Instrument Science Report ACS 2014-01

Post-Flash Capabilities of the Advanced Camera for Surveys Wide Field Channel (ACS/WFC)

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April 7, 2014

Abstract

As a possible method to decrease CTE losses, the ACS/WFC post-flash capabilities have been tested and a reference file has been created. The flash level is highly varied across both WFC CCDs, with a factor of two difference in signal level between the brightest and the darkest parts of the flash. The direction of the variation is such that the post-flash is brightest far from the readout amplifiers, where the CTE trailing is stronger. The added noise and uneven correction of the post-flash, along with the success of the pixel-based and photometric CTE corrections already in place, result in a limited set of cases where post-flash may be helpful.

Introduction

In an effort to mediate the deleterious effects of low Charge Transfer Efficiency (CTE) in the Wide Field Channel (WFC) on the Advanced Camera for Surveys (ACS) the ACS team has explored the use of post-flash. Post-flash is the illumination of the ACS/WFC using an LED lamp (Optodiode OD800) housed between the CCD and the filter wheels. The ACS team has tested the capabilities of the post-flash in the past (Cox 2006), but it has not been recommended for use during science exposures until relatively recently in 2013. Post-flash can be useful in cases where the CTE effects are extremely severe, particularly in cases of very low background (Anderson and Bedin 2010, Chiaberge 2012). If there is an insufficient background level to fill the CCD charge traps responsible for severe CTE losses (Sokol and Anderson 2012), post-flash serves to increase this background. This capability will become more vital as CTE worsens over time. The complete set of WFC post-flash data have been tested and analyzed, as described below. In addition we have created a post-flash reference file that is used during CALACS (ACS image reduction pipeline) processing.

Data

For engineering reasons, we are unable to take a zero second exposure that consists of post-flash alone, so each post-flash contains 0.5 seconds of dark time at the beginning of the exposure. WFC has three post-flash lamp intensity levels: Low, Medium, and High, and two shutter positions: A and B. The camera shutter position has an effect on the post-flash intensity level due to differences in the reflection from the two sides of the shutter. The post-flash level and stability have been monitored at least once a year between 2003 and 2006 with the calibration proposals 9651, 10052, 10371, 10734, and 11047 (Cox 2006). In 2012 the ACS team took several post-flash exposures as part of the proposal 12811 to get a more varied set of post-flash data. After these observations were studied, proposal 13166 was scheduled to take the observations needed to create a post-flash reference file. Table A1 summarizes the raw data from proposals 11047, 12811, and 13166.

Analysis

The median electron levels in the post-flash exposures are very consistent from image to image when the same flash level, flash time, and shutter position are used, with a fractional variance of 0.34% for the B-shutter 13166 observations listed in Table A1. There was a 34% increase in signal from shutter A to shutter B found in the 2012 data. This is similar to what Cox found in the 2003-2006 data (Cox 2006). Figure 1 shows a 40 second post-flash image of WFC Chip 2 calibrated by CALACS (with BIASCORR, BLEVCORR, and DARKCORR processing). There is a large gradient across the image in a sunburst pattern. Chip 1 of WFC shows a similar gradient, but mirrored across the X-axis. We observed that the MED and HIGH lamp settings were much brighter than the signal needed to minimize CTE losses (50 or fewer electrons), and continued our analysis with the LOW lamp setting only.

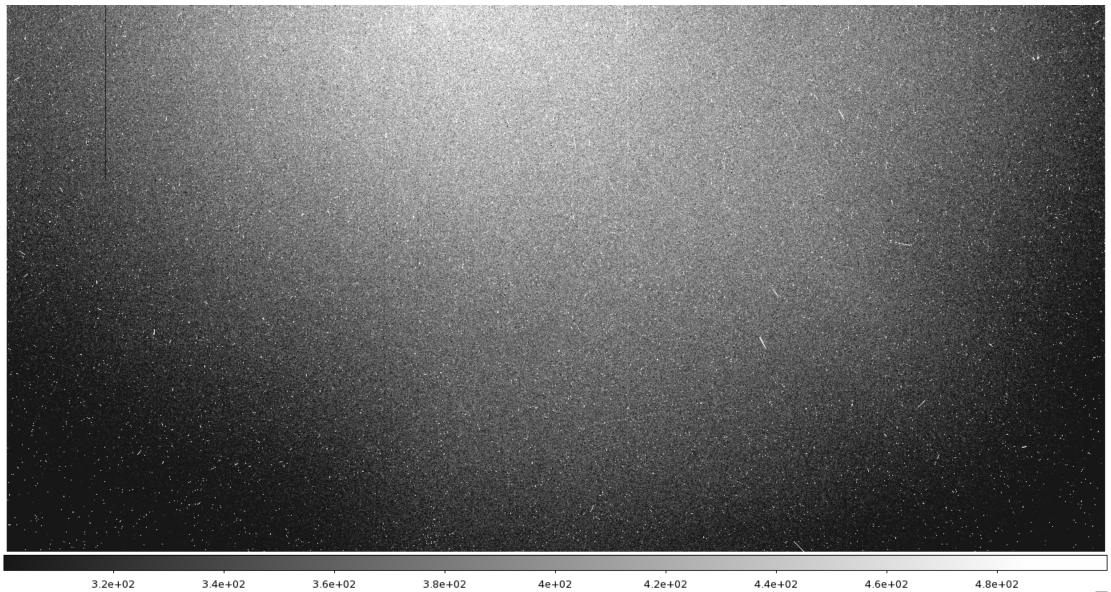

Fig. 1.— *WFC CCD 2, showing a 40 second post-flash FLT fits file. The lamp signal is uneven across the frame. CCD 1 contains a similar pattern mirrored across the X axis.*

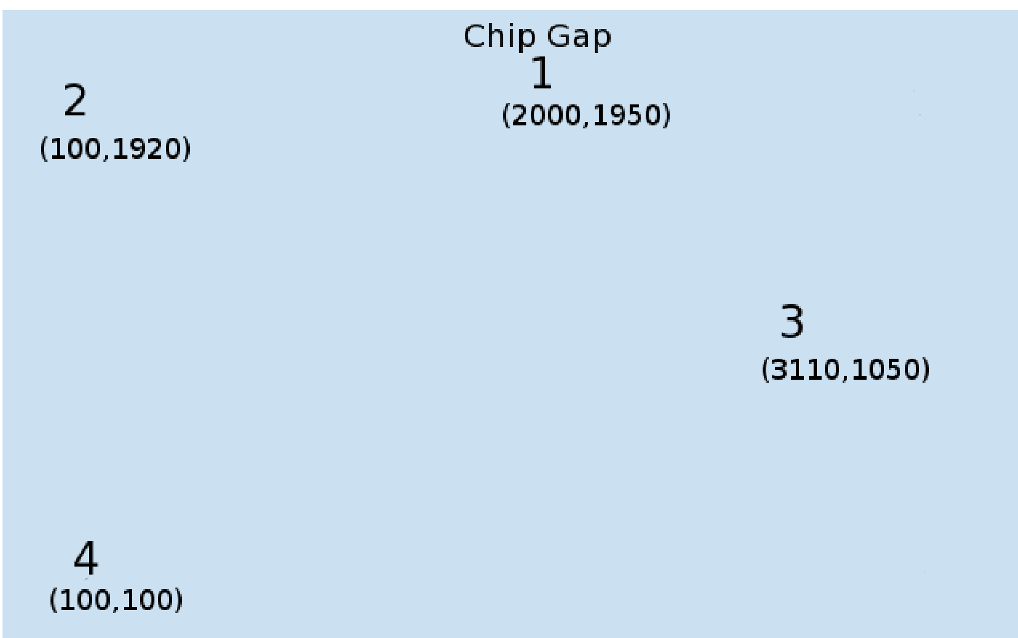

Fig. 2.— *Schematic showing the placement of boxes used to calculate the flash count rate over time for WFC CCD2. Values in parentheses show the pixel positions of the box centers.*

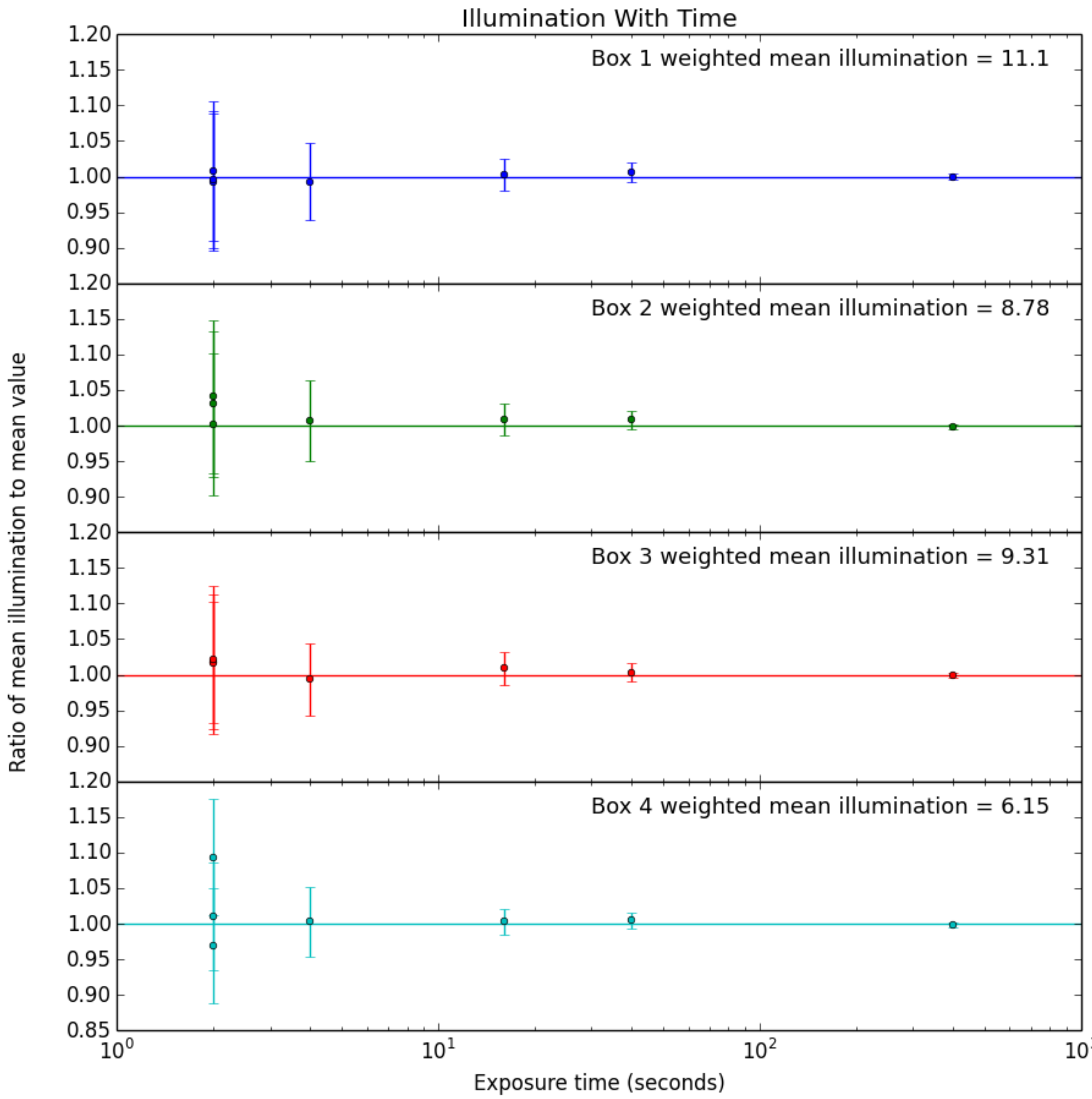

Fig. 3.— *Ratios of a weighted mean illumination to box mean value versus exposure time (seconds) for different areas of the post-flash exposure. All areas of the chip show a linear count rate.*

Linearity of Count Rate with Exposure Time

Although the counts in the post-flash images vary with position on the CCD, the count rate over exposure time is linear and very stable. In order to verify this stability, we looked at the counts in different parts of the chip for different flash exposure times. The following images were used for this analysis: jbxp05hnq, jbxp06i7q, jbxp06i8q, jbxp07fvq, jbxp07fwq, jbxp07fyq. Four 41×41 pixel boxes were placed as shown in Figure 2. A 5σ clipped average was then taken in each box in images with varying exposure times. The data and a final mean (weighted by exposure time and number of pixels) are plotted in Figure 3. The fractional variance of the median values of each box with time is within 3.5%. We see similar results with WFC CCD1.

Long Term Stability

Prior to installation, testing on the LED lamp model was performed, simulating radiation conditions in orbit (Kniffen, Reed & Kim, 2000). These tests showed degradation in the flux over time. Although no major decrease in the WFC lamp count rates was seen between 2003 and 2006, there was a significant decrease in signal between 2006 and 2012. In a 400 second shutter A exposure, the high and medium intensity signal dropped by approximately 30%, and the low intensity signal by approximately 20%. The exposures taken with shutter position B show similar drops in signal over this time period. For this reason the ACS team has decided to implement yearly monitoring of the post-flash levels. An updated post-flash reference file will also be created each year with the new images.

Reference File Creation

The observations used to create the post-flash reference file were taken as part of program 13166 (PI: Ogaz) and are listed in Table A1. We took these images with a flash exposure time of 72 seconds with the LOW lamp setting. Because of the large variation between shutter positions, the ACS team has decided to take all future post-flashed WFC exposures using shutter B.

The raw images went through several processing steps before being combined. The were first run though CALACS, with only the bias and dark subtraction set to PERFORM. As these images have over 800 electrons per pixel the distortion of the image due to CTE trailing is expected to be minimal. Therefore, we did not perform the pixel-based CTE correction.

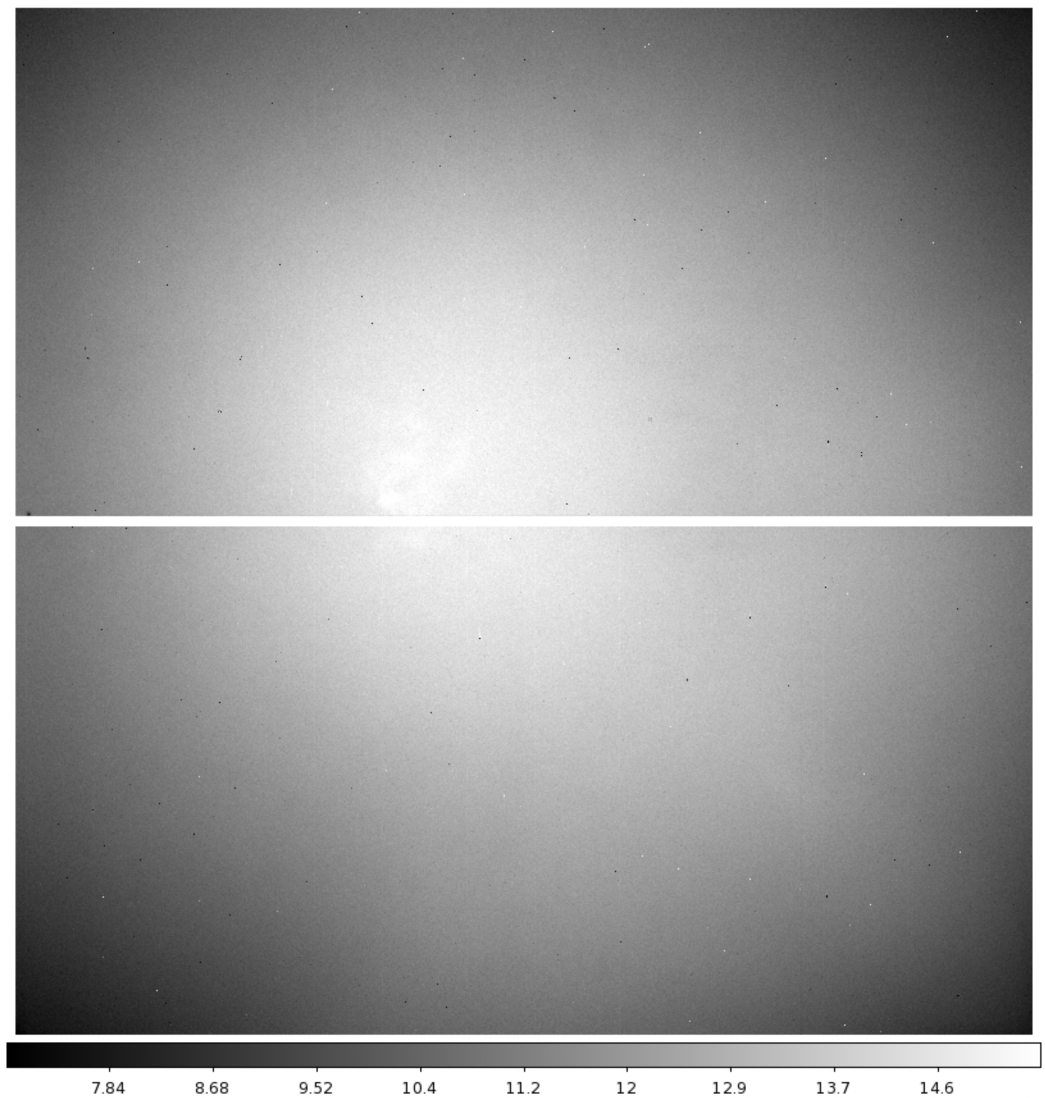

Fig. 4.— *Final post-flash reference file image, in units of electrons per second.*

After processing the images through CALACS, we median combined the 12 images with the acsrej tool (part of the acstools package) to eliminate cosmic rays. Figure 4 shows the final Cycle 20 post-flash reference file image in units of electrons per second. Given the 50% variation over the field, 14 electrons per second was chosen to represent the average flash value for the Astronomer's Proposal Tool (APT) calculations. Figure 5 shows the post-flash image as a percentage of the commanded value, 14 electrons/second, where the green area represents ±5%. The scaling on the image goes from 50% - 110%.

There are various transient hot pixel and flat artifacts present in the final post-flash

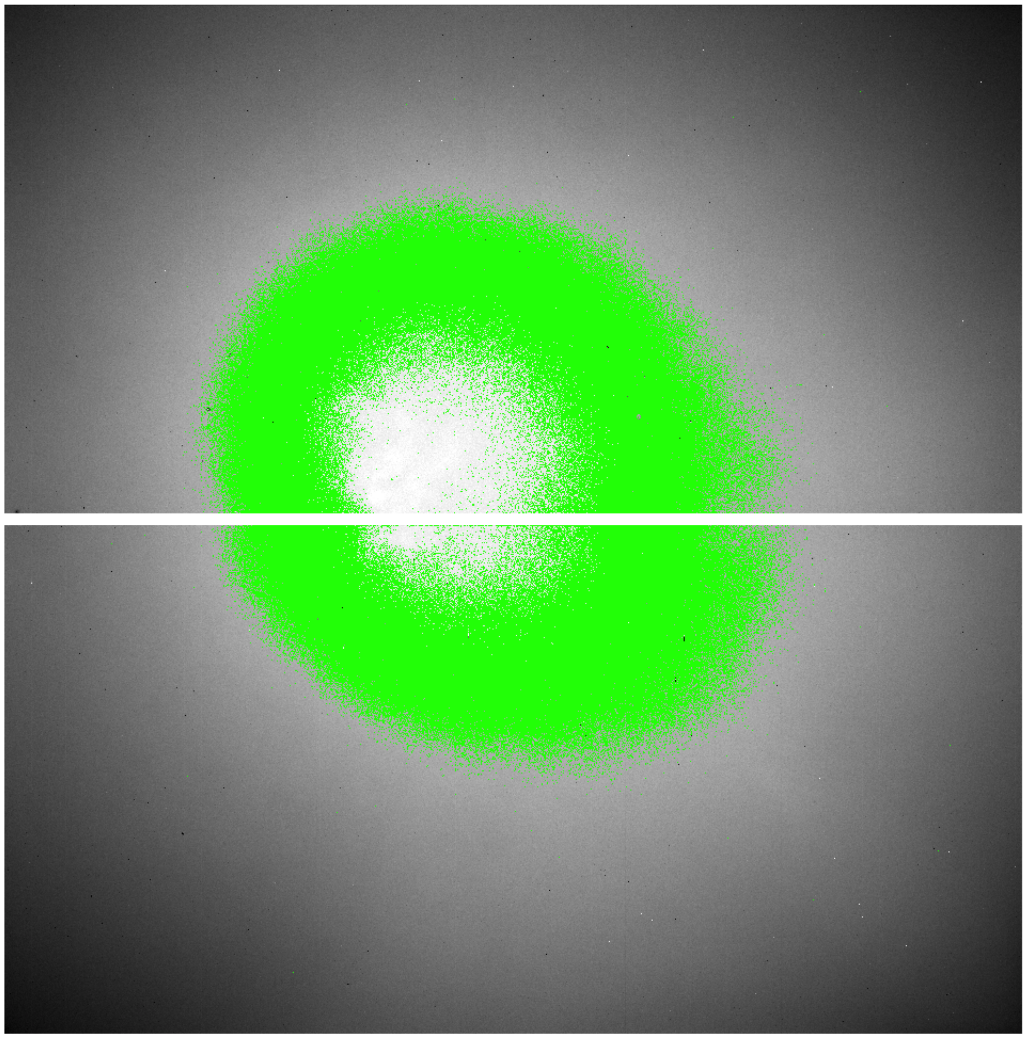

Fig. 5.— *Post-flash reference file image scaled to 14 electrons/second. The green areas cover the area of flash that is within +/- 5% of 14 electrons/second. The scaling on the image goes from 50% - 110%.*

reference image. Because we cannot separate the desired flat field artifacts from the dark artifacts, at the moment there is no efficient way to remove the dark artifacts from the final calibration image. However, the DQ flags from the post-flash image are propagated into the final science image during CALACS processing.

CALACS

The new post-flash reference file was delivered to OPUS[1] in early 2013 and is supported in CALACS as of April 4th, 2013 (CALACS version 8.1.3). The post-flash subtraction can be included or excluded by setting the FLSHCORR header keyword to OMIT or PERFORM prior to running CALACS. Subtraction is done directly after the subtraction of the superdark. A more thorough description of this can be found in the CALACS Data Handbook.

Post-Flash Recommendations

Efforts to determine when post-flash will be most useful are ongoing. At present, post-flash is not recommended for most science observations. Post-flash is unnecessary in the cases where the object is large, as these objects are self-shielded from the worst effects of CTE trailing. Very bright objects are also less affected by low CTE because of their high count rates. However, post-flash may be useful in cases of extremely faint and unresolved/compact (less than approximately 10 pixels in size) targets imaged with short exposure times and/or narrow-band filters that would result in a background of less than 20 electrons. Another possible solution is to place your object near the readout amplifier, thereby reducing the effects of low CTE. The ACS/WFC Exposure Time Calculator (ETC) has now been modified to include a post-flash exposure level, and will issue a warning when the background falls below 20 electrons. The ETC does not currently account for CTE, so the user must manually reduce the brightness of their sources in order to obtain the effective signal to noise ratio. For point sources this adjustment can be estimated using the equations from the ACS 2012-05 ISR (Chiaberge 2012), which the ACS team has incorporated into a web tool[2]. In future cycles as CTE degradation worsens, post-flash may be useful in a wider variety of cases. Users are encouraged to periodically check the ACS website for updates.

Acknowledgments

The authors would like to thank Jay Anderson and Linda Smith, as well as the ACS Team for their help and feedback.

[1] http://www.stsci.edu/hst/observatory/crds/SIfileInfo/ACS/reftablequeryindex

[2] http://www.stsci.edu/hst/acs/performance/cte/ctecorr.py

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Appendix A - Data

Please refer to the Data section for further discussion.

File	Shutter Position-Flash Intensity	Flash Time (seconds)	Median of FLT (electrons)
PID 11047 - PI Cox - 2006 Observations			
j9uv03vcq	A-HIGH	400	41581
j9uv03veq	A-HIGH	400	41478
j9uv03vgq	A-MED	400	32027
j9uv04y6q	A-LOW	400	4678
j9uv04yaq	B-HIGH	400	56238
j9uv04ycq	B-HIGH	400	56219
PID 12811 - PI Chiaberge - 2012 Observations			
jbxp01isq	A-OFF	0	-6.751
jbxp01itq	A-OFF	0	-9.223
jbxp02j1q	A-OFF	0	-3.509
jbxp02j2q	A-OFF	0	-4.814
jbxp03gbq	A-MED	400	22475
jbxp03gdq	A-MED	400	22521
jbxp04ekq	B-HIGH	400	39187
jbxp04erq	A-OFF	0	1696
jbxp04etq	A-HIGH	400	29201
jbxp05hmq	A-MED	40	2273
jbxp05hnq	A-LOW	40	347.1
jbxp06i7q	A-LOW	16	138.2
jbxp06i8q	A-LOW	4	32.77
jbxp07fvq	A-LOW	2	17.56
jbxp07fwq	A-LOW	2	16.71
jbxp07fyq	A-LOW	2	12.77
jbxp08gwq	A -LOW	400	3495
jbxp08gxq	A-MED	2	112.4
PID 13166 - PI Ogaz - 2012 Observations			
jc4802hhq	A-LOW	72	624.4
jc4804hpq	A-LOW	72	625.7
jc4806ihq	A-LOW	72	629.1

File	Shutter Position-Flash Intensity	Flash Time (seconds)	Median of FLT (electrons)
PID 13166 - PI Ogaz - 2012 Observations (Cont.)			
jc4808irq	A-LOW	72	629.6
jc4810j1q	A-LOW	72	629.4
jc4812kfq	A-LOW	72	628.7
jc4814kzq	A-LOW	72	629.1
jc4816llq	A-LOW	72	629.1
jc4818lxq	A-LOW	72	628.9
jc4820moq	A-LOW	72	629.0
jc4822ntq	A-LOW	72	628.8
jc4823bpq	B-LOW	72	836.3
jc4823brq	B-LOW	72	838.9
jc4823btq	B-LOW	72	839.5
jc4824byq	B-LOW	72	844.6
jc4824c0q	B-LOW	72	842.7
jc4824c2q	B-LOW	72	845.4
jc4825b7q	B-LOW	72	842.7
jc4825b9q	B-LOW	72	840.2
jc4825bbq	B-LOW	72	842.9
jc4826bgq	B-LOW	72	836.4
jc4826biq	B-LOW	72	838.2
jc4826bkq	B-LOW	72	839.6

Table A1: *Filename, shutter position, flash intensity, flash time, and median value of all post-flash images used in our analysis and used to create the post-flash reference image. These values are measured in CCD 2 of WFC. Values from CCD 1 are similar.*