

Dark count rates in the STIS MAMA

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June 19, 2013

ABSTRACT

The dark count rates in the STIS MAMA detectors have been monitored. This report covers the period since the Servicing Mission 4 of May 2009. We find both long-term and short-term variations which for the NUV side we express as a function of date and temperature. The NUV dark rate has declined significantly from its surprisingly high initial rate of 0.014 counts/pixel/s that was seen immediately after SM4. By October, 2012 it had dropped to an average value of about 0.002 counts/pixel/sec. The behavior and characteristics of the FUV dark rate remain very similar to that seen in 2004, prior to the STIS side-2 failure and subsequent repair.

Introduction

Proposals 12415 and 12776 which ran in cycles 18 and 19 were designed to monitor the dark rates in the NUV and FUV MAMA detectors. One motive is to look for evidence of change in the dark rate, indicative of detector problems developing, but more routinely, we wish to measure the dark rate to support calibrating science images. If the dark rate is significant compared with the signal and can be accurately predicted, a normalized dark image can then be subtracted from the raw image.

Normally, a pair of 1300 second exposures were taken for the NUV and FUV MAMAs at two-week intervals. Each pair of observations was timed to span a single SAA-free period, the aim being to separate long term temporal variability from short term temperature dependent changes. For both detectors, additional blocks of exposures were taken once a year. These were groups of three 1314 s TIME-TAG darks for each of the MAMA detectors, distributed over a single SAA free interval. This gives more information on the value of the FUV MAMA dark current as a function of the amount of time that the HV has been on, and for the NUV MAMA a better measure of the short term temperature dependence.

STIS was repaired during Servicing Mission 4 (SM4) which took place in May 2009. Before that STIS had not been operable for about six years. The current analysis has been performed on all measurements since then, starting from June 2009.

NUV MAMA

Each image is collected as a 2048 by 2048 array. The header reports a value GOODMEAN which is, in fact, the median value of counts in the pixels not flagged as bad. To match previous reporting (Zheng, 2011) the values have been normalized to a 1024 by 1024 array, simply multiplying the raw numbers by 4.

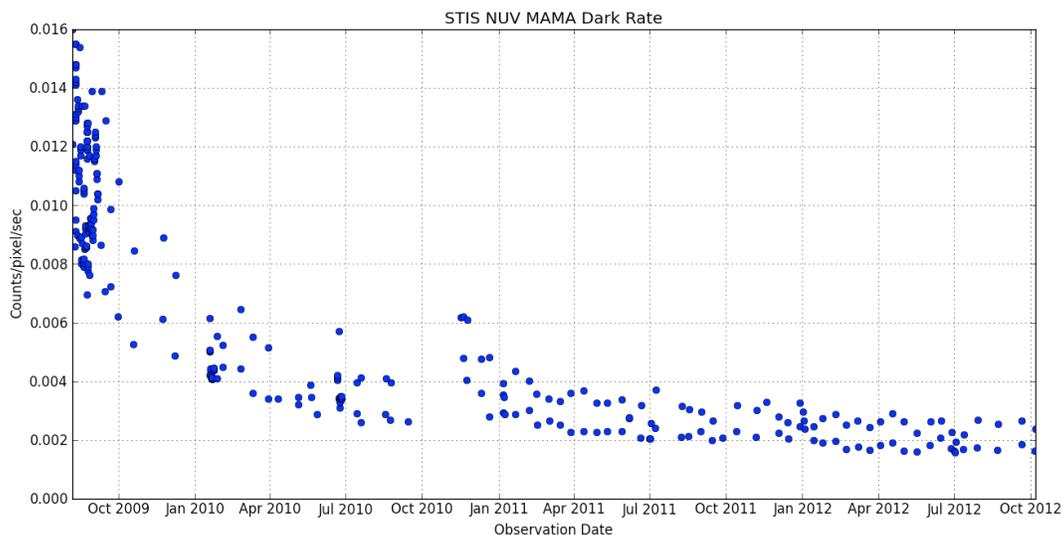


Figure 1: Dark count rate in the NUV MAMA measured from SM4 to present. Rates are counts per pixel per second on a 1024 by 1024 array.

Figure 1 shows the count rates as a function of time. Several features of the data should be noted. In the initial period between June and October 2009, measurements were taken at a higher frequency than in subsequent times. In this period the rate fluctuated more than at other times. Secondly the values at any time can usually be separated into a high and low value. The lower values correspond to the measurements taken at initial turn on while the high value is found at the end of the SAA-free period, usually about nine hours later. Thirdly there is a gap between October and November 2011 during which STIS was not turned on. This was because problems with HST's control and data handling electronics were under study. After this hiatus the dark rate resumed at a higher rate than when it was turned off and then decayed as before. In view of this,

the analysis has dealt with three separate time periods. Each period has been fitted using a single or double exponential function of date plus a quadratic function of the detector temperature which steadily increases from the voltage turn-on time on each observation date.

The exponential decay as a function of time was shown to be expected by Ferguson and Baum(1999) and arises from phosphorescence in the detector faceplate window. No attempt has been made to exactly match any physical model but the general form has been used.

A set of measurements taken on August 10th 2009 shown in Figure 2 provides a valuable indicator of the way the count rate varies following the high voltage turn-on. Plotting the count rate against the detector temperature suggests that the rate varies quadratically with temperature. The green line displays a quadratic function of temperature which clearly fits quite well, and so we have adopted this model to describe the short-term variation.

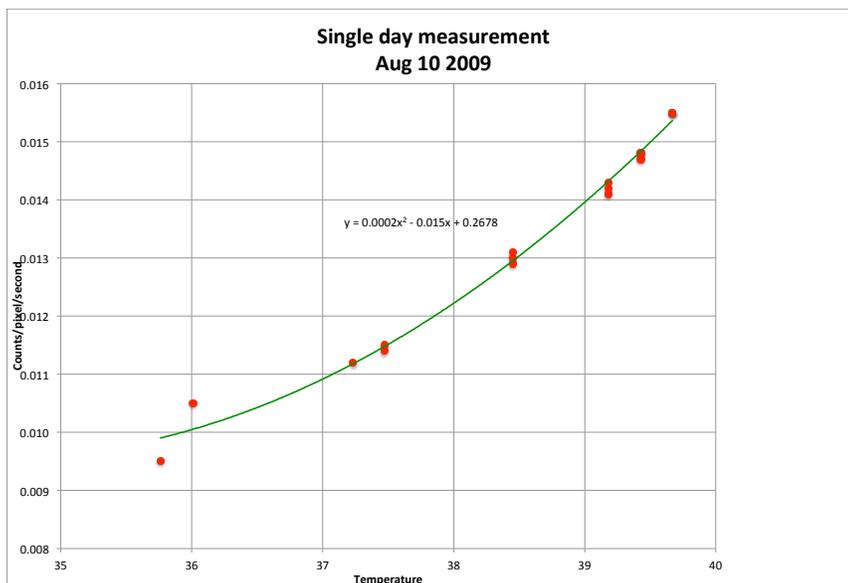


Figure 2: Variation of count rate with detector temperature.

The complete function is

$$A1e^{-(D-DATE)/D1} + A2e^{-(D-DATE)/D2} + TA + TB(TEMP-TEMP0) + TC(TEMP-TEMP0)^2$$

where D is the Julian day and each section begins at day $DATE0$. The long-term variation is described by a sum of two exponentials with decay times $D1$ and $D2$ days. The last three terms describe the effect of detector temperature, $TEMP$ expressed as a difference from a central value of $TEMP0$ equal to 38 degrees Celsius. As an indicator of how well this works, details are plotted in Figure 3. As indicated by the legend, the raw measurements are plotted as blue circles. Next

the temperature function is used to correct these to the values that the model predicts at 38°C shown as red + signs. This illustrates just the long term variation which is compared to the fitted curve (red). Finally the green + signs show the deviation of the measured values from the combined model with an RMS scatter of 1.8×10^{-4} counts/pixel/sec, to be compared with the initial RMS of 0.012. The model used is not based on a full understanding of the physics involved, but is a purely heuristical model providing a way to parametrize the behavior.

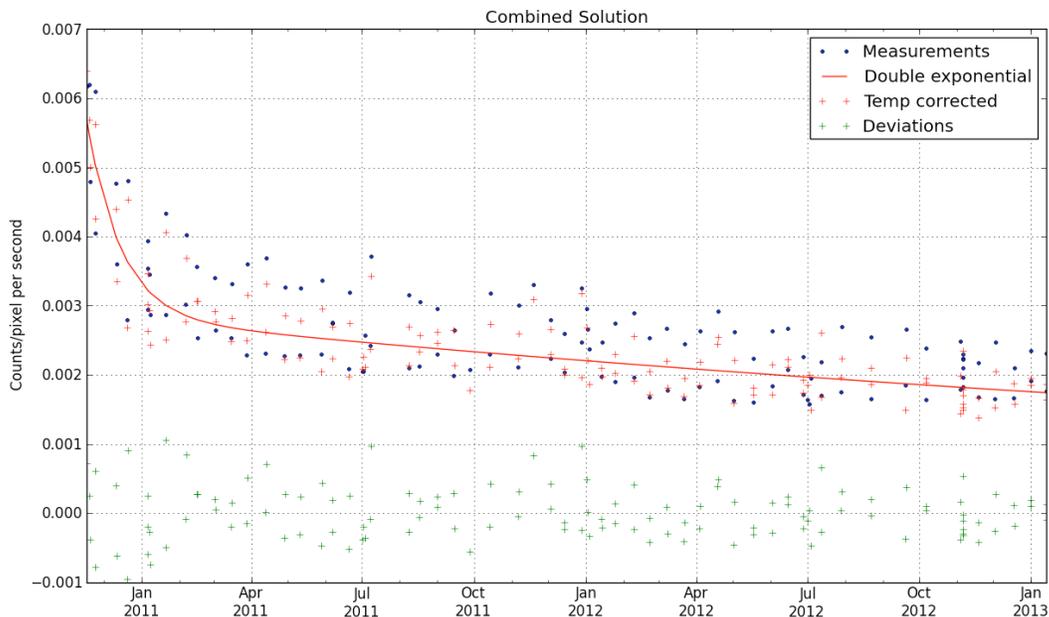


Figure 3: Combined temporal and temperature model from Nov 2010 to present.

Currently, typical count rates are in the range 2×10^{-3} counts per pixel per second at initial turn on rising to 3×10^{-3} counts per pixel per second at later times.

The periods before November 2010 were more erratic and did not fit well to the double exponential model. A single exponential was more stable. The fits are shown in figures 4 and 5

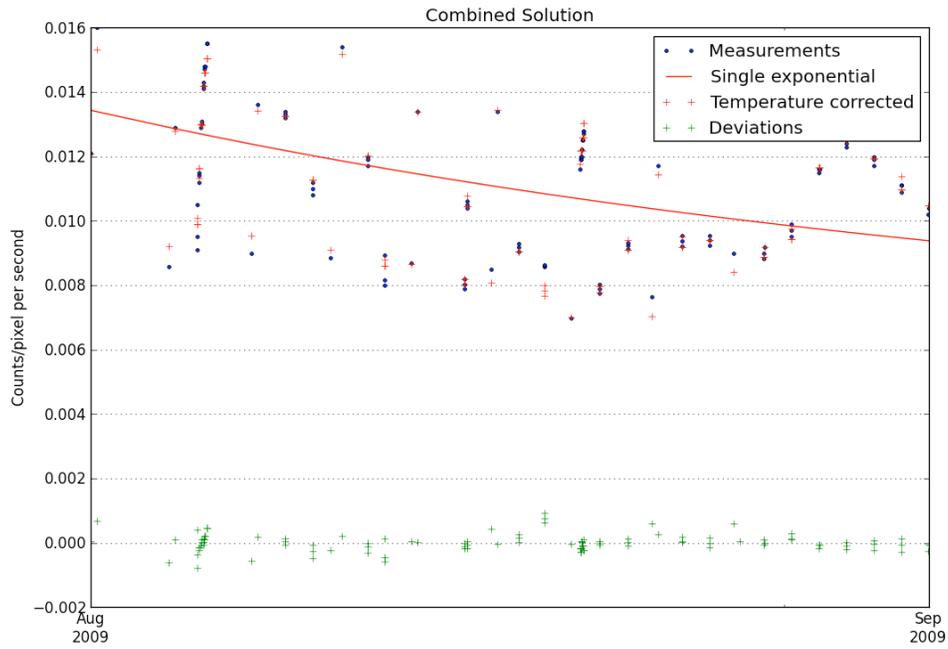


Figure 4: Single exponential fit for period from August to September 2009.

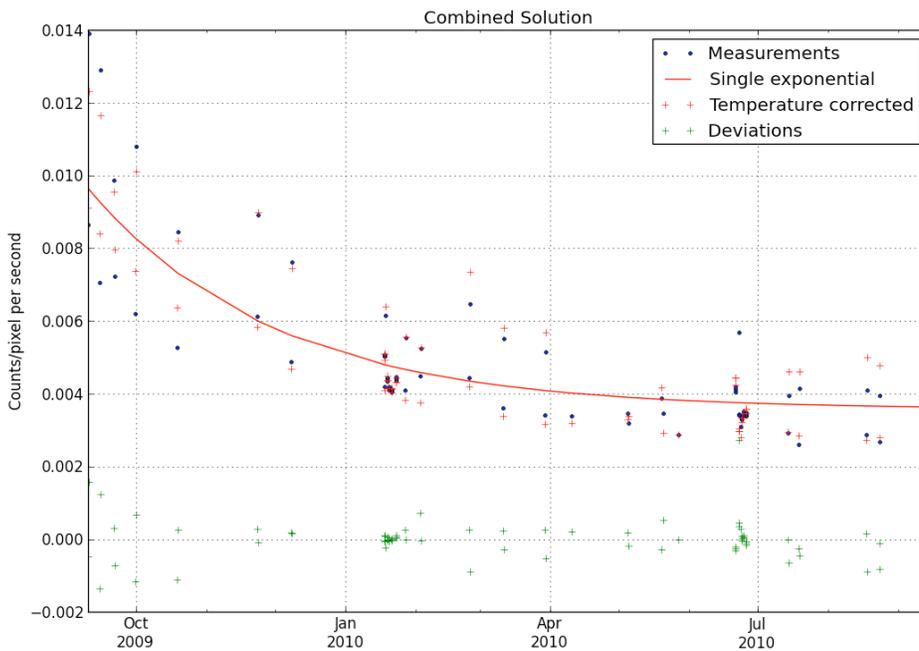


Figure 5: Single exponential fit for period from September 2009 to November 2010

The results of these fits have been incorporated into a newly designed NUV Dark Correction Table with extension .tdc referred to as TDCTAB in image headers. It contains columns DATE0, TEMP0, A1, D1, A2, D2, TA, TB, TC. DATE0 is the julian starting date of each fitted segment. A1 and D1 are the amplitudes and decay constant of the first exponential while A2 and D2 are for the second exponential. TA, TB and TC are the coefficients of the quadratic temperature function which has been shifted to have a reference temperature TEMP0 set to 38 degrees. Explicitly, the temperature function is expressed as

$$TA + TB(T-TEMP0) + TC(T-TEMP0)^2$$

Each row of the table is to be applied from DATE0 on the corresponding row until DATE0 of the next row. That is to say, you use the latest DATE0 that is not later than the observation date. The values are listed in Table 1 according to their effective starting date. A1 and A2 are count rates (counts/pixel/second). D1 and D2 are in days. TA, TB and TC are count rate, count rate per degree, count rate per degree-squared respectively. The two earlier time periods before November 2010 are well fitted by a single exponential, so A2 is set to zero and a dummy value of 1.0 is supplied for D2 to avoid possible numerical overflow that might arise if this were left at zero.

FUV MAMA

An identical program was carried out for the FUV MAMA. Figure 6 shows the summed dark image for measurements taken between January and October, 2012. This image has the same appearance as in previous years. A brighter than average region, named the glow region, is seen in the upper left corner. The mean rate here is about three times the average over the whole detector so we track this in addition to the overall count. The behavior of the FUV dark count has always been complex and not easily modelled. Proffit (2007) discusses this at some length and illustrates spatial clumping of the dark current, an aberration which has disappeared.

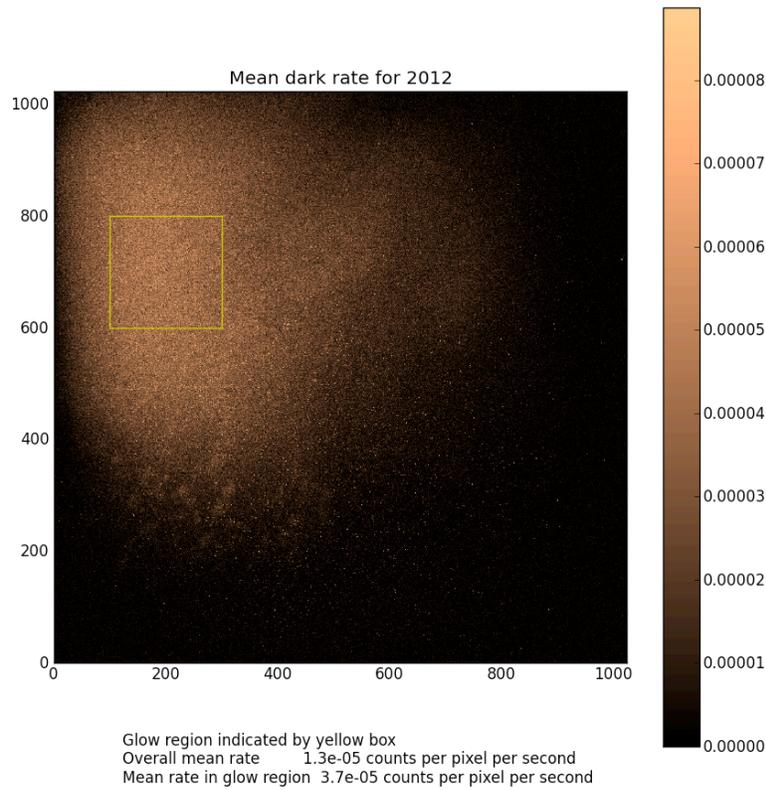


Figure 6: FUV dark image.

The long-term rates are shown in Figure 7. Again, a low and high value is seen at each bi-weekly measurement pair corresponding to the initial turn-on time and after the high voltage has been on for several hours. The initial and second images show a greater degree of disparity than the NUV set. The long term rates are fairly constant for both the full detector and the glow region. There does not appear to be any long-term decay and the average rate increased by about 25% during the October-November 2010 period when STIS was turned off.

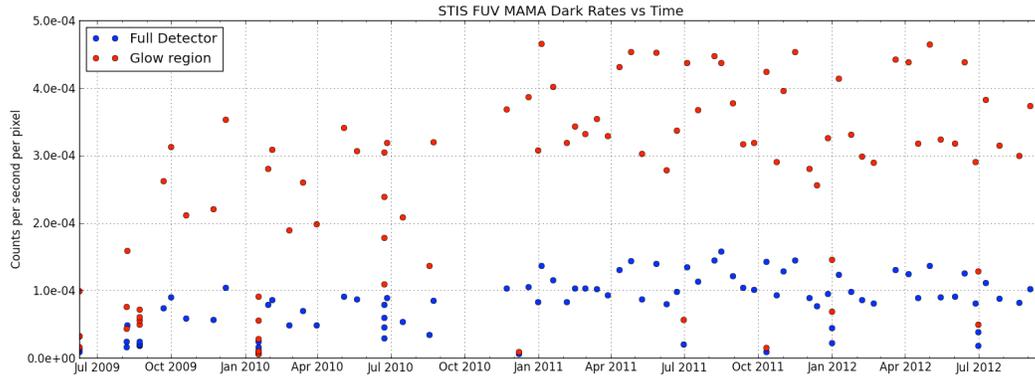


Figure 7: FUV dark rate since Servicing Mission 4.

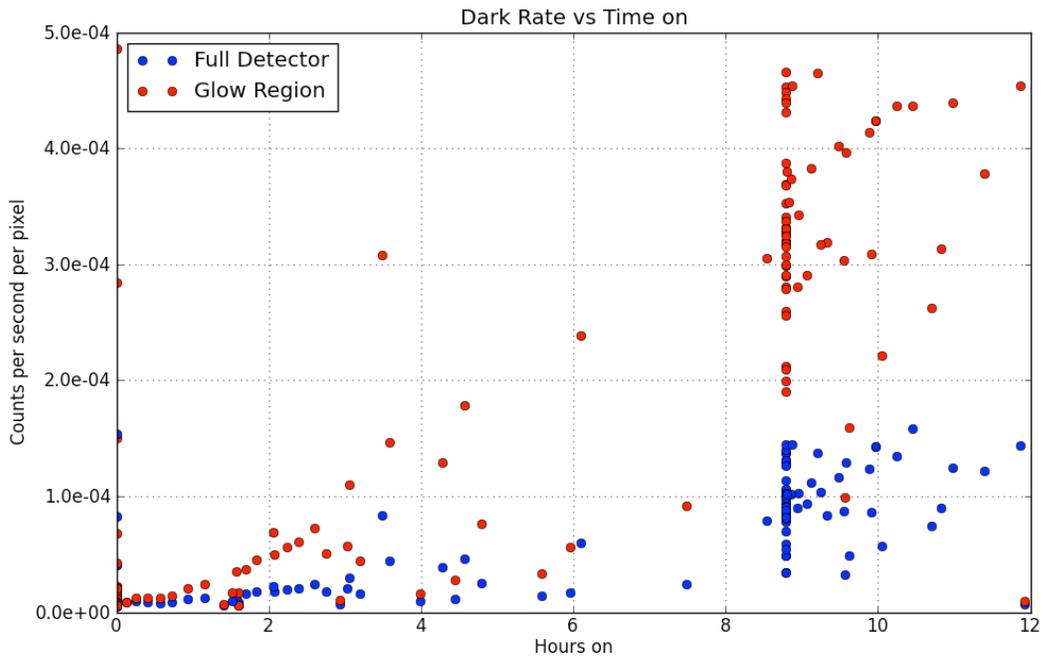


Figure 8: Dark rate as a function of time turned on

The rate as a function of time turned on is difficult to establish. Most measurements were taken at initial turn-on and then about nine hours later. In some cases the second measurement

was taken later than this when the SAA-free period happened to be longer. As shown in Figure 8 there is a wide count rate variation at the second measurement time, probably depending on what other activities occurred on HST and the intervening temperature profile. So no attempt has been made to model this. Observations in Cycle 20 have been designed to obtain more detailed information about the behavior in the first six hours. Nearly all science observations are taken in this period so the calibration will be more applicable to science. Typical overall count rates are 10^{-5} counts per pixel per second at turn-on and 1.5×10^{-5} when the detector has been on for several hours. In the glow region this is about 4×10^{-5} counts/pixel/second.

Table 1: Coefficients for STIS NUV MAMA dark correction table

Start date	Aug 6, 2009	Sep 9, 2009	Nov 16 2010
DATE0	55049.68	55083.94	55516.89
TEMP0	38.0	38.0	38.0
A1	0.00728	0.00607	0.00286
D1	37.62	81.41	11.88
A2	0.0	0.0	0.00165
D2	1.0	1.0	274.06
TA	0.00578	0.00330	0.00193
TB	0.00141	0.000528	0.000256
TC	1.375×10^{-4}	1.038×10^{-4}	3.463×10^{-5}

References

Wei Zheng, Charles Proffitt, and David Sahnou, “Dark Rate of the STIS NUV Detector”, Instrument Science Report STIS 2011-03, September 2011.

C.R. Proffitt, “Changes in the STIS FUV MAMA Dark Current”, Instrument Science Report STIS 2007-02, August 2007.

Harry Ferguson and Stefi Baum, “Scientific Requirements for Thermal Control and Scheduling of the STIS MAMA detectors after SM-3”, Instrument Science Report STIS 99-02, March 1999.