



ACS after SM4: RELATIVE GAIN VALUES AMONG THE FOUR WFC AMPLIFIERS

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ABSTRACT

For the default setting of gain=2, the individual gain values of the four WFC amplifiers are determined from internal flat field observations. The average absolute gain remains unchanged, but matching the flat fields at the boundaries of the four quadrants provides a more accurate determination of the relative gains among the four separate amplifiers.

1. Introduction

Following the HST Servicing Mission in 2009 May (SM4), new electronics are now available for controlling ACS. The available gains (G) with the new electronics are 0.5, 1.0, 1.4, and 2.0 (e-/DN); but only $G=2$ is being used for scientific observations in cycle 17. In cycle 18, only $G=2$ will be supported. CCDs can approach signal detection at the quantum noise limit; however, CCDs are basically analog detection devices. The analog signal charge is read, amplified, and then digitized with an A-to-D converter, which for ACS is 16 bits (0-65535). Because of read noise, distinguishing one electron of signal is rarely useful, so that the signal can be compressed with little loss of information before the digitization step. For example at $G=2$, one Analog Data Unit (ADU) of digitized signal corresponds to 2 electrons of detected charge. Therefore, the ACS/WFC CCD detector with its full well of maximum charge of ~ 85000 electrons can be digitized without saturating the A-to-D converter at $G=2$. A nearly full well of 80000 electrons will be digitized for the telemetry stream at a value of 40000 ADU, which is well below the A-to-D converter saturation limit of 65535.

With the new electronics package installed during SM4, the new absolute gain values for the four ACS WFC detector quadrants (A, B, C, D) have been measured during the SM4 ACS Optimization Campaign by P. L. Lim (private comm.). The accuracy of this photon-transfer method that analyzes the noise properties of the signal is only $\sim 5\%$.

An exact measure of the gain for any particular mode is of little import, because any error is compensated exactly in the calibration of the absolute flux sensitivity. However, to avoid different sensitivity calibrations for different modes, the exact value of the gain *relative* to a fiducial gain value *is* important and should be measured precisely. There are two types of relative gain a) the ratio of the signals for the same source in different nominal gain settings and b) the relative response among the four WFC quadrants at the same gain setting. Following a precise measurement for b), the ratios a) should be the same for all four ABCD quadrants.

For ACS, Gilliland (2004) measured the type a) gain ratio by comparing the same star fields taken at the different gains. Using this same procedure for calibrating the post-SM4 electronics, the exact new G=2 value relative to the same original pre-SM4, fiducial G=1 setting should be measured by comparing stellar signals in the same field as previously used. The fractional adjustment from the star field analysis will apply to the 2.036 average and to the individual ABCD gains quoted in line 3 of Table 1. The analysis of the 47 Tuc star field by Mack, Desjardins, & Bohlin (2009 in prep) is used to define the type a) relative gains and produce the final gain values listed in the last line of Table 1.

For the type b) relative gain that is the topic of this ISR, internal flat field observation define the relative gain among the ABCD quadrants. The relative gain between pairs of amplifiers, i.e. A/B on chip 1 and C/D on chip 2, can be derived from internal flat field images to $\sim 0.1\%$ precision by matching the signal across the two boundaries. The flat fields also provide a more precise determination of the gain ratio between the two WFC chips. However, the chip1/chip2 sensitivity ratio is wavelength dependent. The chip1/chip2 relative gains are reconciled using the internal flats at F625W following the method of Bohlin, Hartig, and Sparks (2002).

2. ANALYSIS

Table 1 shows the average gain and the gain ratios for pre-failure in line 1 and after SM4 in lines 2-4. The average gain value of 2.036 for the G=2 setting in Table 1 is unchanged by our adjustments from line 2 to line 3 for the individual A, B, C, and D amplifiers. Table 2 lists the observations analyzed and discussed below. As normally displayed and as in Figures 1-2, the positions of A to D are in order like you read a book with A at the top left and D at the bottom right. The relative gains are measured along eight pixel wide strips at adjacent edges of the amplifier pairs on each chip and at the adjacent edges, where the two chips are butted together. The IDL program gainrat.pro compares the sum of three F625W internal lamp images obtained on day 190 (July 9) of 2009 to a similar set obtained on 2007 January 11. While our relative A/B and C/D gains measured from the relative response at the adjacent edges of the AB and CD amp pairs are accurate and repeatable to 0.1%, relative values between the chips depends on the assumption of equal sensitivities at F625W. The sensitivity from chip 1 to chip 2 along the chip gap is expected to be similar, because the two chips were cut from the same thinned silicon wafer and are positioned in the same orientation as on the original wafer. With the Table 1 gains derived to make chip 1 match chip 2 for F625W, the

average chip1/chip2 response varies with wavelength, i.e. filter, by $<0.7\%$, except for F850LP, where chip 1 is 1.2% more sensitive than chip 2. However, this same sensitivity variation with filter repeats in the flat field reference files themselves, so that the flux calibrations with the new electronics should remain the same for both chips.

3. UNCERTAINTIES

While the gain values derived here attempt to make the four quadrants within a raw flat field image match, the more important purpose is to make the SM4 flat fields match the pre-failure flats obtained at the same CCD set point temperature of -81C . For the F435W, F625W, and F814W internal flats obtained on 2009 July 9-10, the match is better than $\sim 0.2\%$ for any systematic differences in $8 \times 8 = 64$ bins of 512×512 pixels, except for the lower left corner of F435W where that bin is 0.3% low. However, the F850LP internal flat shows changes of up to 0.4% over an extended region, as shown in Figure 1, while Figure 2 shows the expected uniform ratio for F814W.

The pattern in Figure 1 is strongly reminiscent of Fig. 2 of Bohlin et al. (2005), where the cause is attributed to the known shutter light leak of the WFC. The light that leaks around the shutter has a fixed equivalent exposure time that depends on how long the lamp is on with the shutter closed. Thus, shorter exposures have a larger fractional contamination from extra spurious signal in the blacker region of our Figure 1. The three 2007 images comprising the denominator of Figure 1 have an exposure time of 2s, while the 2009 numerator images have a 4.2s duration. Thus, the denominator has a larger fractional contamination, making the ratio less than one in the contaminated region. The exposure times of the other three filters with 2009 data are all identical to the exposure times of the comparison data obtained in 2007.

With a maximum difference of $\sim 1\%$ between the values in line 2 vs. line 3, our repartitioned gains in Table 1 agree with the absolute gain measurements from the SM4 Optimization Campaign.

Table 1. Average Absolute Gain and Relative Individual Gain Values

Average	Amp A	Amp B	Amp C	Amp D	Comment
1.992	2.002	1.945	2.028	1.994	Gilliland (2004)
2.036	2.090	1.918	2.092	2.045	SM4 optimization campaign
2.036	2.074	1.936	2.071	2.065	This work
1.983	2.020	1.886	2.017	2.011	Mack et al.(2009 in prep)

Table 2. Internal Lamp WFC Observations Analyzed

ROOTNAME	DATE-OBS	Exp(s)	PROPOSID	FILTER
j9v9w1obq	2007-01-10	17.6	11052	F435W
j9v9w1odq	2007-01-10	17.6	11052	F435W
j9v9w1ofq	2007-01-10	17.6	11052	F435W
ja9aw5y0q	2009-07-09	17.6	11374	F435W
ja9aw5y2q	2009-07-09	17.6	11374	F435W
ja9aw5y4q	2009-07-09	17.6	11374	F435W
j9v9w7snq	2007-01-11	3.0	11052	F625W
j9v9w7spq	2007-01-11	3.0	11052	F625W
j9v9w7srq	2007-01-11	3.0	11052	F625W
ja9aw6y6q	2009-07-09	3.0	11374	F625W
ja9aw6y8q	2009-07-09	3.0	11374	F625W
ja9aw6yaq	2009-07-09	3.0	11374	F625W
j9v9wbx1q	2007-01-12	2.9	11052	F814W
j9v9wbxnq	2007-01-12	2.9	11052	F814W
j9v9wbxpq	2007-01-12	2.9	11052	F814W
ja9aw7duq	2009-07-10	2.9	11374	F814W
ja9aw7dwq	2009-07-10	2.9	11374	F814W
ja9aw7dyq	2009-07-10	2.9	11374	F814W
j9v9wcxsq	2007-01-12	2.0	11052	F850LP
j9v9wcxuq	2007-01-12	2.0	11052	F850LP
j9v9wcxwq	2007-01-12	2.0	11052	F850LP
ja9aw8xtq	2009-07-09	4.2	11374	F850LP
ja9aw8xvq	2009-07-09	4.2	11374	F850LP
ja9aw8xxq	2009-07-09	4.2	11374	F850LP

0.995

1.005

lpwi09190sm03f850lp / lpwi07012sm03f850lp

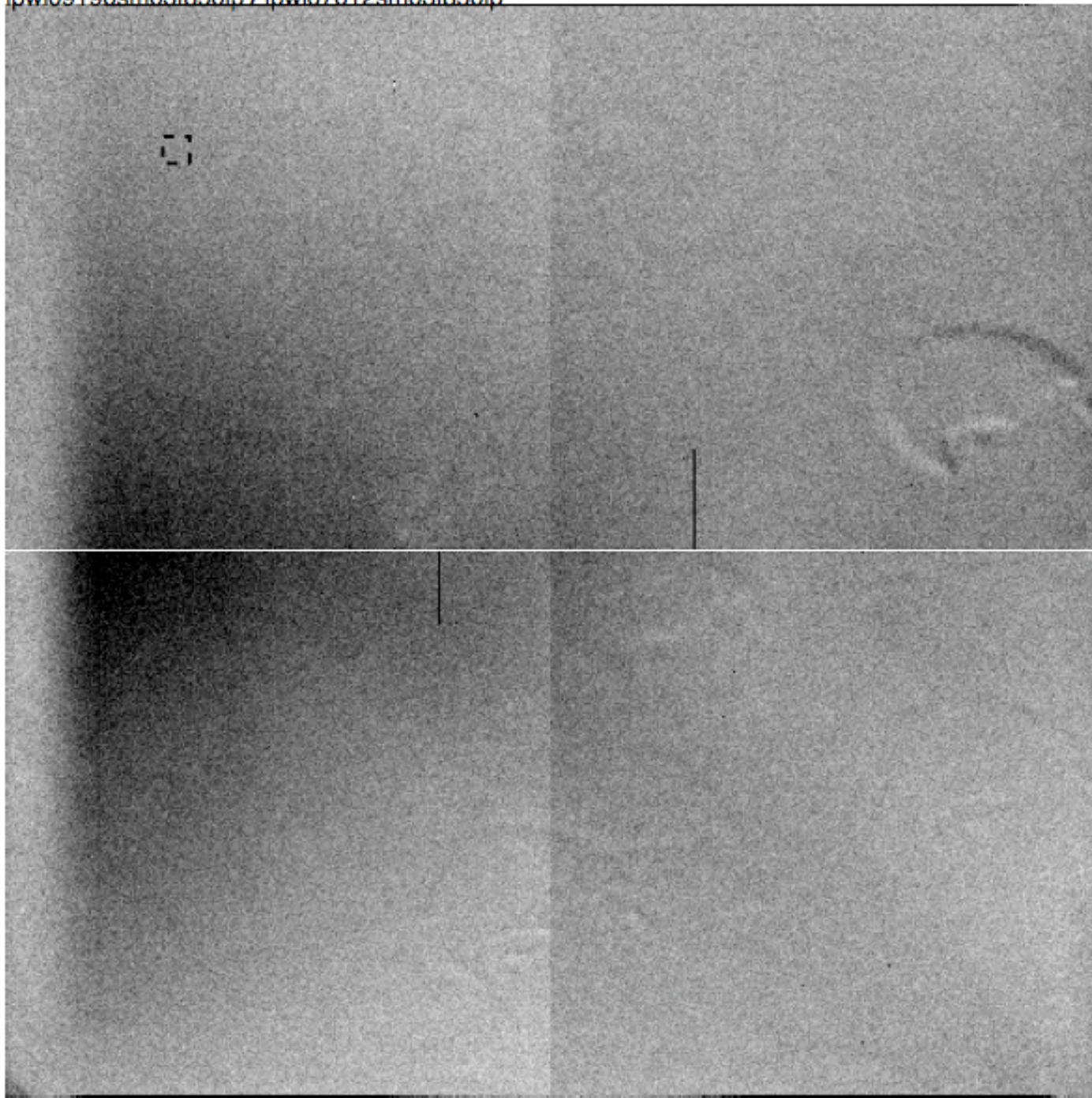


Fig. 1. The ratio for F850LP of the sum of three internal lamp images obtained on day 190 in 2009 (lpwi09190sm03f850lp) to a similar sum obtained on day 12 of 2007 (lpwi07012sm03f850lp). The new gain values from the last line of Table 1 are applied to the 2009 data. The scaling is from 0.995 to 1.005 per the grayscale reference bar at the top. The blacker region near the chip 1 and 2 boundary between amps A and C indicates a systematic difference in the flat fields before and after SM4 at the $\sim 0.4\%$ level. This difference is caused by the shutter light leak.

0.995

1.005

lpwi09191sm03f814w / lpwi07012sm03f814w

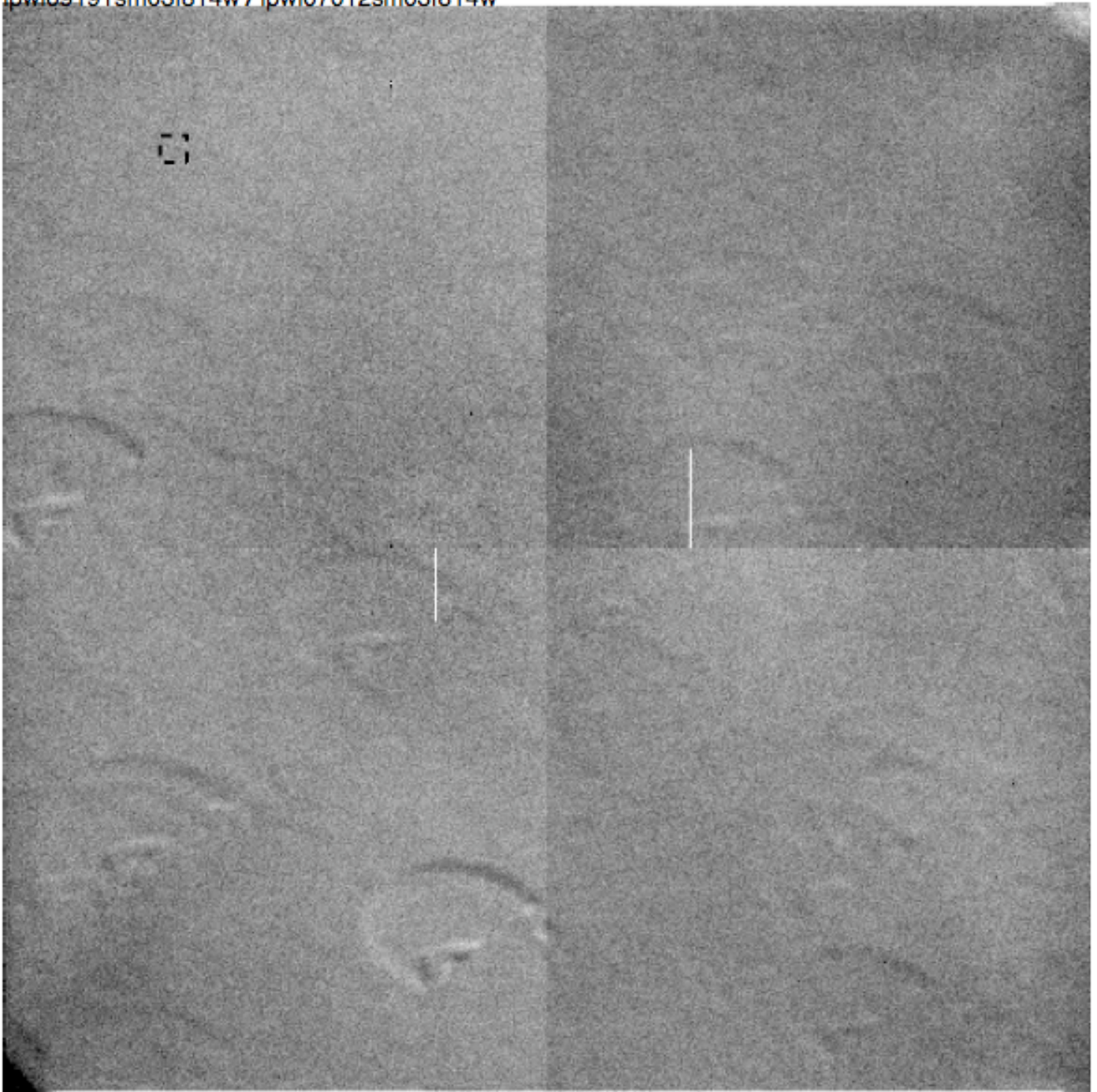


Fig. 2. As in Figure 1 for the ratio in F814W. The artifacts at the $<0.1\%$ level in both Figures are probably caused by slight differences in illumination of the filter because of mechanical positioning tolerances of the filter wheel, as suggested by the slight vignetting visible in the lower left and upper right corners. The offset of 0.12% between amps A and B is due to a 0.01% offset in the numerator amplified by a 0.11% offset of the denominator.

REFERENCES

- Bohlin, R. C., Hartig, G., & Sparks, Wm. 2002, Instrument Science Report, ACS 2002-03, (Baltimore:STScI)
- Bohlin, R. C., & Mack, J., Hartig, G., & Sirianni, M. 2005, Instrument Science Report, ACS 2005-12, (Baltimore:STScI)
- Gilliland, R. L. 2004, Instrument Science Report, ACS 2004-01, (Baltimore:STScI)
- Mack, J., Desjardins, T., & Bohlin R. 2009, Instrument Science Report, ACS 2009-xx, (Baltimore:STScI), in preparation