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WFC3 Thermal Vacuum Testing: IR Flat Fields

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ABSTRACT

WFC3 thermal-vacuum testing with the FPA64 detector took place in September and October 2004. The IR13S01 proceedure was executed twice and the IR13S02 proceedure was executed once. The results show that high quality IR flat fields can be easily constructed and that the IR chip non-uniformities are correctable to < 1%.

1. Introduction

The IR detector on WFC3 is a HgCdTe 1024x1024 array with rectangular pixels which are approximately 0.121 x 0.135 arcseconds. The inner 1014 x1014 pixels are used for imaging, and the border pixels (5) are used as a constant-voltage reference source to measure bias levels. The readout noise is estimated at 23 electrons, and the background noise, including dark current, is estimated to be less than 0.4 e-/s/pixel. The available filters at the time of TV1 (non-grism) are listed in Table 1. The operational mode for the IR channel, MULTIACCUM, begins with an array reset followed by two rapid contiguous read-outs. Next one or more non-destructive readouts are obtained at various intervals, depending on the type of sample sequence and number of samples (up to a maximum of 16) requested by the user. All 16 reads (including the initial two) are recorded and returned for analysis.

Table 1. WFC3 IR Filter Compliment

Filter	Central Wavelength (nm)
F093W	836.18
F105W	1052.11
F110W	1148.06
F160W	1543.17
F125W	1248.68
F098M	984.72
F127M	1273.55
F139M	1383.62
F153M	1533.24
F126N	1258.28
F128N	1283.36
F130N	1300.58
F132N	1319.08
F164N	1645.22
F167N	1667.18

This is the filter set that was available at the time of the TV1 test. The final flight set may be different.

2. Test Contents

The IR13S01 SMS consisted of a total of 15x2 flatfield exposures, the details of which are listed in Table 2 . During the test it was discovered that some of the frames were pushing into saturation, for this reason a second round of images was taken with shorter exposure times where necessary. The results from this ISR only take into account the non-saturated frames. The IR13S02 SMS consisted of a total of 10 flatfield exposures and 10 dark frames, the details of which are listed in Table 3. All the exposures were performed with the full frame four amplifier readout and a commanded gain of 2.5. The CASTLE Optical Stimulus(OS) system was used to provide the illumination. Although darks were taken during the SMS, the superdarks created from IR01S05 were used in the reduction.

Table 2. IR13S01 exposure details

Filter	Repetition	Sample Sequence	Exptime (sec)	Amplifiers	OS Lamp
F093W	2	RAPID	67.0467, 53.63736	ABCD	QTH
F098M	2	RAPID	67.0467,67.0467	ABCD	QTH
F105W	2	RAPID	31.288, 22.3489	ABCD	QTH
F110W	2	RAPID	67.0467,67.0467	ABCD	QTH
F125W	2	RAPID	67.0467,67.0467	ABCD	QTH
F160W	2	RAPID	67.0467,67.0467	ABCD	QTH
F127M	2	RAPID	67.0467, 44.6978	ABCD	QTH
F139M	2	RAPID	67.0467, 44.6978	ABCD	QTH
F153M	2	RAPID	58.10714, 35.75824	ABCD	QTH
F126N	2	RAPID	26.81868, 40.22802	ABCD	QTH
F128N	2	RAPID	22.3489, 35.75824	ABCD	QTH
F130N	2	RAPID	22.3489, 35.7582	ABCD	QTH
F132N	2	RAPID	22.3489, 35.75824	ABCD	QTH
F164N	2	RAPID	17.87912, 31.28846	ABCD	QTH
F167N	2	RAPID	17.87912, 35.75824	ABCD	QTH

Table 3. IR13S02 exposure details

Filter	Sample Sequence	Exptime (sec)	Amps	OS Lamp
F139M	RAPID	67.0467	ABCD	QTH
F139M	STEP25	279.934	ABCD	QTH
F139M	STEP50	504.9339	ABCD	QTH
F139M	STEP100	904.9331	ABCD	QTH
F139M	SPARS10	144.8769	ABCD	QTH
F139M	SPARS25	354.8701	ABCD	QTH
F139M	SPARS50	704.8701	ABCD	QTH
F139M	SPARS100	1404.8687	ABCD	QTH
F139M	MIF600	600.4195	ABCD	QTH
F139M	MIF900	900.50244	ABCD	QTH

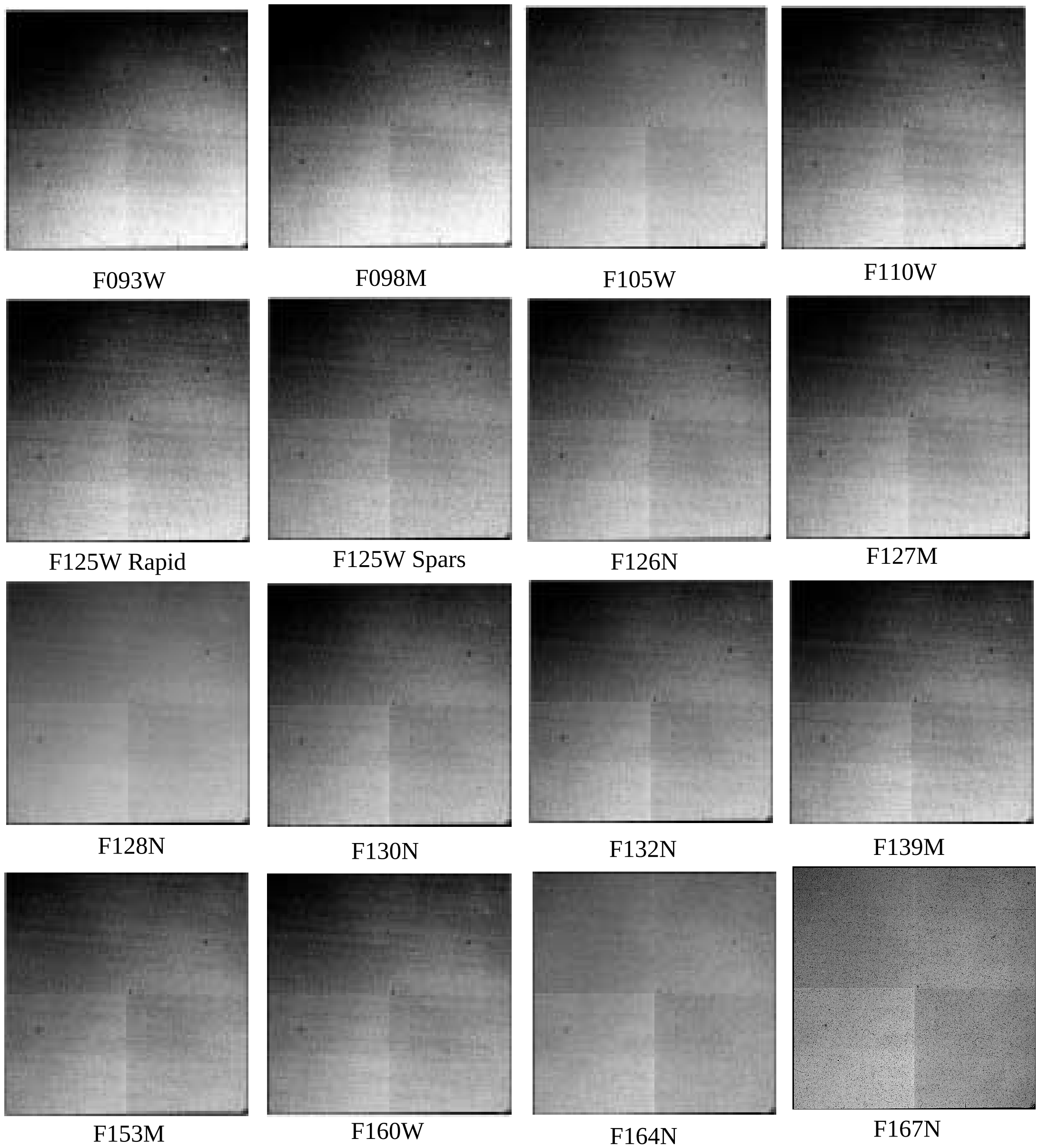
3. Data Reduction

All the data used for this analysis was reduced using the calwf3 pipeline in IRAF. For proper execution, some of the header information in each file needed to be updated. Until some time in September 2004 OPUS was not populating the various exposure time keywords in the IR _raw files correctly (e.g. the SAMPTIME, DELTATIM keywords). A private script in conjunction with the _spt files is being used to update the image headers with the proper timing information. The script's basic function is to poll the _spt image header for the keywords IMGSETUP and INTTIME, then to calculate the appropriate SAMPTIME and DELTATIM values for each sample and store the results in the header keywords DELTATIM, SAMPTIME and PIXVALUE.

The calwf3 pipeline also cares about the WCS coordinate keywords; most importantly in this case are the LTV1 and LTV2. Calwf3 reads and compares the LTV1, LTV2 values in the science image and the reference image in order to figure out if the science image was taken in subarray mode. If so, it needs to figure out the corresponding corners of a subarray to read from the reference image. After being corrected, the _raw flat field images were run through the calwf3 data reduction pipeline, turning on ZOFFCORR, BLEVCORR, DARKCORR, and UNITCORR. The CRCORR step was not turned on for data used in making these reference flat files. It was found in testing the current calwf3 pipeline (which is still under construction) that the parameters for the CRCORR cosmic ray rejection still need some tweaking, and more reliable data was produced with the step turned off. The inclusion of the CRCORR step also produced slightly noisier images since each of the flats had few samples, driving the statistics into small numbers. Turning off CRCORR changes the final output of the image in the SCI extension to a copy of the final science exposure that was taken, rather than the fit of the image stack. The impact on the final product is minimal since with such high incident flux, and ground based data with minimal cosmic ray influence, less than 0.5% difference in flux was found between the median of the image stack and the final exposure itself.

Each of the resulting flats were then tested for pipeline viability on a sample image, using PFLTFILE as the keyword for the reference file. PFLTFILE contains the name of the pixel-to-pixel flat that corrects for variations from one pixel to another. There are two other flatfield reference files which may exist. DFLTFILE is a delta flat which may be used in the future to apply any further corrections the data may require. LFLTFILE is a low order flat used to take out large scale, slowly varying gradients across the field of view. Any combination of one or more of these flats may be applied in the pipeline. No other keywords need to be added to the files at this point to make them run through the pipeline. Other keywords may have to be updated for delivery of superflats to OPUS and ingest into the DADS archive. Figure 1 shows example flatfield images for each of the filters. Some of the images still show evidence of increased flux levels in the quadrants, which was not removed during pipeline processing.

Figure 1: Example flats for each filter, shown at roughly the same scaling.

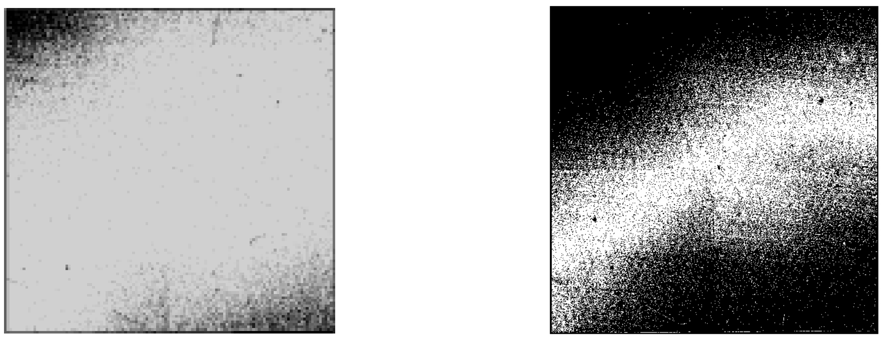


4. Results

4.1 Flat Field Characteristics

All the images, regardless of filter show an illumination pattern that's strongest (values greater than the median) at the lower right of the image and decreases intensity (values lower than the median) as you move to the upper left corner. This is the only large scale structure that is visible and the change from corner to corner has been measured at the 20-30% level, when compared to the median clipped value. Figure 2 shows two masks where all values further away than 5% or 15% of the median value are set to 0 (black). The results are similar for all filters.

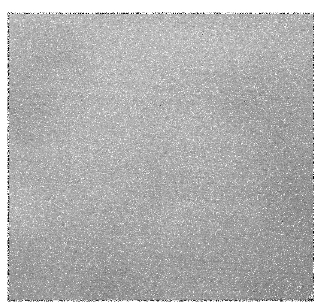
Figure 2: Mask of the F093N flat showing pixles that are > x% from the mean value in black



Pixels within 15% of median   Pixels within 5% of median

The goal of IR13S02 was to show that the flat field pattern was not dependent on the sample sequence. For this, 10 flats were taken with the F139M filter in each of the available sample sequences. Each image was then divided by the F139M image from IR13S01 to test stability. The resulting images have a median value close to 1.007, with an rms around 0.02.

Figure 3: Example F139M image ratio of two different sample sequences



RAPID / MIF900

4.2 CEI Specifications Correspondance

There are 5 seperate CEI specifications dealing with the IR detector flat fields. CEI specification 4.8.10 states that the short term QE stability of the pixels shall be better than

0.5%. Applying the flats created to the other datasets from IR13S01 and IR13S02 show that they are correctable to better than 0.5%, on timescales on the order of a week.

Specification 4.8.11.1 states that the detector should be correctable to a uniform gain per pixel of less than 2% at all wavelengths and that no more than 5% of the pixels shall have a response outside the range of 50-200% of the mean response. The ultimate goal is to have less than 1% of the pixels outside the range of 95-105%. Figure 2 illustrates that the first part of the goal is acieved. There are NO pixels outside the 50-200% range. However, there are quite a few which fall further away than 5% of the median value, with only about 20% of the pixels conforming to the ultimate goal. However, it is not clear whether this large scale gradient is due to the detector itself or the illumination characteristics of the test system.

Specification 4.8.11.2 states that large scale non-uniformities should be correctable to better than 2%. The large scale non-uniformity present in all the flatfields is correctable to at least 1%.

Specification 4.8.11.3 states that no more than 2% of the pixels may be non-functional. This includes dead pixels, hot pixels (that exceed dark current by more than 100 times the mean value) and pixels with uncorrected QE less than 25% or more than 400% of the mean value. Aproximately 2% of the pixels in each filter were found to be non-functional or have uncorrected QE values at the specified levels. Most of these were low QE pixels and visually all seem to be associated with bad pixels on the detector.

Specification 4.8.11.4 states that the difference between two flat fields taken 2 months apart using the same instrument configuration shall not exceed 1% rms (with a goal of 0.5%rms). Also, no more than 5% of the field of view shall vary by more than 5%. This test only provides us with a time scale of a few days, but comparison of those flats shows that the rms is below 1%.

5. Summary

The IR13S01 and IR13S02 SMS executed during the September-October 2004 thermal vacuum testing show that high quality flat field images can be constructed for all the IR channel filters. They are stable to better than 1% within the available timeline and meet most of the CEI specfications for flat field uniformity. The field variance is 20% across the array, with only about 20% of the pixels falling within 5% of the median QE.

6. References

"Hubble Space Telescope Wide Field Camera 3 Contract End Item Specification", STE-66, May 19, 2000.

Sosey, M, Bushouse, H., 2006, "Comparison of the WFC3 IDL and IRAF IR Image Reduction Pipelines", WFC3-TIR 2006-