.

RESIK spectra vs intensity of *RHESSI*



Analysis of the rest spectra: they correspond to >5 cts/s in *RHESSI* 3-6 keV.

We grouped them into classes according to the level of flux in *RHESSI* channel 12-25 keV.

The similar *GOES* temperatures can be obtained based on RESIK spectra for different levels of *RHESSI* 12-25 keV fluxes (top and middle panel). However the RESIK spectra differ much.

Flares with very 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

Take home message

- The analysis of flux ratios for high n Rydberg series of hydrogen and helium-like ions of Si, S and Ar have been made for two flares. This should be regarded as the first approximation only and treated with caution as the ratios observed depend very much on the background level subtracted. In the analysis shown this was done „by eye”.
- As a rule one can obtain the reasonable ratios (corresponding to the accepted temperature regime) during the decay phase.
- During the impulsiv phase and/or maximum the observed ratios are higher than theoretical ones leading to the unrealistically high values of plasma temperature.
- RESIK spectra appear to constitute a good database for the analysis of non-equilibrium conditions of the flaring plasma.