eHeroes activity

Review of RESIK X-ray spectra database

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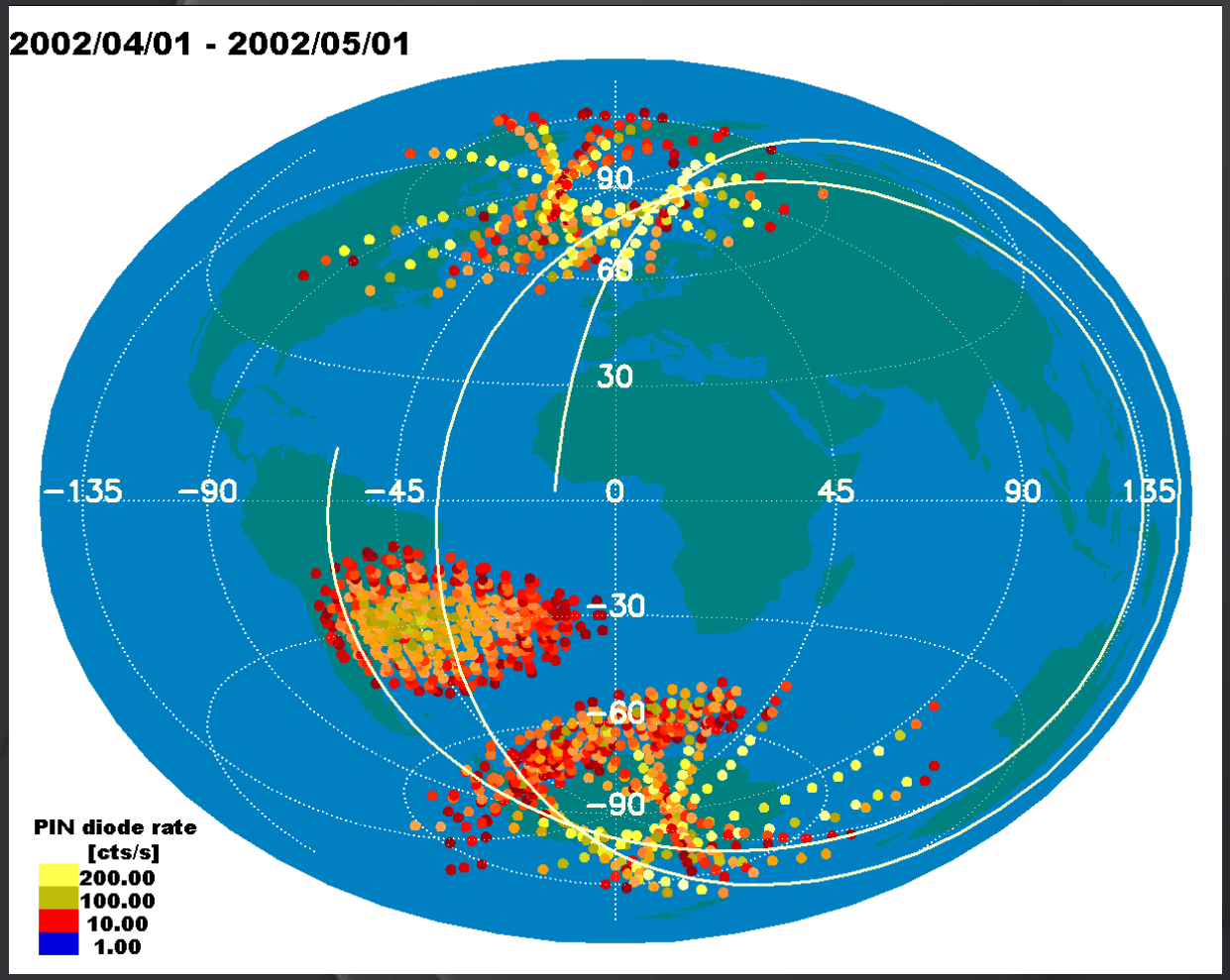
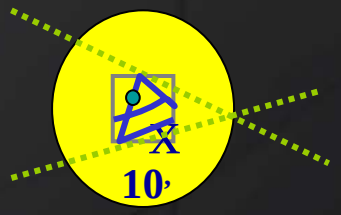
Space Research Centre, PAS
Wrocław

the XIIth Hvar Astrophysical Colloqium September 3 -7, 2012 the 40th anniversary of Hvar Observatory

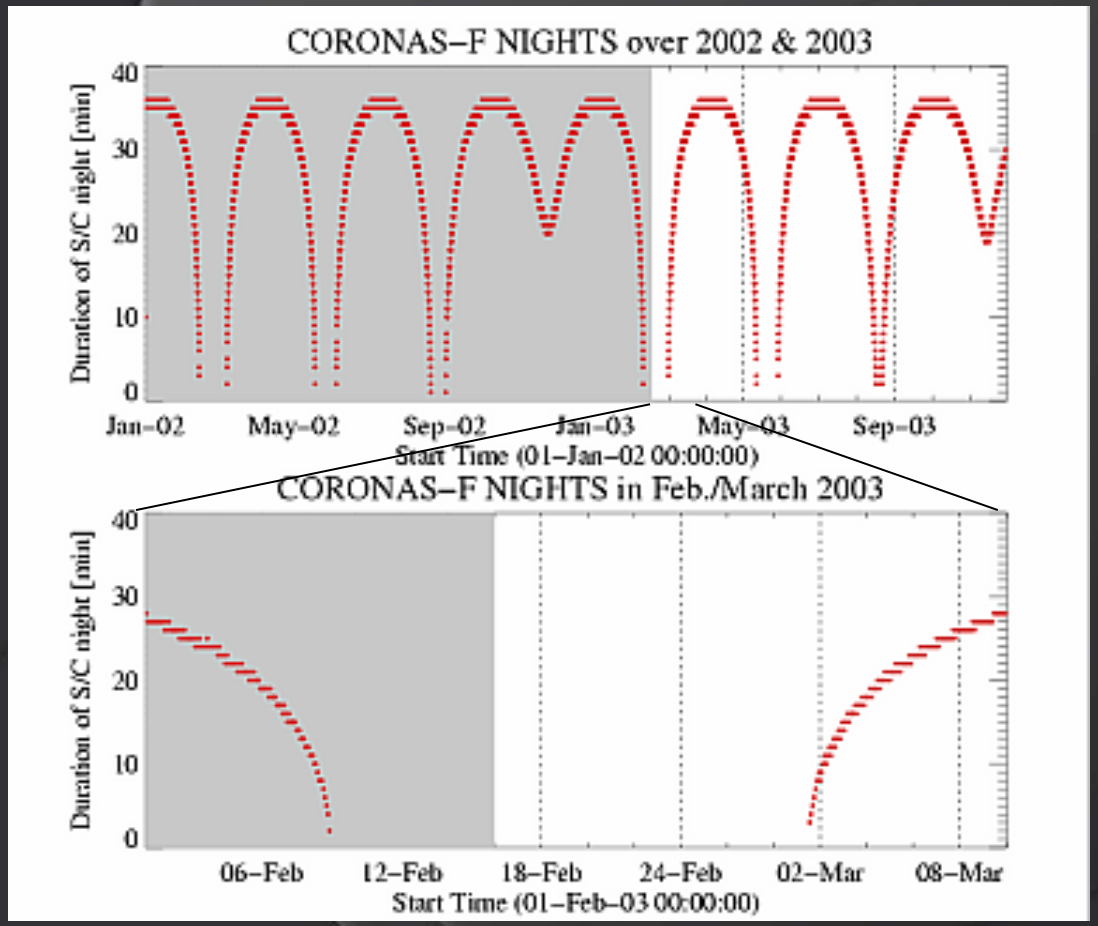
RESIK operated aboard CORONAS-F Russian satellite



Launched 31 July 2001,
polar orbit, 95min, ~550 km
semi-Sun-synchronous

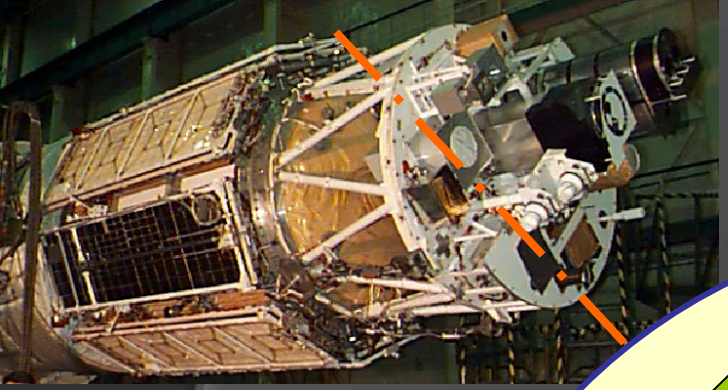


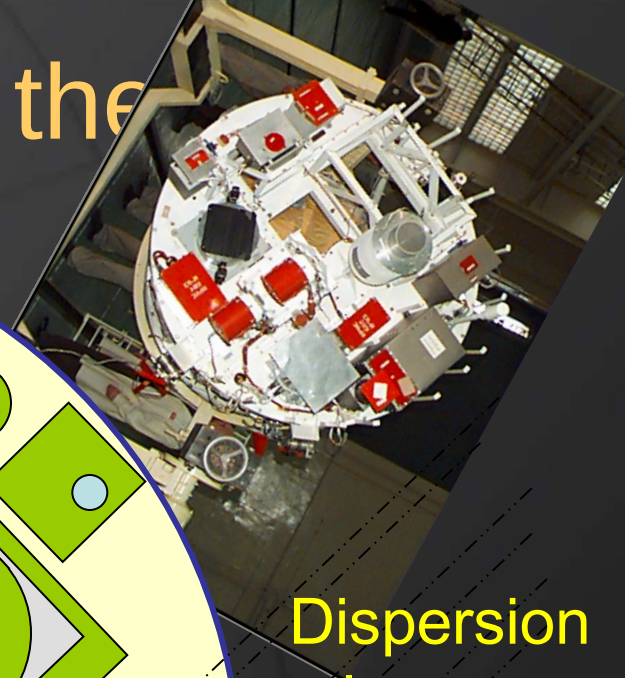
S/C nights & days



polar Sun-synchronous orbit
for most of the time nights interrupt the observations, but detectors were on
Except the high background particles regions

Position on the





complicated wignietting pattern

Dispersion planes

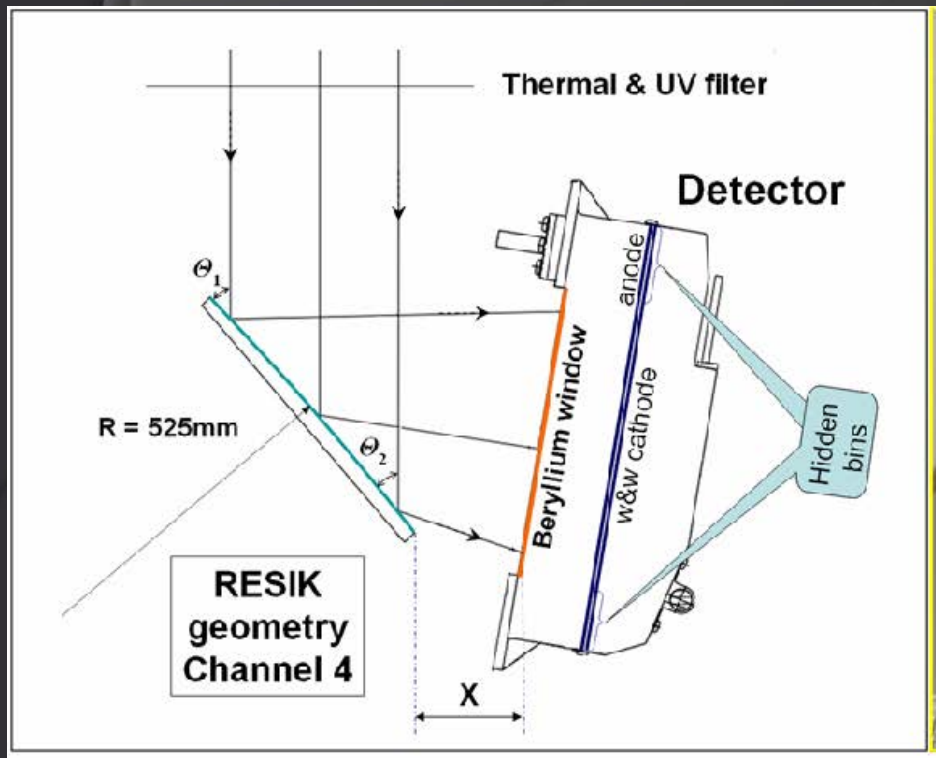
RESIK

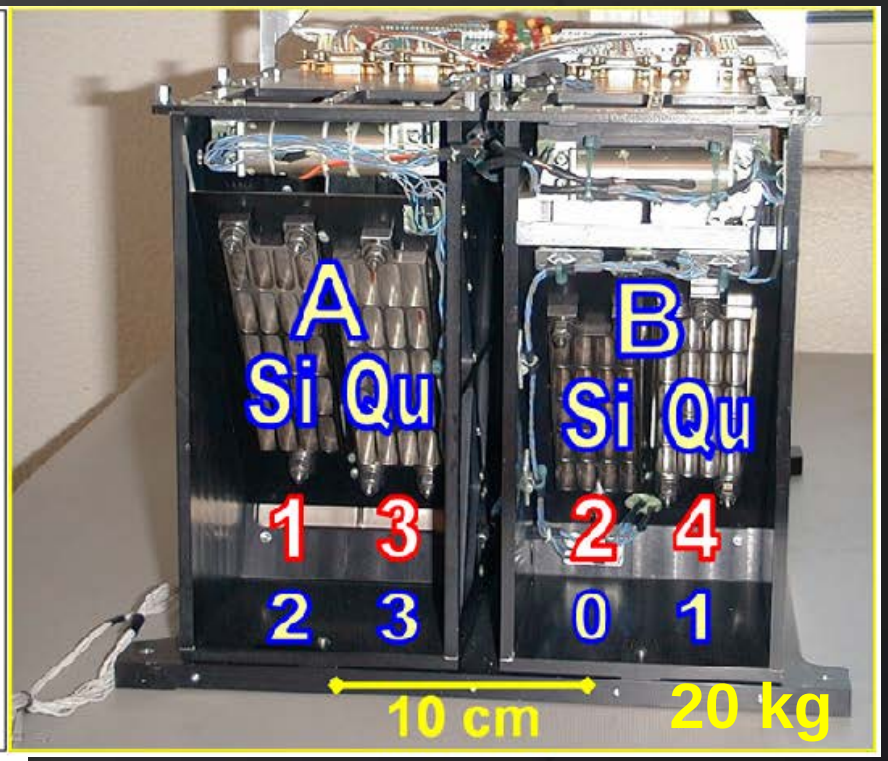
Рентгеновский Спектрометр с Изогнутыми Кристаллами

Bragg law: $k\lambda = 2d \sin\Theta$

RESIK is the lowest fluorescence spectrometer

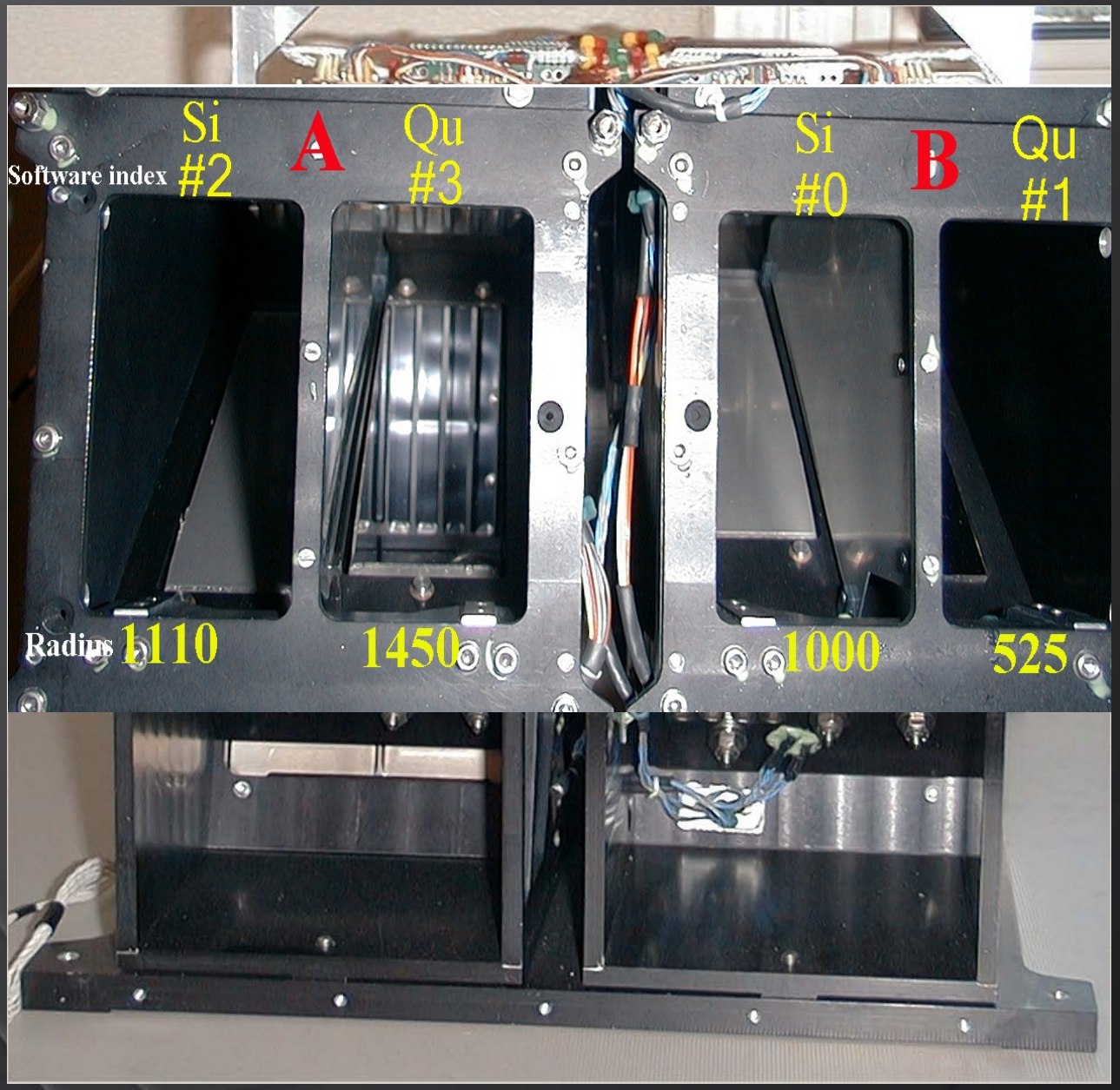
Measures spectra in the range: ~ **3.3 Å ÷ 6.1 Å**, **instantaneously in all λ**



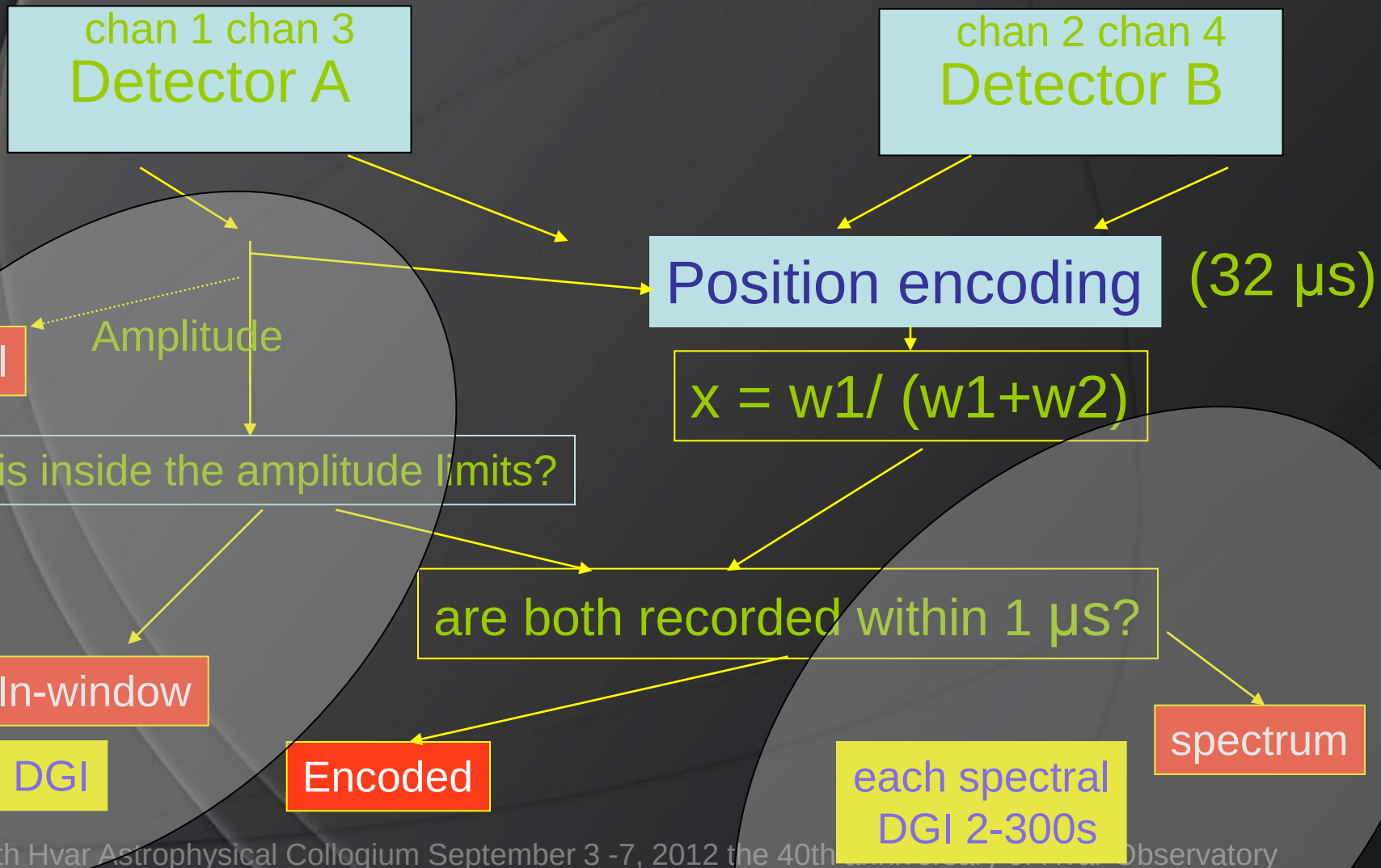


UCL MSSL · CLRC · NRL · POLISH ACADEMY OF SCIENCES SPACE RESEARCH CENTRE · IZMIRAN

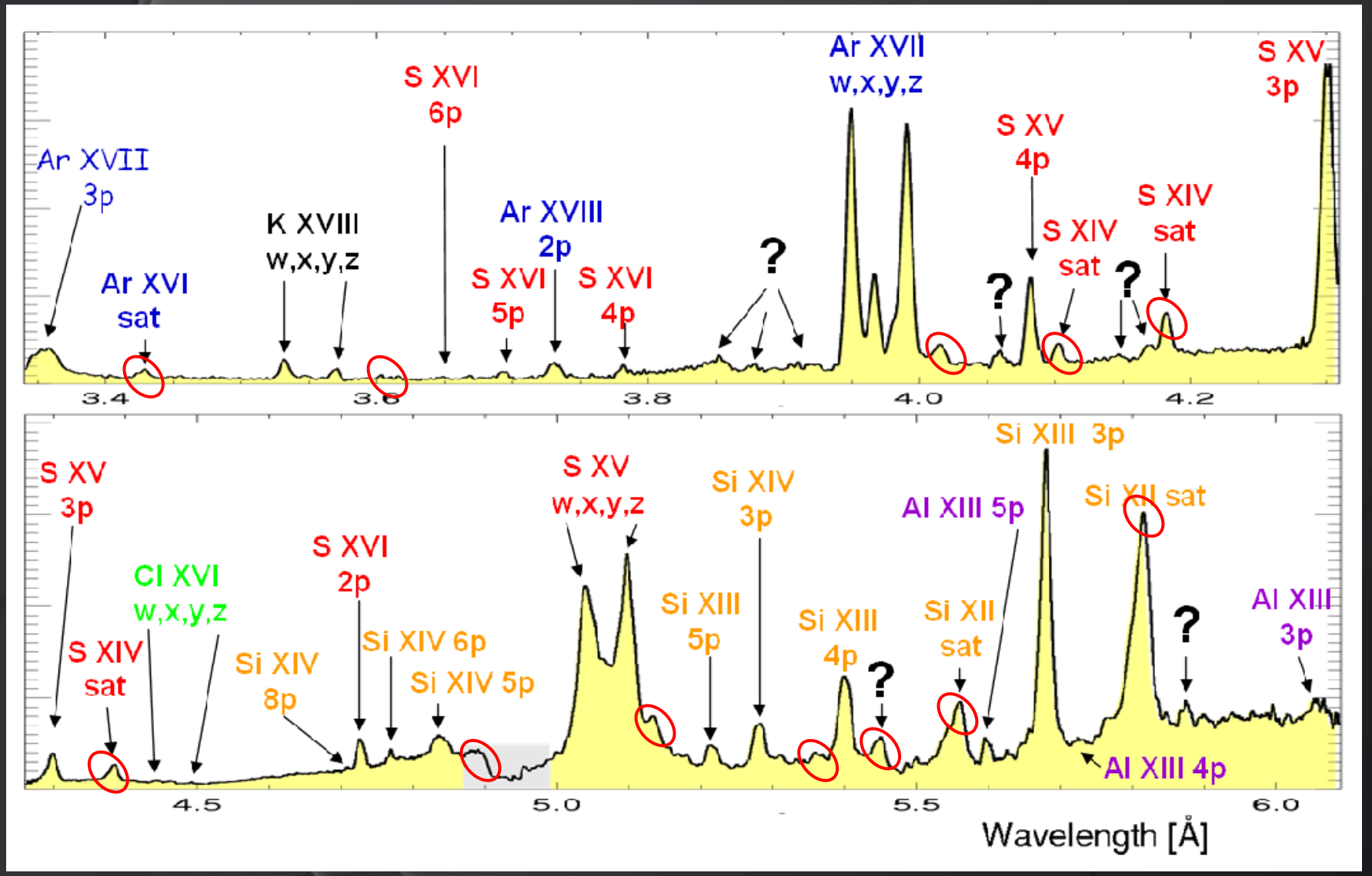
Key people: **Len Culhane, George Doschek**
V.D. Kuznetsov, Jim Lang, R.D. Bentley


Si
#2
A
Qu
#3
Si
#0
B
Qu
#1
Software index
Radius
1110
1450
1000
525

Processing the signal from detectors



Identification of new satellite lines



The database:

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

RESIK data - level 2

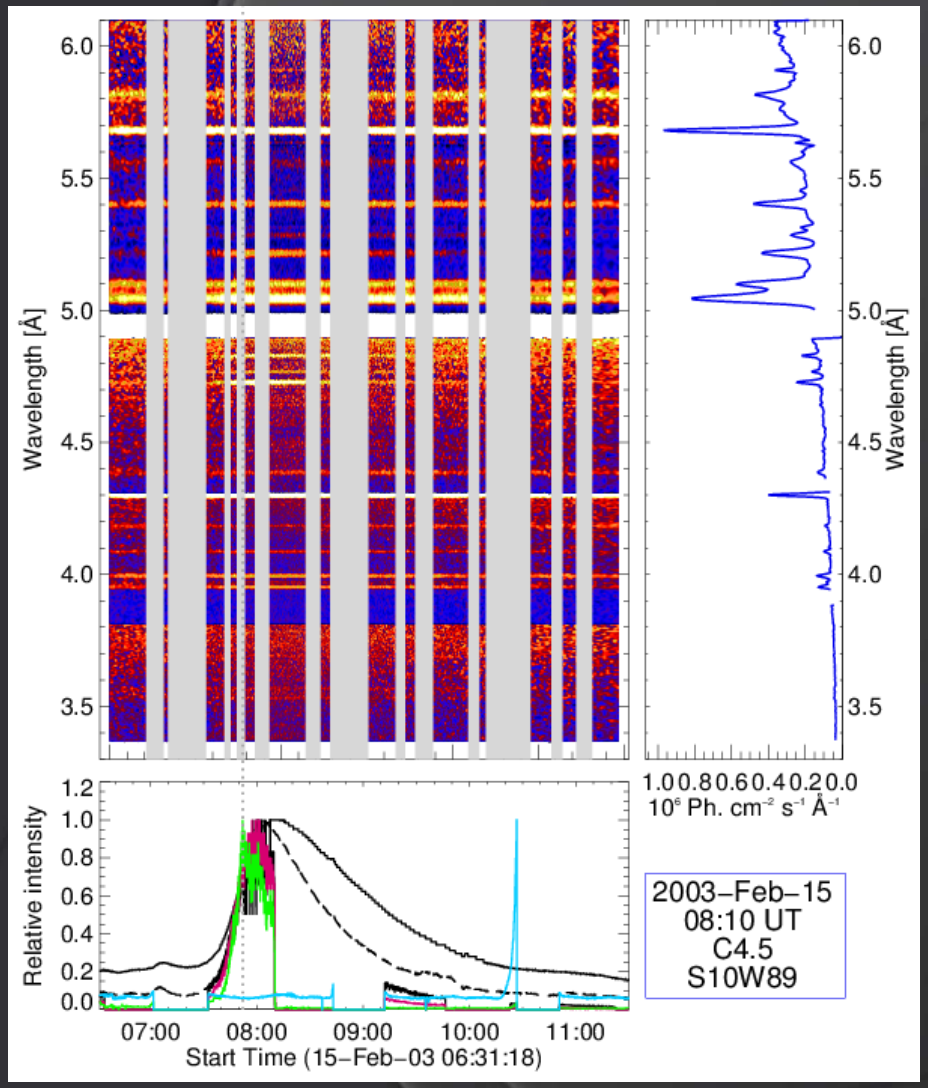
README

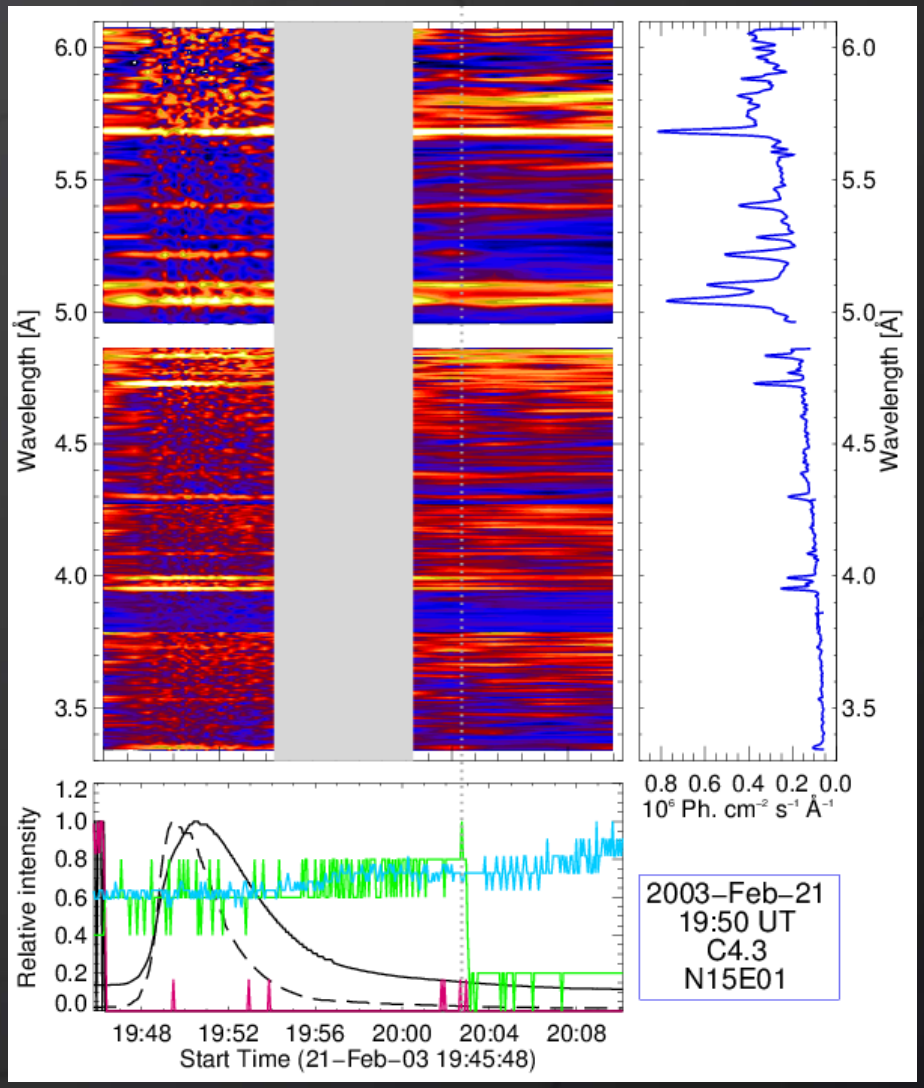
resik_read_fits_fast.pro - program for reading RESIK fits files (8 kB)

Date	GOES class	Location	Date file created
15 April 2002 (max ~ 03:55 UT)	M1.2	S15W01	9 Dec. 2010
26 July 2002 (max ~ 18:29 UT)	C9.5	S22E17	13 Mar. 2012
3 August 2002 (max ~ 19:07 UT)	X1.0	S16W87	4 Jun. 2008
10 September 2002 (max ~ 14:56 UT)	M2.9	S10E43	24 Apr. 2008
20 September 2002 (max ~ 09:28 UT)	M1.8	S24E75	12 Apr. 2012
29 September 2002 (max ~ 06:39 UT)	M2.6	N10E20	20 Mar. 2008
04 October 2002 (max ~ 05:38 UT)	M4.0	S19W09	22 Mar. 2008
12 November 2002 (max ~ 07:49 UT)	C5.3	S12W66	24 Nov. 2009

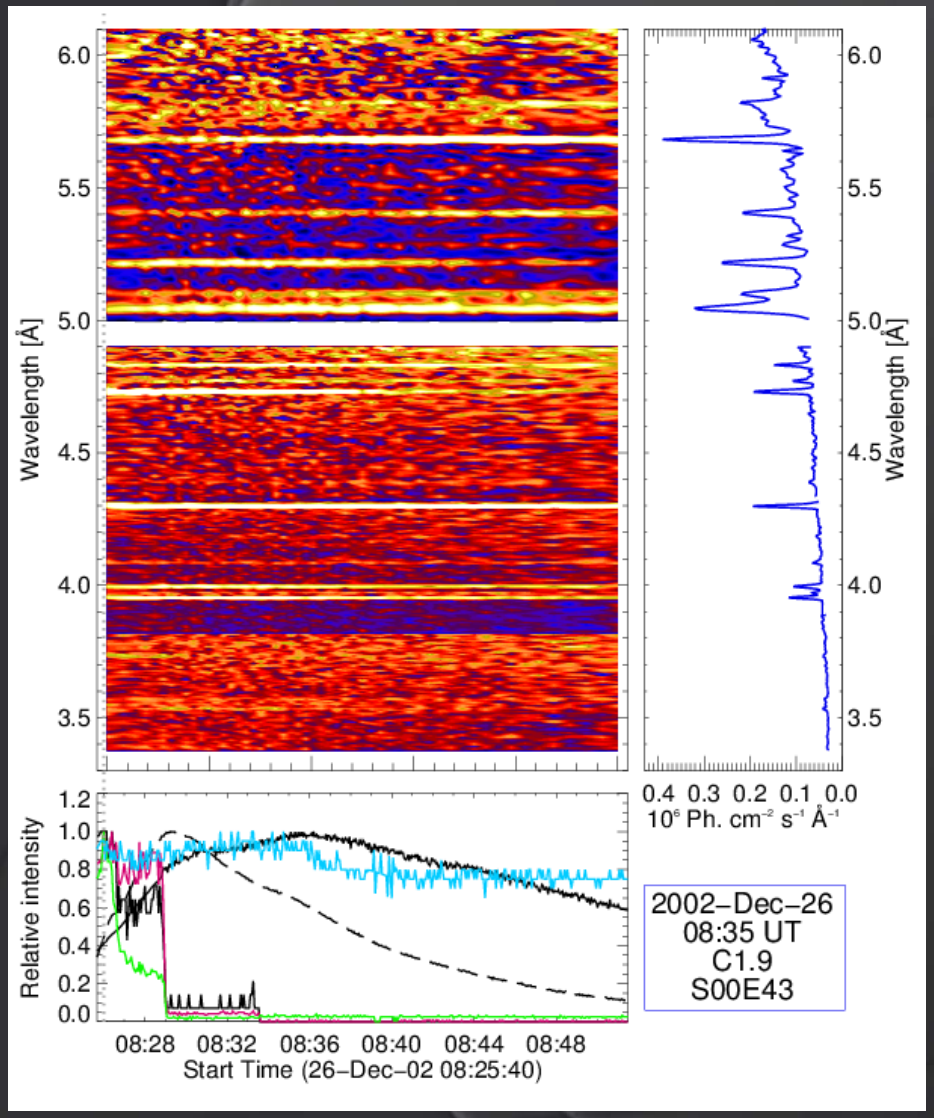
30 flares, ~4000 spectra, AR: ~300 spectra

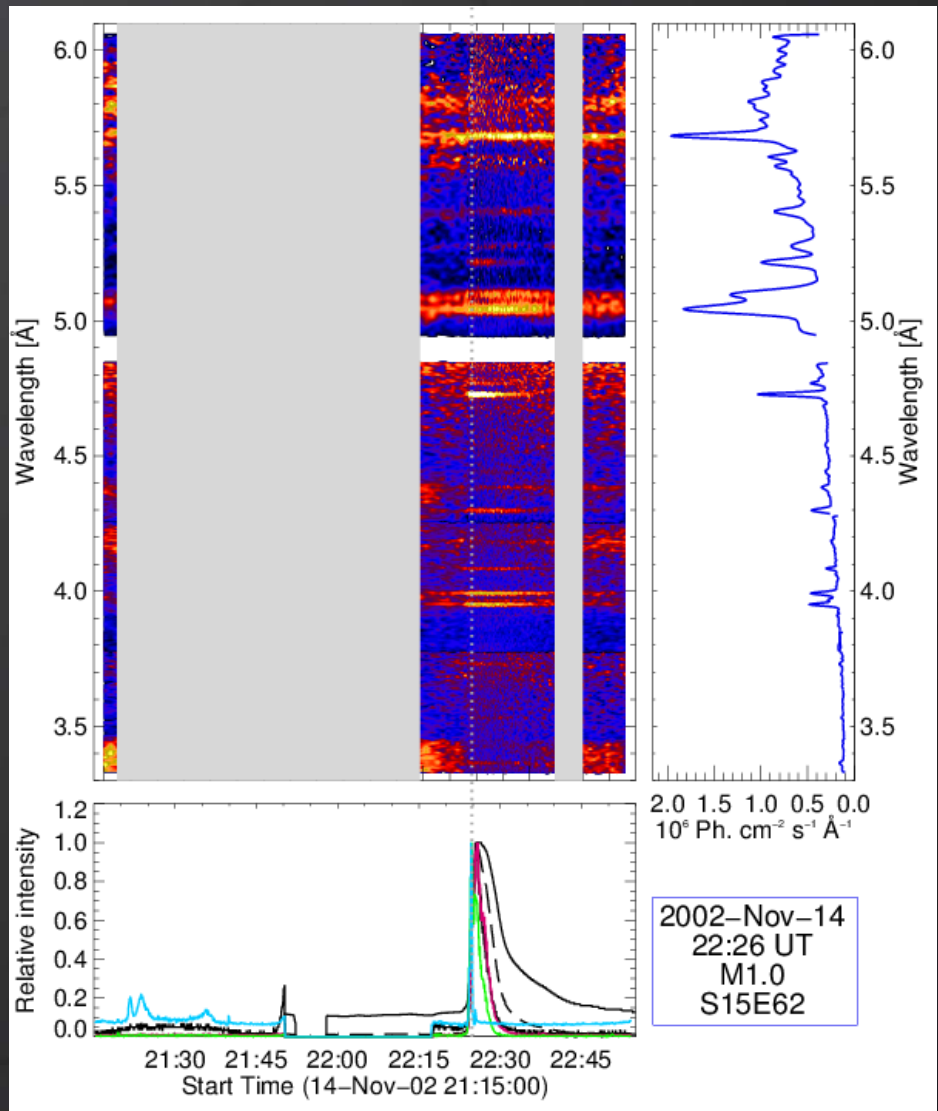
Example summary plots





Example summary plots





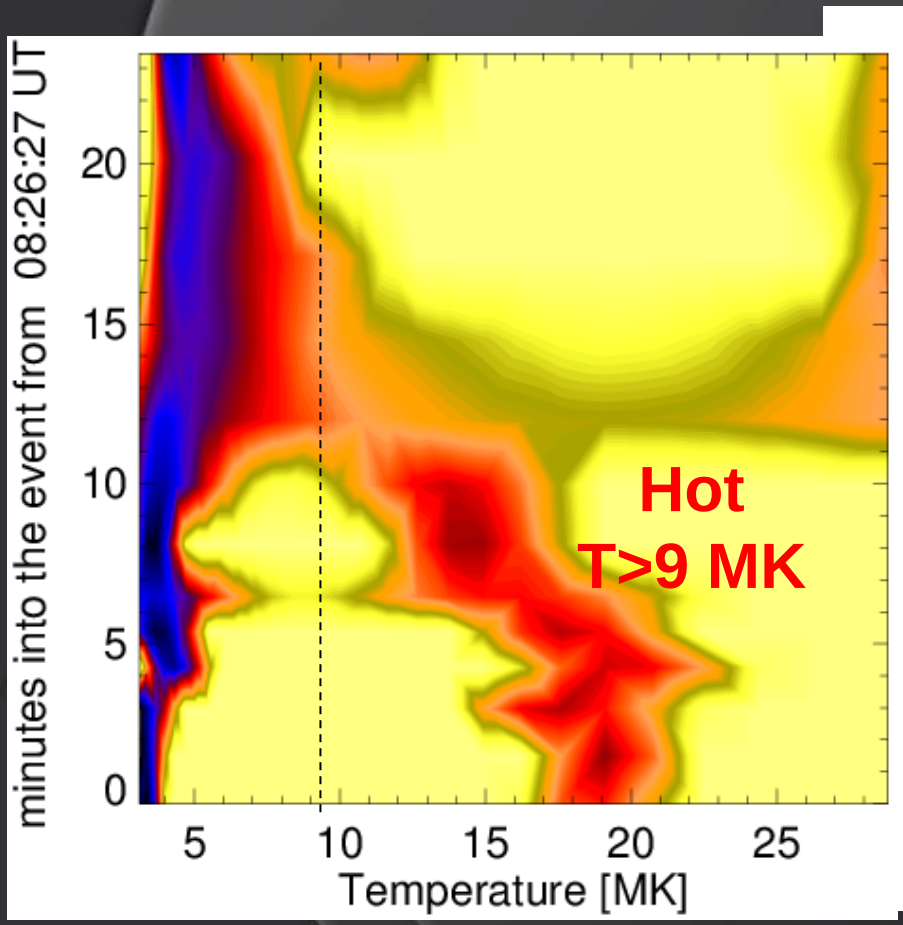
RESIK average abundances compared with other determinations

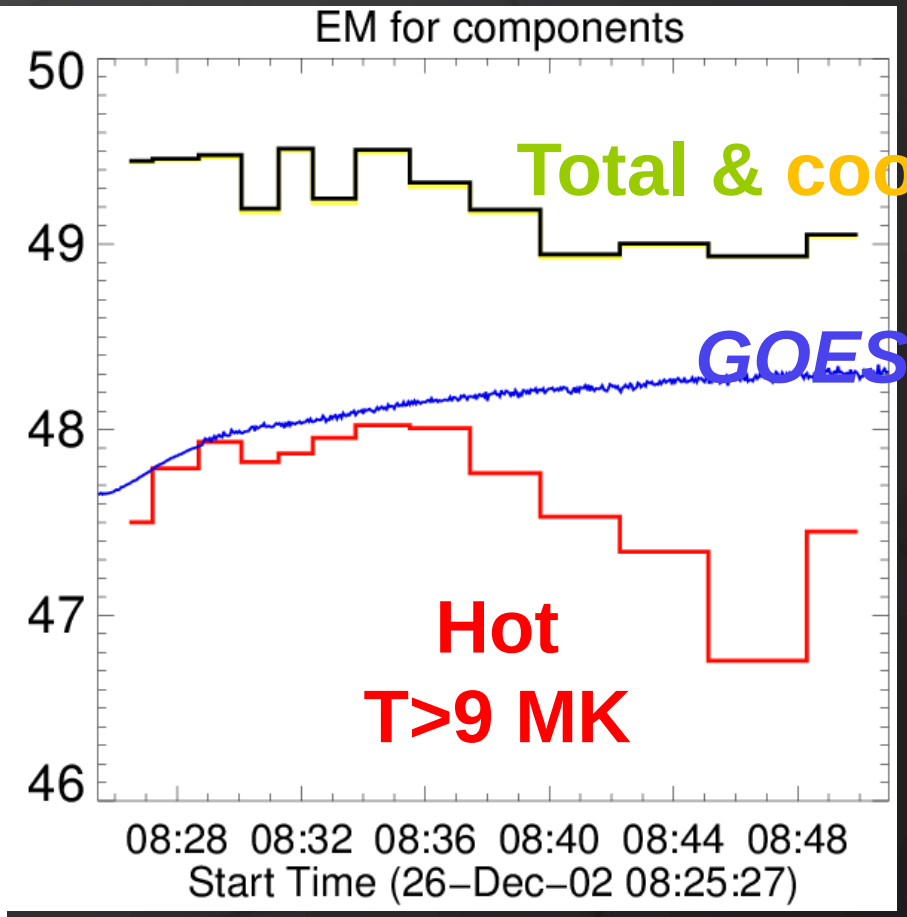
Element & FIP eV	$A_{phot.}$	$A_{coronal}$	A_{RESIK}	References
K 4.34	5.03 ± 0.09	5.67	**5.86 ± 0.20**	ApJ, 710, 2010
Ar 15.76	6.40 ± 0.13*	6.58	**6.45 ± 0.07**	ApJ, 720, 2010
Cl 12.97	5.50 ± 0.30	5.50	**5.75 ± 0.26**	ApJ, 738, 2011
S 10.36	7.12 ± 0.03	7.27	**7.16 ± 0.17**	ApJ, 751, 2012
Si 8.15	7.51 ± 0.09	8.10	**7.91 ± 0.15**	Sol. Phys., submitted

$A_{phot.}$ from Asplund et al. Ann. Rev. Astron. Astrophys. 2009. 47:481–522,
$A_{coronal}$ from CHIANTI, extended coronal, mostly Feldman, U., Mandelbaum, P., Seely, J.L., Doschek, G.A., Gursky H., 1992, ApJSS, 81, 387

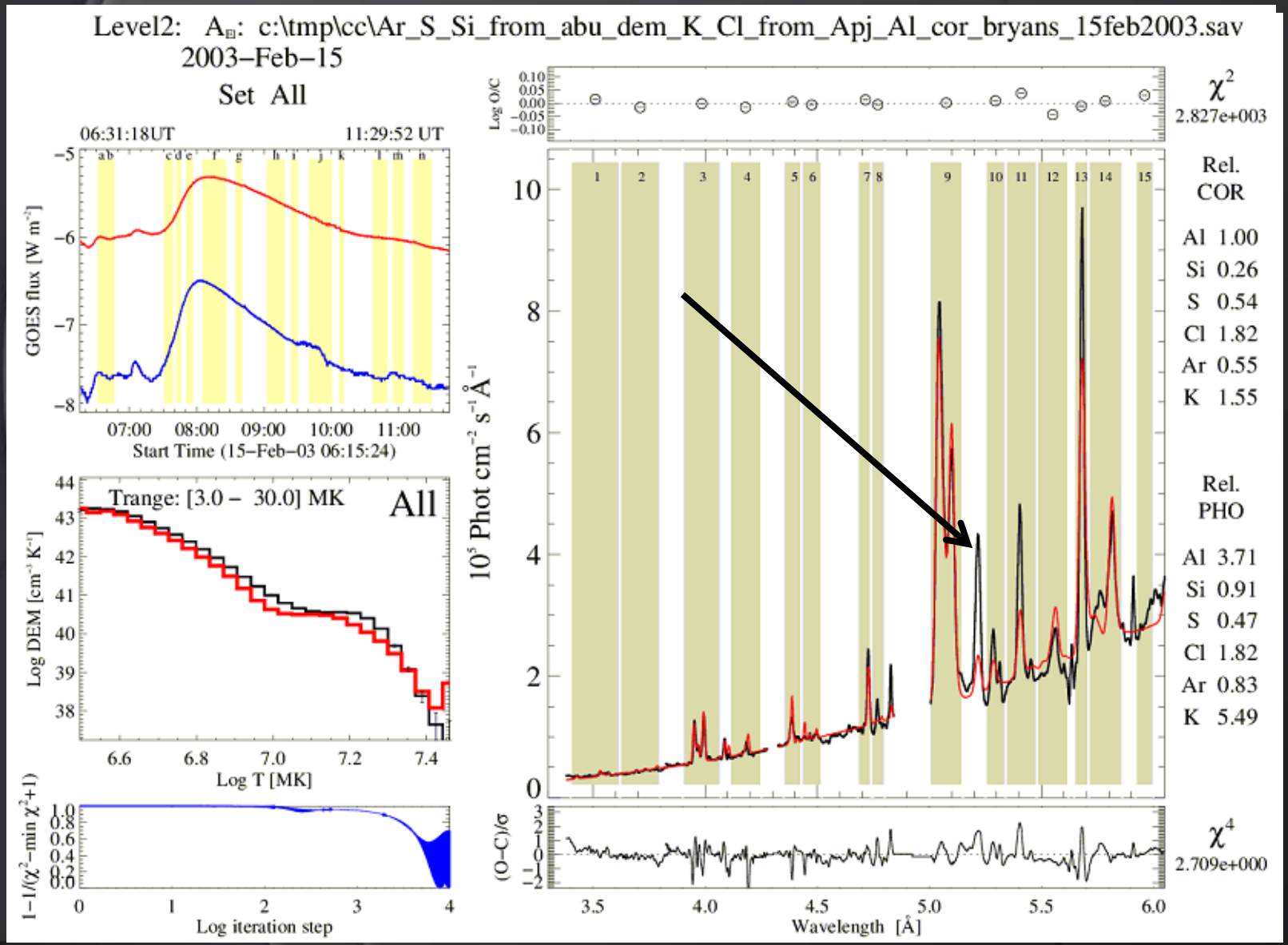
* from proxies

DEM evolution for SOL2002-12-26T08:30
Barbara, Tomek Mrozek

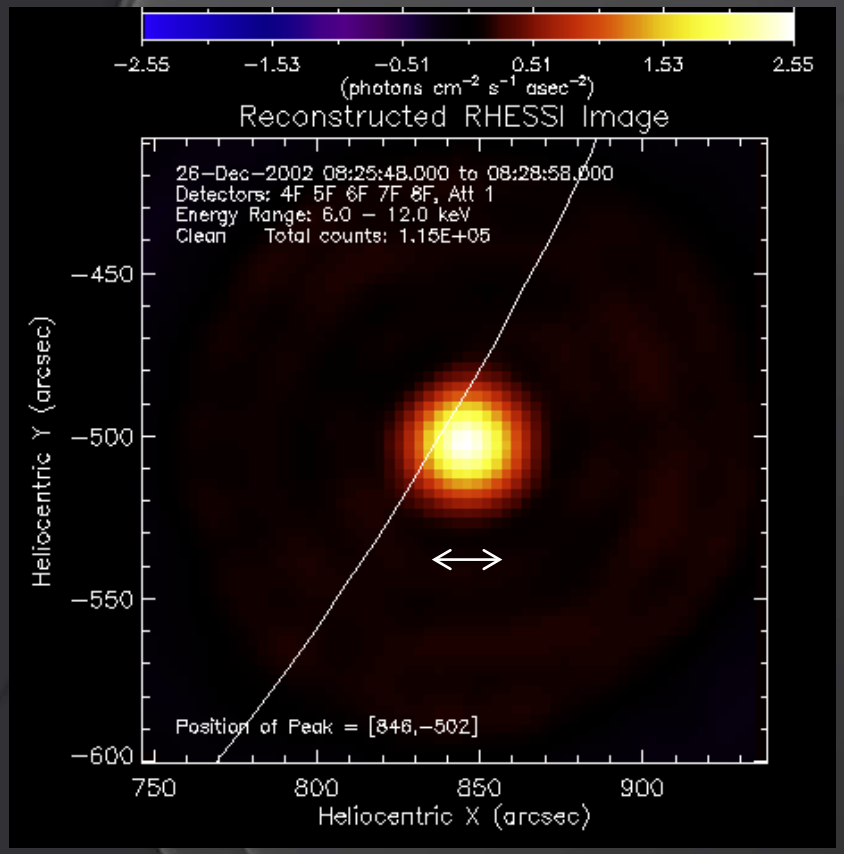


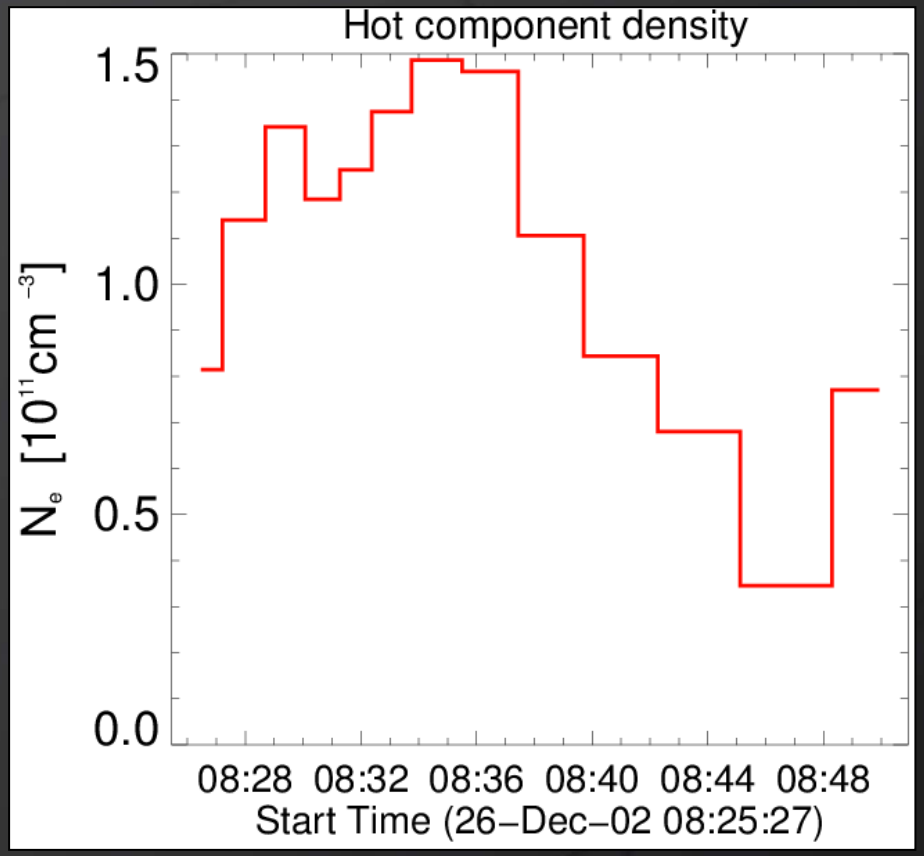


Fitting the spectra in DEM



RHESSI for SOL2002-12-26T08:30

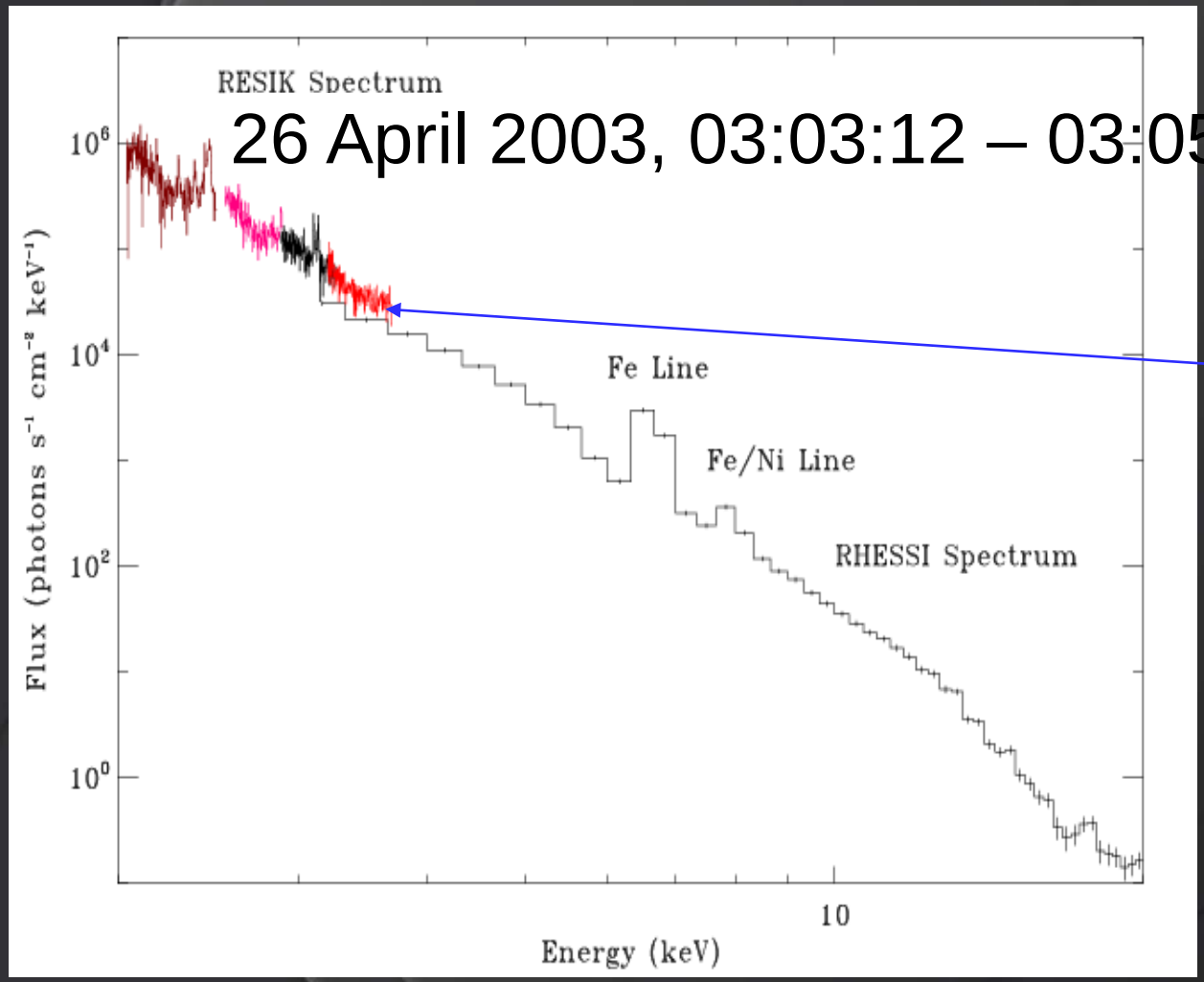




D=4.5 x 10^8 cm

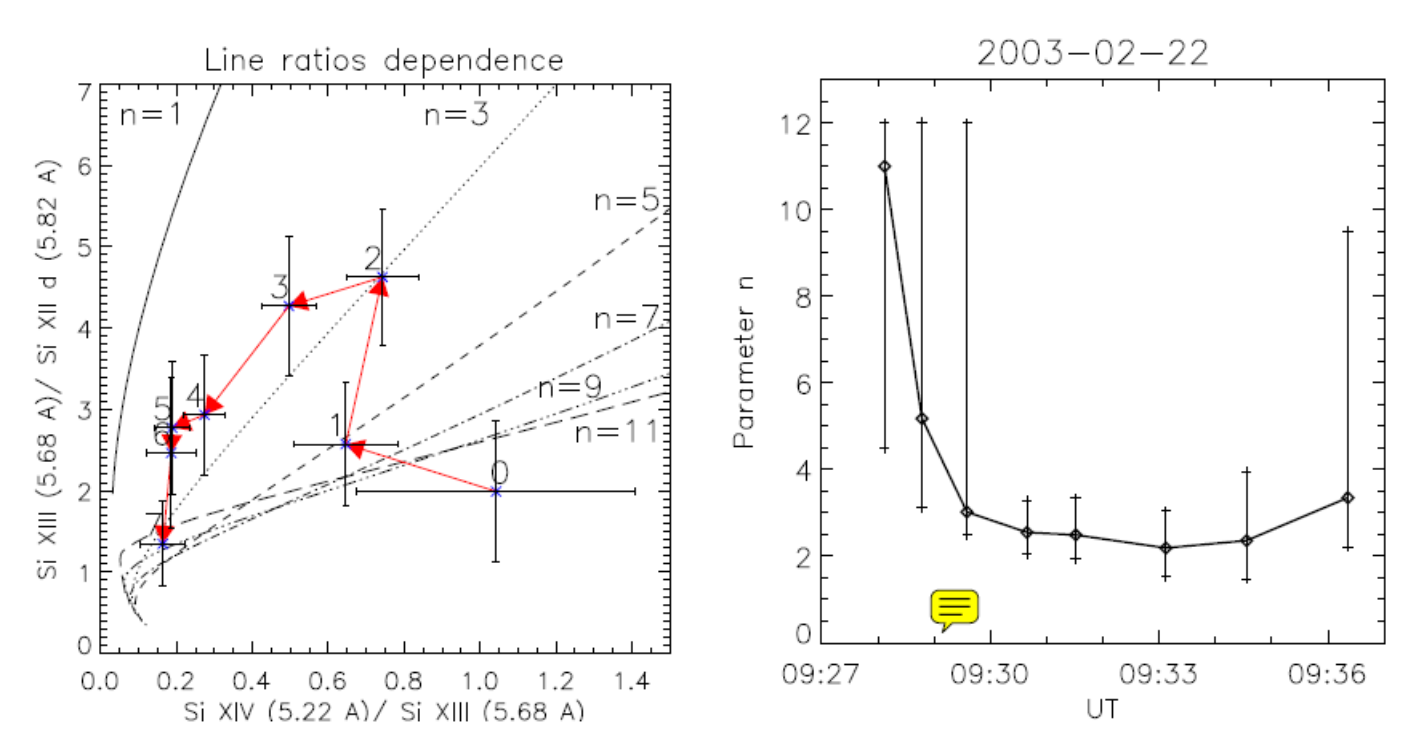
If we consider the total EM of the hot component to be contained in the RHESSI bright kernel, this allows for the estimatation of the **density** of hot plasma.

RESIK & RHESSI



Without attenuators acceptable agreement

Diagnostics of non-thermal distributions Elena, Alena



The nonthermal analysis of RESIK spectra has shown that the largest deviations of the plasma electron distribution from Maxwellian appeared during the impulsive phase of the flare. The decay phase spectra had an almost isothermal character..

The heritage - ADS title:RESIK

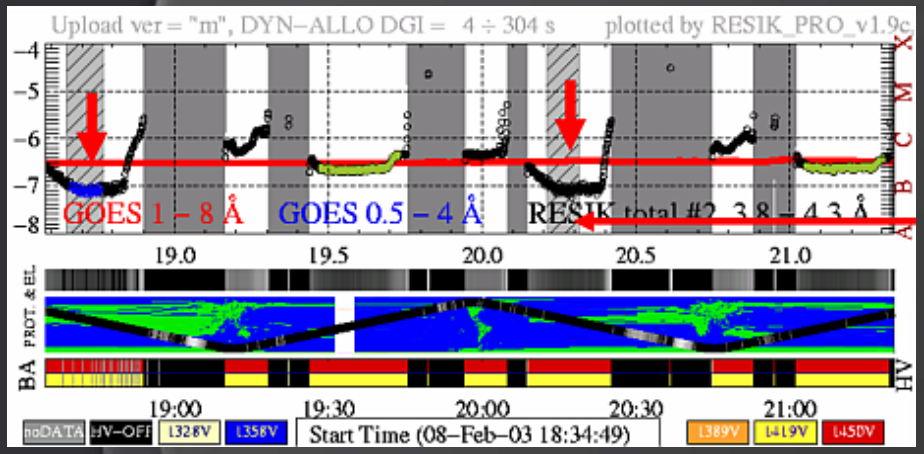
Selected and retrieved **37** abstracts. Total citations: **90**

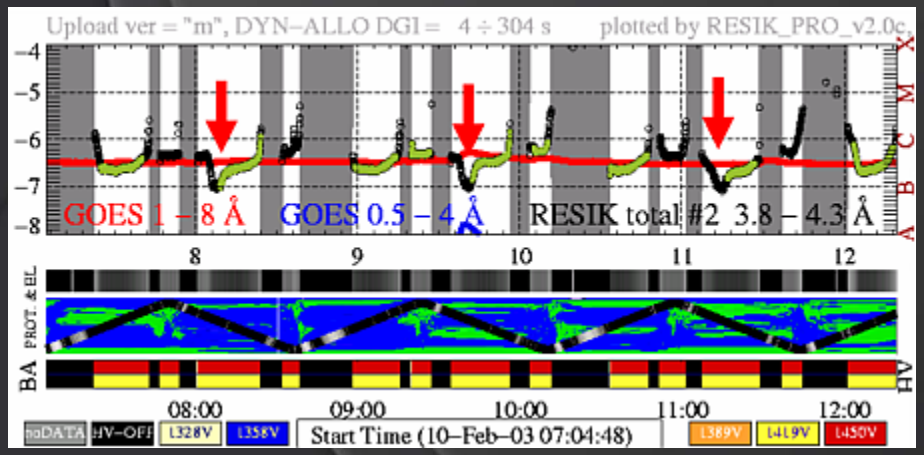
#	Bibcode Authors	Cites Title	Date	List of Links Access Control Help
1	2010A&A...514A..82S Sylwester, B.; Sylwester, J.; Phillips, K. J. H.	12.000 Soft X-ray coronal spectra at low activity levels observed by RESIK	05/2010	A E F X R C U
2	2007A&A...462..323C Chifor, C.; Del Zanna, G.; Mason, H. E.; Sylwester, J.; Sylwester, B.; Phillips, K. J. H.	10.000 A benchmark study for CHIANTI based on RESIK solar flare spectra	01/2007	A E F R C U
3	2008A&A...488..311D Dzifčáková, E.; Kulinová, A.; Chifor, C.; Mason, H. E.; Del Zanna, G.; Sylwester, J.; Sylwester, B.	9.000 Nonthermal and thermal diagnostics of a solar flare observed with RESIK and RHESSI	09/2008	A E F R C U
4	2008ApJ...681L.117S Sylwester, J.; Sylwester, B.; Phillips, K. J. H.	7.000 RESIK Observations of Helium-like Argon X-Ray Line Emission in Solar Flares	07/2008	A E F X R C U
5	2010ApJ...711..179P Phillips, K. J. H.; Sylwester, J.; Sylwester, B.; Kuznetsov, V. D.	6.000 The Solar X-ray Continuum Measured by RESIK	03/2010	A E F X R C U
6	2003ESASP.535..733S Sylwester, J.; Sylwester, B.; Culhane, J. L.; Doschek, G. A.; Oraevsky, V. N.; Phillips, K. J. H.	6.000 Patterns of X-ray line emission variability as observed by the RESIK Bragg spectrometer	09/2003	A F G T C
7	2011A&A...533A..81K Kulinová, A.; Kašparová, J.; Dzifčáková, E.; Sylwester, J.; Sylwester, B.; Karlický, M.	5.000 Diagnostics of non-thermal distributions in solar flare spectra observed by RESIK and RHESSI	09/2011	A E F X R C U
8	2010ApJ...720.1721S Sylwester, J.; Sylwester, B.; Phillips, K. J. H.; Kuznetsov, V. D.	5.000 A Solar Spectroscopic Absolute Abundance of Argon from RESIK	09/2010	A E F X R C U

The main effects that contaminate raw spectra:

- **Fluorescence: crystal (Si Kα 1.75 keV), two longer-wavelenght channels**
- **Fixed pattern structure (notches) – due to the ADC converter in position encoding (depends on HV and ADS values)**
- **Orbital background:**
- **Non-solar X-ray illumination**
- **Auroral Oval and South Atlantic Anomaly**

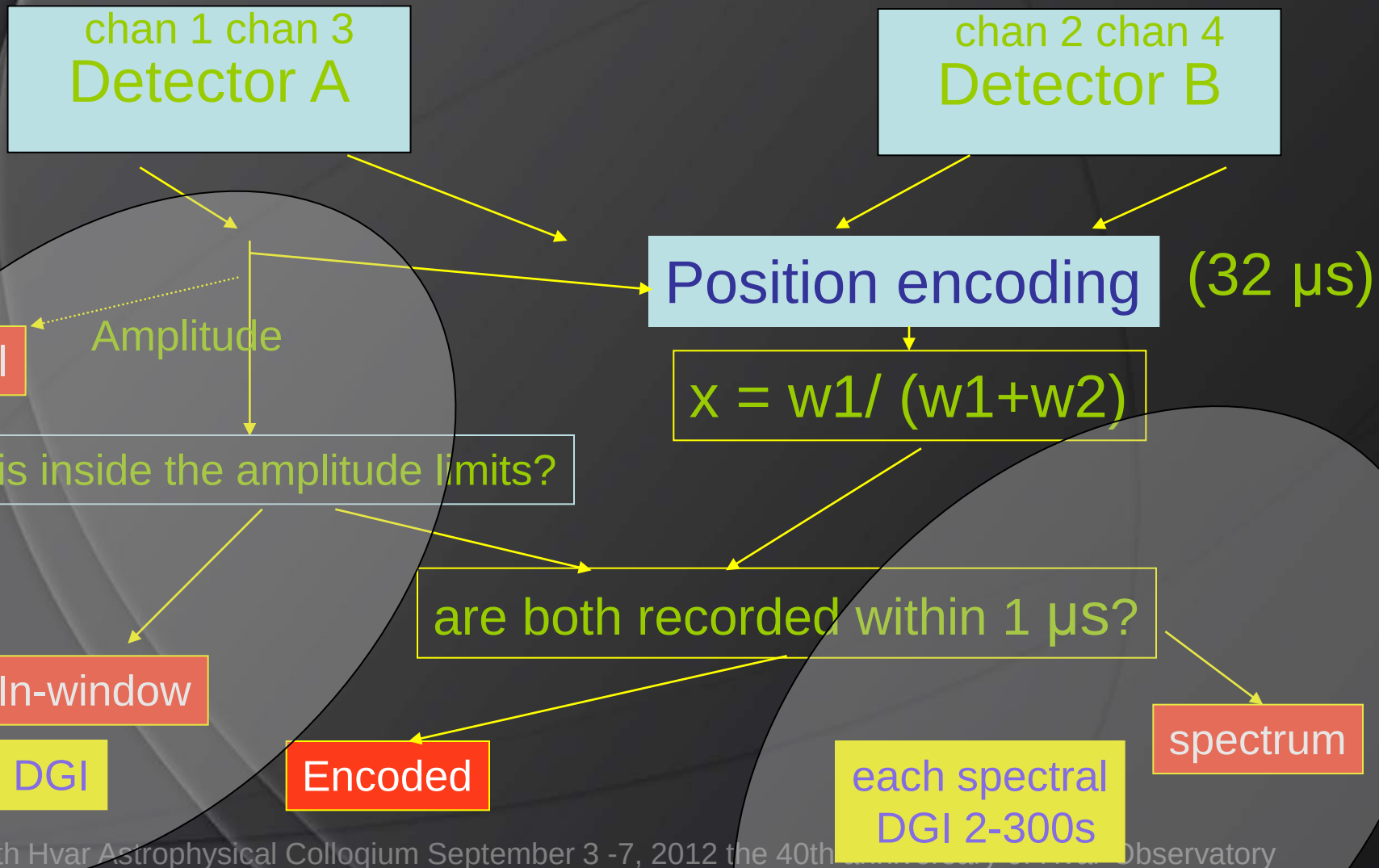
Optical and X-ray nights



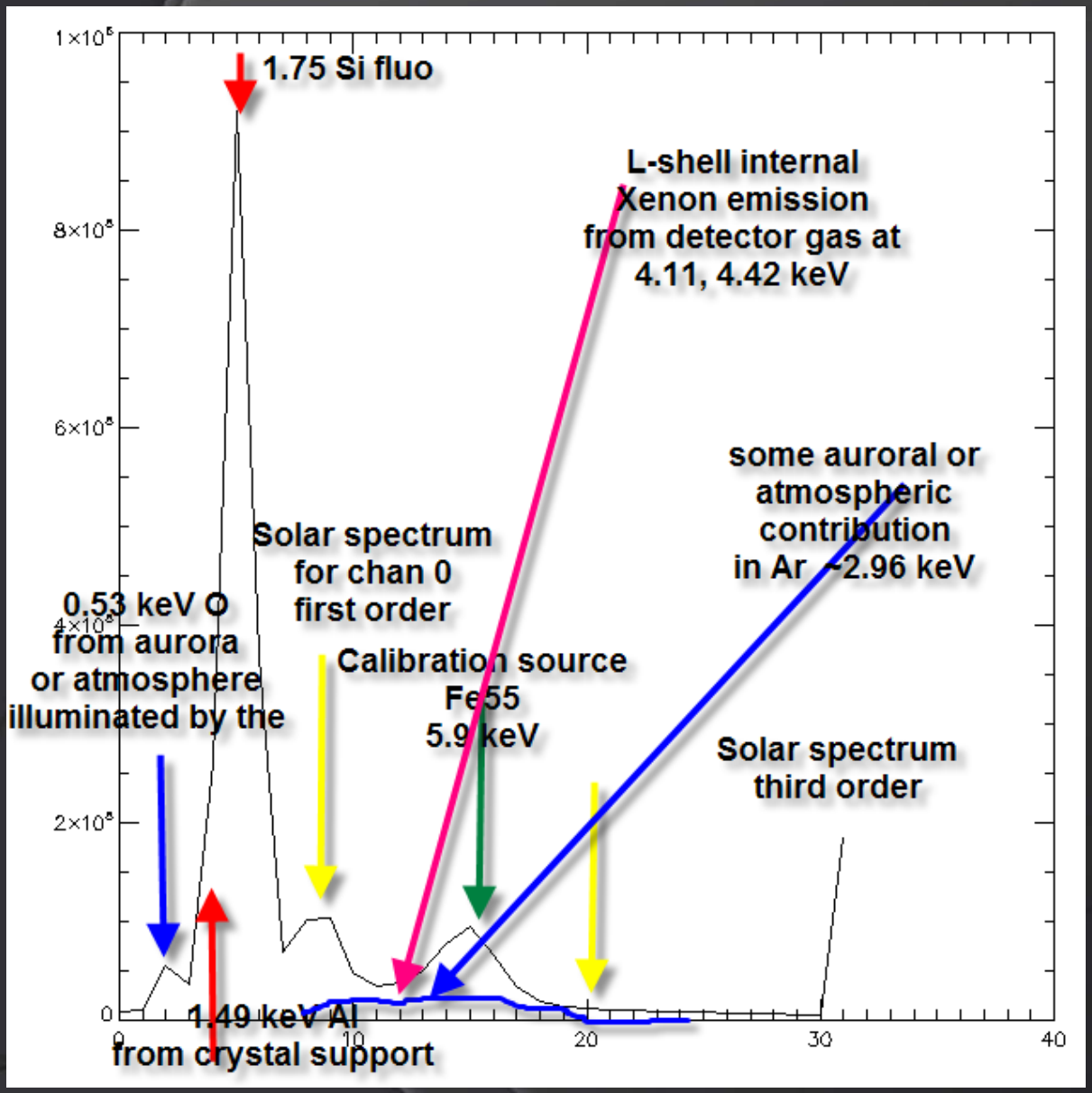


Occultation of X-ray sources takes place earlier/later than in the visible range as the absorption is complete at heights ~100 -150 km

Processing the signal from detectors



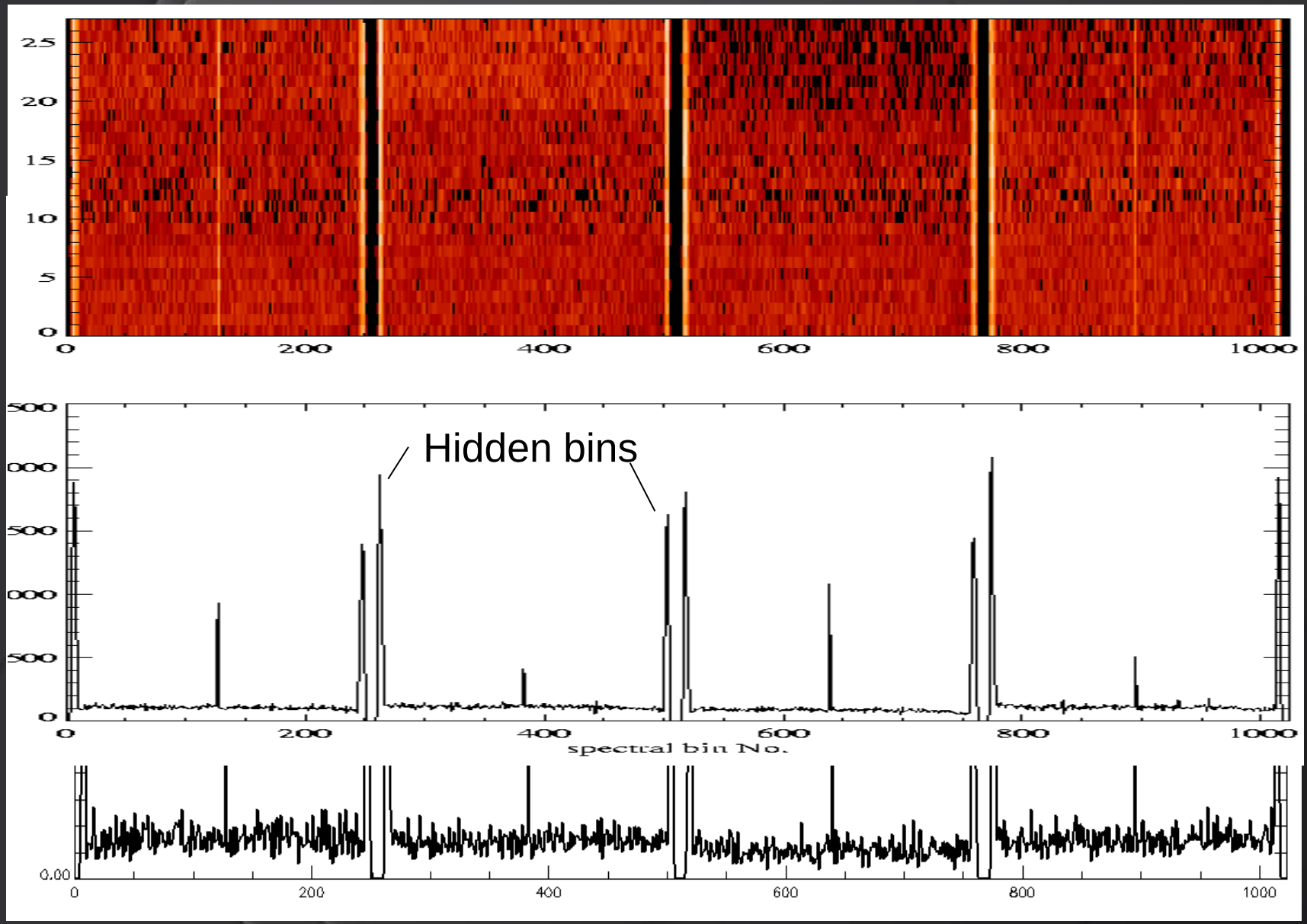
Summed PHA - analysis



Detector B #0

Wavelength channel No 2

Courtesy:
Alena Kulinova


25
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800
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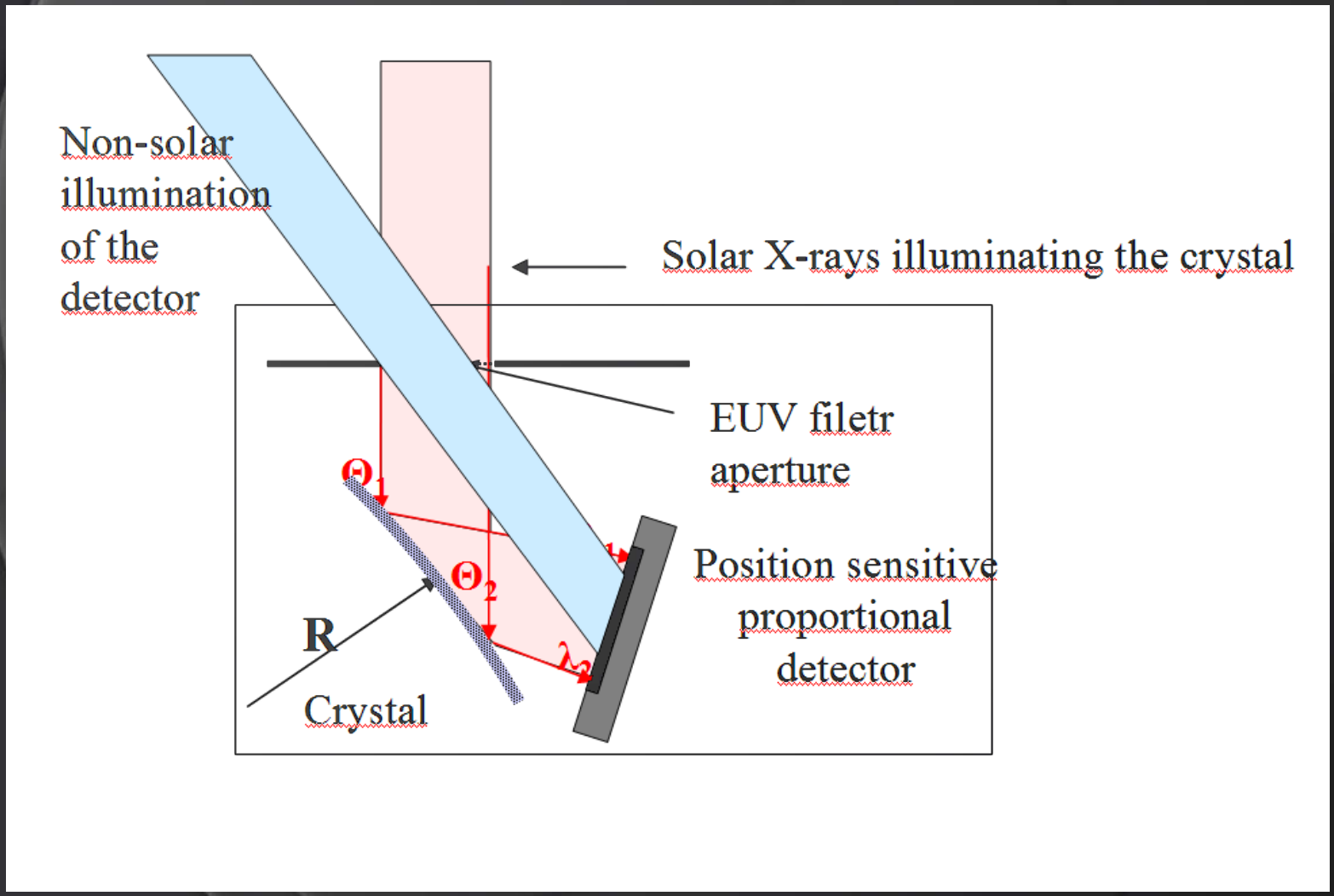
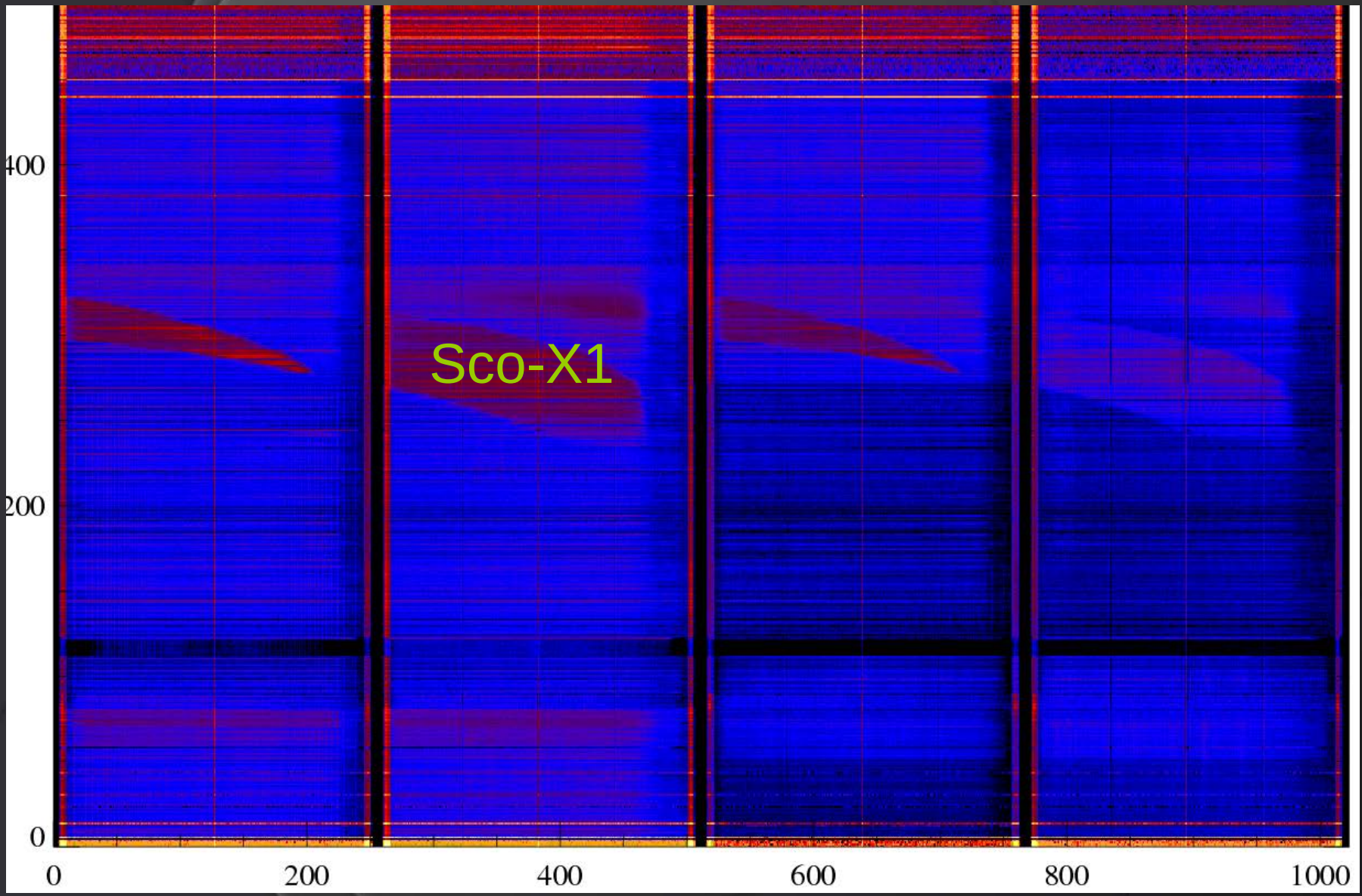
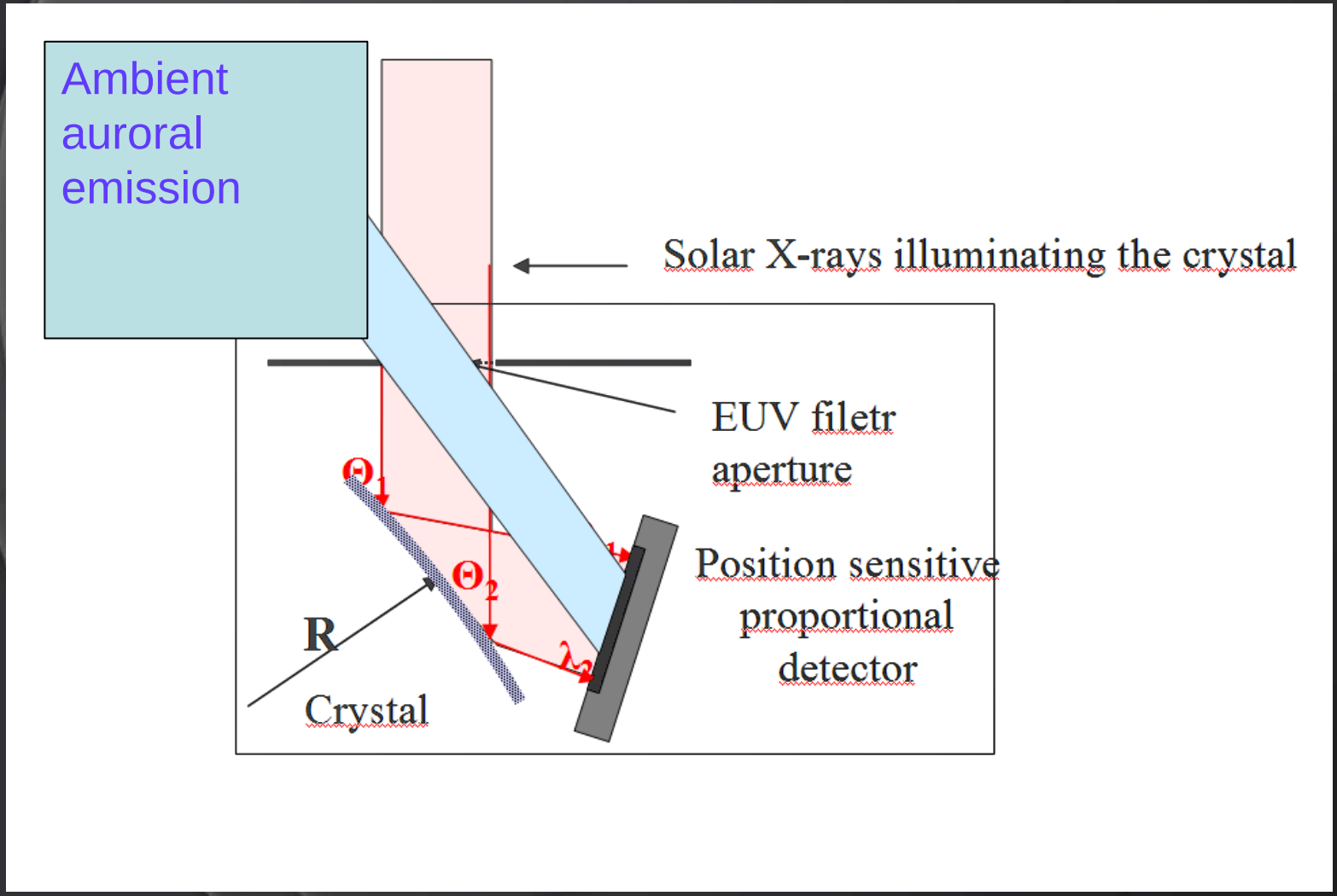
000
500
000
500
0
0
200
400
600
800
1000
Hidden bins
spectral bin No.
0.00
0
200
400
600
800
1000

Non-solar X-rays

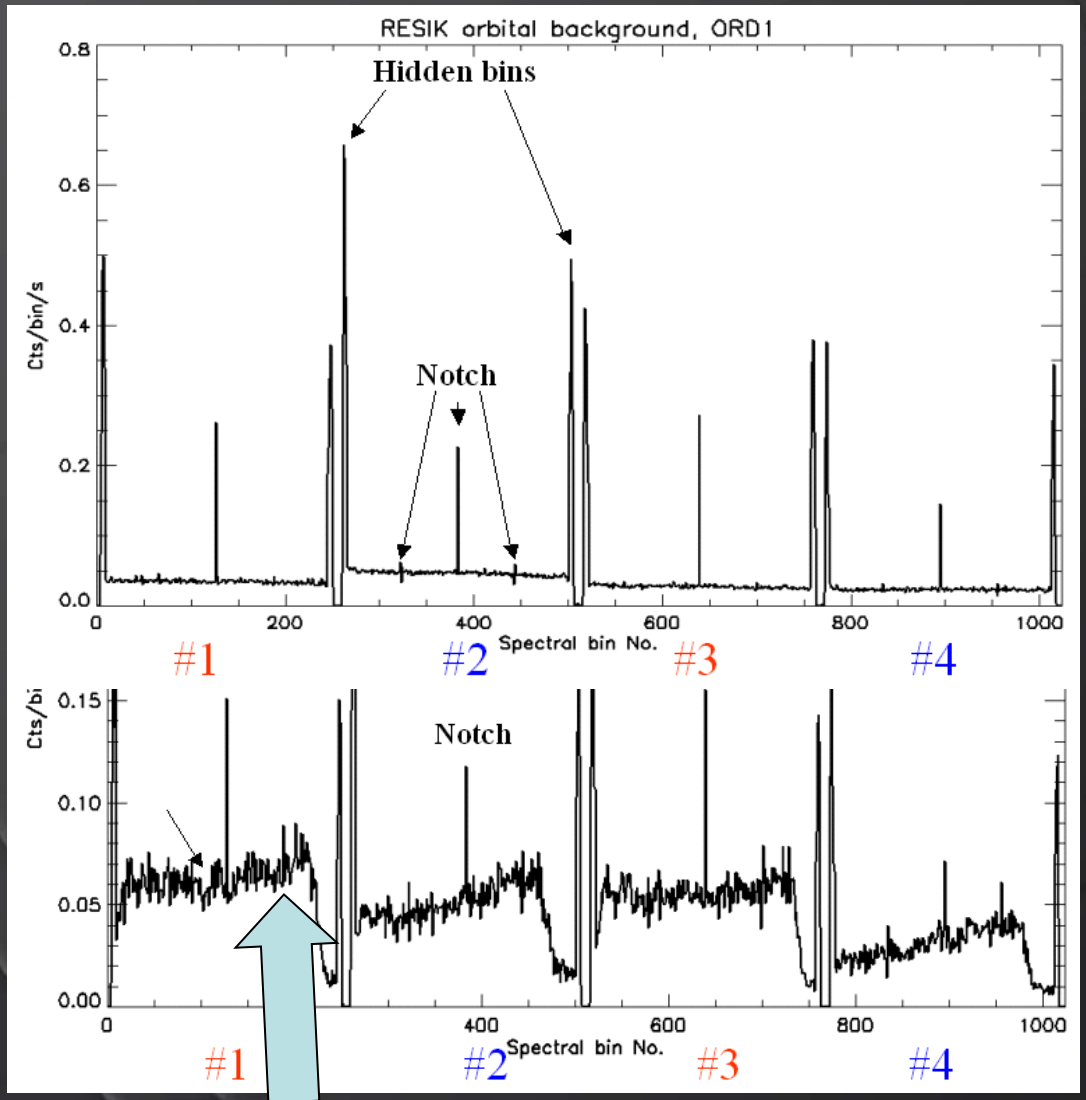



Sco-X1
400
200
0
0
200
400
600
800
1000

Auroras


Ambient auroral emission
Solar X-rays illuminating the crystal
EUV filetr aperture
Position sensitive proportional detector
Θ1
Θ2
λ2
R
Crystal

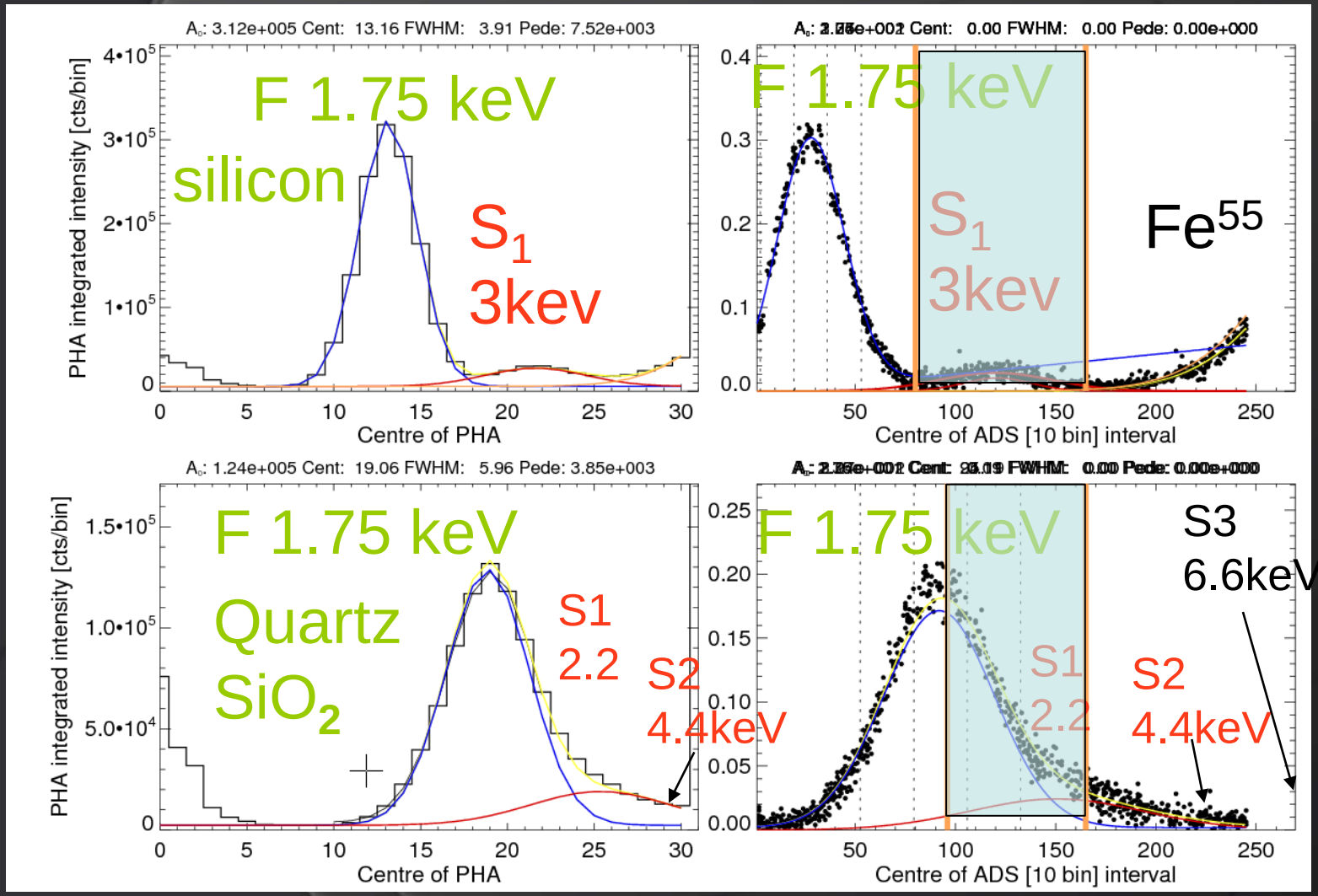
How to recognize X-ray aurora



Equatorial locations

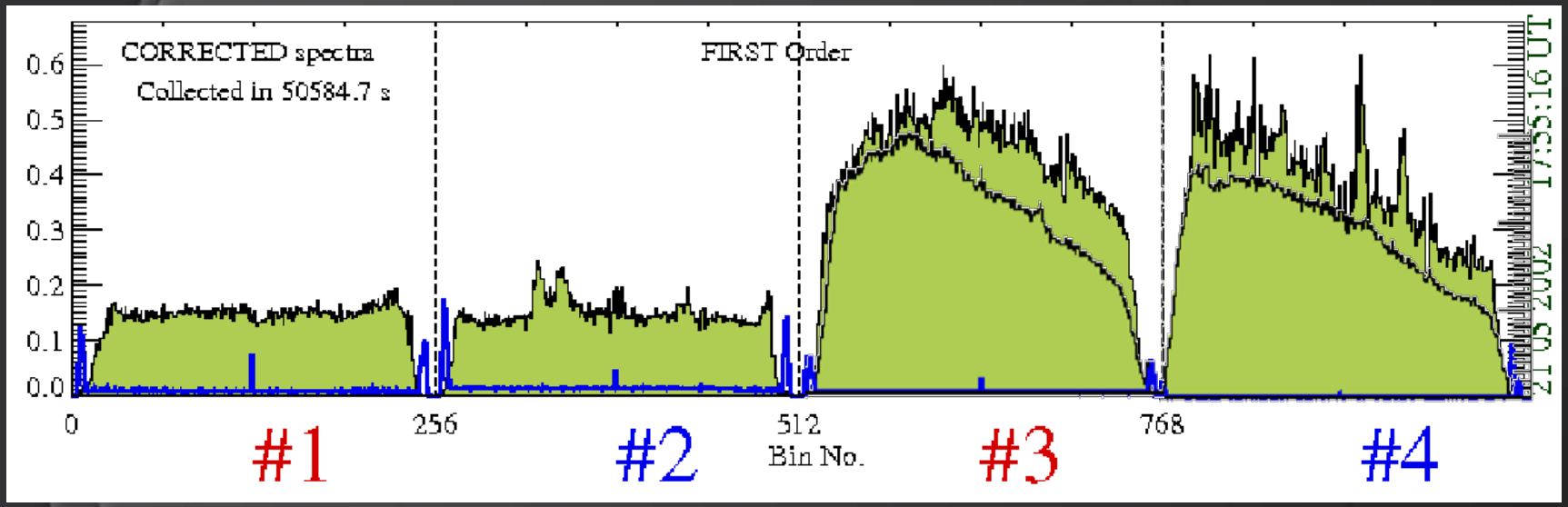
Polar locations

Understanding amplitude signal

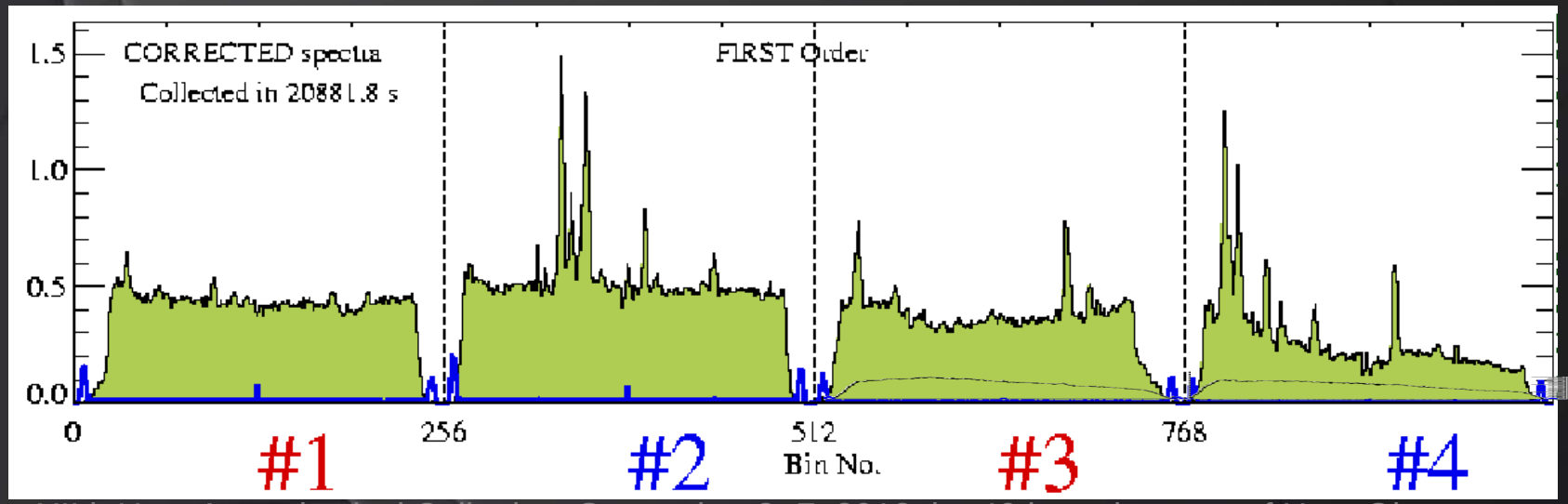


The statistical uncertainties in the number of ion-electron pairs formed and gas gain result in a *pulse amplitude distribution* where photons of constant energy are absorbed. *Detector resolution*, Γ, (in eV) is the full width at half maximum of its pulse amplitude distribution, given empirically b

Components of the spectral signal



early 5% 1% 95% 90%

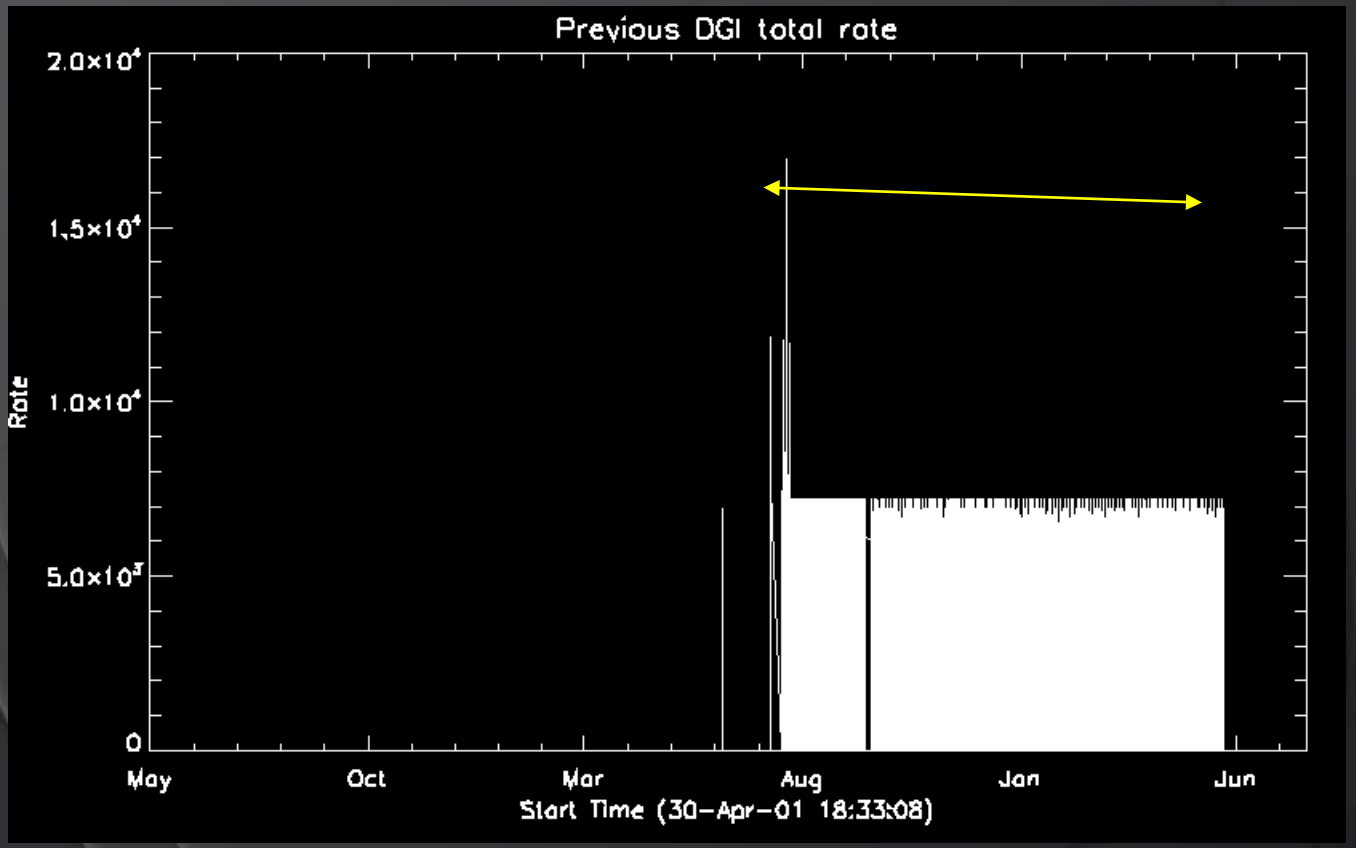


optimum 2% 0.2% 25% 20%

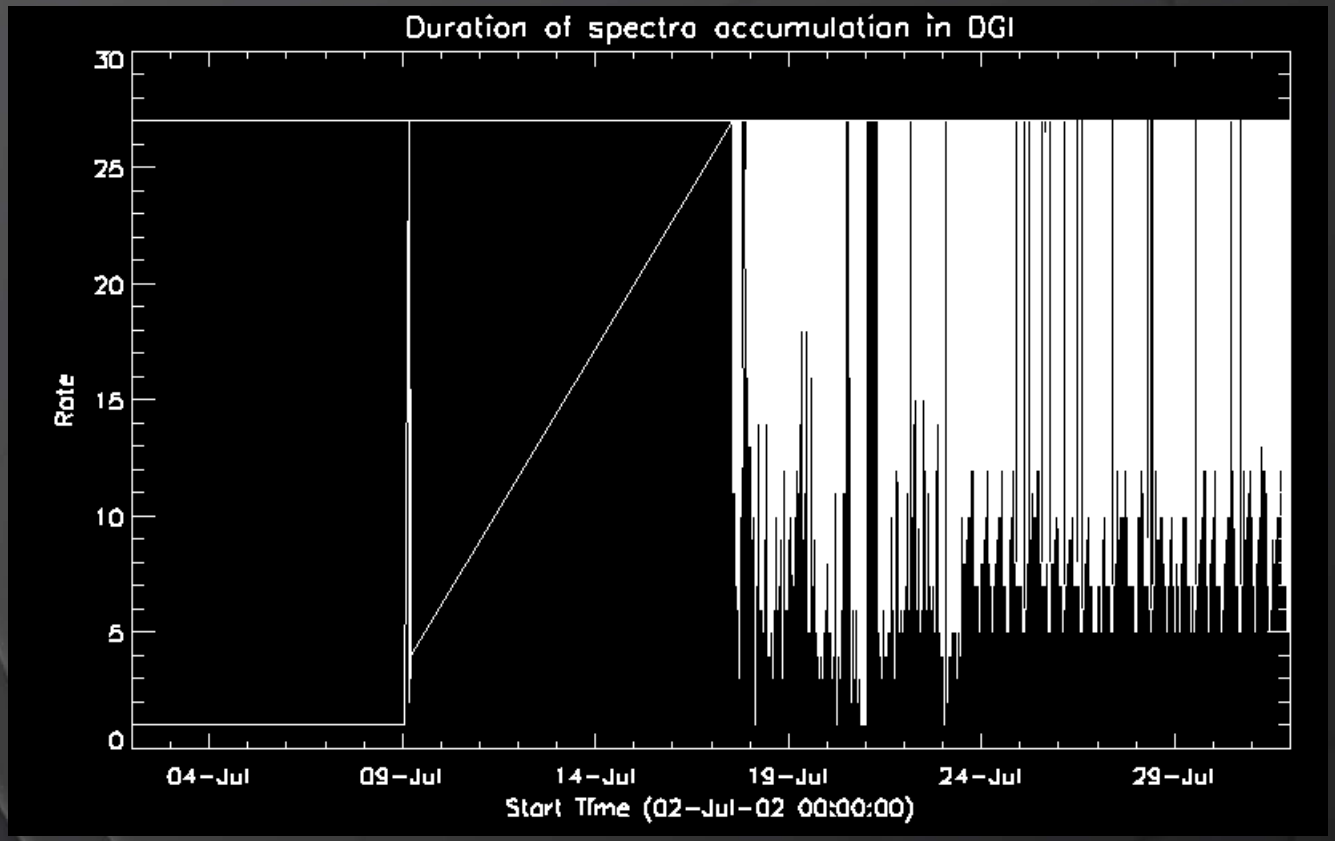
eHeroes
What has changed recently

- New more powerful server is available (128 GB RAM)
- Full set of primary reduced RESIK data can be accessed (30 GB):
  - ~2 mln DGI for signal pulse-height analysis
    - 0.2-10 keV spectra in 31 bins,
    - Particle signal 1 bin
    - DGI, 10 & 2 s
  - ~1.3 mln individual spectra, 60 000 with good settings

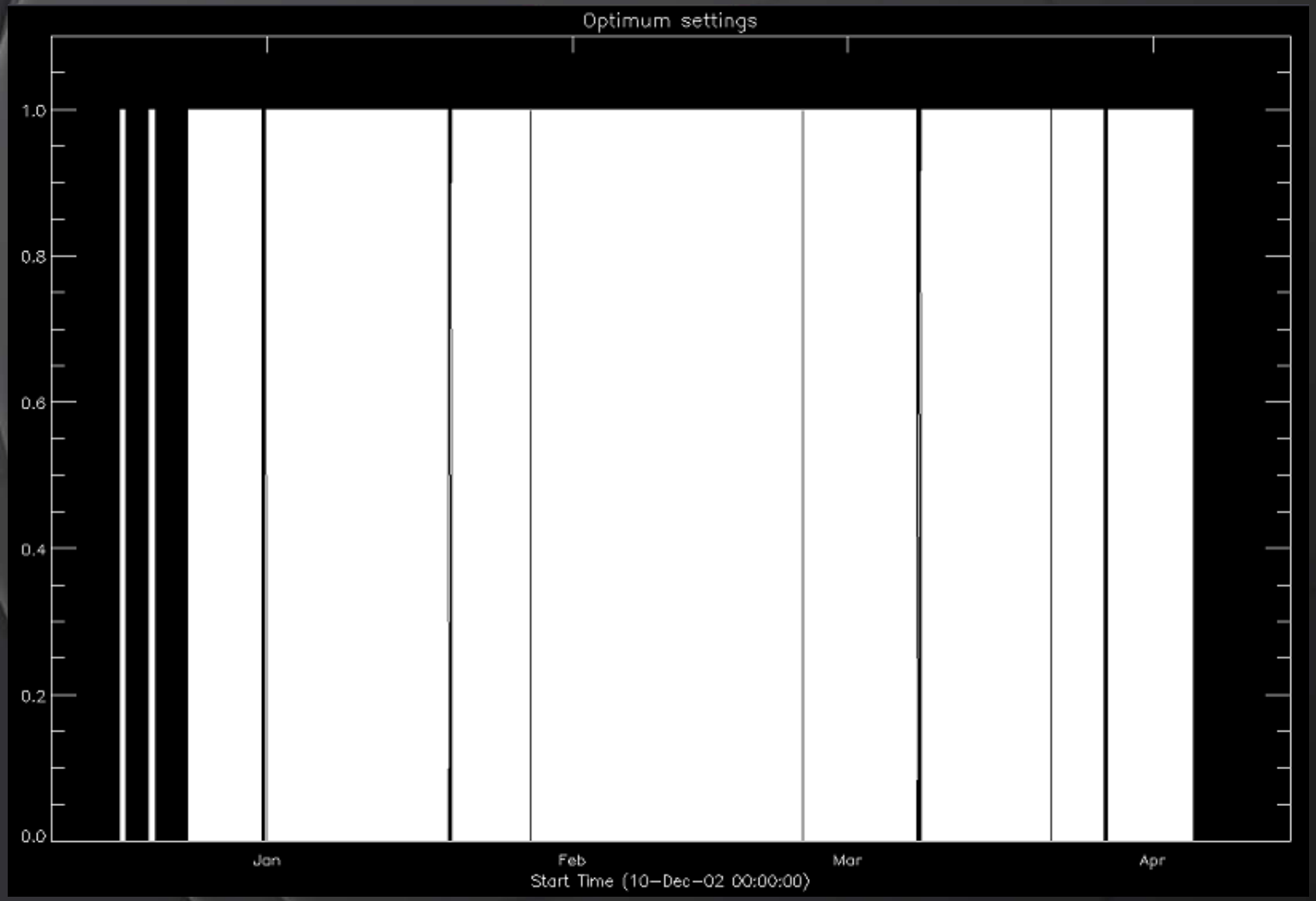
Dynamic spectra collection

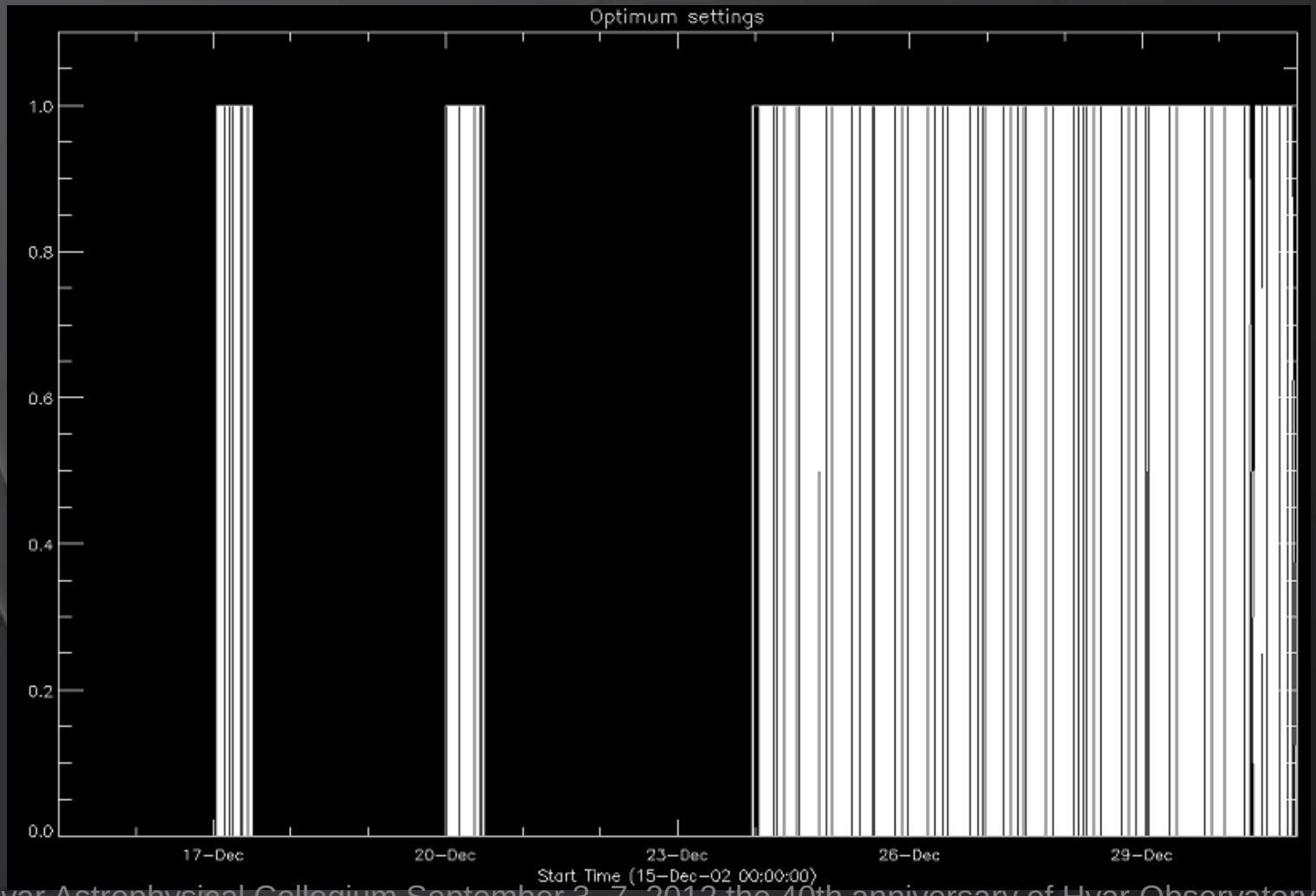


Dynamic spectra collection 2



Optimum settings 60k spectra




Optimum settings
1.0
0.8
0.6
0.4
0.2
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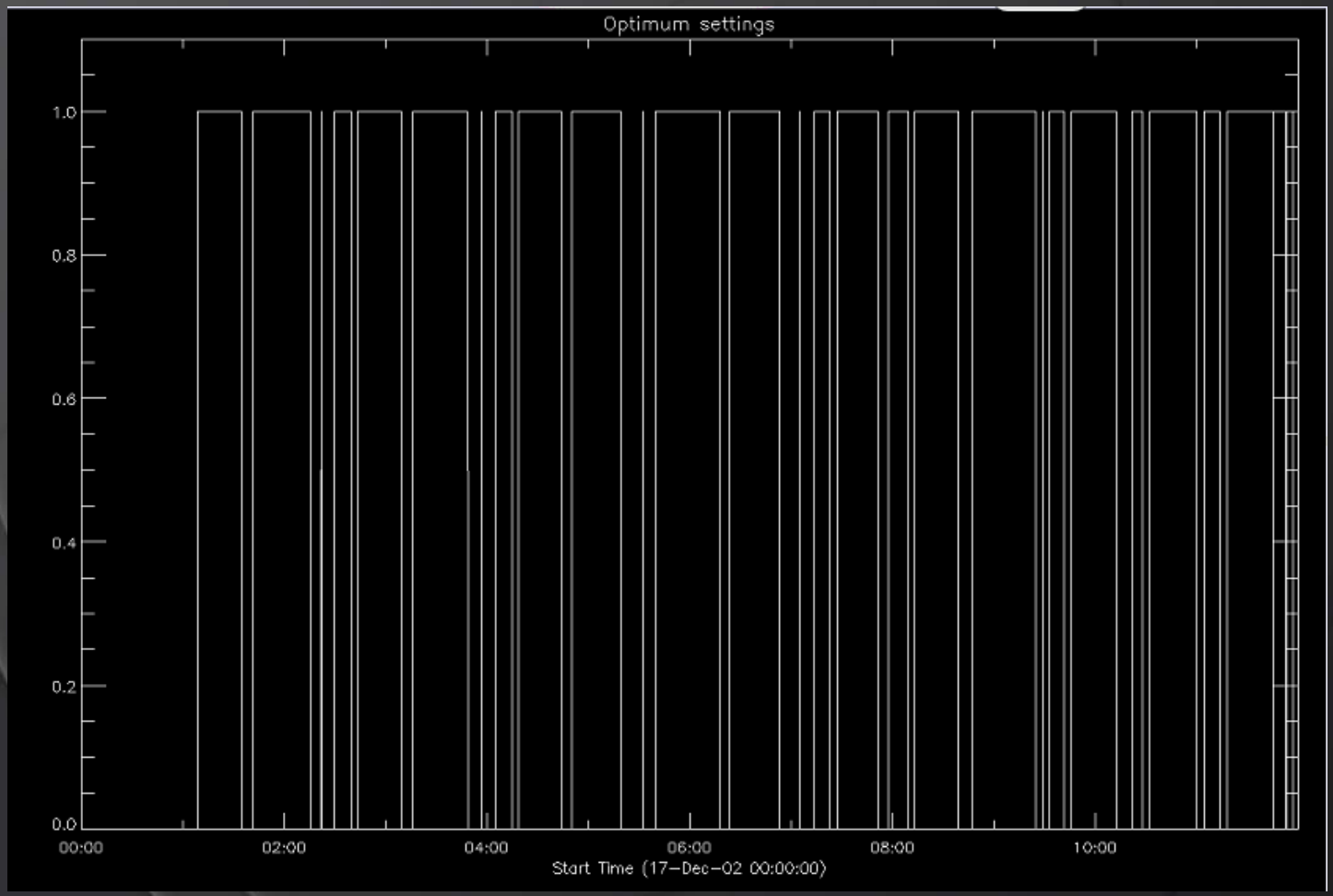
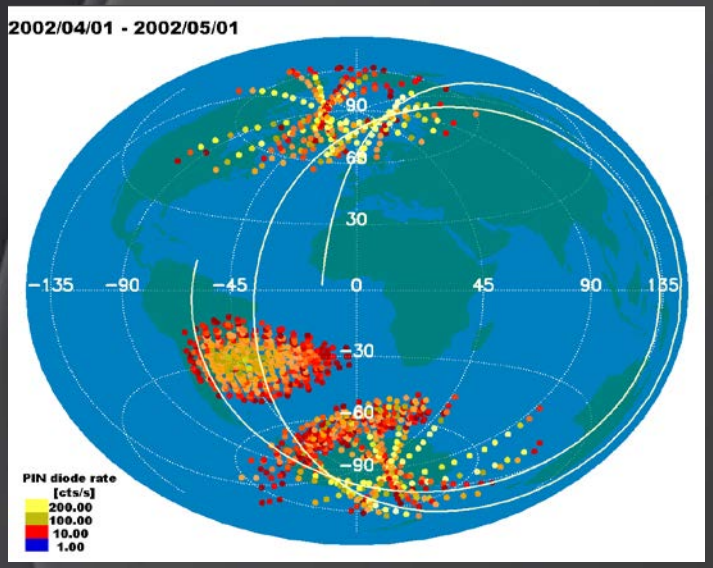
17-Dec
20-Dec
23-Dec
26-Dec
29-Dec
Start Time (15-Dec-02 00:00:00)

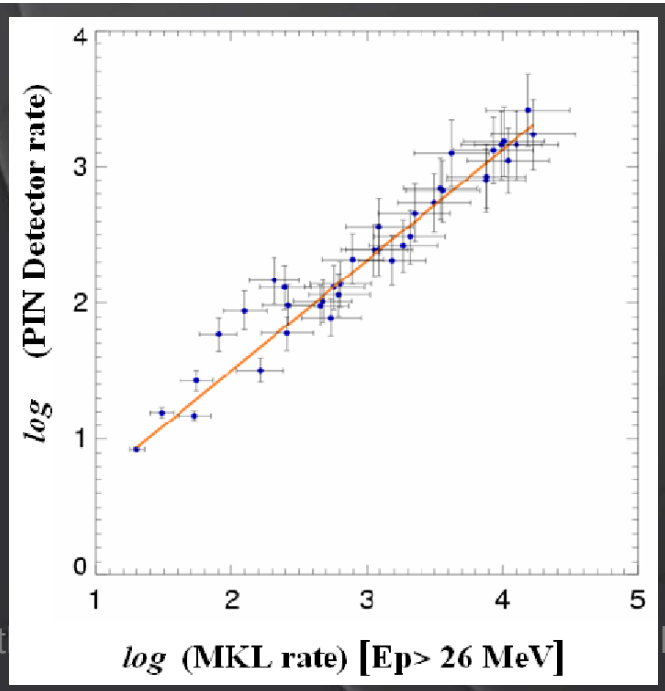

Optimum settings
1.0
0.8
0.6
0.4
0.2
0.0
00:00
02:00
04:00
06:00
08:00
10:00
Start Time (17-Dec-02 00:00:00)

Uninvestigated areas

- Magnetospheric studies
  - Distribution of particles on L shells
  - Study of geomagnetic storms
  - SAA vriability
- Solar studies
  - Reduction of all good spectra to Level2 (90%)
  - Contribution of higher reflection orders
  - Non-maxwellian distribution diagnostics
- Impact on electronics
  - Investigation of all glitches
  - Temperature distribution inside the instrument

Radiation environment

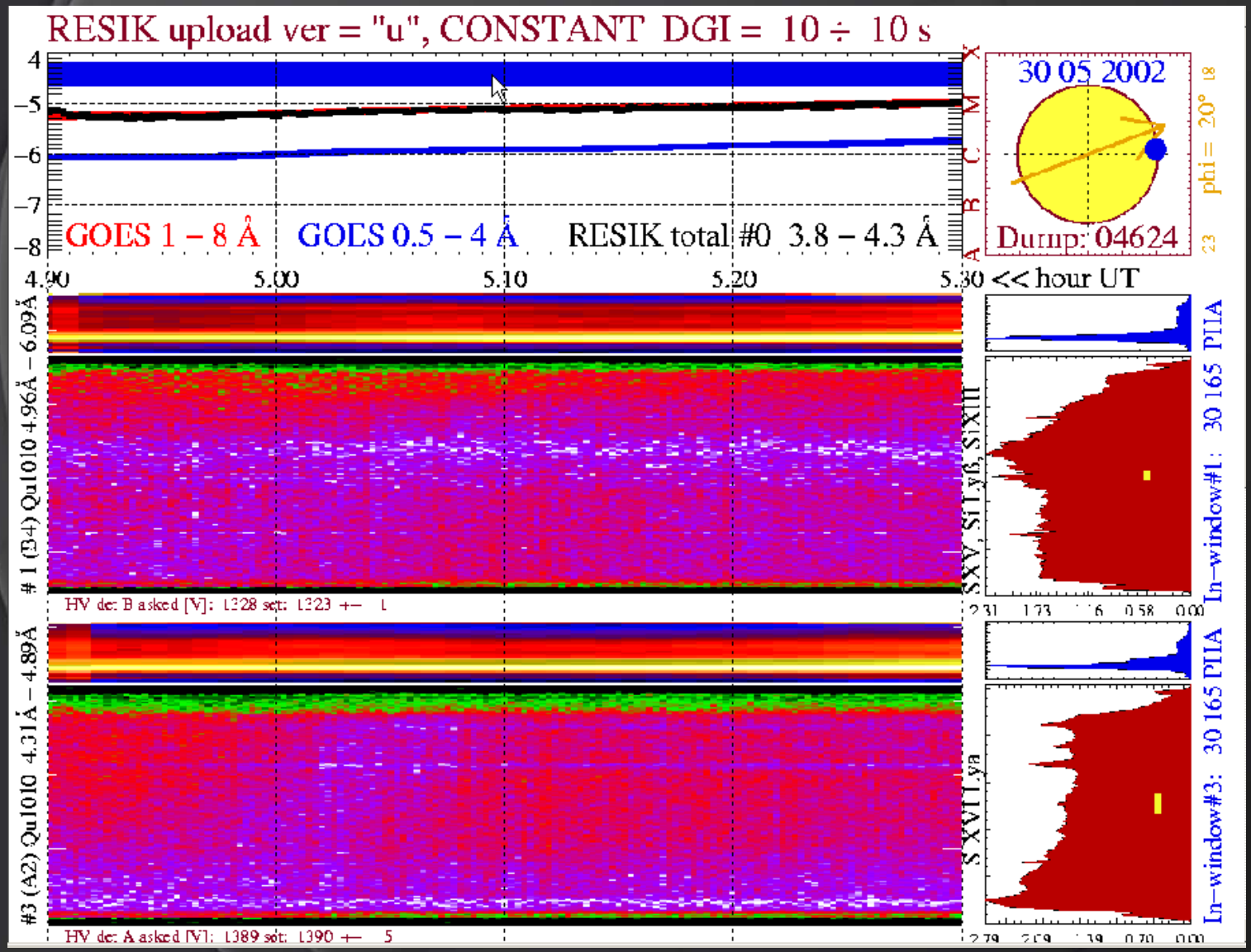




on its circular ~500 km orbit inclined at ~83 deg, polar radiation ovals filled with energetic particles are being crossed 4 times each orbital period

SAA is encountered ~ 6 times a day – best seen on PIN sensor

Higher Orders



Conclusions

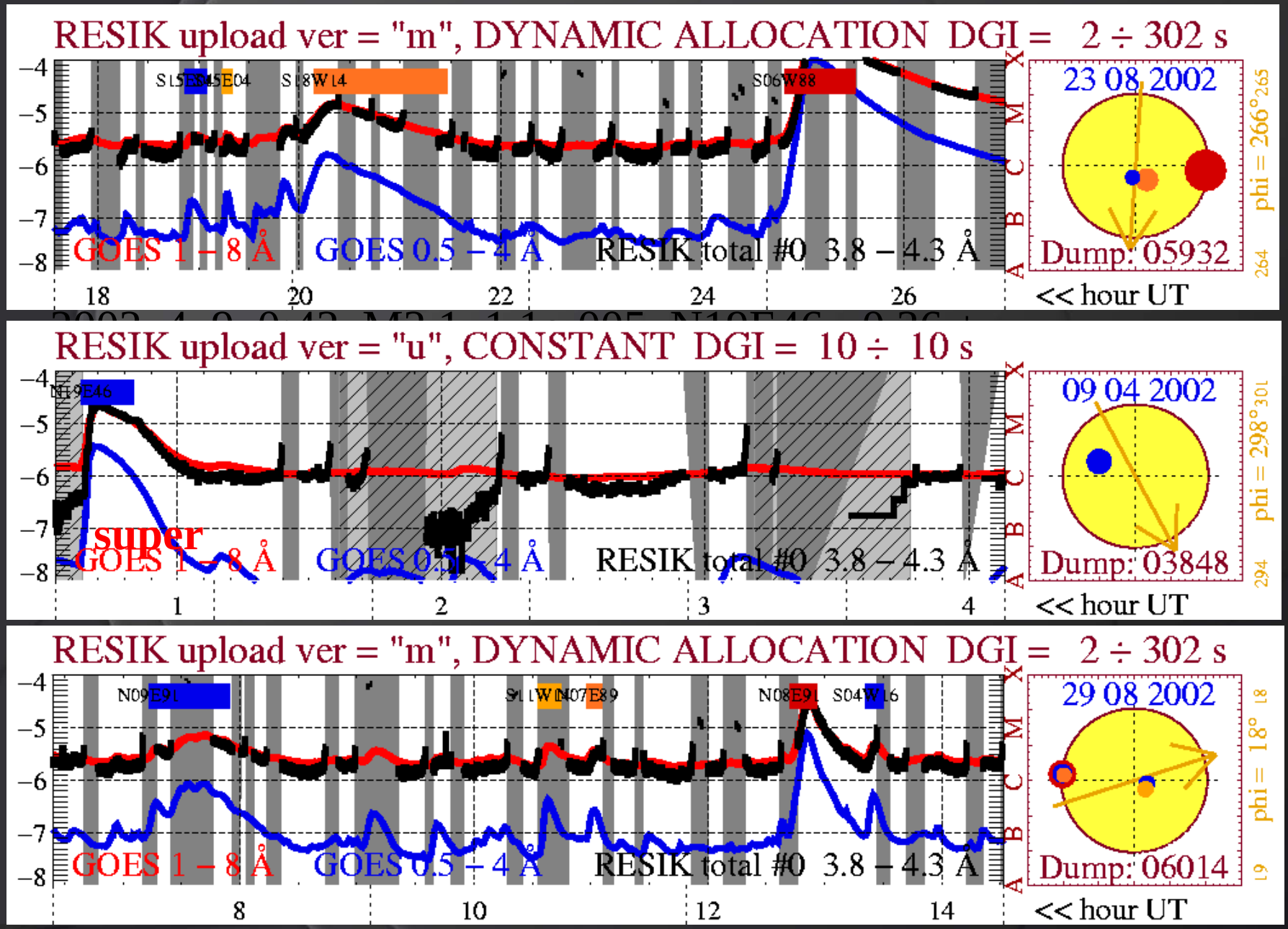
- Access to Resik full database has still a lot of new discoveries to offer
- We are looking for a talented people to invite to work in our group
- We are in a process of converting the data into FITS format and contribute them to the SODA database (SOTERIA)
- Right now, we can provide the IDL *.sav large file with descriptions (30 GB)
  - Altitude & attitude, PHA, spectra, Times JD etc

Thank you !

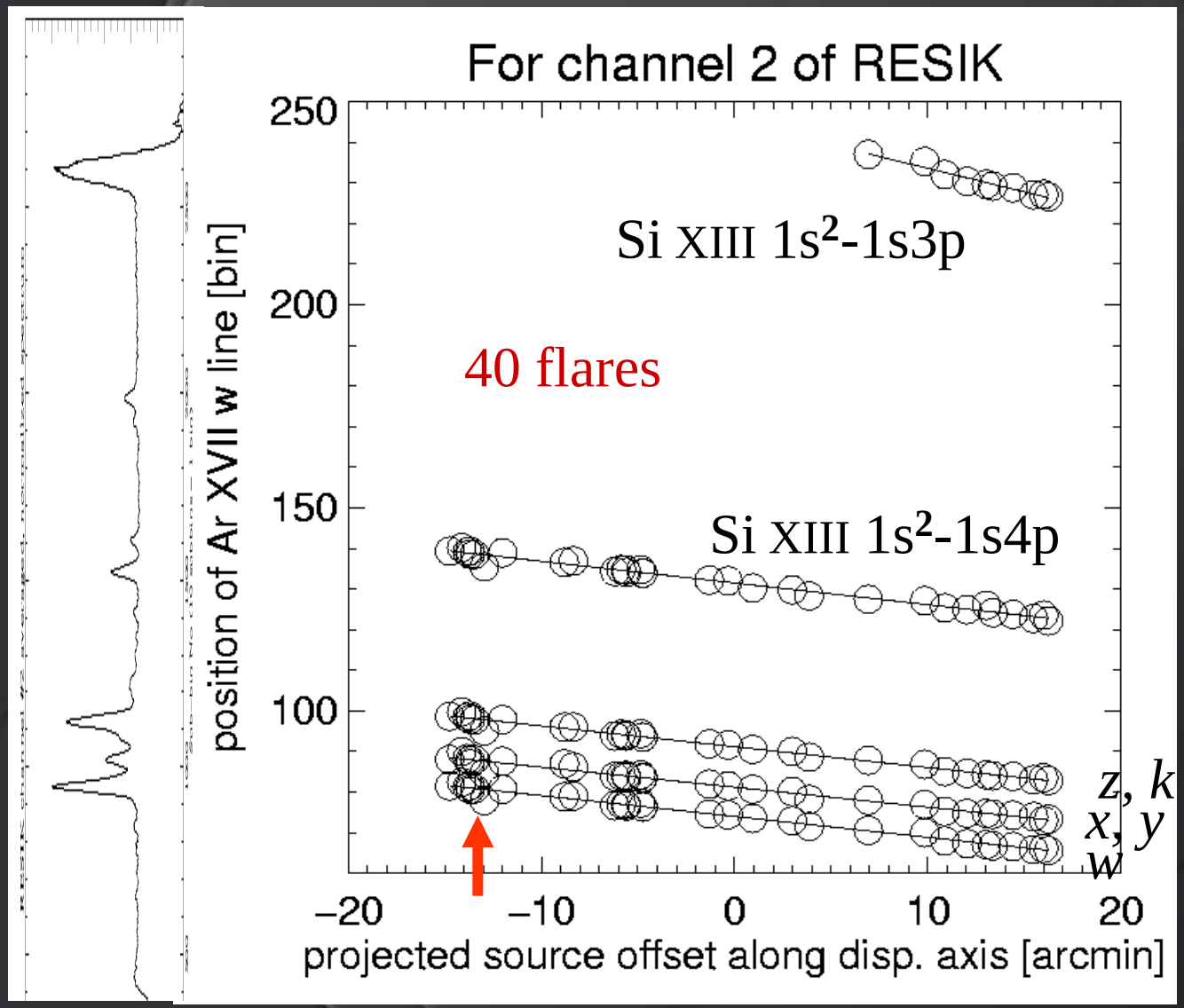
All interested people, please contact me

js@cbk.pan.wroc.pl

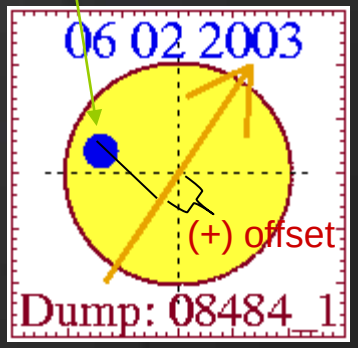
2002 8 24 1:12 X3.1 4.6e-004 S02W81 -16.02 +



Geometry optimization



RHESSI location



Double, position sensitive detector: Yohkoh BCS type

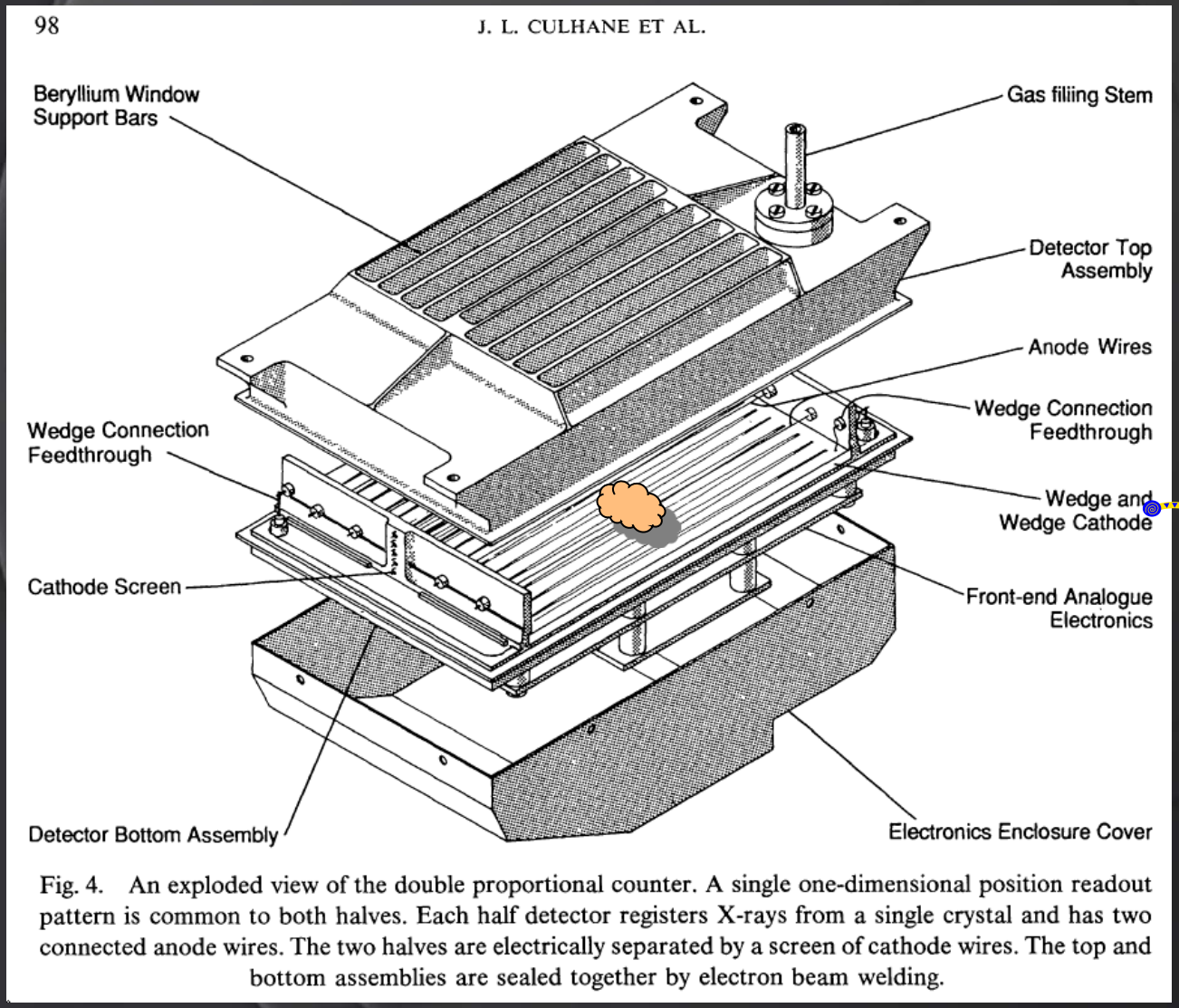
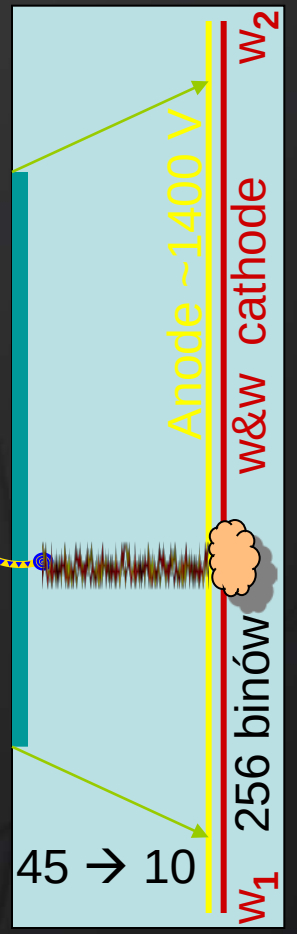
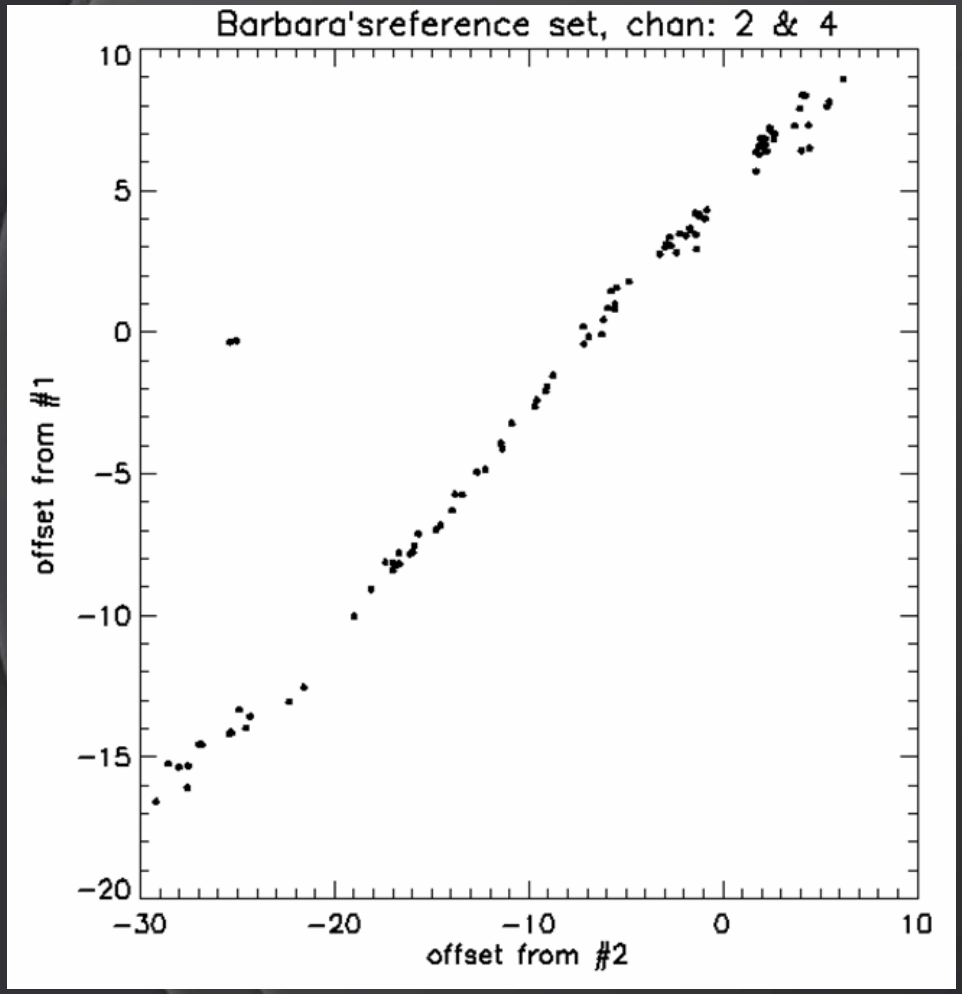


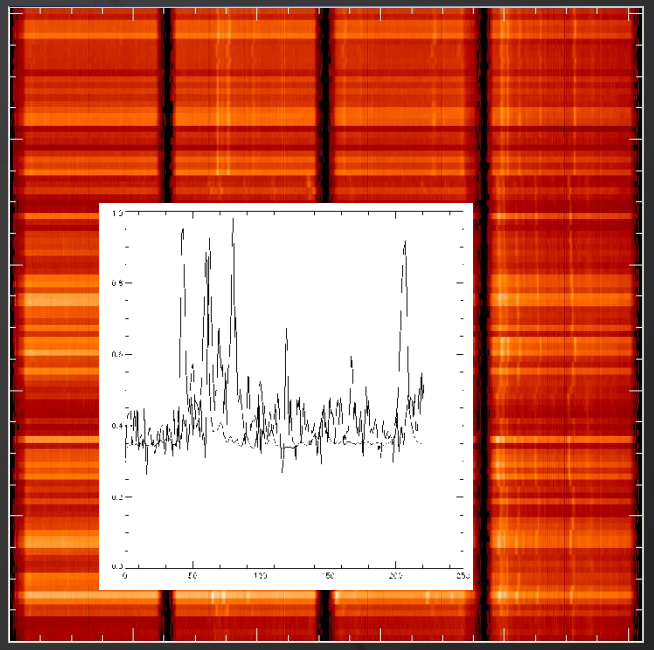
Fig. 4. An exploded view of the double proportional counter. A single one-dimensional position readout pattern is common to both halves. Each half detector registers X-rays from a single crystal and has two connected anode wires. The two halves are electrically separated by a screen of cathode wires. The top and bottom assemblies are sealed together by electron beam welding.

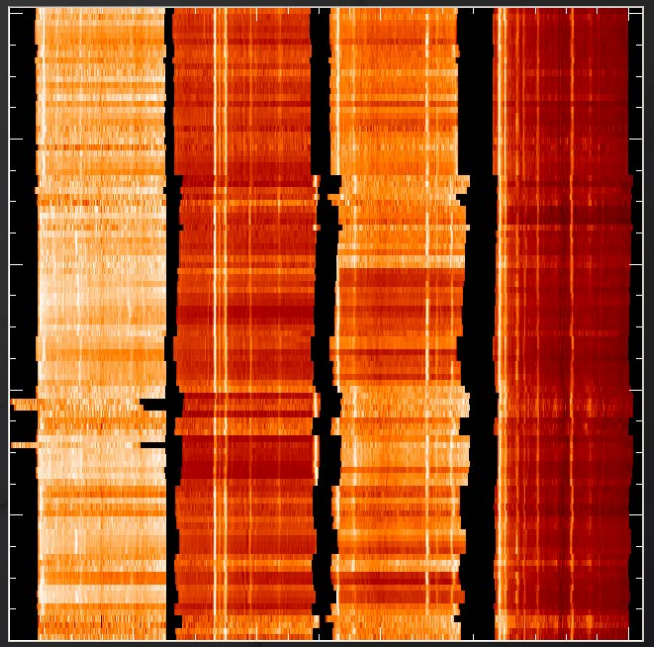


$$\text{Bin No} = \frac{w_1}{w_1 + w_2}$$

Offsets from line positions





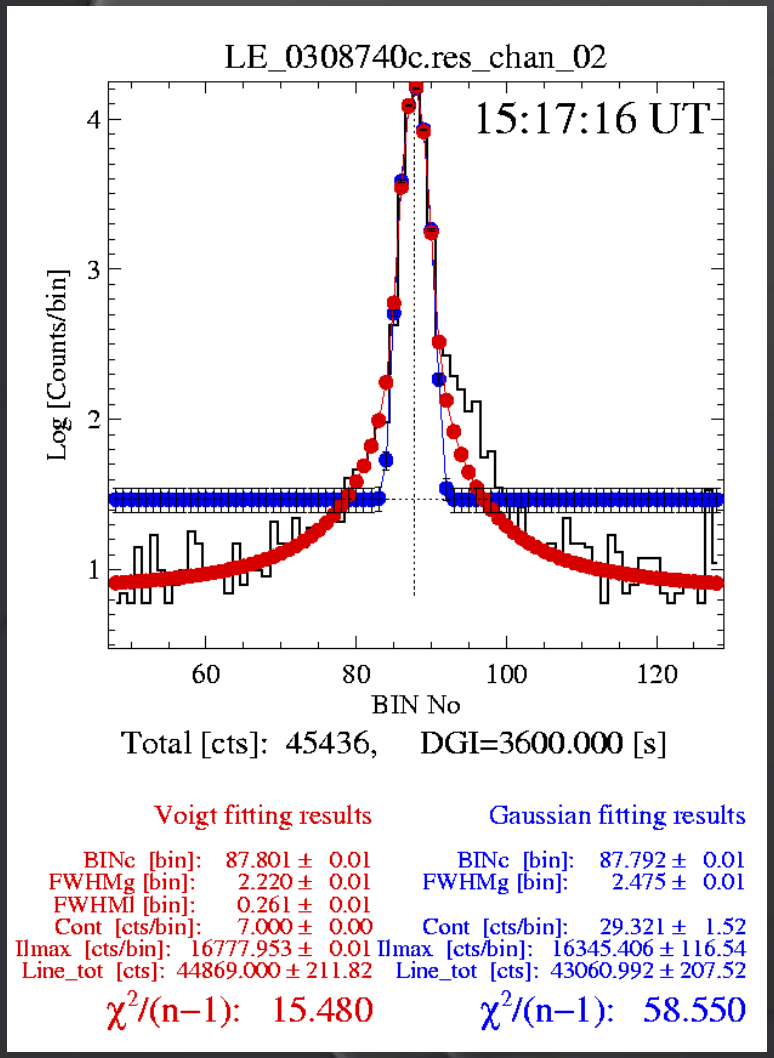


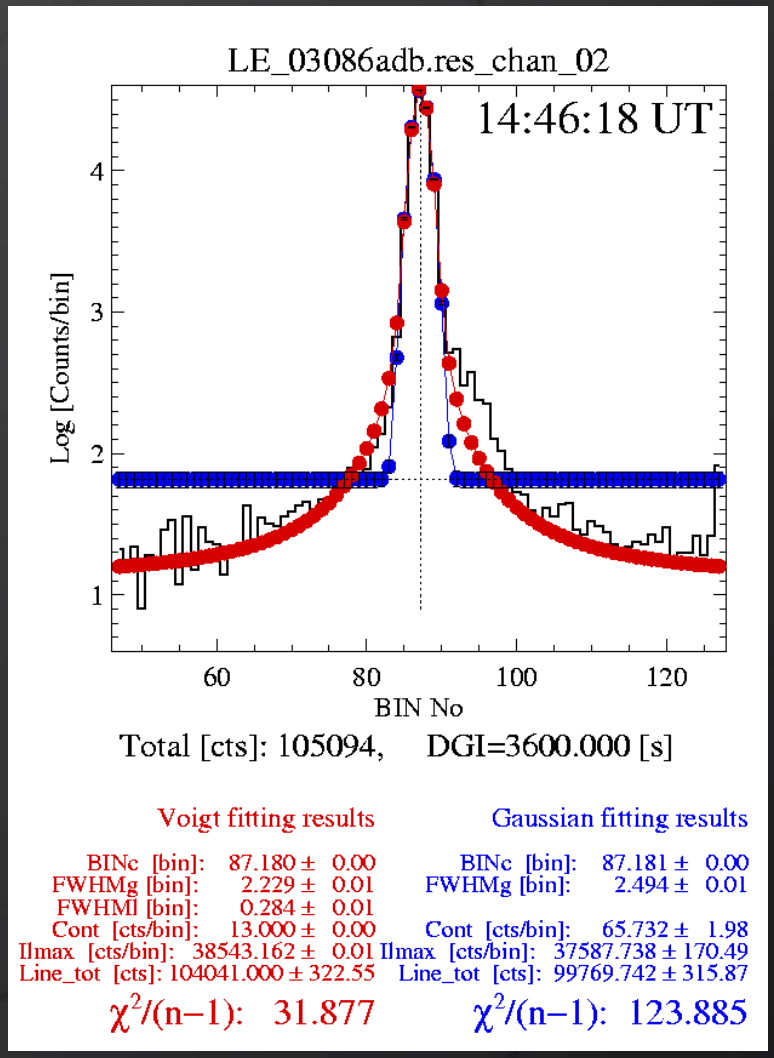
$\Gamma \cong 2.35\sqrt{1.7\,\varepsilon E}$

Instrumental width: detector position resolution

0.16 for Fe55
0.29 for Si

$\lambda/\Delta\lambda \sim 1000$

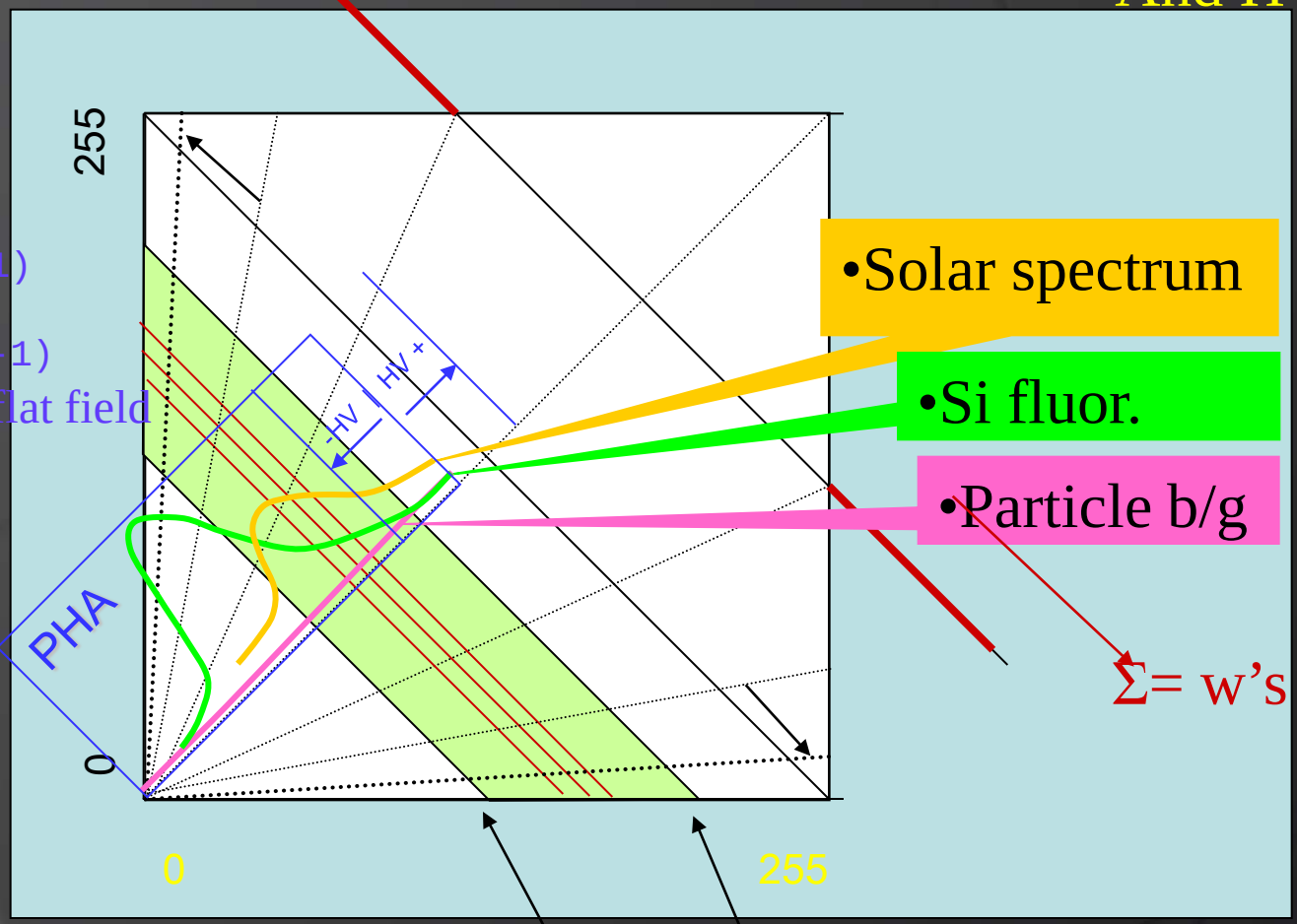




LUT MAP

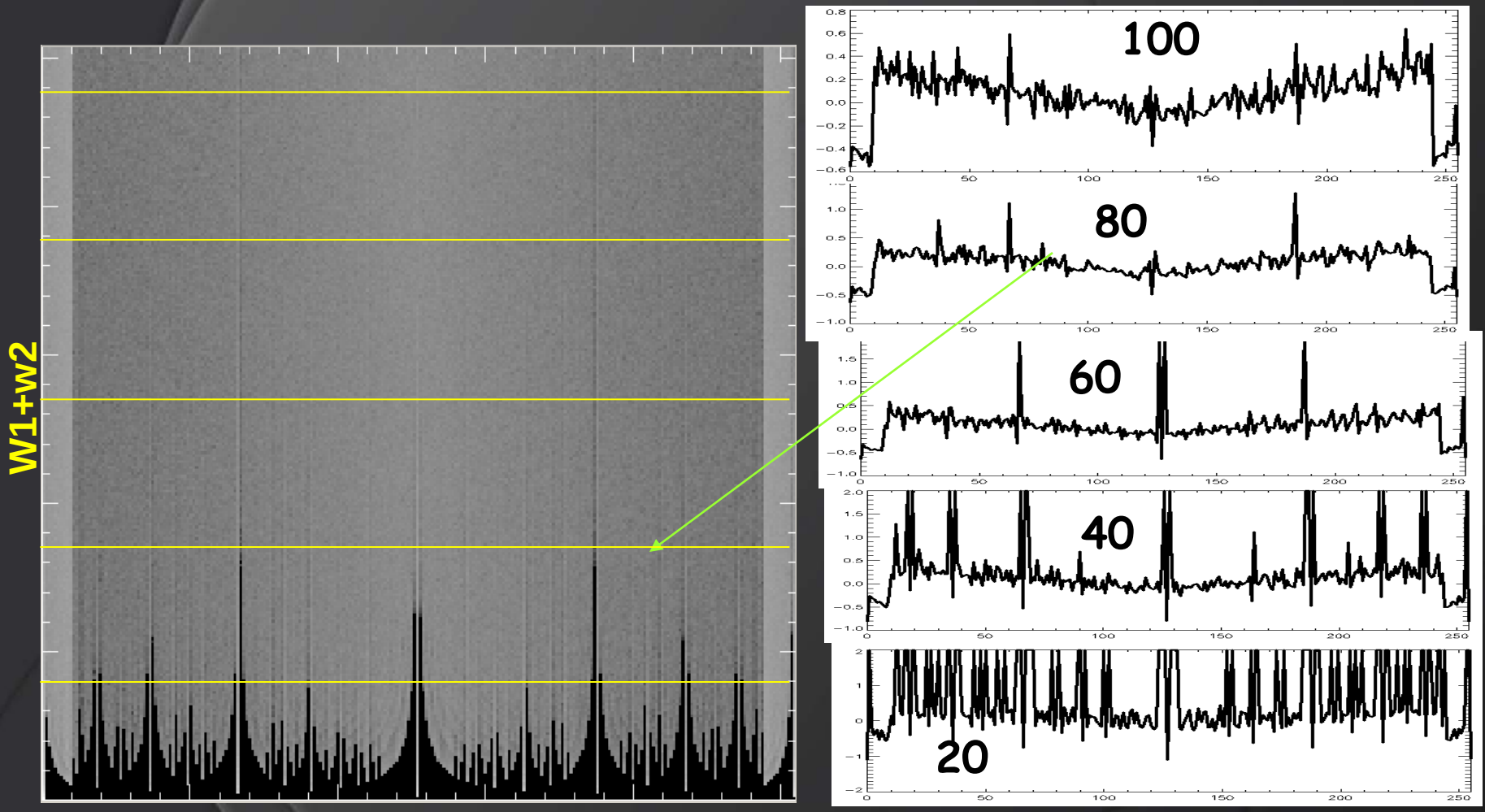
We know ADS
And HV

w(k+1).uu(k+1)
w(k). uu(k)
w(k-1). uu(k-1)
Σ=theoretical flat field
with Notches



In order to obtain realistic look-up "relation" we should sum-up over those uu relations which are of interest for a given set of ADS settings used. The relation is dependent on: HV & ADS

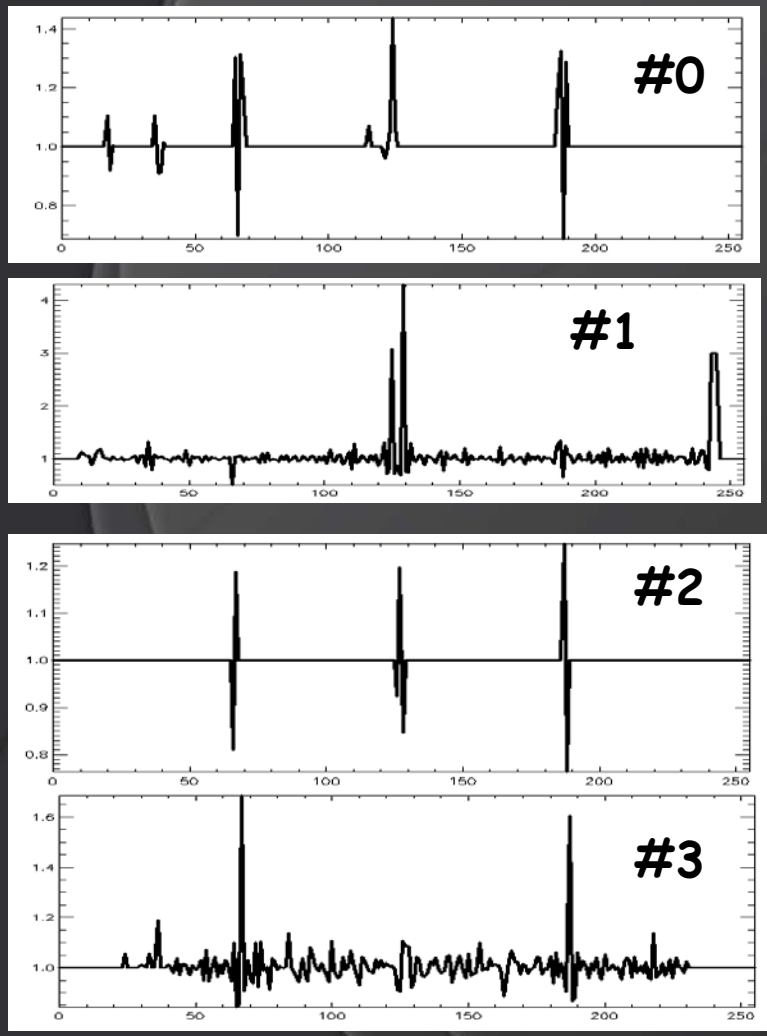
FPS: Monte-Carlo model



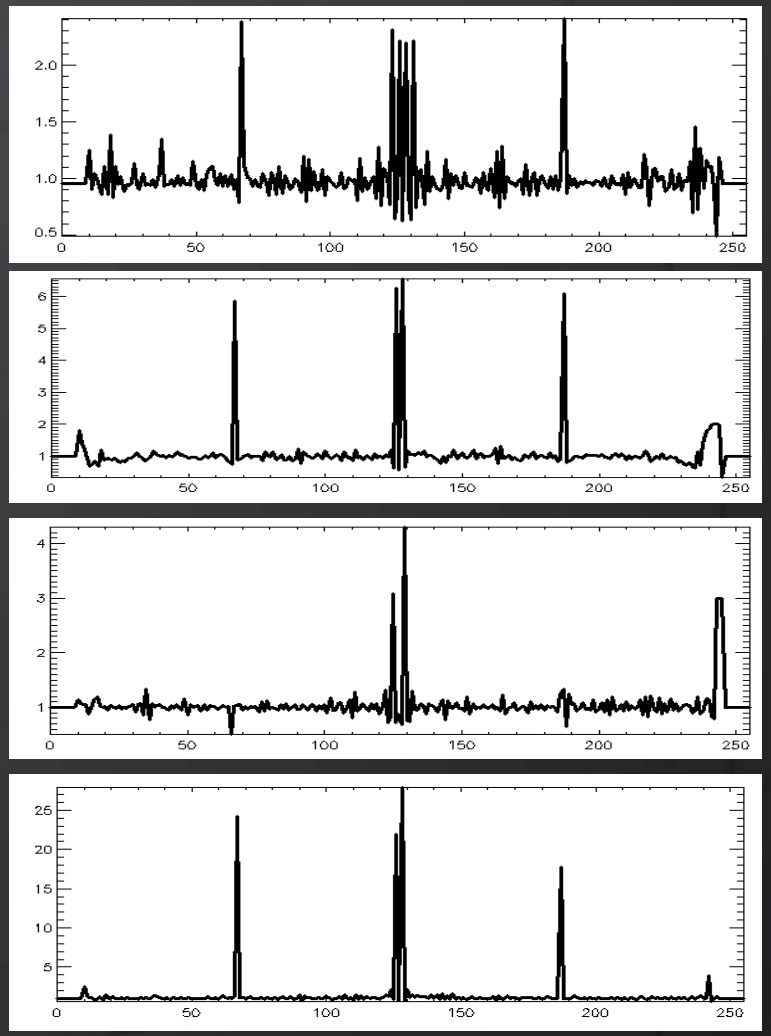
„Uniform illumination" q=<const

Removing FPS – dependence on HV & ADS

Same HV, different # (ADS)



Same channel #1, different HV & ADS



1480 V, 96-165

1480 V, 20-160

1450 V, 135-200

1450 V, 70-120

Calibrations

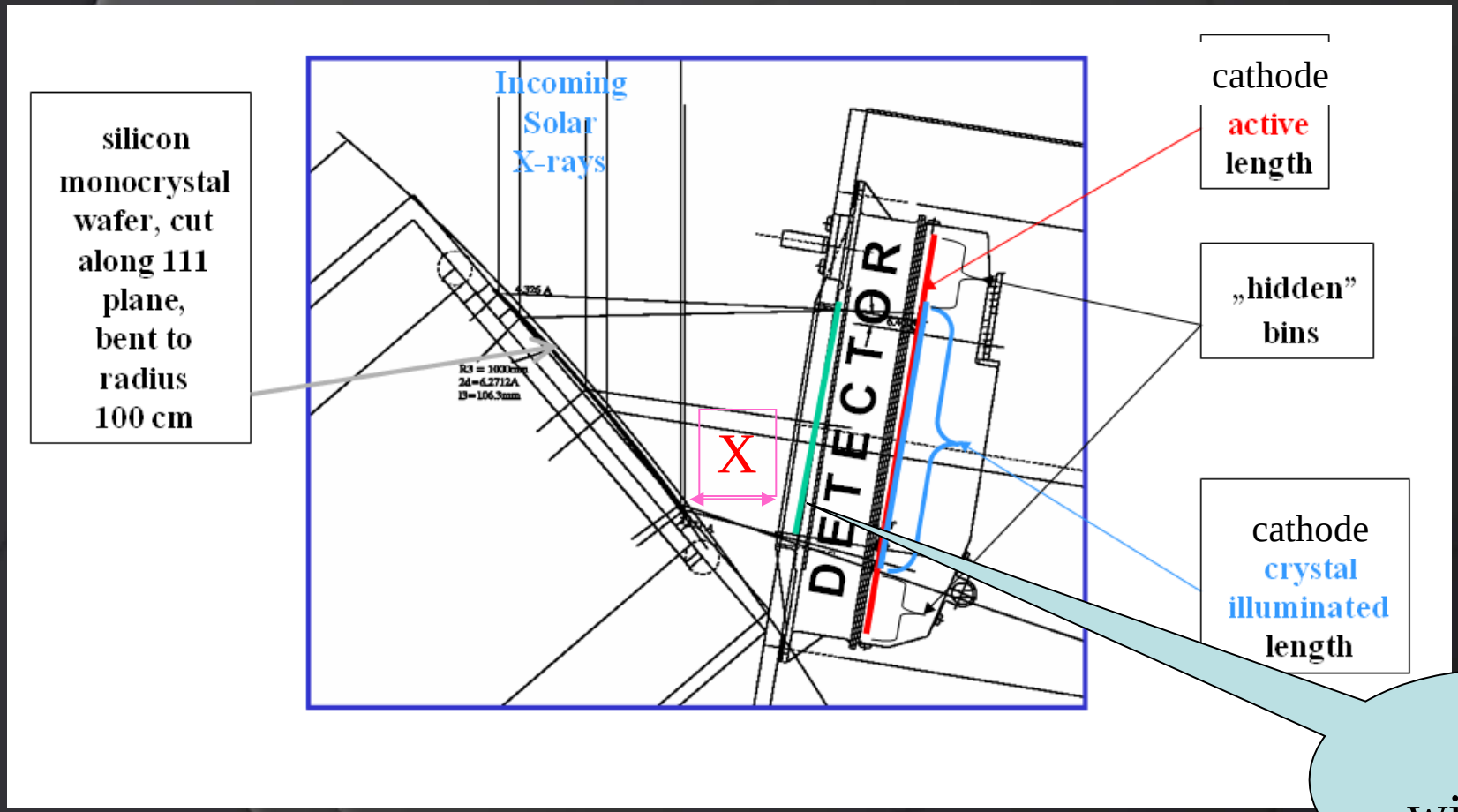
- Laboratory
  - at RAL Yohkoh BCS chamber
  - at MSSL some detector rests
- In-flight
  - Detector ageing (position of Fe55) 5.9 keV peak against the 32 bit amplitude scale
  - ADS (amplitude discriminator settings)

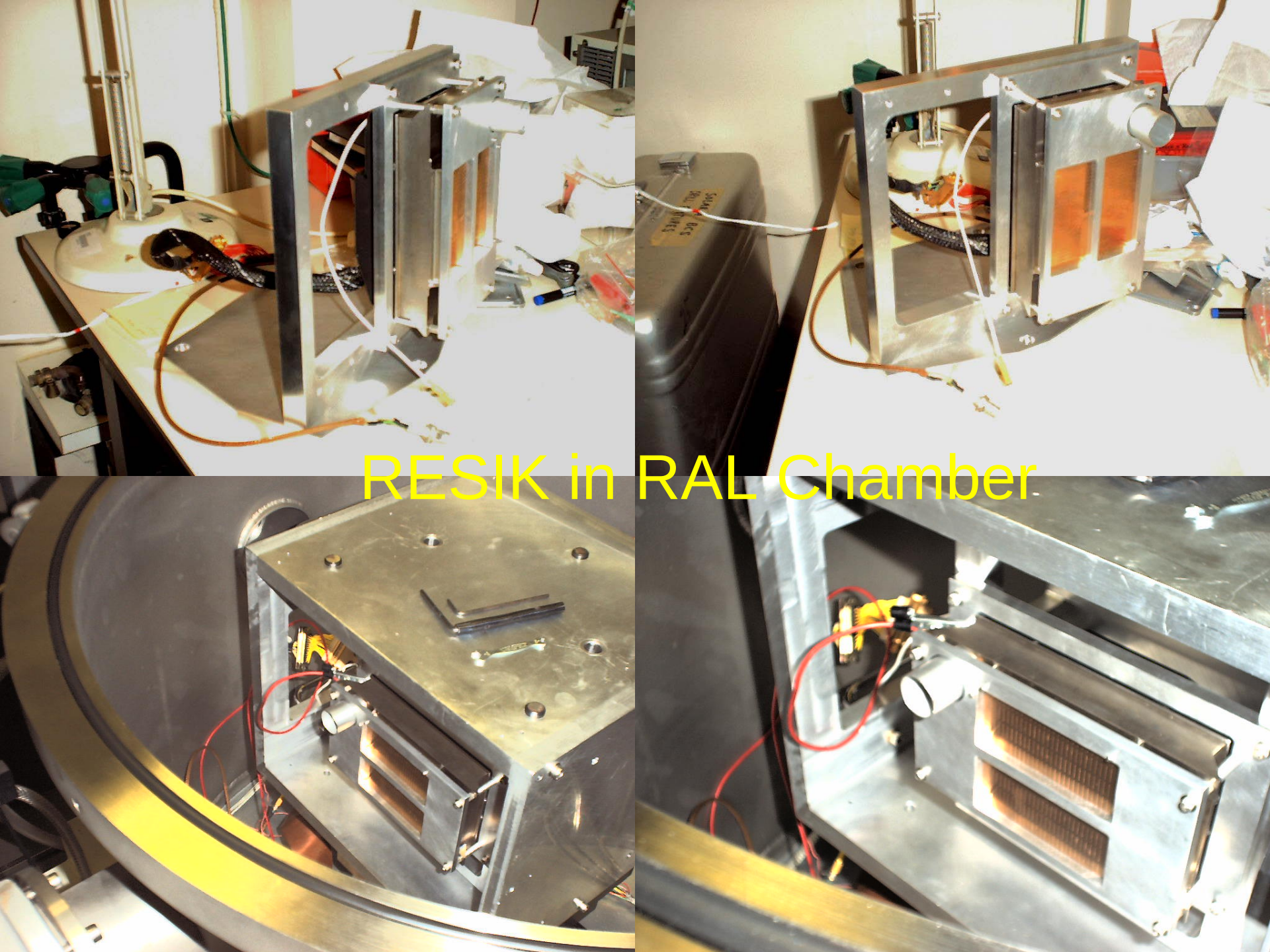

WARNING-HIGH
DO NOT TOU

Instant measurements at all wavelengths no fluorescence from germanium

- Use Cylindrically Bent Crystals
- Use Position Sensing Detector
- Bragg's Law: $\lambda = 2d \sin(\theta)$
  - Must set Crystal angles properly
  - Spacecraft pointing affects wavelength
  - X-ray source position affects wavelength
- $\Delta\lambda = 2d \cos(\theta)\Delta\theta$

How it works

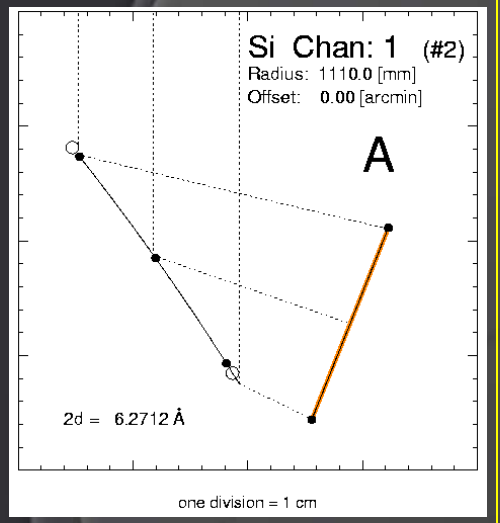

silicon monocrystal wafer, cut along 111 plane, bent to radius 100 cm
Incoming Solar X-rays
DETECTOR
X
cathode active length
„hidden" bins
cathode crystal illuminated length
Be window

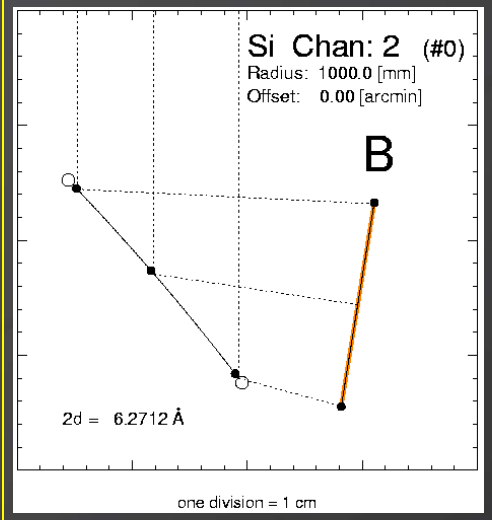

RESIK in RAL Chamber

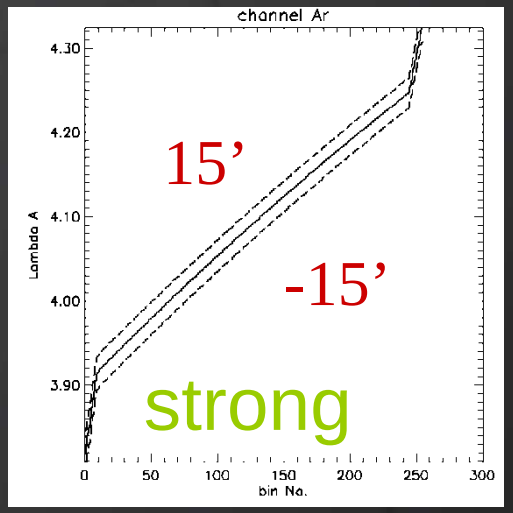

RESIK Alignment

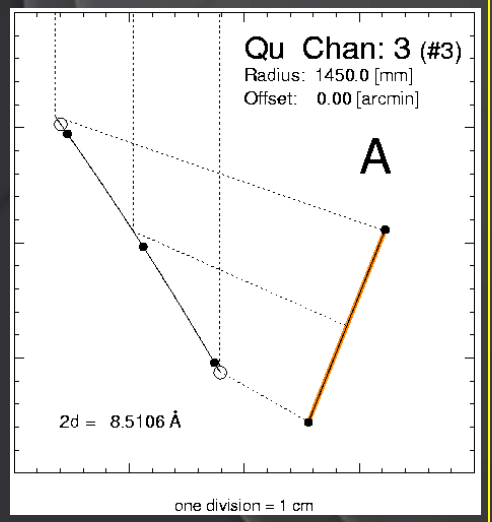

some of RESIK People

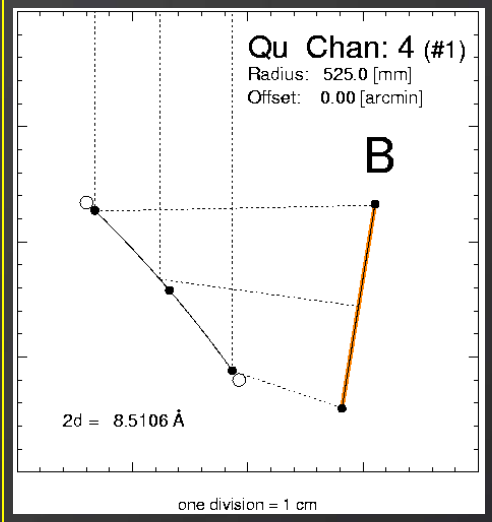
RESIK Geometry (IDL routine)

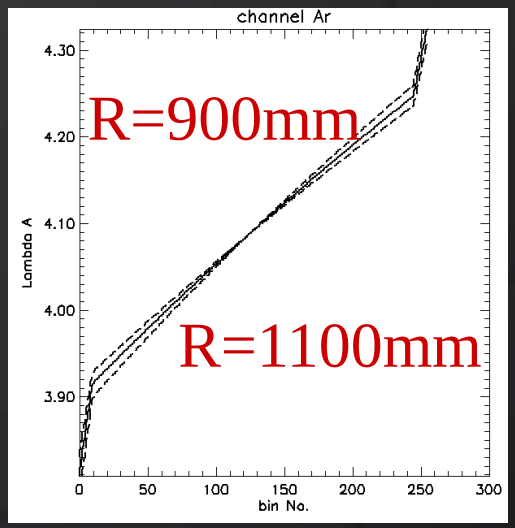








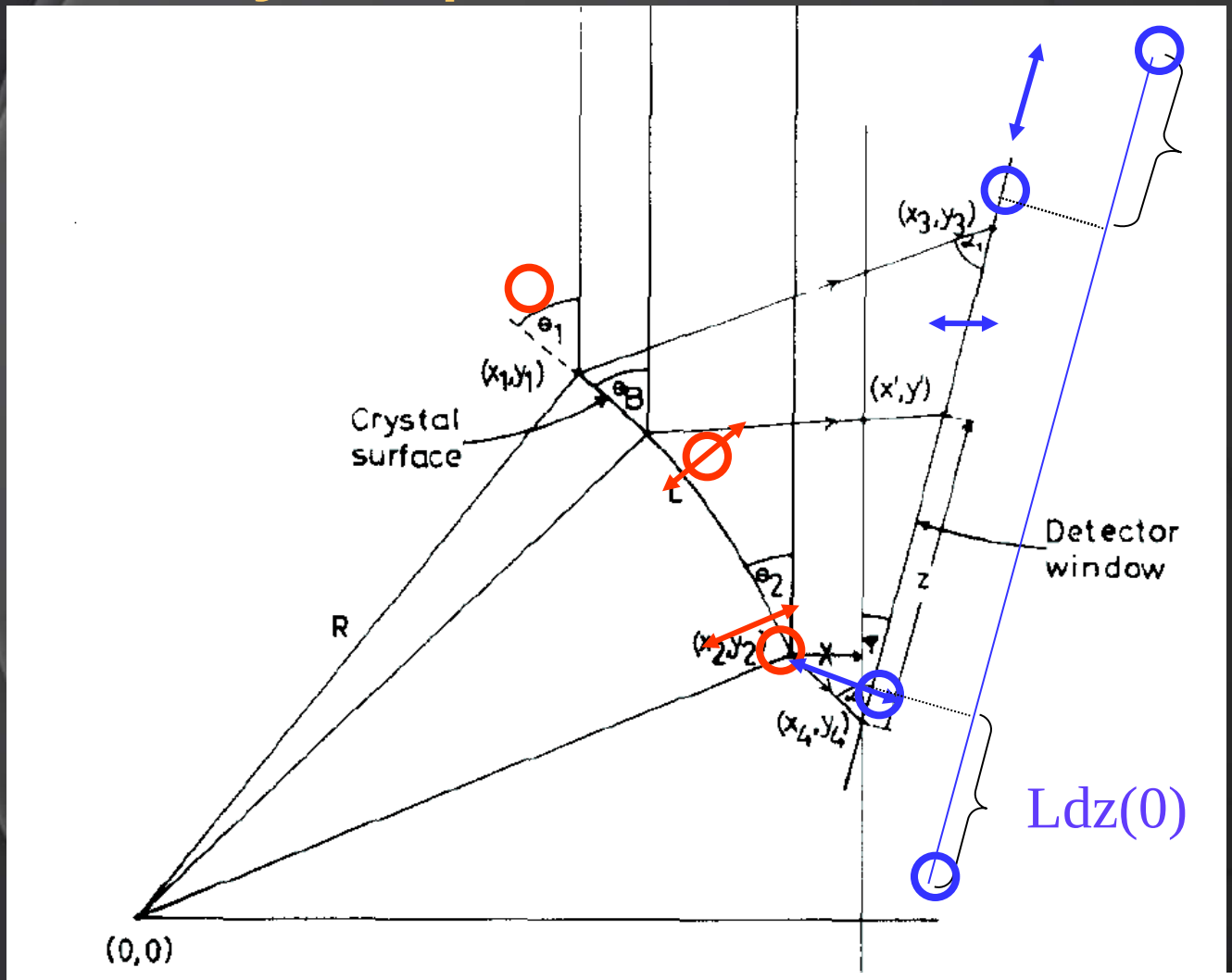




Detector A

Detector B

Accuracy of position determination



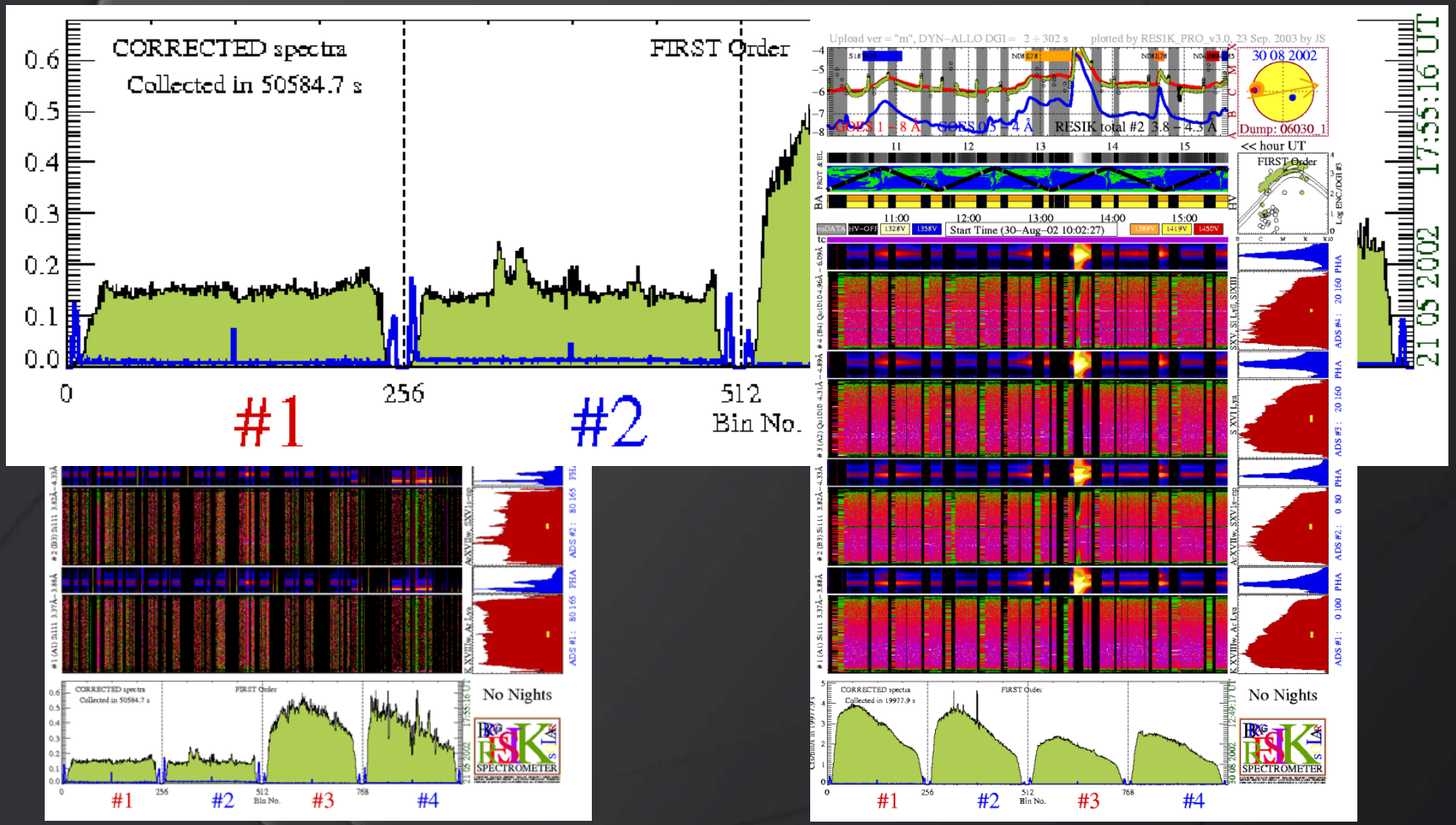
Ldz(1) Hidden W&W length

Ldz(0)

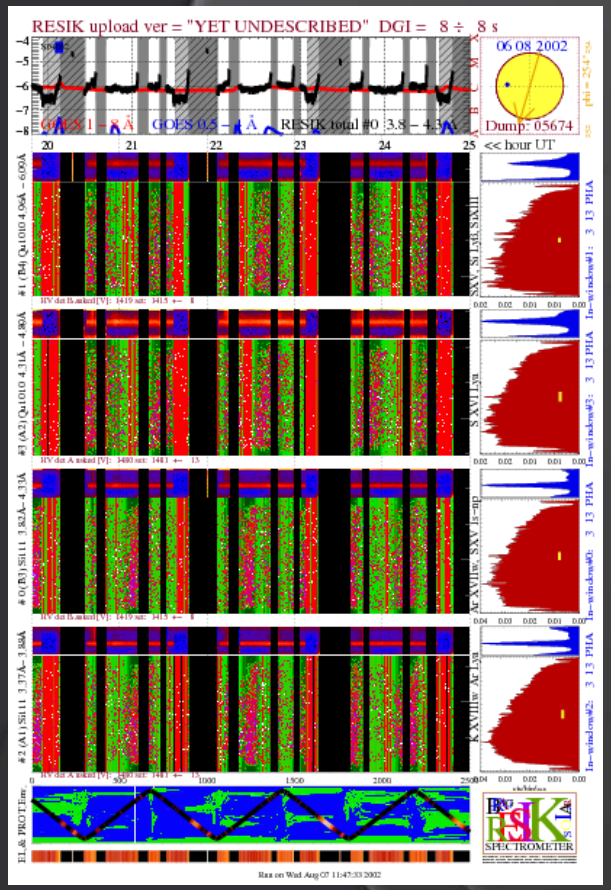
$$z = \sin 2\theta_B[\sin(2\theta_B + \varphi)]^{-1}\{R(\sin\theta_B - \sin\theta_2) - [R(\cos\theta_2 - \cos\theta_B) + X](\cot 2\theta_B) + X\cot 2\theta_2\}. \quad (6)$$

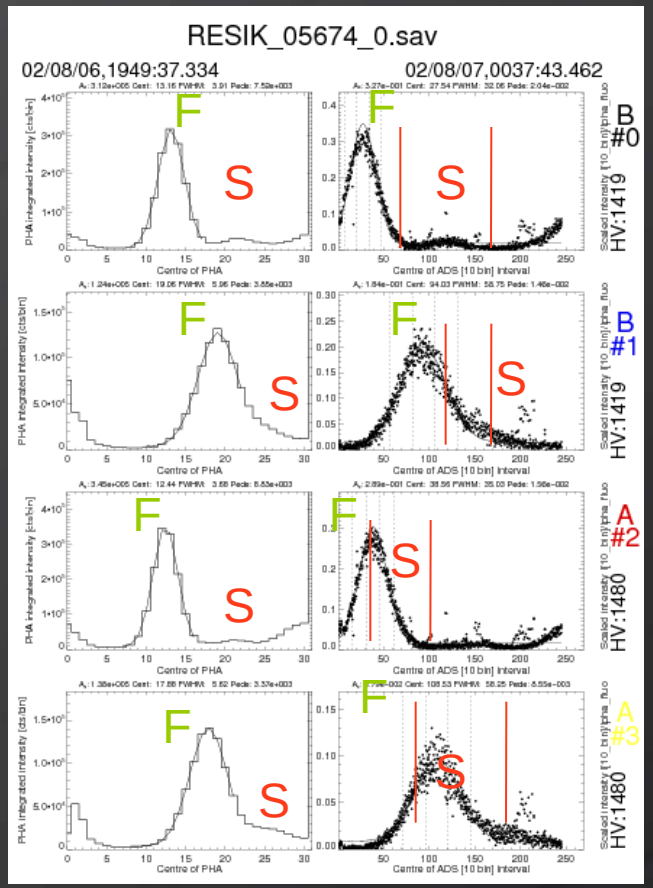
?

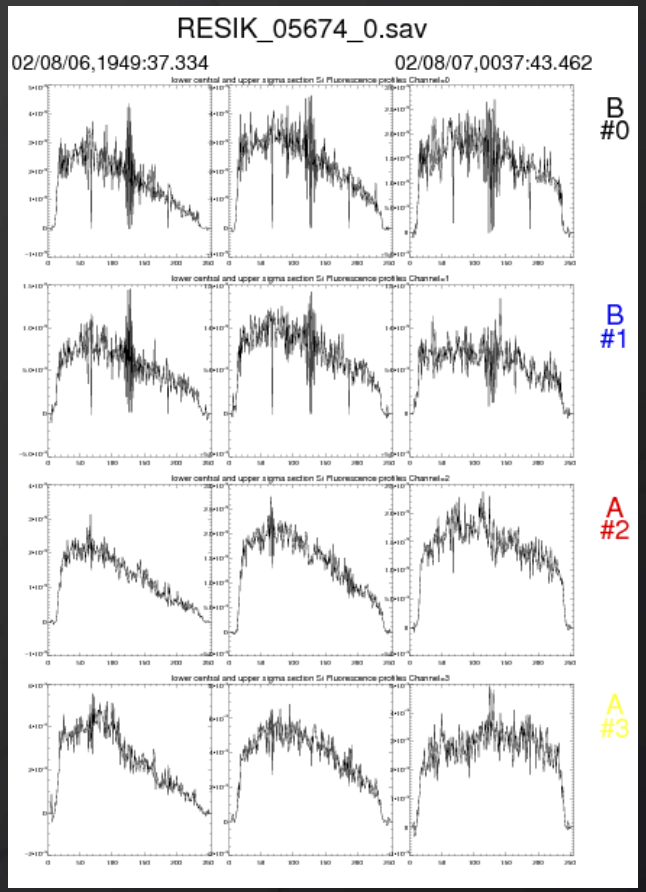
The most unfortunate RESIK discovery



Energy calibration of ADS and PHA

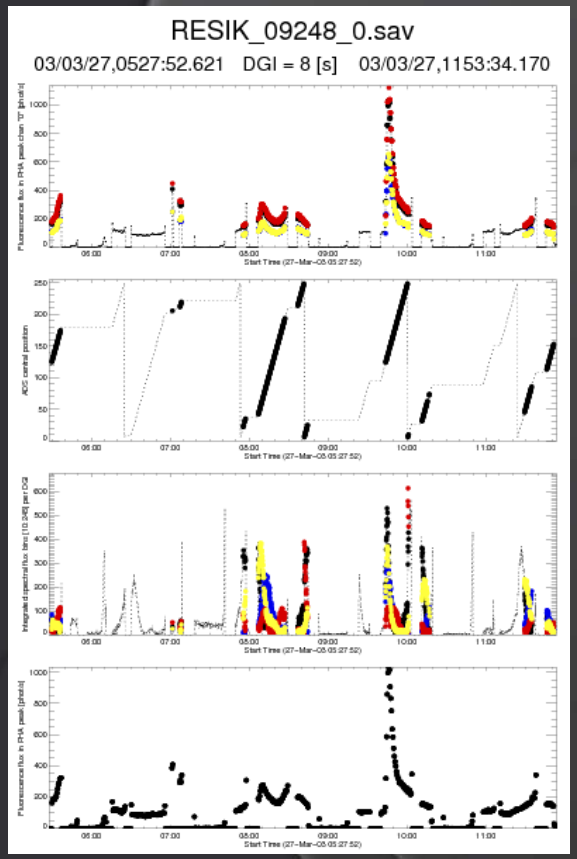


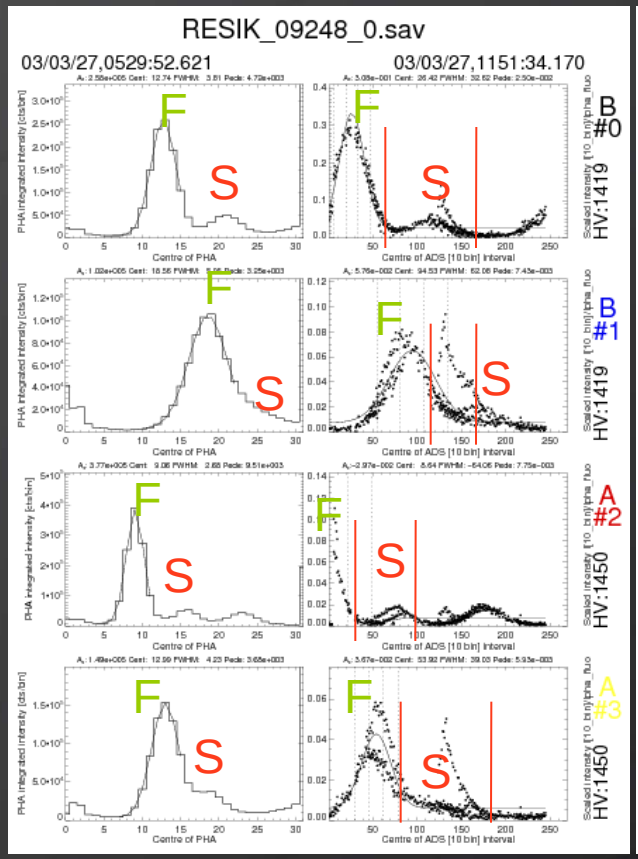


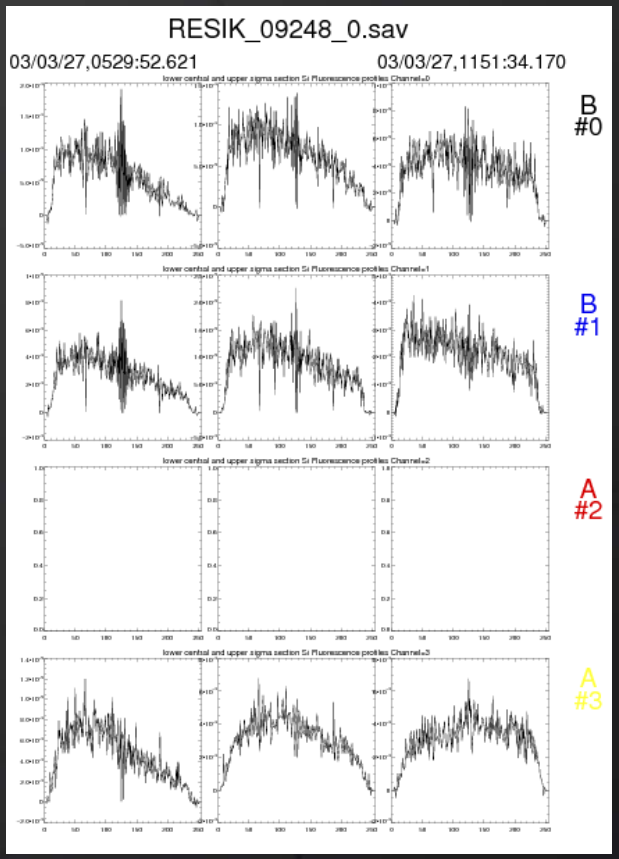


constant flux PHA ADS

Observed pattern of count-rate energy shift dependence





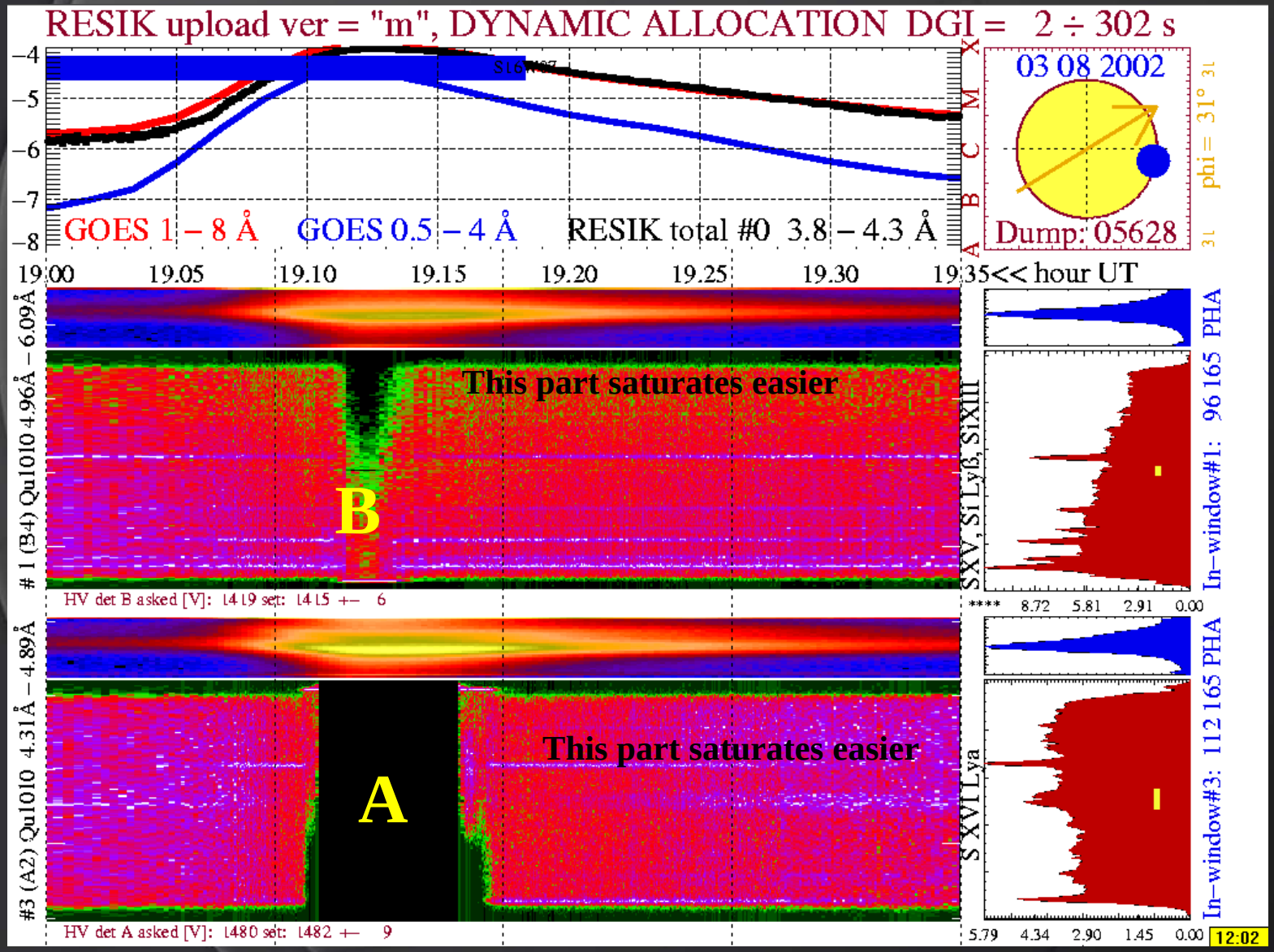


PHA ADS

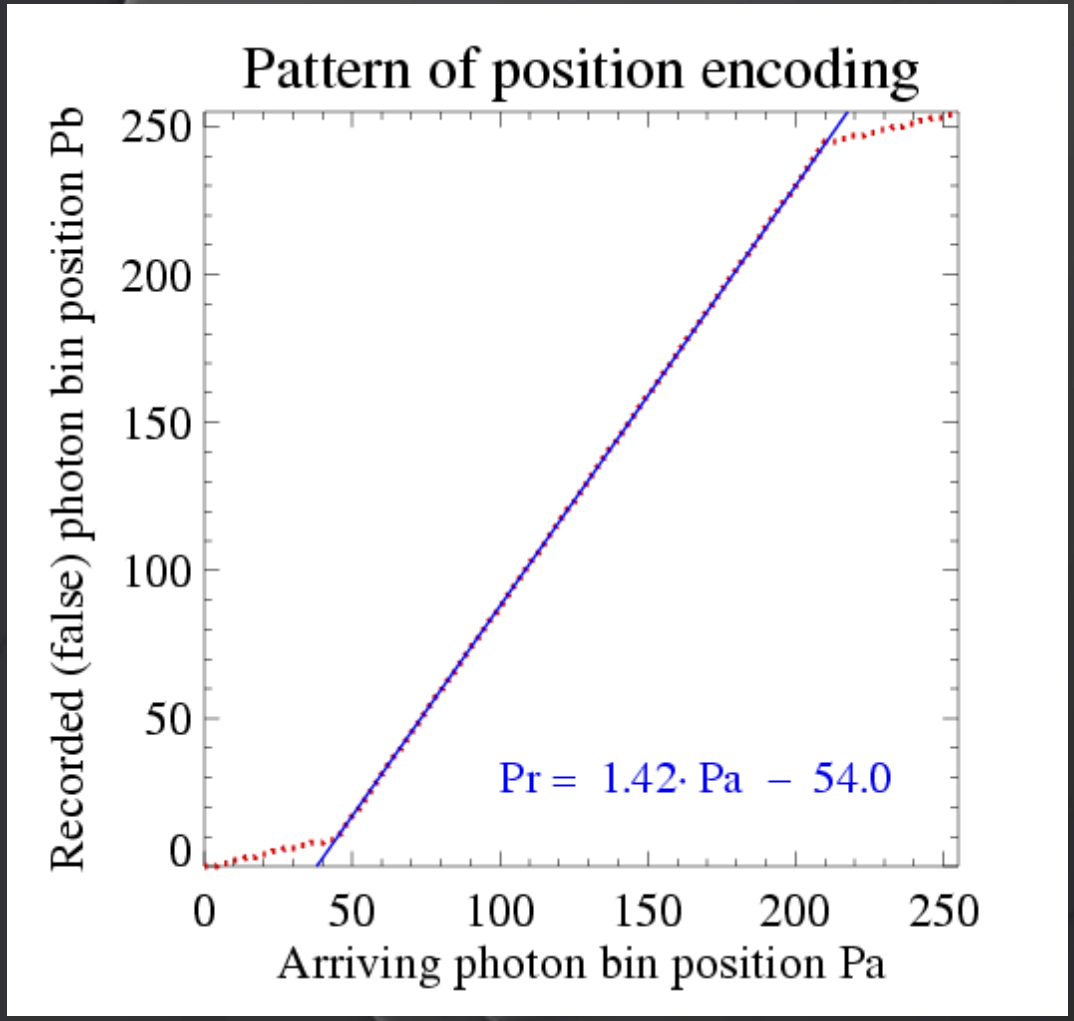
How to subtract fluorescence

- Determine the actual flux from PHA peak
- Determine count rate in detector A & B
- Find countrate dependent conversion between PHA scale and ADS scales
- Calculate probabilities for fluorescence and solar signal in-window proportions
- apply appropriate fluo subtraction profiles
- generate and correct for FPS

Detector saturation for X-class events



Pattern of position encoding

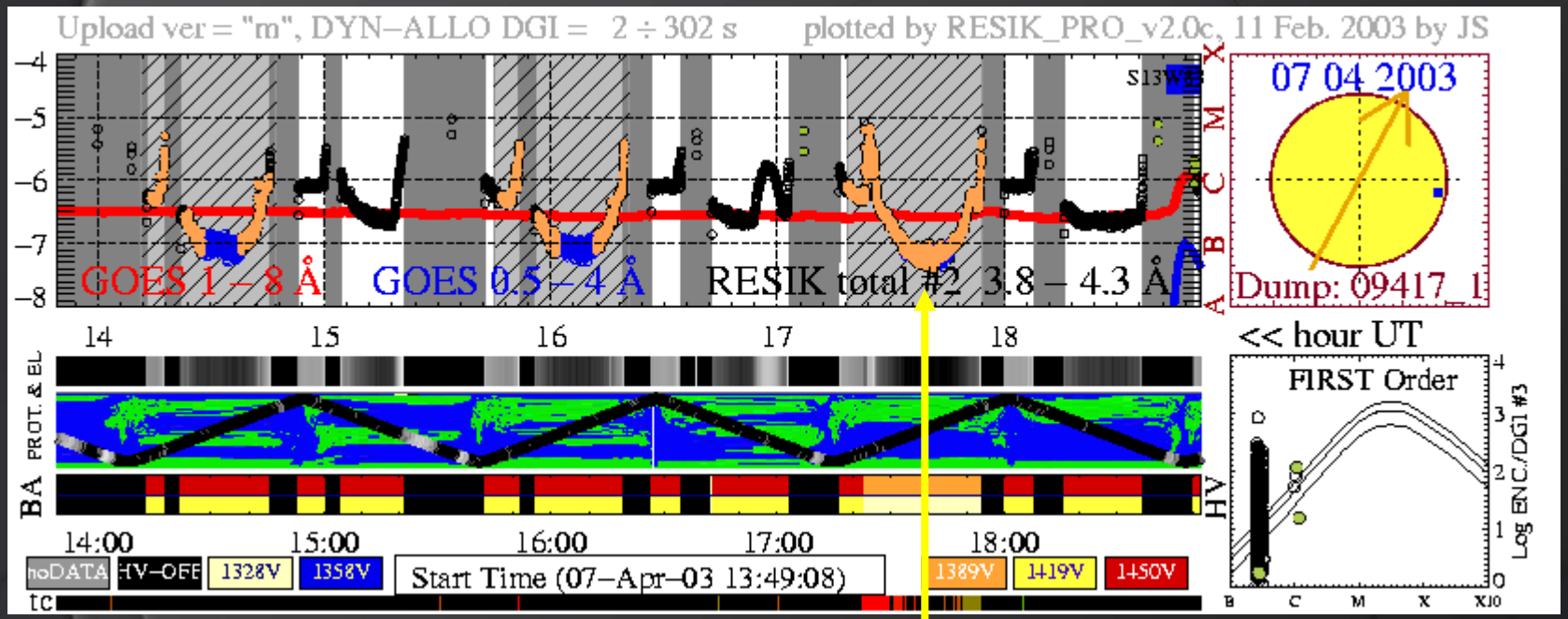


The region along the active length of the position encoding is zoomed electronically at the cost of edge, hidden bins lengths

Background

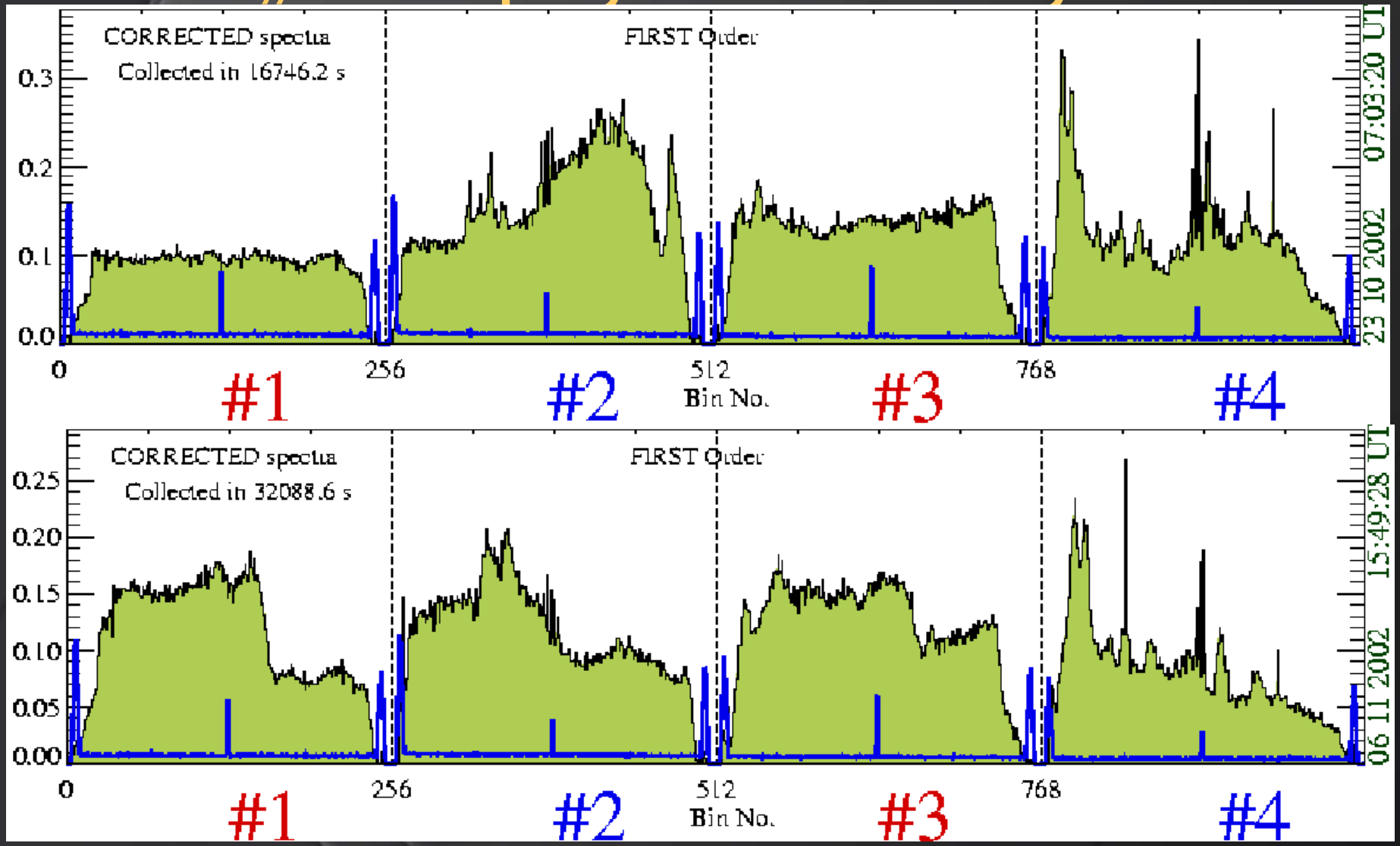
- Orbital, depending on the position relative to Earth magnetic dipole
- Due to auroral, in situ X-ray emission
- Due to non-solar X-ray sources Sco-X1
- Due to energetic particle enriched regions: SAA and Polar Ovals

7. Apr 2003, Dump: 09417_1



Interval selected: 17.5-17.8

„Astrophysical” X-rays



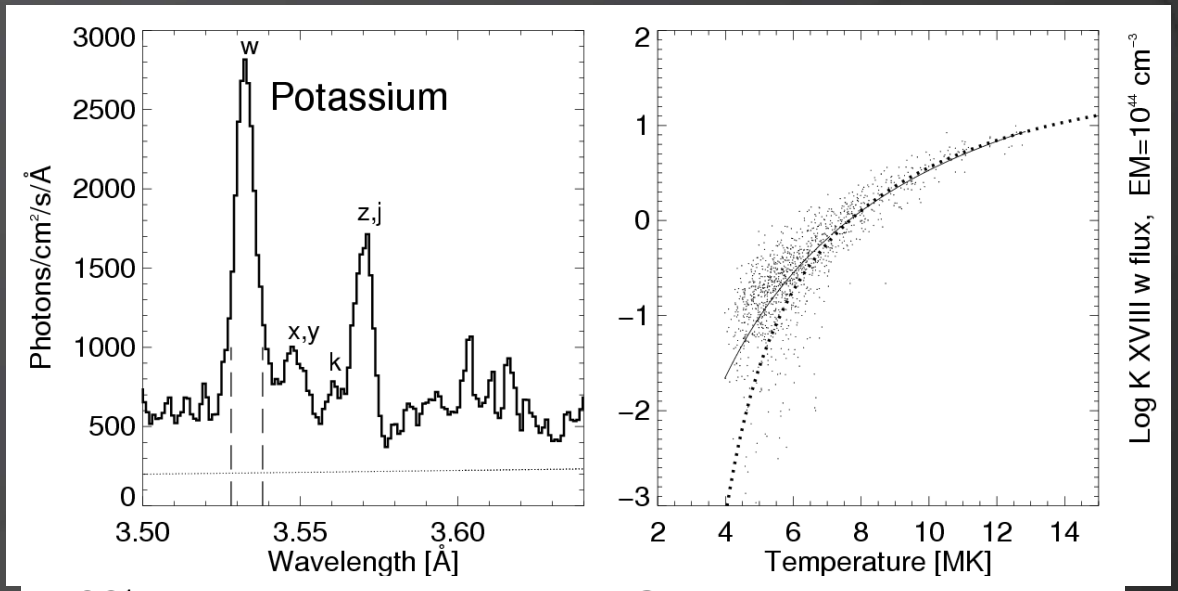
How to check for good RESIK observations

Use RESIN package

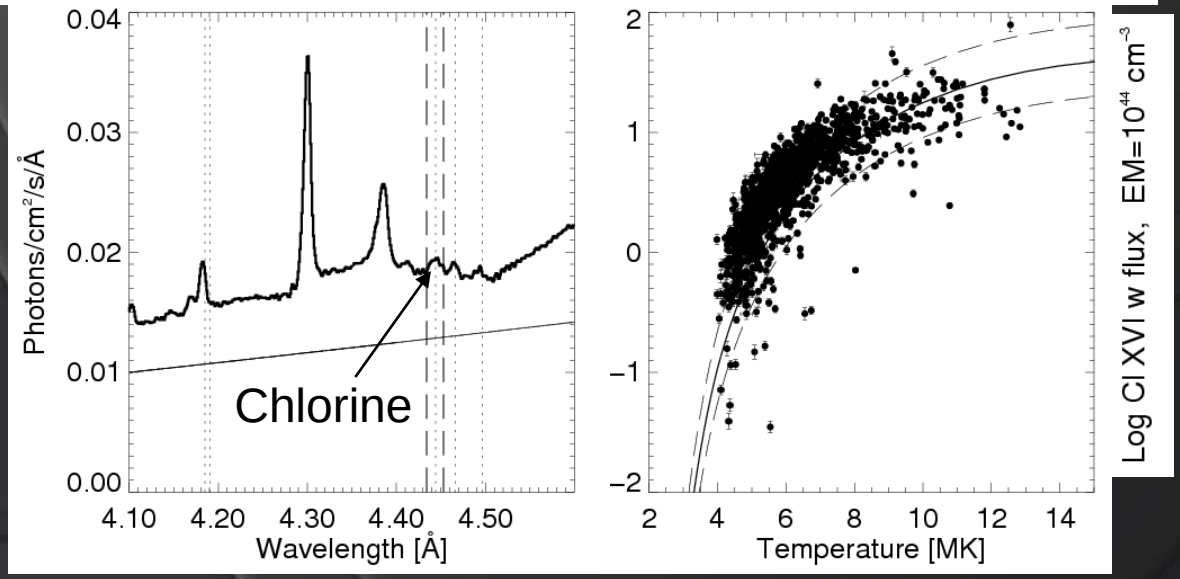
Summary of spectra reduction

- Semiautomatic is possible for „good" ADS settings period using RESIN IDL package:
  1st January 2003 – 13 March 2003 (mid-May)
- Barbara made selection of ~1000 spectral intervals from this period (~10%) of the data available – statistical analysis has been done
- Individual events have to be analysed „by hand" selecting appropriate $E_{ADS\_boundary}$ interactively
  - done on request 1 full day work/event ~10 flares analysed yet
  - simple_resik IDL routine demo on selected event can be run at this Workshop

Absolute K & Cl abundances



$A_K = 6\ 10^{-7}$



$A_{Cl} = 7.7\ 10^{-7}$

work still to be done

- Find
  - detailed relationship:
    count rate→discriminator energy→ fluorescence profile
  - incorporate fluo subtraction within the code.
- Incorporate results of ground calibration
- Recalibrate 85% of the observations
- Auroral X-rays…, Sco-X1
- „Backward" calibration (cts/bin→phot/Å/cm^2/s) depends on highly non-linear relationships (channels 3 & 4)
- Proper treatment → forward direction:

Model (DEM+ geometry+ beams+…) →
instant input spectrum → predicted cts/bin→
comparison of observed & predicted → improved model

Conclusions

- Do not lose confidence with RESIK – with all described problems, it appears to be the „best calibrated" Bragg spectrometer flown!
- A big „discovery potential" exists, as will be shown later-on → each flare or data set we looked into brought oh-achs!
- Systematic studies over entire database are possible for the Ar XVII (channel 2) right now as this channel settings did not changed over the entire active life of RESIK (except for the calibration)