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WFC3 SMOV Proposals 11423/ 11543: IR FSM and Lamp Checks

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ABSTRACT

This report summarizes the results obtained from the SMOV IR FSM (Filter Select Mechanism) and internal lamp check proposals, programs designed to verify the operability of the IR filter wheel and the health of the primary and backup IR internal lamps. A tungsten flatfield was taken in each filter of the wheel, excluding the grisms. The wheel performed as expected and all data were successfully acquired. The resulting flatfield features, e.g the scratches, areas of lower QE, bad and unresponsive pixels, were similar to those seen in ground testing. However, some flatfields (F098M, F130N, F132N, and F167N) showed what appear to be glints and reflections at the few percent level or less, possibly caused by a light leak around the diffuser paddle used to acquire the internal flatfields. The output flux of both lamps is 6-10% higher than it was on the ground, likely due to the lamps running hotter in the space environment than they did in the thermal vacuum test chamber. The relative output of the primary to spare lamp is the same as it was on the ground, to within 1-2%. On a more general note, the behavior of the early reads in the IR multiaccum files could benefit from a closer investigation: there appears to be a significant non-linearity in sequences where the first two reads are taken within 5 seconds or less of each other.

Introduction

Each Hubble Servicing mission is followed by a commissioning period called SMOV (Servicing Mission Observatory Verification) when the telescope and all its instruments undergo a full set of calibration tests in preparation for science observing. The most recent servicing mission in May 2009 installed, among other things the WFC3 (Wide Field Camera 3), and the required SMOV has been completed. Two of the SMOV tests involved validating the IR filter wheel (FSM) and the two calibration subsystem tungsten lamps assigned to the IR channel. Program 11423 executed the FSM test using the primary IR channel lamp while program 11543 ran a similar test using the spare lamp for the IR channel. The analogous tests for the UVIS channel and its tungsten lamps were performed in proposals, #11422 and #11529, respectively, and the results have been reported elsewhere (Baggett 2009).

The IR FSM and lamp tests were designed to exercise the filter wheel, confirm proper wheel operation, and provide an initial set of IR internal flatfields for comparison to ground data and for a foundation for future on-orbit flatfield monitoring. As such, one flatfield was obtained in every filter except the grisms. Subsequent proposals (#11433, IR Internal Flats; #11552 IR grisms) obtained additional flatfields for use in updating the ground-based pipeline superflats and in calibrating the IR grisms. The FSM and lamp test was run after the successful completion of the IR detector function (#11420) but before execution of the initial IR alignment (#11425).

The flatfields have been analyzed and compared to similar flatfields acquired during ground testing, to check for any changes in filter structures, vignetting within field, etc. Flux levels of the tungsten lamps were compared to results based on ground test data to quantify the performance of the bulbs. This report summarizes the analysis results from WFC3 SMOV IR FSM and tungsten lamp proposals 11423 and 11543.

Data

Proposal Structure

The FSM test proposal acquired 15 flatfields and 4 darks, the latter in the same sample sequences used for the flatfields; proposal 11423 used the primary tungsten bulb while proposal 11543 used the spare bulb. All exposures were taken in the default full-frame multi-accum (up-the-ramp) readout mode. The same filters were used in each proposal, only the tungsten bulb changed; prior to launch, lamp #2, the brighter one, had been chosen as the primary bulb and lamp #4 as the backup. The primary lamp is hardcoded into APT (Astronomer's Proposal Tool) such that specifying an internal WFC3 IR tungsten flatfield automatically uses lamp #2.

In order to request the use of the spare IR 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 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: IR01, IR02, IR03, IR04 for lamp 1, 2, 3, and 4, respectively, IR13 to use lamps 1+3 simultaneously, and IR24 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).

Images and Calibrations

The images acquired by the FSM and lamp check proposals are listed in Table 1, along with filter name, exposure time, sample sequence name and number of reads, observation date and time, median count rate in e^-/sec (assuming gain = 2.35 e^-/DN), and lamp number. Data from SMOV have the standard HST nine character image rootnames; ground data have a nine character rootname followed by an '_' and an eleven character timestamp reflecting when the data were acquired.

All files were processed through the standard OPUS pipeline, generating the raw fits files, then processed through the IRAF *calwf3* task for calibration. The on-orbit data was processed with *calwf3* 1.3 (13-Mar-2009) and the ground flatfields with *calwf3* 1.4.1 (27-Apr-2009). Since the differences between these results from these two calwf3 versions were neglibible for the IR flatfield observations, the on-orbit files were not reprocessed with the later calwf3 version.

The calibration steps for both ground and on-orbit data included data quality initialization, zero read signal correction, subtraction of reference pixels, zero read, and dark, as well as the non-linearity and cosmic ray corrections. As the FSM 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: t291659ni_bpx.fits, t2c16200i_ccd.fits, q911321mi_osc.fits, t61193*drk.fits (matched to the particular sample sequence), and sbi18555i_lin.fits for the bad pixel table, detector calibration table, reference pixel table (extension osc), superdark file, and non-linearity correction file, respectively.

The pipeline produces both a calibrated ramp image (*ima.fits), where each individual read has been calibrated and retained in the fits file, and a single calibrated image (*flt.fits), the result of an up-the-ramp linear fit to all the individual reads. The former were examined for any evidence of saturation in the later reads which might invalidate use of the pipeline flt product. For the data evaluated here, no saturation was found and the final results presented in this report are based on the single calibrated images. Of note, however, was that there appears to be some non-linearity between reads 1 and 2, particularly when the second read falls less than about 5 seconds after the first; while an insignificant effect for the purposes of the current analysis, further investigation is warranted as to its possible impact on science results. In addition, the ramps of the individual darks from this proposal appeared quite noisy and non-linear; this was later determined to be due to stray light in the early IR darks, an issue discussed in more detail in the report on the SMOV IR darks (Hilbert & McCullough, 2009a). Because of the poor quality of these early darks, they were not used to try and improve the pipeline dark calibration; only the ground-based superdarks were employed as described in the preceding paragraph.

Table 1. Summary of on-orbit and ground internal flatfields used for the SMOV IR FSM and lamp check. Listed are image root name, filter, exposure time, sample sequence, number of reads, date and time of observations, median count rate (in e^-/sec, assuming gain=2.35 e^-/DN) and lamp number. SMOV images have the shorter names while the ground images

image	filter	exptime	samp_seq	nsamp	date-obs	time-obs	count rate (e^-/sec)	lamp
ii150504r_08080075633	F098M	199.23	STEP100	9	2008-03-20	7:50:35.0	281.4	2
iaam03jrq	F098M	199.23	STEP100	9	2009-06-12	2:40:57.0	310.0	2
ii150505r_08102081831	F105W	82.94	SPARS10	10	2008-04-11	8:16:23.0	663.5	2
iaam01jcq	F105W	82.94	SPARS10	10	2009-06-12	0:57:28.0	705.9	2
ii150604r_08080103931	F110W	41.05	RAPID	15	2008-03-20	10:36:49.0	1426.9	2
iaam03jtq	F110W	41.05	RAPID	15	2009-06-12	2:42:07.0	1548.6	2
ii150605r_08103040329	F125W	43.98	RAPID	16	2008-04-12	4:02:00.0	1073.4	2
iaam03jwq	F125W	43.98	RAPID	16	2009-06-12	2:59:02.0	1148.1	2
ii150507r_08102084118	F126N	899.23	STEP100	16	2008-04-11	8:25:19.0	50.3	2
iaam03juq	F126N	899.23	STEP100	16	2009-06-12	2:57:44.0	54.6	2
ii150607r_08103042313	F127M	224.23	STEP25	14	2008-04-12	4:14:03.0	264.3	2
iaam01jkq	F127M	224.23	STEP25	14	2009-06-12	1:27:29.0	285.7	2
ii150508r_08102085648	F128N	899.23	STEP100	16	2008-04-11	8:40:53.0	58.2	2
iaam01jeq	F128N	899.23	STEP100	16	2009-06-12	1:14:27.0	62.5	2
ii15050ar_08080085017	F130N	899.23	STEP100	16	2008-03-20	8:34:23.0	62.2	2

image	filter	exptime	samp_seq	nsamp	date-obs	time-obs	count rate (e^-/sec)	lamp
iaam03jxq	F130N	899.23	STEP100	16	2009-06-12	3:14:39.0	66.5	2
ii15050cr_08080090537	F132N	899.23	STEP100	16	2008-03-20	8:49:52.0	60.7	2
iaam02jmq	F132N	899.23	STEP100	16	2009-06-12	1:56:30.0	64.9	2
ii150608r_08103042313	F139M	249.23	STEP25	15	2008-04-12	4:18:18.0	236.3	2
iaam01jiq	F139M	249.23	STEP25	15	2009-06-12	1:23:18.0	251.6	2
ii15060ar_08103043834	F140W	38.12	RAPID	14	2008-04-12	4:32:56.0	1541.9	2
iaam03jzq	F140W	38.12	RAPID	14	2009-06-12	3:15:52.0	1646.1	2
ii15060br_08103043834	F153M	224.23	STEP25	14	2008-04-12	4:34:04.0	268.8	2
iaam01jgq	F153M	224.23	STEP25	14	2009-06-12	1:18:42.0	285.1	2
ii190108r_08104131207	F160W	49.23	STEP25	7	2008-04-13	12:50:20.0	1067.3	2
iaam01jdq	F160W	49.23	STEP25	7	2009-06-12	0:58:50.0	1139.0	2
ii15200jr_08104075101	F164N	899.23	STEP100	16	2008-04-13	7:35:16.0	64.6	2
iaam02jpq	F164N	899.23	STEP100	16	2009-06-12	2:25:44.0	69.7	2
ii15050gr_08080094155	F167N	799.23	STEP100	15	2008-03-20	9:26:51.0	68.8	2
iaam02jn	F167N	799.23	STEP100	15	2009-06-12	2:10:18.0	73.2	2
ii15080er_08099055251	F098M	174.23	STEP25	12	2008-04-08	5:49:11.0	329.5	4
iabc03hdq	F098M	99.23	STEP100	8	2009-06-25	0:10:42.0	358.1	4
ii15080gr_08099060623	F105W	74.23	STEP25	8	2008-04-08	6:02:14.0	752.1	4
iabc01gyq	F105W	72.94	SPARS10	9	2009-06-24	22:02:41.0	812.3	4
ii150804r_08099050724	F110W	35.19	RAPID	13	2008-04-08	5:04:48.0	1598.4	4
iabc03heq	F110W	38.12	RAPID	14	2009-06-25	0:11:49.0	1703.8	4
ii150805r_08099050724	F125W	43.98	RAPID	16	2008-04-08	5:05:55.0	1176.3	4
iabc03hiq	F125W	41.05	RAPID	15	2009-06-25	0:27:01.0	1260.4	4
ii150702r_08099025811	F126N	899.23	STEP100	16	2008-04-08	2:42:12.0	55.4	4
iabc03hfq	F126N	799.23	STEP100	15	2009-06-25	0:25:46.0	59.6	4
ii150807r_08099052515	F127M	199.23	STEP25	13	2008-04-08	5:17:20.0	288.1	4
iabc01h6q	F127M	199.23	STEP25	13	2009-06-24	22:37:56.0	310.2	4
ii150704r_08099031200	F128N	799.23	STEP100	15	2008-04-08	2:57:46.0	63.8	4
iabc01h0q	F128N	799.23	STEP100	15	2009-06-24	22:17:35.0	68.4	4
ii150706r_08099032540	F130N	799.23	STEP100	15	2008-04-08	3:11:35.0	68.2	4
iabc03hjq	F130N	799.23	STEP100	15	2009-06-25	0:40:58.0	72.2	4
ii150709r_08099034519	F132N	799.23	STEP100	15	2008-04-08	3:31:00.0	66.2	4

image	filter	exptime	samp_seq	nsamp	date-obs	time-obs	count rate (e^-/sec)	lamp
iabc02h8q	F132N	799.23	STEP100	15	2009-06-24	22:58:23.0	70.1	4
ii150808r_08099052515	F139M	199.23	STEP25	13	2008-04-08	5:21:10.0	256.1	4
iabc01h4q	F139M	224.23	STEP25	14	2009-06-24	22:25:36.0	272.6	4
ii15080ar_08099053910	F140W	32.26	RAPID	12	2008-04-08	5:34:02.0	1673.4	4
iabc03hlq	F140W	35.19	RAPID	13	2009-06-25	0:42:08.0	1775.3	4
ii15080br_08099053910	F153M	199.23	STEP25	13	2008-04-08	5:35:05.0	288.9	4
iabc01h2q	F153M	199.23	STEP25	13	2009-06-24	22:21:25.0	307.4	4
ii19010br_08104131207	F160W	49.23	STEP25	7	2008-04-13	13:01:28.0	1135.7	4
iabc01gzq	F160W	24.23	STEP25	6	2009-06-24	22:03:38.0	1229.5	4
ii15070ar_08099035729	F164N	699.23	STEP100	14	2008-04-08	3:44:54.0	70.4	4
iabc02hbq	F164N	799.23	STEP100	15	2009-06-24	23:24:17.0	74.6	4
ii15070cr_08099041027	F167N	699.23	STEP100	14	2008-04-08	3:57:04.0	74.0	4
iabc02h9q	F167N	699.23	STEP100	14	2009-06-24	23:10:31.0	78.2	4
iaam04k1q	Blank	43.98	RAPID	16	2009-06-12	3:36:47.0	0.11	dark
iaam04k2q	Blank	899.23	STEP100	16	2009-06-12	3:52:07.0	0.13	dark
iaam04k4q	Blank	142.95	SPARS10	16	2009-06-12	3:54:50.0	0.08	dark
iaam04k6q	Blank	274.23	STEP25	16	2009-06-12	3:59:46.0	0.06	dark
iabc04hnq	Blank	43.98	RAPID	16	2009-06-25	0:51:09.0	0.23	dark
iabc04hoq	Blank	899.23	STEP100	16	2009-06-25	1:06:29.0	0.19	dark
iabc04hqq	Blank	142.95	SPARS10	16	2009-06-25	1:09:13.0	0.13	dark
iabc04hsq	Blank	274.23	STEP25	16	2009-06-25	1:14:08.0	0.12	dark

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 (listed in Table 1), scaling each flatfield by exposure time. The resulting ratios for tungsten lamp #2 are shown in Figure 1; for comparison, the individual on-orbit flatfields for lamp #2 are shown in Figure 2. Most of the flatfields are effectively the same as pre-launch . Some of the features are known flatfield structures originating during the manufacture of the device, such the small circular area of bad pixels at the bottom of the lower left quadrant, the semi-circular feature of lower QE pixels on the outside edge of the lower right quadrant, and the handfuls of non-responsive pixels primarily in the upper left and upper right corners and along the upper central perimeter. Other features are due to the calibration subsystem, such as the vignetting in the upper and lower right corners of the flatfields; the former drop to ~75-80% of the overall flatfield level over the last ~100 columns while the latter area of vignetting starts ~150 columns out and dips to lows of ~60% (though it's complicated by the semi-circular region of lower QE pixels in this same region). As expected, the vignetted areas appear relatively flat in the image ratios, indicating that the illumination pattern didn't change significantly due to launch and installation into HST.

However, the ratios do show some unexpected glints or reflections at the 1-2% level. Specifically, the F128N filter exhibits a prominent spray of light near the upper right of the field of view; it's a few percent brighter than the surrounding image level. There is a more general diffuse glow in the upper right corner of F098M, F130N, F132N, and F167N (~2%), as well as a weak, triangular-shaped glow on the left side of the image, extending about 150 columns in from the edge; the effect is strongest in F098M (~1% over the surrounding level) and faintly visible in F128N. Similar types of glints, some at higher levels, have been observed in the subsequent SMOV IR internal flatfield monitoring program as well (Hilbert & McCullough, 2009b). The glints seem to be attributable to a light leak around the diffuser paddle mounted on the channel select mechanism (CSM). The CSM, when in the nominal UVIS position, allows an external beam intercepted by the WFC3 pickoff mirror to travel unimpeded down into the UVIS channel optics and CCDs. When in the IR position, a mirror on the CSM is moved into the external beam and redirects the external light into the IRchannel. Mounted at about 90deg from the CSM mirror is a diffuser paddle; its orientation is such that when the CSM is in the UVIS position, light from the internal calibration subsystem can strike the paddle and be redirected into the IR channel, down to the IR focal plane array. It is this paddle which may be allowing external light into the internal beam, resulting in the observed glints.

Figure 1: Image ratios of the fifteen on-orbit internal flatfields taken with lamp 2 to a matching flatfield from the ground testing. Greyscale stretch is +/-10%. From left to right and top to bottom are the filters: F098M, F105W, F110W, F125W, F126N, F127N, F128N, F130N, F132N, F139M, F140W, F153M, F160W, F164N, and F167N.

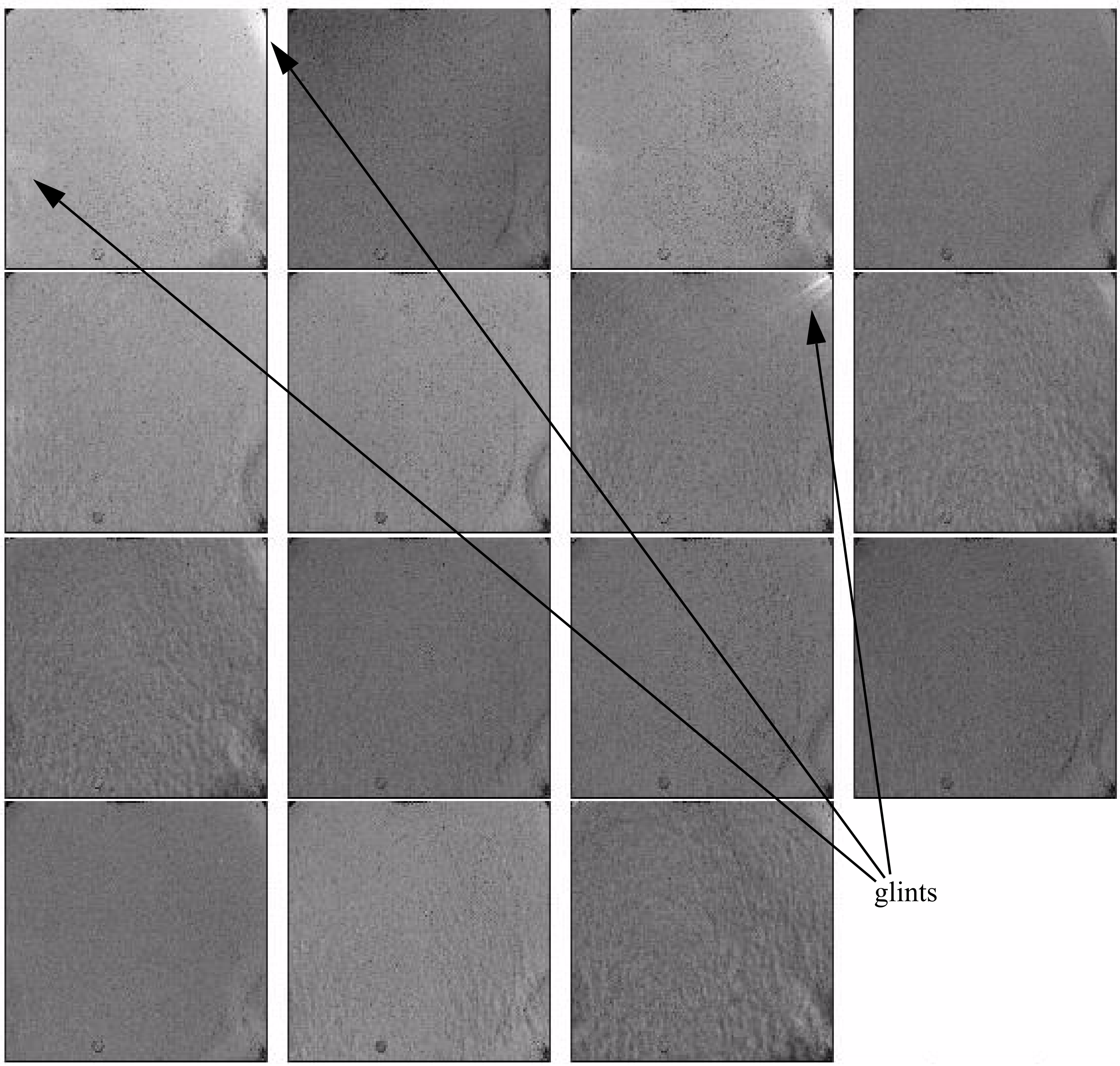
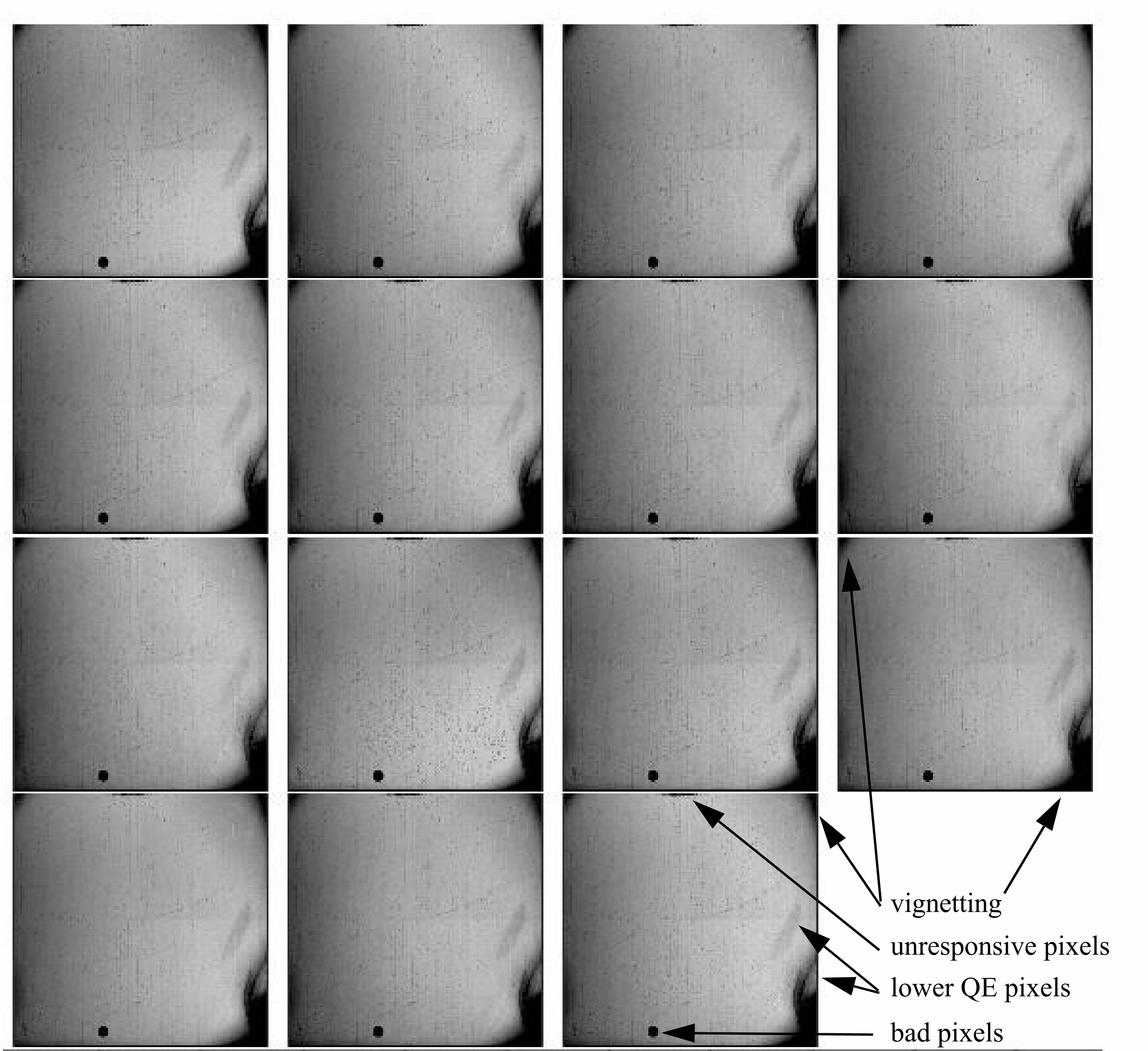


Figure 2: Greyscale images of the twelve on-orbit internal flatfields taken with lamp 3; stretch is +/-20%. From left to right and top to bottom are the filters (in wheel order): F656N, F200LP, F657N, F645N, F625W, F606W, F555W, F763M, F467M, F475X, F350LP, and FQ889N. Wheel 1 is furthest, wheel 12 closest,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



Lamp Output

The characteristics of the lamp output are summarized in Table 1, which lists the count rates for each individual flatfield in e^-/sec (assuming gain=2.35 e^-/DN), and in Table 2, which lists the results from the image ratios. The first half of Table 2 presents the statistics from the lamp #2 on-orbit to ground data ratios, while the second half of the table covers the lamp #4 on-orbit to ground data ratios. Listed for each filter 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, maximum, and midpoint. Based on these values, both the primary and spare lamps are 6-10% brighter on-orbit than they were on the ground. This type of lamp behavior has been seen in other instruments and is speculated to be due to the operating environment: the lamps can run hotter in the vacuum of space because they're not heat sunk as well (Powers 2009). The operating temperature could be probed in the future using model black-body curves and the IRAF synthetic photometry package (synphot); a WFC3 synphot update as well as new reference files based on on-orbit data are expected to be released in the fall of 2009. Temperature measurements performed in the Materials Branch Lab at Goddard Spaceflight Center showed the average temperature of the center of the filament to be around 2670+/-50 K (Powers 2009).

A comparison of on-orbit lamp 2 to 4 ratios showed that overall, lamp 2 is 7-14% fainter than lamp 4. Though the illumination patterns of the two lamps can be different by 10-20% or more across the field of view, the ratio of the overall output of the two lamps is within 1-2% of the ground lamp 2 to 4 ratios. Table 3 provides a summary of these results, listing the filter, mean, standard deviation, and midpoint of good pixels (based on 3 iterations of 3-sigma clipping) for the ratios of lamp2/4 in the ground data and the ratios of lamp2/4 in the on-orbit data.

Table 2. Statistics of the IR internal flatfield ratios (orbit/ground) for the primary lamp and spare lamps, #2 and #4, respectively.

filter	numpix	mean	stdev	min	max	midpt	comment
F098M	1001476	1.101	0.009	1.073	1.13	1.101	orbit/ground, lamp 2
F105W	1004854	1.065	0.008	1.041	1.089	1.065	orbit/ground, lamp 2
F110W	991984	1.088	0.008	1.062	1.114	1.088	orbit/ground, lamp 2
F125W	1020282	1.07	0.008	1.045	1.095	1.07	orbit/ground, lamp 2
F126N	1019128	1.086	0.009	1.05	1.122	1.086	orbit/ground, lamp 2
F127M	1009682	1.083	0.008	1.058	1.109	1.083	orbit/ground, lamp 2
F128N	1018076	1.073	0.010	0.9895	1.155	1.073	orbit/ground, lamp 2
F130N	1023577	1.071	0.011	0.8862	1.237	1.071	orbit/ground, lamp 2

filter	numpix	mean	stdev	min	max	midpt	comment
F132N	1016117	1.069	0.009	1.022	1.114	1.069	orbit/ground, lamp 2
F139M	1011708	1.065	0.007	1.044	1.087	1.065	orbit/ground, lamp 2
F140W	1007057	1.068	0.007	1.025	1.108	1.068	orbit/ground, lamp 2
F153M	1014167	1.062	0.007	1.022	1.099	1.062	orbit/ground, lamp 2
F160W	1015815	1.069	0.007	1.047	1.091	1.069	orbit/ground, lamp 2
F164N	1009657	1.081	0.008	1.057	1.104	1.08	orbit/ground, lamp 2
F167N	1013163	1.063	0.008	1.037	1.089	1.063	orbit/ground, lamp 2
F098M	1019373	1.088	0.009	1.061	1.115	1.088	orbit/ground, lamp 4
F105W	1017858	1.08	0.008	1.036	1.122	1.08	orbit/ground, lamp 4
F110W	985908	1.07	0.007	1.047	1.093	1.07	orbit/ground, lamp 4
F125W	1018008	1.069	0.007	1.046	1.092	1.069	orbit/ground, lamp 4
F126N	1013468	1.076	0.008	1.051	1.1	1.076	orbit/ground, lamp 4
F127M	1016745	1.078	0.007	1.039	1.114	1.078	orbit/ground, lamp 4
F128N	1014462	1.073	0.007	1.05	1.096	1.073	orbit/ground, lamp 4
F130N	1018506	1.061	0.007	1.028	1.093	1.061	orbit/ground, lamp 4
F132N	1018901	1.062	0.007	1.028	1.095	1.062	orbit/ground, lamp 4
F139M	1013298	1.066	0.007	1.043	1.088	1.066	orbit/ground, lamp 4
F140W	1002818	1.066	0.007	1.026	1.102	1.066	orbit/ground, lamp 4
F153M	1012523	1.067	0.007	1.045	1.088	1.067	orbit/ground, lamp 4
F160W	1019286	1.085	0.009	1.057	1.113	1.084	orbit/ground, lamp 4
F164N	1012532	1.059	0.007	1.037	1.082	1.059	orbit/ground, lamp 4
F167N	1020483	1.056	0.007	1.025	1.087	1.056	orbit/ground, lamp 4

Table 3. Comparison of the primary to spare lamp output, from ground tests and on-orbit. Listed for each case are the filter, mean, standard deviation and midpoints.

filter	mean	stddev	midpt	mean	stdev	midpt
	ratio of lamp 2/4, ground images			ratio of lamp 2/4, on-orbit images		
F098M	0.866	0.059	0.858	0.877	0.059	0.869
F105W	0.891	0.055	0.883	0.878	0.056	0.870
F110W	0.892	0.050	0.885	0.909	0.049	0.904
F125W	0.910	0.048	0.905	0.910	0.047	0.904
F126N	0.906	0.047	0.901	0.915	0.047	0.911

filter	mean	stddev	midpt	mean	stdev	midpt
	ratio of lamp 2/4, ground images			ratio of lamp 2/4, on-orbit images		
F127M	0.911	0.046	0.906	0.916	0.046	0.911
F128N	0.907	0.047	0.902	0.907	0.047	0.903
F130N	0.906	0.046	0.900	0.914	0.045	0.908
F132N	0.911	0.046	0.906	0.917	0.046	0.914
F139M	0.917	0.044	0.913	0.917	0.044	0.914
F140W	0.919	0.045	0.914	0.921	0.044	0.917
F153M	0.926	0.044	0.923	0.922	0.044	0.918
F160W	0.934	0.044	0.931	0.921	0.045	0.917
F164N	0.912	0.043	0.909	0.930	0.044	0.928
F167N	0.926	0.044	0.922	0.931	0.044	0.930

Conclusions

The results from the SMOV FSM and internal lamp tests have been summarized. The filter wheel performed nominally and both the primary and spare IR calibration lamps are working well. Flatfield ratios show the illumination patterns are similar to those observed on the ground but there are low-level glints and reflections in the frames, possibly due to light leaks around the diffuser paddle of the CSM. The overall output of both lamps is 6-10% higher on-orbit than it was on the ground. The ratio of the primary to spare lamp output has remained the same as it was on the ground (lamp 2 is 7-14% fainter than lamp 4). Unrelated to the wheel and lamp tests specifically, there appears to be some non-linearity between the first and second reads that merits further investigation.

References

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