Center for Astrophysics

Harvard College Observatory
Smithsonian Astrophysical Observatory

MEMORANDUM

March 9, 1998

To: Steve Murray

From: Ralph Kraft

Subject: X-ray shadowgraph and transmission measurements of the backup HRC-S UVIS

cc: Martin Zombeck, Almus Kenter, Gary Meehan, Mike Juda, Hank Donnelly, Dick Goddard, Deron Pease

We have recently completed X-ray shadowgraph and transmission measurements of the backup HRC-S UVIS. The set of shields is marked as S/N 03. In this memo, we will summarize the results of these measurements. These measurements were similar to measurements made last year on the backup HRC-I UVIS in the HRC laboratory (Kraft 1997). Shadowgraph and transmission measurements were made on all three segments of the shield. The shield was mounted on two translation stages that provided motion in the two axes orthogonal to the x-ray beam. A model 5 Manson source was used to generate characteristic X-rays, and beam filters were used for the shadowgraphs to reduce continuum contamination. An LETG facet ("poor man's monochromator") was used to provide monochromatic X-rays for the transmission measurements. A microchannel plate detector (MCP) with uncoated plates was mounted at the other end of the pipe. These HRC-S UVIS measurements were made with different plates and a different CGCD than were used for the HRC-I UVIS measurements. The different plates were used because the original set developed a region of low gain in the center. The MCP images showed considerably more hot spots than the HRC-I UVIS measurements. A different CGCD were used for these measurements because the size of the gaps in the HRC-I measurements was quite large in one axis. A linear degap parameter of 1.13 was required to make the flat fields appear flat. Neither of these effects will influence the measurements, however. The data sheets and visual inspection reports from Luxel for each segment is attached.

1 Shadowgraphs

Shadowgraphs of each segment of the HRC-S UVIS were made at C K_α and O $K_\alpha$to measure the large scale uniformity of the shield. In addition, a shadowgraph of segment -1 was made at B K_α. The experimental technique was identical to the HRC-I UVIS measurements made last year. Two flat fields were taken for each measurement, one with the shield in the beam (referred to as the IN measurement) and one with the shield out of the beam (referred to as OUT). The ratio image (RATIO=IN/OUT) is a map of the transmission of the UVIS. All detector and beam non-uniformities present in the IN or OUT images will be divided out in the RATIO image. The monitor detector (MD) was run for the C K_α and O K_α flat fields, so that absolute transmissions can be derived. The MD was not run for the B K_α measurement because we were concerned about carbon buildup on the anode. There is no beam stability monitor for this measurement, and the derived transmission may have a large systematic error associated with it. Summaries of the relevant test parameters is given in Tables 1, 2, and 3 for the C K_α, O K_α, and B K_α shadowgraphs, respectively. Note that we took two separate shadowgraphs of the central segment shield at C K_α to determine the repeatability of the measurements. The integration time was chosen to accumulate approximately 1000 cts/mm^2 in each image. The raw data were converted to images with the standard processing software, and was binned by a factor of 128 in both axes (pixels are 823 μm on a side) for the C and O shadowgraphs, and by a factor of 256 in each axes for the B shadowgraph.

Line	C K_α	C K_α	C K_α	C K_α
Anode	Graphite	Graphite	Graphite	Graphite
Filter	33 μm poly	33 μm poly	33 μm poly	33 μm poly
V_A	1 kV	1 kV	1 kV	1 kV
Segment	0	+1	-1	0
IN filename	P1980206a.rd	P1980206c.rd	P1980206d.rd	P1980206f.rd
Counts	3.82E6	4.37E6	4.52E6	3.83E6
Integration time	3600 s	3600 s	3600 s	3600 s
MD counts	122835	147331	150943	123795
OUT filename	P1980206b.rd	P1980206b.rd	P1980206b.rd	P1980206e.rd
Counts	3.99E6	3.99E6	3.99E6	3.99E6
Integration time	3600 s	3600 s	3600 s	3600 s
MD counts	60661	60661	60661	78607

Table 1: Summary of parameters for C K_α shadowgraphs of backup HRC-S UVIS

Line	O K_α	O K_α	O K_α
Anode	MgOH	MgOH	MgOH
Filter	2 μm Cr	2 μm Cr	2 μm Cr
V_A	1 kV	1 kV	1 kV
Segment	0	+1	-1
IN filename	p1980209a.rd	p1980210c.rd	p1980209b.rd
Counts	2.92E6	2.86E6	2.97E6
Integration time	14400 s	14400 s	14400 s
MD counts	288620	285114	279019
OUT filename	p1980210b.rd	P1980210b.rd	P1980210b.rd
Counts	2.67E6	2.67E6	2.67E6
Integration time	7200 s	7200 s	7200 s
MD counts	139555	139555	139555

Table 2: Summary of parameters for O K_α shadowgraphs of backup HRC-S UVIS

Line	B K_α
Anode	B on Mg
Filter	5 Par-C
V_A	0.7 kV
Segment	-1
IN filename	p1980213a.rd
Counts	583943
Integration time	25200 s
MD counts	N/A
OUT filename	p1980214(a and b).rd
Counts	649743 (both images)
Integration time	7200 s each
MD counts	N/A

Table 3: Summary of parameters for B K_α shadowgraphs of backup HRC-S UVIS

We used the same two techniques for analyzing this data as was used for the HRC-I UVIS shadowgraph, a statistical analysis of the distribution of transmission values and a wavelet analysis of the RATIO images. In the first method, the distribution of the pixel values in the IN, OUT, and RATIO images at each energy was considered. The mean and variance of the distribution of pixel values for each of images was computed. Unlike the HRC-I UVIS, the HRC-S UVIS has large scale structure associated with the regions of differing Al thickness, and each spatial region must be considered separately. For the C and B shadowgraphs, the different spatial regions were sorted by transmission value in the RATIO image. The difference in transmission between thin and thick Al on any segment is not large enough at O K_α, so these data were sorted spatially. The results for the three segments are summarized in Tables 4 through 19.

In all cases, the standard deviation of the IN and OUT distributions is considerably larger than the square root of the mean value of these distributions, indicating the presence of some type of spatial non-uniformity in the beam, detector, or shield, or a combination of all three. The ratio and standard deviation (assuming counting statistics alone) of these means is also given. For comparison, a Gaussian was fit to the distribution of pixel values in each RATIO image. As can be seen from Tables 4 and 17 (the C K_α and O K_α shadowgraphs), the centroid and width of these fit Gaussians agree quite well with the ratio of the means and the statistical standard deviation of the ratios. We therefore conclude that any spatial variation in the RATIO image (i.e. non-uniformity in the UVIS) must be well below the level of statistical fluctuations (5%). The quantitative upper limit on that this places spatial variations in the shield depends on the uncertainty in the width of the Gaussian fit to the distribution of pixel values in the RATIO image, but is probably on the order of 2% or less. This is in general agreement with the results obtained previously on the HRC-I shield. Also, we conclude that the spatial non-uniformity found in the IN and OUT measurements is due to detector non-uniformity; previous measurements have found the beam to be uniform.

The average transmission of the shield was determined by two techniques. First, the mean counts in the IN and OUT images were used, corrected by the MD rate. Second, the best fit Gaussian centroid of the region in the RATIO image (again corrected by the MD rate) was used.

The B shadowgraph is a bit more complex. The detector background is insignificant in the C and O shadowgraphs, but is not negligible in the B shadowgraph. The S/N ratio is only $\sim$2 in the region under the thick Al. A uniform background was subtracted from both the IN and OUT images, and hot spots were rejected by the region selection described above. We did not operate the monitor detector, so we have no measure of the temporal or spectral stability of the beam. As can be seen from Tables 18 and 19, the best fit Gaussians are considerably broader than the width one would expect based on counting statistics alone. This would indicate that there may be some level on non-uniformity in the shield. The statistical confidence of the data (particularly under the thick Al) is considerably below the C and O shadowgraphs, and the B shadowgraph images are binned a factor of 4 larger. Considering the lower quality of these data, I regard this result as inconclusive without

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	859.05 cts	3889.48	62.37 cts	29.31 cts
OUT image	964.07 cts	3377.65	58.12 cts	31.05 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				0.891
Transmission at C K_α(IN/OUT)				**0.440**
Statistical std dev of ratio				**0.042**
Gaussian mean of RATIO image				0.888
Transmission at C K_α(Gaussian)				**0.438**
Gaussian sigma of RATIO image				**0.044**

Table 4: Transmission of UVIS S/N 003 segment 0 (region of thick Al) at C K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	1416.47 cts	6815.80	82.56 cts	37.64 cts
OUT image	964.07 cts	3377.65	58.12 cts	31.05 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				1.469
Transmission at C K_α(IN/OUT)				**0.726**
Statistical std dev of ratio				**0.061**
Gaussian mean of RATIO image				1.439
Transmission at C K_α(Gaussian)				**0.711**
Gaussian sigma of RATIO image				**0.073**

Table 5: Transmission of UVIS S/N 003 segment 0 (region of thin Al) at C K_α.

further evidence. It may be an artifact of the low count rate and non-negligible background. Given the low rate from the anode, the long required integration time, and the generally low quality of this data (two full working days were required to take the limited data set presented here), I believe that this is not a useful measurement.

We also performed the wavelet decomposition on all RATIO images to search for large scale non-uniformities in the shield. Unlike the HRC-I shield, all three segments of the HRC-S shield have large scale structure associated with the regions of different Al thickness. One can visualize the shield as having two distinct regions of differing *emission*. The wavelet

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	1651.68 cts	6441.81	80.26 cts	40.64 cts
OUT image	963.19 cts	3359.91	57.96 cts	31.03 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.715
Transmission at C K_α(IN/OUT)				**0.706**
Statistical std dev of ratio				**0.070**
Gaussian mean of RATIO image				1.702
Transmission at C K_α(Gaussian)				**0.701**
Gaussian sigma of RATIO image				**0.057**

Table 6: Transmission of UVIS S/N 003 segment +1 (region of thin Al) at C K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	495.32 cts	1366.67	36.97 cts	22.26 cts
OUT image	963.19 cts	3359.91	57.96 cts	31.03 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				0.514
Transmission at C K_α(IN/OUT)				**0.212**
Statistical std dev of ratio				**0.028**
Gaussian mean of RATIO image				0.500
Transmission at C K_α(Gaussian)				**0.206**
Gaussian sigma of RATIO image				**0.030**

Table 7: Transmission of UVIS S/N 003 segment +1 (region of thick Al) at C K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	1693.54 cts	7367.30	85.83 cts	41.15 cts
OUT image	963.95 cts	3407.49	58.37 cts	31.05 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.757
Transmission at C K_α(IN/OUT)				**0.706**
Statistical std dev of ratio				**0.071**
Gaussian mean of RATIO image				1.739
Transmission at C K_α(Gaussian)				**0.699**
Gaussian sigma of RATIO image				**0.078**

Table 8: Transmission of UVIS S/N 003 segment -1 (region of thin Al) at C K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	519.91 cts	1281.56	35.80 cts	22.80 cts
OUT image	963.95 cts	3407.49	58.37 cts	31.05 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				0.539
Transmission at C K_α(IN/OUT)				**0.217**
Statistical std dev of ratio				**0.029**
Gaussian mean of RATIO image				0.515
Transmission at C K_α				**0.207**
Gaussian sigma of RATIO image				**0.031**

Table 9: Transmission of UVIS S/N 003 segment -1 (region of thick Al) at C K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	857.42 cts	3025.20	55.00 cts	29.28 cts
OUT image	1212.91 cts	4659.23	68.25 cts	34.83 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				0.707
Transmission at C K_α(IN/OUT)				**0.449**
Statistical std dev of ratio				**0.032**
Gaussian mean of RATIO image				0.706
Transmission at C K_α(Gaussian)				**0.448**
Gaussian sigma of RATIO image				**0.024**

Table 10: Transmission of UVIS S/N 003 segment 0 (region of thick Al) at C K_α (second measurement).

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	1433.26 cts	4629.19	68.04 cts	37.86 cts
OUT image	1212.91 cts	4659.23	68.25 cts	34.83 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				1.182
Transmission at C K_α(IN/OUT)				**0.750**
Statistical std dev of ratio				**0.046**
Gaussian mean of RATIO image				1.150
Transmission at C K_α(Gaussian)				**0.730**
Gaussian sigma of RATIO image				**0.047**

Table 11: Transmission of UVIS S/N 003 segment 0 (region of thin Al) at C K_α (second measurement).

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	746.843 cts	5715.57	75.60 cts	27.33 cts
OUT image	622.50 cts	7377.48	85.89 cts	24.95 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				1.120
Transmission at O K_α(IN/OUT)				**0.580**
Statistical std dev of ratio				**0.065**
Gaussian mean of RATIO image				1.193
Transmission at O K_α(Gaussian)				**0.577**
Gaussian sigma of RATIO image				**0.063**

Table 12: Transmission of UVIS S/N 003 segment 0 (region of thick Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	831.20 cts	3744.44	61.19 cts	28.97 cts
OUT image	621.09 cts	1783.17	42.23 cts	24.92 cts
Ratio of means ($\text{Mean}_{IN}/\text{Mean}_{OUT}$)				1.350
Transmission at O K_α(IN/OUT)				**0.653**
Statistical std dev of ratio				**0.072**
Gaussian mean of RATIO image				1.336
Transmission at O K_α(Gaussian)				**0.646**
Gaussian sigma of RATIO image				**0.072**

Table 13: Transmission of UVIS S/N 003 segment 0 (region of thin Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	849.95 cts	7812.38	88.39 cts	29.15 cts
OUT image	597.51 cts	4665.47	68.30 cts	24.44 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.423
Transmission at O K_α(IN/OUT)				**0.696**
Statistical std dev of ratio				**0.076**
Gaussian mean of RATIO image				1.413
Transmission at O K_α(Gaussian)				**0.692**
Gaussian sigma of RATIO image				**0.076**

Table 14: Transmission of UVIS S/N 003 segment -1 (region of thin Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	663.997 cts	1.13E6	1061.57 cts	25.77 cts
OUT image	642.554 cts	5468.34	73.95 cts	25.35 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.033
Transmission at O K_α(IN/OUT)				**0.506**
Statistical std dev of ratio				**0.057**
Gaussian mean of RATIO image				1.085
Transmission at O K_α				**0.531**
Gaussian sigma of RATIO image				**0.056**

Table 15: Transmission of UVIS S/N 003 segment -1 (region of thick Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	859.42 cts	5846.75	76.46 cts	29.32 cts
OUT image	615.81 cts	4034.30	63.52 cts	24.82 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.396
Transmission at O K_α(IN/OUT)				**0.698**
Statistical std dev of ratio				**0.074**
Gaussian mean of RATIO image				1.387
Transmission at O K_α(Gaussian)				**0.693**
Gaussian sigma of RATIO image				**0.072**

Table 16: Transmission of UVIS S/N 003 segment +1 (region of thin Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	714.04 cts	6611.65	81.31 cts	26.72 cts
OUT image	661.497 cts	6197.85	78.73 cts	25.72 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				1.079
Transmission at O K_α(IN/OUT)				**0.540**
Statistical std dev of ratio				**0.058**
Gaussian mean of RATIO image				1.072
Transmission at O K_α(Gaussian)				**0.536**
Gaussian sigma of RATIO image				**0.062**

Table 17: Transmission of UVIS S/N 003 segment +1 (region of thick Al) at O K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	31.48 cts	110.383	10.51 cts	5.61 cts
OUT image	428.935 cts	763.127	27.62 cts	20.71 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				0.0734
Transmission at B K_α(IN/OUT)				**0.042**
Statistical std dev of ratio				**0.0136**
Gaussian mean of RATIO image				0.0632
Transmission at B K_α(Gaussian)				**0.036**
Gaussian sigma of RATIO image				**0.0300**

Table 18: Transmission of UVIS S/N 003 segment -1 (region of thick Al) at B K_α.

	Mean (counts)	Variance	Std Dev	$\sqrt{Mean}$
IN image	384.582 cts	685.492	26.18 cts	19.62 cts
OUT image	428.935 cts	763.127	27.62 cts	20.71 cts
Ratio of means ($\mathrm{Mean}_{IN}/\mathrm{Mean}_{OUT}$)				0.897
Transmission at B K_α(IN/OUT)				**0.513**
Statistical std dev of ratio				**0.063**
Gaussian mean of RATIO image				0.889
Transmission at B K_α(Gaussian)				**0.508**
Gaussian sigma of RATIO image				**0.103**

Table 19: Transmission of UVIS S/N 003 segment -1 (region of thick Al) at B K_α.

decomposition should subtract off the higher *emission* from the region associated with the thinner Al at the smaller spatial scales. The residual *emission* image is then the transmission of the shield with the thicker Al, and any variations are the large scale variations in the thickness of the shield. In practice, this works quite well if the bright *emission* features have spatial scale much less than the size of the image. If these features are on the spatial size of the image, however, the wavelet decomposition will not subtract them out properly. The mean value of the final image of the wavelet decomposition was always between the transmission of the regions. The decomposition did not correctly subtract the excess *emission*. Any structure found by the decomposition is probably not real. I have discussed this issue with Alexey Vikhlinin, and we are in complete agreement that the wavelet decomposition is not appropriate because of the large spatial scale of the shield features.

2 Transmission Measurements

We have also made X-ray transmission (in/out) measurements of each segment of the UVIS using the poor man's monochromator. The technique is similar to that used on the HRC-I shields except that we used only the C and $Mg(OH)_2$ anodes. The Ti or Cr anodes were not used because we found that second and third order continuum contamination was significant. The data were projected at full resolution. The line rates were determined by taking a region of interest around a given spectral line. Since we have transmission measurements at only three energies, we cannot fit absorption models to the data. We can, however, compare the shadowgraph, transmission, and witness sample measurements made by Gary Meehan with the McPherson monochromator[2]. The results are summarized in Tables 20 through 23. The poor man's monochromator transmission measurements agree quite well with the measurements of the witness samples, but the shadowgraph measurements are typically a few percent lower than the other two.

Measurement	Shadowgraph	Transmission	Witness Sample
			(TF101-1025)
	C $\mathbf{K}_{\alpha}$		
Measured Trans.	0.438	0.452±0.003	0.444±0.007
	O $\mathbf{K}_{\alpha}$		
Measured Trans.	0.577	0.615±0.005	0.609±0.009
	Mg $\mathbf{K}_{\alpha}$		
Measured Trans.		0.930±0.007	0.932±0.009

Table 20: Comparison of transmission measurements: segment 0 thick Al

Measurement	Shadowgraph	Transmission	Witness Sample
			(TF101-1220)
	C $\mathbf{K}_{\alpha}$		
Measured Trans.	0.711		0.719±0.007
	O $\mathbf{K}_{\alpha}$		
Measured Trans.	0.646	0.677±0.005	0.656±0.006
	Mg $\mathbf{K}_{\alpha}$		
Measured Trans.		0.948±0.007	0.954±0.010

Table 21: Comparison of transmission measurements: segment 0 thin Al

Measurement	Shadowgraph	Transmission	Witness Sample
			(TF101-1157)
	C $\mathbf{K}_{\alpha}$		
Measured Trans.	0.701	0.742±0.004	0.728±0.007
	O $\mathbf{K}_{\alpha}$		
Measured Trans.	0.693	0.717±0.006	0.705±0.006
	Mg $\mathbf{K}_{\alpha}$		
Measured Trans.		0.958±0.007	0.957±0.014

Table 22: Comparison of transmission measurements: segment +1 thin Al

Measurement	Shadowgraph	Transmission	Witness Sample
			(TF101-1157)
B K_α			
Measured Trans.	0.508		0.472±0.005
C K_α			
Measured Trans.	0.699	0.748±0.004	0.728±0.007
O K_α			
Measured Trans.	0.692	0.726±0.006	0.705±0.006
Mg K_α			
Measured Trans.		0.963±0.007	0.957±0.014

Table 23: Comparison of transmission measurements: segment -1 thin Al

3 Summary and Conclusions

We have made shadowgraph and transmission measurements of each segment of the backup HRC-S UVIS. Statistical analysis of the C K_α and O K_α shadowgraphs indicates no large scale non-uniformities at the few percent level. We were unable to successfully perform the wavelet decomposition for reasons discussed above. We have also made transmission measurements on each segment of the shield with the poor man's monochromator. These measurements agree quite well with the witness sample transmission measurements made by Gary Meehan. The model parameters derived from fitting the witness sample data will therefore provide a good description of the transmission of the shield. We are reasonably confident that the results of this study (i.e. that the shields are uniform to the few percent level, and transmission of the witness samples accurately reflect the transmission of the shields) can be extrapolated to the flight shields.

4 References

Much of the documentation and information related to HRC calibration, including the text of this memo, can be found at the website http://hea-www.harvard.edu/HRC/calib/calib.html.

Kraft, R. P., SAO Internal Memo, 'Shadowgraph and transmission measurements of backup HRC-I UVIS', 1997.

Meehan, G., SAO Internal Memo, 'Calibration of the backup HRC-S UV/Ion Shield witness samples', 1998.

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