COS Sensitivity Trends in Cycle 17

Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

S. V. Penton, S. Osterman
CASA, University of Colorado, Boulder, CO 80309

D. Sahnow
The Johns Hopkins University, Baltimore, MD 21218

Abstract. After the initial on-orbit determination of the absolute flux calibration of the Cosmic Origins Spectrograph was performed, we have been monitoring the instrument’s spectroscopic sensitivity regularly. The bare Aluminum gratings G225M and G285M exhibited sensitivity degradation on the ground relative to the Al+MgF_2-coated gratings, measured during semi-annual grating efficiency tests. The rates of degradation were about 1.8% per year for the G225M and 5.4% per year for the G285M grating relative to the G230L grating. Observations of spectroscopic white dwarf standard stars have shown a decline in sensitivity in the G225M and G285M gratings on the NUV channel, while the gratings with Al+MgF2 coatings (G230L and G185M) appear stable. The trends seen in external targets confirm those seen using internal exposures, and appear to be wavelength-independent but grating dependent. All gratings on the FUV channel are experiencing wavelength-dependent sensitivity degradation, which is worse at longer wavelengths. At the shortest FUV wavelengths the sensitivity decline is around 5% per year, increasing to about 12%/year at 1800 Å.

The sensitivity changes on the NUV and FUV channels appear to be uncoupled. The sensitivity decline of the NUV bare Al gratings appears to be caused by continued growth of an oxide layer, either from additional deposition of atomic oxygen in space or migration of existing atomic oxygen in the system to the outside. Detector QE loss due to localized exposure of the FUV cross-delay line detector to UV irradiation can be ruled out by several tests which examine the sensitivity decline versus total counts in specific regions of the detector. The wavelength dependence of the FUV sensitivity degradation is the opposite sense for contamination to be an issue. The source of the FUV sensitivity decline does not appear to be due to shifts in the pulse-height distribution from gain sag. The loss of quantum efficiency shows the classic signature of photocathode degradation.

1. Introduction

Aloisi et al. (2010) provide a summary of the on-orbit performance of the Cosmic Origins Spectrograph (COS). This paper is a summary of results from the COS spectroscopic sensitivity monitoring calibration programs for the first 9 months of Cycle 17, from September 2009 through early May 2010. This topic is discussed in more detail in Osten et al.
2010. Early results indicate changes in sensitivity for some modes, only some of which were anticipated before installation on HST.

2. Internal Monitoring of Spectroscopic Sensitivity

The internal monitoring of the near-UV spectroscopic sensitivity is performed via grating efficiency tests. These use controlled wavelength calibration lamp exposures and compute ratios of emission lines in common to a pair of gratings. They were designed in 2003 after thermal vacuum testing suggested that the bare Aluminum gratings G225M and G285M on the NUV channel were declining in efficiency. These tests were done on the ground starting in 2003 and performed semi-annually until just before launch in 2009. They were repeated in orbit twice during the time period under consideration here. The grating efficiency test is a relative measure of spectroscopic sensitivity since it uses ratios of lines from different gratings. A summary of GET results from ground data is shown in Figure 1. Each data point plotted is the slope of the fit to the efficiency ratio versus time for an emission line at a particular wavelength. Only ratios relative to the G230L grating are plotted. Both the G185M and G230L gratings are Al coated with MgF$_2$. The G185M/G230L grating ratio appears stable in time, having a slope near 0. The bare Al gratings show a decline relative to G230L, and this decline is a different value for the two bare Al gratings: for G225M relative to G230L it is $-1.8 \pm 0.9\%/\text{yr}$, and for G285M relative to G230L it is $-5.4 \pm 0.5\%/\text{yr}$. The results for the G225M and G285M gratings reveal that the trend is independent of wavelength.

Bare Al can react with oxygen and develop a thin oxide coating. The NUV detector was in a nitrogen purge environment, enabling the possible continued growth of an oxide layer. It was initially thought that this growth would cease once in orbit. The two on-orbit GET measurements appear to be consistent with a continuation of the trends observed on the ground.

3. External Monitoring of Spectroscopic Sensitivity

The external monitoring of spectroscopic sensitivity uses spectrophotometric white dwarf standard stars. Table 1 lists the white dwarf standards and which gratings they are used to monitor. After sensitivity declines in the FUV gratings were detected in early 2010 the monitoring frequency of the medium-resolution FUV gratings was increased to monthly from quarterly. The time-dependent sensitivity (TDS) trends are computed independently for each grating, central wavelength, and detector segment or stripe. Spectral ratios are taken relative to the first spectrum for a given grating/central wavelength/segment or stripe, and then averaged over suitable wavelength ranges to avoid the edges of the spectra or other features like Lyman $\alpha$. These are plotted as a function of time, and linear fits are computed. These slopes constitute the time-dependent sensitivity. A summary is shown in the top panel of Figure 2 for all COS FUV and NUV gratings. Each data point refers to a stripe or segment of a particular configuration. The bottom panel of Figure 2 displays a close-up view of the FUV gratings. For the FUV channel segments A (B) are indicated with open (closed) symbols, respectively. The target acquisition for the G140L+G130M monitoring visits and G160M monitoring visits was changed in February and March 2010, respectively, to use an NUV imaging target acquisition scenario. Prior to those dates dispersed light target acquisitions had been used. The change results in a small displacement of the spectra within the aperture but the effect on throughput is negligible.

The NUV sensitivity decline seen on the ground in the bare Al gratings continues in orbit. The weighted mean change of the G230L sensitivity from external target is $-1.1 \pm 0.4\%/\text{yr}$, and the G185M weighted mean change is $-0.8 \pm 0.4\%/\text{yr}$. The G225M grating shows a sensitivity decline of $-3.3 \pm 0.3\%/\text{yr}$, and the G285M grating shows a decline of
Figure 1: Summary of results from ground-based grating efficiency test. The bare-Aluminum gratings exhibit an efficiency decline relative to the G230L grating which is independent of wavelength, while the G185M grating shows no efficiency decline relative to the G230L grating.
$-10.8 \pm 0.2\%$/year. An unanticipated result was the appearance of sensitivity decline in the FUV channel. The G130M grating has a weighted mean sensitivity change of $-5.6 \pm 0.2\%$/year, and the G160M grating it is $-11.8 \pm 0.3\%$/year. For G140L the decline ranges from a weighted mean of $-7.2 \pm 1.5\%$/year from $1300 < \lambda(\text{Å}) < 1400$ to $-10.9 \pm 3.5\%$/year from $1700 < \lambda(\text{Å}) < 1800$. There is a difference of about 3% between FUV gratings at the same wavelength and segment, as well as different gratings and segment at the same wavelength.

<table>
<thead>
<tr>
<th>Detector</th>
<th>Grating</th>
<th>WD Monitor</th>
<th>Monitoring Frequency in Cycle 17</th>
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</thead>
<tbody>
<tr>
<td>COS/FUV</td>
<td>G140L</td>
<td>WD0947+857</td>
<td>monthly</td>
</tr>
<tr>
<td></td>
<td>G130M</td>
<td>WD0947+857</td>
<td>quarterly initially, monthly since March 2010</td>
</tr>
<tr>
<td></td>
<td>G160M</td>
<td>WD1057+719</td>
<td>quarterly initially, monthly since March 2010</td>
</tr>
<tr>
<td>COS/NUV</td>
<td>G230L</td>
<td>WD1057+719</td>
<td>monthly</td>
</tr>
<tr>
<td></td>
<td>G185M</td>
<td>G191B2B</td>
<td>quarterly</td>
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<tr>
<td></td>
<td>G225M</td>
<td>G191B2B</td>
<td>monthly</td>
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<tr>
<td></td>
<td>G285M</td>
<td>G191B2B</td>
<td>monthly</td>
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4. Tests of Global vs. Local Sensitivity Declines

The rapid rate of FUV sensitivity decline was unexpected. This rate is larger than what other space FUV detectors have experienced (Davidsen et al. 1992, Bohlin 1999, Dixon et al. 2007). The wavelength dependence of the FUV sensitivity decline suggests that it is an issue with the photocathode. Contamination would be expected to have the opposite trend with wavelength, i.e. worse at shorter wavelengths. It is known that cross-delay line detectors such as the one used on COS can experience detector quantum efficiency loss due to localized exposure to UV irradiation (Tremin & Siegmund 2001). In order to test whether the sensitivity decline was a global or local phenomenon, a test (CAL/COS program 12096) was performed which obtained spectra of the sensitivity monitor at positions offset from the default spectral location. Figure 3 shows the TDS trends for the monitoring data obtained through early May, along with spectra obtained at 1.2 and 3.0" from the nominal location. The offset spectra show count rates within 1% of the nominal position, indicating that the sensitivity decline is a global phenomenon.

The regions of the detector where the largest number of photons have accumulated are the regions where geocoronal Lyman $\alpha$ emission fall. There was no evidence of localized sensitivity declines in these regions. However, in the course of examining these regions Sahnow et al. (2010) discovered that the peak of the pulse height distribution is steadily shifting to smaller values in these regions. The gain sag is not related to the time-dependent decline in spectroscopic sensitivity; although the size of the charge cloud of photoelectrons is reduced, this does not affect the probability of detecting the photon.

5. Conclusions

The NUV bare Al sensitivity decline was not unexpected; the general trends in ground-based GETs are being mirrored in on-orbit performance. The cause of the FUV sensitivity loss is still under investigation. Laboratory tests are being conducted to examine the effect of atomic oxygen on the CsI photocathode as one possible cause.

On-orbit measurements of the time-dependent sensitivity have been implemented in TDS reference files, which were delivered on July 14, 2010 for both the NUV and FUV gratings. These files correct for the NUV grating using a wavelength-independent value.
Figure 2: (top) Summary of time-dependent sensitivity trends in COS data obtained through early May 2010. The Y axis gives the values of the linear fit to temporal relative count rate data for each configuration noted. Low resolution grating data are shown in black, medium-resolution NUV data in red, medium-resolution FUV data in blue. For the FUV data, segment A (B) is shown with open (filled) symbols. (bottom) Close-in view of COS FUV TDS results. Symbols are as in the top panel.
Figure 3: Test of global vs. local sensitivity decline. The black stars are sensitivity monitoring data in the G140L/1230 configuration of the white dwarf standard WD0947+857. The red and blue stars correspond to spectra obtained at 1.2 and 3.0” from the nominal location, and do not exhibit any different change in sensitivity.
The correction for FUV data is segment- and grating-dependent, as well as wavelength dependent. The reference file should correct fluxes for time-dependent effects to ±2%. Version 18.2 of the ETC has been updated with sensitivities projected midway through Cycle 18. Further updates to the reference files will be made based on inspection of later data.

6. Recent Developments

Since the HST calibration workshop, there has been a change in the FUV TDS trends. While the sensitivity continues to decline, the wavelength dependence has disappeared and the segment- and grating-dependent differences have disappeared. Data taken since 2010.2 are now consistent with a decline of 4–6 %/year across all wavelengths. These new trends will be incorporated into an updated reference file; check the COS website (http://www.stsci.edu/hst/cos) and STScI Analysis Newsletter for updates.

References

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