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WFC3 TV3 Testing: UVIS Filtered Throughput

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ABSTRACT
During the most recent WFC3 thermal vacuum (TV) testing campaign, several tests were executed to measure the UVIS channel throughput through its 62 filters. These tests complement the tests of the UVIS channel system throughput, which is done without a filter in the beam (i.e., the CLEAR mode). The UVIS filter transmissions were already well-characterized by scans of the filters at JPL and GSFC, so the filtered tests here are geared toward verification instead of characterization. Most of the filters showed good agreement with previous scans, two narrow-band filters (F280N and FQ232N) showed discrepancies at the level of ~15-20%, perhaps due to inaccuracies in the monochromator of the optical stimulus used in these tests. As in previous tests, the F775W filter transmission was 15% higher than expected.

Background

The Wide Field Camera 3 (WFC3) recently underwent ground testing under thermal vacuum (TV) conditions. The flight UVIS detector (UVIS-1') is currently installed in the instrument, replacing the spare detector in use during the 2007 TV tests (UVIS-2). Among the tests performed in TV was a measurement of the UVIS filtered throughput. The UVIS system throughput in the "CLEAR" mode was measured separately, but due to a calibration problem on the reference detector of the optical stimulus (called "CASTLE") used in these ground tests, those data cannot be interpreted until the CASTLE is re-calibrated. The transmission of the UVIS filters can be characterized before this CASTLE re-calibration, because the measurements do not depend on a CASTLE absolute calibration - they simply compare the throughput at a given wavelength with and without a UVIS filter. These filters were already well-characterized by ground tests and both JPL and GSFC, and it would be impractical to obtain a high-resolution scan of each UVIS bandpass under TV conditions. These tests thus checked a single in-band wavelength for each filter. The methodology was very similar to that used in the tests of previous TV campaigns (e.g., Brown 2007, ISR WFC3 2007-24), to which the reader is referred for details.

Results

As with all of the UVIS throughput tests, a 200-micron fiber from the optical stimulus provided flux-calibrated illumination of a spot approximately 20 pixels wide on the UVIS detector. The wide spot allows an average over pixel-to-pixel response and also enables the collection of many counts (>>10,000) without saturating the detector. Except for some of the quad filters (which require moving the target position to the quadrant in question), these filtered throughput tests used an 800x800 subarray on chip 2 in the same location used for the CLEAR system throughput tests. Aperture photometry was used to measure the count rate, with a radius of 40 pixels and a sky annulus of radii 50-70 pixels.

There were two WFC3 exposures at each wavelength, but one employed a UVIS filter and one used the CLEAR mode; each had its own CASTLE flux calibration. We divided the filtered throughput by the clear throughput to obtain the transmission of the filter in isolation, which was then compared to the expected transmission. Both the measured and expected throughput were not calculated at a single wavelength, but instead were calculated as the weighted average in that vicinity, with the nearly monochromatic CASTLE spectrum as the weighting function.

The CASTLE lamps cannot provide an infinitely monochromatic source; with the double monochromator, users can specify a bandpass of 1-13 nm, and the resulting spectrum has a triangular shape with a FWHM at the specified bandpass. E.g., a 10 nm bandpass produces a triangle with a base of 20 nm and a FWHM of 10 nm. Thus, what was measured in this test was a weighted average of the transmission in each filter, where this triangular spectrum was the weighting function. This distinction is unimportant for the medium-band (M), wide-band (W), or long-pass (LP) filters, but it is important for the narrow-band (N) filters, because some have a FWHM of only a few nm. The CASTLE bandpass was set to 10 nm for nearly all medium-band, wide-band, and long-pass filters, with the exception of F845M, F814W, and F850LP, where it was 12 nm. The CASTLE bandpass was also set to 10 nm for all of the narrow-band filters. The N-band test procedure was the matter of some debate during the preparation for the TV campaigns. At any setting of the CASTLE bandpass width, the width of the spectrum produced will be a non-negligible fraction of the WFC3 filter bandpass. Thus the spectrum-weighted average of the filter transmission will be very sensitive to any systematic errors in the CASTLE wavelength calibration and any deviations from a triangular spectrum. The tests of the N-band filters are intended as a crude transmission check, to make sure there has not been a catastrophic failure of a coating or other gross problem.

The results of the filter measurements are shown in Table 1. Most of the filters agreed with expectations at the 5% level or better. The F775W transmission was 15% higher than expected, and this is consistent with the tests of this filter in the 2004 TV campaign (Brown & Reid 2005, ISR WFC3 2005-02) and the 2007 TV campaign (Brown 2007, ISR WFC3 2007-24). The F280N and FQ232N filter transmissions were lower than expected by 17% and 14%, respectively. However, the N band transmission measurements were really meant as a gross verification, given the systematics introduced by the finite CASTLE bandpass and the narrowness of the N-band filters. It is worth stressing that the N-band transmissions are a spectrum-weighted average over the CASTLE bandpass, not the peak transmission of the filter.

Although this test was meant as a verification only, it appears that the JPL high-resolution scan for the F775W filter really did have some kind of normalization problem, because reasonable systematic errors in the CASTLE calibration cannot explain the fact that the measured transmission in this wide filter is 15% higher than expected. The F763M, F775W, and F814W filters were all made from the same sandwich material (RG665 / BK7; S. Baggett, priv. comm.), yet the transmission curve for F775W looks out of family with those of F763M and F814W (peaking at ~84% instead of ~97%). The F775W transmission curve should be scaled upward by 15%. This change will be applied in next revision to the WFC3 Synphot files.

Table 1: Transmission checks for UVIS filters

filter	wavelength (nm)	transmission	relative to expected transmission
F200LP	300.0	0.984	0.999
F218W	218.0	0.192	0.964
F225W	225.0	0.308	0.987
F275W	275.0	0.364	0.968
F280N	280.0	0.080	0.834
F300X	300.0	0.348	0.979
F336W	336.0	0.761	1.032
F343N	343.0	0.687	0.994
F350LP	555.0	0.976	1.000
F373N	373.0	0.329	0.970
F390M	390.0	0.834	0.998
F390W	390.0	0.943	0.996
F395N	395.0	0.583	1.030
F410M	410.0	0.911	1.012
F438W	438.0	0.822	1.016
F467M	467.0	0.894	0.998
F469N	469.0	0.302	1.017
F475W	475.0	0.887	1.005
F475X	475.0	0.925	0.998
F487N	487.0	0.430	0.994
F502N	502.0	0.469	1.010
F547M	547.0	0.833	1.003
F555W	555.0	0.863	0.988
F600LP	642.0	0.973	0.993
F606W	606.0	0.940	0.981
F621M	621.0	0.966	1.009
F625W	625.0	0.895	0.998
F631N	630.0	0.435	1.029
F645N	645.0	0.587	1.057

filter	wavelength (nm)	transmission	relative to expected transmission
F656N	656.0	0.133	0.929
F657N	657.0	0.751	1.023
F658N	658.5	0.215	0.915
F665N	665.0	0.807	1.038
F673N	676.0	0.672	0.912
F680N	688.0	0.917	0.976
F689M	689.0	0.905	0.999
F763M	763.0	0.962	1.004
F775W	775.0	0.953	1.143
F814W	814.0	0.950	0.998
F845M	845.0	0.956	0.999
F850LP	880.0	0.868	1.036
F953N	953.0	0.626	0.975
FQ232N	233.0	0.030	0.862
FQ243N	242.0	0.045	0.923
FQ378N	379.0	0.625	1.025
FQ387N	387.0	0.204	0.930
FQ422M	422.0	0.529	1.015
FQ436N	436.5	0.248	0.966
FQ437N	437.0	0.180	0.930
FQ492N	493.0	0.722	1.051
FQ508N	509.0	0.779	1.039
FQ575N	575.5	0.125	0.917
FQ619N	620.0	0.451	1.000
FQ634N	635.0	0.479	1.024
FQ672N	671.5	0.155	0.955
FQ674N	673.0	0.104	0.911
FQ727N	727.5	0.469	1.005
FQ750N	750.0	0.465	0.955
FQ889N	889.0	0.606	0.951
FQ906N	906.0	0.627	0.965
FQ924N	924.0	0.590	0.932
FQ937N	937.0	0.645	1.032