SPACE
TELESCOPE
SCIENCE
INSTITUTE
Operated for NASA by AURA

Instrument Science Report COS 2010-12

COS NUV Detector Dark Rates During SMOV and Cycle 17

David Sahnow[1], Thomas Ake[2], Steven Penton[3], Wei Zheng[1], and Charles D. (Tony) Keyes[2]

[1] Department of Physics & Astronomy, Johns Hopkins University, Baltimore, MD
[2] Space Telescope Science Institute, Baltimore, MD
[3] CASA, University of Colorado, Boulder, CO

12 July, 2011

ABSTRACT

As part of Servicing Mission Orbital Verification (SMOV) after the fifth Hubble Servicing Mission (SM4), the dark rate of the NUV detector of the Cosmic Origins Spectrograph (COS) was measured. The on-orbit background is spatially uniform, and was found to increase in the vicinity of the South Atlantic Anomaly (SAA). Through Cycle 17, the rate has been increasing with time, and away from the SAA is ~450 counts/second over the full detector as of early 2011; this is slightly above the prelaunch predictions but a factor of three below that seen by STIS after SM2.

Contents

1. Introduction

The COS NUV detector is a Multi-Anode Microchannel Array (MAMA) detector, which was originally built as the spare for STIS NUV channel. The MAMA is a sealed detector with a semi-transparent cesium telluride photocathode deposited on the inside of the window. Photons striking the photocathode generate photoelectrons which are proximity-focused onto the front surface of the microchannel plate (MCP). The charge cloud exiting the back end of the MCP is centroided by the anode array into 1024×1024 25 μm square pixels.

Background counts in the detector can come from a number of sources, including the radioactive decay of atoms in the MCP glass, charged particles from the environment, scattered light from the optical system, and phosphorescence from the window.

2. Observations

2.1 Observing Plan

As part of COS Servicing Mission Orbital Verification (SMOV), measurements of the dark rate of the Near Ultraviolet (NUV) detector were made by collecting science data with the COS instrument shutter closed. The primary SMOV program for this activity was COS-05 (program 11466), which consisted of twenty 3250 second exposures. Since data collection for this program began soon after the NUV detector was turned on, there were two primary goals of the program: (1) to map the dark count rate as a function of time and of position in the orbit; and (2) to verify the nominal operation of the NUV detector and confirm that TIME-TAG data could be properly collected, saved, and processed. Thus, specific observation times were chosen in order to collect dark counts in a variety of orbit types, including those where: (1) HST grazed the edge of the SAA contour, and (2) HST passed through the SAA region. These cases were included in order to determine the suitability of the SAA model, which matches that used for STIS.

As the SMOV dark program neared completion, the Cycle 17 dark exposures (program 11894) began. For this program, two 1330 second dark exposures are taken each week, with no constraint on the orbital location of HST. As a result, the observations are more randomly scattered around the earth. Since the long-term changes in dark rates are of interest, results from this program through Cycle 17 are also included in this ISR. This program is designed to track long-term changes of the background rate as a function of time.

A list of dark exposures that are affected by the SAA is given in the appendix.

2.2 Orbital Track of Observations

The orbital tracks of HST for SMOV dark program 11466 (Figure 1) were chosen by COS Instrument Scientists in consultation with the Mission Planners. As a result, the data taken was concentrated along the boundaries of the SAA in order to sample its edges. The orbits tracks from the Cycle 17 dark program (11894 - Figure 2), on the other hand, are more randomly arrayed on the sky, since their locations were chosen without regard to the SAA location.

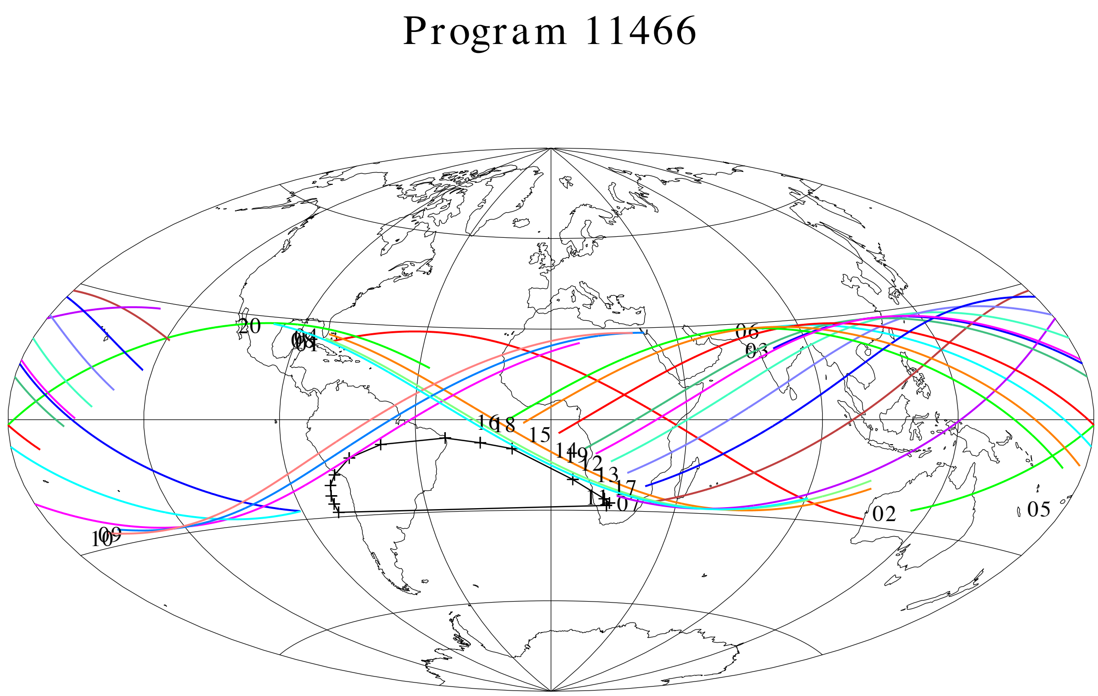

Figure 1 HST ground track for exposures from program 11466. The colors are arbitrary; the labels note the visit number. Orbits are preferentially located near the SAA (marked with + symbols).

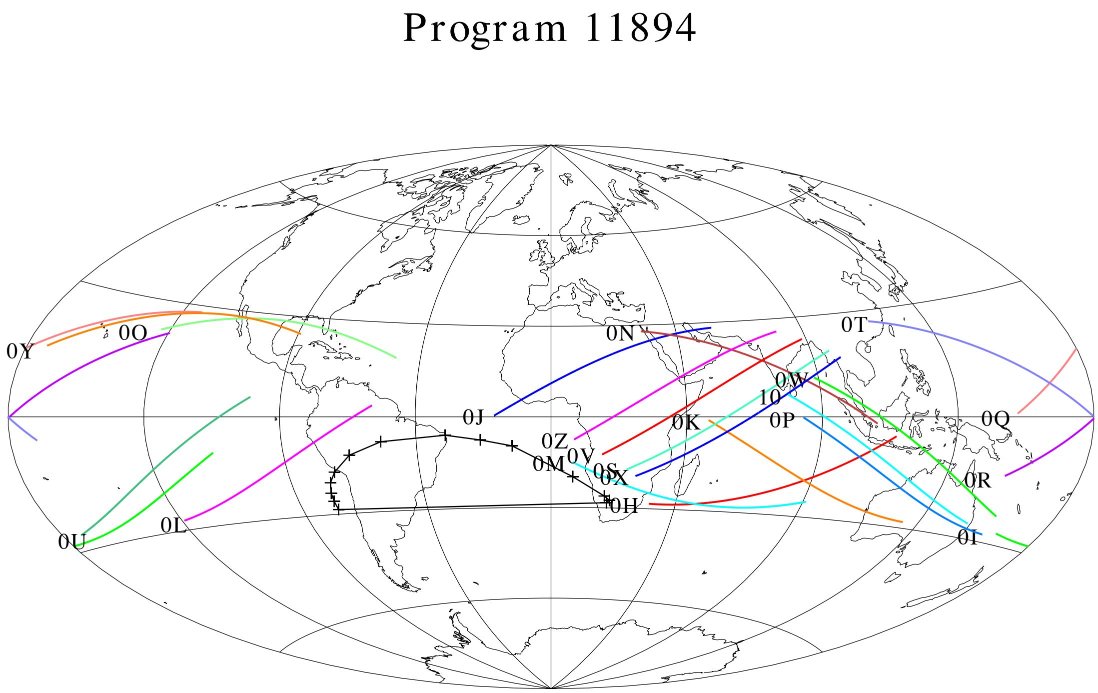

Figure 2 HST ground track for exposures from program 11894 through 30 November 2009. These orbits are more randomly distributed than those in the previous figure. The colors are arbitrary; the labels identify the visit number.

3. Orbital Variation of background

3.1 Science Data

All COS dark exposures are taken in TIME-TAG mode, and thus the count rate as a function of time and orbital position can be investigated using the science data. Plots of rate as a function of time (Figure 3) have been made for all background exposures. As expected, exposures which are taken while HST is near the SAA can have a significantly elevated background rate – up to a factor of ~15 above the nominal value. The figure shows examples of count rate as a function of time for two exposures in program 11466. The top panel (visit 05) shows data taken in an orbit, which grazes the western edge of the SAA (Figure 1), while the bottom panel (visit 06) starts just after HST leaves the SAA.

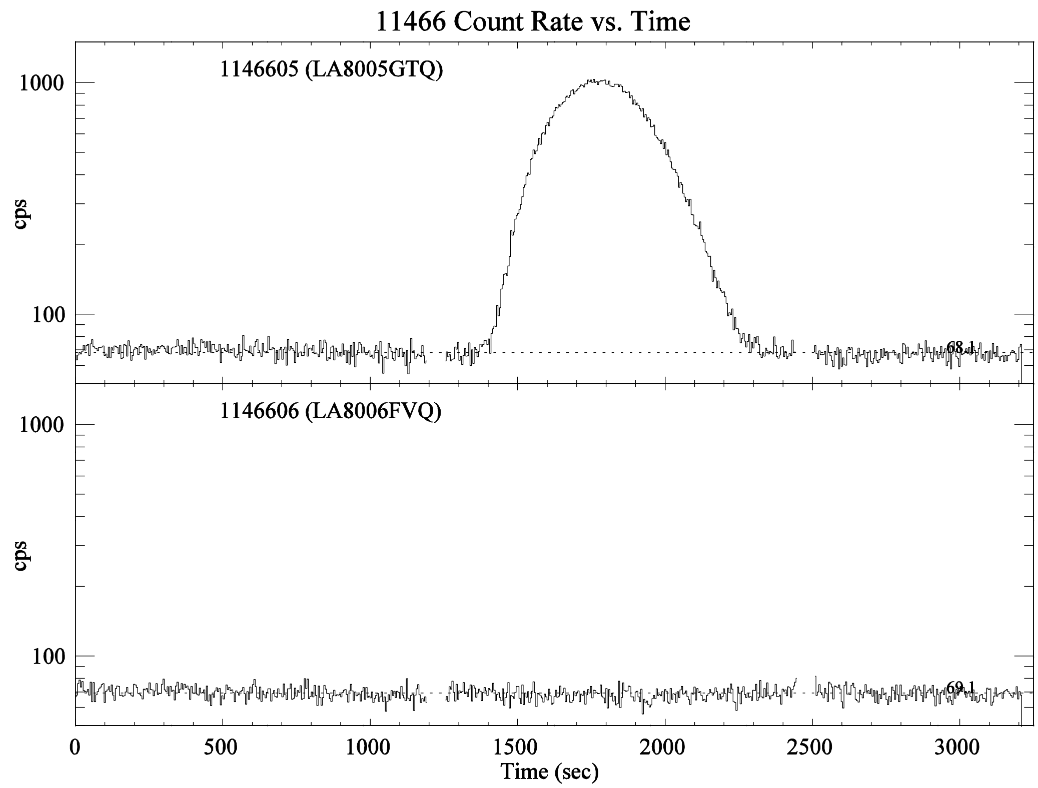

Figure 3 Count rate as a function of time for two exposures in program 11466. The top panel shows an exposure during which HST's orbit passes close to the COS SAA contour, and the total count rate on the detector reaches more than 1000 per second. The bottom panel shows the dark rate for an exposure which begins after HST leaves the SAA region.

3.2 Detector Counters

Whenever the NUV detector electronics is on, the MAMA event counter (LMEVENTS) detector electronics records the number of counts recorded by the detector in 1/10 of a second. This count rate information is collected and sent to the ground every 10 seconds as part of the instrument engineering data stream. Although count rates can only be calculated from the science data when an exposure is being taken, the engineering count rates are always available, except in the rare cases when the detector is turned off completely.

While the exact correspondence between the count rate at HVNOM and HVSAA is not well known, a preliminary attempt has been made to scale the HVSAA data in order to predict the dark rate at full voltage, using data from early in SMOV (Figure 4). Although the predicted rates may have relatively large uncertainties, the shape of the contours is plausible, and shows that the original SAA model did not match what is seen in the data. In particular, the SAA contour had to be extended more to the west, and shortened in the east in order to better match the observed count rate variations. Data collected with the original contours can be filtered to remove the bad times in calcos, as long as it was taken in TIME-TAG mode. ACCUM observations, where this filtering can not be done, are used only on the brightest objects observed by COS, and should therefore be relatively insensitive to an increased background. In any case, calcos should properly scale the measured background in those cases.

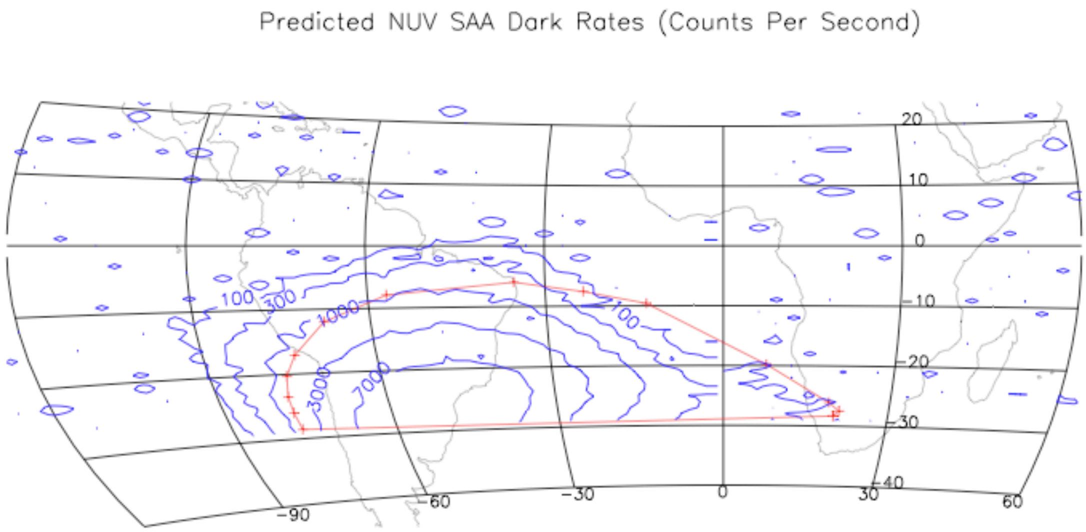

Figure 4 Predicted dark count rates near the SAA, based on measurements of the LMEVENTS counter taken at HVSAA high voltage level. The original SAA model, marked in red, does not properly match the shape and position of the contours.

From the figure, it is apparent that the SAA model, marked in red, is not properly aligned with the measured detector count rate. This is consistent with the background rates seen in the science data, where enhanced count rates are seen on the western edge of the SAA, but not on the eastern side. It also matches what was seen in the FUV detector (Sahnow et al., 2011). The SAA model was updated in May 2010, based on these data and the fact that the SAA is known to vary with time (Furst et al., 2009).

4. Spatial Variation of Background

A sum of 42 NUV dark exposures taken through 21 December 2009 (Figure 5) shows a relatively featureless background. This image includes 12,260,600 counts collected in 88,507 seconds; periods with high count rates due to close passes to the SAA have been excluded. Although the upper left and lower right regions show very slight enhancements over the image as a whole, no strong variations are seen anywhere.

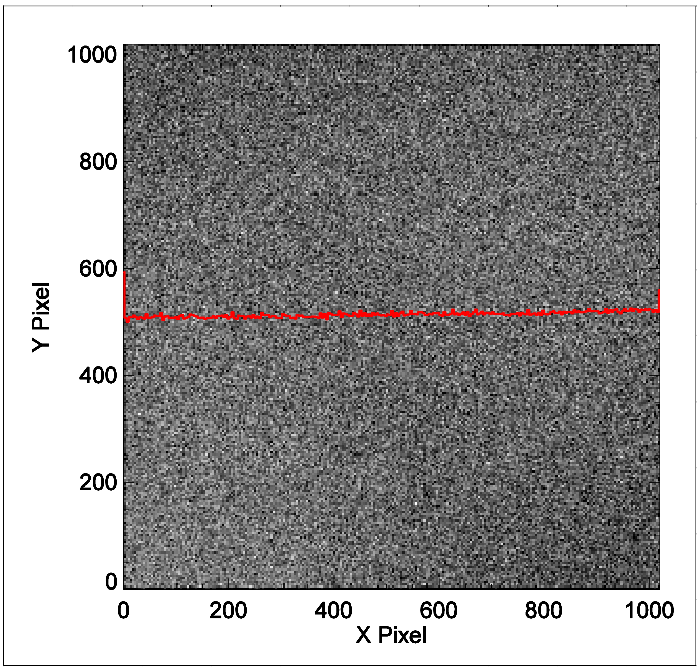

Figure 5 Sum of 49 dark exposures collected from 2 June to 21 December 2009, with SAA-grazing times excluded. The red line shows a projection of the counts along one axis, and appears nearly flat. There is a very slight enhancement on the lower right and upper left, but overall the image is fairly featureless.

5. Long Term Count Rate vs. Time

For reasons that are not yet understood, the NUV background has increased with a linear trend since the detector was first turned on (Figure 6). This increase does not appear to be correlated with temperature, and does not seem to be a short timescale phosphorescence effect due to passing through the SAA, since enhancements are not seen after SAA passes. The level as of February 2011, was ~450 counts/second over the detector, or ~4.3×10^{-4} counts/sec/pixel. If the current trend continues, the dark current will reach ~7.3x10^{-4} counts/sec/pixel by the midpoint of Cycle 19. The latter value has been adopted for use in the Cycle 19 ETC.

Prelaunch tests on the glass used in the COS faceplate suggested that the on-orbit dark rate would be about 25% of the STIS values seen after SM2, or 225 - 250 counts/sec. The background will continue to be monitored bi-weekly through Cycles 18 and 19 in order to track any further changes with time.

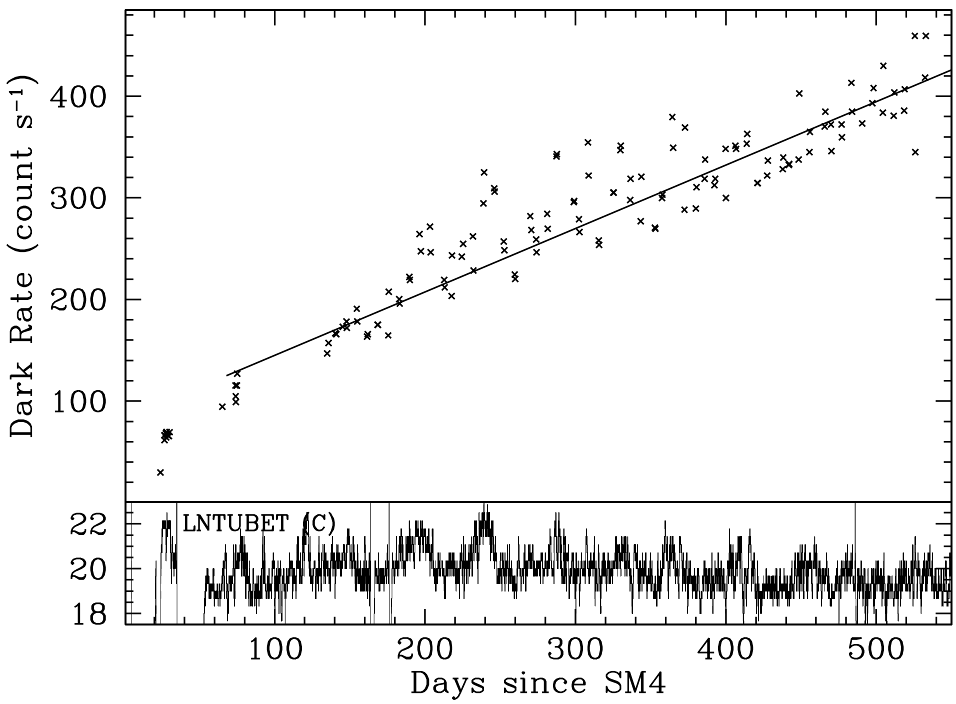

Figure 6 Measured dark rate as a function of time, through October 2010, excluding SAA-impacted times. An overall increasing trend is demonstrated with the fitted line, at the rate of ~200 count/sec per year. The cause of this increase is not understood. In the lower panel, detector temperature LNTUBET is plotted to demonstrate the temperature dependence of the dark rate.

6. References

Furst, F., et. al., 2009, Earth and Planetary Science Letters, 281, p 125.

Sahnow, D. et al., 2011, *COS FUV Detector Dark Rates During SMOV and Cycle 17*, COS ISR-2010-11.

Zheng, W. et al., 2010, in *HST Calibration Workshop*, ed. S. Deustua & C. Oliveira, in press

Appendix

Table 1: List of NUV Dark Exposures Affected by SAA

IPPPSSOOT	DATE-OBS	Affected time (sec)
LA7U03A1Q	2-Jun-2009	504
LA7U04VQQ	4-Jun-2009	1409
LA8005GTQ	8-Jun-2009	990
LA8009AHQ	9-Jun-2009	870
LA8010CCQ	10-Jun-2009	720
LB8R1TA1Q	15-Mar-2010	420