



Instrument Science Report WFPC2 2009-002

WFPC2 F343N Filter Throughput Decline

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April 01, 2009

ABSTRACT

Observations of the standard star GRW+70D5824 indicate a ~50% decrease in the throughput of the F343N filter during the WFPC2 mission. The decline appears to be linear with time and is approximately uniform across the field of view. Essentially identical results are obtained for the PC1 and WF3 detectors, and no features corresponding to the ~50% throughput decline are seen in external flats. Post-flight laboratory tests on the filter are needed to determine its current spectral properties.

Introduction

The WFPC2 narrow-band filters typically contain sandwiches of colored glass and pairs of multi-layered thin-film filters. These multi-layer thin-film filters are not necessarily stable over long periods of time; the literature contains various reports of wavelength change, etc., due to absorption / desorption processes and long-term annealing of the multi-layer stack. It is difficult to assess the stability a priori, since the construction details and manufacturing processes are typically proprietary.

Evidence for a throughput decrease in the F343N filter was first brought to our attention in July 2008 by a planetary observer. Herein we present analyses of standard-star data for this filter from April 1994 to the present epoch, as well as results from Earth flats (observations of the bright Earth). Our results may be used to update the Synphot throughput table at some point in the future.

Data Analysis

We looked at the photometric trend of standard star GRW+70D5824 in F343N, from April 1994 (when the CCD operating temperature was reduced from -76 C to -88 C) to recent data taken in September 2008. Analysis was restricted to PC1 and WF3 because most data were taken using those chips. We selected images that were taken within 10 days after a decontamination to minimize the effects of UV contamination on the photometry.

The images were processed through the standard STScI Archive “on-the-fly” calibration, corrected for geometric distortion (by multiplying the images with the correction image, f1k1552bu.r9h), and the 34th row defect as described by Anderson & King (1999). Aperture photometry was performed using the IRAF *phot* package. The instrumental magnitudes reported in Tables 1 & 2 were obtained using an aperture radius of 0.5”, which corresponds to $r=11$ pixels in PC1 and $r=5$ pixels in the WF chips. We also obtained measurements using $r=3$ pixels for PC1, and $r=2$ pixels for WF chips to calculate CTE loss as described by A. Dolphin (2008).

Figure 1, a plot of CTE-corrected magnitude vs. Modified Julian Date, shows the throughput decline of ~50% over 15 years. A linear fit was applied to the PC1 and WF3 data using the STSDAS task *tlinear*. The linear fits for both chips, as shown in Table 3, are quite consistent, suggesting that the throughput decline is not localized to one section of the filter.

To further study the uniformity of the decline, we analyzed Earth flats taken with the F343N filter from two widely-spaced epochs: 1994-1995 vs. 2007-2008. We selected Earth flats taken in roughly the same post-decon interval (for these samples, more than 20 days after a decon), which had good signal-to-noise and no saturation. The rapid motion of HST creates streaks across the Earth flat images that can be removed by combining several good-quality Earth flats. This was done using the *streakflat* task in *stsdas.hst_calib.wfpc.w_calib*. The combined Earth flat from each epoch was then normalized using the *normclip* task in the same package, which also computes the reciprocal of the input image.

Figures 2a and 2b show the 2007-2008 combined Earth flat effectively divided by the 1994-1995 combined Earth flat. This ratio image was median-filtered using a 3x3 box to remove the effects of hot pixels. Dark areas in the figure correspond to areas of low filter throughput in the 2007-2008 image. Since the F343N filter is located about 20 cm from the HST focal plane, any features on the filter should contribute only large-scale features at the detector. A single bright or dark point on this filter would map into a ~50 arcsecond diameter donut at the detector. The flats do not show any large-scale features corresponding to the 50% photometric loss. At most, a broad 10% to 15% gradient

might be visible across Figure 2b, running from the lower right to the upper left. Apparently the 50% throughput loss is not localized to one area of the filter, but instead must involve the entire filter and be approximately uniform on the relevant spatial scales. We cannot, of course, rule out that numerous small spots are present (few arcsecond or smaller size) which are spread across the filter in some quasi-uniform fashion.

Most of the features visible in Figures 2a and 2b have known causes. The contamination “worms” which are most apparent in WF2 are from the 1994-1995 flats. These were caused by some thin contaminant on the CCD windows that repelled darker contaminants (i.e. worms are bright in the 1994-1995 image). They appeared in all UV images taken early in the mission, and slowly disappeared over the years, presumably due to the contaminant evaporating. Faint streaks are visible in the flat ratio due to Earth features. Very small (but strong) features are due to dust spots on or near the CCDs. Weaker spots or granularity are due to hot pixels, primarily from the 2007-2008 images.

While the throughput loss is clearly present, we do not have any spectral information to constrain the bandpass shape, nor for that matter, the central wavelength. The filter is composed of a sandwich of two multi-layer thin-film filters. A wide range of scenarios are possible – one of the thin-film filter components may not have been properly baked-out during manufacture, and hence may have shifted in wavelength relative to the other component as water or gasses slowly evaporated. Under this scenario, the overall bandpass would become narrowed and shift slightly to larger or smaller wavelengths. But a wide range of other possibilities exist also. Post-flight laboratory tests are needed to determine exactly the current spectral properties of the filter.

Table 1. PC1 F343N observations of GRW+70D5824, taken within 10 days after a decon. The last three columns indicate the resulting instrumental magnitude, magnitude uncertainty, and CTE-corrected instrumental magnitude, respectively.

Image	Date of Observation	Days Since Decon	m (0.5'')	m (0.5'') error	m (0.5'') , CTE-corrected
u2tx020ct	1995-08-27	0.3807	24.344	0.02	24.318
u3ik030cr	1997-08-25	5.2543	24.438	0.022	24.391
u4s60406r	1998-10-17	3.1842	24.455	0.022	24.395
u5ls680ir	2000-04-19	1.0619	24.569	0.024	24.484
u69q380ir	2001-05-17	1.7126	24.636	0.025	24.538
u6hpgj0gm	2002-06-17	5.1540	24.881	0.029	24.765
u8gxcg0br	2002-12-05	0.2272	24.776	0.026	24.668
u8u5bg07m	2003-11-15	1.5605	25.031	0.051	24.878
u9jacg06m	2006-03-15	0.2753	25.005	0.034	24.831
ub0pmo01m	2008-09-26	3.8932	25.373	0.045	25.192
ub0pmo02m	2008-09-26	3.8960	25.383	0.045	25.201
ub0pmo03m	2008-09-26	3.9008	25.156	0.036	24.982
ub0pmo04m	2008-09-27	3.9036	25.139	0.036	24.960

Table 2. Same as Table 1, but for the WF3 detector.

Image	Date of Observation	Days Since Decon	m (0.5'')	m (0.5'') error	m (0.5''), CTE-corrected
u2tx0215t	1995-08-27	0.5592	24.251	0.012	24.223
u3ik0315r	1997-08-25	5.4202	24.39	0.014	24.335
u4s6040hr	1998-10-17	3.2474	24.49	0.014	24.422
u5ls680sr	2000-04-19	1.1279	24.389	0.013	24.311
u69q380sr	2001-05-17	1.7751	24.649	0.016	24.550
u6hpgj0pm	2002-06-17	5.2699	24.774	0.017	24.669
u8gxcg0nm	2002-12-05	0.2974	24.834	0.018	24.722
u8u5hg07m	2004-09-05	2.0842	24.903	0.019	24.758
u948hg07m	2005-09-22	2.1356	25.056	0.021	24.897
u9jahg07m	2006-12-17	4.5384	25.122	0.021	24.955
ub0pmp01m	2008-09-25	2.5001	25.187	0.023	24.993
ub0pmp02m	2008-09-25	2.5029	25.218	0.024	25.025
ub0pmp03m	2008-09-25	2.5078	25.226	0.024	25.056
ub0pmp04m	2008-09-25	2.5105	25.229	0.024	25.058

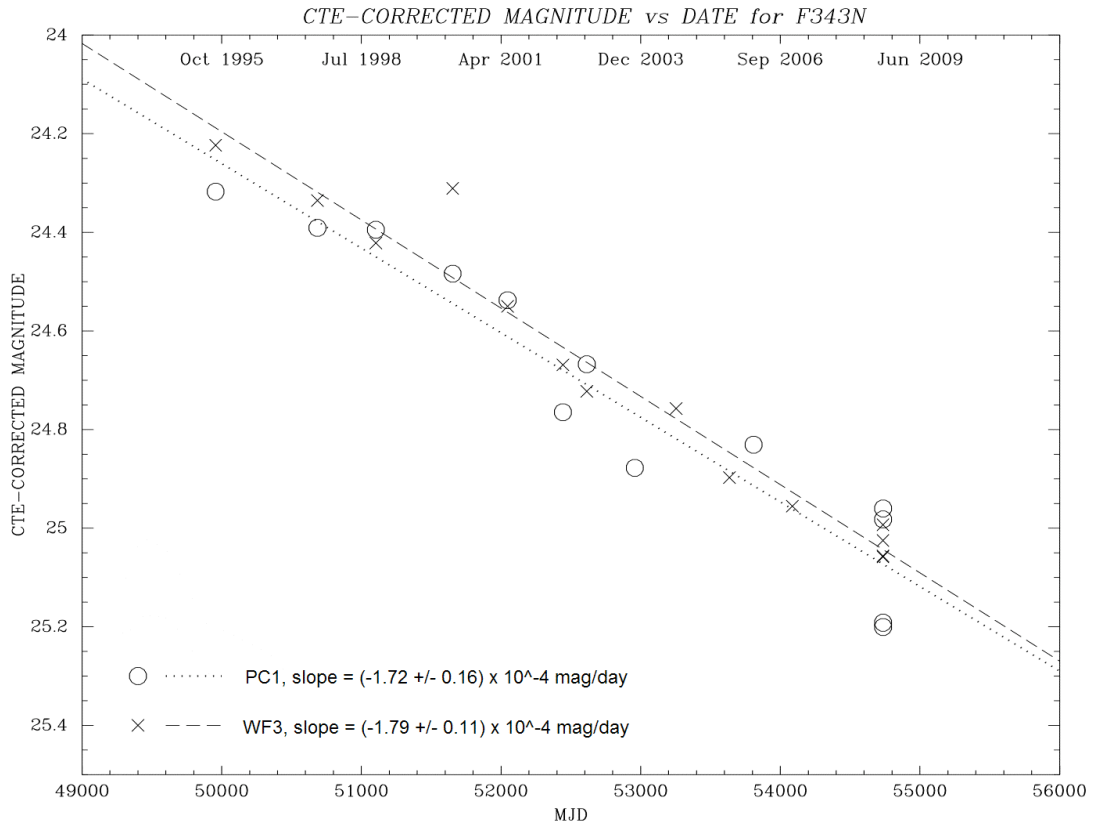


Figure 1. F343N GRW+70D5824 CTE-corrected magnitude vs. Modified Julian Date.

Table 3. Linear fit parameters for F343N CTE-corrected Magnitudes vs. Modified Julian Date: coefficients of the fit (a, b), their standard deviations (sigma_a, sigma_b), and chi squared (chi2).

Chip	# of pts	a	sigma_a	b (slope, mag/day)	sigma_b	chi2
PC1	13	15.68	0.85	1.72E-4	1.61E-5	0.095
WF3	14	15.25	0.56	1.79E-4	1.06E-5	0.047

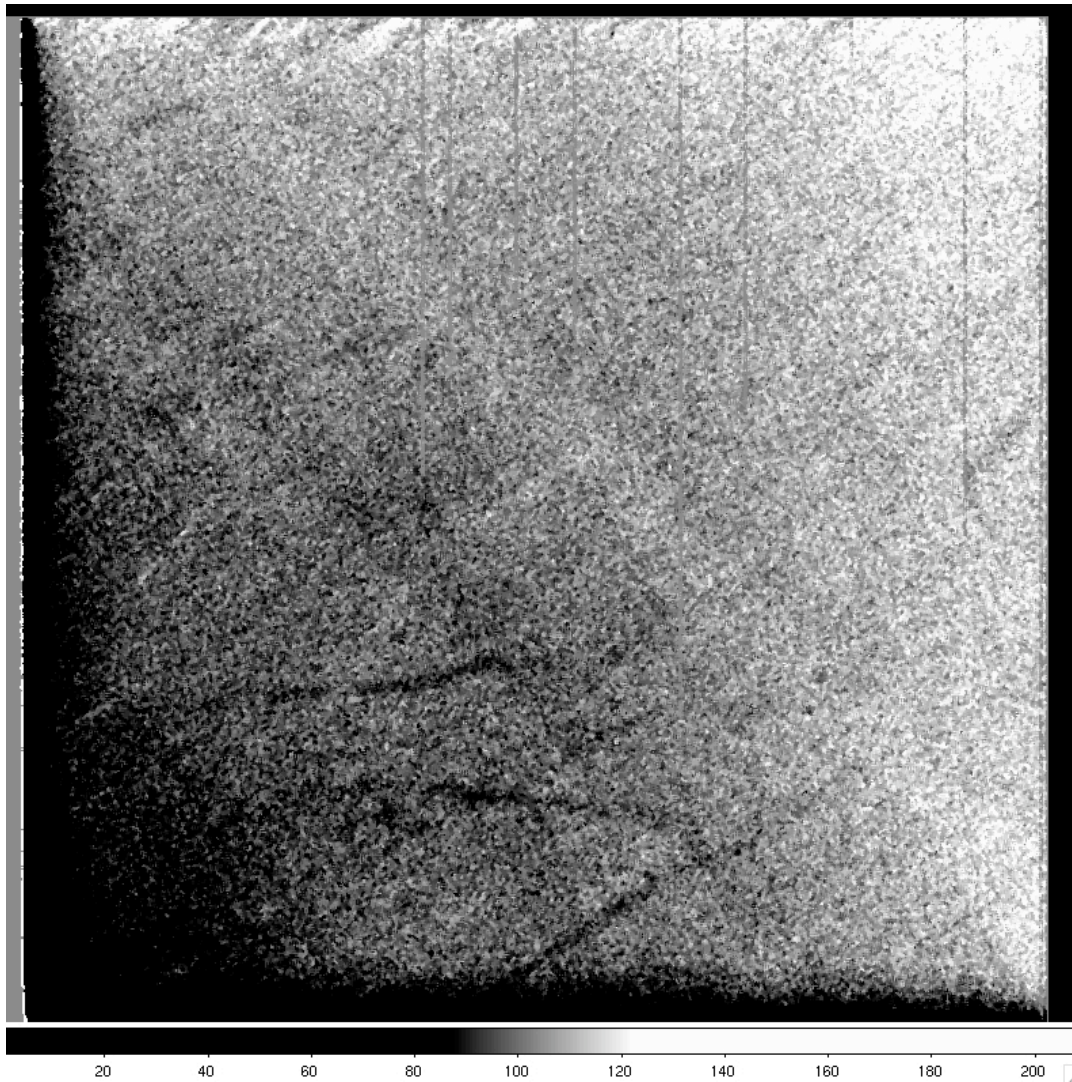


Figure 2a. PC1 ratio image. This effectively shows the 2007-2008 combined Earth flat divided by the 1994-1995 combined Earth flat. This image was 3x3 pixel median-filtered to remove the effects of hot pixels from the latter epoch. The DS9 display range is from z1=0.9 to z2=1.1. Variations due to UV contamination “worms,” scattered light, and residual Earth flat features are visible.

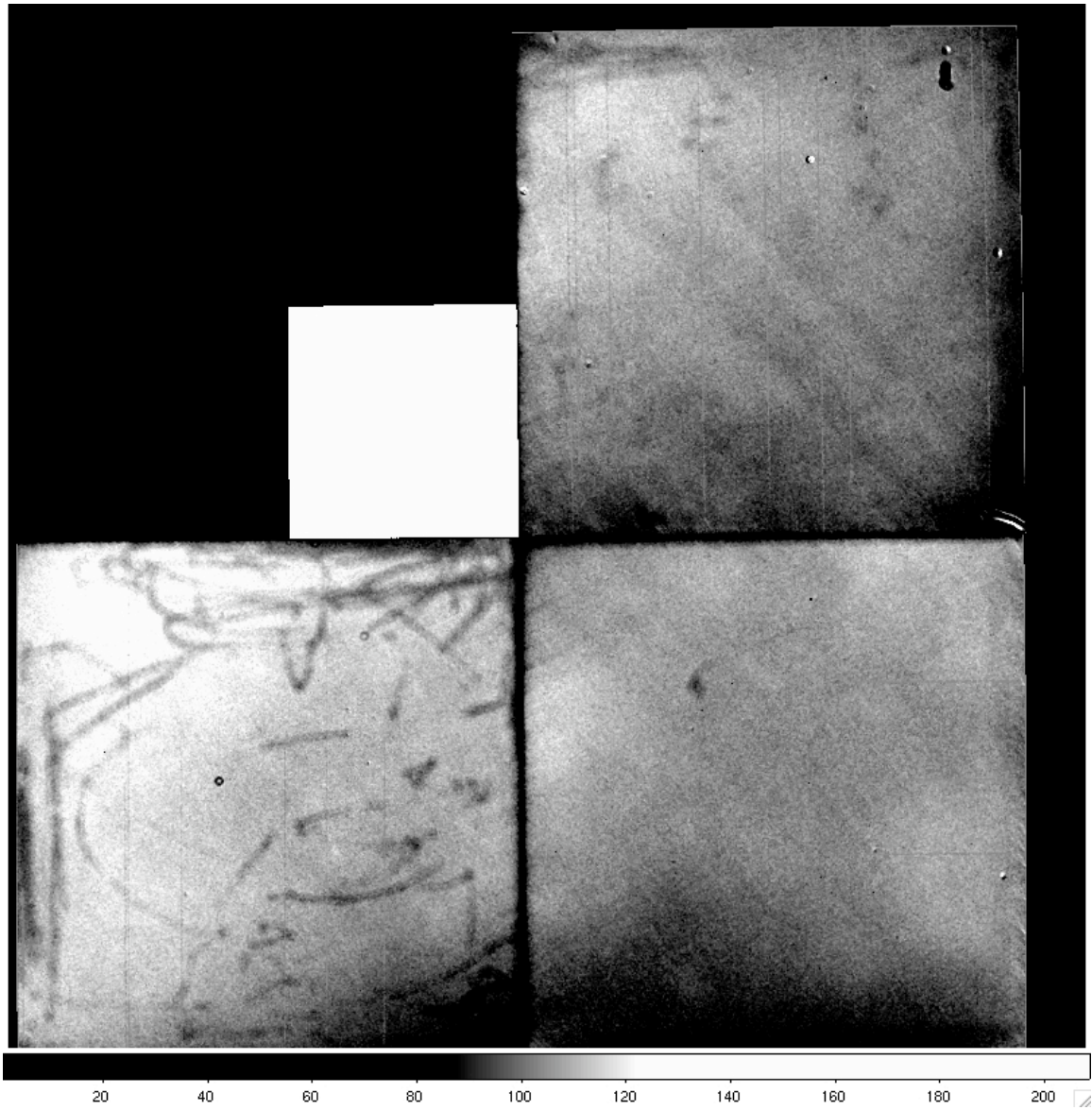


Figure 2b. The same ratio image as Figure 2a, stretched to show the WF chips. The “worm” features in WF2 (lower left) are UV contaminant features from the 1994-1995 epoch; they are not present in the later epoch. The DS9 display range is $z1=0.9$ to $z2=1.1$. Brightness variations on the spatial scales expected for filter anomalies (~ 50 arcseconds) are not stronger than about 10% to 15%.

Conclusions

The WFPC2 F343N filter has undergone a ~50% throughput loss during the 15 year WFPC2 mission. The loss is roughly linear with time and has an average rate of 1.75E-4 mag/day. The loss appears to be more-or-less uniform across the WFPC2 field-of-view – loss rates are similar in PC1 and WF3 CCDs, and no features of comparable strength appear in Earth flats taken in 2007-2008. Post-flight inspections and testing of the F343N filter are needed to determine nature of the problem and the current spectral properties of the filter. Appropriate corrections to the WFPC2 throughput tables will be made at a later date.

Acknowledgements

Our thanks to Dr. Amy Simon-Miller at NASA/GFSC for bringing this anomaly to our attention. We are also grateful to Dr. Van Dixon, Dr. Ronald Gilliland, Ms. Pey Lian Lim, and Dr. Linda Smith for their careful review of this ISR.

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