SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

Instrument Science Report WFC3 2009-27

WFC3 SMOV Proposal 11422/ 11529: UVIS SOFA and Lamp Checks

S.Baggett, E.Sabbi, and P.McCullough
November 12, 2009

ABSTRACT

This report summarizes the results obtained from the SMOV SOFA (Selectable Optical Filter Assembly) and internal lamp check proposals, programs designed to verify the operability of the SOFA wheels and the health of the primary and backup UVIS internal lamps. Tungsten flatfields were successfully acquired in one filter from each filter wheel, each wheel performing as expected. Flatfield features were similar to those seen in ground testing; some flatfields showed minor changes at the level of <1% peak to peak (F657N, F656N, F645N) but most flatfield features were <0.5% peak to peak. The window 'droplet' features are found to have shifted by of order 1 pixel after launch but have been stable since then. The output of both lamps is 10-15% higher on-orbit than on the ground; as on the ground, the spare lamp (#1) is 12-14% fainter than the primary UVIS tungsten lamp (#3).

Introduction

Following the servicing mission in May 2009, during which WFC3 (Wide Field Camera 3) was installed, the telescope and all its instruments underwent a commissioning period called SMOV (Servicing Mission Observatory Verification) in order to validate and prepare them for science observing. Program 11422 performed the SOFA test using the UVIS channel primary lamp and proposal 11529 repeated the test using the UVIS channel spare lamp. The IR primary and spare lamps were tested in two other proposals, 11423 and 11543, respectively, and the results reported are elsewhere (Baggett 2009).

The UVIS SOFA and lamp tests verified the operability of the internal tungsten lamps and each of the 12 SOFA filter wheels by taking an internal flatfield in one filter from each wheel. A subsequent proposal, 11432 - UVIS Internal Flats, obtained additional flatfields in all UVIS filters, providing more complete wavelength coverage. The SMOV plan required that the SOFA wheels and at least one tungsten lamp be operating properly before the CCD functional test (#11419) could be started and on-orbit commissioning of WFC3 could proceed. A side benefit of the SOFA test data sets included acquisition of an initial baseline of internal flatfields over a broad wavelength range, from which on-orbit updates for the calibration pipeline flatfield reference files can be determined.

The overall flux levels of the tungsten lamps and the flatfield illumination patterns were compared to results based on ground test data to quantify the performance of the bulbs and to check for any changes in filter structures, vignetting within field, etc. Because the internal calibration subsystem has a more collimated beam than the external science beam (~f/300 vs f/31, respectively), the internal flatfields accentuate features that are not normally seen in science images. This report summarizes the observing program and analysis results from WFC3 SMOV SOFA and tungsten lamp proposals 11422 and 11529.

Data

Proposal Structure

The SOFA test consisted of two visits, six flatfields per visit, for a total of twelve flatfields. The same twelve filters were used in each proposal, only the tungsten bulb changed: program 11422 used the primary lamp while program 11529 used the spare lamp. Of the two lamps assigned prelaunch to the UVIS channel, #1 and #3, the latter was chosen as the primary bulb based on ground test data which showed it was ~15% brighter than lamp #1 (Baggett 2008). The primary lamp is hardcoded into APT (Astronomer's Proposal Tool) such that a request for an internal WFC3 tungsten flatfield will automatically invoke the use of lamp #3.

In order to evaluate state of the spare UVIS bulb, special commanding instructions were required in APT (Dashevsky, priv.comm.). Specifically, the off-nominal lamp visit must take place within the same alignment and be bracketed by spacecraft (S/C) exposures which invoke the special commanding instruction EITLAMP. The first S/C exposure is used to activate the spare lamp by specifiying QESIPARMs for the power state and lamp desired: LAMPWR=ON and LAMP=<value>. Similarly, the last S/C exposure is used to turn the spare lamp off by specifying the appropriate power state and lamp number QESIPARMs: LAMPWR=OFF and LAMP=<same value as in the 1st exposure>. The QESIPARM <value> to use for each detector/lamp combination are: UV01, UV02, UV03, UV04 for lamp 1, 2, 3, and 4, respectively, UV13 to use lamps 1+3 simultaneously, and UV24 to use lamps 2+4 simultaneously. The latter two options are included here for completeness but these were not used on the ground and there is currently no expectation of using two lamps at once. For details of the APT implementation, please refer to the proposal available in multiple formats from the HST Proposal Information page (http://www.stsci.edu/hst/scheduling/program_information).

All exposures were taken in the default full-frame, four-amp, unbinned readout mode. The specific filters used in the UVIS SOFA and tungsten lamp check proposals were chosen based upon a variety of factors: reasonable countrate with calsystem tungsten lamp (i.e., no long exposure times), science priority of the filter, overall coverage of UVIS wavelength regime, and slot location in the wheel. A log of observations is provided in Table 1, along with filter, wheel and slot location of the filter, exposure time, lamp number, date and time, and whether the image was pre- or post-launch (TV3 vs SMOV).

Images and Calibrations

All files were processed through the standard OPUS pipeline, generating the raw fits files, then reduced with *calwf3*. The on-orbit data were processed with *calwf3* 1.3 (13-Mar-2009) while the ground flatfields were processed with *calwf3* 1.4.1 (27-Apr-2009). Since the differences between the two *calwf3* versions were neglibible for UVIS observations, the on-orbit files were not reprocessed.

The calibration steps for both ground and on-orbit data included the data quality initialization, the overscan correction, and bias and dark file subtractions. As the SOFA test data were acquired before the generation of any post-launch reference files, the ground-based reference files were used for both ground and on-orbit data. We used t2c1533si_bpx.fits, t291659mi_ccd.fits, q911321oi_osc.fits, t4o1622si_bia.fits, t3420177i_drk.fits, for the bad pixel table, ccd table, overscan table, superbias file, and superdark file, respectively.

Table 1. Summary of images used for the SMOV SOFA and lamp checks. Listed are image name, filter, wheel and slot number, exposure time, lamp number, date and time of the observation, and epoch, either SMOV or TV3. Lamp 3 is the primary bulb.

image	filter	wheel/slot	exptime	lamp	date-obs	time-obs	epoch
iaa301ibq_flt.fits	F656N	1 / 4	320.0	3	2009-06-11	21:18:45	SMOV
iaa301icq_flt.fits	F200LP	2 / 3	1.0	3	2009-06-11	21:26:39	SMOV
iaa301ieq_flt.fits	F657N	3 / 3	50.0	3	2009-06-11	21:40:21	SMOV
iaa301ifq_flt.fits	F645N	4 / 4	73.0	3	2009-06-11	21:43:39	SMOV

image	filter	wheel/slot	exptime	lamp	date-obs	time-obs	epoch
iaa301ihq_flt.fits	F625W	5 / 1	4.4	3	2009-06-11	21:58:42	SMOV
iaa301iiq_flt.fits	F606W	6 / 2	3.6	3	2009-06-11	22:01:15	SMOV
iaa302j3q_flt.fits	F555W	7 / 1	11.4	3	2009-06-11	23:58:21	SMOV
iaa302j4q_flt.fits	F763M	8 / 4	4.3	3	2009-06-12	00:00:55	SMOV
iaa302j6q_flt.fits	F467M	9 / 3	300.0	3	2009-06-12	00:14:44	SMOV
iaa302j7q_flt.fits	F475X	10 / 3	11.4	3	2009-06-12	00:22:15	SMOV
iaa302j9q_flt.fits	F350LP	11 / 2	1.0	3	2009-06-12	00:36:11	SMOV
iaa302jaq_flt.fits	FQ889N	12 / 3	39.0	3	2009-06-12	00:38:40	SMOV
iu231105r_08098080136_flt.fits	F656N	1 / 4	420.0	3	2008-04-07	07:48:35	TV3
iu23120gr_08099020500_flt.fits	F200LP	2 / 3	1.3	3	2008-04-08	01:59:36	TV3
iu23140cr_08096113613_flt.fits	F657N	3 / 3	55.8	3	2008-04-05	11:27:08	TV3
iu23120er_08099014815_flt.fits	F645N	4 / 4	94.0	3	2008-04-08	01:44:17	TV3
iu231208r_08099011342_flt.fits	F625W	5 / 1	5.7	3	2008-04-08	01:11:12	TV3
iu231207r_08099011342_flt.fits	F606W	6 / 2	4.7	3	2008-04-08	01:08:36	TV3
iu23170dr_08103134242_flt.fits	F555W	7 / 1	13.0	3	2008-04-12	13:31:48	TV3
iu23130gr_08098113426_flt.fits	F763M	8 / 4	6.1	3	2008-04-07	11:31:24	TV3
iu23130vr_08098150514_flt.fits	F467M	9 / 3	442.0	3	2008-04-07	14:54:53	TV3
iu23300cr_08104035336_flt.fits	F475X	10 / 3	14.9	3	2008-04-13	03:48:27	TV3
iu233005r_08104031845_flt.fits	F350LP	11 / 2	1.2	3	2008-04-13	03:05:41	TV3
iu231407r_08099071749_flt.fits	FQ889N	12 / 3	54.0	3	2008-04-08	07:14:31	TV3
iabr01oiq_flt.fits	F656N	1 / 4	350.0	1	2009-06-13	03:53:40	SMOV
iabr01ojq_flt.fits	F200LP	2 / 3	1.1	1	2009-06-13	04:02:04	SMOV
iabr01olq_flt.fits	F657N	3 / 3	55.0	1	2009-06-13	04:15:47	SMOV
iabr01omq_flt.fits	F645N	4 / 4	80.0	1	2009-06-13	04:19:10	SMOV
iabr01ooq_flt.fits	F625W	5 / 1	4.8	1	2009-06-13	04:34:20	SMOV
iabr01opq_flt.fits	F606W	6 / 2	3.9	1	2009-06-13	04:36:53	SMOV
iabr02owq_flt.fits	F555W	7 / 1	12.0	1	2009-06-13	05:44:48	SMOV
iabr02oxq_flt.fits	F763M	8 / 4	4.6	1	2009-06-13	05:47:22	SMOV
iabr02ozq_flt.fits	F467M	9 / 3	320.0	1	2009-06-13	06:01:11	SMOV
iabr02p0q_flt.fits	F475X	10 / 3	12.0	1	2009-06-13	06:09:02	SMOV
iabr02p2q_flt.fits	F350LP	11 / 2	1.1	1	2009-06-13	06:22:58	SMOV
iabr02p3q_flt.fits	FQ889N	12 / 3	42.0	1	2009-06-13	06:25:28	SMOV

image	filter	wheel/slot	exptime	lamp	date-obs	time-obs	epoch
iu231704r_08103124253_flt.fits	F555W	7 / 1	13.0	1	2008-04-12	12:31:59	TV3

Flatfield Features

In order to help easily identify any areas of change, image ratios were formed between the new on-orbit data and the ground test data, as listed in Table 1, after first scaling each flatfield by exposure time. The resulting ratios for tungsten lamp #3 are shown in Figure 1; for comparison, greyscale images of the individual on-orbit flatfields are shown in Figure 2 (additional examples of ground data are available in Sabbi, 2008). Note: the majority of ground test internal flatfields were taken using lamp #3; only one lamp #1 filter (F555W) had a corresponding ground flatfield.

Figure 1: Image ratios of the twelve on-orbit internal flatfields taken with lamp 3 to a matching flatfield from the ground testing. Greyscale stretch is +/-5%. From left to right and top to bottom are the filters (in wheel order): F656N, F200LP, F657N, F645N, F625W, F606W, F555W, F763M, F467M, F475X, F350LP, and FQ889N. Wheel 1 is furthest, wheel 12 closest, to the detector.

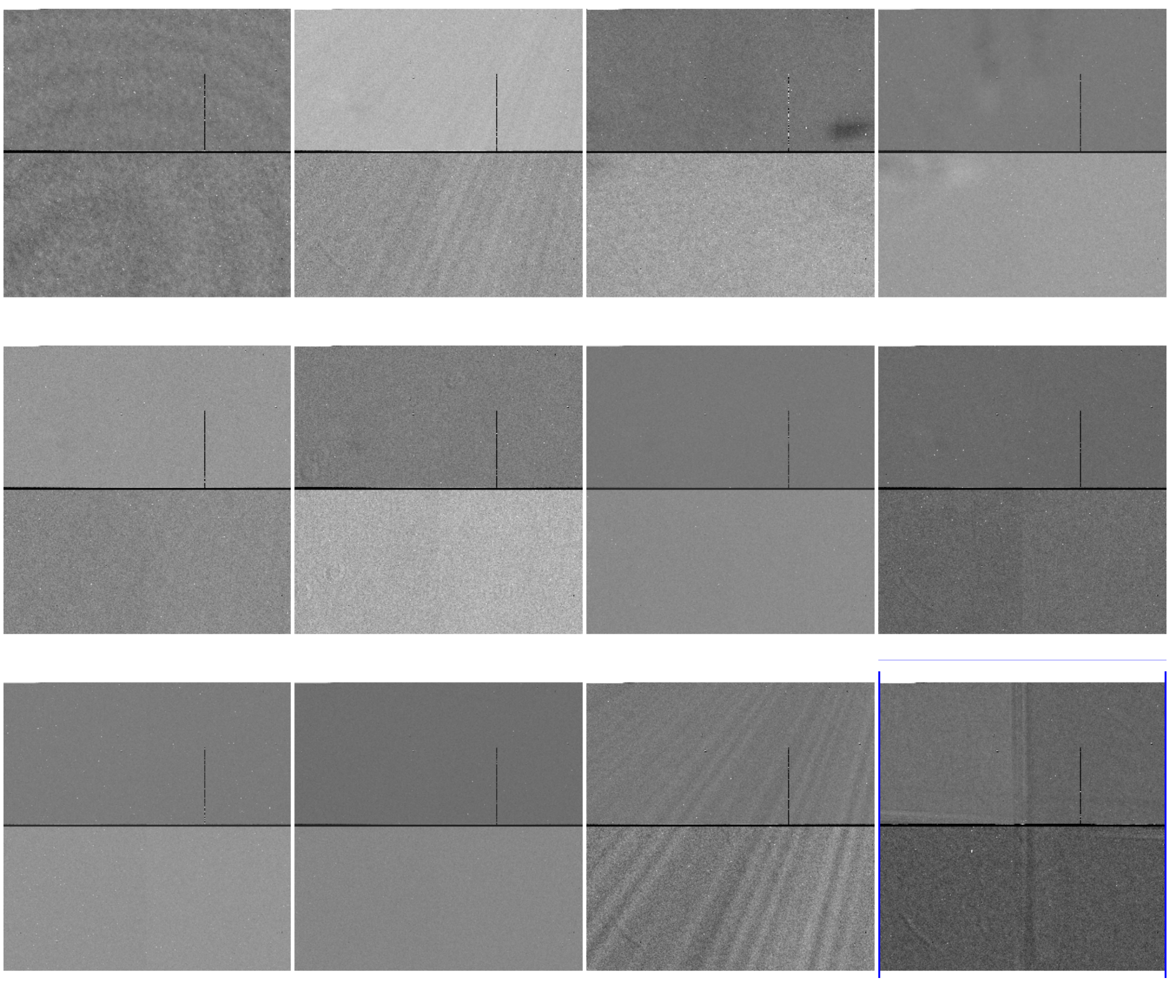
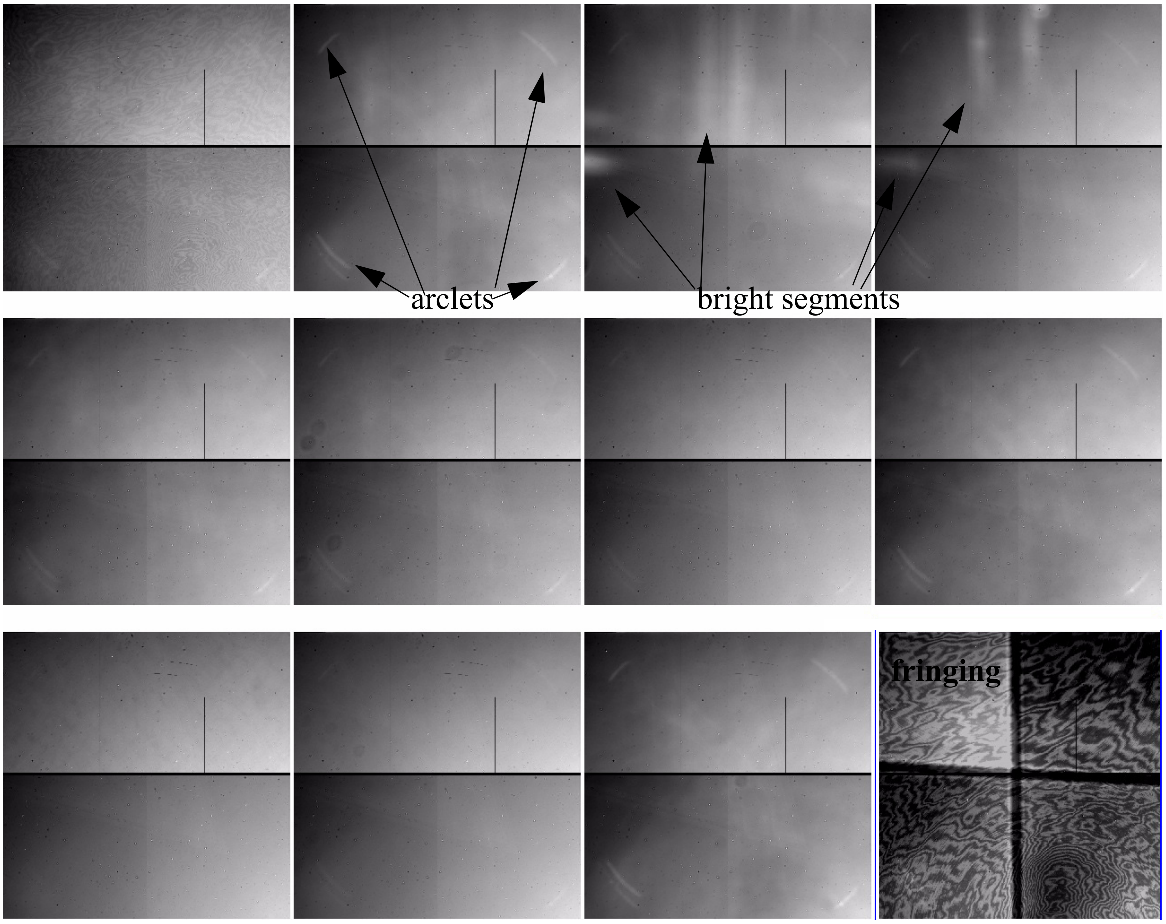


Figure 2: Greyscale images of the twelve on-orbit internal flatfields taken with lamp 3; stretch is +/-20%. From left to right and top to bottom are the filters (in wheel order): F656N, F200LP, F657N, F645N, F625W, F606W, F555W, F763M, F467M, F475X, F350LP, and FQ889N. Wheel 1 is furthest, wheel 12 closest, to the detector.

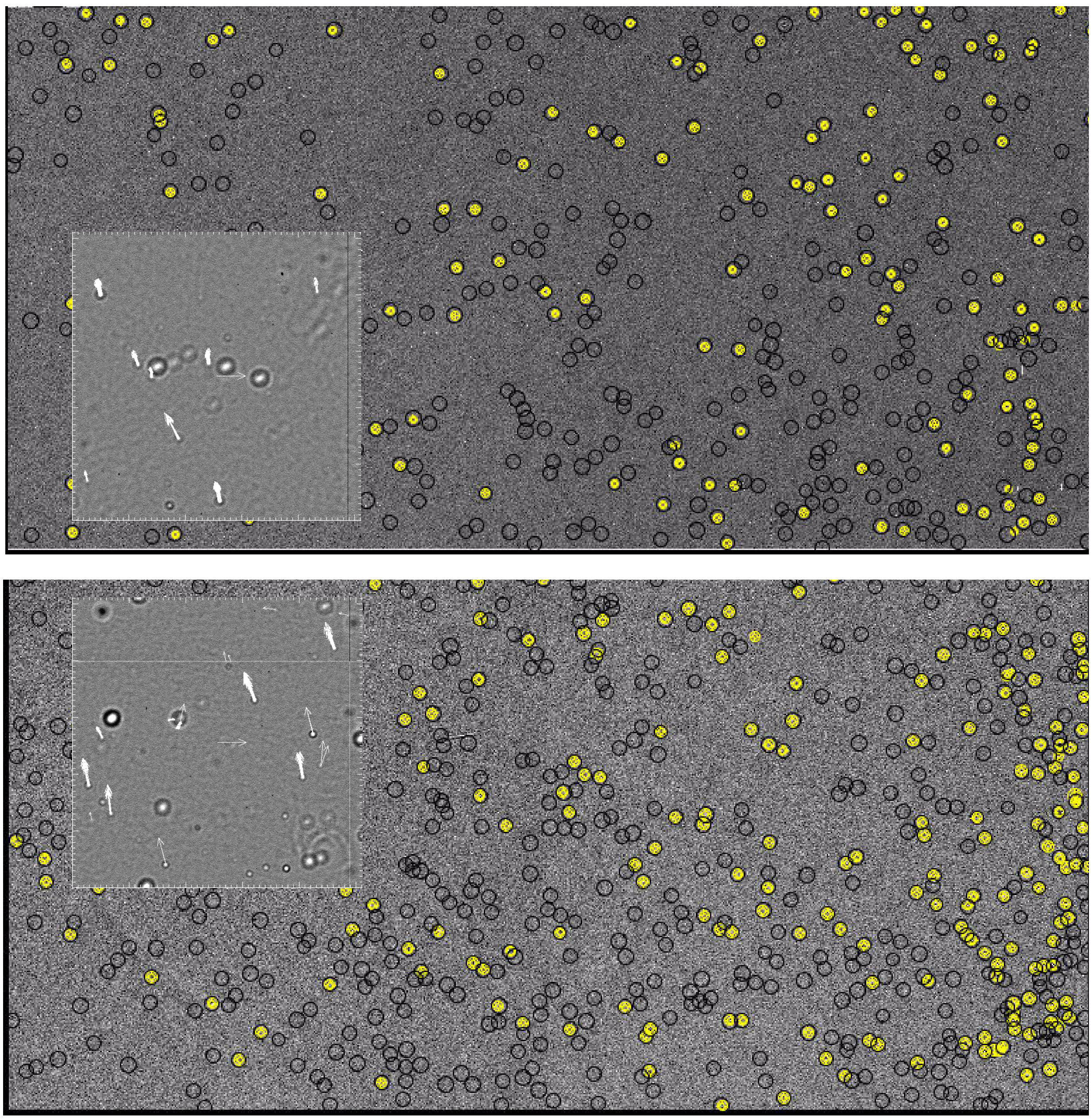


The individual internal flatfields have a great deal of structure at the level of 10's of percent, both overall (e.g. large scale gradient from left to right across the chips, the brighter 'arclets' in each quadrant) and in filter-dependent features (e.g. dust on the filters, fringing in the narrowbands, the bright segments in F657N and F645N). However, the vast majority of these features are repeatable and effectively disappear in image ratios. In averages across the chip horizontally and vertically, the ratios show at most +/-0.1% variations peak to peak and usually less than that, as illustrated in Appendix A, Figure 4 and Figure 5. The most prominent smaller scale features visible in the figures are the relatively bright vertical and horizontal strip segments in e.g. F657N and F645N, which in the ratios are at the 1% and 0.5% level, peak to peak. The cause of these features remains unknown. The diagonal striping in the F200LP and F350LP ratios (Figure 1) are due to variations in the shutter travel speed during very short exposures.

There are smaller features, on the scale of 10's of pixels, that correspond to the window 'droplets'. The 'droplets' are artifacts that were first detected in internal flatfields taken during the last thermal vacuum ground test, named because of their characteristic appearance in the images. Subsequent analyses have shown that they are likely due to mineral condensation residue on the outer detector window and that the modulation of light caused by the droplets varies with wavelength (Brown et al. 2008). The potential impact to science observations was assessed on the ground by stepping an external calibration point source across a strong droplet: the photometric scatter in small apertures was increased by 0.5-1% (Brown et al., 2008). Because the light in the core of the point source is redirected to the near wings, flatfielding will not correct the effect, however dithering and/or the use of larger apertures should be able to reduce the effect. The impacts to science observations will be remeasured on-orbit during Cycle 17 as well (proposal 11904, Kalirai & Deustua).

The status of the droplets has been assessed by evaluating their behavior in ratios of the F606W internal flats acquired during the SOFA test with TV3 internal flats acquired with the same setup. This investigation showed that ~30% of the droplets leave a residual in the ratio indicative of a position change at launch; such a positional shift was not seen in ratios of two post-launch flats or two pre-launch flats. The larger-sized droplets remained fixed. The smallish droplets appear to have moved in a coherent way, as a group moving down and to the right when the flatfields are viewed in the standard orientation (A amp to upper left, D amp to lower right). The motion is the same on chip1 (amps A and B) and chip 2 (amps C and D). Because the droplet density is higher on the right side of the detector, the motion is more easily visible on the right. In addition, the large droplets decrease slightly in size from left to right across each chip. Figure 3 shows a typical internal flatfield ratio, pre- to post-launch; droplets are marked with large green circles while the small red circles denote droplets that appeared to have shifted. Also in Figure 3 is a small close-up of a section of the post-launch F606W internal flatfield; white arrows mark the droplets that appeared to have moved (based on the ratio) and the direction of motion.

Figure 3: Ratio of pre- and post-launch internal flatfield in F606W, in the two full chips. Green circles mark all 'droplets' identified from a single flatfield while small red circles identify those droplets which appeared to shift in an on-orbit to ground ratio. The small insets shows a 512x512 extracted area from each chip of a single post-launch internal flat-field; those droplets that appeared to have moved in the ratio, and their direction of motion, have been marked with a white arrow.



Lamp Output

The characteristics of the lamp output are summarized in Table 2. Shown are statistics of the image ratios: the first half of the table is based on the lamp #3 on-orbit to ground data ratios, along with the one lamp #1 on-orbit to ground ratio available, while the second half of the table covers the lamp #1 on-orbit to lamp #3 on-orbit ratios. Listed for each filter and chip combination is the number of good pixels (3 iterations of 3-sigma clipping were applied to all images), the mean and standard deviation of those good pixels as well as the minimum and maximum. As the table shows, the lamp flux for both primary and spare is about 10-15% higher than on-orbit than it was on the ground. A similar behavior has been seen in other other lamps (e.g. Hyperion) and is attributed to the vacuum in space being much deeper than that on the ground, causing the lamps to run hotter because they're not heat sunk as well as on the ground (Powers 2009). The spare (#1) lamp output is 12-14% fainter than the primary (#3) lamp, very similar to the relative levels observed in the ground tests (Baggett 2008).

Table 2. Statistics of internal flatfield ratios; the first half are based on the lamp 3 ratios shown in Figure 1 and Figure 2 while the second half are the statistics of the spare lamp to the primary lamp.

filter	chip	numpix	mean	stdev	min	max	comment
F200LP	1	8356586	1.086	0.008	1.061	1.111	lamp 3, orbit/ground
F200LP	2	8358831	1.086	0.008	1.062	1.109	lamp 3, orbit/ground
F350LP	1	8353816	1.107	0.008	1.082	1.131	lamp 3, orbit/ground
F350LP	2	8359147	1.107	0.008	1.083	1.13	lamp 3, orbit/ground
F467M	1	8334411	1.152	0.008	1.126	1.177	lamp 3, orbit/ground
F467M	2	8340626	1.151	0.008	1.127	1.175	lamp 3, orbit/ground
F475X	1	8349883	1.139	0.009	1.113	1.164	lamp 3, orbit/ground
F475X	2	8354203	1.138	0.008	1.114	1.163	lamp 3, orbit/ground
F555W	1	8354351	1.1	0.008	1.075	1.125	lamp 3, orbit/ground
F555W	2	8356665	1.099	0.008	1.076	1.123	lamp 3, orbit/ground
F606W	1	8351759	1.123	0.008	1.097	1.148	lamp 3, orbit/ground
F606W	2	8356796	1.122	0.008	1.098	1.146	lamp 3, orbit/ground
F625W	1	8351319	1.12	0.008	1.094	1.145	lamp 3, orbit/ground
F625W	2	8356516	1.119	0.008	1.095	1.143	lamp 3, orbit/ground
F645N	1	8345920	1.116	0.008	1.09	1.141	lamp 3, orbit/ground
F645N	2	8351153	1.116	0.008	1.091	1.14	lamp 3, orbit/ground
F656N	1	8342887	1.112	0.009	1.087	1.138	lamp 3, orbit/ground

filter	chip	numpix	mean	stdev	min	max	comment
F656N	2	8349354	1.112	0.008	1.088	1.137	lamp 3, orbit/ground
F657N	1	8359305	1.1	0.008	1.076	1.123	lamp 3, orbit/ground
F657N	2	8363915	1.1	0.008	1.078	1.123	lamp 3, orbit/ground
F763M	1	8349300	1.089	0.008	1.064	1.113	lamp 3, orbit/ground
F763M	2	8355918	1.088	0.008	1.064	1.111	lamp 3, orbit/ground
FQ889N	1	8352103	1.088	0.008	1.063	1.114	lamp 3, orbit/ground
FQ889N	2	8358711	1.088	0.008	1.064	1.112	lamp 3, orbit/ground
F555W	1	8356589	1.110	0.009	1.083	1.136	lamp1 orbit/ ground
F555W	2	8358624	1.110	0.008	1.084	1.135	lamp1 orbit/ground
F656N	2	8344132	0.8661	0.007	0.844	0.888	lamp1 orbit/ lamp3 orbit
F656N	1	8341281	0.8745	0.008	0.850	0.899	lamp1 orbit/ lamp3 orbit
F200LP	2	8363549	0.8731	0.007	0.851	0.895	lamp1 orbit/ lamp3 orbit
F200LP	1	8361094	0.8816	0.008	0.858	0.905	lamp1 orbit/ lamp3 orbit
F657N	2	8359036	0.8654	0.007	0.845	0.886	lamp1 orbit/ lamp3 orbit
F657N	1	8356550	0.873	0.007	0.851	0.895	lamp1 orbit/ lamp3 orbit
F645N	2	8357394	0.8653	0.007	0.843	0.887	lamp1 orbit/ lamp3 orbit
F645N	1	8354297	0.8733	0.008	0.850	0.897	lamp1 orbit/ lamp3 orbit
F625W	2	8363247	0.8665	0.007	0.844	0.889	lamp1 orbit/ lamp3 orbit
F625W	1	8366019	0.8747	0.008	0.851	0.899	lamp1 orbit/ lamp3 orbit
F606W	2	8364100	0.8661	0.007	0.844	0.888	lamp1 orbit/ lamp3 orbit
F606W	1	8361945	0.8742	0.008	0.850	0.898	lamp1 orbit/ lamp3 orbit
F555W	2	8359974	0.8768	0.007	0.854	0.899	lamp1 orbit/ lamp3 orbit
F555W	1	8358106	0.8849	0.008	0.861	0.909	lamp1 orbit/ lamp3 orbit
F763M	2	8361268	0.8725	0.007	0.850	0.895	lamp1 orbit/ lamp3 orbit
F763M	1	8359218	0.8811	0.008	0.857	0.905	lamp1 orbit/ lamp3 orbit
F467M	2	8353194	0.8661	0.008	0.842	0.890	lamp1 orbit/ lamp3 orbit
F467M	1	8348895	0.8725	0.008	0.848	0.897	lamp1 orbit/ lamp3 orbit
F475X	2	8365061	0.8649	0.008	0.842	0.888	lamp1 orbit/ lamp3 orbit
F475X	1	8362513	0.8725	0.008	0.848	0.897	lamp1 orbit/ lamp3 orbit
F350LP	2	8364021	0.8649	0.007	0.844	0.885	lamp1 orbit/ lamp3 orbit
F350LP	1	8361918	0.8731	0.007	0.851	0.895	lamp1 orbit/ lamp3 orbit
FQ889N	2	8362536	0.8625	0.007	0.841	0.884	lamp1 orbit/ lamp3 orbit

filter	chip	numpix	mean	stdev	min	max	comment
FQ889N	1	8363497	0.871	0.008	0.847	0.895	lamp1 orbit/ lamp3 orbit
F555W	1	8356589	1.11	0.009	1.083	1.136	lamp1 orbit/ground
F555W	2	8358624	1.11	0.008	1.084	1.135	lamp1 orbit/ground

Conclusions

The results from the SMOV SOFA and internal lamp tests have been summarized. The filter wheels performed nominally and both UVIS calibration lamps are working well. Flatfield ratios show the illumination patterns are very similar to those observed on the ground and, with the exception of the window droplet features, the flatfields show relatively primarily minor changes, at the level of ~1% peak to peak. About 30% of the droplets appear to have shifted, by of order 1 pixel, since launch. The ratio of the spare to primary lamp output has also remained the same as it was on the ground; both lamps are brighter on-orbit than they were on the ground by ~10-15%.

References

Baggett, S., “WFC3 TV3 Testing: UVIS Channel Calibration Subsystem Performance,” WFC3 Instrument Science Report 2008-21, Oct 2008.

Baggett, S., “WFC3 SMOV Proposal 11423/11543: IR FSM and Lamp Checks,” WFC3 Instrument Science Report 2009-28, Nov 2009.

Brown, T., Hartig, G., and Baggett, S., “WFC3 TV3 Testing: UVIS Window Contamination,” WFC3 Instrument Science Report 2008-10, May 2008.

Powers, Chuck, Materials Engineering Branch, Code 541, NASA Goddard Spaceflight Center, Greenbelt, MD 20771, priv.comm., June 2009.

Sabbi, E., “UVIS Calysystem Photometric Filter Flat Field Atlas,” WFC3 Instrument Science Report 2008-17, July 2008.

Appendix A.

Figure 4: Line averages (line 10-2000) taken through the flatfield image ratios for lamp #3, amps C and D. Filter names are noted in plot titles.

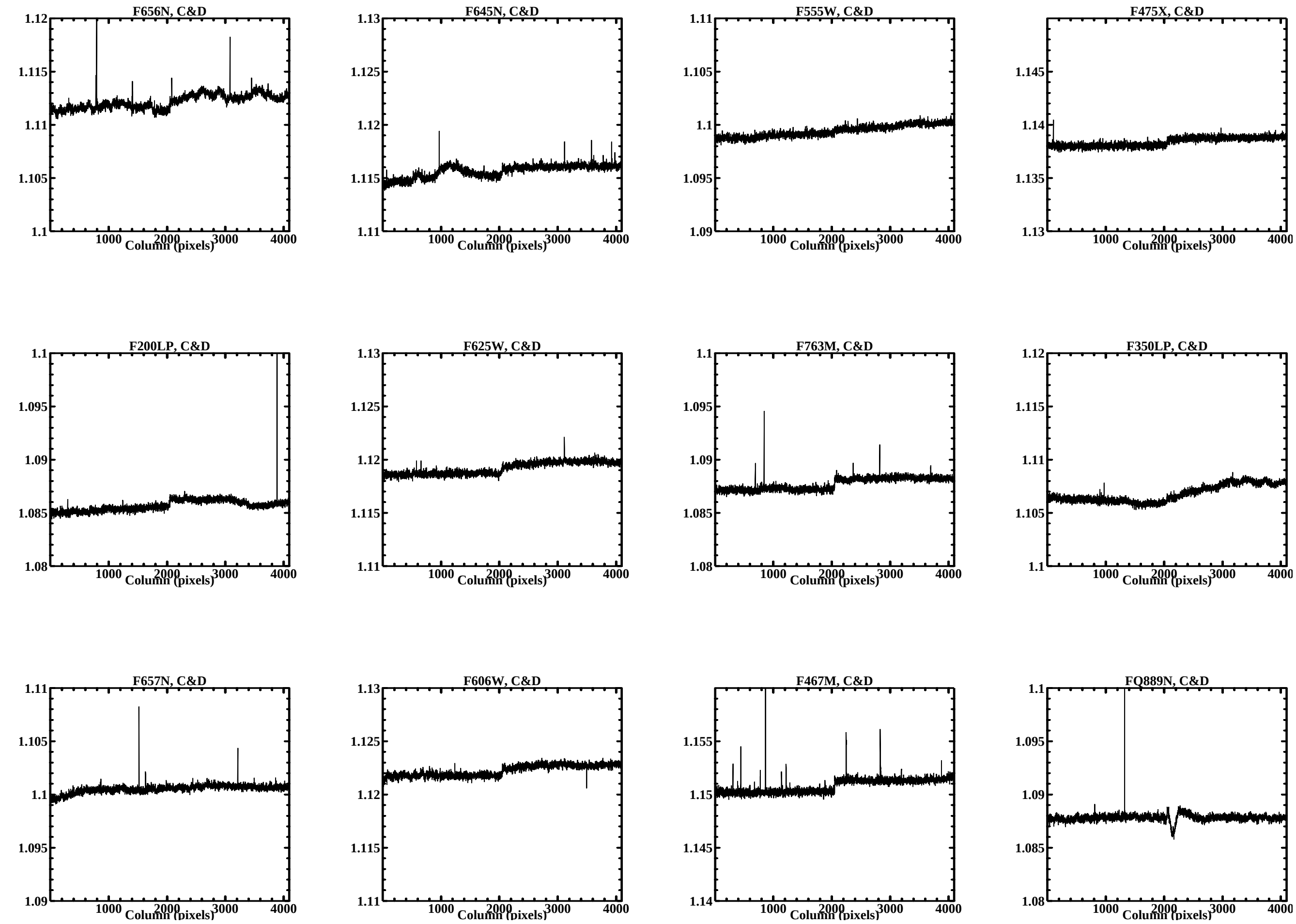


Figure 5: Column averages (columns 10-4000) taken through the flatfield image ratios for lamp #3, amps A and B. Filter names are noted in plot titles.]