

WFC3 SMOV Proposal 11419: UVIS Gain

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ABSTRACT

This report summarizes the gain results obtained from the SMOV UVIS Detector Functional program, proposal #11419. Based on internal calibration flatfields, the gain at the nominal 1.5 setting was measured at 1.61, 1.61, 1.63, and 1.62 e^-/DN , with errors $<0.01 e^-/DN$, for quadrants A, B, C, and D, respectively. These values are $\sim 3\%$ higher than those measured in ground test images and to date have been stable on-orbit: a preliminary measurement of the recent Cycle 17 gain data (proposal 11906, PI Pavlovsky) yielded gains within 1% or better of the SMOV values. The off-nominal gain settings are restricted parameters and unavailable for general use, however, the SMOV proposal obtained data to check these settings on-orbit relative to the nominal 1.5 setting. The values for the off-nominal gains were measured at 1.04, 1.02, 1.04, 1.04 e^-/DN and at 2.17, 2.12, 2.17, 2.16 e^-/DN for the gain 1.0 and gain 2.0 settings. The exposure times for the gain 4.0 images were erroneously set too low to allow a determination of that setting; the observations were not repeated.

Introduction

Every Hubble Servicing mission is followed by a commissioning period SMOV (Servicing Mission Observatory Verification), during which the telescope and all its instruments undergo a suite of on-orbit calibration tests in preparation for science observing. The recent May 2009 servicing mission, during which WFC3 (Wide Field Camera 3) was installed, was no exception. One of the WFC3 SMOV tests performed was the UVIS Detector Functional test, program 11419. This program was designed to measure the base-

line performance and operability of the CCDs using only bias and dark frames as well as internal WFC3 calibration subsystem flatfields. The biases were used to evaluate read noise and provide frames from which to build an on-orbit superbias while the darks were used to analyze dark current, hot and bad pixels; details of these results have been reported elsewhere (Borders & Baggett, 2009a, 2009b). A set of internal flatfields was acquired to provide data for an absolute gain measurement at the nominal gain setting (1.5 e⁻/DN) as well as a check of the alternate gain settings (1.0, 2.0, and 4.0 e⁻/DN). The detector functional test was run only after the successful completion of both the CCD activation program (#11454) and the SOFA and tungsten lamp check (#11422). This report summarizes the analysis method and results from the gain portion of the SMOV detector functional test proposal 11419.

Data

Images and Calibration

Data for the absolute gain check consisted of six pairs of flatfields in the same filter (F547M) taken at a range of exposure levels for application of the mean-variance method. Images for the relative gain were pairs of well-exposed flatfields, with F547M, at each of the three alternate gain settings. Unfortunately, the flatfields at the gain=4.0 setting were underexposed and unusable for gain measurements. Since the off-nominal gains are not expected to be used on-orbit, these exposures will not be repeated.

All images were acquired in the default full-frame, four-amp, unbinned readout mode. The images used in this analysis have been summarized in Table 1; shown are image root-name, gain setting, image type, exposure time, number of good pixels and in DN, the mean, standard deviation, and median of each of the two chips.

Table 1. Summary of images used for the SMOV UVIS gain check; statistics are in units of DN. All are full-frame, unbinned four-amp readouts taken with the F547M filter, acquired on June 12 and 13, 2009.

rootname	gain	image type	exp time	chip 1 (amps A & B)				chip 2 (amps C & D)			
				numpix	mean	stdev	median	numpix	mean	stdev	median
iaao05lkq	1.5	BIAS	0.	8369558	0.11	1.95	0.36	8358361	0.07	1.93	-0.05
iaao05llq	1.5	BIAS	0.	8367571	0.05	1.98	0.14	8363845	0.03	1.97	0.06
iaao05loq	1.5	FLAT	1.5	8384915	1147.	90.62	1140.	8392018	1267.	106.30	1265.
iaao05lpq	1.5	FLAT	1.5	8384271	1174.	92.48	1167.	8391972	1297.	108.30	1296.
iaao05lrq	1.5	FLAT	6.8	8390458	5356.	407.60	5322.	8395417	5924.	479.30	5924.

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rootname	gain	image type	exp time	chip 1 (amps A & B)				chip 2 (amps C & D)			
				numpix	mean	stdev	median	numpix	mean	stdev	median
iaao05lsq	1.5	FLAT	6.8	8390528	5361.	408.10	5327.	8395460	5929.	479.60	5929.
iaao05luq	1.5	FLAT	13.7	8387539	10829.	821.70	10761.	8391106	11987.	962.20	11986.
iaao05lvq	1.5	FLAT	13.7	8387512	10828.	821.50	10759.	8391065	11985.	961.80	11984.
iaao05lxq	1.5	FLAT	22.7	8386753	17986.	1366.	17869.	8391064	19929.	1590.	19931.
iaao05lyq	1.5	FLAT	22.7	8386821	17982.	1365.	17866.	8391096	19925.	1590.	19927.
iaao05m0q	1.5	FLAT	34.1	8381422	27094.	2061.	26920.	8386811	30055.	2385.	30056.
iaao05m1q	1.5	FLAT	34.1	8381414	27105.	2062.	26929.	8386806	30068.	2386.	30068.
iaao05m3q	1.5	FLAT	47.3	8385015	37683.	2871.	37584.	8395705	41856.	3299.	41871.
iaao05m4q	1.5	FLAT	47.3	8385048	37692.	2872.	37594.	8395716	41867.	3299.	41887.
iaao06ncq	1.0	BIAS	0.	8362687	0.11	2.68	-0.06	8357465	0.07	2.65	-0.08
iaao06ndq	1.0	BIAS	0.	8358239	0.10	2.67	-0.15	8362474	0.06	2.69	-0.11
iaao06nfq	1.0	FLAT	40.	8377064	45033.	3049.	44759.	8383825	50581.	3926.	50578.
iaao06ngq	1.0	FLAT	40.	8376339	45758.	3094.	45477.	8396549	51414.	4003.	51402.
iaao06niq	2.0	BIAS	0.	8365752	0.07	1.58	-0.10	8357874	0.09	1.54	0.01
iaao06njq	2.0	BIAS	0.	8366862	0.14	1.58	-0.14	8362250	0.09	1.55	-0.28
iaao06nlq	2.0	FLAT	20.	8386831	10712.	724.80	10648.	8390945	12006.	963.70	12004.
iaao06nmq	2.0	FLAT	20.	8386852	11125.	750.80	11058.	8390930	12470.	996.90	12470.
iaao06o5q	4.0	BIAS	0.	8370781	-0.04	1.14	0.02	8374708	-0.02	1.18	0.10
iaao06o6q	4.0	BIAS	0.	8375190	0.06	1.12	-0.05	8365305	-0.04	1.16	-0.08
iaao06noq	4.0	FLAT	10.	8368986	-0.03	17.36	-0.83	8368827	-0.05	18.29	-0.87
iaao06npq	4.0	FLAT	10.	8368986	0.03	17.36	-0.79	8368828	0.05	18.29	-0.79

All files were processed through the standard OPUS pipeline, generating the raw fits files, then processed through the IRAF calwf3 version 1.4.1 (27-Apr-2009) for calibration. The calibration steps included the data quality initialization, the overscan correction, and the bias and dark file subtractions. Specifically, the reference files employed were t2c1533si_bpx.fits, t291659mi_ccd.fits, q911321oi_osc.fits, 090611120_bia.fits (nominal gain) and t3420177i_drk.fits, for the bad pixel table, ccd table, overscan table, superbias file, and superdark file, respectively. The superbias file for nominal gain was a preliminary, on-orbit version generated from a stack of 120 individual bias frames. Since the pipeline superbias for the off-nominal gains was only a placeholder (t6i1733ei_bia), the

two biases taken at each off-nominal gain setting as part of the functional test were used to perform the bias subtraction.

Analysis

As with previous measurements of the WFC3 UVIS gain (Baggett 2008; Baggett 2005), the standard mean-variance technique has been used for the nominal gain setting. The method assumes there are only two sources of noise: shot noise from the impinging photons and read noise from the detector. Adding these noise terms, in electrons, in quadrature and using the fact that the photon noise is $\sqrt{g \cdot \mu}$, where μ is the mean signal (in DN) and g is the gain (e^-/DN), the noise equation reduces to $\sigma^2 = (1/g) \cdot \mu + (R/g)^2$, where R is the readnoise in electrons. The inverse slope of a linear fit to the plot of the mean of the images (in DN) versus the variance yields the gain.

To generate a mean-variance plot, average and difference images were formed from the pair of flatfields available at each exposure time; the means came from the average images and the variances were computed from the difference images (standard deviation squared divided by two). The statistics were measured from 400x400 pixel regions evenly spread across the detector (>300 regions per quadrant). Three iterations of 3 sigma clipping were performed in order to remove the effects of cosmic rays. The resulting plots have been included in the appendix; the measured gains and the propagated errors of the linear fit are listed in Table 2, along with the values determined for the same detector in the most recent ground test (TV3). The on-orbit gains appear to be about 3% higher than those measured on the ground for reasons not presently understood. Preliminary analysis of the Cycle 17 gain test data (proposal 11906, Pavlovsky et al. 2009), which were taken ~4 months after the SMOV test, show the on-orbit gain has remained stable to 0.2-1%, depending upon the quadrant.

For the relative gain measurements, each pair of flatfields at the off-nominal settings was averaged, ratioed to an average nominal gain image, and multiplied by 1.5, the nominal gain. Statistics were measured across each entire quadrant, using three iterations of 3 sigma clipping. The results are listed in Table 2. As mentioned in earlier, the exposure levels of the gain 4.0 flatfields were insufficient for a gain measurement.

Table 2. Measured gains for the UVIS channel.

quadrant	on-orbit		TV3		on-orbit, off-nominal gain settings			
	gain	fit error	gain	fit error	gain	fit error	gain	fit error
A	1.61	<0.01	1.56	<0.01	1.04	<0.01	2.17	0.01
B	1.61	<0.01	1.56	<0.01	1.02	<0.01	2.12	<0.01
C	1.63	<0.01	1.58	<0.01	1.04	<0.01	2.17	<0.01
D	1.62	<0.01	1.57	<0.01	1.04	<0.01	2.16	<0.01

Conclusions

The gain for the nominal setting as well as some of the off-nominal settings have been measured. Values for A,B,C, and D quadrants respectively are: 1.61, 1.61, 1.63, 1.62 e⁻/DN for the gain 1.5 setting and 1.04, 1.02, 1.04, 1.04 and 2.17, 2.12, 2.17, 2.16 e⁻/DN for the off-nominal settings, with errors at or <0.01 e⁻/DN. Due to an error in the exposure time specification for the gain 4.0 flatfields, the flatfield levels were too low to allow a gain check. At this time, a repeat for of these frames is not deemed necessary: the off-nominal gain settings are restricted parameters unavailable for outside use. If this gain setting should be brought into use in the future, data could be acquired at that time to allow for an evaluation of the precise gain.

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References

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Appendix A.

Figure 1: Mean-variance plots for the four UVIS quadrants, unbinned nominal gain 1.5 mode.

