

# COS SMOV Calibration: Detector Background Performance

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The Cosmic Origins Spectrograph (COS), installed in May 2009 into the Hubble Space Telescope (HST), was designed with two low noise, photon-counting detectors. The FUV channel utilizes a windowless, cross delay line (XDL) microchannel plate detector, with heritage from the Far Ultraviolet Spectroscopic Explorer (FUSE) mission. The NUV side employs a closed tube MAMA detector, which had been the Space Telescope Imaging Spectrograph (STIS) flight spare. The background performance of both channels was measured during the COS Servicing Mission Observatory Verification (SMOV) program and in early Cycle 17 observations. For the FUV detector, the background rate is as expected from prelaunch estimates,  $<2 \times 10^{-6}$  counts/sec/pixel when pulse height thresholding is applied, except at times when HST is close to the South Atlantic Anomaly (SAA). Close to the SAA boundary, the rate can be as high as  $6 \times 10^{-5}$  counts/sec/pixel. Several weak structures are found in the dark exposures. Some of these are likely due to energetic particles trapped in the geomagnetic field and can be recognized by their large pulse heights, while others are low gain events. For TIME-TAG exposures, most features are removed in ground processing by pulse height filtering of the individual events. For ACCUM mode, which is only used for bright objects, suspect regions of the spectra will be marked by data quality flags, but the features are expected to be too weak to be of consequence. For the NUV detector, the background rate has increased to  $\sim 2.4 \times 10^{-4}$  counts/sec/pixel, comparable to prelaunch estimates and about five times lower than the pre-Servicing Mission 4 performance of the STIS NUV detector. A difference in windows between the MAMAs accounts for much of the improvement over STIS. In particular, although the COS background is elevated near the SAA, up to  $1 \times 10^{-3}$  counts/sec/pixel, no long-term phosphorescence occurs in the window after HST passes through the SAA. Little structure is seen in the NUV darks.

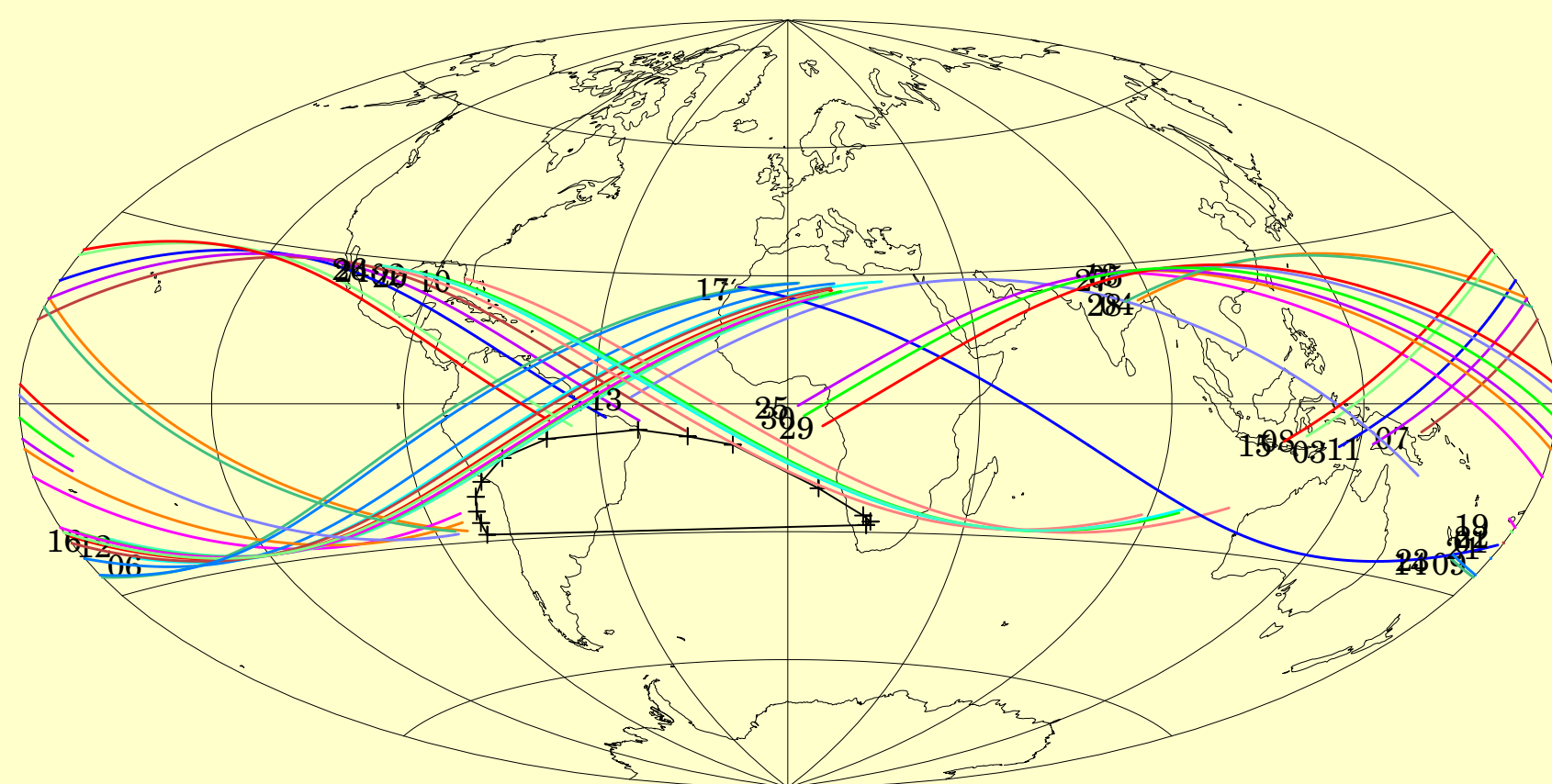
## OVERVIEW

The Cosmic Origins Spectrograph (COS) was installed into the Hubble Space Telescope (HST) in May 2009. COS collects spectra in two channels, each with its own optics and detector: FUV, with a cross delay line (XDL) microchannel plate detector similar to that used for the Far Ultraviolet Spectroscopic Explorer (FUSE); and NUV, with a Multi-Anode Microchannel Plate Array (MAMA) detector, which was originally built as a backup for STIS. An overview of the COS instrument is given in Poster 464.22.

COS was designed to observe faint, point source objects at medium  $\sim 15,000$  resolution. This desire to observe faint objects means that knowledge of the detector background is important in order to improve S/N of observations of faint objects.

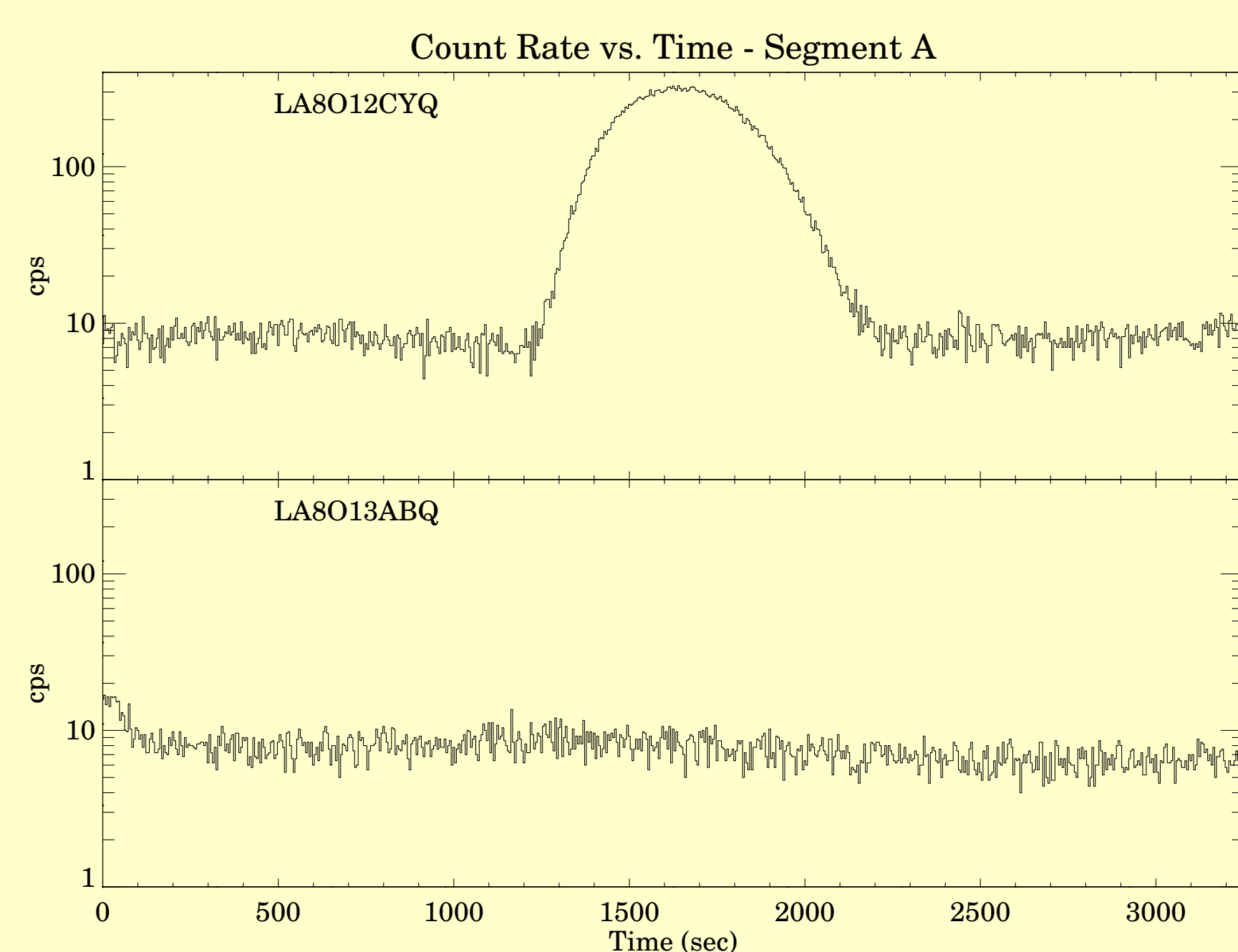
During COS Servicing Mission Observatory Verification (SMOV), the dark rate on both detectors was measured during targeted background programs (FUV: program 11482; NUV: 11466), which consisted of a series of 3250 second exposures with the instrument shutter closed. These exposures were scheduled to sample a variety of orbits, including orbits which (1) passed along the edge of the South Atlantic Anomaly (SAA); (2) began as soon as HST left the SAA; (3) ended as HST approached the SAA; and (4) avoided the SAA altogether.

During Cycle 17, similar calibration programs run weekly in order to monitor changes in the background with time. These consist of either five (FUV – program 11895) or two (NUV – 11894) 1330 second exposures per week, with the orbits not specifically selected. The figures below show an example of the ground tracks of the SMOV orbits for the FUV dark program, along with an example of the count rate increase seen when passing near to the SAA.



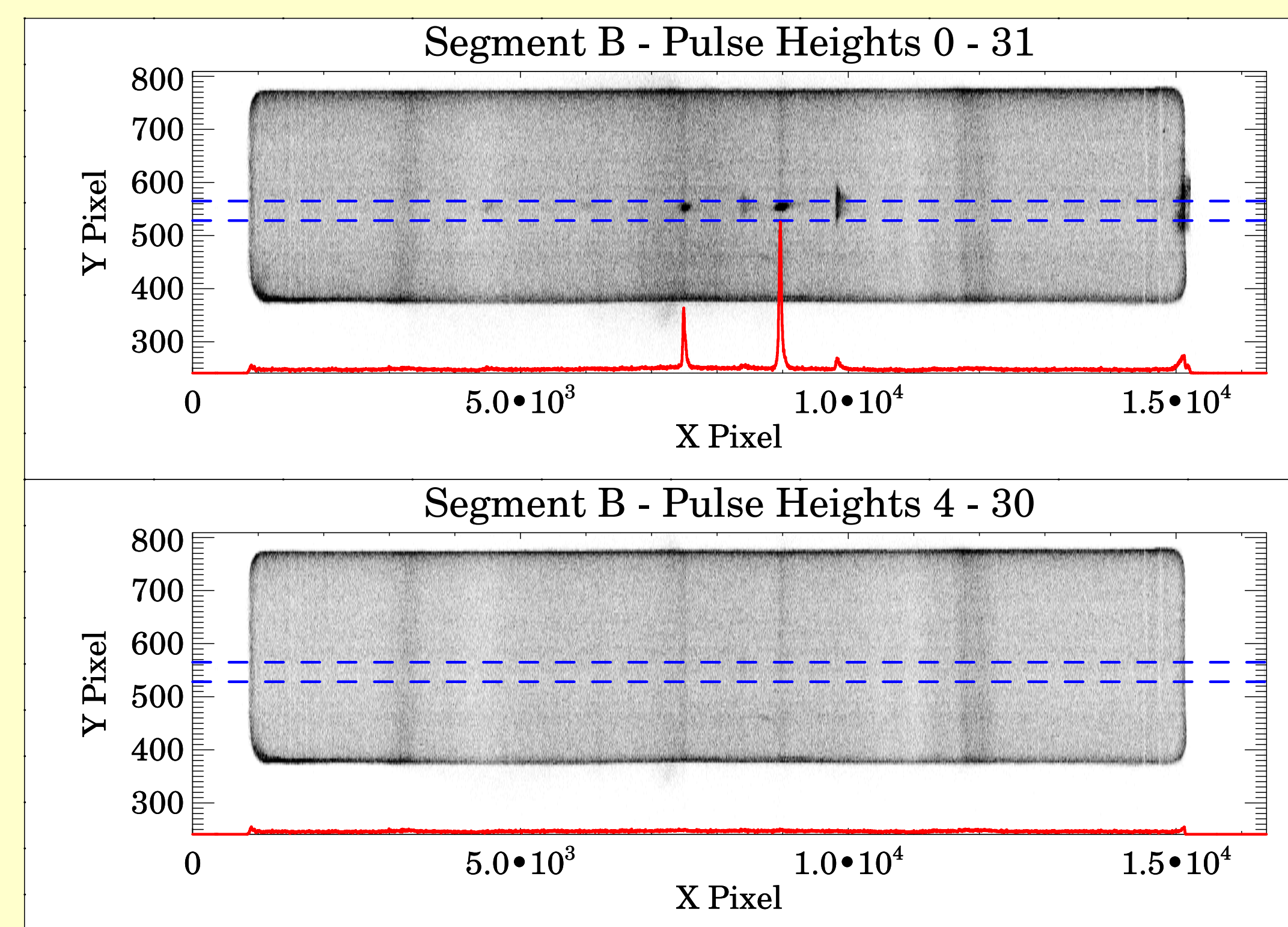
**Figure 1** (above): HST ground track for exposures from program 11482. The colors are arbitrary; the labels note the visit number. Orbits are preferentially located near the SAA (marked with + symbols).

**Figure 2** (below): Count rate as a function of time for two exposures in FUV dark program 11482. The top panel shows an exposure during which HST's orbit passes close to the SAA, and the total count rate on the detector reaches several hundred per second. The bottom panel shows an exposure taken while not near the SAA. The NUV detector shows similar response to the SAA.



## FUV DETECTOR BACKGROUND

Since FUV data taken in TIME-TAG mode contains pulse height information, pulse height thresholding can be used to lower the overall rate and decrease the spatial variation in the background. The figures below show the effect on the background of including only pulse heights in the range of 4 to 30, rather than the full 0 to 31. Pulse height thresholds cannot be applied to ACCUM data, but since only the brightest targets are taken in this mode, the effect of the additional background structure on the data will be small.



**Figure 3** FUV Detector background image on Segment B with all pulse heights included (top) and with only pulse heights 4 to 30 (bottom), for a sum of  $\sim 119,000$  seconds of background taken away from the SAA. Both a two-dimensional image and a projection (red) of the data in the region extracted for the G130M,  $\lambda_c=1309$  setting (marked by the blue lines) are shown. The prominent features are significantly reduced with the tighter pulse height thresholding. Segment A (not shown) is relatively featureless, even with all pulse heights included.

FUV detector backgrounds measured on the ground were very low, and on-orbit values are consistent with those measurements. Dark rates away from the SAA for the FUV channel have remained constant on both segments since launch, with a rate of  $\sim 1.5 - 2.0 \times 10^{-6}$  counts/sec/pixel (equivalent to  $< 1$  count/sec/cm<sup>2</sup>, or  $\sim 4.5 \times 10^{-4}$  counts/sec/resel using the default extraction height). Rates near the SAA can be up to 30 times higher, depending on the track of the orbit (see Figure 2). At some point in the future the SAA model will be adjusted in order to minimize these large excursions. Periods of high background can be excluded for TIME-TAG exposures during pipeline processing by setting user-defined "Good Time Intervals" in order to exclude specific times ranges.

## CALCOS BACKGROUND SUBTRACTION

The BACKCORR step of the **calcos** calibration pipeline determines the background contribution to the extracted spectrum and subtracts it. This is done by computing the number of counts in two background regions of the detector for each exposure, scaling the numbers by the sizes of the regions, and then subtracting off this constant value at each pixel. Thus, increases due to proximity to the SAA and other changes in the background rate with time are properly scaled. However, no information on the spatial structure of the background is presently used.

Since launch, no pulse height screening has been used during the default processing of FUV TIME-TAG data. New threshold values of 4 and 30, as shown above, should be implemented later this month. This change should significantly decrease the structure seen in the segment B background.

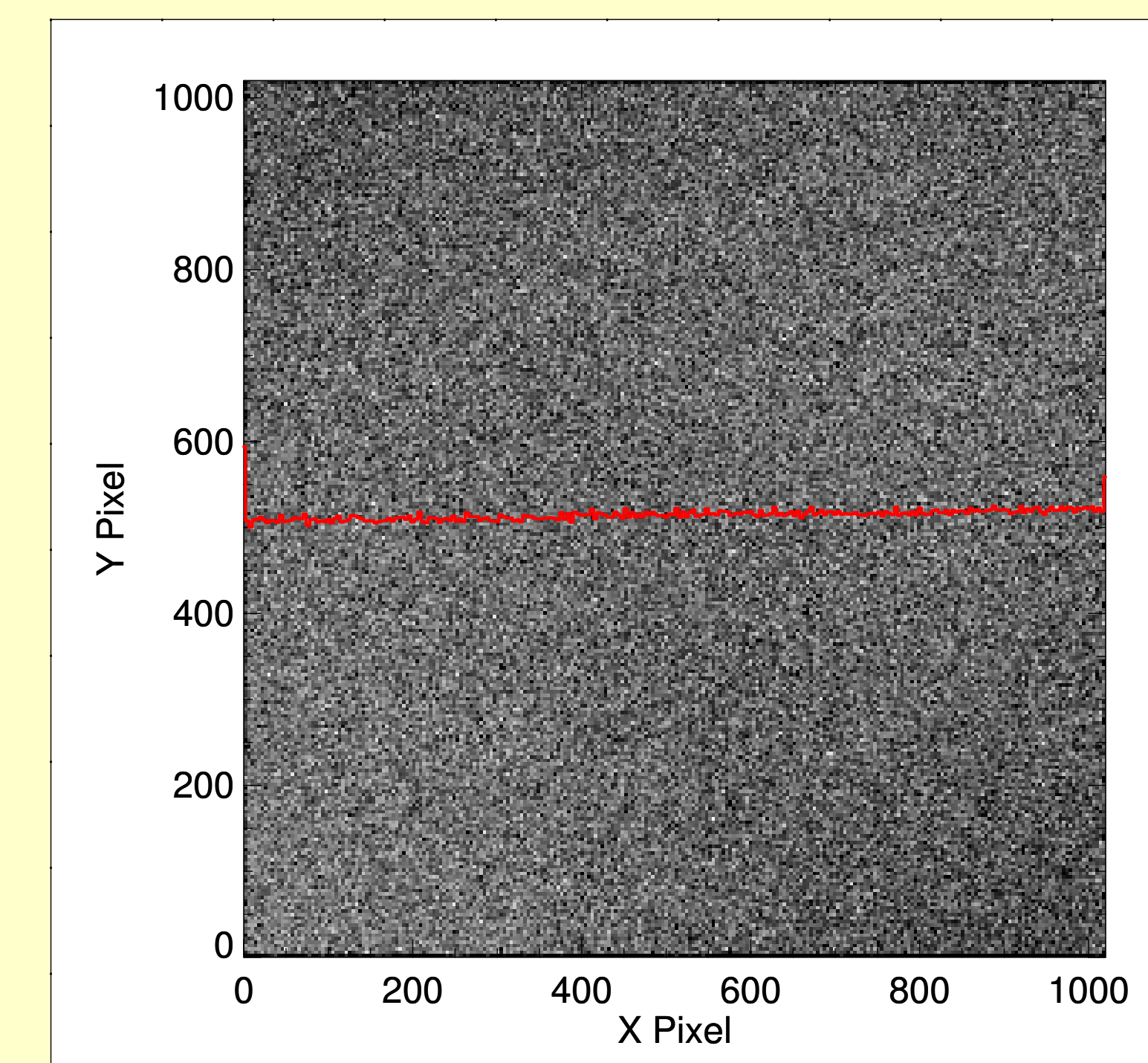
For FUV ACCUM exposures, no pulse height thresholding can be applied, but regions with known background artifacts can be marked using data quality flags.

## NUV DETECTOR BACKGROUND

Like the STIS MAMAs, the COS NUV detector background is dominated by glow from the detector window. The COS detector, however, has a much lower background than STIS. The NUV detector background is also relatively featureless (Figure 4).

For reasons that are not yet understood, the NUV background increased for the first six months after installation. This increase does not appear to be correlated with temperature, and does not seem to be a phosphorescence effect due to passing through the SAA. The most recent measurements appear to show that the rate away from the SAA has leveled off at  $\sim 250$  counts/second ( $2.4 \times 10^{-4}$  counts/sec/pixel; Figure 5), which is comparable to prelaunch predictions and a factor of  $\sim 5$  below that of the STIS NUV detector post-SM4 prediction. The background will be monitored weekly throughout Cycle 17 in order to track any further changes in the rate with time.

No pulse height information is available in the NUV data, so no pulse height thresholding can be done for this detector.



**Figure 4** (above) NUV Detector background for a sum of  $\sim 88,500$  seconds of background exposure. Both a two-dimensional image and a projection of the full detector (red) are shown. The background shows less structure than the FUV detector

**Figure 5** (below) NUV background count rate as a function of time since SM4, as measured in all the SMOV and Cycle 17 background exposures that executed through December 21. The reason for the approximately linear increase in rate for the first six months is not yet understood. The  $\sim 250$  count per second level is close to the value predicted before launch.

