The Solar Mesosphere Explorer

A summary of SME reprocessing efforts and current status

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As part of a larger team effort with Judith Lean (PI),

"How does the Sun's Spectrum Vary?"

Outline

- Motivation
- Recap of Year 2 efforts
  - Measurement uncertainty,
  - Development of processing algorithm (Processing Approach “A”),
  - Initial wavelength calibration efforts (Processing Approach “B”),
  - Potential temperature dependencies.
- Year 3 Efforts
  - “cleaning the time series”
  - uncertainty propagation
  - Incorporating a SORCE/SOLSTICE reference spectrum
  - wavelength calibration
- Year 3 Results
- Remaining steps for no-cost extension period

Motivation

- SME reanalysis will give an improved understanding of solar cycle variability.
- SME observations are potentially stable SSI database due to limited solar exposure and in-flight monitoring of degradation.
  - Re-analyzed SME observations may:
    - constrain UV variability, and – ***through a model and TSI observations*** – further constrain visible and infrared SSI variability.
    - This new knowledge would be used to improve solar variability models.

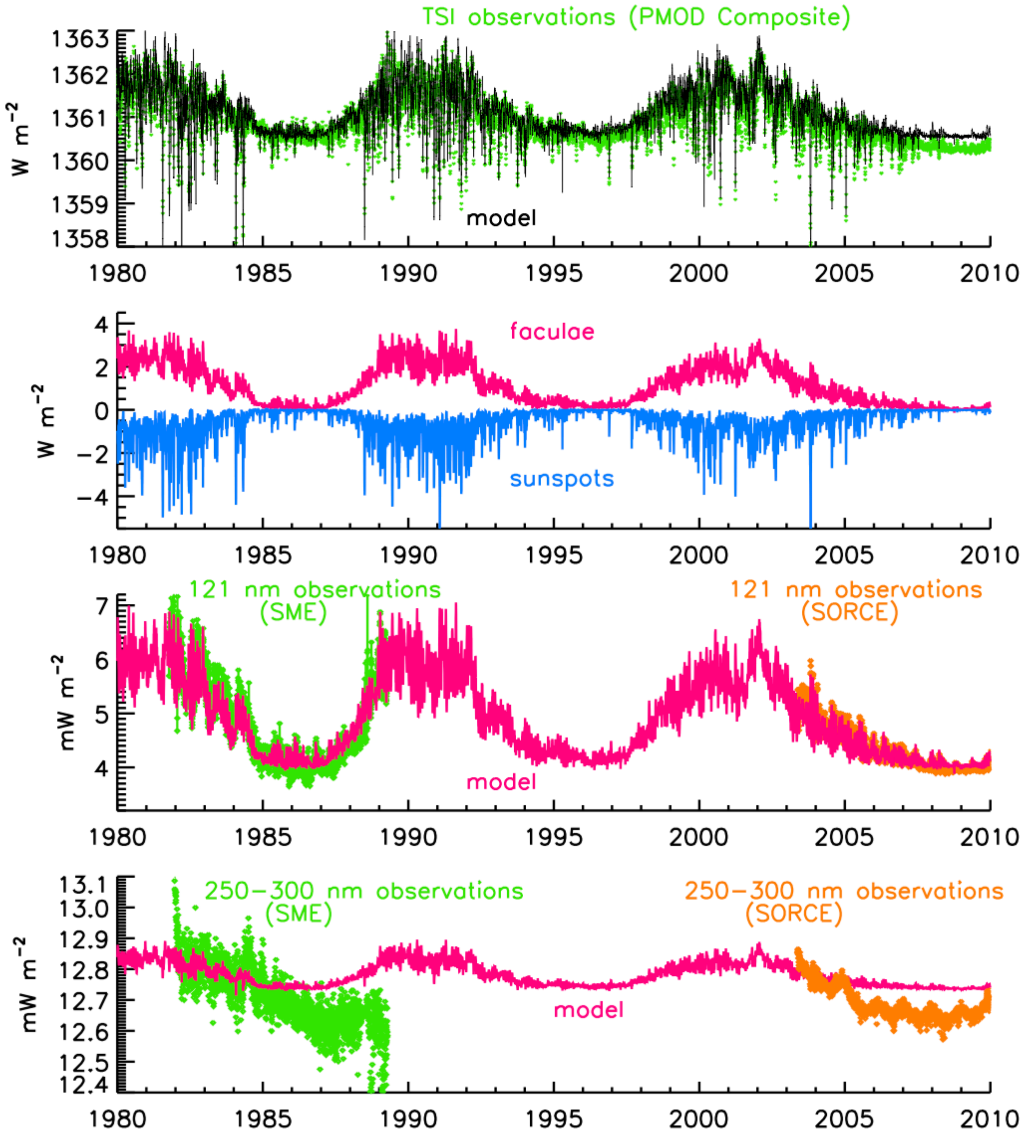


Figure: *Comparisons of modeled and measured solar irradiance over solar cycle time scales along with components of sunspot and facular influence (Courtesy Judith Lean)*

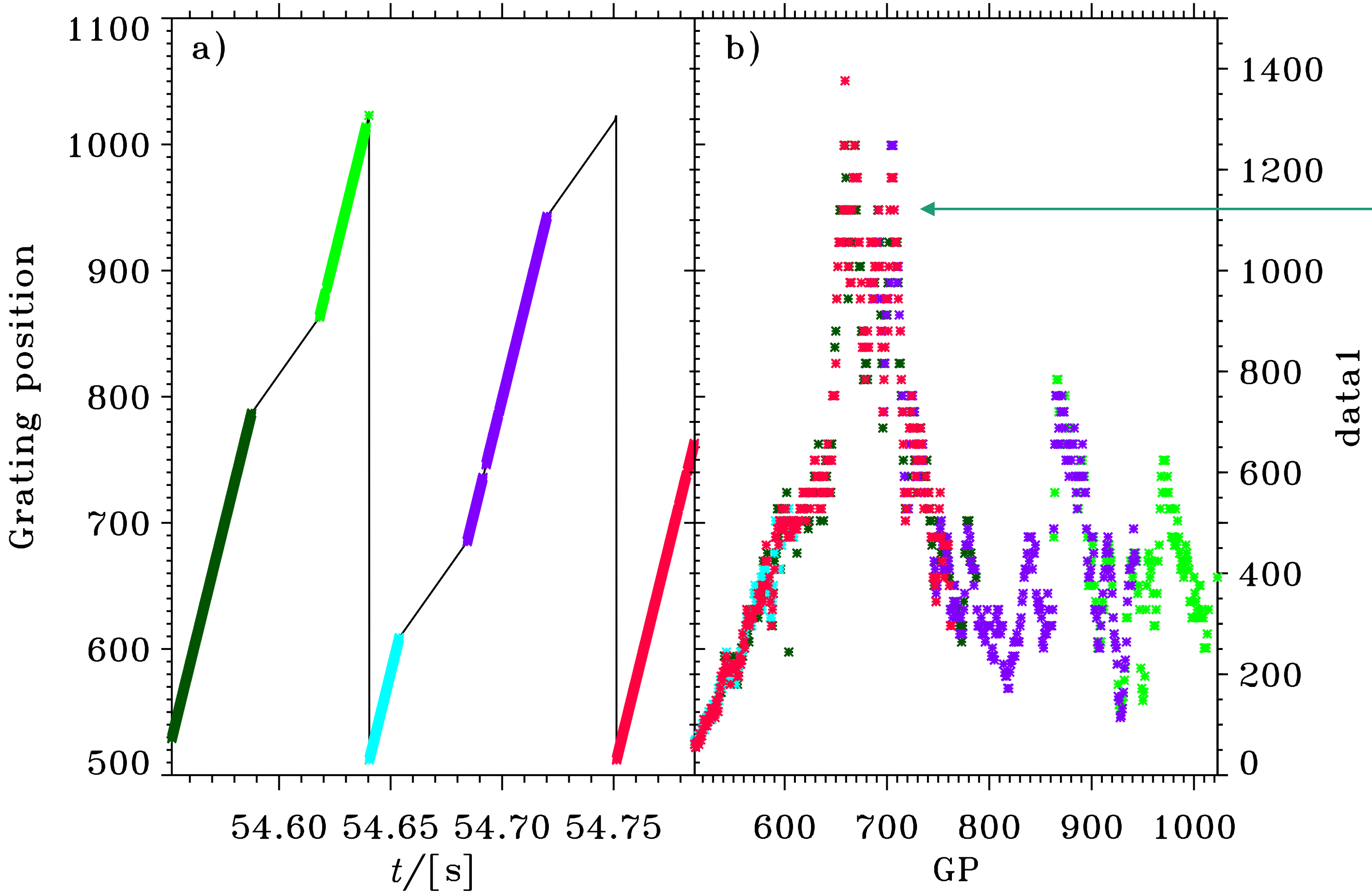
Year 2 Recap

Measurement Uncertainty

Quantization Error and Photon Noise

# of shifts	5-bits of data (DN)	Data increments (DN) "quantization error"	Square root of data (DN) "photon noise"
0	0 to 31	1	0 to 5.6
1	32 to 63	2	5.7 to 7.9
2	64 to 127	4	8 to 11.3
3	128 to 255	8	11.3 to 16
4	256 to 511	16	16 to 22.6
5	512 to 1023	32	22.6 to 32
6	1024 to 2047	64	32 to 45
7	2048 to 4095	128	45 to 64

Sample SME data

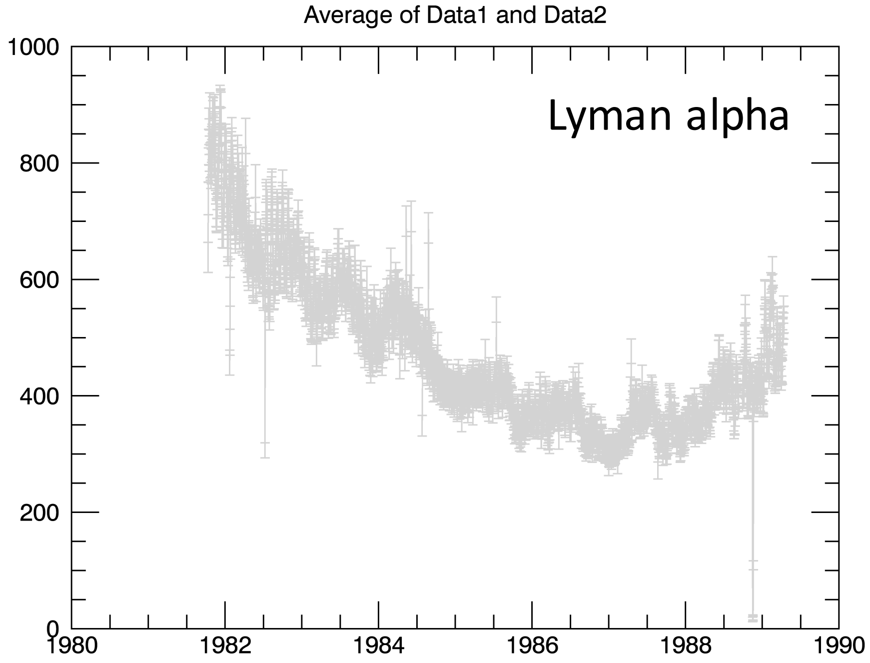


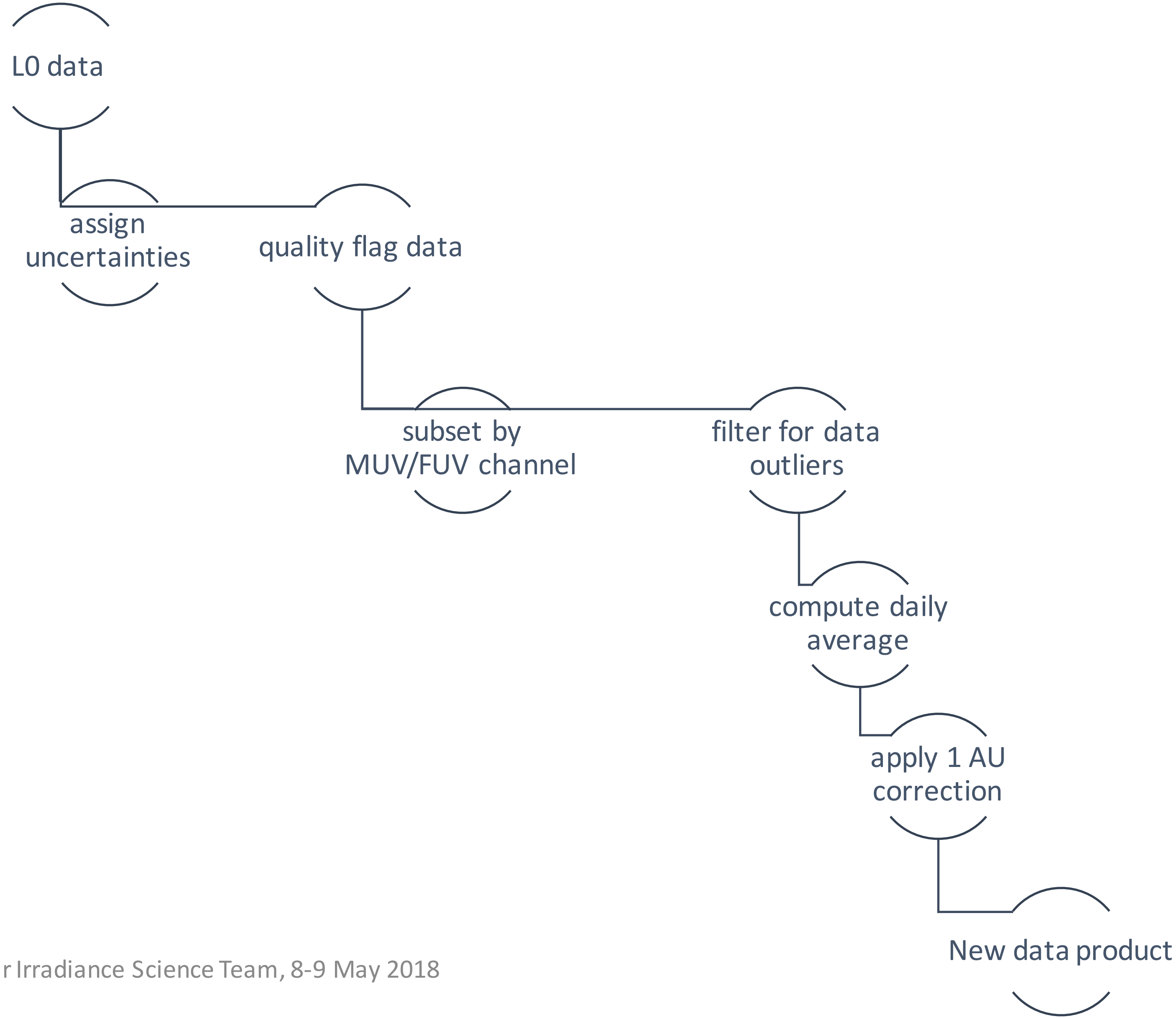
Data discretization more apparent at larger signal magnitude.

Different colors represent individual segments of data collection.

Two Algorithm Processing Approaches

- Approach "A"





- # Approach “B”

**Developed to focus on regions of large solar variability and pronounced spectral features*

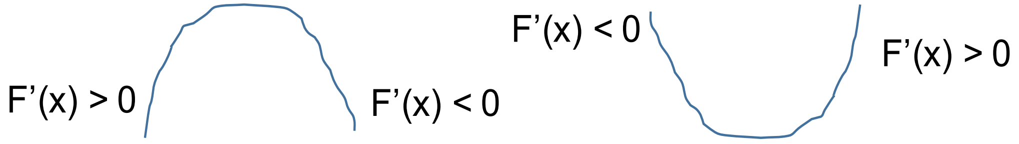
Begins with the daily average spectra from Approach A

Compute derivative of daily average

Identify local extrema in spectrum by peaks of valleys of inflection points

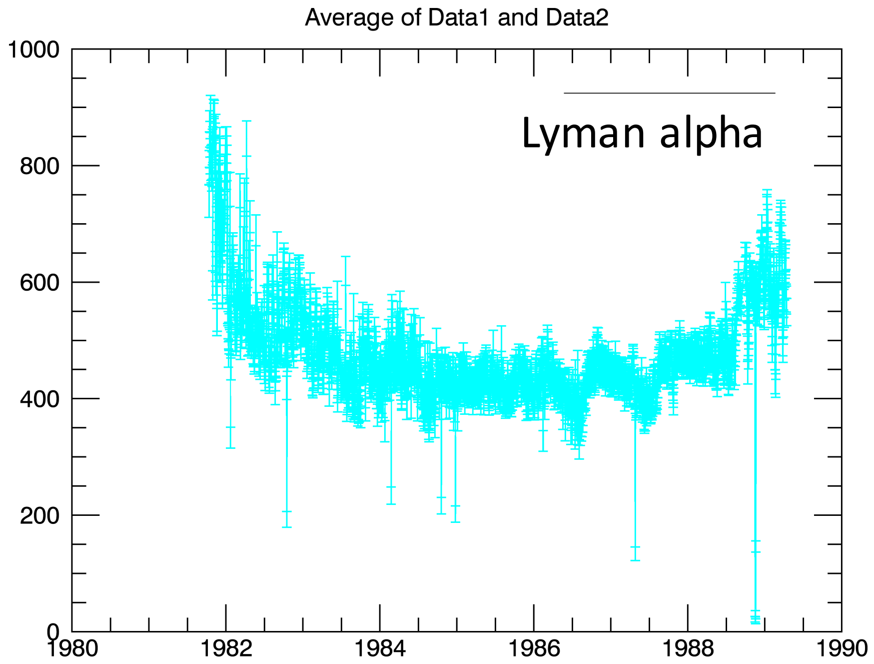
Identify grating position of peak or valley

New Data product (using revised grating positions for select portions of spectrum)



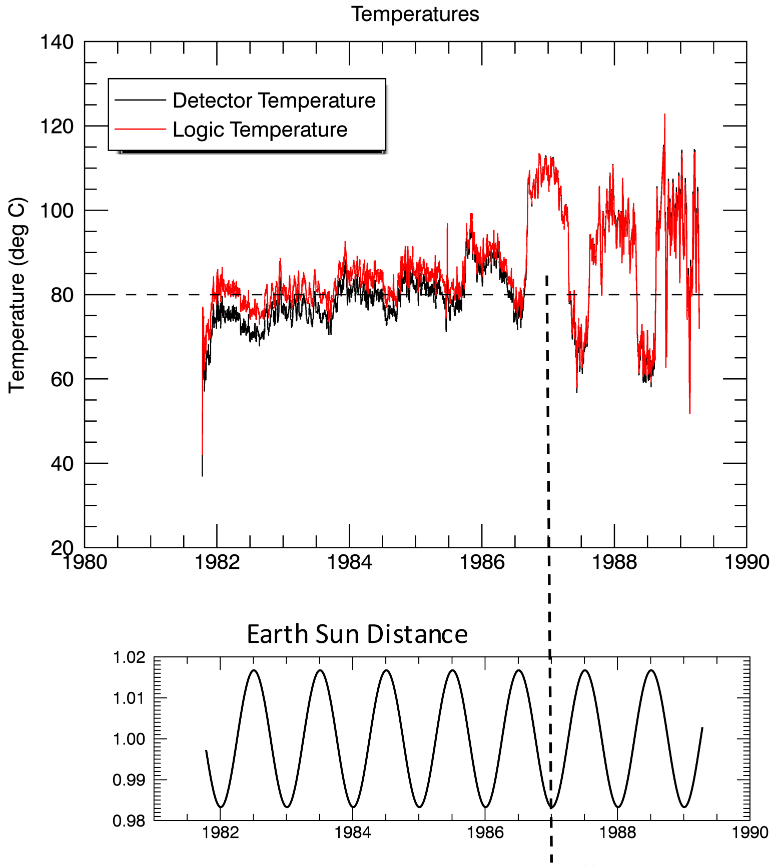
Peak = local maximum

Valley = local minimum

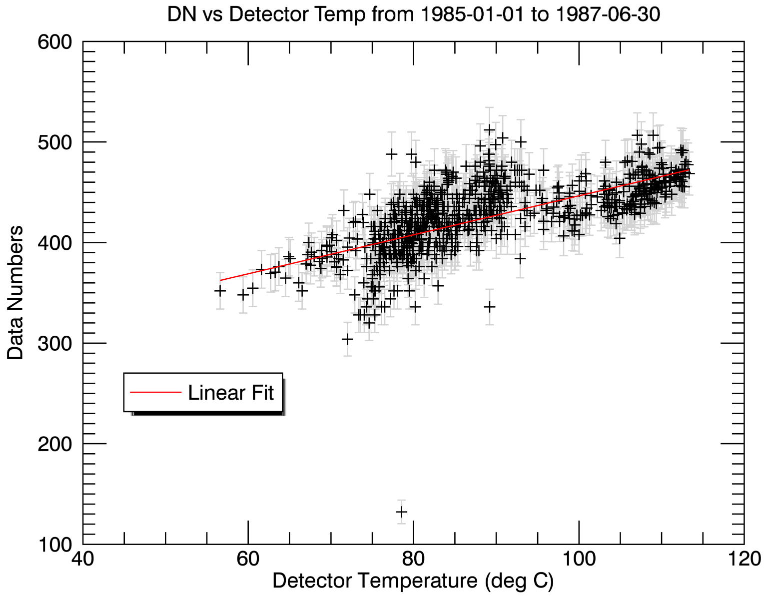


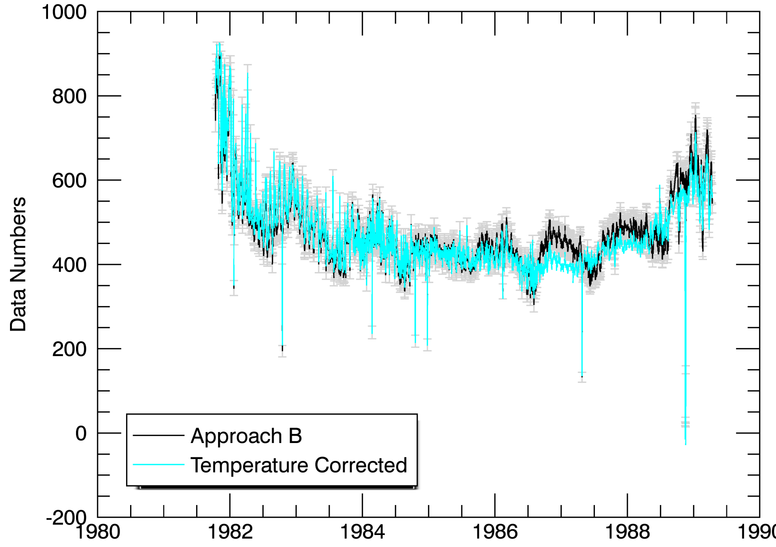
Recognizing and Correcting for a temperature effect

We correct for temperature affects by evaluating (and correcting) the non-zero slope of DN with temperature over solar minimum time period.



Earth-viewing instruments turned off Dec 11, 1986

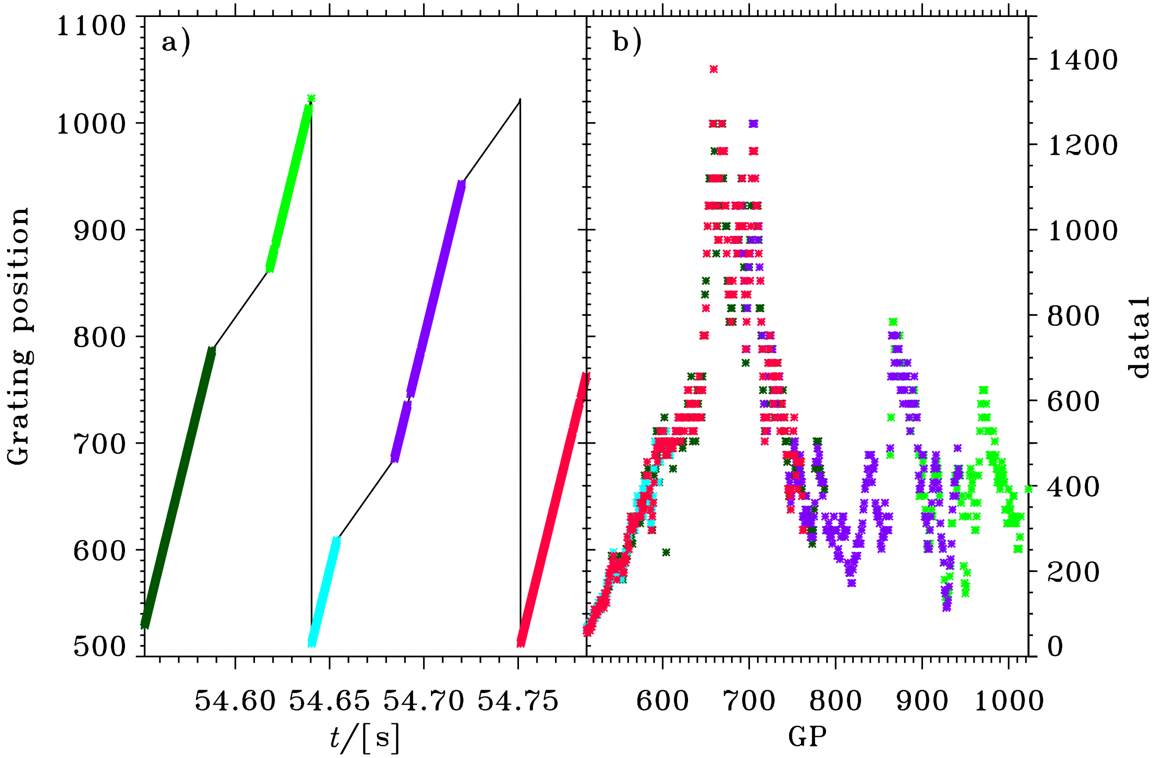




**Corrected to a constant Temperature (80 deg C).*

Year 3 Efforts

“Cleaned” the time series

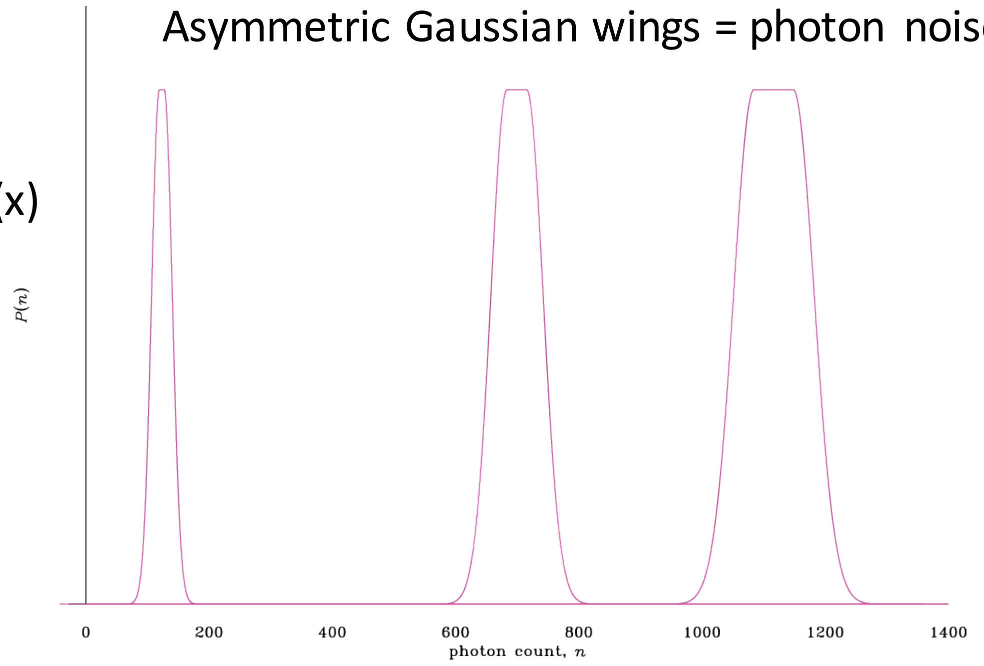


- We identified a small fraction of L0 data that was:
  - Out of chronological order or,
  - Duplicate data points or,
  - Data points with the same time stamp but different data values.
- We “cleaned” the data by:
  - Move the data points to restore chronology or,
  - Remove duplicates

Derived a Total Measurement Uncertainty

Flat top = discretized, telemetered value
Asymmetric Gaussian wings = photon noise

$P_n(x)$



Terms:
2h = size of discretization error
A = amplitude of PDF
ω_1 and ω_2 = width of Gaussian on each end of flat top (photon noise)

- We formalized a continuous probability distribution approach to derive the variance of each SME count

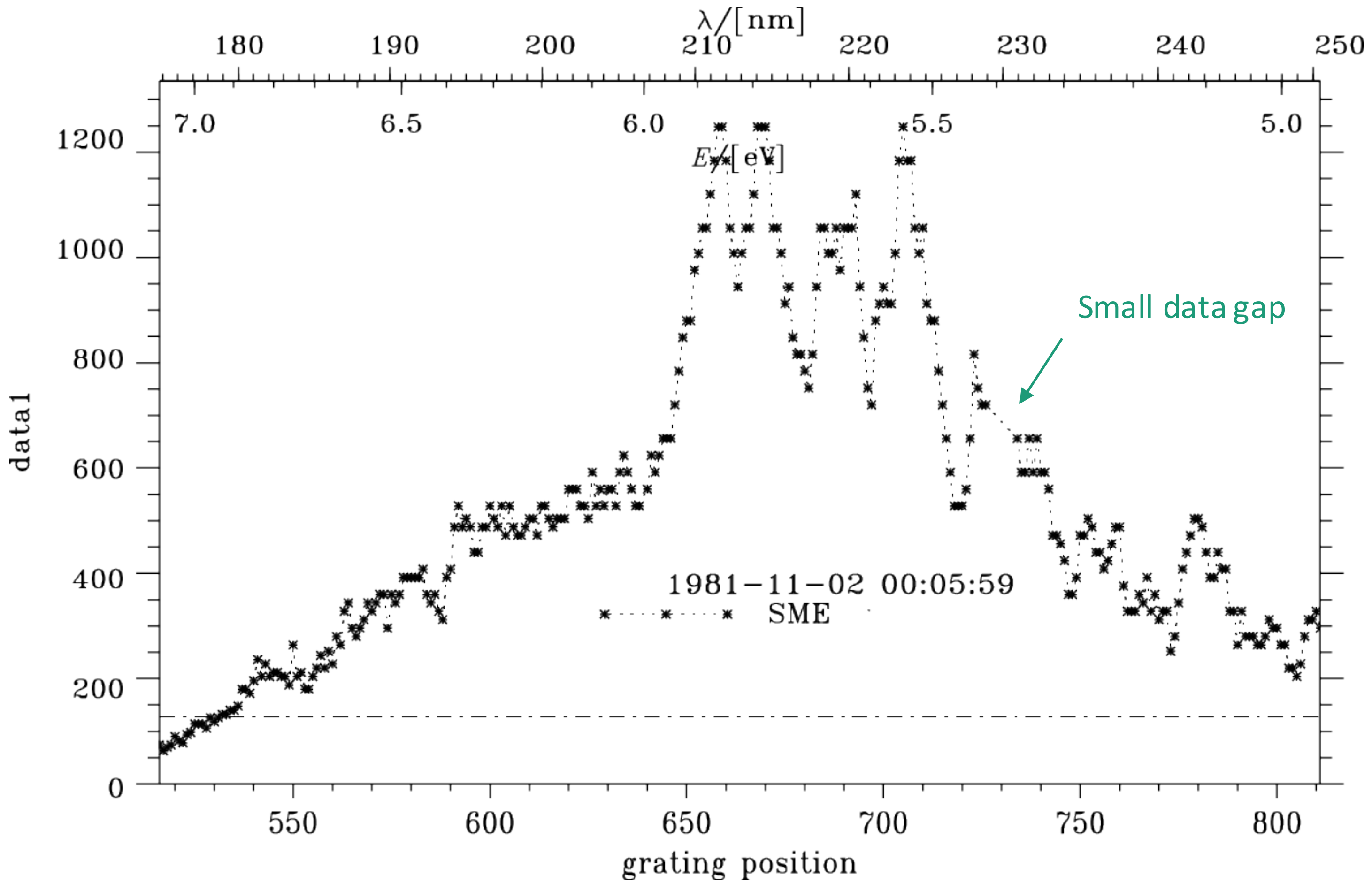
$$Var(x) = \sigma^2 = \int_{-\infty}^{\infty} (x-\mu)^2 P(x)dx$$

$$\sigma_1^2 = Ah\omega_1(h\sqrt{\pi} + 2\omega_1) + A\omega_1^3 \frac{\sqrt{\pi}}{2} + \frac{2}{3}Ah^3$$

$$\sigma_2^2 = Ah\omega_2(h\sqrt{\pi} + 2\omega_2) + A\omega_2^3 \frac{\sqrt{\pi}}{2} + \frac{2}{3}Ah^3$$

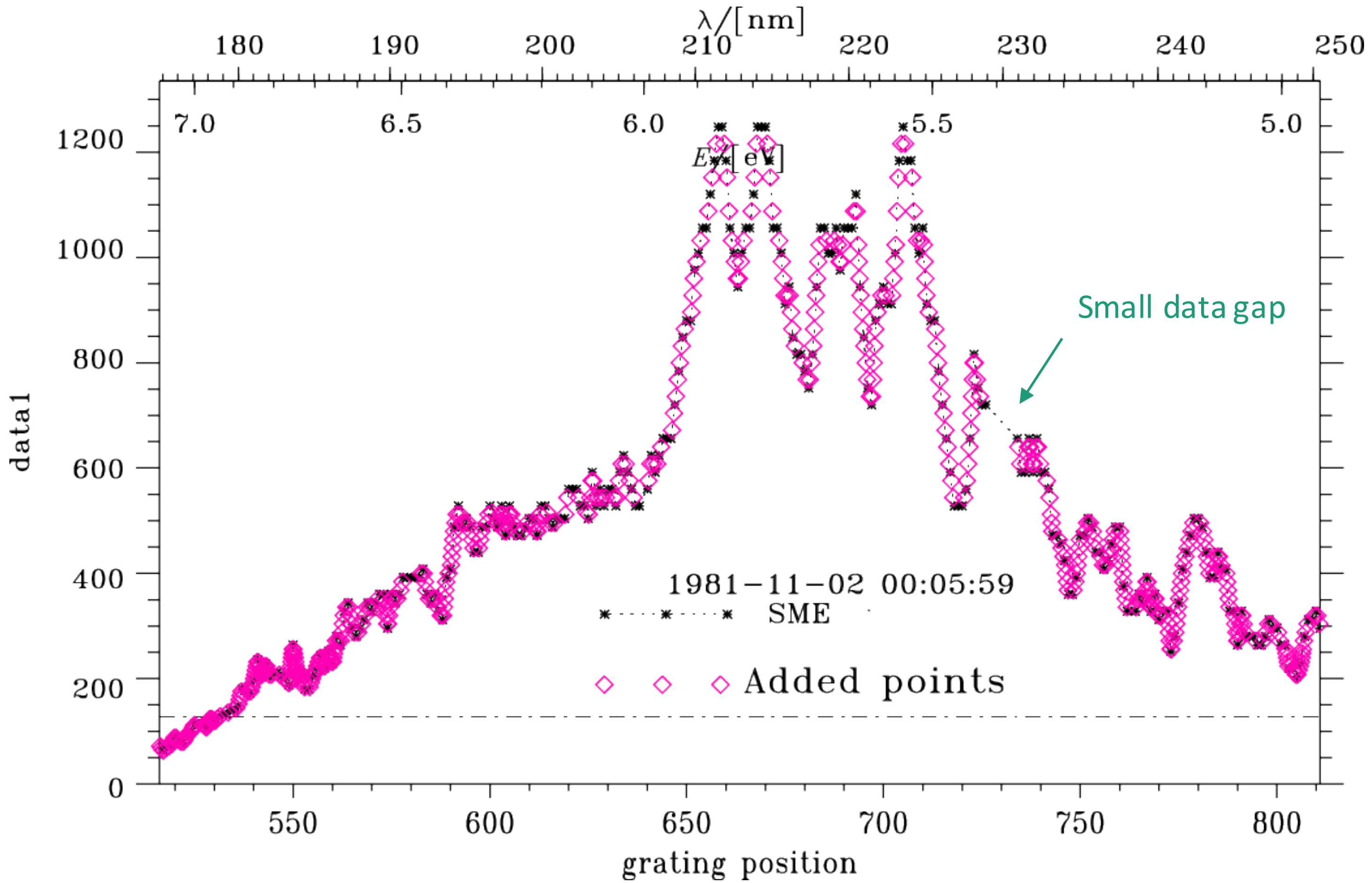
Variances of left and right side of distribution are asymmetric

Recognized the Value of “Bin Borders”



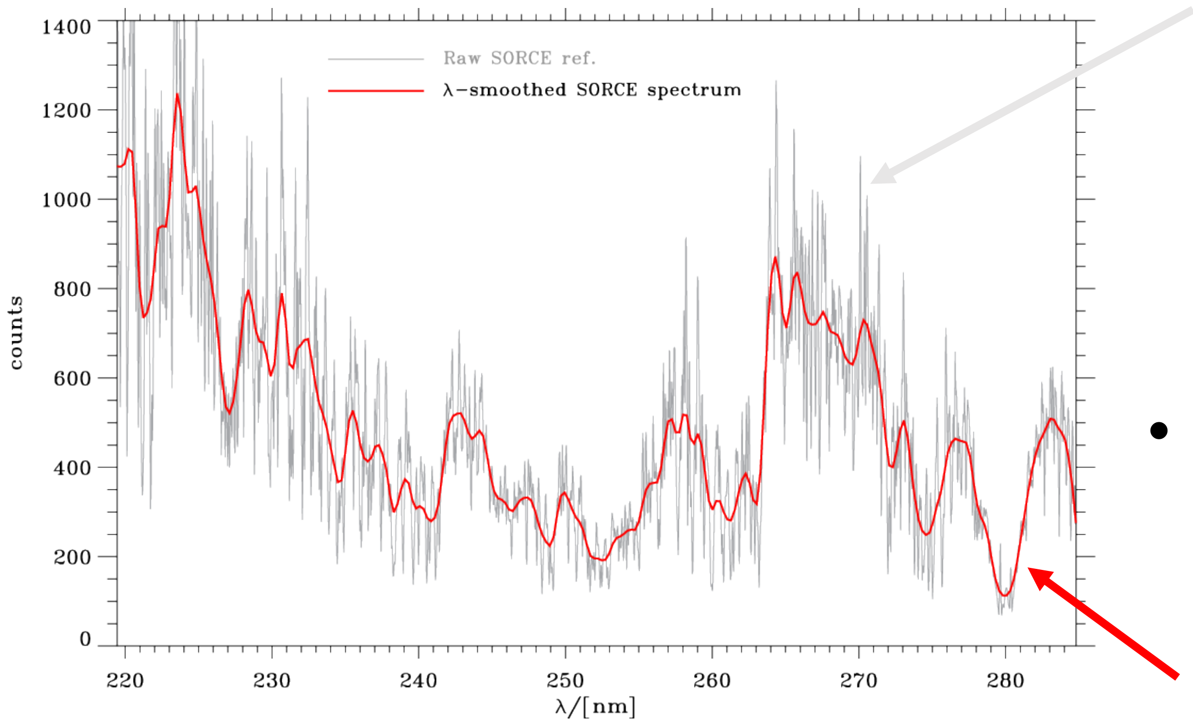
While we don’t know with certainty the “true” data count within a discretized bin, we do know the data count value when the spectrum passes through the borders of neighboring bins.

Recognized the Value of Bin Borders



While we don't know with certainty the "true" data count within a discretized bin, we do know the data count value when the spectrum passes through the borders of neighboring bins.

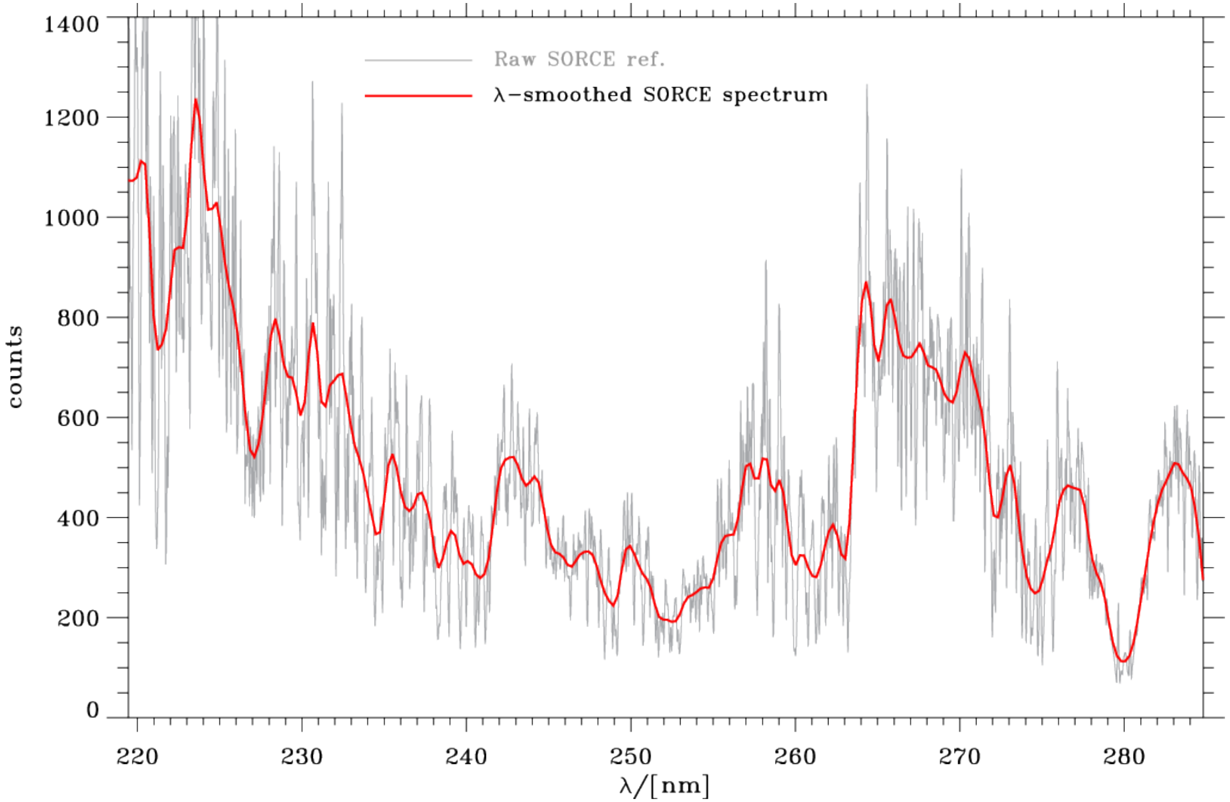
Developed a Reference Spectrum (for wavelength calibration analysis)

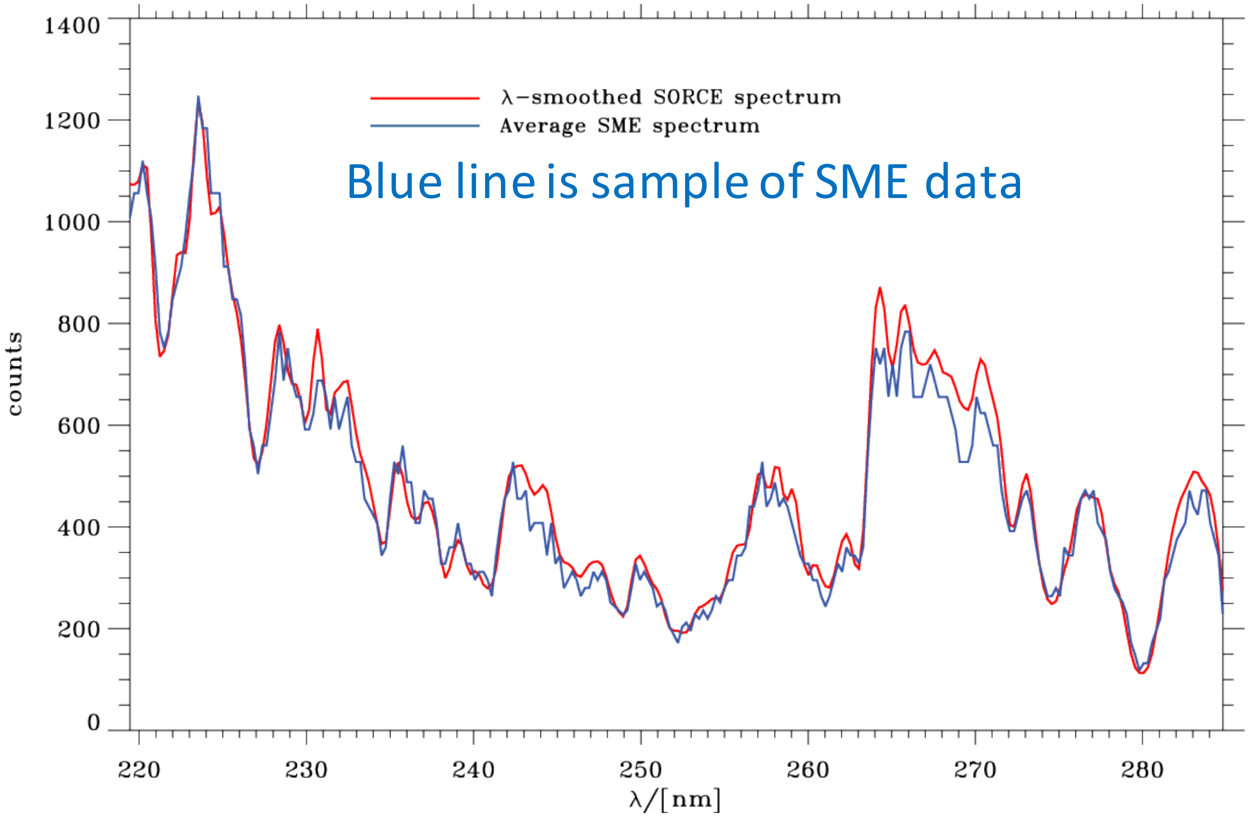


Red line is our "SME/SOLSTICE" reference spectrum

- SORCE/SOLSTICE high-resolution data was the data for our reference
  - Courtesy of Marty Snow
  - Wavelength range – 158-320 nm
  - Spectral resolution – 0.1 nm
  - Grating step size – 0.03 nm
- We convolved the high-resolution SOLSTICE data twice with a box car window (width = 25) for a triangular smoothing kernel.

Developed a Reference Spectrum
(for use in wavelength calibration analysis)





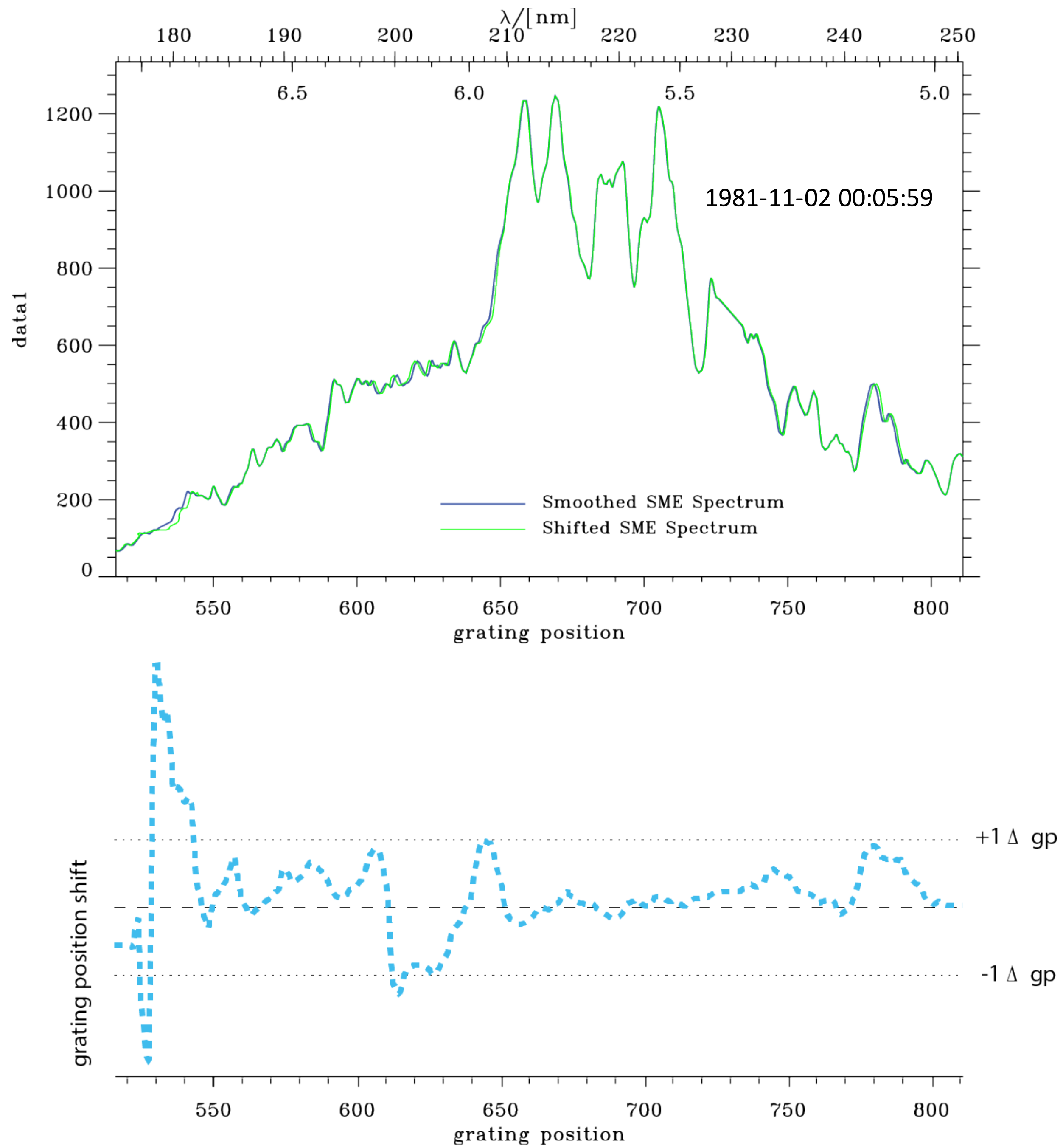
Red line is our "SME/SOLSTICE" reference spectrum

Wavelength Calibration

- Goal: Align each segment of SME data to the SME/SOLSTICE reference
- We tried an *abscissa_shift_and_stretch* IDL routine
  - results were disappointing.
  - 7 trials out of 100 combinations of shift and stretch values produced meaningful results that converged in fewer than 1,200 iterations.
  - Of those, no single shift/stretch solution worked with all segments of SME data.
  - A correlation with our SME/SOLSTICE reference was better with the original SME data than the shifted result.

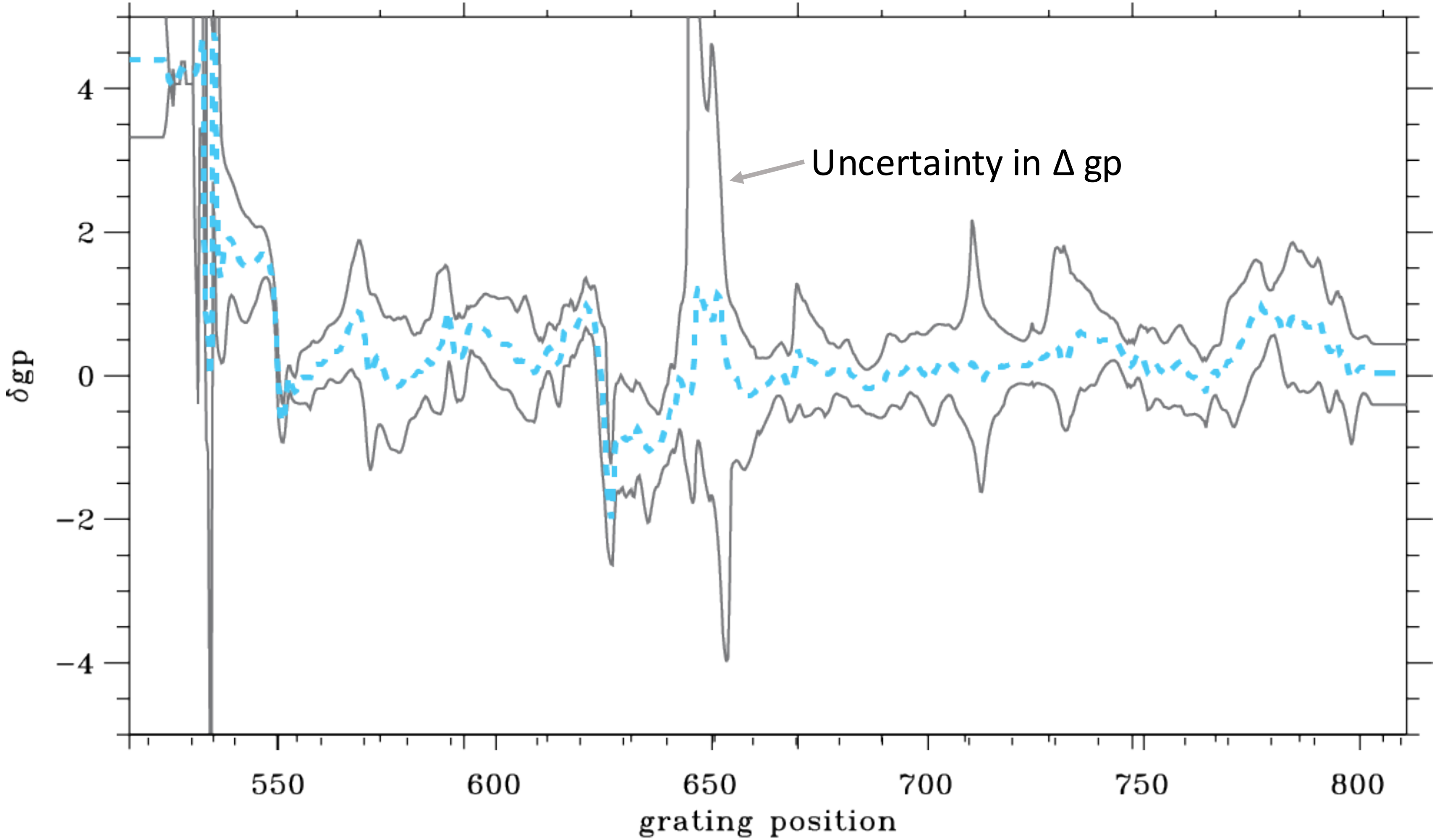
Wavelength Calibration: Cross-correlation Method

- Developed a cross-correlation approach (developed with Regner Trampedach)
  - The grating position of the maximum correlation between the segment of SME data and the “SME/SOLTICE” reference is found.
  - The location of the maximum is interpreted as a Δ gp shift
  - An uncertainty in the Δ gp shift is derived from the width of the correlation function.



λ/[nm]
180
190
200
210
220
230
240
250
6.5
6.0
5.5
5.0
1200
1000
800
600
400
200
0
data1
1981-11-02 00:05:59
Smoothed SME Spectrum
Shifted SME Spectrum
550
600
650
700
750
800
grating position
+1 Δ gp
-1 Δ gp
grating position shift
550
600
650
700
750
800
grating position

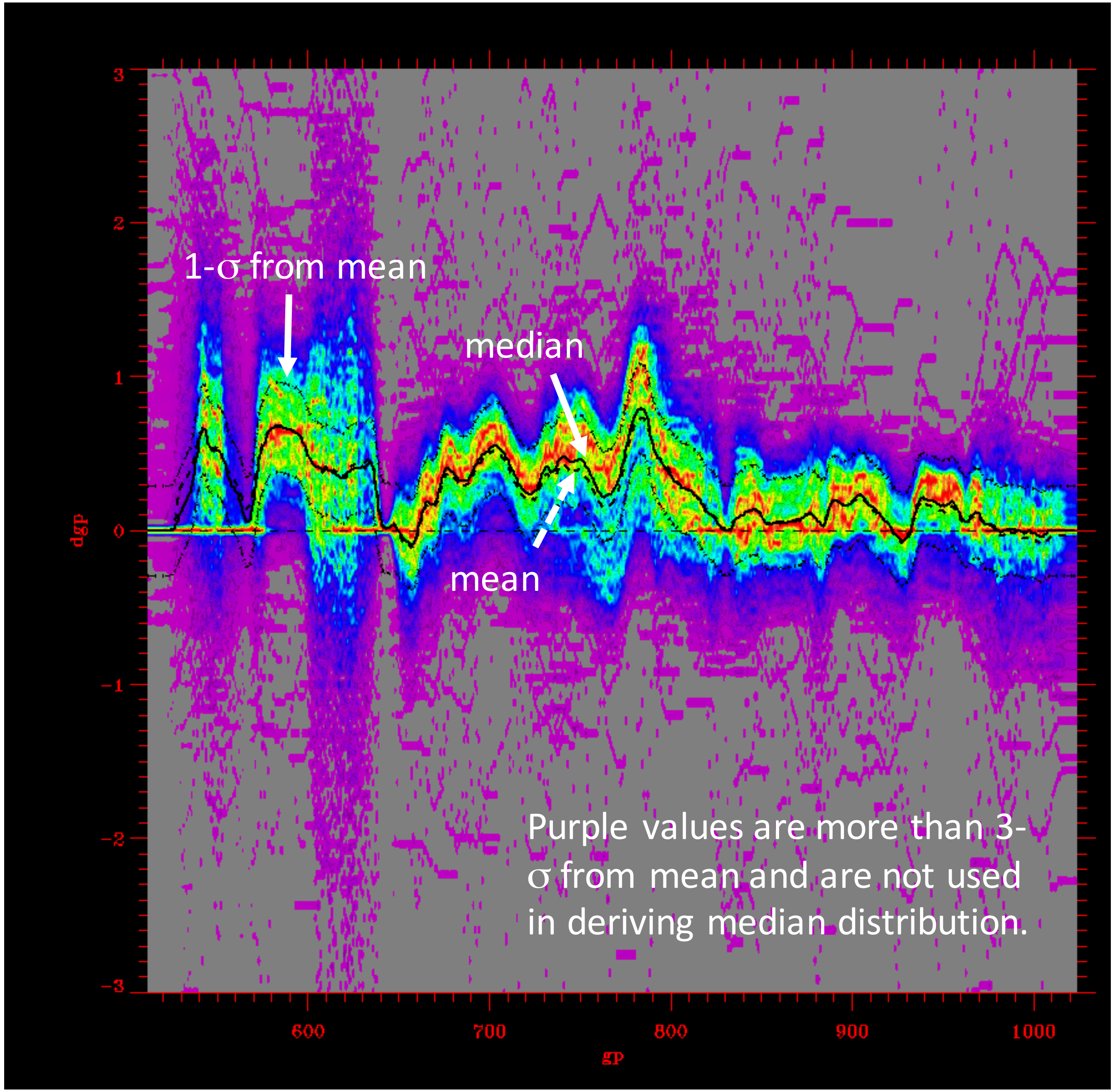
Uncertainties in Grating Position Shift



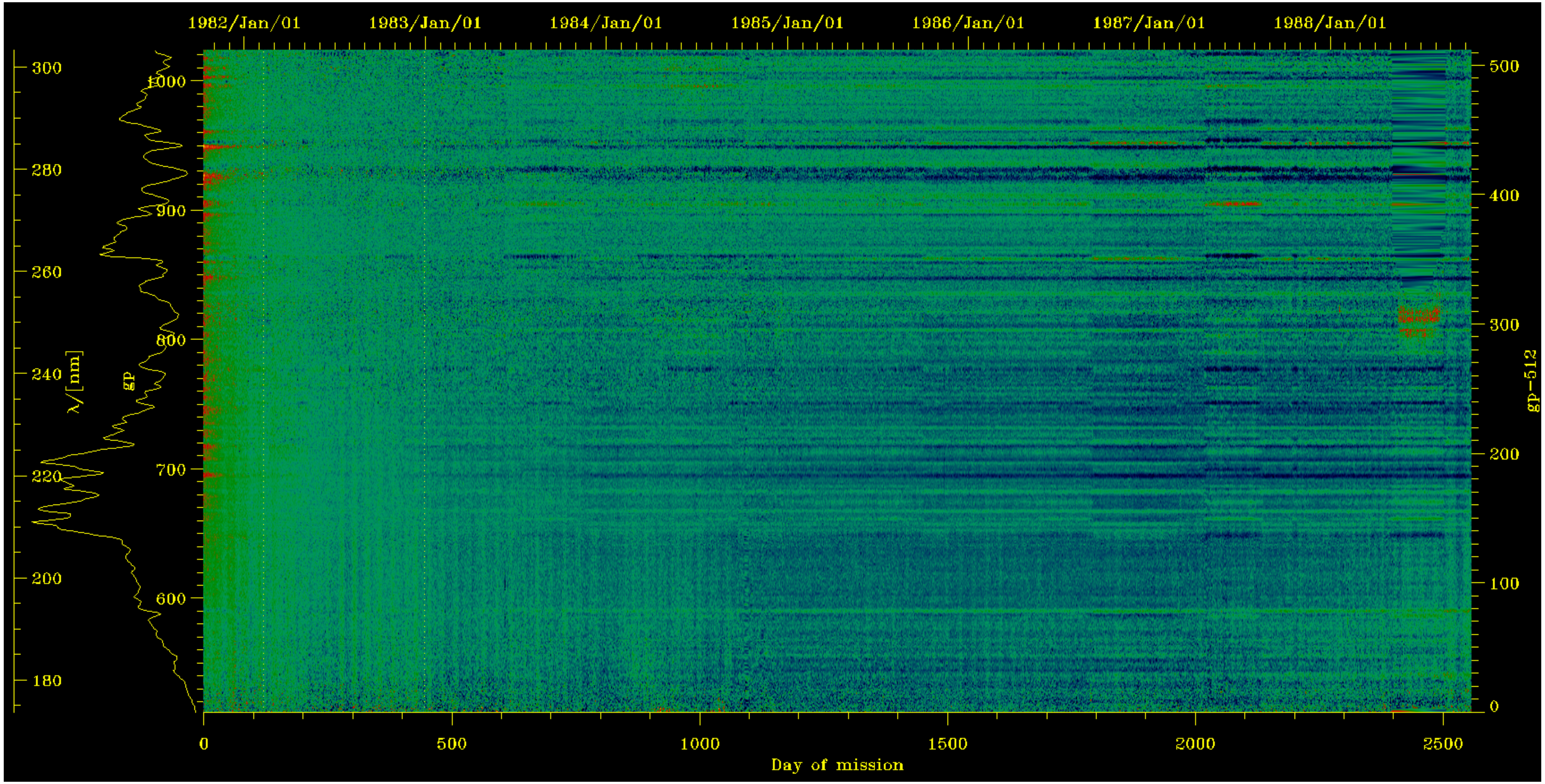
(Future work: translate the Δ gp shift uncertainty to an irradiance uncertainty)

How reproducible is grating position shift from day-to-day??

Shown here is Δ gp from the first 505 days.



How many grating position shifts have we identified?



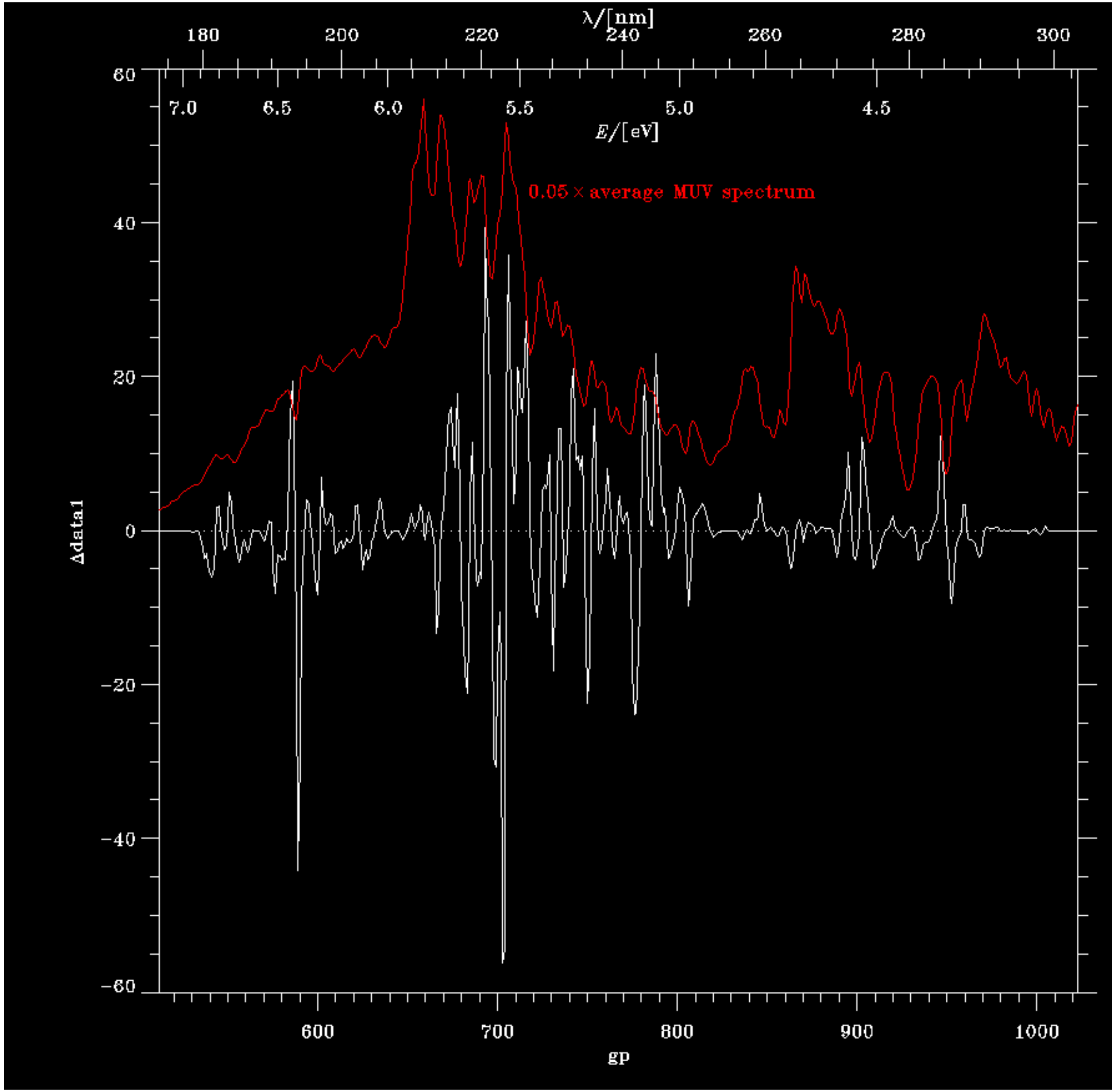
Affected Dates

1983/06/11
1984/10/10
1985/10/03
1986/09/09
1987/04/24
1987/08/16
1987/10/17
1987/10/28
1988/05/05
1988/08/21

Impacts of applying wavelength calibration

The white line shows the average change in DN after applying the wavelength correction relative to no wavelength correction.

(Results for the first 500 days of the mission).



To-Do List

- Add a quality assurance flag for data points that have been "cleaned".
- Determine how reproducible the cross-correlation analysis is – *In progress*.
- Compute the Δgp for the other affected periods - *In progress*
- Translate Δgp shifts into irradiance uncertainty – will do this using the "SME/SOLSTICE" reference
- Apply wavelength corrections to FUV data – will use the closest in time Δgp shifts from the MUV channel.
- Apply temperature correction (developed in Year 2 activities)
- Apply degradation correction (cumulative exposures determined in Year 1 activities).
- Define data level definitions - *In progress*
- Evaluate results
- Prepare new files (.netcdf) for public release
- Prepare manuscript of results.