HST Wide Field Camera 3: Improvements to WFC3/UVIS Photometric Calibration

Catherine Gosmeyer, S. Baggett, A. Bowers, T. Dahlen, S. Deustua, D. Hammer, & J. Mack

224th Meeting, American Astronomical Society
Poster 122.03

Space Telescope Science Institute
Operated for NASA by AURA

Abstract

The Wide Field Camera 3 (WFC3) is a fourth-generation imaging instrument installed on the Hubble Space Telescope (HST) in May 2009. It contains both an IR and a UVIS channel. The latter, which covers the 200-1000nm spectral range, consists of two 2K x 4K CCD chips along with 62 spectral elements and one grism. The two CCD chips were manufactured on different foundry runs. As a result, there are differences in the two chips' properties and behaviors, such as their lithography imprint patterns, their sensitivity responses, and their measured quantum efficiency (QE), particularly in the UV. Therefore, the WFC3 team developed a chip-dependent approach to the photometric calibration, where each chip now has its own separate calibration. We discuss the impacts of this new approach and its implementation in the calibration pipeline, presenting the new zero points and header keywords, as well as the new flat fields. We also present the latest trends in the contamination monitoring, which obtains regular imaging and grism spectroscopy of the white dwarf, GRW+70, in key filters F218W, F225W, F336W, F814W, and F606W.
No contamination effects have been detected, though there is evidence for a small photometric drift (<1% over 3 years). We anticipate that these efforts will improve UV imaging with WFC3.

Photometric Stability and Contamination

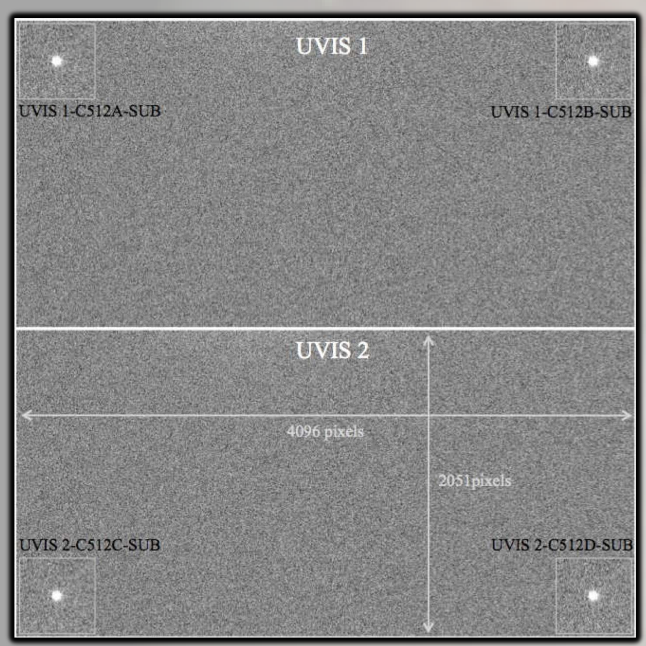

Figure 1 – The to-scale locations of the four corner 512 pixel subarrays on the WFC3 two-chip mosaic. From Kalirai, et al. 2010.

Long-term photometric trends. The white dwarf photometric standard star GRW+70 is observed periodically in a subset of filters (listed in Table 1). These observations, taken in 512x512 subarrays near the outer corners of the UVIS FOV (see Figure 1), show evidence of small photometric drifts.
Over the full five years of observations, there is a 0.2-0.3% decline per year in the red filters, and less in the UV. The drifts are steeper in chip 1 than in chip 2.
Figure 1 shows the change in flux over time in the F225W (UV) and F606W (visible), normalized to the average countrate of the first three images. Table 1 summarizes the linear fits to the data as a function of filter. The cause of the photometric trends is still under investigation (See Gosmeyer et al. 2014 for further discussion.)

No evidence of contamination. Contaminants on the instrument optics would cause a decline in photometric throughput in the UV relative to the visible. In fact, the UV photometry has remained stable to ~0.5% since launch (see Figure 2).

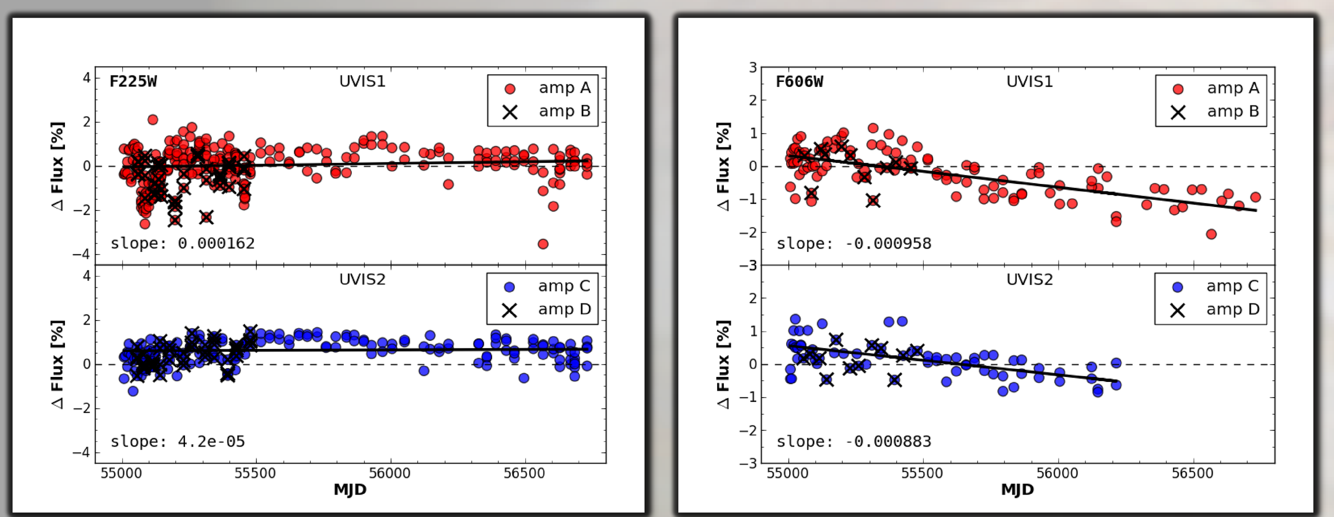

Figure 2 – Percent change in countrate in F225W (left) and F606W (right) as a function of time, from July 2009 to March 2014. Uncertainties are smaller than the plot points.

Table 1 – The slope percent change per year in key filters. Errors are <<0.001/year.

	Slope Change / Year	
Filter	*Amp A*	*Amp C*
F218W	0.164	0.084
F225W	0.082	0.016
F275W	−0.031	0.012
F336W	−0.007	0.001
F390M	−0.288	−0.010
F390W	−0.167	−0.157
F438W	−0.199	−0.168
F467M	−0.338	−0.180
F475W	−0.382	−0.242
F547W	−0.360	−0.227
F555W	−0.250	−0.160
F606W	−0.350	−0.322
F814W	−0.163	−0.134
F850LP	−0.076	−0.199

References and Additional Information

- WFC3 Main Page: www.stsci.edu/hst/wfc3 • STScI Help Desk: help@stsci.edu
- WFC3 Instrument Handbook: http://www.stsci.edu/hst/wfc3/documents/handbooks/currentIHB/wfc3_ihb.pdf
- UVIS Performance Monitoring: http://www.stsci.edu/hst/wfc3/ins_performance/monitoring/
- Deustua et al., 2014, WFC3 ISR 2014-xx, in prep
- Gosmeyer, C., et al., 2014, WFC3 ISR 2014-xx: "Update on WFC3/UVIS Contamination and Stability Monitoring", in prep.
- Kalirai, J., et al., 2009, WFC3 ISR 2009-31: "WFC3 SMOV Proposal 11450: The Photometric Performance and Calibration of WFC3/UVIS"
- Mack, J., et al., 2013, WFC3 ISR 2013-10: "In-flight Corrections to the WFC3 UVIS Flat Fields"
- Mack, J., et al., 2014, WFC3 ISR 2014-xx , in prep.
- Related Posters (http://www.stsci.edu/hst/wfc3/documents/meeting_posters/aas224):
  - WFC3: UVIS Dark Calibration; Matthew Bourque (Session 122.04)
  - WFC3/UVIS Charge-Transfer-Efficiency Losses: Mitigation and Correction; Jay Anderson (Session 122.05)
  - WFC3: News Regarding IR Backgrounds, Spatial Scans, and Cycle 22 Phase 2 Advice; John MacKenty (Session 122.06)

Two-Chip Solution

Photometric calibration is now chip-dependent. The two UVIS chips are two independent detectors, cut from different silicon wafers. To better track the individual behavior of the two chips, including inherent differences in color terms, the WFC3 team has developed a chip-dependent approach to the photometric calibration, such that each chip will now have a unique set of zeropoint values (Deustua et al. 2014), and each chip/filter combination will have its own flat.
New header keywords will be implemented. In applying this change, two new header keywords, PHTFLAM1 and PHTFLAM2, the inverse sensitivity for chip 1 and chip 2 (in units of ergs cm^{-2} $Å^{-1}$ DN^{-1}), will be written to the image headers via the IMPHTTAB image photometry reference file. The pipeline program CALWF3 will be updated with a new calibration switch FLUXCORR, which will scale chip 2 by the ratio of the inverse sensitivity of the two chips (PHTRATIO). The resulting FLT and DRZ products (in electrons/sec) will therefore be continuous across the full detector field of view.
Users will apply a single zeropoint (corresponding to chip 1) to the full frame image. For targets which may have significant color terms, users performing photometry on chip 2 should back out the PHTRATIO correction before applying chip-specific zeropoints and/or color terms.
Implementation of these changes to CALWF3 is expected in Fall 2014.

Two-Chip Zeropoints and Header Keywords

HEADER KEYWORD	DESCRIPTION
PHOTFLAM	Inverse sensitivity for UVIS = PHOTFLAM1
PHTFLAM1	Inverse sensitivity for UVIS1 + filter
PHTFLAM2	Inverse sensitivity for UVIS2 + filter
PHTRATIO	PHTFLAM1 / PHTFLAM2

Table 2 – New header keywords for chip-dependent photometry. Inverse sensitivities are in units of ergs cm^{-2} $Å^{-1}$ DN^{-1}.

CALWF3 SWITCH	DESCRIPTION
PHOTCORR = PERFORM	PHTRATIO is calculated and new keywords are populated in the header
FLUXCORR = PERFORM	Chip 2 is scaled to chip 1

Table 3 – New CALFW3 switches for chip-dependent photometry.

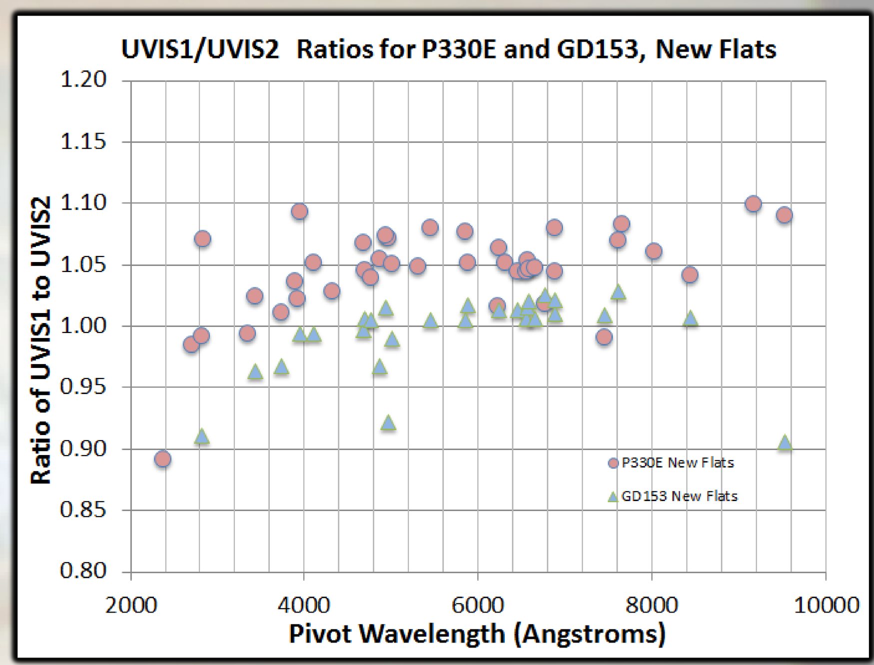

Figure 3 – WD and G-star photometry track chip ratios consistently.

New Flat Fields

Improved UV flat fields will soon be available. Four UV filters (F218W, F225W, F275W, F280N) were obtained in ambient conditions and must be corrected using inflight data. By stepping photometric standards across the field of view, we sample both low and high sensitivity regions in the flat field 'fishscale' pattern. Typical residuals are +/-3.3%, as shown in Figure 4 for F218W. These are now corrected to +/-1.5% in the new flats. (See Mack et al., 2014.)
Chip-dependent flat fields have been generated for the "Two-Chip Solution". Two key differences with respect to the flats in the pipeline include:
1.) L-flats are computed from photometry on a single chip only. That is, they exclude stars dithered from one chip to another. The resulting L-flats have a slightly lower rms than the full detector solutions, and typical differences are less than 0.5%.
2.) Instead of normalizing both chips to a small region on chip 1, the flats are now independently normalized using the median value for each chip. CALWF3 will then scale chip 2 to chip 1 using the chip-specific PHOTFLAM values derived from white dwarf standards.

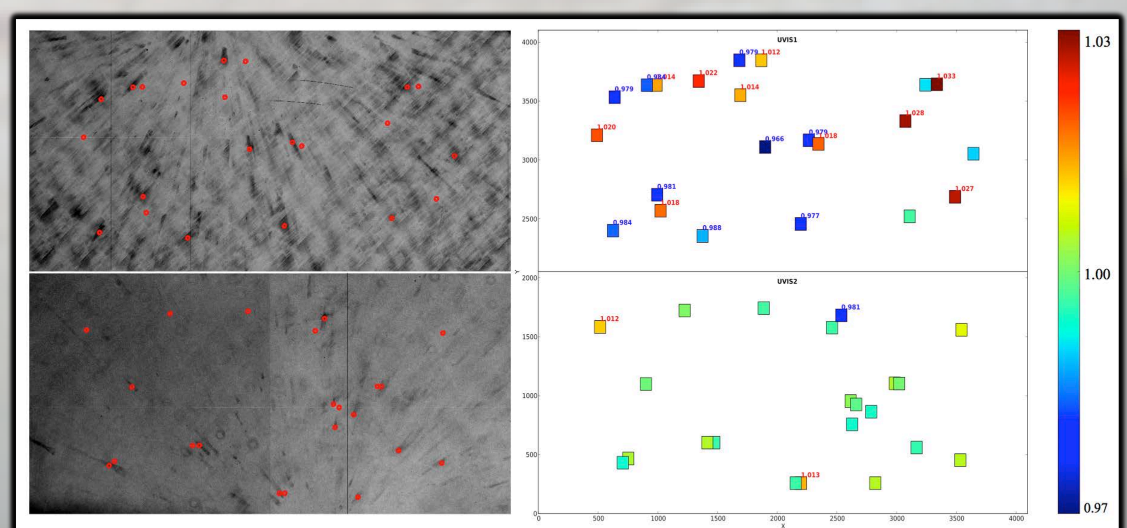

Figure 4 – F218W flat field (left) and photometric residuals (right) computed from stepping a star across the detector. Dark portions of the fishscale pattern represent regions of lower QE in the flat, and these produce photometry which is systematically too faint using the pipeline flats.

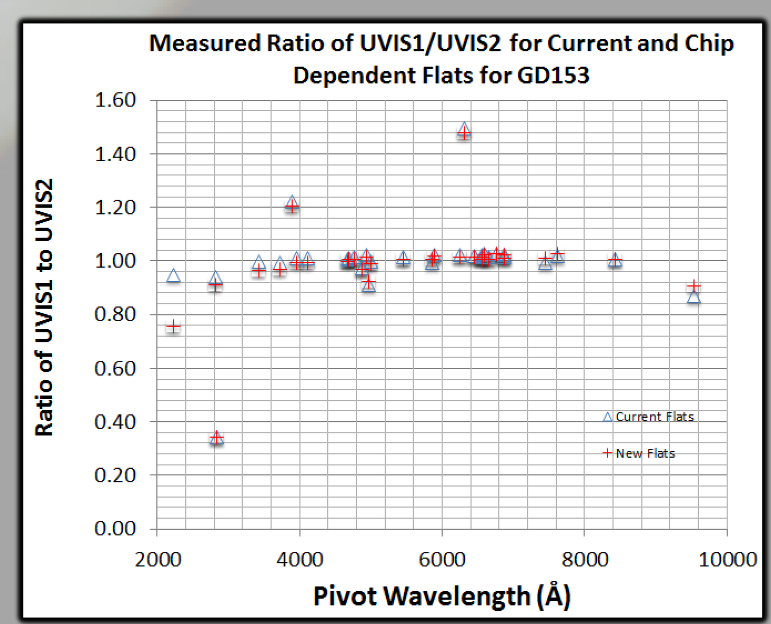

Figure 5 – Current and new chip-dependent flats are consistent.