A New Gain Map and Pulse Height Filter for the LETG/HRC-S Spectrometer

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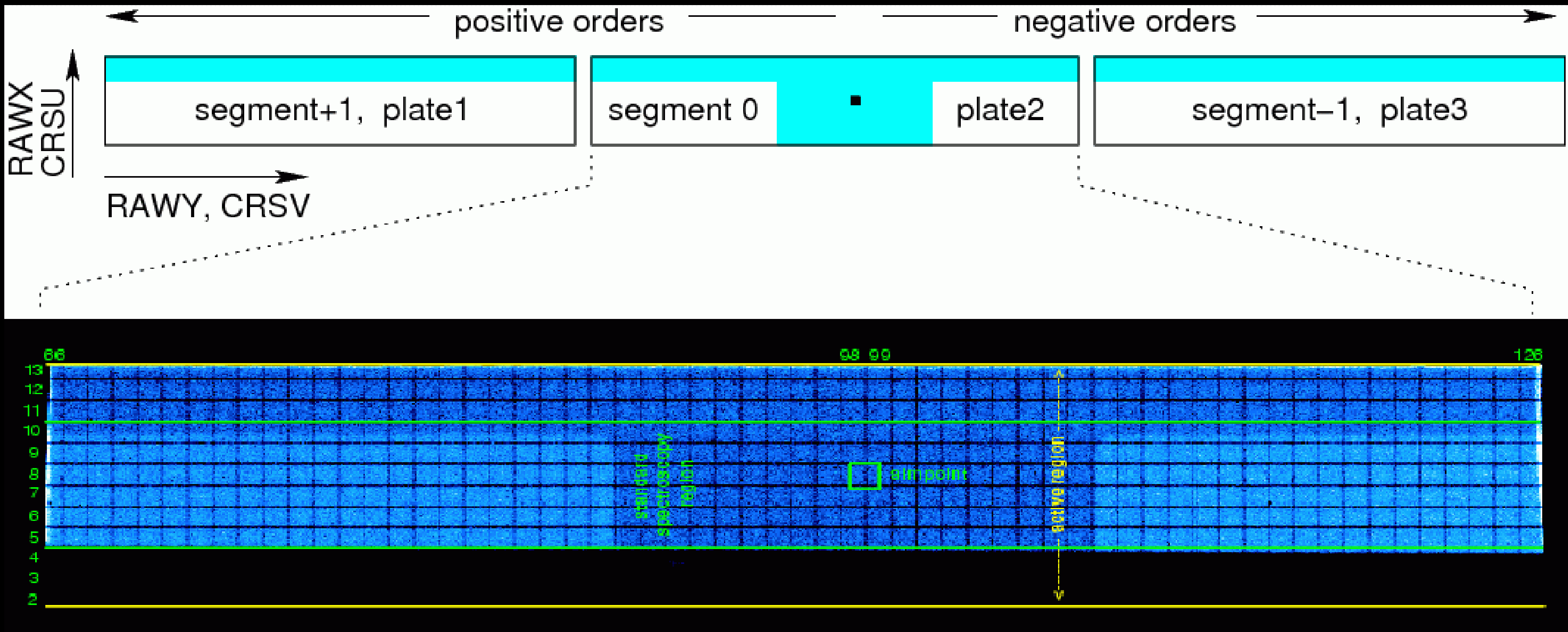
Motivation

Improvements over 2001 gain map:

- Use SAMP instead of PHA for event amplitudes
- Finer spatial grid (1/3 vs 1/2-tap)
- Gain map is a function of position, pulse amplitude, and time
- BG-subtraction of B-K lab data
- Includes detector areas not calibrated with X-rays in lab

A better gain map allows tighter filtering to remove background.

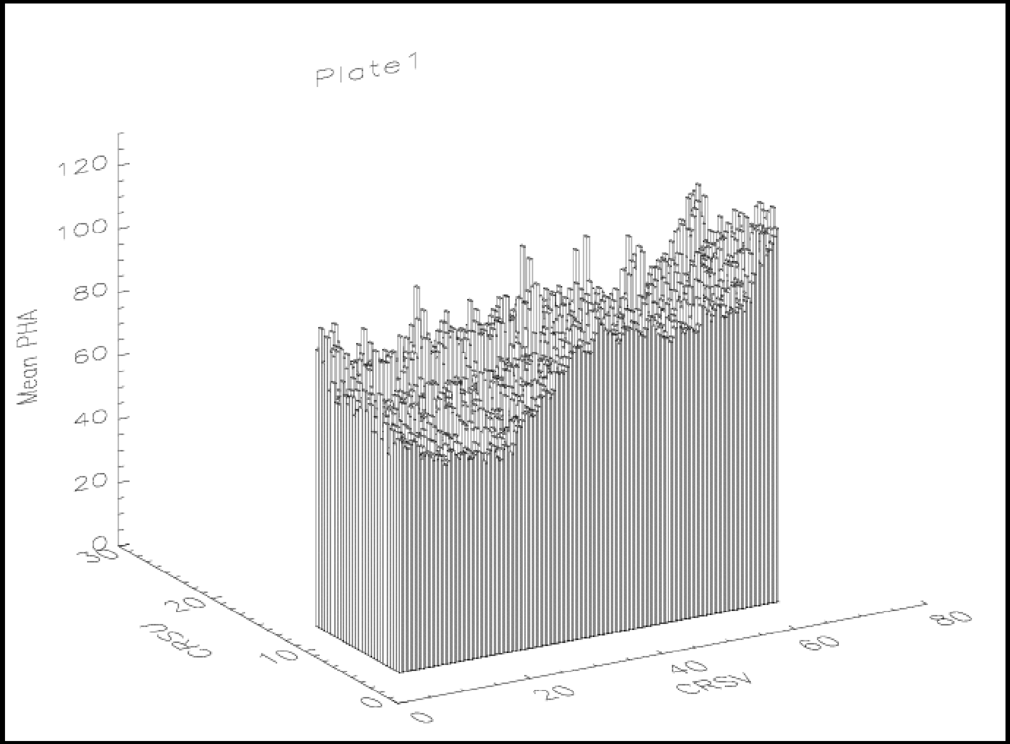
Preflight Lab Calibration (8 energies)



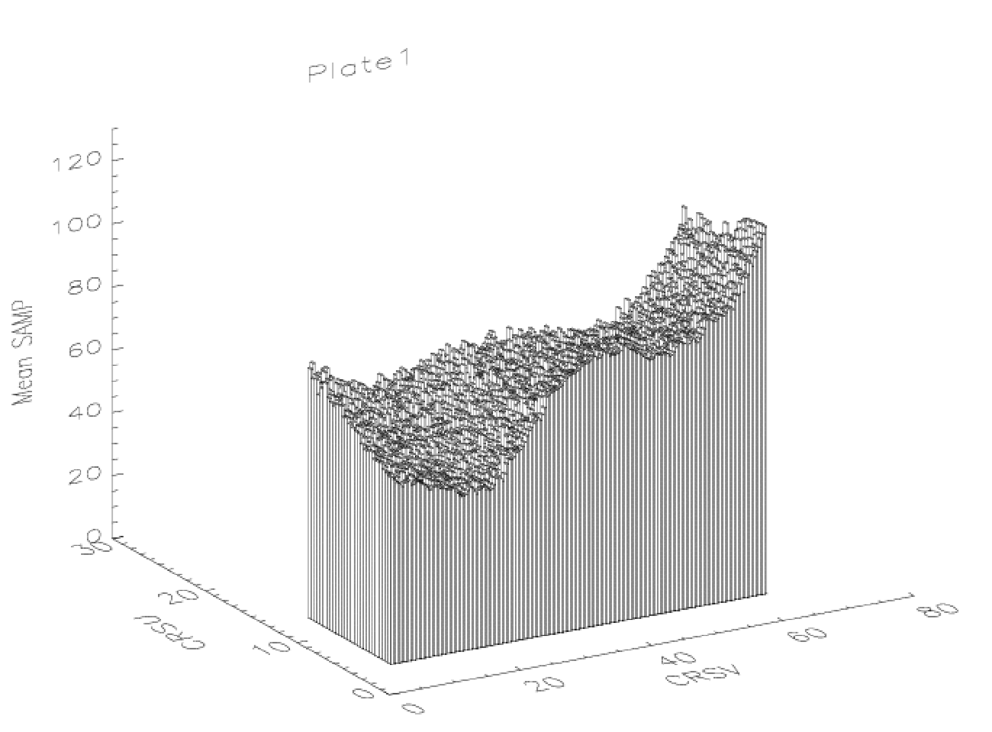
B-K (183 eV) All 3 plates
C-K (277 eV)
O-K (525 eV)
Al-K (1487 eV)

Ni-L (852 eV) Center plate only
Ag-L (2984 eV)
Ti-K (4511 eV)
Fe-K (6404 eV)

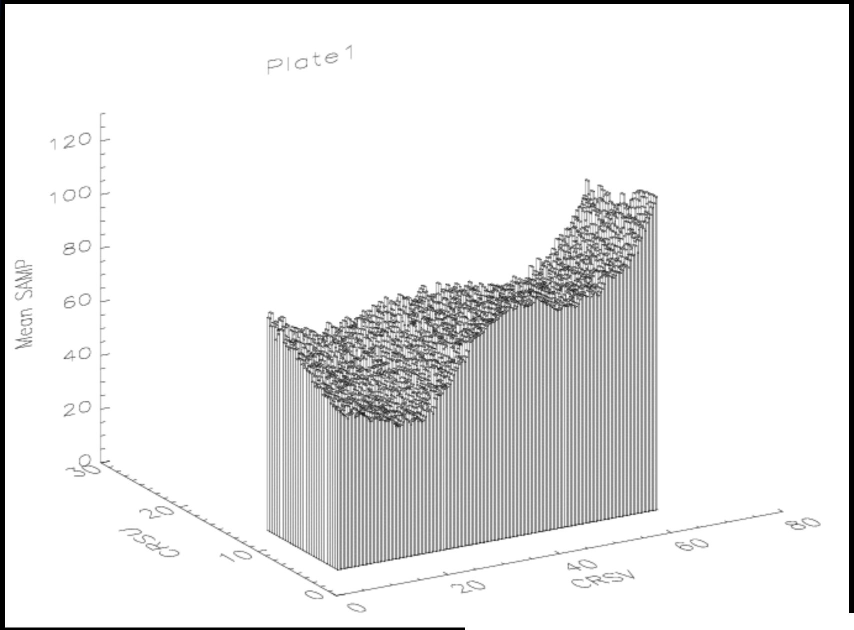
Scaled SUMAMPS (SAMP)

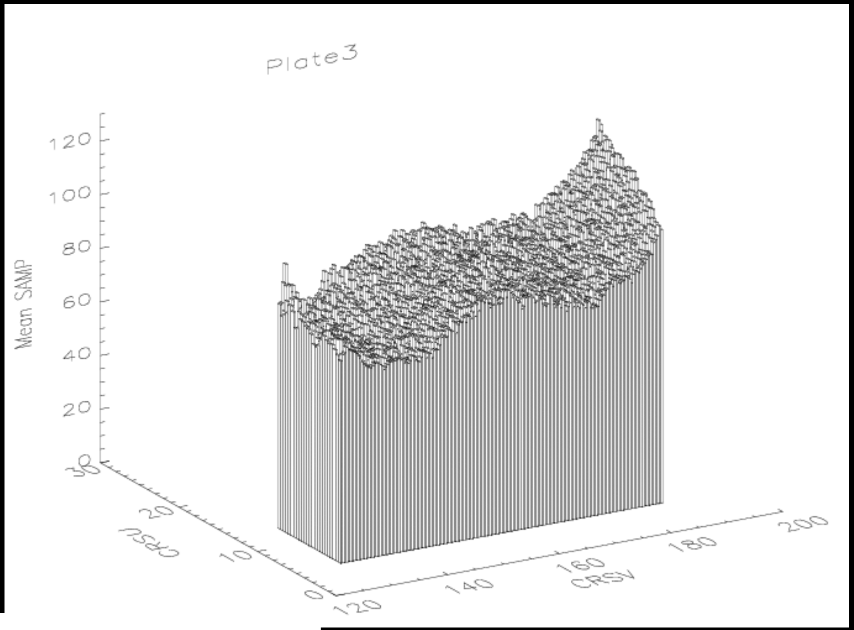


Surface plot of mean PHA for C-K (plate 1).
PHA = sum of all amplifier signals.



SAMP = SUMAMPS $\times$ $2^{(AMP\_SF-1)}/128$.
SUMAMPS = $\sum_{i=1-3} (AU_i + AV_i)$.





Mean SAMP,
Plate 1

Plate 3

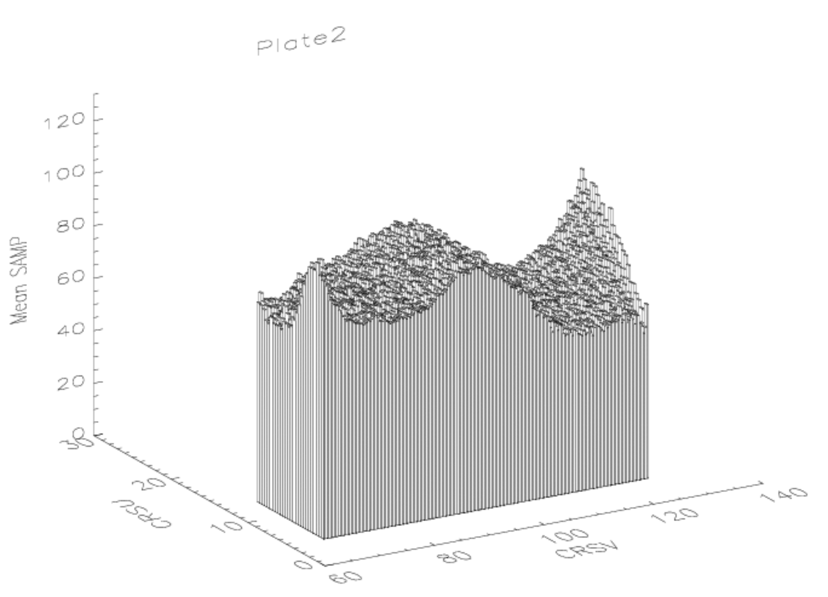


Plate 2

Metrics and Parametrization

3x3 subtaps per tap.

Used truncated means (5-95%; less sensitive to outliers) and IQRs for errors.

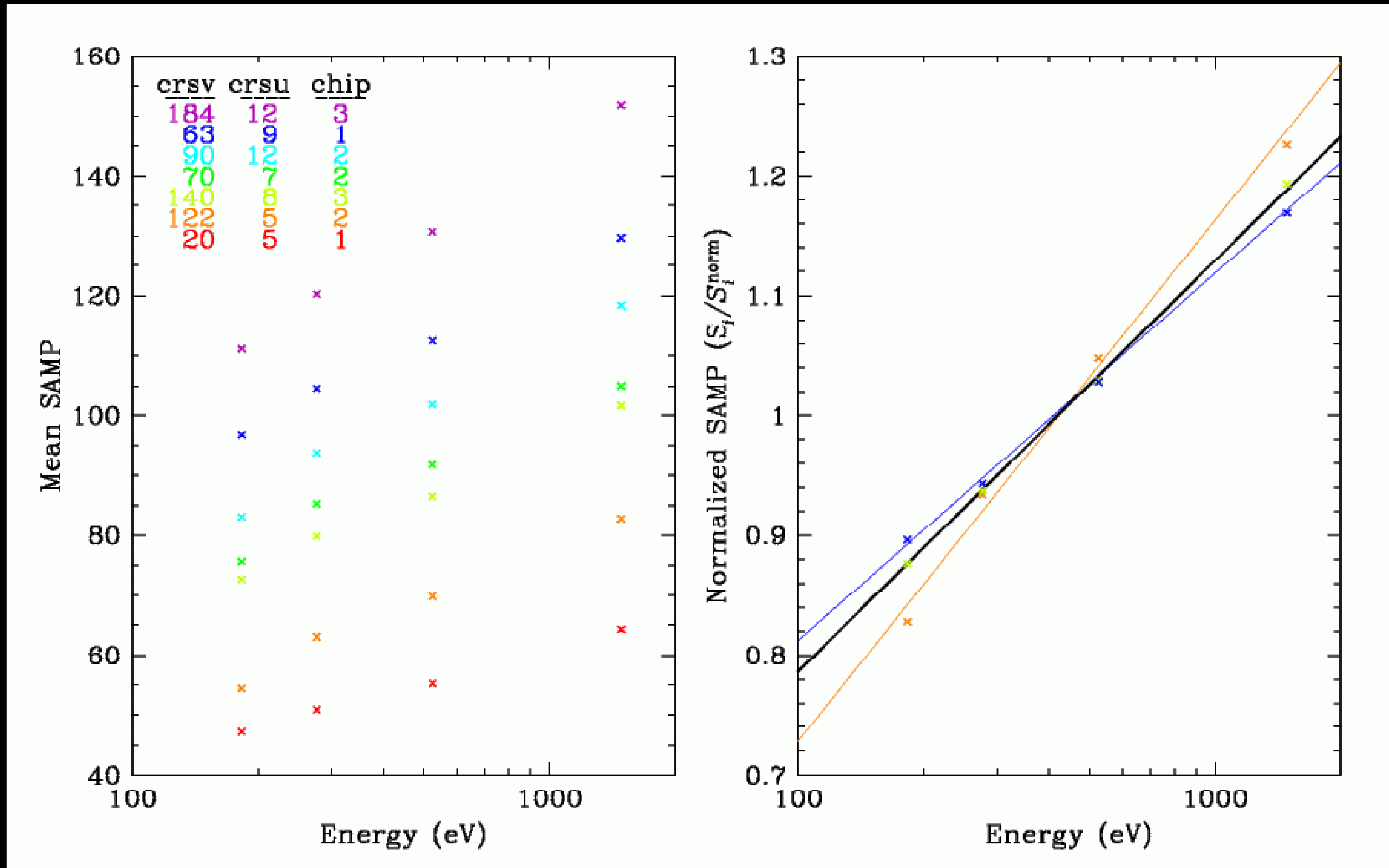
Typically 500 cts/subtap. Sample 1x3 for <150 cts, 3x3 for <100 cts.

B-K data required BG subtraction. Up to 25% BG in outer T regions, leading to 5% increase in mean SAMP if uncorrected.

Use mean SAMP from B, C, O, Al data (collected on all 3 plates) to determine 2 params in gain function. S_i^{norm} = ave of B,C,O,Al means.

SAMP-based PI = SPI = $(38.88/m_i)(SAMP/S_i^{norm} - b_i) + 11.37$

$$= G_1\ SAMP + G_2$$

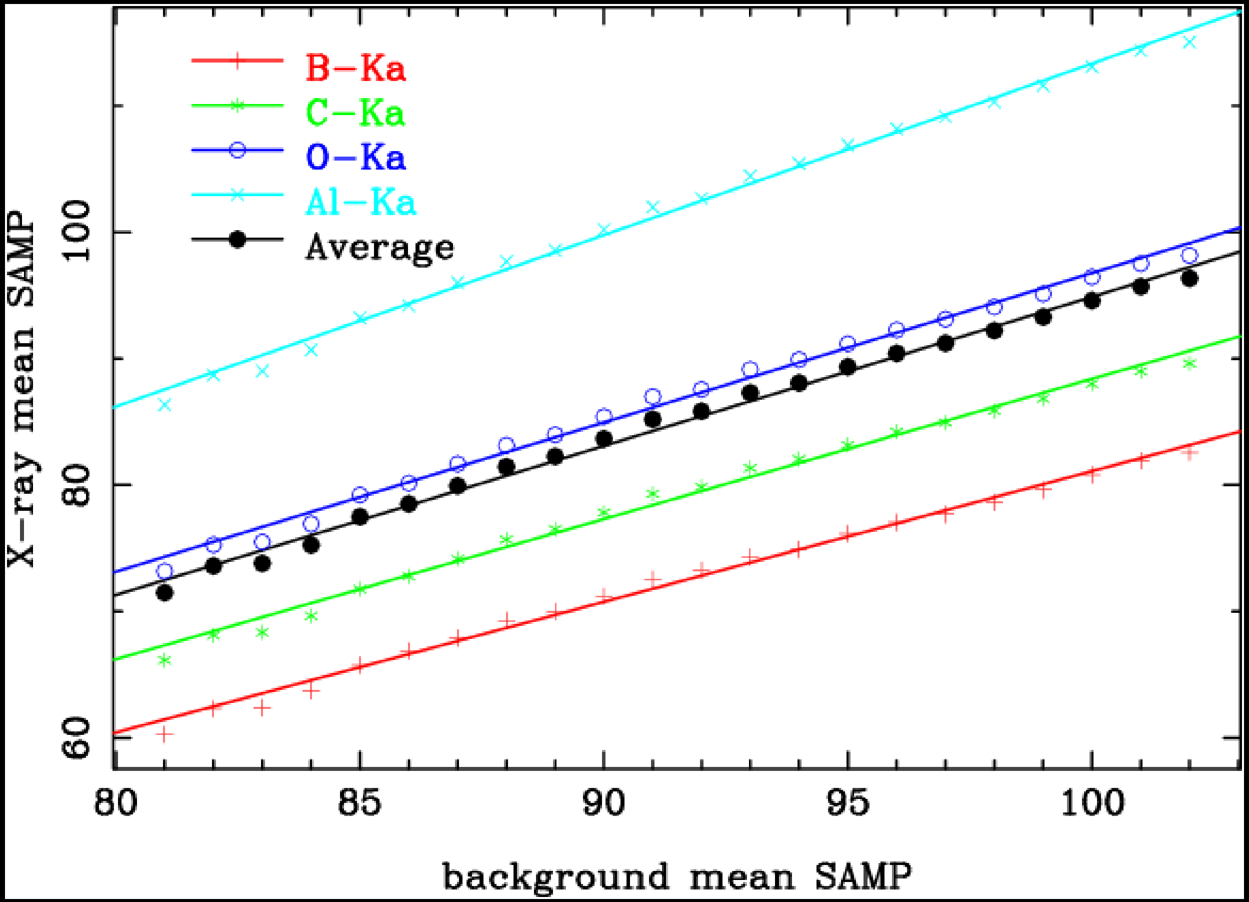


Mean SAMP for 4 energies (183, 277, 525, 1487 eV) at 7 representative locations

Means are norm'd to S_i^{norm}. Thick black line traces reference gain function.

Linear equal-weight fits to the 4 mean SAMP values vs log$E$ yield m_i and b_i.

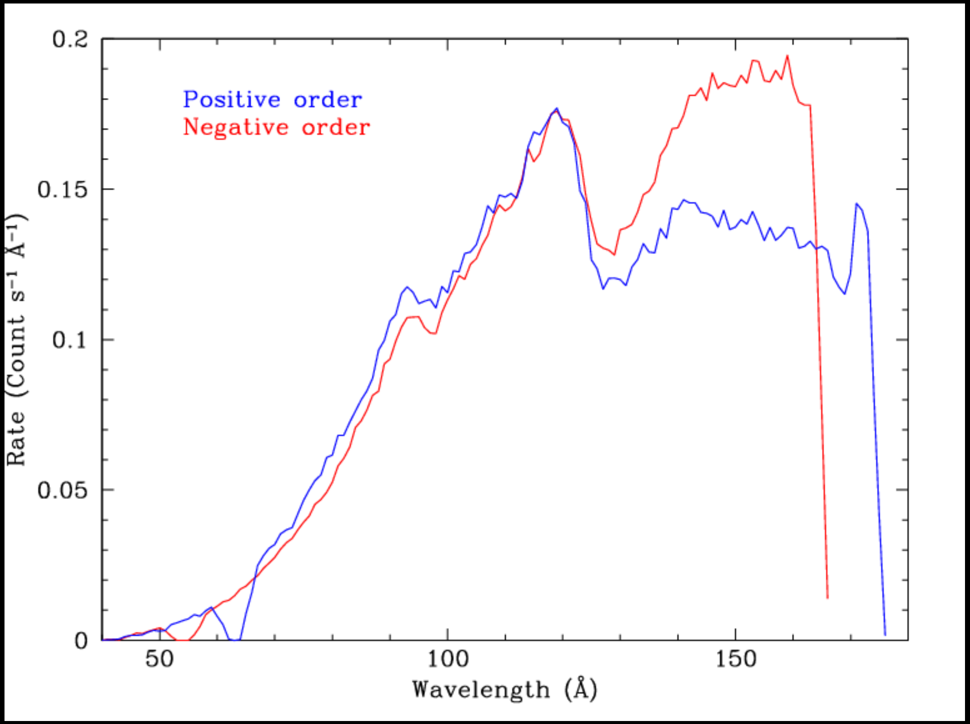
Calibration of Unilluminated Regions



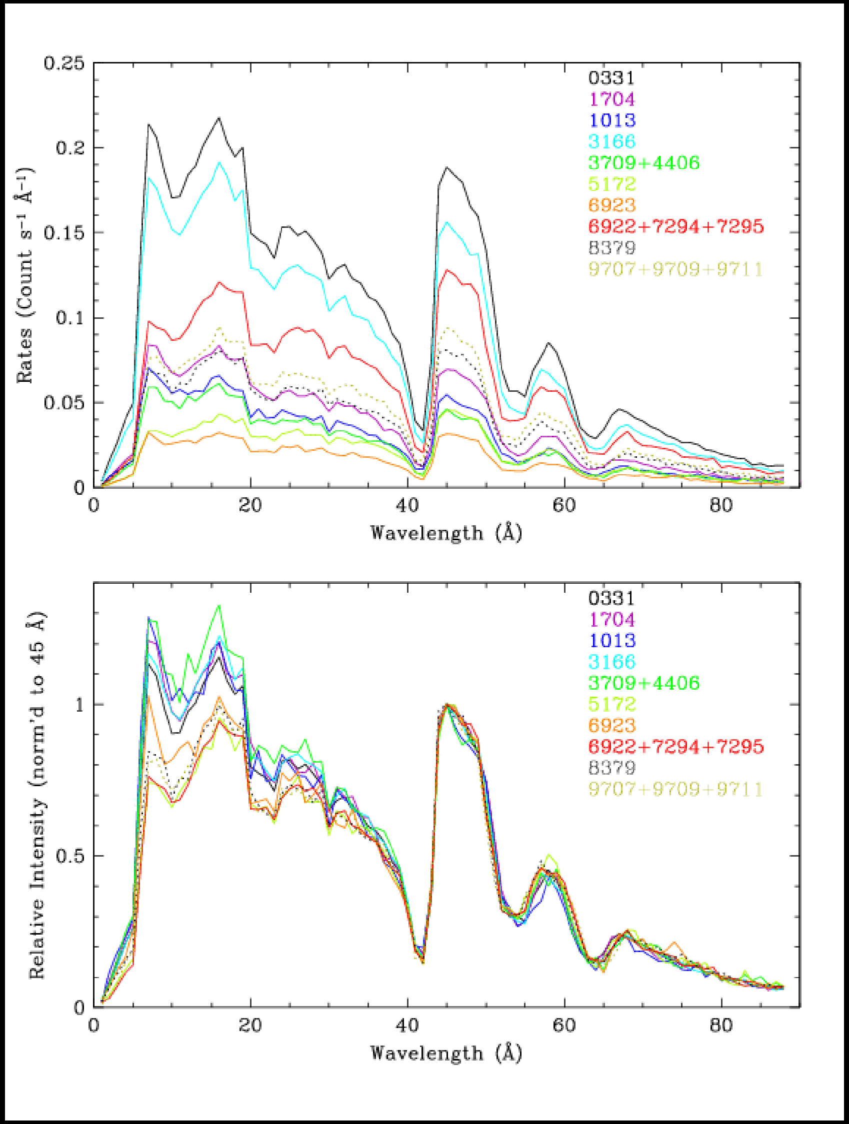
Compare mean SAMP of X-ray and BG data in illum'd areas (3x3 sampling).
$S_i^{norm} = 1.179\ S_i^{BG} - 23.03$. m_i extrapolated from illum'd U subtaps.
Final result is the Lab Gain Map.

Temporal Calibration of On-Orbit Gain

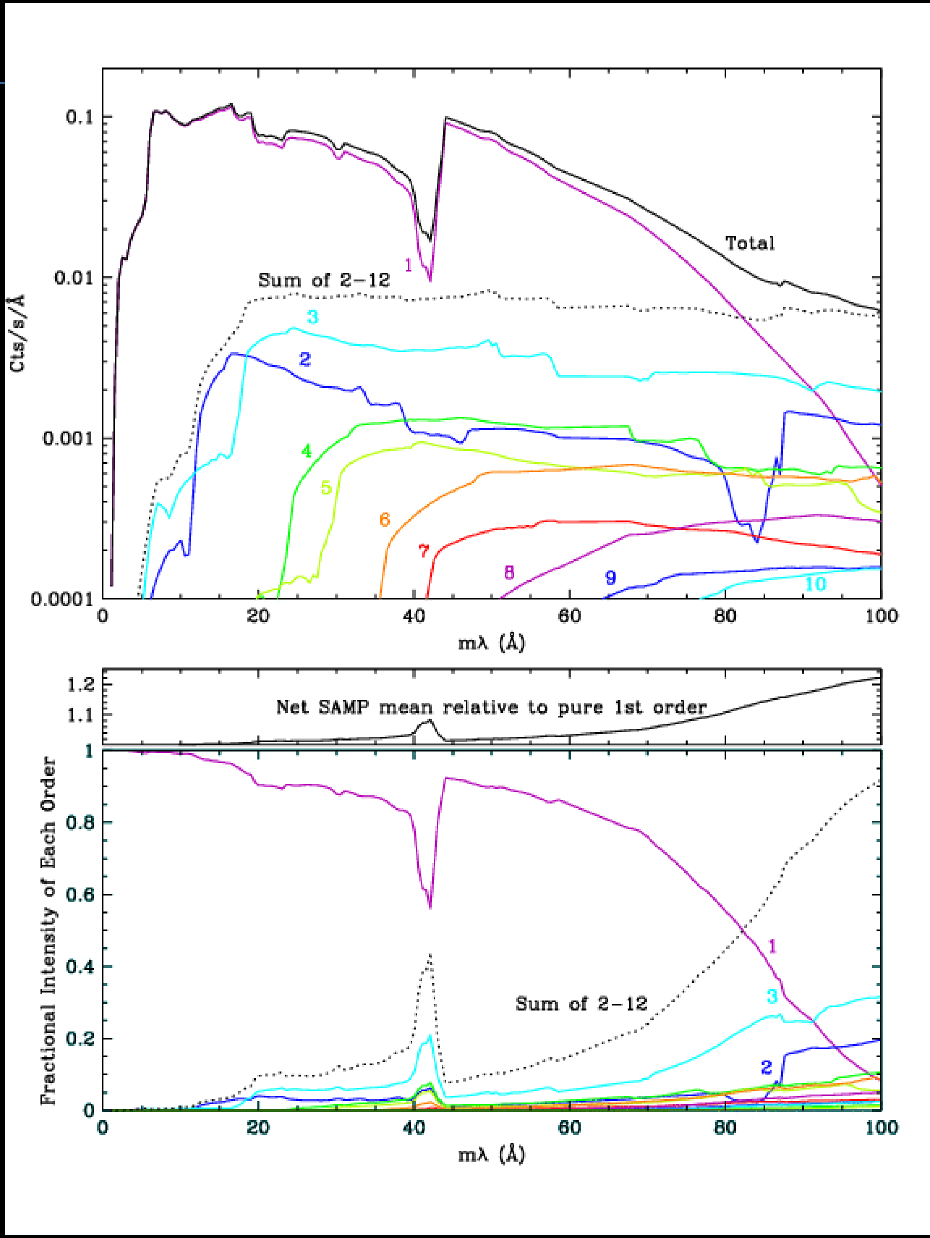
Use bright continuum sources, regularly monitored.



HZ43 for $\lambda \geq$ 50 Å (constant source)



PKS2155 for $\lambda \leq$ 80 Å (variable)



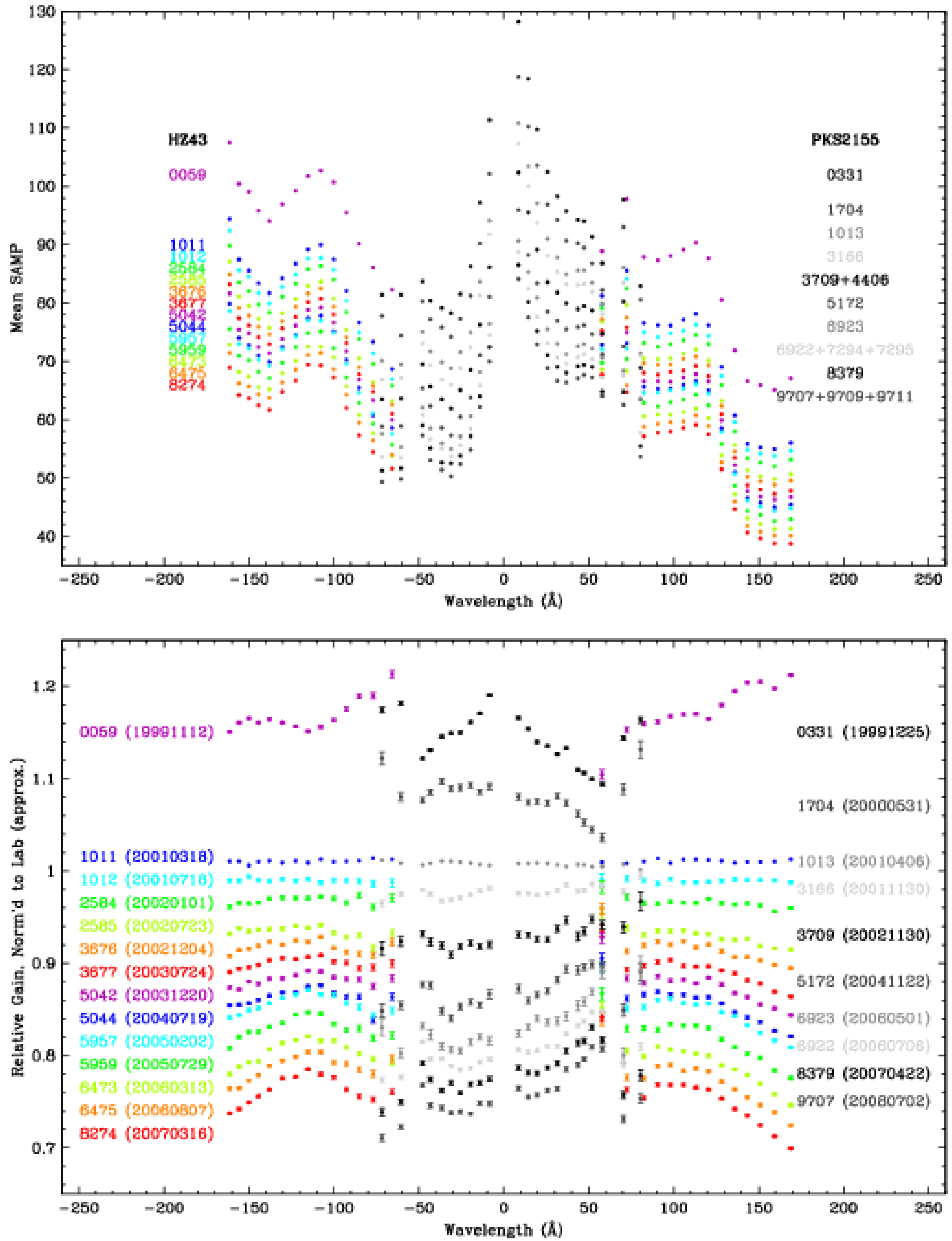
Contribution of higher orders in PKS2155 (ObsID 331) and effect on mean SAMP.

Variable spectrum → variable higher order contributions. Adjust mean SAMP to correct for contam.

Higher-order effects must also be removed to enable comparisons with overlapping HZ43 data.

Measure Mean SAMP in Spectral Slices

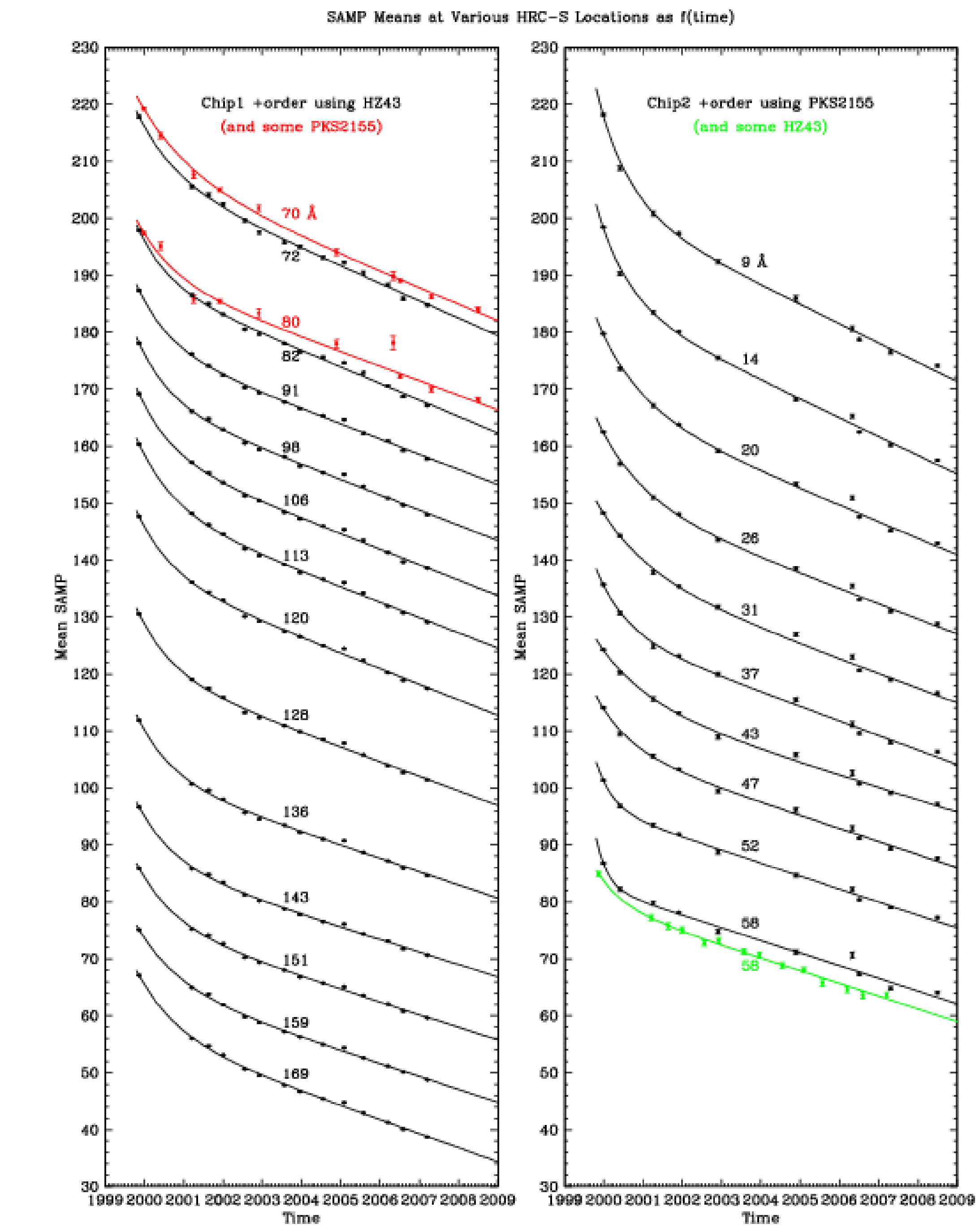
- Only sampling 3 or 4 U subtaps covered by dispersed spectra--apply results to all U.
- Subtract BG spectra.
- Weight subtap data equally in U to deal with dither and aimpoint drift.
- Slice data by wavelength to get adequate statistics, avoiding sharp changes in the spectrum.
- Normalize to epoch 2001.5 based on best agreement between lab and orbit at B-K, C-K, and O-K.

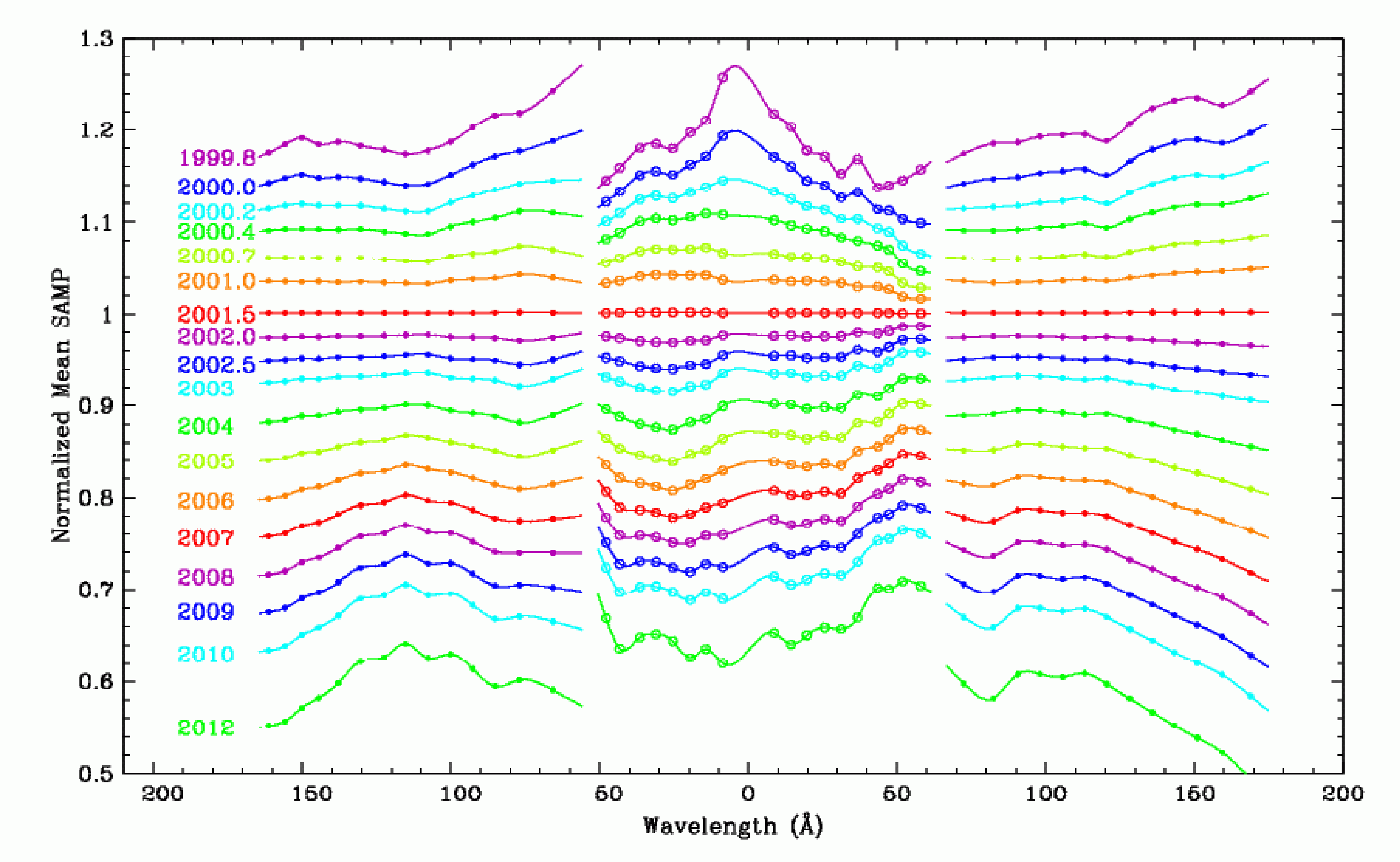

HZ43
0059
1011
1012
2584
2585
3676
3677
5042
5044
5957
5959
6473
6475
8274
PKS2155
0331
1704
1013
3166
3709+4406
5172
6923
6922+7294+7295
8379
9707+9709+9711
Mean SAMP
Wavelength (Å)
0059 (19991112)
1011 (20010318)
1012 (20010718)
2584 (20020101)
2585 (20020723)
3676 (20021204)
3677 (20030724)
5042 (20031220)
5044 (20040719)
5957 (20050202)
5959 (20050729)
6473 (20060313)
6475 (20060807)
8274 (20070316)
0331 (19991225)
1704 (20000531)
1013 (20010406)
3166 (20011130)
3709 (20021130)
5172 (20041122)
6923 (20060501)
6922 (20060706)
8379 (20070422)
9707 (20080702)
Relative Gain, Norm'd to Lab (approx.)
Wavelength (Å)

CXC

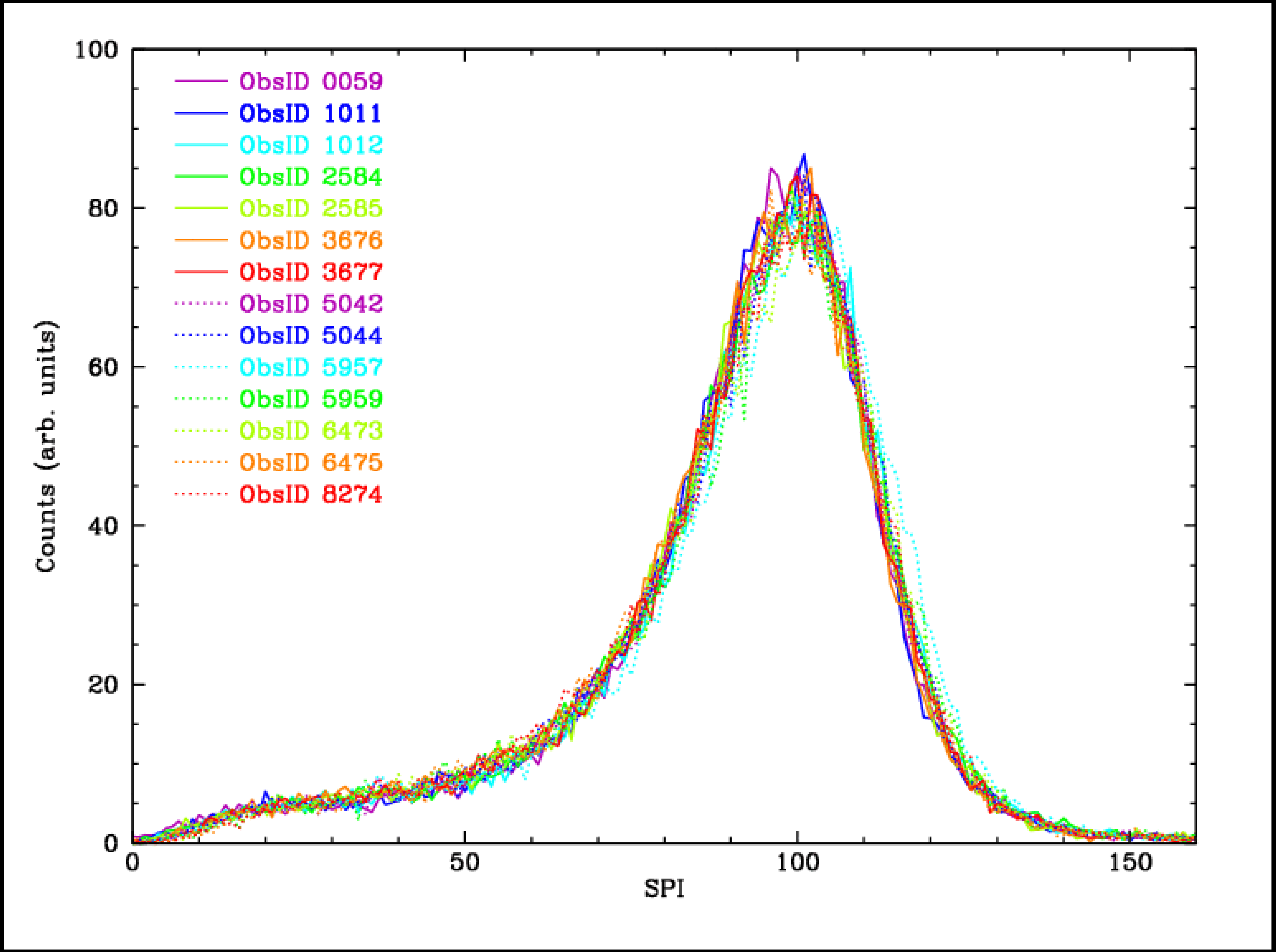
Do temporal fits--exponential plus linear decay.

(Exp+exp slightly inferior.)

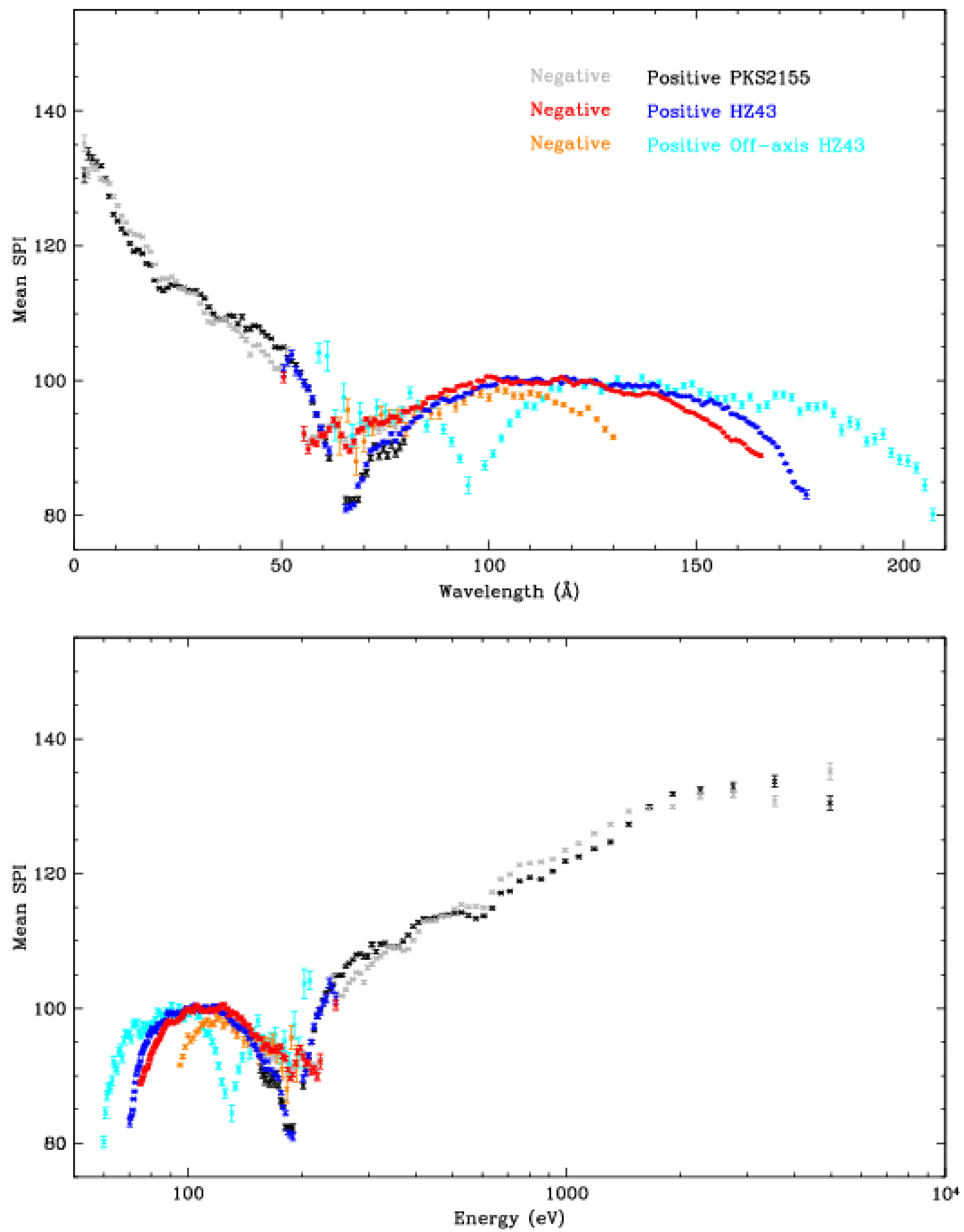




Compute norm'd mean SAMP from temporal fits, then do spline fits as f(λ), yielding gain function for each subtap as f(λ,SAMP, t).



SPI at +160 Å for all 14 HZ43 obs’s, norm’d by number of counts.



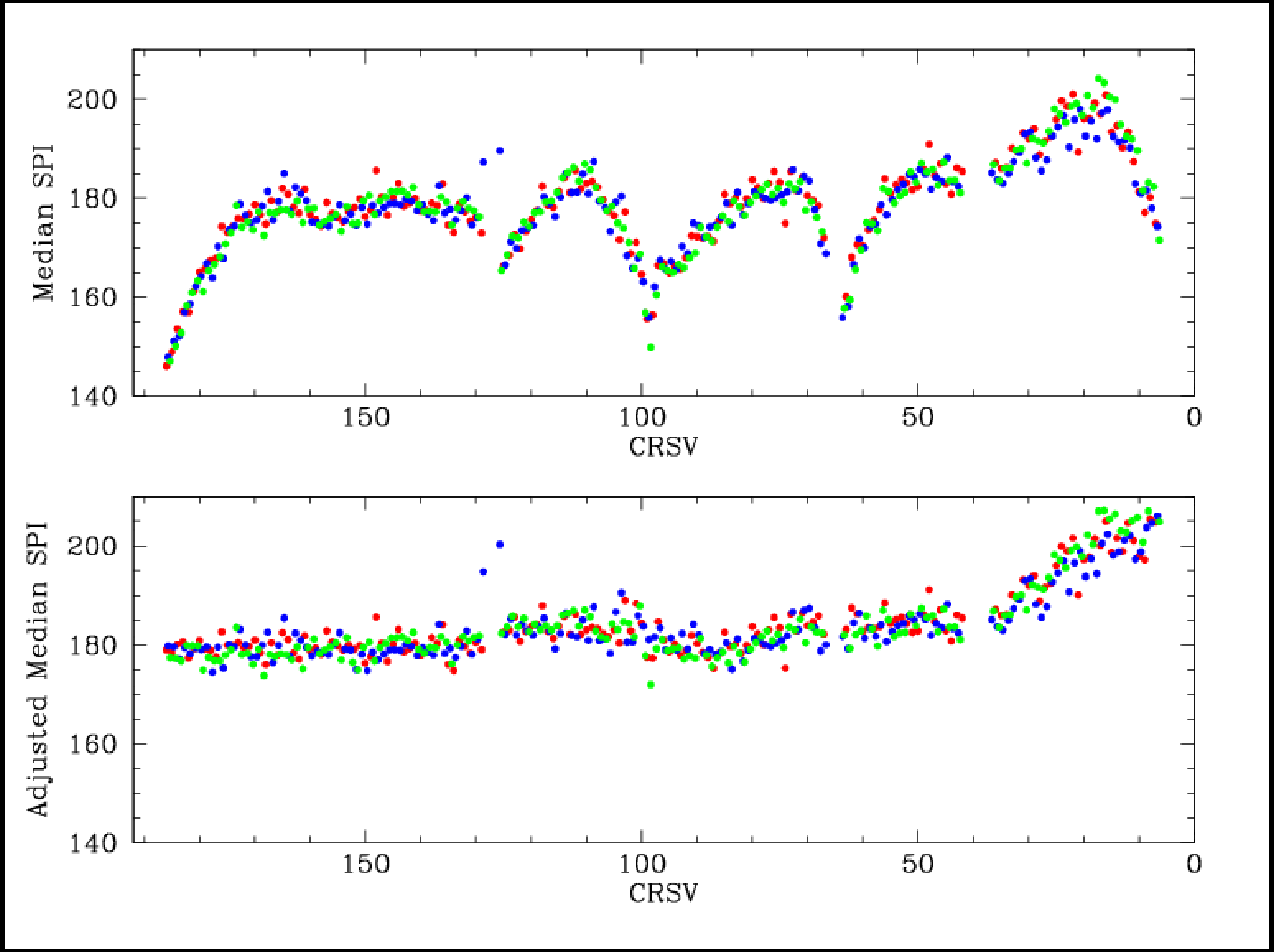
Merge all on-axis HZ43 data, and PKS2155 data, bin by 1 Å , compare mean SPI:

- HZ43 vs PKS2155
- plus vs minus order
- with 10’ off-axis HZ43.

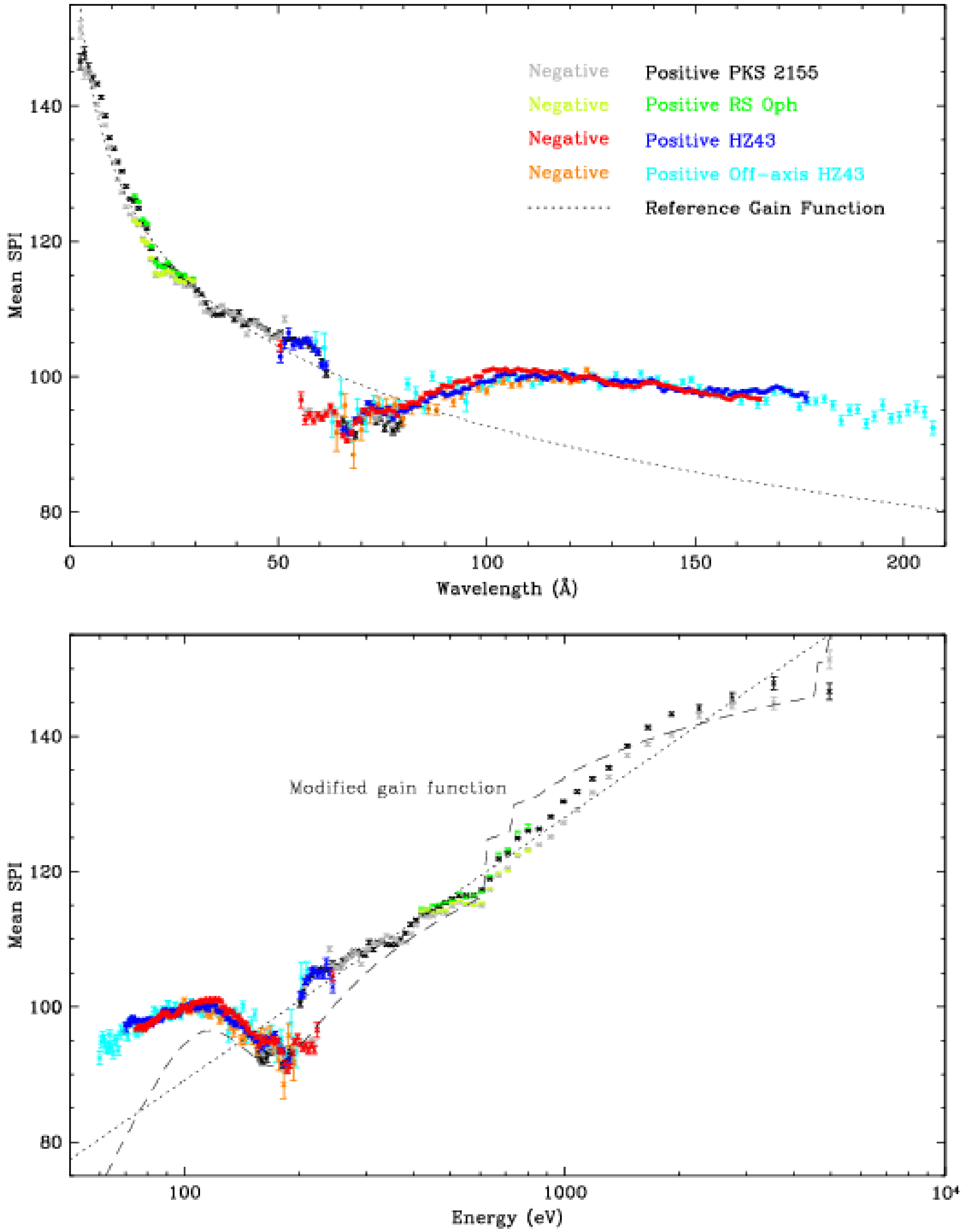
Mismatches caused by additional gain drop (relative to lab calibration) near plate ends.

No on-orbit flat fields--how calibrate? Add gain correction function to gain map such that on-axis and off-axis data agree, guided by …

On-Orbit Background



- Use RXJ1856 obs (long exposure, weak source), excising all X-ray events.
- Use off-axis (in U) Sirius B obs for near aimpoint.
- Medians better behaved than means for BG.
- Central subtap medians (green) increased by 3%.
- Fit smooth curves on plate ends and near aimpoint. (Also adjust around CRSV=155).
- Scale those adjustment curves to get best agreement between on- and off-axis HZ43 SPI.


Negative
Positive PKS 2155
Negative
Positive RS Oph
Negative
Positive HZ43
Negative
Positive Off-axis HZ43
Reference Gain Function
Mean SPI
Wavelength (Å)
Modified gain function
Mean SPI
Energy (eV)

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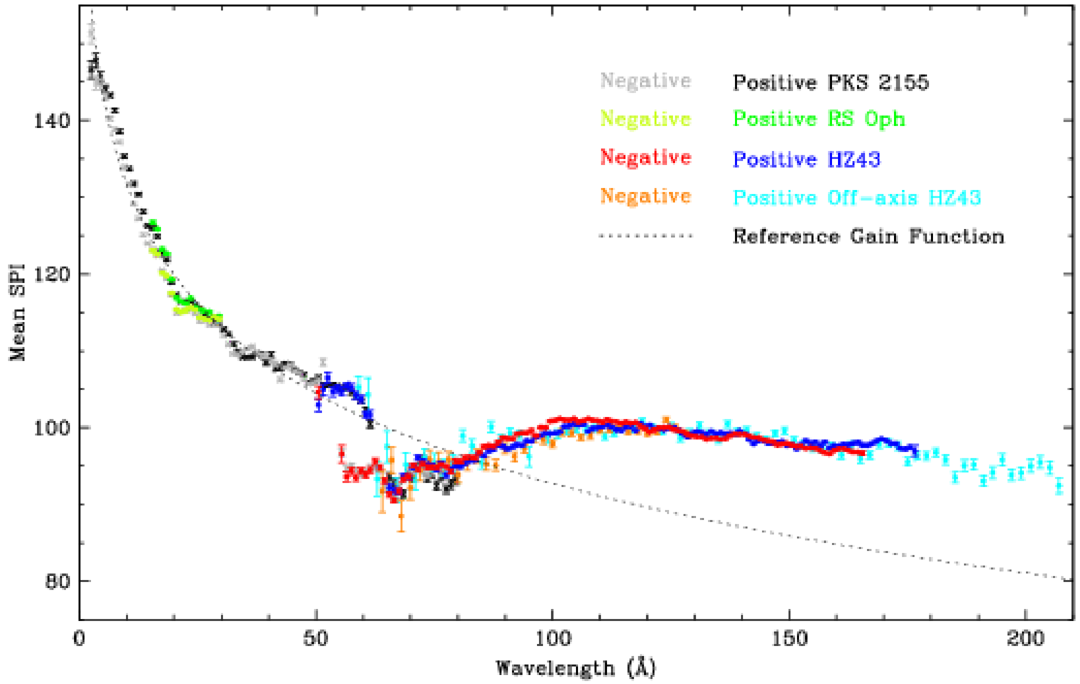
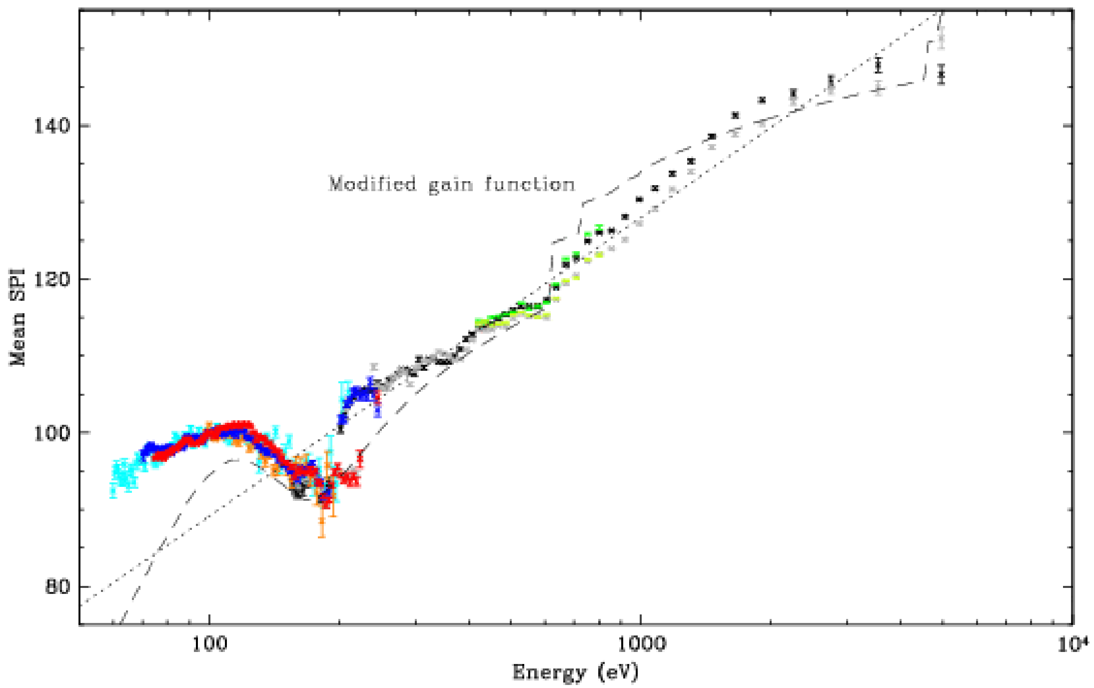
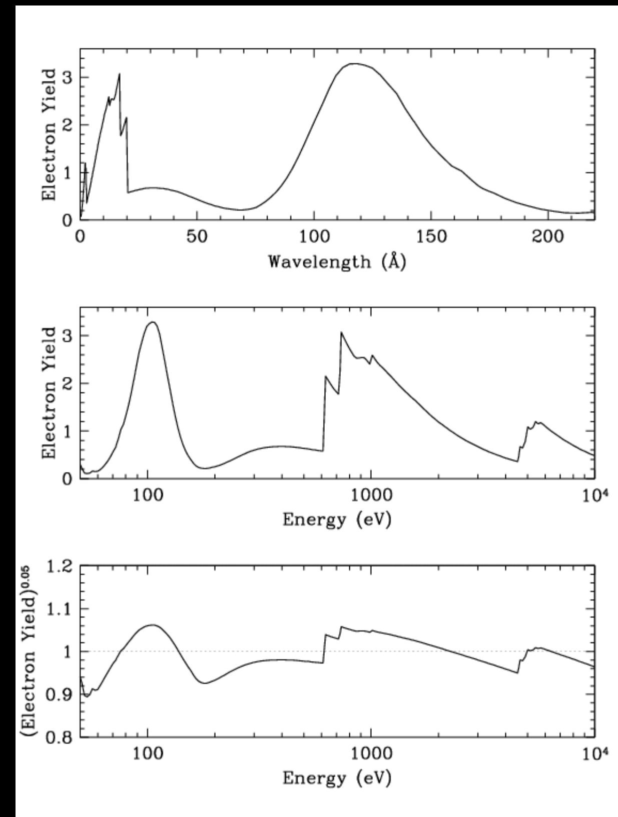




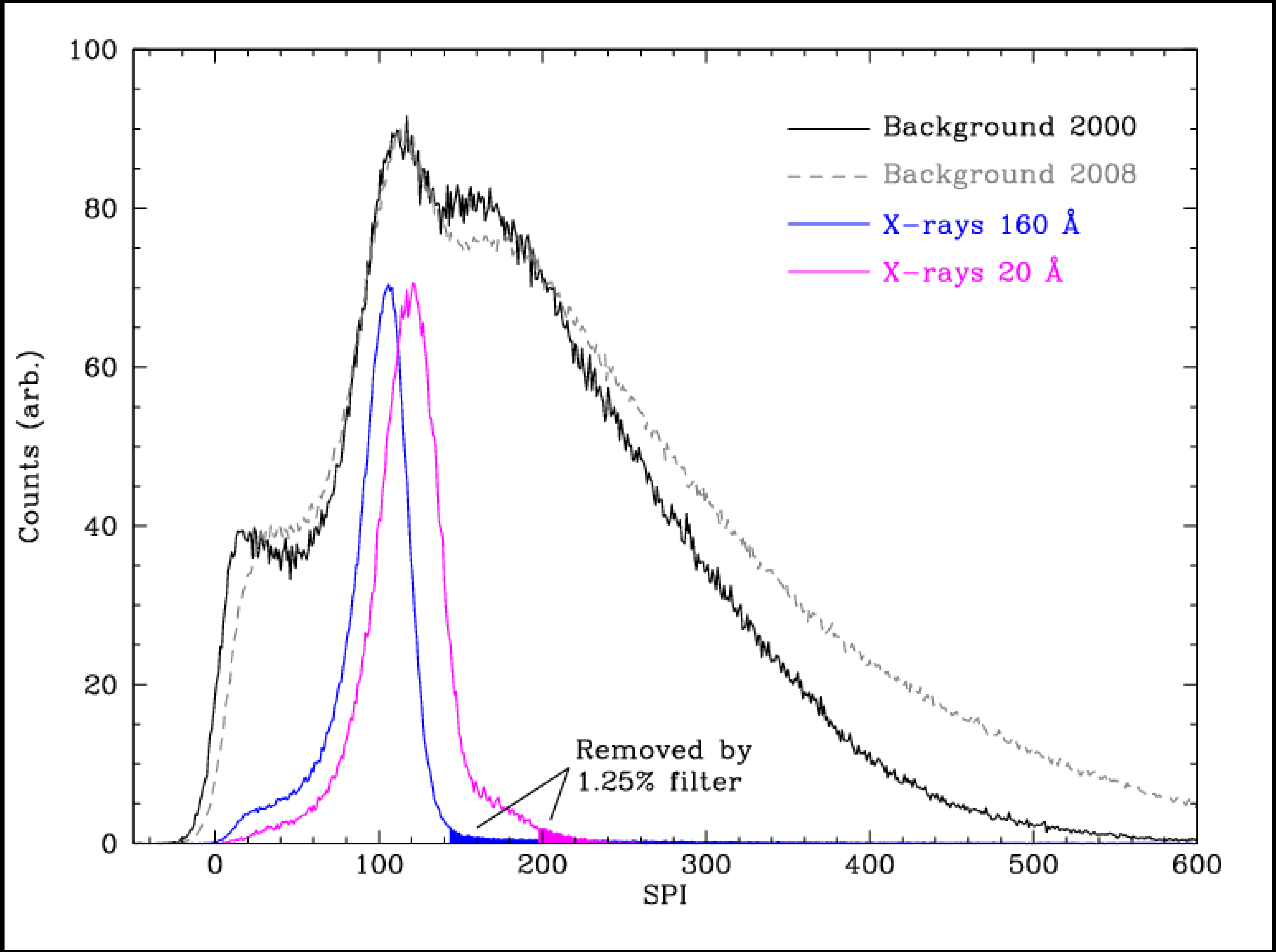


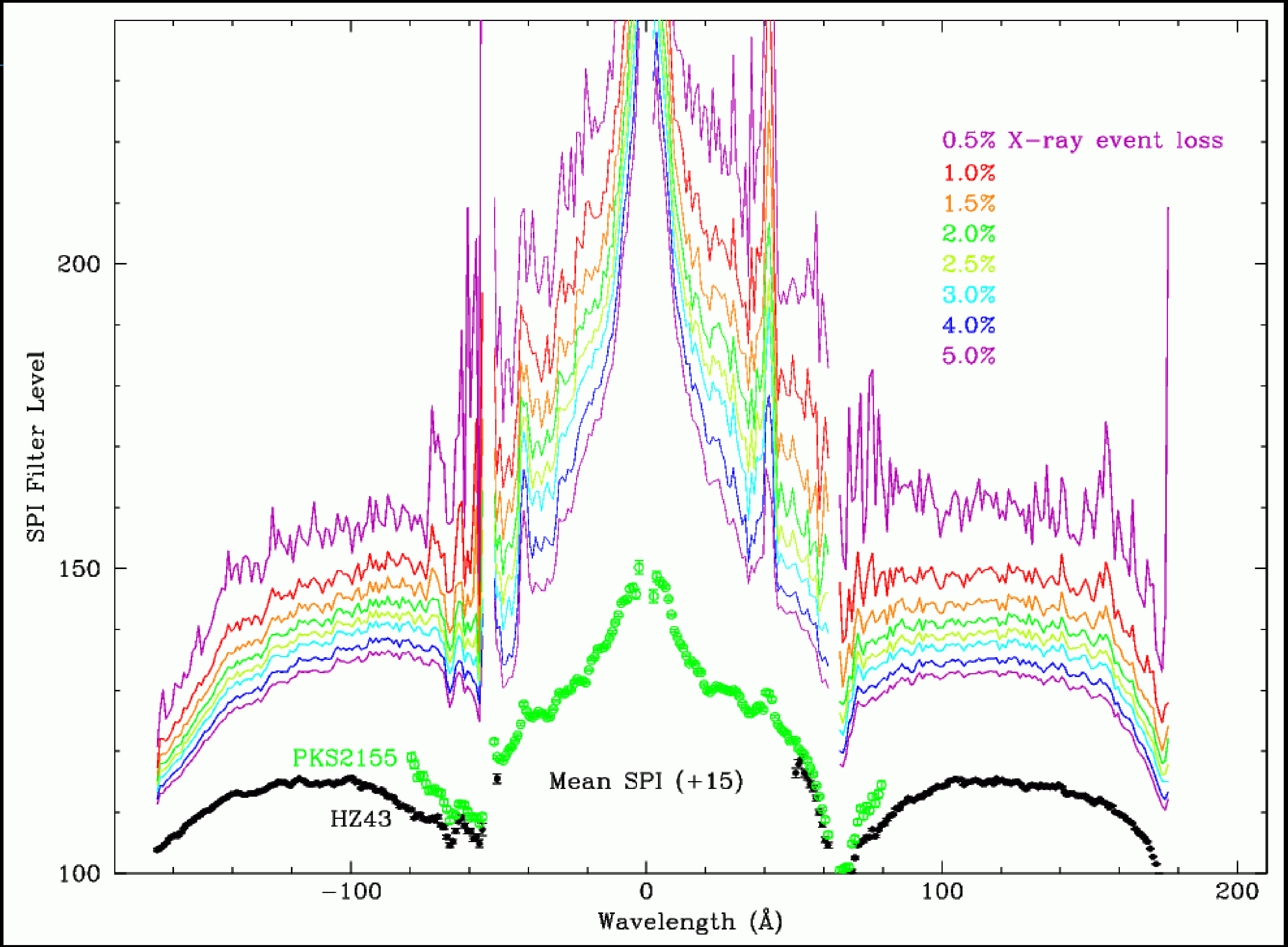
CsI model electron yield

Still some oddities around plate edges--”real” electron yield differences?

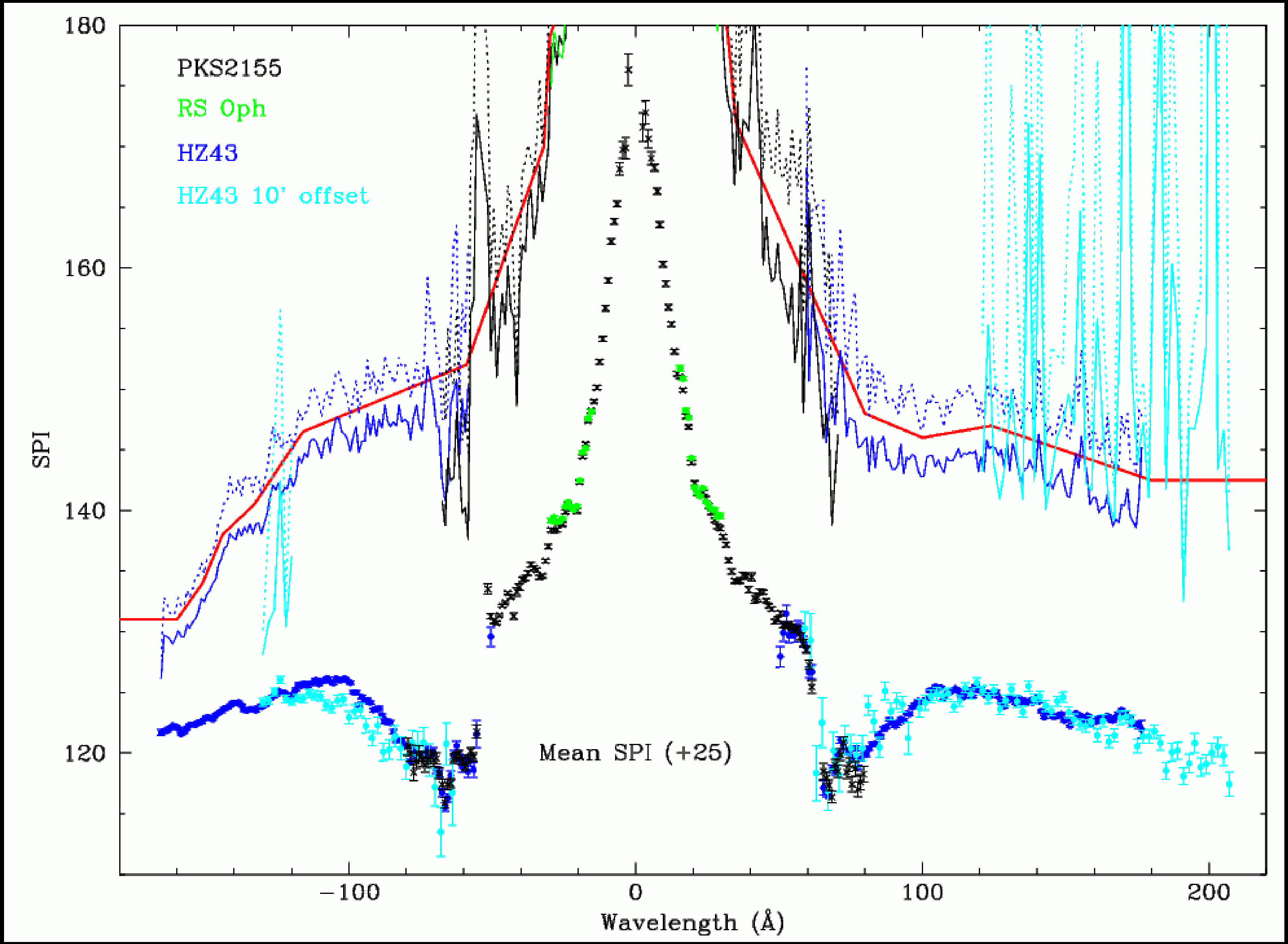
CXC

Background Filtering





Note anomalies around C-K edge and elsewhere from higher orders. PKS2155 HO corrections were scaled by comparing with RS Oph results (15-30 Å, no HOs).

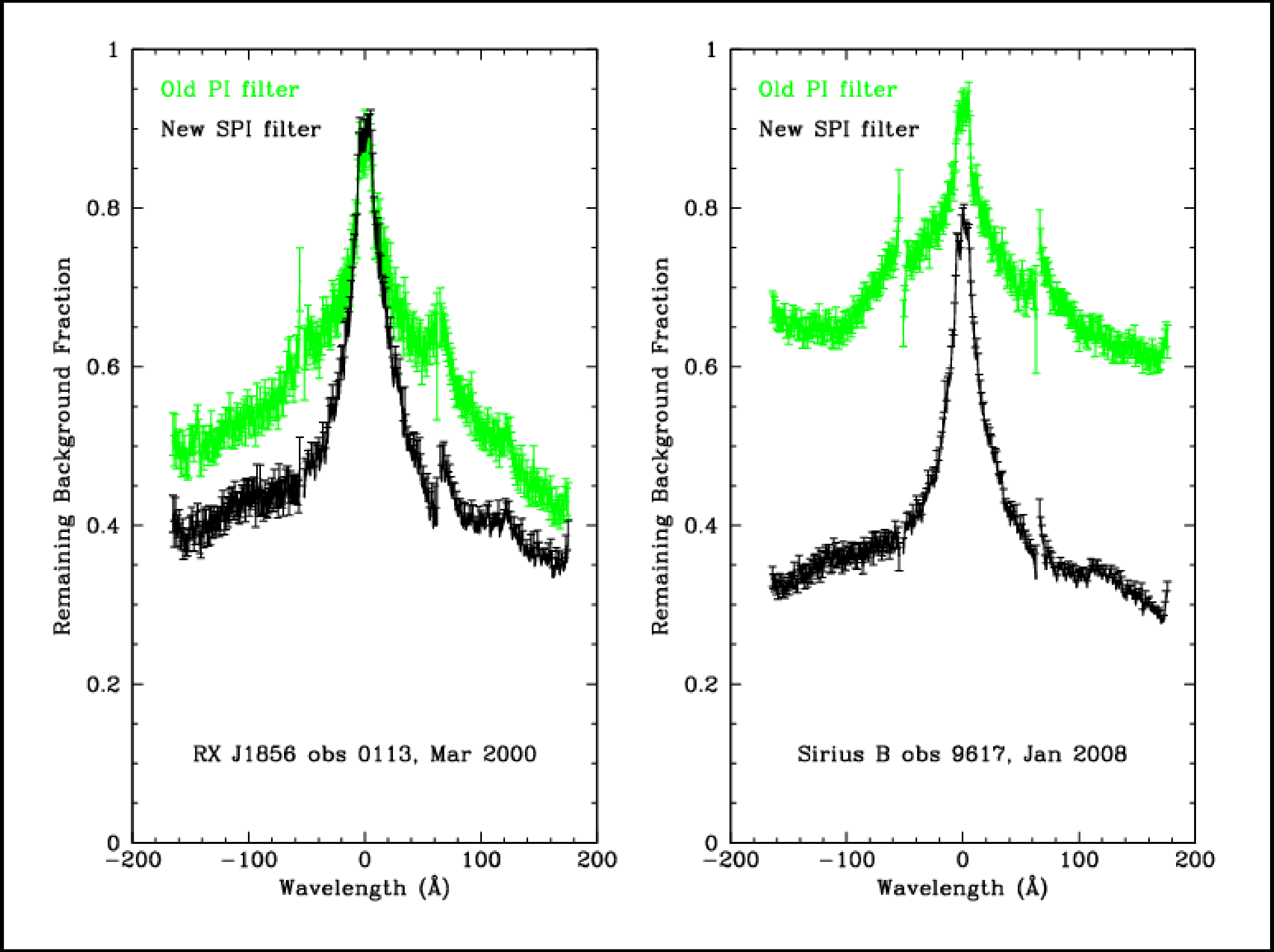


Dotted = 1.0% loss.

Solid = 1.5% loss.

Red line is 1.25% filter limit.

Ignore oddness at plate edges and at C-K edge.


Old PI filter
New SPI filter
Remaining Background Fraction
RX J1856 obs 0113, Mar 2000
Wavelength (Å)
Old PI filter
New SPI filter
Remaining Background Fraction
Sirius B obs 9617, Jan 2008
Wavelength (Å)

Status and Future

Gain map and filter are available as contributed software.

Implementation in CIAO is imminent (Dave Huenemoerder, Kenny Glotfelty, et al.)

Valid to at least 2013 without further adjustments, barring low-channel event losses requiring a detector voltage increase.

Some minor improvements are possible, but probably not worth the effort unless we calibrate around the plate edges using off-axis HZ43 scans, or around the aimpoint.