Updated Status and Performance for the Cosmic Origins Spectrograph

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Abstract

The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope (HST) in May 2009. COS is designed to perform high-sensitivity, medium- and low-resolution spectroscopy of astronomical objects in the 1150-3200 Å wavelength range. COS significantly enhances the spectroscopic capabilities of HST at ultraviolet wavelengths, providing observers with unparalleled opportunities for observing faint sources of ultraviolet light. Provided here is an update on some aspects of detector performance and current calibration projects from the second half of Cycle 17 and through the first half of Cycle 18. Included are discussions on the analysis of gain sag and its effects, changes in the dark current and the time dependent sensitivity, updates to the NUV and FUV flat fields, and upcoming additions to CalCOS.

Flat-field Updates

Grid-wire flat field for G130M and G160M spectra

The two segments of the COS FUV detector are affected by two main types of fixed-pattern noise: 1) small scale irregularities in the response of the detector and 2) shadows on the detector from the repeller grid wires. The grid-wire shadows produce the larger effect, often causing decreases in the observed flux by as much as 20% over 50 pixels or more. Until now, we have flagged these regions and eliminated their contributions to the final, summed spectra. However, a flat field has been developed which corrects for the grid-wire shadows. The grid-wire shadows are the only features corrected because they are insensitive to changes in the location of the spectrum in the cross-dispersion direction, while the rest of the fixed pattern noise varies greatly. Plots of the fixed pattern noise templates for each segment and grating can be seen in Figure 1 and a high s/n spectrum both with and without the grid-wire flat field applied is shown in Figure 2. These new flat fields were implemented on April 6, 2011 and have since been applied to on-the-fly-recalibrated COS data obtained through the archive.

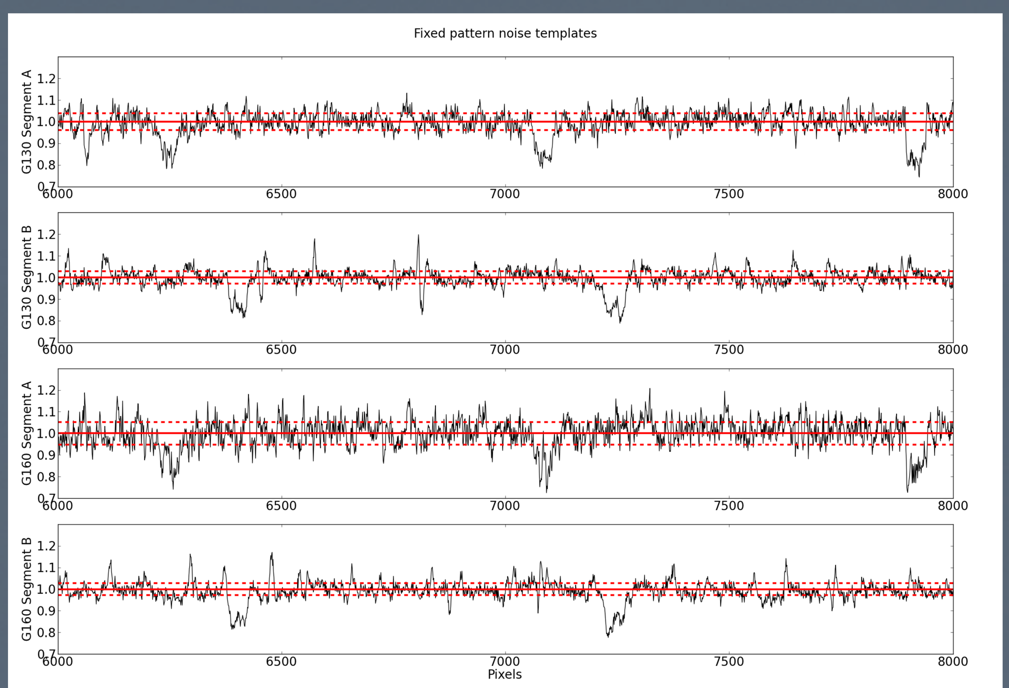

Figure 1 shows crops of the fixed-pattern templates used to create the grid-wire flat fields for each segment and grating. Red lines mark the ±2σ levels for each template. The grid-wire shadows are the largest depressions reaching, ~20%.

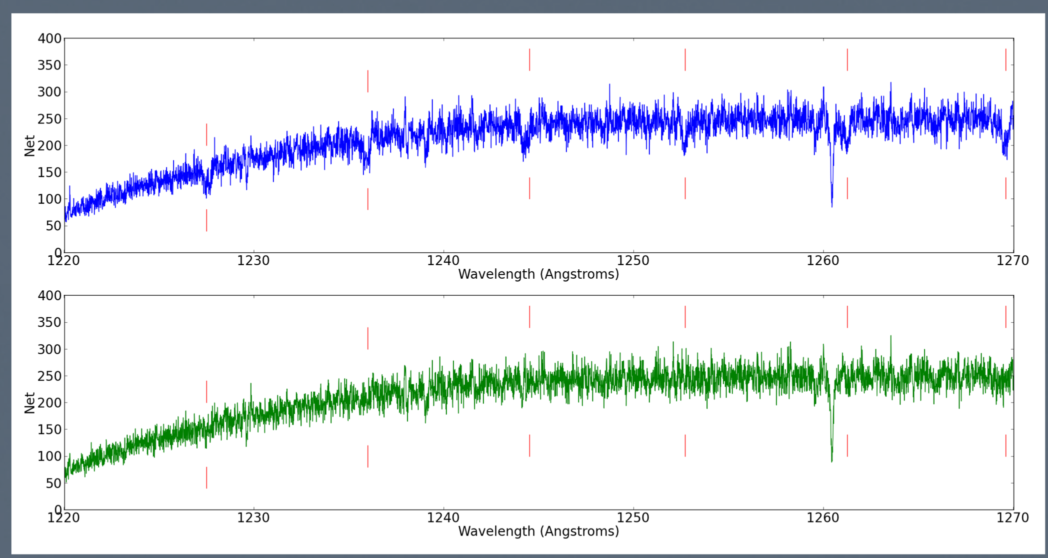

Figure 2 shows the effect of correcting the grid-wire shadows on a single G130M FUVB observation of the white dwarf WD0320-539. This star has a relatively smooth continuum, making the corrections obvious. The upper (blue) spectrum contains grid-wire shadows (indicated by the vertical lines) which are corrected in the lower (green) spectrum. The affected regions are clearly much improved.

Vignetting Removed from COS NUV Flat Field

During SMOV the COS NUV detector showed vignetting in observations of external targets, characterized by a linear ramp down to a 20% depression along the first ~150 pixels at the shortest wavelengths of each stripe for any exposure. The observed vignetting was found to be consistent with the optical beam partially missing the NCM3 mirrors. The vignetting was not observed in the flat field as the path of the D2 lamp is sufficiently different from the path of light from an external target. As the vignetting appeared to be stable, a correction was added into the COS NUV Flat field. Recent analysis of high signal-to-noise data obtained during Cycles 17 and 18 revealed that the location and depth of the NUV vignetting is not constant, but instead has a variation that is strongly correlated with the spectrum's location on the detector in the dispersion direction and is thought to be due to the OSM non-repeatability. The static vignetting correction has been removed from the flat field while a varying correction is investigated. A new NUV flat field, without the vignetting correction, has been used in on-the-fly-recalibration of COS data obtained through the archive since February 14, 2011.

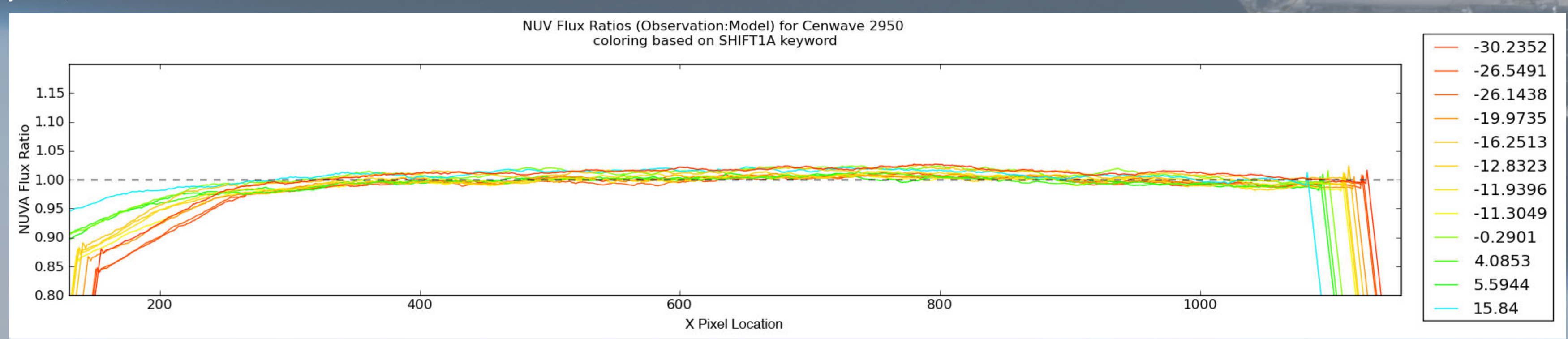

Figure 3 shows the variation of the vignetting with changes in the dispersion direction (SHIFT1A)

Time Dependent Sensitivity

Regular monitoring of spectrophotometric white dwarf standard stars to track the sensitivity of the FUV channels continues, and has revealed a change in the rate at which the sensitivity decline is occurring, as well as its behavior with wavelength. The new trends show that around mid-March 2010, the rate of sensitivity decline slowed markedly and became nearly wavelength independent. Prior to this, the rates at which the sensitivity was declining ranged from 5% per year near 1200 Å to as high as 15% per year at the longest FUV wavelengths. There was variation in behavior at a given wavelength with different gratings and detector segments. Since mid-March 2010, the rate of sensitivity decline has become much more consistent across the FUV gratings and detector segments, with a nearly grey wavelength dependence. The sensitivity decline is now in the range 3-4 % per year between 1100 and 1800 Å. Version 19.2 of the ETC uses the sensitivities projected to April 2012 (Mid Cycle 19) such that the estimated exposure times will be appropriate for all Cycle 19 observations.

These data were used to establish time-dependent sensitivity (TDS) reference files which were delivered on March 18, 2011 to the calibration database system and are now used in on-the-fly-reprocessing of COS data obtained through the archive. During checking of the TDS reference file we determined that there were deviations in the absolute flux calibration of up to 5-10%, and that these files should correct relative fluxes to an accuracy of +/-2%. The updated results of the spectroscopic sensitivity monitoring will be described in an ISR currently in preparation (Osten et al. 2011).

Gain Sag and Y walk

Summary

The COS FUV detectors convert each ultraviolet photon into a shower of electrons, for which the detector electronics calculate the X and Y coordinates and the total charge, or pulse height. Prolonged exposure to light causes the FUV detectors to become less efficient at this photon-to-electron conversion, a phenomenon called "gain sag." As a result, the peak of the pulse-height distribution slowly decreases. As it approaches the minimum threshold imposed by CalCOS, target photons may be rejected as background events and then, eventually, photons may be permanently lost. Gain sag appears first in regions of the detector that are illuminated by bright airglow lines, but eventually affects the entire spectrum

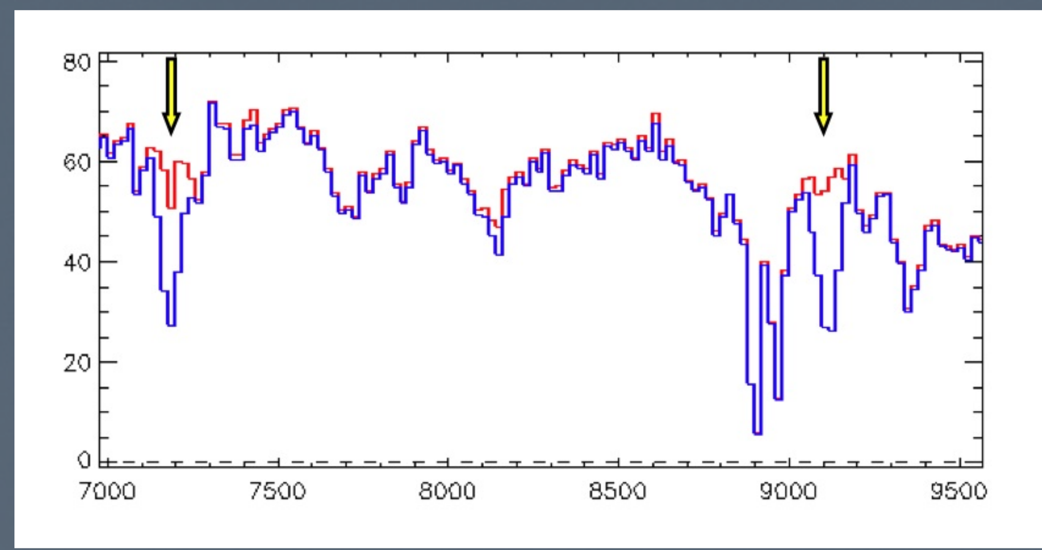

Figure 4 shows the effect of gain sag on the COS FUV detectors using data obtained in September 2010 (before raising of the high voltage on segment B in March, 2011). The blue curve was constructed using only photon events with pulse heights in the range 4-30 (the limits used by CalCOS in late 2010). The red curve includes all photon events. Arrows mark two regions that suffer gain sag: the region near pixel 7200 is illuminated by Lyman alpha when grating setting G130M/1309/FP=3 is used, and that near pixel 9100 is illuminated by Lyman alpha when the setting is G130M/1291/FP=3.

Target Acquisitions

One consequence of gain sag is the mis-registration of photon events in the cross-dispersion (XD) or Y direction, commonly referred to as Y walk. While Y walk does not adversely affect science data, it can reduce the accuracy of target acquisitions obtained in dispersed light. If the target is centered in the aperture, but the Y walk shifts its spectrum in the XD direction, then the ACQ/PEAKXD algorithm will miscalculate its centroid and move the target away from the aperture center. Without a correction we estimate that FUV dispersed light target acquisitions would lead to target mis-centerings of the order of ~0.4"-0.5".

The simplest way to correct this effect is to implement the following in the PEAKXD algorithm:

- Ignore the data from Segment B when computing the spectral centroid. (Gain sag on segment B is worse, due to numerous Lyman alpha airglow lines from G130M observations.)
- Add 2 pixels to the computed centroid to account for Y walk on segment A.

These changes were implemented on April 18 and May 02, 2011, respectively. Cycle 18 programs have been checked and modified as necessary to function with this change, and for Cycle 19, version 19.2 of the COS ETC will compute the S/N for segments A and B separately for dispersed-light target acquisitions.

Future

On March 06, 2011 the FUV high voltage (HV) level was successfully increased, in Segment B only, in order to suppress the effects of gain sag on this Segment. This increase alleviated the extent of gain sag effects both in the depressions from bright airglow lines and the continuum itself. Analysis of data taken at the new HV value shows that no recalibration is needed. This indicates that in the future small increases of the HV will enable us to mitigate gain sag effects on data recorded at any location on the detector used at that time

The long-term solution to gain sag is to move the spectrum to a new position in the cross-dispersion direction (referred to as a new lifetime position). Work is currently underway to prepare for this move by early 2012. The work needed to accomplish this move is extensive and involves a recalibration of the instrument at the new position.

By implementing both new lifetime positions and periodic HV increases, we expect to extend COS's operational lifetime significantly.

Upcoming CalCOS Developments

An upcoming release of CalCOS will add a TIMELINE extension to corrtag files. This will give information such as the altitude of the sun and the longitude and latitude of HST at one-second intervals throughout the exposure. Work is in progress on a timefilter module that will allow users to flag intervals of time in the corrtag table as bad, based on the information in the TIMELINE extension. This will give users the ability to filter their data based on various parameters, such as if the sun is below the horizon, which can be used to decrease the contamination of FUV data by geocoronal lines when only data obtained during orbital night is considered.

A correction for the Y walk caused by gain sag has been added to a version of CalCOS to be released in the near future. Work is in progress to test this correction as well as to determine the best parameters for the associated calibration reference table. This correction will be important to properly implement FUV flat-field corrections into CalCOS.

Dark Current

COS NUV Dark Rate Update

The dark rate of the COS NUV detector has continued to increase with time following an approximately linear trend. At the present time, the mean dark rate is about 4.5 x 10^{-4} cts/sec/pix. However, if the established trend, shown in Figure 5, continues, by the middle of Cycle 19 the mean dark rate will have reached a level of about 7.3 x 10^{-4} cts/sec/pix. This latter value has been adopted for use in the Cycle 19 ETC.

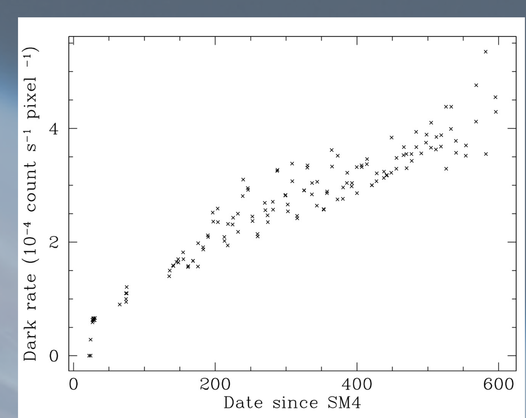

Figure 5 shows the trend of the dark rate increase.