

SM3A SMOV WFPC2 Photometry Check

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ABSTRACT

A check of the photometric throughput of the WFPC2 was performed on January 18, 2000 (program ID: 8496). The standard star GRW+70d5824 was observed with a selection of filters and the standard star was centered in each of the four CCDs. The observations were obtained ~0.6 day after the WFPC2 DECON on January 17, 2000 (program ID: 8491, visit 55). The data indicate that any changes in the photometric throughputs due to SM3A are less than 1% in most of the visible wavelength filters, and less than a few percent in the UV filters. The measured UV throughputs are consistent with the long term trends of the UV sensitivity. The response of the WFPC2 has essentially not changed.

1. Introduction

The Wide Field and Planetary Camera 2 (WFPC2) is a two-dimensional imaging photometer utilizing four charge coupled devices (CCDs) as detectors. WFPC2 is located at the center of the Hubble Space Telescope (HST) focal plane, and the WFPC2 field-of-view (FOV) is divided into four CCD cameras (PC1, WF2, WF3, WF4) by a four-faceted pyramid mirror near the HST focal plane. Each of the four cameras contains an 800x800 pixel Loral CCD detector.

HST entered Zero Gyro Safe mode at 8:30 AM, November 13, 1999. Entry into safe mode was nominal. The HST aperture door closed during safe mode entry and remained closed until the end of HST Servicing Mission 3A (SM3A). Following entry of HST into safe mode, WFPC2 was safed. The power to the heaters was kept on, while the power to the detectors, to the computer, and the mechanical power were turned off. WFPC2 was recovered from safe mode and placed in standby. Enough power was turned on to keep WFPC2 warm and to make sure telemetry was received for monitoring of the instrument. HST was released by the shuttle crew at 6:03 PM, December 25, 1999. The aperture door was opened for the first time in 42 days.

2. DECON

Contaminants collect on the cold CCD windows and reduce the UV throughput of the WFPC2. A warm up decontamination (DECON) procedure is performed monthly to evaporate contaminants from the CCD windows which is followed by a cool down. Four DECONs were performed during SMOV 3A, on December 28, 1999 (MJD=51540.8215), January 3, 2000 (51546.0674), January 17, 2000 (MJD=51560.6854), and January 31, 2000 (MJD=51574.6583).

3. Photometry Monitor Observations

Observations of standard star GRW+70d5824 ($m_v = 12.7$, $B-V = -0.09$) for the photometry check were obtained on January 18, 2000 (program ID: 8496) which was approximately 0.6 day following the DECON on January 17, 2000. The star was positioned in the center of a camera during four 1-orbit visits, one visit per camera. The respective single camera images were readout and sent to the ground for analysis. Observations were obtained with filters F160BW, F170W, F185W, F218W, F255W, F300W, F336W, F439W, F555W, F675W, and F814W. Inspection of the data showed that the central pixel of the star image was saturated in two observations, u60g010ar and u60g0206r. Table 1 lists the observations.

Table 1. 8496 photometry monitor observations (* - central pixel of stellar image was saturated).

filter	PC1	PC1 exptime (sec.)	WF2	WF3	WF4	WF exptime (sec.)
F160BW	u60g0101r	200.0	u60g0201r	u60g0301r	u60g0401r	100.0
F170W	u60g0102r	40.0	u60g0202r	u60g0302r	u60g0402r	40.0
F185W	u60g0103r	100.0	u60g0203r	u60g0303r	u60g0403r	100.0
F218W	u60g0104r	40.0	u60g0204r	u60g0304r	u60g0404r	40.0
F255W	u60g0105r	80.0	u60g0205r	u60g0305r	u60g0405r	40.0
F300W	u60g0106r	12.0	u60g0206r*	u60g0306r	u60g0406r	12.0
F336W	u60g0107r	14.0	u60g0207r	u60g0307r	u60g0407r	12.0
F439W	u60g0108r	14.0	u60g0208r	u60g0308r	u60g0408r	8.0
F555W	u60g0109r	3.5	u60g0209r	u60g0309r	u60g0409r	2.3
F675W	u60g010ar*	8.0	u60g020ar	u60g030ar	u60g040ar	4.0
F814W	u60g010br	14.0	u60g020br	u60g030br	u60g040br	7.0

4. Calibration & Reducing the Data

The OPUS pipeline calibrated data were used for the analysis. No other calibration steps were performed. The IRAF task **imedit** was used to remove cosmic rays around the stars from the individual CCD frames.

Photometry was performed using the APPHOT task **phot** with the star positions manually identified for each camera as input. For the PC1 frames, a photometry aperture radius of 11 pixels was used with the sky fitting region parameters set to `annulus=32` pixels and `dannulus=11` pixels. For the WF frames, a photometry aperture radius of 5 pixels was used with the sky fitting region parameters set to `annulus=15` pixels and `dannulus=5` pixels. The sky fitting algorithm was set to “`ofilter`.” The centering algorithm was set to “`centroid`” with parameters `cbox=5` and `maxshif=1`. The photometry values are listed in Tables 2-5. For Tables 2-5, the table headers are:

`filter` - WFPC2 filter used.

`mjd` - modified Julian Date (Julian Date - 2400000.5) for the observation.

`flux` - the total corrected counts in the respective aperture.

`ct_rate` - actual countrate (DN/s) for the respective aperture.

`ctr_err` - measurement uncertainty of the countrate.

Table 2. 8496 PC1 photometry. Pre-SMOV zeropoints were used to determine the respective HST filter magnitudes (mag). The F675W filter observation was saturated.

<code>filter</code>	<code>mjd</code>	<code>flux</code>	<code>ct_rate</code>	<code>ctr_err</code>	<code>mag</code>
F160BW	51561.5564	16736.0	83.680	0.1808	9.055
F170W	51561.5613	6685.349	167.133	0.6054	9.620
F185W	51561.5634	9916.14	99.161	0.2867	9.878
F218W	51561.5661	5407.032	135.175	0.5562	10.252
F255W	51561.5682	12376.73	154.709	0.3944	10.784
F300W	51561.5710	11508.17	959.014	2.5439	11.230
F336W	51561.5731	10667.61	761.972	2.1084	11.577
F439W	51561.5752	12334.69	881.049	2.2628	12.119
F555W	51561.5773	13121.24	3748.925	9.2872	12.865
F675W	-	-	-	-	-
F814W	51561.5814	18823.04	1344.502	2.7356	14.335

Table 3. 8496 WF2 photometry. Pre-SMOV zeropoints were used to determine the respective HST filter magnitudes (mag). The F300W filter observation was saturated.

filter	mjd	flux	ct_rate	ctr_err	mag
F160BW	51561.6231	7788.212	77.8821	0.23909	9.269
F170W	51561.6259	7684.733	192.1183	0.5975	9.573
F185W	51561.6279	10283.53	102.8353	0.2754	9.934
F218W	51561.6307	5605.957	140.148	0.5132	10.292
F255W	51561.6328	6561.638	164.0409	0.5559	10.775
F300W	-	-	-	-	-
F336W	51561.6370	9221.045	768.4204	2.1719	11.592
F439W	51561.6391	7196.472	899.5590	2.8948	12.107
F555W	51561.6411	8712.167	3787.8986	11.0653	12.872
F675W	51561.6432	8516.099	2129.0247	6.3048	13.709
F814W	51561.6453	9847.85	1406.8357	3.8597	14.299

Table 4. 8496 WF3 photometry. Pre-SMOV zeropoints were used to determine the respective HST filter magnitudes (mag).

filter	mjd	flux	ct_rate	ctr_err	mag
F160BW	51561.6904	6619.847	66.1984	0.2228	9.257
F170W	51561.6932	6247.583	156.1895	0.5419	9.665
F185W	51561.6953	8538.938	85.3893	0.2523	10.019
F218W	51561.6981	5152.403	128.8100	0.4966	10.296
F255W	51561.7002	6427.683	160.6920	0.5515	10.751
F300W	51561.7023	12038.32	1003.1933	2.4847	11.198
F336W	51561.7043	9411.546	784.2955	2.2065	11.567
F439W	51561.7064	6963.971	870.4963	2.8739	12.154
F555W	51561.7085	8578.42	3729.7478	11.0090	12.874
F675W	51561.7106	8233.615	2058.4037	6.1868	13.705
F814W	51561.7127	9257.141	1322.4487	3.7502	14.368

Table 5. 8496 WF4 photometry. Pre-SMOV zeropoints were used to determine the respective HST filter magnitudes (mag).

filter	mjd	flux	ct_rate	ctr_err	mag
F160BW	51561.8245	7037.982	70.3798	0.2294	9.277
F170W	51561.8273	6842.04	171.0510	0.5713	9.627
F185W	51561.8293	9868.771	98.6877	0.2714	9.915
F218W	51561.8321	5519.535	137.9883	0.5152	10.260
F255W	51561.8342	6623.003	165.5750	0.5600	10.739
F300W	51561.8363	11957.92	996.4933	2.4812	11.213
F336W	51561.8384	9391.141	782.5950	2.2068	11.570
F439W	51561.8404	7119.119	889.8898	2.9009	12.124
F555W	51561.8425	8729.536	3795.4504	11.1173	12.862
F675W	51561.8446	8431.069	2107.7672	6.2936	13.699
F814W	51561.8467	9771.252	1395.8931	3.8522	14.316

An IRAF script was used to extract selected fields from the **phot** task output files. The script also determines the count rate (ct_rate) and the associated uncertainty of the count rate (ctr_err). The equations used to determine the count rate error are presented below:

$$\text{sigskysqd} = \text{stdev} * \text{stdev}$$

$$\text{errorsq} = ((\text{abs}(\text{sum} - \text{msky} * \text{area})) / \text{gain}) + \text{sigskysqd} * (\text{area} + (\text{area} * \text{area} / \text{nsky}))$$

$$\text{ctr_err} = \text{sqrt}(\text{errorsq}) / \text{itime}$$

where the parameters (output **phot** fields) are defined as follows:

sum = total number of counts including sky in aperture

area = area of the aperture in square pixels

itime = exposure time (exptime) header keyword value

msky = sky value per pixel stdev = standard deviation of sky value

gain = gain image header keyword value

nsky = number of sky pixels

5. UV sensitivity

The UV sensitivity of the WFPC2 will change depending upon the amount of contamination and will vary between DECONs. Normally the monitor program is executed before and after the decontamination procedures to monitor any change to the UV throughput. The 8496 calibration program executed approximately 0.6-1.2 days following the DECON on January 17, 2000.

Figure 1 presents the UV filter F170W results compared with observations obtained prior to the HST entering Safe mode on November 13, 1999. The measurements have been normalized to the mean count rate. The 8496 measurements are marked with a “cross-hair.” The figure indicates that the UV sensitivity has been recovered, and it also shows the long term trend of increased count rates for the UV throughput (Baggett and Gonzaga 1998).

6. Photometric Response

Calibration data for filters F185W and F300W were retrieved from the Archive. Filter F185W has not been used for the monitor program, and filter F300W was dropped from the monitor program. The data for these two filters were recalibrated using the on-the-fly calibration (OTFC) option within StarView. The data were reduced in an identical manner to the 8496 data.

Table 6. WFPC2 F185W filter photometry, pre-SMOV data.

camera	date	mjd	flux	ct_rate	ctr_err	dsd
PC1	25-Aug-97	50685.3390	3872.957	96.823	0.4876	5.24
	7-Sep-97	50698.2182	3557.605	88.940	0.4671	18.12
	13-Oct-98	51099.1252	3542.301	88.557	0.4732	28.02
	17-Oct-98	51103.2884	3689.915	92.247	0.4780	3.17
WF2	25-Aug-97	50685.3981	3935.136	98.378	0.4364	5.30
	7-Sep-97	50698.2738	3516.207	87.905	0.4112	18.18
WF3	25-Aug-97	50685.5050	3281.393	82.034	0.4022	5.41
	7-Sep-97	50698.3474	2833.934	70.848	0.3751	18.25
	13-Oct-98	51099.1856	2739.333	68.483	0.3688	28.08
	17-Oct-98	51103.3495	3536.039	88.400	0.4131	3.24
WF4	25-Aug-97	50685.5779	3748.342	93.708	0.4310	5.48
	7-Sep-97	50698.4085	3408.931	85.223	0.4162	18.31

Table 7. WFPC2 F300W filter photometry, pre-SMOV data.

camera	date	mjd	flux	ct_rate	ctr_err	dsd
PC1	29-Jan-99	51207.8571	11760.22	980.0183	2.570046	1.81
	09-Sep-99	51430.7133	11517.96	959.8300	2.53666	0.65
WF2	13-Oct-98	51099.2134	9271.048	927.1048	2.613457	28.11
	17-Oct-98	51103.3772	9772.944	977.2944	2.687061	3.26
WF3	13-Oct-98	51099.1897	9323.223	932.3223	2.625705	28.09
	17-Oct-98	51103.3536	9878.305	987.8305	2.702031	3.24
WF4	13-Oct-98	51099.2078	9567.56	956.7560	2.678465	28.11
	17-Oct-98	51103.3717	10080.78	1008.0780	2.742469	3.262

Tables 8-11 presents the 8496 photometric measurements compared to the pre-Safing measurements closest in time to the 8496 observations. The photometric monitor pre-Safing event measurements can be found on the STScI WFPC2 web page (Gonzaga et al. 2000). The 8496 measurements have been ratioed with the pre-Safing event measurements.

Table 8. PC1 photometry, pre-SMOV and 8496 count rates (dsd - day since DECON). The 8496 F675W filter observation was saturated.

filter	Date	dsd	ct_rate	Date	dsd	ct_rate	ratio
F160BW	09-Jun-99	0.6	84.5668	18-Jan-00	0.87	83.680	0.989
F170W	04-Nov-99	1.3	166.4179	18-Jan-00	0.87	167.133	1.004
F185W	17-Oct-98	3.1	92.247	18-Jan-00	0.87	99.161	1.074
F218W	09-Sep-99	0.7	134.7721	18-Jan-00	0.88	135.161	1.002
F255W	20-May-99	1.6	157.7611	18-Jan-00	0.88	154.709	0.980
F300W	09-Sep-99	0.6	959.8300	18-Jan-00	0.88	959.014	0.999
F336W	09-Sep-99	0.7	755.7880	18-Jan-00	0.88	761.972	1.008
F439W	09-Sep-99	0.7	879.8325	18-Jan-00	0.89	881.049	1.001
F555W	04-Nov-99	1.3	3715.3520	18-Jan-00	0.89	3748.925	1.009
F675W	09-Sep-99	0.7	2073.9580	18-Jan-00	0.89	-	-
F814W	09-Sep-99	0.6	1329.2300	18-Jan-00	0.89	1344.502	1.011

Table 9. WF2 photometry, pre-SMOV and 8496 count rates (dsd - day since DECON). The 8496 F300W filter observation was saturated.

filter	Date	dsd	ct_rate	Date	dsd	ct_rate	ratio
F160BW	09-Oct-99	3.5	77.1258	18-Jan-00	0.93	77.882	1.009
F170W	04-Nov-99	1.3	189.8454	18-Jan-00	0.94	192.118	1.011
F185W	25-Aug-97	5.3	98.378	18-Jan-00	0.94	102.835	1.045
F218W	20-Jun-99	3.9	142.5608	18-Jan-00	0.94	140.148	0.983
F255W	09-Oct-99	3.5	165.0441	18-Jan-00	0.94	164.040	0.993
F300W	17-Oct-98	3.26	977.2944	18-Jan-00	0.94	-	-
F336W	09-Oct-99	3.5	776.2471	18-Jan-00	0.95	768.420	0.989
F439W	09-Oct-99	3.5	901.1561	18-Jan-00	0.95	899.559	0.998
F555W	09-Oct-99	3.5	3767.0380	18-Jan-00	0.95	3787.898	1.005
F675W	20-Jun-99	3.9	2143.8780	18-Jan-00	0.96	2129.024	0.993
F814W	09-Oct-99	3.5	1374.0420	18-Jan-00	0.96	1406.935	1.023

Table 10. WF3 photometry, pre-SMOV and 8496 count rates (dsd - day since DECON).

filter	Date	dsd	ct_rate	Date	dsd	ct_rate	ratio
F160BW	04-Nov-99	1.3	68.4227	18-Jan-00	1.00	66.198	0.967
F170W	04-Nov-99	1.3	159.0743	18-Jan-00	1.01	156.189	0.981
F185W	17-Oct-98	3.2	88.400	18-Jan-00	1.01	85.389	0.965
F218W	04-Nov-99	1.3	130.4968	18-Jan-00	1.01	128.810	0.987
F255W	04-Nov-99	1.3	168.5777	18-Jan-00	1.01	160.692	0.953
F300W	17-Oct-98	3.2	987.8305	18-Jan-00	1.01	1003.198	1.015
F336W	04-Nov-99	1.3	770.5485	18-Jan-00	1.02	784.295	1.017
F439W	04-Nov-99	1.3	875.7900	18-Jan-00	1.02	870.496	0.993
F555W	04-Nov-99	1.3	3722.2030	18-Jan-00	1.02	3729.747	1.002
F675W	26-Mar-99	1.0	2056.8380	18-Jan-00	1.02	2058.403	1.000
F814W	04-Nov-99	1.3	1329.2300	18-Jan-00	1.02	1322.448	0.994

Table 11. WF4 photometry, pre-SMOV and 8496 count rates (dsd - day since DECON).
1406.835

filter	Date	dsd	ct_rate	Date	dsd	ct_rate	ratio
F160BW	10-Aug-99	0.8	70.4693	18-Jan-00	1.14	70.379	0.998
F170W	04-Nov-99	1.3	165.8059	18-Jan-00	1.14	171.051	1.031
F185W	25-Aug-97	5.4	93.708	18-Jan-00	1.14	98.687	1.053
F218W	10-Aug-99	0.8	139.7012	18-Jan-00	1.14	137.988	0.987
F255W	10-Aug-99	0.8	166.4179	18-Jan-00	1.15	165.570	0.994
F300W	17-Oct-98	3.26	1008.078	18-Jan-00	1.15	996.403	0.988
F336W	10-Aug-99	0.8	789.2235	18-Jan-00	1.15	782.950	0.992
F439W	10-Aug-99	0.8	889.6107	18-Jan-00	1.15	889.889	1.000
F555W	10-Aug-99	0.8	3746.2780	18-Jan-00	1.15	3795.450	1.013
F675W	10-Aug-99	0.8	2110.5710	18-Jan-00	1.16	2107.767	0.998
F814W	11-Aug-99	0.8	1370.2510	18-Jan-00	1.16	1395.893	1.018

Figure 2 presents in graphical form the ratio (8496/pre-Safing measurements) versus wavelength for each camera. The trends indicate a normal recovery of sensitivity with a slight increase in sensitivity, ~1-2%. The data spike at wavelength 1907 Å is from the F185W filter data. The elevated level of the ratio for this filter, except for WF3, is due to the increasing trend over time of the far-UV throughput (as seen in Figure 1) and the comparison data for this filter are earlier than for other pre-SM3A filter data.

The WF3 UV filter sensitivity ratios (as seen in Figure 2) are different than for the other cameras, indicating a slight decrease in sensitivity. The decreases in the WF3 UV sensitivity are -3.2% for F160BW, -1.8% for F170W, -3.4% for F185W, -1.3% for F218W, and -4.6% for F255W. This does not result from positioning of the target on the WF3 CCD as the visible filters show a slight improvement of the count rate. See Appendix I for a discussion about the positions of the calibration target on the WF3 CCD.

The positions of the calibration target on the CCDs for the January 18, 2000 data (post-SM3A) are consistently closer to the apex of the pyramid and the readout amplifier than for the pre-SM3A data. Due to less loss of charge resulting from CTE, the count rates for the visible filter data should be slightly higher than for the pre-SM3A count rates.

7. Conclusions and Recommendations

The WFPC2 calibration program 8496 executed post-DECON. Observations of the standard star GRW+70D582 were obtained with each camera and with the normal selection of monitor filters (11 filters). Two images were saturated, u60g010ar (PC1) and u60g0206r (WF2). The measurements indicate that the SM3A DECONs prior to January 18, 2000 removed most if not all of the contamination and the UV sensitivity continues to show an increase with time. Each camera performed as expected.

The data indicates that the throughputs for the optical filters, except for the F814W filter, are consistent with no change exceeding ~1% with the throughput for F814W filter consistent with no change exceeding ~2%. Except for the F185W filter, the UV throughput increased by ~1% when compared to pre-SM3A measurements. The WF3 UV throughputs are different than for the other cameras, exhibiting an as yet unexplained slight decrease of ~1-2%, but they are consistent with the long term trends of WF3 (as can be seen in Figure 1). The throughputs show that the WFPC2 suffered no ill effects from the Safing event on November 13, 1999.

8. References

Baggett, S. and Gonzaga, S. 1998, WFPC2 Long-Term Photometric Stability, WFPC2-ISR-98-03.

Gonzaga, S., Ritchie, C., Baggett, S., Casertano, S., Whitmore, B., and Mutchler, M. 2000, "Standard Star Monitoring Memo", available at URL

http://www.stsci.edu/instruments/wfpc2/Wfpc2_memos/wfpc2_stdstar_phot3.html

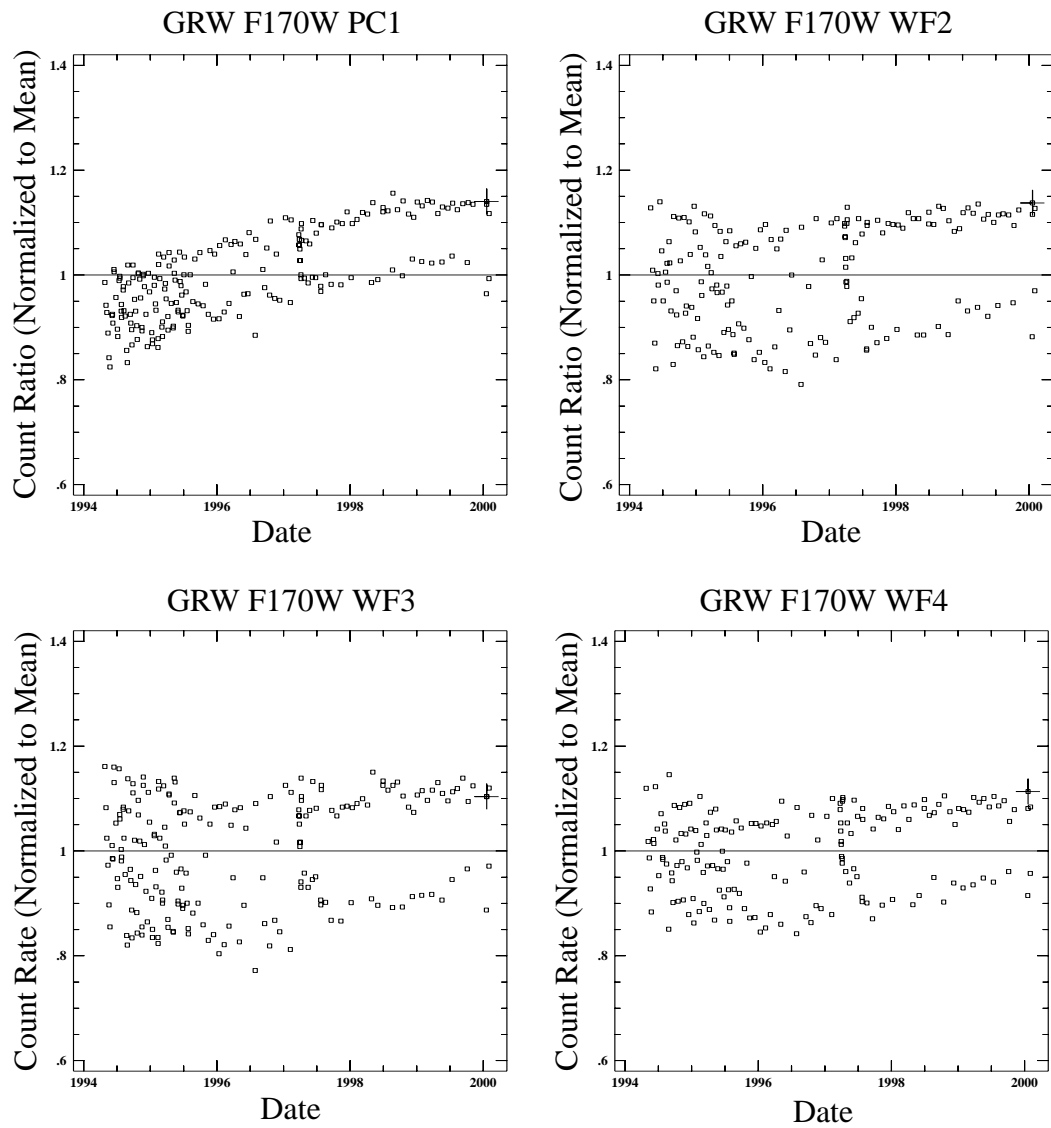


Figure 1: Photometric monitoring of standard star GRW+70D5824. The observations span a time interval from May 1, 1994 to January 31, 2000. The observations executed twice for each decontamination cycle, a pre-DECON and a post-DECON visit. The 8496 data points are marked with a “cross-hair”. The UV sensitivity has been recovered.

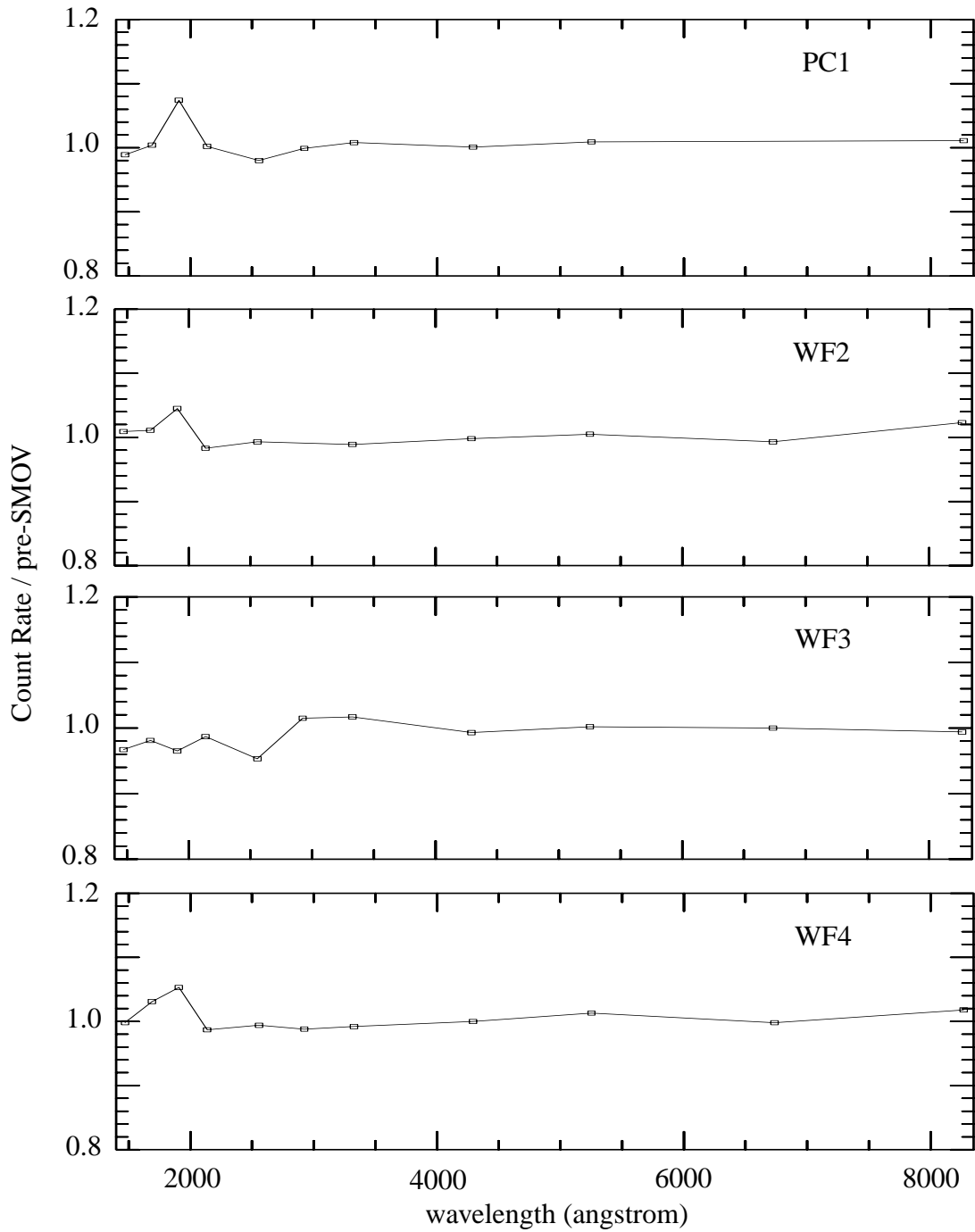


Figure 2: Ratio of 8496 / pre-SMOV 2000 measurements. The data spike at wavelength 1907 Å is due to the F185W filter data. The WF3 UV sensitivity ratio is different than for the other cameras.

9. Appendix I - WF3 Calibration

The WF3 UV sensitivity ratio (see Figure 2) is different than for the other cameras. This could be due to differences in positioning of the calibration target GRW+70d5824 on the WF3 CCD between observations. Table 12 presents the positions of the target on the WF3 CCD. The positioning of the target on January 18, 2000, post-SM3A data, is consistently closer to the apex of the pyramid and the readout amplifier than for the pre-SM3A data. Due to less loss of charge resulting from CTE, the post-SM3A count rates should be higher than the pre-SM3A count rates. In addition, the target position on November 4, 1999 for the F170W filter observation is extremely close to the pyramid apex compared to other observations. The additional charge for the F170W filter count rate would explain the lack of improvement in the ratio for this filter, but positioning on the CCD of the target in general does not explain the UV sensitivity ratio for WF3.

Table 12. WF3 photometry, pre- and post-SMOV observations.

filter	Date	Obs.	x,y (pixels)	Date	Obs.	x,y (pixels)
F160BW	04-Nov-99	u5if7801r	431.97,433.04	18-Jan-00	u60g0301r	419.50,426.31
F170W	04-Nov-99	u5if780br	230.30,230.81	18-Jan-00	u60g0302r	419.60,426.34
F185W	17-Oct-98	u4s6040dr	439.02,435.21	18-Jan-00	u60g0303r	419.75,426.39
F218W	04-Nov-99	u5if7802r	432.20,433.11	18-Jan-00	u60g0304r	419.79,426.39
F255W	04-Nov-99	u5if7803r	432.51,432.48	18-Jan-00	u60g0305r	420.06,425.74
F300W	17-Oct-98	u4s6040lr	432.42,419.02	18-Jan-00	u60g0306r	419.75,426.03
F336W	04-Nov-99	u5if7804r	432.21,433.01	18-Jan-00	u60g0307r	419.77,426.29
F439W	04-Nov-99	u5if7805r	432.19,432.85	18-Jan-00	u60g0308r	419.79,426.03
F555W	04-Nov-99	u5if7806r	432.03,432.79	18-Jan-00	u60g0309r	419.62,426.00
F675W	26-Mar-99	u42w460dr	430.05,422.28	18-Jan-00	u60g030ar	419.88,425.51
F814W	04-Nov-99	u5if7807r	432.00,432.68	18-Jan-00	u60g030br	419.50,425.90