The WFC3/UVIS Reference Files : 2. Biases and Darks

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ABSTRACT

Bias and dark reference files for the Wide Field Camera 3 (WFC3) UVIS flight detector were assembled from ground data acquired in the final thermal vacuum campaign at the Goddard Space Flight Center (GSFC). These represent the first generation of reference files for the UVIS channel and will serve to calibrate the on-orbit data from the early phase of the fourth Servicing Mission Observatory Verification (SMOV4). In this report, we present our methodology for assembling the bias and dark reference data, tabulate the resulting reference files, and discuss their overall features. We also discuss the assignment of their data quality flags. The most up-to-date reference files are available on the STScI WFC3 Web site.

1. Introduction

We have assembled bias and dark reference files for the WFC3 UVIS-1′ flight detector from the calibration data obtained in the third and final thermal vacuum campaign (TV3) at GSFC in Feb-Apr 2008. In this report, we focus only on the biases and darks acquired in the standard four-amplifier read-out mode (binnings of 1, 2, and 3), and when possible, for both Main Electronics Boxes (MEB1 and MEB2). All the files have been delivered to the Calibration Database System (CDBS). These first-generation files will have a short lifetime since they will be updated early in the SMOV4 campaign (and throughout), as some WFC3 programs include monitors of bias and dark frames. The WFC3/UVIS reference pixel-to-pixel flat fields are presented in Sabbi et al. (2008) and the scripts used to generate the entire WFC3/UVIS reference dataset are described in detail in Martel et al. (2008a).

2. The Bias and Dark Reference Files

Before generating the bias and dark reference files, the CCD Characteristics Table (header keyword CCDTAB and file name *_ccd.fits) and the Bad-Pixel Table (keyword BPIXTAB and file name *_bpx.fits) were first updated with the most up-to-date values for the gains, readnoise, saturation level, and bad columns (flag of 4). These values can be found in the most recent WFC3 Instrument Science Reports publicly available on the STScI WFC3 Web site. The final tables for processing the TV3 data are: s9703171i_ccd.fits and s9a1301ni_bpx.fits. For the cosmic ray rejection, the sky value was calculated as the mode of the frames.

We then searched the WFC3 ground database and compiled all the bias and dark frames taken over the TV3 campaign. Priority was given to frames taken in the standard readout configuration (four amplifiers ABCD, commanded gain=1.5, and binning of 1x1) and at the IUVDETMP temperature of -82C, the nominal on-orbit operating temperature. Binned biases and darks (2x2 and 3x3) were also assembled. In order to calibrate some flat fields that were acquired at a "warm" detector temperature of -49C, a separate set of warm biases and darks was also compiled. Even though WFC3 will be operated on MEB2 (also called Side 2) in orbit, the data from the two sides were combined separately to avoid mixing of any possible side-dependent effects in the final reference file. Dark frames contaminated with the bowtie anomaly (Baggett et al. 2008) or taken in charge injection mode were rejected.

The bias and dark reference files were then generated with the Python scripts described in Martel et al. (2008a). The final bias frames are in units of counts and their overscan regions are intact but set to a value of zero. The dark frames are in units of e⁻/sec and all their overscans are trimmed. The resulting set of reference files is tabulated in Tables 1 and 2; all the files have been delivered to the CDBS and uploaded to the *iref* directory at the Institute. Total integration times for the dark frames range from 200 sec to 18000 sec. These superdarks, fully processed with *calwf3* (Version 1.1; Oct 10, 2008) and corrected with a superbias (itself created from over 60 input frames), supersede those analyzed in Martel et al. (2008b). An examination of the superdarks confirms the presence of the glow along the horizontal edge of the AB chip for binnings of 2 and 3 and along the edge of the CD chip for a binning of 1. Histograms of the dark current rate for the nominal on-orbit detector configuration are shown in Fig. 1 for each quadrant. The MEB1 distributions have significantly better S/N ratios than their MEB2 counterparts because of their greater total integration times (a factor of 4.5). The mean dark rate for the four quadrants of the reference files, measured from the mode of the Gaussian fits to the distributions, is 0.17 e⁻/hour for MEB1 and 0.52 e⁻/hour for MEB2, although with greater uncertainty.

Table 1: Bias Reference Files from the TV3 Ground Campaign

File	Number of Input Frames	Amplifiers	Binning	Temperature	MEB
s9j1552ti_bia.fits	12	ABCD	1	-49C	1
s9h15406i_bia.fits	64	ABCD	1	-82C	1
s9j15530i_bia.fits	22	ABCD	1	-49C	2
s9h15408i_bia.fits	63	ABCD	1	-82C	2
s9h15409i_bia.fits	15	ABCD	2	-82C	1
s9h1540ai_bia.fits	19	ABCD	2	-82C	2
s9h1540bi_bia.fits	36	ABCD	3	-82C	1
s9h1540ci_bia.fits	38	ABCD	3	-82C	2

Table 2: Dark Reference Files from the TV3 Ground Campaign

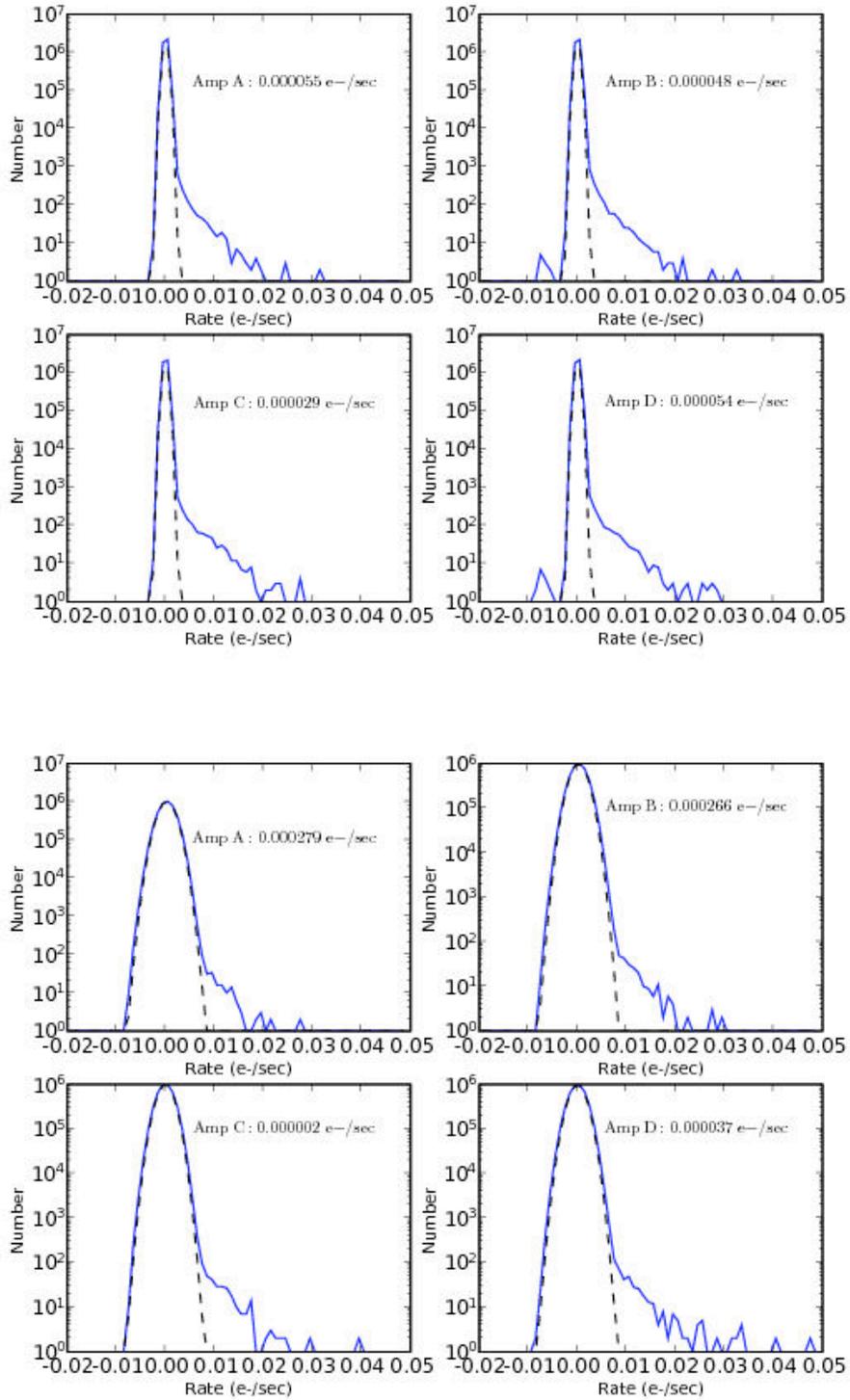| File	Number of Input Frames (Total Time)	Amplifiers	Binning	Temperature	MEB
s9q1628ci_drk.fits	2 (200 sec)	ABCD	1	-49C	1
s9q1628di_drk.fits	6 (18000 sec)	ABCD	1	-82C	1
s9q1628ei_drk.fits	3 (1200 sec)	ABCD	1	-49C	2
s9q1628fi_drk.fits	4 (4000 sec)	ABCD	1	-82C	2
s9q1628gi_drk.fits	2 (2000 sec)	ABCD	2	-82C	2
s9q1628hi_drk.fits	2 (2000 sec)	ABCD	3	-82C	2

Figure 1: Histograms of the dark current rate in each quadrant of the dark reference files (-82C, ABCD, binning of 1x1) for MEB1 (top) and MEB2 (bottom). The dashed line is a Gaussian fit to the peak.

3. The Data Quality (DQ) Flags and Arrays

3.1 General Comments

Populating the DQ arrays (extensions 3 and 6) with the appropriate flags is an important step in the creation of the reference files. These flags may ultimately determine the quality of the output science products. There are several subtleties in the behavior of *calwf3* in treating the DQ arrays. We elaborate on some of these in the following and clarify the strategy that we adopted in setting the flags in the ground and on-orbit bias and dark reference files. A complete list of the WFC3 data quality flags is available in the WFC3 Data Handbook (Kim Quijano et al. 2009).

In the header of all the individual input frames used to generate the WFC3/UVIS reference files, the DQICORR switch is set to PERFORM. The bad pixels defined in BPIXTAB (_bpx.fits; flag of 4 only) will then be flagged in the DQ arrays of the final, CR-rejected output file (_crj.fits if CRCORR is also set to PERFORM) and the affected pixels and columns will have a value of zero in the final science extensions (1 and 4). If DQICORR is set to OMIT, the bad pixels will not be flagged in the DQ arrays of the output file even though they may be bad or unusable.

Setting DQICORR to PERFORM also has another benefit: saturated pixels in the overscan regions (in particular, the parallel virtual overscan which is occasionally hit by cosmic rays) will be flagged and ignored by the 2-dimensional serial and parallel virtual overscan fitting routine in the BLEVCORR step. If DQICORR is instead set to OMIT, then not all outliers may be rejected, which can result in an inaccurate overscan model and subtraction.

If CRCORR is set to PERFORM, as is always the case for the reference files, the *wf3rej* routine will populate the DQ arrays with values of 8192 at the location of cosmic ray (CR) hits in the output _crj.fits file. This 8192 flag basically serves to inform the user that one or more of the input images had a CR hit in a given pixel. But propagating this flag into the DQ array of the final reference file can be misleading since the flagged pixel may in fact have been fully corrected. For example, if the CR hit occurs in only 1 of 4 input images, it will be corrected using the 3 other images. In the rare instance that a pixel suffers a CR hit in each of the input images, the pixel value is assigned the sum of the sky values in the SCI extension (1 or 4), an error of zero in the ERR extension (2 or 5), and the 8192 flag in the DQ extension (3 or 6). This holds true for the current version of *wf3rej*.

As described in Martel et al. (2008a), the hot pixels are identified automatically above some user-defined threshold as part of the Python reference file generation script (not *calwf3*) and are flagged with a value of 16 in the DQ arrays of the final, CR-rejected dark reference frame. The hot pixels are not modified or replaced in the science extensions. The hot pixel flags propagate into the DQ arrays of any file subsequently calibrated with the dark reference frame, such as the flat reference file or science data.

When generating a bias ➡ dark ➡ flat field sequence with their respective nominal calibration switches set to PERFORM, all the DQ flags of the bias and dark are propagated forward into the flat field except for the CR-hit flag 8192 of the bias frame.

For example, three populations of flag 2, one from the bias reference file, one from the dark reference file, and the last from the input flat field frames themselves appear in the DQ extensions of the final, CR-rejected flat field. The CR-hit flag 8192 comes from either the input raw flat field frames themselves or from the DQ arrays of the dark reference frame.

But how do the flags of the bias, dark, and pixel-to-pixel flat field reference files propagate into the final science frame? All the flags from these three reference files propagate into the DQ extensions of the final, CR-rejected science frame (_crj.fits) with the exception of flag 8192 of the bias. Additionally, if a "delta" flat is included (DFLTFILE), its DQ flags also propagate into the DQ extensions of the CR-rejected science frame. More formally, the flags of the bias (except 8192) propagate into the _crj_tmp.fits frame (which is expressed in DNs). If DARKCORR and FLATCORR are set to PERFORM, then the _crj_tmp.fits frame is dark-subtracted, flat-fielded, and converted to units of electrons. This is the final science _crj.fits frame and its DQ extensions will include its own internally generated flags (such as the CR-hit flag 8192) as well as the inherited flags of the bias (except 8192), the dark, and the flat field.

3.2 Ground Data

In the following, we provide some details on the assignment of the DQ flags for the ground bias, dark, and flat field reference files. Essentially, for all three file types, we automatically reset their DQ extensions to zero. Hence, the DQ flags of the final, CR-rejected science frame (_crj.fits) will be entirely determined from the individual input science frames themselves and will not be inherited from any of the reference files.

For the initial set of bias reference files compiled in Table 1, we set DQICORR to PERFORM to insure that saturated pixels in the overscan areas were rejected in the overscan correction step, but then zeroed the entire DQ arrays. As a side effect, the bad pixels and columns listed in BPIXTAB have a value of zero in the final science extensions (1 and 4) but are flagged as "good" (flag of 0) in the DQ extensions (3 and 6). These bad/zero pixels in the bias will not pose a problem in subsequent science datasets, since *calwf3* will always flag them accordingly (as long as DQICORR is set to PERFORM and a BPIXTAB is specified). Also, as mentioned above, the CR-hit flag 8192 of the bias does not propagate into the DQ arrays of subsequent dark or flat field reference files or into the science data.

The DQ arrays of the dark reference files in Table 2 were also uniformly set to zero. Resetting the CR-hit flag 8192 to zero avoids the propagation of this flag into the DQ arrays of subsequent reference files, such as the flat fields, and into the science data. For this preliminary ground dataset, we also zeroed the hot pixel flag, since we do not yet possess sufficient information on the warm, hot, or unstable pixels and their behavior over periods of days, weeks, or months. The on-orbit darks will provide a good understanding of the hot pixels.

The DQ extensions of the ground reference pixel-to-pixel flat fields will also be reset to zero (Sabbi et al. 2008).

3.3 On-orbit Data

For the production of on-orbit bias and dark reference files (and flat fields), we recommend setting the calibration switches (PERFORM or OMIT) as given in Martel et al. (2008a). If DQICORR is set to PERFORM, then the DQ arrays in the final reference files should be reset to zero, except for the flags of the warm and hot pixels in the dark reference files. The warm/hot pixel data quality flag(s) will then be propagated to the flat field reference files and into the science images.

The on-orbit science images should be processed with DQICORR set to PERFORM to flag the bad pixels and columns defined in BPIXTAB and to reject saturated overscan pixels. The *wf3rej* routine will flag the CR hits from the input raw science images; this flag will not be inherited from the darks and flats since the DQ arrays of these files will have already been nulled, as recommended above. The warm and hot pixel identifications will be propagated from the dark reference files.

As a future improvement, instead of uniformly zeroing the DQ extensions of the reference files, the 8192 flag of the few pixels that suffer a CR hit in all their input frames could be preserved, particularly in the darks and flats, and allowed to propagate into the final science frame. The user will then know that these pixels are not calibrated correctly.

4. Conclusion

We have produced first-generation bias and dark reference files for the WFC3/UVIS flight detector from ground data acquired in the final thermal vacuum campaign at GSFC. These files will serve to calibrate the early, on-orbit SMOV4 science images and will be updated through the remainder of SMOV4 and Cycle 17. We have detailed our strategy for dealing with the data quality flags and have provided guidelines for processing the on-orbit reference files.

To reprocess a science dataset, the user should download the most recent reference files, generated with the latest version of *calwf3* and available on the STScI WFC3 Web site: http://www.stsci.edu/hst/wfc3/analysis/reffiles/

References

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