LWR Camera and ITF Performance with 4.5 kv UVC

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Abstract: A comparison of LWR UV-flood lamp images obtained at 5.0 kv and 4.5 kv UVC settings indicates that the current ITF performs equally well at both settings. Thus there is no need to derive a new ITF to calibrate the new configuration of the LWR camera at 4.5 kv. A small effect in the camera response is seen at the extreme edge of the images, corresponding with the slightly lowered sensitivity noted at the ends of the orders of high dispersion stellar spectra by Harris (1984).

1. Introduction

At the May 1984 Three Agency meeting, it was resolved to study the reconfiguration of the LWR camera with a reduced UVC voltage of 4.5 kv in order to avoid the effects of the UVC flare. Before the reconfiguration, we wished to analyze the performance of the current calibrations for the camera. The camera response to the UV-flood lamps used for calibration and the performance of the current Intensity Transfer Function (ITF) are of particular interest for the new configuration.

To provide data on the ITF performance, VILSPA obtained a special set of camera baseline images in June 1984 with the LWR UVC set to 4.5 kv (LWR 17422 - 17432), in addition to the standard images in May with the UVC at 5.0 kv (LWR 17406 - 17415). These images are standard sequences of UV-flood images and nulls similar to those used to construct the ITF calibration. They are normally obtained for each camera at intervals of six months in order to monitor the performance of the cameras. The following analysis is based on these images. Both sets of camera baseline images were processed using the current LWR ITF (ITF1). Since standard exposure times were used for the images, the DN levels and thus the FN levels are proportionally lower for the 4.5 kv images compared to the 5.0 kv images, due to the lower gain at the lower UVC setting.

Two basic questions are to be answered. One is whether or not the relation between the DN and FN is the same for both UVC settings at each pixel in the image (the ITF performance). A second is a comparison of the camera response to the illuminating UV-flood lamps when the UVC is at the two different settings. Several steps were used for the analysis. First, the behavior of the ITF averaged over a large central portion of the image was studied at both UVC settings. Second, the relative behavior of different regions in the similar UV-flood images was analyzed. Next, small regions distributed around the image were chosen for detailed spatial analysis. Finally, an analysis was made of the signal-to-noise in the images for both UVC settings. These results were previously presented to the Three Agencies in two reports (Imhoff 1984, Imhoff 1985).

2. Overall Performance of the ITF for UV-Flood Images

To study the ITF performance on the image as a whole, the mean FN for a 432 pixel by 432 pixel area in the center of each image was computed, using the standard flat-field statistics routine BOXSTAT. If the current ITF calibrates the 4.5 kv images as well as it does the 5.0 kv ones, the relation between the FNs of corresponding images should be a straight line with a slope determined by the difference in gain (and any intervening lamp degradation). The values found for the test images are given in Table 1 and plotted in Figure 1. As one may see, the relation between the mean FNs is indeed a straight line. The slope determined from a least-squares fit is 0.7377, which corresponds to a gain ratio of 1.356 (ignoring lamp degradation). This value agrees very well with the value of 1.37 determined by Harris (1984) from stellar spectra. Thus the current ITF appears to adequately calibrate the overall 4.5 kv LWR images, up to the highest DN levels in the test images. The latter limitation corresponds to saturation in the lower left quadrant of the image, 210 DN at the center of the image, and about 170 DN at 2800 A in the low dispersion spectrum.

3. Tilt in the Photometrically Corrected UV-Flood Images

The second part of the analysis is to examine the relative behavior of different areas within the image. If the ITF performs equally well with 5.0 kv and 4.5 kv UVC settings, the tilt, or deviation from flatness of the photometrically corrected image, should be about the same for images with comparable DN levels. The tilt is defined to be the difference in FNs between two standard regions of 3600 pixels ("B", centered on line = 168 and sample = 528, and "F", centered on line = 636 and sample = 312) in the photometrically corrected image. A perfect ITF should produce uniform FNs across the image. Due to slow changes in the camera since 1978, the current LWR ITF produces some tilt in the 5.0 kv baseline images. Figure 2 depicts the variation in the tilt versus exposure level (mean FN) in Regions B and F for both the 5.0 kv and 4.5 kv images. The relations are the same.

4. Detailed Analysis in Comparable UV-Flood Images

A few of the available UV-flood images were used to perform a detailed analysis of the camera response and ITF performance. Since the standard exposure times were used for both camera baseline sequences, the DN levels are proportionally lower for the 4.5 kv images than the 5.0 kv images. However, for two pairs of images the DN levels are nearly the same (see Table 1). For these images the difference in gain is nearly balanced by the difference in exposure time, resulting in similar DN levels. These pairs of comparable images allow one to examine the response of the camera at the two UVC settings and the performance of the ITF on these images.

Twenty-one areas were chosen, distributed around the image, for this study. Each area consists of a 12 pixel by 12 pixel box, with a mean and standard deviation generated by the standard BOXSTAT routine. The areas are distributed from 96 to 672 in both line and sample number, thus extending over most of the useful area of the camera faceplate.

Figure 3 depicts the mean DNs in each of the 12 areas for each pair of images. Areas that represent regions close to saturation (DN > 240) are indicated by parentheses and omitted from the statistics discussed below. The two nulls are quite comparable, as one might expect since no exposure is performed. The null represents the pedestal of positive signal (typically 25 DN) present after the camera has been prepared but not exposed.

In order to examine the response of the camera to the UV-flood lamp at the two UVC settings, one must first remove the small systematic differences in the DN levels of the pairs of images. For each of the UV-flood images, the null level was subtracted. Then R_i, the ratio of the "signal" (i.e. UV-flood mean DN - null mean DN) at 4.5 kv to that at 5.0 kv for area i, was computed for each of the 21 areas. Specifically:

$$R_i = \frac{UVFDN_i(4.5\ kv) - NULLDN_i(4.5\ kv)}{UVFDN_i(5.0\ kv) - NULLDN_i(5.0\ kv)}$$

The mean of these ratios, $\langle R \rangle$, was computed for each pair of images. The mean represents the overall systematic difference in the DN levels of the two images (0.97 and 0.99 respectively for these pairs of images). Then the residuals for each area compared to the mean were calculated and converted to percentage, that is $100 * (R_i - \langle R \rangle)/\langle R \rangle$. These are given in Figure 4. The residuals may be used to locate systematic or location-dependent effects.

No strong pattern emerges from either of these pairs of images. The second pair of images shows the larger effects, on the order of 2%. This pattern is reminiscent of the "edge effect" seen by Harris (1984) in high dispersion stellar spectra. If one superimposes the location of the high dispersion orders, which run from the lower left to the upper right in the figures, one can see that the ends of the orders would be depressed by about 3% from the centers of the orders. However, the residuals do not repeat very well between the two pairs of images.

To test the performance of the ITF, the same series of calculations were done for the photometrically corrected images. Figure 5 depicts the mean FNs, scaled by a factor of 70, for the 21 areas in each image. Figure 6 shows the residuals, expressed in percentages. As before, no strong patterns are evident in the residuals.

If the ITF works as well for the 4.5 kv images as for the 5.0 kv images, then the pattern of residuals should be the same for the DNs and FNs. Figure 8 shows the differences in the residuals (FNs minus DNs). No strong or repeatable pattern emerges. Most differences are on the order of 1% or less. Thus the ITF appears to work well for images obtained with either UVC setting.

5. Signal-to-Noise Characteristics

Another comparison which may be made is the signal-to-noise for images obtained at 4.5 kv and 5.0 kv. The average signal-to-noise for the central portion of each image (432 pixels by 432 pixels) was determined using the standard BOXSTAT routine (Table 1). No differences in the S/N characteristics were found for UV-flood images with comparable DN values (Figure 8). In addition, the S/N ratios for the 21 areas in the pairs of images were computed to look for location-dependent differences between the 5.0 kv and 4.5 kv images. No pattern is evident.

6. Conclusions

We conclude that the camera responds reasonably equally to the UV-flood lamp at 4.5 kv and 5.0 kv UVC settings. There is some indication at the 2 to 3 % level of the "edge effect" noted by Harris (1984) in high dispersion stellar spectra. The LWR ITF performs equally well at either UVC setting for the exposure levels studied. Thus it is not necessary to obtain a new ITF before using the LWR at the 4.5 kv UVC setting.

References:

Harris, A. 1984, Report to the Three Agencies (November).
Imhoff, C. L. 1984, Report to the Three Agencies (November).
Imhoff, C. L. 1985, Report to the Three Agencies (April).

Table 1

Characteristics of the LWR Camera Baseline Images

	5.0 kv			4.5 kv		
Level	Mean FN	Tilt	S/N	Mean FN	Tilt	S/N
Null	-130	370		-100	350	
20% UVF	1760	450	3.29	1220	440	2.69
60%	5540	520	6.34	4140	540	5.74
60%	5360	530	6.40	3920	510	5.61
120%	10260	390	7.67	7680	520	7.90
160%	13960	300	10.91	10190	430	7.90
220%				13560	280	10.08

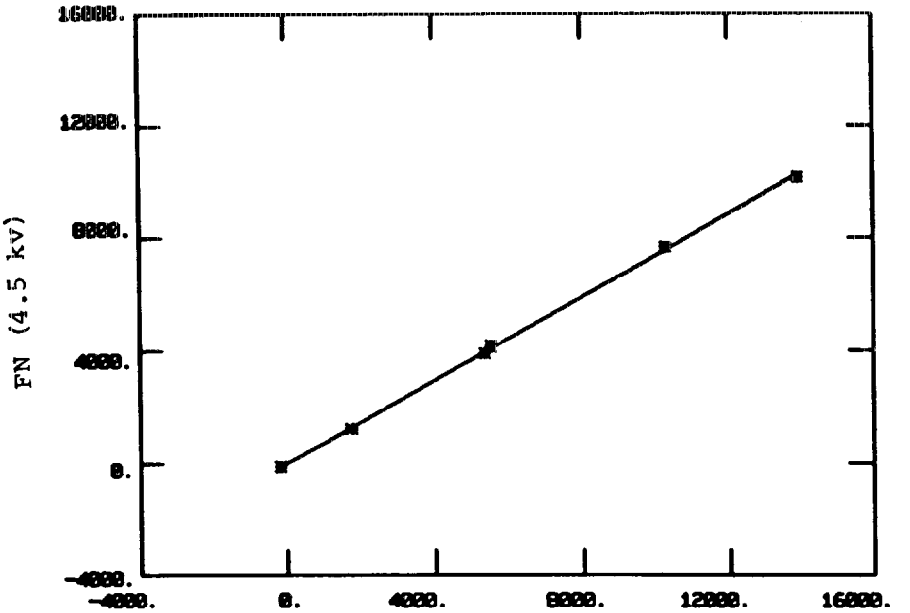

Figure 1: Relation between mean FNs for LWR UV-flood images obtained with 4.5 kv and 5.0 kv UVC settings.

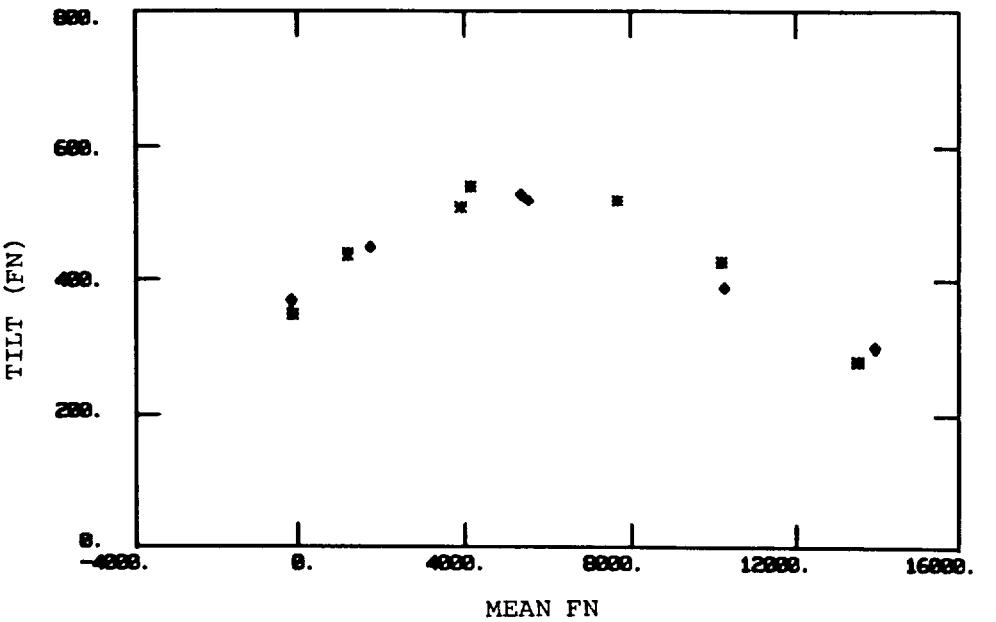

Figure 2: Tilt versus mean FN for photometrically corrected images for both 5.0 kv (diamonds) and 4.5 kv (asterisks) UVC settings.

Figure 3a
Mean DN Levels for 21 Areas in LWR UV-flood Images
Top value: LWR 17412 160% UVF at 5.0 kv UVC
Bottom value: LWR 17429 220% UVF at 4.5 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		169	166	144	
		166	163	149	
240	213	219	177	160	126
	209	213	171	155	124
384	(255)	233	208	166	136
	(255)	227	202	163	133
528	231	(254)	225	185	120
	226	(252)	221	180	116
672		(245)	226	173	
		(244)	219	167	

Figure 3b
Mean DN Levels for 21 Areas in LWR UV-flood Images
Top value: LWR 17409 120% UVF at 5.0 kv UVC
Bottom value: LWR 17428 160% UVF at 4.5 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		137	131	119	
		136	130	117	
240	174	174	136	125	105
	172	174	137	124	103
384	227	189	167	129	110
	221	188	168	130	108
528	182	217	180	145	91
	178	214	177	142	92
672		183	170	131	
		180	167	133	

Figure 3c
Mean DN Levels for 21 Areas in LWR Null Images
Top value: LWR 17415 Null at 5.0 kv UVC
Bottom value: LWR 17432 Null at 4.5 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		30	29	35	
		30	29	35	
240	31	28	24	26	37
	31	27	24	26	37
384	27	22	43	26	27
	27	22	43	26	27
528	10	22	27	24	16
	10	22	27	24	16
672		7	18	18	
		7	19	18	

Figure 4a
Residuals from Overall Mean: Mean DNs of UV-floods minus Nulls
LWR 17429 220% UVF at 4.5 kv / LWR 17412 160% UVF at 5.0 kv
Mean = 0.9701, St. Dev. = 0.0080

	SAMPLE				
	96	240	384	528	672
LINE					
96		+0.9%	+0.8%	-1.4%	
240	+0.8%	+0.4%	-1.0%	-0.8%	+0.8%
384	-	+0.2%	-0.7%	+0.9%	+0.2%
528	+0.8%	-	+1.0%	-0.1%	-0.9%
672		-	-0.9%	-0.9%	

Figure 4b
Residuals from Overall Mean: Mean DNs of UV-floods minus Nulls
LWR 17428 160% UVF at 4.5 kv / LWR 17409 120% UVF at 5.0 kv
Mean = 0.9896, St. Dev. = 0.0153

	SAMPLE				
	96	240	384	528	672
LINE					
96		+0.1%	+0.1%	-1.4%	
240	-0.4%	+1.7%	+2.0%	0.0%	-1.9%
384	-2.0%	+0.4%	+1.9%	+2.0%	-1.4%
528	-1.3%	-0.5%	-0.9%	-1.5%	+2.4%
672		-0.7%	-1.6%	+2.8%	

Figure 5a
Mean FN/70 Levels for 21 Areas in LWR UV-flood Images
Top value: LWR 17412 160% UVF at 5.0 kv UVC
Bottom value: LWR 17429 220% UVF at 4.5 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		196	205	202	
		190	200	195	
240	198	206	202	202	207
	192	199	196	196	204
384	(168)	205	200	198	201
	(168)	198	193	194	197
528	193	(187)	199	204	205
	188	(185)	194	198	199
672		(196)	200	204	
		(195)	193	196	

Figure 5b
Mean FN/70 Levels for 21 Areas in LWR UV-flood Images
Top value: LWR 17409 120% UVF at 5.0 kv UVC
Bottom value: LWR 17428 160% UVF at 4.5 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		142	149	151	
		140	148	146	
240	144	149	147	151	153
	142	150	149	148	149
384	144	148	143	144	148
	140	147	146	146	145
528	142	149	144	150	148
	140	147	142	148	149
672		144	143	147	
		142	141	150	

Figure 6a
Residuals from Overall Mean: Mean FN/70 of UV-floods
LWR 17429 220% UVF at 4.5 kv / LWR 17412 160% UVF at 5.0 kv
Mean = 0.9711, St. Dev. = 0.0063

	SAMPLE				
	96	240	384	528	672
LINE					
96		-0.2%	+0.4%	-0.6%	
240	-0.2%	-0.5%	-0.1%	-0.1%	+1.5%
384	-	-0.6%	-0.6%	+0.9%	+0.9%
528	+0.3%	-	+0.4%	-0.1%	-0.1%
672		-	-0.6%	-1.1%	

Figure 6b
Residuals from Overall Mean: Mean FN/70 of UV-floods
LWR 17428 160% UVF at 4.5 kv / LWR 17409 120% UVF at 5.0 kv
Mean = 0.9920, St. Dev. = 0.0157

	SAMPLE				
	96	240	384	528	672
LINE					
96		-0.6%	+0.1%	-2.5%	
240	-0.6%	+1.5%	+2.2%	-1.2%	-1.8%
384	-2.0%	+0.1%	+2.9%	+2.2%	-1.5%
528	-0.6%	-0.5%	-0.6%	-0.5%	+1.5%
672		-0.6%	-0.6%	+2.9%	

Figure 7a
Difference in Residuals: FNs minus DNs
LWR 17429 220% UVF at 4.5 kv UVC / LWR 17412 160% UVF at 5.0 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		-1.1%	-0.4%	+0.8%	
240	-1.0%	-0.9%	+0.9%	+0.7%	+0.7%
384	-	-0.8%	+0.1%	0.0%	+0.7%
528	-0.5%	-	-0.6%	0.0%	+0.8%
672		-	+0.3%	-0.2%	

Figure 7b
Difference in Residuals: FNs minus DNs
LWR 17428 160% UVF at 4.5 kv UVC / LWR 17409 120% UVF at 5.0 kv UVC

	SAMPLE				
	96	240	384	528	672
LINE					
96		-0.7%	0.0%	-1.1%	
240	-0.2%	-0.2%	+0.2%	-1.2%	+0.1%
384	0.0%	-0.3%	+1.0%	+0.2%	+0.2%
528	+0.7%	0.0%	+0.3%	+1.0%	-0.9%
672		+0.1%	+1.0%	+0.1%	

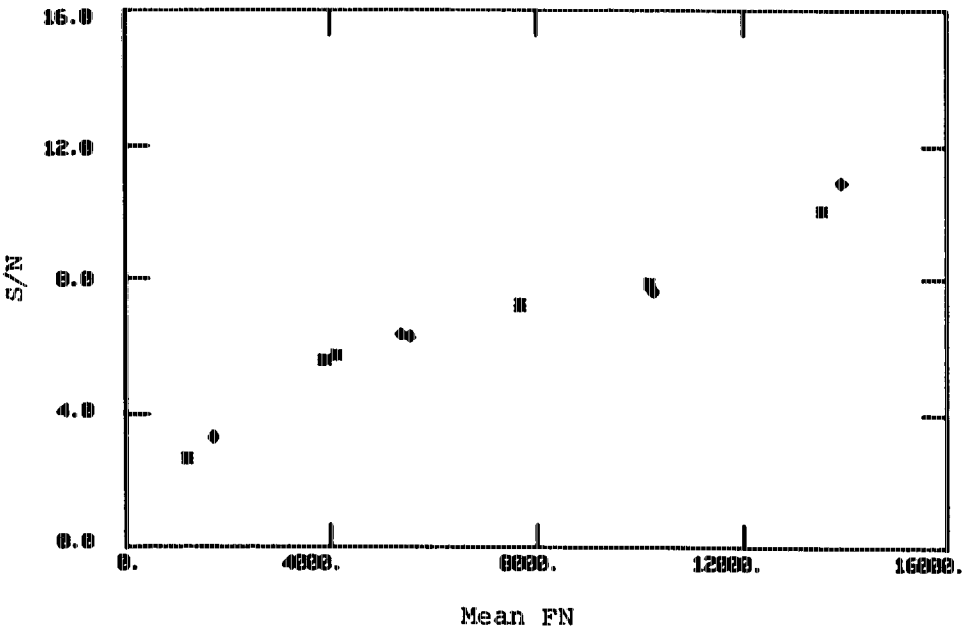

Figure 8: Signal-to-noise versus mean FN for both 5.0 kv (diamonds) and 4.5 kv (asterisks) UVC settings.