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WFC3 TV3 Testing: IR Channel Blue Leaks

Thomas M. Brown

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ABSTRACT

A new IR detector (IR4; FPA165) is housed in WFC3 during the current campaign of thermal vacuum (TV) ground testing at GSFC. As part of these tests, we measured the IR channel throughput. Compared to the previous IR detectors, IR4 has much higher quantum efficiency at all wavelengths, particularly in the optical. The total throughput for the IR channel is still low in the optical, due to the opacity of the IR filters at these wavelengths, but there is a small wavelength region (~710-830 nm) where these filters do not offer as much blocking as needed to meet Contract End Item specifications. For this reason, the throughput measurements were extended into the blue to quantify the amount of blue leak in the narrow and medium IR bandpasses where a few percent of the measured flux could come from optical photons when observing hot sources. The results are tabulated here.

Background

The Wide Field Camera 3 (WFC3) is currently in ground testing under thermal vacuum (TV) conditions. A new IR detector (IR4; FPA165) was recently installed in the instrument, replacing the detector in use during the 2007 TV tests (IR1; FPA129). Like IR1, the new detector has been substrate thinned in order to mitigate a potential issue with these detectors, wherein they produce elevated dark rates in response to cosmic ray impacts; this thinning process also enhances the quantum efficiency (QE) of the detector, particularly at blue wavelengths.

Among the tests performed in TV is a measurement of the end-to-end throughput (i.e., the throughput of the entire instrument excluding the HST OTA). The current tests are very similar to the tests performed during the previous TV campaign (see Brown 2007, ISR WFC3 2007-23 for details). In that campaign, an instability in the CASTLE calibration prevented accurate measurement of the IR throughput until the last day of testing. On that last day, there was only time to test the in-band IR throughput. The measurement of throughput blueward of the nominal IR bandpasses had been performed earlier in that TV campaign, when the CASTLE calibration was unstable at the ~20% level. Given that we now have a stable CASTLE calibration and a new IR detector, it is worth remeasuring these out-of-band throughputs. The in-band throughputs are also being measured, but those tests are still underway, and will be the subject of a future report. So far, the in-band throughputs are very stable and in excellent agreement with expectations from the throughputs of individual WFC3 components.

The Contract End Item (CEI) specification for out-of-band transmission in the medium-band and wide-band WFC3/IR filters is 10^{-4}, while for narrow-band filters it is 10^{-5} (on average, with no peaks over 10^{-4}). This level of blocking was not achieved in the IR filter set. In particular, a small wavelength region (~710-830 nm) blueward of the filter bandpass has significantly higher throughput than desired. These blue leaks were considered insignificant when WFC3 included the original IR detector (FPA064), given its low QE below 900 nm. However, these blue leaks became more significant when we switched to thinned IR detectors with better short-wavelength response (e.g., FPA129 and FPA165). The practical scientific impact is minimal and can be calibrated for those rare instances where it might have an impact. For example, observations of an O star in one of the N-band or M-band IR filters could have a few percent of the detected counts coming from flux at these blue wavelengths; thus, the O star would appear a few percent brighter than it would otherwise appear without the blue leaks, but this would not significantly increase the background generated by an O star in a star field. Another pathological situation that could arise would be the redshift of a strong emission line into the blue leak wavelengths (e.g., a high-redshift emission line galaxy). However, in general, blue leaks in IR filters have far less impact than red leaks in UV filters, because most of the universe is red and hot objects are rare. Red leaks in UV filters can cause false detections in surveys of hot objects and can introduce unacceptably high backgrounds when observing hot objects embedded within large populations of cool objects. In contrast, when observing cool objects with IR filters, the contamination from hot objects should be rare, and even in those cases where a hot object is in the vicinity, the small increase in its flux from a few percent blue leak will generally not make the difference between a successful or unsuccessful observation.

Test Setup

For the IR throughput tests, WFC3 was illuminated with an optical stimulus (called "CASTLE") that can deliver flux-calibrated monochromatic light to the WFC3 focal plane. We employed the 200 micron fiber on CASTLE, fed by a Tungsten lamp in combination with a double monochromator (10 nm bandpass), producing a spot approximately 6 pixels across on the WFC3 IR detector. This large spot allows the throughput to be measured more accurately, because it averages over pixel-to-pixel variation in response and allows a large number of counts in the measurement without approaching the saturation limit of the IR detector. CASTLE measures the photon flux using its own reference detectors, employing a Si photodiode at 1 micron and bluer wavelengths (the same reference detector used at the red end of the UVIS throughput tests), and an InGaAs photodiode at wavelengths above 1 micron.

We checked the blue leak in the current TV campaign by measuring the short wavelength throughput of the 6 IR filters most susceptible to blue leak problems (specifically, those filters that would have the highest fraction of counts coming from blue photons when observing an O star). These tests (IR12S04 & IR12S05) were done with the same methodology for the blue leak tests in the previous TV campaign (Brown 2007). The WFC3 images were obtained with a 256x256 subarray, using a STEP25 sample sequence with 9 reads, for a total exposure time of 78 seconds. The CASTLE spot fell in the lower right-hand corner of this subarray (quad 3). For each throughput measurement, we obtain an image of the CASTLE source and then a contemporaneous dark using the same WFC3 exposure parameters.

Results

The WFC3 images were processed with a minimal IDL-based pipeline that fits and subtracts the signal in the appropriate reference pixels (using 4 of the reference pixel columns along the left and right sides of the image), fits a line to counts vs. time in the non-destructive read sequence for each pixel in an exposure, and scales by the gain. We assume a gain of 2.33 e^-/DN when the IR channel is commanded to a gain of 2.5 e^-/DN. The value of 2.33 e^-/DN is the product of the gain measured via the traditional "mean variance" method (2.65 e^-/DN; B. Hilbert, private comm.) and the inter-pixel capacitance (IPC) correction (0.88; E. Malumuth, private comm.). The rate image from the contemporaneous dark exposure was then subtracted from the rate image from the source exposure. Aperture photometry was then performed on the spot with an 8 pixel radius and a sky annulus of radii 18-28 pixels. Because the source was close to the corner of the subarray, this aperture is necessarily smaller than the aperture used in the standard throughput measurements (20 pixel radius), but still fully encloses the spot (which is about 6 pixels in diameter). Table 3 summarizes the blue leak results for these 6 filters. At most wavelengths, the throughput is at the level of 10^{-6}, but it reaches 10^{-3} to 10^{-2} at specific wavelengths.

Table 1: Blue leak measurements

wave-length (nm)	obs. rate (e^-/s)	F153W through-put	obs. rate (e^-/s)	F164N through-put	obs. rate (e^-/s)	F167N through-put	obs. rate (e^-/s)	F126N through-put	obs. rate (e^-/s)	F128N through-put	obs. rate (e^-/s)	F139M through-put
850	101	3.07E-06	143	4.57E-07	106	3.46E-07	174	5.40E-07	21	5.87E-07	337	9.96E-07
840	168	6.07E-06	132	5.30E-07	127	5.09E-07	130	4.78E-07	10	3.90E-07	1161	4.30E-06
830	169	7.42E-06	349	1.70E-06	316	1.53E-06	96	4.32E-07	13	6.10E-07	2041	9.09E-06
820	415	2.14E-05	752	4.14E-06	720	4.07E-06	201	1.06E-06	236	1.22E-06	2329	1.21E-05
810	1031	5.99E-05	1291	8.05E-06	964	6.00E-06	357	2.11E-06	302	1.77E-06	4542	2.65E-05
800	22589	3.69E-04	2631	4.25E-05	1751	2.84E-05	966	1.51E-05	583	9.08E-06	4965	7.73E-05
790	37529	6.71E-03	489	8.59E-05	259	4.56E-05	1855	3.15E-04	198	3.31E-05	24251	4.03E-03
780	7434	1.35E-02	678	1.22E-03	514	9.39E-04	2259	3.98E-03	1479	2.58E-03	2530	4.44E-03
770	3561	5.62E-03	1946	3.02E-03	2002	3.14E-03	2081	3.10E-03	2607	3.86E-03	1099	1.64E-03
760	12811	2.64E-03	4876	1.01E-03	4667	9.65E-04	7894	1.55E-03	5903	1.16E-03	3312	6.50E-04
750	14995	4.23E-04	10843	3.06E-04	6249	1.77E-04	11984	3.19E-04	9238	2.47E-04	5644	1.51E-04
740	4365	1.41E-04	2294	7.44E-05	1061	3.46E-05	1795	5.55E-05	1546	4.79E-05	1582	4.85E-05
730	1703	3.39E-05	1191	2.32E-05	788	1.56E-05	1083	2.09E-05	820	1.61E-05	578	1.06E-05
720	4197	8.62E-06	4148	8.30E-06	2328	4.75E-06	1883	3.73E-06	2388	4.75E-06	3133	5.88E-06
710	1669	3.06E-06	1522	2.75E-06	1327	2.43E-06	1416	2.51E-06	1056	1.92E-06	1034	1.76E-06
700	887	1.55E-06	839	1.44E-06	694	1.21E-06	495	8.41E-07	522	8.96E-07	657	1.07E-06