Instrument Science Report WFC3-2004-13

WFC3 UVIS Dark Current and Readnoise from Ambient Testing

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August 10, 2004

ABSTRACT

WFC3 underwent instrument-level testing under ambient conditions during late June and early July, 2004 at Goddard Space Flight Center (GSFC). Dark current and readnoise values of the UVIS channel have been measured. At a detector temperature of -70°C, the dark current and readout noise are both well within contract-end item (CEI) specifications. Dark current values range from 0.94 to 1.08 e^-/pix/hr, and are comparable to pre-ship values measured at Ball. Measurements of the readnoise reveal values of ~3 electrons, also comparable to pre-ship values and values measured during the mini-ambient testing performed earlier in the year.

Introduction

WFC3 underwent instrument-level testing under ambient conditions in late June and early July, 2004, at GSFC. This data collection served as a check of the procedures to be run during thermal vacuum (T/V) testing later in the year. A more complete characterization of the instrument will be obtained during T/V testing, but analyses of several properties of the UVIS detector were possible with the ambient data.

This report focuses on measuring the dark current rate and the readout noise of the UVIS detector, and comparing these values with the those obtained during the mini-ambient testing campaign undertaken in December 2003 through January 2004.

Data

Data used for this study include files from the UV01S04 and UV01S01 (Darks and Binned Darks) tests, as well as manually commanded files originally taken for a bias offset study, but also useful for the readnoise measurement. All images in UV01S01 were full frame, unbinned images, while the UV01S04 test was a mix of binned and unbinned images. Both tests were taken at a gain of 1.0 e^-/ADU, with the Spacecraft Systems Development and Integration Facility (SSDIF) lights off. The manually commanded data consisted of full-frame, unbinned bias images, taken at the default gain of 1.5 e^-/ADU. All data were taken with the UVIS detector at a temperature of -70^{o}C. The basic information for the input images is presented in Table 1. The 3000-second dark current image is shown in Figure 1.

Filename	Test	Exposure Time (sec)	Image Type	Binning
iaaabbccr_04190131825_raw.fits	UV01S01	600	dark	none
iu010101r_04190133854_raw.fits	UV01S01	0.0	bias	none
iu010104r_04190144014_raw.fits	UV01S04	3000	dark	none
iu010406r_04190152145_raw.fits	UV01S04	1000	dark	3x3
iu010405r_04190145704_raw.fits	UV01S04	0.0	bias	3x3
iva003b4r_04196114736_raw.fits	manually commanded	0.0	bias	none
iva003b5r_04196115615_raw.fits	manually commanded	0.0	bias	none
iva003b6r_04196120441_raw.fits	manually commanded	0.0	bias	none
iva003b7r_04196121316_raw.fits	manually commanded	0.0	bias	none

Filename	Test	Exposure Time (sec)	Image Type	Binning
iva003b8r_04196122144_raw.fits	manually commanded	0.0	bias	none
iva003b9r_04196123015_raw.fits	manually commanded	0.0	bias	none
iva003bar_04196123846_raw.fits	manually commanded	0.0	bias	none
iva003bbr_04196124715_raw.fits	manually commanded	0.0	bias	none
iva003bcr_04196125545_raw.fits	manually commanded	0.0	bias	none
iva003bdr_04196130415_raw.fits	manually commanded	0.0	bias	none

Table 1. Data files used in the dark current and readnoise analysis.

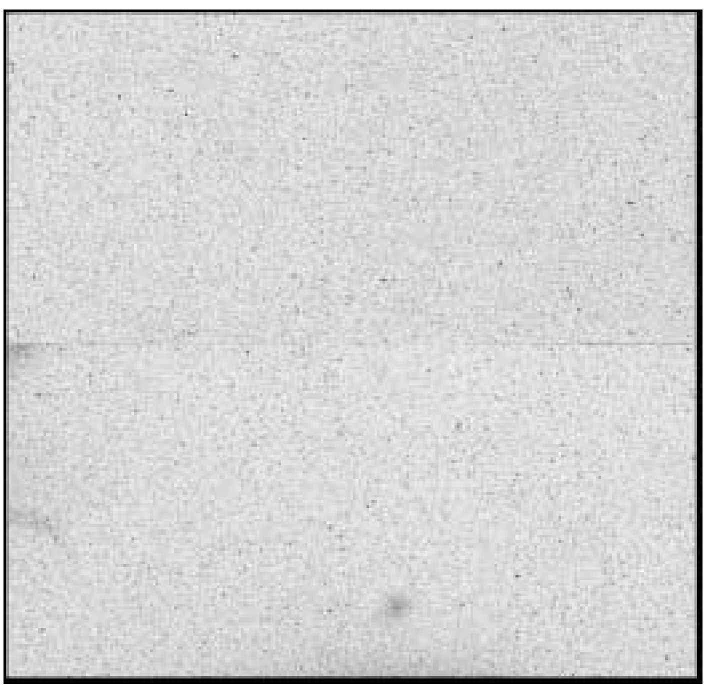

Figure 1: 3000-second UVIS dark frame.

Analysis

Dark Current

Data taken for the UV01S01 and UV01S04 tests were used in the calculation of dark current for the UVIS channel. Dark current analysis proceeded using the same method as that used during the mini-ambient test detailed in Baggett et al. The dark current and bias files were first overscan corrected and converted from ADU to electrons assuming a gain of 1.0 e^-/ADU. Next, the binned bias file was subtracted from the binned dark current file, and the unbinned bias file was subtracted from the 3000-second unbinned dark current file. The resulting dark current files were then scaled to give the measured signal for a one hour exposure time.

A quadrant-by-quadrant measurement of the dark current followed. Pixels in each quadrant were sigma-clipped once at the 10-sigma level. In both the binned and unbinned cases, the sigma-clipping flagged 0.03% to 0.04% of the total pixels in each quadrant. The mean and standard deviation of the remaining pixels were then taken. The means are reported in Table 2 as the quadrant dark currents, while the standard deviations were divided by the square root of the number of pixels in a quadrant before being reported as the uncertainties in the dark current. A histogram of the resulting dark rates for the science pixels in Amp A in the unbinned case is shown in Figure 2. Histograms of the dark rates for other amps in the binned and unbinned cases appeared similar.

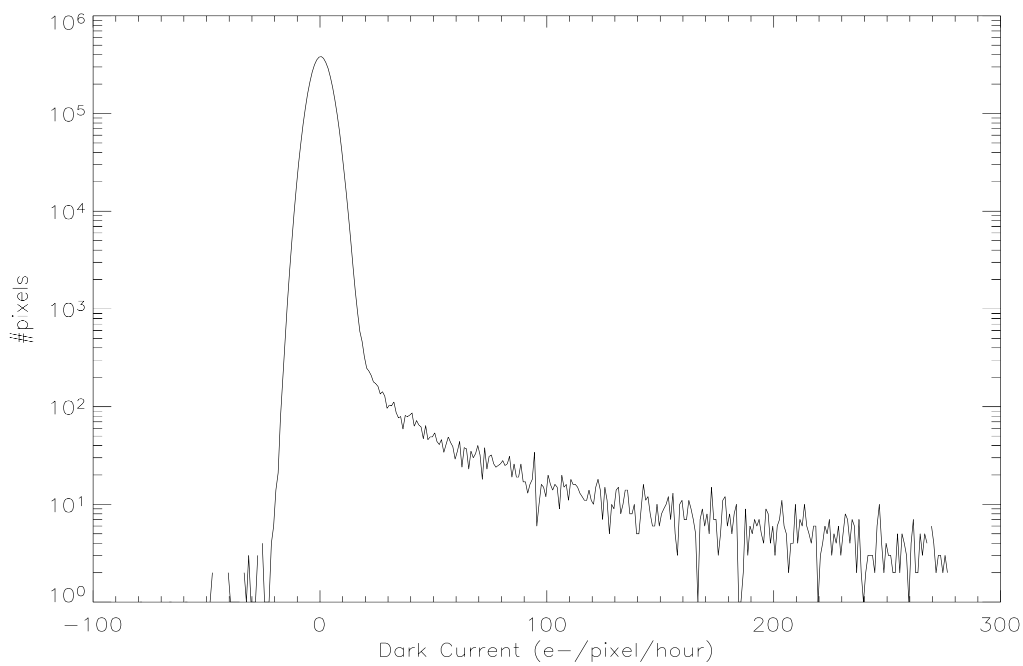

Figure 2: Histogram of dark current rates for the science pixels in Amp A in the unbinned 3000-second dark current file.

An identical procedure was used on the binned data, in order to search for any changes in dark current levels with binning. As seen in Table 2, the measured dark current rate was about 1 e^-/pixel/hour regardless of binning, and well below the CEI specification of 20 e^-/pixel/hr at -83^{o}C. The measured dark rates during ambient testing are 30% to 50% higher than those measured during the mini-ambient testing in December 2003 through January 2004. Mini-ambient testing was conducted at a detector temperature 4^{o}C colder than the temperature during the current testing and a gain of 1.5e^-/ADU (versus 1.0e^-/ADU here) These factors, in addition to some residual light from encoder illumination during the ambient exposures, likely contribute to the elevated dark rates measured during ambient testing.

Amp	File	Dark Rate (-70^{o}C) (e^-/pixel/hr)	Uncertainty (e^-/pixel/hr)	Mini-ambient Dark Rate (-74^{o}C) (e^-/pixel/hr)	Pre-ship Dark Rate (-79^{o}C) (e^-/pixel/hr)
A	unbinned	1.07	0.003	0.81	0.95
B	unbinned	0.94	0.003	0.94	NA
C	unbinned	0.97	0.003	0.67	0.74
D	unbinned	1.08	0.003	0.68	NA
A	3x3 binned	9.02 (1.00)	0.044 (0.003)	NA	NA
B	3x3 binned	8.00 (0.89)	0.046 (0.003)	NA	NA
C	3x3 binned	9.36 (1.04)	0.050 (0.003)	NA	NA
D	3x3 binned	9.23 (1.03)	0.041 (0.003)	NA	NA

Table 2. Dark current rates and uncertainties for binned (1000-second) and unbinned (3000-second) data. The dark rates shown for the binned data are the rates found in one of the 3x3 pixels. The values shown in parentheses are the dark rates divided by 9, in order to provide better comparisons with the dark current rates of the unbinned data. The binned data uncertainties were calculated using the same procedure as that for the unbinned data. The uncertainties listed in parentheses are the results of dividing the binned uncertainties by 9 (to account for binning) and also by the square root of the ratio of the exposure times between the unbinned and binned data (3000sec / 1000sec). The results are uncertainties directly comparable to those given for the unbinned data.

Readnoise

Readnoise values were measured on all files listed in Table 1. Some of these data were taken at a gain of 1.0e^-/ADU, and some were taken at 1.5e^-/ADU. The higher gain is planned as the default gain for WFC3 operations, and matches the gain used during the mini-ambient testing. This higher gain does not sample the noise as well as the 1.0 e^-/

ADU data. As a result, the data taken at the different gain settings show slightly different values for the readnoise, as seen in Table 3.

Readnoise analysis also followed the procedure used on data from the mini-ambient testing. (Baggett et al. 2004) The standard deviation of the virtual overscan region was calculated for each quadrant in each file, and converted to electrons using the appropriate gain value. This procedure was used on all files listed in Table 1.

The results are listed in Table 3. For the gain=1.0 e^-/ADU files, measured readnoise values are generally lower than those measured during the mini-ambient testing by 15% or less. This is due to the different gain used to collect those data versus the mini-ambient testing. The manually commanded bias files, acquired at a gain of 1.5 e-/ADU, gave readnoise values in close agreement with those measured during mini-ambient.

File	**Data Type**	**Binning**	**Gain (e^-/ADU)**	**Amp A (e^-)**	**Amp B (e^-)**	**Amp C (e^-)**	**Amp D (e^-)**
iaaabbccr_04190131825_raw.fits	dark	none	1.0	3.08	2.97	2.92	3.06
iu010101r_04190133854_raw.fits	bias	none	1.0	2.98	2.98	2.94	3.05
iu010104r_04190144014_raw.fits	dark	none	1.0	3.06	2.90	2.92	3.06
iu010405r_04190145704_raw.fits	bias	3x3	1.0	3.05	2.94	2.83	3.04
iu010406r_04190152145_raw.fits	dark	3x3	1.0	3.05	2.99	2.82	3.00
Unbinned Average		none	1.0	3.04 (0.05)	2.95 (0.04)	2.93 (0.02)	3.06 (0.003)
Binned Average		3x3	1.0	3.05 (9e-4)	2.97 (0.04)	2.83 (0.004)	3.02 (0.03)
High Gain Averages		none	1.5	3.29 (0.01)	3.29 (0.05)	3.14 (0.03)	3.30 (0.01)
Mini-ambient average		none	1.5	3.25	3.31	3.30	3.30

Table 3. Measured readnoise values for each quadrant of each file. Numbers in parentheses in the rows with the average values are the uncertainty in the average readnoise.

Conclusions

Dark current and readnoise values for the UVIS channel measured during ambient testing are comparable to those measured during the mini-ambient campaign earlier in the year. Dark current values are roughly 1 e^-/pixel/hour, well below the CEI specification maximum value of 20 e^-/pixel/hour.

Measured readnoise values vary with the gain setting used in the data collection. Measurements made at the default gain of 1.5 e^-/ADU returned a readnoise of roughly 3.3 electrons, while those at a gain of 1.0 e^-/ADU gave a readnoise of close to 3.0 electrons. Mini-ambient testing, conducted at a gain of 1.5 e^-/ADU, also returned a readnoise of 3.3 electrons. At both gains, the readnoise is well below the CEI specification value of 4 electrons per read.

Acknowledgements

References

Baggett, S. and B.Hilbert. **Readnoise and Dark Current in WFC3 Flight CCD Ambient Data**. http://www.stsci.edu/hst/wfc3/documents/ISRs/WFC3-2004-01.pdf. June, 2004.