Strategies for the Mitigation of Gain Sag in the COS FUV Detectors

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Abstract

The far ultraviolet (FUV) channel on the Cosmic Origins Spectrograph (COS) suffers localized flux loss due to gain sag from continued exposure to light. Because of the non-uniformity of observed spectra falling on the detector, gain sag holes in extracted spectra first appear in the most illuminated portions of the detector (those affected by bright airglow lines) and will eventually impact large regions of the continuum as well. In order to preserve the data quality and extend the operational lifetime of COS, strategies have been implemented which impact nearly every aspect of COS operations. These include changes to default observing sequences, improved monitoring, new calibration procedures, changes to detector electronics settings, and a complete relocation of the illuminated portion of the detector.

Gain Sag

The FUV channel on COS employs two open-faced microchannel plate detectors with a cross delay line (XDL) anode. This type of detector is particularly subject to an effect called gain sag, which arises due to the extraction of charge from the microchannel plates. Each incoming photon event produces a cloud of charge as it hits the detector. In addition to the X and Y location, the number of electrons in this charge cloud, or pulse height amplitude (PHA), is measured. Over time, as more charge has been extracted from a given region, the detected PHA becomes smaller. We see this as a shifting of the typical PHA distribution (PHD) for a given pixel to smaller values with more usage of the detector. An example of this can be seen in Figure 1, where the PHD for a particular pixel is shown for 4 different dates. This shift becomes a problem when the distribution drops too low, as the detector electronics are no longer able to accurately register incoming events. To compensate for this effect, the COS calibration pipeline (CalCOS) screens out events with PHA < 2. This will cause part of the detected flux to be lost if the distribution enters this region.

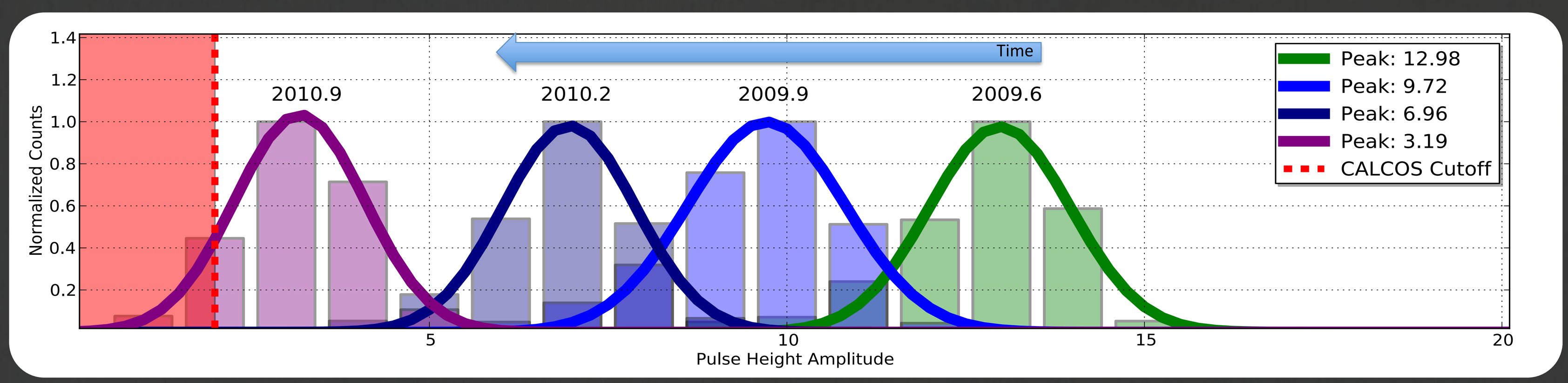


Figure 1: The PHDs for photon events falling in a given region shifts to lower values as charge is extracted from the detector. The normalized distributions from a single area, x=9104-9112 and y=544-548, are shown over 4 different periods from 2009.6 to 2010.9. Over this period, the peak in the pulse height distribution (modal gain), as measured by a gaussian fit, has decreased from nearly 13 to just above 3. The red region on the left shows the CalCOS cutoff value. Any events falling in this area are screened out by CalCOS processing, and the events will be lost to the final spectrum.

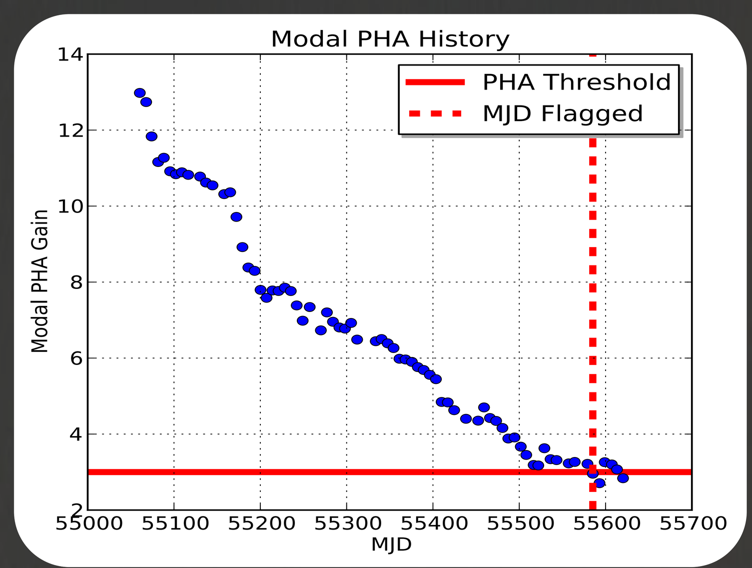
Monitoring and Calibration

To track the progress of gain sag, a new monitoring procedure has been implemented which measures the COS Cumulative Counts Images (CCIs). CCIs are accumulated data over approximately week-long periods, which provide enough data to make useful measurements. Monitoring of these data allow us to track the modal PHA, accrued counts, and extracted charge on a pixel-by-pixel basis over the lifetime of the detector.

Each week, the peak of the PHA distribution in each pixel is determined, and the regions that are found to have dropped to a modal gain of 3 (a level which results in approximately a 5% loss of flux after PHA filtering by CalCOS) are flagged in a new Gain Sag Table (GSAGTAB) reference file. Figure 2 shows the modal gain history of pixels (9104,544) to (9112,548) which are illuminated by LyÅ airglow.

Beginning in an upcoming release of CalCOS, events falling in these identified regions will be flagged and excluded from final x1dsum calibrated products. If this was not done, a portion of the detected flux in those locations would be lost, which would result in artifacts resembling absorption features in the extracted spectrum. An example of this effect can be seen in Figure 3. The gain sag table and CalCOS flagging will be implemented in the OTFR Pipeline starting in Summer 2012.

Figure 2: The modal PHA gain of pixels (9104,554) to (9112,548) with time. The overall trend is not completely linear with time, as any given pixel can undergo periods of more or less usage depending on targets, instrument configuration, and scheduling. When the PHA reaches a value of 3, the region is flagged as bad in the GSAGTAB and excluded from final extracted spectra produced by CalCOS.



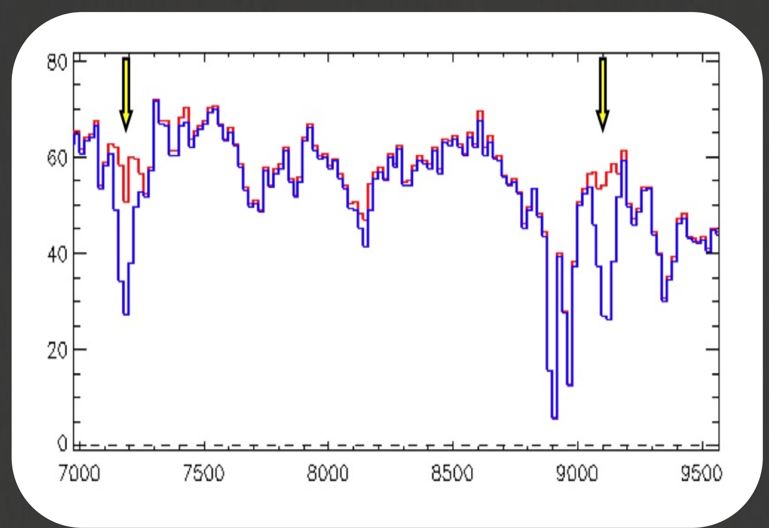


Figure 3: The effect of gain sag holes on an extracted spectrum are shown here. The arrows mark two regions illuminated by airglow lines when the G130M grating is used. These regions have PHA distributions significantly lower than that of the rest of the spectrum. This causes an apparent loss of flux when PHA filtering by CalCOS is performed.

HV Level Changes

Though gain sag will first appear in the brightest of the detector regions illuminated by airglow lines, eventually large portions of the continuum will also be shifted down far enough to hit our CalCOS filtering limits. This would mean that large regions of the spectrum would need to be excluded in the gain sag table in order to retain data integrity. As this limit is approached, it becomes necessary to combat gain sag using another method: raising the operational high voltage (HV) of the detector.

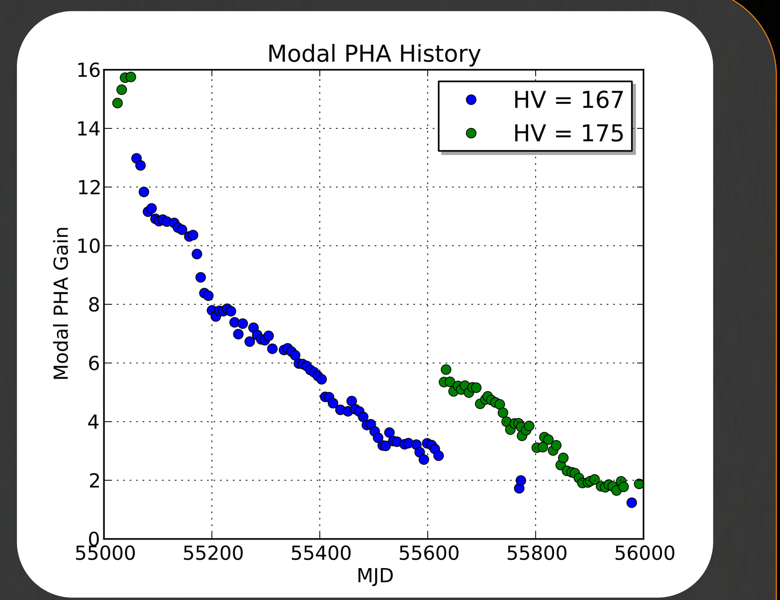


Figure 4: Modal PHA gain history for superpixel 1138,136 with time. Blue points are from data taken at HV = 167, while green points indicate data taken at HV = 175. The effect of the HV increase can be seen in the discontinuity characterized by an increase in PHA gain by ~3.

As seen in Figures 1 and 2, the modal gain of the detector decreases with time as more charge is extracted from the detector. One way to shift the PHA distribution back up is to raise the HV. An example of such an increase can be seen in Figure 4, where the HV was raised from 167 to 175 for Segment B in March, 2011. Such a raise has the effect of shifting the entire pulse height distribution up by ~3 pulse height bins. However, as the voltage can only be raised so high, there will be a point where this is no longer a viable option.

Lifetime Moves

When raising the HV is no longer an option, it will become necessary to shift the entire spectrum to a new location on the detector. Because gain sag only appears where light has fallen, areas of the detector above and below the current spectral location will be free of any degraded effects. The effort to move to a new location is underway, for more information please see #136.03 "A Fresh Start for the COS FUV Detector."

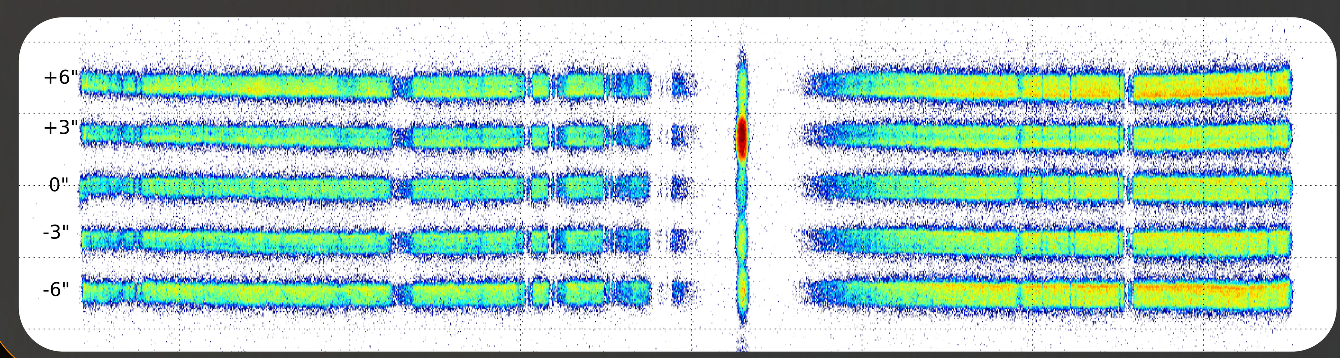


Figure 5: Examples of available new lifetime positions are shown relative to the current position. Relative offsets in arcseconds are marked on the left side, with 0" marking the current position.

Figure 6: A modal gain map (top) and counts map (bottom) across Segment B can be seen below. The modal gain reveals how the uneven illumination by the spectrum affects the measured gain across the detector. The gain in areas above and below the current illuminated location were determined by exploratory programs, and the scale for the gain can be seen in the legend to the right. The modal gain cannot be determined where too few counts fall, so black regions indicate that modal gain information is available. The positions of bright Lyman Alpha airglow lines can be seen in various positions across the detector, and their effect on the localized gain is evident. The appearance of increased sag in the continuum is visible on the left side of this segment.