

# SMOV3b WFPC2 Lyman- $\alpha$ Throughput Check

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## ABSTRACT

*The far-UV throughput of WFPC2 was monitored on March 23, 2002 for any signs of unexpected throughput degradation following Servicing Mission 3b. No significant changes were detected.*

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## Introduction

Servicing Mission 3b (SM3b) occurred in March 2002. A major concern for WFPC2 during any servicing mission is the possibility of contamination due to the servicing activities. The CCD windows can be heated to remove any contaminant buildup; this is routinely and successfully accomplished with decon procedures about once a month during normal science operations. However, during a servicing mission, contaminants could potentially settle on the pick-off mirror (POM) which is exposed in HST's hub area and can not be heated. The Lyman- $\alpha$  throughput tests, based upon observations taken with the F122M and F160BW filters, are designed to monitor the far-UV throughput for any signs of degradation which may be due to a layer of contaminants on the POM.

The concern over the WFPC2 POM stems from the near total loss of Lyman- $\alpha$  reflectivity of the WF/PC-1's pick-off mirror during its stay in orbit. This behavior has not to date been observed in orbit with WFPC2 (MacKenty & Baggett 1996). In addition, Lyman- $\alpha$  monitoring after the previous two Servicing Missions (SM2 and SM3a) also detected no significant change in throughput to within an uncertainty of 20% (O'Dea et al. 1997; Baggett & Heyer 2000). We present here the results from the Lyman- $\alpha$  monitoring (proposal 8951) during Servicing Mission Orbital Verification 3b (SMOV3b).

## Data

### *New Observations*

We have used the standard photometric monitoring target GRW+70D5824 to perform the Lyman- $\alpha$  test. The photometric properties of this star are summarized in Table 1. The Lyman- $\alpha$  contamination check was performed on March 23, 2002. These observations were taken 12 hours after the WFPC2 was cooled down to -88C. To assess the Lyman- $\alpha$  contamination, the target was observed in the far-UV using the filters F160BW and F122W, by themselves, and crossed with F130LP. The crossed filters are used to estimate the contribution of the red leak to the total signal in the F122M filter and to split the F160BW filter in order to calculate the signal in a pseudo ‘‘F120N’’ filter, thereby providing an additional measure of the Lyman- $\alpha$  throughput. Two images of the standard star in each of the four filter combinations (F122M, F122M+F130LP, F160BW, and F160BW+F130LP) were taken on both the PC and WF3 chip. Individual exposure times

**Table 1: Target used for Lyman Alpha Throughput Monitoring<sup>a</sup>**

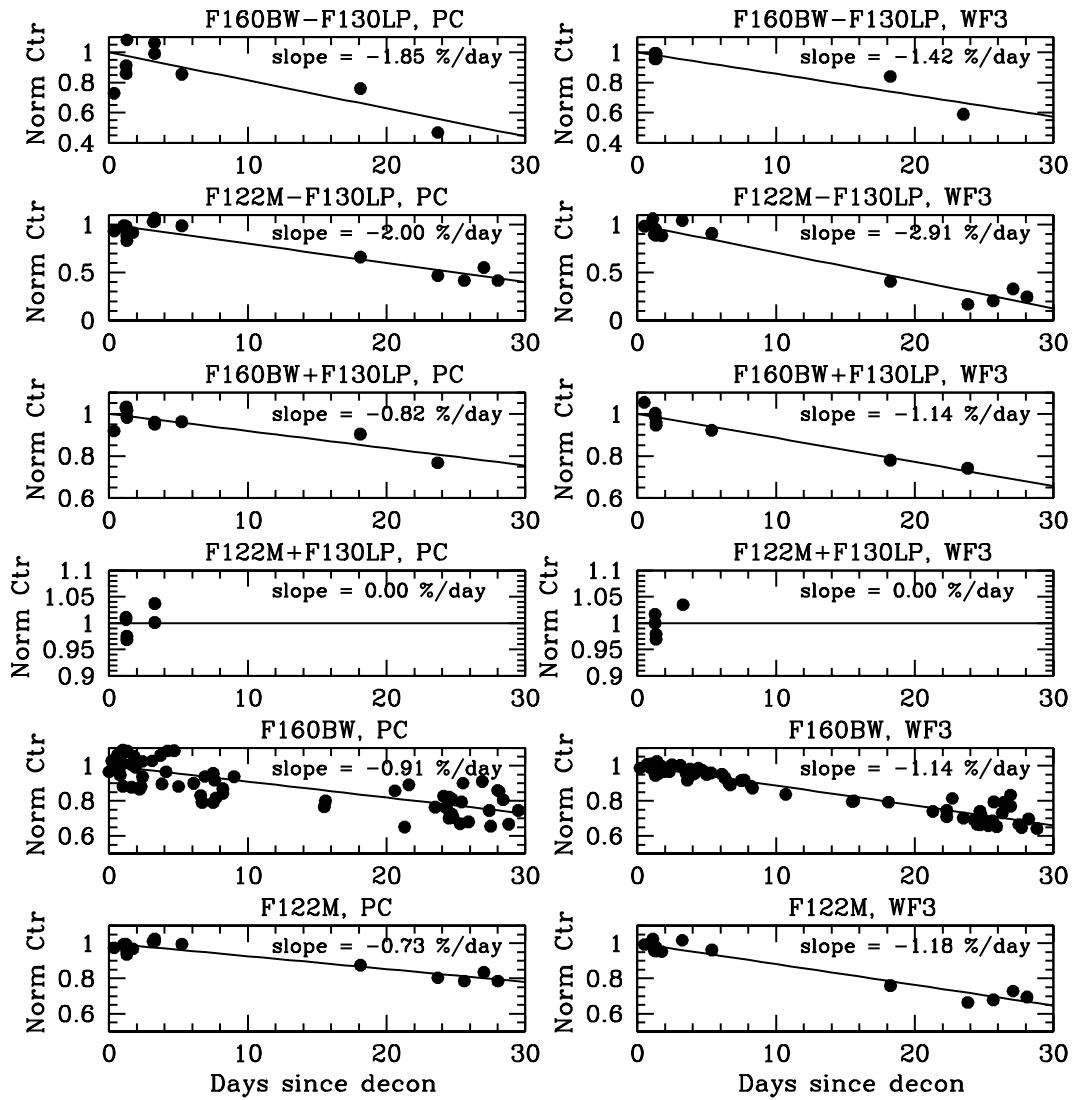
Property	GRW+70D5824
RA (J2000.0)	13:38:51.77
DEC (J2000.0)	70:17:08.5
spectral class	DA3
V	12.77
B-V	-0.09
U-B	-0.84

a. Positions, spectral class, and UBV information from Turnshek et al. (1990).

were 100 sec and 40 sec for the F122M and F160BW filter combinations, respectively. Images were calibrated using the standard STSDAS **calwp2** task. After calibration, we used a photometric monitor script maintained by Shireen Gonzaga to measure the flux from the standard star. This script includes the removal by hand of cosmic rays and hot pixels within the region of interest using the IRAF **imedit** task, centering of the star with the **imcntr** task, and photometry from the **phot** task in IRAF package **noao.digi-phot.apphot**, where we use an aperture radius of 0.5’’ (5 pixels in WF3, 11 pixels in PC) and a sky subtraction annulus from 1.46’’-1.96’’. The pairs of observations were reduced and analyzed individually. To check repeatability, all datasets were reduced and analyzed by the authors individually. A comparison of these results indicate that the values were consistent within the measurement uncertainty; therefore, for the final analysis, we only present results from one person.

*Pre-Servicing Mission Observations*

In order to make a comparison to data taken before the Servicing Mission 3b, we have collected the historical monitoring data of the standard star GRW+70D5824 in the single and crossed filters. Some of these data are publicly available on the WFPC2 website. These data were taken over many years and at various times after the normal monthly decon procedures. Therefore, we must first correct accurately the F122M, F160BW, F122M+F130LP, and F160BW+F130LP data for the throughput loss due to contaminates.



**Figure 1:** Normalized count rate vs. Days since Decon from the historical data in the F122M, F160BW, F122M+F130LP, and F160BW+F130LP filters for the PC and WF3, respectively. The panels on the top two rows indicate the red-leak-corrected data for the F122M filter and the data from the pseudo “F120N” filter created from the F160BW filter combinations (see text for details). Solid line indicates the best-fit, least-square line. The measured contamination rates are listed in the upper right of each panel.

We have used the historical data to measure the rate of contamination by plotting measured flux versus Days since Decon and performing an unweighted least-square fit to all available data. Each point has been normalized to the best-fit y-intercept. The results are shown in Figure 1. The final contamination rates for the two single filters and the two crossed filters, which are used to correct the historical data in the following analysis, are listed in each panel. In the case of the crossed filter F122M+F130LP, there is limited historical data; however, there is no obvious trend in the measured count rate with Days since Decon indicating that the contamination rate in this crossed filter is negligible. This result is expected since the crossed filter samples only the red tail of the F122M filter. In the case of the crossed filter F160BW+F130LP, we observe a similar decline in count rate with Days since Decon as we do for the single F160BW filter. The close similarity between the results for the single and crossed filter is expected since the F130LP filter cuts off only the small fraction of the F160BW filter which extends blueward of 1250 Angstroms.

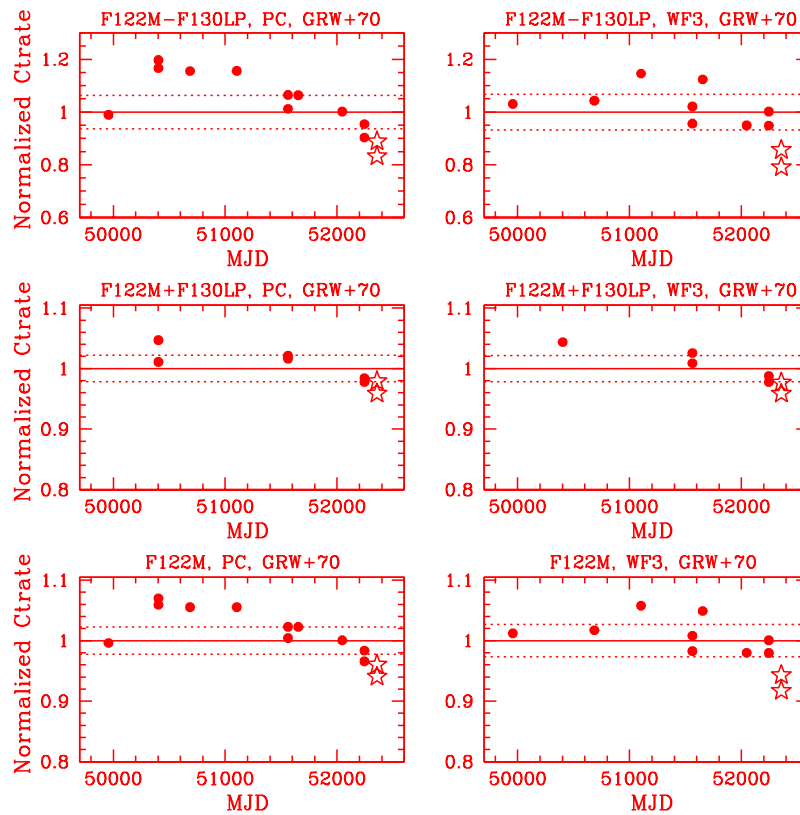
In the panels on the top two rows of Figure 1, we also show how the data for the red-leak-corrected F122M filter and the pseudo “F120N” filter created from the single and crossed F160BW filters declines with the number of Days since Decon. We label these panels as F122M-F130LP and F160BW-F130LP, respectively. We calculate the red-leak-corrected F122M data by subtracting the count rate measured in the crossed filter F122M+F130LP from that measured in the single F122M filter. Since we have shown in Figure 1 that the contamination rate in the F122M+F130LP filter is negligible, we have simply calculated the average of all measured count rates in this crossed filter and subtracted this value from all measurements made in the single F122M filter. The resulting decline in the red-leak-corrected F122M data is approximately 2-3% per day. To create the pseudo “F120N” filter, we subtract the count rate measured in the crossed filter F160BW+F130LP from that measured in the single F160BW filter. Since we have shown that both the single and the crossed filter are affected by contaminants, we only use data from days where there are measured count rates in both the single and crossed filter. The results from these data indicate a decline of approximately 1.5-2.0% per day. We note that, due to the small number of data points in the F160BW-F130LP panels, the errors on the measured contamination rates are large, approximately +/- 0.6%.

## Results

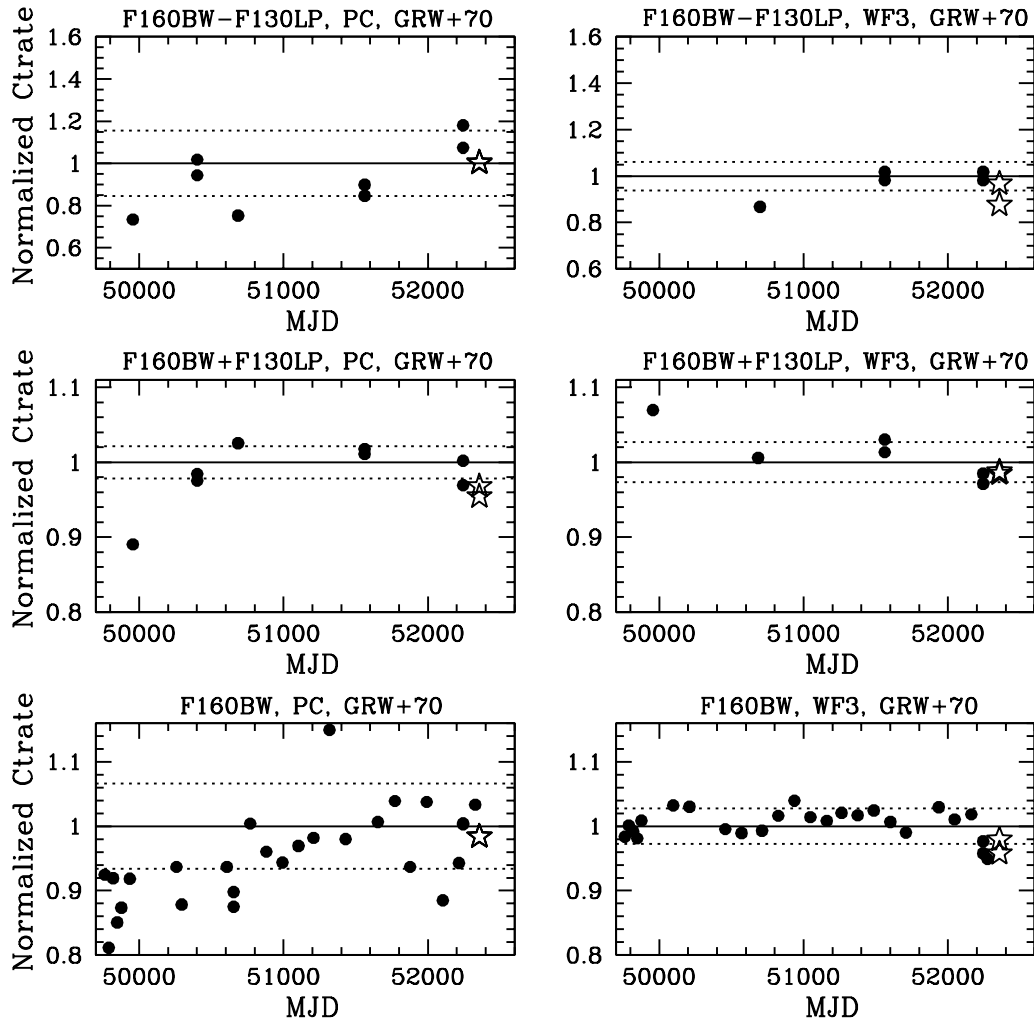
The normalized counts for the new observations and the historical data are shown in Figures 2 and 3 for the F122M and F160BW filter, respectively. The bottom and middle panels indicate data taken in the single filter and the crossed filter, respectively. The red-leak-corrected F122M data and the pseudo “F120N” data created from the single and crossed F160BW filters are shown in the top panels. Left and right panels represent the data on the PC and WF3 chip, respectively. The historical data are indicated by solid dots. The new observations taken during SMOV3b are indicated by open stars. As mentioned earlier, these data were taken in pairs, and the results from each exposure are shown separately. The two measurements agree to 3% or better. The second observation of each pair

typically gives a slightly higher flux measurement than the first, possibly as a result of a mild “pre-flashing” of the pixels by the first exposure (for a discussion, see Whitmore, Heyer & Casertano 1999; Koekemoer et al. 2002).

Historical count rate measurements made in the single filters, F122M and F160BW, and the crossed filters, F122M+F130LP and F160BW+F130LP, have been corrected for the appropriate contamination rate as determined in Figure 1. As discussed above, we calculate the red-leak-corrected F122M data by measuring the average count rate of all data available in the crossed filter F122M+F130LP and subtracting this value from the count rates measured in the single F122M filter. To calculate the throughput from the pseudo “F120N” filter, we subtract the count rate measured in the crossed filter F160BW+F130LP from that measured in the single F160BW filter on days where there are measured count rates in both the single and crossed filter. Each data point has been normalized by the average value of all fluxes measured at MJD > 51200. The solid and dotted lines in each panel indicate the mean and one-sigma standard deviation, respectively, of the historical data.



**Figure 2:** Normalized count rate versus Modified Julian Date (MJD) in the F122M filter, the F122M filter crossed with the F130LP filter (F122M+F130LP), and the red-leak-corrected F122M filter (F122M-F130LP) for the PC (left panels) and the WF3 (right panels). Data points are normalized by the mean value of all points with MJD > 51200. The solid points indicate the historical data (which have been corrected for contamination; see text). The open stars indicate measurements made during SMOV3b. The solid and dotted lines indicate the mean and one-sigma standard deviation, respectively, of the historical data.



**Figure 3:** Same as Figure 2 but for the F160BW filter, the F160BW filter crossed with the F130LP filter (F160BW+F130LP), and the pseudo “F120N” filter (F160BW-F130LP) .

As we can see from these figures, the data taken during SMOV3b are quite consistent with the historical data. All data taken in the single filter F160BW and the crossed filter F160BW+F130LP are within 2 sigma of the mean value. The data in the pseudo “F120N” filter (F160BW-F130LP) is lower than the mean by, on average, 0% on the PC and 8% on the WF3 chip. The biggest deviations are observed in the F122M filter where the count rates measured during SMOV3b are lower than the average value by 2-3 sigma. This corresponds to a reduction in the red-leak-corrected count rates by an average of 14% in the PC and 18% in the WF3 chip. We note, however, that there is a trend in these data of an overall decrease in count rate in the F122M filter with time since MJD  $\sim$  51000, most likely due to the effect of CTE (see Whitmore & Heyer 2002) . The new observations are reasonably consistent with this decline. Specifically, if we perform a linear fit to this trend, we would predict that the count rates measured during SMOV3b to be lower than

the mean by 8% and 6% in the PC and WF3 chip, respectively. We also note that the level of the observed deviations in the red-leak-corrected F122M data is consistent with that found after the previous two Servicing Missions (O'Dea et al. 1997; Baggett & Heyer 2000).

## Conclusions

We find that the Lyman- $\alpha$  throughput measurements made after Servicing Mission 3b in the PC and WF3 chip did not show any significant changes compared to pre-SMOV3b levels, although there is an indication of an overall trend of decreasing throughput in the F122M filter over the past four years. We, therefore, conclude that the WFPC2 pick-off mirror appears to have been protected from any significant contamination related to SM3b activities.

## References

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