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WFC3 Ambient-2 Testing: UVIS Gain Results

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ABSTRACT

The integrated WFC3 instrument recently underwent testing under ambient conditions at Goddard Space Flight Center (GSFC); the UVIS-2 detector was in place, operated at -54 C. One of the tests performed was the relative gain procedure (UV03S01A); analysis of the data show that the gains, assuming a nominal gain of 1.5 e^-/DN for the gain 1.5 setting, are on average 1.03, 2.10, and 4.28 e^-/DN with errors ~0.01 e^-/DN. A check of the absolute gain at the nominal 1.5 setting was performed using a set of flatfield pairs; gains were measured at 1.58, 1.55, 1.65, and 1.61 e^-/DN, with errors ~0.01 e^-/DN, for quadrants A,B,C, and D.

Introduction

Recent testing of WFC3 with the UVIS-2 detector was performed in the GSFC Hubble Space Systems Devlopment and Integration Facility (SSDIF); the operating temperature of UVIS-2 was -54C. Data were obtained using the WFC3 optical stimulus (CASTLE), which simulates the HST OTA (including aberrations) as seen by WFC3. The CASTLE apparatus can provide a variety of point sources at a large range of intensities, and positioned at any location desired in the field of view, as well as uniform flatfield illumination at a large range of flux levels via an integrating sphere. Flatfields were used in the relative and absolute gain measurements; this report summarizes the data used, analysis performed, and resulting gain values.

Relative Gain

The relative gain measurements for UVIS-2 were made from UV03S01A data, consisting of four pairs of 240-second F606W flatfields taken on Apr 15,2007, one pair at each gain (1.0, 1.5, 2.0, and 4.0) followed by an additional pair taken at gain=1.0 to verify the stability of the CASTLE stimulus. The images were full-frame, unbinned, four-amp readouts taken at the nominal bias offset level of 3 (images are listed in Table 2, Appendix A). The UVIS-2 detector temperature was -54 C.

The images were processed through calwf3, performing the overscan correction (BLEVCORR) only, using versions of CCDTAB and OSCNTAB generated in Mar 2005 and Nov 2003, respectively. The average of each pair of flatfields was taken; each average was ratio'd to the average gain 1.5 image and scaled by 1.5 (the nominal gain). The average and standard deviation were measured across the entire quadrant; no pixels were masked. The resulting gain ratios are listed in Table 1. The two sets of gain=1.0 data were analyzed separately but the results were the same within the errors. The gain ratios were also computed using sigma-clipped image statistics (3 sigma clipping, done 3 times); there was no change in the resulting gain ratios.

Table 1. Gain ratios for the four quadrants of UVIS-2, relative to gain 1.5.

Quad	ave set1	stddev	ave set2	stddev	ave	stddev	ave	stddev
A	1.02	0.01	1.01	0.01	2.08	0.01	4.25	0.02
B	1.05	0.01	1.04	0.01	2.14	0.01	4.36	0.02
C	1.02	0.01	1.01	0.01	2.09	0.01	4.25	0.02
D	1.03	0.01	1.02	0.01	2.08	0.01	4.27	0.02

Absolute Gain

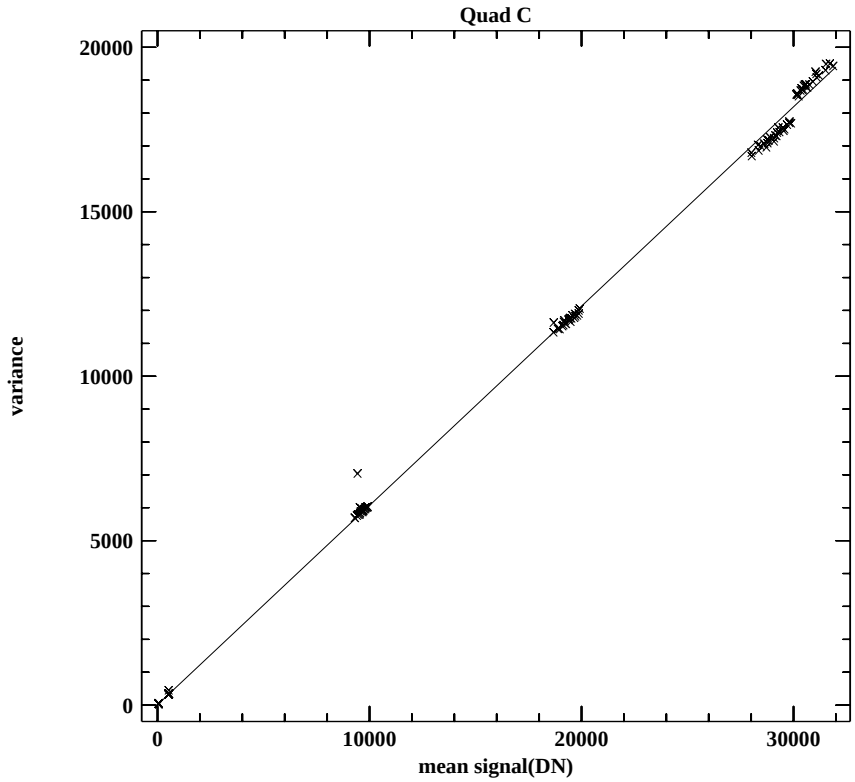
The nominal calibration plan is to determine a gain value for the default gain 1.5 setting using a subset of the linearity (UV05) flatfields. However, due to schedule and instrument restrictions, this procedure was not run during the Apr 2007 ambient testing. Instead, a short set of flatfield pairs at a range of exposure levels were acquired manually without a filter in place (listed in Table 3, Appendix A). The standard mean-variance method was used, where the gain is the inverse slope of a linear least squares fit to a plot of variance versus mean signal level. That is, the total noise, or observed variance, in an image can be written as $(N/g)^2=(p/g)^2+(R/g)^2$, where N is the total noise, g is the gain conversion in units of e^-/DN and the noise terms (photon, p, and readnoise, R) are in units of in e^-. Using the fact that photon noise is the square root of g*signal when the mean signal μ is in DN,

the observed variance σ^2 can be rewritten as $\sigma^2 = (1/g) * \mu + (R/g)^2$ and the inverse slope provides the gain.

Six pairs of flatfields taken Apr 18, 2007 were used, all full-frame, four-amp readouts, unbinned, and taken at the nominal bias offset level of 3. The images were processed through calwf3, performing the overscan correction only and as for the relative gain images, using versions of CCDTAB and OSCNTAB generated in Mar 2005 and Nov 2003, respectively. Average and difference images were formed for each flatfield pair and the mean-variance plot constructed from the means of the average images and the variances of the difference images (standard deviation squared and divided by two). Statistics were measured in sixteen 400x400 pixel regions per quad; Figure 1 shows the quad C results. There is one anomalous point at ~10K DN; this was traced to two bad pixels in one 400-square pixel region (pixels [221,1503] and [222,1503]); removing those two pixels and remeasuring the variance showed that it dropped from 7038 to 5980, more similar to the variances in the rest of the regions in the quad. There is also some indication that Quad C is becoming non-linear around 30K DN; restricting the fit to <30K DN changed the gain by less than 0.5% so the full fit out to ~32K DN was retained. However, in quads A and B, the non-linearity was significantly worse above 30K DN; for those quads, the fit was restricted to signal levels below 30K DN.

The gains were measured at 1.58, 1.55, 1.65, and 1.61 for quads A,B,C and D; gain errors, propagated from the errors in the slope of the linear fit, were ~0.01 for all quads.

Figure 1: Mean-variance plot for quad C.



Conclusions

The gains for UVIS-2 at -54C, assuming a gain of 1.5 e^-/DN for the nominal gain 1.5 setting, were found to be 1.03, 2.10, and 4.28 e^-/DN on average, with errors ~0.01 e^-/DN. The absolute gains for the gain 1.5 setting were measured at 1.58, 1.55, 1.65, and 1.61 e^-/DN in quads A, B, C, and D, with errors ~0.01 e^-/DN.

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Appendix A.

Table 2. Files used for relative gain determination (taken via UV03S01A procedure). Images were all full-frame, four-amp readout, unbinned, offset=3 exposures.

rootname	tvnum	exposure start	filte	exptime	gain	median flux level (DN)
iu031a01r_07105103748	28394	2007-04-15 10:28:25	--	0.0	1.0	0.3 (bias)
iu031a02r_07105103748	28395	2007-04-15 10:31:24	F606W	240.0	1.0	31304
iu031a04r_07105105802	28396	2007-04-15 10:49:19	F606W	240.0	1.0	31569
iu031a05r_07105105802	28397	2007-04-15 10:55:39	F606W	0.0	1.0	0.2 (bias)
iu031a07r_07105111816	28398	2007-04-15 11:08:57	F606W	0.0	1.5	0.3 (bias)
iu031a08r_07105111816	28399	2007-04-15 11:11:52	F606W	240.0	1.5	21643
iu031a0ar_07105113830	28400	2007-04-15 11:29:47	F606W	240.0	1.5	21608
iu031a0br_07105113830	28401	2007-04-15 11:36:07	F606W	0.0	1.5	0.1 (bias)
iu031a0dr_07105115844	28402	2007-04-15 11:49:25	F606W	0.0	2.0	0.2 (bias)
iu031a0er_07105115844	28403	2007-04-15 11:52:20	F606W	240.0	2.0	15463
iu031a0gr_07105121857	28404	2007-04-15 12:10:14	F606W	240.0	2.0	15412
iu031a0hr_07105121857	28405	2007-04-15 12:16:34	F606W	0.0	2.0	0.2 (bias)
iu031a0jr_07105123911	28406	2007-04-15 12:29:52	F606W	0.0	4.0	0.1 (bias)
iu031a0kr_07105123911	28407	2007-04-15 12:32:47	F606W	240.0	4.0	7543.
iu031a0mr_07105125925	28408	2007-04-15 12:50:42	F606W	240.0	4.0	7572.
iu031a0nr_07105125925	28409	2007-04-15 12:57:02	F606W	0.0	4.0	0.2 (bias)
iu031a0pr_07105131939	28410	2007-04-15 13:10:20	F606W	0.0	1.0	0.3 (bias)
iu031a0qr_07105131939	28411	2007-04-15 13:13:15	F606W	240.0	1.0	31770.
iu031a0sr_07105134042	28412	2007-04-15 13:31:10	F606W	240.0	1.0	31718.
iu031a0tr_07105134042	28413	2007-04-15 13:37:30	--	0.0	1.02	0.4 (bias)

Table 3. Files used for absolute gain determination; images were all full-frame, four-amp readout, unbinned, offset=3 exposures. Note that due to schedule and instrument restrictions, the flats were acquired manually without a filter in place (i.e., were not obtained via the intended procedure UV05S01 linearity proposal).

rootname	tvnum	exposure start	filter	exptime	median flux level (DN)
iaaabbccr_07108201228	28972	2007-04-18 20:09:56	--	2.	57.2
iaaabbccr_07108202344	28973	2007-04-18 20:21:06	--	2.	57.2
iaaabbccr_07108203229	28974	2007-04-18 20:30:03	--	0.	-2e-04 (bias)
iaaabbccr_07108204708	28975	2007-04-18 20:44:16	--	20.	567.0
iaaabbccr_07108205559	28976	2007-04-18 20:53:13	--	20.	567.1
iaaabbccr_07108210639	28977	2007-04-18 21:03:33	--	40.	10268.5
iaaabbccr_07108211708	28978	2007-04-18 21:14:03	--	40.	10275.5
iaaabbccr_07108212739	28979	2007-04-18 21:23:53	--	80.	20584.
iaaabbccr_07108213829	28980	2007-04-18 21:34:43	--	80.	20620.5
iaaabbccr_07108215109	28981	2007-04-18 21:46:44	--	120.	30924.5
iaaabbccr_07108220144	28982	2007-04-18 21:57:14	--	120.	30785.
iaaabbccr_07108221344	28983	2007-04-18 22:08:27	--	160.	41245.5
iaaabbccr_07108222524	28984	2007-04-18 22:20:07	--	160.	41272.