The Solar Mesosphere Explorer

Reanalysis of the Solar Mesosphere Explorer Ultraviolet Spectrometer Data

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Talk Outline

- Overview of SME mission and instruments
- Project Goals
- Year 1 Findings:
  - Grating position
  - Diffuser Screen
  - Data Discretization
  - Exposure Time Analysis
  - Relative Instrument Degradation
- Concluding Statements

History & Background

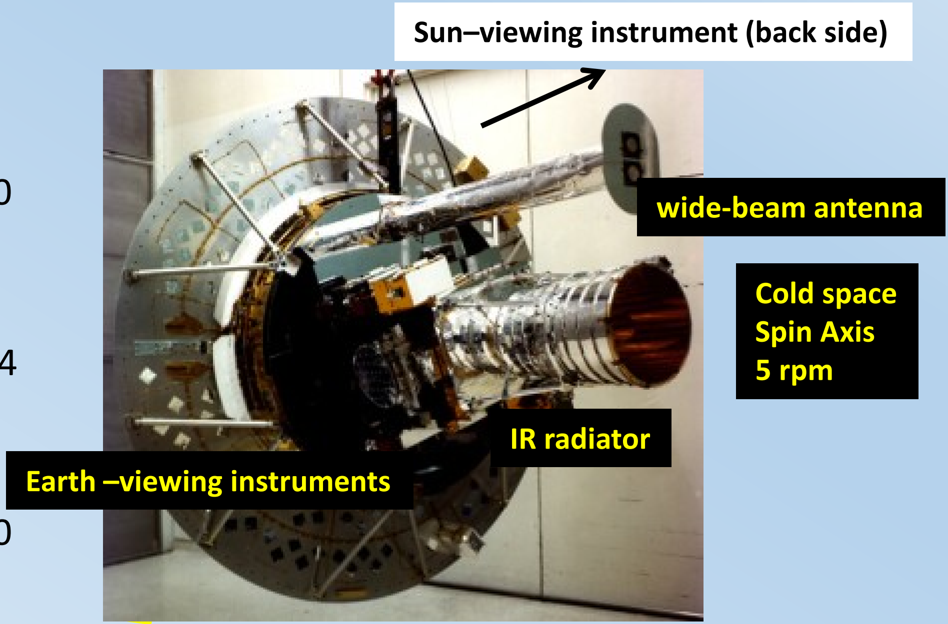
- LASP proposed SME in October, 1974
- ***Primary Objective***: determine how the mesospheric ozone distribution varies with changes in incoming solar radiation.

SME launched October 6, 1981
SME data transmission ceased on April 4, 1989

SME launched on a Delta rocket from Vandenburg AFB, California.

SME had 5 Instruments

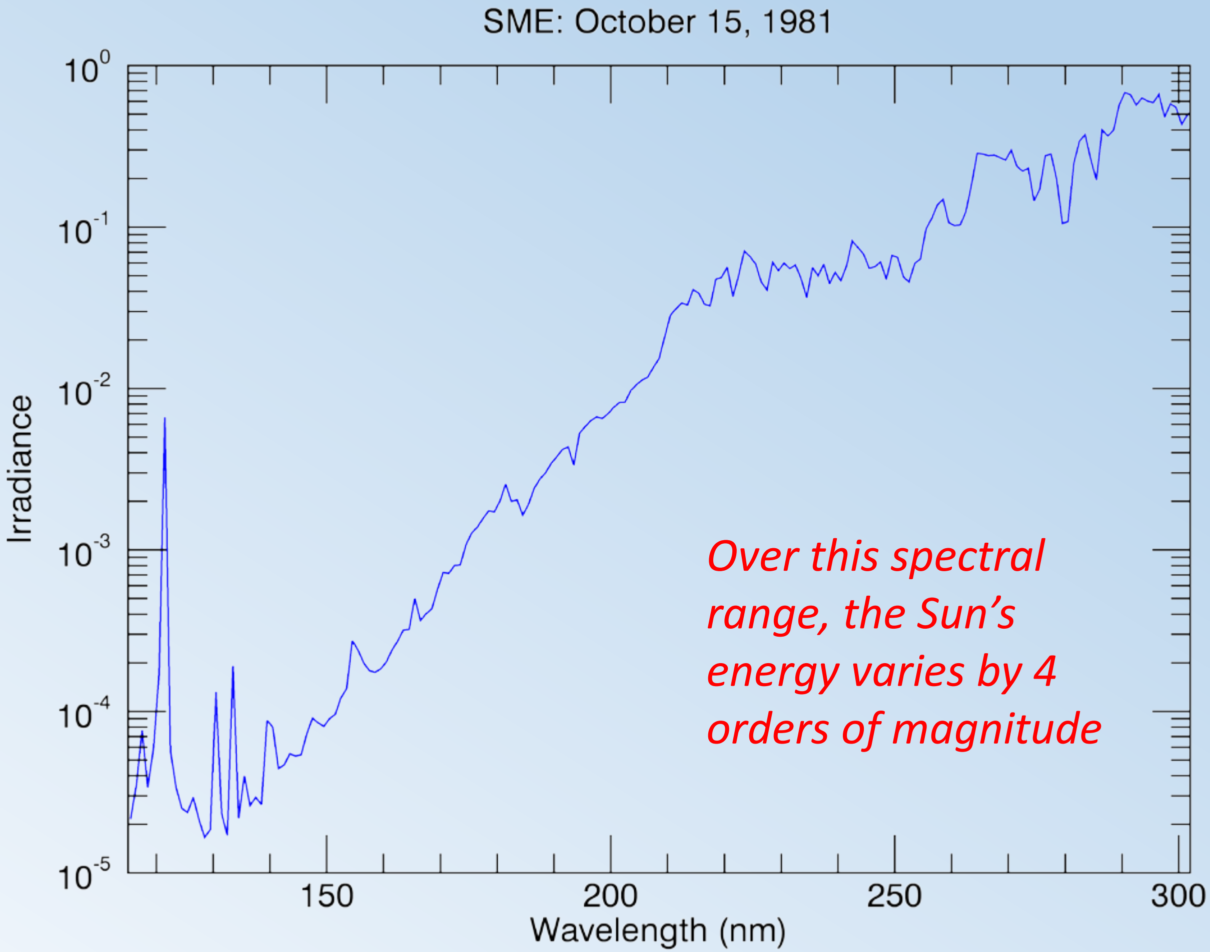
- UV Ozone Instrument
  - Dual channel Ebert-Fastie spectrometer; 240-330 nm
- Airglow Instrument
  - Dual channel Ebert-Fastie spectrometer; 0.7 – 1.4 μm; 1.2 – 2.4 μm
- Nitrogen Dioxide Experiment
  - Dual channel Ebert-Fastie spectrometer; 312-640 nm
- Infrared Radiometer
  - Telescope with four passively cooled Mercury-cadmium telluride detectors/filters.
- **Solar UV Spectrometer**
  - Ebert-Fastie Spectrometer; 115-300 nm, 0.25 nm resolution
  - G-channel: 115 to 210 nm (far-uv)
  - F-channel: 180 to 302 nm (mid-uv)



BALL Aerospace Satellite Bus

<u>Orbit</u>
536 km
Sun Synchonous; 97.5 deg inclination
3 pm ascending node

Sample SME Spectrum



Over this spectral range, the Sun's energy varies by 4 orders of magnitude

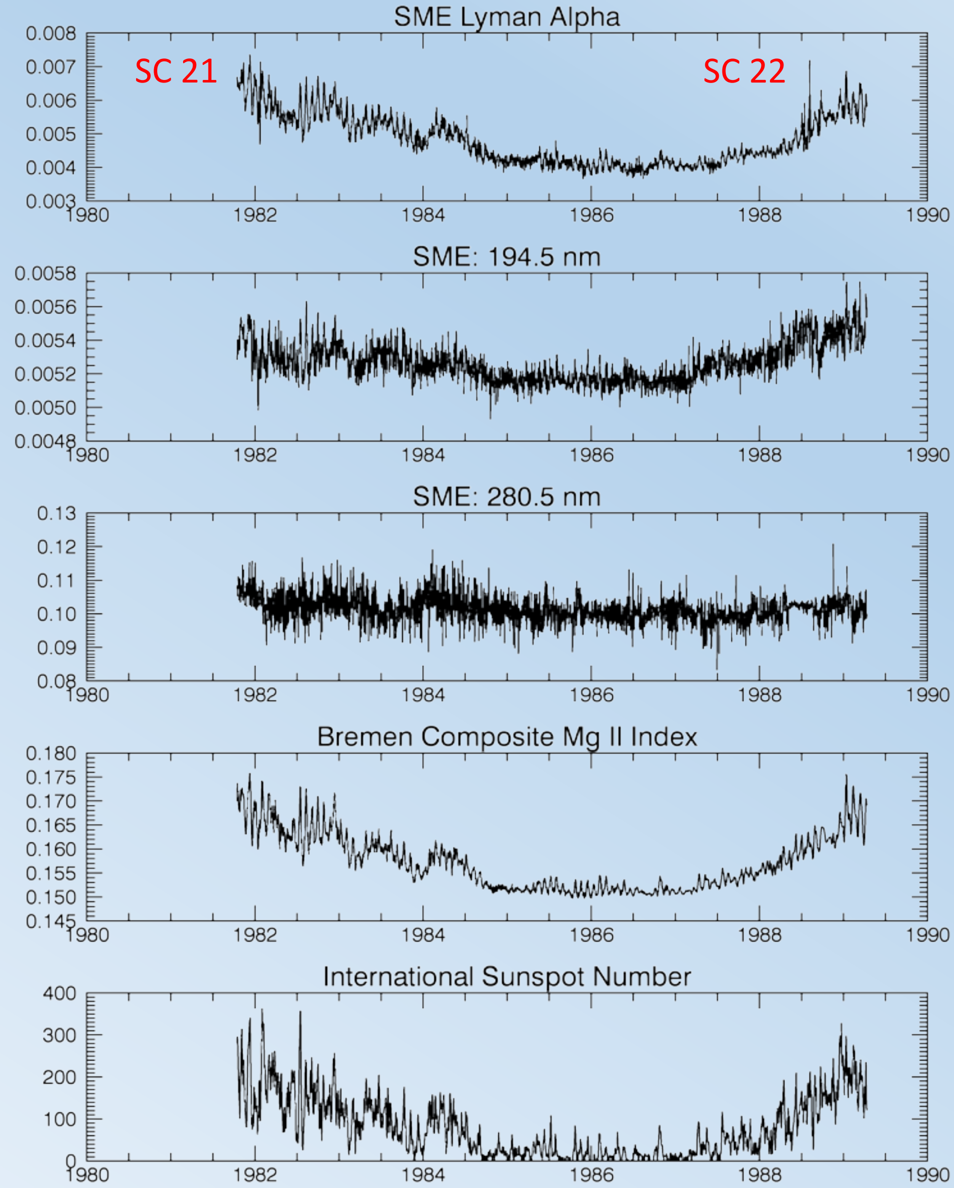
Sample SME Time Series

...and comparison with other independent data sets

SME Irradiance

Univ. of Bremen Composite Mg II Index

International Sunspot Number



Goals & Desired Outcomes

- SME reanalysis will give an improved understanding of solar cycle variability.
  - Constraining the UV variability will constrain visible and infrared variability by extension (by using a model and the SORCE TSI observations).
- Use the new knowledge to improve solar variability models.

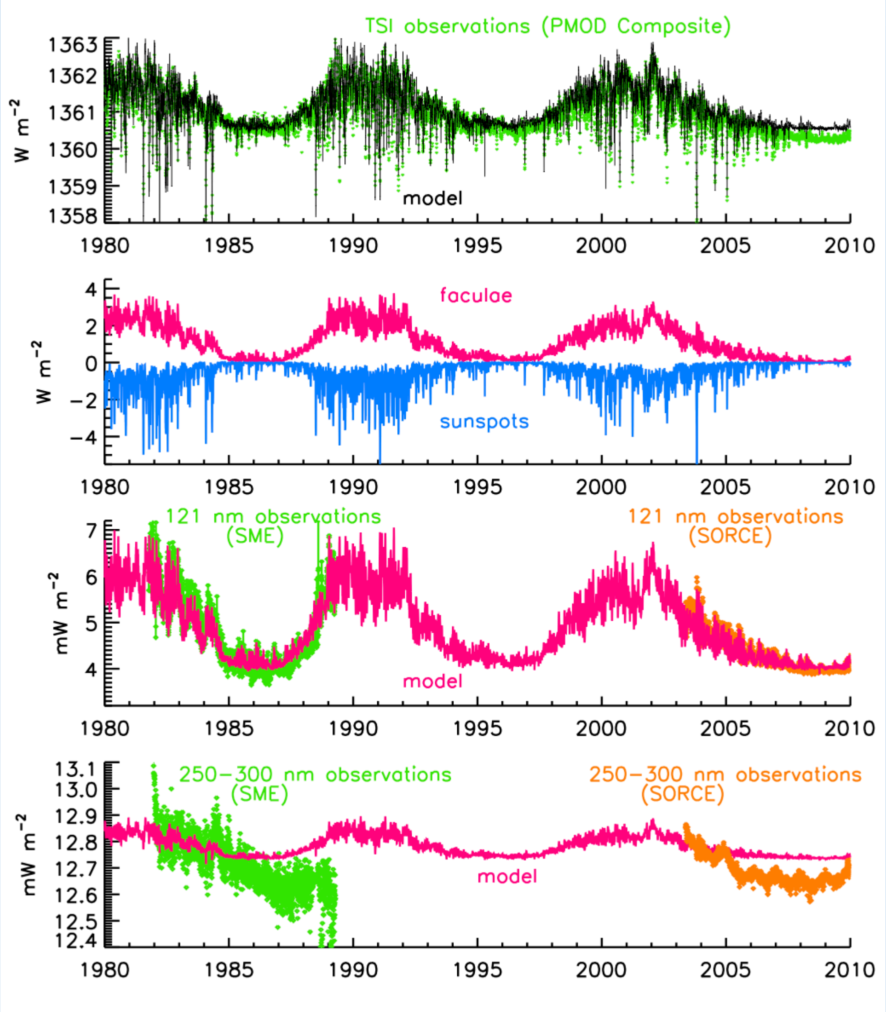
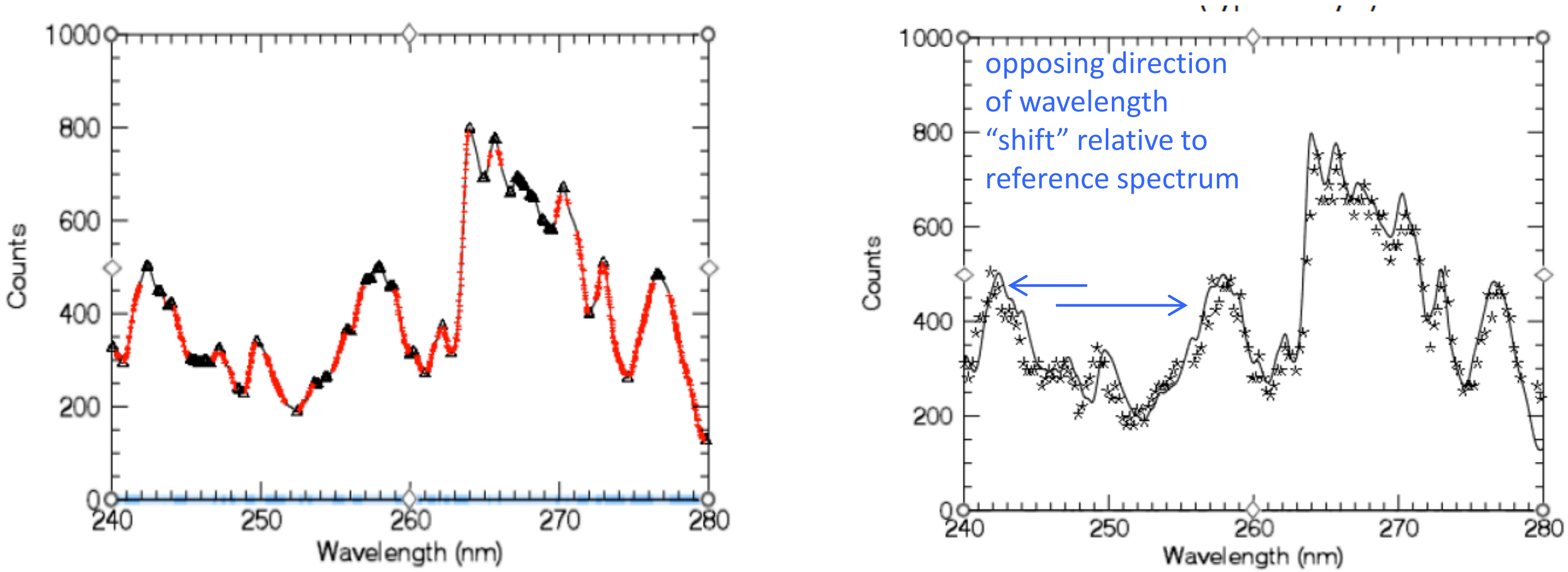


Figure: *Comparisons of modeled and measured solar irradiance over solar cycle time scales along with components of sunspot and facular influence.*

Suspected Source of SME UVS Instability

- A drift in the grating drive mechanism is suspected to cause uncertainty in the wavelength scale, leading to uncertainty in the solar irradiance variability.

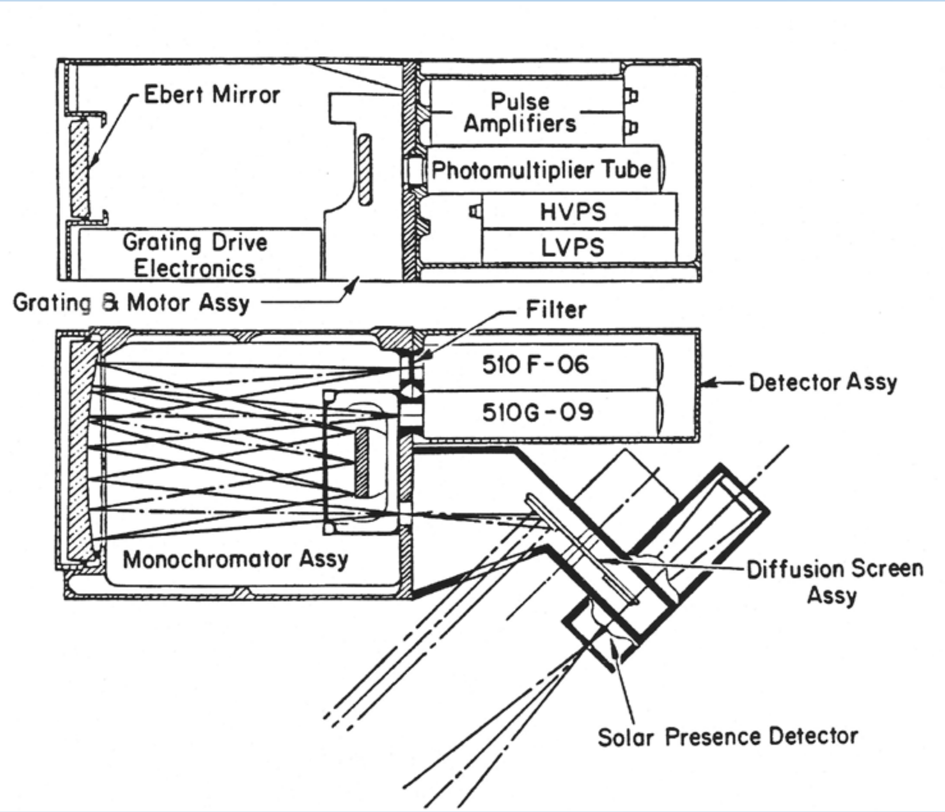


UVS reference spectrum (left) and a comparison of a measured spectrum (right; symbols) to the reference spectrum (right; black line).

Solar Ultraviolet Spectrometer (UVS)

- Monitors solar spectral irradiance scattered from a diffusing screen.
- Optics:
  - f/5, 250 mm focal length off-axis, Al coated, paraboloidal telescope mirror.
- Detectors (photomultiplier tubes):
  - EMR 510-G-09 (FUV; 115 to 250 nm)
  - EMR 510-F-06 (MUV; 173 to 305 nm)
  - Switched between detectors every 4 hr.
- Grating has Al + MgFl coating and 2400 grooves/mm; 1 step = 0.019° = 0.26 nm

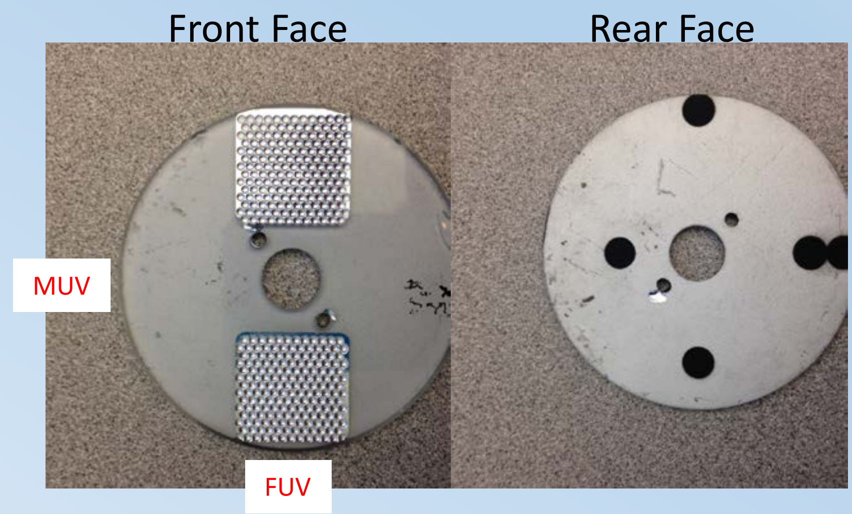
Ebert-Fastie Spectrometer



Absolute uncertainty ~ 15% (based on pre-flight calibrations and a rocket under-flight on 17 May 1982).

Screen Assembly & Grating Drive Assembly

- The grating and grating drive mechanism are common to both FUV and MUV channels
- The FUV channel (‘G’ screen) is a front surface mirror with “fly eyes”. It is overcoated with Al+MgFl to scatter light to detector.
- The MUV channel (‘F’ screen) allows light to pass through the quartz and reflect off rear Al coating
- The screen position sensor is a bit flag reflected off rear face of screen to indicate which screen is in place.



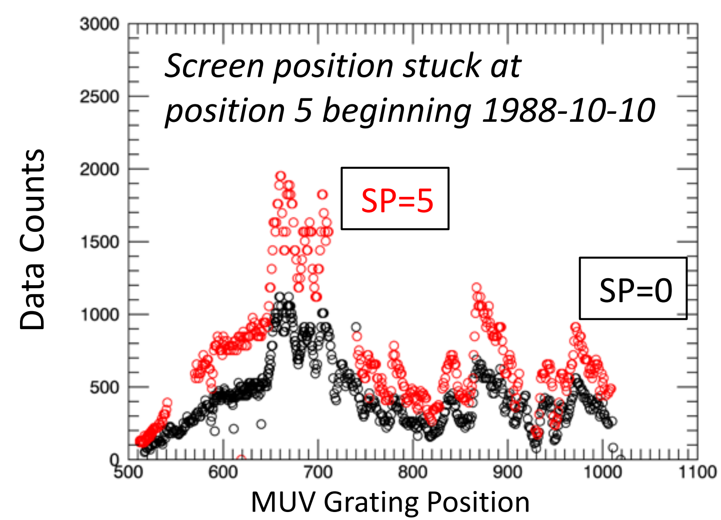
FUV and MUV channels had a primary and backup screen position.

Determining Screen Position

- Used records of ~ 25 calibration days between 1981-10-28 and 1987-07-31 and a statistical approach to identify the most often used channels on “regular” days and “calibration” days

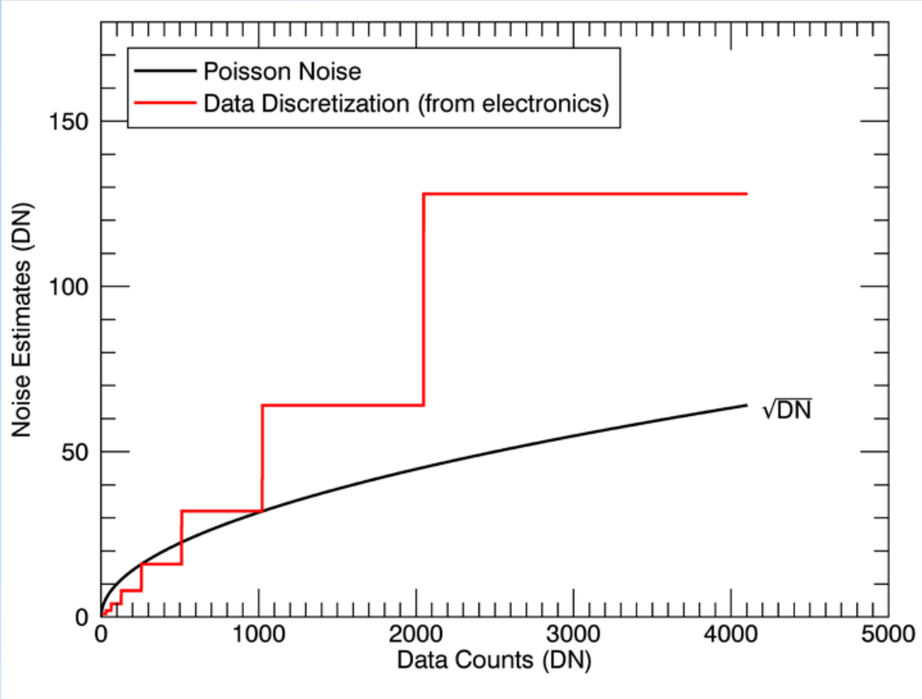
Channel	Screen Position
MUV Primary	0, 1
MUV Calibration	3
FUV Primary	5
FUV Calibration	7

There is evidence that the screen assembly gets “stuck” – ongoing assessment will be part of the project.
Other evidence suggests FUV channel impacted ~ November, 1988.



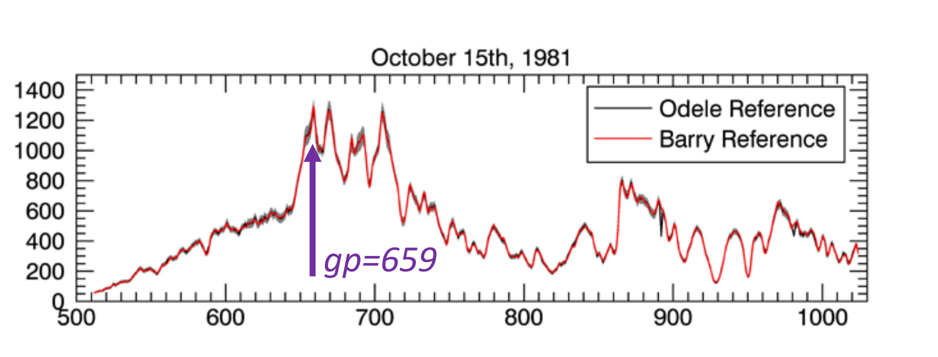
Data Discretization

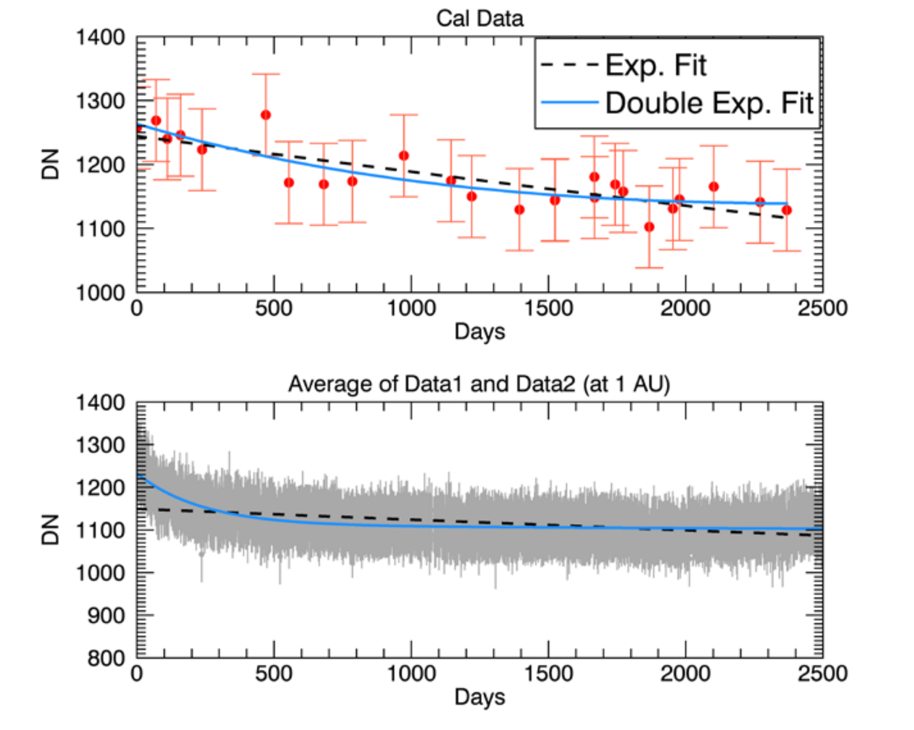
- Photon counting noise: “shot noise” is described by Poisson statistics
- SME Electronics:
  - Instrument counter exceeded size of 8-bit data word
  - Instrument counter was shifted until there were only 5-bits of data, and the number of shifts was inserted in the additional 3-bits
  - Ex. DN of 31 = 00011111 (“0” shift and data increment = 1)
  - Ex. DN of 127 = 01111111 (“2” shift and data increment = 4)



DN’s < ~ 500 are “photon-noise” limited
DN’s > ~ 500 are limited by electronic discretization

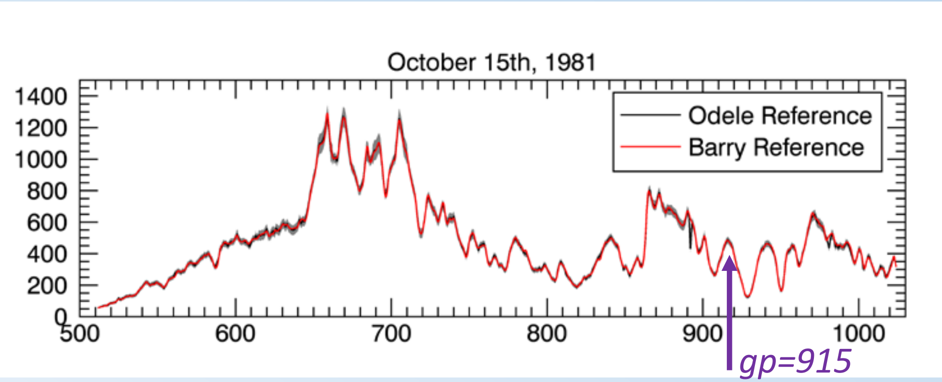
Raw SME Data: Grating Position 659 (211.5 nm)

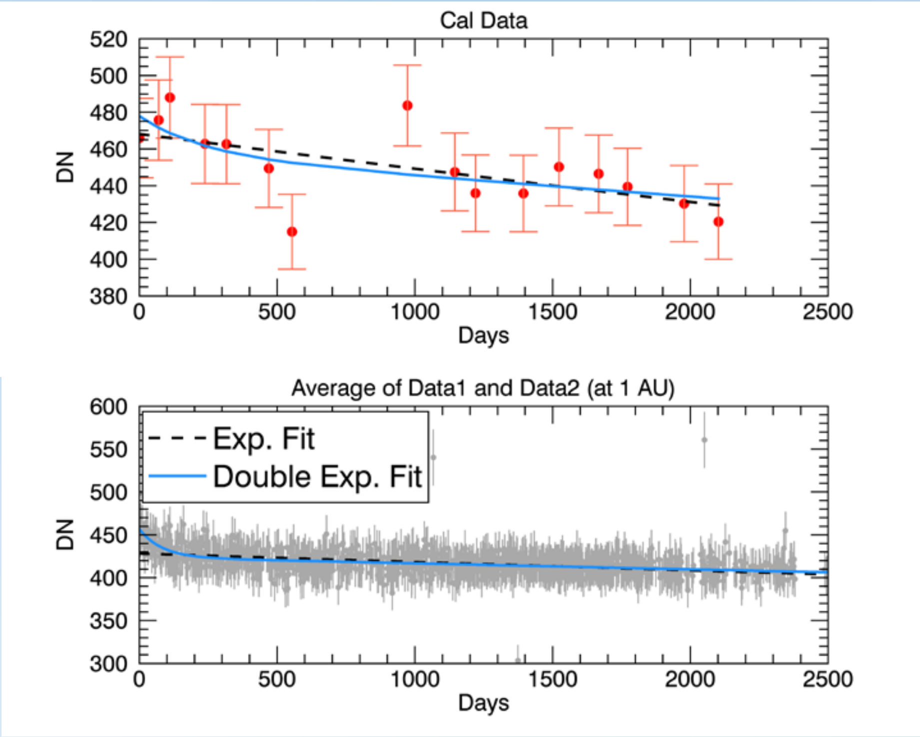




"Double Exponential" = sum of two expontials with different decay rates

Raw SME Data: Grating Position 915 (276.5 nm)





Determining the Wavelength Dependence of the *Relative* Instrument Degradation

Experimental Premise:

- The irradiance in each channel is as a function of time, *t*, wavelength, λ, and the degradation in the channel which is dependent upon the solar exposure, t_e, on the channel.
- Instrumental degradation follows an exponential form; while the exposure times are different we assume the α is the same.
- By analyzing the ratio of the channels, we remove the solar variability from the measured signal.
- Use a fitting routine to converge on an α that best replicates the measured ratio data.

**Wavelength dependence is implied.*

$$\frac{I_{A,t}}{I_{B,t}} \propto \frac{(S_t)}{e^{-\alpha t_e^A}} / \frac{(S_t)}{e^{-\alpha t_e^B}}$$

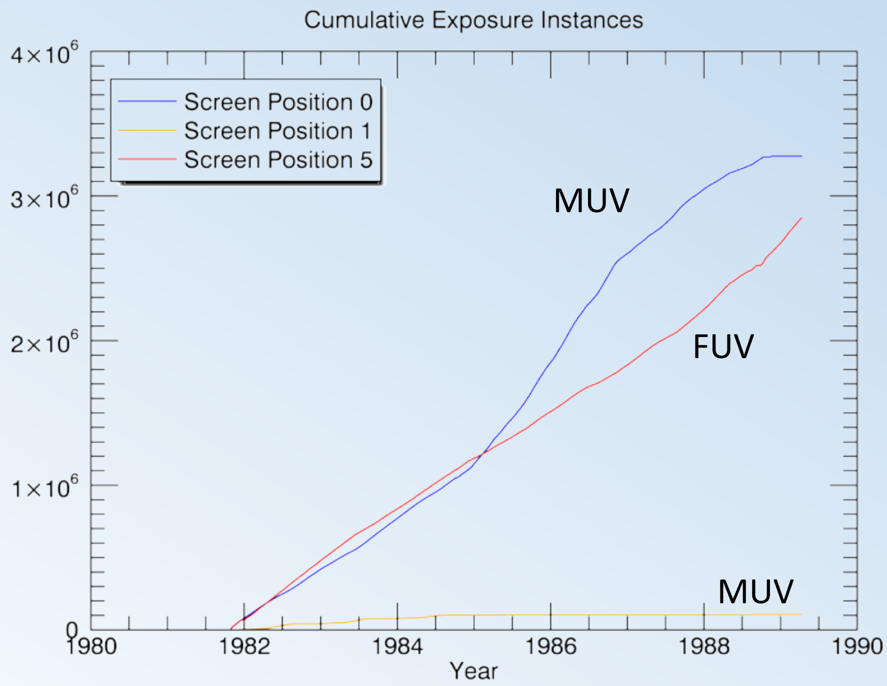
$$\boxed{\frac{I_{A,t}}{I_{B,t}} \propto e^{-\alpha t_e^B} / e^{-\alpha t_e^A}}$$

**The ratio of SME A/B irradiance is proportional to the ratio of the diffuser screen degradation.*

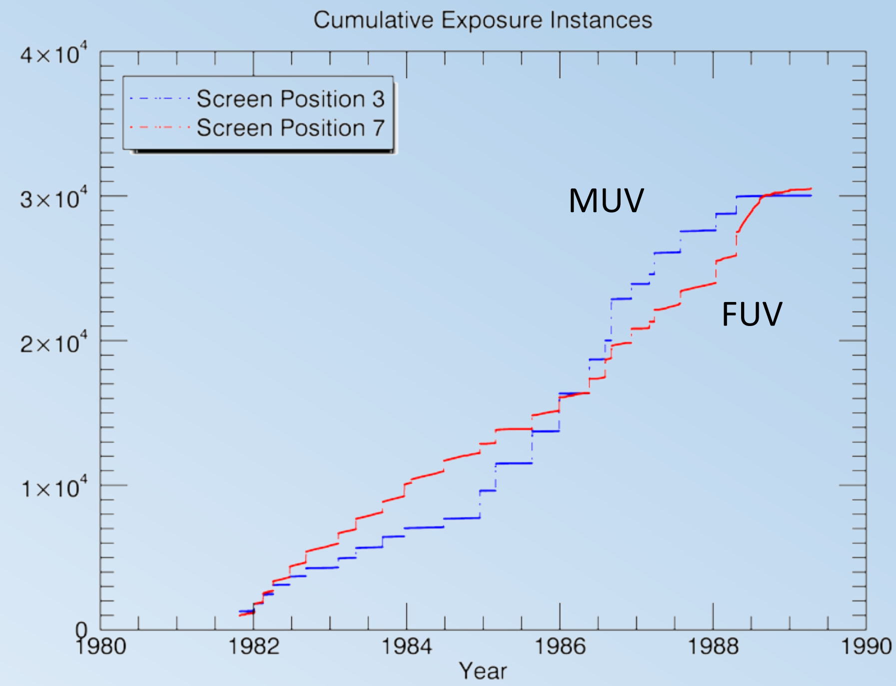
A channel = regular
B channel = calibration

Cumulative Exposure "Instances"

Regular Screen

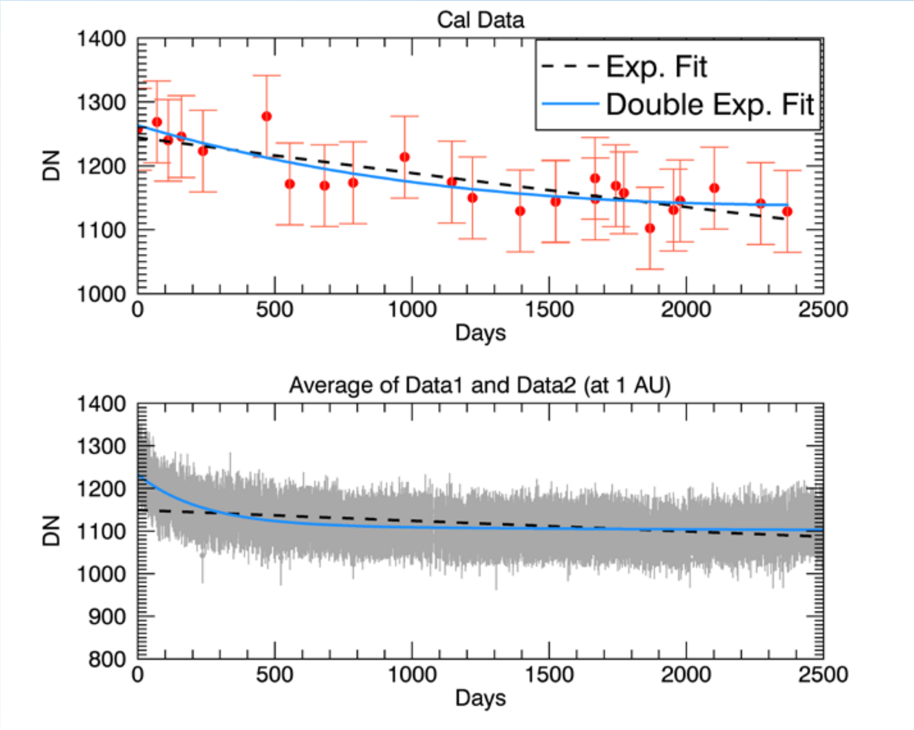


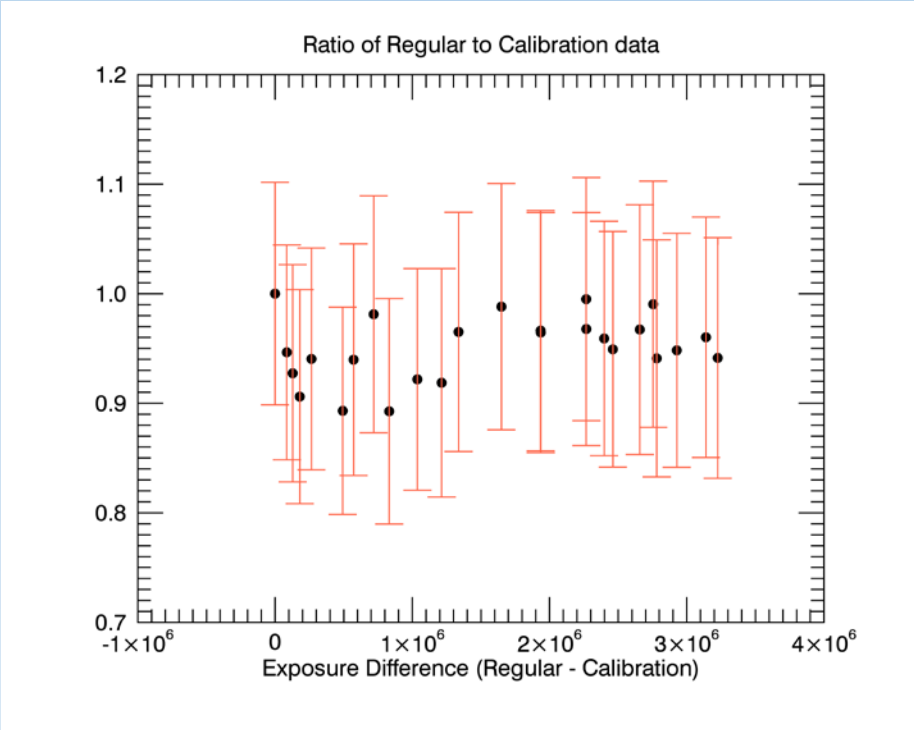
Calibration Screen



Calibration screens are exposed about 100x less than regular screens.

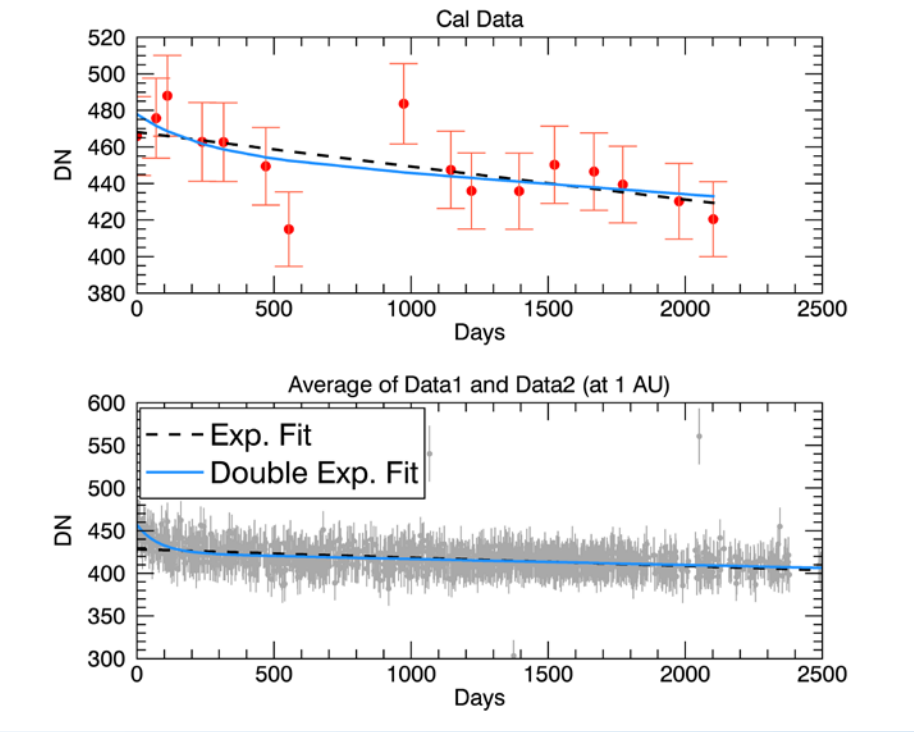
Ratio Data vs. Exposure Time
Grating Position 659 (211.5 nm)

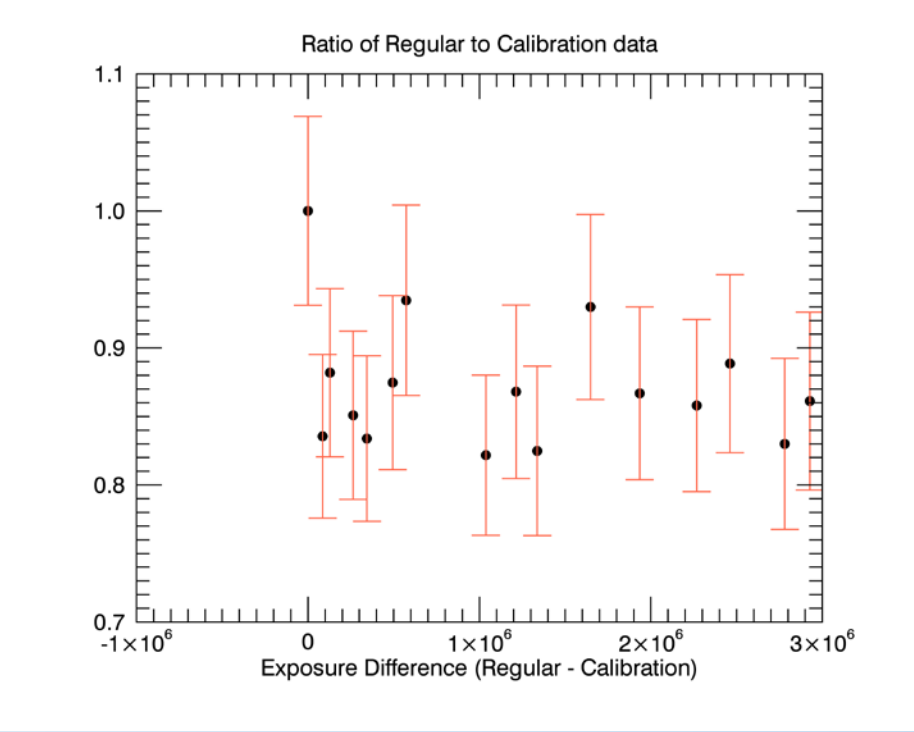




**To compute error in the ratio data, we assume independent and random uncertainties in the regular and calibration data.*

Ratio Data vs. Exposure Time
Grating Position 915 (276.5 nm)





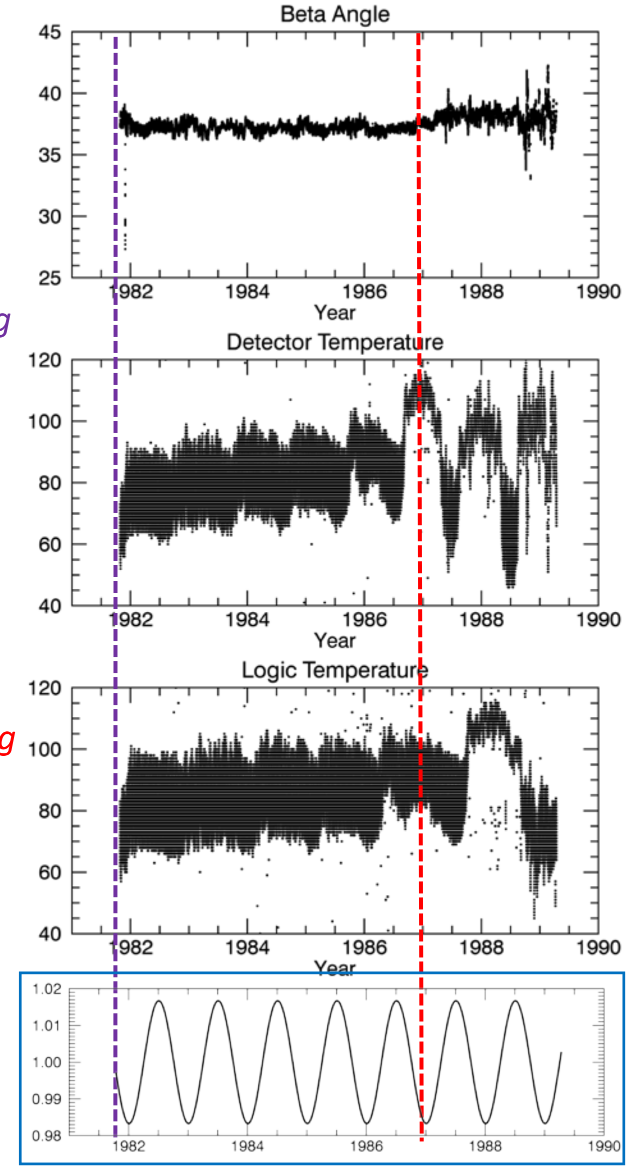
Potential Temperature Effects

- Earth viewing instruments “too cold” at launch (personal communication, Dave Rusch).
  - Shortly after launch, s/c slewed to get higher (and fixed) beta angles (longer sunlight period).
  - Detector/logic temperatures increased correspondingly.
- Earth-viewing instruments turned off Dec 11, 1986
- Solar UVS Detector temperatures modulate with Earth-Sun distance and with each orbit (~ 30 deg C)

Earth-viewing instruments too cold; s/c slewed to lower (and fixed) beta angle

Earth-viewing instruments turned off

Earth-Sun Distance



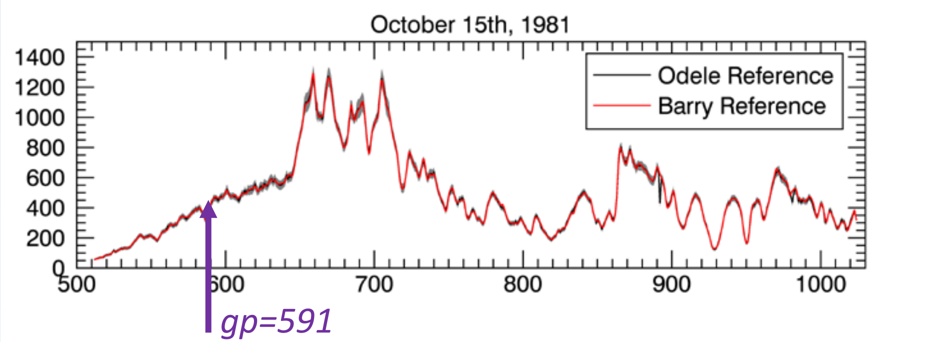
Summary

- Still a lot of work to do to understand diffuser screen degradation and/or temperature effects on the detectors.
  - Analyze more grating positions, in particular:
    - grating positions with MUV/FUV overlap,
    - grating positions with DN values ~ 400-1000 counts
  - Investigate sensitivity of photocathode and the gain of photomultiplier tube to temperature as a function of wavelength. (Literature search, similar detectors at LASP).
- Analysis code developed to monitor the grating position of maxima & minima in solar spectra over time.

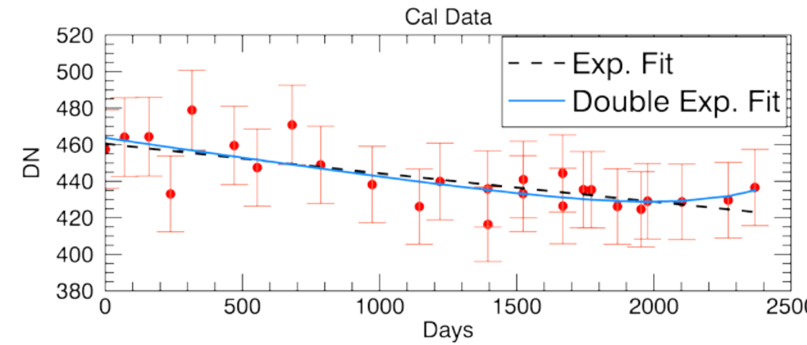
Backups

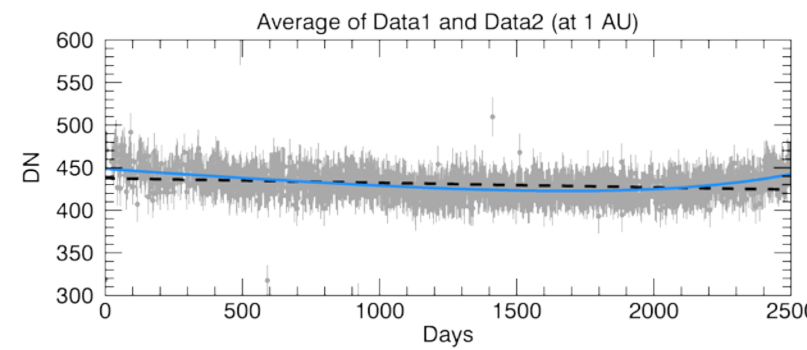
Raw SME Data: Grating Position 591 (194.5 nm)

Reference Spectrum

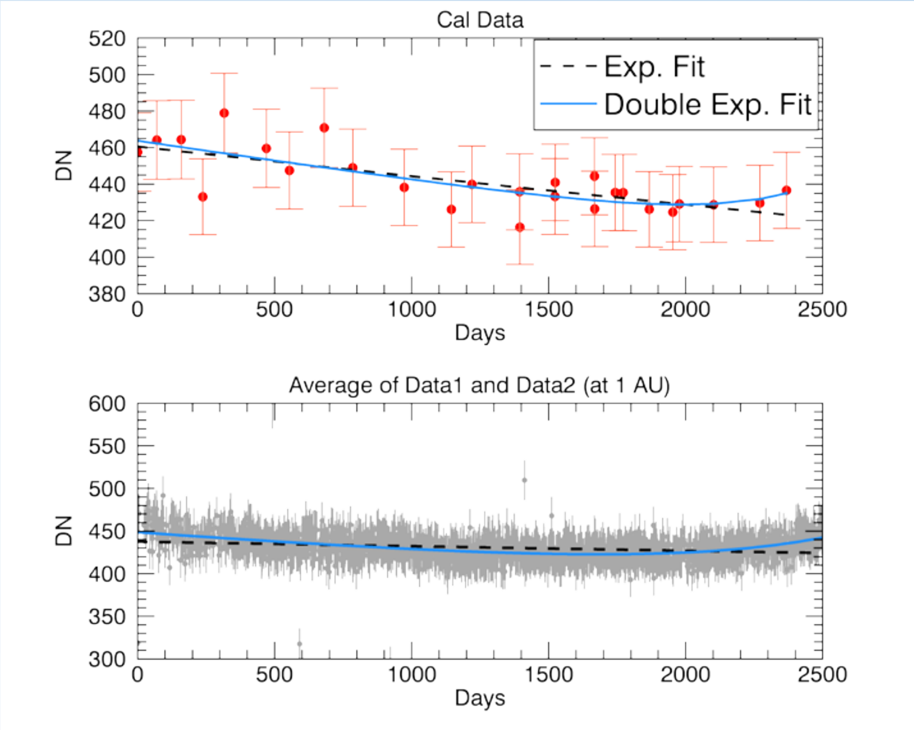


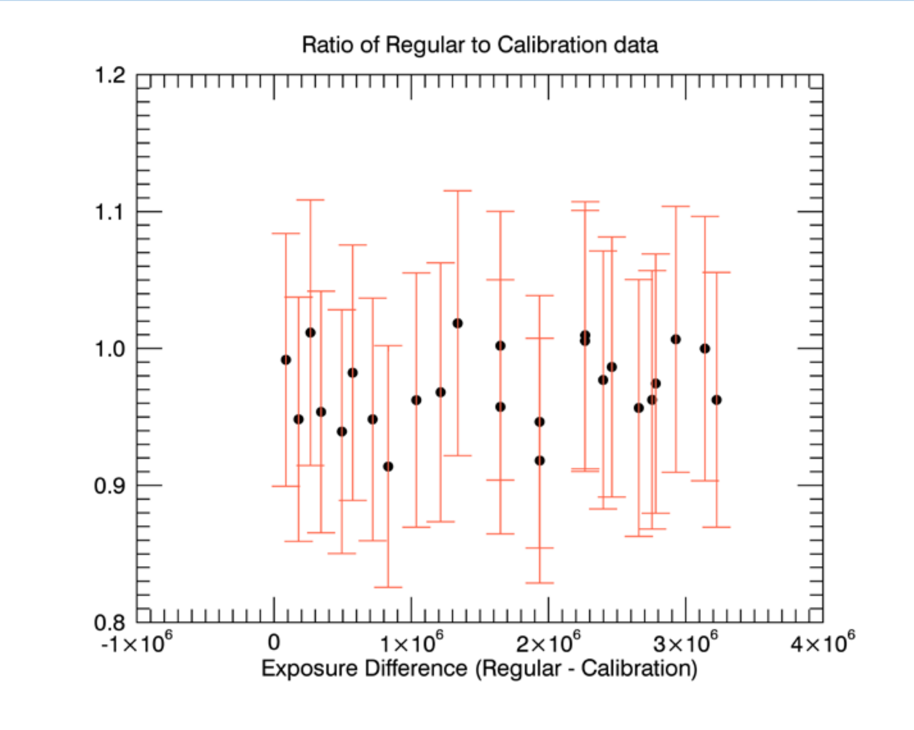
Time Series



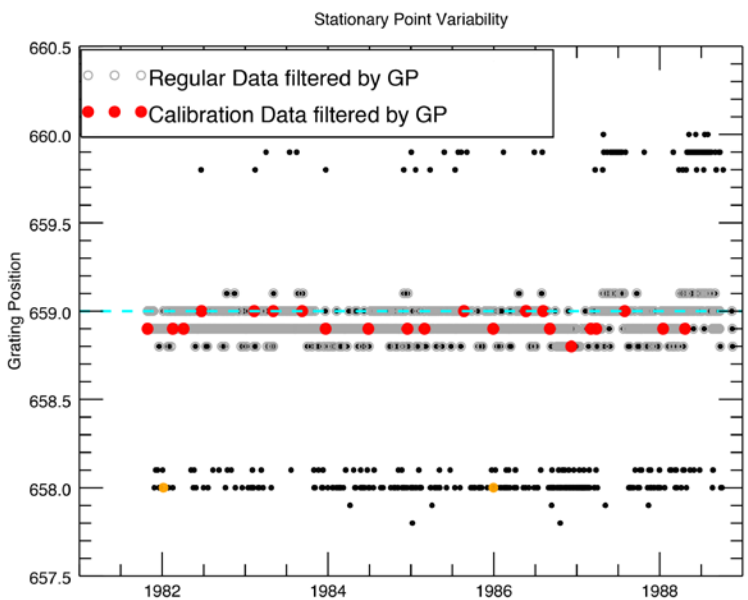


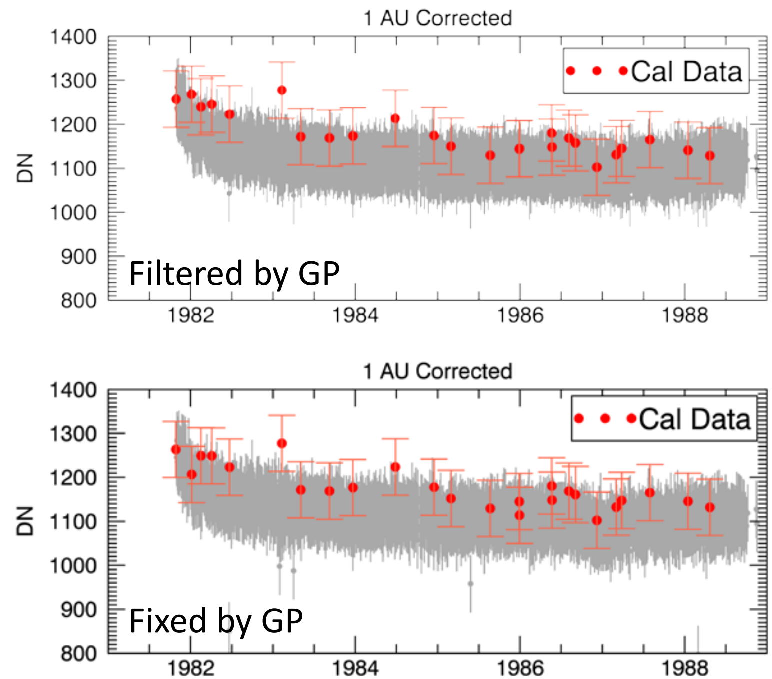
Ratio Data vs. Exposure Time
Grating Position 591 (194.5 nm)



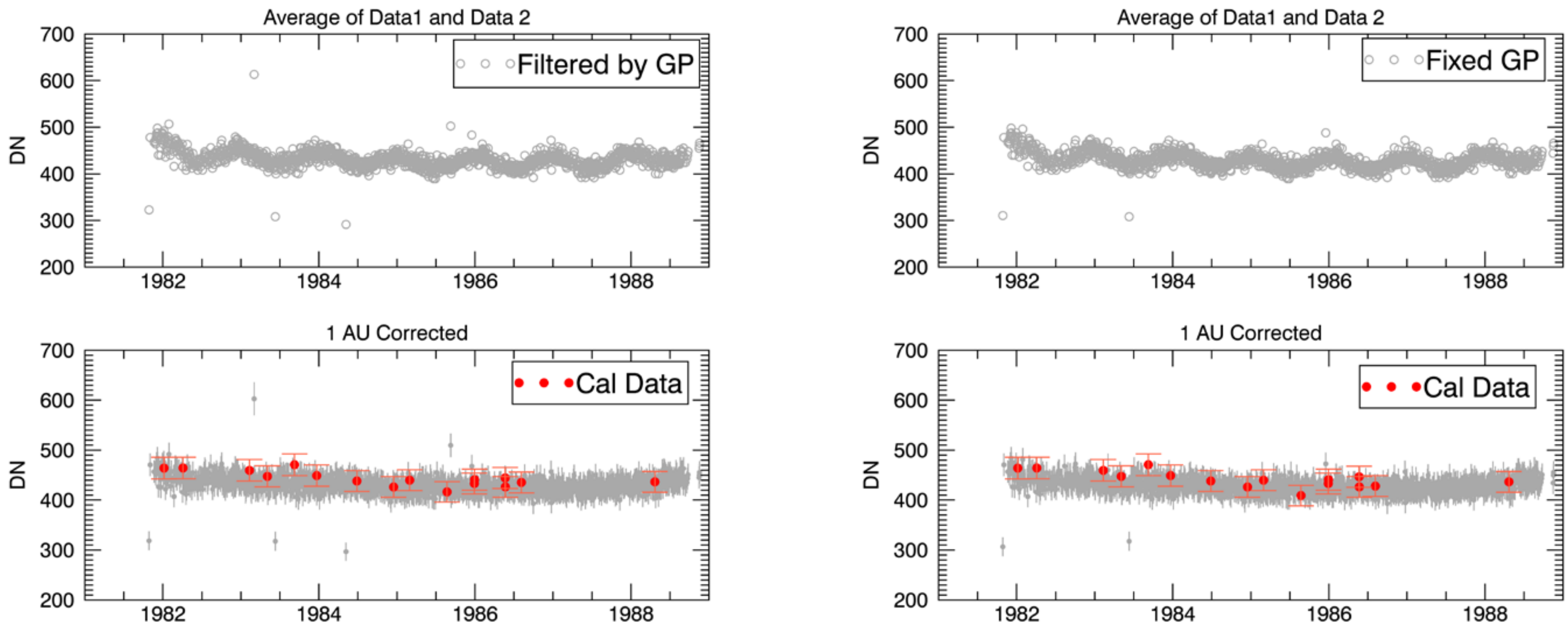


How variable is the grating position for the peak near gp=659?





How variable is the grating position for the peak near gp=591?



How variable is the grating position for the peak near gp=915?